ACHIEVING ZERO LEAKAGE BY 2050: LEAK DETECTION AND LOCATION – NON ACOUSTIC METHODS

Report Ref. No. 17/WM/08/62

Programme Area & Reference	**Water Mains & Services: Leakage WM/08**
Report Title	**Achieving Zero Leakage by 2050: Leakage Detection and Location – Non-Acoustic Methods**
Project Management	**Amanda Fletton, on behalf of UKWIR**
Contractor	**WRc**
Author of Report	**Bold, M** **Bond, A** **Lamont. J** **Snowdon, C**
Period Covered	**2016**

UK Water Industry Research Limited provides a framework for a common research programme to undertake projects which are considered to be fundamental to water operators on 'one voice' issues. Its contributors are the water and sewerage companies and the water supply companies of England and Wales, Scottish Water, Northern Ireland Water and Irish Water.

UKWIR Report Ref No 17/WM/08/62

Published by UK Water Industry Research Limited Room EA1, 1-7 Great George Street, London, SW1P 3AA

First published 2017

ISBN 1 84057 837 8

Printed by Webree.com Ltd.

UK WATER INDUSTRY RESEARCH LIMITED

ACHIEVING ZERO LEAKAGE BY 2050: LEAK DETECTION AND LOCATION – NON ACOUSTIC METHODS

Executive Summary

Objectives

This project is one of five UKWIR projects that form a strategic research programme to address the question "How can we achieve zero leakage by 2050?". The project aimed to identify what research and development will be required to facilitate the path to zero leakage. This report focuses on non-acoustic methods of leak detection and location. It is complemented by a review of acoustic methods that has been carried out by the Institute of Sound and Vibration Research at the University of Southampton (reported separately).

Methodology

In order to achieve this objective, the following activities have been carried out for each review:

- A review of research and development already carried out, and a broad indication of the results.
- Identification of research and development currently in progress.
- Assessment of the gaps, and therefore the additional research that is required to enable the eventual achievement of zero leakage.

The information has been collated from reviews of academic literature and conference proceedings, as well as conversations with key contacts amongst manufacturers and academia. We have also surveyed 14 UK water company representatives to find out the extent to which some of the identified techniques have been trialled and the outcomes of these.

Conclusions and Recommendations

A number of potential research challenges were identified resulting in outlines for three proposed research projects.

- Fibre optic trials for new and existing networks.
- Making best use of aerial monitoring methods.
- Improving the effectiveness of walking the line.

For each of these projects we have provided information on the impact, the background, the objectives and have identified the outcomes that need to be achieved.

For further information please contact UK Water Industry Research Limited, Room EA1, 1-7 Great George Street, London, SW1P 3AA quoting the report reference number

Contents **Page Number**

1 Introduction

UKWIR has recognised a need to undertake major strategic projects to help deliver a step change in innovation in the water industry. The first strategic area that UKWIR is addressing is leakage, and specifically seeks to explore 'How can we achieve zero leakage by 2050?' The rate of reduction in leakage has slowed over recent years, although leakage rates are still significant.

The target of zero leakage is extremely ambitious and cannot be achieved with existing processes, techniques and equipment. Therefore this review, one of six separate reviews, aims to identify what research and development will be required to facilitate the path to zero leakage.

2 Methodology

In order to achieve this objective, the following activities have been carried out for each review:

- A review of research and development already carried out, and a broad indication of the results.
- Identification of research and development currently in progress.
- Assessment of the gaps, and therefore the additional research that is required to enable the eventual achievement of zero leakage.

This report focuses on non-acoustic methods of leak detection and location. It is complemented by a review of acoustic methods that has been carried out by the Institute of Sound and Vibration Research at the University of Southampton (reported separately).

There are many techniques for detecting and locating leaks in water pipes, each suited to a different type of pipe and environment, Table 1 lists the methods available for detecting and locating leaks. Correct selection of these techniques is key for accurately locating leaks, and combinations of techniques are often required in a network to effectively pinpoint leaks. It is because of the diverse range of network materials and ground conditions that such a range of detection methods exist and is required.

Table 1 Leak Detection and Pin-Pointing Techniques

Detection	Detection and pin-pointing*
Step test	Gas detection
Satellite imaging	Radar
Aircraft and drones	CCTV
Network and flow processing	Walking the main

Detection	Detection and pin-pointing*
Multi-senor platforms	Conductivity
Hydraulic pressure	Ferret Leak Detection
Fibre optics	Condition assessment
Customer contacts	

*Pin-pointing refers to the specific location of the leak, as opposed to identifying a section of pipe.

The following sections provide a brief description of currently available and new techniques for leak detection and pin-pointing along with details of any development work being done. The information has been collated from reviews of academic literature and conference proceedings, as well as conversations with key contacts amongst manufacturers and academia. We have also surveyed 14 UK water company representatives to find out the extent to which some of the identified techniques have been trialled and the outcomes of these.

3 Results and Discussion

3.1 Gas Detection

Water leaks can be detected and located using gas injected into the pipe. Typically industrial hydrogen gas (95% nitrogen, 5% hydrogen) is used, although sulphur hexafluoride (SF6) can be used as the tracer gas with an appropriate detector. The gas is injected at a hydrant and the user walks along the length of the pipe with the detector. The hydrogen gas mixture is less dense than the water and so escapes through cracks and holes and diffuses through the ground to be detected at the surface. The concentration of gas is highest nearest to the leak, thus allowing the leak to be located.

The sensitivity of the device is linked to the detectors ability to detect changes in the concentration of hydrogen in the air. This technique is suitable for all types of pipe material. It is more suitable for small to medium sized pipes due to the quantity of gas mixture that is required. The limitation of this technique is that the user must be able to follow the path of the pipe and this is less suitable for pipes under buildings and other infrastructure or where the path of the pipe is unknown. Another factor effecting sensitivity is the soil type, non-porous soils don't allow the gas to escape as easily and so as a result the gas may not be detected at the leak.

This technique is well established and developed and it is used widely in the UK and overseas. Companies who offer this technology include Seba (www.sebakmt.com) and Sewerin (www.sewerin.co.uk). Discussions with the suppliers of this technology showed there is very little, if any, research and development work being done. It is felt that this technique has reached maturity and there is very little which could be done to improve on it.

Figure 1 Gas detection technique

Seba

Of the interviewed UK water companies all were aware of and had used gas detection. The general comments were that it was not used widely due to the cost and the limitation to smaller pipe sizes, most used it on customer side leakage. Some water companies had encountered issues with poor performance due to surface permeability and the technique causing water quality issues. Two water companies are investigating its use for larger pipes using a helium gas tracer.

3.2 Radar

There are two main forms of leak detection using radar: ground penetrating radar (GPR) and ground Doppler radar (GDR). These techniques are less developed for leak detection and while proof of concept testing has been performed there has been limited on-site testing in real world situations.

The results from the survey of UK water companies showed that all the companies who responded were aware of radar leak detection methods and around half had trialled the technology (only half were aware of ground Doppler radar and none had trialled). The feedback on the trials showed that most found the technique to be too expensive with poor results which varied depending on user and ground conditions. Some commented that they use the technique for asset location where it is effective. Those who have not trialled radar methods reasons were either due to it not being considered cost-effective, being at too early a stage to trial or not needing this type of technology.

3.2.1 Ground Penetrating Radar

GPR utilises electromagnetic radiation which propagates through the ground and is reflected back to the surface where it is detected. The reflections occur at changing soil conditions, specifically when the dielectric constant changes. The velocity that the waves travel through the soil is dependent on the dielectric constant and so by analysing the detected reflections energy knowledge of the subsurface structural variations and conditions of the soil can be obtained.

GPR is typically used for asset location (metal and plastic pipes) in the UK as the ground conditions make it less effective at leak detection. Land-Scope (www.land-scope.com) offer asset location using GPR in the UK. This technique is most suitable for leak detection in areas where the soil is dry and so a leak causes a significant change in the dielectric constant.

Figure 2 Ground Penetrating Radar Technique

Land-Scope

The EU funded project GPIR Waterpipe (www.waterpipe-eu.org) was undertaken between 2006 and 2009 to develop a ground penetrating imaging and radar (GPIR) instrument capable of detecting leaks and that contained a decision support mechanism for assessing damage to water pipes to enable the most effective and economic rehabilitation to be performed. The collaborative project successfully built a prototype instrument that used ultra wide band pulse signals to allow for leak detection and asset condition to be recorded.

Microwave signals have been shown as an improvement to the traditional acoustic signals used in GPR, due to the greater Doppler shift that can be seen. An EU co-funded research project, GPR Leaking (GRD1-2001-40284) (www.leaking-project.com/English/index.htm), was conducted in 2001 to develop a prototype instrument for leak detection using microwave based GPR. The project built a prototype which was tested in the UK, Greece and Germany on a range of pipe materials. The device was shown to be particularly effective at detecting leaks on PVC pipes and performed better than traditional GPR. From the trial it was estimated that the length of time for a survey was eight hours per 30km of pipeline. UK partners involved in this project included Sewerin (www.sewerin.co.uk), a company who specialises in leak detection and pipe location. However at present Sewerin do not offer any form of GPR service and there is no plan to commercialise the prototype built at present.

'Sensport' (sites.uclouvain.be/SENSPORT) is a project being done at the Georadar research centre Louvain (2013-2016) and is sponsored by La société wallonne des eaux (www.swde.be/en) (Belgian Water Utility Company) which aims to develop a GPR technique that can be used to detect leaks in water distribution networks. This project also uses microwaves along with a vector network analysis to improve the data processing. The final outputs of this research will be available in July 2016 and the head of the project stated that depending on the outcomes commercialisation may be an option.

Mapping the Underground (www.mappingtheunderworld.ac.uk) is a large collaborative project being conducted in the UK comprising of contractors and universities, funded by the EPSRC, with the aim of creating a multisensory device capable of tracing all underground assets. Advanced GPR techniques are covered in the project and research is being conducted into the effects of soil on GPR with the aim of improving GPR so it can be used in the UK. While the project is not looking at leak detection the fundamental research is applicable and could help advance the research into GPR for leak detection.

3.2.2 Ground Doppler Radar

GDR uses a similar principal to GPR but uses the Doppler shift in the frequency of reflected waves to identify leaks. In order to tell whether a Doppler shift is present, and the extent of the shift, greater data processing is required. This is one reason why this technique is less developed than GPR.

The FOI (www.foi.se/en) (Swedish Defence Research Agency) is working on developing a faster detector for GDR[1]. The detector set up in this device is different because it detects pure fluctuations of the water surface. These occur if the shape of the water surface is changing due to water flowing through the ground, such as a leak from a pipe. This device has a much faster detection time than other GDR systems. It is unclear yet whether this technique would be more suitable for use in the UK than GPR at detecting leak as testing has not been done. However, in theory it should be more effective in cold and wet soils because you are detecting the flow of water through the ground. As a result of the project a patent was filed for the device and method for detection of water flow in ground (US 9057792 B2).

3.3 Continuous Monitoring Technologies

There are two main categories for continuous monitoring technologies: fibre optics and multi-sensor platforms. Fibre optic cables are permanently installed onto the network, whereas multi-sensor platforms can moved around and retrofitted.

3.3.1 Fibre Optic Cables

Fibre optic cables can be used to detect leaks in two ways: distributed temperature sensing (DTS) and distributed acoustic sensing (DAS). In both cases a fibre optic cable is laid along the length of the pipe. When a leak occurs the signal from the cable can be used to locate the leak along the length of the pipe based on the time delay of the signal.

DTS cables measure changes in temperature to detect a leak. Generally the temperature of the water is different to that of the surrounding soil, therefore when a leak breaks out the temperature of the soil changes. The temperature differential is seen as a change in the reflection of the laser beam pulse. This technique is most suitable when the water and soil temperatures are different, and it can be used on all pipe materials. In the UK these conditions are achieved only in certain circumstances, for example in winter when the soil temperature is at its lowest (~3^{o}C) and water from a surface water source is warmer (~12^{o}C). A second example is when pipes that are close to the source and so the heat of the water has not had time to dissipate. This means that the system is not suitable for wide scale deployment in the UK.

DAS cables measure Rayleigh scattering to detect leaks. A leak in a pipe causes strain on the cable which affects the acoustic frequencies in the fibre. These changes can be detected and used to locate the leak along the pipe. This technique is suitable for most types of network. Acoustic leak detection is being covered in greater detail for this study by Southampton University.

Many providers of this technique combine both methods into one cable to improve the effectiveness. This is known as distributed temperature and strain sensing (DTSS), such as TTK (www.ttkuk.com/water-acids-leak-detection), E S&S (www.esands.com/Newsletters /GEO/FibreOpticSensing.html), and Silixa (silixa.com/technology/idas). The major limitation of this method is that the cables are best installed as the pipes are laid. It is difficult to install them later for DTS, as the cables must be on the outside of the pipe. Methods of installing fibre optic cables when pipes are laid are covered in Lot 4 – Laying Leak Free Networks.

Retrofitting fibre optic cables to the inside of pipes is simpler and could be a possible solution for DAS cables. In Japan telecommunication fibre optic cables are installed into sewers and the technology exists to install them on their own or as part of a rehabilitation programme using cured in place liners.

Half the UK Water companies we contacted were aware of the potential for fibre optics to be used in leakage detection, but most considered it not necessary as part of their current mix of tools and technologies. One company was actively considering a trial, but was at early stages in discussions.

In Australia one system – HAWK (http://www.hawk.com.au/productdetail.asp?id=59) – is being trialled, with results expected during 2016. This has included looking at options for insertion of the optic fibre cable into live water main (http://www.iwn.org.au/pipe-rover-leak-detection-program/).

3.3.2 Multi-Sensor Platforms

Multi-sensor platforms use a range of parameters to assess if a pipe is leaking, these include: pressure, transients, acoustics and temperature. Using the combination of sensors allows for better leak location, the risk of false positives is reduced by requiring multiple parameters to register that a leak has occurred.

These sensors are located at points along the pipes (separation distance depends on the type of network and manufacturer) typically near to hydrants where access is easier. Sensors and data loggers are generally battery powered with battery lives of 5-10 years. As batteries continually improve the life of the loggers are also improving, and have multiple options for data transmission.

There are a variety of sensors available for different types of pipe material making this a suitable solution for most networks, in particular urban networks where there is a higher density of pipes and better telecommunication facilities. Companies which offer multi-parameter systems include Ashridge (www.ash-eng.com) (TextLog), Syrinix (syrinix.com) (TransientMinder) and Echologics (www.echologics.com) (EchoShore).

Syrinix (syrinix.com) PipeMinder is a solution that will monitor specific lengths of pipe. This uses higher resolution pressure, flow and vibro-acoustics data. This can then manage risk of failures on certain strategic or critical lengths of pipes for example near to railways.

Transients are known to cause network problems and increase the risk of leaks and bursts. Locating sources can be problematic and there are now solutions developed for this specific purpose. Many logger manufacturers now do some sort of transient or fast logging though inflowmatix (inflowmatix.com/) is a start-up dedicated to extensive investigation of hydraulic transients. This combines hardware and software to combat transients and protect network assets.

Current development work by both the technology suppliers and research groups is focussed on improving the accuracy of the sensors so they are less sensitive to background interference. Development work is also being carried out to improve the algorithms used to identify leaks from the signal. This involves changing sampling frequencies so they are higher at night when there is less background noise and improving the matching criteria for a leak to enable smaller anomalies to be identified and monitored from the background noise.

Research into new analysis models includes using the 'Extended Kalman Filter' which improves the aspects of modelling related to the pipe diameter. In most current models using the Water Hammer Equations, the pipe parameters are assumed to be constant along the length of the pipe. In reality this is not the case and thus results in uncertainty in the leak detection. By using the Extended Kalman Filter method, which accounts for variability in pipe properties, smaller anomalies can be detected in the profile.

A supplier of this technology told us that there are two main methods of leak detection currently being developed: acoustic correlations and statistical analysis from static pressure. The supplier told us that there is a growing trend in more permanent monitoring of the network for leaks and different methods are more suited for different types of pipe. Their product is aimed at large diameter pipes where as other companies specialise in products for particular pipe materials. The supplier told us that at present most water companies hire their system to conduct leak detection surveys (providing a service) rather than training their staff to use the equipment (providing a product). This is because the sensors are usually moved around the network and there are few places where they are installed permanently.

However they believe that in the future permanent logging in the network is going to be more common rather than just scanning the network, especially in high risk areas. This is because permanent logging allows leaks to be found as they form and allows them to be monitored to find the most economic time to fix them and to improve work planning. It allows for other aspects of the network to be prepared for leak repair, such as exercising valves to ensure they work properly and to prevent large pressure transients forming from improper valve use.

The supplier feels that the technology already exists to challenge background leakage levels and beat the natural rate of rise but the issue is the slow uptake of technology within the water industry. The supplier has sensors for distribution and trunk mains and the software to support wide scale deployment of these sensors. However, this requires a large investment and a change in operations, there has not been wide scale adoption.

Most of the UK water companies surveyed were aware of this type of technology with different products having different levels of awareness and had trialled at least one product. Generally the feedback was good with most adopting the technology as part of their leakage management system. Those that have not used this method main reason were cost, although one company said their trial gave poor results.

3.3.3 Hydraulic Pressure Sensors

Technologies such as the Ferret Leak Detection system (www.ferret-Technology .com) that uses a simple hydraulic process to locate leaks by noting changes in upstream and downstream pressures either side of a leak. The process is powered by the water pressure in the leaking pipe, which moves the inflatable head along the pipe using the water pressure until it meets a leak where the change in pressure stops the device. The technology is not reliant on leak noise or prior knowledge of the pipe route to deliver extremely accurate leak locations.

The system can be used on the full range of pipe materials and a sonde can be attached to the sensor to locate and determine the depth of the pipe. It is currently used for customer supply leakage but the company is seeking to develop a larger version of the device that is more suitable in the distribution network.

Of the interviewed UK water companies almost all were aware of and had trialled the Ferret Leak Detection System. Most of these have continued to use the technique finding it cost-effective, and giving good results. Those who did not adopt this technique said the reason was due to poor results in the trials. Another company commented that while they use it the method has limited application.

3.4 Active Interventions

The main form of active intervention for leak location is step testing. Step testing involves shutting of sections of the network (typically sub-DMA) and monitoring how the flow and pressure changes. If one area changes more than the others (seen as a step when viewed graphically) it is most likely due to a leak. This procedure is generally carried out at night to reduce the impact of customer use on the flow data. Estimations have to be made for legitimate customer use, in the same way as needed for other night flow analysis.

This is a mature technology which is widely used in the UK and the technique remains relatively unchanged and is provided by companies like Palmer Environmental (www.hwm-water.com) and Seba (www.sebakmt.com). The main recent developments of step test technology include:

- improving the range over which the equipment can communicate (this has limitations as a larger distance covered will not improve the ability to narrow down areas with high leakage); and

- improving the sensitivity of the flow and pressure sensors. This will improve the ability to detect small leaks in the section. This must also be combined with improvements to the data analysis so that leaks can be separated from background noise which is detected.

Step testing can be carried out on all pipe materials and sizes. There is a need to have a proficient workforce who can operate valves appropriately to stop transients and surges which could trigger a leak or burst at weakened points in the network. Pressure transients can also trigger water quality issues in the network by disturbing sediment in the pipe[2].

All the UK water companies who responded to the survey knew about step testing and had used it at some point. Many water companies considered it to be 'business as usual' or standard practice using this method widely. One water company stated that they do not do step testing often due to the need to close valves. Another commented that they see step testing as a methodology rather than a technology to detect leaks.

Figure 3 Step Test Technique

Palmer Environmental

3.5 Visual Inspections

There is a range of visual inspection techniques which require varying levels of technology. The most advanced methods use light aircrafts, drones and satellites, while the least advanced involve walking the main and looking at the ground.

There are several methods for locating leaks visually: using thermal images, vegetation cover and looking at chemical signatures.

Large areas of land are scanned with both thermal cameras and normal cameras. This technique is most effective in areas with hot, dry climates, as the temperature difference in the soil caused by leaking water is more clearly seen. Vegetation cover can also be used as an indicator for leakage, calculated using the normalised difference vegetation index (NDVI).

Lush vegetation is often seen around pipes with a leak compared to other areas along the pipe without a leak. The combination of infrared and visual imaging can then be used to find leaks.

Visual inspection is generally performed in rural areas where vast areas of land need to be covered[3]. However it can be used in certain types of urban environments with the imaging carried out closer to the ground. The imaging in urban areas need to be closer to the ground so that buildings and other infrastructure do not obscure the view of the pipe and to reduce thermal distortions caused by buildings and pollution.

Development in this technique is focused on improving the automatic detection of leaks from the images. The technology hardware is commercially available (thermal cameras, drones etc.) and is being developed by other industries which is making this technology cheaper and more widely available. For this technique to be successful a higher degree of leak detection is needed automatically.

When asked about thermal imaging, spectral and vegetation density scanning using aircrafts, drones and satellite images most interviewed water companies were aware of at least one of the techniques, although thermal and spectral imaging were more widely known. Several water companies are in the process of trialling or were planning to trial these methods. The use of aircraft and drones was more common than satellite imaging.

Vegetation density scanning had been tested by one UK water company we spoke to; however they indicated the results had not been positive. Others who were aware of this method but not trialled it reason was that it was not considered viable, mainly due to the amount of rainfall received in their catchments or being only useful in rural areas.

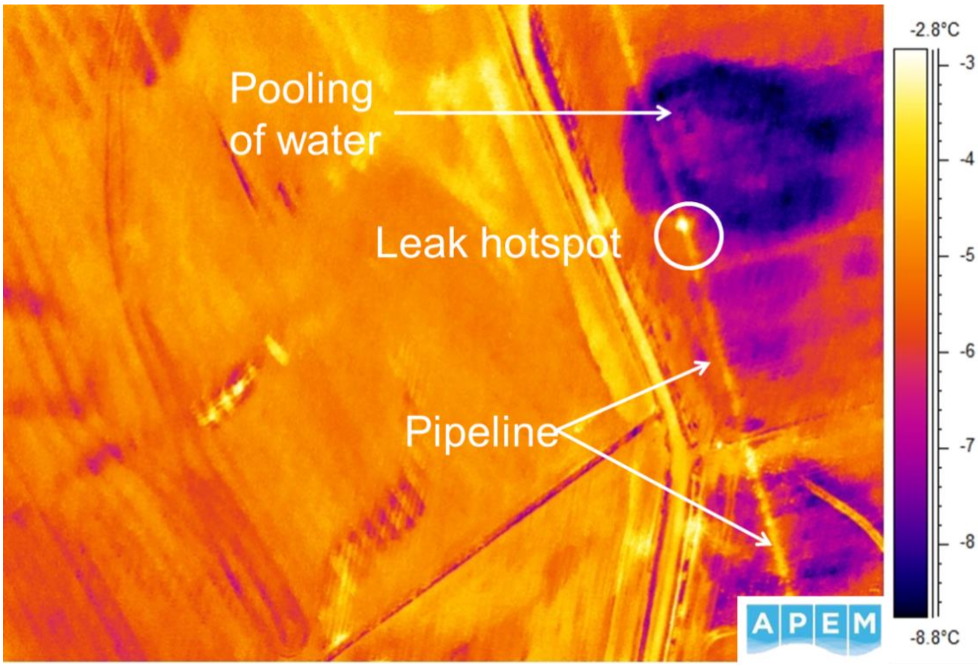
3.5.1 Aircraft and drones

A study in Qatar[4] used the combination of ground penetrating radar (GPR) with infrared (IR) imaging to locate leaks. The GPR was used to identify and locate the pipes and then IR photography was used to detect leaks. The two images where overlaid to give the location of the leaks along the pipes with an error of 2.9-5.6%.

Thermal and visual imaging services are available in the UK, by companies such as APEM (www.apemltd.co.uk). APEM has two methods for leak detection, using colour and near infra-red imaging to measure vegetation density and the other using thermal imaging to detect temperature differentials. Measuring vegetation density is best done in the summer and in periods of water scarcity because this allows for the greatest difference in vegetation growth to be seen. Thermal imaging inspections are generally conducted in winter when the ground is colder than the water; Figure 4 shows a thermal image of a leak.

Both techniques have been successfully used to identify leaks in the UK. More research is needed to improve the automation of leak detection and the accuracy of identifying leaks. APEM told us that the more surveys that are conducted the quicker they will be able to improve the leak identification. This requires clients to follow up and feedback on which were real and which were other types of anomaly. APEM feel that this technique is most useful at early stage leak location in rural areas to allow the prioritisation of more intensive on ground leak location activities on trunk mains. This technique is not suitable for urban areas where there is less vegetation and there is more background interference for thermal images.

Figure 4 Thermal imaging of a leak



APEM

3.5.2 Satellite images

Collaboration between Cyprus University of Technology, Foundation for Research & Technology, Hellas, and Frederick University[5] is working on developing algorithms for detecting vegetation anomalies from QuickBird satellite images. These could be used to signify a leak from visual images along with improving the analysis of thermal differences in the soil for identifying leaks.

Spectral aerial images from satellites can be used to detect leaks. By overlaying the satellite images on GIS images it is possible to identify which assets are causing the leaks. Utilis have developed a leak detection system using this approach which is based on microwave reflectometry as water exhibits a high value of relative dielectric permittivity and so allows a measurement of water in soil to be made. Utilis's system has been successfully trialled by AEGEA in Brazil. The spectral satellite images for the area of interest are acquired and radiometric corrections are applied to enhance the image. Using a special algorithm the leaks are then detected and displayed on a web based app. The leak detection algorithm uses the fact that drinking water has a particular spectral signature which can be identified in the images. This means that leaking drinking water can be identified around the pipe network.

This method allows for large areas to be investigated in a short space of time. This technique is suitable for urban environments as the drinking water signature can be picked out from the background pollution. It does not rely on differences in factors such as temperature, which other visual inspections methods use. Assessments can be carried out at regular time intervals and direct comparisons can be made by looking at the images and observing the progression of leaks. The system has been shown in the field to have an accuracy of between 6 and 24m with a minimum leak detection size of 0.1 litres per minute. Ground leak detection teams are still required to pin point the leak.

Rezatec (www.rezatec.com) use satellite images to monitor land use for catchment management but their system can also be used for leak detection by looking at soil wetness and vegetation density. This is a similar method to APEM but using satellite images.

3.5.3 CCTV

CCTV inspections can be conducted on live water mains to give images of the inside of the pipe. This can be used to identify defects in the pipe, along with build of sediment or invasive species like Quagga mussels.

The camera is inserted through a specialist fitting and is pulled through the pipe recording the video. The video can be reviewed in real time or later and the location is stamped on the video footage so that interventions can be performed in the correct location. Companies who perform CCTV on live water mains include WRc Assess and Address® (www.wrcplc.co.uk/pipeline-assess-address) and JD7 (www.jd7.co.uk).

The technique is relatively well advanced, and is used commonly in the wastewater network. The development of this technology lies in the improvements in imaging, as the quality of CCTV cameras improve more detail will be seen which will allow for smaller defects to be detected.

Around 75% of the interviewed water companies were aware of CCTV as a method for detecting leaks with almost all of them trialling or using it. The feedback from those who use the technique showed that it was mainly used in specific situations such as on construction sites, where there is complex pipe work, for complex leaks or difficult to access areas such as river crossings. Those who have not adopted it reasons were it was not needed or they found it more effective for condition assessments.

3.5.4 Walking the main

This method of leak detection involved a technician walking along the path of the water pipe looking for signs of leaks. It is often combined with basic acoustic techniques like listening sticks. This is a very basic form of leak detection and can only find visible leaks. If it was combined with a more sophisticated inspection technique, such as infrared goggles (to identify changes in temperature which could be a leak) a technician may be able to find more leaks. There is little development work currently being done to improve this method, despite it being a major activity undertaken by most UK water companies.

3.5.5 Customer contacts

Customers can report visible leaks or suspected leaks on their supply pipes by contacting their water company. Most do this online via the company website or sites such as Fix my Street (www.fixmystreet.com) or by calling the water company report line. This is a cost effective form of reactive leak detection because it requires minimal effort from the water company. However it only results in visible leaks, and is also highly weather dependent as leaks often are not spotted by the public after rainfall events (as the ground is wet).

The potential of this method of leak detection could be maximised through the use of gamification or citizen science techniques, or by having a simple app to use which can use the location from the phone to place the location of the leak. Social media, in particular Twitter (twitter.com), has become a popular way for customers, of all industries, to report problems as the visibility of the issue means they tend to be resolved quicker. While this method of leak detection may be limited in the types of leaks it can find, it is becoming more effective at relaying the information to water companies.

All of the water companies contacted for the survey were aware of using customer contacts to detect leaks and most of them used this in some way. Many of the water companies used social media, such as twitter, but activity levels varied with some being very active describing it as 'business as usual', while others would be informed by the social media team if someone reported a leak. One water company said they were in the process of creating a twitter account. Some of the water companies also have developed apps to allow people to report leaks. One water company does not use social media for leak detection as they already have a good rate of visible leak reporting.

3.6 Network Pressure and Flow Data Processing

There are a variety of offerings and technology that can help engineers and technicians to monitor and optimise the water distribution network for leakage purposes. There are an ever growing number of solutions and systems that offer different benefits. Normally there are two key components, the data gathering (data logging) and the use of the data (software analytics). The aim of these systems is to give a more holistic view of network performance. This kind of technology is often referred to as Smart Network technology.

3.6.1 Sensing and data gathering

The backbone of this data gathering network in the UK is the DI (Distribution Input) meter and DMA (District Metered Area) meter that is used for calculations in the estimations of leakage that are reported to Ofwat. Most DI/DMA meters now have loggers (or attached to SCADA systems) associated with them that return data in 15 minute intervals once or twice a day. Even this basic level of data gathering can be analysed to detect increases in flow that could correspond to leakage.

There has also been a rise in the quantity of domestic meters with a particular increase in smart meters that return higher resolution data more frequently to water companies. This can be used to understand demand patterns and consumption in areas more effectively. This can prevent confusion in trying to work out what is legitimate increased usage from leakage.

It should be noted that information on the type of meters being logged also needs to be understood and recorded by water companies. There is a lot of uncertainty in the accuracy of meters. One large water company estimates that around 1200 Ml/day pass through their meters above 500 mm; a 1% error in this figure is equal to 12 Ml/day. This can mask leakage or suggest there is leakage when there is not. WRc is currently conducting research to help evaluate the accuracy of all meters with a focus currently on large meters.

Flow logging can be combined with pressure logging at key parts of the network. This has traditionally been done for short periods to enable calibrated models of areas to be produced. There has now been a shift toward more permanent monitoring of pressures along with flows.

Flow data tells engineers how a network is performing though it is the pressure data that can be used by engineers to control the network. It is vital to understand the link between the two in an area to drive leakage down as low as possible using pressure management. This means that key parts of the network need to be logged to enable this. This includes the most critical part of the network in terms of low pressure to ensure DG2 levels are met, PRVs (pressure reducing/regulating valves) where pressures are set and potentially key parts of the network to detect service and/or network issues.

There are many logger manufacturers for logging in the distribution network in the UK and internationally that can be used to record pressure and flow data. Technolog (www.technolog.com/water/products/pressure-and-flow-monitoring/) are the most dominant in the UK with other offerings from Halma (www.hwmglobal.com/products/water-networks/data-logging/), i2O Water (en.i2owater.com/solutions/dnet/) and Seba KMT (www.sebakmt.com/en/products/water-networks/water-leak-detection/pressure-flow-measurement.html).

3.6.2 Data management, visibility and analysis

Data from loggers in the past was manually downloaded from devices for building network models. It could also be used for other purposes through offline tools like excel by competent engineers. This could indicate that there is a leakage problem though it is a laborious process that needs certain skills and a level of network knowledge to undertake.

Loggers installed today normally send through their data via GSM/GPRS (or sometimes radio) to central servers. Often these are initially third party systems that then transfer data to corporate systems. Once here the data can be more easily more easily manipulated.

Most hardware providers offer a level of software with their loggers for free and are now offering more paid for offerings. Technolog have WaterCore (www.technolog.com/water/products/environmental-monitoring/35/watercore-web-based-data-analysis-software.html) web based data analysis software and i2O Water has developed iNet (en.i2owater.com/solutions/inet/) for data visualisation and also for insight into network operation. These solutions also enable management of the new assets which is vital for continual monitoring.

Leak detection is possible with these data management systems because they can be used to identify changes in flow and pressure. This can begin to tell engineers that there is a potential issue in network operation with examples around higher flows, especially at night, drops in pressure in remote parts of the network leading to service failures to customers and potentially indicating a burst in that part of the network. The more loggers that are available the more insight can be gathered. These systems are still generally rather manual and need a level of interpretation by skilled engineers to understand what is happening.

They do offer some level of alarm or event functionality to tell a user that something has changed in the system. These are generally threshold alarms that need to be manually set by engineers. Many people have identified the need for more “intelligent” alarms based on a divergence of network activity from normal. These systems can significantly reduce the run time of errors by highlighting in much more real time that there is a network issue that need to be resolved.

Development around meter data management is still very active and covering a wide range of challenges, including data collection (the cloud, security), data interoperability, and data processing. Companies such as Microsoft (www.microsoft.com), Cisco (www.cisco.com) and Qualcomm (www.qualcomm.com) are developing solutions to tackle data collection and data interoperability. Data processing solutions and software are offered by companies including iSIGMA (www1.isigma.net), Generis (www.generis.co.uk) and Siemens (www.siemens.co.uk). AND Technology Research (www.andtr.com) has developed ConnectZED ZigBe module, an inexpensive single-chip communication device which can be linked with a range of sensors and systems. The ConnectZED is a low power wireless device which can transfer small amounts of data (<250kbits/s) across a range of around 200 m. The interoperability of this product to work across current and future systems provides a potential solution for creating cost effective smart meter networks.

The fact that the data is now available centrally through consistent, time stamped data then allows it to be used and manipulated in other systems. Crowder Consulting’s (www.crowderconsult.com) Netbase (www.crowderconsult.com/water-network-management-system-netbase/) offering, which is seen as an industry standard, will take data from various sources such as SCADA, telemetry, loggers and AMR / AMI and represent them in graphical and spatial ways. The main driver for this system has been leakage reporting with inbuilt analysis for reporting leakage figures, NRW, water balance calculations etc. This enables engineers to prioritise areas for leakage control and drive intelligently and cost effective work methods. The quality and quantity of flow data from district meters is historically higher than for pressure data.

With improvement in distribution pressure logging there are now systems that can make use of this in real time. TaKaDu (www.takadu.com/) offer a solution based on big data analytics that will detect and begin to localise network issues such as bursts, leaks and pressure issues. This can reduce water loss through faster identification and zonal localisation of issues leading to faster resolution and repair.

Other providers known for Consultancy and Software are also entering the Smart Water space. IBM Intelligent Water (www-03.ibm.com/software/products/en/intelligentwater), Accenture Water Analytics (www.accenture.com/gb-en/service-water-analytics) and Rolta OneView (www.rolta.com/products/rolta-oneview/) all offer solutions to centralise data management, perform data analytics and improve network and worker utilisation through actionable insights. These can all help to enable engineers to use all available data sources such as repair histories, customer contacts, asset registers along with flow and pressure data to make informed decisions.

3.6.2.1 Modelling

Models have traditionally been offline in nature with significant investments in time and money needed to fully calibrate and use them. They were used mainly as strategic tools looking at long term planning and operation of networks. Models rely on asset information and an understanding of the network logic i.e. what connects to what. This would also include information on assets such as sizes and types along with any degradation information that might affect the network hydraulics. This asset information is improving in water companies with increased effort in ensuring that GIS (geographic information systems) are kept up to date and corrected when discrepancies are found.

With the rise in mobile technology there is now a chance to combine the data that is being collected in much more real time with the network models to provide even more information to engineers to make decisions. This is particularly important in cases where technicians might be working in new or unfamiliar locations where they do not have the "local knowledge" that they rely on when making changes in their normal area.

The improvement in logged data will mean that models become more accurate and this in turn can be combined with the logged data to improve its interpretation and visualisation when gleaning insights from the data. This means that a low pressure logged in one area could be more easily linked to other low pressures suggesting a source of the issue that would normally take much longer to identify.

GL Burstfinder (www.gl-group.com/pdf/Burstfinder_Datasheet.pdf) and Bentley Watergems (www.bentley.com/~/asset/14/1805.ashx) both combine logged data with models. This provides greater understanding of network performance and enables enhanced analysis and visualisation. It also means that leaks can be detected and partially localised when pressure and flow data is outside normal.

WRc in conjunction with University of Manchester are currently undertaking work looking at the combination and use of the most up to data network data combined with powerful network models. This would then allow the use of fast quasi-calibrated models using the current network data to make decisions in more real time from the field.

3.6.2.2 Specific Solutions

Customer demand can also be monitored to help find supply pipe leaks. Systems can then be used to plan on site detection and repair activities. Waterscan (waterscan.com/) and Advizzo (www.advizzo.com/) both offer software solutions to enable end users to improve their water use. Waterscan is aimed at large users who will be entering a competitive market in 20117. The solution will enable users to get the best commercial deal though other services ensure that excessive consumption and leakage is identified and reduced. Adzizzo is aimed at water companies to help improve customer experiences. It offers the added benefit of identifying wasteful usage and potential leakage on customer supply pipes.

Invenio (www.invenio-systems.co.uk) has developed a new product called StopWatch which is attached at an external stop tap or exposed supply pipe and analyse the data collected to asses flow patterns through the pipe. It does not directly measure flow but collects data every 20 to 40 seconds.

A prototype of this technology has been successfully trialled by a UK water company and a version of the battery powered device is commercially available. Development work is being done to improve the communication facilities on the device. StopWatch can be used to detect leaks on supply pipes that are below the audible limit of the human ear as well as on long supply pipes where the sound may not travel to the stop tap. Internal plumbing losses can also be detected along with an indicator of the size of the leak and which side of the stop tap the leak is on. StopWatch can also be used for other studies such as assessing meter uncertainty, water efficiency auditing, identifying void properties and pipe tracing. Invenio are continuing trials with water companies across the UK.

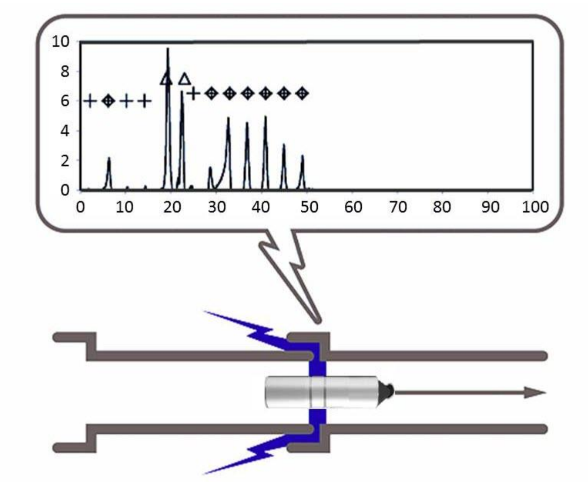
Most of the water companies surveyed were aware of at least one method of network and flow data processing for leak detection. Many of these water companies had trialled at least one technique. Most water companies used network management systems; although some commented they used it for leakage reporting rather than detection. Some companies are still exploring this area or have on-going trials. Those who did not use this type of method commented that it was due to it not being cost effective or not being ready to use this type of technology.

Just over half the contacted companies were aware of Invenio's Stop Watch and most have been involved in trialling it. For many of the companies the trials are still on-going or the results have not been published yet so an indication of leak detection success could not be obtained. One water company uses it occasionally.

3.7 Conductivity

For non-metallic pipes it is possible to use electrical conductivity to finds leaks. Non-metallic pipes, such as plastic, are poor conductors of electricity hence when the water in the pipe is electrically charged the charge stays in the pipe. If a leak is present the charge will escape which is detected at the point of the leak as shown in Figure 5.

Figure 5 Conductivity Leak Detection



Electroscan

This technique is suitable for all pipe sizes and can find all sizes of leaks. The detected signal relates to leak size and allows each leak to be quantified. The sensor is inserted into the pipe through a special fitting and pulled along the length of the pipe. Electroscan (www.electroscan.com/) is the only technology provider for this product, and is an exclusive technology partner to WRc Assess and Address® in the UK.

The technology has not been widely used in water networks and is more commonly used in wastewater networks in the USA. The development is based around obtaining more accurate pinpointing of the leaks.

This was the least well known of the leak detection methods by the surveyed water companies with just under half being aware of this technique. Two of the water companies have trialled this technology, one has continued to use it and the other was not aware of the outcomes of the testing. One of the companies who have chosen not to trial stated their reason as it not being suitable for the small size of their company. Another said that it has not been trialled but it looks promising.

3.8 Condition Assessment

The condition of a pipe allows for burst prediction to be undertaken. While this is not directly detecting leakage it is detecting where the leaks are likely to form, allowing the pipe to be replaced before it bursts. This is a key component in reaching zero leakage. Only in-pipe condition assessment techniques are covered in this section, as while other external inspection tools exist, they require the pipe to be excavated which is expensive and disruptive to customers.

A range of condition assessment tools exists for metal pipes. This is due to the electromagnetic properties of the pipes which can be exploited in a variety of ways to assess the condition of the pipe. Typical methods involve measuring wall thickness variations with ultrasound and magnetic flux leakage. Companies such as Pure Technology (www.puretechltd.com) offer in-line inspection techniques. Pure Technology is an exclusive technology partner to WRc Assess and Address® in the UK.

In-pipe eddy current inspection techniques are being developed in the oil and gas industry. Research being conducted by Indian Oil Corporation Ltd (IOCL) [6] and ExxonMobil[7] with Innospection (www.innospection.com) has developed prototypes which have successfully detected metal loss and defects on pipelines.

4 Conclusions

There exists a great diversity of methods for detecting leaks in the water network, see Table 2 for more details. These techniques are capable of detecting and locating leaks in a wide range of scenarios, however, a major issue all new techniques face is the reluctance of the water industry to commit and invest in new technology which holds back its development.

Techniques which provide continual monitoring of the network such as multi-sensor platforms, fibre optic cables and network and flow data processing require equipment to be permanently installed on the network which is expensive to set up and maintain. These techniques are capable of identifying sections of pipes which contain the leak, but a pin-pointing device is still needed. However, leaks are detected as soon as they break out and the growth of these leaks can be monitored which allows for economic and prioritisation decisions to be made regarding the rehabilitation of the pipe. These methods allow for background leakage levels to be reduced as they can detect small leaks which may otherwise go unnoticed.

Gas detection and radar methods allow for the location of the leak to be pin-pointed, however they are time-consuming for performing routine surveys of an area. This is because the line of the pipe must be walked by the operator, often repeating the path several times to collect sufficient data. These techniques are best used for locating known leaks.

Step testing is a common way to identify smaller areas of the network which contain higher levels of leakage for more detailed investigation. This method is effective providing that the infrastructure can cope with the changes in pressure that can be caused. However, as customer supplies are cut during the test, careful planning is needed in advance to minimise interruptions to the customers supply.

Visual inspection techniques – satellite, air crafts and drones- are becoming more realistic options for leak detection as satellite images and drones become more affordable and readily available. The major advantage of these techniques is that very large areas can be scanned, including remote areas that would be otherwise difficult to access. The current limitation is the data processing algorithms, which need further development to improve the automation of the leak detection process. Low-tech visual inspection methods such as walking the main and customer contacts are currently key to identifying, however as technology develops and more monitoring systems are put in place in the network these will begin to become redundant as the water company will know about the leak long before it becomes visible on the surface.

Conductivity can be used to find and locate leaks, though it is not widely used. Like many of the other non-acoustic methods it is effective but lack of uptake is holding its development back. This technique can also be combined with CCTV and other forms of in-pipe visual inspection to gain more information about the asset.

Condition assessment is a key component in reducing leakage, because until you can effectively replace pipes you will never beat the natural rate of deterioration. There is a range of methods for performing condition assessment which give different information about the pipes condition, these need to be combined with failure models to prioritise pipe replacement.

4.1 Gap Analysis

There is a great variety of techniques available for leak detection and lots of research being conducted into new techniques. Based on the information gathered, certain gaps in research have been identified.

The first is the need for a guidance document for water companies to enable decisions to be made about what the most appropriate detection method for their network. At present basic acoustic methods are the most commonly used for leak detection but they are not always the most accurate or efficient methods. The guidance document should inform about the different methods and provide an economic assessment of each technique and should be conducted by an independent water industry consultancy.

Several research gaps have also been identified and are summarised in the text and in Table 2 below. These are areas where active research and development is not currently being undertaken. They are:

- Ground Doppler radar – more research into this technique to build a prototype is required. This should be conducted by universities or as part of collaborative projects such as mapping the underworld.

- Drone – at present drones can only be flown in British airspace within line of sight. This limits their range, hence their usefulness in leak detection. Research into safe beyond line of sight inspection is needed before this technique can be fully utilised. This is research that technology providers should investigate with appropriate aviation authority.

- Water quality – several leak detection methods can lead to water quality issues, such as step testing and inserting sensors which can disturb sediment and biofilms, all future research should take water quality into consideration to ensure a holistic approach is taken for the network.

- Customer leakage – while there are methods for finding supply pipe leaks internal plumbing is generally not included, however can be considered to be leakage. Water companies should investigate initiatives encouraging customers to check for internal plumbing losses and work with plumbers to set up a range of checks which could be easily included as part of a plumbers visit to a property.

Areas of leak detection which have active research but have yet not achieved suitable solutions for the water industry include:

- Ground penetrating radar – Mapping the Underworld has spent 10 years working on advanced GPR systems for asset location but there are still issues with the technique. These fundamentals need to be addressed in order for GPR to reach the level of sophistication required for leak detection. An independent review of research should be conducted to assess the reasons why a successful method has not yet been developed and what fundamental questions still need to be answered.

- Smart networks – large amounts of research and development is being done in creating smart water networks. This is mainly being done by the supply chain and is becoming increasingly software focused. The main topics of interest are the cloud, IoT (internet of things), big data analytics, machine learning, data security and data interoperability. This research was developed to combat leakage and there are now many diverse offerings available under the smart tag. The development of the technologies continues at a fast pace though there is a need to understand what technologies should be used under what circumstances.

Table 2 Summary of techniques (part one)

Method	Gas detection	Ground penetrating radar	Ground Doppler radar	Fibre Optics	Multi-sensor platforms	Step testing	Aircraft and drones
Use	Detection and pin-pointing location	Detection and pin-pointing location	Detection and pin-pointing location	Detection	Detection	Detection	Detection
Pipe material	All	All	All	All	All	All, providing structurally sound	All
Pipe size	No limit providing sufficient tracer gas is available	All	All	All	All, different equipment for different sizes	All	All
Pipe Location	Surface above pipe must be accessible Accuracy dependant on soil type	Surface above pipe must be accessible, dry soil	Surface above pipe must be accessible	NA	Access points for sensors	Need to be able to isolate area	Surface above pipe must be visible. Rural

Method	Gas detection	Ground penetrating radar	Ground Doppler radar	Fibre Optics	Multi-sensor platforms	Step testing	Aircraft and drones
Inspection details	Small area covered: pipe section with suspected leak. <1 day to find leak on average	Small area covered: length of pipe with suspected leak. <1 day to find leak on average	Small area covered: length of pipe with suspected leak. <1 day to find leak on average	Continual network coverage. Immediately alerted if leak occurs and where	Continual network coverage. Immediately alerted if leak occurs and where	Medium sized areas covered to identify where leaks are occurring	Aircraft fly over large areas recoding images. Identification of leaks from images
Maturity of technique	Mature and well established	Established for pipe location. Prototypes for leak detection	In development, patent awarded	Commercially available, low uptake	Established and widely used but few permanent installations	Mature and well established	Early stages of development

Method	Gas detection	Ground penetrating radar	Ground Doppler radar	Fibre Optics	Multi-sensor platforms	Step testing	Aircraft and drones
Further development / Next steps	Better promotion of the technology to increase uptake in the right situations	Improve the detection ability to identify leaks in a range of soil conditions Commercialise prototype – or assess why a successful prototype has not been developed considering the amount of research in the area	Improve the detection ability to identify leaks in a range of soil conditions Further research to prove proof of concept Trial of prototype	Improving the robustness of the cables See lot 4	Improving anomaly detection and noise reduction Greater uptake of technology required to gain full benefits	Improving range and sensitivity	Improving identification of leaks from other anomalies

Table 2 Summary of techniques (part two)

Method	Satellite imaging	CCTV	Walking the main	Customer contacts	Network and flow data processing	Condition assessment	Conductivity
Use	Detection	Detection and pin-pointing location	Detection and pin-pointing location	Detection	Detection	Detection and pin-pointing location	Detection and pin-pointing location
Pipe material	All	All	All	All	All	All	Non-metallic pipes
Pipe size	All	Sufficient to install camera	All	All	All, different equipment for different sizes	Sufficient to install sensor	All, different equipment for different sizes
Pipe Location	Surface above pipe must be visible. Rural	Access points for camera	Surface above pipe must be accessible	Surface above pipe must be accessible	Access points for sensors and meters	Access points for sensor	Access points for sensor
Inspection details	Large areas covered – new images dependant of satellite frequency. Computer processing of images	Camera is inserted into pipe and the footage reviewed manually	A technician walks along the length of a main looking for signs of leakage	When a customer finds a leak they alert the water company	Continual network coverage. Immediately alerted if leak occurs and where	Instrument is inserted into pipe and moves along the pipe taking readings	Sensor is inserted which charges the water in the pipe. Leaks cause the charge to escape which can then be detected at the

Method	Satellite imaging	CCTV	Walking the main	Customer contacts	Network and flow data processing	Condition assessment	Conductivity
							point of the leak
Maturity of technique	In development	Commercially available, used for condition assessment	Mature technique	Mature and widely used	Established and used but few permanent installations	Commercially available, some methods in development.	Commercially available, not widely used
Further development / Next steps	Improving anomaly detection algorithms Commercialisation	Improvements to camera resolution to improve defect detection	Use of sophisticated inspection tools, such as IR goggles	Incentivise customers to report leaks, improve interaction with customers	Greater uptake of technology required to gain full benefits	Improved defect detection Combining with leakage programme	Improved defect detection Greater uptake of technology

5 Recommendations for further research

We have considered all of the recommendations for further research identified within the gap analysis (Section 11) and identified three that would offer the greatest potential to advance the UK water industry from current methods in the medium term. Each of these three ideas has been expanded upon in the following sections, with an idea on how a research project on the topic could be designed.

5.1 Fibre Optic trials for new and existing networks

5.1.1 Impact

Fibre optic detection of leaks offers potential for rapid identification and pin-pointing of leak location on networks. It could be deployed on all pipe materials and sizes.

5.1.2 Background

Fibre optic cables can be used to detect leaks in two ways: distributed temperature sensing (DTS) and distributed acoustic sensing (DAS). In both cases a fibre optic cable is laid along the length of the pipe. When a leak occurs the signal from the cable can be used to locate the leak along the length of the pipe based on the time delay of the signal. There are existing available commercial products that combine both techniques (DTS and DAS) into one cable. DAS cable can be retrofitted into existing pipes, whilst DTS must be laid outside of the pipe.

Research is currently being carried out in Australia looking at deployment methods for fibre optics into live water mains. No UK water company we spoke to has yet trialled the use of fibre optics in new or existing networks.

5.1.3 Objectives

It is envisaged the project could comprise 2 parts:

Part 1 – Trial of fibre optic installation in new network to ascertain reliability and usefulness of data collection.

Part 2a – Review of methods for deployment of fibre optics into existing live water mains. Identification of viable approaches suitable for trialling.

Part 2b – Trial of deployment and monitoring of fibre optics on existing live water mains.

5.1.4 Outcomes to be achieved

For both parts of work a suitable technology supplier or suppliers would need to be identified to partner on the project such as TTK, E S&S, Silixa or HAWK. It is also recommended that an independent technical services provider is appointed to ensure the compliance of the technologies with relevant standards and codes, and to independently assess the results of trials.

Part One – This work needs to gather evidence to enable a robust business case on the use of fibre optics to be developing, including information about locations and parameters where the technology would, and would not be beneficial to UK water companies. The work would need to be carried out in conjunction with a supplier, or suppliers of fibre optic technology such as TTK, E S&S, Silixa or HAWK.

Part Two – This work needs to gather evidence to enable a robust business case on the use of fibre optics on existing networks to be developed. This needs to include consideration of deployment and effectiveness compared to other methods in use by UK water companies.

5.2 Making best use of aerial monitoring methods

5.2.1 Impact

Aerial detection including via satellite, aircraft and drone offer an effective way to gather information across a wide area very quickly. These techniques have the potential to be particularly useful in rural areas where there can be very long pipe runs, and would not typically be picked up by customers.

5.2.2 Background

Thermal and visual imaging services offer potential for change in, for instance, vegetation growth, temperature differentials etc. to be identified. Both techniques have been successfully trialled; however more information is needed to improve the automation of leak detection and accuracy of identification.

5.2.3 Objectives

The project should aim to identify when different methods of imagery are most beneficial (using GPR, infra-red and visual imagery) and to gather evidence to allow improvement in the identification of leaks. Additional data from aerial monitoring should be collected in conjunction with technology partners as required, with verification of leaks by traditional methods.

5.2.4 Outcomes to be achieved

For this project it is likely that a suitable technology supplier or suppliers would need to be identified to partner on the project such as Rezatec, Utilis or APEM.

The project should deliver improved confidence in the identification of leakage through aerial monitoring techniques. This will allow the method to be weighed up alongside other inspection techniques that are currently used in rural areas of the existing network to identify leaks.

5.3 Improving the effectiveness of walking the line

5.3.1 Impact

There is potential to improve the cost effectiveness of the current walking the line activity through the use of novel technologies in the short to medium term.

5.3.2 Background

Walking the line is currently a major leak detection activity undertaken by many UK Water Companies. However, it is carried out in a very low-tech manner, at relatively high cost. It is likely that efficiency of the method could be improved through the use of novel technologies including thermal imaging, and augmented reality.

The latest technologies would allow a user to view the location of pipes, joints, historic leaks etc. as an overlay to the ground when walking the line. This would allow likely locations of leaks to be readily identified. Further, thermal imaging (e.g. infra-red goggles) would potentially allow alternative methods of spotting leaks.

5.3.3 Objectives

To identify and trial with a number of leakage operatives new technologies for improving cost effectiveness of walking the line.

5.3.4 Outcomes to be achieved

Working with a set of leakage operatives who regularly 'walk the line', test different options for improving effectiveness. It is envisaged the work would involve initial familiarisation with technologies currently being used and a survey testing their opinion on different options for provision of additional data through new technologies. Trials could then subsequently be specified with relative efficiencies assessed quantitatively and qualitatively.

6 References

Swedish Water and Wastewater Association Publications New method for leak detection, 2 (2013) (11) (original footnote number highlighted in yellow)

EPA The Potential for Health Risks from Intrusion of Contaminants into the Distribution System from Pressure Transients, (2004) (25)

A. Agapiou et al, Investigation of Ground Remote Sensing Techniques for Supporting an Early Warning Water-Leakage System. Integrated use of space, geophysical and hyper spectral technologies for monitoring water leakage in water supply networks, chapter 2 (2015). (26)

A. Atef, T. Zayed, A. Hawari, M. Khader, O. Maselhi, Multi-tier method using infrared photography and GPR to detect and locate water leaks. Automation in Construction 61:162-170 (2016) (27)

A. Agapioe, D.D. Alexakis, K. Thermistocleous, D.G. Hadjimitsis, Water leakage detection using remote sensing, field spectroscopy and GIS in semiarid areas of Cyprus, Urban Water Journal 13-2:221-231 (2016). (29)

D. Mukherjee et al, Development of secondary sensor system based on eddy current technology for in-line inspection tool, BARC Newsletter 335 (2013). (61)

S. Asher, A. Boenisch and K. Reber, Magnetic eddy current in-line inspection tool development for CRA pipelines, Pipeline Technology Conference (2015). (62)