7. LEAKAGE REDUCTION

7.1 Overview

Leakage detection and control is one of the conservation measures that provide a water authority with a significant potential to impact water demand and usually provides a significant positive economic benefit/cost ratio.

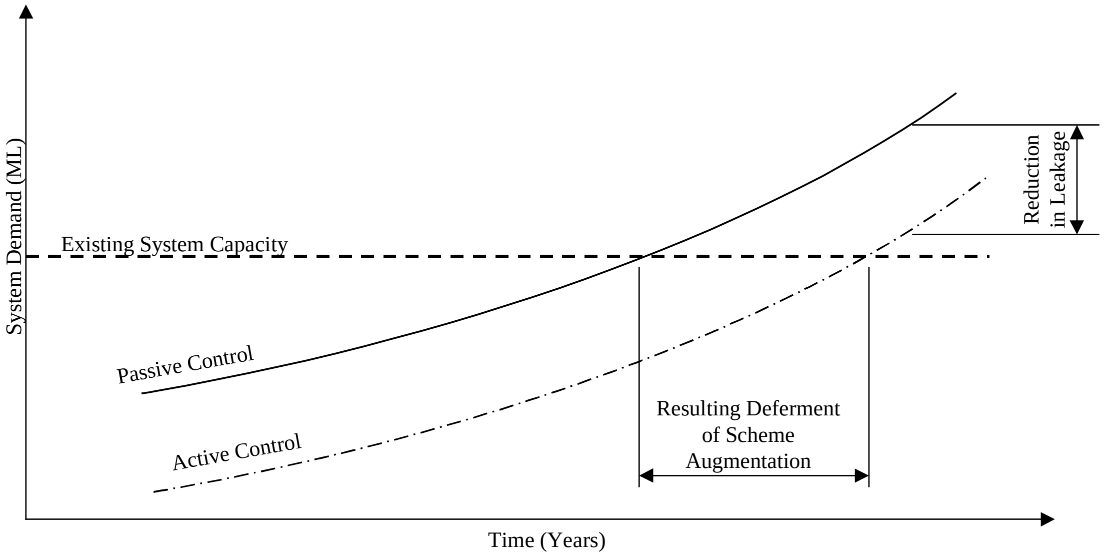
7.1.1 What is Leakage?

Leakage is the unaccounted loss of water that occurs in all water supply systems and is normally expressed in litres/connection/hour (L/conn/hr). Leakage rates can also be expressed in terms of the proportion of annual demand. While this quantity is easier to visualise, it can be misleading as leakage remains relatively constant while annual demand can vary markedly from year to year.

7.1.2 What Does Leakage Cost?

The cost of leakage arises from two sources, namely operating costs and capital costs. The operating cost component comprises the additional chemicals and power to treat and pump water which goes to waste. The capital cost component comprises the cost of constructing works of a larger capacity than necessary to supply demands or to construct them earlier than otherwise required. By reducing system leakage levels, operating costs are reduced and the construction of proposed demand related capital works could be deferred as shown in **Figure 7.1.**

Figure 7.1: Leakage Control Program - Deferral of Works



This particularly applies to headworks, where design is primarily related to annual demand. The reduction of leakage has much less impact on works designed to supply peak demands.

As a leakage control program has a cost, it is necessary to carry out a strategy study and an economic analysis to determine if it is cost effective. For this analysis to be meaningful the leakage levels in the system under consideration must be accurately measured.

7.2 Leakage Assessment

There are two main methods for estimating system leakage, these being:

- the total integrated flow method
- the total night flow method.

Both of these methods involve subtracting the measured output (i.e. water consumption) from the measured input (i.e. water production). The remaining unaccounted for water is non-revenue water, the majority of which is related to system leakage. Non-revenue water includes:

- errors to measurement of inflow (i.e. water production) and outflow (i.e. water consumption) which may be either positive or negative
- water which is used legitimately but is not metered including mains flushing, fire fighting and, supply to un-metered premises
- illegal connections
- system leakage.

7.2.1 Total Integrated Flow Method

The total integrated flow is calculated by subtracting all measured consumption, based on customer meters, from the measured supply recorded by all bulk inflow meters. It is normally calculated annually after consumer meters have been read for water billing purposes. The changes from one accounting period to another are influenced by:

- water meter error, particularly slow reading meters
- water meter failure
- seasonal variations in demand
- the timing when water meters are read.

As such, this method is not very accurate as large quantities, subject to certain errors, are subtracted from each other to obtain a small quantity of water with a potentially large error. Consequently, the method is only suitable for broadly assessing the level of system leakage.

One of the main issues relating to the integrated flow approach is that the percentage calculated is dependent on the demand conditions during the year. The levels of leakage in a system remains relatively constant as it is related to system pressure. Therefore if the total demand varies significantly from one year to the next then the calculation percentage of unaccounted for water, and level leakage, will also increase.

This approach also requires a high level of water meter coverage. Where a level of less than 100% occurs estimates would need to be made of the water consumption of un-metered properties and often Council facilities, which introduces further uncertainties to the analysis results.

7.2.2 Total Night Flow Method

Estimation of system leakage using the total night flow method provides a more accurate and reliable figure. This method subtracts small flows (ie night consumption) from relatively large flows (i.e. system inflow) in order to obtain a relatively large flow. The difference is still non-revenue water, however, as legal and illegal un-metered use, and meter error are negligible, it can be assumed that system leakage is the major component.

The recommended method for the total night flow rate is the reservoir drop test. Flow leaving a supply reservoir is measured by recording the fall in reservoir water level over a period and multiplying this by the reservoir cross sectional area. As this approach is undertaken during low demand periods, the large bore in-line flowmeters typically installed at reservoir outlets do not provide the required accuracy.

7.3 Assessment of Leakage Reduction

7.3.1 Definition of the Economic Target Leakage Level

The detection and location of leaks that are not physically evident requires regular monitoring and testing of the reticulation system. There are several methods of leakage detection and control, and the selection of the appropriate method is based on the magnitude of leakage, the benefits of reducing the leakage and the costs involved in implementing the method.

While the costs of applying any particular method are similar for different water supply systems, the benefits vary considerably depending mainly on pumping and treatment costs and impending capital expenditure on system expansion. Therefore once the method has been chosen for leak detection, the intensity of resources required to achieve control must be evaluated to ensure that benefit/cost ratios attained are positive and are compatible with the resource available. The point where the cost of actually locating and repairing system leakage equals the savings in deferred capital and operating expenditure is called the *economic target leakage level*.

7.3.2 Economic Target Leakage Level

The following terms are used to describe the various levels of system leakage and their associated costs. These include:

- *Passive Leakage Level* – The level of system leakage associated with repairing customer reported leaks only. This is method employed by most water authorities in Australia.
- *Active Leakage Level* – The level of system leakage associated with an ongoing program of leakage location and repair. This will vary from system to system and will depend on the method of leakage detection adopted, social, economic and political factors.
- *Base Leakage Level* – The level of system leakage that no matter how much expense or effort is expended in locating and repairing leakage in a system, no further reduction in leakage is possible. This level is achieved when the only leaks in a system are small weeps and minor leaks at fittings and joints. Based on experience this level is generally around 3.0 L/conn/d.

7.3.3 Calculation of the Cost of Leakage Reduction Curve

The method adopted in this study to derive the leakage reduction cost curve is based on the equations presented in Appendix B of the UK Water Industry, Managing Leakage – Setting Economic Leakage Targets Report (Report C), Engineering and Operation Committee, October 1994.

This method requires one actual data point, the current cost of leakage control and the actual system leakage level and two constraining parameters which are the base level of leakage and the passive level of leakage. These three parameters define the shape of the curve describing the costs of active leakage control. The equations used in the leakage reduction cost curve are:

$$C = \frac{-1}{\delta} \times \frac{\ln(L - L_p)}{(L_p - L_b)}$$

and

$$\delta = \frac{-1}{C_a} \times \frac{\ln(L_a - L_b)}{(L_p - L_b)}$$

where:

C = cost associated with a program of leakage control (\$/conn/a);
L = level of leakage associated with a program of leakage control (kL/conn/a);
L_a = actual level of leakage for the area, adopting the results obtained from the test of 53.3 kL/conn/a;
C_a = actual cost of leakage control for the area, assumed at \$0.30/conn/a;
L_b = base level of leakage, assumed at 0.45 times the actual level of leakage (kL/conn/hr). This provides a practical lower limit of 3.0 L/conn/hr; and
L_p = passive level of leakage, assumed at 1.05 times the actual level of leakage (kL/conn/a).

This approach has been adopted by Rous County Council in their Regional Leakage Analysis and Control Study, Gold Coast Water and many NSW and Victorian water authorities in their preliminary assessment and economic analysis.

7.3.4 Cost of Water Leakage

During the data collection process, information was collected from each of the local governments involved in the study. Of the five pilot areas none have an active leakage reduction program. All have estimated unaccounted for water (UFW) using the integrated flow method. The estimated UFW levels are given in **Table 7.1**.

Table 7.1: Estimated Levels of Unaccounted For Water

Pilot Area	UFW	Volume	
		ML/d	ML/a
Mackay	20%	6.2	2,263
Maroochy	11%	4.2	1,533
Toowoomba	12%	3.4	1,241
Emerald	17%	1.1	401
Ingham	12%	0.4	146

Assuming that the level of leakage is around 75% of the total UFW (in some systems such as Mackay this may be lower due to a poorly performing meter fleet) the cost of leakage and the leakage per connection per hour can be determined. **Table 7.2** summarises these results.

Table 7.2: Estimated Levels of System Leakage

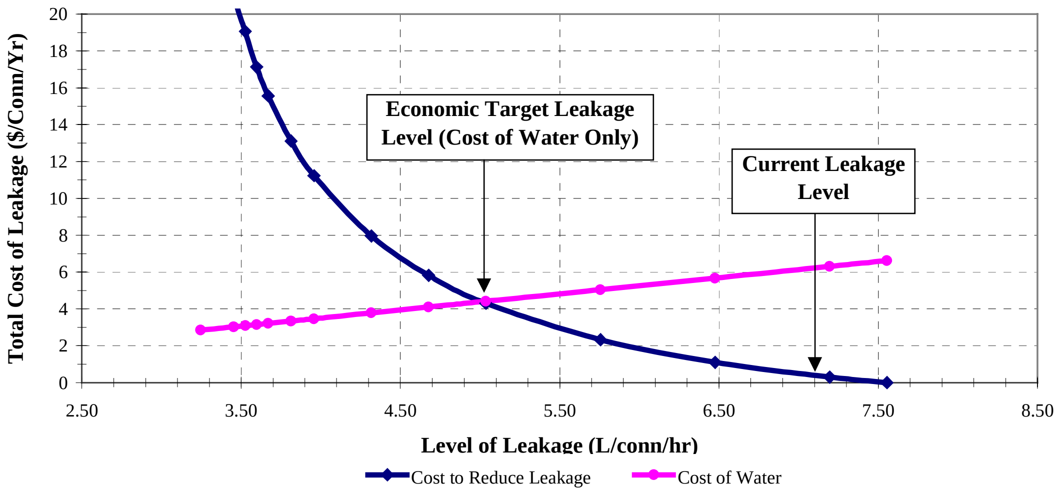
Pilot Area	Production Cost per ML	Leakage Level	Leakage Volume		Cost of Leakage	
			ML/d	ML/a	Daily	Annual
Emerald	$100	11%	0.83	301	$82.50	$30,113
Ingham	$62	9%	0.30	109	$18.60	$6,789
Mackay	$100	15%	4.65	1697	$465.00	$169,725
Maroochy	$95	8%	3.15	1149	$299.25	$109,226
Toowoomba	$108	9%	2.55	930	$275.40	$100,521

7.3.5 Target Leakage Level Assessment

A graph of the cost of leakage reduction versus the level of system leakage is presented in **Figure 7.2** for the Mackay system.

The cost of water lost due to system leakage is the straight line and includes the water treatment and the operations and maintenance costs for the system. As more water is lost through leakage in a system, the greater is the cost. The curved line represents the costs associated with reducing the level of system leakage. The curve indicates that as the system leakage rate is reduced the associated costs in reducing the level of system leakage increase. Based on the cost of water and O&M costs alone the target reduction leakage level is around 4.8 L/conn/hr which represents a reduction of around 33% over the existing level of 7.2 L/conn/hr. Based on similar programs it is possible to reduce leakage by around 33% using a waste metering approach.

Figure 7.2: Target Leakage Level – Mackay (Cost of Water Only)



This level of reduction was transferred to the DSS and the level of expenditure was determined for a B/C ratio of 2.0. This level was adopted to provide a reasonable return on investment and to factor in the high risk and uncertainty of the program costs and benefits considering that the data being used in this study is preliminary. A program cost of say $750,000 over 5 years and an annual maintenance cost of $20,000 per annum above current levels returned the B/C ratio of 2.0. The average water saving that may be achieved from this program was 1.65 ML/d. Therefore a program costing approximately $6.70 per connection per year for five years would be expected to return a maximum B/C of 2.0.

A similar analysis was undertaken for the remaining pilot areas and the results were as follows:

- *Toowoomba* The results from the Toowoomba evaluation indicated that a reduction from 3.0 to 2.0 L/conn/hr was cost effective through the expenditure of $5.70 per account per year for five years. The total cost would be $950,000 and the major benefits would be gained from delaying the next stage of the treatment plant. The low growth in demand in Toowoomba causes any reduction in demand to have significant effect on the B/C. Even though the B/C is high in this area it is difficult to justify a program to lower a system's demand from an already low level of 3.0 L/conn/hr. However the adoption of new techniques may well make this possibly and therefore an initial zonal testing program is recommended prior to deciding to proceed.
- *Maroochy* The analysis of leakage at Maroochy Shire provided results similar to those at Toowoomba. The program costs to provide a B/C of 2.0 were $1,200,000 over five years providing a reduction of 33% from 3.0 to 2.0 L/conn/hr. Again this is a good performance by national standards and as the B/C is high the initial assessment of leakage per zone to fully assess and confirm performance would be warranted.
- *Emerald* The analysis showed that the reduction of leakage from 8.0 to 5.3 L/conn/hr would save the community 0.52ML/d and a total of $439,000. A program expending $175,000 over five years ($9.80 per connection per

annum) would produce a B/C ration of 2.0. In fact the leakage rate could probably be lowered further through regular sounding to around 4.0.

- *Ingham* The Ingham system has low cost to treat and transfer water and a small capital works program and therefore it is not economic to reduce leakage below the current level of 4.8 L/conn/hr. The B/C for this system when expending an average amount of $5 per connection per year to reduce the leakage by 33% was a low 0.19.

It should be noted that the analysis has been undertaken using the integrated flow method, which is not an accurate method for assessing leakage levels. Reservoir drop tests or similar night flow measurement techniques should be used to accurately determine leakage levels in the systems and to identify priority zones for future work..

7.4 Australian Leakage Levels

Tests carried out within various Australian water supply systems since 1985 have provided a wide range of results. Leakage rates have ranged from 3.5 L/conn./hr to 32 L/conn/hr or 7% to 35% of average annual demand. The average leakage rate was in the order of 15 L/conn/hr or 18% of average annual demand. These tests were undertaken on a zonal not system wide basis. Although the overall system may exhibit low levels of leakage, some zones may have a high leakage level which may in fact be economical to reduce.

Some general observation can be made on factors affecting the level of system leakage:

- Higher levels of leakage were identified in systems with a large proportion of old pipes, particularly in systems with asbestos cement pipes manufactured prior to autoclaving;
- Climate, topography and soil type also influence the level of system leakage, Higher leakage levels were associated with high rainfall, sandy soils and steep terrain, and lower levels with arid climate, clay soils and flat terrain; and
- Cost of water also appears to be a factor possibly due to an awareness by both consumers and maintenance teams of the importance of reporting and promptly repairing leaks where cost of water is high.

7.5 Leakage Control

There are many methods of leakage control currently practiced. Each method involves field leakage detection except pressure control, which can be considered to be supplementary to each of the other methods. Each method requires a different level of staff input and equipment and consequently each has different capital and operating costs. Each method will also maintain leakage at different levels and consequently, depending upon the costs of supplying water and the characteristics of the system, different types of leakage control will be appropriate to each system analysed. Details of the procedures and equipment used for each type of leakage control are outlined below.

7.5.1 Passive Leakage Control

This requires the least effort on the part of the water authority but in most cases also results in the highest levels of leakage. No attempt is made to measure or detect leaks and generally only those leaks which are reported as a result of either water showing on the ground surface or from consumer complaints of poor pressure are repaired. Leak location may still be required for some of these self-evident leaks as the water may reach the surface at some considerable distance from the actual leak.

This type of leakage control will not normally be cost effective except in areas where water is very cheap and/or soil conditions are such that underground leaks are quickly detected at the surface.

7.5.2 Pressure Control

Leakage reduction by pressure control is probably the simplest and most immediate way of reducing leakage within the distribution system as the detection of leaks is not involved. Pressure reduction may be achieved in a number of ways such as reducing pumping heads, installing break pressure tanks and, most commonly, using pressure reducing valves.

7.5.3 Routine or Regular Sounding

Leakage sources are located by deploying teams of inspectors who systematically work their way around the system sounding all stopcocks, hydrants, valves and other convenient fittings listening for the characteristic noise of leaking water. The frequency of sounding varies from undertaking to undertaking.

An alternative method of regular sounding, is differential sounding. This method consists of dividing the system into a number of sections. Records of the number of faults found in each section are then used to determine the future inspection frequency for that part of the system. This results in those parts of the system with the greatest number of faults being sounded more frequently than the rest.

The arguments normally put forward in favour of these methods are based on the premise that most leaks are located by sounding and each part of the distribution system will always contain a certain number of unknown leaks. Consequently, time spent on district metering (as described below) can be more effectively used for locating leaks. These conclusions would be true provided leaks were evenly distributed throughout the system and occurred at evenly spaced intervals of time. However, this situation is not usually the case. Therefore, although this method of leakage control may cost less to implement than those incorporating metering, it results in higher post rehabilitation leakage levels.

A range of sounding equipment is available from simple listening rods and electronic stethoscopes to sophisticated leak noise correlators. Regular sounding will probably be most effective in areas where the value of saving water is fairly low and where the soil conditions are such that large leaks show themselves fairly quickly so that only small underground leaks need to be detected by inspector staff.

7.5.4 District Metering

Flow meters are installed at strategic points within the system so that areas of about 2,000 to 5,000 properties supplied via one pipeline and the integrated flow into each area measured.

Meters are normally read at regular periods, weekly or monthly, and the results analysed to determine any areas in which significant increases in supply have occurred. If no legitimate reason can be found for the increase in flow, the inspection teams sound all stopcocks, hydrants, valves and other fittings searching for the characteristic noise of leaking water.

This method of leakage control had the advantage that the inspectors are always working in those districts where leakage is anticipated to be the highest and therefore are likely to return the greatest benefits for their efforts.

District metering is not as sensitive to changes in leakage as is waste metering nor does it so closely determine the position of leaks. There can also be a reduction in system flexibility through the loss of permanent interconnection with adjacent districts. This type of control can be justified in the majority of systems.

7.5.5 Waste Metering

Waste metering involves setting up areas of between 1,000 and 2,000 properties such that when appropriate valves are closed these areas can be supplied via a single pipe in which it is possible to site a flow meter. The flow meter is one which is capable of measuring low rates of flow and is normally referred to as a “waste meter”.

The waste meter, which may be permanently installed on a by-pass line or be portable, is used only to measure night flow rates. Recording charts are put on to the waste meter and the night flow rates recorded for subsequent examination. If the minimum night flow rate has increased above some predetermined level or it is above the previously recorded minimum night flow in that waste district, then it is indicative of leakage and the area is inspected. The inspection may consist of sounding the entire area supplied by that meter or more commonly by repeating the measurement and successively closing valves starting with those most downstream of the meter within the district.

This approach isolates sections of the district and enables the corresponding reduction in flow rate to be determined. A large reduction in flow rate indicates the existence of a leak within the section last isolated. This procedure is performed at night and is generally known as a step test. At the end of the step test those sections showing evidence of leakage are investigated by the inspectors.

This type of leakage control has the advantage that it is sensitive to small leaks and also establishes the position of that leak between valves. This type of leakage control is likely to be appropriate in areas where the value of saving water is fairly high.

7.5.6 Combined District and Waste Metering

This method of leakage control is a combination of the last two methods discussed. District meters are used to monitor large areas (ideally 2,000 - 5,000 properties) of the system and when these indicate an increase in consumption, waste metering is used downstream to determine more precisely the position of the leakage.

7.6 Summary of Findings and Recommendations

The analysis of UFW and leakage levels of the five pilot areas has shown that:

- Active leakage management programs have not been implemented in any of the pilot communities.
- All authorities were capable of determining total Unaccounted For Water (UFW) using the Integrated Flow Method however the accuracy or split between leakage and other sources of UFW.
- The estimated level of UFW calculated using the Integrated Flow Method, ranged from 12 to 20% of total production. It is possible that the Mackay level was even higher due to an aged meter fleet. Leakage was estimated at 75% of UFW levels for the purposes of the analysis.
- Analysis showed that it is feasible to implement leakage reduction programs at Emerald and Mackay. Due to the limited benefits in Ingham, a leakage reduction program was not shown to be cost effective.
- Leakage levels at Toowoomba and Maroochy were shown to be low (3.0 L/conn/hr), however it is economical to undertake a leakage assessment on a zonal basis to determine whether a program should be implemented in prioritised parts of the system.

Based on the analysis of system leakage undertaken for this report the following recommendations are made:

- The practice of reporting leakage levels based on the Integrated Flow Method, be discontinued, as misleading performance data is provided by this approach.
- Leakage should be calculated and reported on a per connection per hour (or day) basis. Such calculations need to be undertaken using the night flow analysis approach, based on reservoir drop tests. A standard procedure should be developed for Queensland local governments.
- Active leakage programs, where proven to be beneficial through a rigorous benefit/cost analysis, should be commenced in Queensland and supported by the State Government loans program.