China – UK, WRDMAP
Integrated Water Resources Management Document Series

Thematic Paper 3.3: Active Leakage Control as a Key Component in Increasing Efficiency in Urban Water Supplies

3. Demand Manage-ment

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中国水利 CHINA WATER

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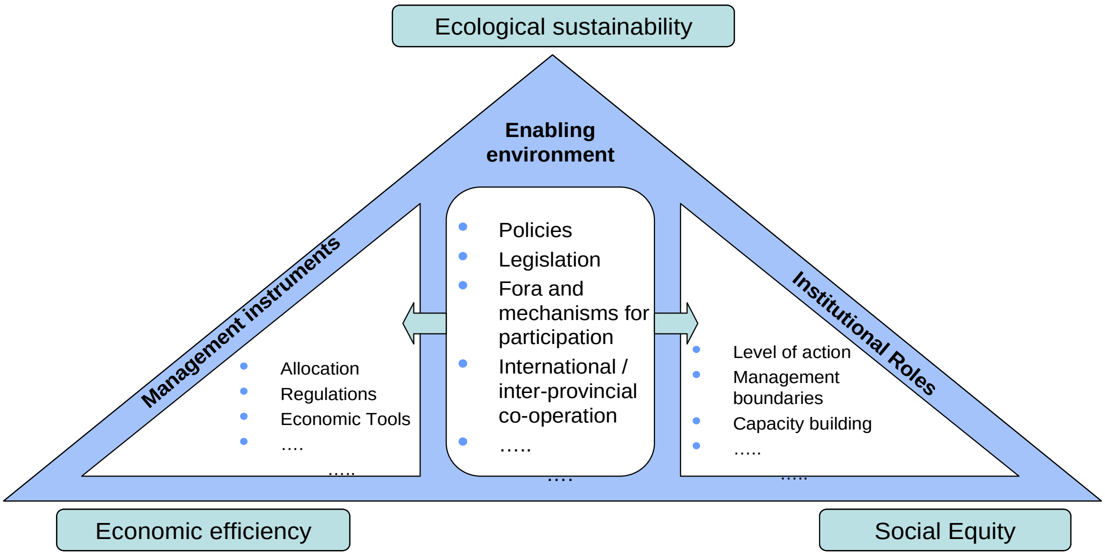
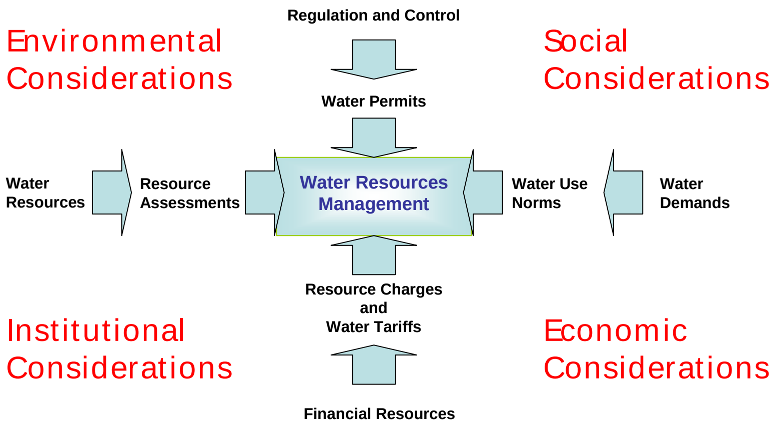
Integrated Water Resources Management (IWRM)

(Basics after Global Water Partnership)



Driving Elements of Integrated Water Resources Management



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Summary: As supply-side solutions become exhausted, water supply companies (WSCs) will, increasingly, have to apply demand management in order to balance the future demand with available resources. Reducing leakage from pipe networks can delay the need to invest in new water sources to meet rising demand or existing demand where demand is not satisfied. WSCs should calculate leakage targets as an integral part of their long term water resource plans to ensure that the most efficient range of options is selected to balance the supply and demand for water.

This paper describes the role of an **Active Leakage Control** programme as a means of achieving water savings. More details can be found in other documents in this series (see bibliography).

This document covers the following topics:

- Introduction to demand management and the role of leakage control
- Water supply company (WSC) perspective
- Leakage control policy selection
- Customer service
- Implementing district metering, leak detection and repair
- Case studies of leakage control:
  - UK
  - Thailand
  - Northern China (WRDMAP project)
- Conclusions

The Ministry of Water Resources have supported the Water Resources Demand Management Assistance Project (WRDMAP) to develop this series to support WRD/WAB at provincial, municipal and county levels in their efforts to achieve sustainable water use.

1 Introduction

1.1 Sustainable water use

Although domestic water use is not a major part of water consumption in the world today, it plays a crucial role in people's daily life, and it is directly related to social welfare and public health issues. Therefore, the efficient use of limited domestic water resources is one of the central concerns of policy makers.

Water supply efficiency and water use efficiency are recognised as increasingly important in terms of **sustainability**. The means by which these efficiency goals are achieved are referred to as 'demand management' tools.

Box 1 Demand management

Water demand management aims to reduce the wasteful use of water in order to meet objectives of economic efficiency, social development, social equity, environmental protection, sustainability of water supply and services, and political acceptability.

The aims of demand management are to:

- Prevent wasteful use of water, limit consumption and hence minimise investments needs
- Ensure an equitable distribution of potable water supplies to all consumers
- Ensure water supply systems are sustainable, providing customers with the level of service they want at a price they can afford while covering the total costs of providing water

- Ensure an efficient and equitable distribution of available water resources between municipal water supplies, industry, agriculture and the environment

Further information on this topic can be found in Thematic Paper 3.2 ‘Urban Water Supply Demand Management’ (see bibliography).

Water saving in the urban sector can have a strong economic justification since the water lost has often had high delivery and treatment costs associated with it.

Water supply or water use efficiency is never static and cannot be assumed to be always increasing. Potential water savings can decay over time due to equipment breakdown, lack of maintenance, or decline in behavioural compliance with conservation activities.

This paper is concerned with the loss in efficiency represented by leakage from the water supply distribution network.

1.2 Leakage

The primary benefits of leakage reduction are seen as:

- Reduced abstraction and therefore environmental improvement
- Increased reliability of water supplies
- Deferment of capital expenditure on water resources and supply schemes
- Reduced operating costs (if above the economic leakage level (ELL) - see Section 3.2)
- Improved public perception of water companies

The means of reducing system leakage are broadly the following:

- Pressure management
- District metering, followed by active leak detection and repair
- Replacement of old pipework that is in poor condition

A fundamental fact about leakage control is that every possible leakage control measure follows a law of diminishing returns on the investment. As more money is spent, the return in terms of water saved due to lower losses, becomes progressively less. Some level of each activity will form part of an economic strategy to reduce water losses or leakage in a system.

This paper focuses on active leakage control by means of district metering, leak detection and repair.

2 Water Supply Company Perspective

2.1 Water resources – supply plans

Every WSC must plan investments to balance available raw water resources against forecast demand for potable water within their service area. The framework within which such planning is undertaken will reflect the national and local regulatory and institutional arrangements, the physical raw water resource available, the economic situation and the targets and aspirations of the company’s management.

Most face a challenging task as competition for water increases, environmental requirements are raised, and the demand for their product grows driven by population growth, urbanisation and rising living standards. Potential impacts of climate change must also be addressed.

As supply-side solutions become exhausted, water supply companies will, increasingly, have no choice but to apply demand management in order to balance the future demand with available resources. Reducing leakage from pipe networks can delay the need to invest in new water sources to meet rising demand or existing demand where demand is not satisfied.

WSCs should calculate leakage targets as an integral part of their long term water resource plans to ensure that the most efficient range of options is selected to balance the supply and demand for water.

2.2 Asset management – serviceability

Asset management in the water supply sector involves the management of physical assets (such as pipe infrastructure, pumping stations and water treatment works) to achieve the required levels of service at the minimum cost, with an acceptable level of service failure risk. This implies that a WSC's asset management processes are forward-looking, economic, risk-based and customer service-centred. Levels of service may vary between WSCs and for different assets or different customers.

Serviceability is the ability of assets to provide service now and in the future. Service now is measured by service indicators e.g. number of supply interruptions, leakage rates in different parts of the distribution network etc. The WSC asset management system should have a reporting function that allows such indicators to be regularly monitored. Service in the future is considered using measures of asset performance e.g. number of mains bursts. Analysis of historical data about leaks and repairs within a network can highlight areas where pipeline replacement, rather than individual leak repairs, may be more cost effective in the long-term.

WSC management need to have a good understanding of potential benefits and costs, including social and environmental costs, when determining appropriate levels of service.

Further information on asset management is given in Advisory Note 3.3/2 'Asset Management for Small or Medium Size Water Supply Companies'.

Management of physical assets

2.3 Non revenue water

The impact of water losses in the performance of a WSC needs to be understood. All the scalar attributes of Figure 1 should be known to the WSC and reviewed on an annual basis.

Figure 1: Standard water supply company water balance

Own water sources	System Input quantity	Water exported				Billed Exported Water
		Gross water supplied	Authorised Consumption	Billed Authorised Consumption	Revenue Water	Billed Metered Consumption
Water imported						Billed Unmetered Consumption
				Un-billed Authorised Consumption	Non-Revenue Water (NRW)	Unbilled metered consumption
						Unbilled unmetered consumption
			Water Losses	Apparent Losses		Unauthorised consumption
						Customer metering inaccuracies
				Real Losses		**Leakage** in the mains
						Leakage and overflows at storages
						Leakage on service connections up To the point of customer metering

Source : International Water Association (IWA)

Non revenue water (NRW) is the difference between the amount of treated water produced by the WSC and the amount of water that has been billed and payment received.

The term 'non revenue water' is now generally preferred to the previous term 'unaccounted for water' (UFW). NRW comprises:

- Physical losses
  - Leakage from the pipe network, storage tanks and transmission mains
  - Leakage from consumer connection pipework up to the meter, or property boundary
  - Master meter inaccuracies
  - Internal losses within consumers' premises where the consumer meter is not functioning or there is no meter
- Commercial losses
  - Unregistered consumption through illegal connections and bypasses to consumer meters
  - Connections that are not recorded and billed due to

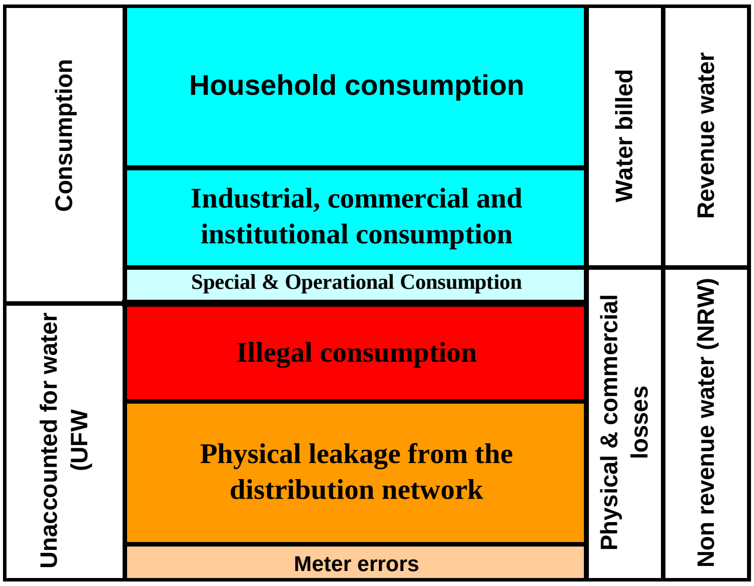
deficiencies in the WSC billing system

- Under registration by consumer meters
- Legitimate unbilled consumption for fire fighting, mains flushing, etc.
- Billings for which payment is not received

The definition of NRW and UFW is presented diagrammatically in Figure 2.

UFW is slightly less than NRW. Legitimate unrecorded use is usually a very small component of NRW, so the difference is not significant.

Figure 2: Diagrammatic representation of UFW and NRW



The most significant component of NRW is usually leakage from the pipe network.

Taking action to minimise NRW directly reduces the demand through the reduction in leakage and indirectly by ensuring that all customers are properly billed and charged for water used, which discourages wasteful use.

NRW and its reduction must be a priority for all water operating organisations.

2.4 Understanding the leakage problem and targeting action

There is usually measurement of total volumes within a water company's entire distribution system but the area is often too large for detailed analysis of NRW levels. Within the distribution

system there are likely to be variable NRW levels and amalgamating the whole may mask high and low NRW areas. Areas of high NRW need to be defined for effective targeting of leakage control resources.

Likewise the distribution of pressure across the entire WSC network is likely to be quite variable especially if there is considerable topographic variation across the area. Problem areas in terms of pressure will be known to the WSC through customer complaints.

Section 5 describes an approach of dividing up the WSC's network into district meter areas that makes a very valuable contribution to management understanding of the critical locations where leakage control would be best focused.

2.5 Water pricing

In the context of tariff design (see Advisory Note 5.4 'Tariff Setting for a Small to Medium Size Water Supply Company') one of the factors in deriving the level of tariff necessary to recover costs, if full cost recovery is to be followed, is the level of NRW. The costs associated with the organisational set up and the operations of a WSC are linked to the gross volume of water handled from source, through treatment, into the distribution system. The revenue of the WSC depends on the sales of water made to customers. Hence, if not all the water put into the distribution system is paid for by customers then tariffs have to be higher than necessary to meet the level of cost recovery required or agreed upon with a regulator.

If the level of NRW can be brought down, by reducing both illegal consumption and physical leakage, it can represent a win-win situation – more income and less operational costs for the WSC and better service and potentially a lower tariff for those customers who have been paying for their supply.

A well designed active leakage control programme will reduce the level of NRW and thus have a direct impact on prices to customers and/or income to a WSC.

3 Leakage Policy

3.1 WSC perspective

Leakage within a water company's distribution system is inevitable, given the task of containing pressurised water within underground pipelines. The initial integrity of distribution systems is dependent on good design, quality of materials and standard of installation but even the best system will suffer some losses that will increase over time: joints tend to leak over time, pipes corrode, ground movement disturbs pipes and there is always the possibility of accidental damage.

It should be recognised that the objective of a leakage control policy is not to eliminate all leakage (which would be prohibitively expensive) but to maintain it at an acceptable level which can be justified on economic terms.

Leakage control can be passive or active as described below. The type of leakage control policy will vary for each water company. However, where there is competition for scarce water resources, eg for irrigation, industrial and domestic demands, and the nature of the water supply system incurs significant operating expenditure, such as power for pumping, then an active leakage control policy is likely to be appropriate. This is expected to be the case for WSCs in China.

There are various ways of reducing leakage. The decision on whether and how these should be implemented will depend on the relative costs of the measures and the potential benefits to be obtained. The intensity of leakage control activities should be increased until the marginal cost of leakage control exceeds the marginal value of water saved. The means of reducing system leakage are broadly the following:

- Pressure management
- District metering, followed by active leak detection and repair
- Replacement of old pipework that is in poor condition

These are likely to be in order of increasing cost, so pressure management, where appropriate will offer the greatest benefit cost ratio. Large scale replacement of distribution pipes will be an expensive solution, and should only be adopted where large sections of pipe are in poor structural condition or badly laid resulting in a high rate of leak repairs.

Passive leakage control

Passive leakage control is a response to situations which have to be dealt with because of unacceptable visual leakage (reported by water company staff or the public) or a dramatic loss of supply due to bursts. WSCs often monitor network pressures as a means of alerting them to a drop in the normal network pressure which is likely to be indicative of a burst main. This use of network pressure is not normally considered to be an active leakage control approach, as defined below, since it only alerts the WSC after the burst event has occurred. As the term suggests, there is a low level of activity and commitment from a WSC that adopts a passive policy.

> Box 2 Wasting financial resources
>
> In one Indonesian city with a passive leakage control policy the introduction of a new water treatment works with a production capacity of 86,000 m^3 per day resulted in additional water sales of only 30,000 m^3 per day.

Active leakage control

Well managed water supply companies realise that leakage is an important issue, not only because it is a loss of a valuable resource in economic, environmental and social terms, but also because it presents a poor image to the customers it is serving. These companies adopt an active approach to leakage while others are prepared to treat the problem in a passive way, as described above.

An active leakage control policy means monitoring the distribution system closely for signs of leakage, including those that are unseen and do not have significant local impacts, as well as providing the resources needed to detect and repair leaks as they occur and are reported. The objective is to continuously monitor network leakage levels to maintain them at acceptable levels and to actively detect leaks when the leakage level rises above an acceptable level.

The policy provides recovery of physical and financial losses for a water company and enhances its reputation with the community it serves. Successful implementation can delay future capital works as minimising losses maximises supply resources. In areas where demand is not satisfied (resource or supply poor) then making available water which would otherwise have been lost is an effective additional resource and source of revenue.

Research suggests that up to 65% leakage reduction can be achieved through district metering compared with a passive leakage control policy. However, in practice the reduction achieved will depend on a variety of factors including:

- The existing level of leakage in the distribution system.
- The pressures in the system.
- The type of pipe in the system. It is more difficult to detect leaks on non-metallic mains than on metallic mains.

An active policy necessarily demands human and financial resources in order to gain the benefits derived from that policy. In particular, a management and organisational structure needs to be established to arrange and co-ordinate policy activities. Staff must be made available and committed to the continual monitoring and maintenance of leakage control procedures and processes.

For WSCs, setting leakage control targets requires consideration of:

- Economic leakage level – the optimum between cost and benefit (see Section 3.2)
- Practicality in terms of data needs and implementation
- Sustainability in the long term and flexibility in the short term
- Consistency with the WSC's water resources plan
- Social and political aspects

Box 3 Sydney Water leakage control

Sydney Water's Leak Reduction Programme involves five activities:

- Active leakage detection, where the system is acoustically scanned for leaks. Around 18,000 kilometres of mains are being scanned for hidden leaks each year.
- Improved speed and quality of leak repairs, to reduce the amount of water lost from each leak and ensure that it does not occur again.
- Adjusted system pressures to reduce high pressure areas which can cause leaks and damage household fittings.
- Improved flow metering to better identify leak location.
- Water main renewals to ensure old pipes are replaced before they become a problem, with nearly 100 kilometres replaced each year.

It is estimated that nearly 17 billion litres of water per year is presently saved.

Source: 2006 Sydney Metropolitan Water Plan

Clearly cost-benefit analysis is important to target setting but other factors, often external to the WSC, should not be neglected.

3.2 National perspective

National water resource managers should expect all WSCs to calculate leakage targets as an integral part of each WSC's long-term water resource plans. This ensures that the most efficient range of options is selected to balance the supply and demand for water.

Targets are required to be set for leakage reduction programmes:

- To ensure efficient operations

- To safeguard future water supplies
- For technical comparisons between water supply organisations, nationally and internationally, and between supply zones
- To demonstrate continual improvements to customers – public perception
- To take account of political considerations
- To meet regulatory requirements

It is expected that national bodies will provide policy guidance, information on best practice, support scientific research on innovative techniques etc.

In terms of leakage management two different approaches have been developed:

- Technical targets based on best available practice
- Economically justifiable targets

The latter is particularly associated with privately run water industries, although there is no reason why value for money should not also be a driver for a public sector service provider.

Technical target approach

The infrastructure leakage index (ILI) is often used internationally as part of a target setting approach. ILI is the ratio of current losses to unavoidable losses, where unavoidable losses are estimated based on best achievable background and burst losses at a standardised system pressure. ILI can be used to benchmark performance of leakage detection and repair activities.

In China for example national targets have been set for leakage minimisation (Box 4). These represent a major challenge to WSCs, especially those with aging or poorly maintained distribution systems and those in weak financial circumstances.

Box 4 China leakage minimisation targets

Leakage control standards for Urban Water Supply Pipeline Networks have set the allowable leakage rate at no greater than 12% of distribution input, with an adjustment of -2% to +3% depending on the length of network and water quantity supplied.

Source: Ministry of Housing and Urban-Rural Development, Standard CJJ92-2002

Economically best value solution

The Water Research Centre, UK, defines the optimum leakage level as '*that level of leakage where the marginal cost of leaking water equals the marginal cost of active leakage control'*. In other words, this is an economic calculation. Once the level of leakage is known, the cost of that leakage can be determined. The cost of active leakage control will have been determined during initial active control and the data sets are then available to calculate the optimum level.

In effect this means that leakage reduction should only be undertaken when the cost of saving 1 m^3 of water is less than the cost of providing 1 m^3 (ie. the cost of abstracting, treating and distributing it to customers). In this case, the cost of providing water should include operating costs and capital costs, i.e. the cost of replacing assets and the cost of new resources and facilities to meet an increase in water demand. It may also include the associated environmental and social costs if deemed appropriate.

Much debate surrounds the issue of the economic level of leakage (ELL) and how it is derived (see Box 5).

Box 5 Definitions still open to debate

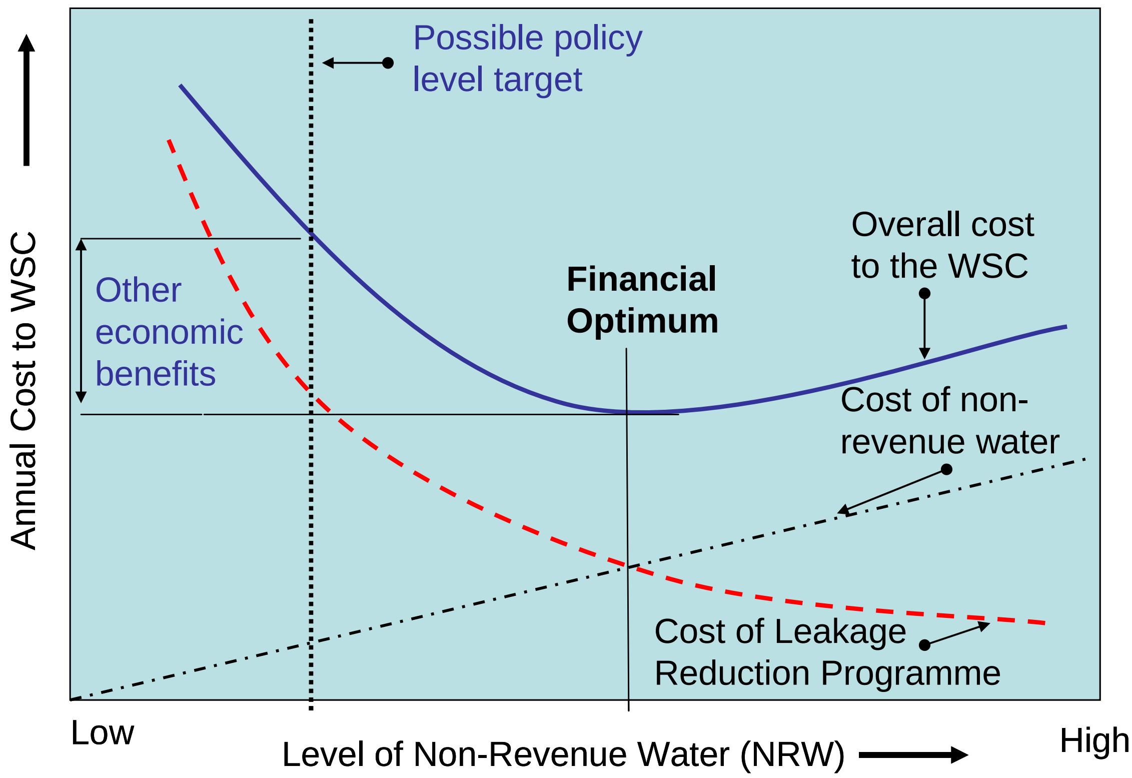
'There is insufficient clarity as to the methodologies of deriving ELL, for the short and longer term, for it to be universally agreed. The evaluation of the long term ELL is dependent on the cost and timing of other means of maintaining an adequate surplus of water supply over demand, such as demand management and water resource and supply enhancement. In undertaking a holistic approach to the costs and benefits there is a requirement to include social as well as environmental costs. There remains uncertainty as to the factors to include and how to cost them.'

Viewpoint of the Chartered Institution for Water and Environmental Management (CIWEM), UK responding to the regulator Ofwat's public consultation on setting leakage targets, 2003.

Figure 3 illustrates how the target might be derived by comparing costs: the level of NRW, ie the cost of the 'lost revenue', against all costs to the WSC of supplying water. The cost of NRW includes the cost of water resource fees, pumping and treatment. The cost to the WSC includes the cost of maintaining DMAs and the active leakage detection and repair teams, the cost of repairs and replacement of pipework, the cost of curbing illegal consumption (debt collection and enforcement), the cost of customer relations teams dealing with complaints about supply interruptions, etc.

The financial optimum balances the cost of leak reduction against cost of NRW – this is one definition of ELL.

Figure 3 Economic Level of Leakage (ELL)



However, Figure 3 shows another possible definition of ELL referred to as 'possible policy target level'. This accepts a higher cost to the WSC and reduces NRW further. The benefits of selecting such a target for ELL include:

- Reduced frequency of bursts
- Fully employed specialist leak detection and repair teams
- Reduced capacity for pumping equipment
- Improved customer relations and less illegal usage
- Satisfied regulator

In the UK, Ofwat, the water services regulation authority, has recently considered a further development of this approach to address sustainability more directly - the **sustainable economic level of leakage** (SELL), although there are a number of difficulties in assessing the true value of the environmental and social costs to apply in this calculation as indicated in Box 5.

3.3 Role of the Regulator

For any WSC, the drivers to undertake an active leakage control programme may be low. In a situation where demand problems have always been resolved by supply side interventions, the trouble and cost of significantly reducing leakage is an impediment to action. In many countries, this situation can best be resolved by the intervention and control of a regulator. A regulator can set agreed levels of NRW and also leakage reduction targets. This issue is addressed in another document in this series: Thematic Paper 4.3 'Regulation of Small and Medium Size Water Supply Companies'.

4 Customer Perspective

4.1 Customer view of WSC

Customer satisfaction with their water service provision is typically dominated by three factors:

1. Reliability of supply
2. Quality of water supplied
3. Cost of supply

Leakage plays an important role in all three, both directly and indirectly.

Most WSCs would aim to provide a 24 hours supply at adequate pressure and of potable quality through their distribution system. Bursts clearly have the potential to force parts of the distribution system to be shut down for emergency repairs, but sometimes the leakage losses are such that customer supply is reduced on a frequent basis. Customer surveys in communities receiving a poor level of service from their WSC reveal the social costs particularly for women who are the main water users in the home. Minimising such disrupted supply should be a key performance indicator for the WSC.

Minor leaks, especially where there is discontinuous supply or very low pressure, can be a cause of poor water quality especially after rain when untreated water can enter the pipe network.

WSCs should provide a 'hot line' for reporting leaks and take rapid action on any leak reported by customers. Visible leak detection teams and maintenance teams can help improve customers' perception of the WSC's performance.

Issues relating to broken or inaccurate meters can also sour public relations. The WSC needs to respond to concerns over meter accuracy promptly because leakage within the customer's property is often a contributing factor to high meter readings.

4.2 Customer-related problems for the WSC

The WSC can have a number of customer-oriented problems related to NRW and leakage among which are the following:

- Theft of water either through illegal connections or tampering with customer meters
- Losses within customer properties that do not have a working meter (ie lost revenue to WSC and wasted water)

Box 6 Household leakage (UK)

Most leakage in the UK is from water company owned pipes. However, around a quarter of total leakage is from customer owned supply pipes which convey water onwards from the boundary of the property. At its Water Summit in May 1997 the British Government urged water companies to take responsibility for the leakage of customer supply pipes and to offer a free leakage repair service. Although this has been accepted by most companies this approach has clouded the matter of responsibility and brought into the debate future ownership of customer supply pipes.

Implementing district metering (Section 5) and active leak detection can contribute to identifying where such problems are occurring within the overall network.

High levels of leakage in households and buildings can adversely affect the ability to undertake an active leakage control programme since the night-flow noise detection process related to the isolated pipe distribution area being investigated is affected by the distracting noise of losses in the buildings. If high levels of losses exist in buildings, any flow to the buildings should be controlled by isolator valves.

5 Implementing District Metering, Leak Detection and Repair

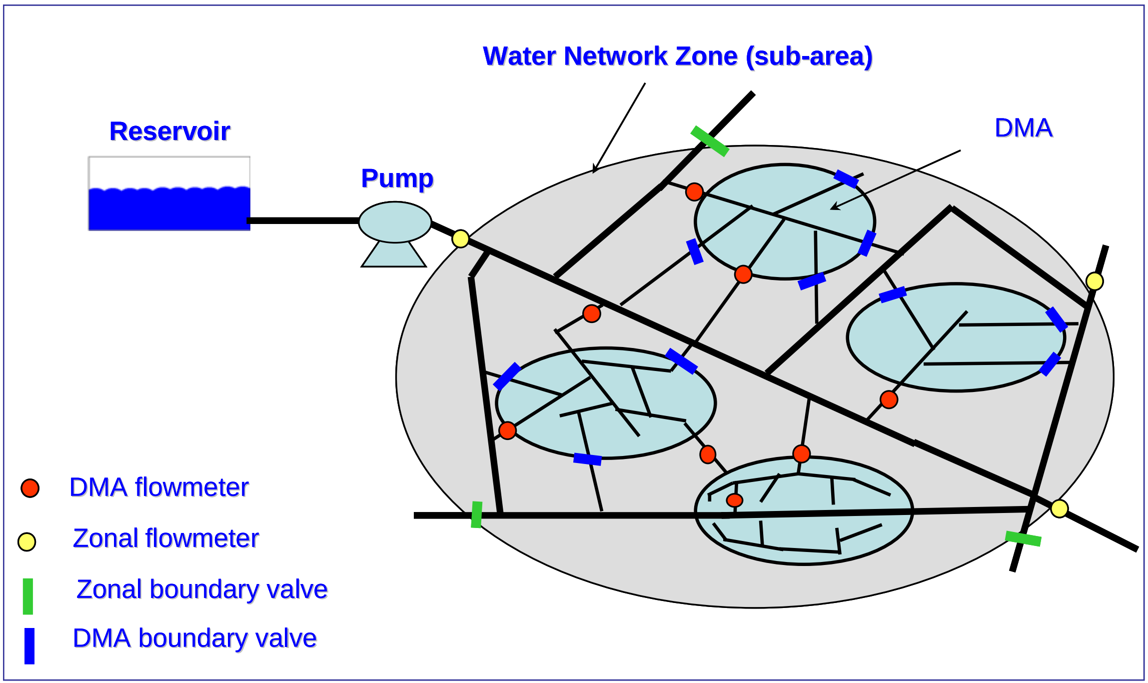
5.1 General

District metering requires the installation of flow meters at strategic points in the distribution system, each meter recording flows into and, where appropriate, out of a discrete district that has a defined and permanent boundary. Such a district is called a District Meter Area (DMA). A DMA normally contains about 1,000 to 5,000 customer connections.

The DMA concept is illustrated in Figure 4.

After establishing the DMA, the minimum night flow is measured and the net night flow (the minimum night flow less an allowance for legitimate use) is determined to give an estimate of physical leakage. Where leakage is above the target level, a programme of leak detection and repair is undertaken to bring it down below the target level. The night flows are then monitored and when the leakage level rises again, a further programme of leak detection and repair is undertaken. This process continues indefinitely.

Figure 4 District meter area (DMA) concept



5.2 Benefits of establishing DMAs

Management of a DMA comprises:

- Downloading and analysis of flow data to check DMA leakage level (at regular intervals and after leak repairs)
- Leak detection surveys by manual sounding and use of ground microphone and/or automatic correlating leak noise loggers (field work plus analysis of results)
- Leak location using leak noise correlator
- Leak repair
- Quality checks on leak repairs.

Experience in Asia suggests that a three man leakage team can normally manage 10 DMAs.

DMAs are ideally utilised as a means of continually monitoring flows and pressures and, therefore, continually assessing leakage levels. Within any DMA, or any part of a distribution system, leakage levels are dynamic. An optimum level may have been achieved within a DMA but it is inevitable that the level will increase over time. There will be occasions where a sudden burst will demand attention and even where these are not visible, they can be detected through the monitoring process. But the real value of DMA monitoring is to track the gradual change over time of increasing leakage levels. A level needs to be determined where intervention by leak detection teams is necessary to bring the level back down to the target level. The intervention level may well be different for each DMA – situations are different, costs are different – pipe materials, depth of pipe, density of population – and the intervention level will again be set according to specific economics but essentially the level is when the cost of leakage is greater than the cost of detection and repair.

5.3 Leak detection and repair

All currently used methods are reliant on the presence of 'leak noise' as the means of detecting and locating underground, non-visible leaks. Water escaping from a pressurised pipeline into the non-pressurised environment around the pipe creates noise as a result of this pressure differential. The particular frequency and volume of noise created is dependent on several factors such as pipe material, system pressure and ground type, with the most critical of these being system pressure.

The frequencies generated by leaks change as the noise travels away from the leak. Higher frequency noise is attenuated over distance depending on the pipe material. In metallic pipe that attenuation is slow but quicker in plastic pipes, so that detecting leak noise is easier on metal pipes. In some situations, where there is considerable background noise, sounding is carried out at night as there is less traffic noise and generally greater pressure.

Leak detection equipment generally comprises:

- Pipe locator
- Valve box locator
- Acoustic sounding stick
- Ground microphone
- Noise loggers and correlating noise loggers
- Leak noise correlator

A prerequisite to leak detection is often the need to trace unknown or poorly documented underground pipes.

Leak detection and repair should not be regarded as a one-off exercise. Once initial repairs have been undertaken the area should be tested again to ensure that further leaks have not been overlooked.

Leak detection in progress

5.4 Confirmation of leakage reductions

Accurate estimation of leakage requires accurate measurement of the volume of water delivered to customers in their properties. This depends on the coverage and reliability of metering systems in place. If only some 33% of household supplies are metered (as per the UK – see Section 6.1), accurate measurement has not yet been achieved. Leakage estimates are therefore built upon components which themselves are subject to potentially large errors in estimation. However, although this is generally recognised, leakage is still reported as absolute values despite the uncertainties in its estimation and the consequences for target setting.

The estimation of leakage for any one supply zone cannot be separated from the total water supply balance i.e. the summation of water consumed (measured and unmeasured) and not consumed (leakage, exports etc.) compared with the total put into supply (distribution input). Hence the robustness of the water balance is a key factor in supporting leakage figures. In turn the very nature of establishing more precise measurements of water into supply at a zonal level through 'district metering' can improve estimates of legitimate use and in doing so improve the water balance.

The extent and coverage of flow metering is therefore an important factor in being able to reliably determine whether or not target leakage reduction levels have been achieved. Nevertheless, even with a low coverage of metering, changes in gross supply levels should show a discernable change with an effective active leakage programme.

> Box 7 Accuracy to which system losses are known
>
> In many situations internationally, the level of knowledge of system losses is very poor. However, this does not stop the reporting of efficient water delivery systems with low losses of 15% to 20%. There is only tacit acknowledgement that in fact the real losses are higher than 40% in some situations.

In China, the coverage of potable water supply metering is relatively high compared to many countries although often the reliability of the meters and repair programmes can be questioned.

5.5 Performance indicators

It is important to be able to assess a WSC's performance on leakage control and to measure the effectiveness of the selected leakage control policy. Ideally, performance comparators should allow stakeholders to compare the performance of "their" WSC against other similar WSCs. Leakage Performance Indicators typically focus on performance measures rather than cost comparators, primarily because cost definitions are difficult to standardise across WSCs.

The International Benchmarking Network for Water and Sanitation Utilities (IBNET) operated by the World Bank is an initiative to encourage water and sanitation utilities to compile and share a set of core cost and performance indicators, and thus meet the needs of the various stakeholders (see http://www.ib-net.org/). A total of 37 water companies in the China already participate. There is no leakage indicator but NRW is included both as a percentage of production and m^3/km/d.

Figure 5 China Country Report (downloaded November 2009)

The International Benchmarking Network for Water and Sanitation Utilities
IBNET

Country Report

China

Indicator	2003	2004	2005	2006	2007
1.1 Water Coverage (%)	94	93	94	94	95
2.1 Sewerage Coverage (%)	N/A	N/A	N/A	N/A	N/A
4.1 Total Water Consumption (l/person/day)	221	208	196	185	183
4.7 Residential Consumption (l/person/day)	85	80	77	74	77
6.1 Non Revenue Water (%)	20	27	27	27	21
6.2 Non Revenue Water (m3/km/day)	71.3	89.9	82.0	75.3	54.3
8.1 % Sold that is Metered (%)	99	99	99	99	98
11.1 Operational Cost W&WW (US$/m3 water sold)	0.17	0.19	0.21	0.27	0.30
12.3 Staff W/1000 W pop served (W/1000 W pop served)	1.6	1.7	1.5	1.3	1.0
18.1 Average Revenue W&WW (US$/m3 water sold)	0.18	0.21	0.21	0.27	0.28
23.1 Collection Period (Days)	82	116	111	99	92
23.2 Collection Ratio (%)	N/A	N/A	N/A	N/A	N/A
24.1 Operating Cost Coverage (ratio)	1.03	1.08	1.02	1.03	0.92

6 Case studies of leakage control

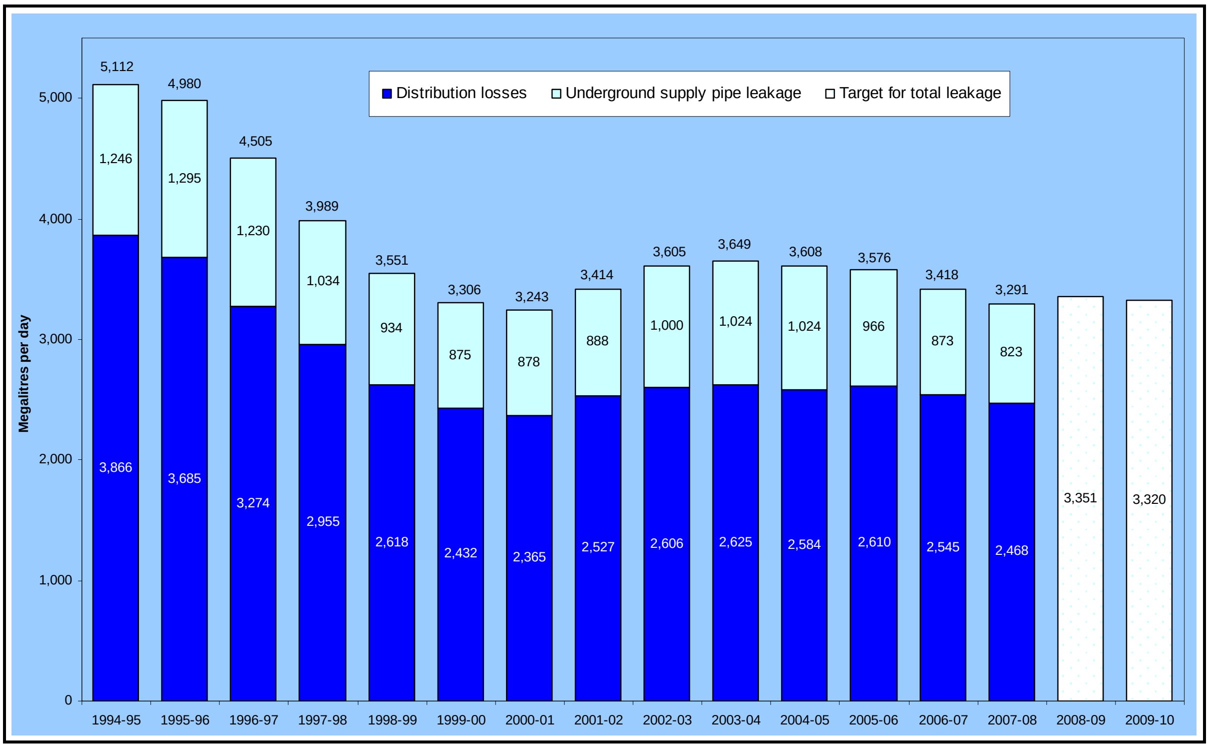
6.1 UK Ofwat targets and WSC achievements

The 23 private water companies in England and Wales have a statutory duty to promote water efficiency. From 2010 the water sector regulator Ofwat (The Water Services Regulation Authority for England & Wales) will set mandatory water efficiency targets in addition to mandatory targets for reducing burst water mains and distribution system and overall leakage that have been set since 1994.

The regulatory environment is based on 5-year cycles of review of WSC performance, with annual monitoring against over 30 financial and technical performance indicators. WSCs are required to submit their plans and actual performance information to Ofwat to support the review process.

Targets for leakage are set for **each WSC** following a published assessment procedure to develop the local sustainable economic level of leakage (see Section 3.2). Ofwat's policy for assessing a leakage target failure takes account of a company's performance over a three-year period. Failure to meet the target can result in heavy fines and bad publicity. Figure 6 shows that the water industry in England and Wales has significantly reduced overall leakage since 1994.

Figure 6 Trend in leakage losses in England and Wales



Source: Ofwat

Figure 6 shows that after a 7-year falling trend the rate rose again before improving again. This reflects the fact that the 'quick wins' have been made.

In 2007-08 on average the NRW was 19% of water input to the distribution system. Leakage represented on average 89% of this NRW. Total leakage averaged 9.7 m^3/km/d.

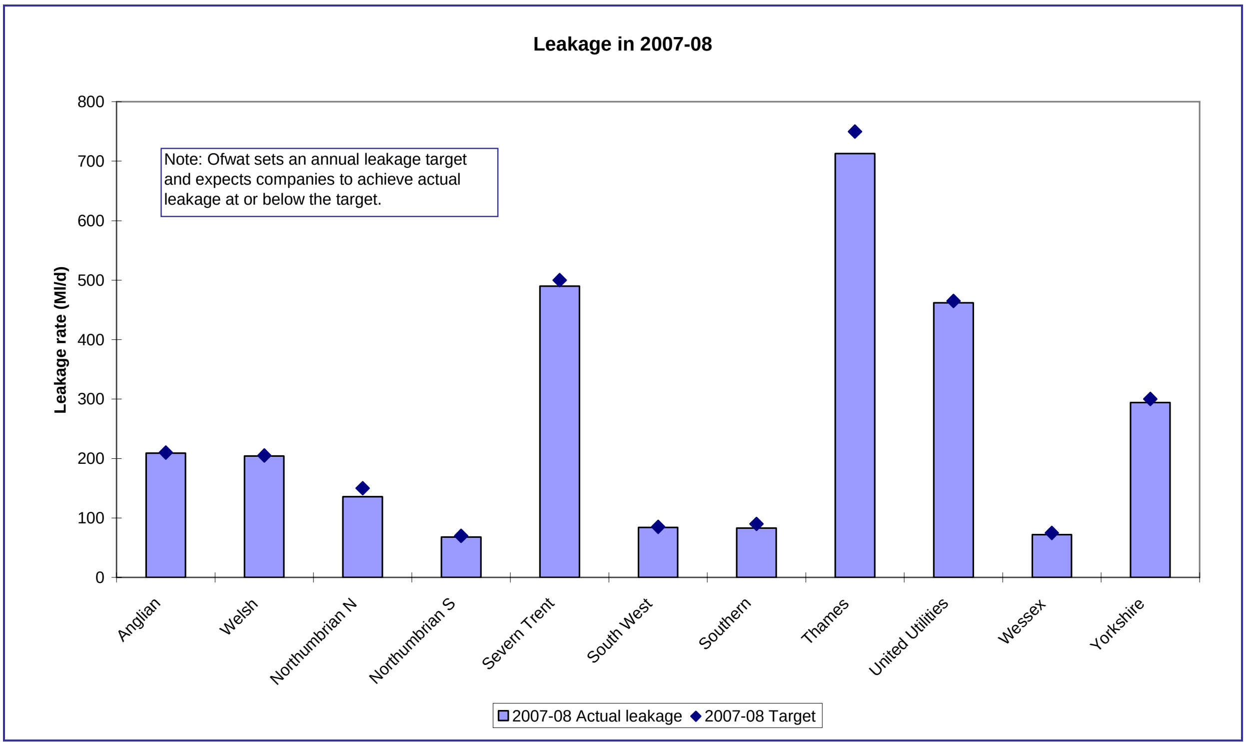
Box 8 Ofwat

As the economic regulator of the water industry Ofwat's role is to protect consumers, promote value and safeguard the future. Among others Ofwat does this by setting the companies challenging efficiency targets (including leakage).

Source: http://www.ofwat.gov.uk/aboutofwat

Figure 7 shows that the agreed target for each WSC is different, and that in 2007-08 all the companies met their targets, with Thames Water (the London supplier) doing better than the target agreed with Ofwat despite the great complexity and age of its distribution systems. The WSCs with the higher agreed targets are those covering major urban and industrial centres with larger and older systems.

Figure 7 Variation in WSC agreed target leakage (economic level of leakage)



Source: Ofwat

Ofwat does not use leakage as a % of distributed water as a performance indicator, but this percentage can be calculated from the information provided by the WSCs. For 2007-08 the average figure for all WSCs was 17%, with a range between 10% and 21%, for leakage from the distribution network, but if leakage from the customer's portion of the supply pipework is included the average rises to 22%. Both these figures exclude any losses inside the house itself.

It should be noted that while most business and industrial customers have a metered supply, in 2009 only 33% of household connections were metered. New properties are however routinely metered. This means that both Ofwat and the WSCs have to use a complicated analysis based on sample areas to corroborate overall leakage estimates. Comparisons with other leakage rates from other countries should therefore be treated with some caution.

6.2 Thailand – active leakage control achievements

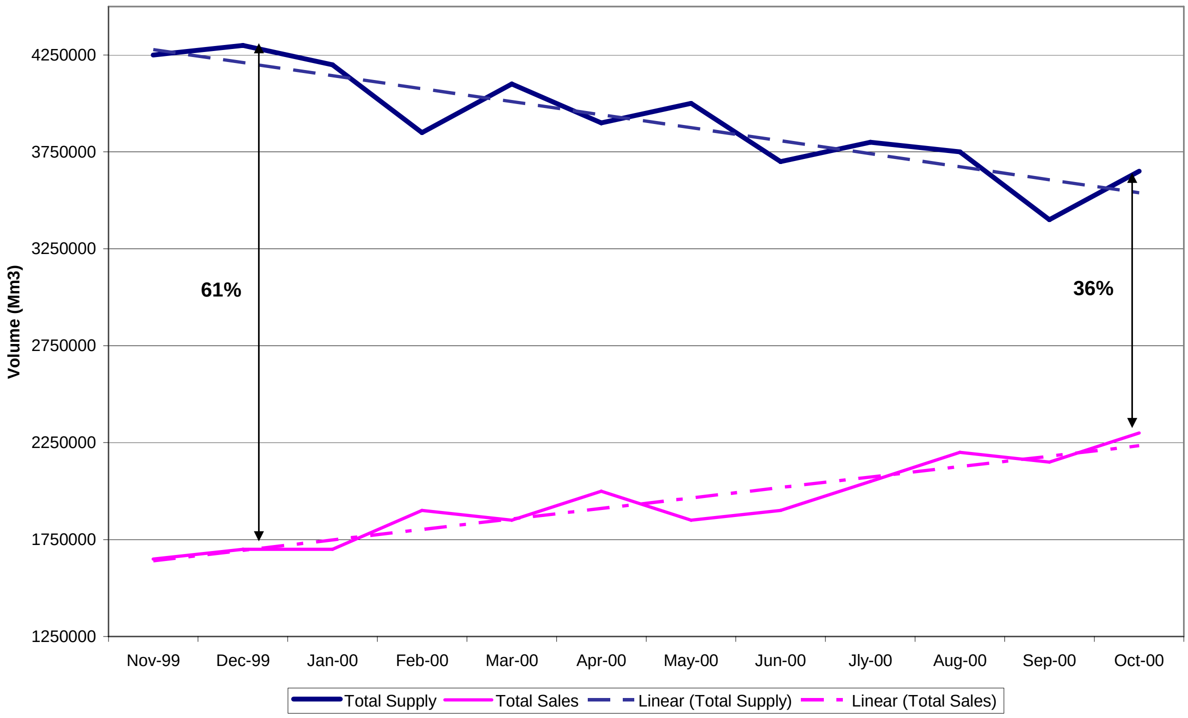
The Non-Revenue-Water Reduction for Pathumthani-Rangsit Water Supply Project is an example of the successful introduction of an active leakage control policy in Thailand.

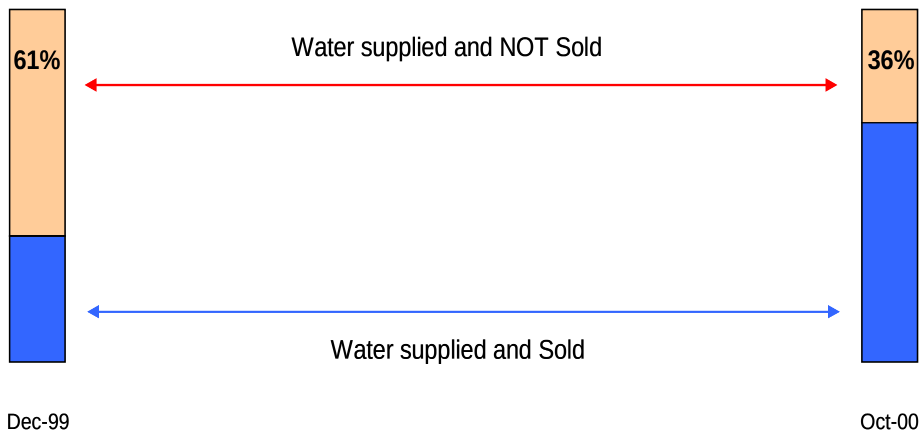
Before commencing an active leakage control policy, NRW was 61% of water produced for sale. By implementing an active leakage control policy based on district metering NRW was reduced to 36% in less than a year, as illustrated in Figure 8. Within 2 years NRW was reduced to 29%, some 3 years ahead of schedule.

As the demand for water was not satisfied, part of the additional supply made available through leakage reduction was sold. Thus, as well as leakage reducing, extra revenue was generated for less operating costs, as can be seen from the graph.

The percentage of NRW as of March 2007 was 21%. This shows a pattern similar to that of Figure 6 in the UK, whereby the after an initial rapid decline it becomes more difficult to drive the rate down.

Figure 8 Trend in non-revenue water and sales for the Pathumthani-Rangit water supply





6.3 WRDMAP Liaoning survey and Beipiao detail

In 2008 under WRDMAP, the organization and operations of ten water supply companies were surveyed in Liaoning Province, China. The ten WSCs surveyed were Beipiao, Chaoyang, Shenyang, Benxi, Dengtai, Haicheng, Kaiyuan, Teiling, Xiaoshi, and Xiuyan.

Most of the water supply companies in the province are State Owned Enterprises and as such are expected to operate on commercial principles. However, none of them are able to generate sufficient revenue to cover costs and therefore either receive subsidies or accumulate an operating deficit. Price Bureaux, who have an influential role in tariff changes, are more concerned with affordability rather than cost recovery. As a result most water is sold to domestic customers at below cost.

Most companies provide a continuous supply of water, with Beipiao being the only company which routinely rations supplies to customers. Although most customers are metered, little effort is made to manage demand by identifying high consumption. Most wastage occurs in the distribution network where estimated leakage rates range from 20% to 40%. The limited number of District Meter Areas in use suggests the true extent of leakage is unknown.

At Beipiao water supply company

As Liaoning is a water stressed province demand management at all levels is of great importance. A key feature of demand management for piped water supplies is accurate information on water use; this is most easily obtained through universal metering. China has a policy of universal metering, including metering of individual households in apartment complexes where most urban residents live. Countrywide, metering in urban areas is relatively widespread with an average of 90% connections metered. The towns surveyed showed high levels of metering, although not all domestic users are metered. For example, Beipiao is reluctant to meter bungalows due to the risk of meters freezing during winter months.

Another important aspect of demand management is the detection and repair of leaks. The Chinese Waterworks Association claims that non-revenue water (consisting largely of leakage losses in the distribution networks) is only 20% on average and less than 10% for the best utilities. This is very low by international standards and one explanation may be that most people live in apartment complexes with their accompanying compact distribution systems. A more likely explanation may be that the definition and measurement of non-revenue water in China is not directly comparable with other countries as surveys in Beipiao show that there are high losses in the internal plumbing of apartment blocks.

The levels of leakage (as a % of production) reported in the survey range from 20% to 40%. Some towns have set a target for acceptable leakage rates of between 10% and 20% which is optimistic. All companies claim to have a functioning and well equipped Leak Detection Units but only one reported having established District Meter Areas (DMAs).

Table 1 provides details of metering, leakage and leak detection measures in the survey towns.

Table 1: Metering and leak detection

Category	**Bei**	**Cha**	**She**	**Ben**	**Den**	**Hai**	**Kai**	**Xiu**	**Teil**	**Xia**
Domestic meters (%)	70	100	99	90	40	80	90	80	40	90
Non-Dom meters (%)	100	100	100	10	60	100	100	100		10
Leakage - present (%)	30		27	35	25	20	40	40	20	35
Leakage - target (%)	15		15		10				20	
Leak Detection Unit	✓		✓	✓	✓	✓	✓	✓	✓	
DMAs (nr)	2		12						4	

Beipiao (Bei), Chaoyang (Cha), Shenyang (She), Benxi (Ben), Dengtai (Den), Haicheng (Hai), Kaiyuan (Kai), Teiling (Teil), Xiaoshi (Xia), and Xiuyan (Xiu)

Beipiao WSC participated in a WRDMAP case study that established a pilot DMA in the Tianyuan Community

Source: WRDMAP survey 2008

Tianyuan Community in Beipiao

The results from the surveyed towns in Liaoning Province can be compared to 'best practice' as demonstrated by Shenzhen in Guangdong Province in the south (Box 9).

Box 9 Leading the way

Shenzhen is a leading city in water shortage management and has been recognised as one of the best cities in the areas of water conservation. The city's current network leakage rate is down to 12%. Shenzhen Water Authority has managed to reduce unaccounted for water from 20% in 2005 to 14% in 2007.

Source: Asian Development Bank

Shenzhen Water

7 Conclusions

As demand management is increasingly important to water resource planners so there is pressure on WSCs to take action on leakage. In the past a passive leakage repair policy may have been acceptable but now WSCs are expected, both by the authority responsible for permitting abstractions and the WSCs' own customers, to adopt a pro-active approach and actively locate and repair leaks.

Across the world WSCs are moving to active leakage control. Early adopters are the larger undertakings but the lessons learnt can help smaller WSCs to design active leakage control programmes that will be the most cost effective.

When planning to start an active leakage control programme a WSC should bear in mind the following:

- In order to evaluate the actual savings achieved by the programme, the bulk meter readings and minimum night flows should be monitored for a period before implementation of the leakage detection and repair exercise. Monitoring should then be continued during the leakage reduction programme.
- The best approach to undertaking a leak detection exercise is to make use of a combination of techniques. Some methods are better suited for a rough first sweep of an area while others can be used to pin point the exact location of leaks.
- Leak detection and repair should not be regarded as a one-off exercise. Once initial repairs have

been undertaken the area should be tested again to ensure that larger leaks have not been overlooked.

- The WSC should concern itself with the level of leakage on its customers' premises offering a repair service (possibly at cost or free), and should deal promptly with meter failures.

The greater the water scarcity that a WSC faces the greater the effort that can be justified to operate an active leakage control programme. Leakage cannot be completely eliminated and therefore the WSC should weigh up the costs and benefits to determine the economic level of leakage. The benefits calculation should consider the potential investment saving, ie by estimating the costs of adding new resources to a volume equivalent to the water saved by the active leakage programme.

Although there can be a lot of science and economics behind the setting of a 'target' leakage level for a particular system, in many situations where little attention has previously been given to active leakage control a staged introduction is probably advisable. The first step should be to try to determine what the current leakage losses are and where they are located. This requires an audit of the network. This will then indicate where improved metering is required to better estimate leakage levels throughout the system.

An open acceptance of levels of leakage must be adopted. Thereafter a programme of leakage targets should be set over a period. Reference should be made to Box 4 where an 'eventual' target leakage level of 12% is set. Moving towards this will require many interventions with an active leakage control programme being a key element.

Document Reference Sheet

Glossary:

DMA	District meter area – typically a relatively small hydraulically defined area established within the pipe network where inflows and, if applicable, outflows are metered. Used as a management tool to allow a structured approach to the determination of leakage levels.
ELL	Economic leakage level – level of leakage at which any further reduction would incur costs in excess of the benefits derived from the savings
IBNET	International benchmarking network for water and sanitation utilities
ILI	Infrastructure leakage index – the ratio of current losses to unavoidable losses
NRW	Non revenue water – the water produced for sale but for which no income is received
SELL	Sustainable economic leakage level – operating at SELL requires the cost of reducing leakage to balance the value of the water saved, *including any associated environmental and social costs and benefits*. Setting leakage targets at the SELL ensures best value for consumers and the environment.
UFW	Unaccounted for water – the total of illegal consumption, leakage, and meter errors
WSC	Water supply company

Document Reference Sheet

Bibliography:

CJJ92-2002 'Urban Water Supply Distribution System Leakage Control and Evaluation Standard', Ministry of Housing and Urban-Rural Development

Sydney Water '2006 Metropolitan Water Plan'

Ofwat UK http://www.ofwat.gov.uk

International Water Association

Asian Development Bank

Related materials from the MWR IWRM Document Series:

Thematic Paper 3.2	Urban Water Supply Demand Management
Advisory Note 3.3/1	Implementing an Active Leakage Control Programme for Small Water Supply Companies
Advisory Note 3.3/2	Asset Management for a Small or Medium Size Water Supply Companies
Manual 3.3	Active Leakage Control Manual for Small to Medium Size Water Supply Companies
Thematic Paper 4.3	Regulation of Small and Medium Size Water Supply Companies
Advisory Note 5.4	Tariff Setting for Small to Medium Size Water Supply Company
Thematic Paper 5.7	Financial Management and Modelling in Small and Medium Water Supply Companies

Where to find more information on IWRM – recommended websites:

Ministry of Water Resources: www.mwr.gov.cn

Global Water Partnership: www.gwpforum.org

WRDMAP Project Website: www.wrdmap.com

China – UK, WRDMAP

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