Force Main Condition Assessment

Water Environment School

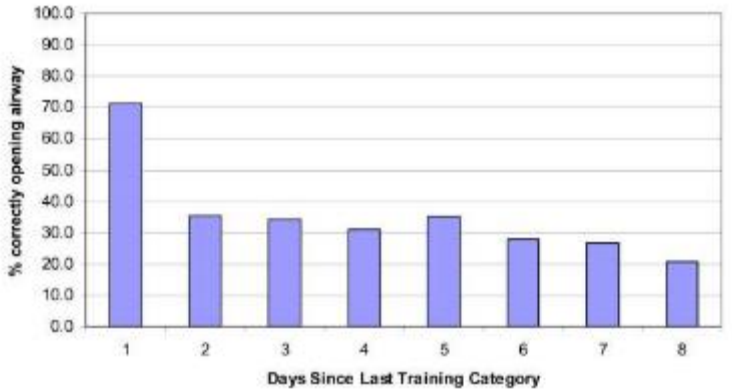
March 2017

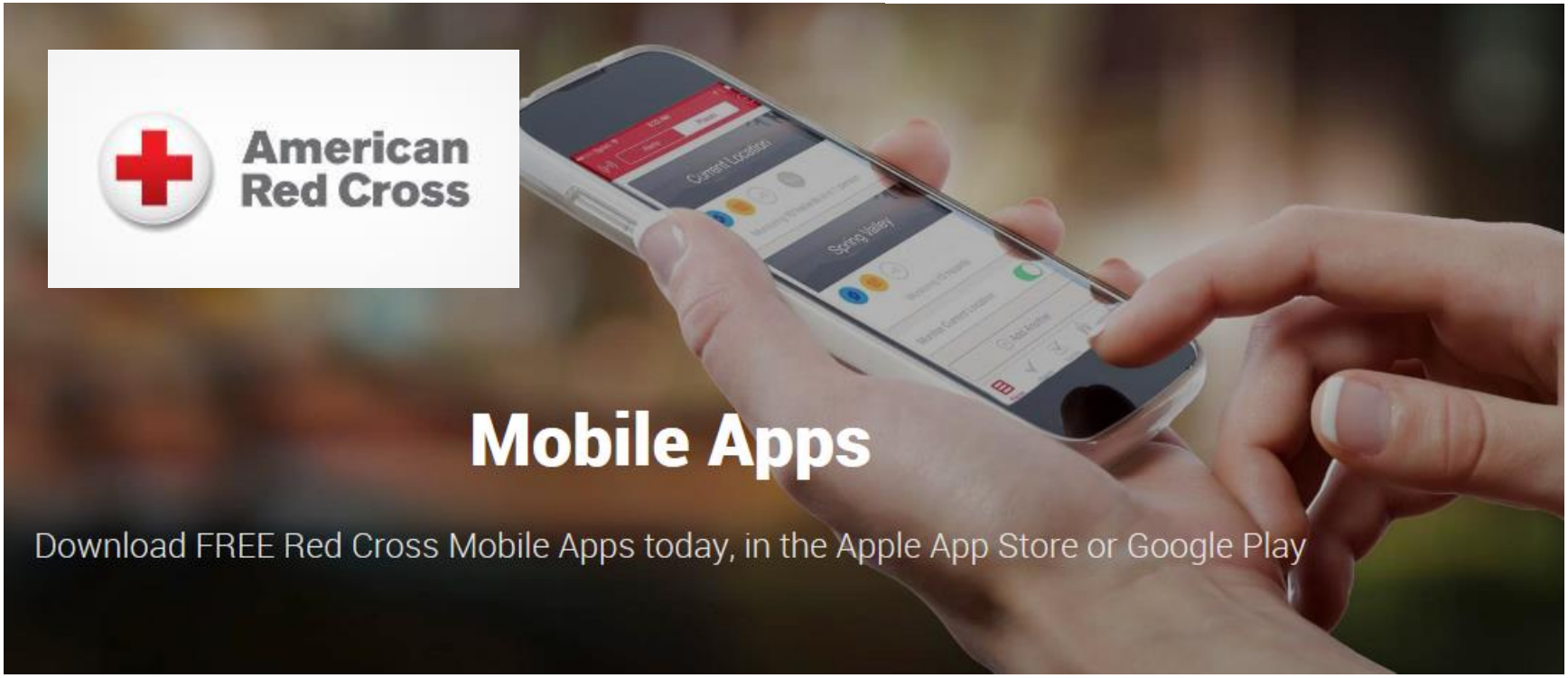
Clackamas Community College

ch2m SM

Safety Moment – First Aid App

- Studies show that most workplace first aid training is forgotten over 90 days after certification
- Mobile apps are available with easy-to-follow refresher modules



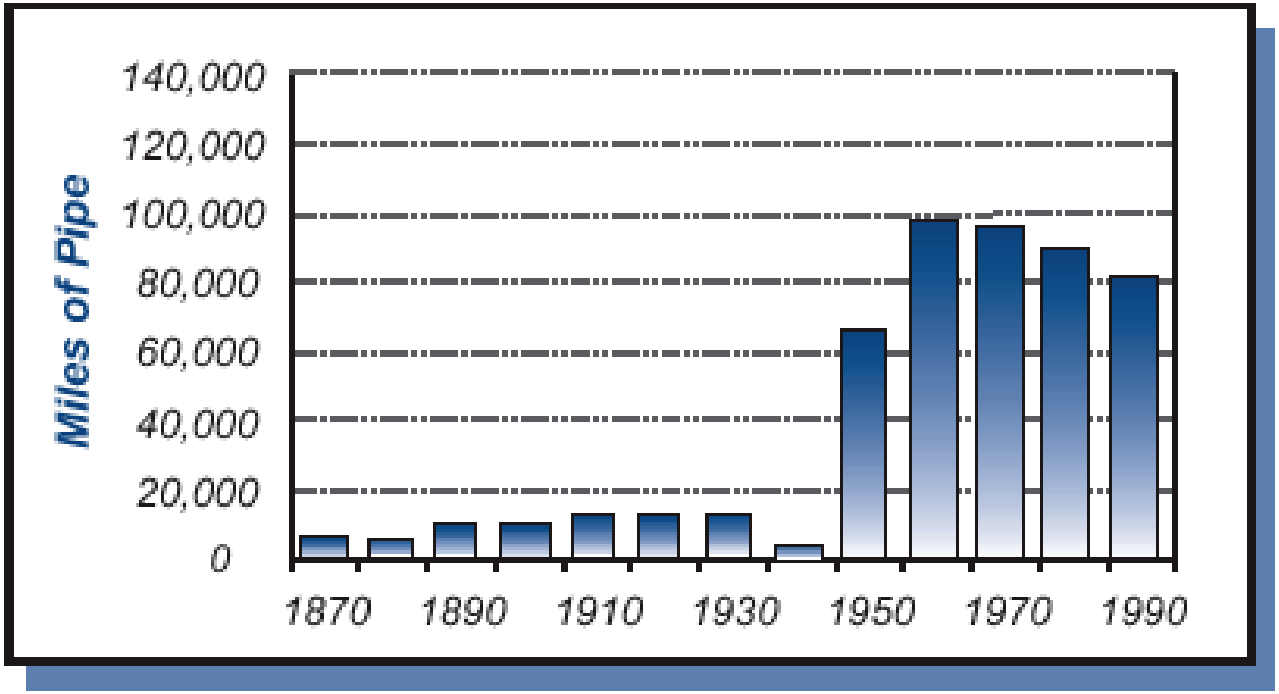


Presentation Overview

- Industry Drivers
- Force Main Condition Assessment Strategies
- Operational Example
- Case Studies

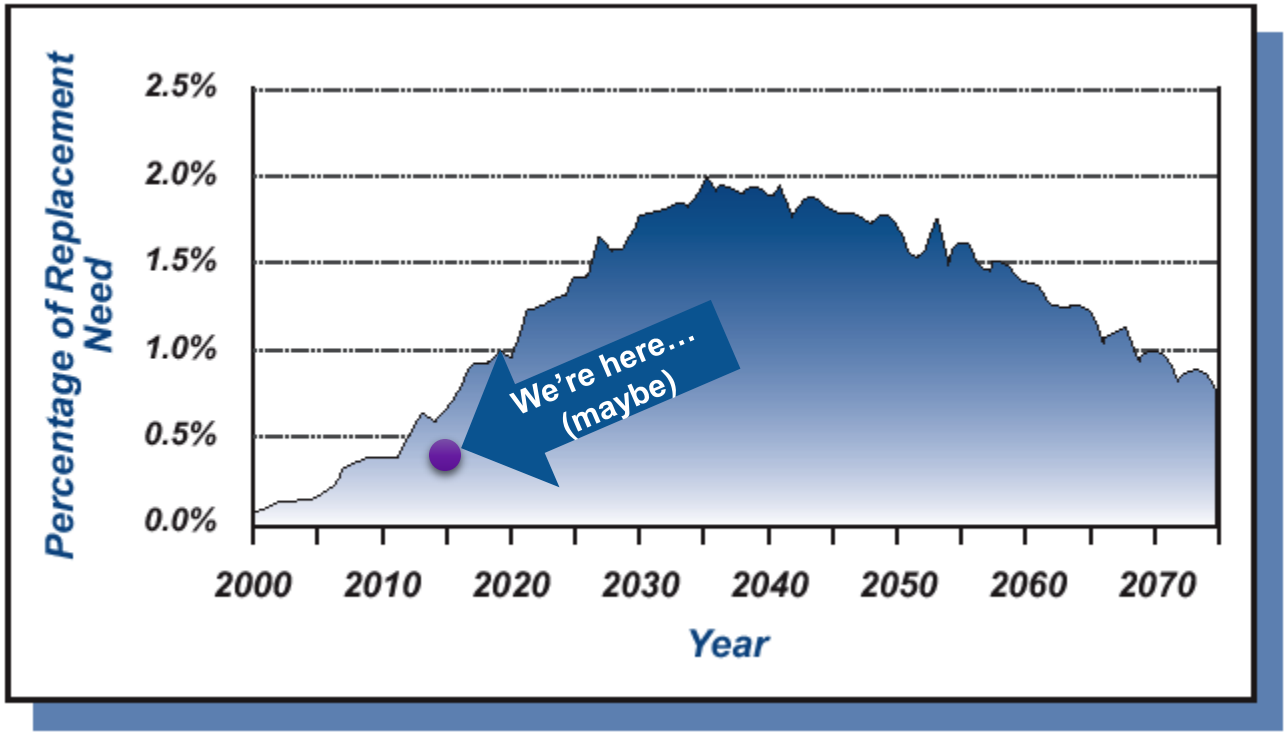
Industry Drivers

Infrastructure Investment Outlook



Source: EPA Gap Analysis

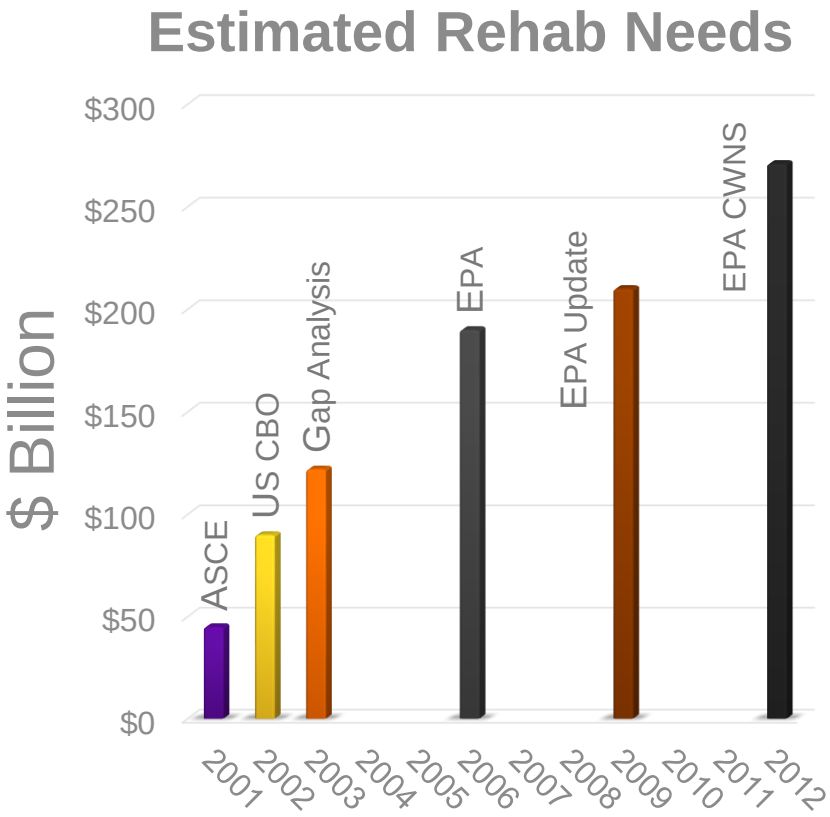
Infrastructure Investment Outlook



Source: EPA Gap Analysis

Infrastructure Investment Outlook

- **Total Assets - $1.0 trillion (Sanitary Sewers)**
- **15-20% of Public Works Infrastructure**
- **Current Annual Rehab Spending: ±$10 Billion**

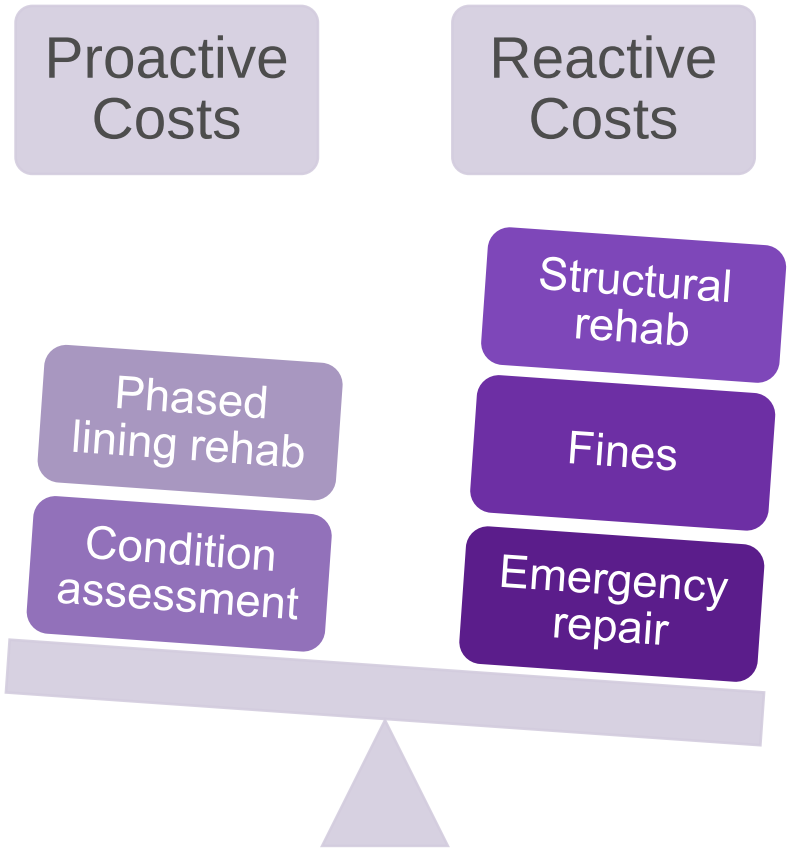


Where do force mains fit in?

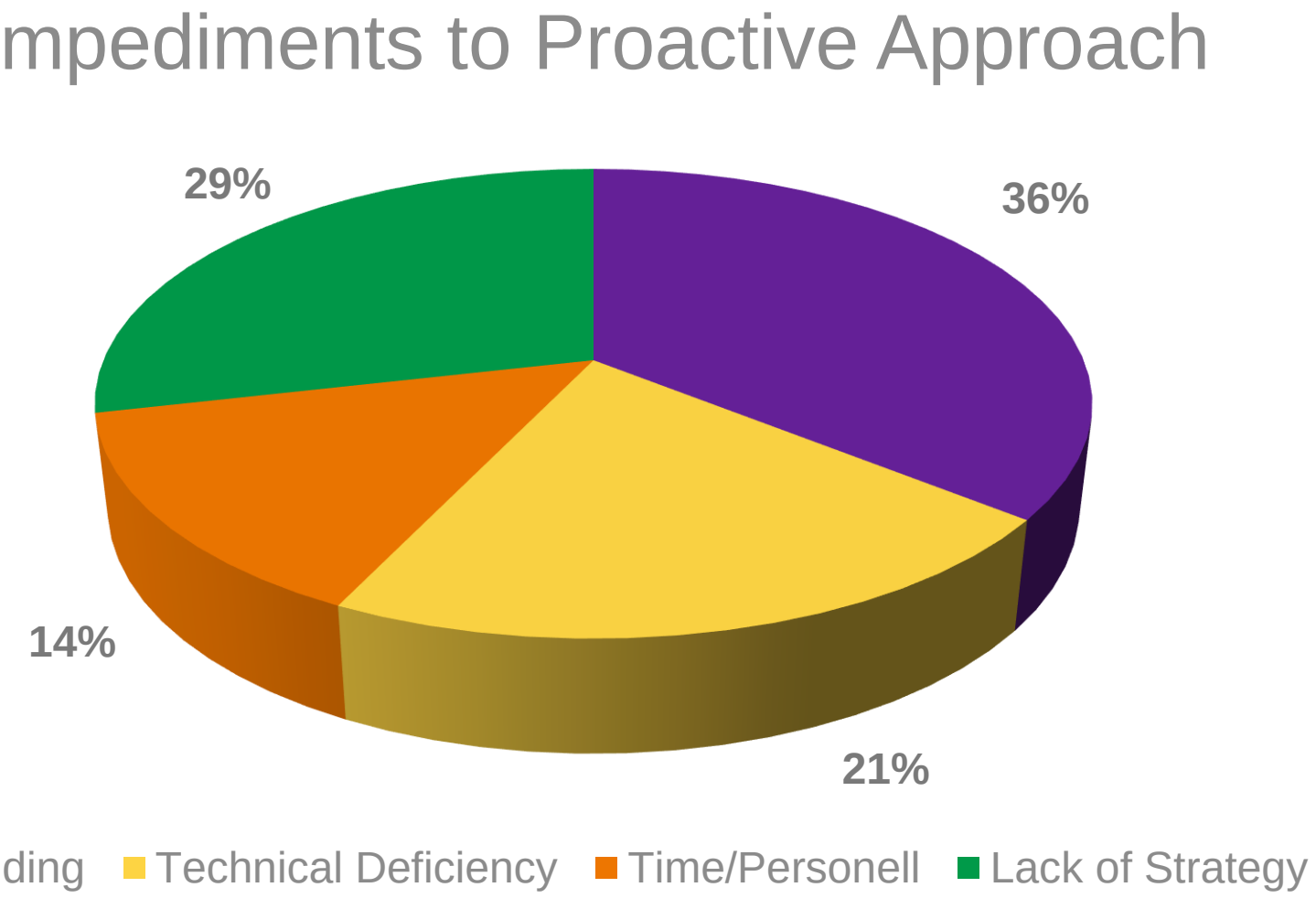
Average emergency repair cost for > 20-inch = $500K (WRF 2013)

Structural rehab costs 130-200% of the cost of lining rehab (TTC 2003)

Condition assessment costs = 2-6% replacement value

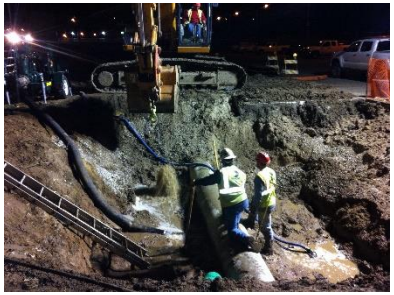


Why the Gap?


Impediments to Proactive Approach
29%
36%
14%
21%
Funding
Technical Deficiency
Time/Personell
Lack of Strategy

Force Main Condition Assessment Strategies

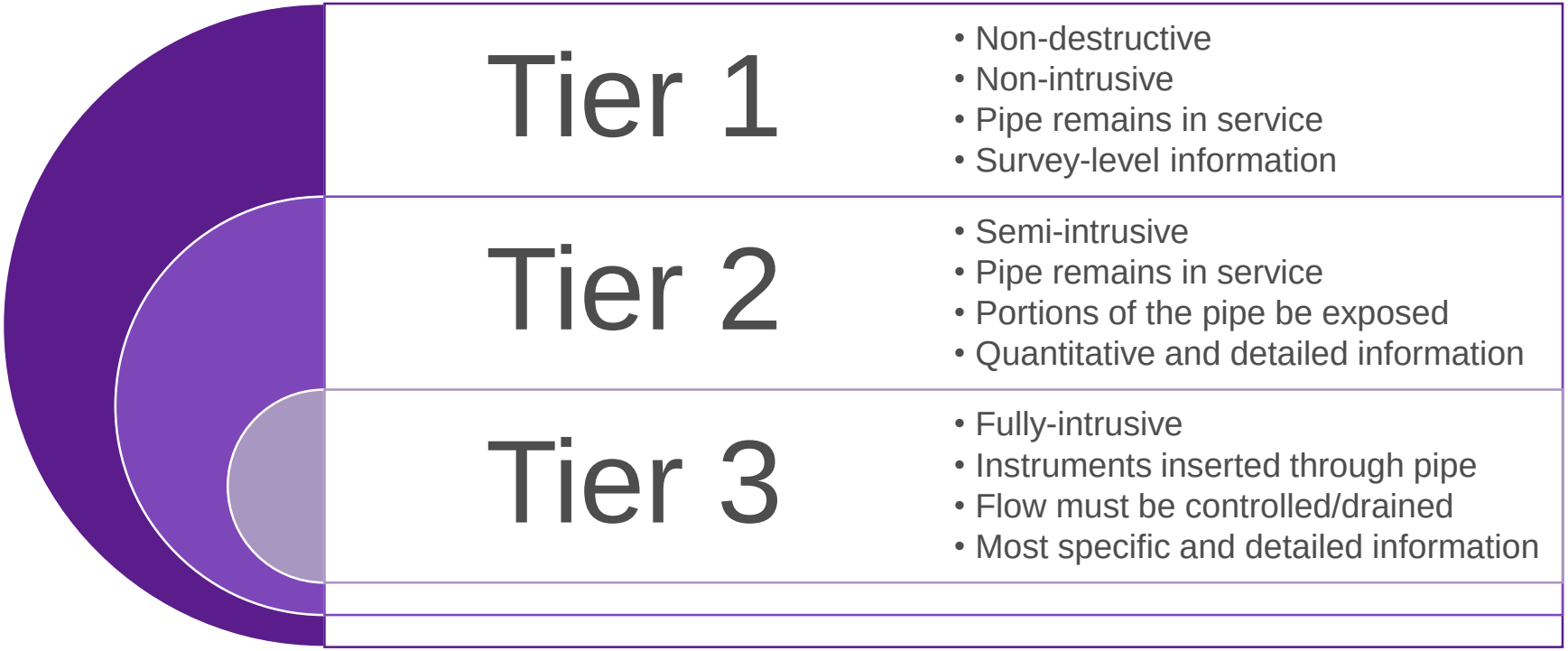
Common Force Main Defects



- Leaks
- Pitting Corrosion
- Ruptures
- Tuberculation
- Coating/Lining Damage
- Joint/weld defects

- Air binding
- Deformation
- Abrasion
- Hydrogen embrittlement (PCCP Class IV wires only)

Tiered Approach: Force Main Assessment



Tiered Approach

Tier 1

- Soil survey
- Surface insp.

"Identify Suspects"

Tier 2

- Test pits
- Direct insp.

"Confirm Rehab Needs"

Tier 3

- Specialty Tools
- "Smart Pigs"

"Design Repair"

Lowest Cost, Identify Issues → **Higher Cost, Design Data**

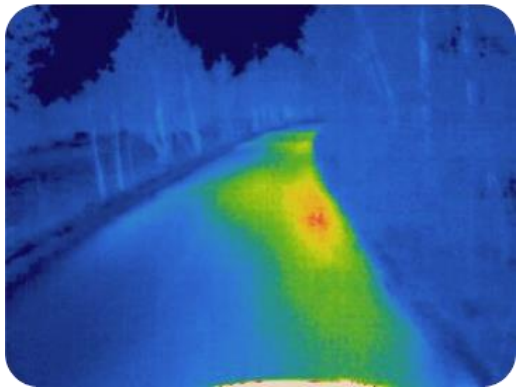
Tier 1: Technologies

- 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		

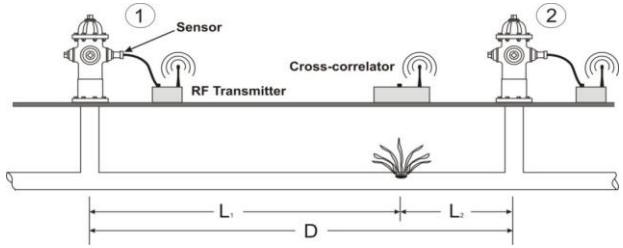
Infrared Thermal

- Provides heat signature images which may indicate leaks in water lines or effluent discharges
- Survey level technology
- No excavation/special access needed
- Equipment commercially available, moderate training required



Acoustic Methods: Leak Detection

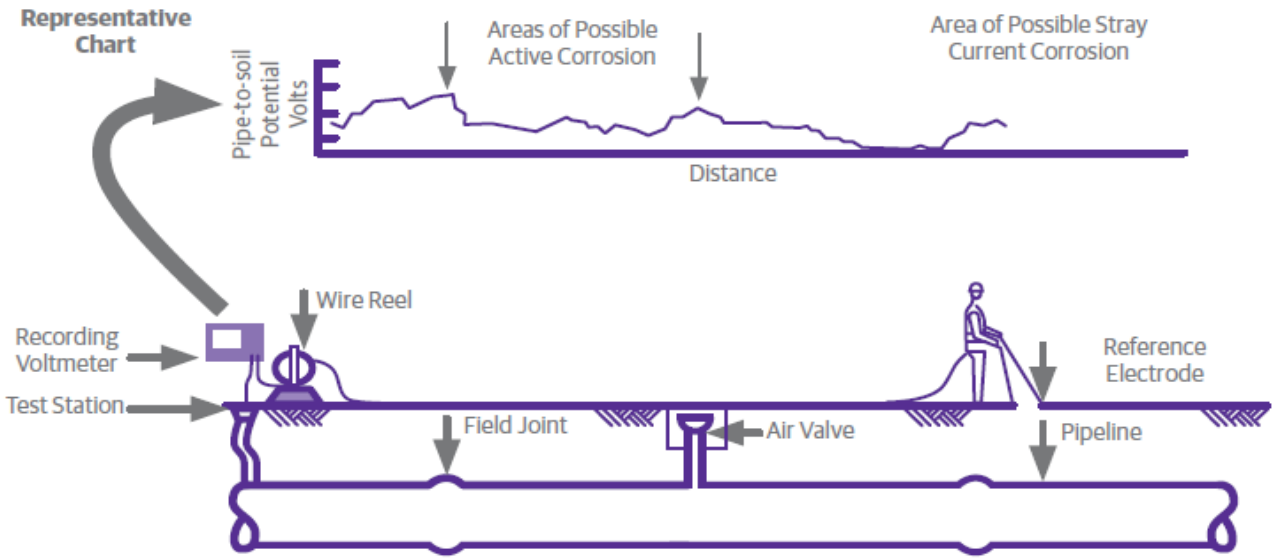
- Acoustic Correlator (Echologics)
  - Benefits
    - Locates leaks along the pipe
    - Pipe remains in service
    - Works on all pipe sizes/materials
  - Limitations
    - Does not quantify leak rate
  - Cost approx. $20-25K/mi



- 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
  - Cost approx. $300/mi

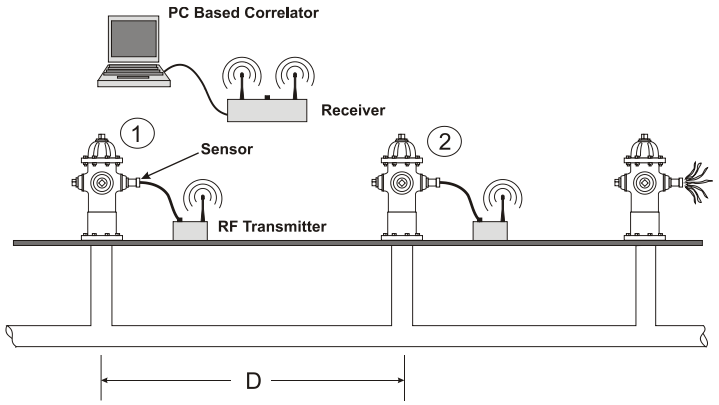
Soil Survey / Corrosion Analysis

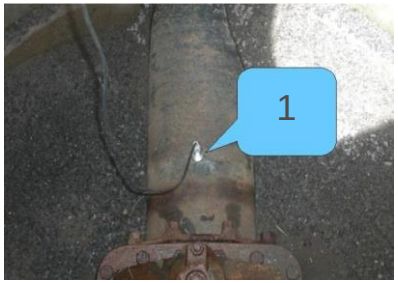
- Benefits
  - Rapid, wide deployment
  - Measures resistivity of soils (corrosion potential)
  - Survey-level tool
  - Best used in conjunction with pipe excavation
- Limitations
  - Does not provide information on full pipe length
  - Data relevant for metallic pipes/appurtenances only
- Cost approx. $10,000/mi



Acoustic Methods: Wall Thickness

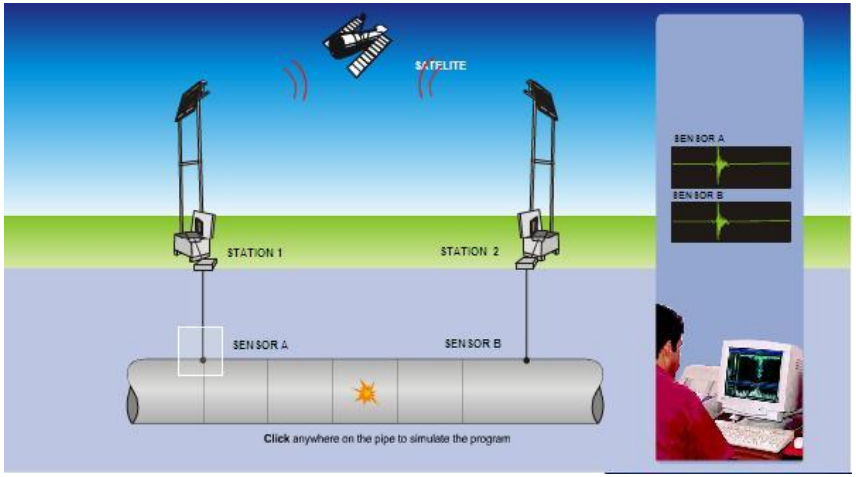
- Acoustic Correlator (Echologics)
  - Benefits
    - Measures average wall thickness between nodes (stiffness in non-metallic pipes)
    - Pipe remains in service
    - Works on all pipe sizes/materials
  - Limitations
    - Does not identify discrete defects
    - Minimum amount of measurements for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





Acoustic Methods (Emission Monitoring)

- Advantages
  - Monitors sudden appearance or propagation of microscopic cracks
  - Monitors sudden break of a 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



Pressure Flow Monitoring

Ultrasonic Transit-time Strap-on

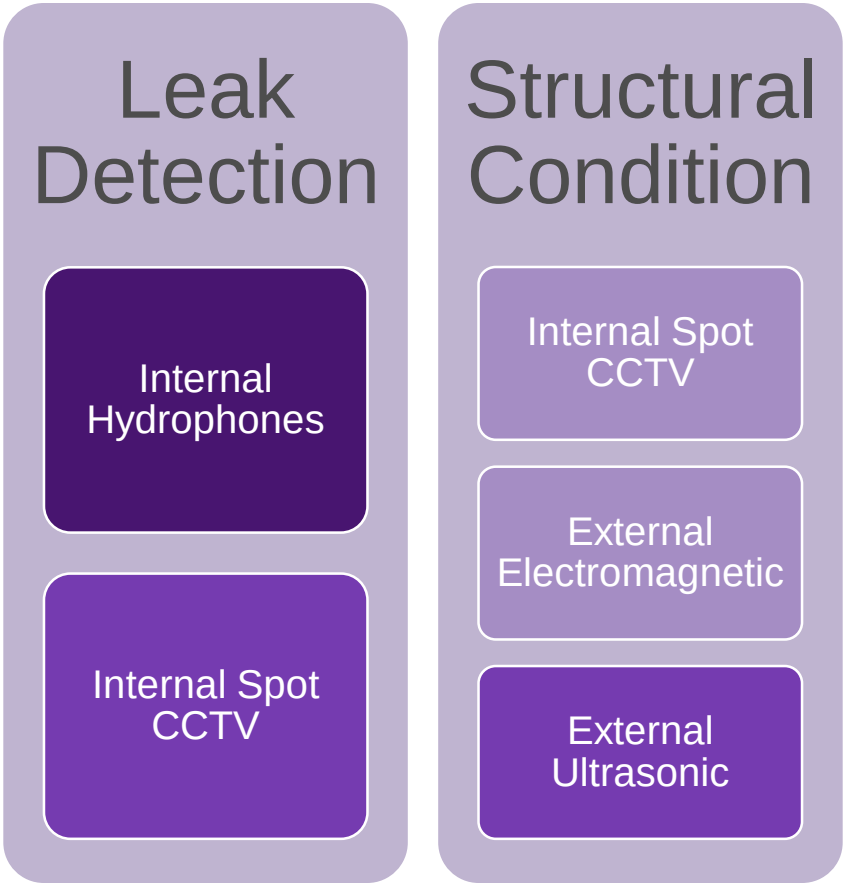
- Benefits
  - No in-line insertion required
  - Accuracy +/- 2%
- Limitations
  - Average flow rate
  - Best with clean water applications

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”

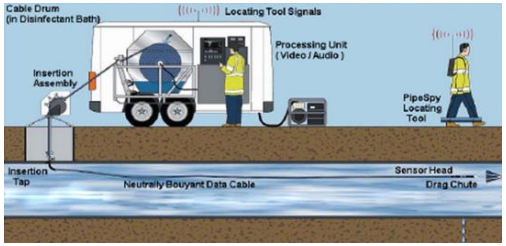
Tier 2: Technologies

- Semi-intrusive
- Pipe remains in service
- 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*
    - No pipe wall assessment data

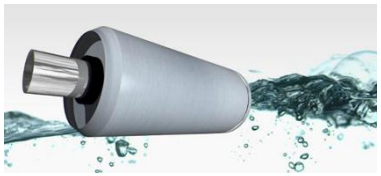


- Pure Sahara
  - Benefits
    - Locates leaks and gas pockets
    - Pipe remains in service
    - Works on all pipe sizes/materials +6” (2” access)
    - Measures specific defect location
  - Limitations
    - No pipe wall assessment data *Yet*
    - Deployment distance limited by number of bends in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

Free-Swimming Internal Hydrophones

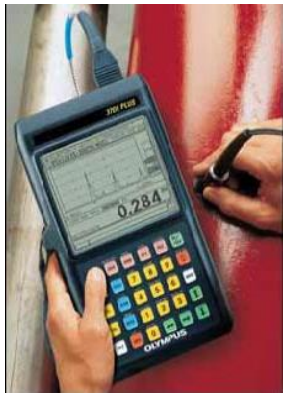
- Pure “SmartBall”
  - Benefits
    - Locates leaks and gas pockets
    - Pipe remains in service
    - Works on all pipe sizes/materials +6” (4” access)
  - Limitations
    - Defect location is approximate
    - No pipe wall assessment data

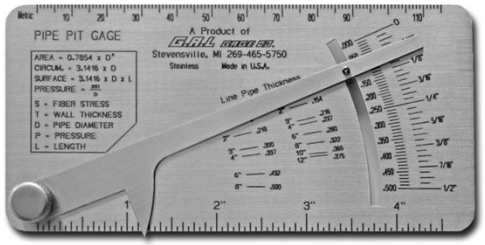
- JD7 “Bullet”
  - Benefits
    - Locates leaks
    - Pipe remains in service
    - Works on all pipe sizes/materials
    - Records visual images
  - Limitations
    - Defect location is approximate
    - No pipe wall assessment data
    - Tethered system for retrieval



Ultrasonic / Pit Depth Measurement

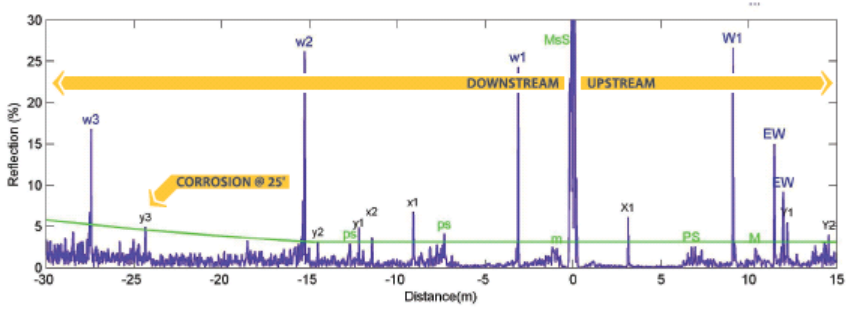
- Benefits
  - Quantitative measurement
    - Pipe wall thickness
    - Pit depth
  - Simple methods and tools
- Limitations
  - Exposure of pipe exterior required
  - Difficult to determine localized metal loss inside pipe with ultrasonic
  - Most commonly used on metallic pipes
- Cost approx. $15,000/mi





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
  - Extensive data post-processing



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
    - Extensive data post-processing/interpretations

Magnetic Flux Leakage (External)

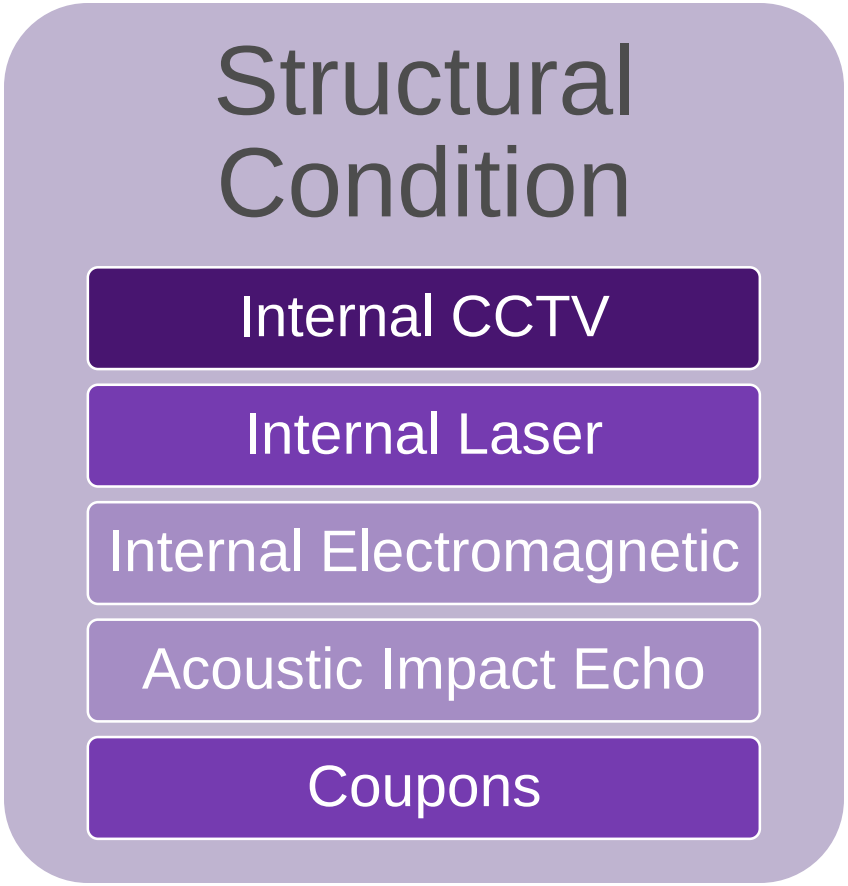
- Advantages
  - Tools available for small and large diameter pipes
  - Identifies remaining wall thickness
  - Identifies size and location of defects (including pits)
- Disadvantages
  - Excavation of buried pipes and replacement of coating or insulation are required, which make it economically questionable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

Bracelet Probe (PICA)

- Benefits
  - Hand-held
  - Reads through coatings/linings
  - Identifies wall pitting locations, and in some instances can estimate pit depth/size
  - Faster post processing
- Limitations
  - Newer technology
  - Best used for “spot checks”
  - Production rate 10 ft/min
- Cost approx. $15,000/day

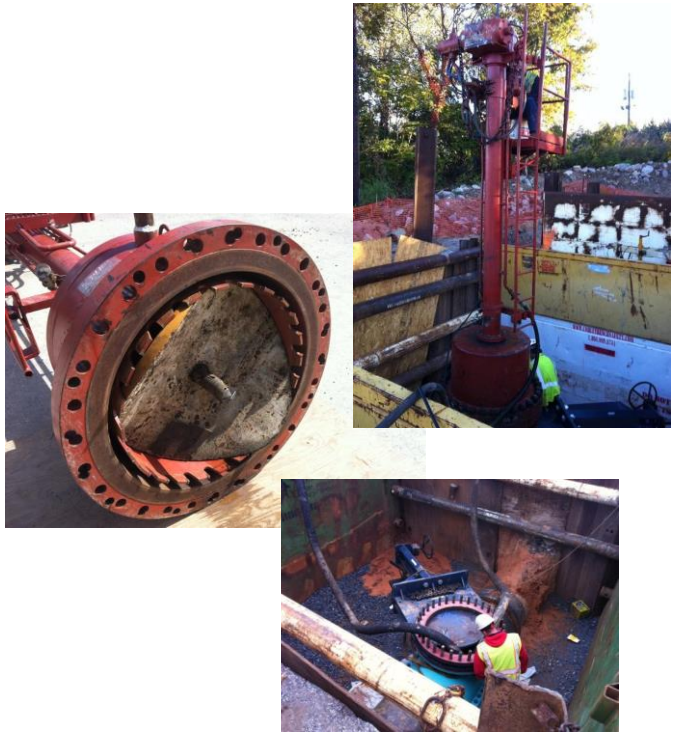
Tier 3 Technologies

- Fully-intrusive
- Flow must be controlled/drained
- Instruments inserted through pipe
- Most specific and detailed information



Coupons

- Benefits
  - Multiple structural and metallurgic tests may be run on the coupon
  - Most definitive data set
  - Possible to remove coupons from an operational main by using tapping technologies
- Limitations
  - Provides discrete point information only
  - Requires portion of the pipe to be exposed



Ultrasonic Pig

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

Broadband Electromagnetic (Internal)

- 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
  - Extensive post-processing/interpretation
  - Ferrous pipe only

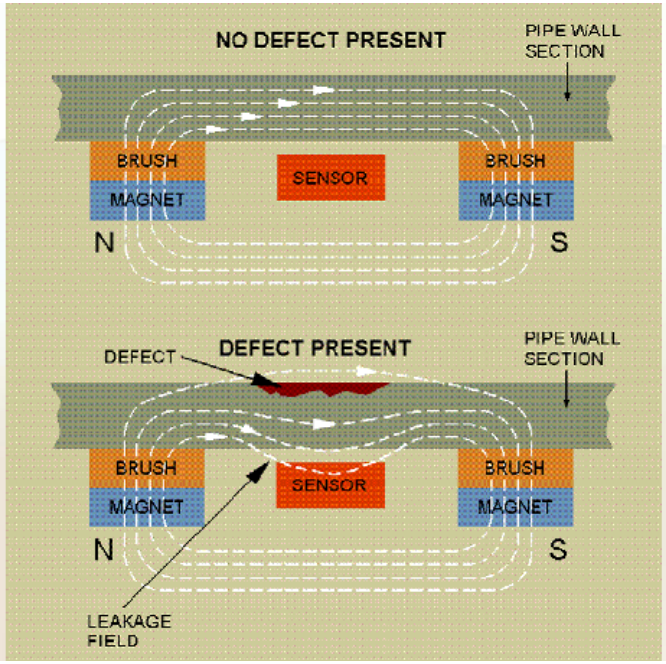
Electromagnetic (Internal)

- Pure PipeDiver/Robotic
  - Benefits
    - Locates broken prestressed wires in PCCP
    - Locates areas of extensive wall loss in metallic pipes
    - Free swimming and tractor options
  - Limitations
    - Must control flow rate
    - Large insertion assemblies required
    - Not suitable for detecting pitting corrosion or joint defects

- PICA SeeSnake
  - Benefits
    - Measures localized wall thickness and pitting
    - Measures through linings
    - Free swimming or tethered
  - Limitations
    - Must control flow rate
    - Large insertion assemblies required for +24” sizes
    - Extensive cleaning required
    - Metallic pipe only

Magnetic Flux Leakage (Internal)

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

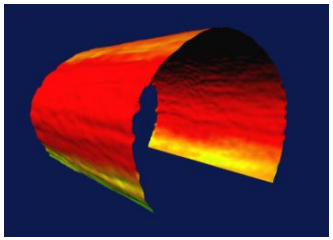


Acoustic Impact Echo

- Benefits
  - Detects delamination of concrete pipes
  - Detects voids beyond the pipe wall
  - Lower-cost inspection method
  - Works through paint/coatings
  - Only one side of the structure needs to be accessible for testing
- Limitations
  - Requires dewatered pipe
  - Most applicable for concrete structures
  - Discrete point measurements only

Laser

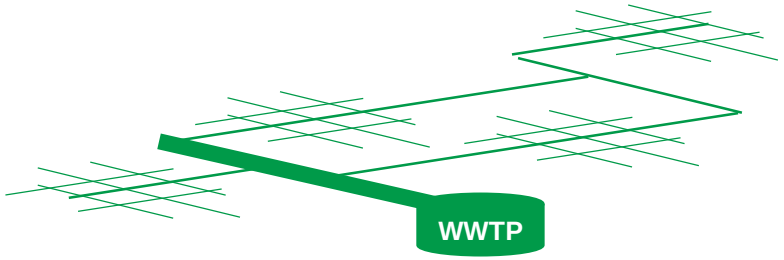
- Benefits
  - High-precision scan of pipe interior dimensions to measure deformation
  - Contributes to design for CIPP, sliplining, swagelining, etc.
- Limitations
  - Only functions above water level
  - Cannot distinguish scanned materials (can be influenced by tuberculation or buildup)



Operational Example

Operational Example

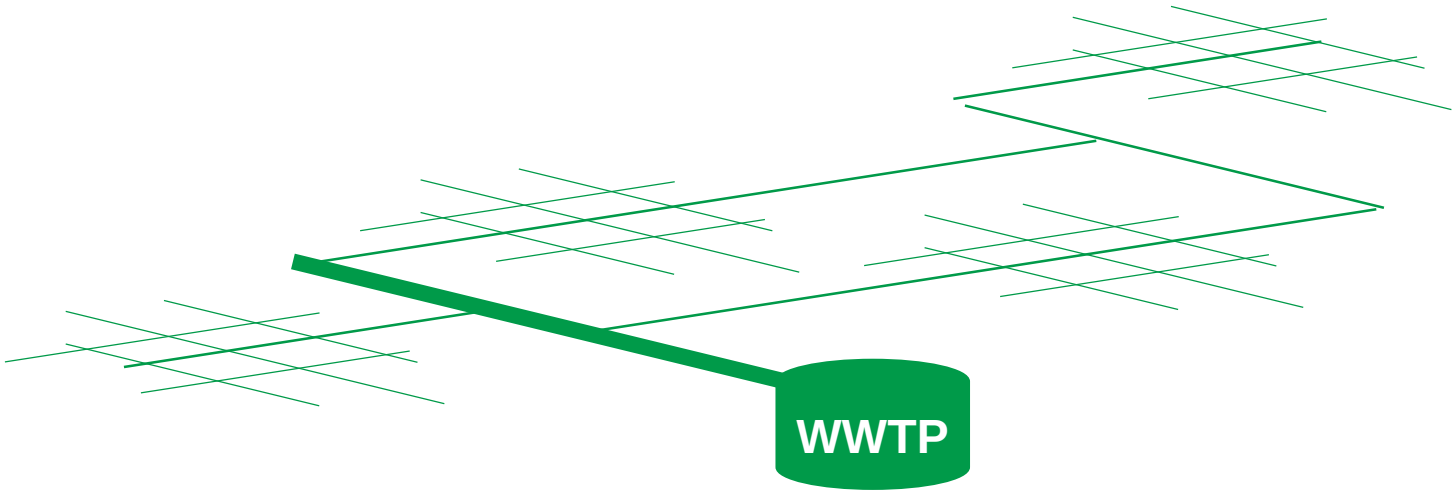
- Force Main Network (20 miles)
- DIP and CCP
- Corrosive soils
- Leakage concerns



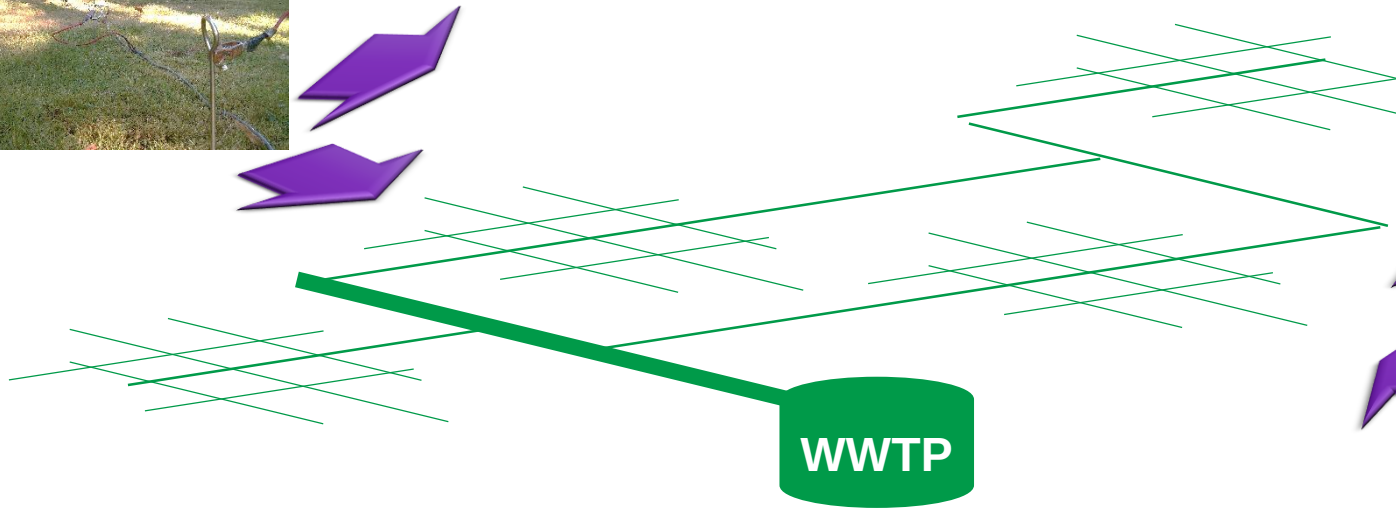
Operational Example

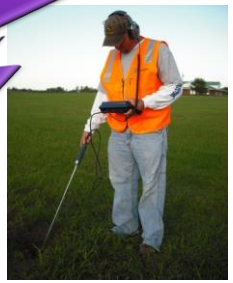
- Tier 1
  - Soil survey
  - Appurtenance inspection
- Tier 2
  - Test pits
- Tier 3
  - Electromagnetic

Operational Example

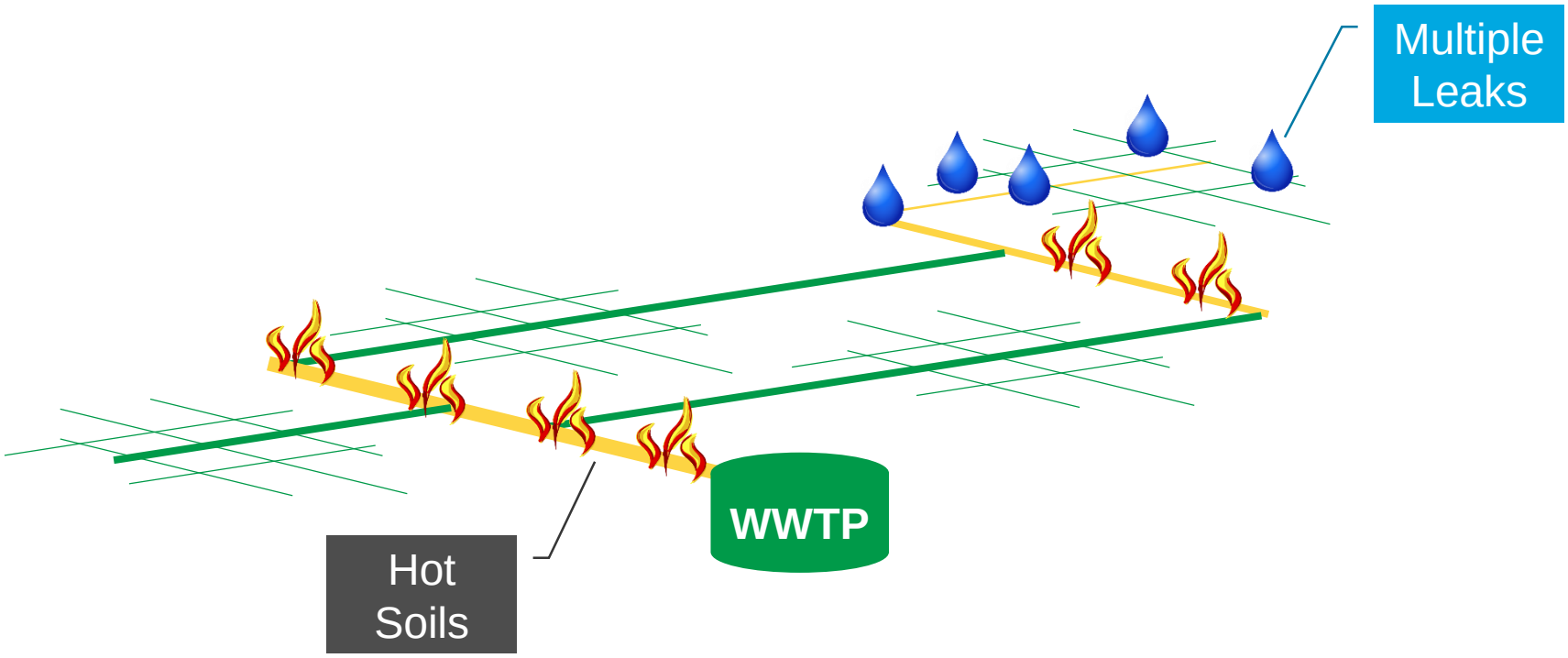


Tier 1 – Soil Survey & Appurtenance Inspection



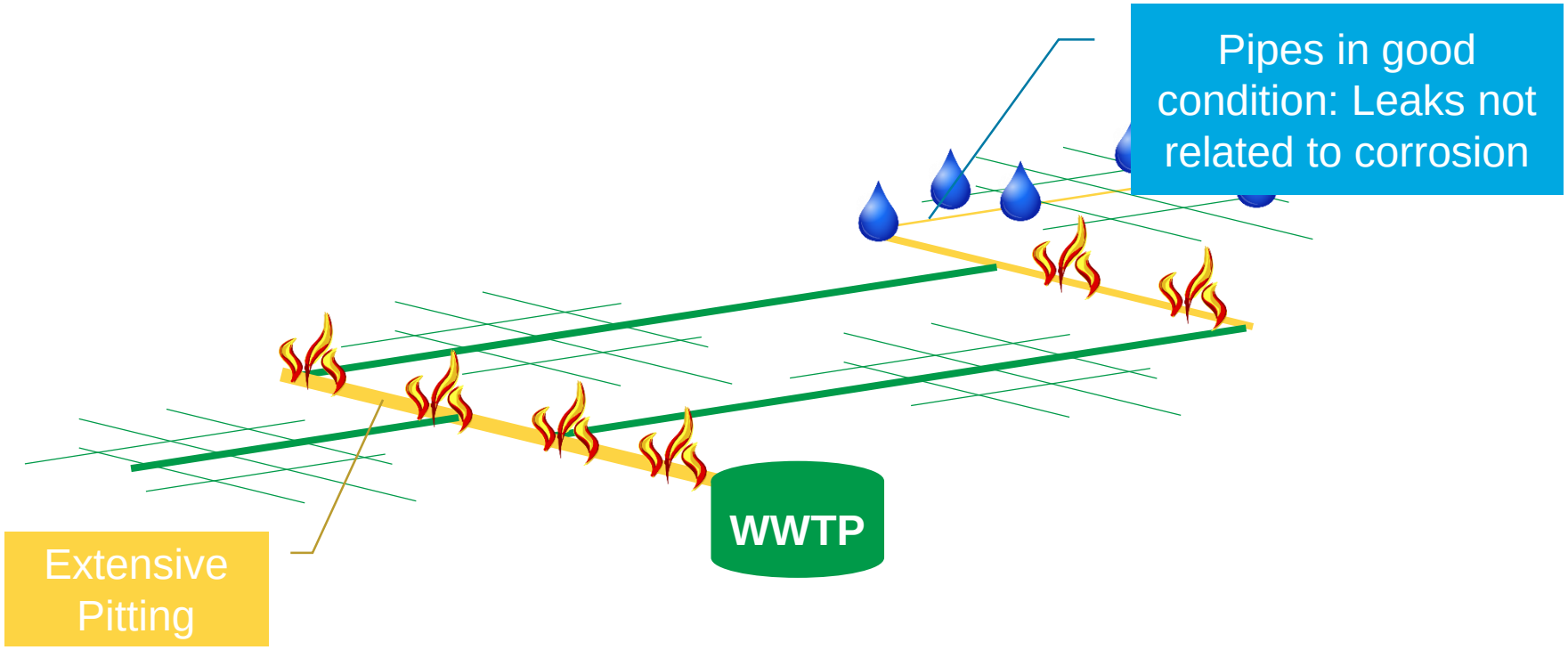


Tier 1 – Soil Survey & Appurtenance Inspection Results

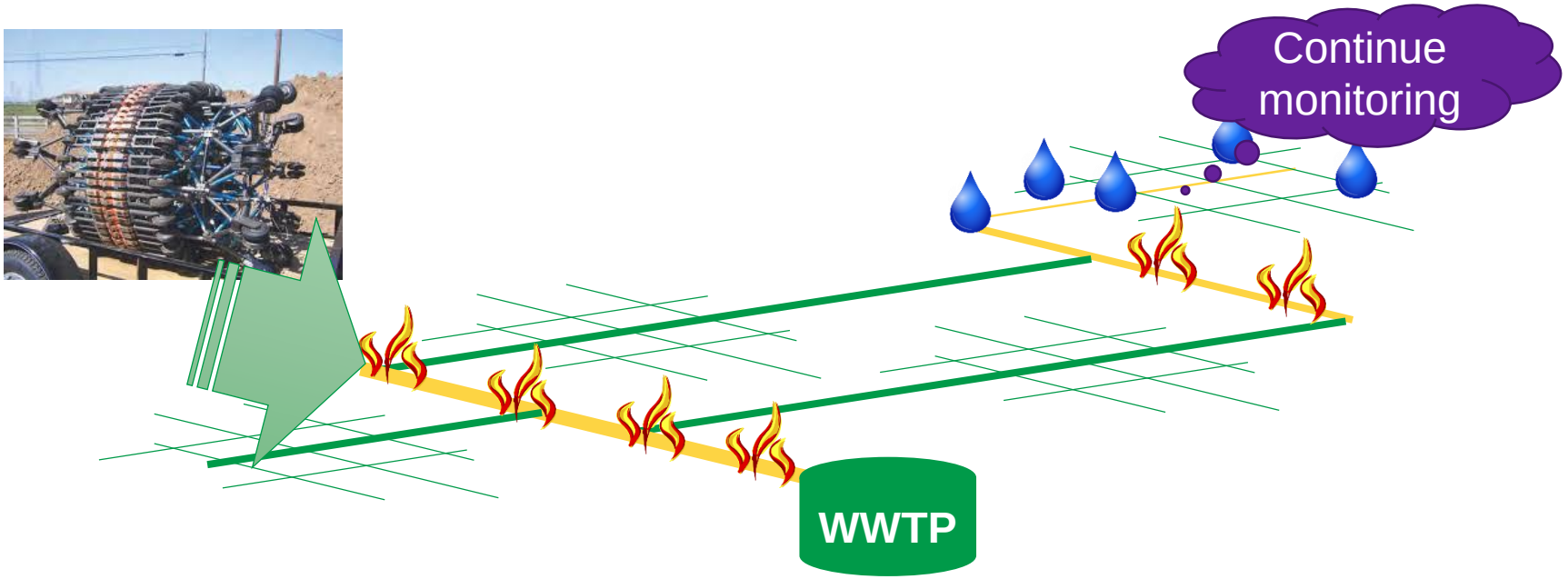


Tier 2 – Test Pits

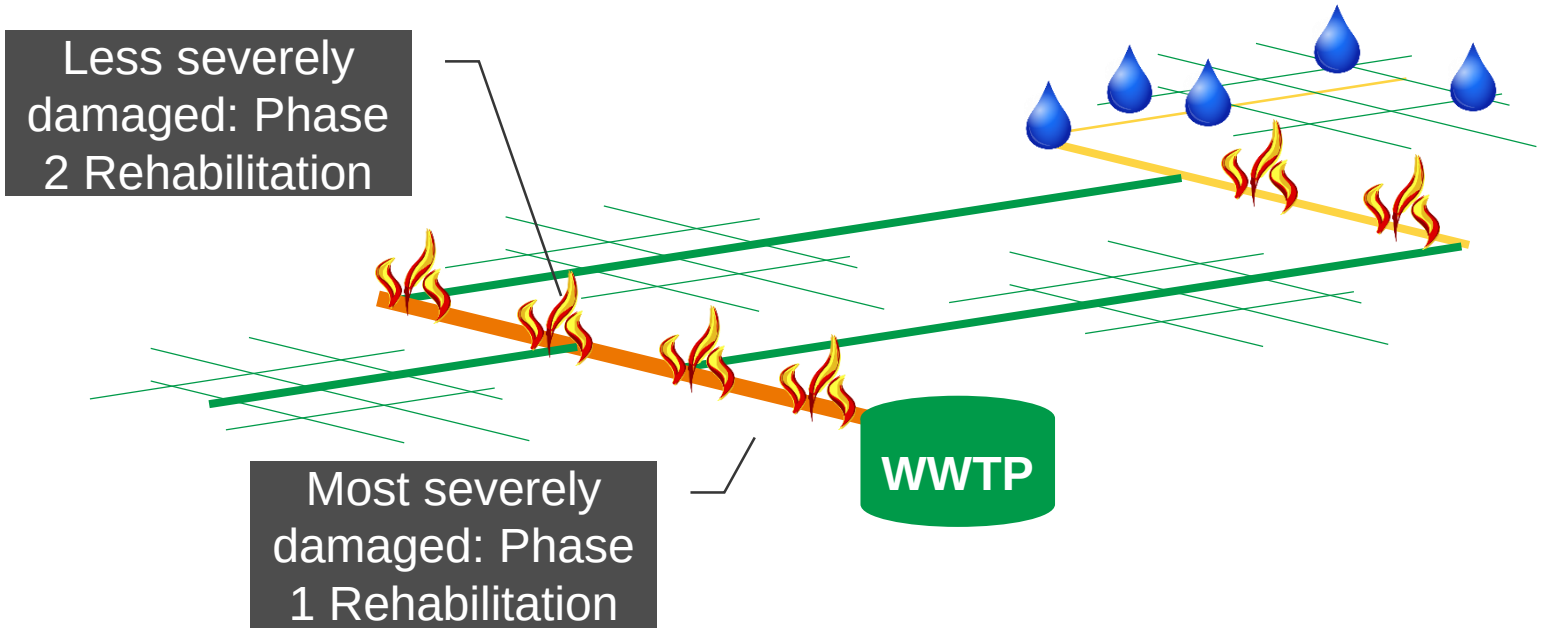
Tier 2 – Test Pit Results



Tier 3 – Electromagnetic



Tier 3 – Electromagnetic Results



Cost Comparison: 20 mile force main network

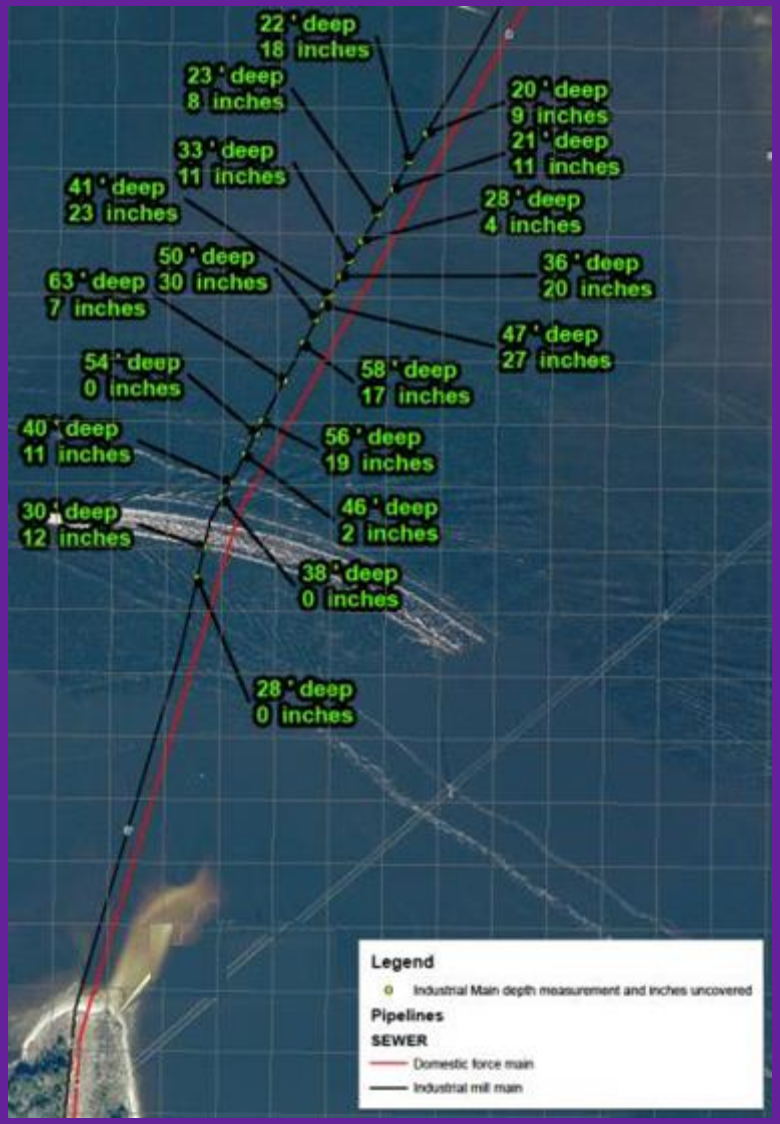
Assessment Technology	Conventional	Tiered Approach
Soil Survey/Appurtenance Inspection	N/A	$200,000
Test Pits	N/A	$200,000 Assume 50% of major force mains are investigated
Advanced Investigations (Electromagnetic)	$1,000,000 Assume 50% major force mains investigated	$200,000 10% requires advanced assessment
TOTAL	$1,000,000	$600,000

Case Study

Project Background

- 9,800 LF of 36”-54” diameter C301 PCCP (Lined-Cylinder Pipe)
- Constructed in early 1970s
- Approx. 4,300 LF subaqueous, up to 60 ft depth
- Portions of subaqueous pipe uncovered
- Wastewater can reach 140°F
- Average flow 18-24 MGD
- Facility only has two days per year of low flow < 4 MGD

Portions of Subaqueous Pipe Uncovered



- Original construction included both restrained and unrestrained joints
- Installation was performed by commercial divers into a dredged trench
- Prior surveys indicated erosion had exposed portions of the water crossing

Project Drivers

- Industrial asset management strategy included condition assessment of critical pipelines
- Increased regulator sensitivity due to river crossing and constituency of industrial wastewater
- Approaching presumed half-life for PCCP
- Potential replacement costs on the order of +$15M

Condition Assessment Approach

Tier 1 – Site Reconnaissance and Appurtenance Inspection

- Identified locations most susceptible to external corrosion
- Scouting locations for possible access improvements

Tier 2 – Test Pits and Coupons

- Confirmed possible deterioration of PCCP

Tier 3 – Electromagnetic Methods

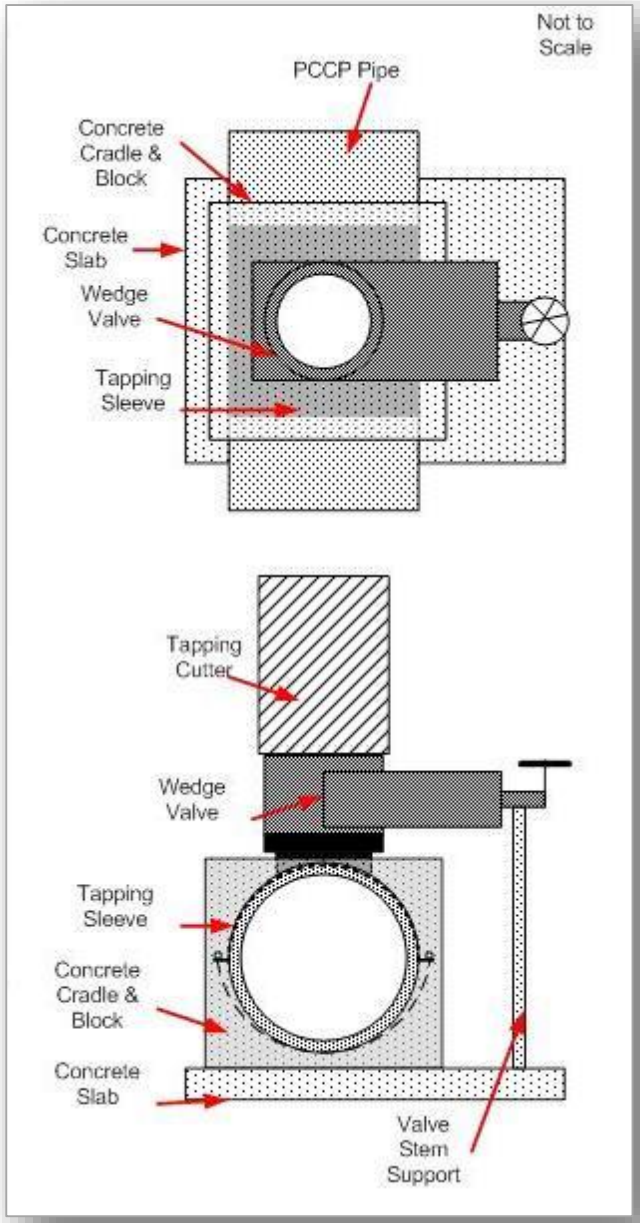
- Devices inserted into the pipe at special access structures
- Electromagnetic sensors detect prestressed wire breaks
- In-line acoustic sensors listen for leak frequencies and gas pockets

Condition Assessment Approach

- Final Tier 3 Technology Selection
  - Paid companies for visit; improves correspondence and pre-planning
  - Electromagnetic “smart pigs” determined viable
  - Tethered/powered crawlers selected to minimize risk of equipment loss
  - Transponders map the pipeline location
  - Would required special access to deploy robotic equipment
  - Very narrow 1-week plant shut-down window for prep, access, inspection, and restoration

Special Access Installations

Design Layout for 24” Access Taps



Providing Condition Assessment Access

24” Pipe Coring

Upstream Access Tap

Downstream Access Tap & Flow Diversion

Special Access Ways Required Geotechnical Support

Electromagnetic Robot Deployment

In-Line Acoustic Equipment Deployment

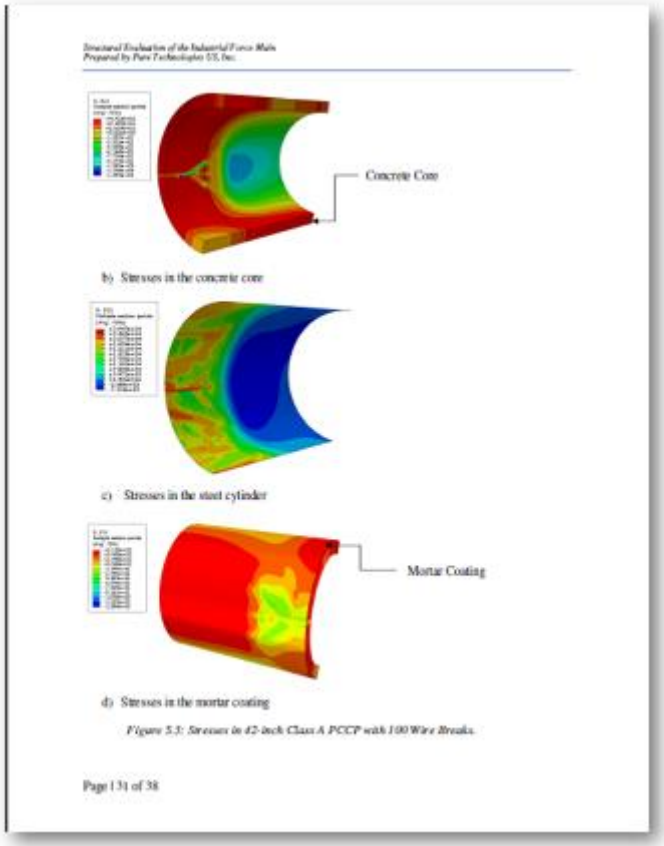
Sonde Tool Deployment

- Difficulty tracking crawler from the surface
- Portable detection sensors limited by surface topography
- Future technology generations may include specific underground transponders and location sensor networks (like those used for HDD operations) to accurately track the device and map the alignment.

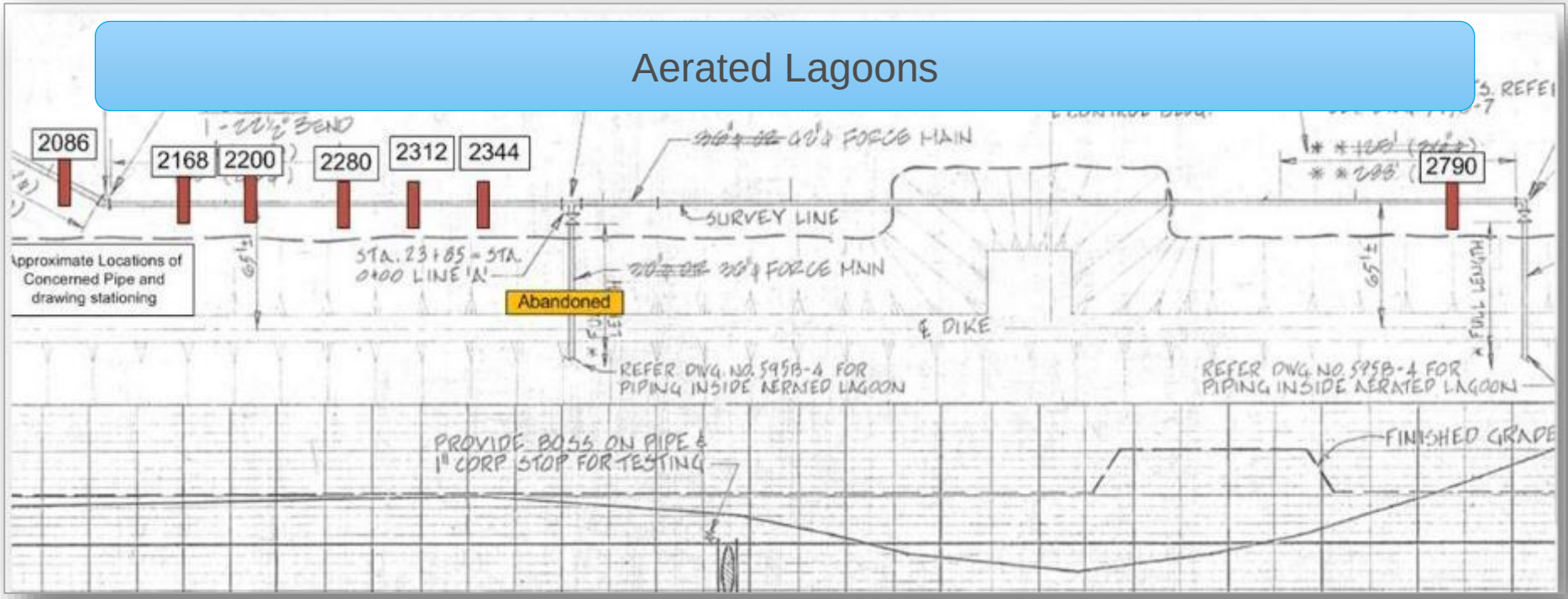
Inspection Results and Analysis

Number of Wire Breaks

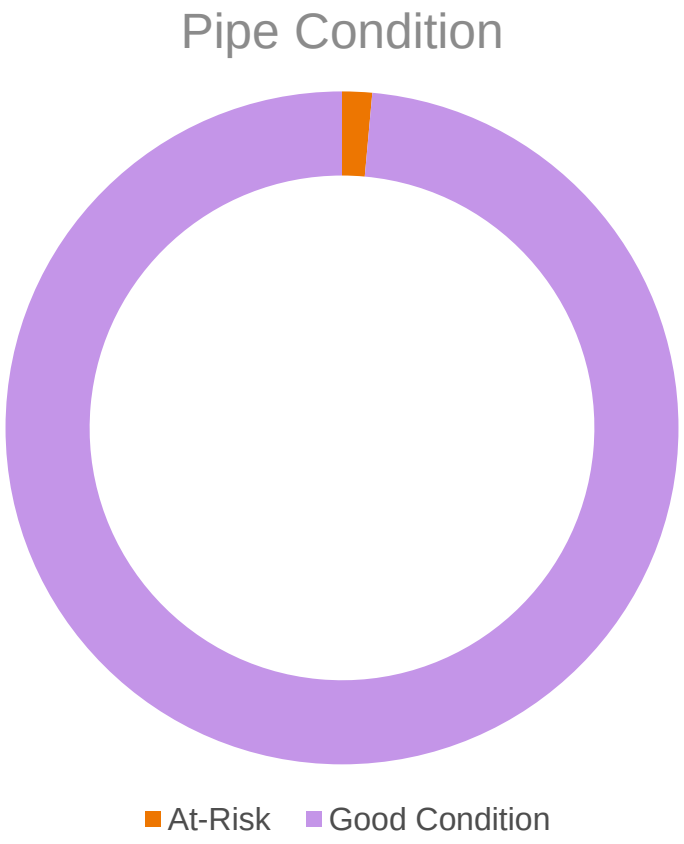
Pure Ref #	JB Conserve As-Built Drawing Number	Piece #	Low STA	Pipe Length (ft)	Reported Class	Distance from Insertion (ft)	Break Region Location (ft from Low STA)	#WB by Region	Total #WB	Layout	Comments
2250	595B-9	N/A	17+23	16	N/A	240					
2251	595B-9	N/A	17+39	16	N/A	256					
2252	595B-9	N/A	17+55	16	N/A	273					
2253	595B-9	N/A	17+71	16	N/A	289					
2254	595B-9	N/A	17+87	16	N/A	305					
2255	595B-9	N/A	18+03	16	N/A	321					
2256	595B-9	N/A	18+19	16	N/A	337					
2257	595B-9	N/A	18+35	16	N/A	353					
2258	595B-9	N/A	18+51	16	N/A	369					
2259	595B-9	N/A	18+67	16	N/A	385					
2260	595B-9	N/A	18+83	16	N/A	401					
2261	595B-9	N/A	18+99	16	N/A	417					
2262	595B-9	N/A	19+15	16	N/A	433					
2263	595B-9	N/A	19+31	16	N/A	449					
2264	595B-9	N/A	19+47	16	N/A	465					
2265	595B-9	N/A	19+63	16	N/A	481					
2266	595B-9	S-76	19+79	16	N/A	497	9.5;12.0	5;5	10	10	11ft SP in lay sheets. Data indicates 16
2267	595B-9	S-76A	19+89	16	N/A	513					
2268	595B-9	N/A	20+05	16	N/A	529	11.0	5	5	5	
2269	595B-9	N/A	20+21	16	N/A	545	9.5;11.0	5;5	10	10	
2270	595B-9	N/A	20+37	16	N/A	561	3.5;5.5	5;10	15	15	
2271	595B-9	N/A	20+54	16	N/A	577	6.0	5	5	5	
2272	595B-9	N/A	20+70	16	N/A	593					
2273	595B-9	N/A	20+86	16	N/A	609	4.0;8.0;10.0;13.0	5;20;20;10	55	55	
2274	595B-9	N/A	21+02	16	N/A	625	7.5;9.0	5;5	10	10	
2275	595B-9	N/A	21+18	16	N/A	641					
2276	595B-9	F-77	21+34	2	N/A	657					
2277	595B-9	N/A	21+36	16	N/A	659	7.0;10.0	5;5	10	10	
2278	595B-9	N/A	21+52	16	N/A	675					
2279	595B-9	N/A	21+68	16	N/A	692	3.0;6.0;8.5;11.0	10;15;10;5	40	40	
2280	595B-9	N/A	21+84	16	N/A	708	10.5	5	5	5	
2281	595B-9	N/A	22+00	16	N/A	724	3.5;7.0;12.0;13.5	5;15;15;20	55	55	
2282	595B-9	N/A	22+16	16	N/A	740	13.0	5	5	5	
2283	595B-9	N/A	22+32	16	N/A	756	6.5;10.5	5;5	10	10	
2284	595B-9	N/A	22+48	16	N/A	772					
2285	595B-9	S-78	22+64	16	N/A	788					
2286	595B-9	N/A	22+80	16	N/A	804	3.5;6.0;9.0;10.5;12.5	5;5;5;5;5	25	25	
2287	595B-9	N/A	22+96	16	N/A	820					
2288	595B-9	N/A	23+12	16	N/A	836	1.5;5.5;8.0;12.0;13.5	15;5;15;25;20	80	80	
2289	595B-9	N/A	23+28	16	N/A	852					

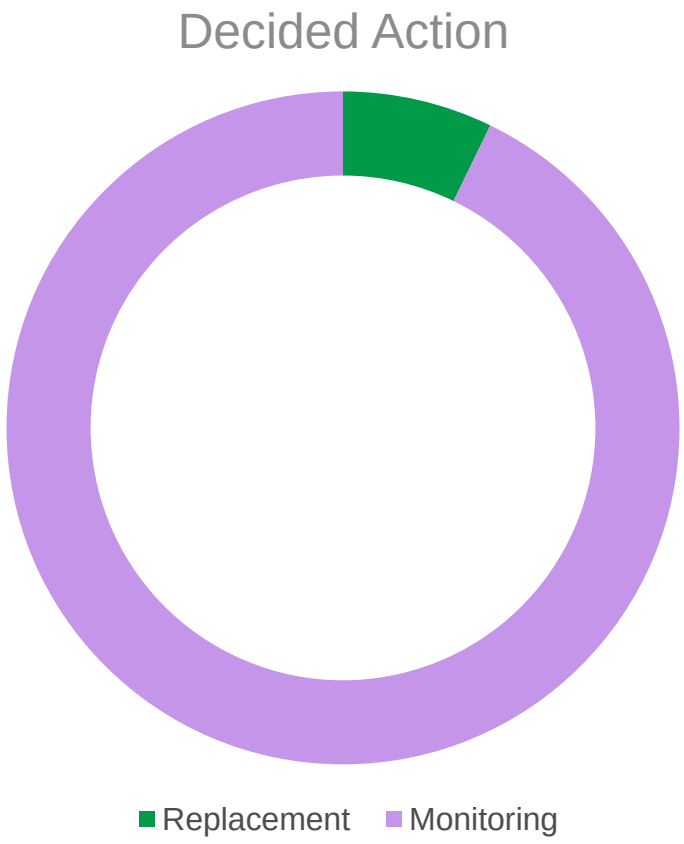


Seven Pipe Segments on 42” PCCP Adjacent to Aerated Lagoon Recommended for Replacement



Owner Elected Conservative Approach to System Improvements and Replaced Total 800 LF Reach





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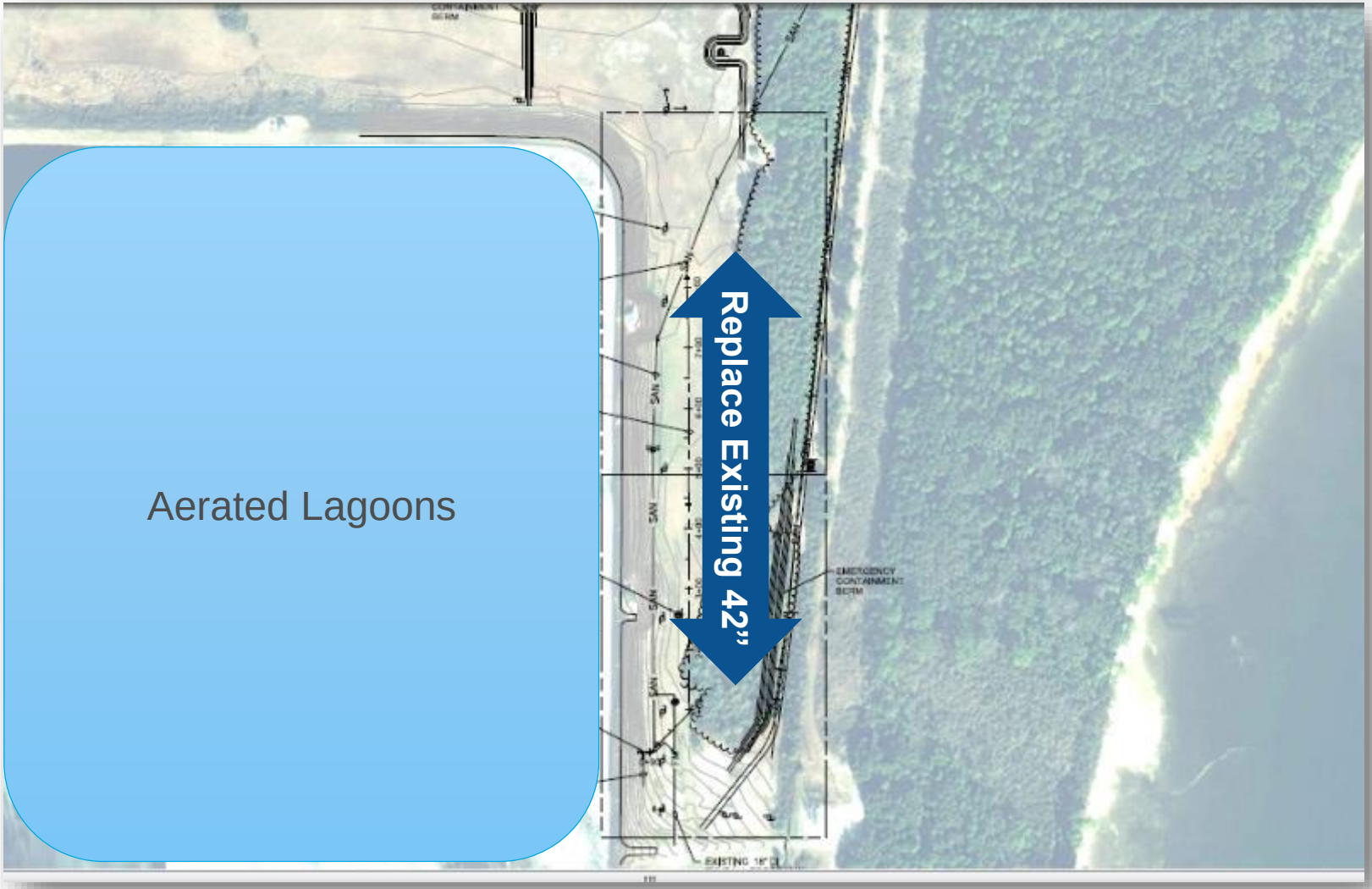
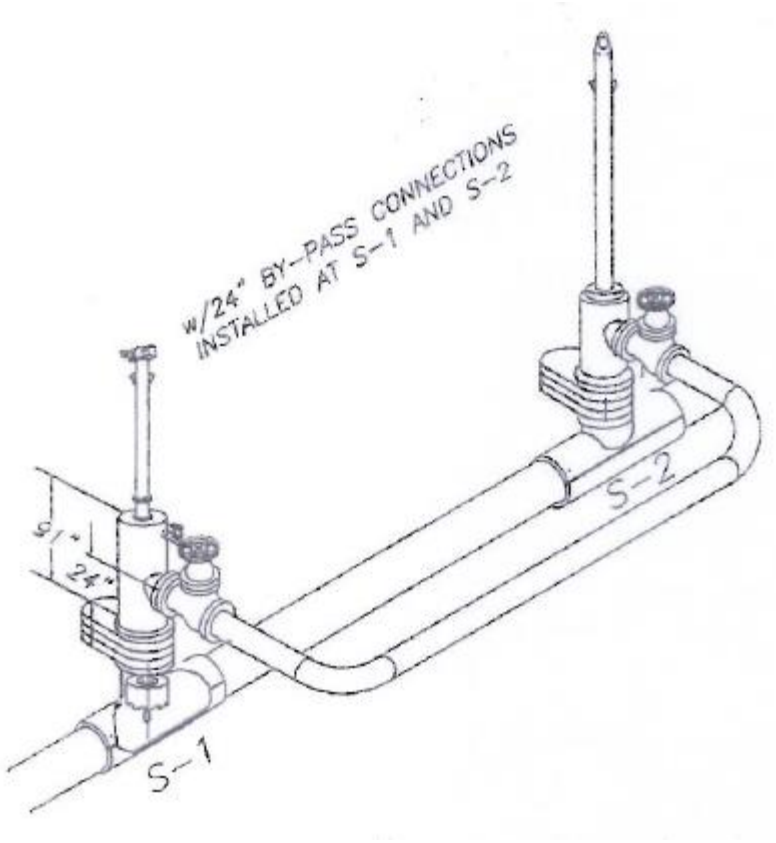
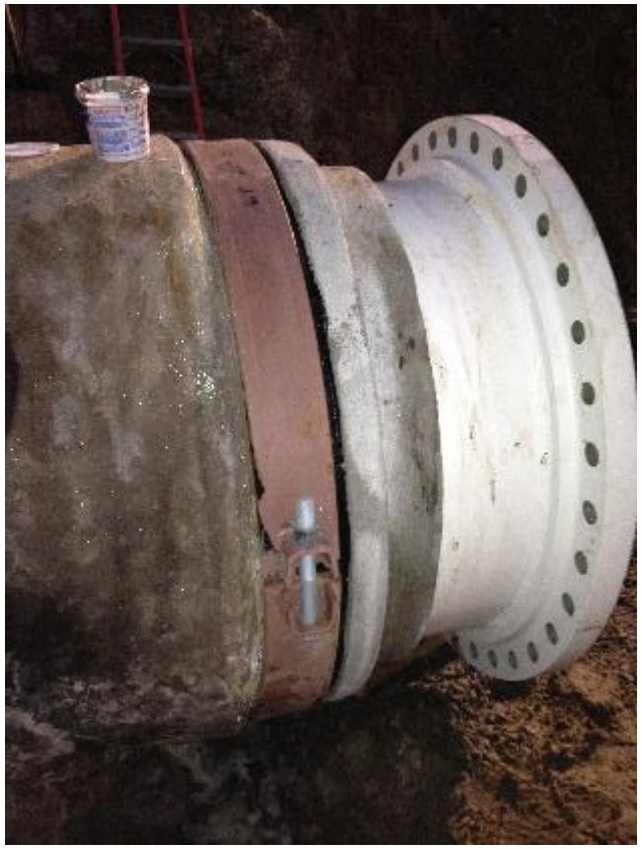


Hot Line Tapping Bypass



PCCP-DIP-HDPE Repair Combination

Couplings are Key



Making Connections and Restraining Forces

Overall Project Costs

Item	Cost
Pipe Access Construction	$166,000
Electromagnetic Inspection	$260,000
Pipe Repairs	$850,000

Project Challenges, Lessons Learned, and Next Steps

- Challenges
  - High level of regulatory interest (typical for large diameter forcemain water crossings)
  - Limited access
  - Extremely tight and critical activity schedule
  - High temperature wastewater
- Lessons learned
  - Constructing access ways requires thoughtful planning, design, installation
  - Industrial wastewater stream resulted in thick layer of buildup
  - Core sample and petrography tests important to validate NDE
  - Introduction of repair/rehabilitation products different than the host pipe requires special accommodations (restraint, thermal effects, etc.)
- Next Steps
  - Ongoing forcemain monitoring and contingency plan

Thank You

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