



# Using Risk Assessments to Support Dam Safety Decision-Making

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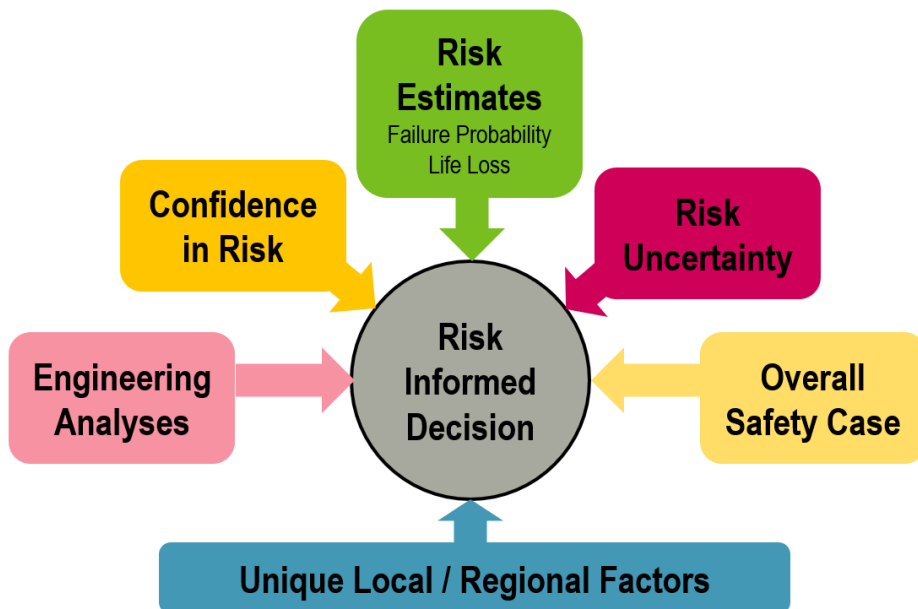


## Potential Failure Modes for 4 dams

- Dam 1: Spillway gates on top of concrete dam will fail for a horizontal seismic load of  $0.4g$
- Dam 2: Impervious material of a core trench for an embankment dam is placed directly on an untreated rock foundation
- Dam 3: Embankment dam overtops by 7 feet for 60 hours during a probable maximum flood event
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# **What is Risk Informed Decision Making (RIDM)?**

# Dam and levee safety is not a “yes or no” question



## Standards Based Approach

Long-standing traditional approach  
Dam safety is judged deterministically.  
*Can the dam pass the “PMF” ? (yes or no)*  
*Will it survive a “MCE” ? (yes or no)*  
*Is the minimum factor of safety satisfied?*

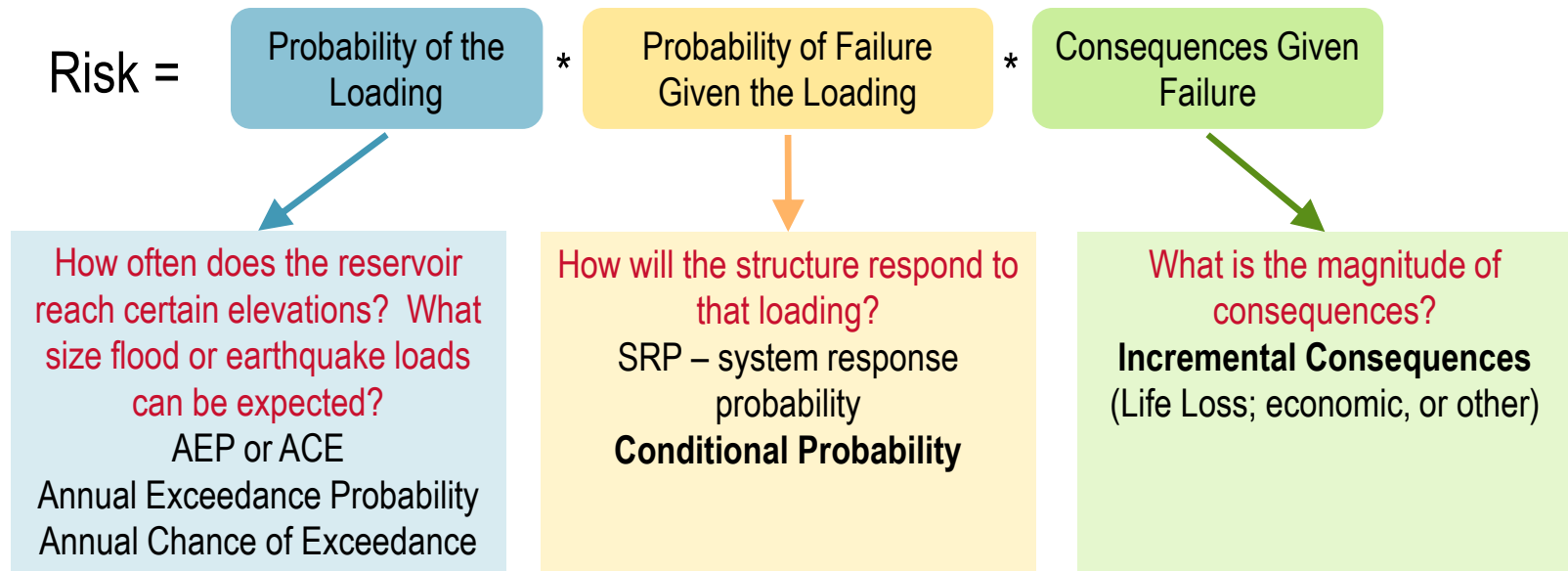
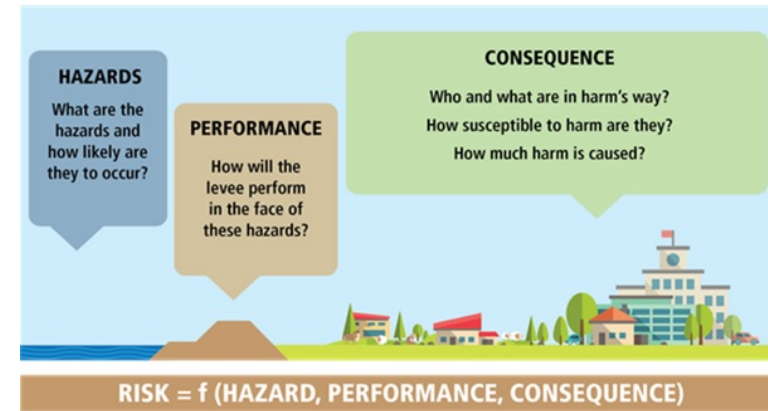
## RIDM

Safety is not a “yes or no” question  
Long history in other industries  
Relatively new to dam/levee safety

# Definition of term “Risk”

Risk analysis of a failure mode: The product of the likelihood of a structure being loaded, adverse structural performance, (e.g. dam failure), and the magnitude of the resulting consequences

**Dam / levee safety risk is measured in terms of lives/year (or \$ / year).**



# Everyday example...

- Most structures don't have serious fires, but we still assess our risk
  - Loading: Fire
    - Wildfire
    - House Fire
  - How will the structure respond?
    - Wood frame
    - Steel or brick structure
    - Vegetation
  - Consequences
    - Loss of life
    - Loss of structure
    - Personal belongings



# What are the benefits of using RIDM for dam / levee safety?

- Improved understanding of the structure and system
- Provides a way to evaluate safety in areas where no traditional SBA have been established
- Provides an understanding of the real liabilities associated with dams and levees
- Allows consequences of failure to be accounted for



## Risk includes Consequences (Life Loss)

*Which one are you more concerned about?*



Embankment dam that satisfies all SBA criteria with 300 people living **immediately** downstream



Factor of safety of 1.1 for 0.3g seismic loading

# **Guidance Documents & Terminology**

# Key Risk Guideline Documents:

- FEMA (2015) Federal Guidelines for Dam Safety Risk Management
  - Overarching guidance for all Feds (potential framework for states)
- USACE (2015) ER 1110-2-1156
  - Guidelines, policy, procedures, governance (..being updated)
- Reclamation Public Protection Guidelines (2011)
  - Guidelines, policy. (...being updated)
- Best Practices in Dam and Levee Safety Risk Analysis (2019)
  - 40+ chapters and presentations on “how to” estimate risk
- FERC RIDM Guidelines (2016)
  - Regulatory guidelines, process
- FERC Engineering Guidelines for the Evaluation of Hydropower Projects, Chapters 15 through 18 (2021)
  - Formalizing PFMA and RIDM with Part 12D process; guidelines, procedures, process



# Montana Dam Safety Program

- TN1 – Analysis of Spillway Capacity
  - Determining minimum IDF for dams based on loss of life
- TN2 – Loss of Life Determination for Spillway Capacity
  - “As potential for life loss downstream increases, the spillway standard increases...”
- TN7 – Guidelines for Conducting an FMA for Montana Dams



## Technical Note 1

**Determination of the Inflow Design Flood  
for High Hazard Dams in Montana**



## Dam Safety Program Technical Note 2

**Estimating Loss of Life for  
Determining the Minimum Inflow Design Flood Recurrence Interval**

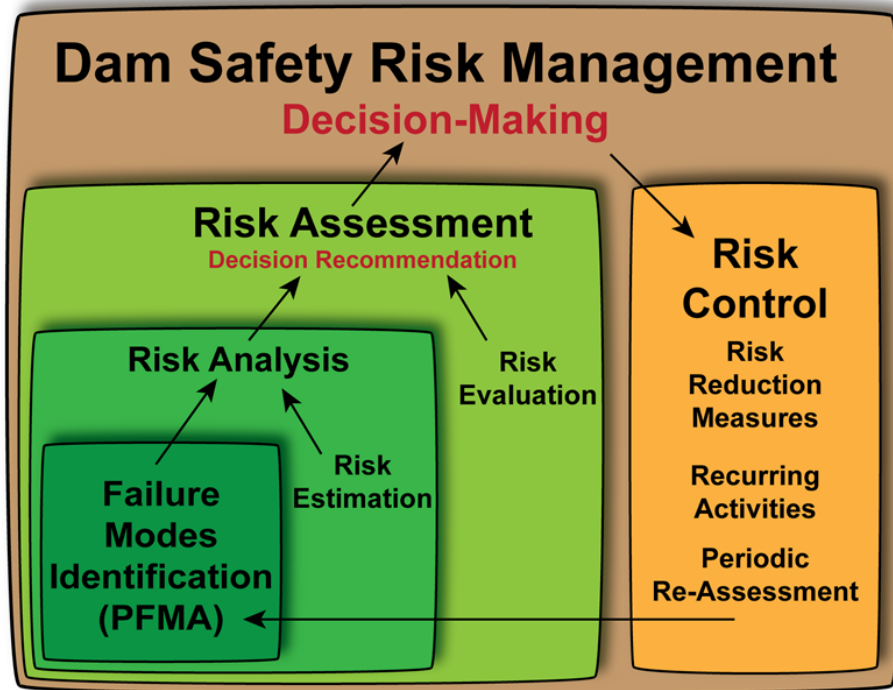


## DAM SAFETY PROGRAM TECHNICAL NOTE 7

**GUIDELINES FOR CONDUCTING A SIMPLIFIED FAILURE  
MODE ANALYSIS FOR MONTANA DAMS**

# Elements of Dam Safety Risk Management

- Terminology



## Federal Guidelines for Dam Safety Risk Management

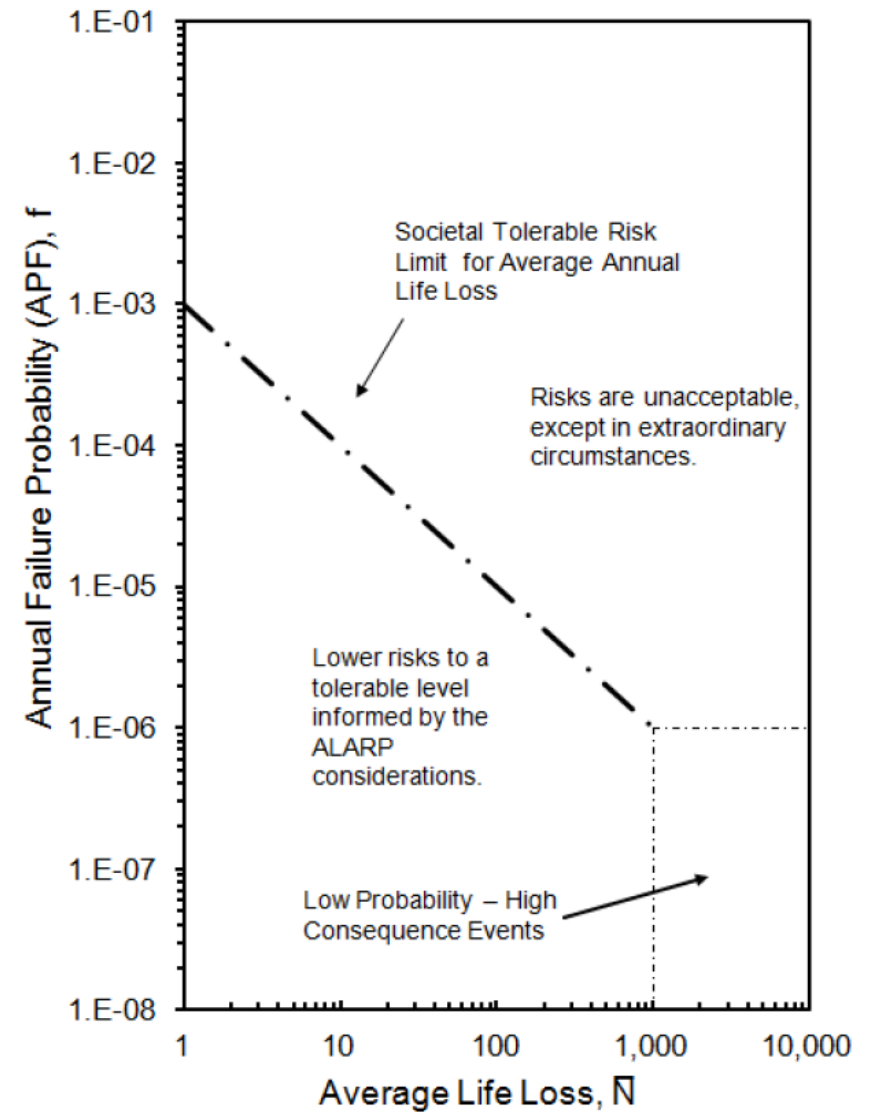
FEMA P-1025/January 2015



FEMA

# Risk Portrayal and Tolerable Risk Guidelines

- Risks that society is willing to live with to secure certain benefits (e.g. flood protection, irrigation water, hydropower, etc.)
- Portrayed by a diagonal line of equal societal risk that indicates the annual failure probability ( $f$ ) decreases as the average life loss ( $N$ ) increases
- Common set of guideline values for all federal agencies
- Agency processes and methods of implementation vary by organization



# Risk Portrayal (life safety)

Colorado Dam Safety

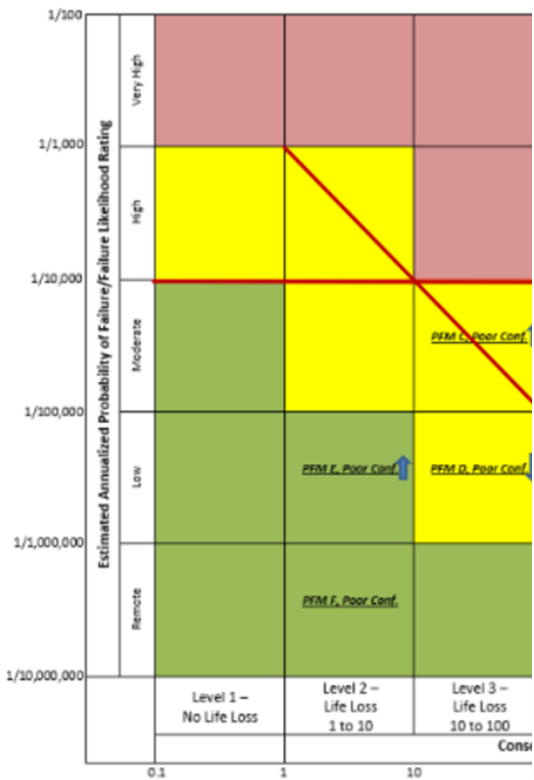


Figure 12 - Colorado Dam Safety Branch Risk Matrix (colored boxes (blue up and down arrows)).

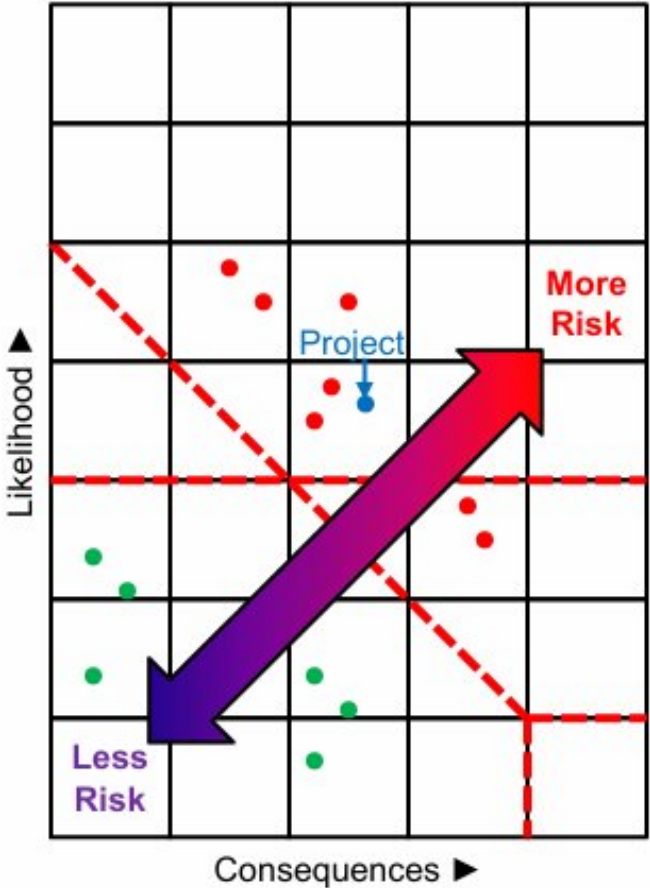
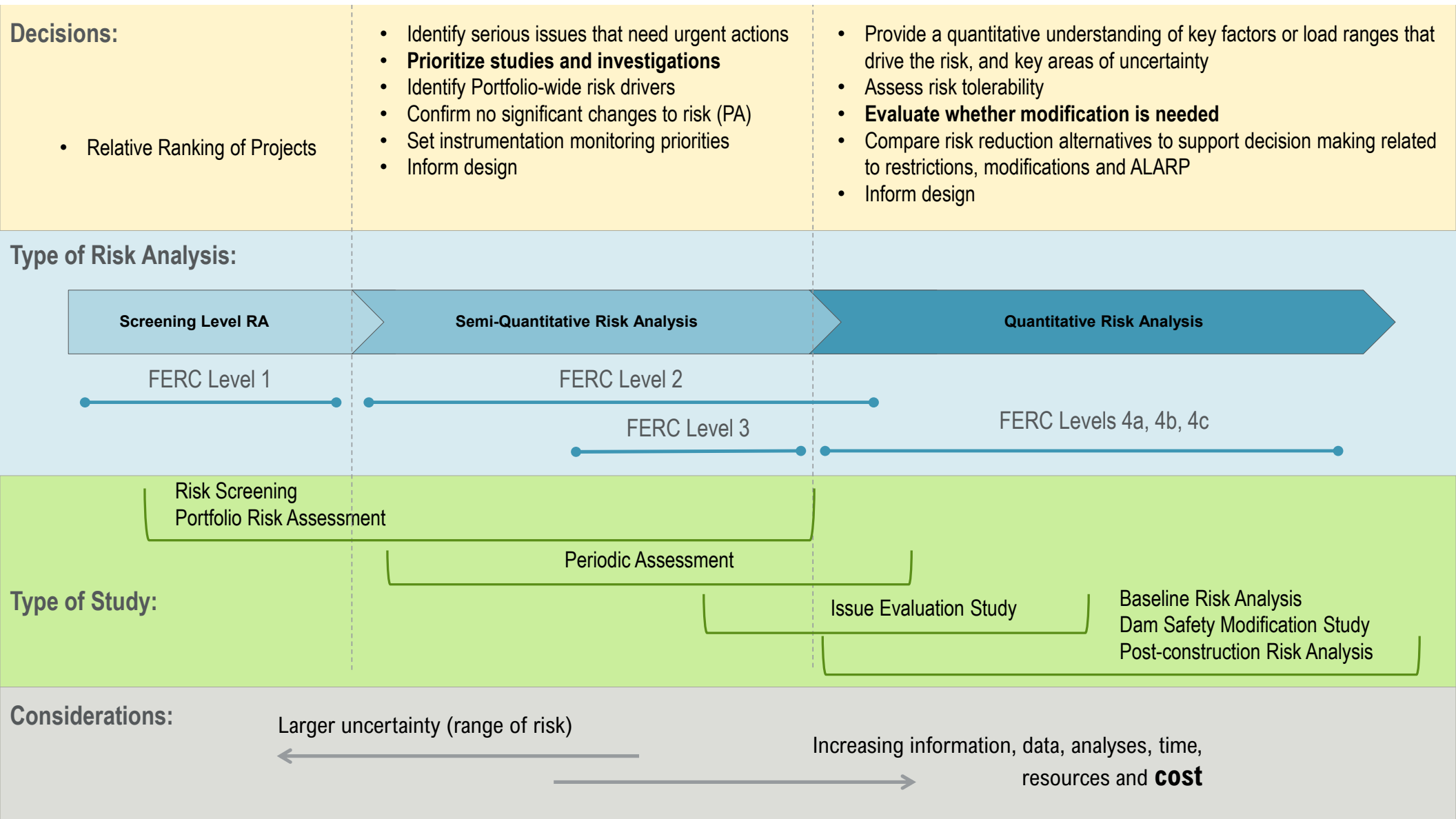


FIGURE 10. RISK ANALYSIS MATRIX FOR SOCIETAL INCREMENTAL LIFE SAFETY RISK

Risk analysis matrix  
(ERC Chapter 18)



# **Types and Purposes of Risk Analyses for Dam Safety**



# Risk Team Composition

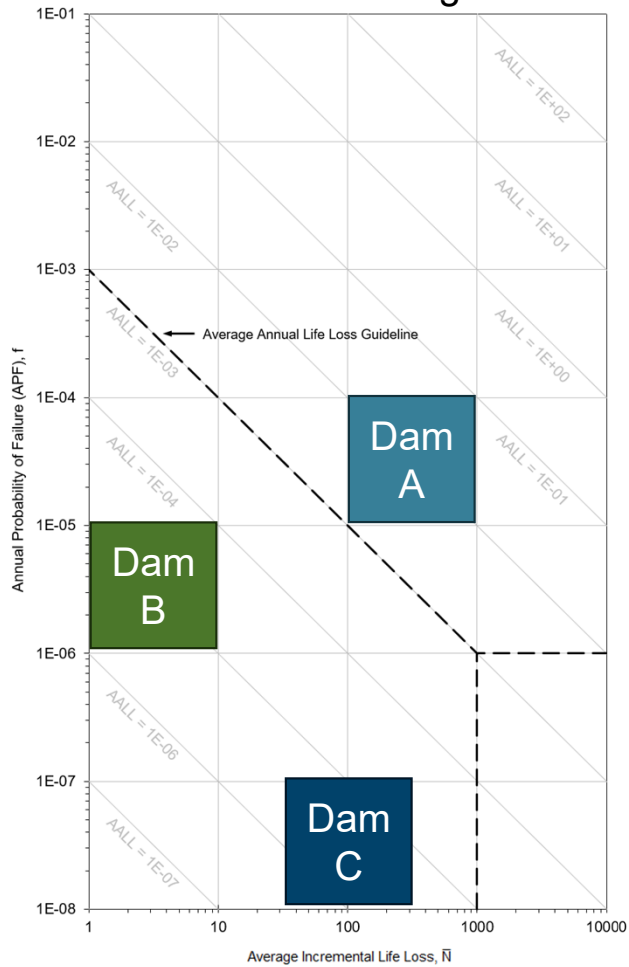
- Facilitator
- Note Taker
- Subject Matter Experts (risk estimators)
- Loading Specialists
  - Hydrologic
  - Seismic
- Consequences Specialist
- Risk Modeler (for QRAs only)
- Other Participants
  - Owner representatives, regulators, other consultants, observers and advisors

## Types of Risk Analysis

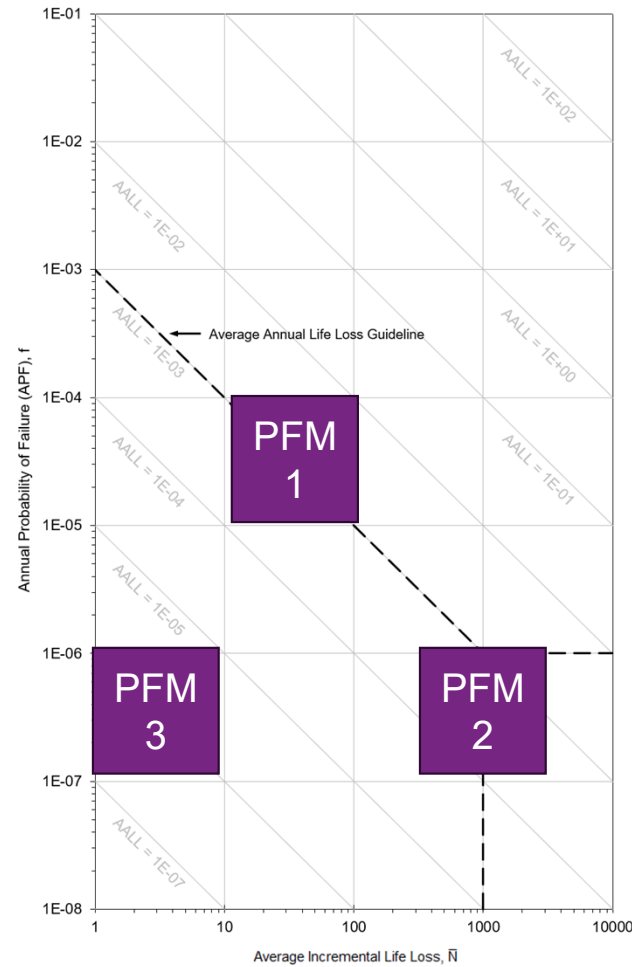
- Screening Level – 2 to 3 individuals
- SQRA – 3 to 8 individuals
- QRA – 10+ individuals

# Examples

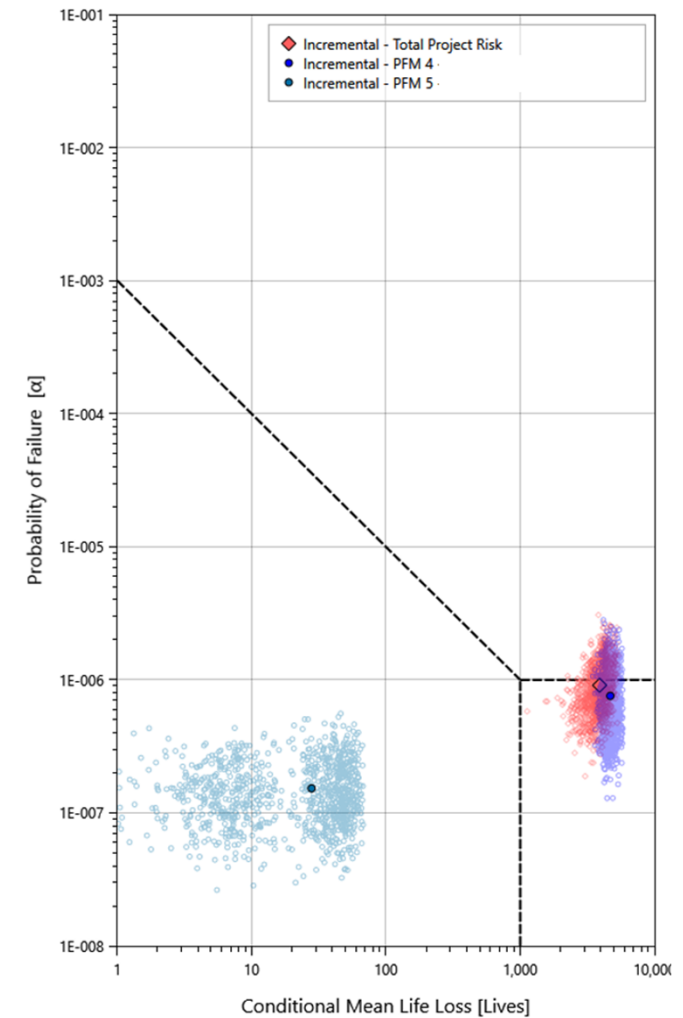
## Portfolio Screening Level



## SQRA for 1 Dam



## QRA



# **Value of Risk Informed Decision Making**

# Dam / Levee Safety Decisions

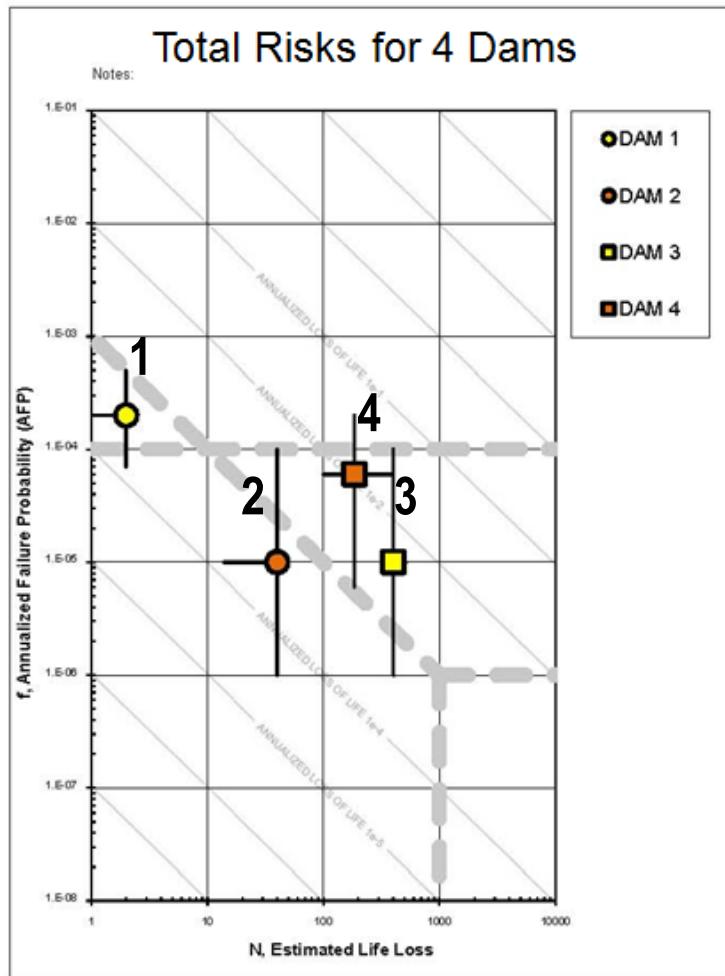
- Is it a dam/levee safety issue? How bad?
- Fix now or investigate and study more?
- How far down to drive risk?
- Which remedial alternative to choose?
- What design features to include?
- Are we spending too much?
- Implement reservoir restrictions?
- Invest in EAP, structural fix or both?

**It Depends...**

{ Location on a risk plot  
Confidence  
Uncertainty

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**Questions?**

