Managing leakage economically

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ABSTRACT

The need to keep a low leakage level is a priority for most water utilities. It has been demonstrated in many parts of the world that the most effective way of doing so, is by dividing the network into a number of sectors called District Meter Areas (DMAs), each supplied by a single pipe on which is installed a flow meter. In this way it is possible to permanently control the level of leakage, identify the presence of a new leak and more efficiently eliminate it. Leakage is an economic problem and as such needs to be managed accordingly. This paper describes an innovative Decisional Support System (DSS) which compares the cost of repair with the value of the water recovered, to decide whether an intervention is economically justifiable. In addition, it has a self-teaching algorithm which allows the prediction to be tailored to the characteristics of each individual DMA.

Introduction

There are many reasons for attaining and subsequently maintaining a low leakage level in water networks, chief amongst which is the environmental and social damage that the over exploitation of such a valuable natural resource can cause. Of even more significance perhaps to many water utilities, is the economic impact of pumping and treating almost twice as much water than is delivered to the customers.

Historically, leakage location was undertaken either in a passive way, whereby a repair was executed only when the leakage become visible, or in more advanced situations, by systematically surveying the whole network using acoustic instruments. Although reasonably successful in locating leaks, neither method was particularly efficient. What was needed was a control system which allowed the leakiest parts of the network to be targeted at the most appropriate moment.

The recognition of the need to permanently control leakage, occurred in the UK around 25 years ago with development and application of the District Meter Area (DMA) concept. The basis of the approach is to divide the network into a number of discrete areas, preferably supplied by a single pipe, on which is installed a flow meter. In this way, it is possible to quantify the leakage level in each district. When the presence of a new leak becomes evident, the leakage location activity can be directed to that part of the network where the leak is located. This approach has been applied with universal success all over the world, to such extent that it is now considered the optimum method for controlling leaks. Some difficulty has been experienced in dividing very complicated and inter-connected networks, but this can be overcome with the application of mathematical simulation models. New, advanced GSM logging and transmitting technology has been developed to allow on-line control of leakage to such an extent that leakage teams can be on site locating a leak almost before it has occurred. The Guidance Notes of the IWA Water Loss Task Force describes in detail the process of defining, and setting up DMAs.

As the number of DMAs to be managed has increased, so have the availability of automatic decisional systems to prioritise the leakage location activity. Invariably, such systems are based just on the quantity of water lost. What they don't take account, is that leakage is first and foremost an economic problem. It costs money to extract, treat and distribute water. To loose a large part of it through burst in the pipe, represents therefore a very significant economic loss. But to eliminate a leak is also costly. So the question that needs to be addressed is whether it is economically worthwhile to intervene. This paper outlines a Decisional Support System, developed by the University of L'Aquila in central Italy in collaboration with DEWI S.r.l., which has extensive experience of applying leakage control technology all over the world and INGEA S.r.l. which is currently involved in undertaking what is probably the largest leakage control project ever undertaken in Italy, with the aim of answering this question. The project was funded primarily by the European Union and the Region of Abruzzo.

Technical approach

There are a few basic principles that need defining at the outset, which are summarised below:

- any DSS aimed at the management of DMAs assumes that they already exist in the field;
- that the flow data is transmitted to the control centre at regular intervals, at least weekly and preferably daily.

Leakage is most accurately quantified at night when the consumption of the customers is minimum. It can be calculated with the following expression:

$$Ln = Qnf - (Cd * Me * DFdn + Cc * Me * DFcn + Ci * Me * DFin + Spnf * Me)$$

where:

- Ln = night time leakage
- Qnf = Minimum night flow into the DMA
- Cd = Total domestic consumption in the DMA read by the meters
- Me = correction for meter error, ideally determined by monitoring a sample of properties in the field or alternatively using typical values from publications
- DFdn = typical night Demand Factor of domestic properties obtained ideally by monitoring a sample of properties in the field or alternatively using typical values from publications
- Cc = Total commercial consumption in the DMA read by the meters
- DFcn = typical night Demand Factor of commercial properties obtained ideally by monitoring a sample of properties in the field or alternatively using typical values from publications
- Ci = Total industrial consumption in the DMA read by the meters which don't have a significant night-time consumption
- DFin = typical night Demand Factor of industrial properties ideally obtained by monitoring a sample of properties in the field or alternatively using typical values from publications

- Spnf = Consumption of large consumers or at least those having a significant and irregular night consumption, monitored directly from the meter.

The advantage of quantifying the leakage in this way is that even if the precise demand factors and meter accuracy values are unknown, they have little impact on the final values, unless the leakage level is exceptionally low in the first place. It should be remembered that night time leakage will usually be greater than the average value, due to higher night time pressures.

The same approach can also be applied to networks with intermittent supply, just that it has to be related to a period when there is water in the network. Although it is likely that the accuracy of the final leakage value will be much reduced in this way, it is largely irrelevant as the probable cause of the interrupted supply is the high leakage level. For management purposes, it is sufficient to be able to compare values for the same period.

In the DSS which is presented in this paper, a module was developed to quantify automatically the current leakage level on a daily bases. Checks were built in to ensure that no anomalies existed in the flow data which could result in erroneous leakage vales and consequently incorrect decisions. This relates in particular to problems with the flow meters, open boundary valves or pipe closure for undertaking maintenance in the DMA. A weekly average leakage value is then calculated to even-out any slight fluctuations in real consumption from one day to another.

There are three factors which need to be assessed in order to decide whether it is economically viable to undertake a leakage reduction intervention:

- the cost of the intervention;
- the quantity of water which can be recovered;
- the value of the water.

These are discussed in more detail in the following paragraphs.

Cost of intervention

Leakage is probably one of the most important elements to be considered when rehabilitating water networks, not just because it usually yields an immediate economic return, but because it is likely to be the cause of other standard of service non-compliances. As such, the cost of the intervention to eliminate a leak should always be considered in any system based on economic evaluation and not simply the cost of leakage location which is often insignificant anyway in the overall costs. DEWI S.r.l. has undertaken numerous leakage control projects all over the world and has derived a curve which relates the recovery of leakage to the cost of intervention. Figure 1 shows the curve relative to the Italian condition based on real data. It shows how the cost of intervention gets progressively more expensive with increased recovery, reflecting the significant impact of pipe replacement.

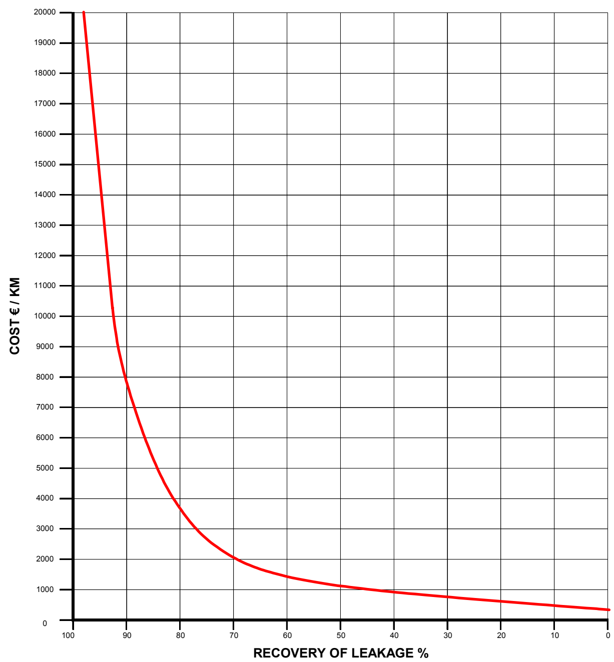

Figure 1: Typical Cost / leakage recovery

Quantity of water to be recovered

The quantity of water that can be saved, is composed of two components: the short term recovery which results from the intervention and the long term return frequency as the leakage tends to return to its original level. These values will depend on the type of the intervention (repair or pipe replacement etc) and the initial condition of the network; but again, based on the results in real projects it is possible to make estimates. Figures 2 and 3 for instance show the return frequency of two districts in southern Italy. It can be seen that the return frequency differs from one DMA to another, but in both cases the frequency is less than 1 l/s every 4 months.

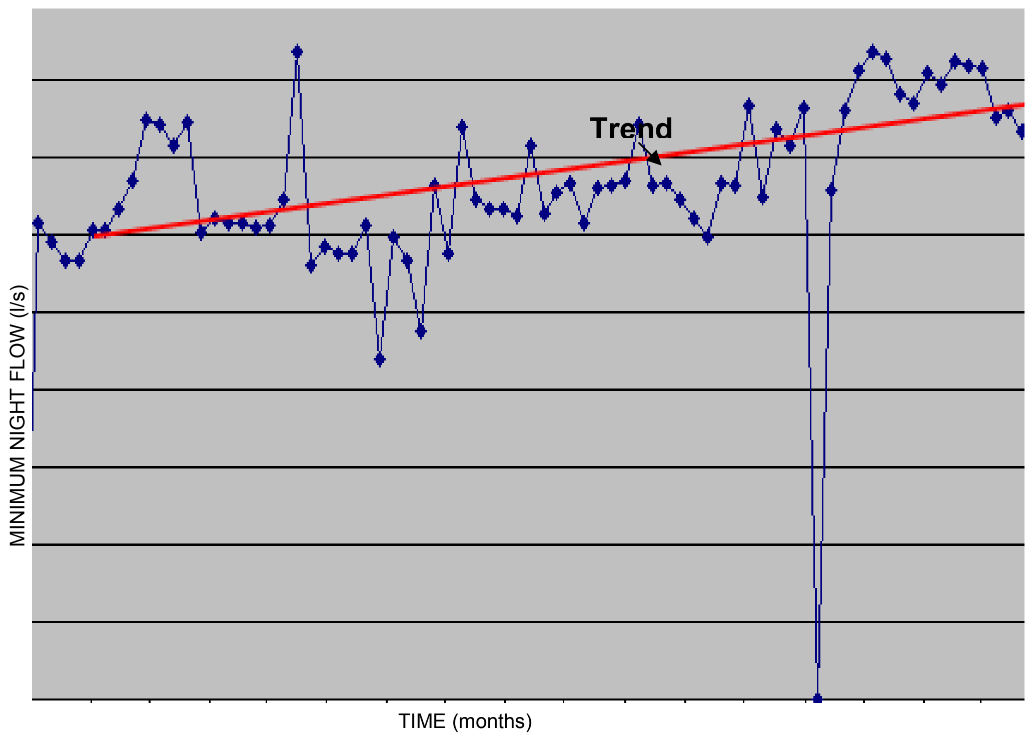

Figure 2: Return Frequency 1: 4.6 in Italian DMA

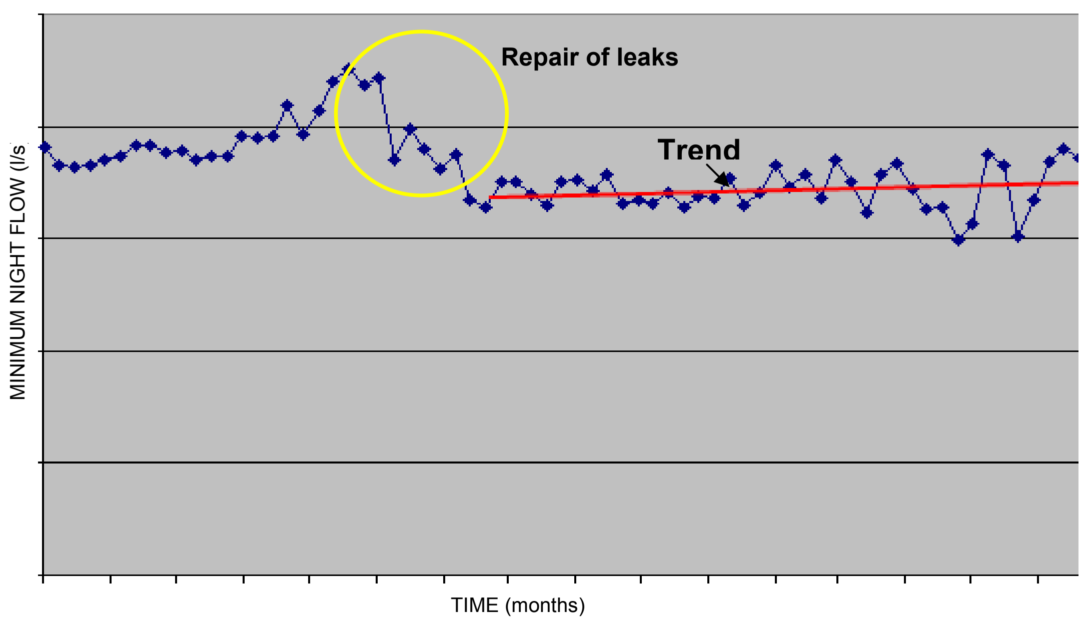

Figure 2: Return Frequency 1: 14.3 in Italian DMA

Value of the water

The value of the leakage is dependent primarily on pumping and treatment costs. In networks which suffer intermittent supply, the investment required to find and create a new source of water should also be considered, provided that the recovery of the leakage is sufficient to satisfy the existing short fall in supply. Typical values range from € 0.15/m^3 for ground water to over € 0.5/m^3 for desalinated water.

Operating mechanism

The operating mechanism of the DSS is illustrated below in Figure 4.

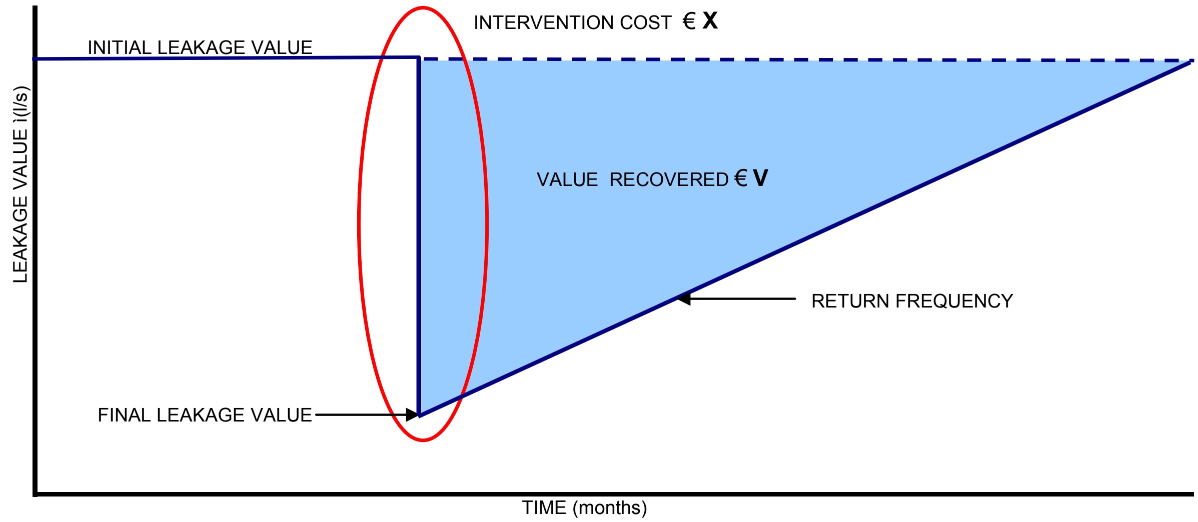

Figure 4: Operating mechanism of DSS

It starts from the initial leakage level and estimates the recovery which is based on a combination of the final leakage level and the return frequency. The intervention is economically viable if:

$$V > X$$

where:

- V is the total recovery and is made up of the cost of water x total volume recovered.
- X is the cost of the intervention

It is assumed that the existing leakage level remains constant over time if no intervention is undertaken, which is not a totally accurate reflection of reality, but as it slightly under estimates the real quantity that can be recovered, is considered acceptable.

It is clear that in the initial assessment, before any leakage work has ever been undertaken in the DMA, that most values have to be estimated based on typical historical data. It is possible therefore that the leakage recovered is less than anticipated or that the return frequency is greater. It could be argued that this is a flaw in the system, but it should also be remembered that it is already significantly more accurate than the manual assessment that is applied to the management of most DMAs where decisions are often based just on sensations.

What is clear is that the operation of a DMA cannot be generalised. This means that the amount that can be recovered, the intervention required and even the return frequency, will almost certainly vary, not just from network to network, but from DMA to DMA. For this reason, the DSS presented in this paper has a self-teaching mechanism which once the first data is recorded, continuously updates the prediction based on the real operation of each DMA. This is done by determining the average trend over time.

Consequently, as each new leakage value is added, the trend is updated and projected forward. This results in an unique return frequency for each DMA, based on its historical behaviour.

The definition of an unique return frequency curve for the DMA is very important for the long term management of the DMA. Whilst the first prediction is a one-off occurrence which inevitably has to be based on the historical data, the system also continuously evaluates the feasibility of intervening each time a new leak breaks out. It does this by allocating to the current leakage level, the unique return frequency for that DMA to predict what will happen if no intervention is undertaken and simply compares it with the same trend when applied to the lowest recorded leakage value as illustrated in Figure 5.

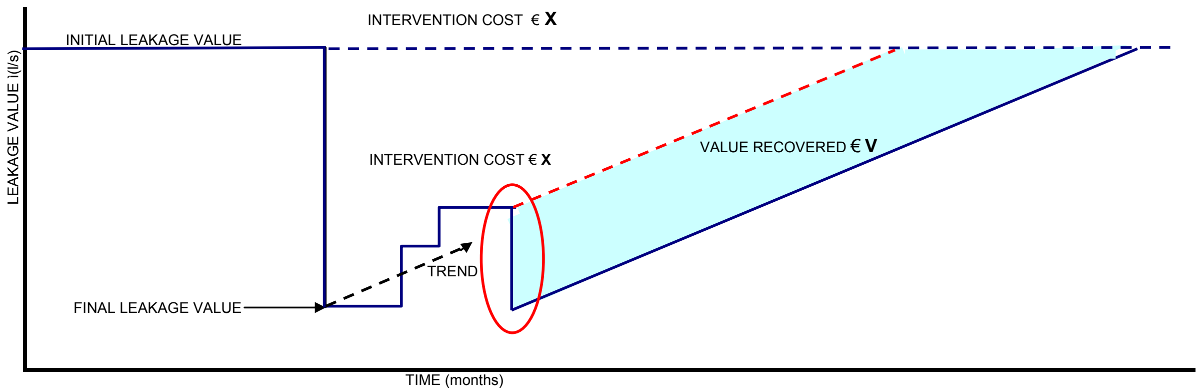

Figure 5: Management of DMAs

The value of the extra volume recovered is related to the estimated cost of the intervention to determine the validity of the operation. The difference this time is that the prediction will be significantly more accurate as it is now based on real data. The cost of the intervention is calculated by the typical recovery / cost curve as previously illustrated in Figure 1, suitably updated with the real data for the DMA.

Future development

The DSS is currently being tested on one of the largest leakage control projects ever undertaken in Italy at Avezzano, in central Italy. Although it early days, the results are very encouraging with the real network showing surprisingly good correspondence with the prediction. This is probably a reflection of the effectiveness of pressure control system to significantly reduce the occurrence of new leaks. In particular, the testing has shown the following:

- it is cost effective to intervene to repair leaks once they occur, particularly if there is a pressure control system which significantly reduces the return frequency;
- that the cost of replacing pipes changes significance the cost / benefit relationship;
- the higher the return frequency, the more need there is for costly pipe replacement.

Future developments which are planned for the DSS involve linking it to the GIS system, so that the historical repairs can be directly incorporated into the decision making process to improve the quantification of the interventions. In this way, it will be possible to include automatically in the intervention cost for the replacement of pipes which have an excessive break frequency.

Another aspect requiring further investigation is the definition of the real value of the water, particularly in networks subjected to intermittent supply. It is clear that in such cases, the value of the water is much greater than the simple production costs as there is a significant social impact to the shortage.

Conclusions

The social and environmental impact of a high leakage in a world facing acute water shortages is very evident. But almost as important for the operators and customers alike is the economic consequence of pumping and treating water which is then lost even before it arrives at the customer connection.

It doesn't always follow that it is economically viable to achieve and maintain a very low leakage level in every network. In extreme cases, where there is a plentiful supply of pure water supplied by gravity, it might be more economical to leave a leak, than to intervene. Conversely, when water is scarce or expensive to produce, it could be beneficial to locate and eliminate even the tiniest drop of leaking water. As such, any attempt to define a minimum technical level of leakage is probably irrelevant. It depends on local economic factors.

International experience has clearly shown that the most effective way to reduce and maintain a low leakage level in a water network, is to divide it into permanent sectors called DMAs. Ideally they are supplied by a single pipe on which is installed a flow meter. In this way, by analysing the minimum night flow, it is possible to not only quantify with accuracy the leakage level, but immediately identify the presence of new leaks.

Application of this methodology in many parts of the word has yielded significant reductions in the leakage level. What has been less impressive is the long-term management of these systems, which has often resulted in the leakage level returning near to its original level. There are many reasons for this, not least the lack of priority given to monitoring the system when it doesn't cause any operational problems.

The solution is an automatic decisional support system which allows the optimum economic leakage level to be maintained irrespective of the individual characteristic of the network. This is achieved by comparing the estimated value of the water recovered over time with the cost of intervention. What is unique in this system is its self-teaching algorithm which allows the return frequency trend to be defined for each individual DMA enabling the DSS to simulate more realistically the network that it manages. As more data is accumulated, the better will be the prediction will be.

The significance of this DSS, is that not only does it manage leakage economically, it integrates the control of leakage with the definition of the rehabilitation requirements which is an often overlooked factor in water distribution management. In addition, it combines the latest optimising techniques with a solid practical bases which is readily available on the market, offering water companies and contractors alike the possibility of finally achieving the goal, of managing leakage economically.