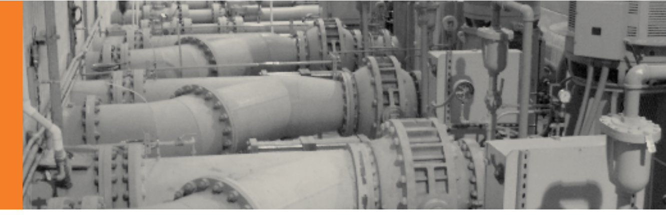
EXTENDING ASSET LIFE

Meet the challenge of aging infrastructure through effective condition assessment



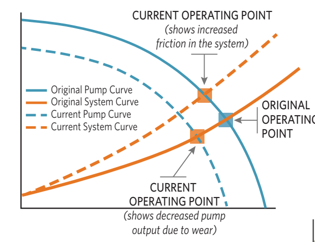
Treatment Plants and Pumping Stations

	ARCHITECTURAL	STRUCTURAL	MECHANICAL (HVAC AND PLUMBING)	PROCESS	ELECTRICAL AND I&C	SITE CIVIL
COMPONENTS	• Building conditions • Masonry and exterior walls • Insulation • Sealants • Doors and windows • Roofing systems • Floors and ceiling • Paint systems and finishes • Occupancy and life safety • Accessibility • Means of egress	• Process structures • Building structures • Cast-in-place concrete • Precast/prestressed concrete • Structural steel • Concrete masonry • Miscellaneous metals, including aluminum and stainless steel • Equipment foundations and supports • Piping support systems	• Air handling equipment • Make-up air units • Heating equipment • Cooling equipment • Ductwork • Boilers • Chillers • Cooling towers • HVAC controls • Hot/chilled water systems • Plant water systems • Plumbing fixtures and piping systems • Supply and exhaust fans	• Process equipment • Process basins • Pumping equipment • Chemical feed systems • Valves, piping, and pipe supports • Flow control and gates • Process efficiency issues • Ancillary equipment	• Switchgear and switchboards • Site power distribution and transformers cables • Standby power and transfer switches, UPS systems • MCCs and VFDs • Panelboards, and disconnects • Major motors • Conduits, raceways, and conductors • Lighting systems, and emergency lighting • Grounding and surge protection • I&C equipment – field devices, primary elements, control panels, PLC's • Control approach and SCADA system • Security systems	• Overall site review • Site access • Site roads, parking, and fencing • Exterior lighting • Landscaping • Storm water management • Neighborhood concerns
SUGGESTED ELEMENTS TO ASSESS	• Asset ID and age • Maintenance history • Type of construction – roof, walls, floors • Roof type and condition • Exterior walls and insulation condition • Interior walls condition • Doors, windows, and hardware condition • Stairs, ladders, and guardrail condition • Coatings condition and corrosion issues • Accessibility compliance	• Asset ID and age • Maintenance staff assessment • Previous evaluations/inspections • Exposure and loading conditions • Overall condition – structural distress or movement • Surface condition – cracking, spalling, corrosion conditions • Strength of concrete or grout per ASTM • Petrographic examination of concrete • Concrete sounding and other non-destructive testing methods • Half-cell corrosion testing per ASTM • Phenolphthalein testing • Microstructural analysis per ASTM	• Equipment ID, age, and nameplate • Historical maintenance information • Overall condition and reliability • Spare parts • Previous reports/inspections • Control cabinets and controls • Fan and heating system performance • Ventilation issues • Plumbing issues	• Equipment ID and nameplate data • Historical maintenance records and operational history • Asset management information • Equipment age/normal asset life • Equipment reliability and impact of failure • Performance rating and condition • Spare parts availability • Previous facility evaluations • Performance tests – pumps, blowers, etc. • Ancillary systems - air, seal water, priming, etc.	• Asset/equipment ID, age, and nameplate • Visual inspection • Maintenance history • Equipment condition and reliability • Conduit/wire condition • Equipment suitability for environment • UPS requirements • Lighting level • Primary elements condition • Data communication • SCADA controls performance • Interview plant operating staff • NEC/NFPA compliance review	• Site paving • Site drainage issues • Site lighting condition and levels • Landscaping condition • Site access/control • Noise/neighborhood issues • Storm drainage system
STANDARDS/CODES	• International Building Code • International Existing Building Code • International Fire Code • International Energy Conservation Code • NFPA • ANSI • ASTM • FM Global • Underwriters Laboratory (UL)	• International Building Code • International Existing Building Code • American Concrete Institute (ACI) • American Institute of Steel Construction (AISC) • American Welding Society (AWS) • ASTM/ANSI • SEI/ASCE 11 for Existing Buildings • SEI/ASCE 7 Minimum Design Loads for Buildings and Other Structrures	• NFPA • IBC Codes • Underwriter Laboratory (UL) • ANSI/AWWA • ASME/ASTM • ASHRAE • NEMA	• State regulatory requirements • 10 state standards • Hydraulic Institute • AWWA standards • NSF ratings • ASTM/ANSI	• National Electric Code (NEC) • IBC Codes • NFPA • IEEE • Underwriters Laboratory (UL) • NEMA/ANSI • ISA	• Applicable local standards • AASHTO • ASTM • U.S. Army Corps of Engineers – COE

Identifying Best-Value Improvements

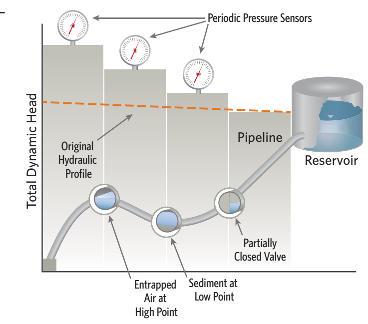
Through Pump Station Trending

Pump station trending helps you determine the cause of decreased pump performance. Though decreased performance is often attributed to premature pump wear, in many cases the cause is a constriction — either upstream (clogged intake screen) or downstream (sediment accumulation, entrapped air) — that can be addressed through maintenance.



In the figure to the left, comparison of the current operating point to the original operating point may indicate either impeller wear (reduced pump curve) or increased headloss in the system (increased system curve).

There are many potential causes of increased headloss in the system, as shown in the figure to the right. Pressure sensors and portable flow meters at strategic locations can be used to pinpoint specific issues, such as reduced cross sectional area due to entrapped air (air valve failure) or accumulated sediment.



Concrete and Steel Tanks

1 Inspection Recommendations

INSPECTION TYPE	DESCRIPTION	STAFF REQUIREMENTS
Routine (daily to weekly)	Exterior inspection to detect acute changes such as storm damage and vandalism.	One person
Periodic (quarterly to annually)	Exterior inspection and limited internal visual inspection from hatch to monitor areas of concern.	Two to three staff members. Requires safety procedures and coordination.
Comprehensive (every five years)	Internal and external physical evaluation, review of operations and maintenance records, and performance evaluation.	Multi-disciplined team, including staff familiar with operations, maintenance, water quality, reservoir design, and structural engineering

2 Triage

Typically conducted in the first few months of a program, a triage assessment is carried out with the tank in service.

- ✓ Perimeter and site walk
- ✓ Exterior roof assessment
- ✓ Interior visual assessment from the hatch
- ✓ Review of historical O&M data
- ✓ Cathodic protection coatings assessment (steel tanks only)

3 Comprehensive Inspections

Based on triage assessment, tanks are prioritized for comprehensive assessment

	CONCRETE	STEEL
Visual Inspection Internal raft inspection for concrete tanks or dry inspection for steel tanks.	✓	✓
Code Conformance Analytical evaluation comparing the tank's condition to design and prevailing codes. • Concrete – International Building Code references ACSE 7-05 for minimum loads • Steel – Per AWWA D-100 and SEI/ASCE 11-99	✓	✓
Water Quality Challenges (See adjacent table)	✓	✓
Ventilation Calculated per ASHRAE Fundamentals Handbook. Requirements depend on the tank and ambient conditions. Ventilation affects long-term reservoir performance.	✓	✓
Deck Movement Decks are frequently found to be improperly constrained or not performing as designed. Deck movement can compromise the roof and expose metals to corrosion.	✓	
Cracking ACI 350, Code Requirements for Environmental Engineering Concrete Structures and Commentary, has replaced ACI 318. ACI 350 calls for a higher reinforcement ratio to minimize crack widths and produce water-tight structures.	✓	
Leakage Perform leak tests per ACI 350. Evaluation should also consider liner type and condition, if applicable.	✓	✓
Cathodic Protection Assessment (See adjacent section)		✓
Steel and Coatings Testing Will vary according the tank and level of assessment. Common tests include those shown to the left.		✓

Water Quality Challenges

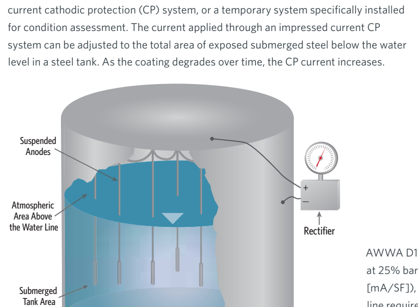
CHALLENGE	CAUSATIVE FACTORS
MICROBIAL	
Proliferation of Bacteria/Bacterial Regrowth	Detention time, temperature, food sources, bacterial sources, lack of residual
Biodegradation of Tank Coatings and Materials	Exposure time, surface area, material properties
Nitrification	Temperature, presence of ammonia, detention time, lack of residual
CHEMICAL/PHYSICAL	
Short-Circuiting/Dead Zones	Detention time, common inlets and outlets, insufficient baffles or mixing
Disinfection By-Product Formation	Detention time, presence of precursors, presence of excess sediment

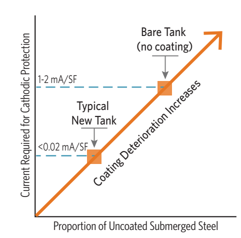
Common Steel and Coatings Tests

- Ultrasonic thickness testing of exterior shell, bottom, and roof
- Interior and exterior weld inspections
- Pit-depth measurements
- Visual coating inspection per SSPC-VIS2
- Dry-film thickness measurements
- Adhesion testing per ASTM 3359 Method X-Cut
- Qualitative lead testing

Leveraging a Cathodic Protection System for Rapid Condition Assessment

Condition of steel tank coatings can be efficiently assessed using either a permanent current cathodic protection (CP) system, or a temporary system specifically installed for condition assessment. The current applied through an impressed current CP system can be adjusted to the total area of exposed submerged steel below the water level in a steel tank. As the coating degrades over time, the CP current increases.

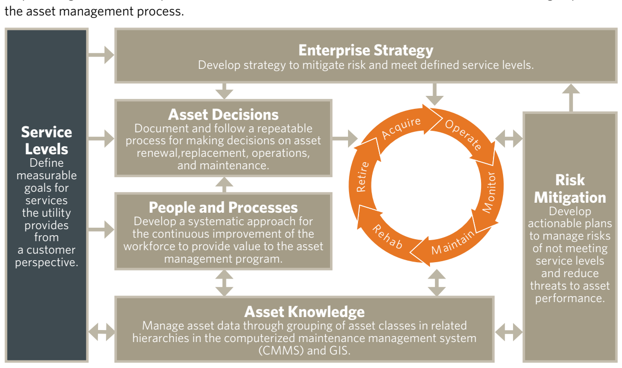




AWWA D102 recommends complete removal and recoating at 25% bare (current of 0.25 to 0.5 milliamps per square foot [mA/SF]), or when the atmospheric area above the water line requires recoating. As CP systems do not protect the atmospheric area, recoating of tanks with CP systems is often targeted at protecting this more vulnerable area.

Integrating Condition Assessment into Your Overall Asset Management Program

Asset Management is a structured approach to optimizing the lifecycle cost of asset ownership and focuses on providing reliable and dependable levels of customer service. Condition assessment is an integral part of the asset management process.

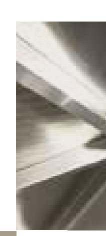


- **Acquire** — Condition assessment data used to prioritize CIP
- **Operate** — Condition monitoring is part of the operating strategy
- **Monitor** — Set up and manage a condition assessment plan
- **Maintain** — Use condition data to adjust the maintenance strategy
- **Rehab** — Analyze condition trending to develop renewal strategies as part of an asset plan
- **Retire** — Plan for retirement based on economic useful life and risk planning

CONDITION ASSESSMENT PROCESS

- Planning
- Initial evaluation
- Inspection
- Engineering analysis

Smart Condition Assessment Stretches Your Utility Dollars



The Challenge of Our Time

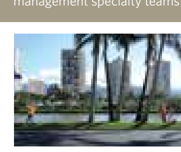
Your utility is facing the demands of aging infrastructure at a time when there is increasing pressure to hold down rates. Utility managers, engineers, and operators all face difficult decisions on where to invest ratepayer dollars in maintaining, rehabilitating, or replacing assets.

The Value of Investing in Condition Assessment

Condition assessment is a critical component of your asset management life cycle. A well thought out condition assessment program will extend asset life, reduce catastrophic failures, protect water quality and the environment, and reduce the lifecycle cost of your assets. The question is not whether you can afford to invest in condition assessment, but whether you can afford not to.

HDR Can Help

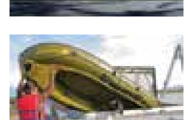
Condition assessment options abound. It can be hard to identify the right approach and level of investment for your system. HDR has helped utilities both large and small manage all phases of the asset life cycle, combining local project leadership with the expertise of regional condition assessment and asset management specialty teams.



WORKING IN PARTNERSHIP WITH YOU TO DEVELOP AND IMPLEMENT YOUR ASSET MANAGEMENT STRATEGY

City and County of Honolulu | Honolulu, Hawaii

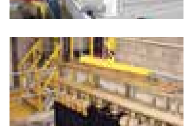
When an EPA consent decree required the City and County of Honolulu to rehabilitate 10 percent of their wastewater collection system immediately, HDR's asset management experts helped city staff target high-risk pipe for early inspection and developed program plans based on what was learned.



DEVELOPING AND DELIVERING COMPREHENSIVE CONDITION ASSESSMENT PROGRAMS

Tucson Water | Tucson, Arizona

HDR developed a five-year comprehensive inspection and tank maintenance and rehabilitation program for Tucson Water's 68 water storage reservoirs.



IDENTIFYING REHABILITATION SOLUTIONS THAT MAXIMIZE THE VALUE OF YOUR PAST INVESTMENTS

Submerged Membrane Retrofit | Kennewick, Washington

HDR was able to increase the treatment capacity, implement high-quality membrane filtration, and save the city considerable amounts of money by reusing all the existing structures, properly sizing replacements for underused equipment, and replacing multiple inefficient chemical systems with a fewer number of more robust, modern pumps.

To order free copies of EXTENDING ASSET LIFE please go to: http://www.hdrinc.com/condition-assessment

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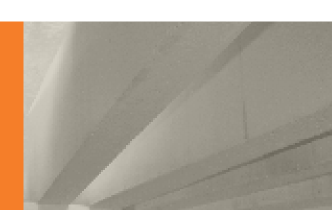

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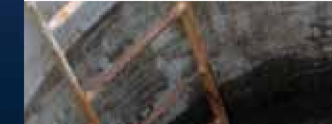

EXTENDING ASSET LIFE

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Gravity Pipes (Storm and Sanitary Sewers)

DESCRIPTION	FLOW MONITORING	SMOKE TESTING (RAINFALL SIMULATION)	DYED WATER TESTING	FLOW ISOLATION (NIGHT RAIDS)
Diameters	6 inches and larger	4 inches and larger	4 inches and larger	4 to 24 inches (practical), but could be used at any size
Description	Sensors to measure depth of flow, or depth of flow and velocity, installed in hydraulically suitable key manholes.	Introduction of harmless, non-toxic chemical smoke into isolated regions of the collection system. Smoke distributed through test section by large blowers. Defects photographed and cataloged by crew.	Introduction of dyed-water to verify leaks, voids, and cross connections between the sanitary sewer and the storm sewer. Often performed in tandem with a CCTV inspection.	Between midnight and 6 a.m., measure flow rate in each influent sewer in the manhole at the most downstream location of the test basin; flow in the sewer at this time is attributable to infiltration through leaking joints and broken sewer pipes. Continue working upstream along each pipeline branch where significant flows are measured until flow becomes minimal.
Expected Information	Wastewater flows used to determine dry weather diurnal flows, wet weather I/I flows for master planning, projection of capacity requirements, and identification of deteriorated pipelines on a mass scale.	Primarily used to identify inflow points. Escaping smoke helps identify uncapped cleanouts, storm drain interconnections, poorly fitting manhole covers, roof leaders, and – under certain conditions – broken main sewer and house lateral pipe.	Correlates estimated flow rates from storm sewer system to sanitary sewer. Can also identify locations where flow is transferred from the sanitary sewer to the storm sewer, and determine the presence and location of leaks in, or voids around, the pipeline.	Identifies sewer areas with measured high rates of ground water infiltration. Identifies reaches with significant flow changes as segments to be further evaluated.
Comments	Advances in technology include more reliable data storage units, wireless data transfer capabilities, and longer lasting batteries.	Requires an aggressive public notification program prior to testing.		

DESCRIPTION	CLOSED-CIRCUIT TELEVISION (CCTV) INSPECTION	LASER PROFILING (LIDAR)	SONAR PROFILING	MULTI-SENSOR DATA COLLECTION	PIPE PENETRATING RADAR	MANHOLE INSPECTION
Diameters	4 to 120 inches	18 to 144 inches	18 to 144 inches	18 to 144 inches	18 inches and larger	N/A
Description	Digital cameras provide ability to quantify pipeline defects and perform "virtual" pan and tilt to focus inspection on any potential defect.	Used for above water inspection in pipelines. Typical collection rate of 12x/second.	Used to assess pipelines that continuously operate in a high flow condition. May also be used for siphons and force mains. Typical collection rate of 1x/second.	Common to provide concurrent high-definition (HD) CCTV, LIDAR, and sonar inspection. HD sampling at a typical rate of 6x/second, which normally cross-sections images and measurements every 50 feet, and at significant defects as determined by the CCTV operator.	Application of principles of ground penetrating radar (GPR) to in-pipe inspection. Can be combined with concurrent CCTV and laser profiling. Radar signals are directed toward the pipe wall, then reflections and refractions are measured to identify material interfaces. Can extend to 5 feet beyond the pipe wall and measure to an accuracy of ±1/8 inch.	Visual inspection can be completed without entering manholes to determine and record moderate to significant manhole defects. Manhole entry can be performed to provide more detailed inspection and testing. Tools such as remote CCTV cameras can be used to enhance inspection without requiring manhole entry (but do not provide for testing).
Expected Information	Longitudinal pipeline cracks, circumferential cracks, fractured pipe, offset joints, roots, vertical and horizontal misalignments, broken lateral connections, protruding taps, rodents and vermin, etc.	Identifies loss of pipe wall due to corrosion. Quantifies ovality of pipe. Compares deflection versus design in horizontal and vertical directions.	Calculates debris levels and volumes in pipe for quantification of subsequent removal costs. Helps determine whether pipe capacity issues can be addressed by cleaning, or if pipe upsizing is needed. Identifies major structural anomalies.	Consider completing all three inspections concurrently, even if only one is specified, to allow subsequent recovery of additional data if determined valuable.	Pipe wall thickness, variation in pipe wall thickness (indicative of corrosion), voids outside the pipe.	Reveals structural integrity of manholes, signs of historic surcharge, and signs of I/I (root intrusion, stains and active water flow). May also help identify blockages that can be cleared to reduce SSOs.
Comments	All individuals involved with the internal inspection and evaluation of sanitary sewers should be trained to perform work using a recognized standard, such as NASSCO's Pipeline Assessment and Certification Program (PACP).			Can also measure hydrogen sulfide levels, temperature, and many other parameters.	Can be used only in non-metallic pipelines.	As with internal inspection programs, associated staff should be trained to use an established standard such as NASSCO's Manhole Assessment and Certification Program (MACP).

DESCRIPTION	LATERAL INSPECTION (LIDAR)	JOINT PRESSURE TESTING	ELECTROSCAN INFILTRATION DETECTION	MANHOLE VACUUM TESTING	MANHOLE HOLIDAY (SPARK) TESTING
Diameters	4 to 6 inches	6 to 42 inches	6 to 60 inches	N/A	N/A
Description	Specialized CCTV camera equipment developed to allow inspection of laterals where cleanouts are provided. Mainline CCTV equipment can inspect areas around each lateral connection with good results.	Tests selected pipe joints for integrity as part of I/I reduction.	Uses electrical currents to determine if leakage potential exists.	Determines I/I leakage potential through use of vacuum.	Uses high voltage instruments to determine integrity of manhole linings.
Expected Information	Identifies lateral defects similar to mainline CCTV.	Determines the extent of joint leakage and helps prioritize rehabilitation.	Indicates joints and other portions of pipe where water is electrically connected to the ground.	Indicates which manholes are not completely sealed and might be sources of I/I.	Provides information regarding lining integrity.
Comments	All individuals involved with the internal inspection and evaluation of sanitary sewers should be trained to perform work using a recognized standard, such as NASSCO's Lateral Assessment and Certification Program (LACP).	Often done in conjunction with a chemical grouting operation.	Requires temporary flow stoppage in order to fill the pipe with water for testing.	Requires stopped or bypassed sewer flows.	Requires manned entry. Generally requires flow interruption.

Pressure Pipe and Force Mains

METHOD	CORROSIVITY SURVEY	ACOUSTIC	REMOTE FIELD ELECTROMAGNETIC	ULTRASONIC	MAGNETIC FLUX LEAKAGE	BROADBAND ELECTROMAGNETIC	OTHER	TYPICAL RECOMMENDED APPROACH
DESCRIPTION	Various electromagnetic, electrical, and laboratory methods characterize the corrosivity of soils, measure corrosion activity, and assess corrosion protection and cathodic protection.	Acoustic velocity: pipe wall stiffness is calculated from the speed of sound transmission. Acoustic monitoring: alerts and pinpoints the location of wire breaks. Leak detection. (Access requirements vary widely according to type of pipe and technology provider.)	Changes in electromagnetic signals indicate broken wires, corrosion pits, and changes in wall thickness. Tool must be proportionally sized for the pipe. Works through coatings, linings, and scale. (Access requirements vary widely according to type of pipe and technology provider.)	Reflection of sound waves is used to measure the thickness of various types of materials. Tool must have direct contact with material being measured.	Changes in magnetic fields are used to detect corrosion pits and other defects. Tool must be at a constant, close distance from pipe wall.	Changes in electromagnetic signals indicate corrosion pits and changes in thickness. Scanner works through coatings, linings, and scale when held near pipe.	Sampling of pipes for various physical tests. Manned entry for visual and sounding (delamination testing). Petrographic (microscopic) examinations of concretes and mortars.	GENERAL APPROACH (all pipe types): 1) Records review (leak/break repairs, drawings, specs, reports, soil info) 2) Statistical analysis of available data 3) Risk prioritization (likelihood and consequence of failure) 4) Site reconnaissance (accessibility, traffic conditions, other utilities) 5) Inspection planning (shut downs, bypass, permits, alternatives) 6) Leak detection and/or field condition assessment inspection
Asbestos Cement (AWWA C402)	Assess potential for concrete deterioration (pH and sulfates).	Acoustic velocity has been used with moderate success.	n/a	n/a	n/a	n/a	Testing of samples: • Phenolphthalein stain • SEM/EDS • Petrography	1) Tests of opportunity samples from repairs and service taps 2) GIS mapping of soil data, breaks, and condition assessment data 3) Targeted condition assessment of high-consequence pipes
Prestressed Concrete Cylinder Pressure Pipe (AWWA C301 and C304)	Assess potential for metal and concrete deterioration. Monitor corrosion activity.	Acoustic monitoring for detection of wire breaks.	Used to detect broken wires.	n/a	n/a	n/a	Internal sounding to detect delamination. Internal visual (manned entry or CCTV).	1) Risk analysis based on pipe type, manufacturer, wire type, year of manufacturer, and corrosivity 2) Manned entry for visual and sounding inspection 3) Electromagnetic scanning
Non-Prestressed Concrete Pressure Pipe (AWWA C300, C302, and C303)	Assess potential for metal and concrete deterioration. Monitor corrosion activity.	Has been tried with limited success with AWWA C303.	Has been used to detect broken bars.	n/a	n/a	n/a	External direct assessment. Petrographic analysis of mortar/concrete.	1) Alignment corrosivity survey 2) External direct assessment where corrosion risk is highest 3) Manned entry for visual inspection
Ductile Iron Cast Iron (AWWA C150 & C153)	Assess corrosivity to iron. Monitor corrosion activity.	Acoustic velocity may be able to detect gross deterioration.	Used for detailed internal scan of pipes. Works with cement mortar and tuberculation.	Used for external spot assessments.	Internal scanning of non-CML lined pipes. External spot assessments.	External spot assessments. Emerging method for internal scanning.	Petrographic analysis of mortar.	1) Alignment corrosivity survey 2) Remote field electromagnetic
Steel (AWWA C200)	Assess potential for metal and concrete deterioration. Monitor corrosion activity.	Acoustic velocity may be able to detect gross deterioration.	Used for detailed internal scan of pipes. Works with cement mortar and tuberculation.	Used for external spot assessments.	Internal and external scanning of both CML and non-CML pipes.	External spot assessments. Emerging method for internal scanning.	Forensic analysis (polyethylene bag).	1) Pipe-to-soil potential; cathodic protection assessment 2) Alignment corrosivity survey 3) Remote field electromagnetic or magnetic flux leakage
Copper	Assess potential for metal deterioration.	n/a	n/a	n/a	n/a	n/a	Forensic examinations of failed pipes. Electrochemical noise monitoring.	1) Evaluate construction methods and standards 2) Evaluate soil corrosivity 3) Forensic exams of failures
Plastic Pipes (HDPE – AWWA C906) (PVC – AWWA C900)	n/a	n/a	n/a	n/a	n/a	n/a	Forensic examinations of failed pipes, using laboratory and mechanical tests.	1) Forensic examination, if early or frequent failures have occurred

LEAK DETECTION METHODS apply to all pipes. Leak noise correlation is most effective on small diameter, metallic pipes. Internal leak detection tools apply on large diameter pipes with few appurtenances. Leak detection methods can also detect gas/air pockets.

VISUAL INSPECTION METHODS apply to all pipes. Where manned entry is impractical, CCTV may be used.

Pipeline Rehabilitation Approaches

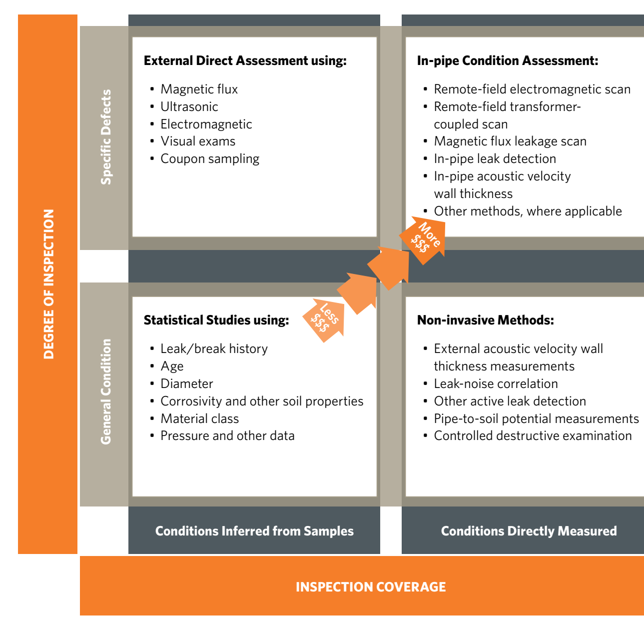
METHOD	OPEN CUT	SLIPLINING	CURED-IN-PLACE PIPE LINING (CIPP)	FOLD-AND-FORM LINING	SPIRAL WOUND LINING	DIE-DRAW LINING/ ROLL-DOWN LINING
DESCRIPTION	Traditional method of excavating, bedding, laying, and backfilling a pipeline.	Placement of a solid or segmented pipeline inside an existing pipeline. Typical materials include PVC, HDPE, steel, and VCP.	Insertion of a felt liner impregnated with thermosetting resin inside an existing pipe, forming a new structural pipe inside the old pipe. For pressure pipe applications, felt may be reinforced with fiberglass, polyester, or carbon fibers.	Similar to sliplining, insertion of a plastic pipe (either PVC or HDPE) inside an existing pipe.	Strips of ribbed PVC are spun inside an existing gravity pipe to create a new pipe within the old pipe.	Method that reduces the diameter of a PE pipe to facilitate insertion into an existing pipe.
ADVANTAGES	1) Has been used for thousands of years 2) Numerous contractors with experience	1) If butt-fusion pipe is used, number of joints is limited 2) Typically, only one pit is required (to pull pipe into the line) 3) If segmented pipe used, bypassing of wastewater is not required	1) Structurally, provides a full replacement pipe 2) Small reduction in cross section 3) No entrance or exit pits required 4) Liners can be cured with hot water, steam, or ultraviolet light 5) Can be used for non-circular conduits	1) Small reduction in cross section 2) Excavation pit not required	1) Adds more competition among lining methods 2) Can be used for non-circular conduits 3) Relatively long installation lengths possible	1) Small reduction in cross section 2) Adds more competition among lining methods
DISADVANTAGES	1) Significant surface disruption 2) Significant geotechnical requirements 3) Typically most costly, depending on existing surface improvements	1) Significant reduction in cross-sectional area of pipe 2) Laterals must be externally reinstated 3) Failures include separation of pulling head from pipe, joint failure, excessive pulling loads leading to pipe failure, and missed laterals	1) Bypassing required 2) Unit costs are somewhat high, relative to other lining methods and, sometimes, open-cut 3) Failures have occurred due to improper wet-out, delays in transport, [illegible] failure during cure, poor design, lack of cleaning, and hydrostatic forces 4) Styrene – a byproduct of some liners – has an identified potential to interfere with WWTP biological processes	1) Bypass required 2) Failures can result from operator error, equipment failure, improperly sized pipe, and liner slippage in service	1) Relatively high cost compared to other lining methods 2) Failures caused by equipment breakdown, and unexpected obstructions	1) Relatively high cost compared to other lining methods 2) Failures caused by equipment breakdown, and unexpected obstructions

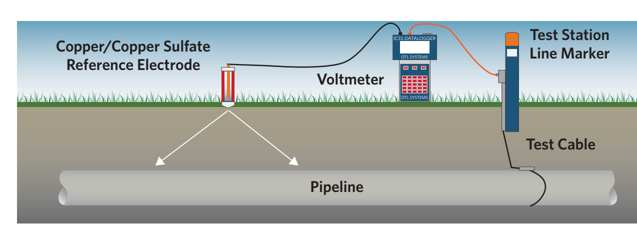
METHOD	PIPE BURSTING/ PIPE REAMING	SPOT REPAIRS	CROWN SPRAYING	CHEMICAL GROUTING	CEMENT MORTAR LINING	SPRAY APPLIED POLYMER LINING
DESCRIPTION	Class of methodologies in which the existing pipe is broken and replaced with a new pipe of equal or larger diameter.	Various methods to repair short sections of pipe. Common methods include internally or externally applied fiber reinforced polymer methods and internal pipe seals.	Application of magnesium hydroxide to protect concrete gravity sewers and retard corrosion.	Involves the use of a packer and grouter to test the seal of individual gravity pipeline joints and, if necessary, apply grout to seal the joint.	Mechanical cleaning followed by spray-applied mortar, per ANSI/AWWA Standard C602. Oldest pipeline rehab method; introduced in the 1960s.	Mechanical cleaning followed by spray applied epoxy, polyurethane, or polyurea, or fiber-reinforced geopolymers. Applicable to water, wastewater, or storm drainage pipelines.
ADVANTAGES	1) Allows existing pipe to be upsized 2) Cost is less than open-cut 3) Reduces surface disruption	1) Minimal surface disruption 2) Small reduction in cross section with internal repairs	1) Low unit cost 2) Provides protection of corroded concrete pipes 3) Can be applied quickly	1) Proven and relatively low cost 2) Does not require bypassing 3) Not affected by active infiltration	1) Proven, low cost, several competing companies 2) Improves water quality and hydraulics – stops internal corrosion, and provides internal corrosion protection 3) No work needed to restore services	1) Proven, low cost, several competing companies 2) Improves water quality and hydraulics – stops internal corrosion, and provides internal corrosion protection 3) Cured material can have compressive strength as high as 8,000 psi to provide structural improvement
DISADVANTAGES	1) Need geotechnical information in pipe zone and in trench over the pipe 2) Can cause ground heave 3) Failures caused by equipment breakdown, insufficient ground cover, curved pipes, narrow previous trenches, and rocky soils 4) Pipe reaming is a patented process that requires licensed contractors	1) Requires excavation for external repairs 2) High unit cost due to limited length of pipe replaced	1) Temporary (1-2 year expected life) 2) Only protects pipe above the flow zone	1) Subject to failure when used in areas with fluctuating groundwater levels 2) Grout materials may be banned or limited in use in the near future 3) Failures include operator error, wet/dry cycling, equipment failure, and improper mixing	1) Minimal structural improvement 2) Only applicable to unlined cast iron and steel water mains 3) Not recommended for soft water	1) Ability for thick linings to serve as "fully structural" rehabilitation not proven 2) ANSI/AWWA Standard C620 exists for 1 mm epoxy lining only

Choosing an Assessment Method

That Fits Your System's Needs and Budget

Risk assessments determine which assets merit detailed assessments. The degree of inspection and the inspection coverage influence the cost. Some methods may not be practical due to access limitations.





Efficiently Assessing Corrosion Risk

With Alignment Corrosivity Surveys

Phase 1	Alignment Corrosivity Study	Electromagnetic Soil Conductivity Alignment Survey (ASTM D6639)	Identifies areas for detailed analysis by Wenner Four Pin and/or sampling and chemical analysis
		Wenner Four Pin Testing (ASTM G57)	Provides detailed vertical data on soil strata resistivity in the pipe zone
		Stray Current Source Reconnaissance	Identifies possible sources of stray current for research, testing, and mitigation
Phase 2	Surface Potential Mapping	Corrosion Test Station or Test Point Survey (NACE TM 0497)	Helps determine areas of corrosion activity
		Close Interval Survey Techniques (NACE SP0207)	Helps target the most actively corroding or coating-deficient areas
Phase 3	Soil Chemistry and Direct Examination	Soil Sampling and Testing (AWWARF #2608)	Provides detailed data on soil chemistry for determination of specific soil corrosivity
		Direct Examination and Inspection (NACE SP502)	Confirms and documents reliability of indirect assessment data and information

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