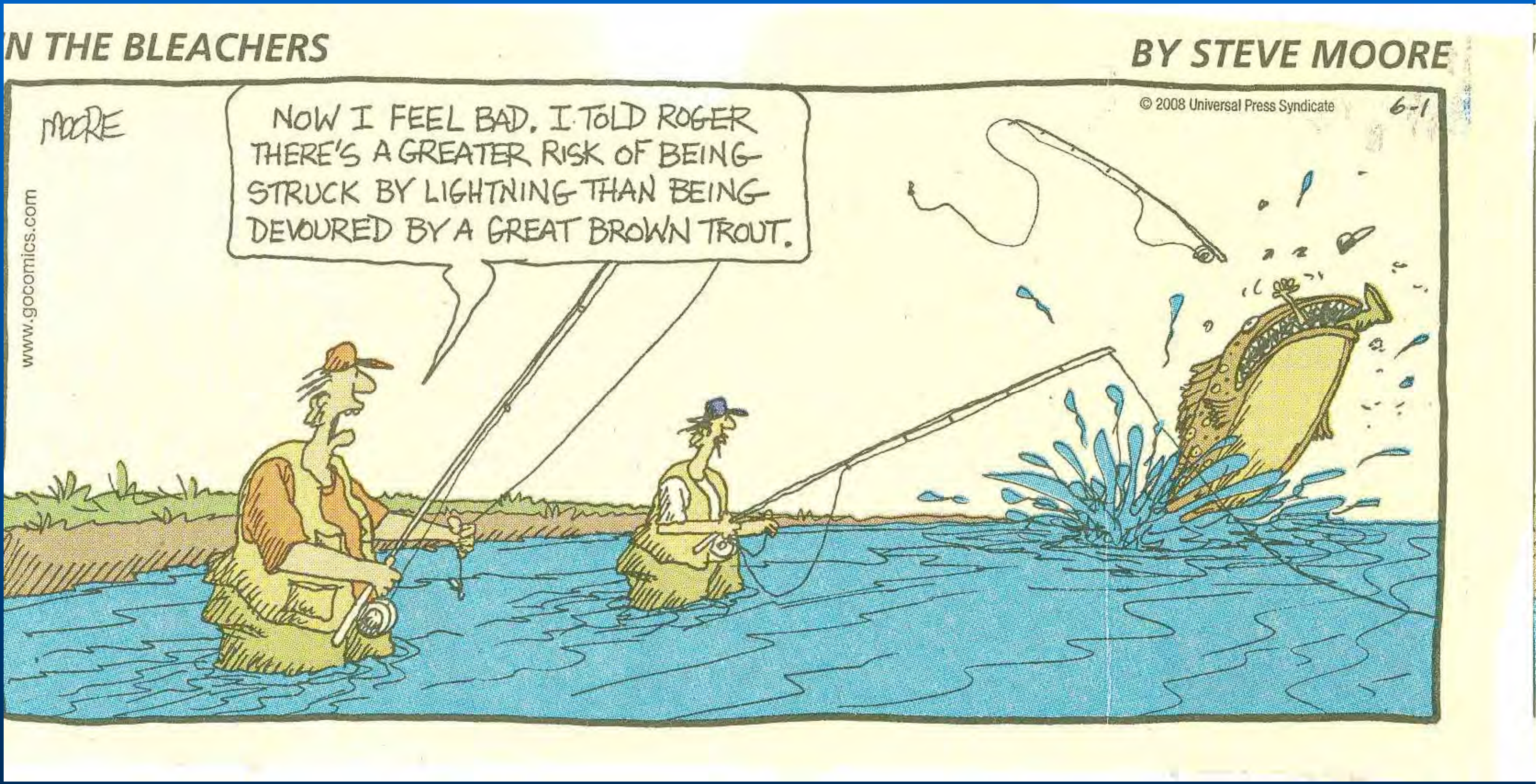
2013 RIDM
Level 2 Workshop

RIDM Training Tool Concepts

FEDERAL ENERGY REGULATORY COMMISSION
OFFICE OF ENERGY PROJECTS
DIVISION OF DAM SAFETY AND INSPECTIONS

How to Calculate Risk?



What is Risk?

- “Risk is a function of three terms: ν_{LL} (frequency of life loss), LL (actual number of lives lost), and p (probability that provides a measure of the uncertainty in the analysis) *Martin McCann, Stanford University*

Risk

Risk = Probability of Failure x Consequences

Probability of Failure = Probability of Load x Structural Response Given Load

RIDM Challenges

- Current PFMs are not universally well described
- Some PFMAs did not consider all pertinent PFMs
- No existing PFHA information readily available
- No existing PSHA information readily available
- No to very limited consequence information (PAR, PLL) information available

Risk Analysis Needs

- Improve PFMs
- Develop all pertinent PFMs
- Develop PFHA curves
- Develop PSHA curves
- Develop consequence information (PAR, PLL)

Risk Evaluation

- **Not all PFMA Category I and II PFM's are equivalent:**
  - **Is a Cat II piping failure mode driven by past observance of sediment retained behind a seepage weir many years ago for a dam 15 miles upstream of one or two houses the same as**
  - **A Cat II overtopping failure mode due to PMF flows failing a dam with a small town located immediately downstream of the dam the same as**
  - **A Cat II overtopping failure mode due to inoperability of the dam's only spillway gate during a 300-year flood for a dam with a large population center located a short distance downstream of the dam?**

RIDM Approach

- Four Phases

1. Original PFMA w/3 Qualitative Categories (I, II, and IV)

2. Screening Level Portfolio RA (SLPRA) – FERC Internal
   - Simple potential life loss estimates
   - Flood and seismic failure modes loading estimated
   - Estimates within about 2 orders of magnitude for Annualized probability of failure APF

RIDM Approach

- Four Phases

3. Team-Based Semi-Quantitative RA – Includes Owners, Consultants, and FERC staff

4. Quantitative Risk Analysis (QRA)

Semi-Quantitative Risk Analysis (SQRA)

- Next logical step in PFMA process
- Taking PFM's and categories to a deeper understanding
  - Ability to estimate potential consequences to public safety resulting from dam failure
  - Ability to more closely compare probability of failure between various potential failure modes
  - Ability to identify need for additional information, about PFMs, instrumentation and monitoring, inspection frequency, EAP testing requirements
  - Ability to more consistently define urgency of response and action

SQRA

- The FERC is developing SQRA to be a formal part of our RIDM program.

- The Corps of Engineers is using a version of SQRA to conduct Periodic Assessments of their dams every 10 years.

- SQRA uses more complete information than the RIDM TT or the FERC Screening tool (SPRA).

SQRA

- Compared to SLPRA
  - Slightly to significantly more refined loads (PSHA and FFA)
  - Better potential life loss estimates
  - Simple event trees for critical failure modes
  - Estimates within about 1 order of magnitude for APF.

RIDM Training Tool

RIDM Training Tool

- The RIDM Training Tool is similar to the SLPRA screening tool used to train FERC staff.

- The RIDM TT is also a semi-quantitative risk analysis tool.

- The tool uses improved and complete PFM descriptions to develop the PFM likelihood categories.

RIDM Training Tool

- The tool also develops basic consequence information
- Confidence limits are estimated to help in decision making about each PFM and consequence categorization
- The likelihood and consequence information is plotted on a matrix.

RIDM Training Tool

- We are using the RIDM TT to teach the concepts of risk.
- The RIDM TT is a simpler version of the Semi-Quantitative RA (SQRA) procedure currently being developed by a D2SI Risk Engineering Guidelines Committee
- The next slides describes how the RIDM TT is to be completed.

Step 1: Potential Failure Mode Analysis (PFMA)

Describing a PFM

Three key elements of a potential failure mode description are:

- **The Initiator** (e.g. reservoir load, deterioration/ aging, operation malfunction, earthquake, flood, etc…)
- **The Failure Mechanism/Progression** (Including location and/or path) (**Step-by-step progression**)
- **The Resulting Impact on the Structure** (e.g. full or partial failure, rapidity of failure, breach characteristics)

Potential Failure Mode Considerations

- The list of **items** to consider for potential failure modes is almost **never ending**, especially for some embankment dams.
- Each dam is **unique** in precise PFMs but four sets of loading conditions should be considered as a minimum, normal, flood, earthquake, and operational.
- **Continue** developing the PFM until you hit a "**wall**".
- Use engineering judgment / common sense
- Daily use of **risk** thinking

Revised Potential Failure Mode

- **Unedited (insufficient detail – 2 PFMs): Sliding of the concrete dam foundation.**

- **Edited – PFM 1:**
  - As a result of high reservoir levels and a **continuing increase in uplift pressure** on the old shale layer slide plane at about elevation 1135 on the right side of the dam, sliding of the buttresses initiates.
  - Major **differential movement between two buttresses takes place causing the deck slabs to be unseated** from their simply supported condition on the corbels.
  - **Breaching** failure of the concrete dam **through two bays results**.
  - Lateral loading of adjacent buttresses causes "domino" buttress **collapse to the massive spillway section in the center of the dam**.

Revised Potential Failure Mode

- **Unedited (insufficient detail – 2 PFMs): Sliding of the concrete dam foundation.**

- **Edited – PMF 1A:**
  - As a result of high reservoir levels and a **decrease in shearing resistance** due to gradual creep on the slide plane at about elevation 1135 on the right side of the dam, sliding of the buttresses initiates
  - Major **differential movement between two buttresses takes place causing the deck slabs to be unseated** from their simply supported condition on the corbels
  - **Breaching** failure of the concrete dam **through two bays results.**
  - Lateral loading of adjacent buttresses causes "domino" buttress **collapse to the massive spillway section** in the center of the dam**.**

Developing Likelihoods for PFMs

- Review existing PFMs
  - Descriptions must be complete
  - PFMs must be comprehensive
- Review favorable and adverse factors
- Develop PFMs as fully as possible.

Developing Likelihoods for PFMs

- Develop a list of all PFMs.
- Select critical PFMs.
- Develop critical PFMs into event trees as follows.
  - Initiator: For instance, deterioration of a metal drain leads to beginning of backward internal erosion.
  - Step-by-step: Each step of developing a pipe to connect to the reservoir is developed.
  - Breach: Dam failure develops.

Step 2: RIDM TT Likelihood

RIDM TT Likelihood

- Likelihood is combination of the probability of the **initiating event** times the **adverse reaction** of the structure.

Initiating Condition - Probability of Load

- Probability of Load
  - Static Loading = Reservoir Elevation Frequency Curve
  - Flood Loading = Basic Probabilistic Flood Hazard Analysis (PFHA) Curve
  - Earthquake Loading = Probabilistic Seismic Hazard Analysis (PSHA) Curve, if available, or USGS Web information

RIDM Likelihood Categories

- The following tables were used for the SLPRA.
- The COE uses a similar but slightly different table for SQRA
- For a FERC SQRA these tables may change.

Likelihood of Failure

Category	General Description	APF
Remote	The physical ***conditions do not exist*** for its development or the likelihood is so remote. Several ***events must occur concurrently*** or in series to trigger failure. Most, if not all of the events are ***very unlikely***. Or, it would likely take a flood or earthquake with a return period of more than ***1,000,000*** years to ***trigger*** the potential failure mode.	< 10^{-6}
Very Low	The possibility ***cannot be ruled out***, but there is ***no compelling evidence*** to suggest it has occurred or that a ***condition or flaw exists*** that could lead to its development. Or, a flood or earthquake with a return period of between ***100,000 and 1,000,000*** years would likely ***trigger*** the potential failure mode.	10^{-6} to 10^{-5}
Low	The fundamental condition or ***defect is known to exist***, ***indirect evidence*** suggests it is ***plausible***, but evidence is ***weighted more heavily toward unlikely than likely***. Or, a flood or earthquake with a return period between ***10,000 and 100,000*** years would likely ***trigger*** the potential failure mode.	10^{-5} to 10^{-4}

Likelihood of Failure

Category	General Description	APF
Moderate	The fundamental condition or ***defect is known to exist***, indirect evidence suggests it is ***plausible***, but evidence is ***weighted more heavily toward likely than unlikely***. Or, a flood or earthquake with a return period between ***1,000 and 10,000*** years would likely ***trigger*** the potential failure mode.	10^{-4} to 10^{-3}
High	There is ***direct evidence*** or substantial indirect evidence to suggest it ***has occurred or is likely to occur***. Or, a flood or earthquake with a return period between ***100 and 1,000*** years would likely ***trigger*** the potential failure mode.	10^{-3} to 10^{-2}
Very High	There is ***direct evidence*** to indicate that it is ***actively occurring or is likely to occur***. Or, a flood or earthquake with a return period of ***less than 100*** years would likely ***trigger*** the potential failure mode.	$> 10^{-2}$

Likelihood Considerations

- The failure likelihood categories described above indicate the associated general range of annual probability of failure.
- Assign the failure likelihood category based on combination of likelihood of initiating loading and likelihood of dam failure from that loading.
- If the potential failure mode is initiated by a flood or seismic event, the probability of the load will greatly influence the appropriate failure likelihood category.
- For example, the failure likelihood category can be considered ‘very low’ or ‘remote’ for most PFMs initiated by floods near the PMF, if this extreme flood can be passed with reasonable flood routing assumptions.

Likelihood Considerations

- The "initiator" node of an event tree likelihoods are usually relatively easy to estimate.
- There are many more nodes (branches) on a given event tree associated with the facility response.
- The factors increasing or decreasing the likelihood of each node can be used to adjust the likelihood that the initiating event will actually lead to a dam failure, and thereby build the case for the likelihood category that best fits the given potential failure mode.

Confidence

- We can also assign a confidence to qualitative estimates of PFM likelihood
- Confidence: High, Moderate, and Low Confidence

Confidence

- High confidence in a likelihood estimate means we are unlikely to revise our estimate with more information.
- Low confidence means we are likely to revise our estimate with more information
- Moderate confidence means we are unsure about the potential to change the estimate

DISCUSSION/QUESTIONS?

Step 3: Risk Consequences

Consequences

- The consequence information will be discussed in the next presentation.