

Presentation to UKOPA Technical Seminar

# UKOPA Dent Assessment Algorithms: A Strategy for Prioritising Pipeline Dents

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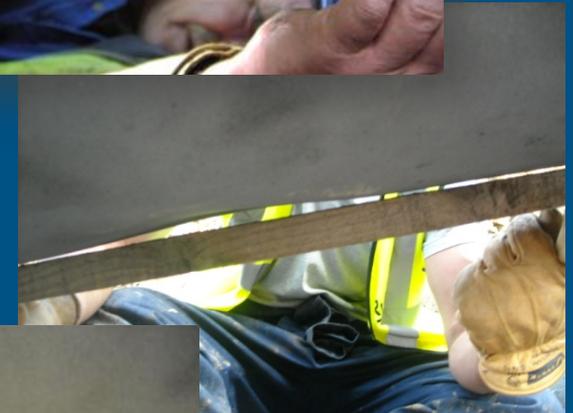
Barry Dalus – Northern Gas Networks Ltd

# The Problem Statement

- Improvements in caliper tool inspection mean that dents below previous detection limits are being reported
- Operators can be faced with hundreds of dents which require assessment
- Application of code guidance, particularly with respect to fatigue, can leave large number of dents requiring investigation or repair
- Dent fatigue failures are beginning to be reported and are raising technical concerns with operators
- Best practice guidance required for safe and economic operation of dented pipelines

# Overview of Presentation

- Review of Dent Acceptance Standards
- Review of Dent Management Strategies
- UKOPA Dent Algorithms
- Review of Dent Fatigue Assessment Methodologies
- Further Work Planned
- Conclusions



# Static Assessment Methods

## Depth Based

	Plain Dents	
	Constrained	Unconstrained
ASME B31.8	Upto 6%OD	
ASME B31.4	Upto 6% OD in pipe diameters > NPS 4 Upto 6mm in pipe diameters < NPS 4	
API 1156	Upto 6%OD >2% OD requires a fatigue assessment	
EPRG	≤7%OD at a hoop stress of 72%SMYS	
PDAM	Upto 10%OD	Up to 7%OD
Z662	Upto 6mm for ≤ 101.6mm OD or <6%OD for >101.6mm	

# Static Assessment Methods

## Depth Based

	Dents at welds	Dents with cracks or gouges	Dents with corrosion
ASME B31.8	<ul style="list-style-type: none"> <li>Upto 2%OD or 4%strain on ductile welds</li> <li>Not allowed on brittle welds</li> </ul>	Not allowed	Assess individually
ASME B31.4	Not allowed	Not allowed	Not allowed
API 1156	<ul style="list-style-type: none"> <li>Upto 2%OD or 4%strain on ductile welds</li> <li>Not allowed on brittle welds</li> </ul>	Not allowed	Not considered
EPRG	Not allowed	Not allowed	Not allowed

# Dent Assessment: Code Requirement and Guidance

## In gas pipelines:

- Due to re-rounding effects dents  $>2\%OD$  are likely to be constrained
- Dents on the bottom of the pipe (particularly deep dents) assumed to be plain rock dents

## In liquid pipelines:

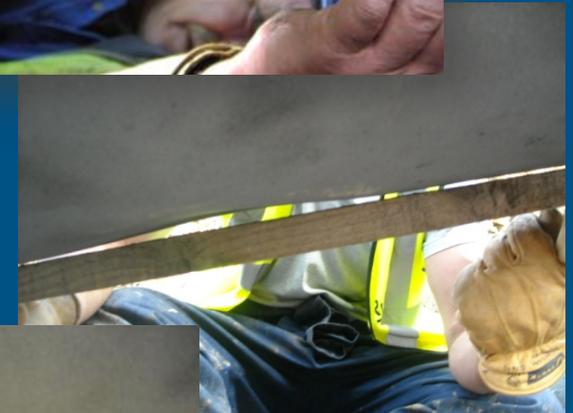
- Unconstrained dents  $>5\%OD$  extremely unlikely
- Acceptability of unconstrained dents  $>2\%$  should be based on a dynamic assessment

## Fatigue assessment:

- No codified methodology for assessment of dent fatigue

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# Requirements of Dent Management Strategy

- Be easy to use with field measurements that can readily be taken in field
- Not require extensive or expensive FEA to be conducted on every dent
- Recognise key parameters for stress and strain concentration
- Relate to the pipeline pressure cycling regime



# Dent Management Strategy Review

## Fleet Technology (BMT) Dent Assessment Model

- Dent relative risk factor calculated from pressure factor and geometry factor
  - Geometry factor includes dent depth, D/t ratio and parameters relating to dent shape
  - Pressure factor determined using cycle counting and Miner's rule
- Relates factors associated with stress concentration and rerounding and includes a link to likelihood of fatigue cracking

Dinovitzer, A., et al., 2003, "Dent Integrity Assessment", Presented at the API 54th Annual Pipeline Conference, American Petroleum Institute.

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# Dent Management Strategy Review

## Enbridge/Fleet Rapid Characterisation Method

- Used early results of Fleet Technology work
- Used three shape factors to produce a 'relative severity factor'
  - dent depth, shoulder angle, dent width ratio

Ironside, S.D. and Carroll, L.B., 2002, "Pipeline Dent Management Program", *Proceedings of the 4th International Pipeline Conference*, Calgary, Alberta, Canada : American Society of Mechanical Engineers.

## PII Ltd Dent Strategy

- Developed a series of algorithms for application with ILI data; metal loss only, caliper only and metal loss + caliper
- Did not allow dents to be prioritised
- Recommendations made which included:
  - Both metal loss and caliper is required to make a full dent assessment
  - Care should be taken with constrained dents on bottom of line
  - Fatigue study should be considered for all dent sizes

Race, J.M., 2002, "Dent Assessment Based On In-Line Inspection Results", *Proceedings of the 5th International Conference on Pipeline Rehabilitation and Maintenance*, Manama, Bahrain : GICC.

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# Dent Management Strategy Review

## API1156 Field Guide for Dent Assessment

- Gives a risk-ranking methodology for dent severity

$$P = (P_m + P_i) \frac{d}{D} = (A + B + C + W + M + R) \frac{d}{D}$$

- $P_m$  represents the pipe properties and operational characteristics
  - A = geometry (D/t) ratio
  - B = relative risk of brittle fracture
  - C = relative operational risk – pressure cycling factor
- $P_i$  represents ILI data
  - W = presence of welds & severity of welds
  - M = corrosion caused metal loss
  - R = dent location

Kiefner, J.F and Alexander, C.R., 1999, "Effects of Smooth and Rock Dents on Liquid Petroleum Pipelines (Phase II)", American Petroleum Institute.

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# Dent Management Strategy Review

## DEGT Dent Strategy

- Uses dent strain and dent depth as governing criteria
- Dents are initially characterised based on HR-MFL data
  - Dents with metal loss, dents on welds, dents with significant signal response
- HR caliper inspection run if there are a number of high risk dents
- Strain measured using radius of curvature templates
- Compared to 6% strain criterion
- Only conducted on dents that fail depth criterion
- Enables strain measurements to be made in the field

Warman, D.J., et al., 2006, "Management of Pipeline Dents and Mechanical Damage in Gas Pipelines", *Proceedings of the 6th International Pipeline Conference*, Calgary, Alberta, Canada, American Society of Pipeline Engineers.

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# Dent Management Strategy Review

## GE Energy Dent Strategy

- Applies longitudinal dent strain criterion to rank dents in lines not heavily pressurised
- Applies fatigue risk assessment to pressure cycled pipelines

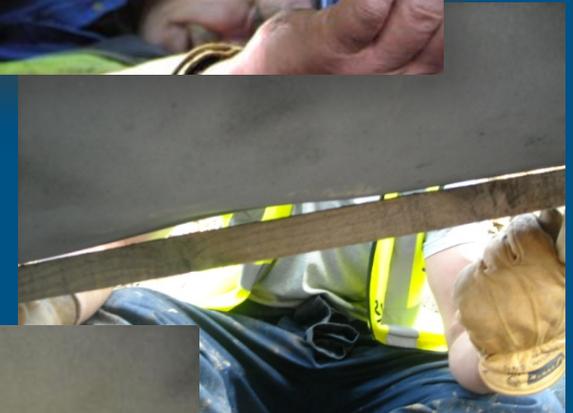
$$\text{Fatigue Life} \propto \frac{1}{\frac{LdW}{D^2t}}$$

- Correlation between Rinehart and Keating SCF formula and cyclic hoop stress range and therefore fatigue life

Dawson, S.J., Russell, A. and Patterson, A., 2006, "Emerging Techniques for Enhanced Assessment and Analysis of Dents", *Proceedings of the 6th International Pipeline Conference*, Calgary, Alberta, Canada, American Society of Pipeline Engineers.

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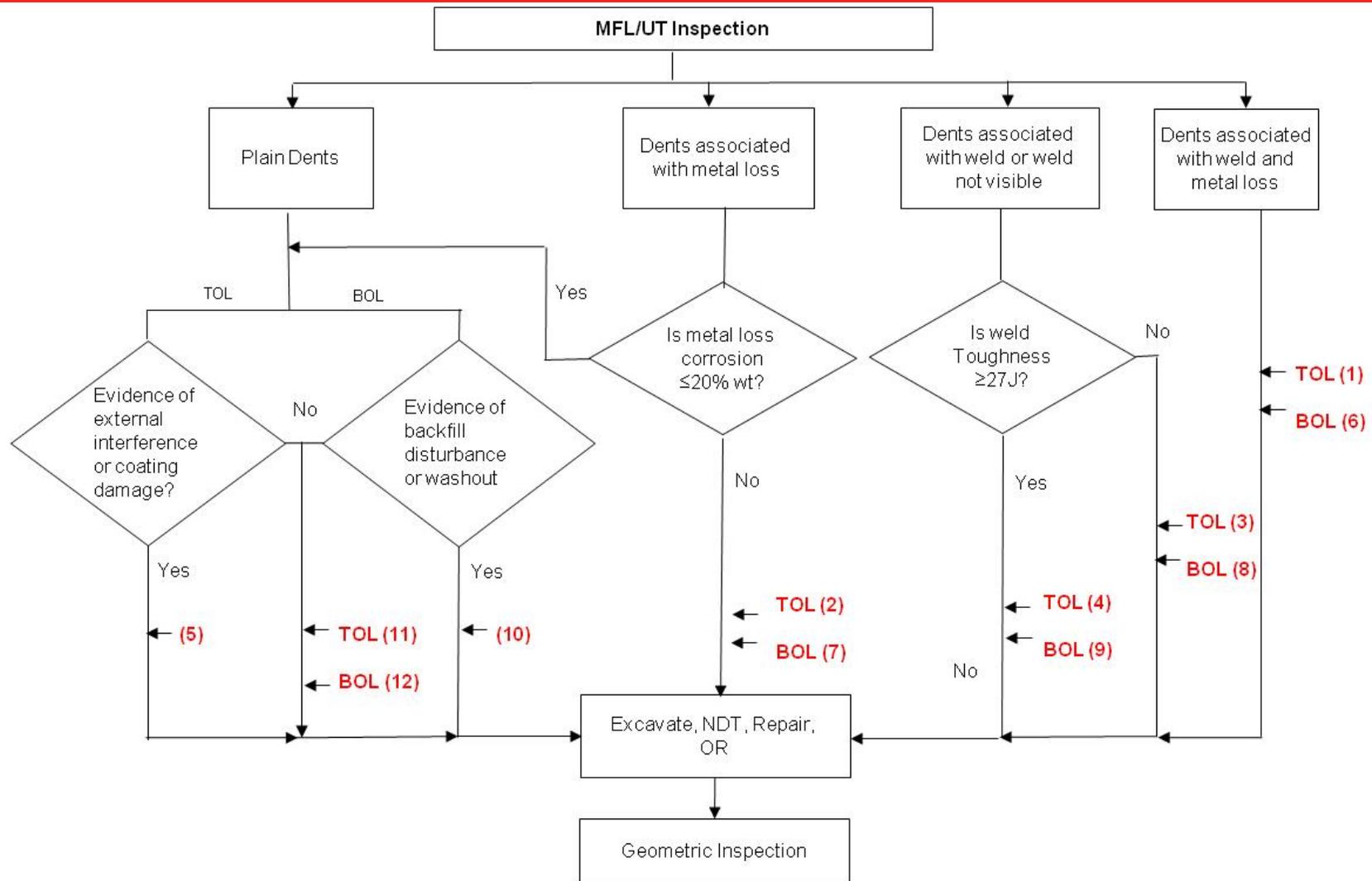
# UKOPA Dent Assessment Rules

- Kinked dents (*i.e.* dents with rapid changes in contour) should be repaired
- For static dent assessment:
  - Plain dents  $>7\%OD$  or  $6\%$  strain should be repaired
  - Dents  $>2\%OD$  or  $4\%$  strain associated with welds should be repaired
  - Dents  $\leq 2\%OD$  or  $4\%$  strain associated with welds should be repaired only if the weld toughness and quality are unacceptable
  - If the dent is associated with corrosion and the corrosion is  $\leq 20\%wt$ , then the dent can be assessed as a plain dent

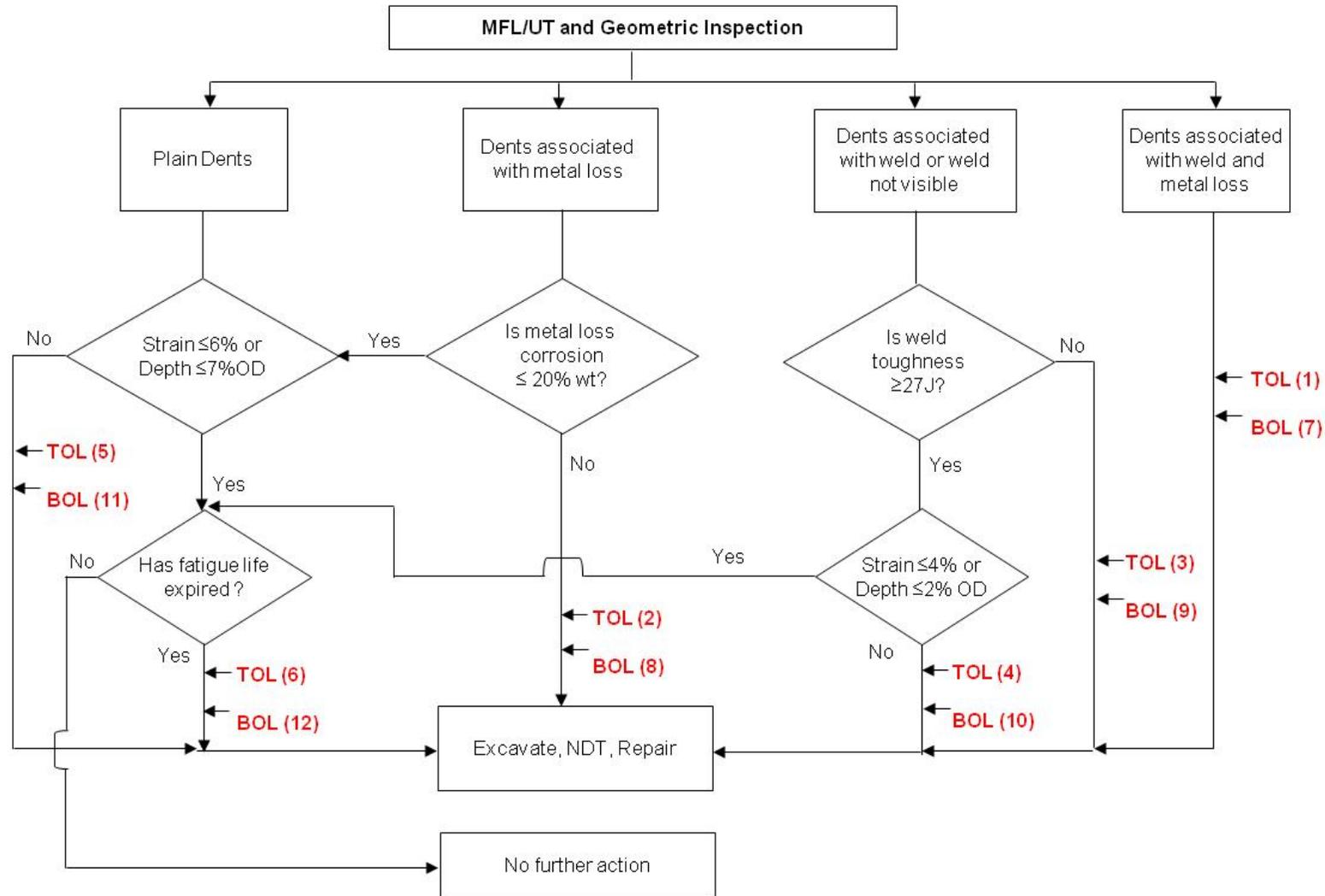
# UKOPA Dent Assessment Rules

- If the pipeline is pressure cycled the pipeline should be assessed for associated damage which could enhance the risk of fatigue failure:
  - Top of line dent locations should be inspected for coating damage using DCVG or Pearson above ground surveys.
  - Bottom of line dent locations should be assessed for backfill disturbance or washout.
  - Bottom of line dents in rocky locations should be monitored not excavated.
  - Dents  $>2\%OD$  should be subject to a fatigue assessment.
- All new dent features identified between successive ILI inspections should be investigated
- If there is no indication of associated damage, the dent fatigue life should be assessed using a recommended dent fatigue S-N curve

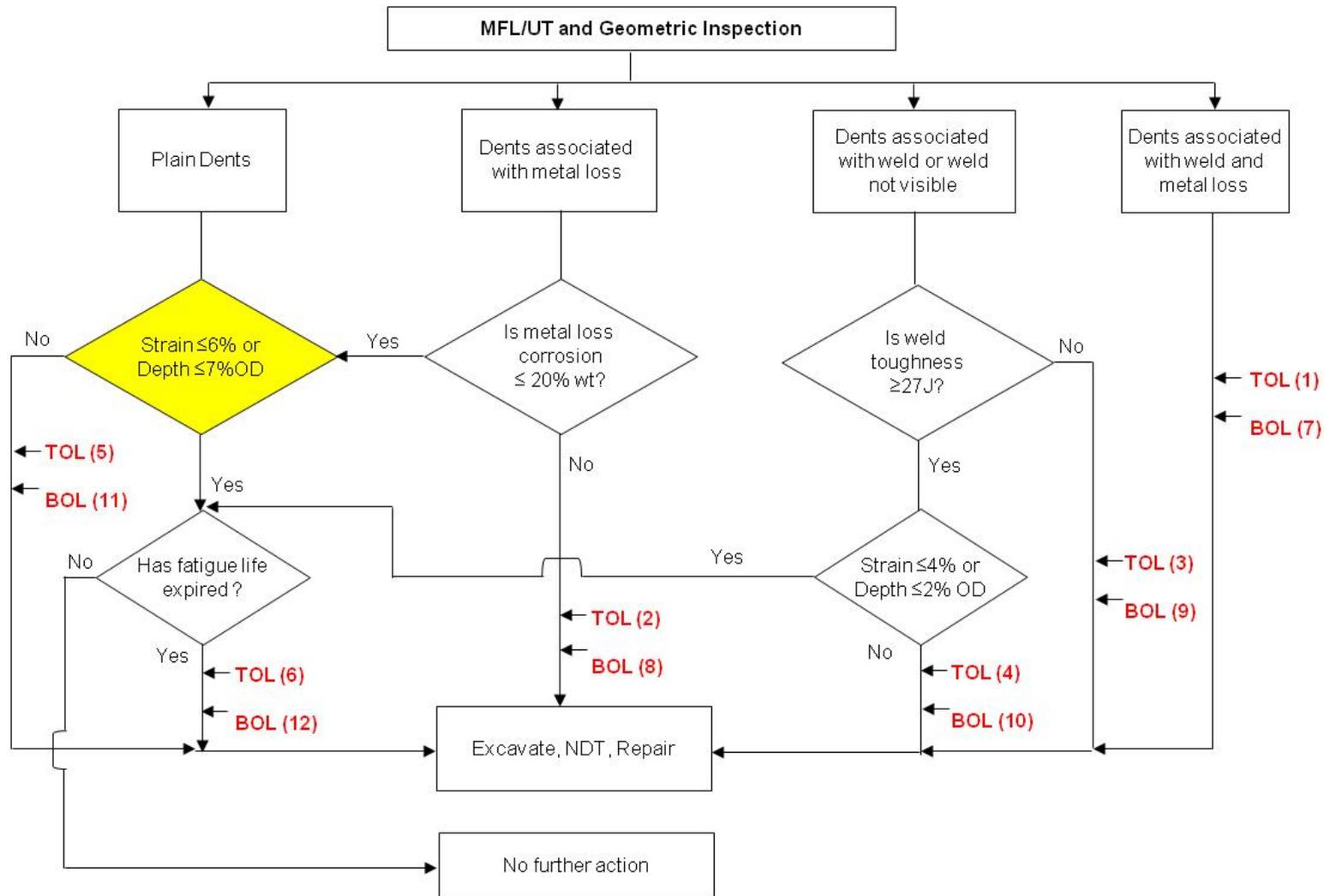
# Dent Assessment Algorithms (MFL/UT Data Only)



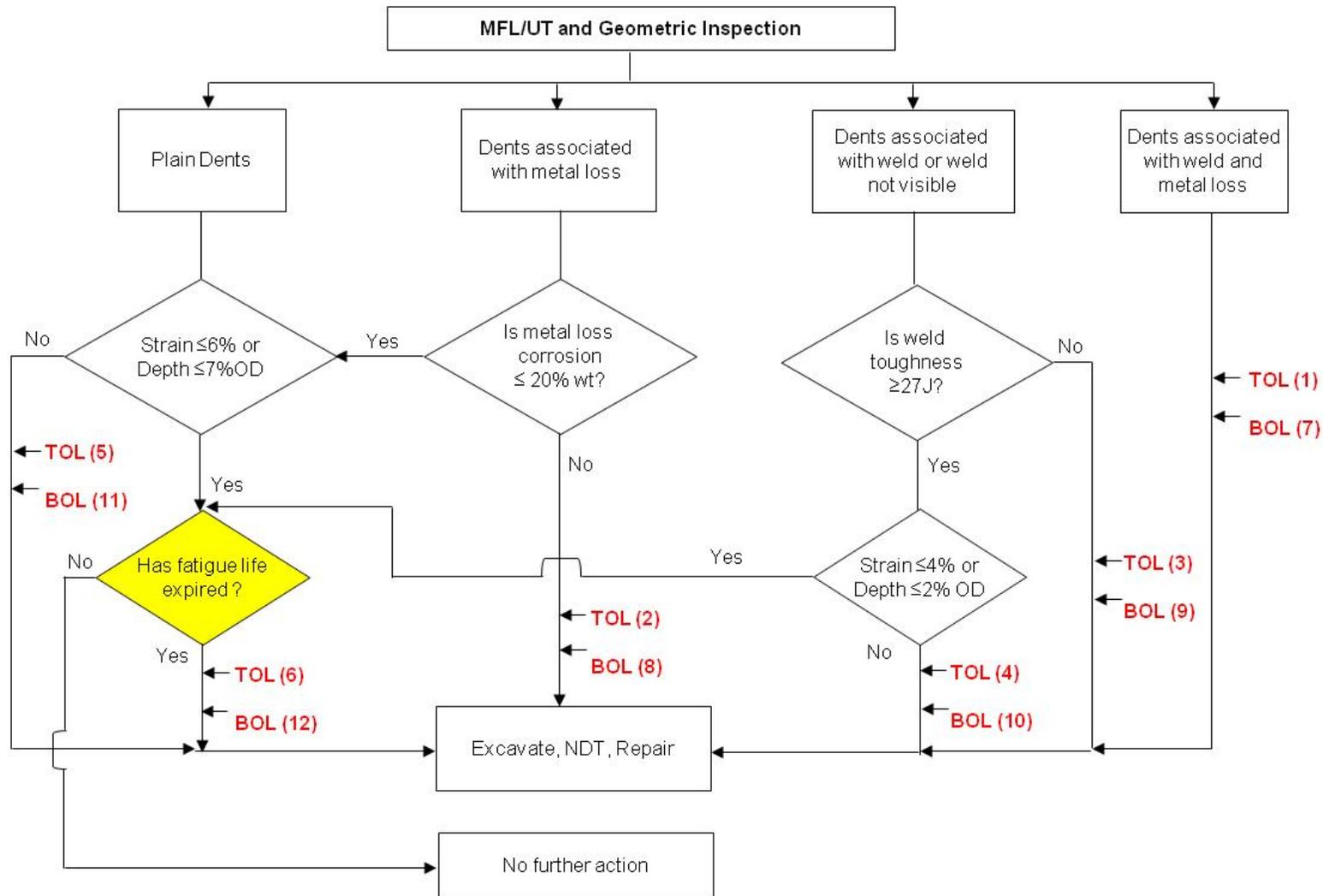
# Dent Assessment Algorithms (MFL/UT + Caliper Data)



# UKOPA Algorithms – Key Assumptions



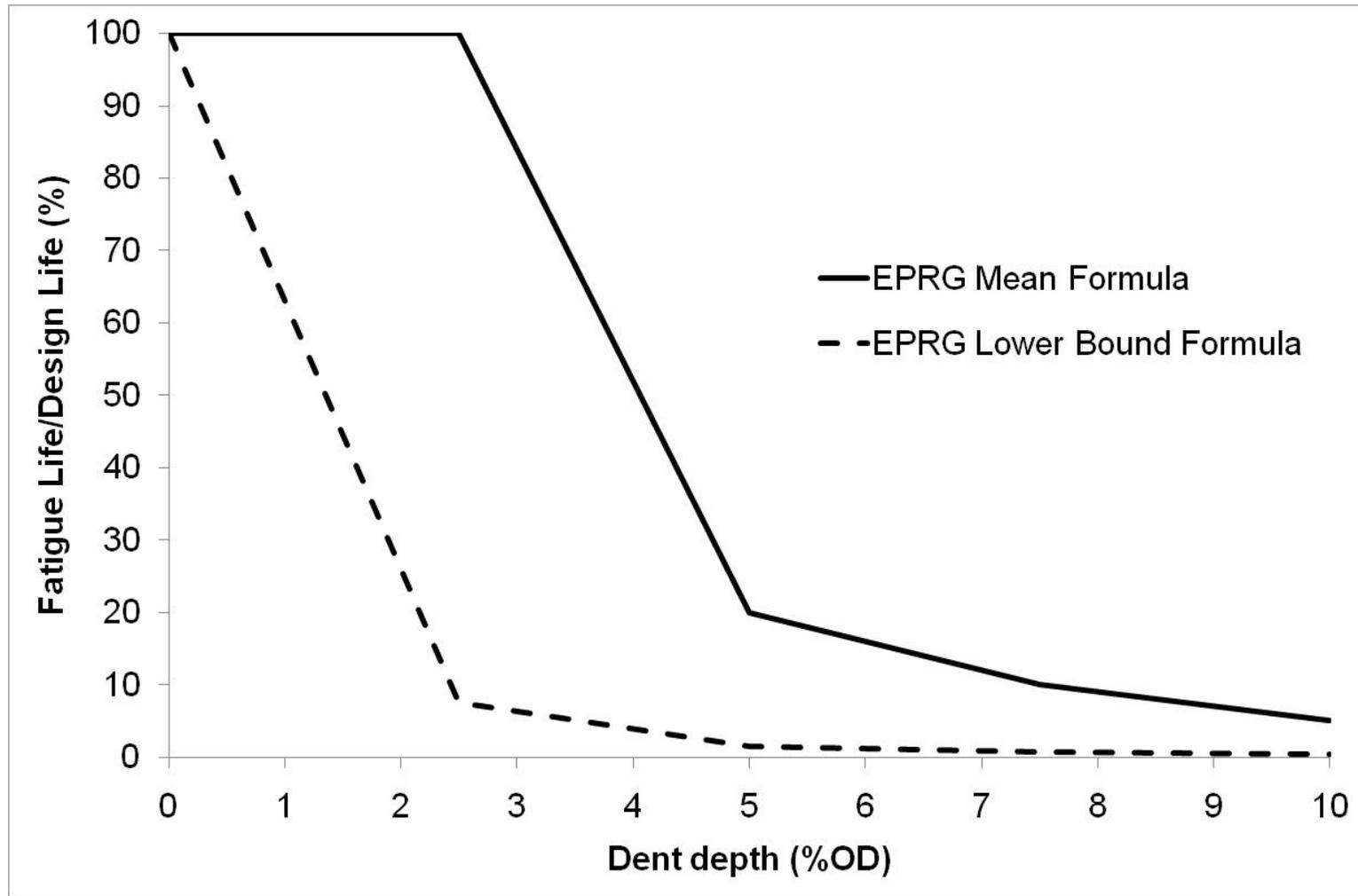
# UKOPA Algorithms – Key Assumptions



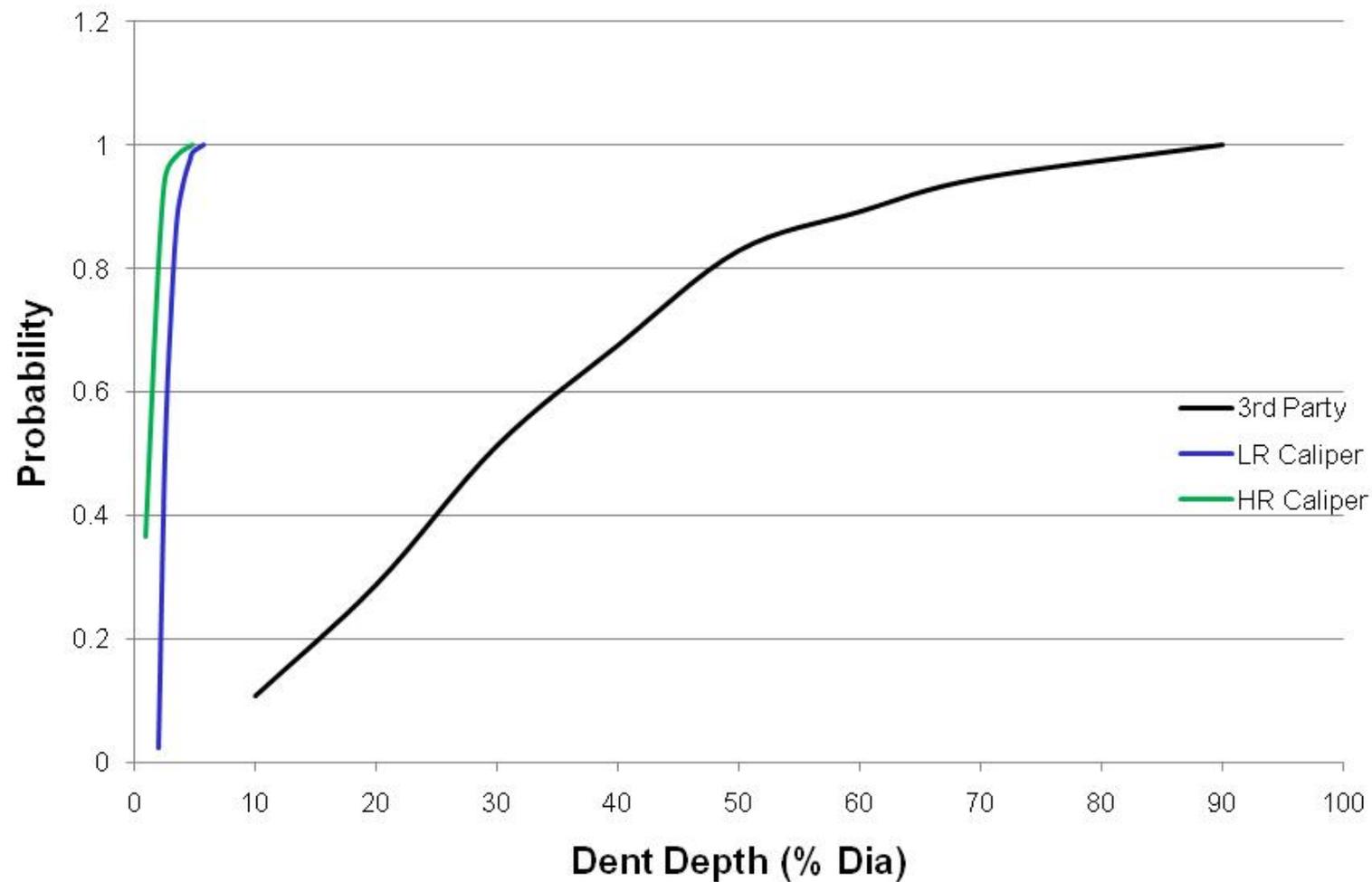
# Review of Dent Fatigue Models

- Based on SCF applied to the cyclic stress range on an appropriate S-N curve
- No standard methodology for determining SCF
- No agreement regarding appropriate S-N curve to use:
  - DIN 2413 (Longitudinally submerged arc welded pipe)
  - Curve X' in API-RP2A
  - DOE-B curve
  - ASME B31.3 curves
  - ASME Section VIII Division 2 Appendix 5 curve
  - AWS A-curve
- PDAM recommends use of EPRG approach using DIN 2413 curve with a safety factor of 13.3

# Simple Assessment of Dented Pipelines



# Distribution of Dents in Operating Pipelines



# Further Work Planned

- Collate and review existing dent investigation data, including measured depth vs strain comparisons
- Investigate dent strain & stress concentration factors
  - Finite element modelling
  - Neural networks
- Assess alternative SN fatigue models



Enter pipeline data

24" Select Diameter

12.7 Wall thickness (mm)

643 Dent length (mm)

179 Dent width (mm)

115.82 Dent depth (mm)

X80 Select Steel Grade

Estimate

Estimated strain = 17.0%

# Conclusions

- UKOPA have developed a series of algorithms that can be used with ILI data to assess and prioritize dents
- UKOPA recommend that dent assessments are made using more than one set of ILI data i.e. metal loss + geometric inspection where possible
- Further work is needed to understand the requirement to conduct either dent depth or dent strain assessments or whether a combination approach is acceptable
- There is no codified methodology or consensus in the literature regarding the most appropriate method for calculating the fatigue life of a dent.
- Current recommendations using EPRG can result in:
  - Large numbers of recommended investigations
  - Latent fatigue problems in pipelines due to dents below the detection limit
- Further work is required to standardise the fatigue assessment of dents



# Newcastle University

The authors would like to acknowledge the help and contribution to this paper of the UKOPA Risk Assessment Working Group who have provided data on which to test the algorithms and also “field tested” the approaches