Financial Optimization of Condition Assessment Spending for Pipeline Replacement Programs

Gerard Hientzsch– Echologics

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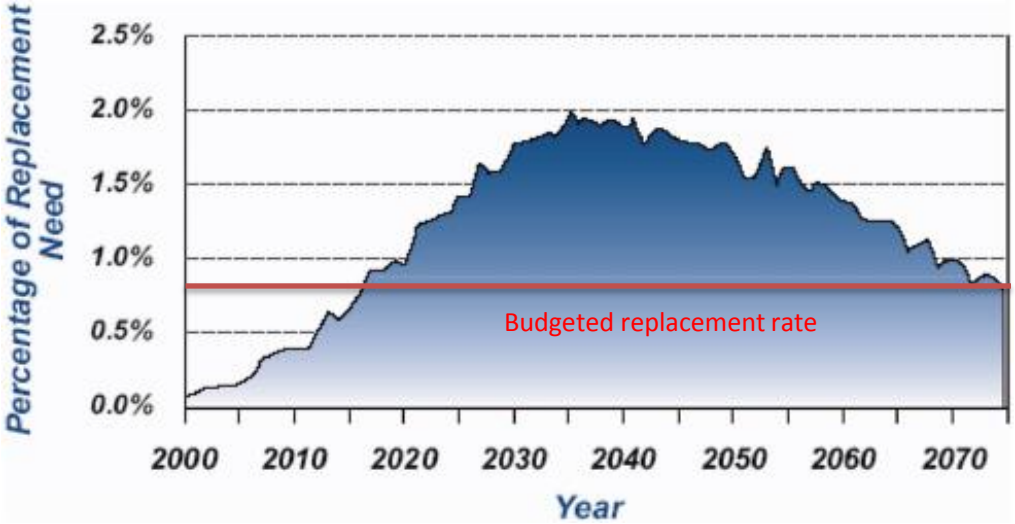
Water Mains Reaching End of Life

- Many water mains were installed between 1950 and 1980
- These will reach their design life together in a large wave
- Capital funds insufficient to meet the need



Projected annual replacement needs for transmission lines and distribution mains, 2000–2075. SOURCE: EPA (2002c)

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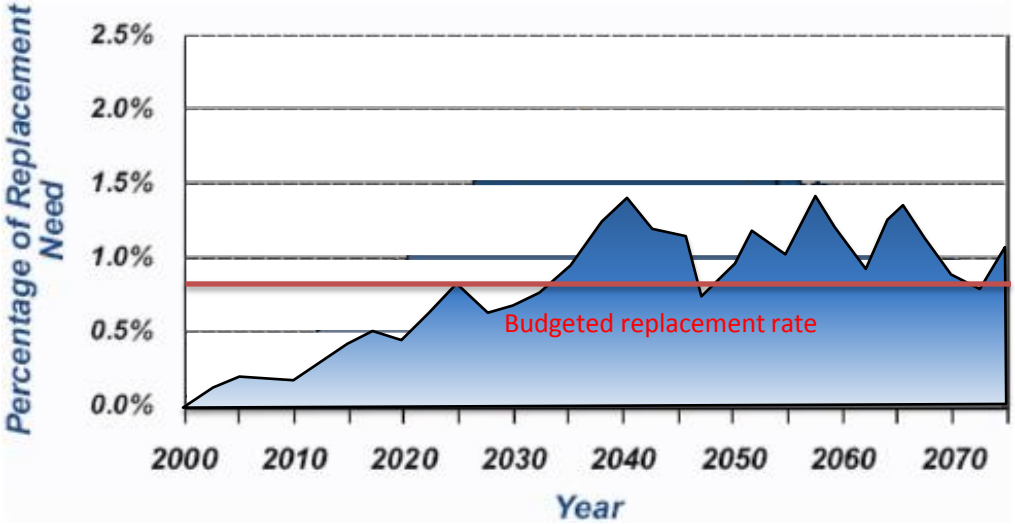
The Impact of Asset Management

- Base the need for replacement on condition instead of age
- Reduces the need for investment to bring it in line with available investment funds



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Financial Risk of Decision Errors

- Limited information means a risk of errors

- Consider the risk in this “3 shell game”
  - Choose the right shell, you lose nothing
  - Choose the wrong shell, you lose € 5

- Risk = Probability of a wrong choice (66.7%)
  x Consequences of a wrong choice (€ 5)
  = € 3.33 per play

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Financial Risk in Pipe Replacement

- Similar to the 3 shell game
  - Some mains need to be replaced
  - Other are in good condition
  - Mains are covered, so distinguishing is difficult
- Replacing a good main wastes a valuable asset
  - The remaining useful life of the old main is lost
- When replacing a main:
  - Risk = Probability the main is in good condition
    x Residual value of the good main

Limited Data → Uncertain Decisions

Pipeline 1	Pipeline 2
Installed 1860	Installed 1860
Brown sandy soil	Brown clay soil
Moderate soil corrosivity	Moderate soil corrosivity

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Limited Data → Uncertain Decisions

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Installed 1860	Installed 1860
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Decision = Replace

Decision = Replace

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Limited Data → Uncertain Decisions

Pipeline 1	Pipeline 2
Installed 1860	Installed 1860
Brown sandy soil	Brown clay soil
Moderate soil corrosivity	Moderate soil corrosivity

Decision = Replace ✓

Decision = Replace ✗

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We Can “Pay To Peak”

- More information… for a price
- Pay € 1 to peak under one shell
  - 33% chance you find the pea → 0% chance of error
  - 67% chance you don’t → 50% chance of error
  - Risk of error is now 33% x € 5 = € 1.67 per play
- Cost = Information Cost + Risk of error
  = € 1 + € 1.67
  = € 2.67 per play
- Risk without the extra information was € 3.33 per play

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Paying to Peak at a Pipe

- Pipeline inspection:
  - Buying more information
  - Total Cost = Inspection Cost + Risk of Error

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Paying To Peek at a Pipe

Pipeline 1	Pipeline 2
Installed 1860	Installed 1860
Brown sandy soil	Brown clay soil
Moderate soil corrosivity	Moderate soil corrosivity
Inspection Results: 31% degraded	**Inspection Results: 1% degraded**
Inspection Condition Prediction: **Poor**	Inspection Condition Prediction: **Good**

Decision = Replace

Decision = Keep

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Paying To Peek at a Pipe

Pipeline 1	Pipeline 2
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Inspection Results: 31% degraded	**Inspection Results: 1% degraded**
Inspection Condition Prediction: **Poor**	Inspection Condition Prediction: **Good**

Decision = Replace ✓

Decision = Keep ✓

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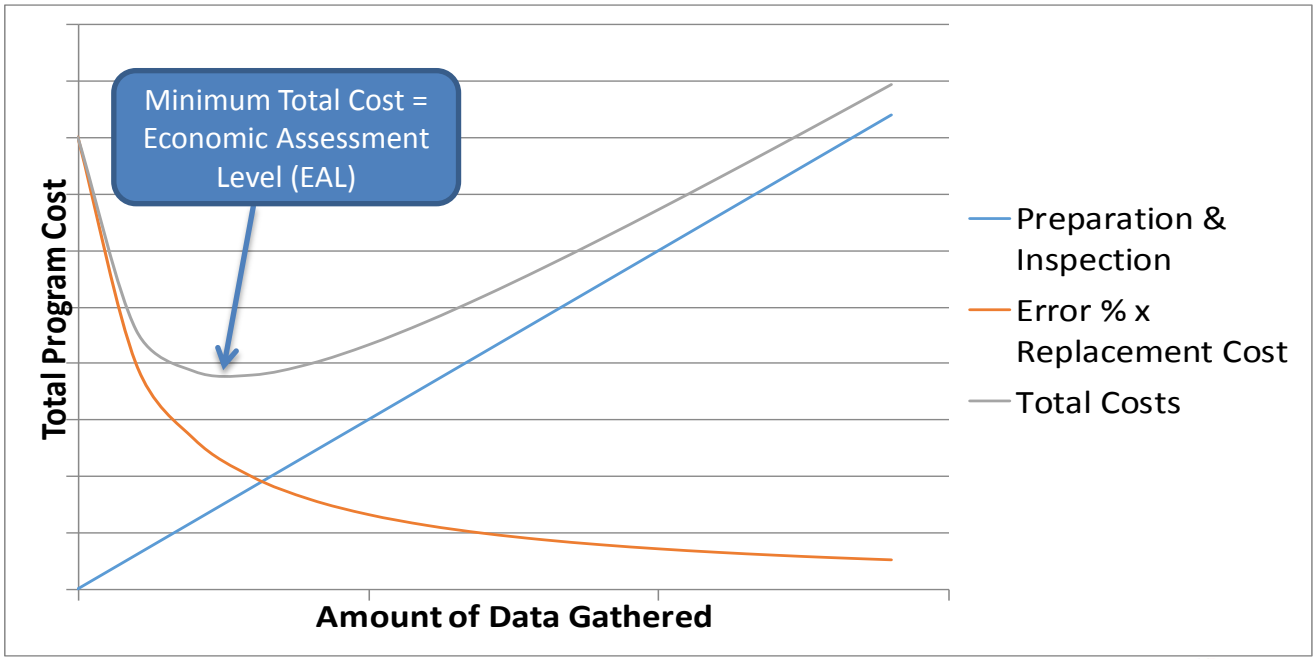
Total Cost Has a Minimum

Total Cost = Assessment cost + Incorrect replacement cost



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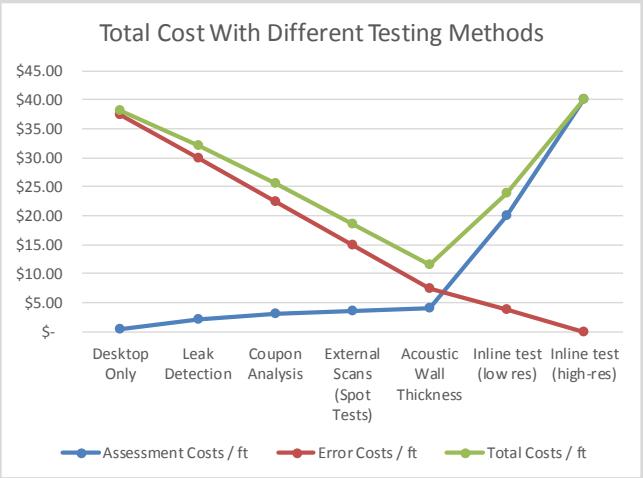
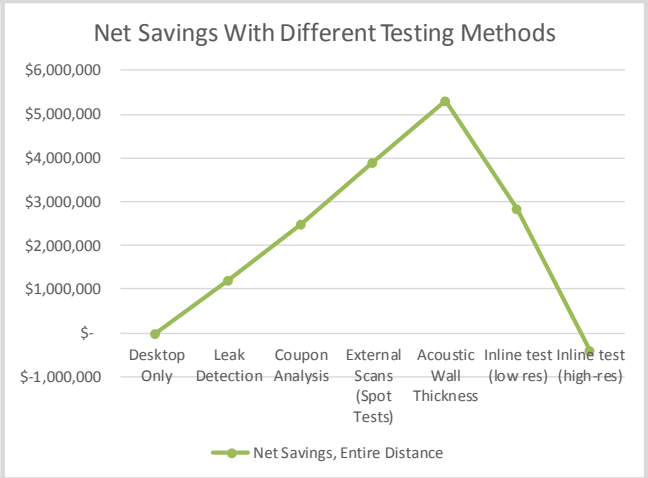
Total Cost Comparison Method

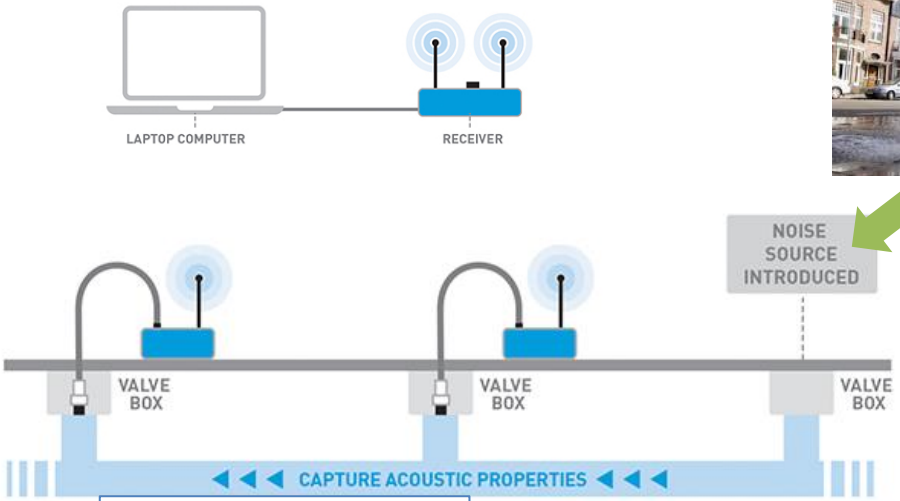
Input Parameters							
Replacement cost	$ 150.00	/ ft		Fraction of replacement value lost if replaced incorrectly:			50%
Distance under consideration	200	miles					
Scenario	Desktop Only	Leak Detection	Coupon Analysis	External Scans (Spot Tests)	Acoustic Wall Thickness	Inline test (low res)	Inline test (high-res)
Cost of Preparation	$ -	$ 0.50	$ 2.00	$ 1.00	$ 0.50	$ 10.00	$ 20.00
Cost of Inspections	$ 0.50	$ 1.50	$ 1.00	$ 2.50	$ 3.50	$ 10.00	$ 20.00
Decision error rate	50%	40%	30%	20%	10%	5%	0%
Results Output							

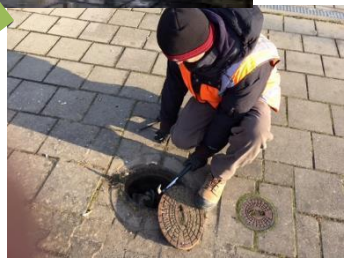




Case Study Technology: ePulse

Non-invasive tests of Average Wall Thickness



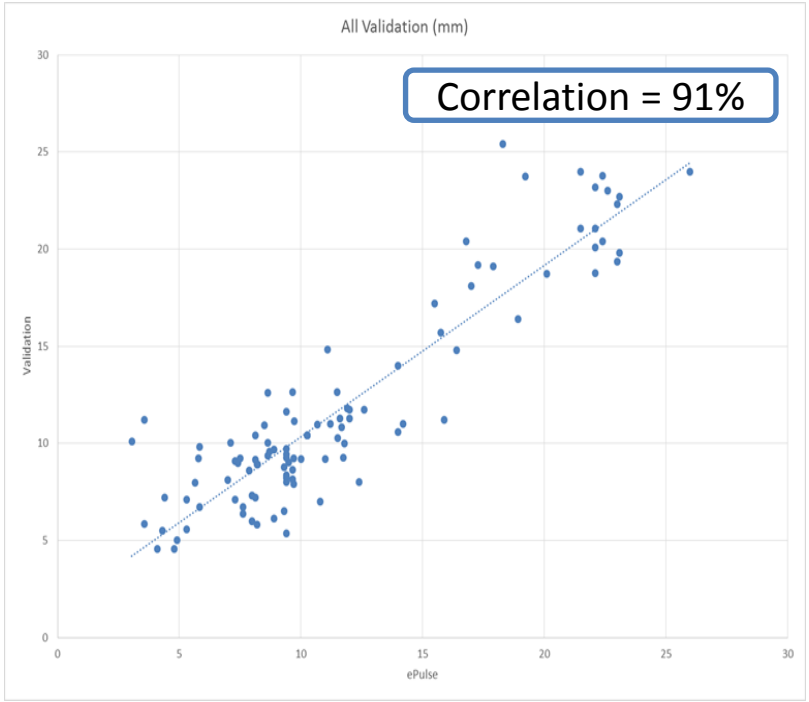


<--100 m to 200 m-->

ePulse Method is Established and Verified

- >10 years
- >10,000 scans
- >100 validations

- But, decision errors can be made even with reliable data



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ePulse Can Scan Part Or All Of a Main

Section	Diameter	Length	Material	Original Thickness	Measured Thickness	Thickness Loss
1	8 in	546 ft	CI	0.38 in		
2	8 in	251 ft	CI	0.38 in		
3	8 in	252 ft	CI	0.38 in		
4	8 in	428 ft	CI	0.38 in		
5	8 in	427 ft	CI	0.38 in		
6	8 in	516 ft	CI	0.38 in		
7	8 in	513 ft	CI	0.38 in		
8	8 in	491 ft	CI	0.38 in	0.35 in	9%
9	8 in	354 ft	CI	0.38 in		
10	8 in	398 ft	CI	0.38 in		
11	8 in	526 ft	CI	0.38 in		
12	8 in	412 ft	CI	0.38 in		
13	8 in	554 ft	CI	0.38 in		
14	8 in	474 ft	CI	0.38 in		
15	8 in	549 ft	CI	0.38 in		
16	8 in	481 ft	CI	0.38 in	0.36 in	6%
17	8 in	775 ft	CI	0.38 in		
18	8 in	829 ft	CI	0.38 in		

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Section	Diameter	Length	Material	Original Thickness	Measured Thickness	Thickness Loss
1	8 in	546 ft	CI	0.38 in		
2	8 in	251 ft	CI	0.38 in		
3	8 in	252 ft	CI	0.38 in		
4	8 in	428 ft	CI	0.38 in	0.35 in	7%
5	8 in	427 ft	CI	0.38 in		
6	8 in	516 ft	CI	0.38 in		
7	8 in	513 ft	CI	0.38 in		
8	8 in	491 ft	CI	0.38 in	0.35 in	9%
9	8 in	354 ft	CI	0.38 in		
10	8 in	398 ft	CI	0.38 in		
11	8 in	526 ft	CI	0.38 in		
12	8 in	412 ft	CI	0.38 in	0.37 in	4%
13	8 in	554 ft	CI	0.38 in		
14	8 in	474 ft	CI	0.38 in		
15	8 in	549 ft	CI	0.38 in		
16	8 in	481 ft	CI	0.38 in	0.36 in	6%
17	8 in	775 ft	CI	0.38 in		
18	8 in	829 ft	CI	0.38 in		

ePulse Can Scan Part Or All Of a Main

Section	Diameter	Length	Material	Original Thickness	Measured Thickness	Thickness Loss
1	8 in	546 ft	CI	0.38 in		
2	8 in	251 ft	CI	0.38 in	0.29 in	14%
3	8 in	252 ft	CI	0.38 in		
4	8 in	428 ft	CI	0.38 in	0.35 in	7%
5	8 in	427 ft	CI	0.38 in		
6	8 in	516 ft	CI	0.38 in	0.39 in	0%
7	8 in	513 ft	CI	0.38 in		
8	8 in	491 ft	CI	0.38 in	0.35 in	9%
9	8 in	354 ft	CI	0.38 in		
10	8 in	398 ft	CI	0.38 in	0.33 in	13%
11	8 in	526 ft	CI	0.38 in		
12	8 in	412 ft	CI	0.38 in	0.37 in	4%
13	8 in	554 ft	CI	0.38 in		
14	8 in	474 ft	CI	0.38 in	0.27 in	30%
15	8 in	549 ft	CI	0.38 in		
16	8 in	481 ft	CI	0.38 in	0.36 in	6%
17	8 in	775 ft	CI	0.38 in		
18	8 in	829 ft	CI	0.38 in	0.36 in	5%

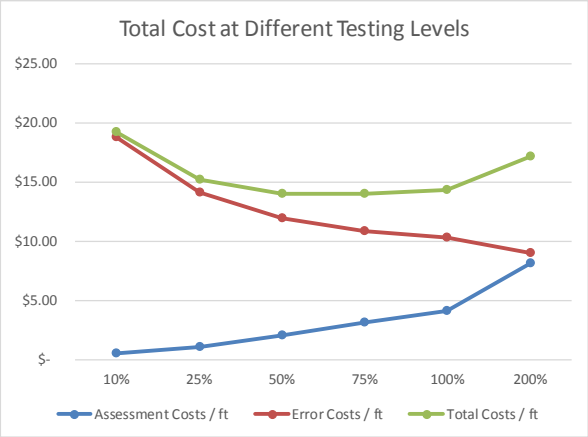
ePulse Can Scan Part Or All Of a Main

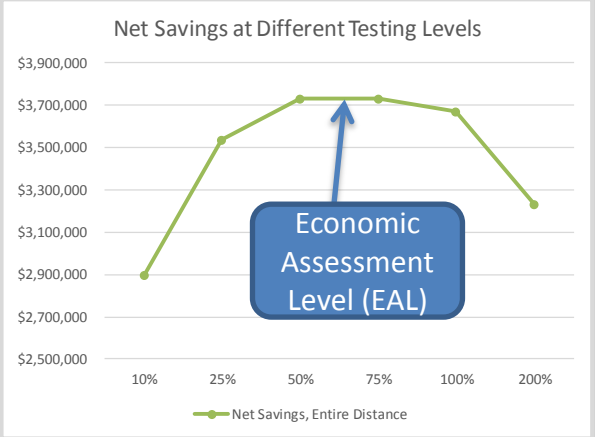
Section	Diameter	Length	Material	Original Thickness	Measured Thickness	Thickness Loss
1	8 in	546 ft	CI	0.38 in	0.31 in	20%
2	8 in	251 ft	CI	0.38 in	0.29 in	14%
3	8 in	252 ft	CI	0.38 in	0.34 in	11%
4	8 in	428 ft	CI	0.38 in	0.35 in	7%
5	8 in	427 ft	CI	0.38 in	0.37 in	4%
6	8 in	516 ft	CI	0.38 in	0.39 in	0%
7	8 in	513 ft	CI	0.38 in	0.32 in	17%
8	8 in	491 ft	CI	0.38 in	0.35 in	9%
9	8 in	354 ft	CI	0.38 in	0.38 in	0%
10	8 in	398 ft	CI	0.38 in	0.33 in	13%
11	8 in	526 ft	CI	0.38 in	0.38 in	0%
12	8 in	412 ft	CI	0.38 in	0.37 in	4%
13	8 in	554 ft	CI	0.38 in	0.35 in	7%
14	8 in	474 ft	CI	0.38 in	0.27 in	30%
15	8 in	549 ft	CI	0.38 in	0.38 in	0%
16	8 in	481 ft	CI	0.38 in	0.36 in	6%
17	8 in	775 ft	CI	0.38 in	0.35 in	9%
18	8 in	829 ft	CI	0.38 in	0.36 in	5%

Cost Optimisation Tool

Input Parameters							
Replacement cost	$ 150.00	/ ft			Fraction of replacement value lost if replaced incorrectly:		50%
Distance under consideration	30	miles			Cost to dig a 4-inch hole to top of pipe:		$ 1,325
Inspections unit price	$ 3.50	/ ft			Number of 4-inch holes needed per mile:		2
Inspections mobilization cost	$ 10,000	Fixed					
Testing Amount	0%	10%	25%	50%	75%	100%	200%
Cost of Preparation / ft	$ -	$ 0.05	$ 0.13	$ 0.25	$ 0.38	$ 0.50	$ 1.00
Cost of Inspections / ft	$ -	$ 0.41	$ 0.94	$ 1.81	$ 2.69	$ 3.56	$ 7.06
Decision error rate	50%	25%	19%	16%	14%	14%	12%

Results Output





Case Study 1: UK Water Company– Summary

- 22,000 miles of mains serve 4.3 million customers
- Replacing 50 miles of mains per year
- Rehabilitating a 4.5 mile long 18-inch main
- One 650 ft section was difficult to rehabilitate, as it ran through an environmentally protected area
- Replace at a cost of $150,000, or leave in place?
- Acoustic testing confirmed main in good condition
- Net savings of over $130,000 achieved

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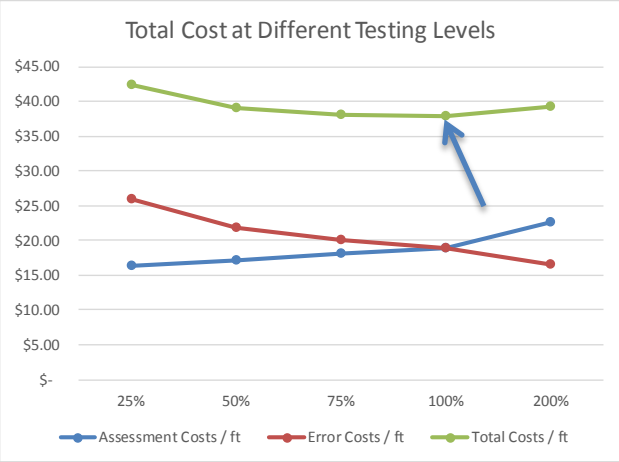
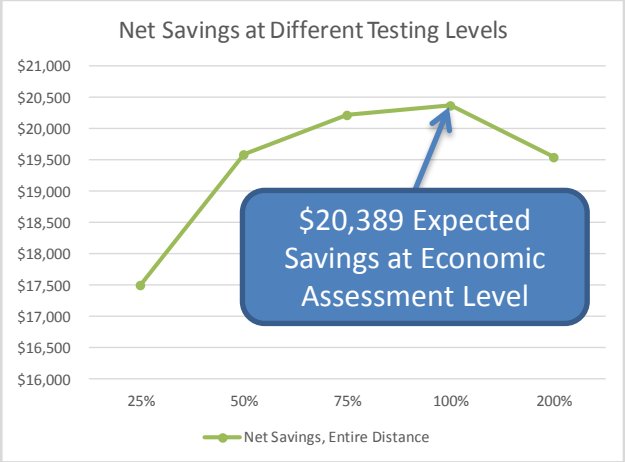
Case Study 1: UK Water Company– Summary

Input Parameters							
Replacement cost	$ 230.77	/ ft				Fraction of replacement value lost if replaced incorrectly:	60%
Distance under consideration	0.123	miles				Day cost for enabling work (if required):	$ 360
Inspections unit price	$ 3.50	/ ft				Number of days needed for assessment	1
Inspections mobilization cost	$ 10,000	Fixed					
Testing Amount	0%	10%	25%	50%	75%	100%	200%
Cost of Preparation / ft	$ -	$ 0.01	$ 0.02	$ 0.03	$ 0.05	$ 0.07	$ 0.14
Cost of Inspections / ft	$ -	$ 15.73	$ 16.26	$ 17.13	$ 18.01	$ 18.88	$ 22.38
Decision error rate	50%	25%	19%	16%	14%	14%	12%

Results Output





Case Study 2: Dutch Water Company – Summary

- 11,500 miles of mains serve 1.2 million customers
- 186 miles / year of replacement
- Group mains into cohorts with same neighbourhood, material, and year of construction
- Take several condition measurements in each cohort
- Old program: cut out samples of older pipes
- New program: non-invasive, non-destructive testing
- Currently testing 7% of mains

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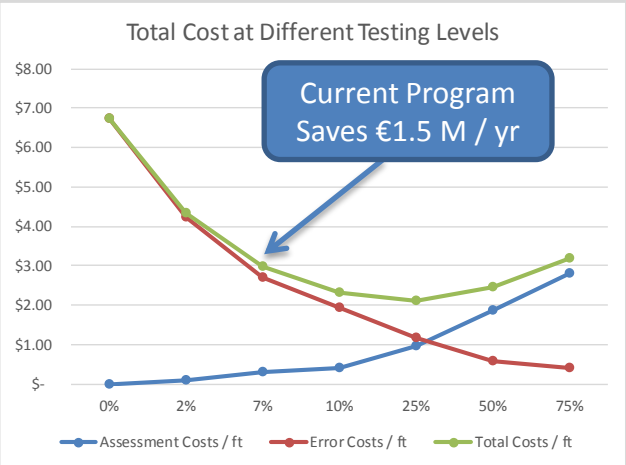
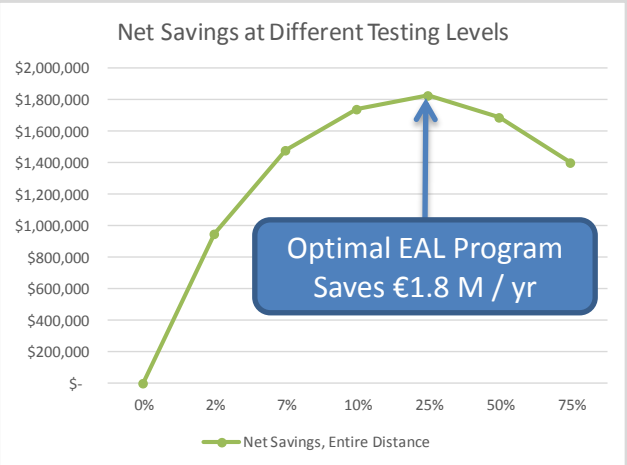
Case Study 2: Dutch Water Company – Analysis

Input Parameters							
Replacement cost	$ 48.00	/ ft				Fraction of replacement value lost if replaced incorrectly:	40%
Distance under consideration	75	miles				Cost to prepare & support 1 day of inspections:	$ 650
Inspections unit price	$ 3.50	/ ft				Number of field days needed per mile:	1.6
Inspections mobilization cost	$ 10,000	Fixed					
Testing Amount	0%	2%	7%	10%	25%	50%	75%
Cost of Preparation / ft	$ -	$ 0.00	$ 0.01	$ 0.02	$ 0.05	$ 0.10	$ 0.15
Cost of Inspections / ft	$ -	$ 0.10	$ 0.27	$ 0.38	$ 0.90	$ 1.78	$ 2.65
Decision error rate	35%	22%	14%	10%	6%	3%	2%

Results Output





Case Study 3: American Water Company – Summary

Pilot Project Details

- 43 miles of ePulse testing
- $ 850.000 project
- 10 weeks of testing
- 0 excavations, 0 service disruptions

Pilot Project Result

- >20 miles of good pipe found
- $14M redirected from pipes actually in good shape
- Bonus: found $117k worth of leaks

Results:

✓ Program for **75 miles** of testing per year
✓ Inspection data incorporated into asset management decisions
✓ Reduced waste by over **$12.5 million** per year
✓ Acheived a **17% efficency gain** in capital spending

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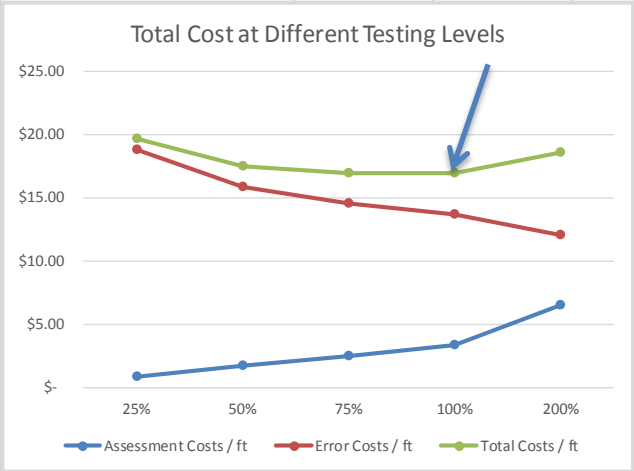
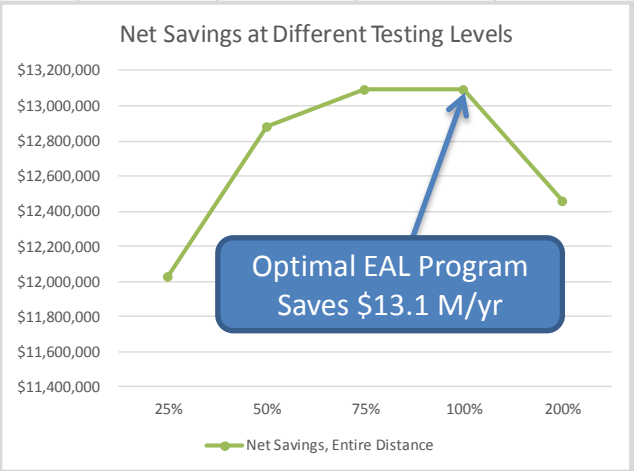
Case Study 3: American Water Company – Analysis

Input Parameters							
Replacement cost	$ 200.00	/ ft		Fraction of replacement value lost if replaced incorrectly:			50%
Distance under consideration	75	miles		Cost to dig a 4-inch hole to top of pipe:			$ 1,325
Inspections unit price	$ 3.25	/ ft		Number of 4-inch holes needed per mile:			0
Inspections mobilization cost	$ 10,000	Fixed					
Testing Amount	0%	10%	25%	50%	75%	100%	200%
Cost of Preparation / ft	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Cost of Inspections / ft	$ -	$ 0.35	$ 0.84	$ 1.65	$ 2.46	$ 3.28	$ 6.53
Decision error rate	50%	25%	19%	16%	14%	14%	12%
Results Output							





Conclusions

- Decision making under uncertainty can be managed using the idea of financial risk
- Economic Assessment Level can be calculated
- More expensive mains justify more testing
- Less expensive mains still need some testing
- Any amount of testing is better than none at all

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Questions?

Gerard Hientzsch – ghientzsch@echologics.com

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