

### Risk analysis of dams: French practices through Safety Review Risk Assessment (SaRRA)

Laurent Peyras (INRAE) and Guirec Prévot (French Minister of Environment)





- From 2007, the French regulations introduced the obligation to carry out risk analyses through "Safety Review Risk Assessments" (SaRRA) :
  - for the large dams (class A: 200 dams) every 10 years
  - and the medium-sized dams (class B: 400 dams) every 15 years
- The aim of the SaRRA is to assess the internal or external risks of a dam:
  - The external risks are linked to natural hazards: floods, earthquakes, landslides, environment (failure of other structures)
  - The internal risks include the dam's condition and behavior, its performance, the operation of the safety structures, and organizational and human causes
- SaRRA include less severe events but with a higher probability, like operation accidents and incidents
- The framework of SaRRA respects the general principles defined in:
  - ICOLD Bulletin 130 "Risk assessment in dam safety management"
  - The normative risk management process ISO/CEI 31010:2009 "Risk management Risk assessment techniques"



SaRRA is firstly a SAFETY REVIEW: SaRRA

- SaRRA includes an assessment of the dam's design and condition:
  - initial design and construction
  - operating conditions and maintenance
  - behavior based on monitoring results, visual inspections and in-depth examinations

SAFETY REVIEW

 SaRRA covers all the structures of the dam: parts usually underwater, difficult to access, safety appurtenant works



All these elements constitute the input data for the risk analysis



- SaRRA is also a Risk Assessment: SaRRA
  - RISK ASSESSMENT
- Risk assessment in SaRRA includes:
  - determining the probability of failures and accidents
  - assessing the consequences of their effects in terms of intensity, kinetics, and severity
- The risk analysis concludes with the measures required to reduce the probability and the consequences of accidents of the dam studied





- SaRRA propose different measures for reducing the risks in the short and medium term, and their planning
- Expected benefit of these risk reduction measures is indicated
- Most of 600 SaRRA studies have been carried out in France since 2007





- The CFBR has produced a bulletin for the risk analysis of dams, available in French and English
- The bulletin is a summary of the feedback from the first generation of SaRRA carried out in France between 2007 and 2018.
- It describes the methods used in the practices and includes numerous illustrative examples
- To download (free): <u>https://www.barrages-cfbr.eu/IMG/pdf/fr-en\_recommandations\_cfbr\_2021\_analyse\_de\_risques.pdf</u>
- The Working Group:

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# Organisation of the course

- Part 1 Introduction to Risk Analysis for Dams: French practices through Safety Review Risk Assessment (SaRRA) Laurent Peyras (INRAE) and Guirec Prévot (French Minister of Environment)
   09:00 to 09:30
- Part 2 Functional Analysis applied to Dams Risk Analysis Input Data and Data Collection Eric Vuillermet (BRLi) and Jérôme Sausse (EDF) 09:30 to 11:00
- Part 3 Methods For Dam Failure Modes: Preliminary Risk Analysis (PRA), Failure Modes and Effects Analysis (FMEA), Failure Modes, Effects and Criticality Analysis (FMECA), – Jean Charles Palacios (SUEZ - SAFEGE) 11:00 to 12:00

Break 12:00 to 13:30

- Part 4 Tree based Methods to model scenarios of dam failure: Event Tree Analysis, Fault Tree Analysis, Bow Tie method Laurent Peyras (INRAE) and Guillaume Groell (ISL)
   13:30 to 14:30
- Part 5 Assessment of the Probabilities of Failures and Dam Reliability: quantitative probabilistic methods, semiquantitative probabilistic methods – Frédéric Laugier (EDF) and Laurent Peyras (INRAE)
   14:30 to 15:30
- Part 6 Assessment of Consequences and Criticality: flood wave, issue assessment, assessment of exposed populations, criticality analysis Guirec Prévot (French Minister of Environment) and Thomas Adeline (TA conseils) 15:30 to 16:30
- Part 7 Conclusions: Positive Impacts of Safety Review Risk Assessment in Dam Safety Management Guirec Prévot (French Minister of Environment) and Laurent Peyras (INRAE)
   16:30 to 17:00



#### End 17:00 pm

# Concepts of Risk

- Many definitions in the concept of Risk
- Concept well defined in Risk Engineering:
  - measurement of a level of danger [Modarres, 93]
  - association of two variables: [Leroy, 92]
    - 1) probability & 2) consequences

« the Risk is the measurement of a danger (a limit-state) with the measurement of the occurrence of the undesirable event related to the danger and

the measurement of its consequences if the undesirable event occurred »

[Villemeur, 88], [Crémona, 03]

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#### **Process of Risk Control**



des barrages et réservoirs

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#### What is Risk Analysis?

- Risk Analysis consists to answer to the three following questions: [Kaplan, 97]
  - 1. What could lead to a danger situation?
    - $\rightarrow$  determine the scenarios S<sub>i</sub> which could lead to a failure
  - 2. What are the chances that these scenarios occurred?
    - $\rightarrow$  measurement of the occurrence  $P_i$  related to the scenarios  $S_i$
  - 3. If these scenarios occurred, what would be the consequences?
    - $\rightarrow$  measurement of the consequences  $C_i$  related to the scenarios  $S_i$
- Risk Analysis consists to assess the triplet: [Modarres, 93]

 $\Rightarrow R = \langle S_i, P_i, C_i \rangle$ 





## Concept of Risk

#### Measurement of the occurrence of an undesirable event (a limit-state)

1. the probability of a limit-state

➔ probabilistic approach

- 2. the frequency or the failure rate of a system
  - ➔ frequency approach
- 3. possibility of a limit-state

→ expert approach

#### Measurement of the consequences of an undesirable event (a limit-state)

- human cost

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- economic cost
- environmental cost



### **Risk Measurement**

- Multiplication of the occurrence measurement with the consequence measurement : RISK = PROBABILITY x CONSEQUENCES

   → [Euros / year] or [fatalities / year]
- Frequency/gravity graph [Farmer, 67]

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#### **Risk Analysis VS Diagnosis**



### Society Risk Acceptation

- **10<sup>-6</sup> / year probability of dying** [Fischhoff, 99]
  - smoke 1,4 cigarettes / day
  - living to 2 mouth with a cigarette smokeur
  - driving 250 miles
  - living 50 years closed to a nuclear plant
  - living 50 years downstream a large dam





### Principles et steps of a Risk Analysis Study



## Methods for a Risk Analysis Study



NRAQ



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