CH2MHILL

Drinking Water Pipeline Condition Assessment: Part 2




PNWS-AWWA Conference – Spokane, WA
May 10, 2013

Part 1 Recap

1. Introductions
2. ***Benefits***
3. General Condition Assessment Approach
   - Prioritization Methods
   - Field Technologies
4. Rehabilitation Alternatives
5. Additional Resources

Quantifying Benefits of Condition Assessment

Cost of Failure

"Just in Time" Renewal

Societal Costs

Damages

Emergency Repair

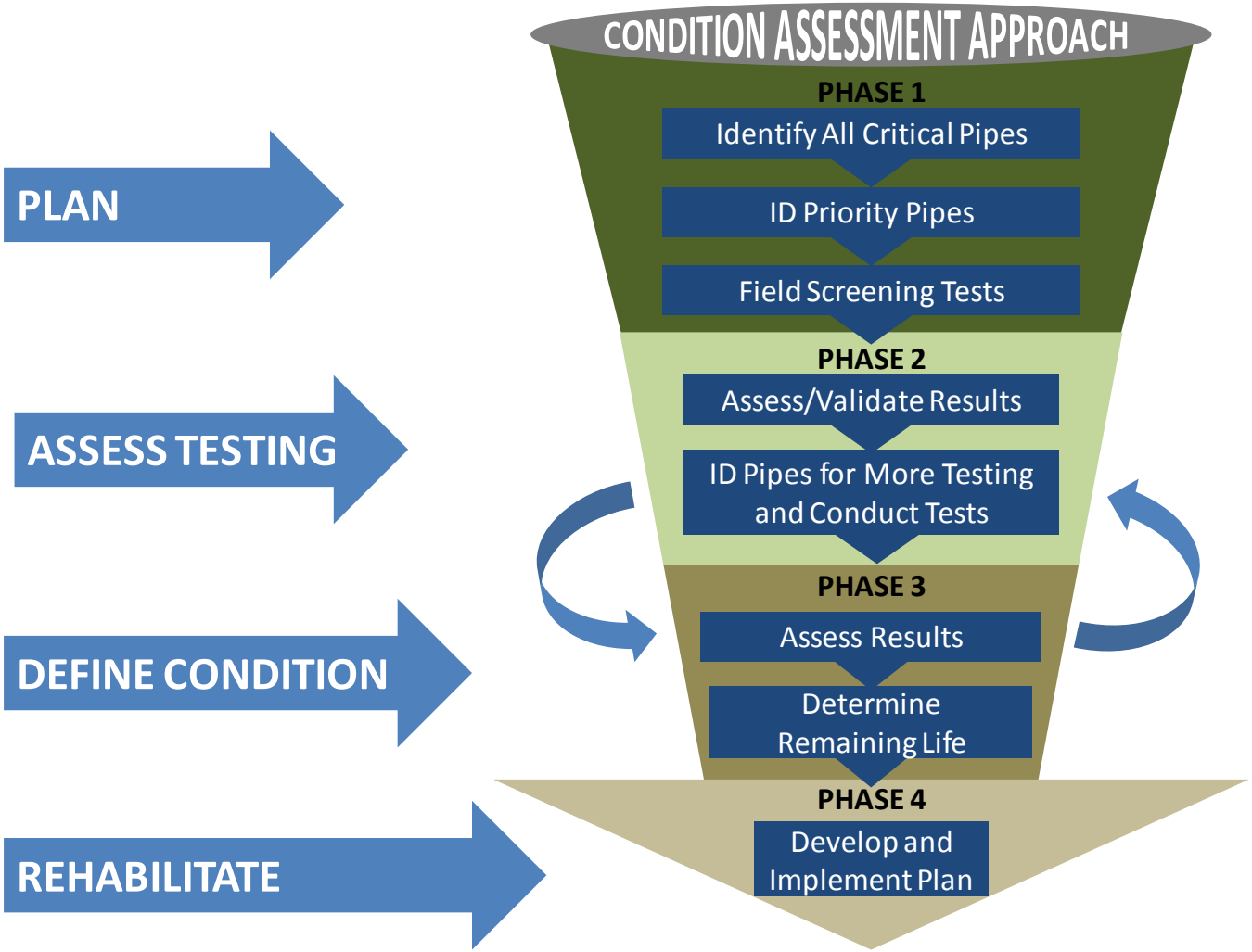
Planned Rehab Expenditures

Condition Assessment

Part 1 Recap

1. Introductions
2. Market Drivers and Opportunities
3. ***Approaches to Condition Assessment***
   - ***Prioritization Methods***
   - Field Technologies
4. Rehabilitation Alternatives
5. Additional Resources

Prioritization Methods



1. Introductions
2. Market Drivers and Opportunities
3. ***Approaches to Condition Assessment***
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   - ***Field Technologies***
4. Rehabilitation Alternatives
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Field Technologies

- Complex and shifting marketplace
- New companies and trade names emerging and evolving
- Frequent updates to technologies, or new applications/capabilities of existing technologies

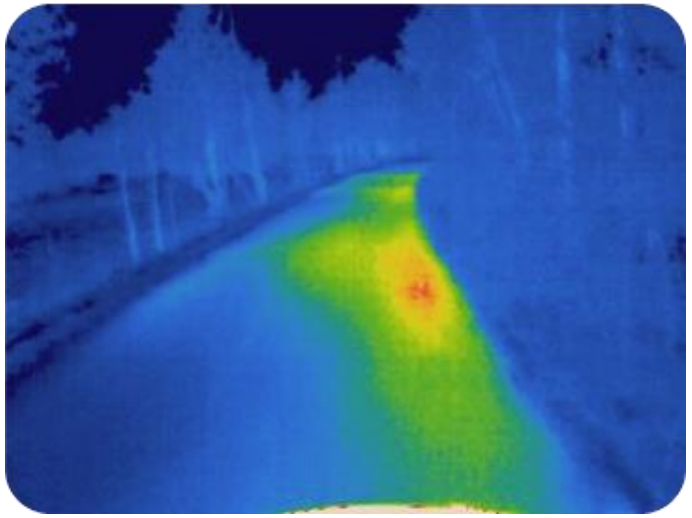
Phase 1: Technologies

- Non-destructive
- Non-intrusive
- Pipe remains in service
- Survey-level information

Leak Detection	Structural Condition	Hydraulic Performance
Infrared thermal	Visual Inspection	Pressure and Flow Monitoring
Acoustic Emissions	Soil Survey and Corrosion Analysis	
Acoustic Correlator Methods	Ultrasonic/Pit Depth	
	Guided Wave	

Infrared Thermal

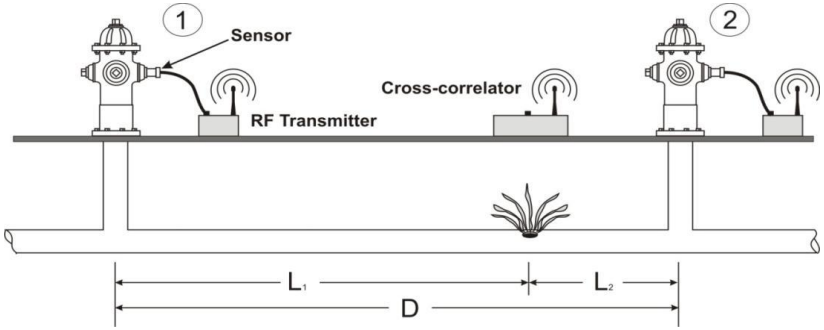
- Thermographic Imaging
  - Provides heat signature images which may indicate leaks in wastewater lines or wastewater effluent discharges
  - Survey level technology
  - No excavation/special access needed



Acoustic Methods: Leak Detection

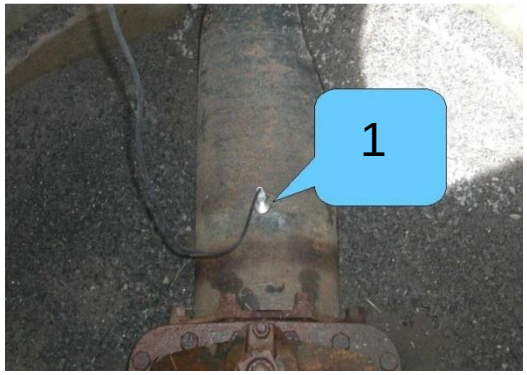
- Acoustic Correlator (Echologics)
  - Benefits
    - Locates leaks along the pipe
    - Pipe remains in service
    - Works on all pipe sizes/materials
  - Limitations
    - Does not quantify leak rate

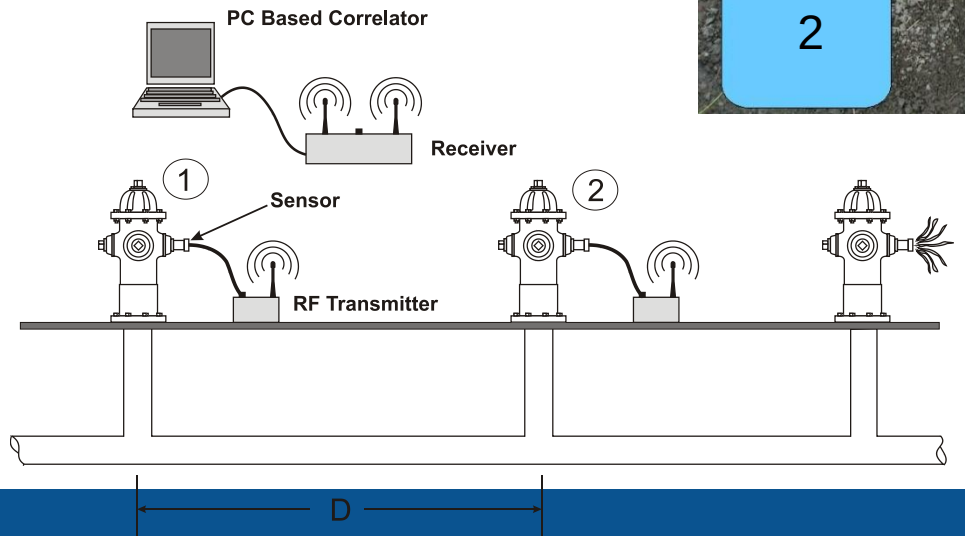
- Acoustic Microphones
  - Benefits
    - Locates leaks along the pipe
    - Pipe remains in service
    - Works on all pipe sizes/materials
  - Limitations
    - Does not quantify leak rate
    - Background noise can interfere



Acoustic Methods: Wall Thickness

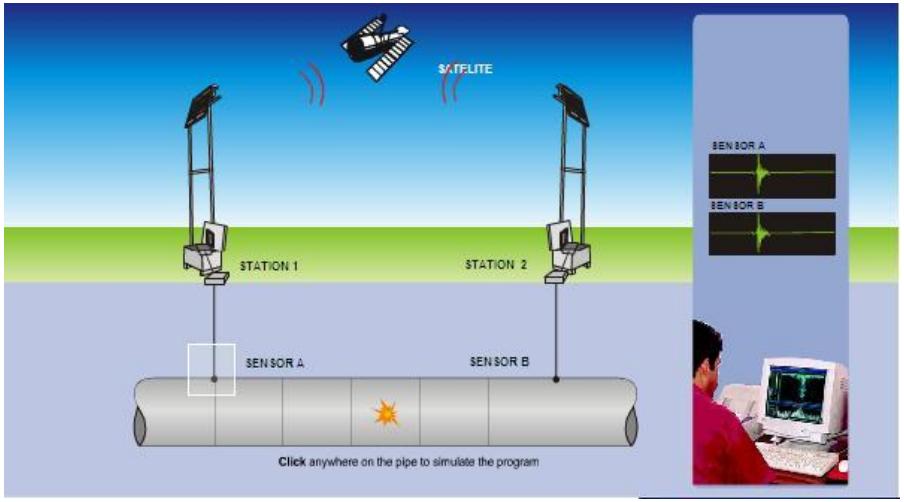
- Acoustic Correlator (Echologics)
  - Benefits
    - Measures average wall thickness between nodes (stiffness in non-metallic pipes)
    - Pipe remains in service
    - Works on all pipe sizes/materials
  - Limitations
    - Does not identify discrete defects
    - Minimum amount of measurements for accurate statistical analysis may vary





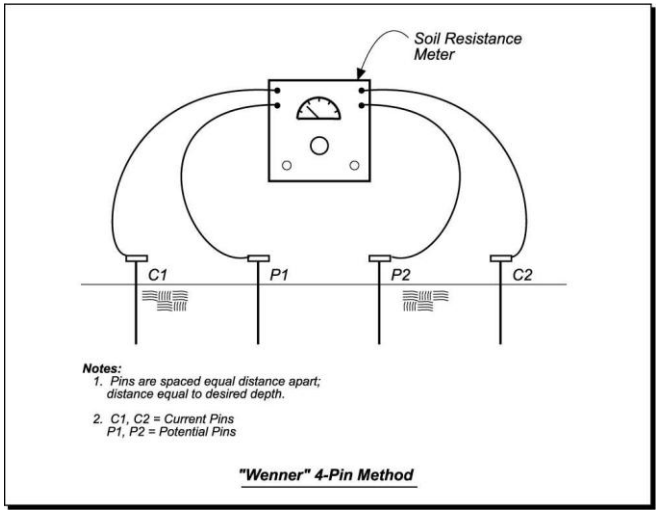
Acoustic Methods (Emission Monitoring)

- Advantages
  - Monitors the acoustic emission when a sudden appearance or propagation of a microscopic crack occurs within a material under load or the break of prestressed wire in PCCP
- Limitations
  - Can only detect what is happening during monitoring period (no indication about past deterioration)
  - Installation of sensors may need interruption of service
  - Quantitative information (e.g., size) about the crack is not available



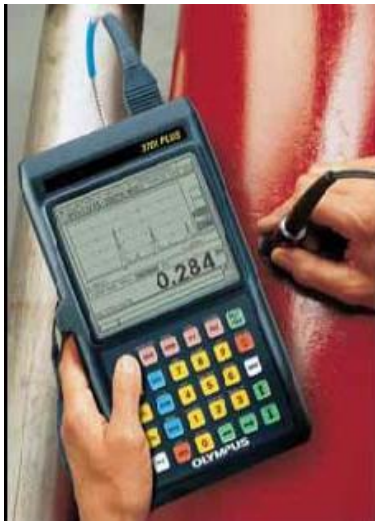
Soil Survey / Corrosion Analysis

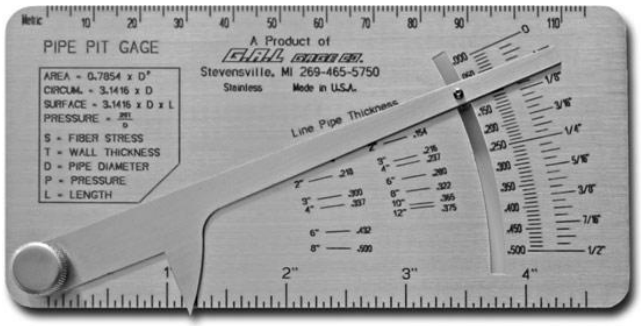
- Benefits
  - Rapid, wide deployment
  - Measures resistivity of soils (corrosion potential)
  - Survey-level tool
  - Best used in conjunction with pipe excavation
- Limitations
  - Does not provide information on full pipe length
  - Data relevant for metallic pipes/appurtenances only



Ultrasonic / Pit Depth Measurement

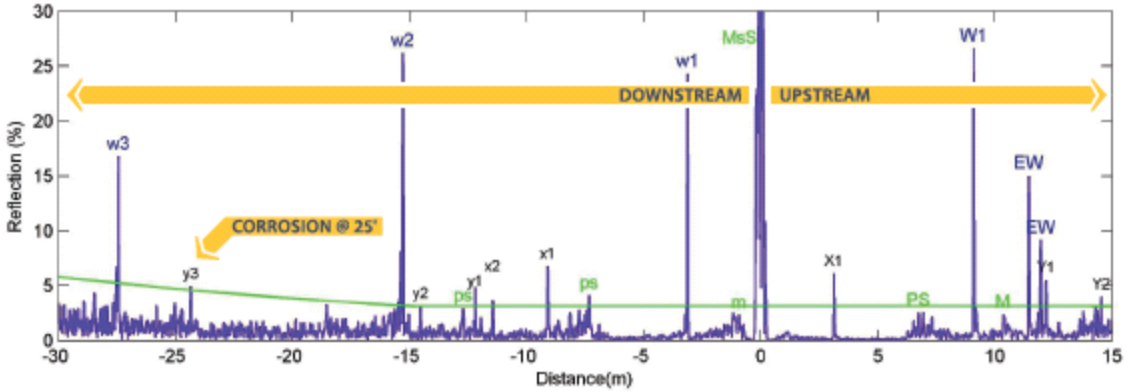
- Benefits
  - Quantitative measurement
    - Pipe wall thickness
    - Pit depth
  - Simple methods and tools
- Limitations
  - Exposure of pipe exterior required
  - Difficult to determine localized metal loss inside pipe with ultrasonic
  - Most commonly used on metallic pipes





Guided Wave

- Benefits
  - Screening of long lengths of pipe
  - 100% of pipe wall is inspected
  - Detects corrosion in insulated and buried pipes
- Limitations
  - Variable Range: 1”-60” and 60-1,000LF
  - Exposure of pipe exterior required
  - Applies to metallic pipes only



Pressure Flow Monitoring

Ultrasonic Transit-time Strap-on

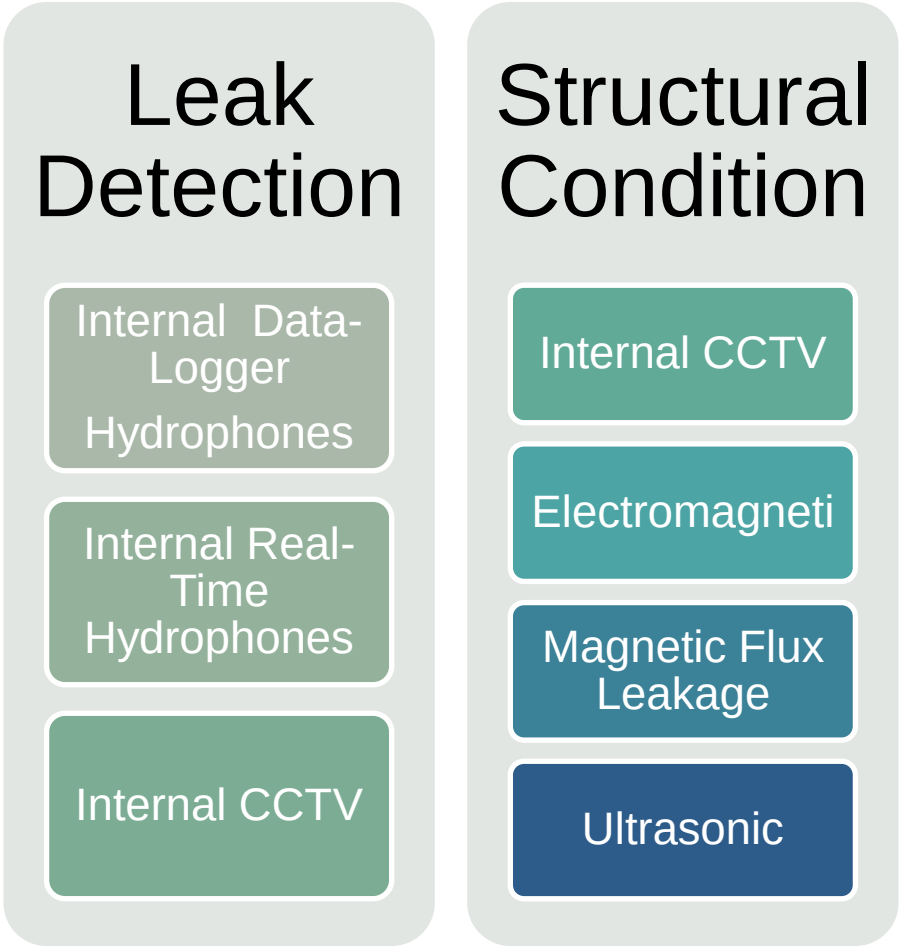
- Benefits
  - No in-line insertion required
  - Accuracy +/- 2%
- Limitations
  - Average flow rate
  - Frequently used for treated water applications

Electromagnetic Insertion

- Benefits
  - Accuracy +/- 2% point velocity
  - Bi-directional flow
  - Remote data transmission
- Limitations
  - Access to 1" tap/ball valve
  - Challenging high-pressure insertion
  - Pipe diameters 8”-78”

Phase 2: Technologies

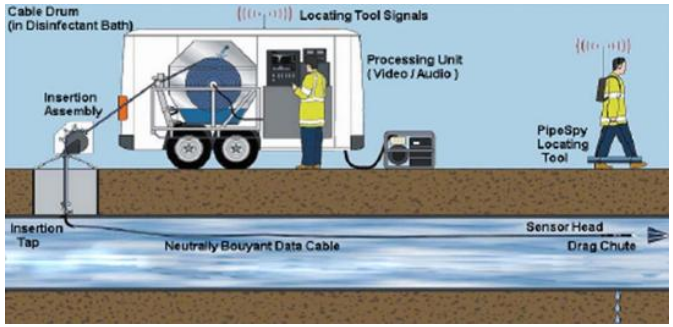
- Semi-intrusive
- Pipe remains in service
- Requires instruments be inserted into the pipe, or a portion of the pipe be exposed
- Quantitative and detailed information



Internal Hydrophones

- JD7 “Investigator” / “LDS1000”
  - Benefits
    - Locates leaks and gas pockets
    - Pipe remains in service
    - Works on all pipe sizes/materials
  - Limitations
    - No pipe wall assessment data *Yet*

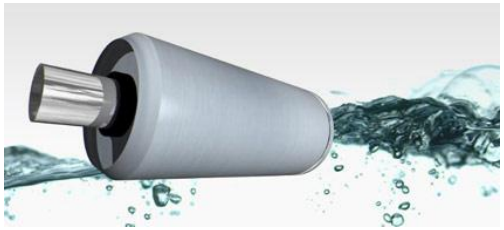
- Pure Sahara
  - Benefits
    - Locates leaks and gas pockets
    - Pipe remains in service
    - Works on all pipe sizes/materials +6” (2” access)
    - Measures specific defect location
  - Limitations
    - No pipe wall assessment data *Yet*
    - Deployment distance limited by number of bends in pipe
    - Tethered system requires numerous access points



Free-Swimming Internal Hydrophones

- Pure “SmartBall”
  - Benefits
    - Locates leaks and gas pockets
    - Pipe remains in service
    - Works on all pipe sizes/materials +6” (4” access)
  - Limitations
    - Defect location is approximate
    - No pipe wall assessment data

- JD7 “Bullet”
  - Benefits
    - Locates leaks
    - Pipe remains in service
    - Works on all pipe sizes/materials
    - Records visual images
  - Limitations
    - Defect location is approximate
    - No pipe wall assessment data
    - Tethered system for retrieval



Free-Swimming Electromagnetic

- PICA SeeSnake (RFT)
  - Benefits
    - Measures localized wall thickness
    - Measures through linings
    - Free swimming or tethered
  - Limitations
    - No leak/gas pocket detection
    - Large insertion assemblies required for +24” sizes
    - Extensive cleaning required
    - Metallic pipe only

- Pure PipeDiver
  - Benefits
    - Locates broken prestressed wires
    - Pipe remains in service
    - PCCP pipe only, +24”
  - Limitations
    - Site specific access requirements
    - No leak detection *yet*

Broadband Electromagnetic

- External Method
  - Benefits
    - Measures localized wall thickness
    - Pipe may remain in service
    - Measures through linings/corrosion
  - Limitations
    - Ferrous pipe only
    - Must expose pipe

Magnetic Flux Leakage (External)

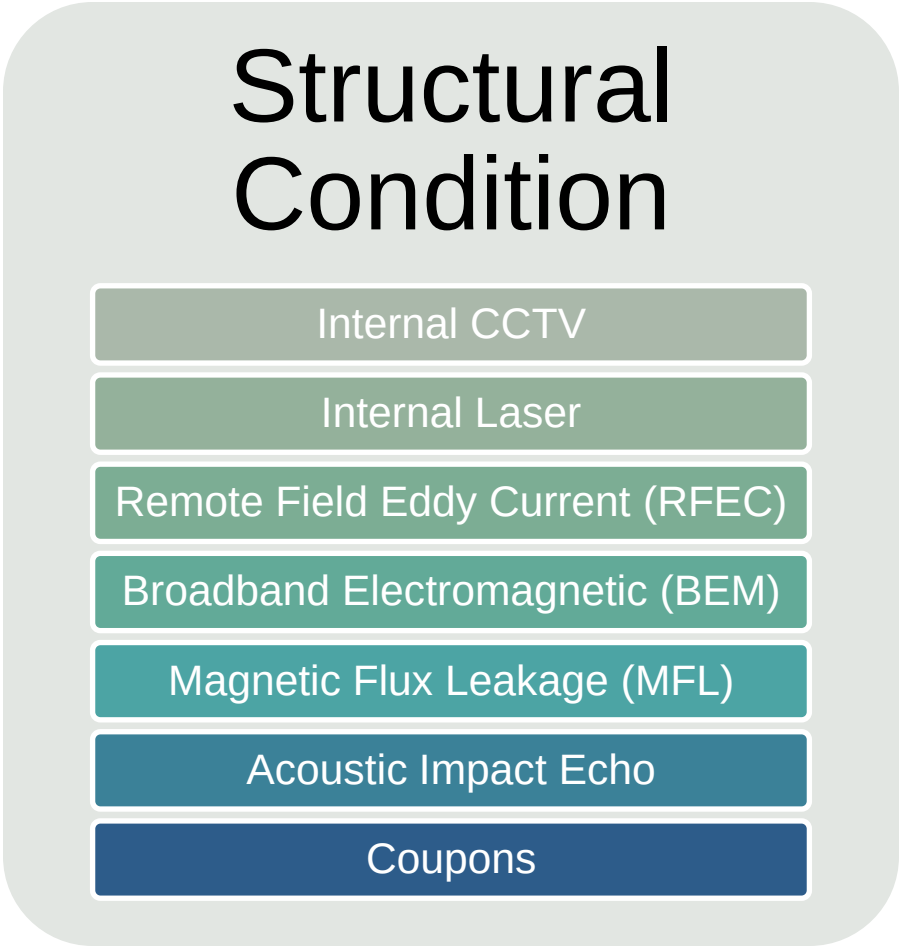
- Advantages
  - Tools available for small and large diameter pipes
  - Identifies remaining wall thickness
  - Identifies size and location of defects (including pits)
- Disadvantages
  - Excavation of buried pipes and replacement of coating or insulation are required
  - Still emerging as technology for water pipelines

Ultrasonic Pig

- Benefits
  - Measures localized wall thickness
  - Free swimming or tethered
- Limitations
  - No leak/gas pocket detection
  - Cannot measure through linings
  - Large insertion assemblies required
  - Extensive cleaning required
  - Ferrous pipe only

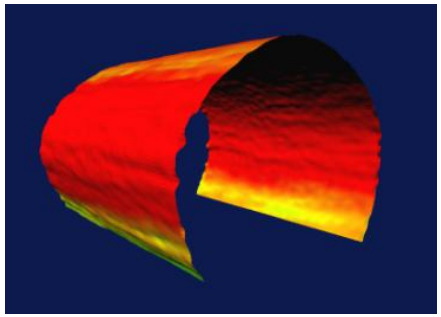
Phase 2: Technologies

- Fully-intrusive
- Pipe must be dewatered
- Most specific and detailed information



Laser

- Benefits
  - High-precision scan of pipe interior
  - Contributes to design for CIPP, sliplining, swagelining, etc.
- Limitations
  - Limited underwater capabilities
  - Cannot distinguish scanned materials

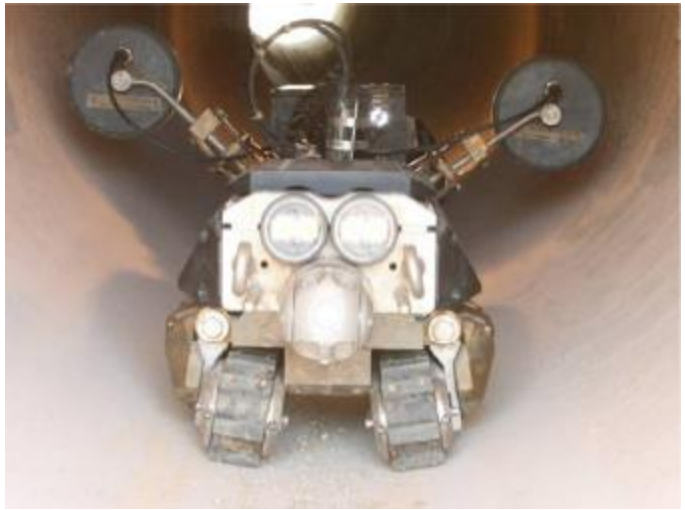


Broadband Electromagnetic

- In-Line
  - Benefits
    - Measures localized wall thickness
    - Measures through linings/corrosion
  - Limitations
    - Pipe must be dewatered & cleaned
    - Time consuming (non-continuous scan)
    - Unable to detect pin-holes/pits
    - Large insertion assemblies required
    - Ferrous pipe only

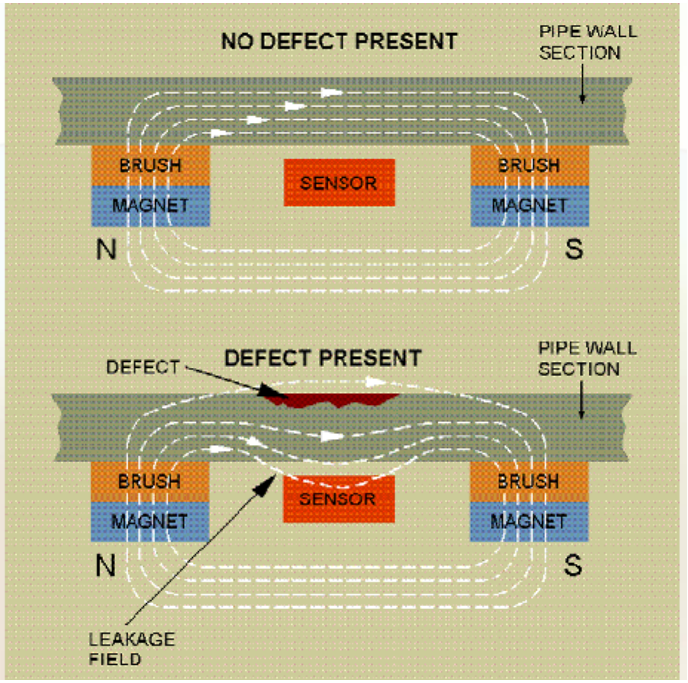
Remote Field Eddy Current

- Benefits
  - Inspect ferrous pipes as well as metallic components of composite pipes
  - Detect broken wires
  - Measure corrosion pits
  - Direct contact with pipe wall not required
- Limitations
  - Data interpretation needs experience and skill
  - Some tools require pipe cleaning and/or dewatering before inspection

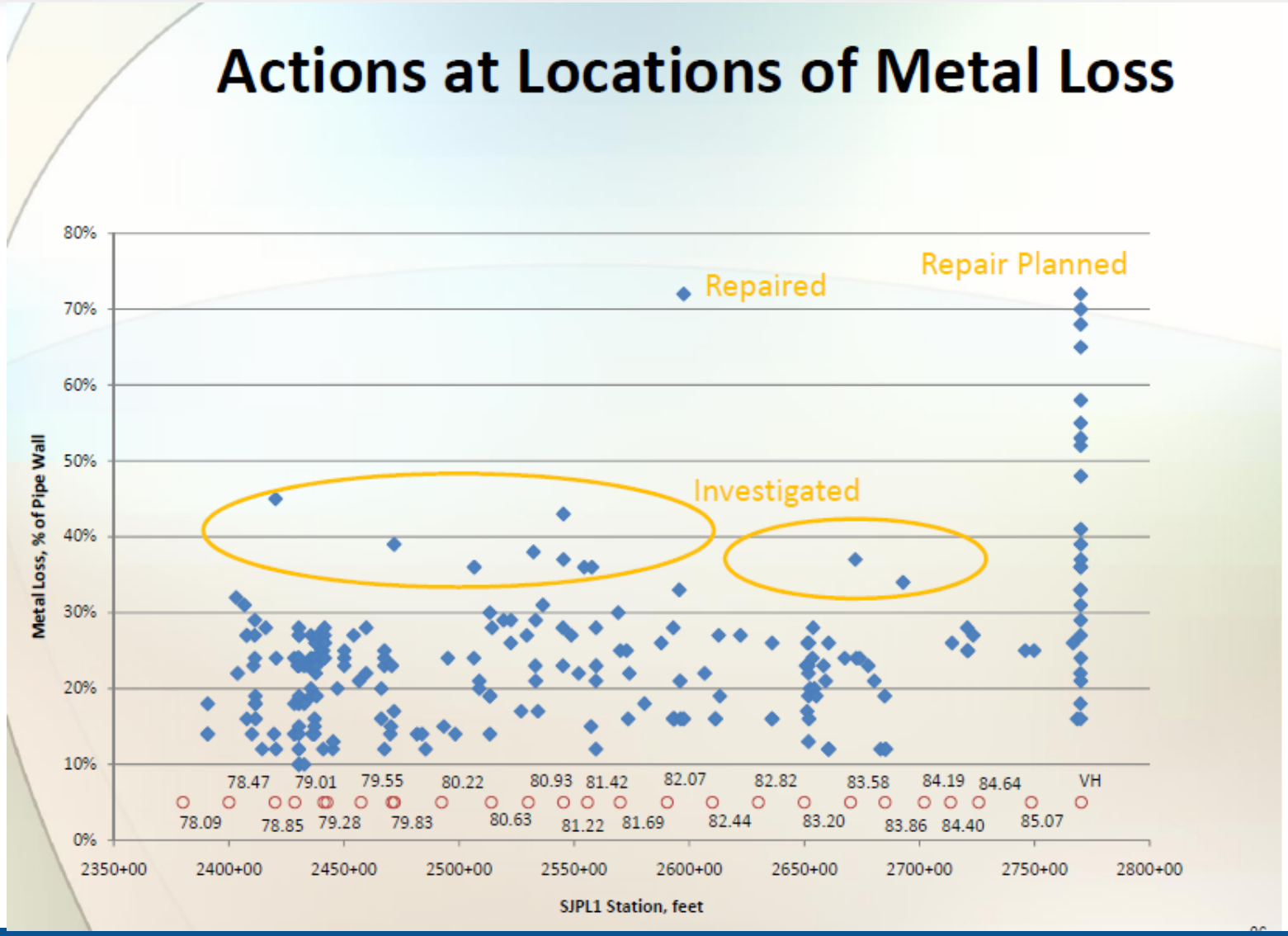


Magnetic Flux Leakage

- Advantages
  - Precise comprehensive inspection
  - Identifies remaining wall thickness
  - Identifies size and location of defects (including pits)
- Disadvantages
  - Pipe must be dewatered, and cleaned (some exceptions)
  - Still emerging as technology for water pipelines
  - Ferrous pipes only
  - High cost



Magnetic Flux Leakage INI
Hetch Hetchy Case Study Accuracy



Coupons

- Benefits
  - Multiple structural and metallurgic tests may be run on the coupon
  - Possible to remove coupons from an operational main by using tapping technologies
- Limitations
  - Provides discrete point information only
  - Requires large portion of the pipe to be exposed
  - Often requires main to be taken out of service

Echologics – Case Study Accuracy

- 60” Cast Iron Fire Water Pipeline
  - Combination of acoustic PIT and sample measurements increased statistical confidence

Data Set	Number of Samples	Average Wall Thickness	Confidence Interval	Upper Limit	Lower Limit
Echologics	14	1.44”	0.161”	1.60”	1.28”
Coupons and Corrosion Pits	31	1.36”	0.056”	1.42”	1.31”
Combined Data	45	1.39”	0.063”	1.45”	1.32”

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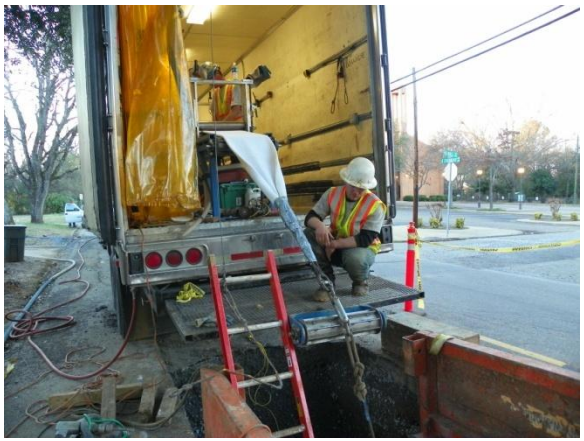
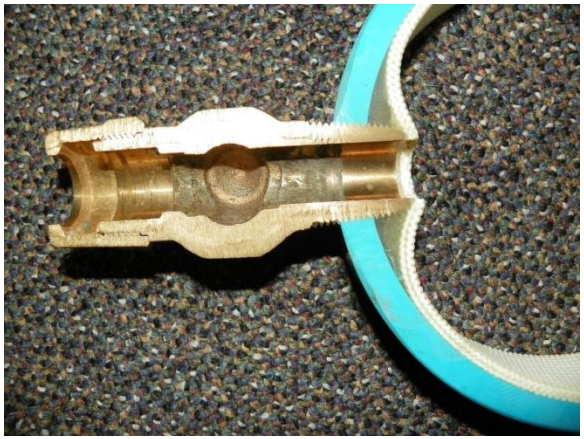
Rehabilitation Alternatives

- Similar to condition assessment technologies: complex and fast-evolving field
- Rehab technology selection is increasingly tailored to the condition assessment data collected





Overview

Method	Pipe Parameters			Work Requirements				Features		
	ID Dia. Range*	Repair Length	Working Pressure psi	Pit Excava-tion	Resin/ Coating** Cure Time	Annular Space Grouting	Excavation for Service Reopening	AWWA Classifi-cation	Cross Section Change	Status of Technology (U.S.)
Level of Cleaning Needed: Very Good										
Woven PE/epoxy lining	3-24"	Varies	150	S/N	Yes	Adhered	No	II	Minor	Emerging
Level of Cleaning Needed: Good										
CIP	8-96"	<2,500'	200	S/N	Yes	No	No	III	Minor	Mature
Deform-reform, PRP	3-12"	<1,000'	230	S/N	No	No	No	III	Minor	Novel
Deform-reform, PE	3-48"	<1,000'	150	S/N	No	No	No	III	Minor	Mature
Spraying, cement mortar	3-24" and up	<1,000'	NK	S/N	Minimal	No	No	I	Minor	Mature
Spraying, epoxy	3-36"	<1,000'	NK	S/N	Yes	No	No	I	Minor	Mature
Spraying, polyurethane	3-48"	<1,000'	NK	S/N	Yes	No	NK	II	Minor	Novel
Spraying, polyurea	3-36"	<1,000'	NK	S/N	Minimal	No	NK	IV	Decrease	Novel
Level of Cleaning Needed: General										
Sliplining	>4"	<5,000'	360	L	No	Varies	Yes	III	Decrease	Mature
Compression-based SR*	4-20"	<1,000'	New pipe	M/L	No	No	Yes	IV	Minor	Emerging
Tension-based SR*	3-36"	<1,000'	New pipe	M/L	No	No	Yes	IV	Minor	Emerging
Grout-in-place (GIP)	4-12"	<600'	NK	L	Yes	Integral	No	III	Decrease	Novel
Level of Cleaning Needed: None or Not Applicable										
Pipe bursting, static	2-36"	300-400'	New pipe	L	No	No	Yes	IV	Same/ increase	Mature
Pipe bursting, pneumatic	2-36"	20-500'	New pipe	M	No	No	Yes	IV	Same/ increase	Mature
Pipe bursting, hydraulic	2-36"	NK	New pipe	M	No	No	Yes	IV	Same/ increase	Mature
Pipe extraction	1-60"	NK	New pipe	M	No	No	Yes	IV	Same/ increase	Rare
Pipe reaming	4-24"	1,600'	New pipe	M	No	No	Yes	IV	Same/ increase	Mature
Carbon fiber reinforced pipe (CFRP)	Man entry	NA	High pressure	M	Yes	No	Yes	IV	Minor	Emerging
Spot repair / joint repair	4-54"	12-36"	Varies	S/N	Minimal	Adhered or none	N/A	IV	Same/ decrease	Mature

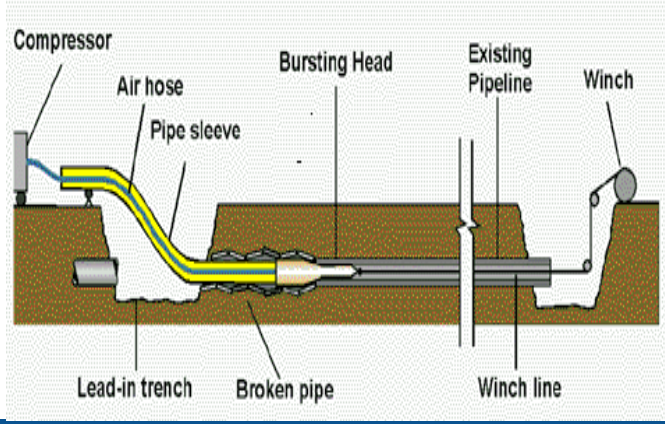
* SR = Symmetrical Reduction; NK = Not known; S/N = Small or none; M/L = Medium or large; L = Large;
AWWA classification of potable water rehabilitation systems I = Nonstructural; II = Semi-structural without inherent ring stiffness (depends on adhesion); III = Semi-structural with inherent ring stiffness (self supports); IV = Structural.

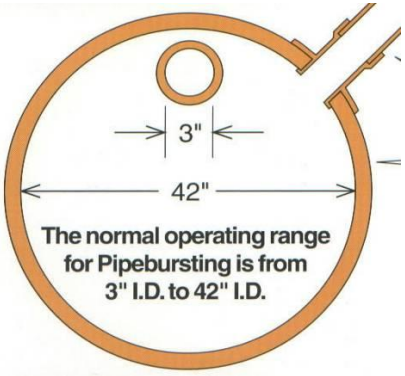
Spray Applied Liners

Principal Advantages	Principal Disadvantages	Features
• Semi-structural. • No large scale disruption compared to PE slip lining. • Excellent abrasion resistance. • Long-term corrosion protection material. • Usually bypass service is not required.	• Semi-structural • Easier leakage detection on metal pipes. •Recommended for pipes prone to local damage and well suited for local host pipe damage.	<u>Materials</u>: • Polyeurethane • Polyurea •Epoxy •Polymeric <u>Specifications:</u> NSF/ANSI Standard 6 AWWA M28 Class 3 Rehabilitation technology

Pipe Bursting

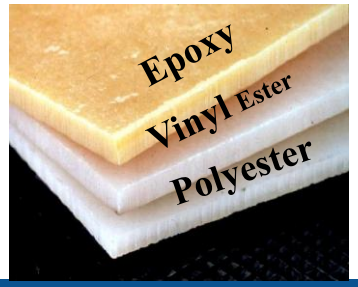
Principal Advantages	Principal Disadvantages	Features
• Pipeline Upsize available (2XDia.) • New structural pipeline installation • Cost-effective where lateral connections are minimal • Potential to install from existing manhole structures	• Disruptive to adjacent utilities • Limited availability of experienced contractors in many geographies • Damage to existing service connections • Upheave of displaced material possible • Entry pit may be required	<u>Materials</u>: • HDPE • Steel • PVC • DIP/Restrained Joint <u>Specifications</u>: AWWA C906 ASTM F714 ASTM C1208





Cured-in-Place Pipe (CIPP)

Principal Advantages	Principal Disadvantages	Features
• Faster installation than open cut • Minor excavation • Accommodates bends and minor deformation • Maximizes capacity • Annulus grouting not required • Internal lateral reopening • Designed for full structural conditions	• Full bypass pumping necessary • High setup costs on small projects • Does not correct lateral defects or sags • Point repairs may be required prior to installation • Relies on existing pipe for installation	Materials: • Thermosetting resins and felt • Standard and custom sizing available •Pre-inspection and high-pressure cleaning required • Curing: steam, hot water, UV Specifications: ASTM F1216; D5813; F1743 NASSCO: Yes

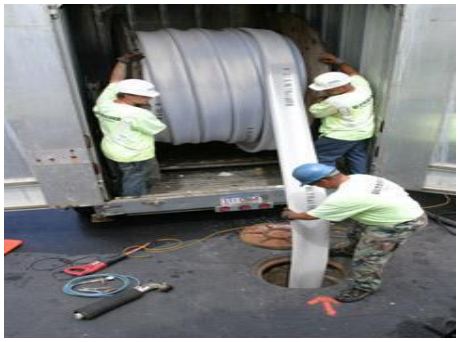


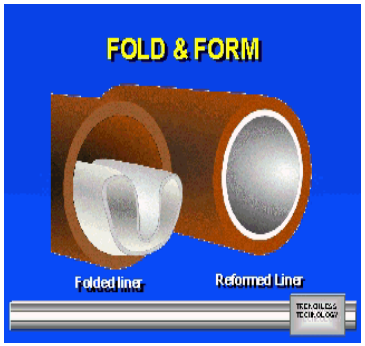
Sliplining

Principal Advantages	Principal Disadvantages	Features
• Less excavation than open-cut • Designed for full structural pipe • Extensive history of successful installations	• Limitation for grade changes and curved alignments • Requires robust excavation pit • Removal of structural obstructions and heavy debris • Reduction of effective inside pipe diameter • Quality control of grout operation	<u>Materials</u>: • HDPE • PVC • GRP <u>Specifications:</u> ASTM D3262; D4161; F1803; D1784; D3212; F477 AWWA M45

Fold & Form

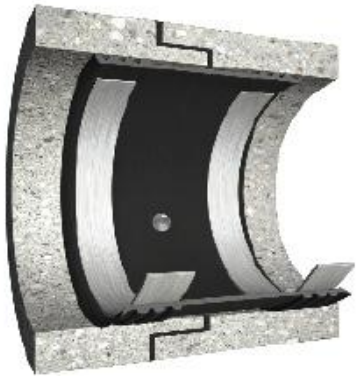
Principal Advantages	Principal Disadvantages	Features
• Rapid installation • Continuous pipes • Maximizes capacity • No excavation • Grouting not required • Internal lateral re-connection	• Plastic alloy – not full composite pipe • HDPE version has thermal expansion considerations • Does not correct lateral defects or sags • Point repairs required prior to inst • Relies on existing pipe for installation support • Lateral locations must be located exactly • Cannot be used high flow temperatures	<u>Materials</u> PVC HDPE <u>Standards:</u> ASTM F1216; F1504; F1867; F1871

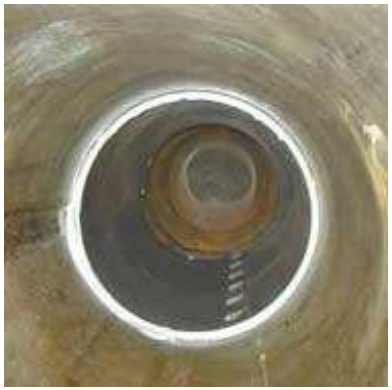


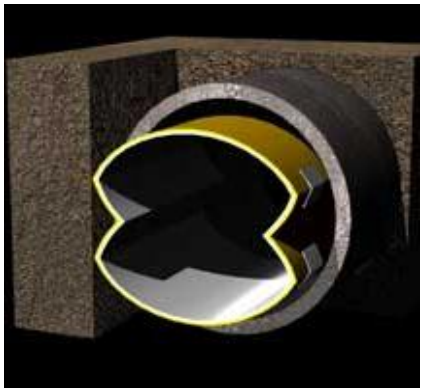


Spot Repairs

Principal Advantages	Principal Disadvantages	Features
• Focused on isolated problems • Internal and external solutions are available • Minimizes surface disruptions • Optimizes rehabilitation construction costs • Structural and hydraulic repairs	• May require limited excavation for certain types/locations of defects • Costly • Does not fix entire pipe	Materials: All pipe materials Specifications: ASTM Various AWWA M11

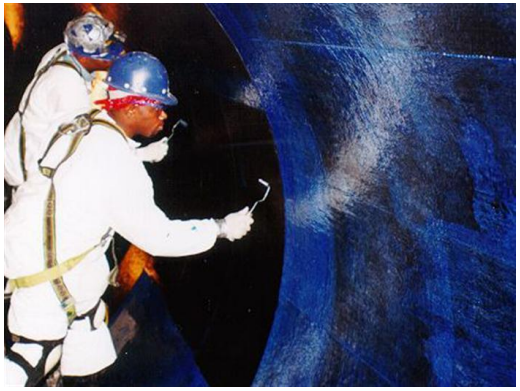






Carbon Fiber Wrap

Principal Advantages	Principal Disadvantages	Features
•Structural rehabilitation •Can increase pipeline strength above original design •Corrosion protection •Minimal loss of flow capacity	•Limited to sectional repairs as cost can be high •Requires highly trained and experienced technicians •Extensive surface preparation •Best suitable for pipe sections with no fittings. •30 through 201 inches and above •50 psi to 350 psi	<u>Materials</u>: Layers of carbon fibers and glass fibers, epoxy <u>Specifications:</u> ANSI/NSF 61 certified, but no standardized design guides yet



External Reinforcing

Principal Advantages	Principal Disadvantages	Features
• Pipe can remain in service • Structural repair • Straightforward installation technique • Long track record	• Damaged pipe segment must be exposed • Does not address defects in steel cylinder (leaks) • Requires additional corrosion protection • Isolated repair only	Materials: PCCP

Joint Sealing

Principal Advantages	Principal Disadvantages	Features
• Seals leaking joints and minor cracks or holes • Prevents soil loss • Low cost due to minimal disruption • Can use with all pipe materials • Hydraulic only	• Some materials easily damaged during installation • Plastic pipe requires annular space grouting • Does not correct sags • Joint problems on curved pipes • May require person entry • External lateral connection – trenching • Point repairs required prior to some installation	<u>Materials</u>: RCP; VCP; PCCP <u>Specifications:</u> ASTM: Various

1. Introductions
2. Market Drivers and Opportunities
3. Approaches to Condition Assessment
   - Prioritization Methods
   - Field Technologies
4. Rehabilitation Alternatives
5. ***Additional Resources***

Additional Resources

- 2007 WERF Condition Assessment Strategies and Protocols for Water and Wastewater Utility Assets (Appendix F reviews 85 techniques and technologies)
- 2009 EPA Condition Assessment of Ferrous Water Transmission & Distribution Systems - State of Technology Review Report
- 2012 EPA Condition Assessment Technologies for Water Transmission and Distribution Systems
- 2013 EPA Field Demonstration of Innovative Condition Assessment Technologies for Water Mains at Louisville, KY
- 2009 EPA Rehabilitation of Wastewater Collection and Water Distribution Systems

Discussion

Supplemental Information

Echologics – Case Study Accuracy

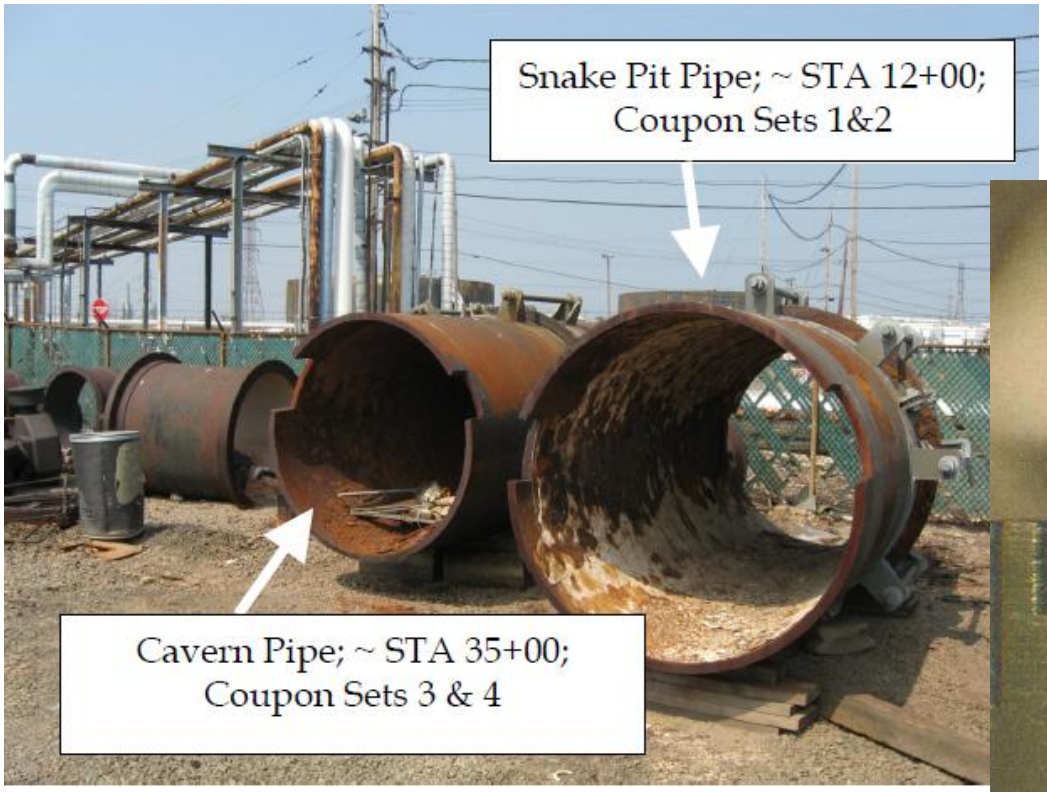
- Conoco Phillips 60” Cast Iron Pipe
  - Surveyed 4300 LF of 1922 era CIP
  - Divided pipe into 14 discrete segments for analysis
  - Generally confirmed findings of coupon and pit depth measurements
  - Some measurements were outside of expected range (high) and source of error not found

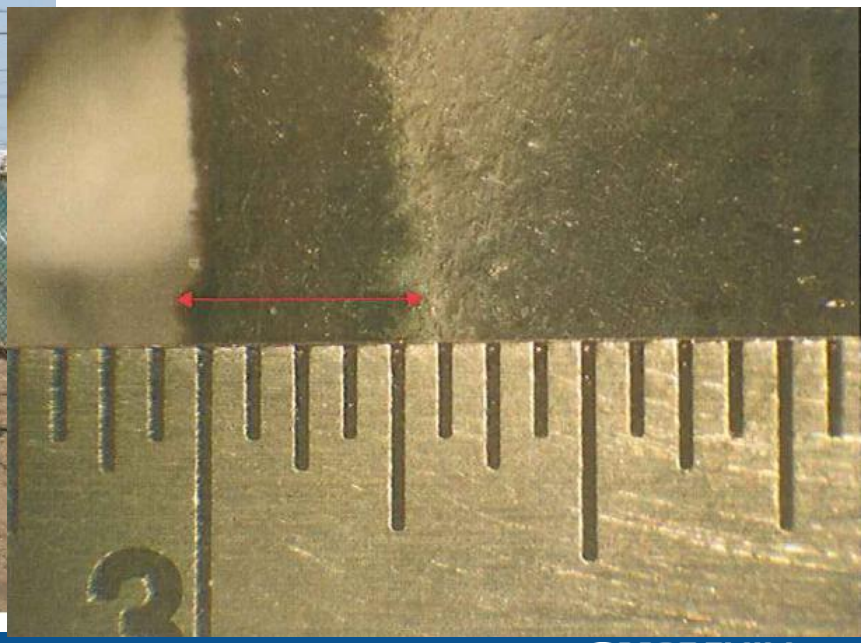
Case Study: Homestake System Inspection
Pure Technologies *PipeDiver/RFEC*

- Content from Matt Krumholz/DEN and Liv Haugen/DEN

Echologics – Case Study Accuracy

- Conoco Phillips 60” Cast Iron Pipe
  - Combination of acoustic PIT and sample measurements increased statistical confidence





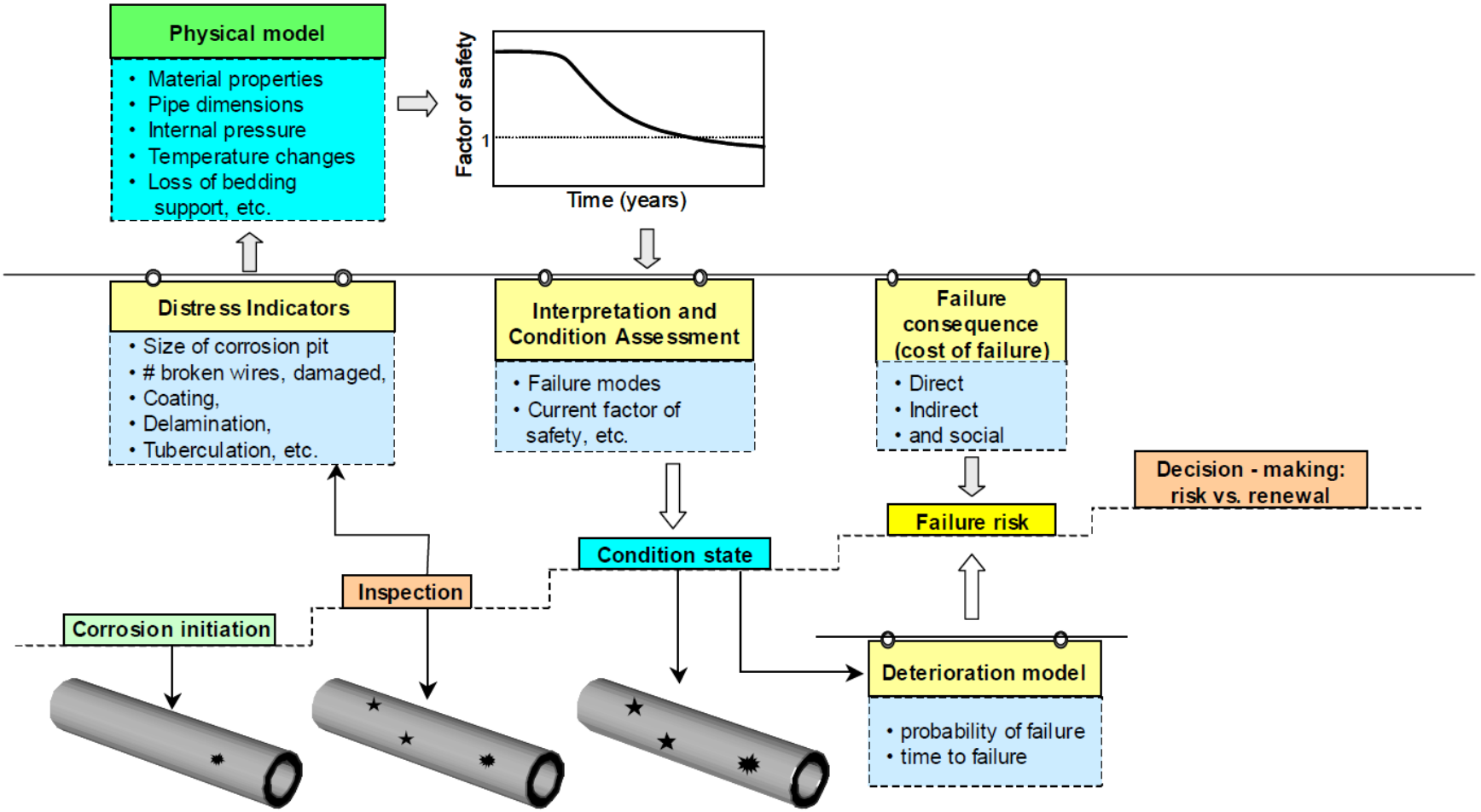
Smart Ball – Case Study Accuracy

- Rock-Tenn 42” RCP Force Main
  - PURE reports leak location to +/- 5 feet, but no leaks found on this force main
  - Smart Ball was inserted, traversed 7,900 LF and was recovered
  - Detected no leakage or trapped gas in pipeline
  - A robot mounted electromagnetic tool did, however, find defective wires in the dewatered RCP during a plant shutdown

Risk of Failure

Consequence of Failure

Schematic for Inspection, Condition Assessment, and Risk Evaluation of Pipes



Phased approach provides step-wise process to make the best decisions about rehabilitation

Likelihood of Failure		
Critical Pipe Criteria	GIS	Age/Material Type Soil Conditions/Railroads
	CMMS	Break History Leak History Nearby Construction
	Facility Data	Age Material
Hydraulic Model		Pipe Pressure Pressure Range Roughness/Field testing based

Consequence of Failure		
Critical Pipe Criteria	GIS	Affected Population/Buildings Transportation Impact (freeway, railroad, tunnel, bridge)
	Critical Facilities	CBD Hospital, School, Industry, Commercial
Hydraulic Model		Pipe/Valve Criticality Flow/ Pressure limitations