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Research Note

Non-Revenue Water Losses: A Case Study

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Abstract: Management of non-revenue water requires understanding of the reasons and the factors influencing its components. Techniques and procedures are developed, and tailored for specific characteristics of the network and local factors, to tackle each of the priority components. This is followed by the implementation of solutions which are practicable and achievable to develop a strategy. The first step in developing a strategy is the network characteristics and the operating practices, and then use the available tools and mechanisms to propose appropriate solutions. A case study of non-revenue water for an area in Selangor was done. Levels of losses were estimated at approximately 40 to 50 percent which are high by international standards. This work seeks to present a way forward for dealing with loss levels by utilizing modern concepts and definitions currently in use and presenting technologies for the implementation of a comprehensive water loss programme. Strategies for the assessment of leakage levels and determination of an optimum or economic level of leakage and the benchmarking of the local situation making use of the infrastructure leakage index.

Key words: Non-revenue water, case study, leakage management.

Introduction

Throughout the world, many public water utilities suffer from high levels of Non-Revenue Water (NRW). Performance indicators for losses from water supply systems were suggested by Alegre et al. (2000), Carpenter et al. (2002), Hirner and Lambert (2000) and Lambert et al. (1999). In cases where the utility has surplus water resources, the high levels of NRW only have a negative impact on the utility's finances by increasing operating costs and reducing revenues as described by Lambert et al. (1998). In cases where the utility has no surplus water resources, high levels of NRW can also result in water shortages during peak demand periods, reducing the level of service provided to customers. Water loss is a problem for all water utilities. NRW is between 15% and 30% in the developed world but elsewhere it is more likely to be in the 30% to 60% range. In Malaysia, it stands at an average of 40%. Active leakage control (ALC) and monitoring as described by Malcolm and Stuart (2003) and White et al. (1999) have proven to be cost effective throughout the world. Increased effort in monitoring leakage such as extra reporting, specific investigations and, where necessary, enforcement orders have also been successful. At the same time consumers also need to be thoughtful in their use of water.

Real losses comprise leakage from pipes, joints and fittings, from leakage through service reservoir floors and walls, and from reservoir overflows. Real losses can be severe, and may go undetected for months or even years. The volume lost will depend largely on the characteristics of the pipe network and the leak detection and repair policy practised.

It is difficult to be prescriptive as to the methodology which should be followed for setting leakage targets and for deriving an appropriate strategy for managing leakage. An appropriate leakage reduction plan can only be set with due regard to the funding requirements. Even if leakage targets can be shown to be economical, the work has to be funded up front in order to achieve a pay back over a longer term—in some cases over 20 years. Funding could come from raising charges to customers, from

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government sources, from international grants and loans, or by accepting a lower level of profit during the leakage reduction work. It may be necessary to review the organisation structure and to make changes to the leakage programme management. Whenever the workload warrants the appointment of a leakage manager, it could be the preferred course of action. A target should be set for the leakage reduction, and that this target be monitored and maintained.

Research Objective

(a) To detect leakage at the level of pipeline.
(b) To investigate the effectiveness of leak-detection equipment.
(c) To recognize and analyze the water leaking level and the cost due to the loss of water.

The case study will include the leakage zone specified by Syarikat Bekalan Air Selangor (SYABAS). The zone area is Taman Pinggiran Batu Caves which was then used to study the level of water losses in the area. This zone is a residential area with a few shop-houses. It was constructed approximately seven years ago and contains 1292 service connections. Within this zone there are 10.6 km of distribution system pipework, consisting mainly of AC pipes. The scope includes the reduction of real losses (leakage) and apparent losses (meter under-registration). Whilst leakage reduction is of the utmost importance because of the limited water resources of the State of Selangor, the reduction of apparent losses will automatically lead to an increase of revenue for the water utility. The performance target set in this study were divided in two categories as stated below. Projected annualised volume saved in cubicmetres (combined savings from reduction in physical losses and increases in meter accuracy) is shown in Table 1.

Table 1: Projected Annualised Yearly Performance Targets

Year	*Cumulative Number of NRW Zones Implemented*	*Cumulative Number of Revenue Meter Replacements*	*Annual Performance Target (Mm^3)*
1	30	25,000	2.65
2	50	50,000	17.46
3	95	75,000	32.41
4	160	100,000	43.65
5	196	120,000	52.88
6	210	145,000	60.24
7	210	150,000	67.95
8	210	150,000	72.17
9	210	150,000	72.60

Many 'non-working' meters were replaced. Where metered consumption was zero, consumption was estimated for billing purposes.

Methodology

Average duration of detectable leaks and bursts consists of three components: awareness, location and repair time. The typical parameters which would be assumed to influence components of annual real losses in different parts of the infrastructure are shown in Table 2.

In 'Burst and Background Estimates' (BABE) analyses, components of real losses are considered to consist of background leakage at joints and fittings, reported leaks and bursts and unreported leaks and bursts. The components of the water balance can be measured, estimated or calculated using a number of techniques as indicated by Lambert and Morrison (1996) and Morrison (2002). The type of soil/ground can influence the frequencies of leaks and bursts, and the speed with which leaks and bursts become visible at the ground surface. There are other factors which constrain performance in managing real losses, which can vary widely between individual distribution systems: continuity of supply, length of mains, number of service connections, location of customer meters on service connections, and average operating pressure.

Equipment

The equipment used in this study included the telemetry and pressure control—"PrimeLog" and "Workabout", leak detection instruments/pipe, cable and valve locators, leak repair materials and consumer meters. Apart from standard office software, such as the Microsoft "Office" Suite, the following software, which were particularly relevant to this project, were utilized:

- *"AutoCAD Map", "MapInfo"* or other suitable software for the preparation of maps and a Network Information System
- *"BABE"* (Burst And Background Estimates) or other suitable software

Results and Discussion

The BABE analysis for this zone predicted excess losses of 413 m^3/day. An initial leakage survey was carried out in October 2003 to investigate the potential for physical loss reduction. An insertion flow meter (I.F.M) was first

Table 2: Parameters used for calculating components of Annual Real Losses

Component of Infrastructure	*Background (undetectable) Leakage*	*Reported Burst and Overflows*	*Unreported Burst and Overflows*
Mains	Length Pressure Min loss rate/km	Number/year Pressure Average flow rate Average duration	Number/year Pressure Average flow rate Average duration
Service Reservoirs	Leakage through structure, % of capacity/day	Number of reported overflows/year Average flow rate Average duration	Number of unreported overflows/year Average flow rate Average duration
Service Connections, Main to Property Boundary	Number of service Connections Pressure Min loss rate/connections	Number/year Pressure Average flow rate Average duration	Number/year Pressure Average flow rate Average duration
Service Connections after Property Boundary	Length Pressure Min loss rate/km	Number/year Pressure Average flow rate Average duration	Number/year Pressure Average flow rate Average duration

installed. A permanent meter chamber was constructed in September 2003. The initial nightline was measured at 8.84 litres/second.

The first baseline was measured over the period 21st to 28th October 2003 and the average initial inflow into the zone (Q_i) was calculated to be 2948.7 m^3/day. The leakage survey detected a total of 37 leaks, which were repaired over the period 29th Oct to 17th Dec 2003. These repaired leaks consisted of 18 service connections, one main pipe, 11 sluice valves, three air valves, and four fire hydrants.

As a result of these repairs, the nightline was reduced to 6.94 litres/second. Pressure management was then utilised in this zone. The night pressure at the inlet to this zone was reduced from 45 metres to 37 metres. This resulted in a further reduction in the nightline to 6.31 litres/second.

The second baseline readings were carried out over the period 19th to 26th Dec 2003 and the average inflow into the zone at the end of the works (Q_e) was calculated to be 2741.3 m^3/day.

The provisional NRW reduction achieved in this zone, on the basis of ($Q_i - Q_e$) is therefore 208 m^3/day. The consumption of water for Taman Pinggiran Batu Caves was taken every 30 minutes over 24 hours. It was shown that the consumption for the first baseline reading and second baseline reading were almost the same. However, the highest reading was recorded at 7.30 p.m and the lowest consumption was at 3.30 a.m.

Readings for bursts in Taman Pinggiran Batu Caves were taken for every 30 minutes over 24 hours. It was shown that the bursts occurred at a higher frequency before the leakage reduction work compared to the frequency after leakage reduction work. The highest burst was at 4.4 litres/second while the lowest burst was at 2.4 litres/second.

Flow data readings for Taman Pinggiran Batu Caves were also taken every 30 minutes over 24 hours. It could be seen that the flow data for the first baseline readings were higher than the second baseline readings. Therefore, it could be concluded that the total inflow before leakage reduction work was more than the total inflow after leakage reduction work. The highest total inflow was at 7.30 p.m and the lowest total inflow was at 3.30 a.m.

The pressure data readings for Taman Pinggiran Batu Caves were taken every 30 minutes over 24 hours. It was shown that the average zone pressure for the first baseline readings was higher than the second baseline readings. Therefore, it could be concluded that the pressure before leakage reduction work was higher than after leakage reduction work. The total inflow and average zone pressure for Taman Pinggiran Batu Caves over a period of 24 hours could be compared. When the flow was decreased, the pressure would increase.

Table 3: Results summary for Taman Pinggiran Baru Caves

Infrastructure Data				
Connections	nr	1292		
Mains length	km	10.6		
Connection density	nr/km	122		
Baseline Data		*First Baseline Data*	*Second Baseline Data*	*Change*
Date		10/22/2003	12/24/2003	
Day		Wednesday	Wednesday	
Total Inflow	m^3/d	3,004	2,646	358
Bursts	m^3/d	362	217	144
Background leakage	m^3/d	219	110	109
Sub-total physical losses	m^3/d	580	327	253
	l/conn/d	449	253	196
	$m^3/km/d$	55	31	24
	% of Inflow	19%	12%	
Consumption	m^3/d	2,424	2,319	105
	l/conn/d	1,876	1,795	82
Minimum night flow	l/s	9.63	6.31	3.32
Net night flow	l/s	7.31	3.99	3.32
Infrastructure condition factor		7.0	7.0	-
Savings Summary				
Reduction in physical losses from leak repair	m^3/d	89		
Reduction in physical losses from pressure change	m^3/d	164		
Reduction in consumption	m^3/d	105		
Reduction in total inflow	m^3/d	358		

It was shown that the physical losses for the first baseline readings were higher than the second baseline readings in Taman Pinggiran Batu Caves. Physical losses before leakage reduction work were about 6 to 7 litres/second while after leakage reduction work they were about 3 to 4 litres/second.

It could be seen that the background leakage before leakage reduction work was higher than that after leakage reduction work for the case of Taman Pinggiran Batu caves. The highest background leakage occurred at 2.8 litres/second.

The BABE components for the first baseline in this zone for Taman Pinggiran Batu Caves showed the consumption of water by consumer, the component of burst and background leakage and average zone pressure of water. When the consumption of water was high, the pressure of water was low. It could also be seen that the component of burst and background leakage was high before leakage reduction work.

The consumption of water, average zone pressure, bursts component and background leakage component in Taman Pinggiran Batu Caves for the second baseline readings were also shown. It could be seen from the BABE components that the pressure after leakage reduction was lower than before the leakage reduction work. However, background leakage and burst component were reduced after this analysis.

Conclusions and Recommendation

The experience in Selangor NRW reduction project demonstrated that Performance Based NRW Reduction project worked well. Although the management of water losses is receiving increased attention internationally, many systems have NRW which is higher than desirable. For benchmarking of true performance, there is a need to use standard terminologies, calculation methods and performance indicators.

Effective management of pressures is the essential foundation for an effective leakage management strategy through the control of surges and rapidly fluctuating pressures. During the leakage reduction phase, the primary management incentive is achieving the leakage target. Once it has been achieved and maintained for a period (say 1 to 2 years) the next strategic aim should be to continue to achieve the same level of leakage at an ever reducing operational cost.

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