RESEARCH AND CASE STUDIES ON WATER LOSSES IN DISTRIBUTION NETWORKS USING GPR AND DRONES WITH THERMAL CAMERAS

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ABSTRACT: *The detection of water losses is a topic of great interest world-wide, with a major impact especially in arid areas on the globe. The technologies used to date have been adapted and research and studies are conducted for faster and more efficient methods in detecting underground water losses.*

By combining two current technologies, infrared scanning and the use of drones, devices have been created to help identify water leaks. It has been found that certain high-resolution infrared cameras could detect from a low height the temperature change that occurs on the ground or asphalt when water is lost in the form of underground leaks.

The proposed quadcopter drones would fly short distances and, using GPS technology, pinpoint exactly where a leak has occurred to allow faults to be repaired as soon as possible. For longer distances, an airplane-type drone to which an infrared camera is attachedcan be used to be piloted along the pipeline routes.

The paper comprises a series of cases we actually encountered on site and successfully identified using the GPR and pre-encountered with the thermal cameras and drones.The cases are explained, illustrated with on-site images and have been confirmed by visual inspection in the concerned areas and by other devices on Mobile Laboratory for Loss Detection and by conducting surveys (mechanized excavation) at those specific points.The methods used on site to identify water losses provide good results as a secondary procedure for leak detection.

Keywords: *best practicesinwater loss control; water leak detection; distribution networks; ground-penetrating radar (GPR); GPS; thermal scanning drone;*

1.Introduction

Access to clean water is often taken for granted, just like the fresh air we breathe. We forget that drinking water is a product and that producing it in sufficient quantity is actually a comprehensive and detailed process in the context of scarce resources. If we add inadequate management of water distribution, we face a less visible but crucial problem: that of water losses, also known as non-revenue water (NRW).

Non-revenue water is basically potable water produced and lost somewhere in the water distribution system, never reaching its final destination. This means water not consumed or paid for, affecting local economies and available local resources.

There are many reasons for water losses: water leaks, broken pipes, poor water management, illegal connections or unauthorized consumption.

A World Bank study estimates global water losses at 32 billion cubic meters each year, with half of these losses occurring in developing countries. If these water losses could be halved, it would be enough to provide water for about 90 million people.

Leaks cause water losses in the network and occur, among other things, due to pipe breaks. This means that drinking water is wasted and never reaches consumers.

Therefore, water losses due to leaks affect both the economy of utility companies and the environment through the nuisance created and contribute to the unnecessary waste of resources.

Leaks and burst pipes can occur suddenly or gradually over time due to lack of maintenance, corrosion or wear and tear.

In many parts of the world, poor management of resources contributes to water loss. Poor management can be, for example, lack of maintenance of power networks leading to leaks or lack of meters at customers, so that utility companies cannot bill actual consumption.

Operating a water distribution network is no easy task. A network often covers a large area and a complex system of pipes, which makes it difficult to detect changes, damage or illegal connections. Managing water loss or non-revenue water in an open system would also mean acting in a passive and reactive manner by taking action only when a loss becomes visible or is reported.

Dividing the water supply network into District Metering Areas (DMA) is an efficient technique that provides the possibility to calculate water losses individually, per area, and operators can plan and prioritize their actions.

Leaks can be easily identified by noise detectors integrated into street boxes mounted at ground level, allowing operators to intervene effectively where needed. This ensures a quick repair of the affected area, which means less water loss and less disruption to customer service.

By investing in a targeted detection program, in most cases it is possible to reduce distribution network leakage by at least 30-40%.

By using DMA it is possible to measure and manage the water pressure in the different areas of the water supply network.

Water scarcity and the future threat of changing climate conditions have intensified the need to develop appropriate water management approaches aimed at maintaining a balance between water supply and demand. Losses from water distribution systems should be of interest to every water supplier, especially in areas of our planet where water is found in very limited quantities. It is therefore imperative that water suppliers apply simple and effective methodologies in accounting for water losses in their transport and distribution systems.

The Water Losses Task Force (WLTF) of the International Water Association (IWA) has established a water audit method that follows water from its source through the system and ultimately derives the revenue and non-revenue component, in other words a water accountability methodology and an integrated approach to water loss control. Many water suppliers around the world recognized at an early stage the importance of establishing a proper water audit system and developed their infrastructure in such a way that they can efficiently and correctly manage all produced water.

The reduction and control of water loss is achieved by applying a holistic strategy based on the approach developed by the WLTF of the IWA. The integrated part of this approach is the establishment and operation of DMA, accompanied by pressure management.

2. Water loss control

Efficient and effective water loss control should be recognized as a first priority for improving drinking water supply. Decision makers at all levels of water services must understand that any water loss control strategy to be effective must be an ongoing activity based on a long-term strategy and should be an integral part of the supplier's vision. The success of the strategy will inevitably depend on commitment and dedication at all levels within the supplier and, of course, on the adoption of appropriate strategies and techniques.

2.1. Methodology

The IWA Water Loss Working Group has played a leading role in promoting water loss control strategies, methodologies and procedures worldwide and developing world-class tools and techniques to reduce losses and increase accountability in revenue generation. Methodologies have been developed by WLTF in the following areas of urban water network management, which have been tested in numerous utilities worldwide with very good results in reducing non-revenue water: These methodologies and practices can be summarized under the following broad categories: accurate and complete measurement; water balance; apparent losses; real losses.

2.2. Real losses

The IWA Water Loss Working Group has for several years promoted the four leakage control strategies to reduce actual losses from urban water distribution systems, namely: active leakage control; pressure management; speed and quality of repairs; targeted renewal of infrastructure.

These must be balanced to achieve the most cost-effective program that reduces losses to an economically, environmentally and socially acceptable level. This approach is well tested and has been applied worldwide with extremely positive results for suppliers.

The above WLTF methodologies and strategies have a global application and represent what could be called "best practice" in the field of water loss control.

As a first step in reducing leaks in water distribution networks, it is recommended that network pressures be examined and optimized so that any excess pressure is eliminated. Leakage is a function of pressure and any reduction in pressure would result in a corresponding reduction in leakage. Dividing the network into discrete areas called District Diversified Areas (DMAs) provides an efficient and effective method of managing pressures and controlling leakage, thereby reducing actual losses to an economically acceptable level.

Actual losses cannot be completely eliminated. The lowest technically achievable annual volume of physical losses for well-maintained and well-managed systems is known as actual annual unavoidable losses (UARL). This leads to the definition of the Infrastructure Leakage Index (ILI), which is a performance indicator for physical benchmarking.

Actual losses include leakage on transmission and distribution networks (fig. 1), leaks and spills from storage tanks, and leakage at the service connections to the customer's meter. Leaks in transmission and distribution networks are usually large events, so they are quickly reported by the public. These can cause serious damage if not repaired quickly. Less visible forms of leakage are more difficult to detect and repair.

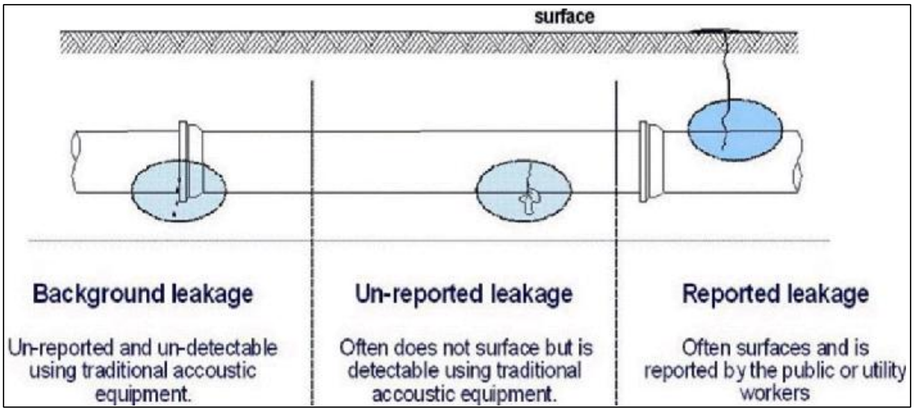

Fig. 1. Types of real leaks

3. Using GPR and drone with thermal camera

Ground penetrating radar (GPR) is a geophysical locating method that uses radio waves to capture images below the surface of the ground in a minimally invasive way. The huge advantage of GPR is that it allows crews to pinpoint the location of underground utilities without disturbing the ground.

3.1. Cases encountered using GPR

GPR works by sending a tiny pulse of energy into the ground then recording the strength of reflected signals and time it takes them to return to the receiver. A scan consists of a series of pulses over a single area. While some of the GPR energy pulse reflects back to the receiving antenna, some energy continues to travel through the material until it dissipates, or the scanning session simply ends.

The rate of signal dissipation varies widely, depending on the properties of the materials. As the energy pulse enters a material with different dielectric permittivity or other electrical conduction properties, it produces a reflection. The strength, or amplitude, of the signal is the result of the contrast in the dielectric constants and conductivities between the two materials. A pulse moving from wet sand to dry sand will produce a very strong reflection, for example, in comparison to the relatively weak reflection produced by moving from dry sand to limestone.

The ground itself can limit how deep GPR signals penetrate up to 30 meters deep. The ground has electrical resistivity, which means it opposes the flow of electric current to some degree. As the signal penetrates deeper, it naturally gets less effective.

This depends mostly on the type of soil or rock being surveyed and the frequency of the antenna used. For example, the maximum penetration depth in concrete is usually about 0,7m. In moist clays and other high conductivity materials, GPR signals depth is significantly shallower, reaching about 1 meter or less.

A case encountered in situ was in Piatra Neamt, Izvoare street, a water loss identified by the loss office and confirmed in the field using GPR (fig. 2). In that area, the pressure on consumers began to decrease gradually, therefore it was suspected that there must be some water losses somewhere. Thus, verification and measurement work started, reaching to the identification of a pipe damage (fig. 3).

Another interesting case using GPR, was on Violetei Street, from Piatra Neamt, where an anomaly was identified a day before the water loss was fixed. Thus, during a routine check on that street, an anomaly was found that would correspond to a major damage in the area. In the scanned area, an accident took place a few years before, which can also be inferred from

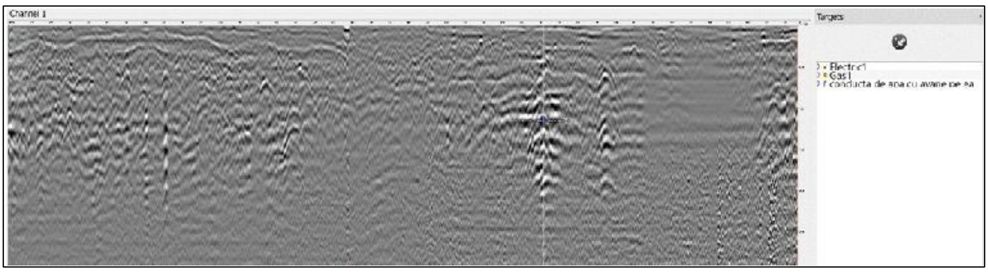

Fig. 2. A radar scan of the identified water-loss

Fig. 3. Identified pipe and loss

the disturbed ground at the site, recorded on the scan (fig. 4). Carrying out the GPR scan on the street, the presence of a possibly damaged pipe was found. After mechanized digging, the loss was identified exactly in the place where it was scanned (fig. 5).

medicine, research, surveillance, etc.

Unmanned drones on the market today are no longer only an entertaining gadget for hobbyists, nor are they only equipped with low-resolution, standard optical cameras. Many of today's drones can be equipped with

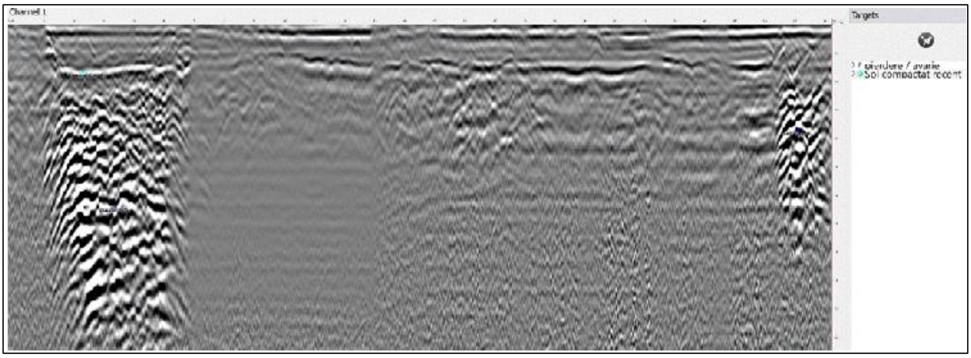

Fig. 4. A scanned street where the anomaly was found

Fig. 5. Water loss identification

Another case encountered by the NRW office was on Progresului Street, intersection with Lamaitei street, where, following a request, several anomalies were identified in the area, anomalies that turned out to be several water losses, many thermal pipes, gas pipes and electric cables (fig. 6). Thus, basedon the scans the decision was made to replace a section of the drinking water distribution pipe (fig. 7).

3.2. Cases encountered using a drone with thermal imaging camera

Thermal vision offers incredible solutions for a growing number of applications: maintenance, construction, transportation,

high-precision, high-quality thermal cameras that have a wide array of uses in government applications and private industry. Typical thermal cameras that are mobile and portable, and those installed on stationary structures for continuous coverage and surveillance, were great first steps in the use of thermal imaging devices. With the advancement in drone technology and the production of smaller, less costly, commercial drones, attaching thermal cameras to drones seemed to be a logical next step.

One such case in which a drone equipped with a thermal camera proved its usefulness, was on Aprodu Arbore Street, Roman City, where following reports from that street

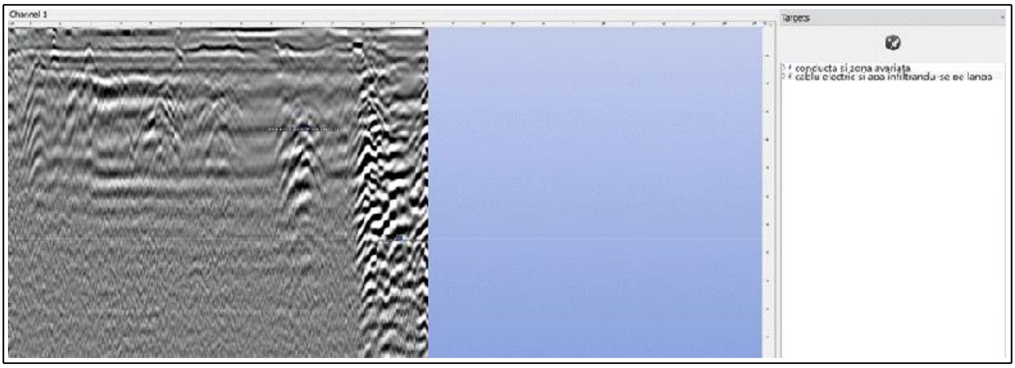

Fig. 6. GPR scan showing many anomalies

Fig. 7. Pipe replacement

regarding the drinking water service which was not provided within standards, an attempt was made to identify the problems in thatarea. Using all the equipment provided, a non-metallic pipe crossing the street was identified using the drone on site (fig. 8), that pipe being damaged, which was confirmed in the field and by the use of the GPR (fig. 9).

The pipeline shows up in the thermal scanning with the drone, due to the fact that the temperature of the water in the pipeline is colder than the external temperature on the

Fig. 8. Normal drone camera

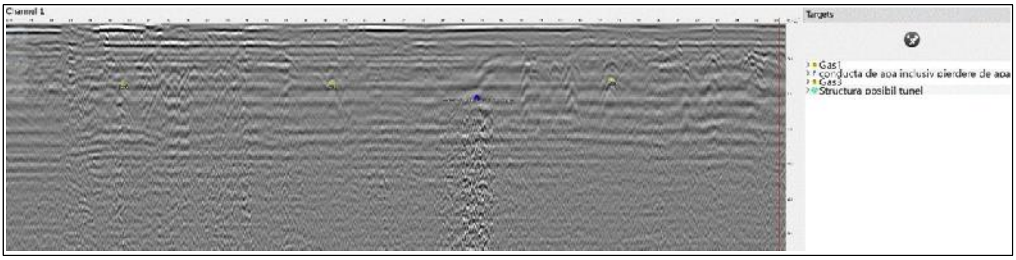

Fig. 9. GPR scan confirming the water loss

surface of the asphalt, in conjunction with the small depth, the situation being thus remedied (fig.10).

From there it was just a simple click to send the picture to the design team with the precise position, as the drone is provided with GPS and


Fig. 10. Thermal imaging camera

Similar case but on a different street like Sucedava also in Roman City was conducted, by using the same drone to identifya plastic pipe (fig. 11). By switching to thermal camera we can clearlysee the water pipe showingon the image (fig. 12).

RTK sensors.

Another case of drone identification of potable water losses from pipelines was on Tineretului Street, where following a drone flight to create the ortho-photomap (fig. 13), after a careful analysis of the thermal images


Fig. 11. Normal image


Fig. 12. Thermal image

Fig. 13. Normal camera

Fig. 14 Thermal camera result

(fig. 14), the presence of an anomaly has been observed on one side of the pavement. During a field check in that location with the Hydrolux HL7000 device (electronic ear), the presence of a water loss on the metal distribution pipe was confirmed.

4. Results

The methods presented throughout the encountered casescan be used successfully if the necessary conditions for the use of this equipment in the field are met and can be used in cases where those methods do not give expected results, such as the influence of external noises, lack of intermediate manholes or lack pipe access, extreme temperatures.

5. Conclusions

Drone pilots are discovering more opportunities to use thermal imaging sensors as he technology in this fascinating area advances.

Drones equipped with thermal cameras are now being routinely used to increase solar plant performance, to monitor and check livestock, to quickly detect thermal runaway switches on electrical supply lines, to inspect infrastructure at mines, to maintain agricultural systems, and to assist in search and rescue missions.

As drone technology improves and as new industries find uses for remotely-operated drones, the use cases for drones equipped with thermal cameras will only continue to grow.

In conclusion, the paper analyzes the use of less atypical methods for identifying losses compared to conventional ones (using the method of listening with dedicated equipment) and should not be perceived as universal replacement of all the so far existing devices, as they are complementary devices on certain loss detection segments.

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