MECHANICAL DAMAGE: HOW BIG IS THE PROBLEM ? A EUROPEAN PERSPECTIVE

Mechanical Damage Workshop: February 29th, March 1st, 2006

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February 28th, 2006

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1. How frequent is Mechanical Damage in Europe? Indications from the EGIG database
2. EPRG R&D contributions to handle this threat
3. Ghislenghien July 30, 2004 (prepared by J. Duhart)
4. Summary & Conclusions

1. How frequent is Mechanical Damage in Europe? Indications from the EGIG database

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Mechanical Damage - How Big Is the Problem ?

- What « metrics » to use for such a threat?
- Risk = occurrence frequency x consequences
- Consequences scale with the amount of released hydrocarbons
- Occurrence of rare events is difficult to evaluate
- Sufficiently large pipeline exposure (length x time) is needed in order to pool data, and provide reliable occurrence frequency figures
- Incident data bases need also to be consistent in terms of technology and environment
- Examples of Data bases : US DOT, EGIG, CONCAWE, ENSAD, etc.

The 6th EGIG Report 1970 – 2004, December 2005

- **EGIG = *E*uropean *G*as Pipeline *I*ncident *G*roup**

- **Started in 1982 with 6 gas transmission operators, now 12 European major gas transmission system operators:**

  - DONG - Denmark
  - ENAGAS – Spain
  - FLUXYS – Belgium
  - GASUM – Finland
  - Gasunie – Netherlands
  - GRTgaz – France
  - E.ON Ruhrgas – Germany
  - SNAM Retegas – Italy
  - SWISSGAS – Switzerland
  - NATIONAL GRID – UK
  - RWE TRANSGAS – Czech Republic
  - TRANSGAS - Portugal

- **Website: www.EGIG.nl**

EGIG data base - Criteria for incident definition

- **Incident led to an unintentional gas release**
- **Pipelines:**
  - **Onshore**
  - **Steel**
  - **Design pressure > 15 bar (218 psig)**
  - **Located outside fences of installations**

EGIG data base - Contents

- Pipeline data – MAOP, D, t, grade, coating, depth of cover, age
- Incident data:
  - Leak size – Pinhole/crack, d < 2 cm (0.79"); Hole, 2 cm < d < D; Rupture, d > D
  - Cause – External interference, corrosion, Construction defect / material failure, Hot tap by error, Ground movement, Other / unknown
  - Ignition – occurred or not
  - Consequences
  - How it was detected – contractor, patrol, landowner, etc.
  - Free text for additional information
- Additional information on causes, e.g.
  - External interference – activity causing the incident, equipment involved, installed protective measures

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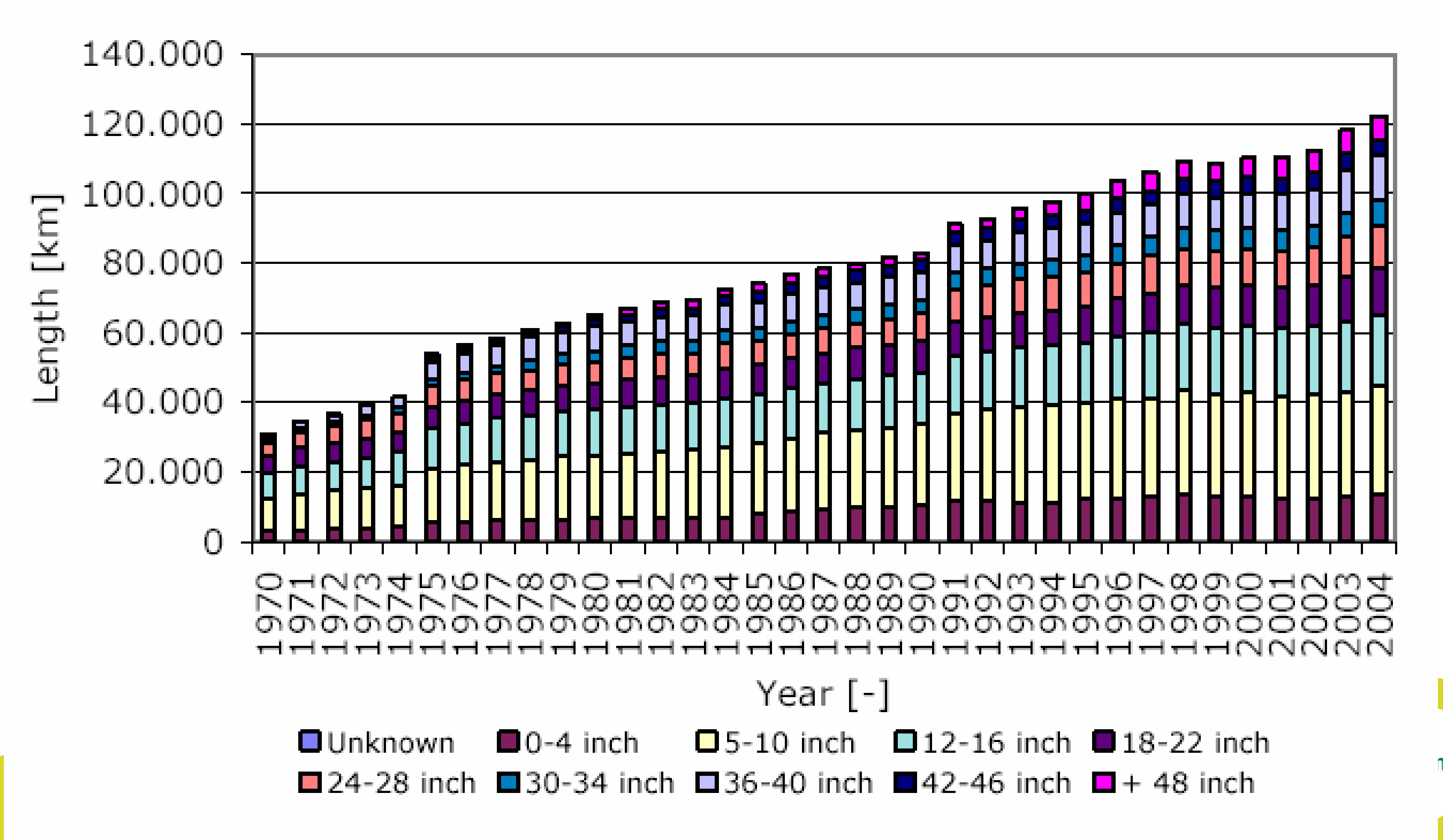
The 6th EGIG Report 1970 – 2004, Definitions & …

- Network length: 122 168 km, i.e. 75 912 miles
- Exposure: length of a pipeline x exposed duration
  = > 2.77 million km x years, i.e. 1.72 10^6 miles x years
- Failure frequency = Number of incidents / System exposure
- To distinguish safety improvements, a moving average over the last 5 years is used
- Step changes in length in 1975, 1991, 1998 and 2003 are due to new members joining

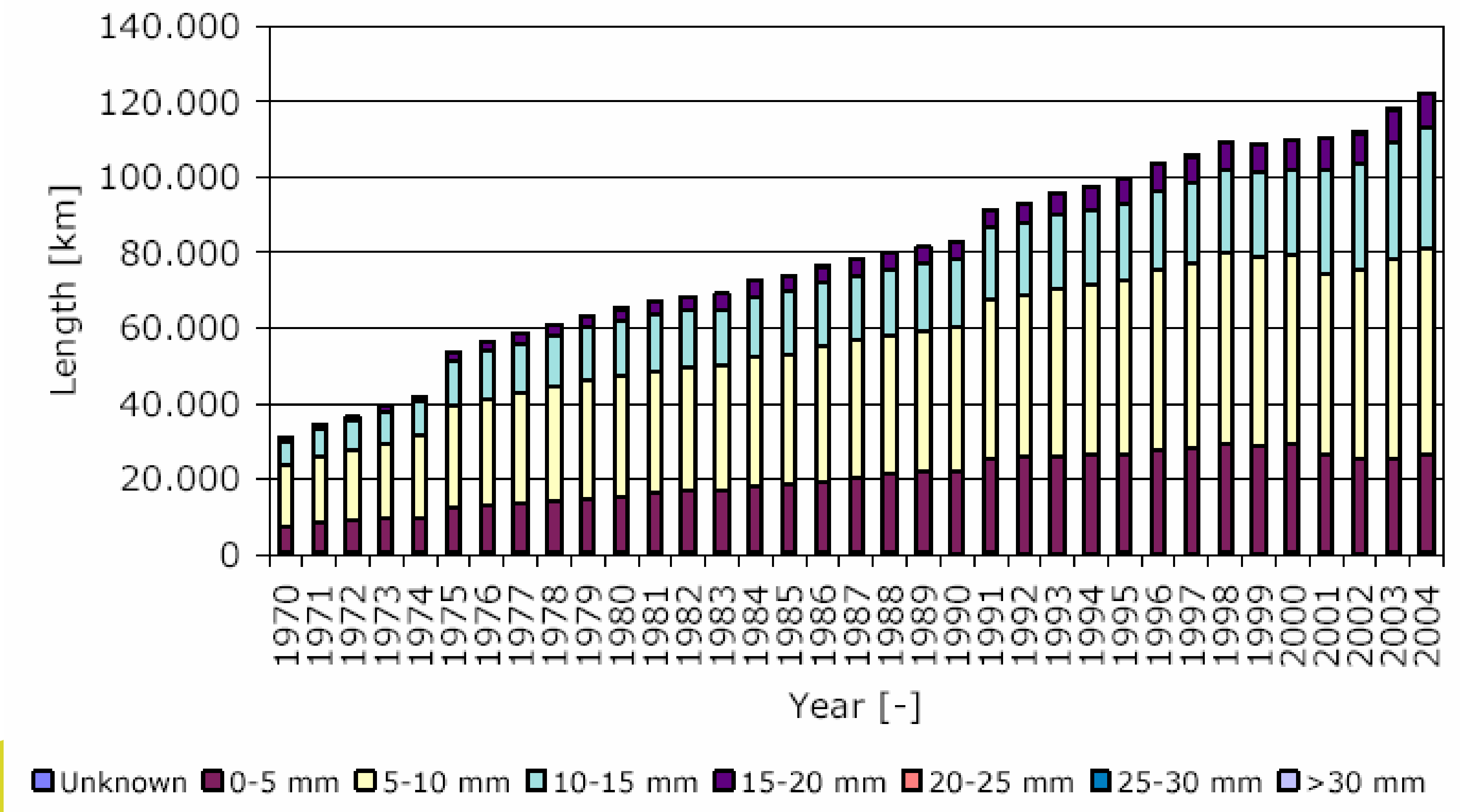
The 6th EGIG Report - Network description

- **Most common pipelines are in the 5" to 16" range**
- **D ≥ 18" account now for half the population, rather than a third in the ‘70**



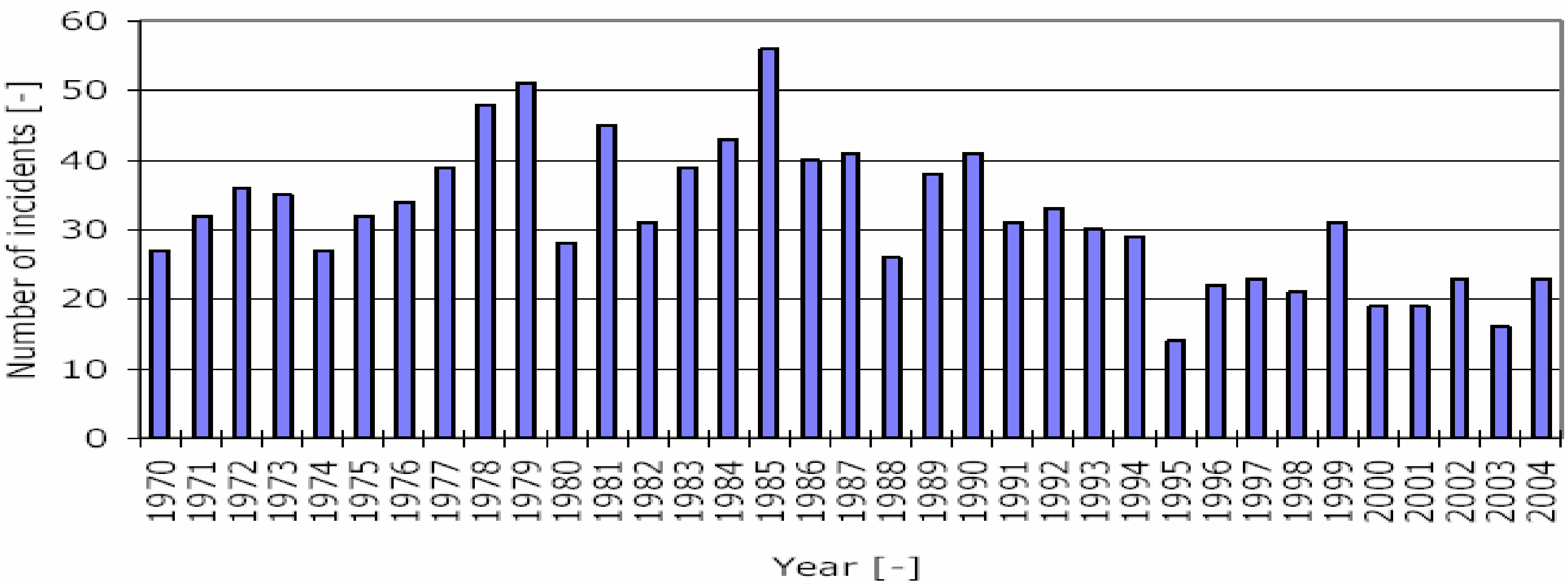
The 6th EGIG Report - Network description

- **Most commonly used wall thickness 5 – 10 mm (0.197" to 0.394")**
- **All wall thickness classes increase linearly, except 0 – 5 mm, constant since 2001**



The 6th EGIG Report – Primary Failure Frequencies

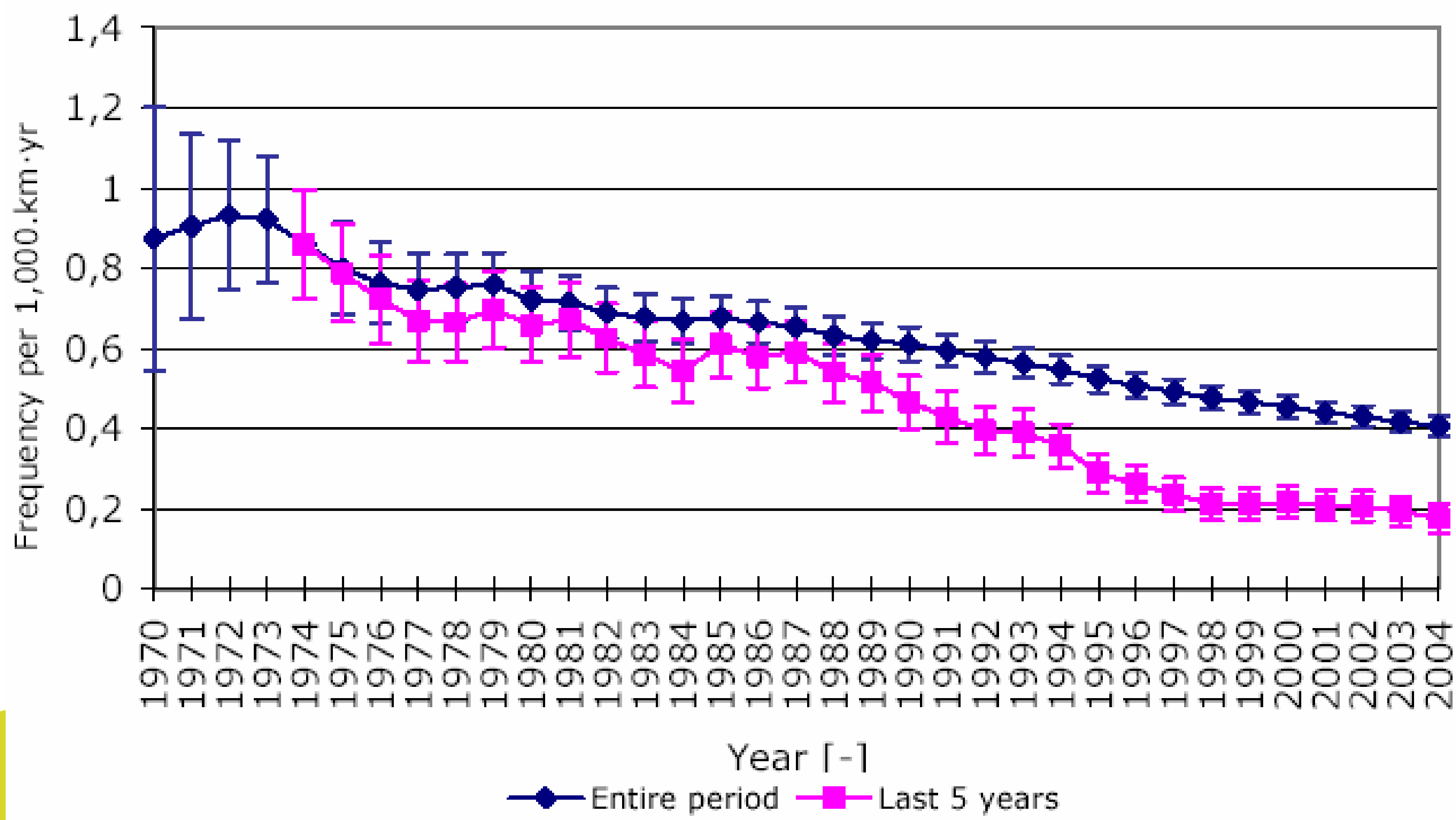
- **Annual number of incidents is variable, averaging yields an improvement trend**
- **Failure frequency over the last 5 years is less than half that of the entire period (0.11 / 1000 miles.yr vs. 0.25 / 1000 miles.yr)**



Period	Number of incidents [-]	Total system exposure [km.yr]	Primary failure frequency [1000 km.yr]
1970-2004	1123	$2.77.10^6$	0.41
2000-2004	100	$0.57.10^6$	0.17
2004	23	$0.12.10^6$	0.19

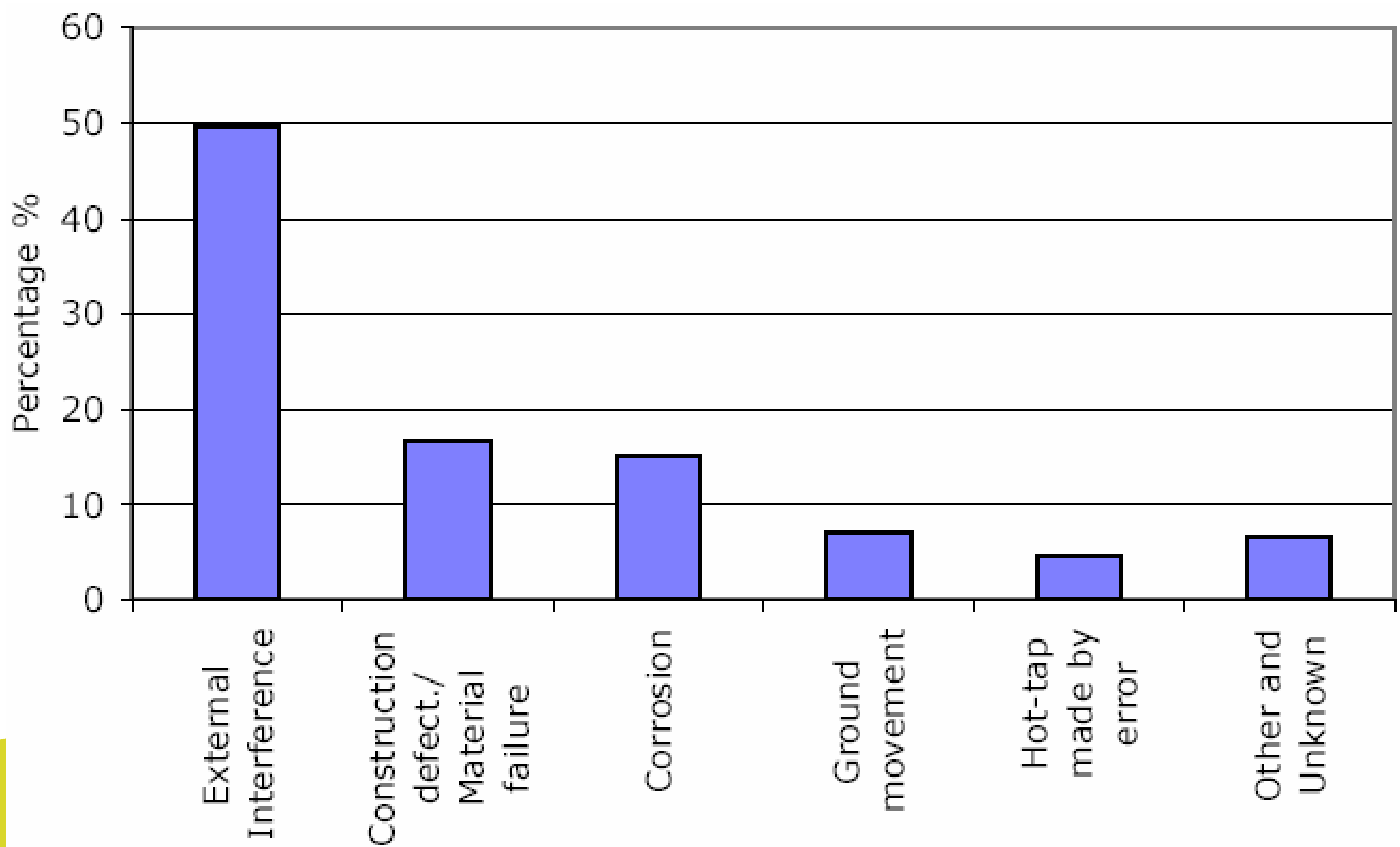
The 6th EGIG Report – Primary Failure Frequencies

- Confidence intervals are calculated assuming a Poisson distribution of incidents (classical distribution for « rare events »)
- The global failure frequency is decaying steadily since the mid '70
- Failure frequency 1970-2004 = 0.41/1000 km.yr, 95% confidence interval of ± 0.02
- Failure frequency 2000-2004 = 0.17/1000 km.yr, 95% confidence interval of ± 0.03



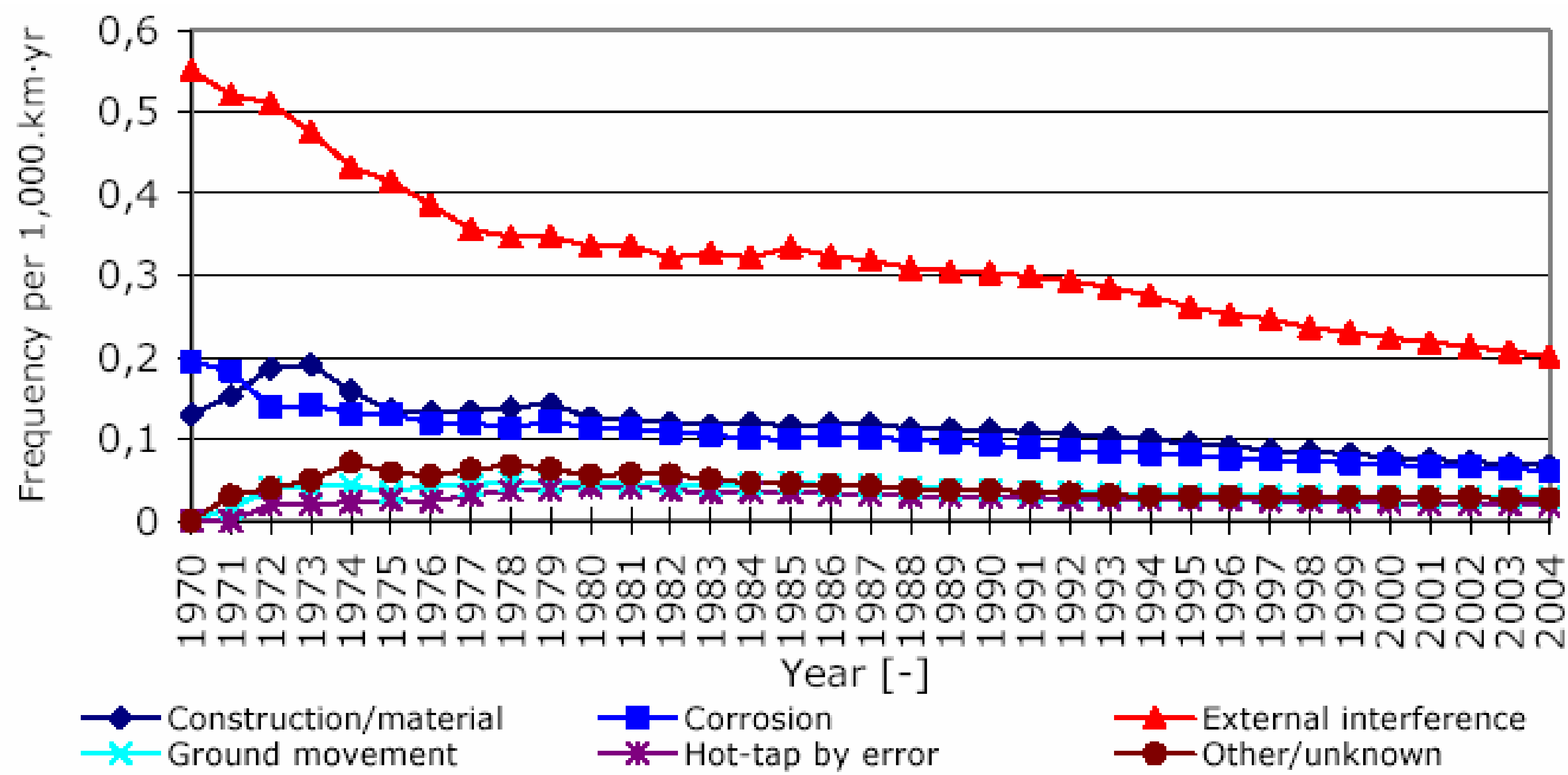
The 6th EGIG Report – Distribution per Cause

- **External interference accounts for the largest part of incidents - 50 %**
- **Corrosion & Construction defects / material failures: 15 – 17 %**
- **The three other causes are marginal, around 7 % and below**



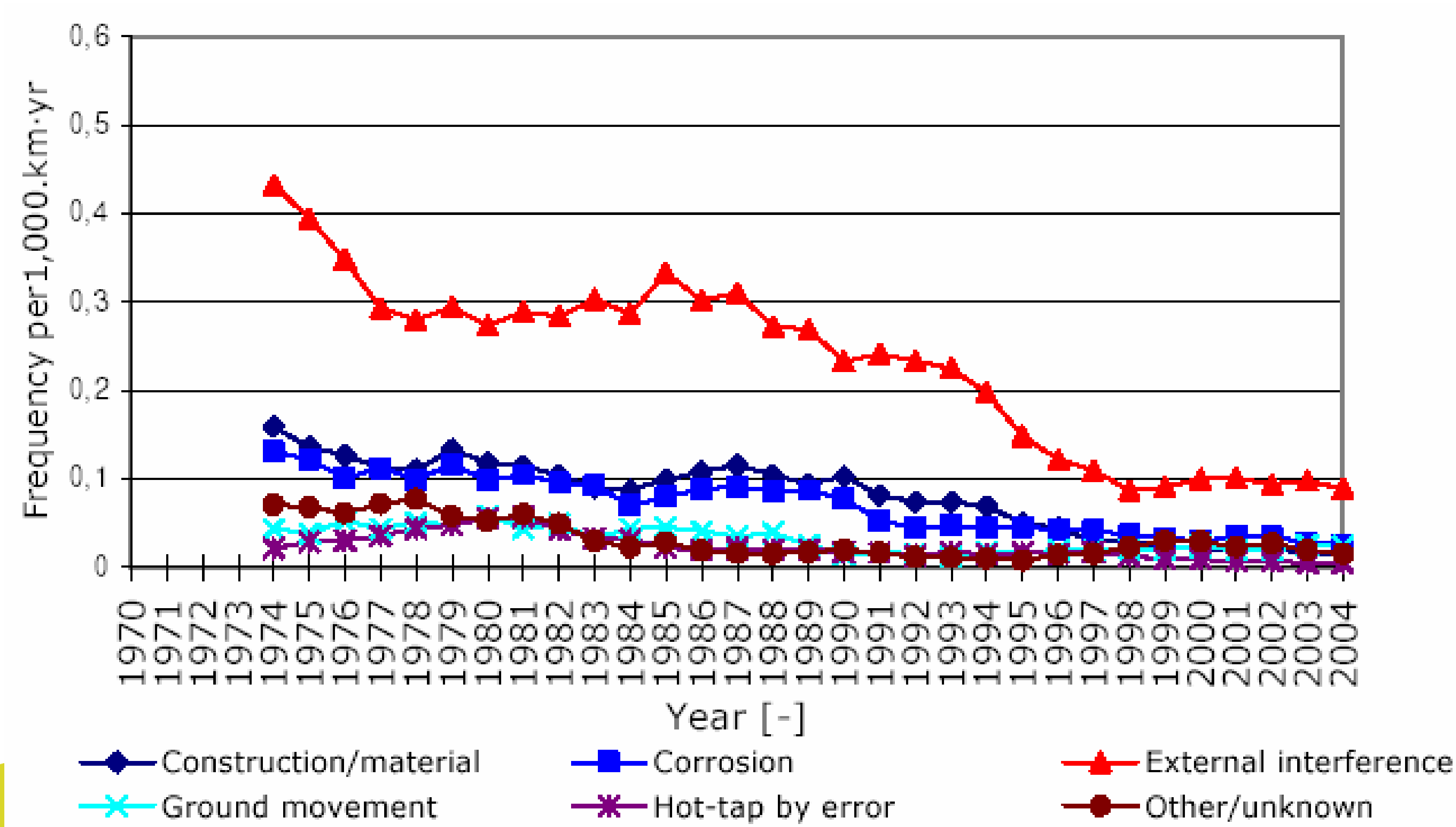
The 6th EGIG Report – Distribution per Cause

- Failure frequencies for all causes are decaying over the last two decades
- External interference is the fastest decaying cause on average



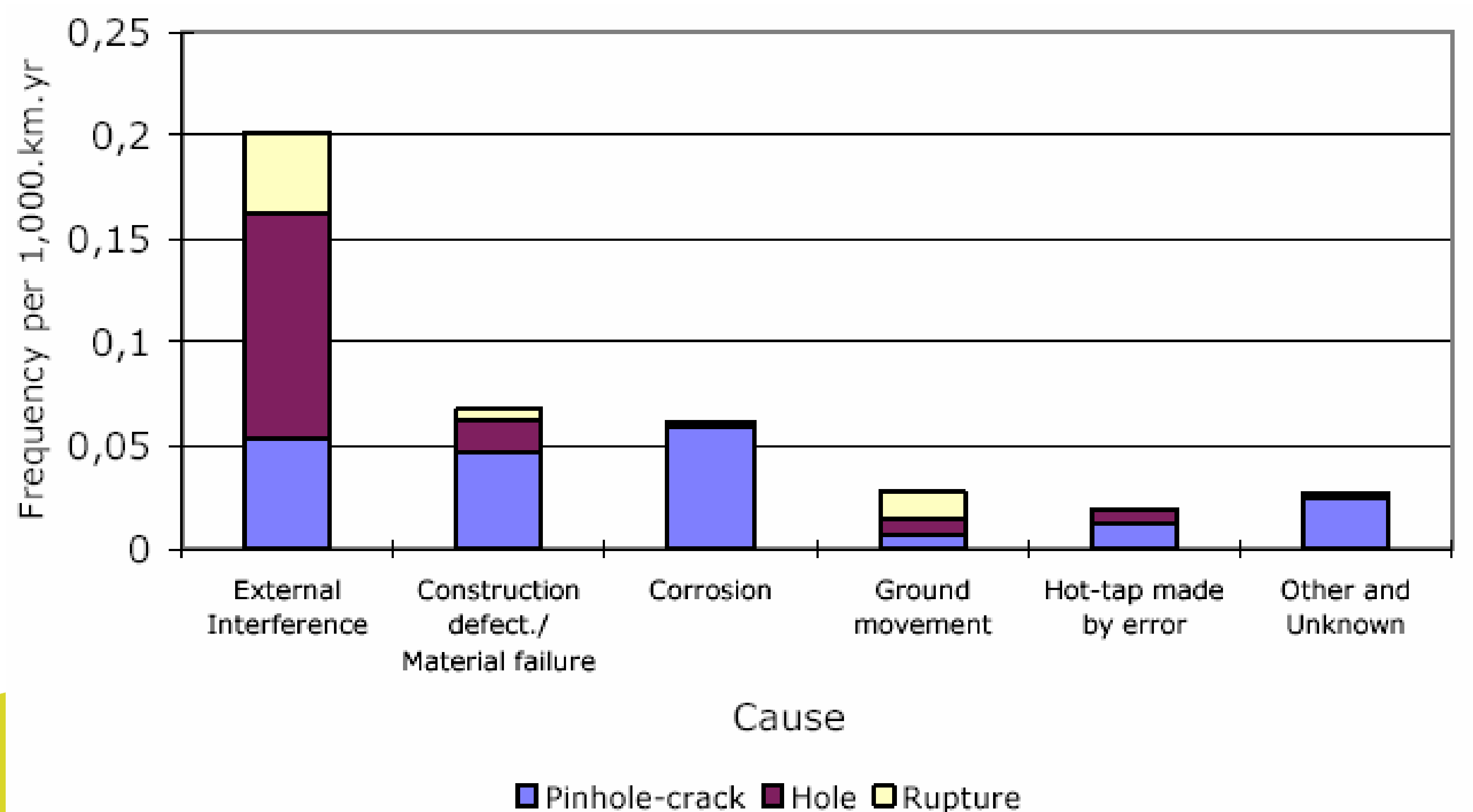
The 6th EGIG Report – Distribution per Cause

- External interference shows four periods on the 5 years moving average plot: initial fast decay until ’77, one decade of stabilization, followed by a decade of significant decrease, and again stabilization since ’98 at a third of the value of the preceding plateau



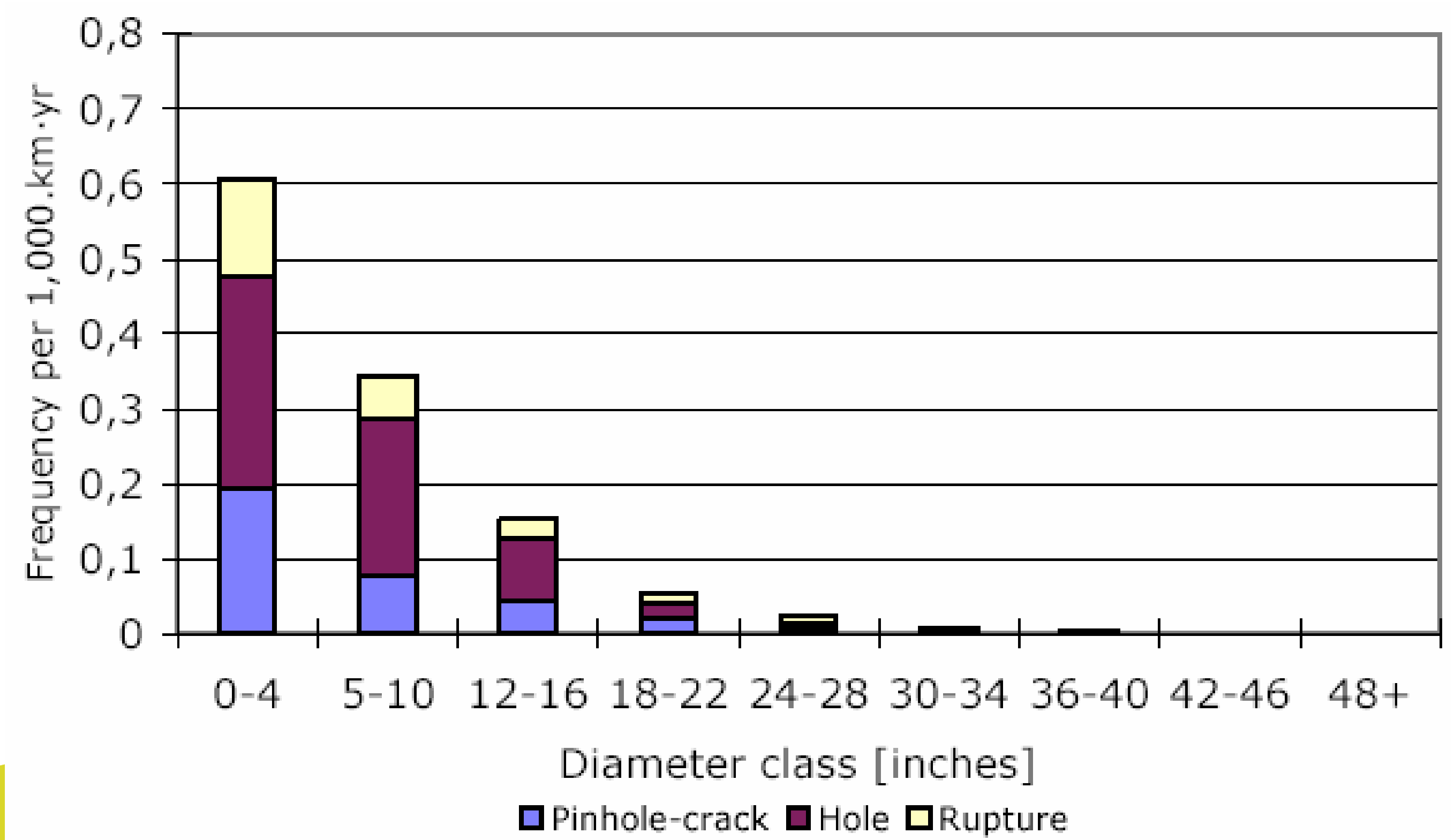
The 6th EGIG Report – Relation Cause – Damage Size

- Larger leaks (holes & ruptures) are mainly due to external interference, which is also the most frequent cause (50 % of incidents)
- External interference activities causing most incidents are: excavators' digging (39%), drainage works (8 %), public works (8 %), activities related to agriculture (8 %)



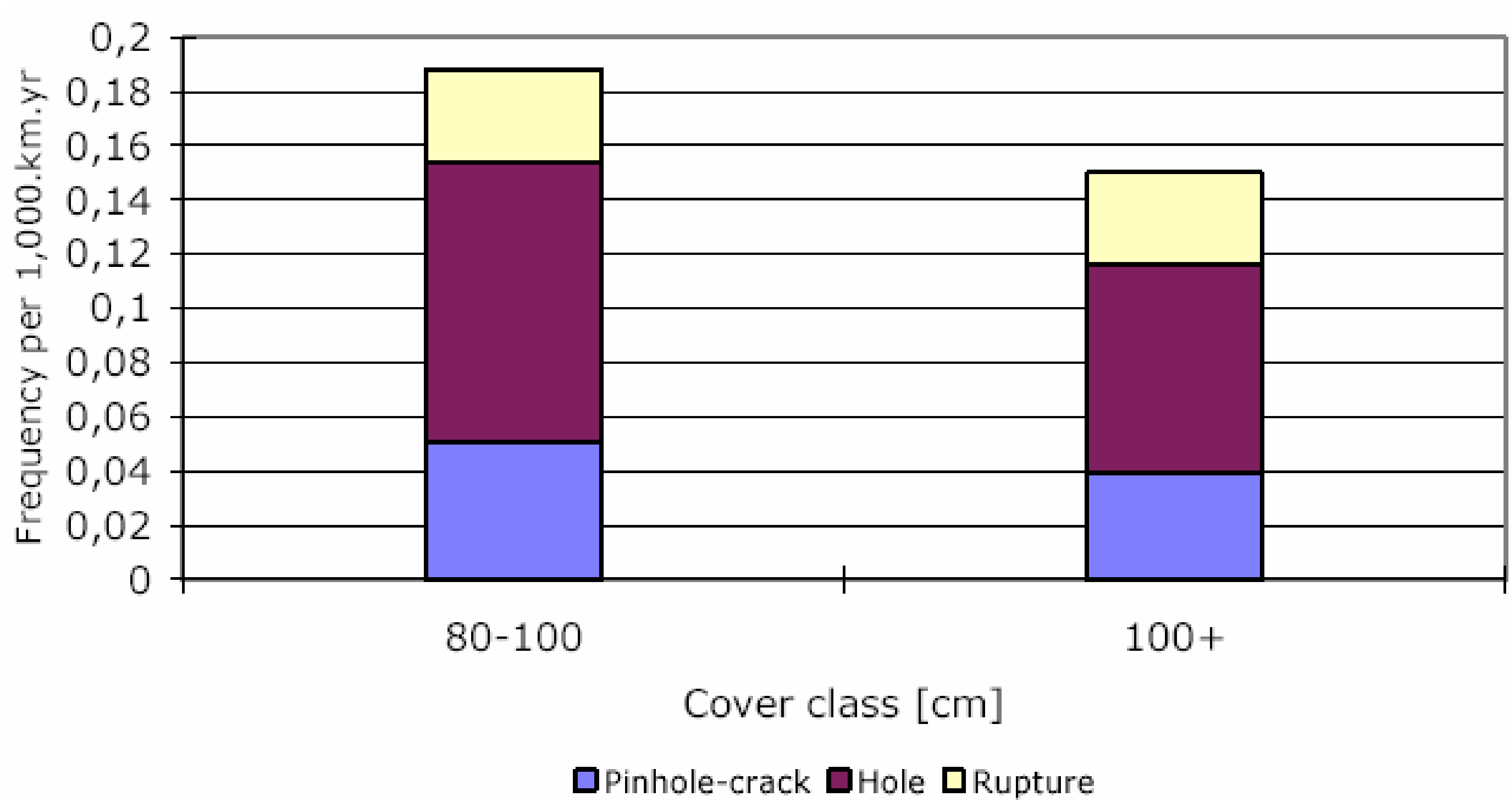
The 6th EGIG Report – Relation Failures – Diameter

- Small diameter pipelines are more vulnerable than larger diameter pipelines
- They can be more easily hooked up, and have thinner walls



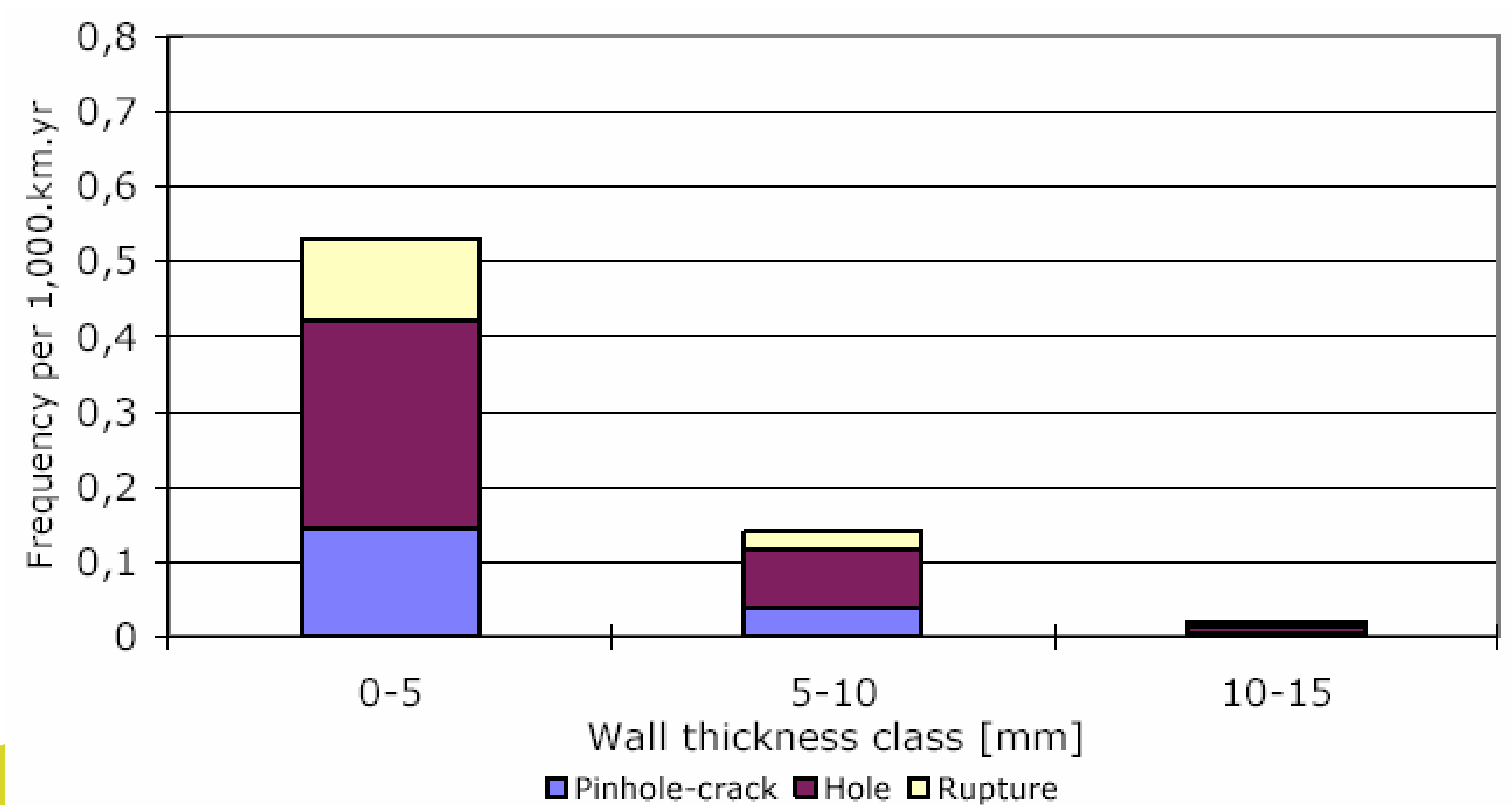
The 6th EGIG Report – Relation Failures – Cover

➢ **A 21 % decrease in incident frequency can be achieved through deeper burial**



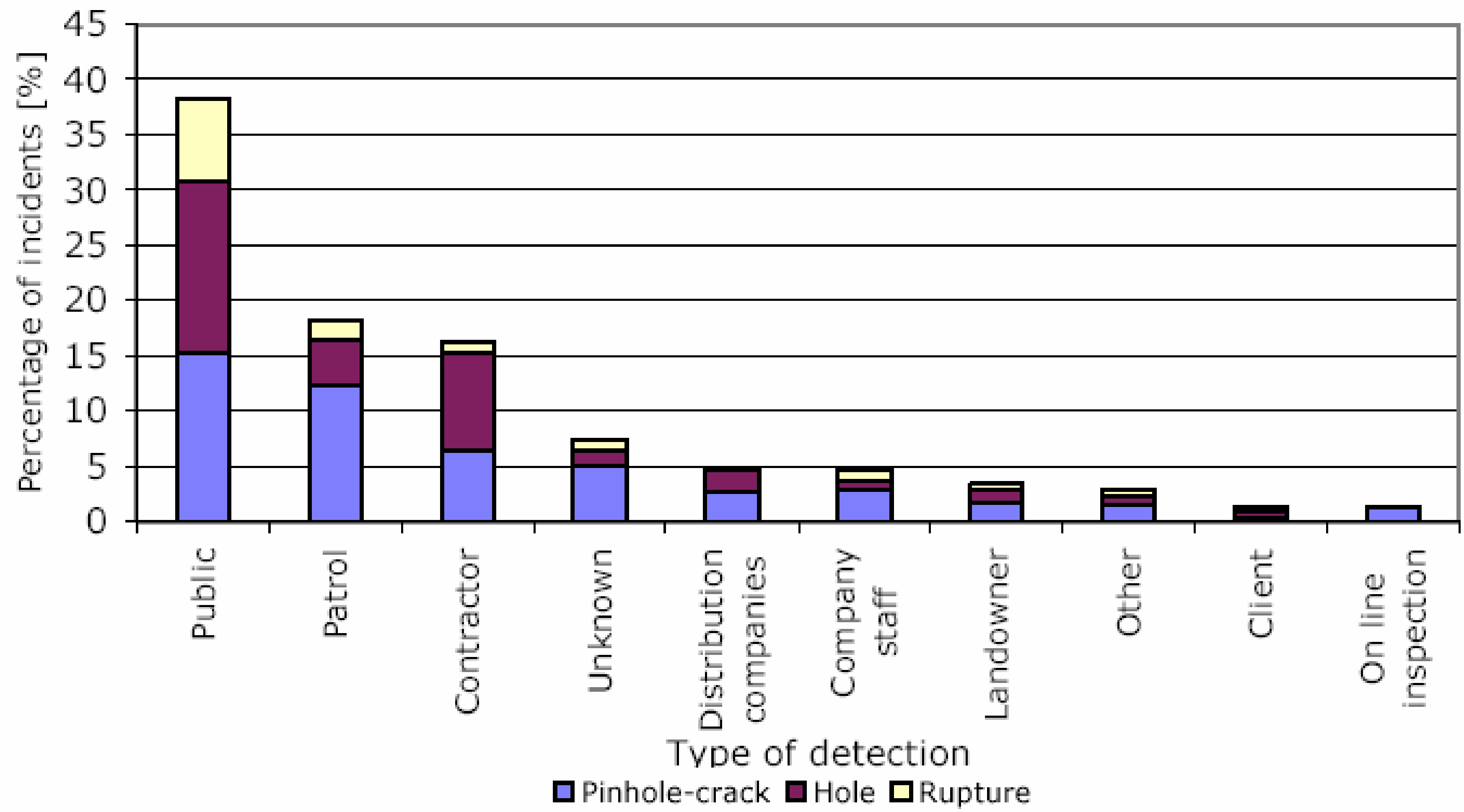
The 6th EGIG Report – Relation Consequence – Thickness

- **While the 5 – 10 mm thickness is the most widely used class (> 40 %), it is the 0 – 5 mm class that is the most vulnerable**
- **A thicker pipe provides therefore a protection against external interference**



The 6th EGIG Report – Incident detection

- **The public is closest to pipelines on a year-long basis, so it is the prime detector**
- **Patrols are efficient, second best**



The 6th EGIG Report – Ignition probability

- In the period 1970 – 2004, only 4.1 % of the EGIG reported releases ignited
- Data base provides a link between size of leak and ignition probabilities
- Ruptures of large diameter pipelines have the highest likelihood of leading to an ignited release, but they are also very rare events

Size of leak	Ignition probabilities [%]
Pinhole-crack	3
Hole	2
Rupture <= 16 inches	9
Rupture > 16 inches	30

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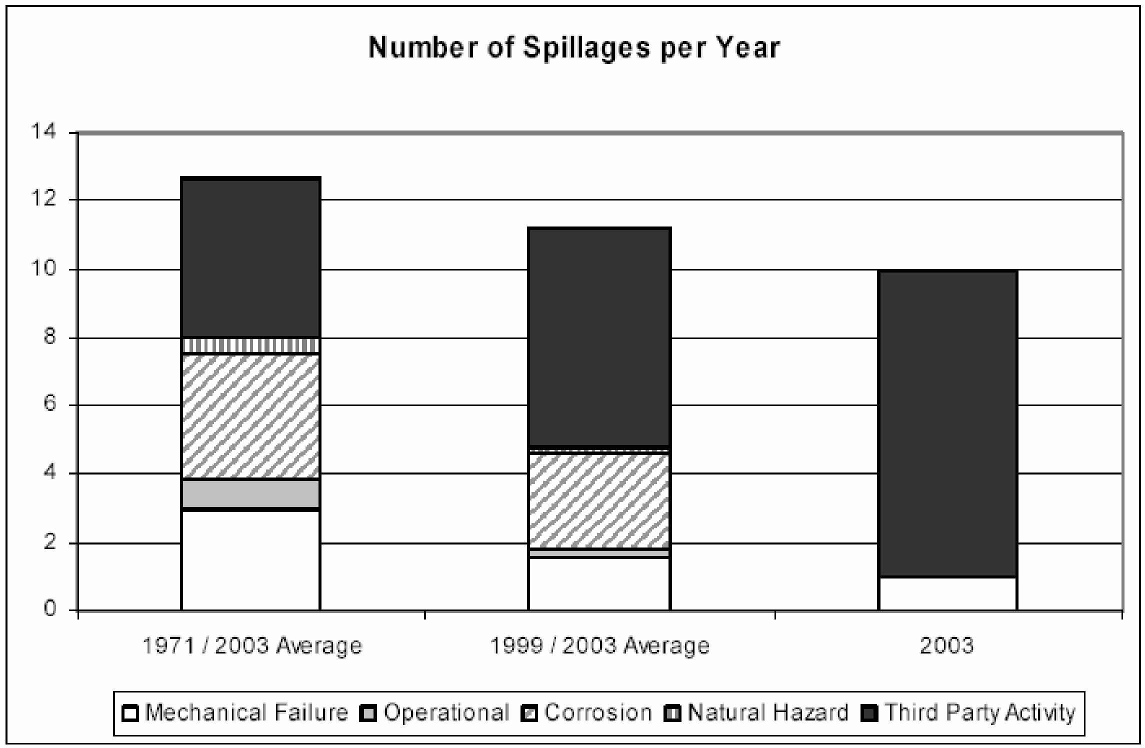
The 2003 CONCAWE Report – Oil Pipelines

- **Covers 36 422 km (22 632 miles) onshore oil pipelines from 65 European companies & other bodies, followed since 1971, and monitors spills, their causes, consequences and clean-up costs, ILI inspection**

- **Spills frequency:**
  - 0.27 spills / 1000 km.yr (0.17 / 1000 mi.yr) in 2003 vs.
  - 0.53 spills / 1000 km.yr (0.33 / 1000 mi.yr) long-term average over 1971 - 2003

- **Causes:**
  - Third party actions
  - Natural hazard
  - Corrosion
  - Operational
  - Mechanical

- **Third party actions 1st cause**



2. EPRG R&D contributions to handle this threat

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EPRG – European Pipeline Research Group

- Established since 35 years
- Uniquely combines 10 European gas transmission operators and 10 European Pipeline manufacturers
- Performs R&D in the area of steel transmission pipelines, in order to improve their safety and quality
- Three committees : Materials, Corrosion, Design
- Organizes together with PRCI and APIA a Joint Technical Meeting every two years, in order to improve information exchange between research communities in this specific area
- Example publications: recommendations for fracture arrest, weld defects, mechanical damage, etc.

EPRG Methods to assess resistance of pipelines to Mechanical Damage

- R&D effort lasted for more than a decade, and was concluded by a set of two papers published in 3R International, 12/1999 (Roovers, Zarea et al.)
- Underlying models are based on mechanics or semi-empirical models and are validated by experimental results; their application range is explicitly indicated
- Part 1 : Assessing the remaining burst and fatigue strength of part-wall mechanical damage defects:
  - Gouges
  - Dents
  - Dent and gouge combinations
- Part 2 : Assessing pipeline resistance to mechanical damage:
  - Puncture resistance
  - Aggression capacities of excavators
- These results are used in everyday operating practice in Europe

EPRG – Work went on in the MD arena, e. g.:

- Hooking of pipelines
- Behavior of gouges in low toughness pipes, complementary to PRCI work on corrosion defects on low toughness pipes
- Update the burst strength model for dent and gouge combinations to incorporate nowadays improved knowledge of this complex problem – and decrease the scatter of the model
- There is an opportunity to coordinate with PRCI work on this subject
- EPRG contractors work also for PRCI: Advantica, CSM, Gaz de France R&D Division, …
- PRCI contractors work also for EPRG: C-FER, …
- Five operator companies are members of both organizations – they can contribute to specific collaboration projects

3. Accident on HP gas transmission pipeline in Ghislenghien July 30, 2004 (Belgium)

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Main information

- Accident occured during a planned pipeline maintenance shutdown, resulting in pressure increase above the value at which the damage was inflicted.
- Defect failure resulted in a leak, producing a gas cloud, that caught fire after transition to rupture
- Defects were introduced by a subcontracted soil stabilizing work needed to build an access road to a new parking lot, for the new Diamant Boart factory
- The operator had reviewed the yard with the contractor
- Depth of cover was reduced due to ground leveling
- Operation of a soil stabilizing equipment does not give any view of what happens beneath the soil surface

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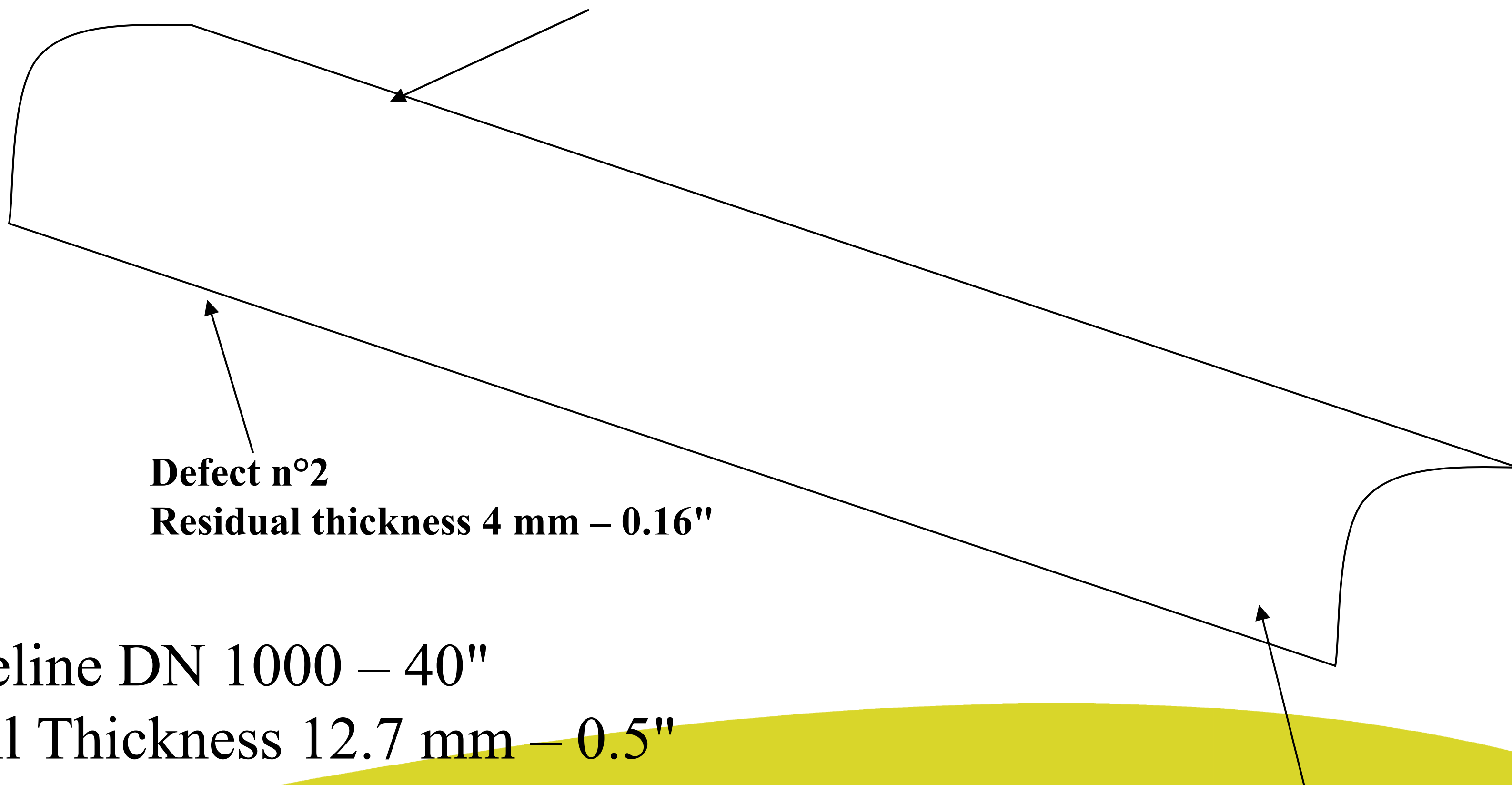
Defects on piece of broken pipe



Pipeline DN 1000 – 40"
Wall Thickness 12.7 mm – 0.5"
Piece 11 m – 36 ft long
Weighs about 6 tons

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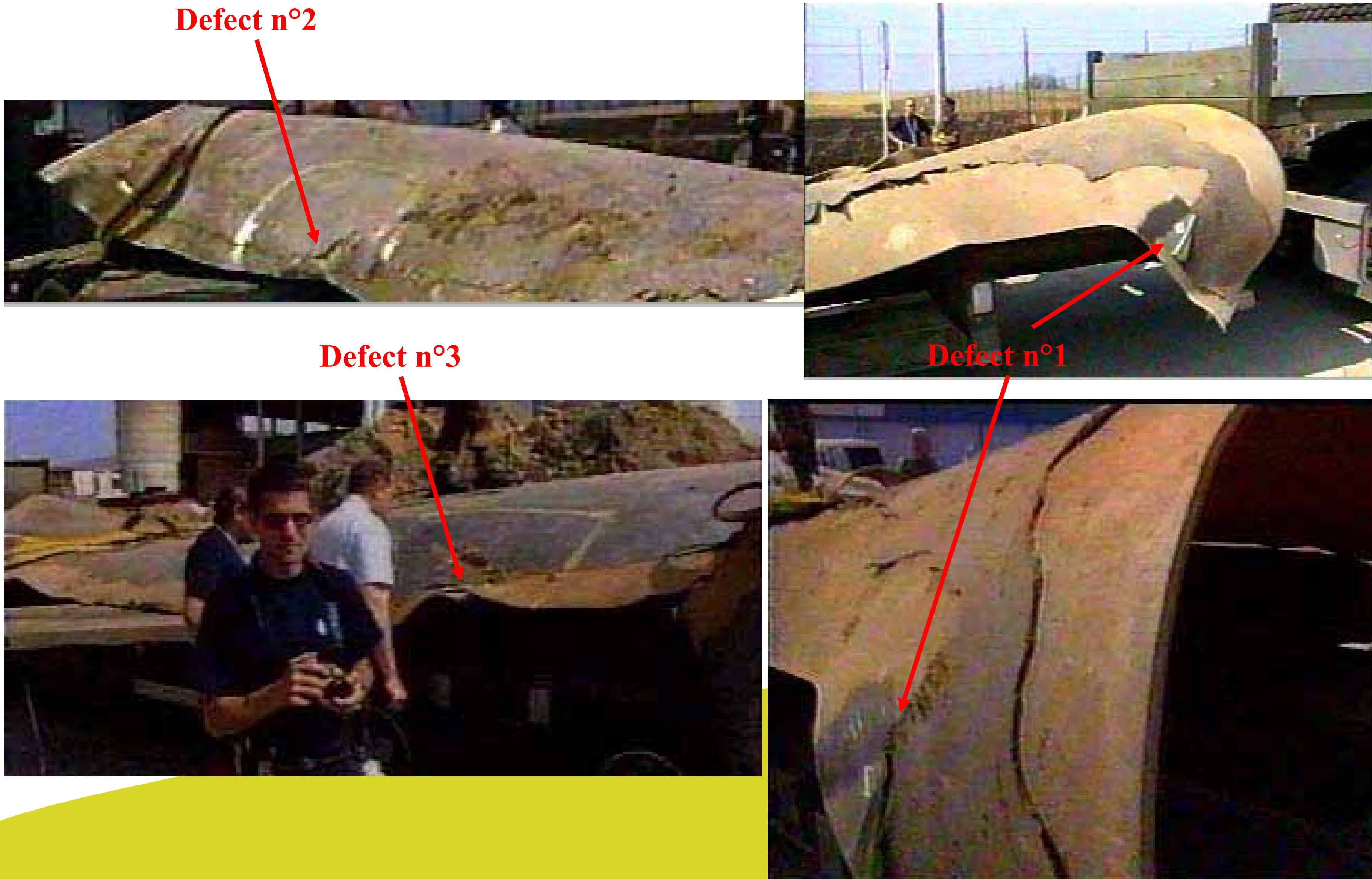
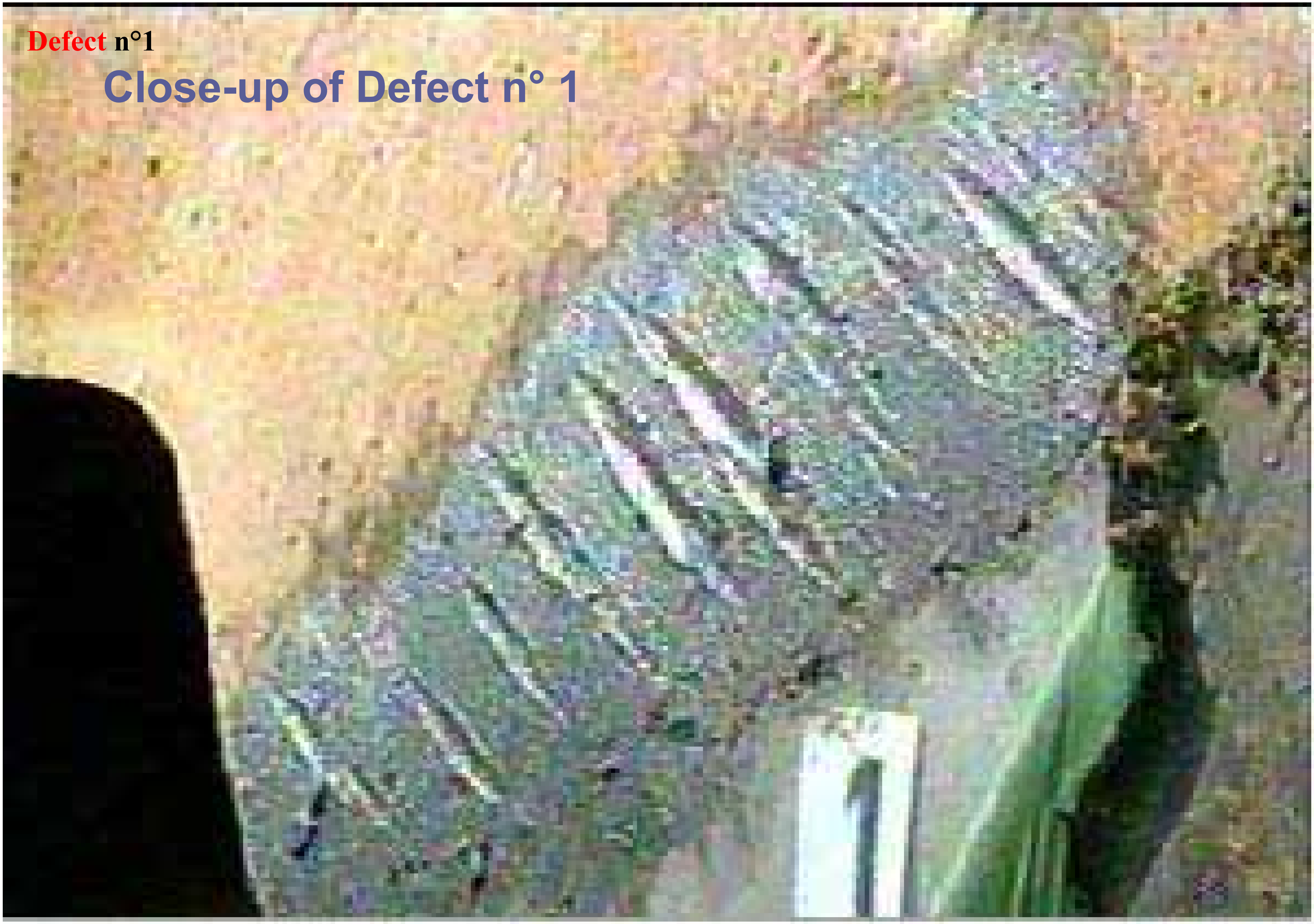
Defects on piece of broken pipe

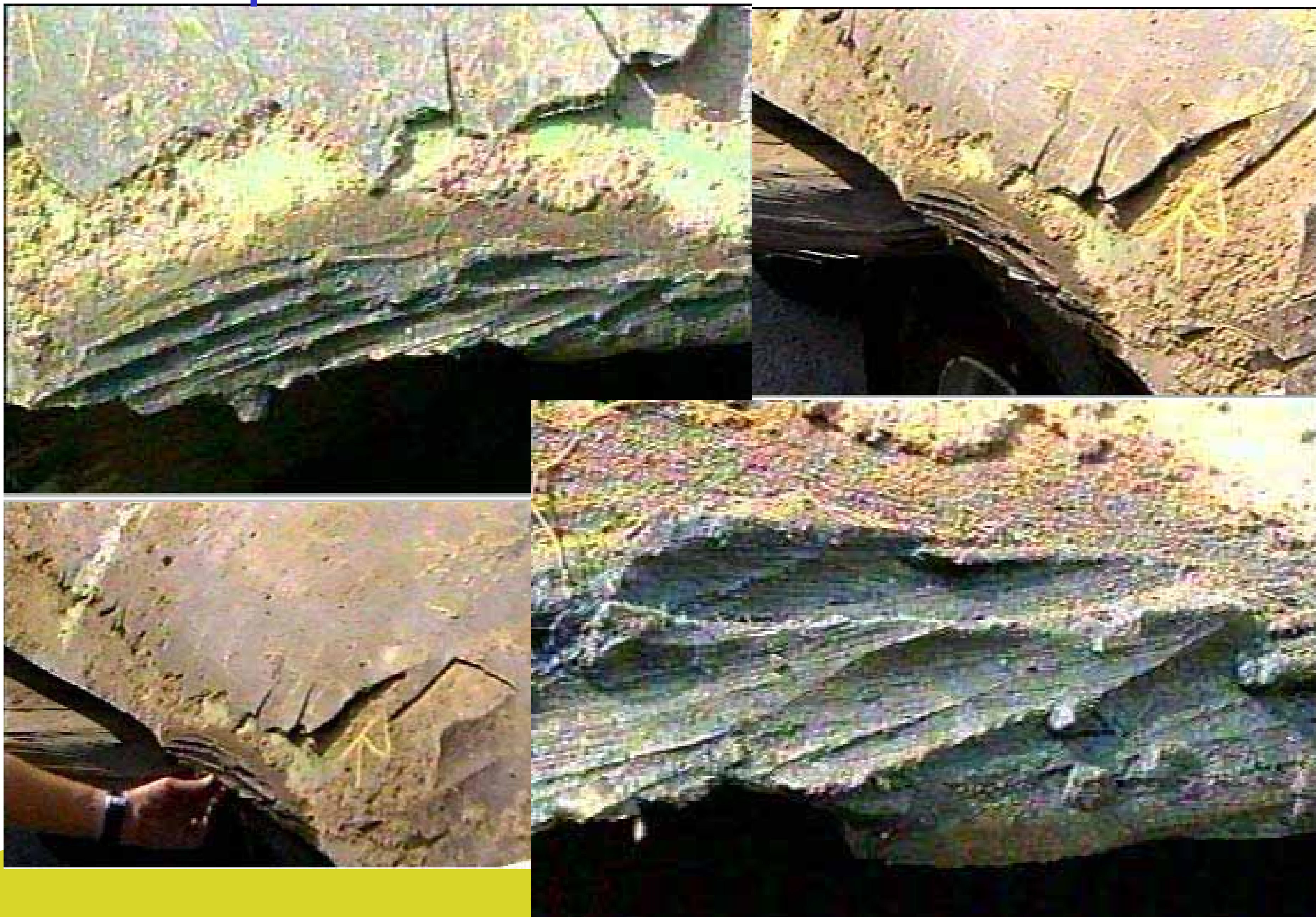


Defect n°1

Close-up of Defect n° 1

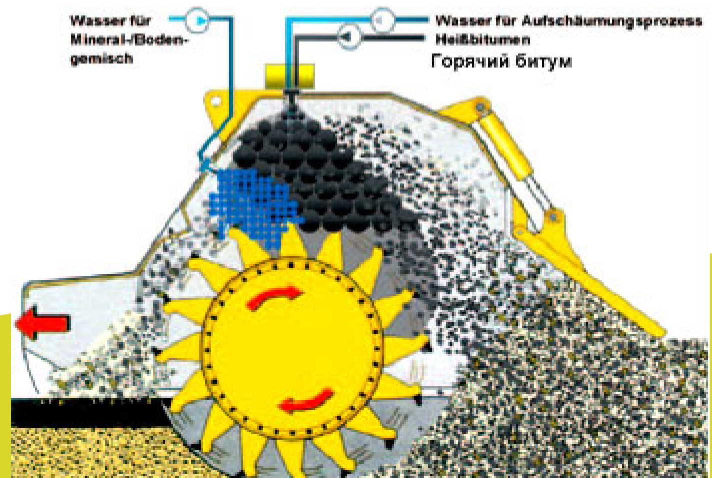


Close-ups of Defect n° 2



Close-up of Defect n° 3

Example of soil stabilizing equipement for road construction



Site map: factories and pipeline

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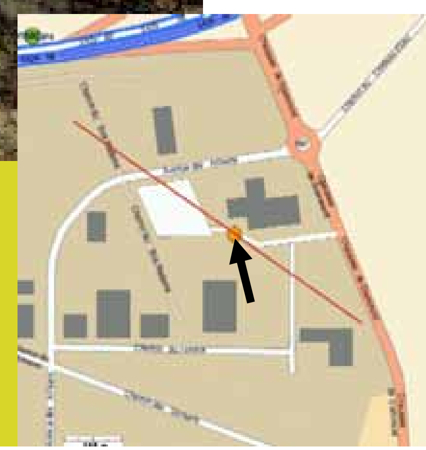
The crater



The crater

The crater

Aerial view of the area from the south

Aerial view of the area from the south west

Aerial view of the area from the south east

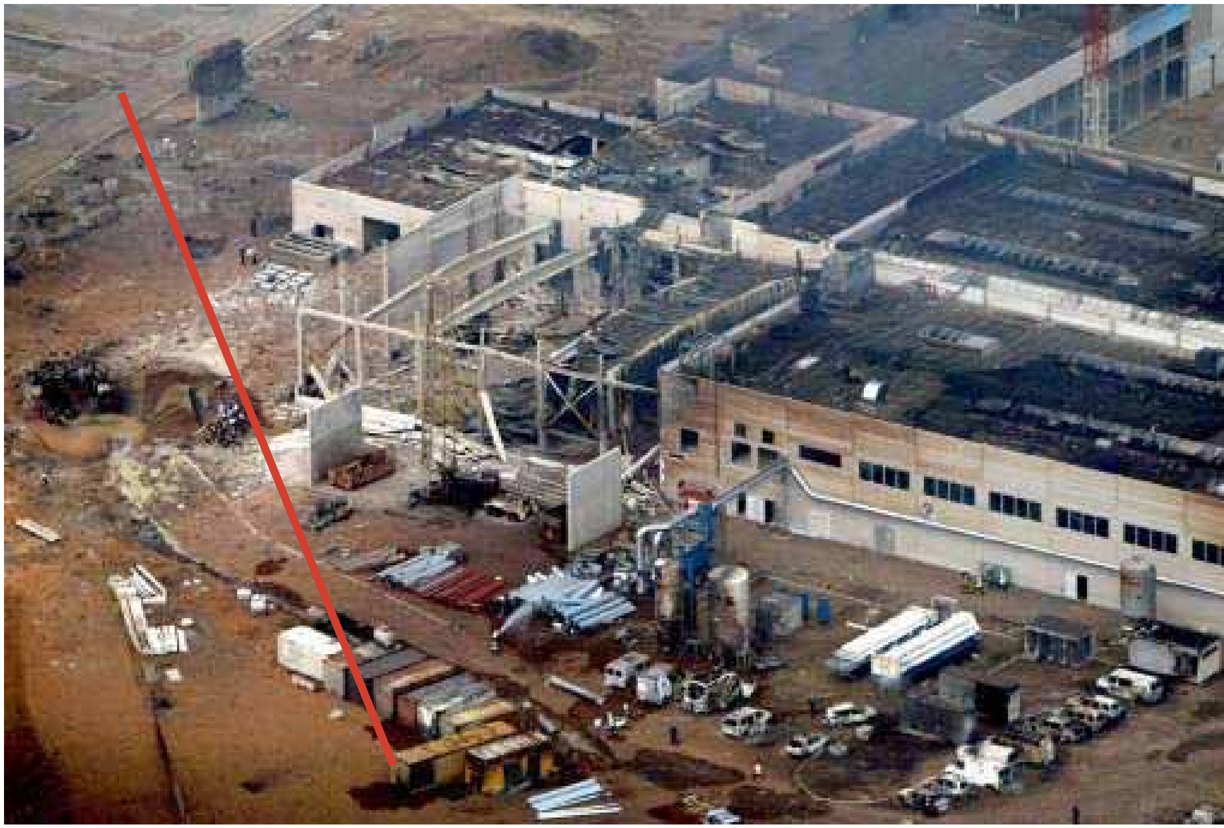
Aerial view of the area from the north east

East entrance to Diamant Boart

Wheat field to the east of Diamant Boart

East entrance to Diamant Boart

Aerial view of Diamant Boart from south east



Construction crane

North west entrance to Diamant Boart parking

Diamant Boart parking seen from north west

Aerial view of JS Packaging from north west

JS Packaging seen from north west

Deformation of building structure @ 150 m to south east of crater

Burnt down vehicles (not localized)

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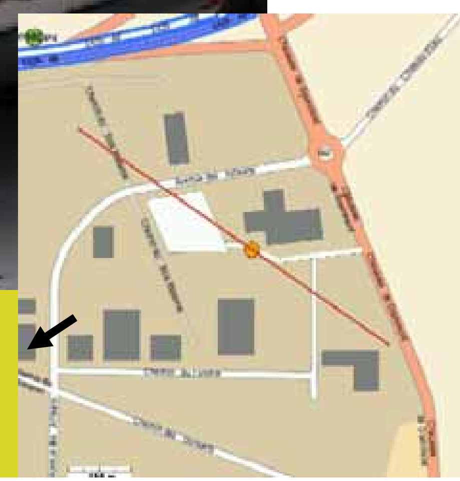
Burnt down vehicles (not localized)

Damaged vehicle : molten plastics and blistered paint (@ 160 m – 524 ft towards north east)

Damaged vehicle : molten plastics (@ 400 m – 1312 ft towards west)



Damaged vehicle : molten plastics (@ 400 m – 1312 ft towards west)

Burnt vegetation

Gas plume seen from 10 km to the north (with condensation in the atmosphere)

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Gas plume seen from the south (with condensation in the atmosphere)

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Flame

Flame seen from south

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Flame seen from north west on highway

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Flame seen from the south

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Flame seen from the south

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Flame seen from the south

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Flame seen from the south

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Flame seen from the north

Flame seen from the south east

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Reduced flame seen from highway

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First aid

First aid

First aid

U37 marker post (south east of crater)

Valve station (not localized)

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Inspection of pipeline (DN 900 – 36"or DN1000 - 40")

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Analysis of accident effets

- Effects of overpressure
- Effects of thermal radiation

Observed effects due to overpressure phenomena

- Effects on people : 3 persons projected at 200 m – 656 ft to the east of the crater
- Effects on buildings : damaged concrete structure of Diamant Boart factory
- Projections of objects on several hundreds of meters (pipe segment found at 150 m – 492 ft)

Overpressure phenomena

- **Overpressure due to pipeline rupture**
  - Several bars within meters, very close to rupture
  - Quick attenuation with distance
- **Overpressure due to gas ignition**
  - GDF Risk assessment package « Persée » calculations : 33 mbar (0.48 psi) maximum, 20 mbar (0.29 psi) @ 392m and 10 mbar (0.145 psi) @ 888 m
  - Limited consequences
- **First phenomenon dominated**

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Thermal radiation effects observed

- **Effects on people :**
  - 22 persons present at the Diamant Boart site when the rupture occured, within 200m, died. (Out of 22, 3 were projected & 6 passed away later due to their injuries)
  - About 130 persons injured by severe burns
- **Effects on structures :**
  - Two factories burnt
  - Metallic structure deformed on nearby building
  - Several cars burnt within 150 m – 492 ft
  - Vehicle plastics meltdown within 400 m – 1312 ft
- **Burnt vegetation within 250m – 820 ft**

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4. Summary & Conclusions

Summary & conclusions

- « Metrics » provided by existing incident data bases on HP pipelines, although perfectible, are of great practical value to assess the different « dimensions » of such a complex problem

- Good news are that HP pipelines are globally safe, and that in addition, the overall failure frequency has steadily decreased since the '70, but further progress can be achieved

- While mechanical damage is the most important single cause of leaks in HP pipelines, it has consistently and significantly decreased over the last three decades, and for gas pipelines, more than any other cause

- This fact shows a continuous and effective commitment from gas transmission operators to deal with this subject

- A thorough understanding of the wide and complex nature of this subject is necessary to go on improving even further the current status, and structured field feed-back (statistics and case-studies) as well as R&D, new technology, and improved communication are complementary means to achieve this goal