Quantitative Risk Assessment in Chevron

Chevron

Human Energy®

Use in Decision-Making Involving Major Risks

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Presentation Outline

- Risk, quantitative risk assessment (QRA) and risk tolerance criteria
- Use of QRA in Land Use Planning around Major Hazard Facilities
- QRA Techniques

Risk and Quantitative Risk Assessment Defined

- Risk A measure of human injury, environmental damage, or economic loss in terms of both the incident likelihood and the magnitude of the injury, damage, or loss… or the probability that a hazard will result in a specified level of loss
- Risk is defined mathematically as:

$$\text{Risk} = [\text{Consequences}] \times [\text{Likelihood}]$$

$$[\text{Severity}] \times [\text{Frequency}]$$

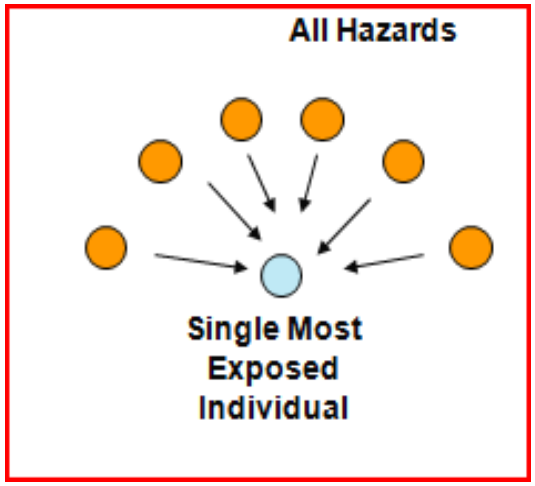
- Quantitative risk assessment (QRA) The systematic development of numerical estimates of the expected frequency and consequence of potential accidents associated with a facility or operation based on engineering evaluation and mathematical techniques.

Risk Tolerance and Risk Tolerance Criteria

- **Risk Tolerance**
  - A “willingness by society as a whole to live with a risk so as to secure certain benefits in the confidence that the risk is one that is worth taking and that it is being properly controlled. However, it does not imply that … everyone would agree without reservation to take this risk or have it imposed on them.” [United Kingdom, Health and Safety Executive, 2001]
- **Risk tolerance criteria**
  - A predetermined measure of risk used to aid decisions about whether further efforts to reduce the risk are warranted.

Individual Risk

- **Individual Risk** represents the likelihood that a person will sustain a fatal injury by all of the hazardous events to which he or she may be exposed. Presented as a frequency number (fatalities/year). Individual risk ensures that each person is not exposed to an aggregation of different risk exposures, the sum of which leads to an overall high risk exposure for the individual.



Example of Individual Risk Criteria

Specifies an upper limit amount of 10^{-4} fatalities/year for individual members of the public exposed to an industrial hazard

Individual Risk Criteria Examples

- **Singapore**
  - The 5 x 10^{-5} per year Individual Risk Contour remains within the fenceline
  - The 5 x 10^{-6} per year Individual Risk Contour extends into Industrial Developments only
  - The 1 x 10^{-6} per year Individual Risk Contour extends into Commercial and Industrial Developments only

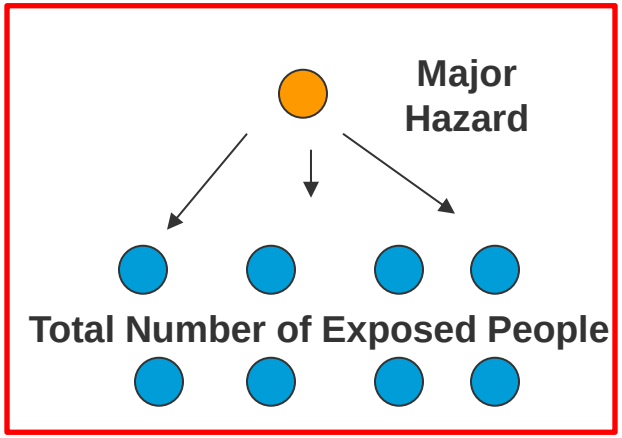
  Source – Singapore Pollution Control Department Guidelines for Quantitative Risk Assessment, April 2007

- **Western Australia**
  - A risk level in residential zones of 1 x 10^{-6} per year or less is so small as to be acceptable to EPA
  - A risk level in “sensitive” areas of 5 x 10^{-7} per year or less is so small as to be acceptable to EPA
  - Risk level from Industrial facilities should not exceed 5 x 10^{-5} per year at the boundary

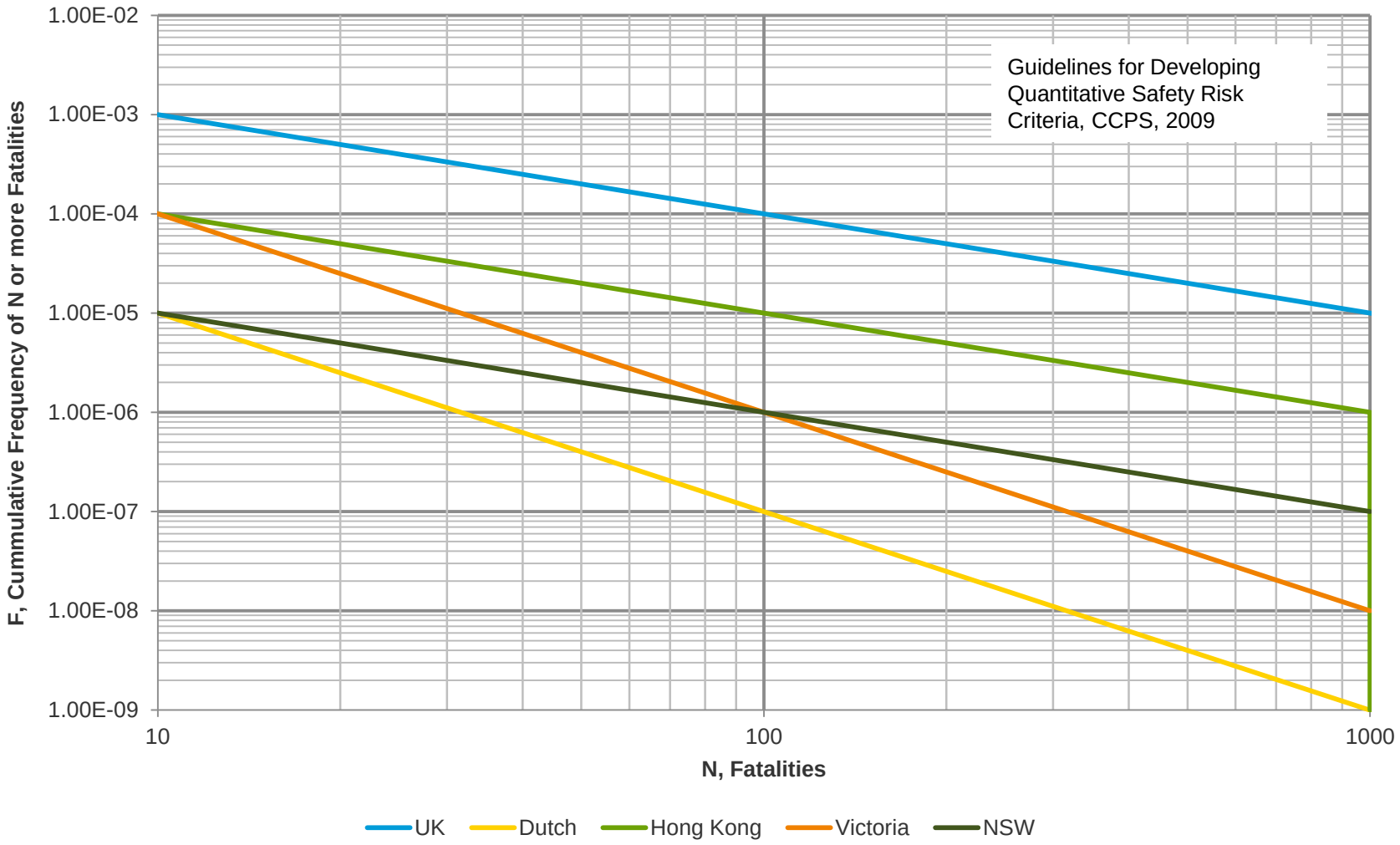
  Source - Guidance for Risk Assessment and Management: Offsite individual risk from Hazardous Industrial Plant, No.2 WA EPA, July 2000

Societal Risk

- Societal Risk represents the number of people who may be killed by large, single events and how often those events might occur. Presented as F-N Curves (Plots depicting the frequency “F” of exceeding “N” or more fatalities) which set:
  - Risk criteria for the public
  - Risk criteria for employees



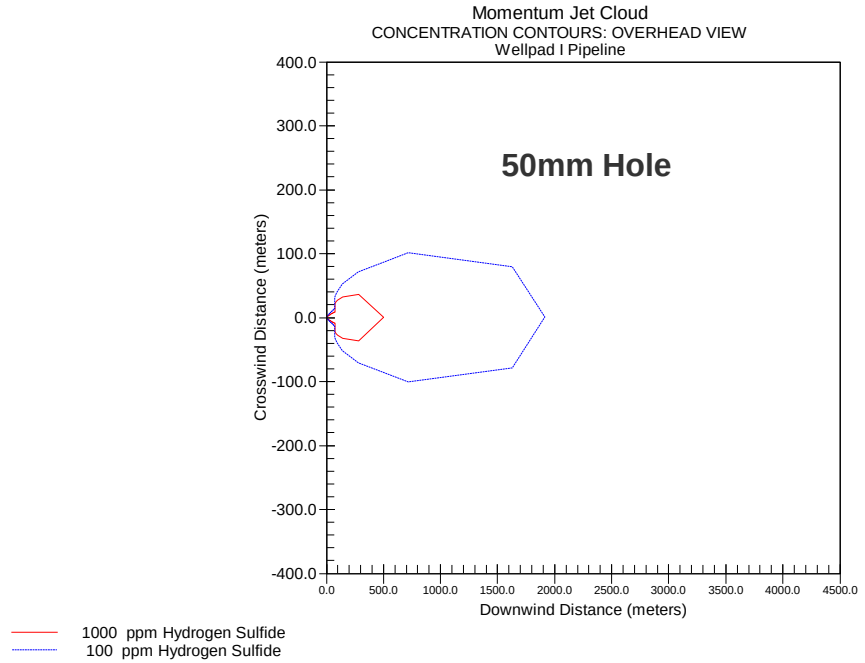
Societal Risk Criteria Examples

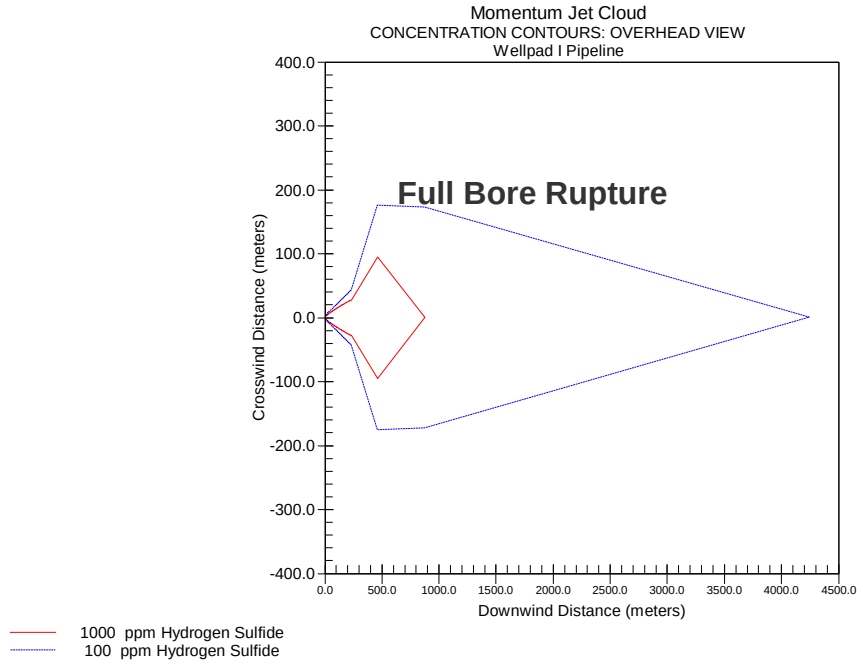


Consequence vs. Risk-Based Approach to Land Use Planning

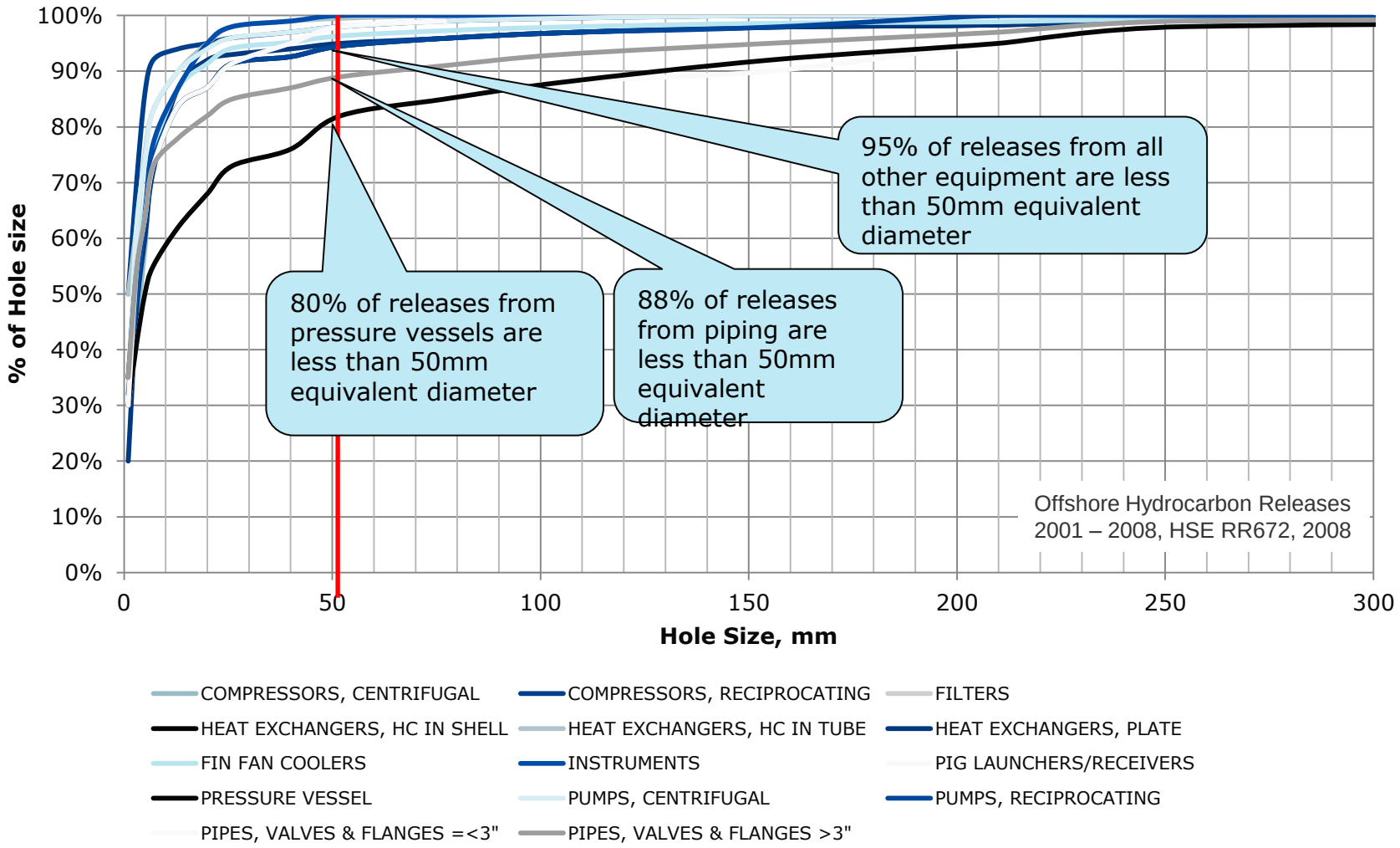
- Consequence (Deterministic) approach uses only the consequence variable in the risk equation. Theoretically this approach would ensure no fatalities will occur as the result of facility operations, but typically results in impractical and unenforceable requirements
  - Examples "All airplanes must be designed to never crash" or "no toxic release shall never pass a facility fence line"
- Risk approach uses both the consequence and the likelihood parameters of the risk equation, taking into account the significant safeguards in place that lower the frequency of major accidents/releases and align the risk with overall societal nor
  - Example "Require an exclusion zone where the risk of fatality to any individual exceeds the chance of 1 in 10,000 years"

Consequence (Deterministic) Approach





Likelihood of Different Consequences



Why Chevron Use a Risk-Based Approach

- Many countries worldwide have recognized that a consequence based approach results in land use requirements for industrial developments that are not sustainable.
- This is particularly true of densely populated regions such as UK & Europe, Singapore, Hong Kong and the urban areas of Australia and the risk based approach is therefore enshrined in law in these countries
- Chevron (in common with the majority of international energy companies) has adopted a risk based approach as its default position for the management of hazards associated with its operations

Governments that Require (or Use) QRA and Set (or Use) Risk Criteria

- Australia
- Brazil
- Canada
- China (Hong Kong)
- Czech Republic
- Demark
- France
- Hungary
- Netherlands
- Norway
- Singapore
- Switzerland
- United Kingdom (UK)
- US Department of Energy/Nuclear Regulatory Commission

Predominant Worldwide Practice is to Use a Risk-Based Approach for Land Use Planning

Some Companies/Industries Using QRA for Risk Decision-Making (Not Exhaustive)

Oil Industry

- BP
- Chevron
- Conoco/Phillips
- ExxonMobil
- Norske Hydro
- Shell
- Statoil
- Total

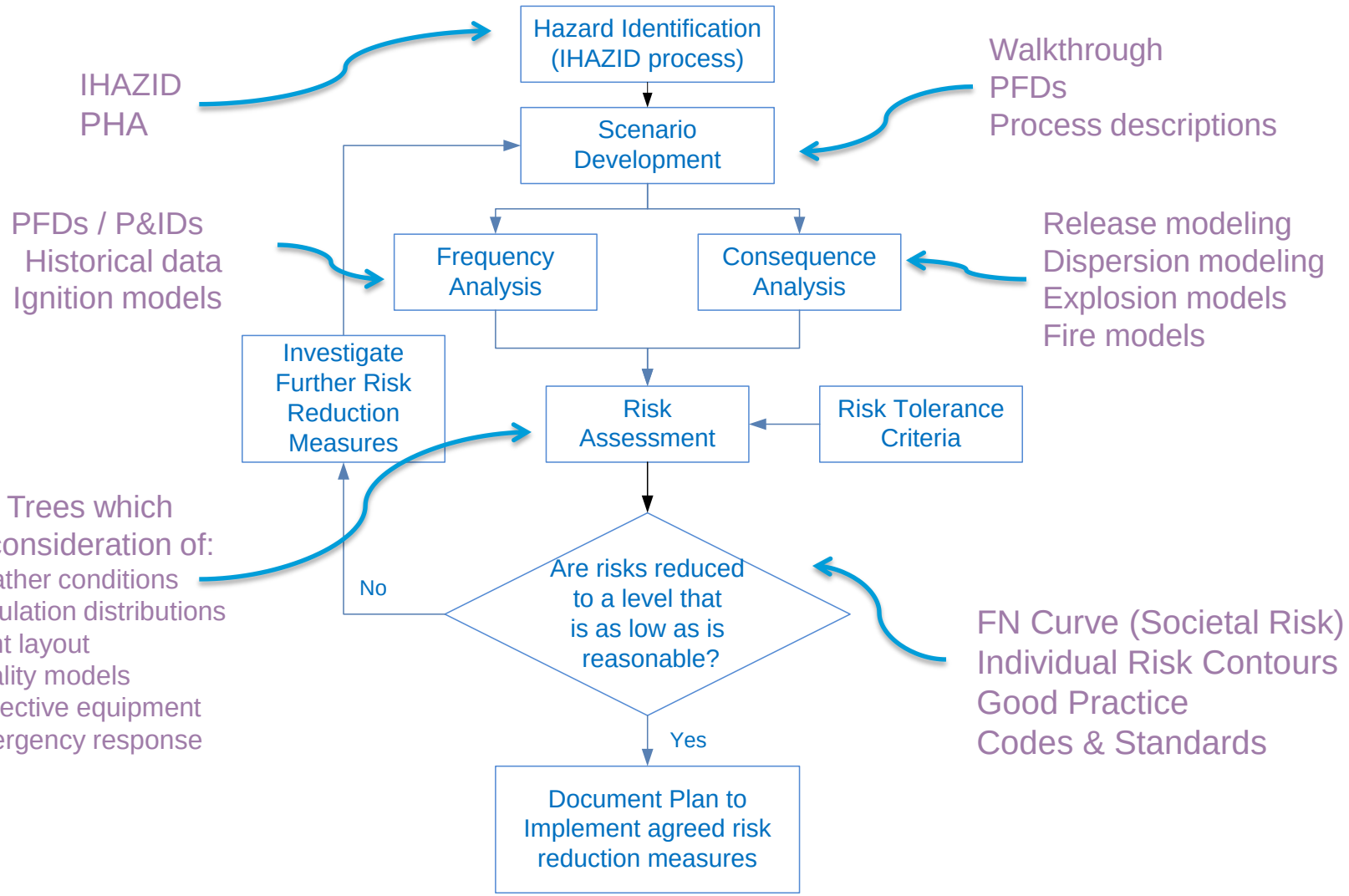
- Pharmaceutical Industry
  - Merck
  - Eli Lilly and Company

Chemical Industry

- Eastman Chemical Company
- Albemarle
- Air Products and Chemicals, Inc.
- Rohm and Haas Company, retired
- Solutia, Celanese
- Dow Chemical
- Lyondell Basell Industries
- DuPont
- Croda, Inc.
- Intel

Aerospace/Defense/Nuclear

QRA Process



How Do We Quantify Risk?

- Primary means of quantification is through event trees
  - These take an initiating event (e.g. ¼-inch release from compressor suction scrubber) and develop it into all possible outcomes – unignited, early ignition leading to jet fire, delayed ignition in open leading to flash fire, delayed ignition in congested / confined region leading to explosion.
- Supported by fault trees, FMEA, part counts, reliability analysis and ignition modeling to quantify frequency and branch probabilities
- Supported by dispersion analysis, fire analysis, explosion analysis and vulnerability assessments to quantify consequence

Event Frequency Determination

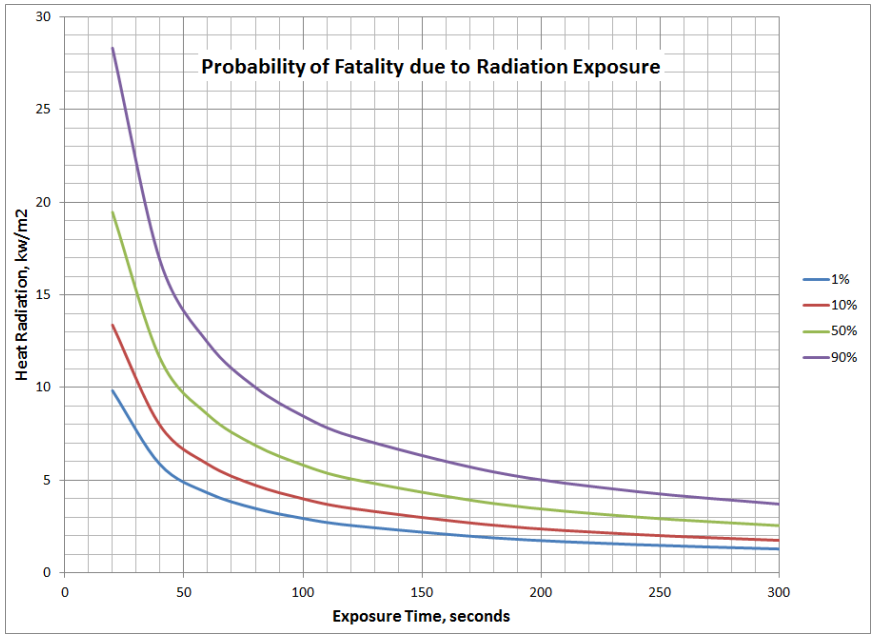
Loss of Containment Event / year		Probability of Hole Size		Ignition?		Delayed Ignition?		Explosion?	Outcome
	Small		Yes		Yes		Yes		Explosion
							No		Flash Fire
					No				Jet Fire
			No						Toxic Exposure
	Medium		Yes		Yes		Yes		Explosion
							No		Flash Fire
					No				Jet Fire
			No						Toxic Exposure
	Large		Yes		Yes		Yes		Explosion
							No		Flash Fire
					No				Jet Fire
			No						Toxic Exposure
	Massive		Yes		Yes		Yes		Explosion
							No		Flash Fire
					No				Jet Fire
			No						Toxic Exposure

Vulnerability Determination

Flammables

- Probability of Fatality =

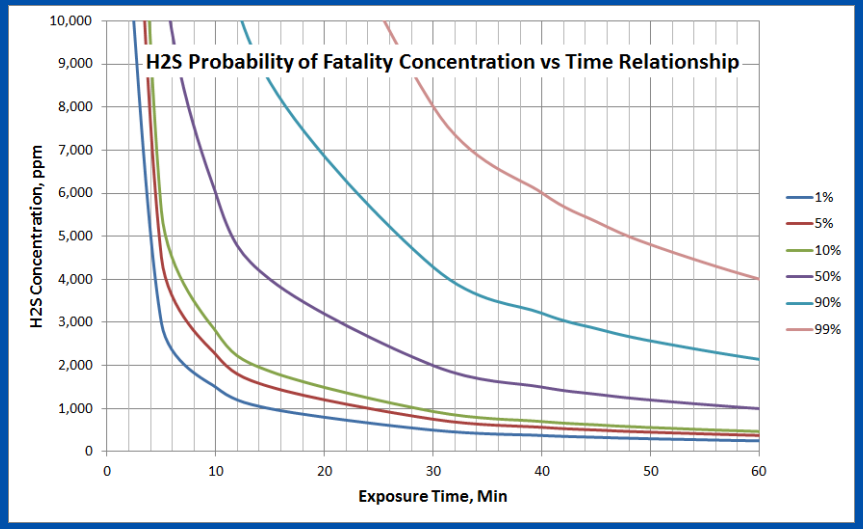
$$a + b(Q^{4/3}t)$$



Toxics

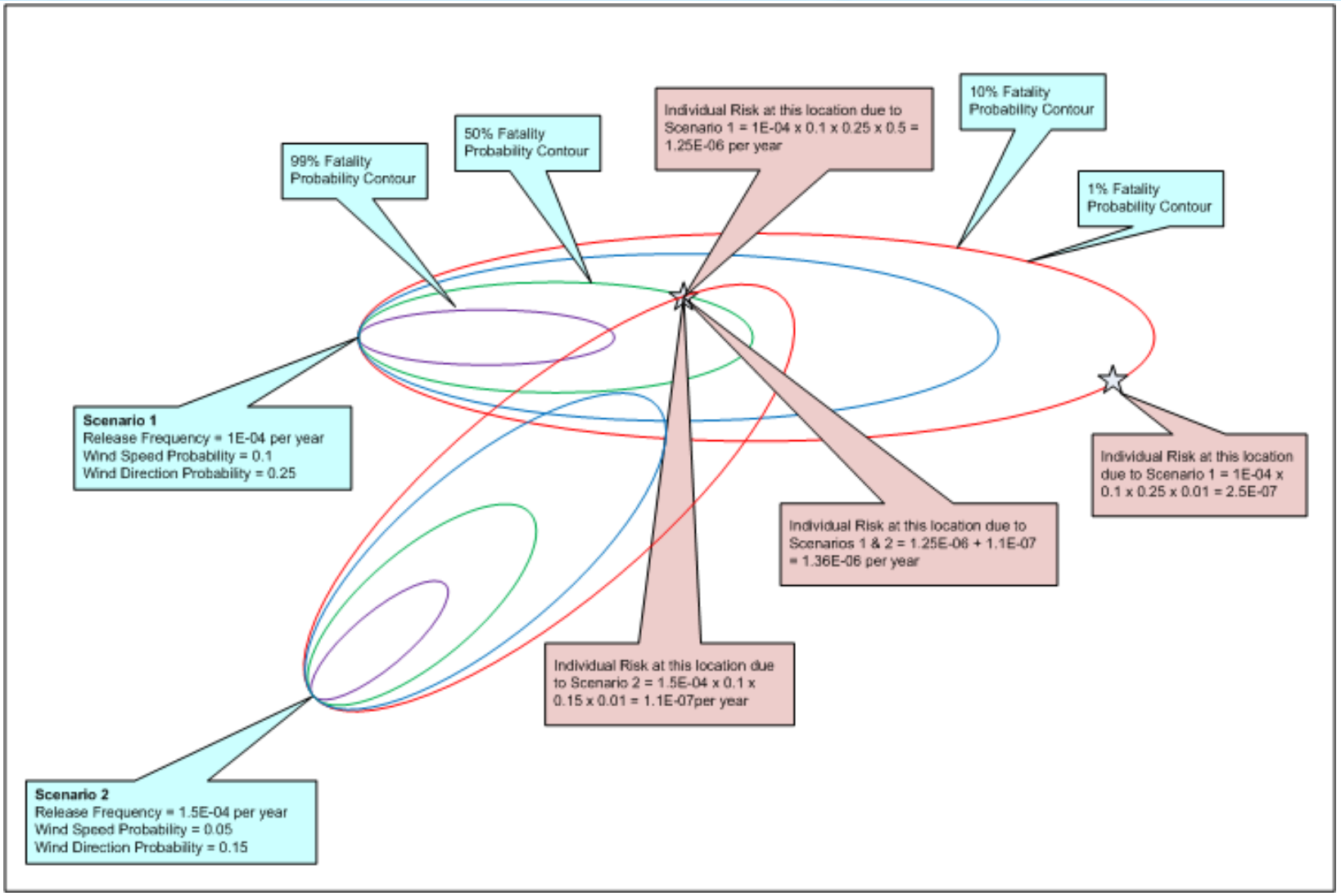
- Probability of Fatality =

$$a + bLn(C^n t)$$



QRA Approach

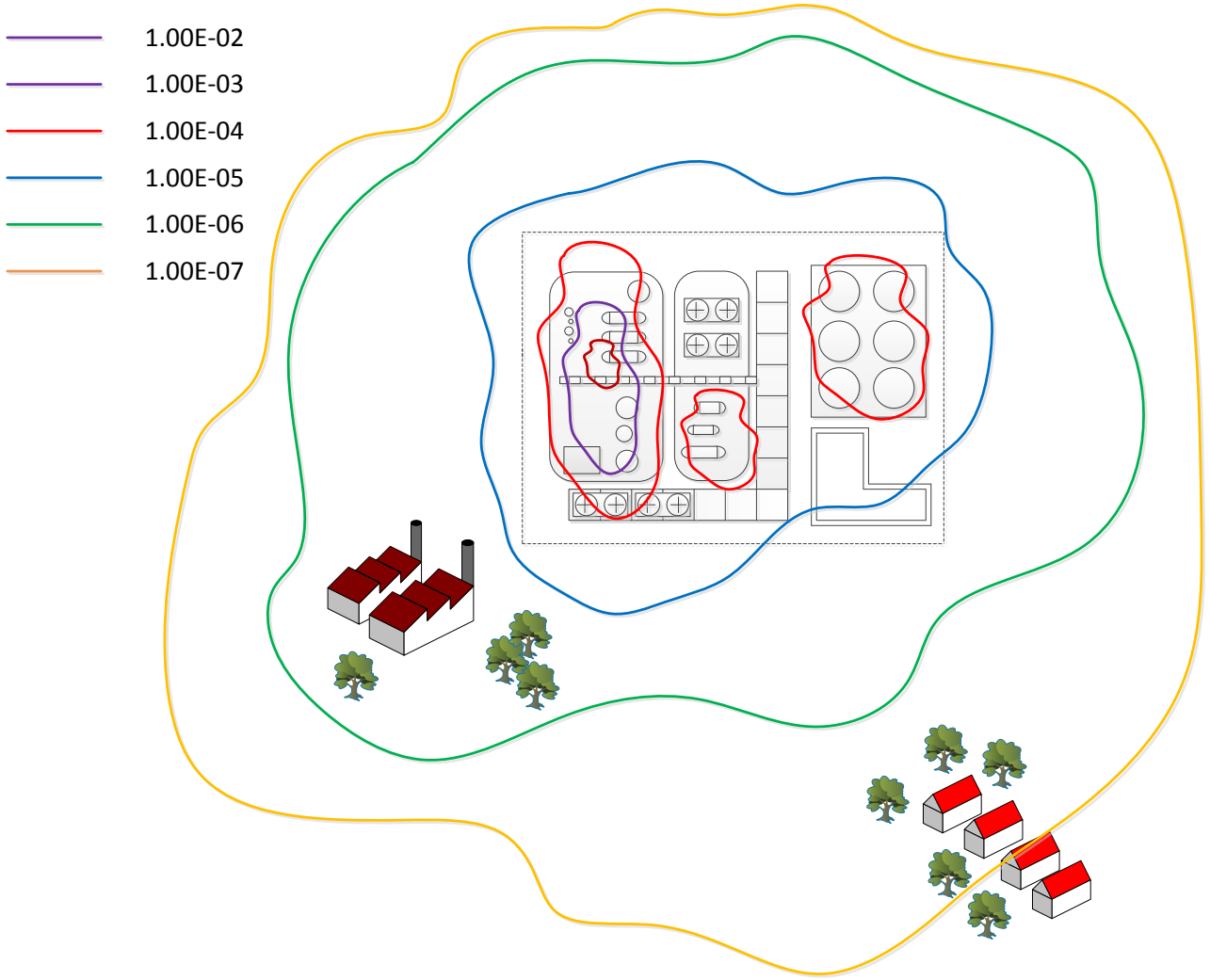
Determination of Risk Contours



Risk Measures

- Risk Contours
  - Probability of fatality per year to an individual located on the spot 24 hours per day/365 days per year
  - Graphical representation of the potential impact zone of hazards
  - Used primarily for public exposure since people living in close proximity to a facility can be continuously exposed
- FN Curve
  - Measure of the risk of incidents which can cause multiple fatalities
  - Typically used to gauge the acceptability of having large congregations of people exposed to hazards (for example, in schools, hospitals, etc. or during turnarounds or in occupied buildings on site)
- Individual Risk per Annum (IRPA)
  - Likelihood of fatality per year for an individual based on their exposure to that risk. Used primarily for workers who are only exposed to the risk when at work

Typical QRA Output



Further Reading

- *Guidelines for Developing Quantitative Safety Risk Criteria, CCPS, 2009*
- *Guidelines for Chemical Process Quantitative Risk Analysis, CCPS, 2000*
- *Reducing Risks, Protecting People, Health and Safety Executive, 2001*

Q & A