TransCanada's Risk Management System for Pipeline Integrity Management

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Pipeline Risk & Integrity Management Enabler

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The PRIME project was started in 1998 to develop a Risk Management process for Pipeline Integrity and the infrastructure necessary to support it.

Through the PRIME project, the following items and processes were developed/acquired:

- Facilities and integrity data model.
- System wide facility data.
- A GIS system.
- PRIME Process: The Risk Management and Decision Analysis process used to develop TransCanada's Integrity Programs.
- PRIME Risk Models: The Hazard, Consequence, Risk Assessment and Decision Analysis Models used to execute the PRIME Process.

PRIME Process

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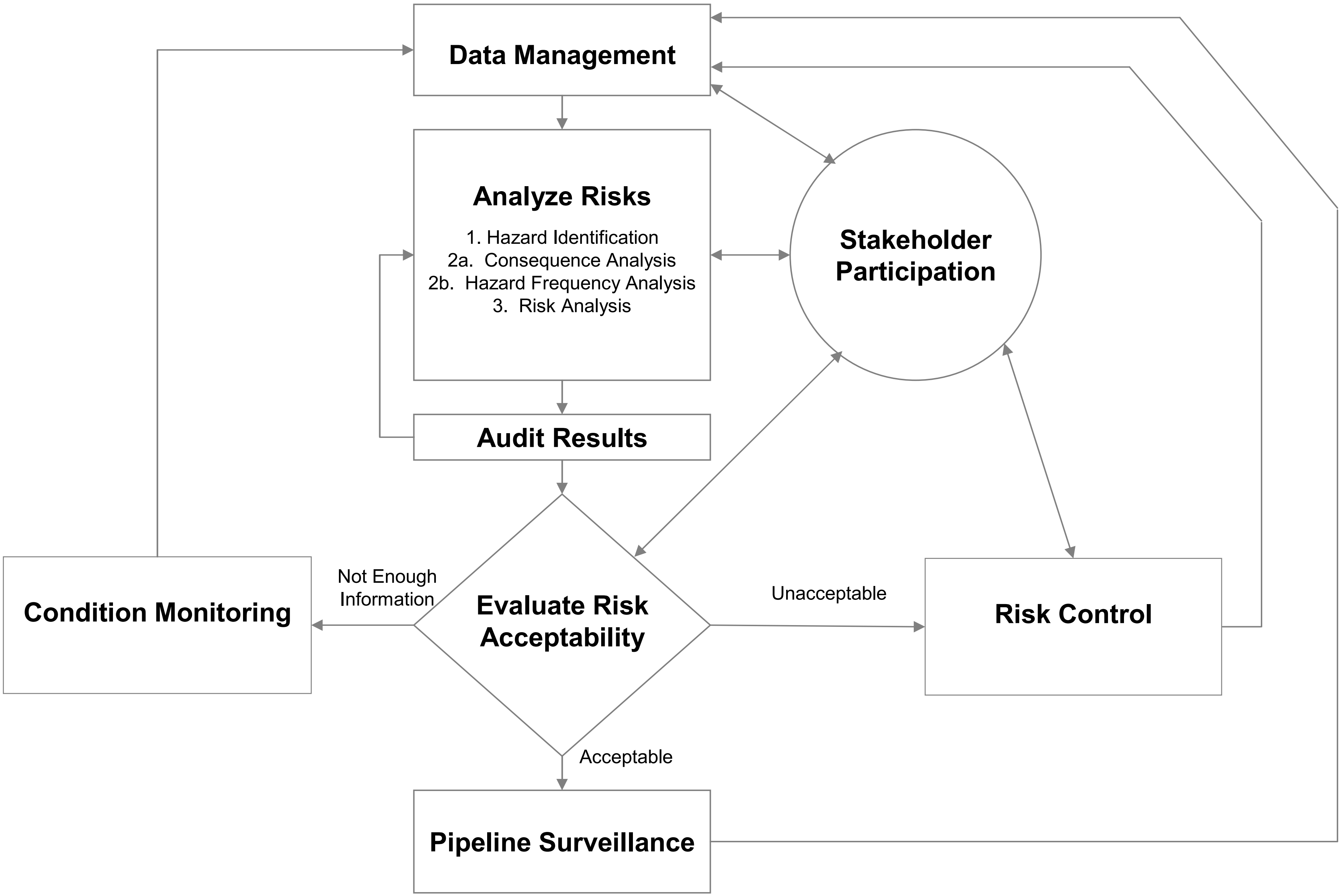
The PRIME Process is a risk-based decision making process used to develop and evaluate the majority of maintenance programs:

- MFL In-Line Inspections
- Hydrostatic Tests
- Condition Monitoring Investigations & Repairs
- Discrete Pipe Replacement/Recoating.



PRIME Process Flow Diagram

Decision Making Framework

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PRIME contains a framework for evaluating risk acceptability that provides:

- Common Goals
- Common Measures
- Common Decision Criteria

…to facilitate decision making

Pipeline Maintenance Goals

A Risk Management methodology should flow from the goals of a company's pipeline maintenance program.

Decision Criteria should reflect and be directly traceable to the company's goals.

Pipeline Maintenance Goals

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TransCanada's Pipeline Maintenance Goals include:

1. Provide an adequate level of safety to the public and employees.

2. Maintain lowest long-term operating and capital costs, except where there is conflict the above goal.

…among others

Measures of Safety

Goal: 1. **Safety of Public and Employees**

Measure: **Individual Risk**

Individual risk is a measure of the total risk faced by a risk receptor from all potential risk sources measured as an annual risk of fatality.

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Measures of Safety - Individual Risk

Individual Risk can be calculated both for known population and generically.

- Specific population data can quickly become ‘out-of-date’.
- Generic or ‘inherent’ individual risk can be used to establish and maintain a ‘baseline’ level of safety for a pipeline.

Measures of Safety - Inherent Individual Risk

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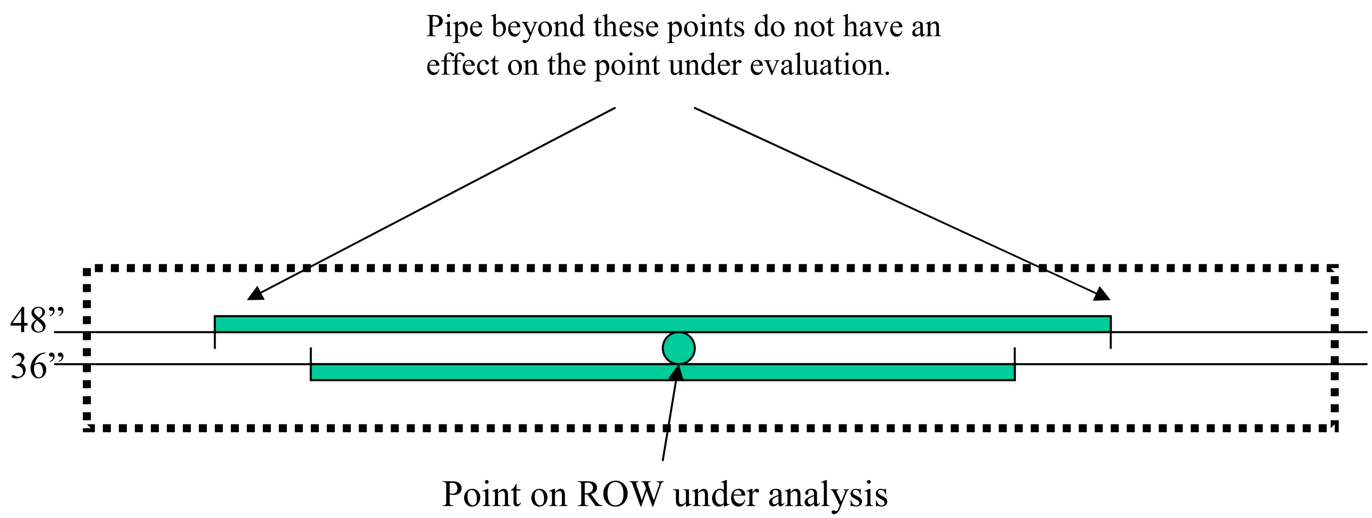
'Inherent' individual risk assumes constant occupation by a single individual on top of the right-of-way.

Main variable is failure frequency.

Each meter of ROW is evaluated independently.

Individual Risk is calculated for each meter (Risk Source) of P/L relative to a specific point on the ROW (Risk Receptor).

The sum of the risk from each meter of pipe highlighted gives the Individual Risk for the point on the ROW below.



$$Individual\,Risk = \int_{-X}^{+X} F_x \times (P_{Ignition} \times P_{Fatality}(R, R'))_x \, dx$$

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Safety Decision Criteria

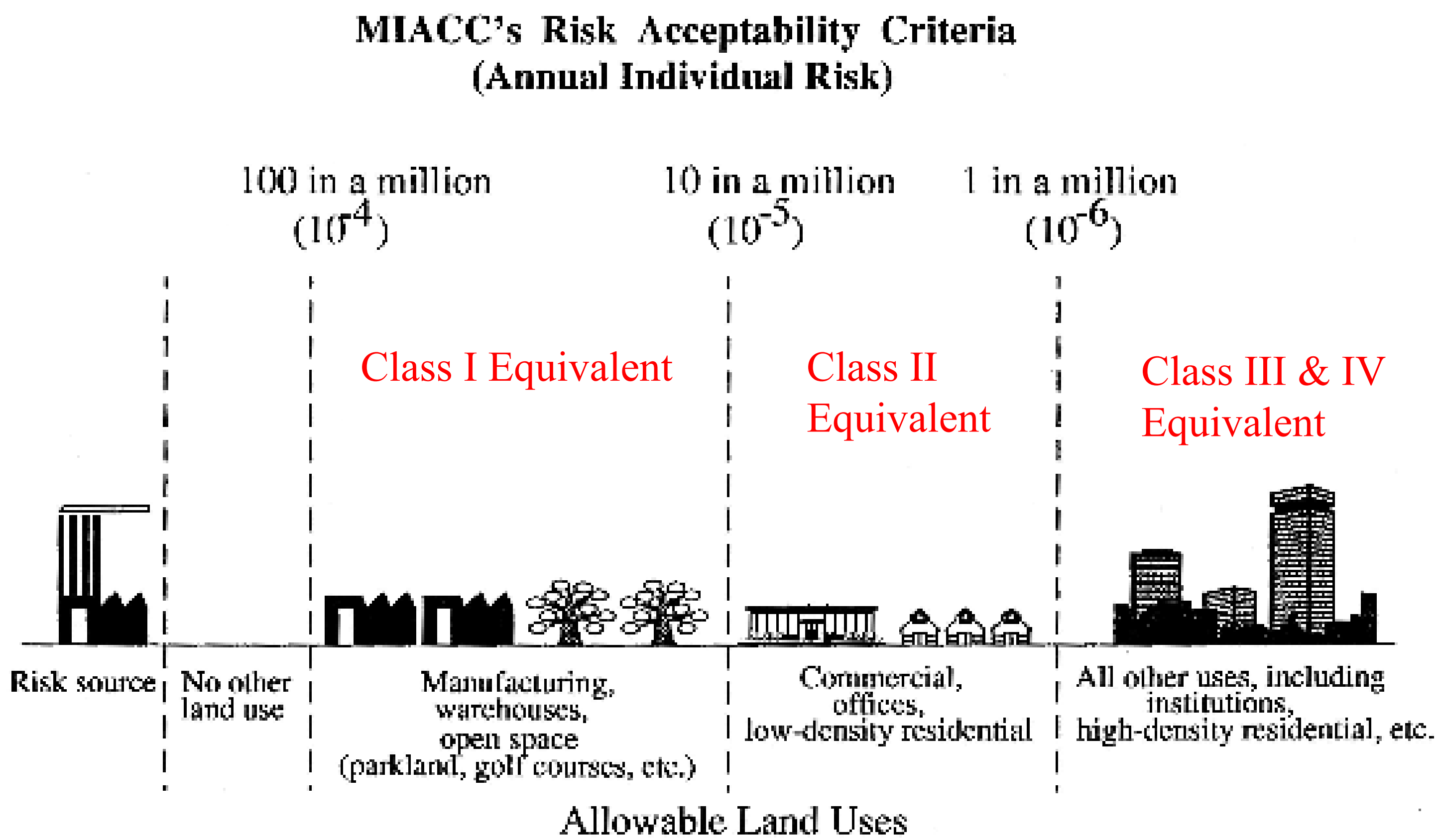
Goal: 1. **Safety of Public and Employees**

Measure: **Individual Risk**

Decision Criteria: **MIACC Land Use Guidelines**

MIACC (Major Industrial Accidents Council of Canada) published risk-based land use guideline in the early 1990's.

Land uses types have been interpreted in the context of pipeline class location definitions.



Risks exceeding the risk acceptance threshold for the pipeline's corresponding class must be reduced to a level below that threshold.

Safety Decision Criteria

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Goal: 1. **Provide an adequate level of safety to the public and employees.**

Measure**: Individual Risk measure of the annual risk of fatality. Inherent risk and risk to known receptors.**

Decision Criteria**: MIACC Land Use Guidelines define 'an adequate level of safety'.**

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Financial Measures

Goal: 2. **Lowest long-term operating and capital costs**
Measure: **'Value Ratio' VR**

Key to achieving low long-term costs is considering both the cost of pipeline incidences and the cost to mitigate risk.

VR generated on a project by project basis.

VR = Risk Reduced ($) / Cost of Project ($)

Financial Measures - Calculating 'Risk Reduced'

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A pipeline failure can generate a variety of consequences.

- Consequences are measured as:
  - A short-term direct financial loss.
  - A longer term indirect financial loss.
  - Losses to the company or society that are not financial in nature.
- In order to produce the VR measure, non-financial losses need to be mapped to an equivalent dollar loss

Financial Measures - Calculating ‘Risk Reduced’

Major consequence categories are:

- Direct Financial Impact
  - Cost of repair.
  - Purchase of linepack.
- Indirect Financial Impact
  - Fines
  - Proving the integrity or ‘fitness for service’ of the affected pipeline.
  - Longer term impact to the company’s image or ability to do business.
    - Community or regulatory relationship.

Financial Measures - Calculating 'Risk Reduced'

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Major consequence categories are:

- Customer Impact
  - Financial loss incurred by the customer
    - Through-put restriction
    - Impact to Firm Service contracts
- Third-Party Impact
  - Property Damage
  - Court Settlements
- Environmental Impact
  - Fines and Penalties
  - Site Restoration Costs

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Financial Measures - Calculating 'Risk Reduced'

The total consequence of a pipeline failure is the sum of the consequences calculated under the previous five categories.

The total failure frequency of a pipeline is the sum of the annual per meter failure frequencies contributed by each applicable hazard.

Risk = Total Consequence X Total Failure Frequency

Units of $/m*yr.

Financial Measures - Calculating 'Risk Reduced'

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The risk reduction benefit of a pipeline maintenance project requires risk to be calculated for both the 'as is' or base case and the 'after maintenance' or remaining risk case.

$$RiskReduced = \sum_{i=1}^{m} (\sum_{t=1}^{n} (R_{i,t(Base)} - R_{i,t(\text{Re}maining)}))$$

m is the affected length of pipe.
n is the number of years over which the project will have a measurable benefit.

Financial Decision Criteria

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Goal: 2. **Maintain lowest long-term operating and capital costs, except where there is conflict with the first two goals.**

Measure**: VR**

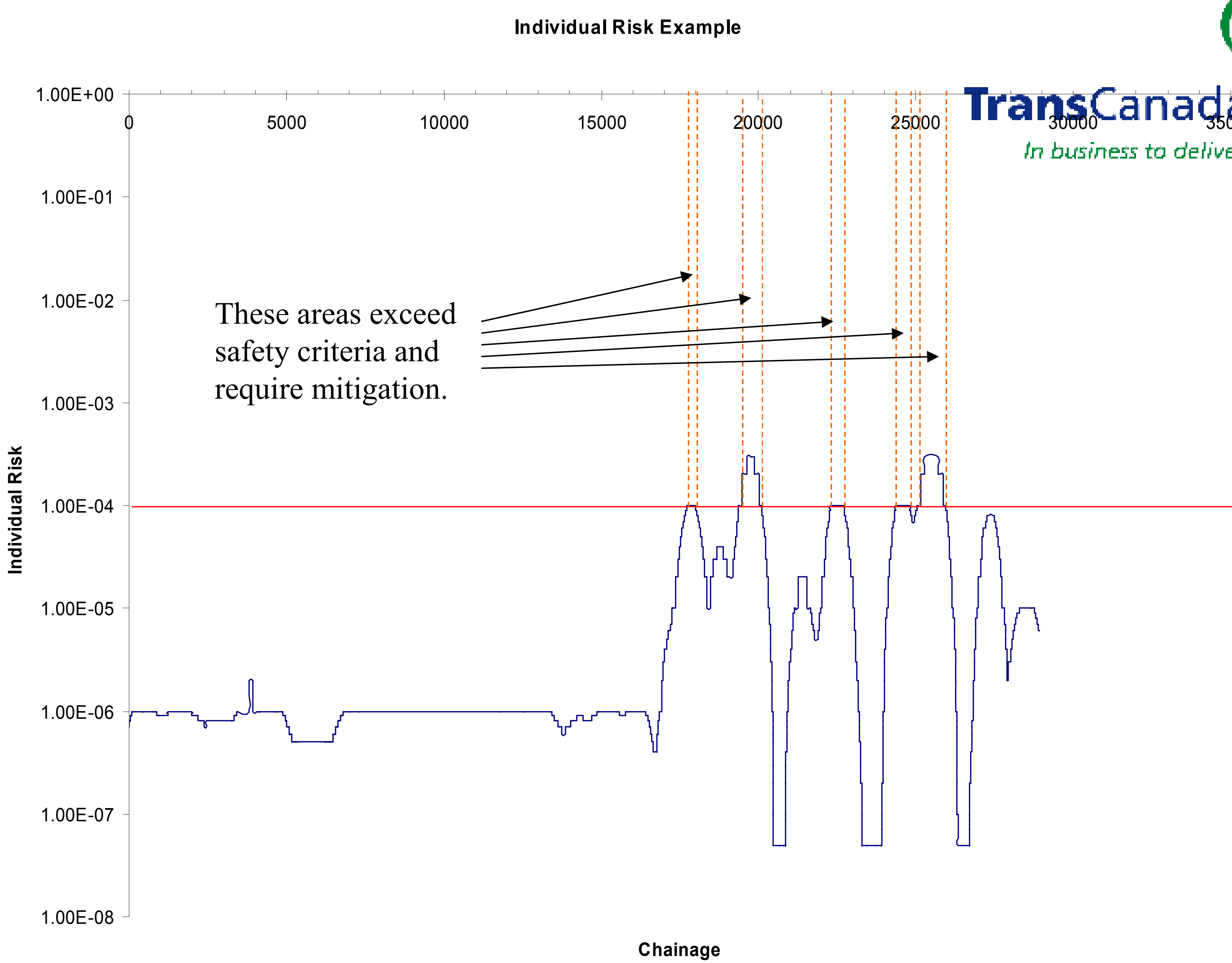
Decision Criteria**: VR's greater than one represent projects whose cost is justified based on an expectation of future aversion of loss.**

Example

Evaluating a 35km NPS 36 Class I pipe.

Analysis Steps:

- Individual Risk is calculated and evaluated against acceptance criteria.
- Projects are identified that mitigate safety risk to an acceptable level.
- Project with most beneficial VR implemented.



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Example - Alternative Analysis

The following four options were identified as being able to reduce the safety risk to an acceptable level.

Pipeline Maintenance Options	Cost	Risk Reduction	IPV
Hydrostatic Test	$900,000	$5,300,000	5.89
Traps + In-Line Inspection + Digs	$2,000,000	$2,300,000	1.15
Pipe Recoating (~5 km)	$5,100,000	$2,200,000	0.43
Pipe Replacement (~5 km)	$8,700,000	$2,500,000	0.29

The VR analysis identifies hydrostatic testing as providing the greatest risk reduction value.

Risk Based Decision Framework

This framework for quantitative risk-based decision making provides:

- Consistent decision making
- Clear relationship between company goals, risk measures, and decision criteria
- Prioritizes safety
- Facilitates alternative analysis

Risk Analysis - Hazard Identification

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Focused on hazards that are a relevant to the TransCanada system, including:

- Corrosion
- Mechanical Damage
- Stress Corrosion Cracking
- Geotechnical - Slope Movement

Corrosion Management

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The primary method for addressing the hazard of external corrosion is through MFL In-Line Inspection and Defect Management

- Majority of the system can be inspected
- ILI provides the most accurate information on External Corrosion of any available technique
  - MFL data is still an indirect measurement

Standard Industry Practice

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Standard industry practice is to excavate MFL defects based on deterministic depth and failure pressure criteria. TransCanada's are:

- Depth > 70%
- Failure Pressure < 1.25(MOP)

Deterministic criteria implicitly accounts for uncertainty by increasing conservatism

Goal is to restore original design factor and prevent pipeline incidents

Deterministic Criteria

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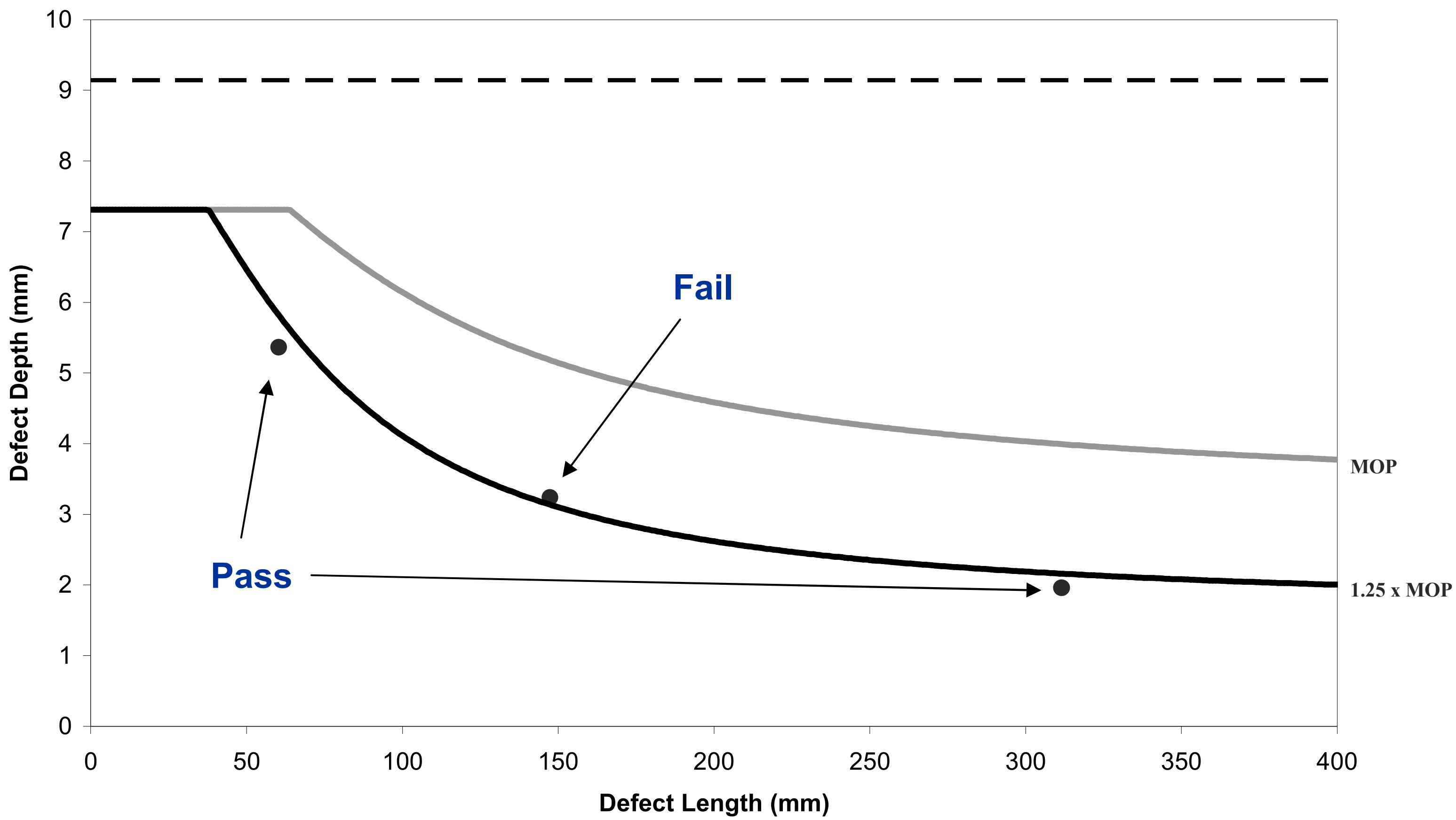

Probabilistic Criteria

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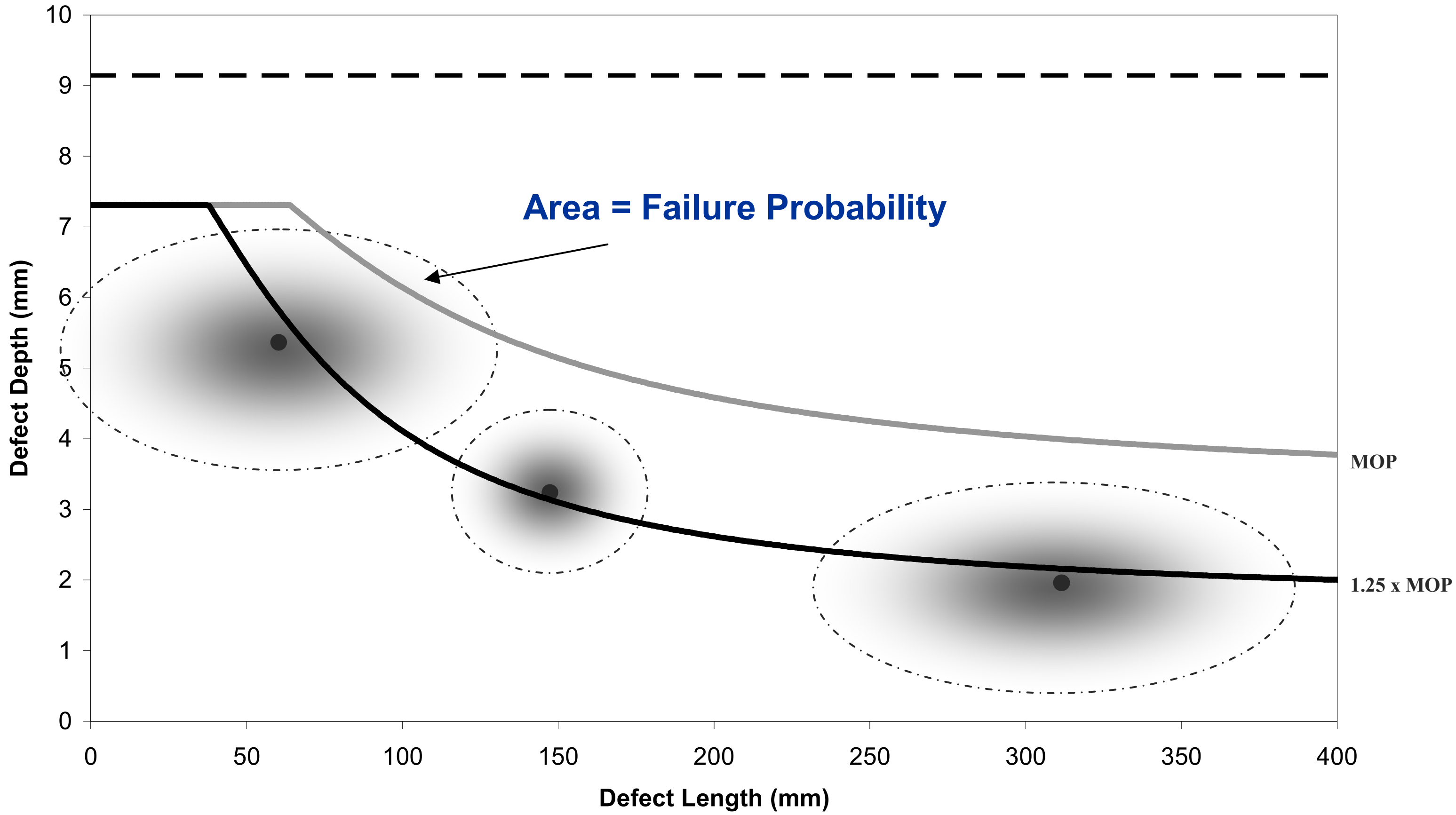

Calculating Defect Failure Probability

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Defect Risk Management Process:

- Probabilistically quantify:
  - depth error
  - length error
  - growth rate
    - As applicable
- Identify failure probability through simulation

$$p(Rupture) = \sum_{i=1}^{N} \mathrm{I}_{\{(\mathrm{P}(\mathrm{L}_i, \mathrm{AD}_i(\mathrm{L},\mathrm{W}))\text{-}\mathrm{P}_{\mathrm{Err}})>\mathrm{M})\}} / N$$

  - Simulation Size Depends on Desired Accuracy

- Assess defect acceptability (Risk Management Process)

MFL Data – Depth Uncertainty

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Depth Accuracy: +/- 10% 80% of the time

- Equivalent to a normal distribution with:
  - Mean: 0%
  - Standard Deviation: 7.8%

- More complex corrosion:
  - Standard Deviation: 11%

- As more data is collected for a particular line, these statistics are updated

MFL Data – Peak Depth Accuracy

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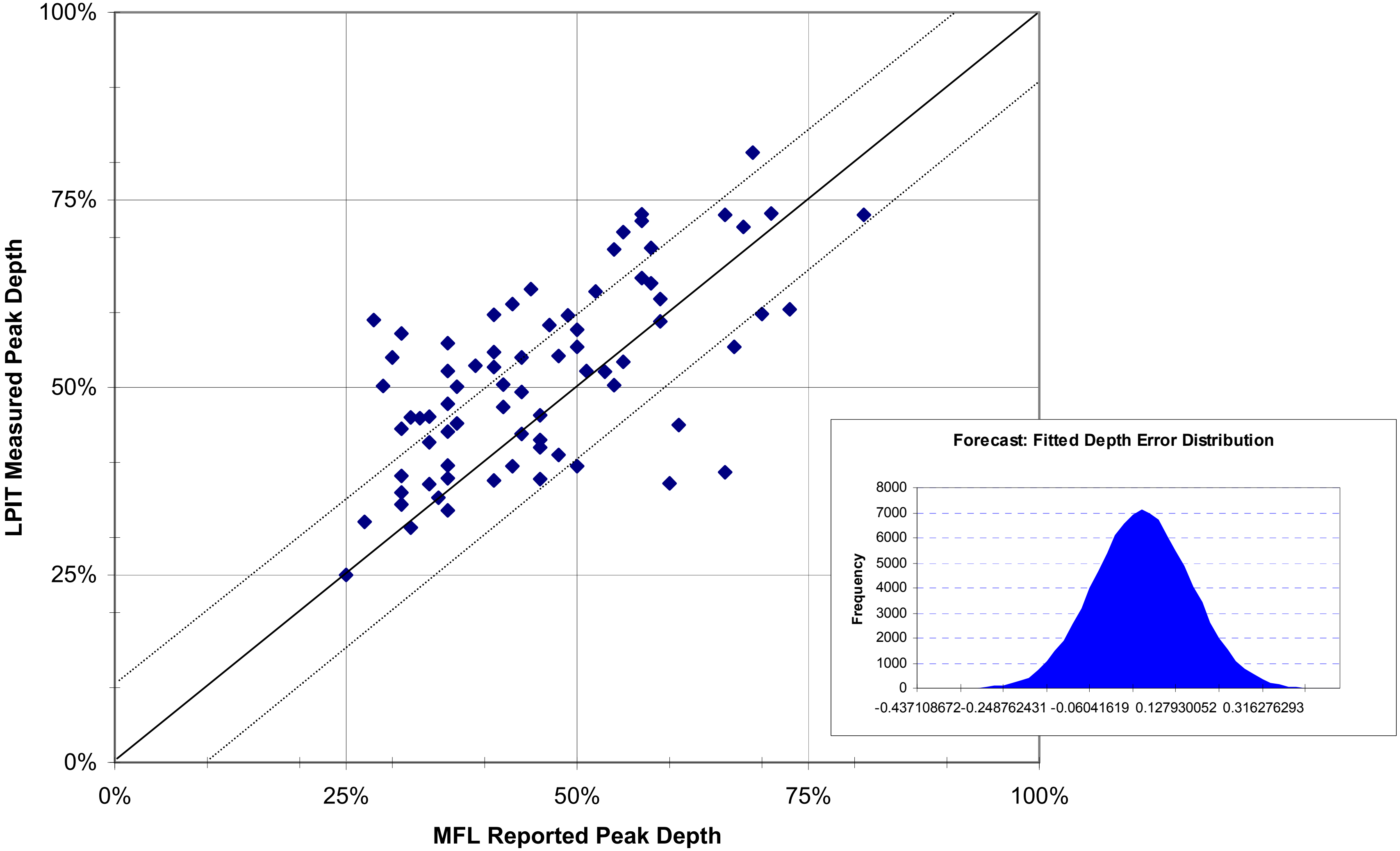

MFL Data – Length Uncertainty

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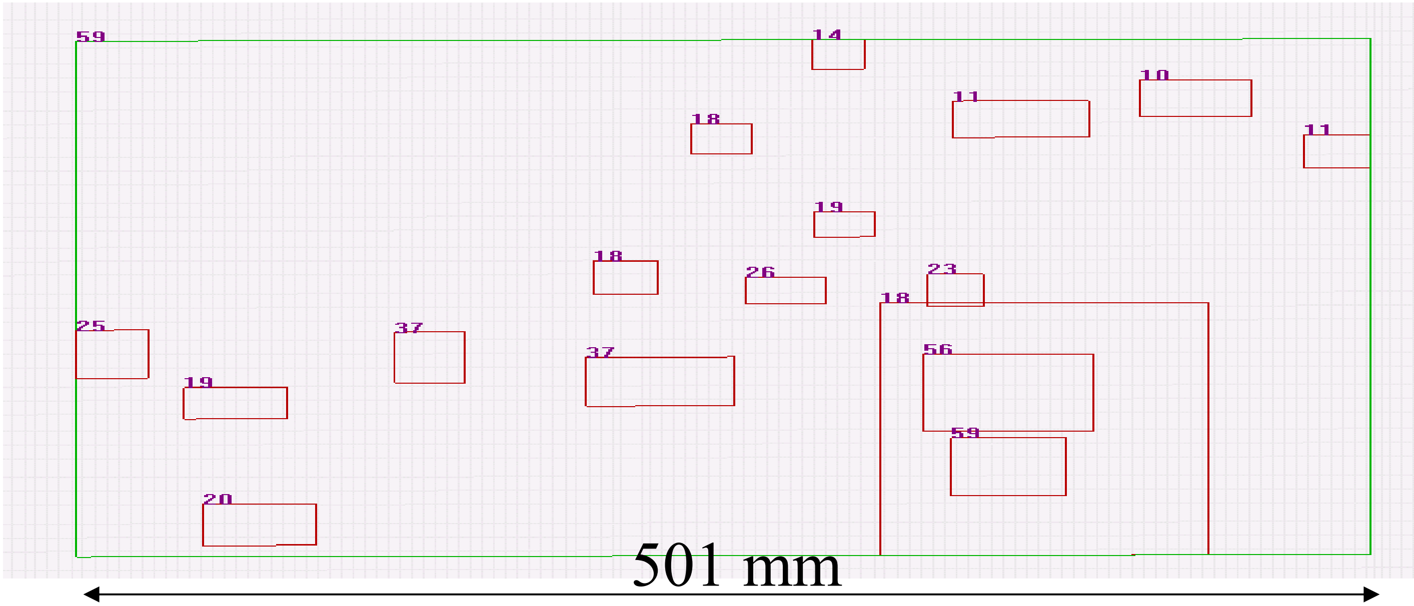
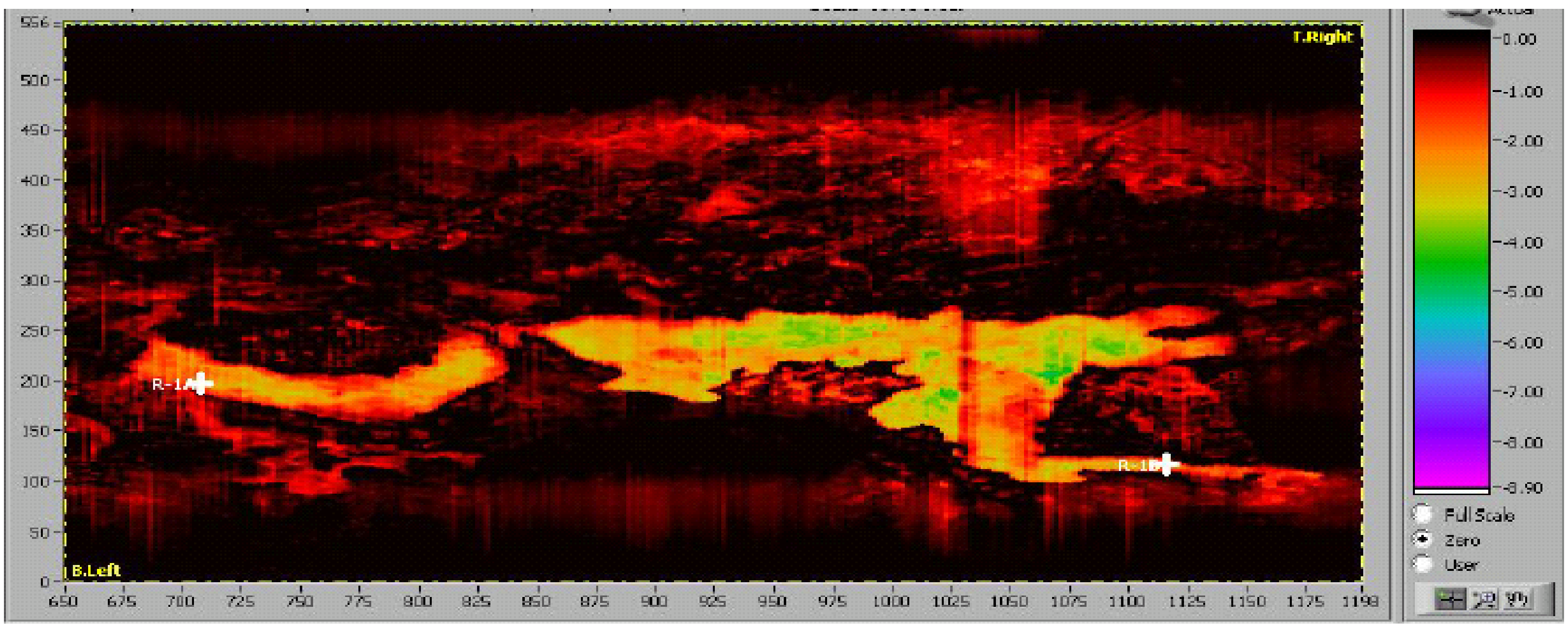
Length Accuracy: +/- 20mm 80% of the time

- Equivalent to:
  - Mean: 0 mm
  - Standard Deviation: 15.6 mm

- Also affected by complexity of the corrosion

- Clusters consisting of several boxes:
  - Standard Deviation: 22 mm


59
14
18
11
10
11
19
18
26
23
18
25
37
37
56
19
59
20
501 mm


T.Right
B.Left
R-1A
R-1B
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
-8.00
-8.90
Full Scale
Zero
User

Signal Comparison

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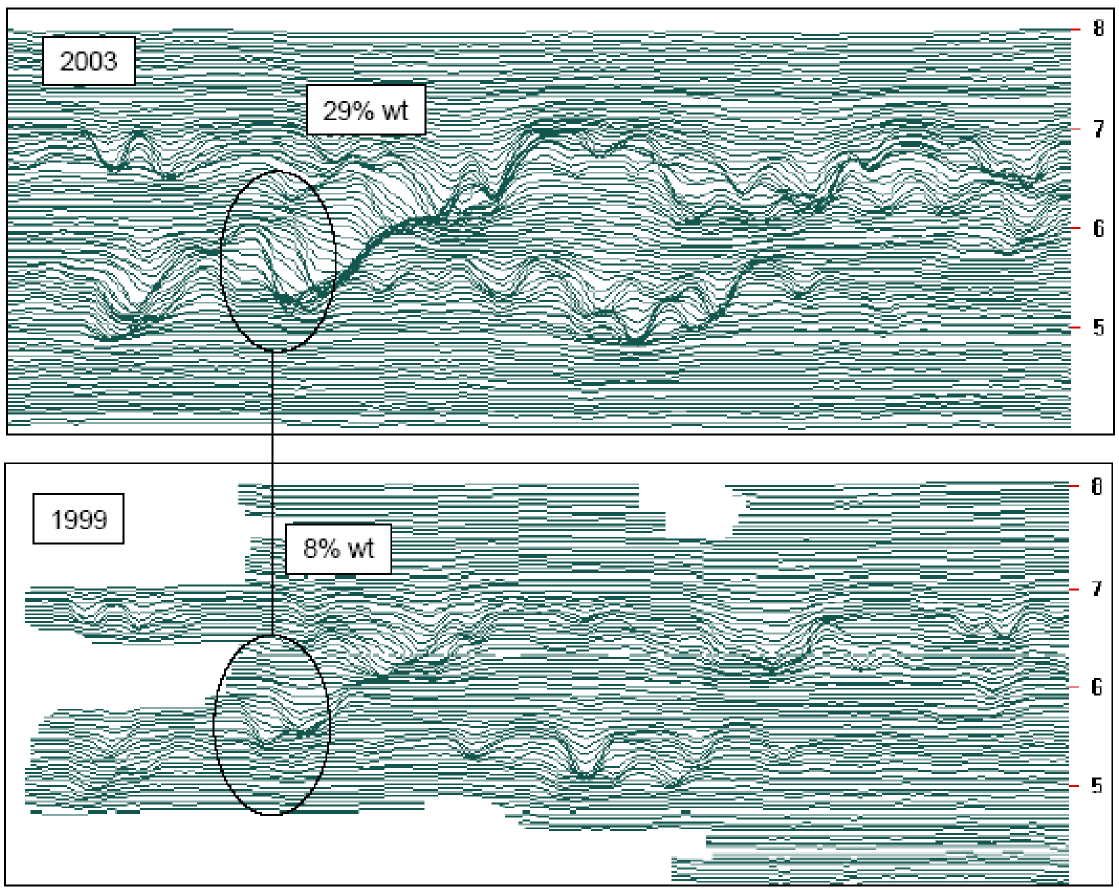
Estimating corrosion growth critical to determining when currently sub-critical defects will require repair

Corrosion growth rates estimated through a comparison of MFL signal data



Segmenting Pipeline by Measured Growth

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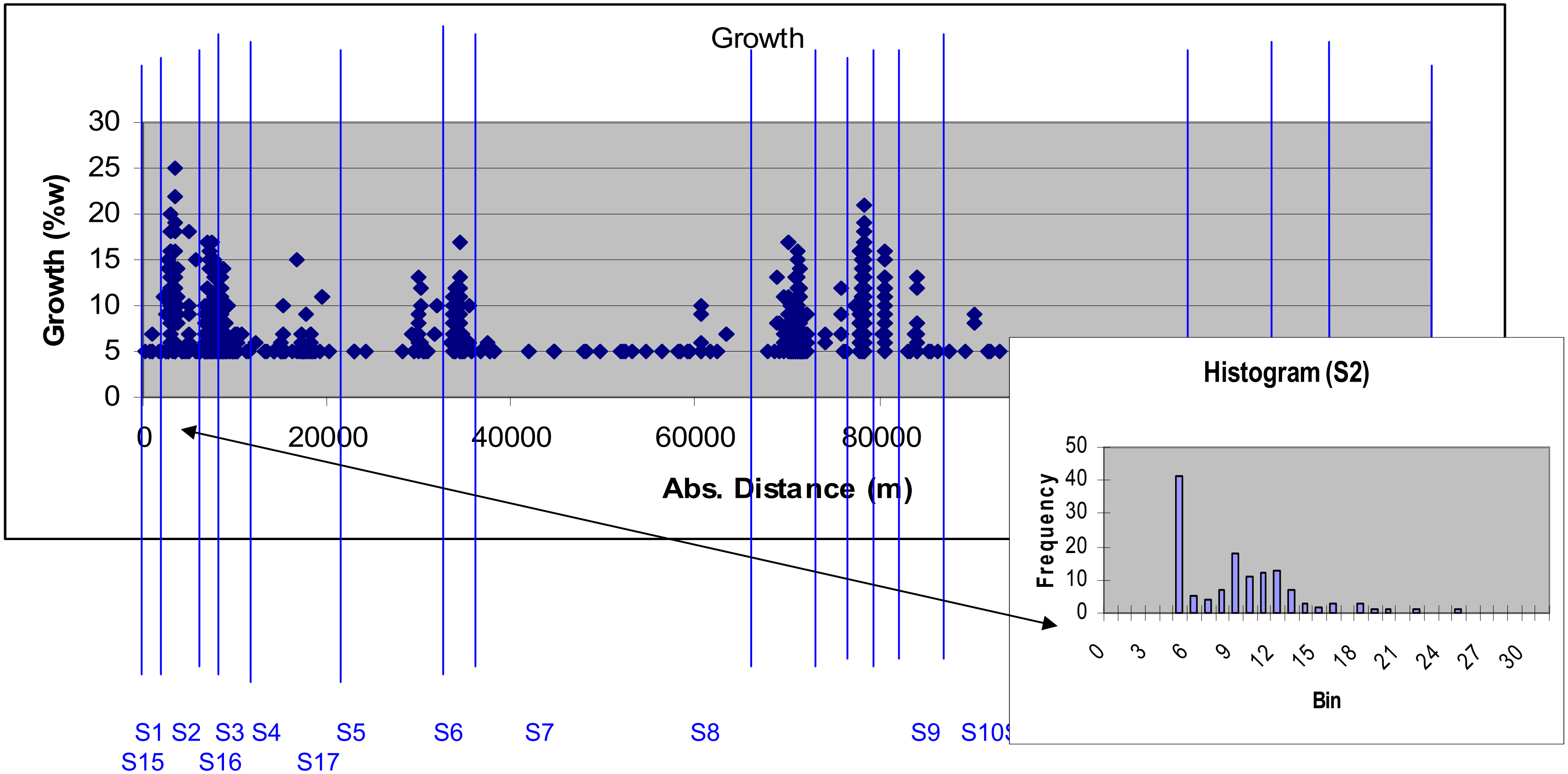

Regression Tree Analysis

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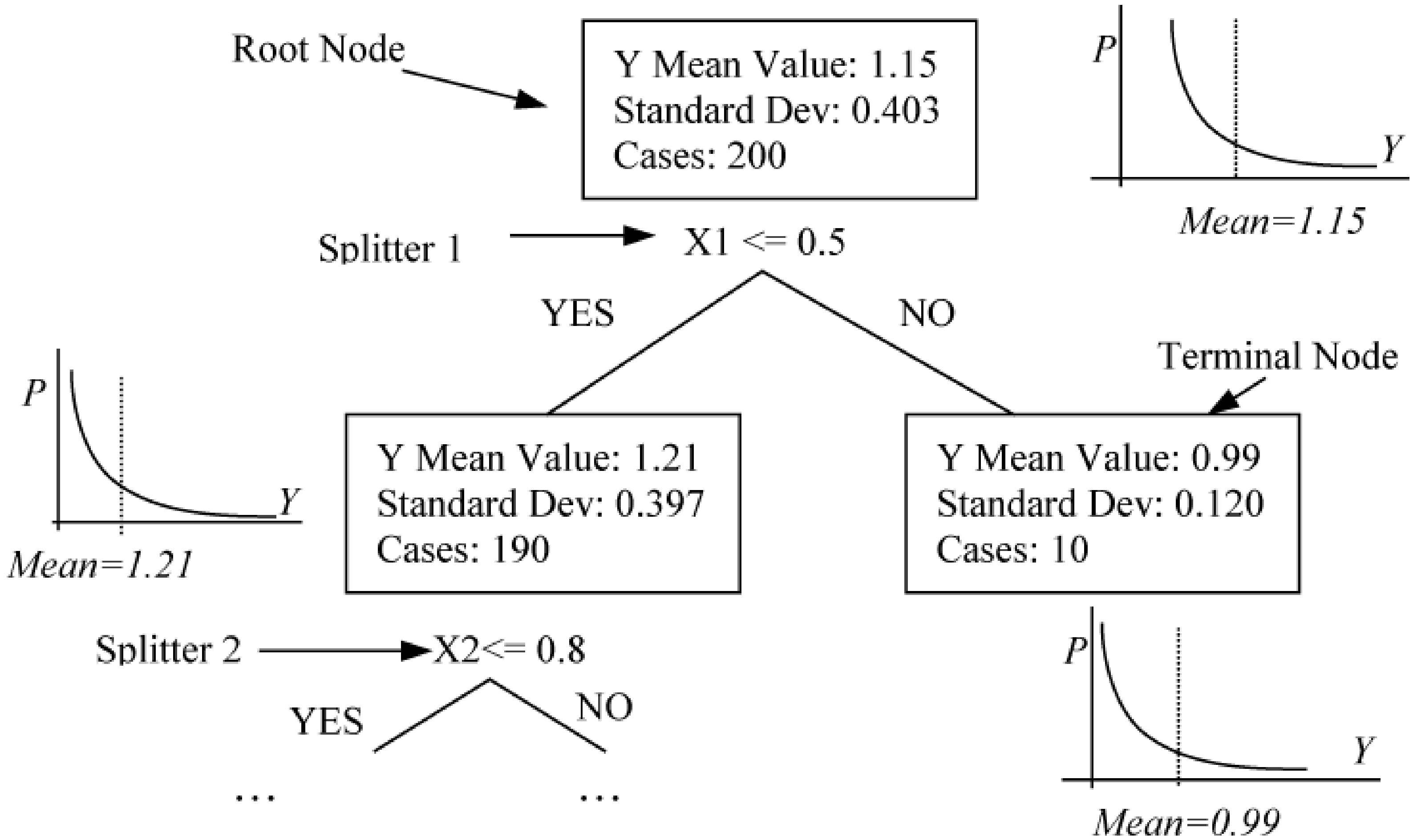

Risk Acceptance – Individual Risk Criteria

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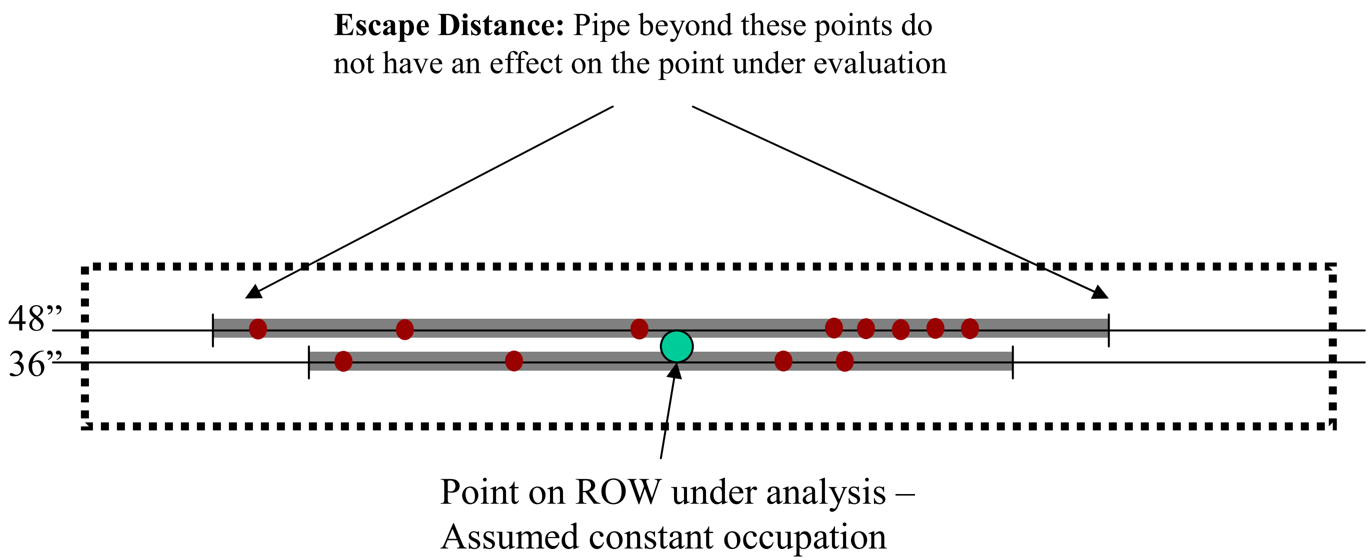
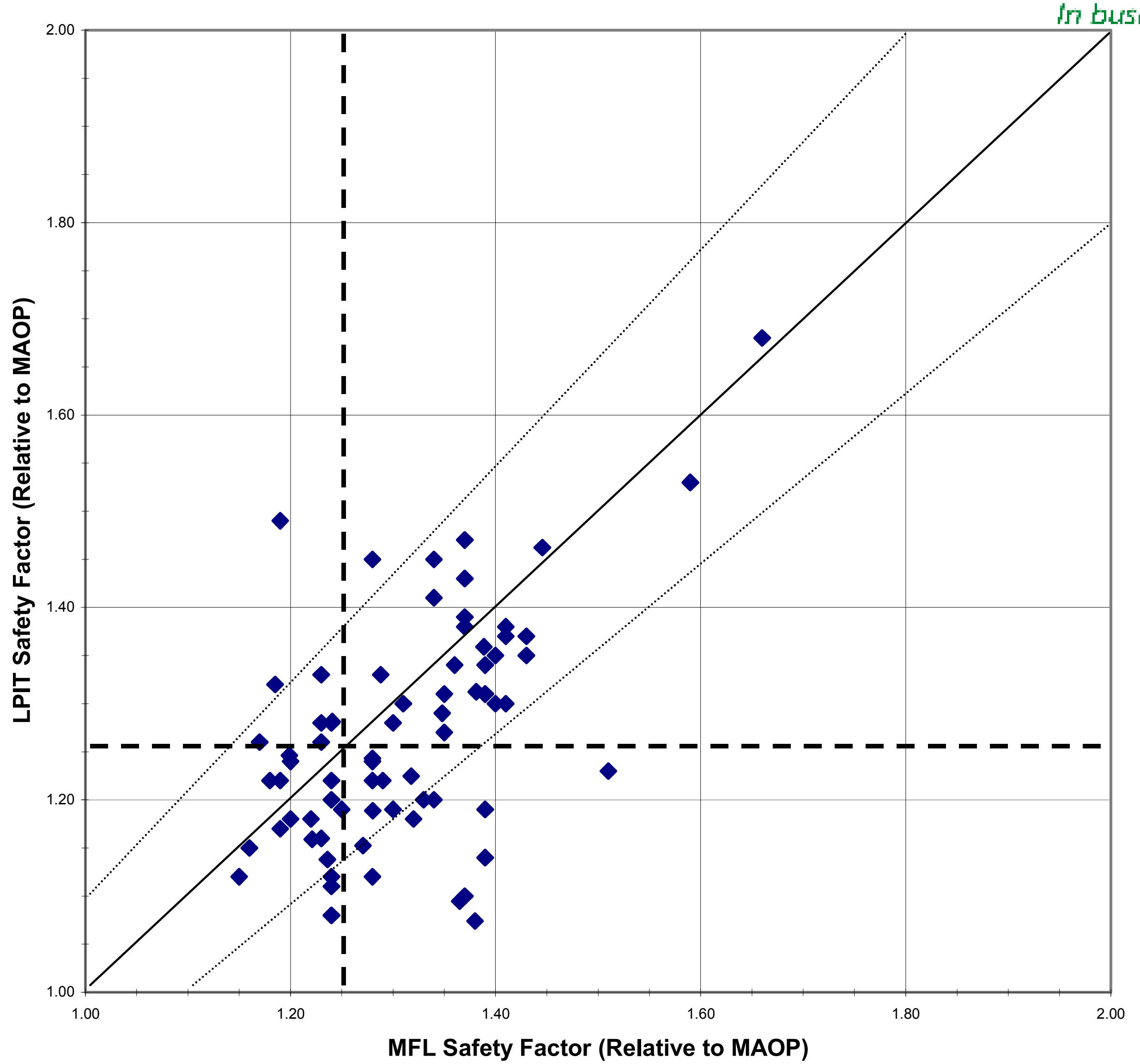


$$IndividualRisk = \int_{-X}^{+X} P_x \times (P_{Ignition} \times P_{Fatality}(R, R'))_x \, dx$$

Correlation Results – Risk Based Digs



Risk Based Digs - Results

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Increased Dig Program

- 27 Defects Deterministic -> 73 Defects Risk Based

Significant Defects Found and Repaired

- 18 Defects Deterministic -> 37 Defects Risk Based

Worst Defect Identified Through Risk Process

Improving Rupture Frequency Trend

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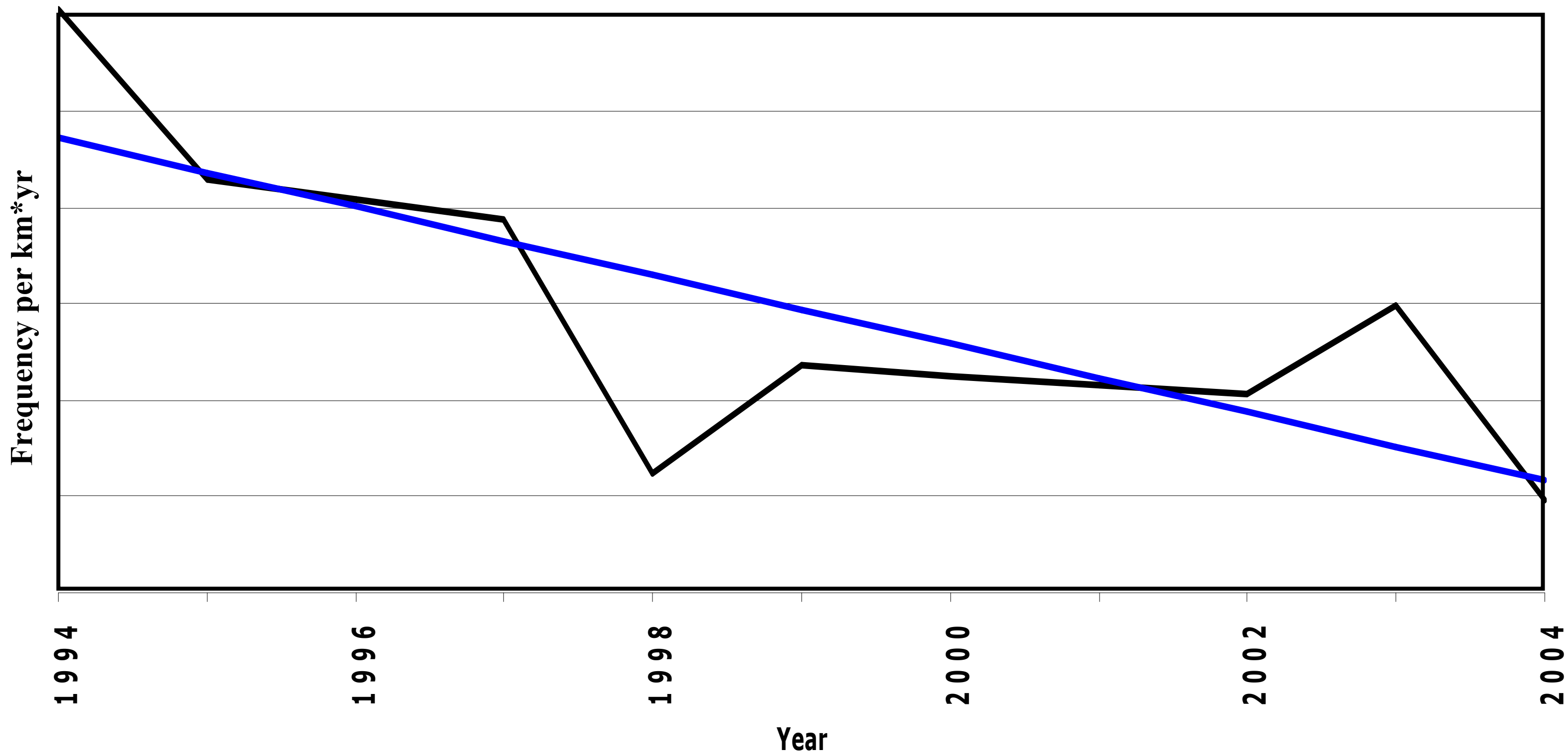

Pipe Maintenance Program Spending Trend

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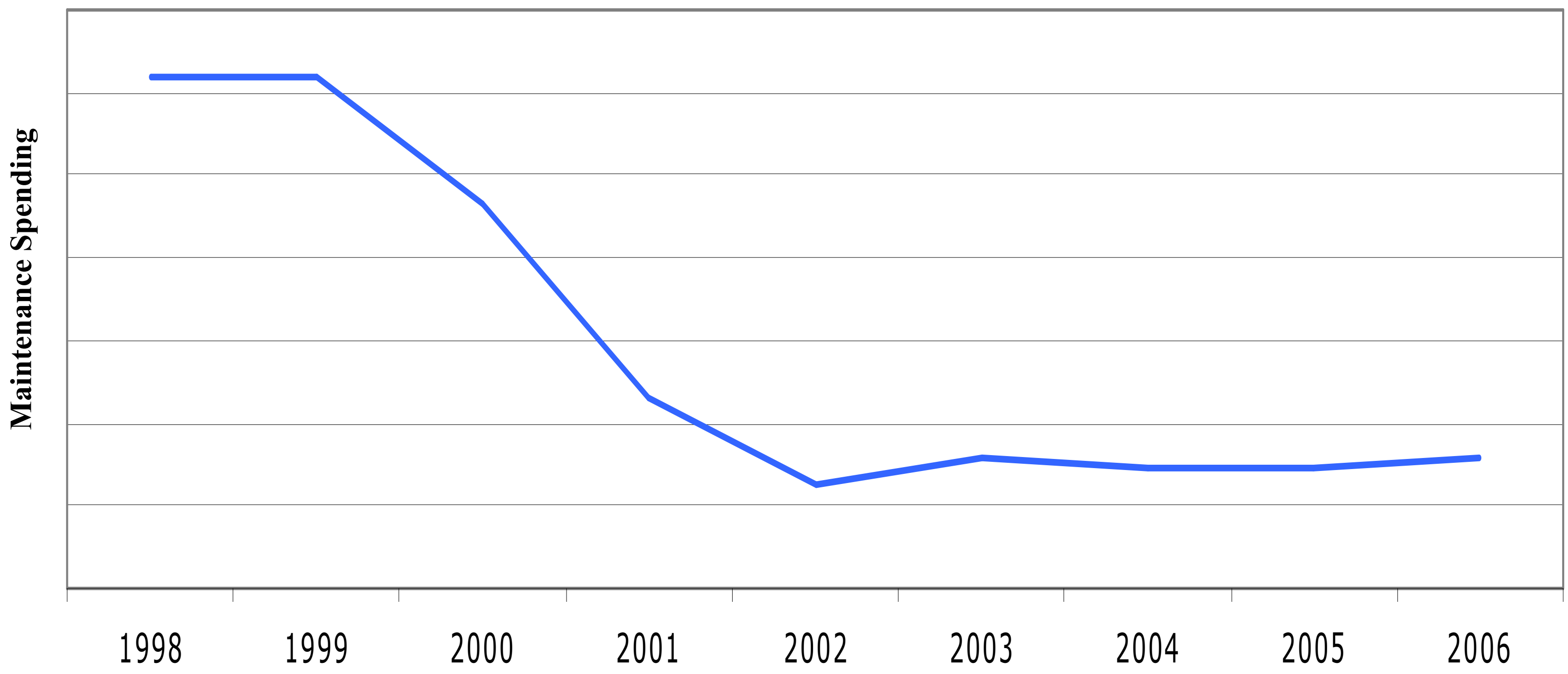

Conclusions

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The PRIME process resulted in both:

- Significant cost savings relative to the industry standard approach
- Improving reliability and reduced risk exposure relative to the industry standard approach.

Provides a rationale for determining maintenance spending levels and allocating those resources

Provides a mechanism for continuous improvement through the incorporation of new quantitative information.

Second Generation Pipeline Risk Management Why Upgrade?

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- Operating Experience
- Scope
- Regulatory Change
- Scientific Advancement
- Data Availability
- Computing Power
- Obsolescence and Support

Operating Experience

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Decision criteria dominated by two types of consequence

High dependence on data

- Physical and spatial attributes
- Maintenance data
- Third-party data sources (ILI, LPIT, Imagery, etc.)
- Industry statistics

Platform dependence is an issue (OS, desktop, network, related apps)

Ongoing technical support burdens

Limited ability to revise and enhance

Scope

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- System growth, primarily through acquisitions
- Support required for several pipelines in U.S.
- Need for liquids pipeline support
- Acquisition of off-shore facilities
- Greater number of users; differing areas of expertise

Regulatory Change

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- Changes to Canadian regulations
- Introduction and Changes to U.S. regulations
- Changes to Industry standards (CSA Z662 and ASME B31)

Scientific Advancement

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Improvements to existing engineering models

New engineering models

Capitalizing on previous R&D effort

Data Availability

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- Electronic access to 3rd party information
- Migration of old data
- Industry adoption of standardized data structures (ISAT, PODS, etc.)

Computing Power

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- Order of magnitude increase in desktop computing power
- Order of magnitude increase in server/network throughput
- Fewer compromises required
- Better tools for development, deployment and support

Obsolescence and Support

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- Tools (PERL SDK, Tk, ODBC)
- Platform (PERL runtime, Windows XP, IE, Office 2003, Oracle)
- Stand-alone versus I.S. support

Thank you

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