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Leak detection and water loss management

B. Charalambous[1], D. Foufeas[2] and N. Petroulias[3]
[1] *J2C Water Ltd, Lemesos, Cyprus, e-mail: bcharalambous@cytanet.com.cy.*
[2] *Olympios, Athens, Greece, e-mail: d.foufeas@olympios.gr*
[3] *Olympios, Athens, Greece, e-mail: N.Petroulias@olympios.gr*

Abstract: Water shortage and the future threat posed by changing climatic conditions has intensified the need for the development of appropriate water management approaches, which aim in keeping a balance between water supply and demand. Losses from water distribution systems must be of concern to every water utility, especially in areas of our planet where water is found in very limited quantities. It is therefore imperative that water utilities apply simple and effective methodologies in accounting for water losses from their transmission and distribution systems. The Water Loss Task Force (WLTF) of the International Water Association (IWA) has established a water audit method, which traces water from its source right through the system and derives at the end the revenue and non-revenue component, in other words is a methodology for water accountability and an integrated approach to water loss control. Many water utilities around the world recognised at a very early stage the importance and significance of establishing a proper water audit system and developed their infrastructure in such a way in order to be able to account efficiently and accurately for all water produced. Reduction and control of water loss is achieved through the application of a holistic strategy based on the approach developed by the WLTF of the IWA. Integral part of this approach is the establishment and operation of DMAs coupled with pressure management.

Key words: District Metered Areas, Leakage Reduction, Pressure Management, Urban Distribution Systems.

1. WATER LOSS CONTROL

1.1 General

Efficient and effective water loss control should be recognised as a first priority for improving potable water supply. Decision makers at all levels in water utilities must understand that any water loss control strategy in order to be effective must be a continuous activity based on a long term strategy and should form an integral part of the utility's vision. The success of the strategy will inevitably depend on the commitment and dedication at all levels within the utility and of course on the adoption of appropriate strategies and techniques.

The benefits of a water loss control strategy could be summarised as follows:

- Saving a precious and valuable resource.
- Increasing the efficiency of existing systems.
- Delaying huge infrastructure investments.
- Increasing the life expectancy of the systems.
- Increasing the revenues for the water utility.
- Reducing energy requirements.
- Improving the Carbon Footprint of the utility.

1.2 The Methodology

The IWA Water Loss Task Force (WLTF) has played a principal role in the advancement of water loss control strategies, methodologies and procedures world wide and in the development of world class tools and techniques to reduce losses and increase water accountability in revenue generation. Methodologies have been developed by the WLTF in the following areas of urban water networks management which were tested in many Utilities world wide with very positive results in reducing Non-Revenue Water: These methodologies and practices may be summarised under the following broad headings:

- Accurate and comprehensive metering
- Water balance
- Apparent losses
- Real losses

1.3 Real Losses

The IWA Water Loss Task Force has been promoting for a number of years the four leakage control strategies to reduce Real Losses from urban water distribution systems, namely:

1. Active leakage control
2. Pressure management
3. Speed and quality of repairs
4. Targeted renewal of infrastructure

These have to be balanced in order to achieve the most cost effective leakage programme which reduces leakage to an economically, environmentally and socially acceptable level (Figure 1).This approach is well tested and has been applied around the globe with extremely positive results for utilities.

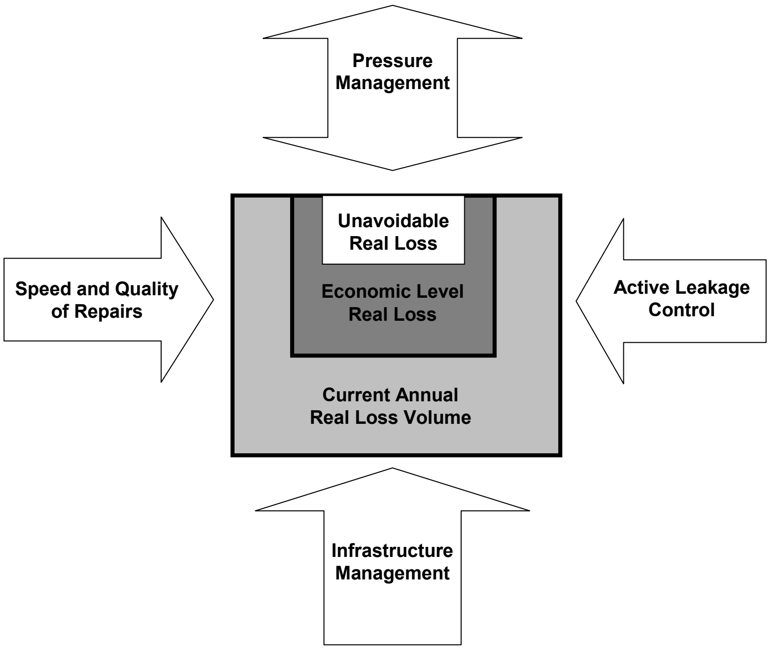

Figure 1. Four Leakage Control Strategies.

The above WLTF methodologies and strategies have a global application and represent what could be termed "best practice" in the area of water loss control. They have been implemented successfully in countries in Europe, North and South America, the Caribbean, Australia, New Zealand, Pacific Islands, South Africa and South East Asia.

As a first step in the reduction of leakage from water distribution networks it is recommend that pressures in the network are examined and optimised in such a manner that any excess pressure is removed. Leakage is a function of pressure and any reduction in pressure would result in a corresponding reduction in leakage. Dividing the network in discrete areas called District Metered

Areas (DMAs) provides an efficient and effective way of managing pressures and controlling leakage thus reducing the Real Losses to an economically acceptable level.

Real Losses cannot be eliminated totally. The lowest technically achievable annual volume of Physical Losses for well-maintained and well-managed systems is known as Unavoidable Annual Real Losses (UARL). This leads to the definition of the Infrastructure Leakage Index (ILI), which is a performance indicator for the benchmarking of physical

Real losses include leakage on transmission and distribution mains; leakage and overflows from storage tanks; and leakage on service connections up to the customer meter. Leakages from transmission and distribution mains are usually large events so they are reported quickly by the public. They can cause serious damage unless they are repaired quickly. Less conspicuous types of leakage are more difficult to detect and repair.

The strategies shown in Figure 1 are regarded as pillar strategies for controlling real losses (leakage). The strategies are briefly described below.

Active Leakage Control involves identifying and quantifying existing leakage losses on a continuous basis, typically by performing acoustic leak detection surveys at regular intervals as well as when necessary based on information and data obtained from continuous monitoring of flows and pressures at Zonal or District Metered Areas level.

Active Leakage Control (ALC) is vital to cost-effective and efficient leakage management. The concept of monitoring flows into zones, or district meter areas (DMAs), where bursts and leaks are unreported is now an internationally accepted and well-established technique to determine where leak location activities should be undertaken. The quicker the water utility can analyse DMA flow data, the faster bursts or leaks can be located. This, together with speedy repair, limits the total volume of water lost.

In practice, the effectiveness of ALC is strongly impacted by the underlying design of the distribution network and the quality or level of degradation of specific sections of pipe within the network e.g. in terms of design, where a distribution network includes optimised pressure management in its original design and has been designed to facilitate maintenance, including inter-alia sectorisation and/or the formation of District Metering Areas (DMAs), then ALC tends to be much more effective.

However, it must also be noted that water distribution networks are rarely homogenous in the quantity of their design and installation and have typically evolved over decades or centuries where in the same network system may contain sections where the design facilitates effective operation and maintenance and the effective application of ALC, and others that are inefficient and difficult to operate and/or maintain and difficult to gain effective yields from ALC measures.

Speed and Quality of Repairs aims to ensure timely and lasting repairs and is regarded as critical to the success of the overall Real Loss control program. The length of time a leak is allowed to run affects the volume of real losses, so repairs should be completed as soon as possible once a leak is detected. Repair quality also has an effect on whether the repair is sustained. Key issues to be considered by water utilities when formulating a repair policy include:

- Efficient organisation and procedures from the initial alert through to the repair itself
- Availability of equipment and materials
- Sufficient funding
- Appropriate standards for materials and workmanship
- Committed management and staffs

It is of paramount importance to have high quality of service connections since the majority of leaks are on service connections.

Pressure Management aims at minimising excess (unnecessary) pressures in the water distribution system as well as removing transients. It can be implemented through suitable pressure zoning and DMA management. It should be borne in mind that simple and inexpensive pressure management activities can often lead to considerable reductions in Real Losses.

Pressure management is one of the fundamental elements of a well-developed leakage management strategy. The rate of leakage in water distribution networks is a function of the pressure applied by pumps or by gravity. There is a physical relationship between leakage flow rate and pressure and the frequency of new bursts is also a function of pressure:

- The higher or lower the pressure, the higher or lower the leakage. The relationship is complex, but water utility managers should initially assume a linear relationship (10% less pressure = 10% less leakage)
- The lower the pressure the lower the number of new bursts. Water utility managers should initially assume that for 10% reduction in pressure 14% reduction in new breaks until a relationship is established based on actual data relevant to the specific distribution network.

To assess the suitability of pressure management in a particular system, water utilities should first carry out a series of tasks, including:

- Identify potential zones, installation points, and customer issues through a desktop study
- Identify customer types and control limitations through demand analysis
- Gather field measurements of flow and pressure (the latter usually at inlet, average zone point and critical node points)
- Model potential benefit using specialized models
- Identify correct control valves and control devices
- Model correct control regimes to provide desired results
- Analyse the costs and benefits

There are a number of methods for reducing pressure in the system, including variable speed pump controllers and break pressure tanks. However, the most common and cost effective is the automatic pressure reducing valve (PRV). PRVs are instruments that are installed at strategic points in the network to reduce or maintain network pressure at a set level. The valve maintains the pre-set downstream pressure regardless of the upstream pressure or flow-rate fluctuations. PRVs are usually sited within a DMA, next to the flow meter, as shown in the photos below. The PRV should be downstream of the meter so that turbulence from the valve does not affect the accuracy of the meter. It should be noted that in recent years advanced pressure management techniques have been introduced such as flow and time modulation and critical control point pressure management which reduce even further the pressure in the network achieving corresponding reduction in leakage and new breaks.

An indirect benefit of pressure management is the extension of the life of the assets due to lower operating pressures.

Pipeline and Asset Management deals with all network assets which should be regularly maintained in order to continue to provide the required service and of course replaced in a timely and programmed manner by the end of their useful life.

Asset management is good engineering and business practice, and it includes all aspects of water utility management and operations. Good asset management is a necessity for long-term economic leakage management, and the objective is to tackle leaks in the most cost-effective way.

Understanding Real Losses requires priority setting and decisions on whether to repair, replace, rehabilitate, or leave the assets as they are, while simultaneously implementing pressure management and improving the operation and maintenance programme. The critical factors of asset management are:

- Understanding how assets are currently performing
- Collecting data and turning it into useful information for planning
- Good information systems

Particularly relevant to developing an NRW reduction strategy is the ageing of the pipe network and making decisions on when to replace or renew the network infrastructure. This requires an understanding of the assets' conditions and deterioration rates. Burst frequency modelling, using data from burst records, helps prioritise pipe rehabilitation, renewal, or replacement. In addition, active leakage control will identify clusters of pipes in the network where bursts and repairs are a continuous occurrence.

When these activities do not lead to reduced leakages, utility managers should undertake a condition assessment programme to decide whether to replace pipes or conduct further repairs.

The combined effect of the above strategies assists water utilities in reducing and sustaining their real loss component at an economic level.

2. DISTRICT METERED AREAS

2.1 Definition

A District Metered Area (DMA) is defined as an area of the supply network having ideally about 2000 properties supplied preferably from a single entry point which is metered (water entering and leaving) and pressure controlled.

2.2 Objective

The main objective of establishing a DMA is to reduce real losses to an economically acceptable level and to maintain this level through the application of proactive strategies, such as Active Leakage Control.

2.3 Advantages

There are a number of advantages in setting up DMAs, namely:

- The areas of the network are smaller, more manageable.
- The application of active leakage control is easier.
- Leaks are identified quicker based on MNF monitoring.
- Run time of leaks is much shorter.
- Better pressure optimisation.
- Lower water losses.
- Financial savings.

2.4 Disadvantages

Minor problems may be encountered in the formation of DMAs which of course with proper planning and design can be resolved. These problems are:

- Water quality problems associated with "dead ends" in the network.
- Customer complaints due to reduction in water pressure in the system.

3. DMA LITERATURE REVIEW

Farley and Trow, 2003, referring to the DMA concept stated that "the technique of leakage monitoring is considered to be the major contributor to cost-effective and efficient leakage management. It is a methodology that can be applied to any network."

Dividing the distribution network into a number of leakage monitoring Zones or DMAs has been proved to be an efficient and effective technique for monitoring and controlling water loss. In Manual no. 4 of Managing and Reducing Losses from Water Distribution Systems, 2002, is stated that *"dividing a distribution system into sectors such as PMZs and DMAs, which are then individually managed and monitored, enables:*

- *Continuous monitoring and recording of the total quantity of water entering each sector.*
- *Leak detection teams to target sectors and minimise the length of time leaks run for, if total supply is inexplicably high in particular sectors.*
- *Water quality incidents, for example dirty or discoloured water, to be contained within one sector and not spread throughout the network.*"

The application of the DMA concept has universal application. Irrespective of geographical location or distribution network size it has been established that this technique is reliable for leakage reduction and monitoring. However, it is important in order to maintain results to achieve long-term sustainability of the DMA concept.

MacDonald and Yates, 2005, stated that "*the experience of DMA implementation at Halifax Regional Water Commission has been nothing but success"*.

Sturm and Thornton, 2005, reported that on the basis of their research project findings on nine North American Utilities with the goal to assess how international best practices can be transferred to North America, DMA techniques are applicable to Utilities in North America.

On the issue of sustainability, especially in developing countries, Loveday and Dixon, 2005, stated that "*DMA implementation is a key component of NRW reduction activity and their maintenance must be seen as a long-term commitment"*.

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