Risk and Reliability Targets used by TransCanada

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Risk and Engineering Strategy, Pipeline Integrity

TransCanada
In business to deliver

Agenda

- **Introduction**
- **Why do we need risk and reliability targets?**
- **Risk and Reliability Targets in System Wide Risk Assessment (SWRA)**
- **Reliability Targets in Corrosion Assessment**
- **Risk and Reliability Targets in Engineering Assessments (EAs)**

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TransCanada Corporation (TSX/NYSE: TRP)

One of North America's Largest Natural Gas Pipeline Networks

- Operating 90,300 km (56,100 miles) of pipelines
- Transports 27 per cent of continental demand

North America's Largest Natural Gas Storage Operator

- More than 664 Bcf of capacity

Canada's Largest Private Sector Power Generator

- 17 power facilities, 10,700 MW
- Diversified portfolio, including wind, hydro, nuclear, solar and natural gas

Liquids Pipeline System

- Keystone Pipeline System: 4,300 km (2,700 miles), 545,000 bbl/d contracted capacity
- Safely delivered more than 1.3 billion barrels of Canadian oil to U.S. markets since 2010

Definitions

Risk is the expected value of loss.

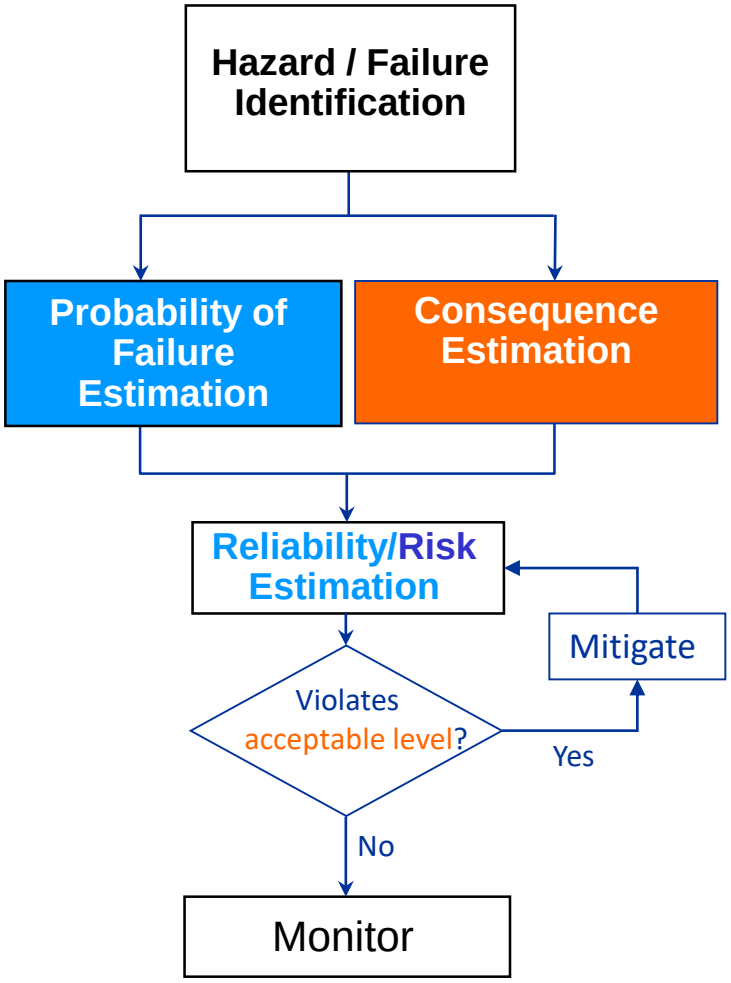
Risk = f(Probability of Failure - POF, Consequences of Failure)

Reliability = Probability of being safe
= 1- POF

POF is from the pipeline's perspective

Risk is from the risk receptor's perspective

Different risk measures – Individual risk, Societal risk



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Providing Safety levels

A system is only as strong as its weakest link

Engineered systems provide safety levels by:

- **Target Risk levels**
  - Qualitative methods cannot target consistent risk levels but has unknown varying levels of risk
  - Quantitative methods can achieve more consistent levels of risk
  - Risk targets are smeared which makes it more appropriate for segment risk
- **Target reliability levels**
  - Deterministic methods have implicit reliability targets
  - Reliability methods have explicit reliability targets
  - Reliability targets are more location specific and appropriate for site specific and defect specific management

Risk Targets

- From the risk receptors and risk measure perspective
- Can be independent of infrastructure if units match (transferable between industries)

Generally based on:

- Societal acceptance levels e.g., mortality rates of accepted lifestyles as in MIACC, HSE 10^{-4} /person/yr
- Safety levels implicit in code designs (back calculated and average considered acceptable) as in UK IGEM TD/1
- Safety levels based on statistics of different consequence categories as in PD-8010 based on both design considerations and real incidents – adopted by SWRA
- Due to units, varying risk aversion levels for occupations, acceptance definitions, and assessment methods it could vary considerably

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RISK TARGETS IN SWRA

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Risk/Reliability Measures Used in SWRA

- **Three different measures and targets are used:**
  - Risk
    - Individual Risk
    - Societal Risk
  - Reliability
    - LOF or POF

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Individual Risk

- **Objective of IR**
  - To protect the individual that could potentially be there, and not the full time residents. It basically accounts for uncertainties in human activity.
- **Assumptions**
  - An individual is always present 24/7 at each interaction length (conservative)
- **Actual IR**
  - Calculated using the predicted failure frequencies and the predicted consequence
- **Acceptable IR**
  - Set through regulations and industry experience; actual IR must be below acceptable IR in order for the pipeline to be deemed safe

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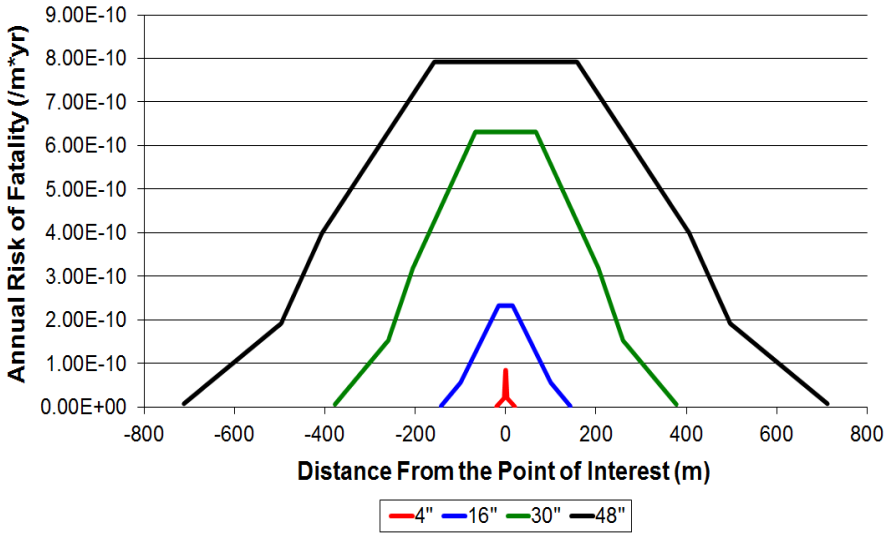
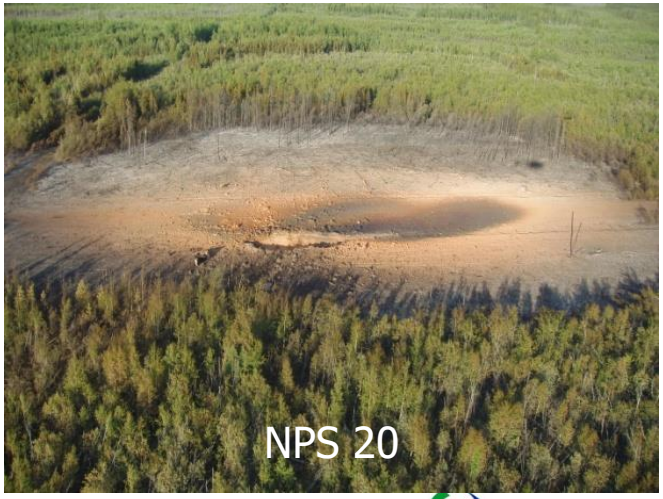
Significance of IR

- **Constant Likelihood of Failure, different pipe OD**
  - **Significantly different impact zones**



San Bruno rupture NPS 30



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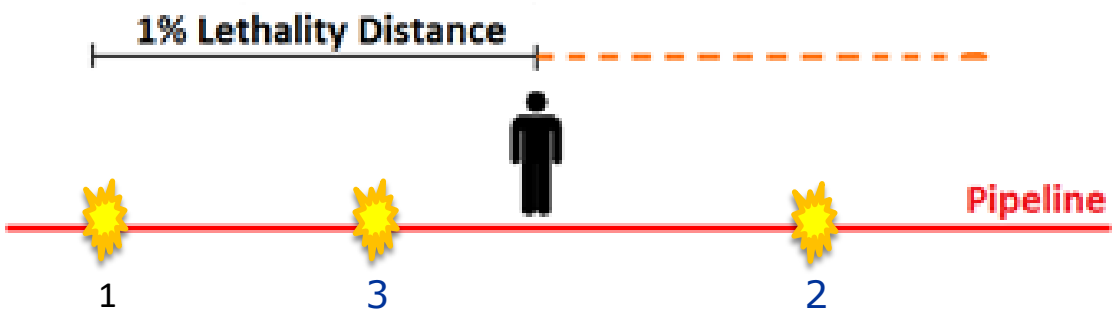
Individual Risk - Summary

- **Annual probability that an individual will become a casualty due to hazards to which they are exposed**

- **Calculation algorithm assumes risk to an individual at certain location is due to all possible scenarios that would affect the individual**



- **IR tolerability criterion – established by examining risk posed by everyday activities**

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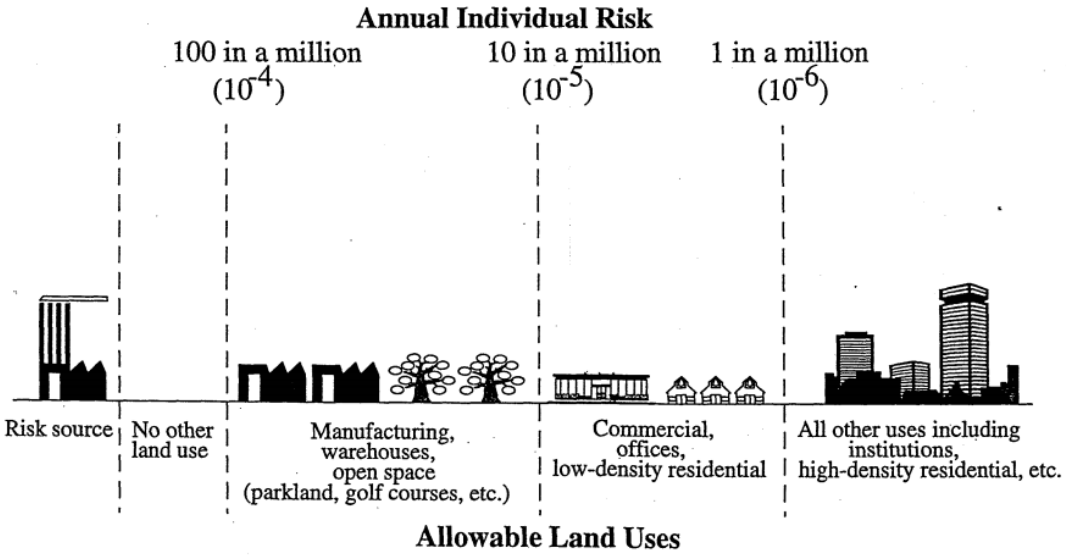
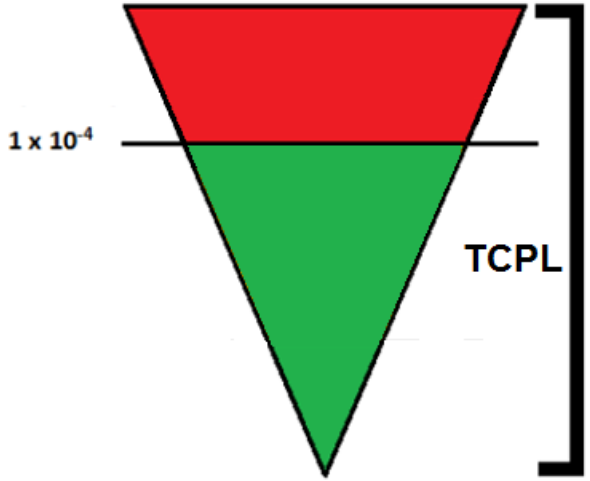
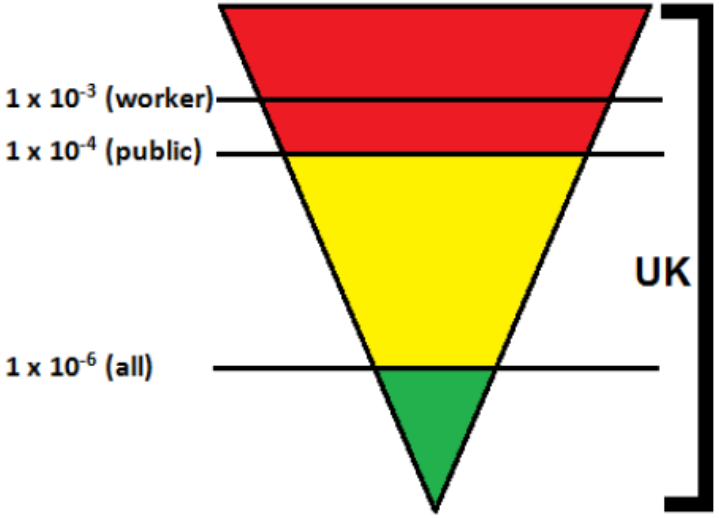
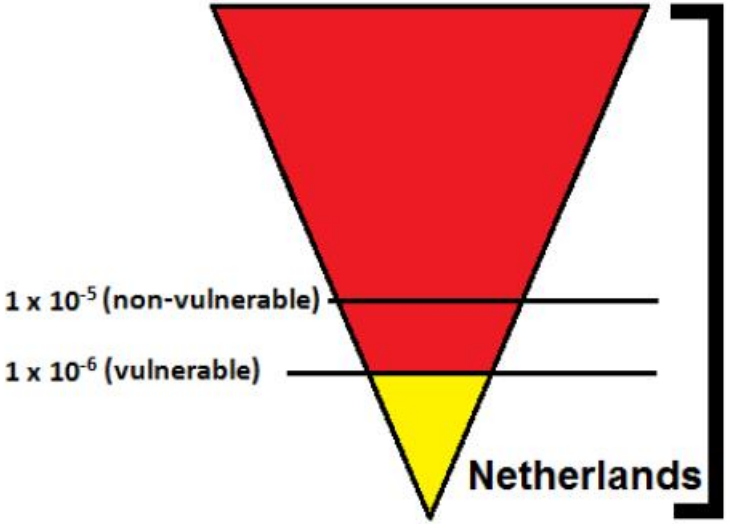
Individual Risk Criteria (fatalities/yr)

MIACC









Societal Risk

- **Objectives of SR**
  - To capture the consequence of a pipeline failure to the residents that could potentially be affected by that failure.
- **Actual SR**
  - Calculated using the predicted failure frequencies and the predicted consequence
- **Acceptable SR**
  - Set through regulations and industry experience; actual SR must be below acceptable SR in order for the pipeline to be deemed safe
- **Risk aversion**
  - Captures lower tolerance to high consequence incidents

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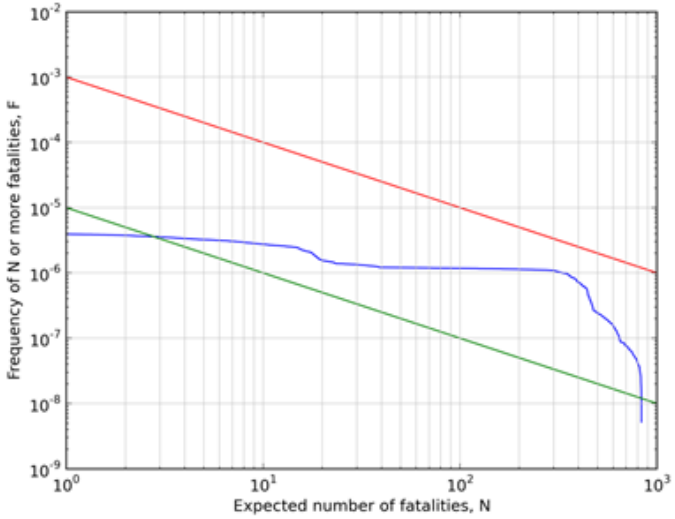
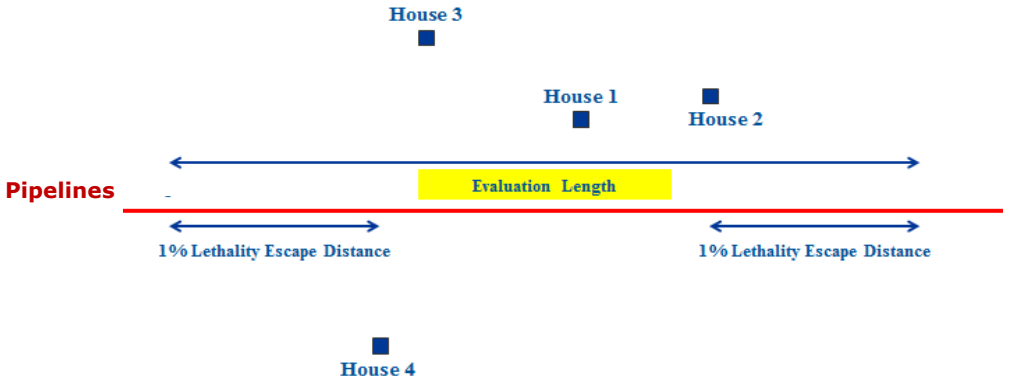
Societal Risk (SR)

- **Risk to a group of people that are potentially affected by the risk source**



- **Generally expressed in terms of an FN curve over the evaluation length in terms of two variables:**
  - N – Expected Number of Fatalities
  - F – Frequency of N or More Fatalities

- **Incorporates risk aversion**



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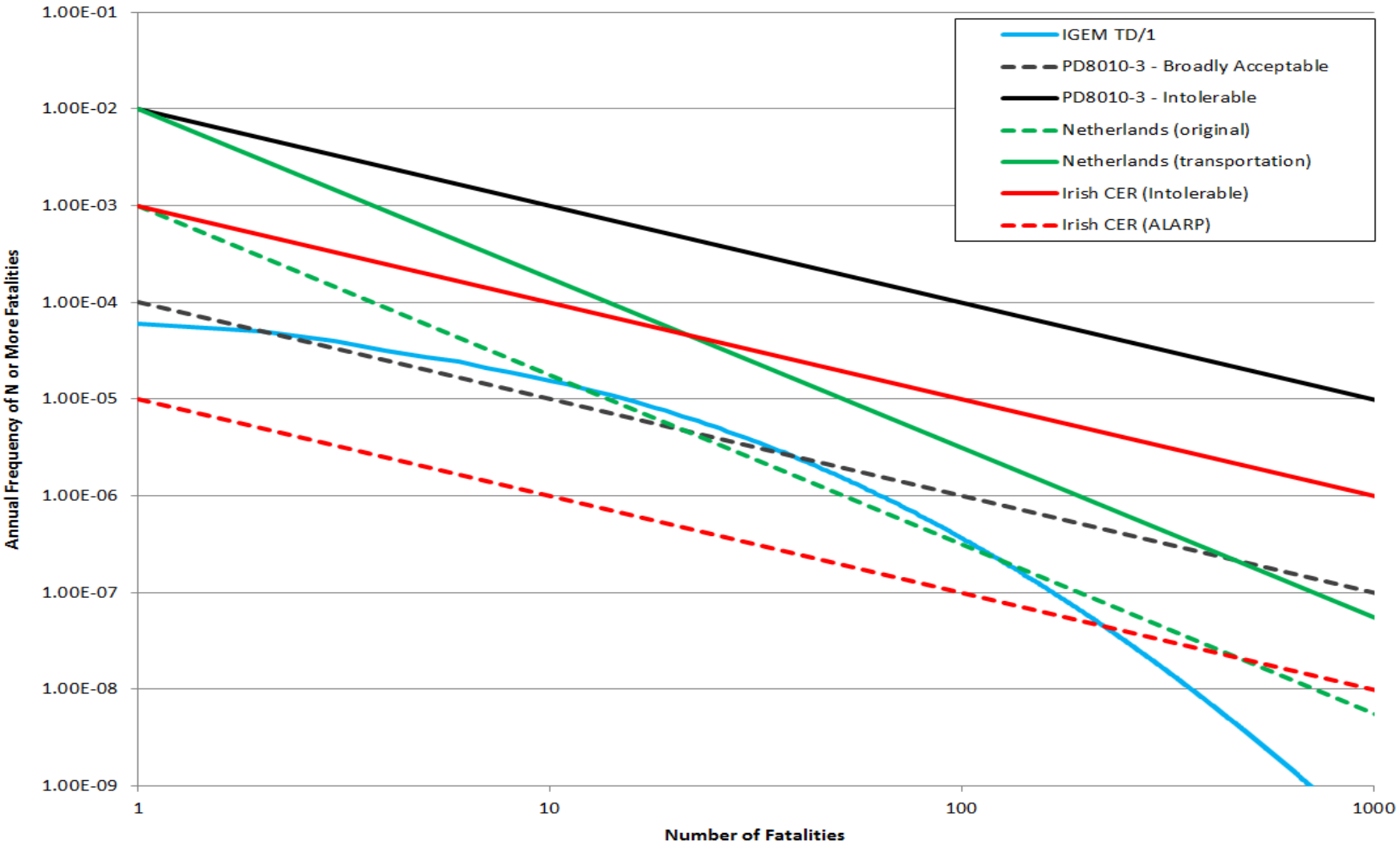
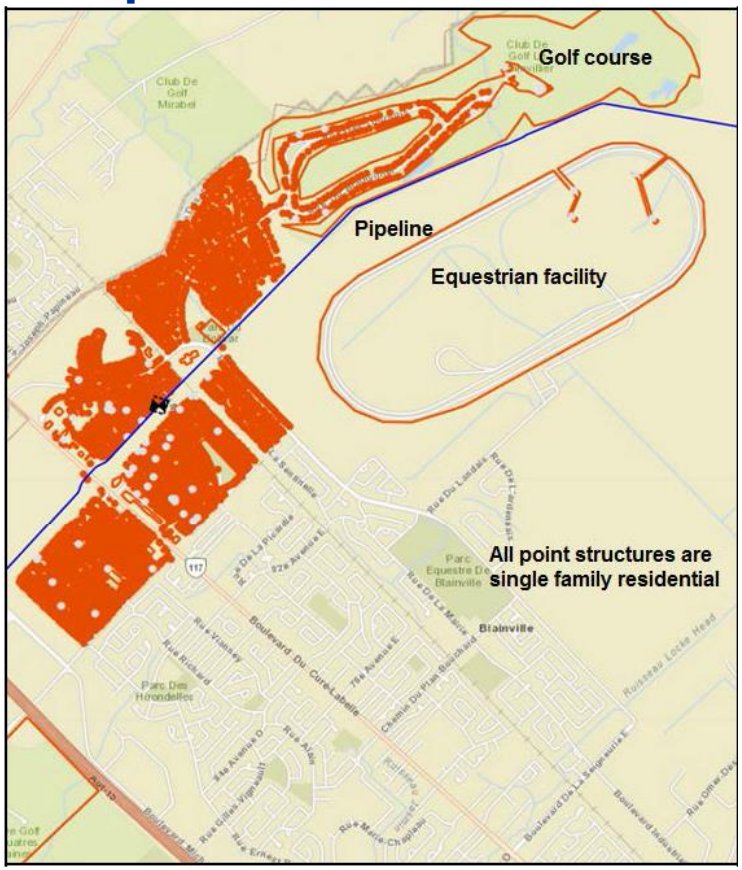
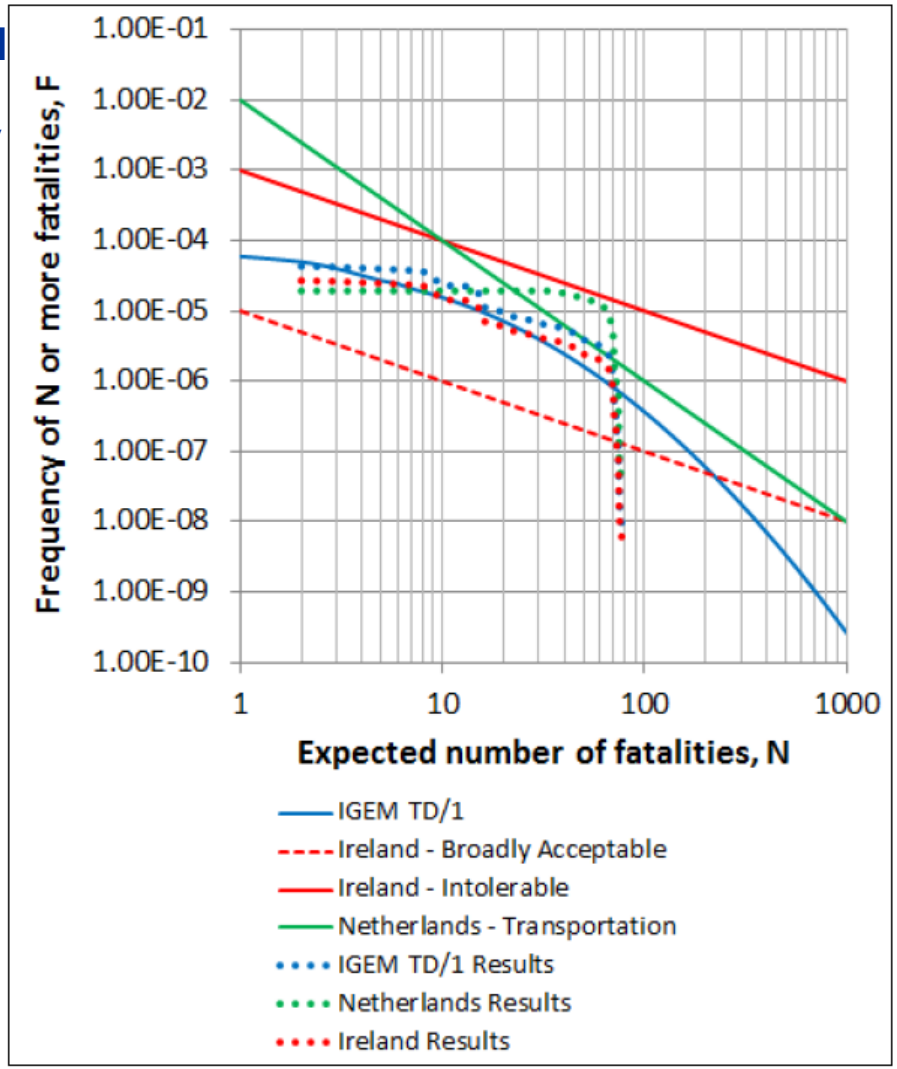
Societal Risk Criteria



SR - TransCanada Practical Cases

- **Approximately 3.5km of pipe evaluated**
- **24” pipeline, low POF of approximately 10^{-6} failures/km/yr**
- **High consequence**





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Reliability Targets

Reliability is infrastructure dependent (pipelines/km/yr)

Generally based on:

- **Code calibration to design for consequence categories as in CSA Z662 Annex O calibrated to designs**
- **Historical statistics based – has to be inline with lower percentiles of historical failure rates**
- **Reliability levels implicit in safety factors as in structural codes and Carlo program**
- **Relative reliability levels as in Engineering assessments (site specific calibration to code acceptance)**

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Reliability in Deterministic vs Probabilistic methods

Failure Pressure Ratio (FPR) = Rupture Pressure Ratio (RPR)

$$FPR = \frac{Predicted\ Burst\ Pressure}{MOP}$$

Remediation criterion: **FPR ≤ SF (safety factor)**

Resistance to rupture at a given feature /load that causes the rupture

Reliability = 1- Probability of Failure (POF)

Remediation criterion:

- Reliability ≤ Reliability Target, or
- POF ≥ Max. Allowable POF

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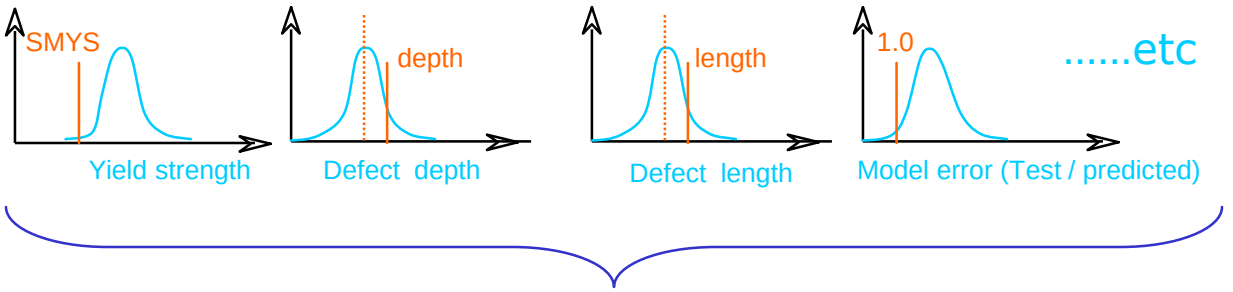
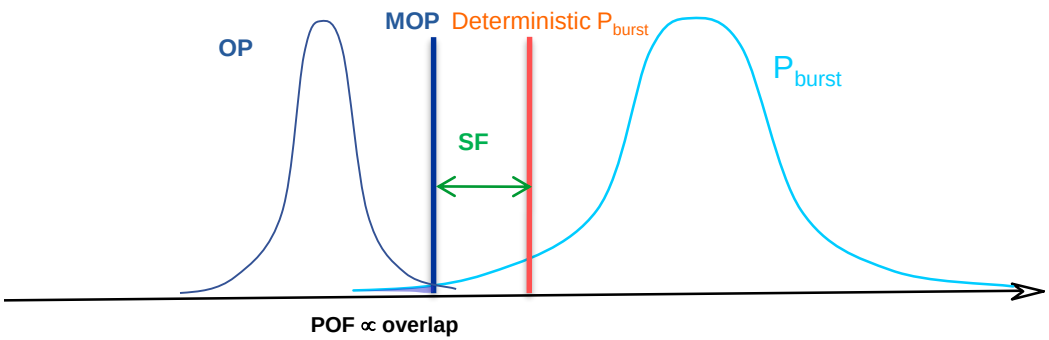
Providing safety using deterministic methods

Each variable involved has uncertainty



Conservatism in deterministic assessments

1. conservative constant inputs (e.g., SMYS) – *accounts for uncertainty in variables*
2. further conservatism with minimum safety factors (SF) – *accounts for different consequences, human error, unaccounted uncertainties etc.*

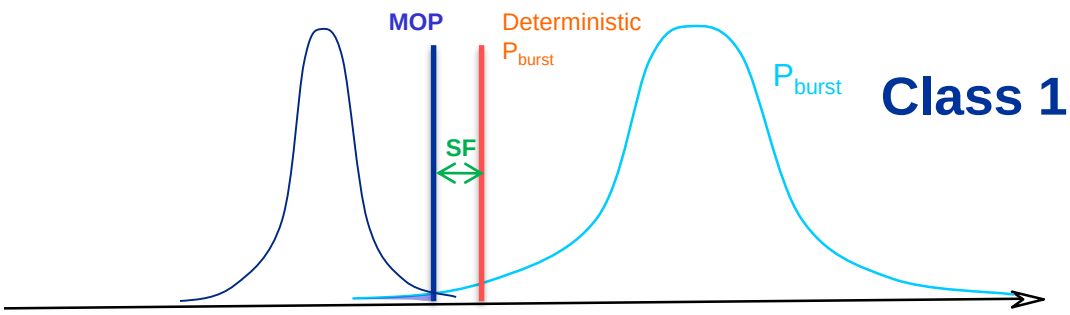


POF < acceptable POF => acceptable

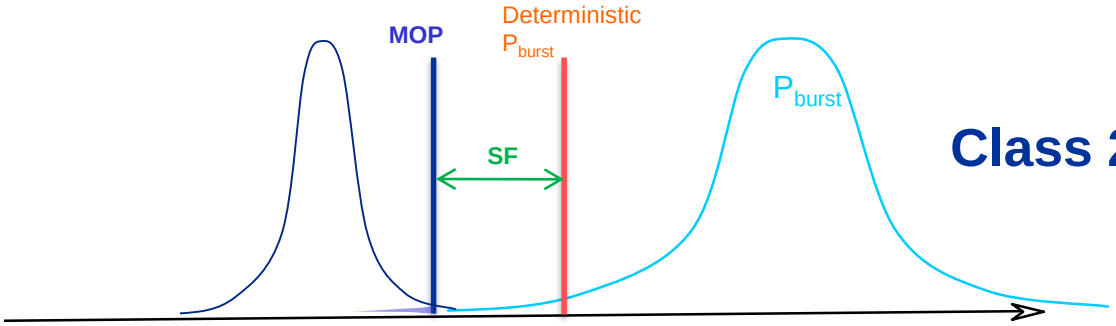
RPR = $P_{burst\ Det}$ / MOP > min SF => acceptable

For a given defect and pipeline using same equation a RPR (or SF) corresponds to a POF value.

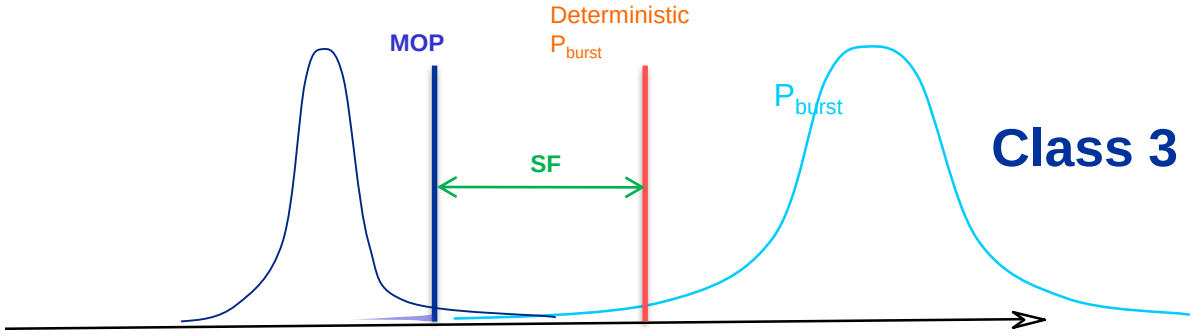
Higher SF for higher classes



Class 1



Class 2



Class 3

- **For consistent safety/risk in higher consequence areas**
  - Provide lower probability of failure by using higher SF
- **Design principles are the same**

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Within class variation in Risk for deterministic code designs

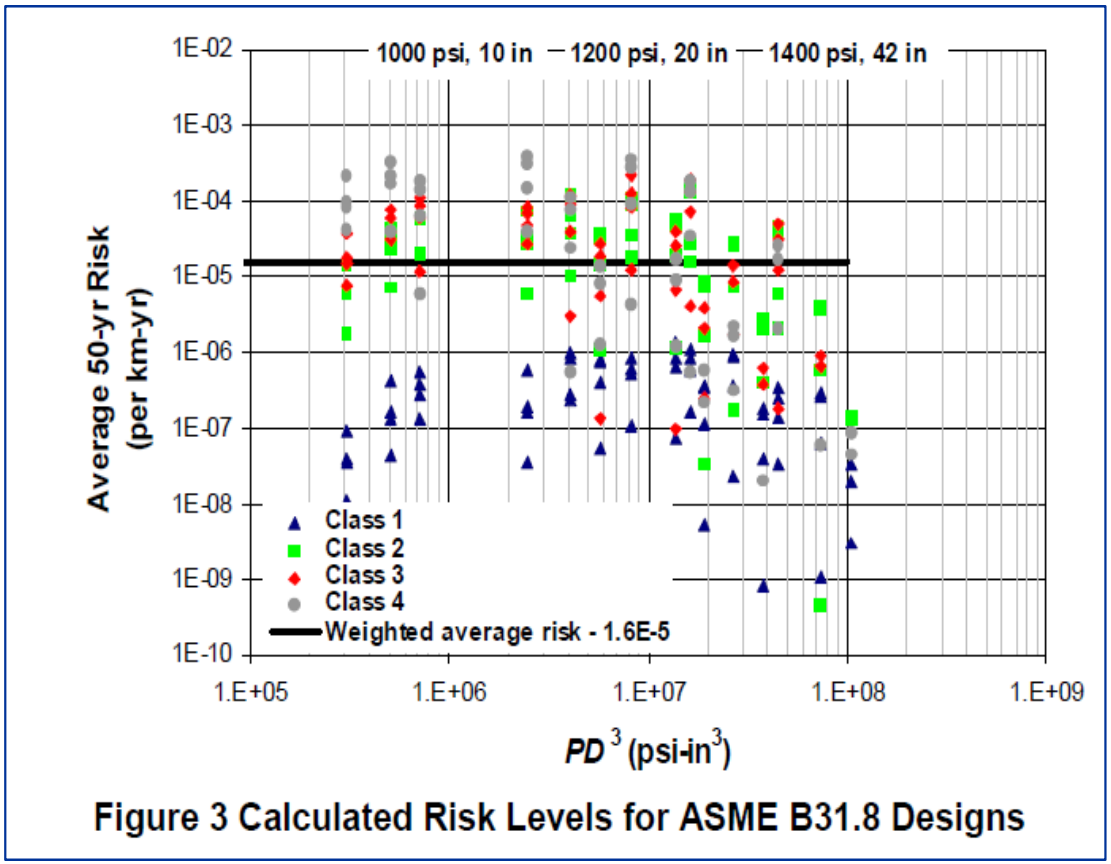

Figure 3 Calculated Risk Levels for ASME B31.8 Designs

Risk Levels Inherent in Compliant Pipelines [Nessim et al. 2004]

Deterministic compliance leads to highly variable risk levels

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SWRA - LOF Criteria for Gas Pipelines

Why we need LOF criteria in addition to risk criteria,

- Risk and LOF are not equal concepts
  - A high LOF pipeline ≠ safety risk, if there is no risk receptor (i.e. no safety consequence)
- To reduce the number of incidents
  - Failures without safety risk but could cause significant business interruption
  - Negative impact to the company's reputation, e.g.
    - NCC
    - Otterburne
- To accommodate regulatory drive towards zero incidents

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RELIABILITY TARGETS IN CARLO AND CRACK ANALYZER

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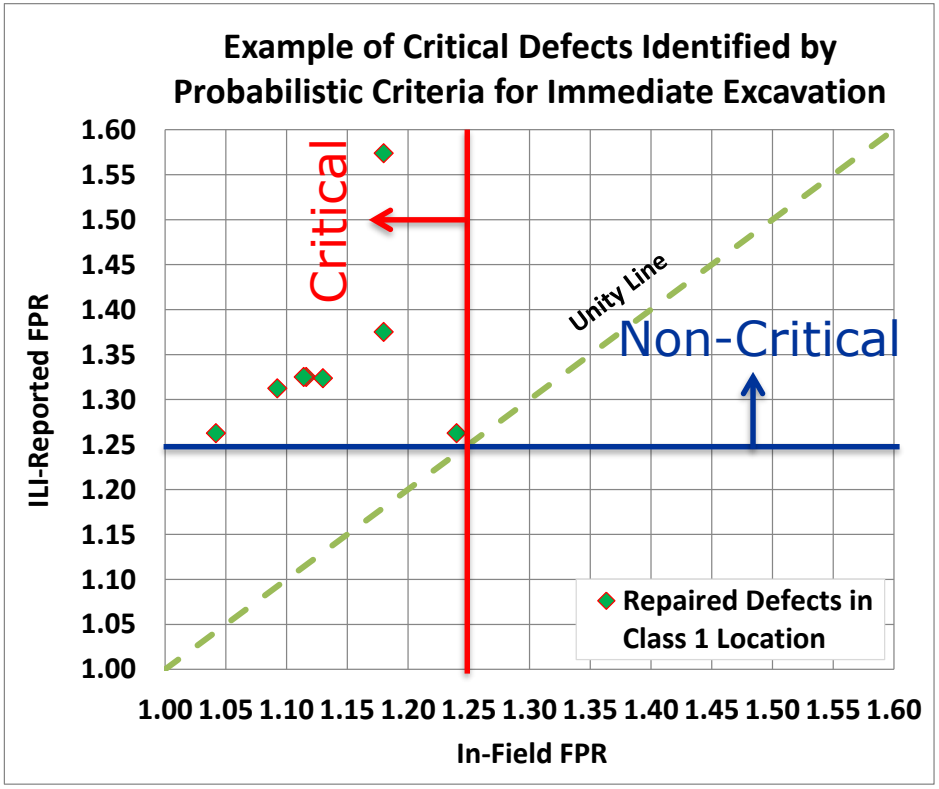
Limitations of Deterministic Approach

- **Does not acknowledge and account for any uncertainties**
- **Consequently, conservative in general, but not necessarily assure safety**

E.g. conservative when assessing long defects, but…



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Reliability-Based Approach for Defect Assessment

- **Reliability-based approach provides more consistent safety levels**

  Reliability targets available for assessing defects in the industry?

- **CSA Annex O Reliability Targets – not in per-defect basis**
  - Rupture (in per km-yr)
    - Function of OD, pressure and population density
    - developed for total reliability
    - average of all design cases
  - Leak
    - Max. allowable POL = 1.0E-03 (per km-yr)

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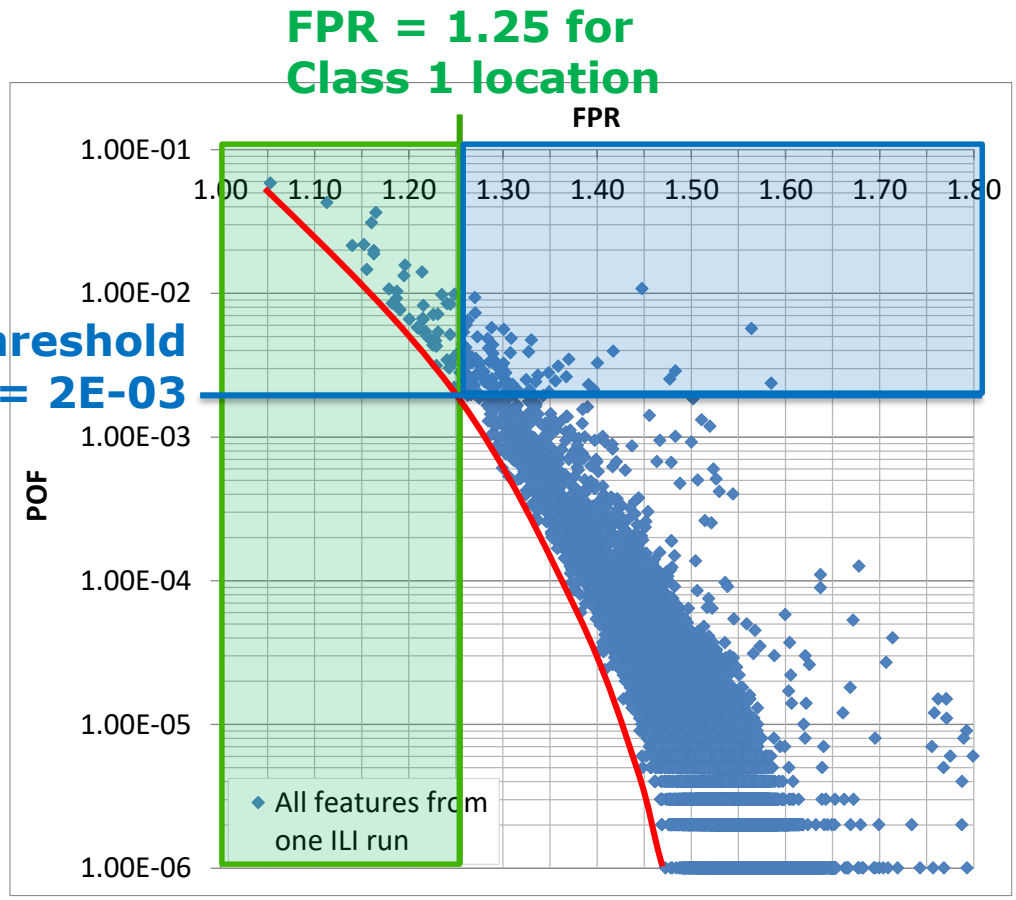
TCPL's Reliability-Based Criteria for Rupture

- **Pipeline- and ILI-run-specific**
- **Location-class specific**
- **Rationales**
  - Benchmarked to demonstrated acceptable safety levels;
  - Explicitly account for all uncertainties - more risk-consistent
  - Appropriate for defect assessment



TCPL's Reliability-Based Criteria for Leak

- **1E-03 per year (per defect)**
- **Rationales**
  - Equivalent to CSA Z662 Leak Reliability Target, i.e. 1-1E-03 per km-yr
  - Equivalent to 72%wt ILI depth
  - Practically aligned with TCPL's ILI depth criteria of 70%wt for excavation, since
    - MFL's limitation in sizing pinhole or complex corrosion features

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Benefits of Reliability-Based Approach and Criteria

Repaired-to-excavated ratio

= # of repair sites / total # of excavated sites

- Critical defect for repair (cutout or sleeve)
  - i. In-field FPR <= FPR safety factor, and/or
  - ii. Field-measured maximum depth >= 70%wt

- **Comparison** (based on 2011 and 2012 excavation data)

Approach	Repaired-to-excavated ratio	
Deterministic	15%	
Probabilistic / Reliability-Based	Overall	25%
	Immediate response	32%

Developing similar approach for crack assessment!

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RISK AND RELIABILITY TARGETS IN ENGINEERING ASSESSMENTS

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Reliability Targets Used in Engineering Assessments

- **Two types of reliability targets are used in EAs**
  - Defined targets – recommended values in code and standards (e.g., CSA Z662 Annex O) or TransCanada's internal targets (e.g., SWRA and Carlo)
  - Relative targets – calculated values for the code accepted mitigation options (such as pipe replacement or derate).
- **Use of defined or relative targets are determined on a case by case basis**

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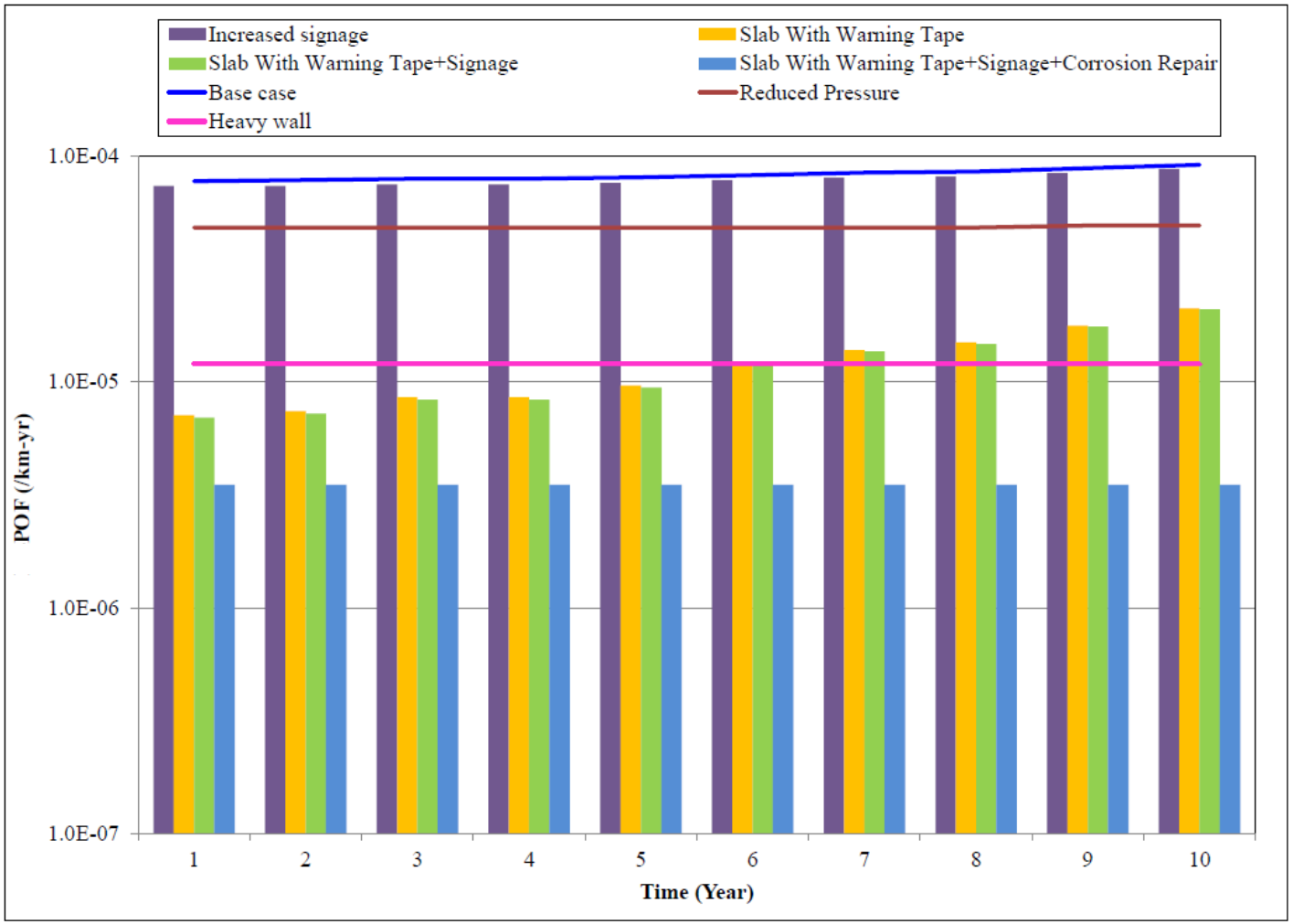
Relative Targets



Use a target that meets safety level implicit in code

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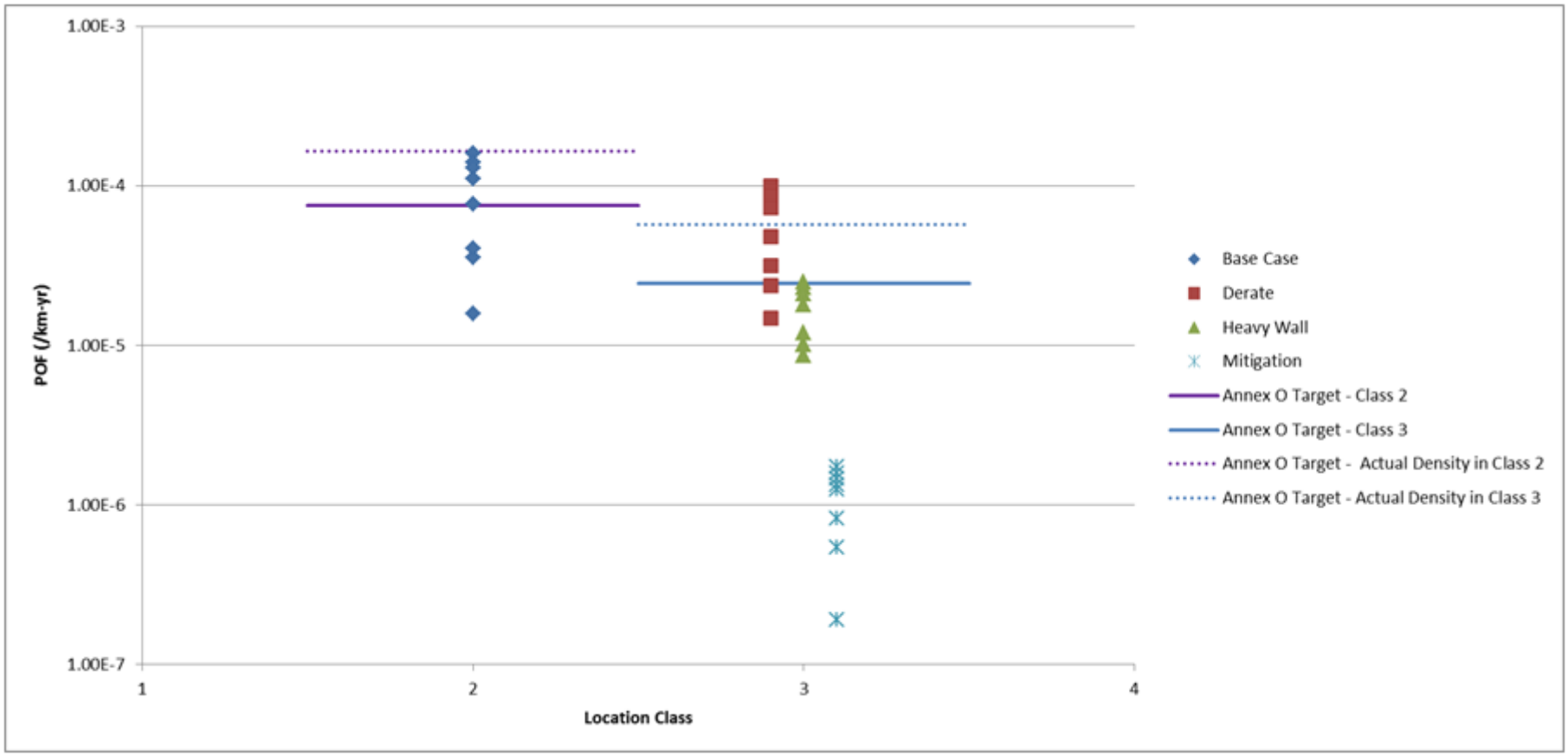
Comparison Between Annex O Target and Target Used in Out-of-Class EAs



The relative targets used in our EAs are similar and consistent with the targets defined in CSA Z662 Annex O

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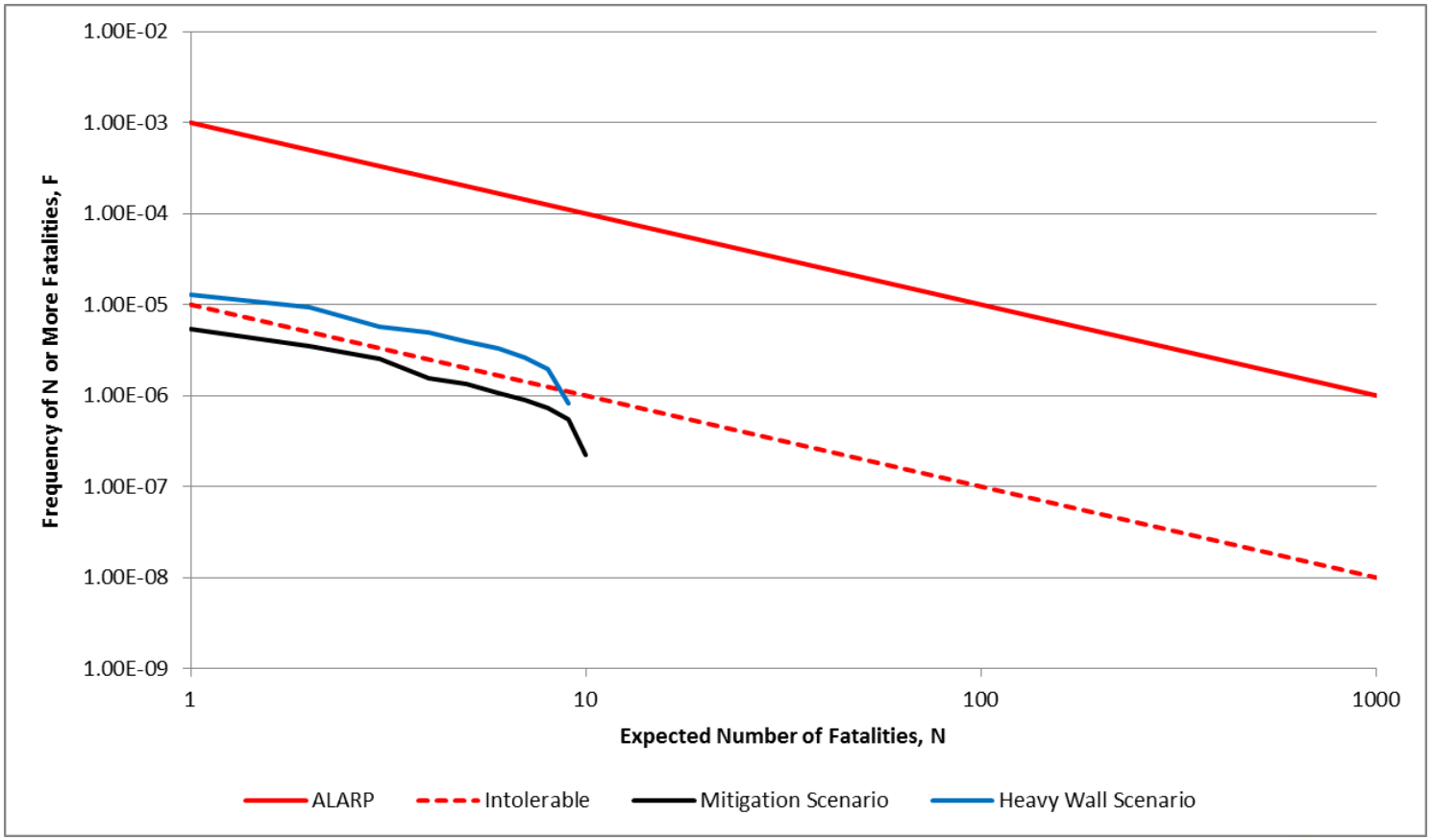
Ensuring Acceptable Risk Level in EAs

Compliance with IR and SR are also demonstrated in EAs by comparing mitigation option with the risk criteria



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Summary – Risk & Reliability Targets

A system is only as strong as its weakest link

- **Target Risk levels**
  - QRA methods can achieve more consistent levels of risk
  - SWRA targets
    - Follows best practice in industry IR and SR,
    - Consistent with actual statistics
    - Are aligned to practical TC scenarios to be realistic
  - Risk targets are smeared (averaged) -appropriate for segment risk
- **Target reliability levels**
  - Location specific explicit reliability targets - more consistent
  - Consistent with code safety factors, code accepted safety levels
  - In line with IR, SR, and Annex O targets

Consistency between best practices in industry

- **Deterministic designs based on Codes or Standards provide higher reliability for higher consequences on average –high variability**
- **Codes and Standards provide minimum standards for broad categories (e.g. class based designs) and common hazards**
- **Actual reliability varies around common cases based on site specific conditions not considered in design e.g., Ptape vs FBE, defects**
- **Risk and reliability criteria is often benchmarked to successful code practice (avg) and statistics but gives more consistent safety**
- **Reliability criteria - Site specific/local considerations make the calculation more precise and accurate (avoids failures)**
- **Risk and reliability methods have reasonable agreement when based on same assumptions**

Generic

Specific

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Questions?

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