Use of district metered areas coupled with pressure optimisation to reduce leakage
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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 at 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.

The Water Board of Lemesos, Cyprus recognised at a very early stage the importance and significance of establishing a proper water audit system and has over the years developed its 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 was 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.

Key words | active leakage control, district metered areas, leakage reduction, pressure optimisation

DISTRICT METERED AREAS
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.

Objectives
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.

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.

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:

- Possible water quality problems associated with “dead ends” in the network.
- Potential customer complaints due to optimisation of water pressures.

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 State of Queensland Manual no. 4 of Managing and Reducing Losses from Water Distribution Systems (2002), it 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 & Yates (2005) stated that “the experience of DMA implementation at Halifax Regional Water Commission has been nothing but success”.

Sturm & 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 & 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”.

REAL WATER LOSSES

The IWA (Task Force on Water Losses 2000) recommended definition of Real Water Losses, sometimes referred to as “physical losses”, is the annual volume of water lost from the system through all types of leaks and overflows from reservoirs and from bursts in mains and service connections up to the point of customer metering (Fanner 2004). The Water Board has placed great importance in reducing the real losses and this is reflected in its adopted strategy over the years.

The development of the system infrastructure took place in a much organised fashion with new areas of supply being incorporated into their respective pressure zones, which are strictly governed by contours. Each pressure zone is subdivided into DMAs, having a single metered source with physical discontinuity of pipe network between DMA boundaries.

The DMAs vary in size from 50 properties to 7,000 although the average size being approximately 3,000 properties. Distribution main diameters within the DMAs vary between 100 mm and 250 mm and where possible, interconnecting ring systems within the DMAs have been formed to minimize head loss at peak demands.

The Water Board has maintained records of its operational activities since 1963, which include production of water from sources, distribution through district meters and consumption from consumer meters. Meter readings at water sources (boreholes and treatment plant) are connected via a SCADA telemetry system to the control room.
This enables continuous monitoring of the water source outputs and accurate recording of flows. Likewise storage reservoir outlet meters are monitored on SCADA providing the same ability to observe trends as well as to record daily, weekly, monthly and yearly totals.

As all the trunk mains, made of ductile iron, are purely dedicated to transferring water from sources to the storage reservoirs, it is possible to carry out a water balance between production meters and storage reservoir outlet meters. The results show that on a yearly basis the difference between the production meters and reservoir outlet meters is less than 1% which is considered to be negligible and is attributed to meter registration errors.

Distribution of water to the DMAs is effected through dedicated ductile iron mains from the storage reservoirs. Each pressure zone has its own dedicated storage reservoir supplying the DMAs within the specific pressure zone. Each DMA has a single feeding point, which is metered. With this arrangement it is possible to carry out a water balance between the storage reservoir outlet meters and the DMA meters. The results show that on a yearly basis the difference is about 2%, which is attributed to meter inaccuracies.

Therefore it could safely be assumed that all real water losses are within the DMAs.

**DMA REDESIGN**

Since 1993 leakage management was effected through data logging, pressure reduction and leak location. Data logging for flow and pressure was carried out using ten “Radcom” data loggers. Logging was typically done for a period of 7 days and the loggers were then removed, the data downloaded, and deployed again to monitor other DMAs. In this way each DMA was monitored 3 to 4 times a year for a period of one week each time. It was also recognised that there was potential for pressure reduction and in 8 out of a total of 27 DMAs, Pressure Reducing Valves (PRVs) were installed. Initially leak location was done using step testing and sounding. Since 1999 the Water Board employs state of the art technology for leak identification and location including, acoustic loggers, correlators and ground microphones.

The above methodology, however, presented several shortcomings. The data available from the periodic logging were insufficient to enable proper monitoring and control. Awareness, Location and Repair (ALR) time of leaks was extremely long and it was very difficult to prioritise intervention activities. The deployment and removal of loggers was time consuming and labour intensive.

It was obvious that there was a need for an immediate review of the Water Board’s leakage management strategy. After careful consideration and examination of the available techniques, methodologies and technologies it was decided that in order to achieve further reduction of real losses from the distribution network it was imperative that a proactive approach in evaluating the efficiency of the network needed to be adopted based on continuous monitoring of flow and pressure in all DMAs.

Therefore, it was considered important to first carefully examine the size of the DMAs in the pressure zones in an effort to further reduce the real losses from the network and provide better and more effective active leakage control.

The key factors for good DMA design (Water Loss Task Force 2004) formed the basis of the redesign. These were:

- minimum variation in ground level across the DMA,
- easily identified boundaries that are robust,
- area meters correctly sized and located,
- single entry point into the DMA,
- discrete DMA boundaries,
- pressure optimised to maintain standard of service to customers,
- degree of difficultly in working in urban area.

The variation in ground levels across the supply area was examined and particular attention was given to the influence of the pressure within the DMAs. Main highways and physical features, such as streams were chosen to form discrete boundaries between DMAs. A single entry point into the district was chosen where a meter chamber was constructed to house the district meter, a pressure reducing valve and a pressure sensor. It must be stressed that the implementation of the redesign was not an easy task due to the difficulties and restrictions imposed in executing works in built up areas. These works involved inter alia, the construction of new district meter chambers, laying new lengths of pipeline and installation of new telemetry system for continuous monitoring of flow and pressure.
The redesign process yielded DMAs of smaller, more manageable size with physical pipework discontinuity between DMAs. In order to verify that all interconnecting pipes between DMAs were located and isolated, a zero pressure test was carried out which involved closing the valve at the inlet to the DMA thus isolating the DMA and observing that the pressure within the DMA dropped immediately indicating that all interconnecting pipes were isolated. This test was usually carried out between 02:00 and 04:00 in the morning in order not to inconvenience consumers.

It is essential, for the effective operation of DMAs, to establish a reliable continuous monitoring system in order to apply best practice DMA management which involves the analysis of DMA night flow referred to as the Minimum Night Flow (MNF) in order to assess leakage. For this purpose each district meter is equipped with a programmable controller which is powered in most cases by solar energy panels providing a cheap and effective solution, approximately €1800 per station. Most importantly the operating cost of such a solution is extremely low, €14/month. The continuous monitoring of the district meters combines information technology and telecommunication networks to transfer the data via the World Wide Web.

PRESSURE REDUCTION

Continuous flow monitoring began immediately upon completion of the redesign works in each DMA. This enabled the establishment of the flow pattern for the DMA providing essential information such as maximum and average daily flows as well as minimum night flows. Data required to establish legitimate customer night use and background leakage in each DMA were collected. Having available this information the Burst and Background Estimates (BABE) component approach to leakage was used to analyse the Minimum Night Flow (MNF).

Management of pressure is a key factor in an effective leakage management policy. This has long been recognised by the Water Board and the ultimate goal is for all DMAs to be equipped with PRVs to reduce pressure where possible and to control and stabilise pressure in DMAs where pressure reduction is not practicable.

Measurements of pressures within the DMAs were carried out to establish operating pressures at the low, medium and high points of the DMA as well as the Average Zone Night Pressure (AZNP) for each DMA. Furthermore, the pressure measurements were critically examined with the aim to reduce pressure as much as possible whilst maintaining the minimum standard of service to the consumers. As a rule a minimum standard of service of 2 bars at the highest point in the DMA at maximum demand was considered. This of course had to be reconsidered in some cases where there were high rise buildings which use the network’s pressure to get the water to their roof tanks. In these cases the Water Board will subsidise the installation of ground tanks and pumping systems in order to pump the water to the roof tanks of the high rise buildings thus enabling further pressure reduction to be effected.

The reduction of pressure in the DMAs was effected (Figure 1) over a period of a few hours and amazingly enough

![Pressure reduction](https://example.com/pressure_reduction.png)

**Figure 1** | Pressure reduction.
no complaints were received from consumers except in some cases where people were using the mains pressure to water their lawns. It was explained to them that they can no longer rely on the mains pressure to water their lawns and they were assisted by the Water Board to install small irrigation pumping systems for garden irrigation. Pressure measurements were repeated in each DMA after pressure reduction was effected to ensure that there were no potential problems and that the minimum standard of service was maintained.

**RESULTS**

**Background and locatable losses**

Having implemented the DMA redesign works, data was collected and BABE calculations were carried out in order to determine background and locatable losses for each DMA. A similar calculation was carried out after applying pressure reduction in each DMA. It must be stressed that the values used for actual MNF were field values measured over a period of approximate one month before and one month after the application of the pressure reduction so that the values of the flows before and after are comparable and are not influenced by seasonal variations.

Pressure reduction was effected in all DMAs without attempting to locate and fix the locatable losses in these DMAs. The application of the pressure reduction resulted in a reduction of 38.1% in the background losses and in a reduction of 38.8% in locatable losses.

It is worthwhile noting that due to pressure reduction there was an immediate reduction of 25% in the volume of water required for whole of Sector 2 which meant a saving of 220,000 m³ per annum valued at €170,000.

The leakage–pressure relationship \( \frac{L_1}{L_0} = \left( \frac{P_1}{P_0} \right)^{N_1} \) is valid for calculating the possible leakage reduction in a water distribution system for a given pressure reduction. The exponent “\( N_1 \)” is specific to the distribution network depending on the type of material that the pipework is made of. In order to establish the “\( N_1 \)” values for the Water Board’s network the ratios \( P_1/P_0 \) and \( L_1/L_0 \) were calculated and the “\( N_1 \)” exponent derived for each DMA. The leakage ratio included both background and locatable losses.

The values of \( N_1 \) vary between 0.64 and 2.83 with an average value of 1.47. These figures are of the same order of magnitude as figures reported by others (Lambert 2001), which reinforce the use of the leakage – pressure relationship \( \frac{L_1}{L_0} = \left( \frac{P_1}{P_0} \right)^{N_1} \). The distribution mains in all of the DMAs under consideration is a mixture of asbestos cement and uPVC with MDPE communication pipes.

**New burst frequency**

Records were kept of reported leaks before and after pressure reduction and an analysis of these shows a reduction of leaks both for distribution mains and communication pipes. The results shown in Table 1 cover a period of seven months before pressure reduction and the corresponding seven months after pressure reduction.

The weighted overall Average Zone Night Pressure for Sector 2 was 52.5m before the reduction and 35.8m after. This meant that there was an overall pressure reduction of 32%. Therefore, for a 32% overall pressure reduction there was an overall reduction in new leaks on mains, fittings and communication pipes of 41% which compares favourably with a similar case in Australia reported by Lambert 2001, where a 40% reduction in one sector of a city reduced frequencies of all new leaks on mains, services and fittings in that sector by 55%. Of course there many other factors affecting burst frequency of mains such as: weather conditions, accidental damages, etc. (Farley & Trow 2003).

It was estimated that based on the above percentage reduction in new bursts the Water Board saved in labour and material costs that would have incurred for locating and repairing these bursts approximately €100,000 per annum.

**Table 1 | Reported leaks**

<table>
<thead>
<tr>
<th>Description</th>
<th>No. of leaks reported</th>
<th>Reduction of leaks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distribution mains</td>
<td>49</td>
<td>27</td>
</tr>
<tr>
<td>Communication pipes</td>
<td>296</td>
<td>178</td>
</tr>
</tbody>
</table>
CONCLUSIONS

The Water Board of Lemesos operates a well organised supply and distribution system with permanent pressure zones and District Metered Areas thus providing a solid foundation on which an effective leakage control policy has been developed.

The DMA redesign and the application of pressure reduction has produced favourable results with both background leakage and locatable losses being reduced by approximately 38%. Furthermore the frequency of reported leaks was reduced by approximately 41%. The overall pressure reduction for the fifteen DMAs under consideration was of the order of 32%.

The target of the Water Board of Lemesos is to reduce the NRW to about 8% of the system input volume, which is considered to be the economic level of leakage (Lambert & Fantozzi 2005). The Water Board demand forecasts indicate an increase of approximately 30% by the year 2020 and the leakage reduction will go some way towards offsetting this increase in demand as well as a provide considerable cost saving.

REFERENCES


