Recent developments in predicting the benefits and payback periods of introducing different pressure management options into a Zone or small distribution system

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Abstract Substantial advances have been made by the IWA Water Loss Task Force members in the last few years in the development of practical water loss management methods, including the benefits of active pressure management, calculation of economic intervention frequency for active leakage control, and economic levels of leakage. This paper proposes a practical way in which the changes in leak flow rates, changes in numbers of leaks and repair costs, and changes in income from metered customers can be included in calculations of the benefits and payback periods of introducing different pressure management options.

Keywords pressure management, burst frequency, economic management, water losses.

INTRODUCTION

Pressure management can be defined (Thornton and Lambert, 2005) as "The practice of managing system pressures to the optimum levels of service ensuring sufficient and efficient supply to legitimate uses and consumers, while reducing unnecessary or excess pressures, eliminating transients and faulty level controls all of which cause the distribution system to leak unnecessarily".

An International Water Association Report on Water losses management and Techniques in 30 countries, to the Berlin Congress in 2001 (Lambert, 2002) concluded that ' Pressure Management is receiving increasing attention as an effective means of Leakage Management; the basic understanding of pressure:leakage rate relationships has improved.' The Report stated that 'Numerous successful pressure management projects have been implemented in Brazil, Denmark, Cyprus, Hong Kong, Israel, Japan, Malaysia, Malta, South Africa, Spain, Taiwan and UK. Italy, Romania, Portugal, Norway, New Zealand, Thailand, Australia and USA appear to be aware of the potential for pressure management benefits, but numbers of actual projects seem relatively small.' The Spanish National Report identified reduction of excess pressures as ' the preventative measure par excellence'.

Until very recently, calculations of the economic case for pressure management were usually based only on the predicted reduction of flow rates of existing leaks. However, the effect of pressure management on burst frequency is now also receiving increasing attention, and the results of some 50 tests worldwide showed that many systems experienced significant reductions in new burst frequency following quite moderate reductions in average pressure (Ogura, 1979; May, 1994; Thornton, 2002, 2003; Thornton and Lambert, 2005, 2006, 2007; Fantozzi and Lambert, 2007). This information has already produced a notable increase in the numbers of pressure management projects in Australia, Croatia, Italy and Malaysia.

Therefore effective management of system pressures is the foundation of a successful and economic leakage management policy.

Published examples of successful implementation of pressure management initiatives are encouraging other Utilities to manage their water losses more effectively. But the task of communicating the new improved methodologies to thousands of Water Utilities continues to be a significant challenge.

PRESSURE MANAGEMENT STRATEGY – MAKING IT HAPPEN

The authors of this paper, as well as other colleagues based in North America, Europe and Australia, use a common approach when explaining to Utility personnel how to begin to implement effective management of system pressures, as follows:

- **Step 1: Assess probability of Pressure Management opportunities**, based on type of supply (gravity or pumped) and average pressure, according to International Best Practice.
- **Step 2: Proceed to investigations and predictions in individual sectors of a system,** using best practice methodology.
- **Step 3: Identify opportunities for achieving economic management of operating pressures,** to reduce frequencies of new leaks, and flow rates of running leaks.
- **Step 4: Select what type of pressure management is most appropriate**

This process has become much easier to accomplish during 2007, as there are now software packages (developed by Water Loss Task Force members), that allow the user to assess probability of pressure management opportunities, to assess achievable economic benefits in individual sectors of a system and to select what type of pressure management is most appropriate.

Step 1: Assess probability of Pressure Management Opportunities based on type of supply (gravity or pumped) and average pressure, according to International Best Practice.

In Developed Countries the assessment assumes a minimum standard of service for pressure of around 20 metres at all times. In Developing Countries, a lower standard of service for pressure is assumed to apply, with greater opportunities for pressure management at lower pressures.

First of all it is important to understand the principles as to how pressure management may influence leak flow rates, frequency of new bursts, and consumption.

Excessive pressures and surges (transients) adversely influence:

- the flow rates from existing leaks
- the number of new leaks and bursts that occur each year, and their repair costs
- the efficiency and frequency of active leakage control interventions
- infrastructure replacement program investments

Average pressures may also influence some elements of consumption, and revenue.

A free software (CheckCalcs) allows for an overview assessment of pressure management benefits and opportunities.

Table 1.1: Overview predictions of Pressure Management opportunities and reductions in leak flow rates, new burst frequencies and residential consumption

Wide Bay Water			
Anytown			
Average System Pressure Pav is	65.0	metres	
System is supplied principally by gravity with	Continuous supply		
Using this information, and the assessment method shown in Cells G15 to M21, the probability of pressure management opportunities for this system can be provisionally categorised as	HIGH		
Assumed change in average system pressure	-15.00	metres	
Assumed % change in Pav	-23.1%		
% of annual residential consumption outside property	30%		
Do customers have private storage tanks? (Yes/No)	No		
Probable range of predicted changes:	**Lower**	**Median**	**Upper**
% change in current leak flow rates	-12%	-23%	-33%
% change in new burst numbers and annual repair costs	-5%	-48%	-88%
% change in residential consumption	-0.9%	-2.4%	-3.8%

Step 2: Proceed to investigations and predictions in individual sectors of a system, using best practice methodology

The first essential part of Step 2 is to check for the presence of surges by short-period pressure measurements (1 second time interval or less), not only is systems with pumped or intermittent supply, but also in gravity systems, as surges may be caused by customers' activities. Action to limit and reduce surges is essential. Then, check for excess pressures by pressure measurements at the critical point.

Thornton and Lambert (2006) summarised methods for analysis and prediction of pressure:leak flow rate and pressure:consumption relationships using the FAVAD (Fixed and Variable Area Discharges) concept, using the exponent N1 for components of leakage, and N3 for components of consumption. The methodology requires that data used are properly collected and checked, and that key concepts and parameters like AZP (Average Zone Point), N1, N3, NDF (Night-Day Factor) etc. are used in calculations.

According to latest developments and research results, here is no doubt that new burst frequencies can be significantly reduced by reduction of surges (pressure transients) and excess pressures. Thornton and Lambert (2007) show 112 examples from 10 countries, the average reduction in new burst frequency being around 1.4 times the average reduction in maximum pressure. The paper also demonstrates developments in methods for predicting how new burst frequencies will reduce with pressure management, with separate predictions for mains and services, based on simple analysis of the current burst frequencies. The concepts and methodology are described in the LEAKSSuite software PressCalcs, and are used in the CheckCalcs, PreMoCalcs and ELLCalcs softwares, that have been created to provide an introduction to practical predictions of how changes in pressure management are likely to influence leak flow rates, new leak frequency, repair costs, consumption, operating costs and revenue for individual distribution systems.

The above mentioned LEAKSSuite softwares, updated to include the latest prediction methods for pressure:leak flows and pressure:burst frequency and also for pressure:consumption relationships (Lambert, 2007), can also be used to quickly assess if it is likely to be advantageous to introduce pressure management in a particular Zone.

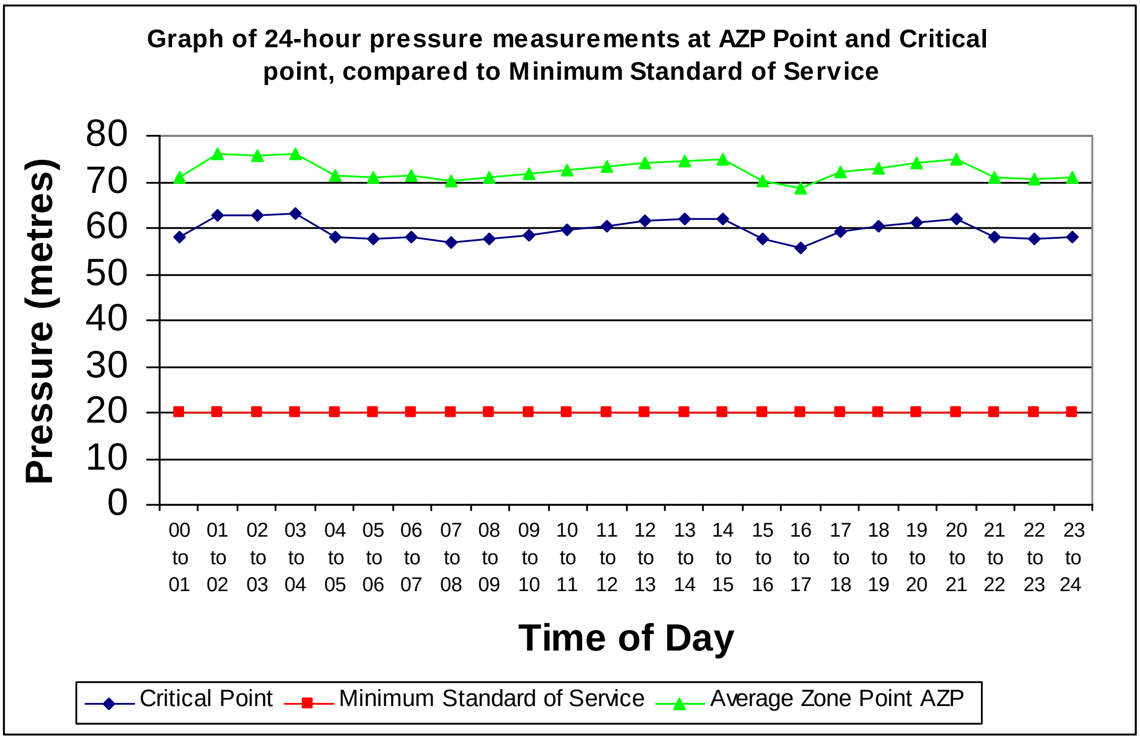

Figure 2.1 Pressure measurements and at AZP Point and Critical Point (Software PressCalcs).

Figure 2.2 shows change in break frequency on services and on mains after pressure management has been implemented in a zone in a water utility in Bosnia and Herzegovina (Kovacs, 2006).

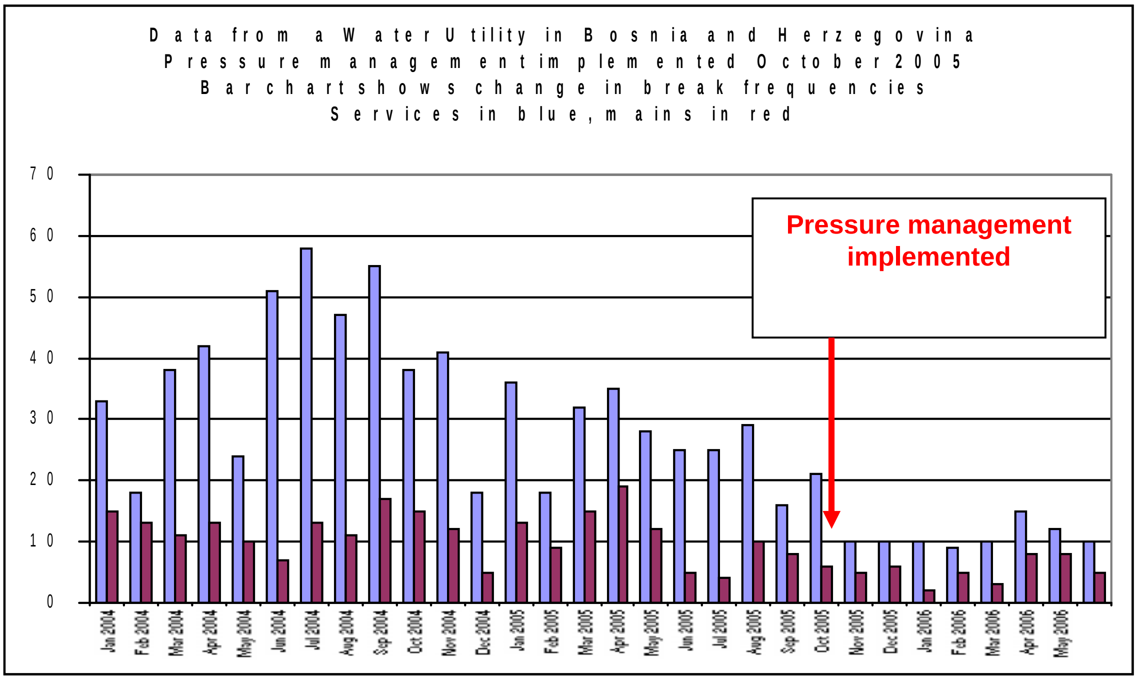

Figure 2.2 Change in break frequency after pressure management implemented (Software PressCalcs).

Step 3: Identify opportunities for achieving economic management of operating pressures, to reduce frequencies of new leaks, and flow rates of running leaks.

The '4-Component' diagram, shown in Figure 3.1, is now widely used internationally, to explain the practical concepts for managing Real Losses that are promoted by the Task Force.

For any distribution system, the large box represents the Current Annual Real Losses CARL (calculated from a standard IWA Water Balance, preferably with 95% confidence levels). The Unavoidable Annual Real Losses UARL are calculated from the equations developed in Lambert et al (1999), based on mains length, number of service connections, customer meter location and average pressure. The Infrastructure Leakage Index (ILI) is the non-dimensional ratio of CARL/UARL, and is the recommended 'best practice' Performance Indicator for operational management of Real Losses.

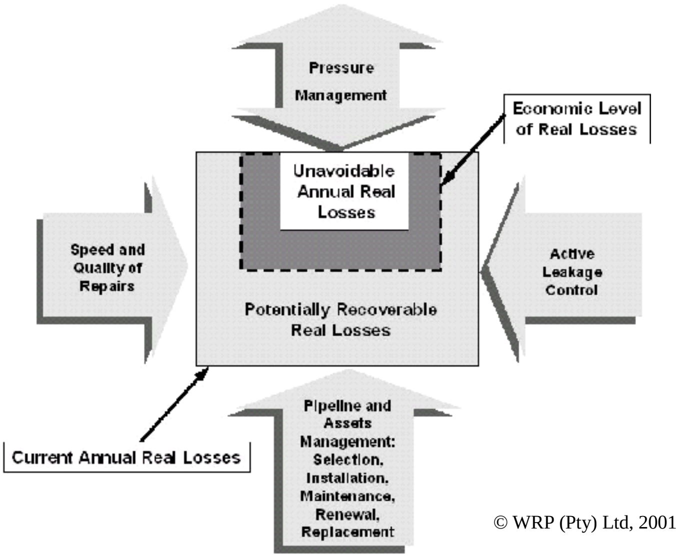

Figure 3.1: The Four Components Approach to Management of Real Losses

Real Losses can be constrained and managed by an appropriate combination of all of the four management activities shown as arrows. For each system, at any particular time, there will be an Economic level of Real Losses, this usually lies somewhere between the CARL and the UARL.
When a Utility starts to apply the 'Four Component Approach' to management of Real Losses in its system(s), activities of 'Pipeline and Assets Management' almost always (in the experience of the authors) have considerably longer payback periods than the other three activities 'Speed and Quality of Repairs', 'Pressure Management' and 'Active Leakage Control'.
So, by concentrating on these three activities, for the first few years at least, Utilities with initial high leakage levels (expressed in volume/day) can usually achieve substantial reductions in Real Losses with short payback periods (Charalambous et al. 2005; Fantozzi and Lambert).
Latest developments allow for predicting how pressure management influences:

- frequency and flow rates of reported leaks
- rate of rise of unreported leakage
- economic intervention frequency of Active Leakage Control (ALC)
- reduction in background leakage

While there are varying degrees of sophistication of pressure control and active leakage control, the initial objective should be to 'get started' with each of the simple basic activities. In this paper, the term '*Short Run Economic Leakage Level (SRELL)*' is defined (according to Fantozzi and Lambert, 2007 and Lambert and Lalonde 2005), as that which should be achievable by:

- ensuring all detected leaks and bursts are repaired promptly and to a high standard
- introducing basic pressure management, to reduce excess pressures and surges
- active leakage control by regular survey, at an economic intervention frequency

It is therefore possible to predict:

- SRELL at current pressure
- SRELL at any alternative new pressure
- Reduction in current leakage by pressure management only

so that a wide range of options can be quickly evaluated and compared, with confidence limits.

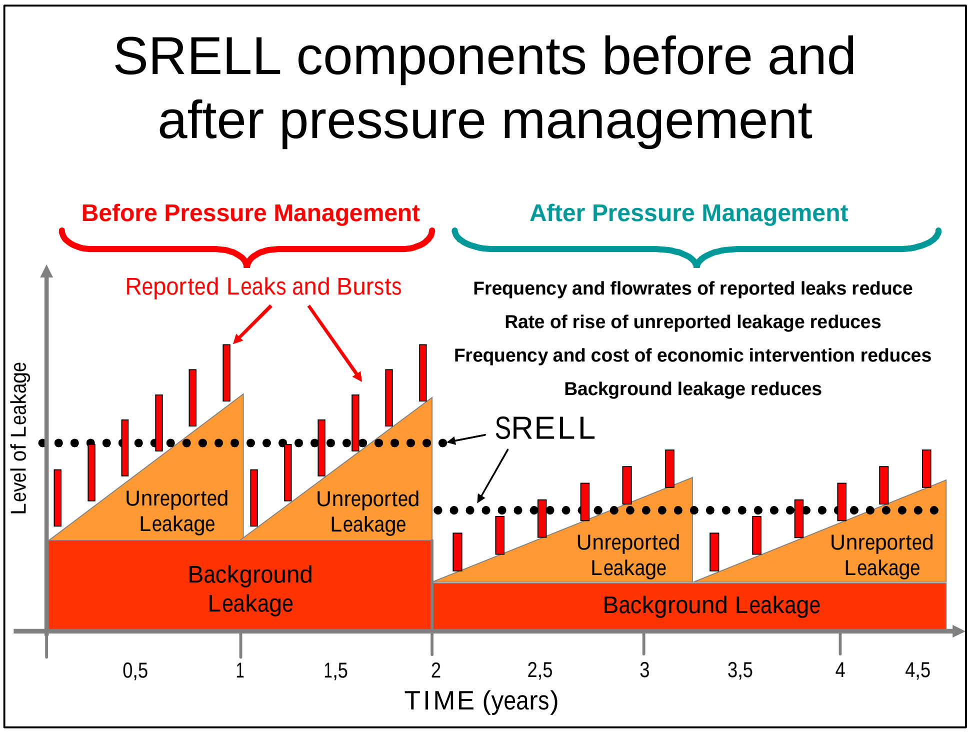

Figure 3.1 Influence of pressure management on simplified BABE (Bursts and Background Estimates) components of SRELL.

Step 4: Select what type of pressure management is most appropriate

The analysis of a 24-hour test in which inflows to the Zone are measured, together with pressures at the Inlet Point, Average Zone Point and Critical Point is necessary for predicting the benefits and payback periods of introducing different pressure management options into a Zone or small distribution system.

As an example, Figure 3.2 and Table 3.1 below, from the Pressure Management Options software PreMoCalcs, predicts the various components of volume and cost savings for options of Fixed Outlet, Time Modulation and Flow Modulation, based on a 24-hour Zone test in a Brazilian system in which inflows are measured at the Inlet point, and pressures are measured at the Inlet, Average Zone Point and Critical Point.

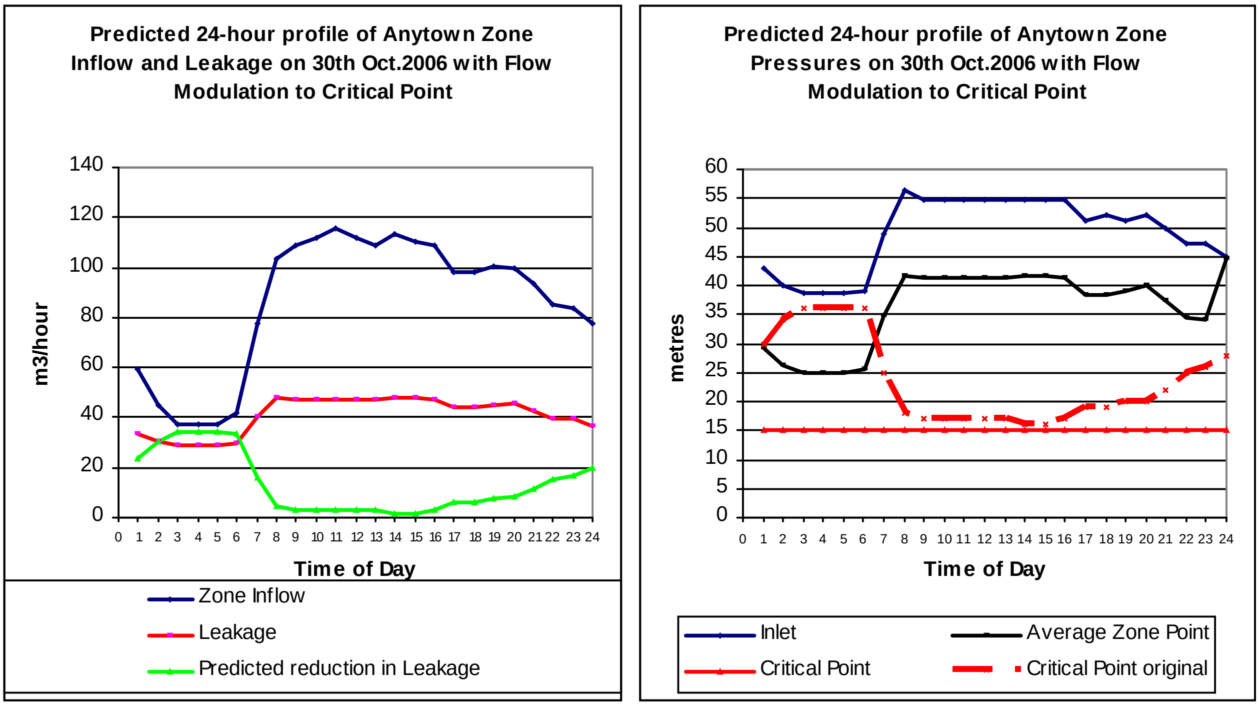

Figure 3.2 Predicted profiles of Flow, Pressure and Reduction in Leakage with flow modulation to Critical Point (Software PreMOCalcs).

The software PreMOCalcs allows the user to manage all data needed to do the calculations, to summarise the results of the predictions and to calculate payback periods for each of the 3 pressure management options. It also includes quality control and audit checks.

Table 3.1 Various payback periods for Pressure management options in a Zone in Brazil (PreMoCalcs)

CALCULATION OF PAYBACK PERIODS			Fixed Outlet	Time Modulation	Flow Modulation
Predicted Changes	Leakage	Euro/yr	21572	45830	71397
	Repairs	Euro/yr	2790	4680	6240
	Income	Euro/yr	-2331	-2419	-5866
Implementation Cost		Euro	20000	30000	40000
Predicted Payback Periods, allowing for:	Leakage only	Months	11.1	7.9	6.7
	Leakage + Repairs	Months	9.9	7.1	6.2
	Leakage - Net Loss of Income	Months	12.5	8.3	7.3
	Leakage - Net Loss of Income + Repairs	Months	10.9	7.5	6.7

SUMMARY AND CONCLUSIONS

- Pressure has an important influences on the management of water distribution systems
- Free softwares for assessing probability of Pressure Management opportunities, based on type of supply (gravity or pumped) and average pressure, are now increasingly available
- Initiatives based on training workshops and educational softwares can significantly speed up the application of the methods by large numbers of Utilities in individual countries
- An increasing number of Utilities is progressively applying the methodology and achieving results, also thanks to available software supporting practical application.
- The example shown in the paper demonstrates that the many influences of pressure on all components of leakage, and on costs of repairs and economic active leakage control, are simply too substantial to be ignored
- Research continues into testing and refining the prediction methods, and the calculation of economic effects of pressure management.

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