Uncertainties, Frequency-consequence Diagram

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Methodic uncertainties at the level of plant model

Fault Tree (CCF,HRA), Event Tree (scenarios, physical phenomena)

- Adequacy of modeling approach: static approach vs. dynamic behavior; exclusion of certain failure types (e.g. human error of commission); system boundaries.
- Quantification of the model
  - Data base: statistical basis
    - o Engineered judgment
    - o Generic
    - o Plant specific
  - Population, relevance, uncertainty bands ($\rightarrow$ error propagation)
  - Assumptions: rare event approximation, „cut-offs", „binning" ($\rightarrow$sensitivity studies)

- Completeness of accident scenarios ($\rightarrow$ large number) and model validity ($\rightarrow$check against experiments and experience)

Overview of PRA methodology
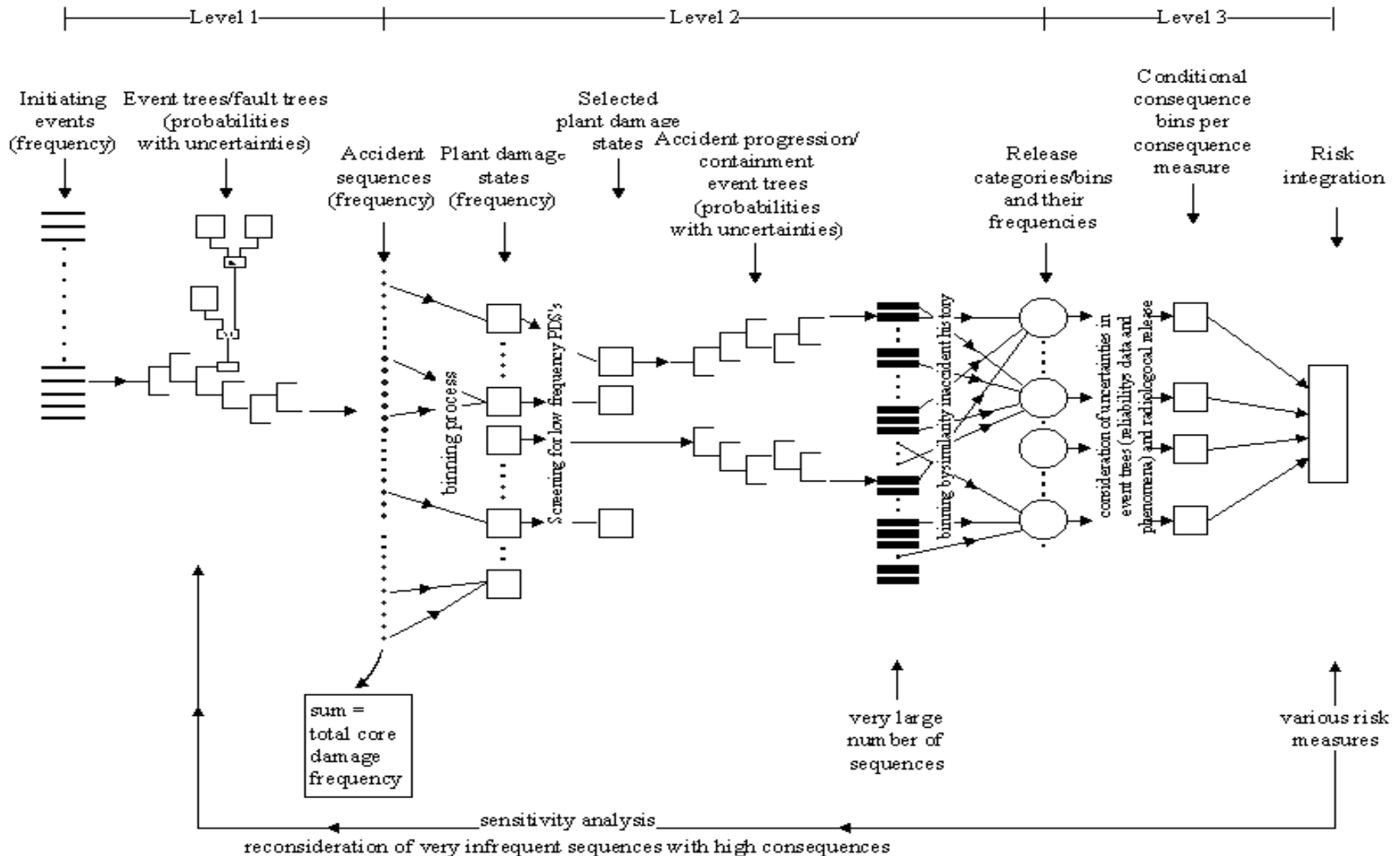
Uncertainty: Percentiles

- A percentile is the value of a variable below which a certain percent of observations fall.

- So the 95th (5th) percentile is the value below which 95% (5%) of the observations may be found.

- The 50th percentile is the value where half of the outcome will be higher and half will be lower. It is called the **median**.

- The 50th percentile and the **average** are different meassures.

  Example:

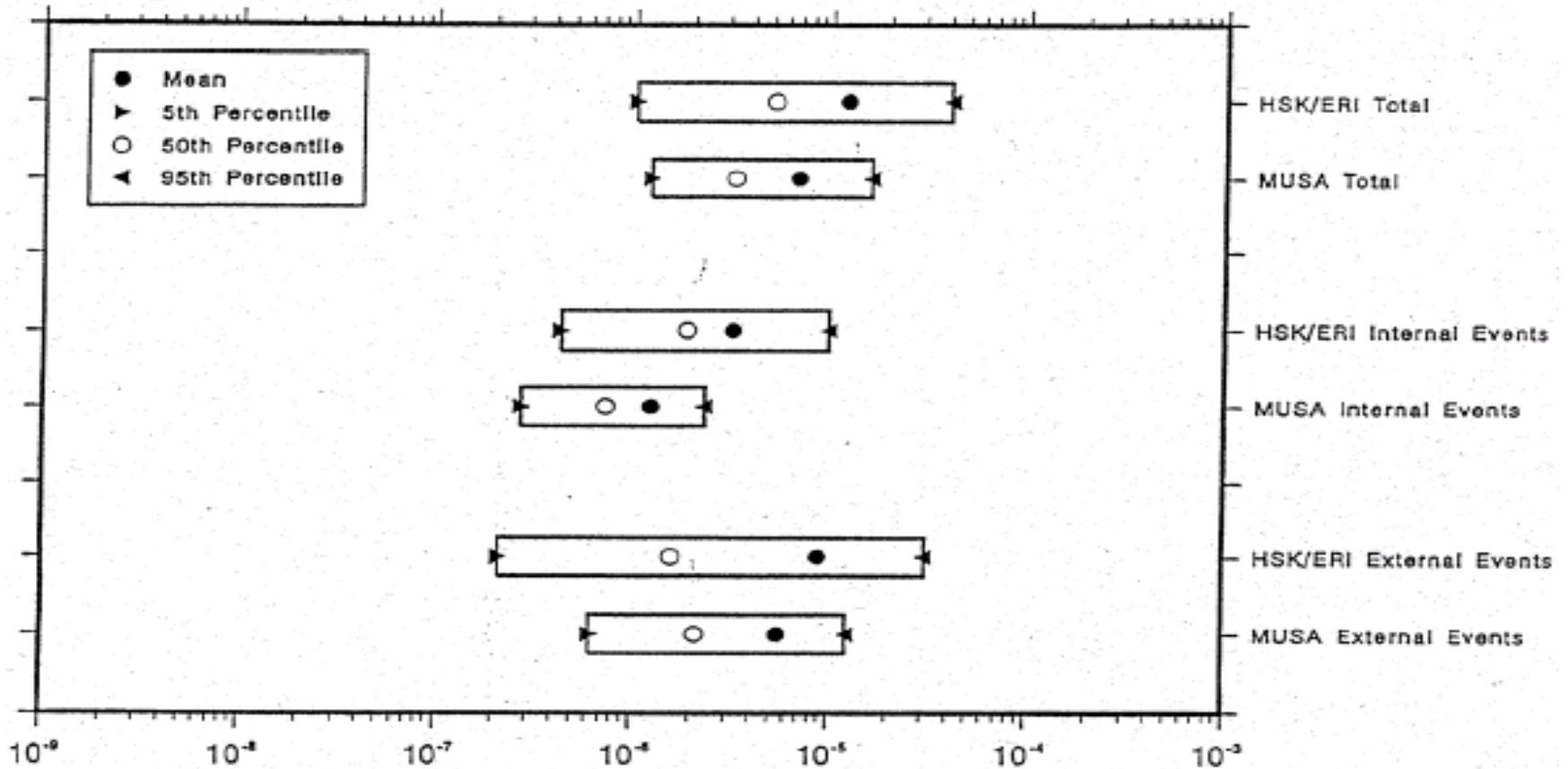 2, 3, 5, 9, 11

  50th percentile=5   Average=6

n= (P/100)*N+1/2
P: the value of percentile
N: the number of total ordered values

# Level 1 PRA results for KKM in comparison ("peer review")

MUSA: Mühleberg Safety Analysis
HSK: Hauptabteilung für Sicherheit von Kernanlagen
ERI: Energy Research, Inc.

# Representing results of a full scope risk analysis

- **Risk** is represented by the parameters **frequency** and **consequence** of undesired event and related scenarios
  - The **frequency** of an event is estimated by the direct use of accident statistics, assessments and models (FMEA, Event/Fault Trees) with statistical data at components' level
  - The **consequences** for the public and the environment are estimated by use of dispersion/transport models and dose-effect relationships.

- The results of the risk analysis are often represented in **frequency-consequence** diagrams with cumulative frequency and consequences plotted against each other. For a given extent of an event the frequency and associated uncertainties can be read out of the diagram.
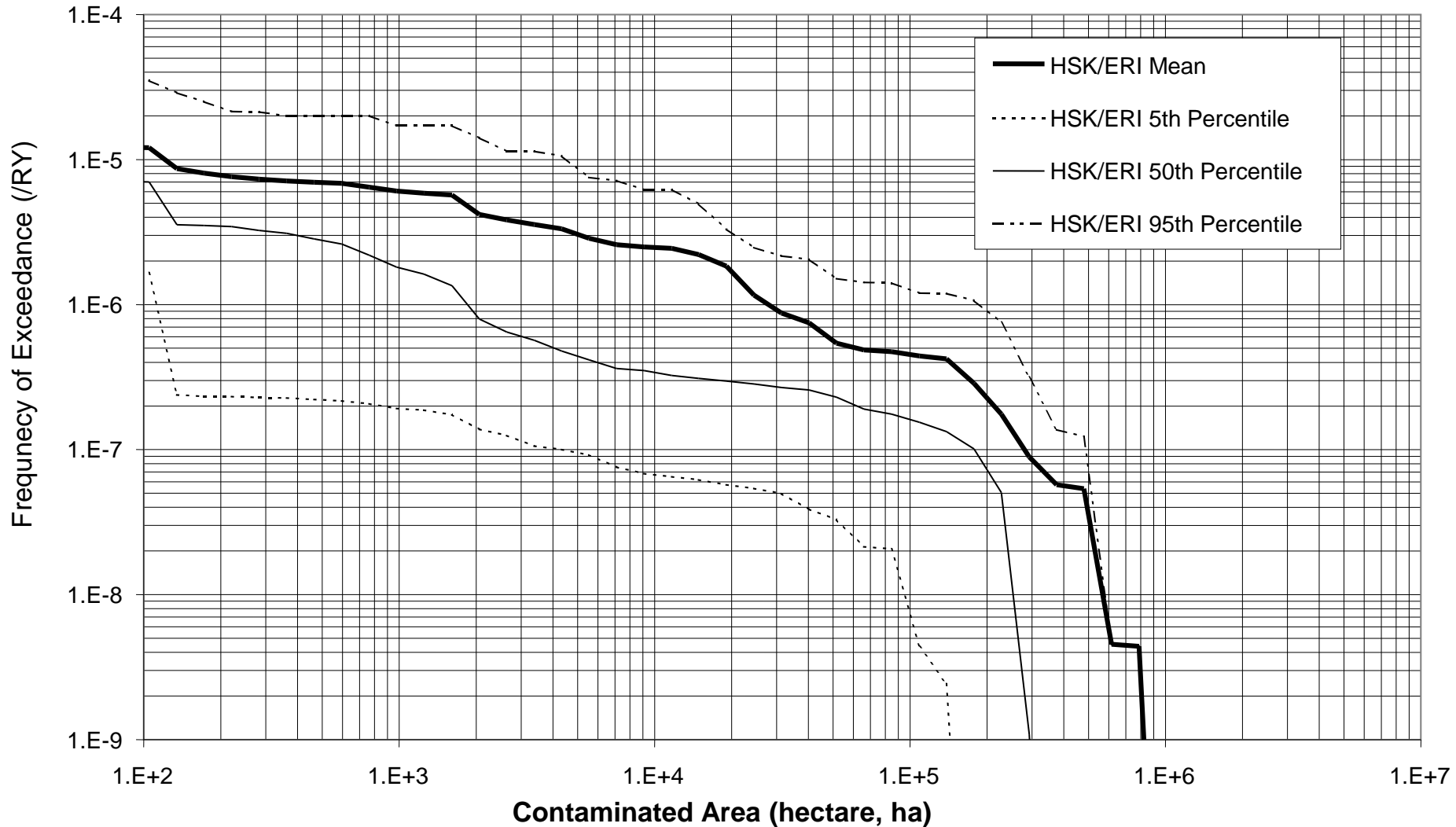
Result Representation
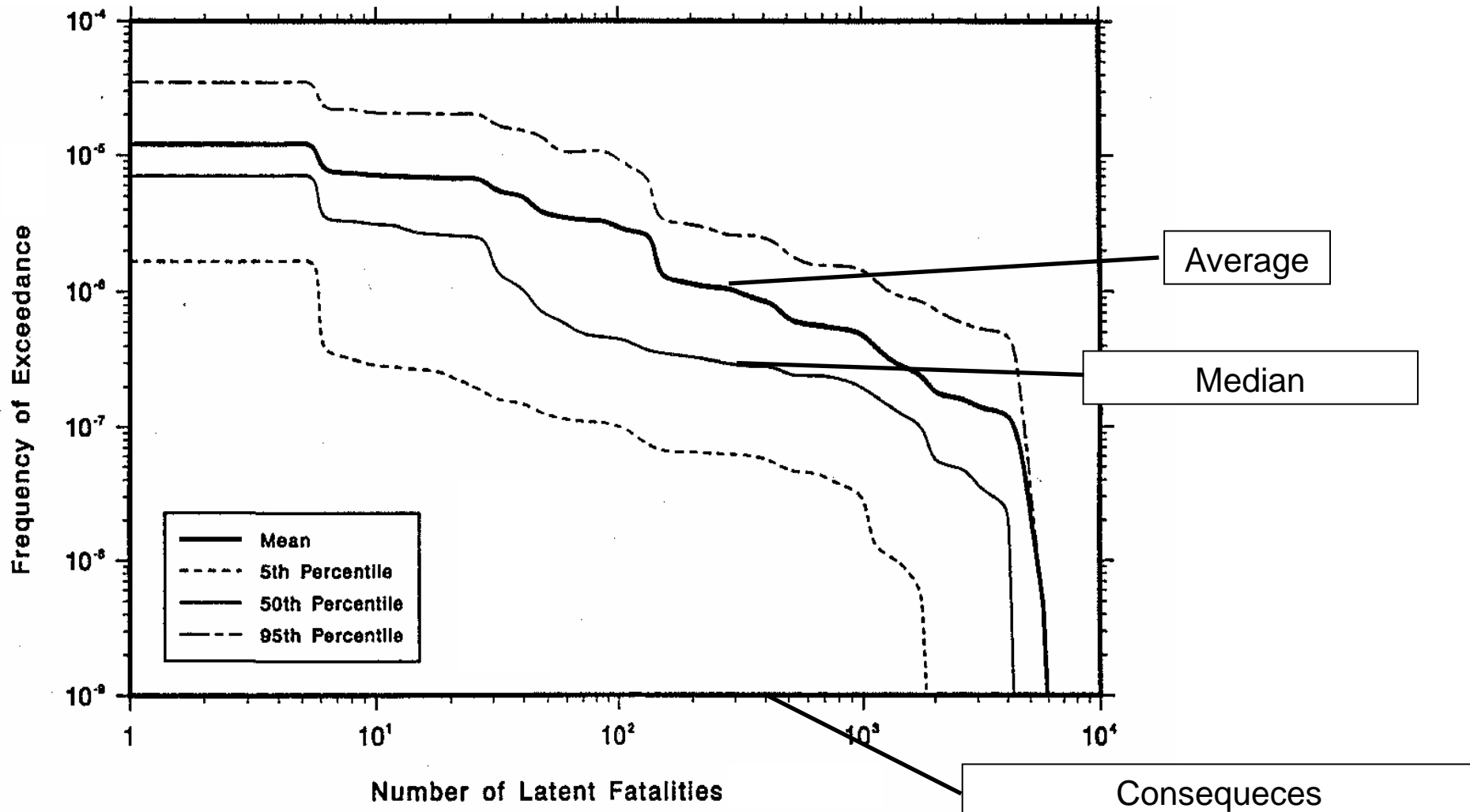
Examples of estimating consequences
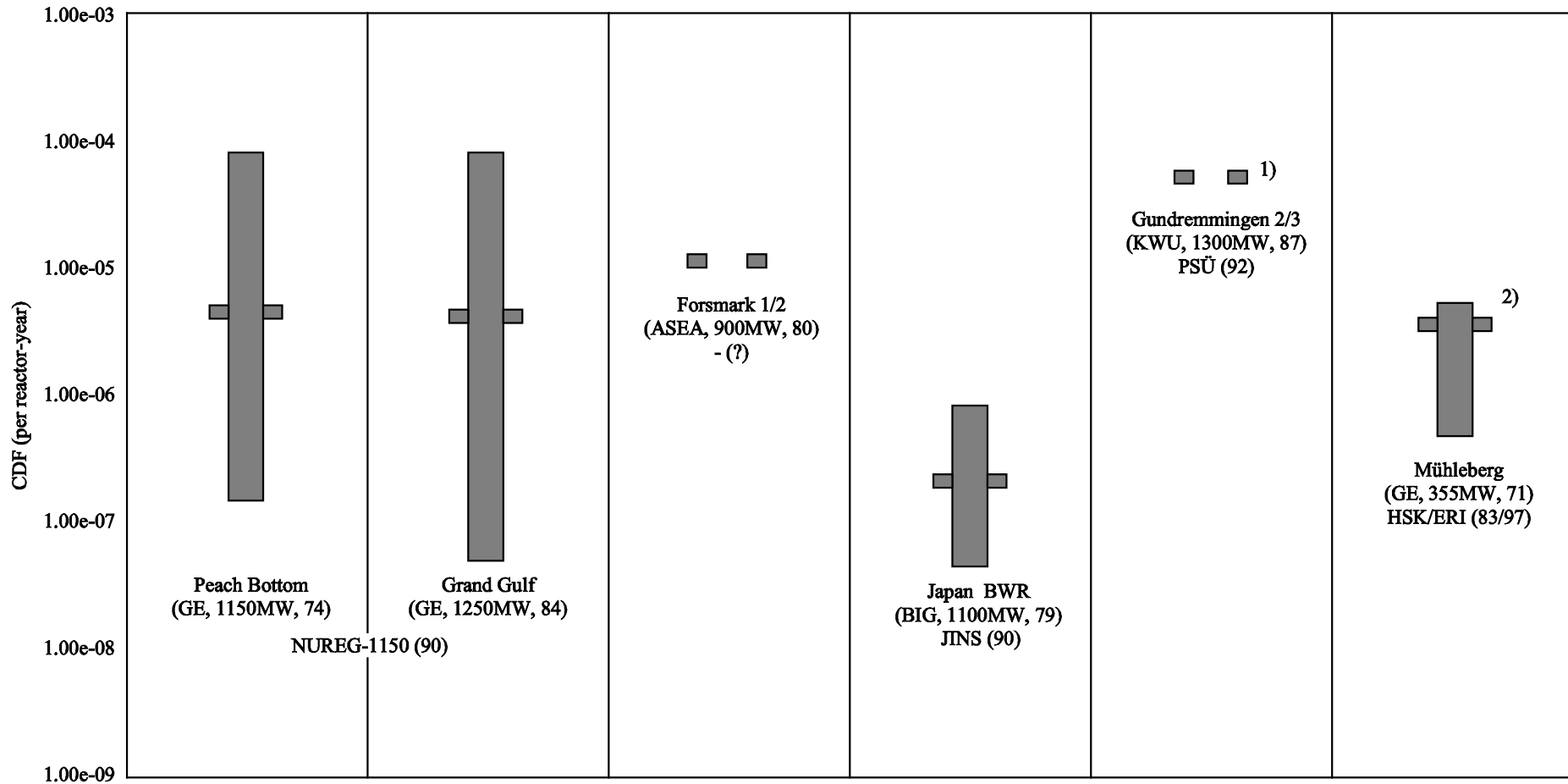## A complementary cumulative yearly frequency of a calculated collective dose

100 rem = 1 Sv
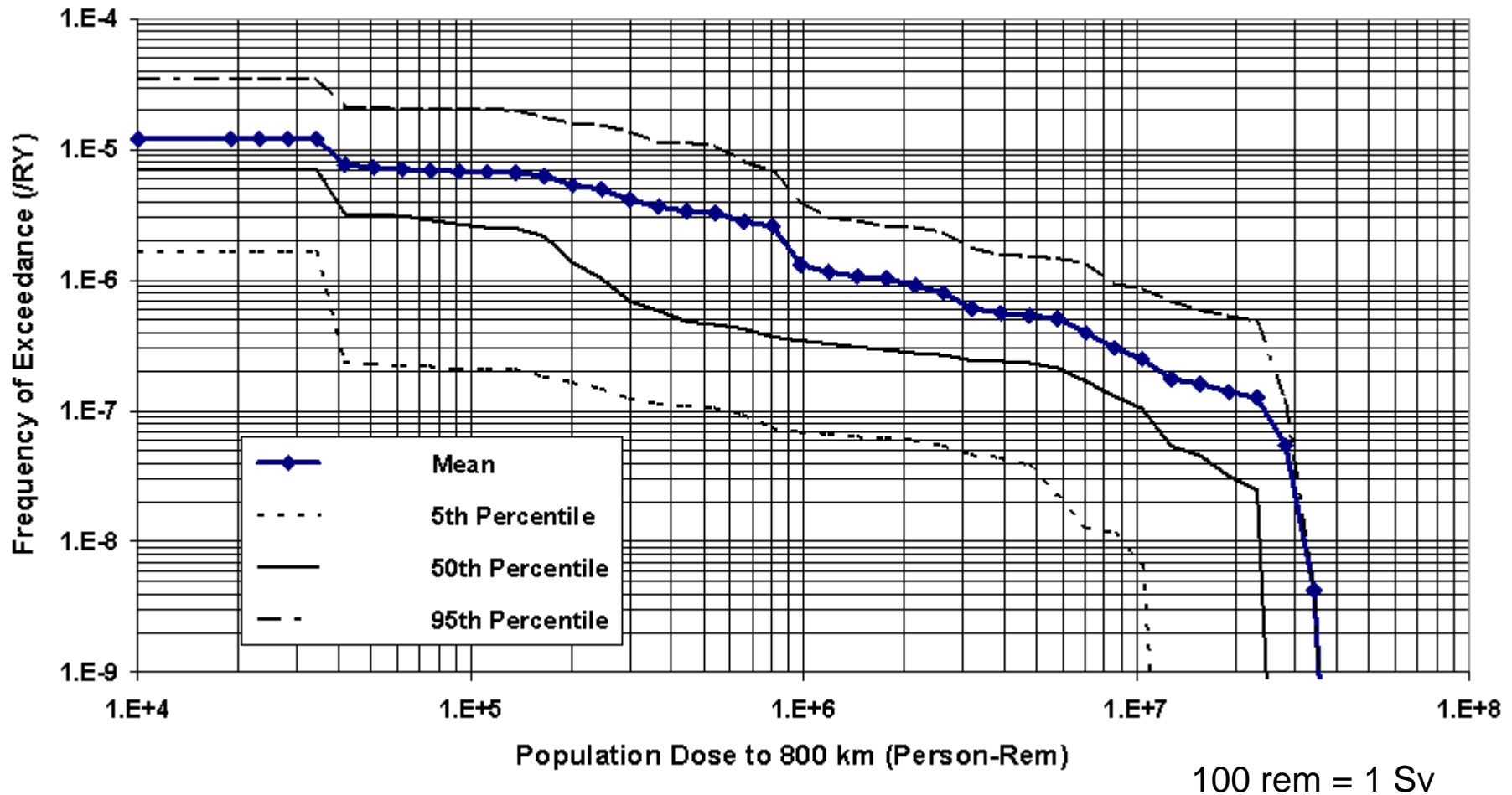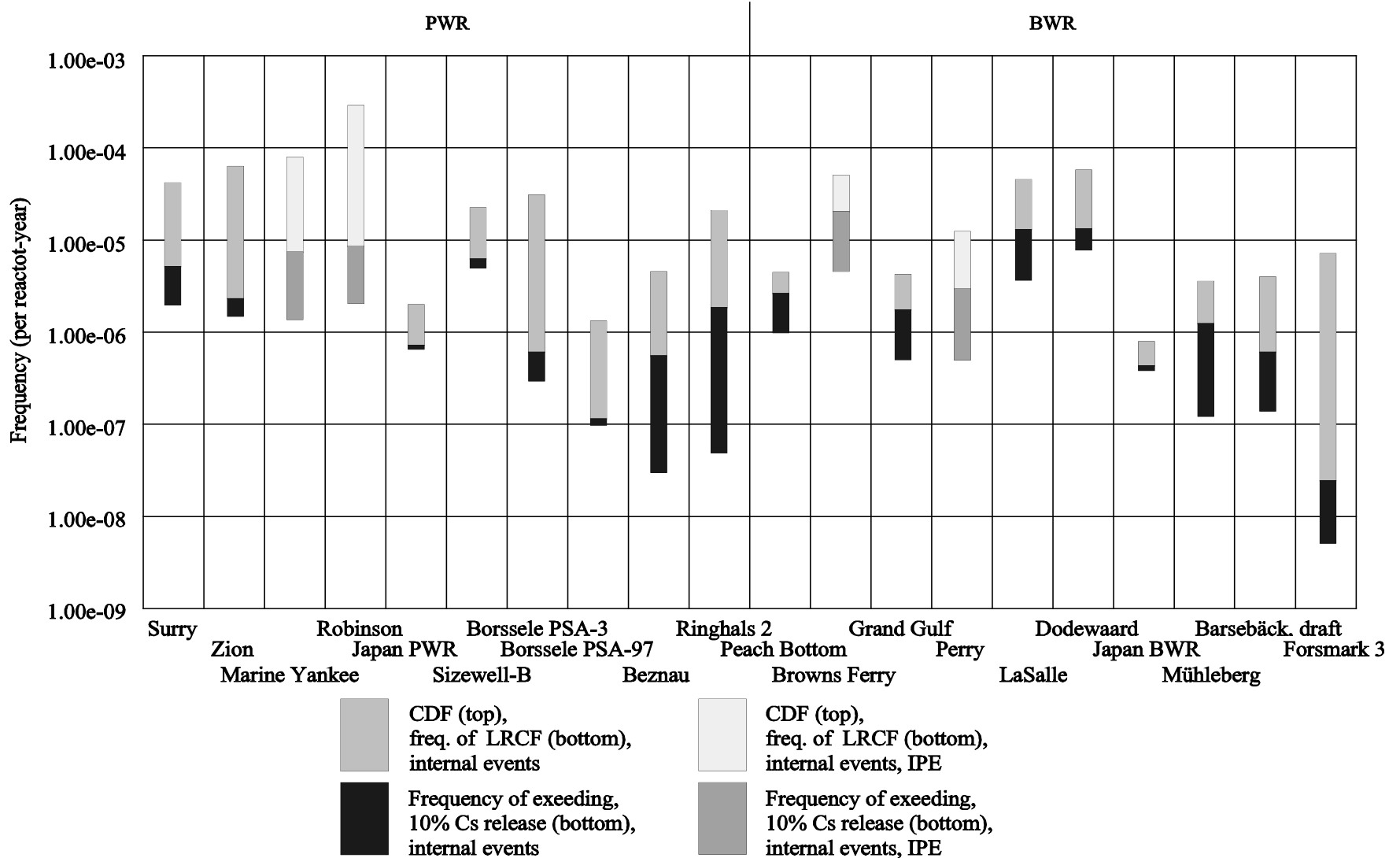
Contaminated Area

Core Damage Frequencies (mean and 5th-95th percentiles interval), BWRs (interval events)

Frequencies of Core Damage and of Large Release Containment Failure, Western PWRs and BWRs

Frequency-Consequence Diagram for full energy chains world-wide

Frequency of Events causing X or more Fatalities (per GWe*a)

Number of Fatalities, X

Hydro power OECD experience (Teton)

Hydro (world-wide)

Nuclear, world-wide (Chernobyl, immediate fatalities)

Nuclear, world-wide (Chernobyl, latent fatalities)

PSA for nuclear power plant Mühleberg (latent fatalities)