Probabilistic Analysis of Systems in Engineering

Process of natural hazards

Dam Safety Assessment

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functions of dams:

1. flood control
2. Water conservation
3. Water supply
4. Hydropower generation
5. other uses

A dam risk analysis model:

1. The loading conditions
2. The system response probability
3. Consequences estimates

Risk analyisis for dam safety is the process of identifing the likelihood of dam failure and estimating adverse consequences* resulting from dam failure. Objects:

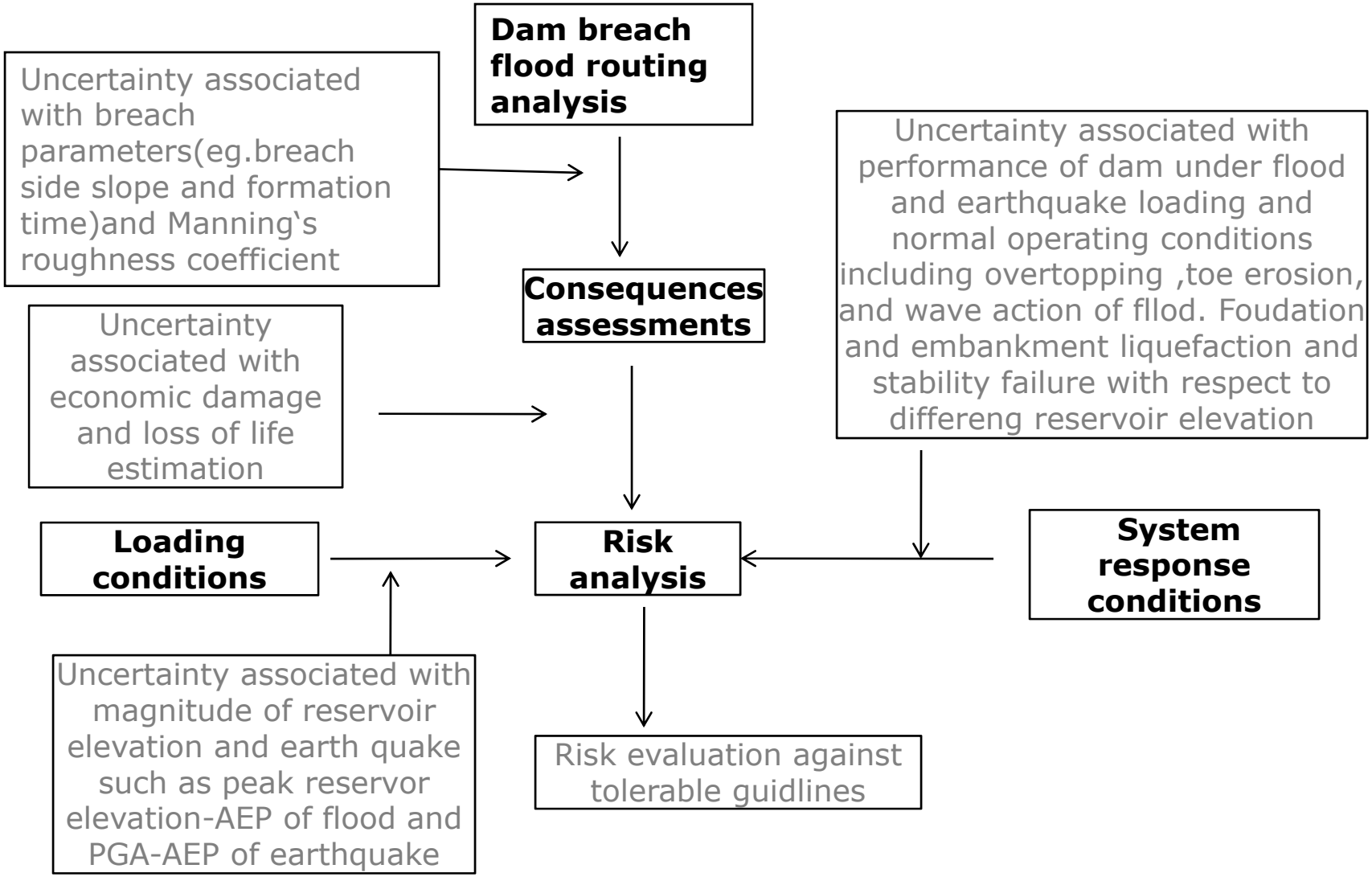
Provides a **framework** for dam safe assessment

Provides information for decision-maker

Risk analysis requires:

1. A great deal of engineering and computer modeling analysis
2. Extensive statistical estimation from empirical data
3. The professional judgement of experts when available data are limited
4. Making simplified assumptions

(*Baecher and Christian,2001)



framework of uncertainty analysis for dam safe assessment

Methods for consequences of dam failure

Life loss estimation from dam failure suggested by Graham's(1999),providing Fatality Rates based on:

- The flood severity – low, medium or high
- Amount of warning- warning time
- Flood severity understanding- a measure of whether people understand the severity of the flooding

Uncertainty Propagation Methods

•Scenario tree

It is a simple way to investigate all possible combinations of each level of each input with each level of each other input

•Probability tree

The uncertainty in each variable is quantified by attaching conditional probability to each branch of the scenario tree.

•Sampling method

A representative sampling method is the Monte Carlo simulation technique

(Isukapalli,1999) applied to the reliability assessment of structure

Dam breach flood routing analysis

Uncertainty of dam breach Parameters are the shape, size(depth and bottom width), formation time of dam breach, and other breach characteristics.

The dam breach dimension and time for the breach development are strongly effect by the structural type and size of a dam, foundation geology and treatment during construction.

A very important parameter: **Manning's roughness coefficient** represents channel resistance to flow in rivers, used for calculating frictional losses.

In general ,the values are determined using the historical data of dam failure and the available guidelines or equations.

The differences in characteristics of dam breach floods compared with natural flood*:

•1.flood occur in previously un-inundated areas, so that previous flood data are not very useful in estimating Manning coefficient

•2.inundated areas often contain more flow resistance in the form of trees ,house ,etc, which are not typical of the resistance that was encountered by most normal flood

•3.the floodplain flow may short-circuit a meandering channel ,thus causing additional flow resistance

•4.Debris, trees, etc. uplifted and transported by the flood ,may become impinged on permanent structures, and this leads to additional undefined flow resistance

*Fread (1981)

The differences in characteristics of dam breach floods compared with natural flood*:

•5.Sediment entrapped behind the dam and released during the failure may slightly reduce the flow resistance when deposited on the floodplain

Thus Manning's roughness coefficient estimating based on the historical flood events should be adjusted to apply, and the uncertainty of dam breach flood routing results due to the coeffcient must be properly explained.

Process of dam safety risk assessment

The process consists of four major components:

- 1.risk identification
- 2.risk estimation
- 3.Risk evaluation
- 4.risk treatment

- 1.Risk identification is to define the external and internal initiating events and failure modes that can be caused by the initiating events .

- External: Earthquake ,upstream dam failure
- Internal: Piping

•system response: overtopping deformation slope instability
•Outcome: Breach or No Breach
•Exposure: Time of day , season, warning time
•Consequence :Economic damage, Loss of life ,Environmental, social

•2.Risk estimation determined loading conditions and system response probabilities.
The risk of dam failure is computed by using the probability and consequence estimates for the various failure and no-failure scenarios model.

•3.Risk evaluation judges the significance of the estimated risk for the existing dam and each risk reduction alternative using risk-based guidelines and other consideration.

•4.Risk treatment makes some decisions for improving dam safety and prioritizing dam safety work.

loading conditions

Flood loading:

It was characterized using a peak reservoir elevation versus annual exceedance probability relationship for the existing dam and each flood.

earthquake loading:

It is described with a peak ground acceleration versus return period relationship.

Internal loading:

The internal or static loading conditions are characterized by the number of days that reservoir elevation equaled or exceeded each elevation and the reservoir stage relationship. They are described with a reservoir stage versus duration relationship that is obtained from daily inflow record of many years .

Failure Modes

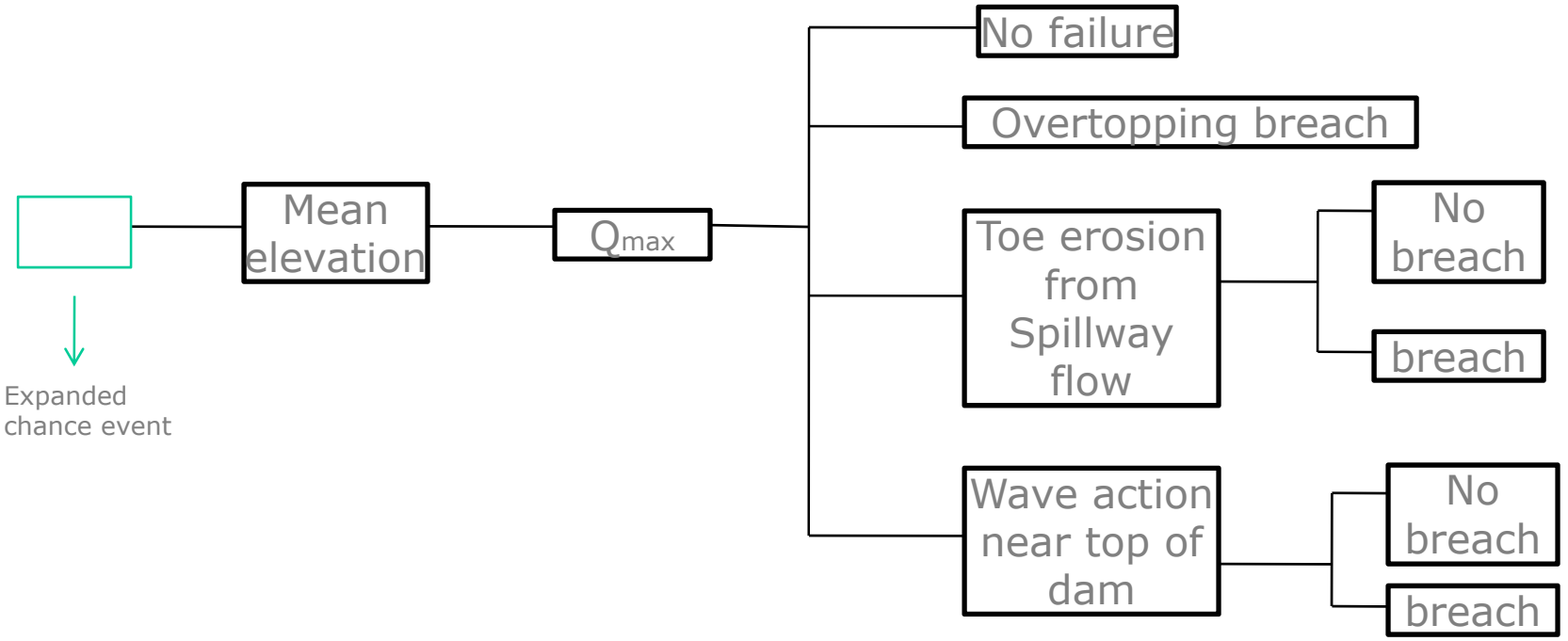
Flood failure modes: overtopping, crest erosion, toe erosion, and wave action

earthquake failure modes :Foundation liquefaction and embankment liquefaction

Internal failure modes :Embankment piping and slope stability

Process of dam safety risk assessment

The example event tree for the flood is shown as



System Response Probabilities for flood

As shown on the event tree for flood loading, take the overtopping system responsibility as example, a number of factors are taken into consideration:

1.The erodibility of the material on the downstream face of the dam

2.The well maintained and paved dam crest

3.The potential duration of overtopping

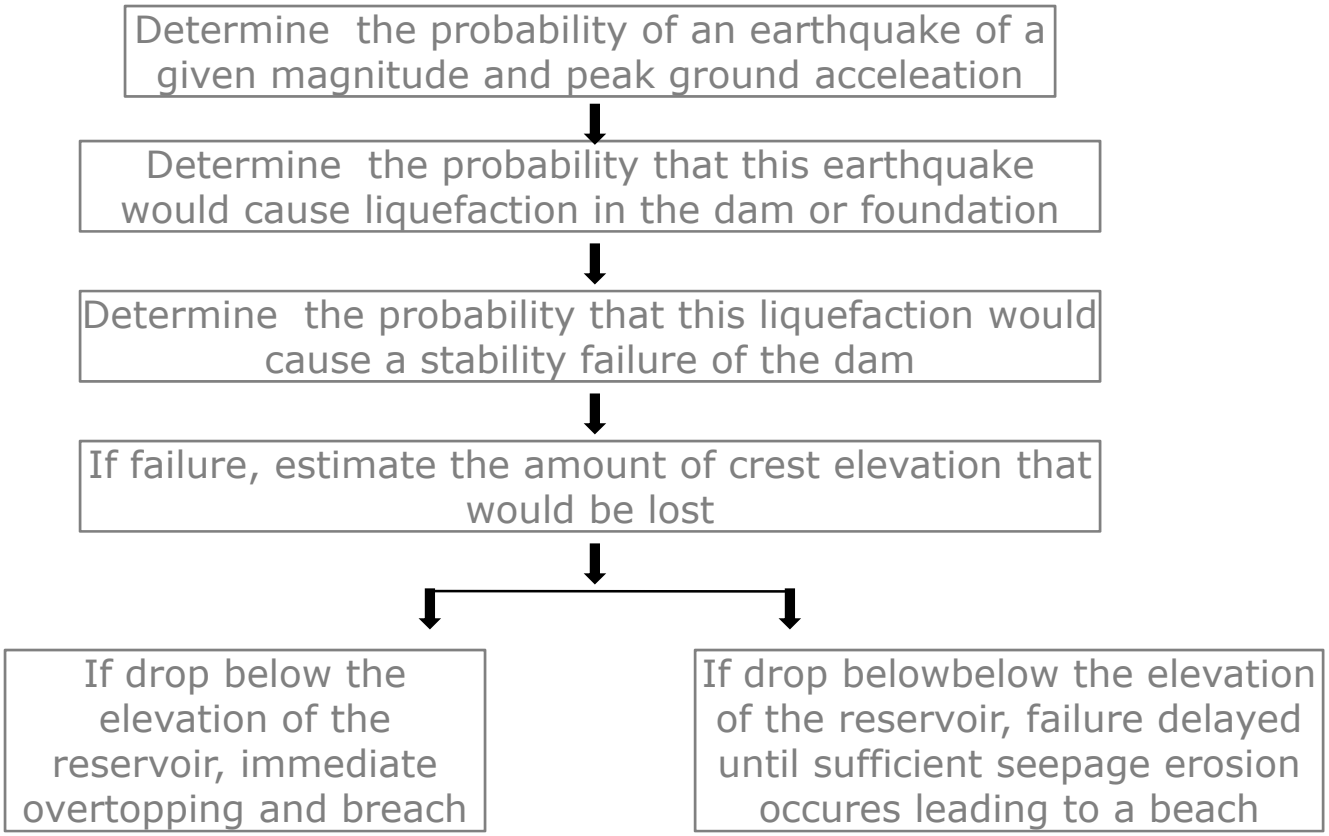
4. The protection of the groins where flow would be concentrated

5.Comparisions with relationships developed for other dams

The relationship is a function of given depths of overtopping. The System Response Probability increase as the depth of overtopping increase.

System Response Probabilities for earthquake

It is estimated with respect to the conditional probability of liquefaction, a stability failure ,and a breach.



System Response Probabilities for internal loading

The static case are different from the previous cases, because there is no specific loading event to trigger the event tree failure pathway.

So estimating base on the historical failure record for dams.
using Embankment piping and slope stability, because they are functions of reservoir elevation.

There are various types of **risk reduction alternatives** according to potential failure modes. The descriptions and expected cost of an example are as follows:

Partial flood fixes	Downstream toe protection	1.59
	Wave protection at crest	1.47
	Raise embankment ,includes above two	9.03
Complete flood fixes	Hardening downstream embankment face (concrete)	31.22
Earthquake and internal fixes	Upstream and downstream berm	47.86
	Downstream berm	14.81
	Soil mixing of foundation material/ chemical grouting	40.09

Summery

Uncertainty factors involved in the procedures of dam safety risk assessment are different from dam to dam and vary with time and space. therefore, it requires a tremendous amount of information and time to consider all uncertainty factors that effect a dam safety risk assessment.

Here , it just shows the frame and process including some importance parameters and considerations. They are very importance concepts in the specific calculation afterwards.

Thank you!