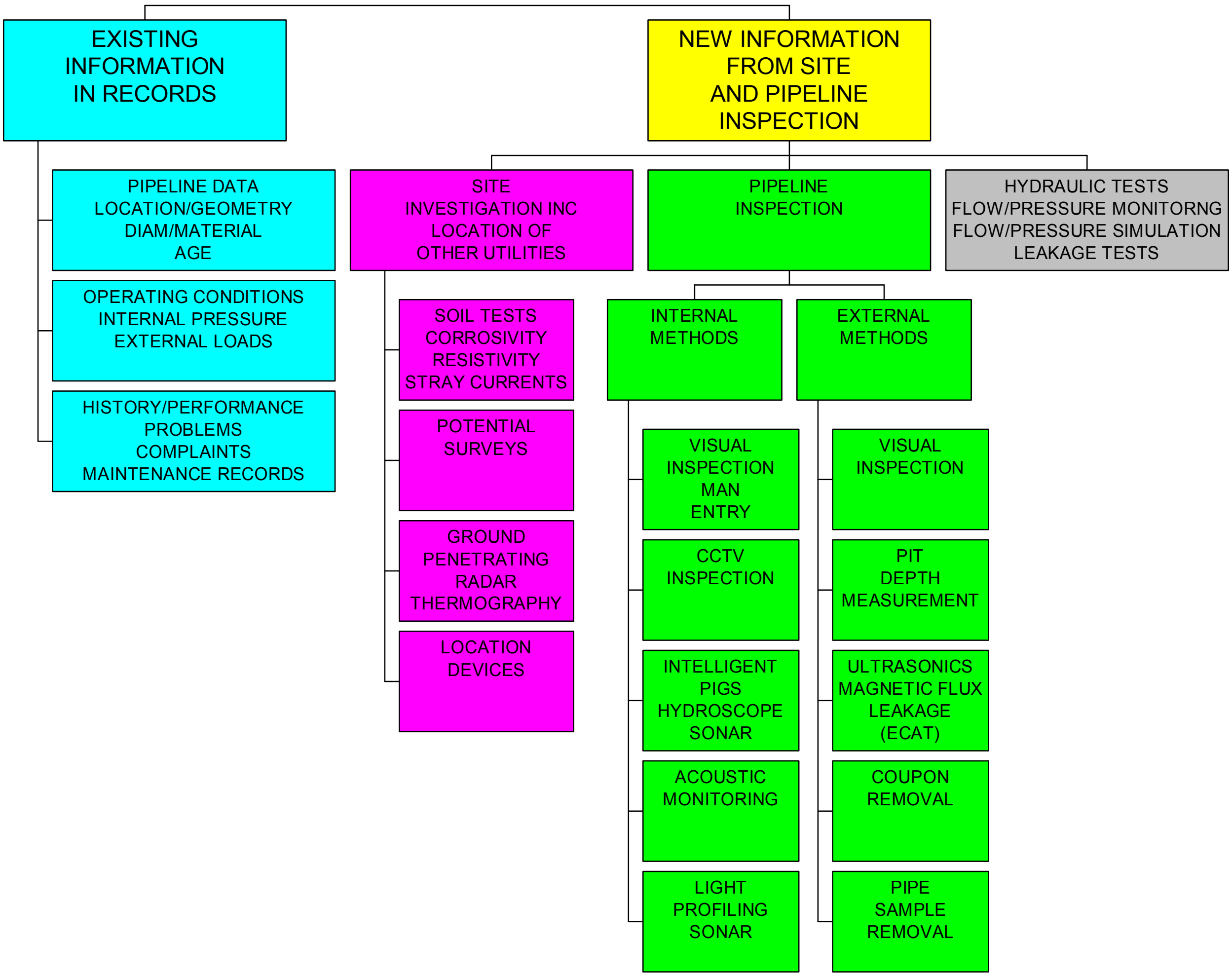
INTERNATIONAL SOCIETY FOR TRENCHLESS TECHNOLOGY	**TRENCHLESS TECHNOLOGIES RESOURCE CENTRE**	
	CONDITION ASSESSMENT AND REHABILITATION PLANNING	
	CONDITION ASSESSMENT INSPECTION TECHNIQUES	**OCTOBER 2005**

1 INTRODUCTION

A wide range of techniques is available to inspect buried pipes and assess the condition of the pipe. And these are summarised in Fig 1. They range from simple visual inspection to highly sophisticated electromagnetic techniques. The most widely used technologies are described in more detail in subsequent sections of this document

TYPE	NAME	PRNCIPAL	APPLICATION
TRADITIONAL METHODS			
EXTERNAL	VISUAL INSPECTION	The pipe is inspected at locations where it s exposed and the surface condition noted including the presence and condition of any corrosion protection	
	PIT DEPTH MEASUREMENT	Direct measurement of corrosion pit depth and distribution on ferrous pipes	
	ULTRASONICS	Ultrasonic inspection to determine wall thickness	
	COUPON REMOVAL	Use of under pressure tapping technology to remove a small coupon for laboratory evaluation	
	PIPE SAMPLE REMOVAL	Removal of full pipe samples for laboratory evaluation	
INTERNAL	VISUAL INSPECTION	Direct inspection in man entry pipe	
	CCTV SURVEY		
	SONAR		
	LASER PROFILE		
ADVANCED/XPERIMENTAL METHODS			

FIG 1.1 -INFORMATION SOURCES



TRADITIONAL MEHODS

EXTERNAL INSPECTION TECHNIQUES

VISUAL INSPECTION

These techniques make use of existing points at which the pipe may be exposed or points at which it is deliberately exposed for the purposes of inspection. In the case of metallic pipelines the inspection checks for signs of corrosion and any damage to external protection. However, most commonly these techniques are combined with one or more of the others described below.

PIT DEPTH MEASUREMENT

On metallic pipelines such as cast and ductile iron and steel it is possible to measure the extent of external corrosion by assessing the depth and distribution of corrosion pits. It is first necessary to expose the metal surface by removing any corrosion product and then mark a suitable grid on the surface. A simple gauge is then used to measure individual pit depths.

ULTRASONICS

On metallic pipelines ultrasonic equipment can be used to measure the remaining wall thickness of the pipe and to some extent the amount of pitting. However, special techniques are needed with cast iron pipes due to the in homogeneity of the wall, which can be rise to false internal reflections. The simple form of this technique is based on a hand held device but more sophisticated systems are available

COUPON REMOVAL

This technique involves use of under pressure tapping equipment to remove a coupon (50mm diameter) from the pipe wall while it is still operational. Examination of the coupon gives an indication of the type and extent of corrosion and in combination with measurement of external diameter it can also be used to determine the ID of the pipe. In the case of asbestos cement pipe the coupon can be tested in a compression rig and the results used to determine the residual strength of the pipe wall.

PIPE SAMPLE REMOVAL

This is the most effective and accurate method to determine the nature and extent of corrosion but since it involves closing down the section of pipe it is also the most expensive and disruptive. Typically a one metre long sample is extracted every 250 metres, sent to the laboratory for evaluation. A careful procedure is followed in which the corrosion product is removed and the weight change recorded and then direct measurement of internal and external pits carried out. This method is often used to calibrate the results of non-destructive testing.

The UK water companies have used this method on many thousands of samples and established a database of relevant information.

INTERNAL INSPECTION TECHNIQUES

VISUAL INSPECTION

In man entry size pipes this involves closing down the line and then manually inspecting the pipe wall to determine the degree of corrosion and other problems. The inspector would normally carry a video recorder and dictation device to retain the data.

In non-man entry pipes the inspection is carried out by a close circuit TV survey (CCTVS) as described below.

CCTV SURVEY

A wide range of equipment is available which can be mounted on a small tractor device or sled and driven or pulled through the pipe while recording an image of the pipe wall. This is the main technique used to assess the condition of brick concrete and vitrified clay sewers using a standard method of coding the observed defects to enable lengths of pipe to be assigned a structural grade from 1-5 (1 best and 5 worst).

In the most recent developments the camera has a pan and tilt capability to enable closer inspection of defects or lateral openings. Special software is available to control the progress of the survey and process the incoming data. The most sophisticated equipment (SSET) uses a special type of lens, which allows observation of sections of wall behind and in front of the camera and then automatic processing of the data to give a structural grade.

In addition to structural defects such as longitudinal and circumferential cracks the survey can also determine the location and condition of lateral openings and the condition of joints based on observation of live infiltration. Equipment is also available to survey laterals over distances of up to 20 metres when launched into the lateral from inside the main pipe. In the early days of sewer rehab the decision to renovate or replace a section of sewer was entirely based on information from the CCTV survey. However, more recently in the UK the decision to rehabilitate is based on the performance pipe as a sewer rather than the degree of degradation it has suffered.

SONAR

These methods are used as a supplement to the CCTV inspection of sewers in situations where the sewer is heavily silted or flowing. They provide information on the condition of the pipe beneath the surface of the sewage and/or silt layer. The equipment is frequently mounted on the same tractor as the CCTV equipment so the results can be integrated.

LASER PROFILE

This technique is used to determine the shape of a sewer and in particular any ovality or vertical deflection caused by the interaction of sewer defects and external loads. This information is important since it affects the design of liner systems.

ACOUSTIC MONITORING TECHNIQUES
Acoustic monitoring can be used for two purposes

a) To detect and locate leakage
b) To detect and locate the degradation and failure of the prestressing wires in Prestressed Concrete Pressure Pipes

Leakage

For leakage detection, water distribution system can be systematically checked for leaks using acoustic equipment to detect the sound or vibration, induced by water as it escapes from pipes under pressure. Traditional techniques have relied on the detection of leakage from above ground using accelerators or hydrophones attached at strategic location to the pipeline

A recently completed study of leak detection methods for plastic pipes demonstrated that leaks in plastic pipes could be located using acoustic equipment. More recent work indicates that the use of inverse transient analysis for signal interpretation of transient events in water network pipelines may offer a methodology for the detection of leaks in a complex networks and alleviate many of the problems associated with signal interpretation in cross correlation techniques. Similarly to the work discussed above, studies are also being carried out on wavelet analysis to try to relate the changes occurring in wavelets associated with transients, to losses in pressure and the location of leaks.

Recent developments in acoustic detection of leaks in pipelines have concentrated on in-pipe assessment. Sahara uses an in-line acoustic sensor attached to an umbilical cable, which is fed along up to 2 km's of pressurized pipe. This is used to detect the exact location of leaks in the pipeline by logging the distinctive acoustic signal in the pipeline generated by a leak as the sensor passes along the pipe.

A major task still to be undertaken in the area of acoustic detection, is the relation of the size and frequency of leaks to the overall condition of the systems and the cost benefits that can be obtained by repairing or replacement of pipes with significant leakage

PCCP CONDITION MONITORING

Techniques have been developed to detect locate and evaluate the sounds emitted by failing prestressing wires in PCCP pipes. Such monitoring can then be used to trigger localised rehabilitation to prevent final failure and the catastrophic contingent damages frequently associated with such failures

ADVANCED/EXPERIMENTAL TECHNIQUES
ELECTROMAGNETIC METHODS

These techniques induce an electro magnetic field in the pipe wall from a transmitter and then determine the extent to which the field is changed in amplitude and/or frequency by its passage through the pipe wall. The signal is then evaluated by sophisticated computer software to produce a plot of local thickness variation. There are a number of different techniques

In Remote Field Technology (RFT), the signal is induced into the pipe by an internally or externally placed coil (exciter), which is energised by a low frequency voltage. This generates eddy currents and magnetic flux lines, which radiate as an electromagnetic field from the exciter. At a distance of about three pipe diameters, the field in the pipe wall is stronger than the field within the pipe, and sensors positioned in this 'remote field region' can detect minor variations in the field strength. The signal arriving at the detector is typically very small (only a few micro volts) and very sensitive electronics are required for its measurement. Broad Band Electro Magnetic (BBEM) induction techniques record data over a broad range of frequencies and consequently should have advantages over RFT. The principle of BBEM is to transmit a signal that covers a broad frequency spectrum (i.e. perhaps 3 decades). The received signal resulting from a broadband transmission contains more information, and allows detection and quantification of various wall thicknesses as well as the effective conductivity of the complex through-wall components of the pipe. Instruments for acquiring BBEM data are based on the time-domain electromagnetic techniques (TDEM) initially developed in the 1970s where the transient decay of the magnetic field is measured following the interruption of current flow in the transmitter coil. This technology has now been extensively modified for pipe diameters of 100 mm and greater. However, Low Frequency Electromagnetic (LFEM) has some advantages over BBEM in that it is consequently faster and can be more cost-effective.

The methods also differ in their dependence on the distance of the sensor from the pipe wall and the effect of corrosion products. The least sensitive method is BBEM, which can use a hand held transmitter and sensor or a special version of the equipment can be lowered into a micro-excavation and held just above pipe surface. The other techniques use equipment mounted on an assembly, which facilitates scanning of either a circumferential or a longitudinal strip of the pipe or maintaining the sensor at the correct distance from the pipe wall.

This type of equipment can also be mounted on an Intelligent Pig and used to scan the inside of the pipe. The PIG is either propelled through the pipe by water pressure or pulled with a winch. This provides data covering a continuous section of pipe wall between access points and hence is the most accurate and comprehensive means of assessing pipe condition. However, it does involve shutting down the pipe and in the case of water mains dealing with the effects of disturbing the corrosion product layer.

Use of this technique can be expensive and time consuming, and a number of contractors in the USA have attempted to justify the cost by setting them against the savings, which can be obtained by postponing rehabilitation or using a less expensive renovation technique. A number of attempts can be made in the USA to achieve the inspection contract, which recognises the savings and expenditure and sets it against reduced costs in new treatment works.

LINEAR POLARISATION RESISTANCE

A number of methods have been suggested to allow correlation of the corrosion of metallic pipes with the corrosivity of the soil. These include the pipe to soil potential, Pearson surveys, remote resistivity and direct current voltage gradient However, the most advanced technique appears to be linear polarization technique (LPR), which is based on laboratory measurement of the polarization resistance of soil samples taken near metal pipes and is used to determine their corrosion rates in various soil types. By knowing the polarization resistance, R_p, an estimate of the corrosion rate of metal pipes can be made to allow an estimate of their lifetime and their future propensity to fail and leak Although the limitations of LPR are known, it is a practical and low cost method for corrosion assessment, and has been successfully applied in combination with extreme value statistics to determine the performance of many critical mains in Australia.

USE OF INSPECTION RESULTS

THE ROLE OF CONDITION MONITORING

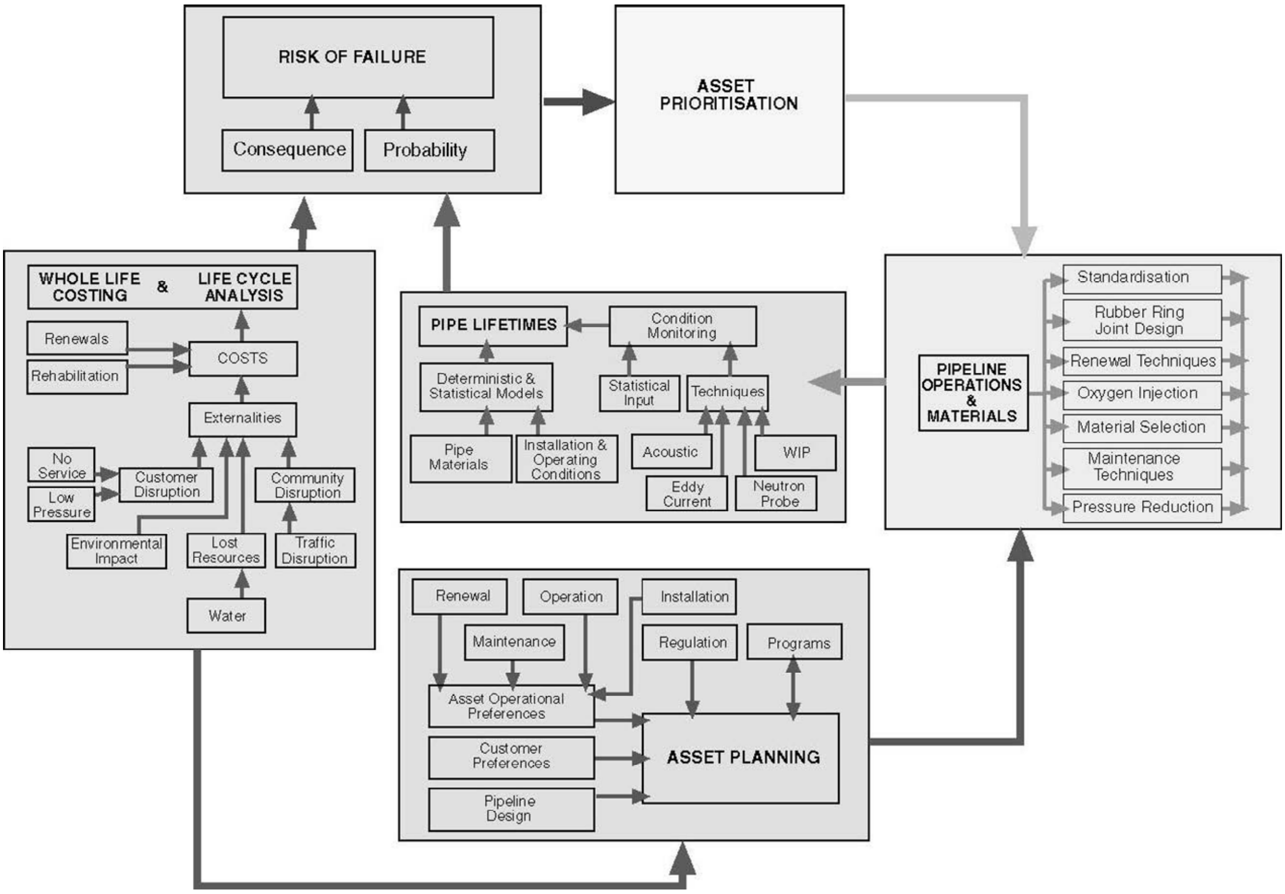
The development of asset planning and prioritization models has highlighted the need for accurate failure data for the range of pipeline materials installed in a water or sewer network working under varied installation and operating conditions. Either this failure data can be developed at a cohort level or where possible for individual assets, depending entirely upon the amount of statistical or empirical data that is available to allow models to be generated. The assessment of the failure probability or condition of a pipeline is central to any decision with regard to its upgrading or replacement and as shown in Figure 1 condition monitoring is a critical factor in confirming the lifetimes to be used in asset planning or prioritization (Burn et al., 2001).

The increasing need for more reliable data during condition monitoring of pipelines has prompted infrastructure managers to start looking for enhanced alternatives to CCTV. Although, in most instances the extra costs associated with these techniques has precluded their use, except in those areas where the consequence of failure is a critical factor in the pipeline operation.

CONDITION MONITORING TECHNIQUES

The condition monitoring technique required to assess the condition of an individual pipe asset is pipe type specific, and to a lesser extent, location specific. To allow assessment of the remaining life of a pipeline or to establish its probability of failure, information is required on a significant number of factors, which varies from pipe type to pipe type, but may include, pipe wall thickness, pipe wall defects, pipe deflection, soil support conditions, soil movement index and soil corrosivity . For water pipelines, these systems have concentrated on assessment of a single property such as remaining wall thickness or the presence of leaks, whereas for sewer systems the use of multi sensor systems has been investigated however, water pipelines require significant information on a number of properties to allow condition or lifetime assessment. Consequently, the development of multi-sensor systems for water pipelines that can be inserted through a hydrant or used from the ground above the pipe would seem to be necessary. The reasons for this lack of development of in-pipe systems for water pipelines stem from a large number of difficulties associated with water quality issues, due to the disturbance of sediments, the need to maintain continuity of supply and the lack of easy access into the pipeline, hence the need to insert the system through a valve such as a fire hydrant.

The relationship between the various types of inspection results and the components of an AMP for water mains are illustrated in the diagram below.


RISK OF FAILURE
Consequence
Probability
ASSET PRIORITISATION
WHOLE LIFE COSTING & LIFE CYCLE ANALYSIS
Renewals
Rehabilitation
COSTS
Externalities
No Service
Low Pressure
Customer Disruption
Community Disruption
Environmental Impact
Lost Resources
Traffic Disruption
Water
PIPE LIFETIMES
Condition Monitoring
Deterministic & Statistical Models
Statistical Input
Techniques
Pipe Materials
Installation & Operating Conditions
Acoustic
WIP
Eddy Current
Neutron Probe
PIPELINE OPERATIONS & MATERIALS
Standardisation
Rubber Ring Joint Design
Renewal Techniques
Oxygen Injection
Material Selection
Maintenance Techniques
Pressure Reduction
Renewal
Operation
Installation
Maintenance
Regulation
Programs
Asset Operational Preferences
Customer Preferences
Pipeline Design
ASSET PLANNING