THE BASIC WATER LOSS BOOK

A Guide to the Water Loss Reduction Strategy and Application

PART 1

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EDUCATION and CULTURE

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"PROWAT:PLANNING AND IMPLEMENTING A NON-REVENUE WATER REDUCTION STRATEGY IMPROVES THE PERFORMANCE OF WATER SUPPLY AND DISTRIBUTION SYSTEMS"

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The Basic Water Loss Book

Introduction

A few years ago many world leaders shied away from the problems hidden in the deteriorating water systems below the streets of the towns and cities. It was a case of out of sight out of mind. Politicians were shown on televisions or in newspapers cutting the red ribbon on new treatment plants costing millions of Euros whilst scant resources were spent on the crumbling underground infrastructure. Increasing demand, changing weather patterns and dwindling resources have resulted in an “awakening” to the problem of water loss from water distribution systems. There has been increasing awareness and an international effort to develop a comprehensive and integrated approach to making the water networks around the world more efficient.

In the late 1990s the International Water Association (IWA) set up a Task Force to develop international terminology and a set of performance indicators for water loss. In 2002 the Water Loss Task Force embarked on developing best practice on all aspects of water loss. The output of this group has been widely disseminated around the World and accepted by practitioners in many countries. PROWAT, through its group of partners is represented on the Water Loss Task Force. Various water associations in Europe and around the world have supported this effort, adding momentum to the objective of developing best practice in reduction and control of water loss. Also, the World Bank Institute and European Investment Bank are investing in water loss management. In 2007, a major conference on Water Loss was held in Romania and attended by over 300 delegates from 41 countries with 91 papers being presented. This clearly demonstrates the great interest and desire for efficient water loss management in Europe and beyond.

The PROWAT project has as its aim the reduction of water loss through improved planning and implementation of water loss reduction strategies leading to more efficient performance of water supply and distribution systems. It is intended that this book will provide managers with a greater understanding of the nature of water loss management, the concepts involved in the development of strategies to reduce the loss and assist engineers and technicians with their implementation.

The Basic Water Loss Book is published in two parts.

Part 1 is primarily intended for senior managers and policy makers; it outlines the background to the subject of water loss from transmission and distribution systems. Part 1 also provides principles and guidance on all aspects that will enable an appropriate water loss reduction and control policy to be determined for any water utility in any European country.

Part 2 is principally a technical manual. Its aim is to assist engineers and technicians plan and implement a water loss reduction strategy. The process of assessing the components of water loss, strategy development, the economics of leakage right through to the practical activities required to reduce leakage are discussed in detail. It is recommended that this book is used in conjunction with all the other products of the PROWAT project to equip engineers and technicians with a “toolbox” that will assist them to develop a ‘tailor made’ and most importantly, a sustainable strategy to suit the local conditions and influencing factors. Some of the content of Part 1 is repeated in Part 2. The authors consider that it is important to reinforce the message in certain sections rather than risk loss of understanding through omission. Several successful case studies from various parts of Europe are also featured in the book.

The Basic Water Loss Book Part 1

1.1 Basic Facts about Water Supply and Water Loss

Water is a daily touchstone in the life of every citizen, sustaining health, economic development and ecosystems not only in Europe but also on the whole Planet. As water is so precious and important to our lives, protecting and using our water supplies wisely is a responsibility that we all share. Reducing and controlling water loss from water supply and distribution networks is the main aim of the PROWAT project.

The combination of increased demand and dwindling resources is placing pressure on water resources (Figure 1.1). The result of this is water shortages and restrictions being imposed upon industrial and other uses in many countries throughout Europe and, indeed, the World. There are also incidents of serious damage occurring in ecosystems. According to European Environment Agency (published in July 21, 1999) and FAO AQUASTAT (*Water Resources* published in 2002), one third (1/3) of European countries have relatively low availability of water, i.e. less than 5000 m^3/head/year. Southern countries are particularly affected, with Malta having only 100 m^3/head/year. The heavily populated countries of northern Europe such as Belgium, Denmark and the UK that receive moderate rainfall also come within the low availability group. As recent as the summer of 2007 Turkey and South-east Europe suffered from a severe drought. In Southern countries, the demand for water is generally greater, especially for agriculture although industry remains the major user of water in Europe. For Europe as a whole, 53 per cent of abstracted water is for industry, 26 per cent is for agriculture and 19 per cent for household use but with wide variations between countries.

Figure 1.1 A depleted reservoir caused by drought conditions (Source: Halcrow Group)

In recent years there has been a growing realisation that the increasing demands for water throughout Europe are not sustainable. As a result of increased understanding of the problem there has been a move away from the traditional approach of just increasing supply, through developing new resources and transfer schemes, to demand management. Demand management focuses on the more efficient use of water, reducing losses, less wasteful use of water, more efficient appliances and water recycling. In many cases it is cheaper and more effective to improve water use efficiency than it is to increase water supplies.

On the supply side, water losses from the distribution system are estimated to amount to an average of around 30 to 40% water put into the networks. In some of the former eastern European countries it is not uncommon to find water loss exceeding 50% of the total amount of water put into the system. Utilities that have cheap and plentiful sources have often been reluctant to spend money on dealing with water loss. Most of these utilities practised what is termed a "passive leakage control". This generally meant that they repaired visible leaks and those reported by the public but did not have a policy of detecting non-visible or unreported leaks. After all, finding and repairing leaks is costly, and because the reduction of losses does not translate into higher water prices there has not been the incentive for some utilities to reduce leakage to an acceptable level.

Reliable data on water utility efficiency in many European countries is unfortunately not yet available but large differences in use efficiencies are likely. For example, in Italy the levels of water loss range from 15 – 60% of water put into the system (ISTAT 2003). The collection and exchange of this information enabling comparison between utilities and countries will help to achieve more efficient water use across Europe. Although there has been much improvement in water supply network since the first European law, little progress has been made on the integrated management of water loss reduction strategies, which is the most effective way to address water loss control. This is also one of the other aims of the PROWAT project

1.2 What is Water Loss?

Water Loss or Non-Revenue Water (NRW) represents inefficiency in water delivery and measurement operations in transmission and distribution networks and, for some systems, can amount to a sizeable proportion of total water production. The Water Losses for a whole system or for a partial system are calculated as the difference of Systems Input Volume and Authorised Consumption. The Water Losses consist of Real and Apparent Losses:

- ***Real Losses*** are physical losses of leaks, bursts and overflows from the pressurized system, up to the point of metering on the service connections (Figure 1.2.a).
- ***Apparent Losses*** consist of all types of meter inaccuracies (input, output, and customer meters) and unauthorised consumption (theft and illegal use). Also termed as commercial losses (Figure 1.2.b).

The terminology used in this book was developed by the International Water Association (IWA) and is widely used around the world. A full glossary of terms is provided in Part 2 Chapter 13.

Water loss occurs on all the systems, it is only the volume that varies and it reflects the ability of a utility to manage its network. To understand the reasons why, how and where water is being lost managers have to carry out an appraisal of the physical characteristics of the network and the current operational practice. In many instances the problem of water loss is caused by poor infrastructure, bad management practice, network characteristics, operational practices, technologies, skills and social and cultural influences. A high level of real or physical loss reduces the amount of precious water reaching customers, increases the operating costs of the utility and makes capital investments in new resource schemes larger. A high level of apparent or commercial losses reduces the principal revenue stream to the utility.

a) Physical water losses **b) Commercial water losses (e.g, illegal use)**

Figure 1.2 Examples of water loss (Halcrow Group, 2002 and Pilcher, 2003)

Figure 1.3 below shows the typical components of a water transmission and distribution system using the International Water Association terminology.

Water loss is by no means a new phenomenon, the reduction and control of physical water losses (principally leakage from water mains and house service connections) has been an activity associated with water distribution since some of the earliest systems were built (Figure 1.4). The Romans were aware that a good proportion of the water put into supply did not reach its intended destination.

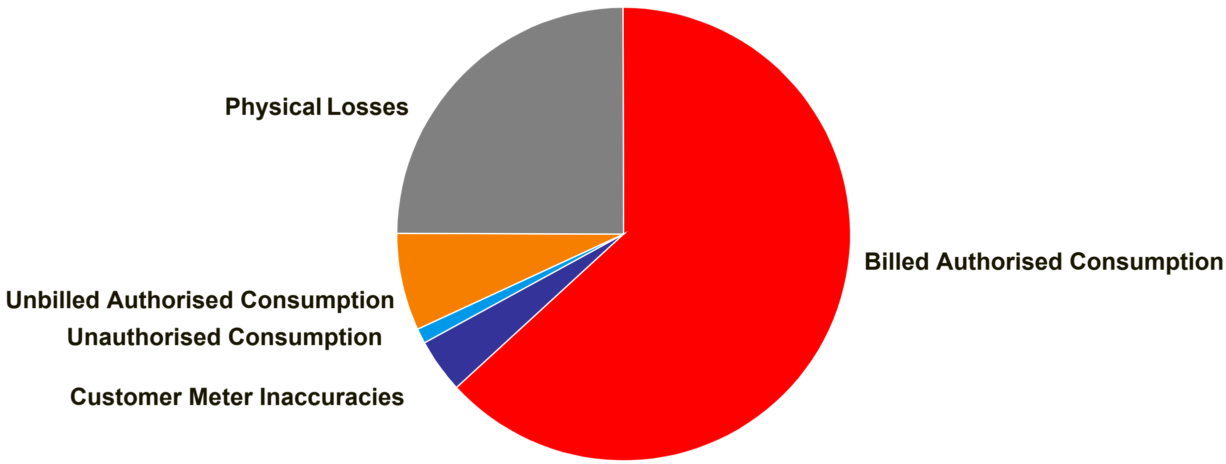

Figure 1.3 Components of distribution system input volume

Sextus Julius Frontinus, Water Commissioner to Rome, used a crude measuring device to assess losses in the system and he estimated that over half the water put into the system disappeared. Although illegal connections were commonplace it was apparent that water loss through leakage was a serious problem, similar to many of today's distribution systems around the world. Thus, whilst the water engineers and technicians of today have the same problem as the Romans, insomuch that the fight for the reduction and control of losses is never ending, they have available to them a variety of equipment and techniques that have been developed to help them tackle the problem of locating non-visible leaks with precision in a highly efficient manner.

Figure 1.4 Ancient water systems

1.3 *Why Reduce Water Loss?*

Despite the advances in the understanding of water losses and leakage many water supply utilities around the world have not been able to reduce and control them. This may have been because there was little understanding of the nature of losses, no appreciation of the impact of losses or grossly underestimated the cost of a comprehensive water loss reduction programme.

NRW captures key elements of operational/financial efficiency and sustainability by way of service continuity, water quality, asset management, financial flows and demand management. Unfortunately in practice it is a complex issue, with many components such as the sources of losses, choice of indicators, determining an appropriate target and strategy.
The reduction of Non-Revenue Water has to begin with a standard approach to benchmarking and reporting of leakage management performance. The senior management or policy makers in any organization must demonstrate a commitment to reducing NRW by:

- Making the reduction of water loss a stated priority
- Fixing targets and a timescale for achieving them

Following the statement of intention trained engineers and technicians can then develop a water loss reduction strategy. This is achieved through gaining a better understanding of the reasons for losses and the factors which influence them. They can develop techniques and procedures that can be adapted to the specific characteristics of a network and local influencing factors, and importantly, to tackle each of the causes in order of priority. It must be borne in mind that any strategy for water loss reduction must address both components of water losses, physical and commercial.

To assist the European water industry to move forward with these issues, one of the PROWAT's main goals is to provide technical assistance to water utilities by developing "Vocational training courses". These courses are for engineers, middle & higher technicians working in Water Institutions, public sector and construction companies and will assist them to tackle water loss, improve network efficiency and implement a strategy for recovering a potentially huge lost resource.

1.4 European Directives, Legislation, International and National Situation – Why are there European Directives?

Today, population growth accompanied by modern & rapid urbanization, new lifestyles and economic development has led to over 1 billion people on the planet, especially over 2.2 billion people in developing countries with lack of access to safe water, inadequate sanitation and poor hygiene, namely preventable diseases. EU member states (25 EU countries) are among the most important donors in the water development sector and can draw on a wealth of experience in respect of International development, cooperation and water management.

On 23 October 2000, the "Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy or the EU Water Framework Directive (WFD) was finally adopted. Its fundamental objective establishes a legal framework to protect and restore clean water in sufficient quantity across Europe or in other words maintains "high status" of waters where it exists, prevents any deterioration in the existing status of waters and achieves at least "good status" in relation to all waters by 2015 on European scale. Meanwhile the main focus of an international effort is to try and halve, by 2015, the proportion of people who are unable to reach or afford safe drinking water and the proportion of people who do not have access to adequate sanitation.

The Water Framework Directive sets out clear deadlines for each of the requirements which add up to an ambitious overall timetable. According to 'Official Journal of European Union'
Published on 15th February 2006, the key milestones are listed below:

- 2008: Present draft river basin management plan
- 2009: Finalise river basin management plan including progamme of measures

- 2010: Introduce pricing policies
- 2012: Make operational programmes of measures
- 2015: Meet environmental objectives, First management cycle ends
- 2021: Second management cycle ends
- 2027: Third management cycle ends, final deadline for meeting objectives.

European Water Policy has undergone a thorough restructuring process with early European water legislation began in 1975 with a "first wave", with standards for those of our rivers and lakes used for drinking water abstraction. This culminated in 1980 in setting binding quality targets for our drinking water. It also included quality objective legislation on fish waters, shellfish waters, bathing waters and ground-waters. As an outcome of this whole process, the Commission presented a Proposal for a Water Framework Directive (WFD) with the following key aims that the PROWAT Project will work along to help achieving:

- expanding the scope of water protection to all waters, surface waters and groundwater
- achieving "good status" for all waters by a set deadline
- water management based on river basins
- "combined approach" of emission limit values and quality standards
- getting the prices right
- getting the citizen involved more closely
- streamlining legislation

In 2008 The WFD is about to enter a critical phase as all interested parties have to complete draft River Basin Management Plans (RBMP) and Programmes of Measurables (PoMs) and the final RBMP and PoMs made statutory by December 2009.

The European Commission is also trying to bring better regulation to the EU through simplification of the Common Agricultural Policy (CAP), and to review the relationship between CAP and the WFD. The Commission is confident of producing firm proposals during 2008 and these will almost certainly have an impact on the European water sector.

Climate change is also a priority for 2008 in respect of the Commission's work programme. In July 2007 the Commission published a Green Paper on adapting to climate change in Europe. The Commission is currently analyzing the responses to this Paper and they proposes to produce a White Paper in 2008 that will contain proposals and definitive actions and these could also have an effect on the European Water Industry.

2 Defining Water Loss or Non-Revenue Water (NRW)

Over the last 20 years, there has been one topic that has been prevalent in the development of water services worldwide and that is the reduction of water loss or Non-Revenue Water from transmission and distribution systems. As stated in the introduction, NRW represents inefficiency in water transmission and distribution systems and inaccurate measurement of the volume of water put into a system or at the customer's meter. For some systems this can amount to a reasonably high percentage of total water put into a system. NRW is of great importance to water service provision and the basic steps involved in developing a strategy to reduce it to an acceptable sustainable level. There has gradually become an acceptance of the strategic importance of water loss to water utilities. This is particularly true in Europe where many countries are developing or have developed policies and programmes for reducing and controlling water loss. These programmes contain a mixture of Non Revenue Water reduction activities that are appropriate to that water utility.

This book will provide basic guidance to managers, engineers and technicians on how to asses the level of water loss, develop and implement a NRW reduction programme with the appropriate mix of water loss reduction activities that will result in improved distribution network efficiency and operation.

2.1 Definition of Non-Revenue Water (NRW)

NRW can simply be defined as:
"The water which a water utility produces or purchases in bulk and distributes to its customers for which it generates no income"

Water Loss or Non Revenue Water (NRW) is comprised of two components:

- Real losses or physical losses
- Apparent losses or commercial losses

Examples of real (physical) losses are:

- Reported and unreported bursts on pipes
- Background leakage on pipes and fittings
- Leakage and overflows from service reservoirs

Examples of apparent (commercial) losses are:

- Errors on source and production meters
- Errors on customers meters
- Unauthorized use i.e. illegal connections and theft

The volume of water lost through physical leakage depends on the condition of the infrastructure and the leak detection and repair policy of the particular utility. The factors that affect the amount of water lost are:

- Pressure in the system
- Frequency of bursts and their flow rates
- Length of time the leak runs before it is located and repaired
- Level of undetectable small leaks (background losses)

The level of apparent losses depends upon:

- Utility's customer meter change policy
- Utility's law enforcement policy for dealing with unauthorized use

Figure 2.1 shows the typical components of Non-Revenue Water in a transmission and distribution system. In gaining an understanding of water loss from any system it is important to differentiate between real and apparent losses. Real or physical losses from a network represent a lost resource. Consequently a reduction in leakage means that a utility has additional water that can be supplied to customers, especially if there had previously been a shortage of water. If a water utility is planning to develop a new source then capital expenditure can be deferred or avoided by reducing leakage from the system. Apparent or ccommercial losses as they are more commonly known is water that is being taken from the system and used but not paid for and, therefore, is a loss of potential revenue to a water utility. Reducing commercial losses will generate more revenue but does not represent an increase in resources. Commercial losses are valued at the retail billing tariff whereas physical losses are valued at the variable cost of water production and distribution.

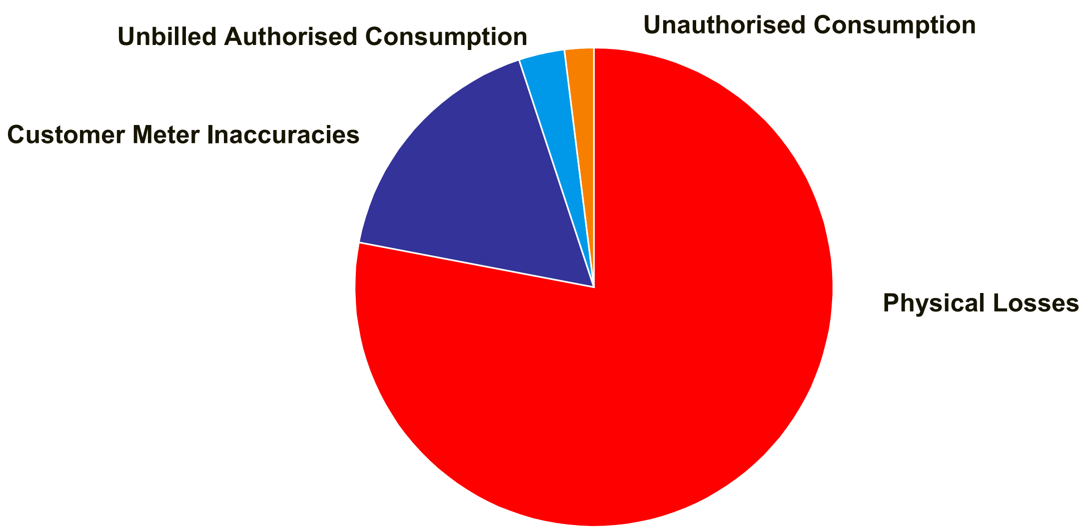

Figure 2.5 Components of NRW

2.2 *Volume and Value of Non-Revenue Water*

Water loss occurs on all the systems and can be as high as 60% of the amount of water put into a system. The level of loss reflects the utility's management of its network. To understand the reasons for water loss an audit or assessment of the volume of how much water is being lost, an appraisal of the physical characteristics of the network and the current operational practice needs to be undertaken. In most systems the greatest amount of NRW is physical loss i.e. leakage. Typically, the proportion of total losses approximately 75 to 80% will be attributed to physical losses and 20 to 25% to commercial losses. In most cases, commercial losses are mainly caused by the under-registration of customer's meters and the amount of water lost through being stolen is often less than 1% of the amount of water put into a system. A detailed methodology of assessing water loss through the calculation of a water balance can be found in Chapter 3 in Part 2 of this book.

If we consider a water utility that supplies water to an area containing 2 million people, and, on average each person consumes 175 litres per day and the utility estimates the 33% of the water put into the system is lost, then the amount of water that has to be produced, or purchased in bulk will be 525,000 m^3 per day of which 350,000 will be consumed. Thus NRW is 175,000 m^3/day. If physical loss is 80% of total losses and commercial losses 20% then:

- Real or physical losses 175,000 x 80% = 140,000 m^3/day
- Apparent or commercial losses 175,000 x 20% = 35,000 m^3/day

On an annual basis this would represent 63,875 Megalitres and for the majority of water utilities this would be unacceptable. If is often the financial value of water lost from a network that has the greatest impact for the utility. Therefore, if the cost of producing the water was 50 cents per m^3 and the tariff to the customer was 1.00 Euros then the value of water lost every day is 105,000 Euros or 38.3 million Euros annually.

If this utility was to implement a strategy that reduces physical losses to 15% and commercial losses to 5% of system input volume then the value of water lost would be 54,638 Euros/day or 19.9 Million Euros/annum. The saving would be Euros 50,632 or 18.4 million Euros/annum which could be interpreted as increased revenue. It is important to determine the cost of making the reduction in NRW as the effort used in making these reductions should not exceed the above figure.

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3 Assessing Water Loss

3.1 Conducting a Water Audit

The starting point for any water utility is to make an assessment of how much, where and why water is being lost from their network or part of their network i.e. between its point of entry into the transmission and distribution system (often a water treatment plant) and the customer's meter. The amount of water loss can be determined by conducting a water audit and this process contains two elements:

- A review or appraisal of network operating practices
- The quantification of the amount of water that is being lost from the network

3.1.1 Reviewing Network Operational Practices

In order to fully understand why water is being lost from a network a review of the distribution network and how it is being operated should be undertaken. The review will answer questions relating to the condition of the infrastructure, behaviour of the system and how well it is being managed.

The review should assess:

- Regional characteristics, local factors and components of water loss
- Current methods used for operating and managing the distribution system
- The level of technology for monitoring and detecting leakage
- Staff numbers, skills and capabilities
- The utility's current data and methodology for estimating current level of loss

The appraisal should also include interviews with senior managers to gain views on the current management culture, financial and political constraints of the utility. There should also be discussions with key staff involved with the day to day operation of the system, especially with regard to:

- Information about the system e.g. population served, length of mains, topography, typical demand and source management
- Condition of the system including frequency of bursts
- Estimates of current level of leakage
- Customer metering policies
- Billing data
- Economic information i.e. the cost of producing water
- Current method of leakage control and repair policy practiced by the utility

3.1.2 Quantifying Water Loss

The second component of an audit is the estimation of the amount of water that is being lost from the network. There are three methods for estimating the level of losses in a system:

- The establishment of a water balance.
- Night flow analysis (bottom up leakage assessment)
- Component analysis.

The calculation of water balance is the most common method of assessing losses. It must be emphasized that before embarking upon the development and introduction of a water loss strategy it is vitally important to know the starting position.

3.2 The Water Balance

The amount of water loss from a system can be determined by constructing a water balance. This is based on the measurement or estimation as to the amount of water produced (taking account of any water imported and/o exported), consumed and lost. In its simplest form the water balance is:

Losses = Distribution System Input - Consumption

The calculation of a water balance is very important because:

- It is the basis of assessing the level of water loss for any utility.
- A first time calculation reveals the availability and reliability of data and level of understanding.
- Mechanism for benchmarking.
- Provides a first step towards improvement.
- Understanding a water balance is essential for prioritizing actions and investments.

Ten years ago there was a diversity of definitions and formats for the calculation of water loss. In the late 1990’s the IWA recognized the need to have a workable water audit structure with common terminology and as a result its Water Loss Task Force developed a standard water balance. This standard water balance has now been accepted with or without some minor modifications and used worldwide.

System Input Volume	Authorized Consumption	Billed Authorized Consumption	Billed Metered Consumption	Revenue Water
			Billed Unmetered Consumption	
		Unbilled Authorized Consumption	Unbilled metered Consumption	Non-Revenue Water
			Unbilled Unmetered Consumption	
	Water Losses	Apparent (Commercial) Losses	Unauthorized Consumption	
			Metering Inaccuracies	
		Real (Physical) Losses	Leakage on Transmission and/or Distribution Mains	
			Leakage and Overflows at Utility's Storage Tanks	
			Leakage on Service Connections up to Customer Metering	

Figure 3.6 The IWA standard water balance

3.3 Water Balance Terminology

The component parts of the IWA standard water balance are:

- **System input volume** is the annual volume of treated water input to that part of the water supply system to which the water balance calculation relates
- **Authorized consumption** is the annual volume of metered and/or unmetered water taken by registered customers, the water supplier and others who are implicitly or explicitly authorized to do so by the water supplier for residential, commercial and industrial purposes.
- **Water losses** are the difference between System Input Volume and Authorized Consumption. Water losses can be considered as a total volume for the whole system, or for partial systems such as transmission or distribution schemes, or individual zones. Water Losses consist of Real Losses and Apparent Losses.
- **Apparent losses** accounts for all types of inaccuracies associated with production and customer metering as well as data handling errors (meter reading and billing), plus unauthorized consumption (theft or illegal use).
- **Real losses** consist of physical water losses from the pressurized system, up to the point of customer use. In metered systems this is the customer meter. The annual volume lost through all types of leaks, bursts and overflows depends on frequencies, flow rates, and average duration of individual leaks, bursts and overflows.
- **Non-Revenue Water (NRW***)* is the difference between the System Input Volume and Billed Authorized Consumption; NRW consists of Unbilled Authorized Consumption (normally only a very small proportion of the water balance), Apparent and Real Losses.

3.4 Calculating a Water Balance

In order that the water balance can be calculated the constituent pieces of data need to be measured or estimated. Whilst some of the key components can be measured others may have to be estimated. In most cases there will be a mix of data accuracy and it will be necessary to estimate the exactness of each of these components

There are four clear steps to calculating a water balance:

- **Step1** – determine system input volume by identifying all sources and quantities of water entering the network.
- **Step 2** – determine authorized consumption through analysis of billing records and identifying authorised use that is either unbilled or unmeasured.
- **Step 3** – estimate apparent (commercial) losses by assessing the level of customer meter under-registration and estimates of illegal connections and theft.
- **Step 4** - calculate physical (leakage) losses by adding the volumes from steps 2 and 3 and subtracting from step 1.

3.5 Limitations of Water Balance Calculations

The water balance is a very important tool for understanding the basic components and relationships. However, it has a limited usefulness if a utility lacks the information to construct a meaningful water balance or there is little information on the nature of leakage.

The calculation can be improved or verified by taking leakage measurements the objective of which is to make an analysis of night flow into the system when customer use is at its lowest and leakage at is highest. Component analysis is used to verify water loss estimates based upon the water balance and night flow methods. It is particularly useful if there insufficient data concerning zone flows and customer use. These methodologies are detailed in Chapter 3 in Part 2 of this book

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4 Performance Indicators

The purpose of a Performance Indicator (PI) is twofold, it helps to measure changes in NRW performance over time and allow for inter utility comparison (benchmarking) and to provide guidance on target setting. It is important to have standardized performance indicators, calculated according to a clearly defined methodology and using standard definition. There are several traditional PIs for the measurement of water loss within distribution systems, but some are better than others, and some may be inappropriate for particular circumstances.

"Percentage of system input volume*":* is easily calculated and frequently quoted. However, the IWA does not recommend its use for assessing the efficiency of management of distribution systems because calculated values of % NRW do not distinguish between Real (leakage) and Apparent (commercial) Losses. They are strongly influenced by consumption and are difficult to calculate for intermittent supply situations. It is useful, however, as a communication tool with 'shock value'.

"Per billed property, per unit of time": in many countries, a single service connection can serve a large number of properties i.e. apartment blocks. The water balance calculation is usually based on leakage up to a single master meter on the service connection. Therefore this PI is not recommended.

"Per length of mains, per unit of time": distribution losses expressed in m^3/km mains/day are very strongly influenced by density of connections. From experience the PI length is appropriate where there are fewer that 20 service connections per km main i.e. a rural situation. Below are some realistic guideline leakage values from water systems in average condition when leakage is expressed in m^3/km main per day:

- Good performance < 10 m^3/km main per day
- Average performance 10 – 20 m^3/km main per day
- Poor condition >20 m^3/km main per day

"Per service connection, per unit of time": the International Water Association (IWA) considers that of all the traditional PIs this one is recommended for systems with more than 20 service connections/km mains. Below are a range of typical values of achievement when leakage is expressed in litres/connection/day at an assumed average pressure of 50 metres head:

- Good performance < 125 litres/connection /day
- Average performance 125 - 250 litres/connection/day
- Poor performance >250 litres/connection/day

"Infrastructure Leakage Index (ILI): The ILI is the most useful and practical performance indicator and was developed by the IWA's Water Loss Task Force in 2000. The ILI is defined as the ratio between the Current Annual Real (Physical) Losses (CARL) to the Unavoidable Annual Real (Physical) Losses (UARL). For most systems the UARL would represent the lowest level of leakage that could be technically achieved. For illustration, CARL is represented by the large rectangle in Figure 4.1. As new leaks occur each year, this volume will gradually increase unless all four management techniques of pressure management, active leakage control, prompt and efficient repair and good management of pipelines (represented by the 4 arrows) are effectively applied.

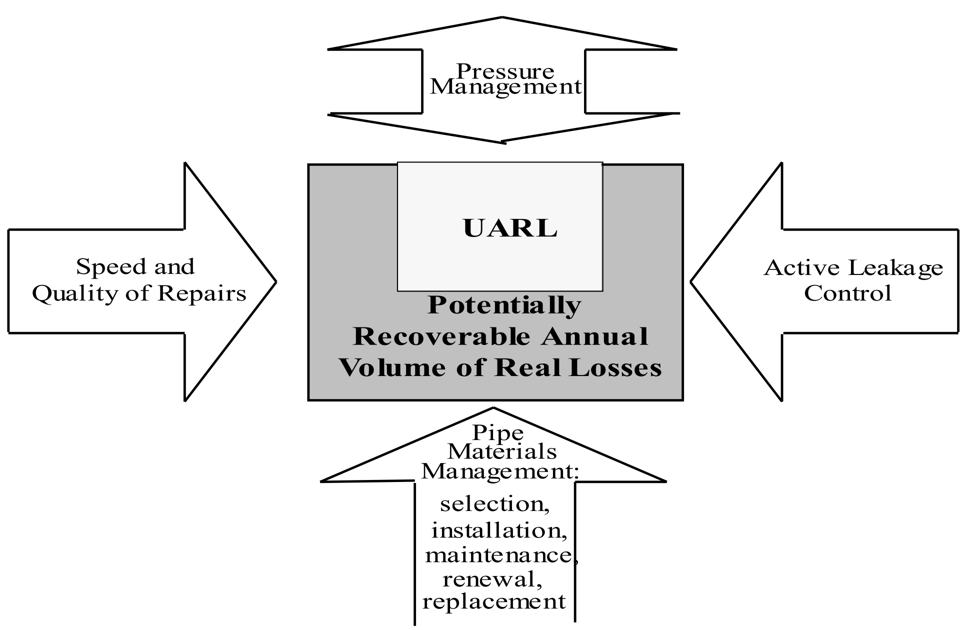

Figure 4.7 The Infrastructure Leakage Index Ratio (IWA Water Loss Task Force)

Figure 4.2 shows some ILI values from utilities around the world. Some of the best managed utilities achieve ILI values in the range of 1.5 to 4.0. In most cases this would represent their economic level of leakage. The ILI has gradually gained acceptance as the most useful PI for physical losses and is used in many countries by utilities and auditors because as, with all good PIs it is easily measurable so that progress can be tracked during a NRW reduction project.

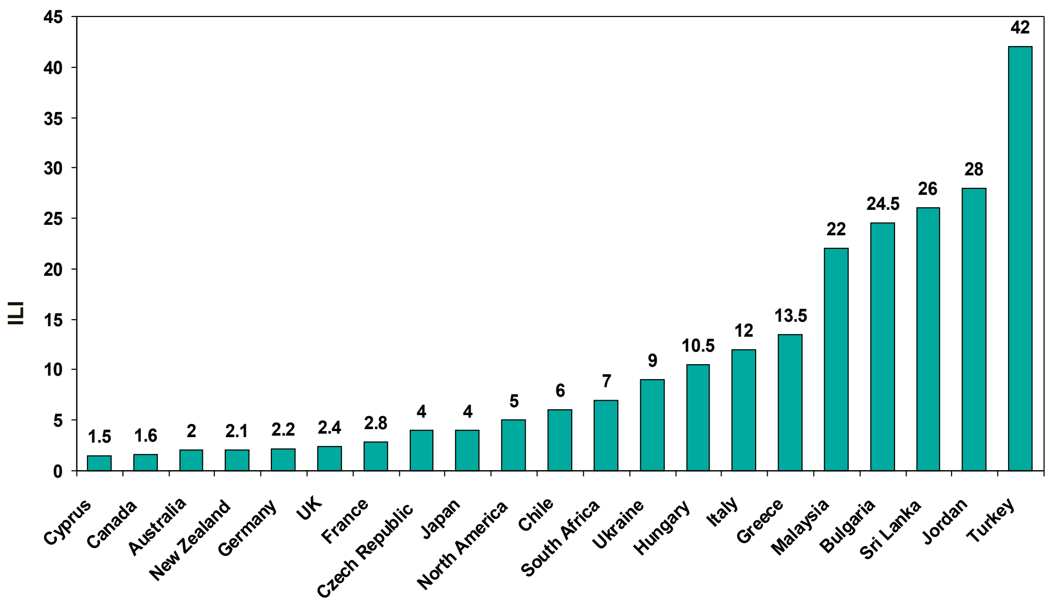

Figure 4.8 ILI values from around the world (Seago, et al., 2005)

The World Bank Institute in its role of providing greater understanding of all aspects of NRW developed a simplified target matrix for real or physical losses. The matrix shows various ILI values and compares them with values for the traditional PI, litres/connection /day. The matrix is shown in Figure 4.3 and is a clear practical guide as to what can be achieved in a well managed utility.

Following the privatization of the water industry in England and Wales in 1989 the government appointed regulator, the Offices of Water Services (OFWAT) introduced a performance rating system. This system which was designed as a method of comparing the accuracy and robustness of the water balance components. OFWAT uses a confidence grading system consisting of reliability bands A – D. This is shown in Table 4.1. The World Bank Institute adopted the system as a method of comparing performance between utilities and incorporated it into the target matrix (Figure 4.3).

Proposed use of ILI as PI in developed and developing countries

Technical Performance Category		ILI	Liters/connection/day (when the system is pressured) at an average pressure of:				
			10 m	20 m	30 m	40 m	50 m
Developed Countries	A	1–2		< 50	< 75	< 100	< 125
	B	2–4		50–100	75–150	100–200	125–250
	C	4–8		100–200	150–300	200–400	250–500
	D	>8		>200	> 300	> 400	> 500
Developing Countries	A	1–4	< 50	< 100	< 150	< 200	< 250
	B	4–8	50–100	100–200	150–300	200–400	250–500
	C	8–16	100–200	200–400	300–600	400–800	500–1000
	D	>16	> 200	> 400	> 600	> 800	> 1000

Figure 4.9 The simplified physical loss target matrix (World Bank Institute; Liemberger, 2005)

Table 4.1 Confidence grading system for NRW performance (World Bank Institute; Liemberger, 2005)

Category	Performance Rating
A - Good	Further loss reduction may be uneconomic, careful analysis required to identify cost effective improvements
B - Average	Consider pressure management, better active leakage control practices, and better maintenance
C - Poor	Tolerable only if water is cheap and plentiful; even then intensify NRW reduction efforts
D - Very poor	Inefficient use of resources; NRW reduction programme imperative and should be a priority

With regard to PIs for apparent or commercial losses the IWA recommend m^3/service/connection/year. However in systems where all customers are metered and the component of illegal use is small (% distribution input), it may be preferable to express commercial losses as a percentage of authorised consumption, as major part of these losses will be customer metering inaccuracies.

For the calculation of the financial performance indicator the volume of each of the main components of NRW is assigned a valuation in local currency/m^3, appropriate to local circumstances, and the value of the NRW component is expressed as a percentage of the annual cost of running the system. This PI can also have a ‘shock’ value.

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3. Lambert AO and McKenzie R. Practical Experience in using the Infrastructure Leakage Index. Paper presented to the IWA Leakage Management Conference Cyprus 2002.

4. World Bank Institute, NRW Training Module 6, Performance Indicators. Roland Liemberger 2005.

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5 Target Reduction in NRW

In all water utilities, whether water resources are cheap or expensive, scarce or plentiful, the reduction of NRW and minimization of leakage is currently a key issue. As stated in the introduction, Water Loss is one of the major topics in management of water supply systems in Europe in the 21st century. This is largely because diminishing water resources means it is more important to reduce losses of the existing quantities of treated water that are put into transmission and distribution networks.

An acceptable level of NRW depends mainly on two parameters the “economics” and the “availability of raw water”. It is obvious that limited water resources will force the utilities to reduce physical losses as much as possible in order to satisfy the demand, the economics will play a lesser role and the target will be strongly influenced by social needs. On the other hand economical considerations should be used under all other circumstances to determine the economic level of NRW and in particular the economic level of leakage.

The reduction of NRW can only be achieved when both physical and commercial water losses are reduced in a systematic way. In many systems it will be more economic to start with measures for the reduction of commercial losses such as customer meter under-registration as this has a direct impact on utility cash-flow. For many utilities putting in place an adequate customer metering policy should be considered as a priority activity. However, technical measures for the reduction of physical losses in the water network should accompany the work in lowering of commercial losses

Economics of Water Loss – Basic Information

Ideally most water utilities would like to operate a perfect system that has zero leakage but, of course this is not possible as the majority of pipe work is buried under the ground and out of sight of the operators. There are many causes of leaks and bursts and in any water distribution system a certain level of loss will always be present and will have to be managed.

The overall target is the improvement of the performance of the water utility in terms of reduced operational costs and increased revenues that will enable a utility to cover its day to day operations as well as investment requirements. Moreover a reliable and well maintained supply network results in additional benefits in respect of improved level of service to the customer, less health risk and environmental protection due to reduced use of source water.

Successful implementation of rehabilitation and upgrading works result in following benefits:

- Improvement of public opinion on performance of utility – customer responsive
- Reduction of production costs (power and chemicals consumption) for treatment and pumping
- Achieve consistent, reliable 24 hour supply
- Improved customer's willingness to pay for water – higher billing and collection efficiency
- Improve quality of potable water – reduced contamination risk through leaks
- Reduce NRW rate to a range of 20 % or below
- Efficient use of treated water – careful use of resource water – environmentally friendly

5.2 Economic Level of Water Loss

The economic level of leakage has been simply defined, as that level of leakage at which any further reduction would incur costs in excess of the benefits derived from the savings. The concept is easy to understand as the more effort is put into reducing leakage the more it is going to cost and, therefore, it obeys the laws of diminishing returns. In other words there is a level of leakage below which it is not cost effective. The diagram shown in Figure 5.1 below shows this very clearly. By differentiating to find the slope of the Active Leakage Control curve, we can express the cost curves in a more user-friendly marginal cost format.

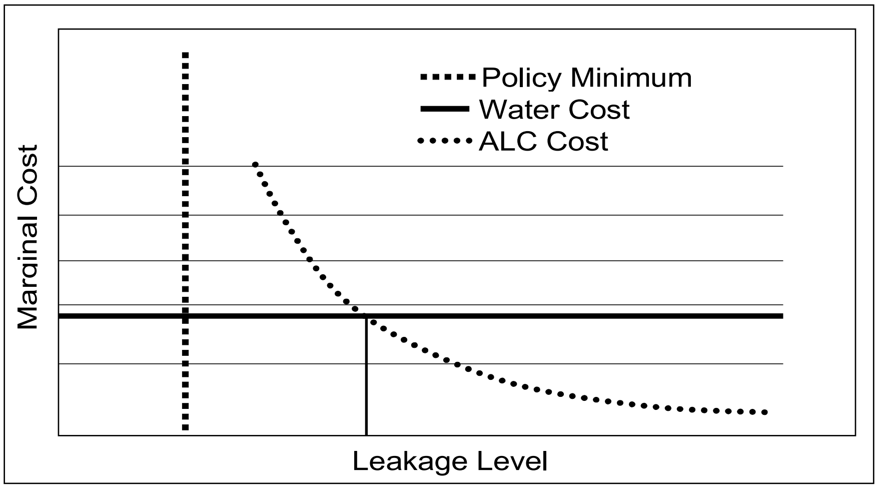

Figure 5.10 Active leakage control cost curve–law of diminishing returns (Farley and Trow, 2003)

The main issues in calculating the Economic Level of Leakage (ELL) are:

- ELL will change over time and will be affected by factors such as mains renewal programmes and burst frequency changes due to abnormal weather conditions.
- Implementing leakage management activities such as pressure management, district metering and the level of active leakage control will also have an impact on the ELL.
- The value of the production of water will inevitably change, increase in electricity tariffs will make an impact as will water shortages caused by droughts. Also water quality regulations may change, resulting in a need to invest in upgrading water treatment plants.
- Leak detection techniques and practices are constantly changing and it is feasible that the development of new leak location equipment will result in more efficient leak detection, thus lowering the cost of active leakage control.
- In calculating an ELL utility specific data should be used and, if a utility is only part way through a water loss reduction programme the values that make up the calculation will be constantly changing. It is recommended that if this is the case the ELL should be reviewed every two years.

Reference.

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6 Developing a Water Loss Reduction Strategy

Once the losses for a water supply and distribution network have been assessed and a better understanding of the system has been gained, including any local factors that may influence its components a strategy for NRW reduction can then be developed. The most important aspect of any water loss strategy is the target and therefore the strategy will be developed to:

- To reduce these losses to an acceptable or economic level and to improve performance.
- To maintain the strategy and sustain the improvements that have been gained.

Although there are several important stages to a water loss management strategy there is no standard approach as each network is different. The strategy needs to be developed in a "tailor made" manner to suit an individual utility and its distribution system. A staged approach of activities is recommended and priorities can only be set under the parameters of which are budget and timescale.

For any water network the design and introduction of the strategy contains the following components:

- **Understanding** – a review of any water supply and distribution system should be made in order to gain a full understanding of its behaviour and operation.
- **Quantifying the level of water loss** – this will be ascertained during the water audit.
- **Setting targets** – short term and provisional long term.
- **Planning and design** – having the appropriate mix of NRW reduction activities.
- **Implementing** – introduce initial or pilot study stage followed by second stage to reduce water loss to target level.
- **Monitoring and maintaining** – sustain the improvements that have been made and undertake annual review of strategy.

The first three components were addressed in the two previous chapters and the next three components of planning and design, implementing and monitoring and maintaining are discussed in this chapter.

6.1 Key Pointers in Strategy Development

6.1.1 Technical Issues

The water audit will have answered questions relating to the condition of the infrastructure, behaviour of the system and how it is managed. The calculated water balance will have identified the priority areas of the network that are worthy of further investigation.

Accurate measurement of the volume of water entering a transmission and distribution system (generally at source or production) is essential to good NRW management practice. Meters should be installed in accordance with manufacturer's instructions and calibrated at regular intervals (this also applies to temporary installed meters).

During the water audit, effort should be made to assess where leakage is occurring. With many systems between 65 to 90% of leaks occur on the service connection i.e. between the main and the meter on the property being served. Where active leakage control has not been practised there will be a significant backlog of undetected bursts.

Control of distribution system pressure is the foundation of good leakage management:

- Leakage flow rate is approximately proportional to system pressure i.e. halving system pressure will halve leakage.
- Burst frequency varies approximately according to the cube of system pressure i.e. doubling system pressure results in typically 8 times the burst rate.
- Background losses – individual breaks too small to be detected can only be reduced by reducing system pressure.
- Frequent or sudden changes in pressure increase the number of bursts on a system

- Pressure management is important even in areas having reasonably low pressures as, during the low usage night hours, pressure can rise significantly increasing the number of bursts.
- Design and operation of direct pumping into the system must suppress surges in the system pressure if high bursts in the proximity of pumping stations are to be avoided.

Division of the distribution network into zones or districts serving between 1,000 to 5,000 connections, ideally with a single point of supply, the flow and pressure should be recorded onto data loggers or telemetered. This facilitates the monitoring of night flows, analysis of which is nearly always vital for the effective application of leakage reduction and control.

In addition to identifying the potential for pressure management, good leak detection techniques and practices need to be planned and implemented. The basic stages for leak detection and repair, commonly known as Active Leakage Control in a district are indicated in the flow diagram below in Figure 6.1

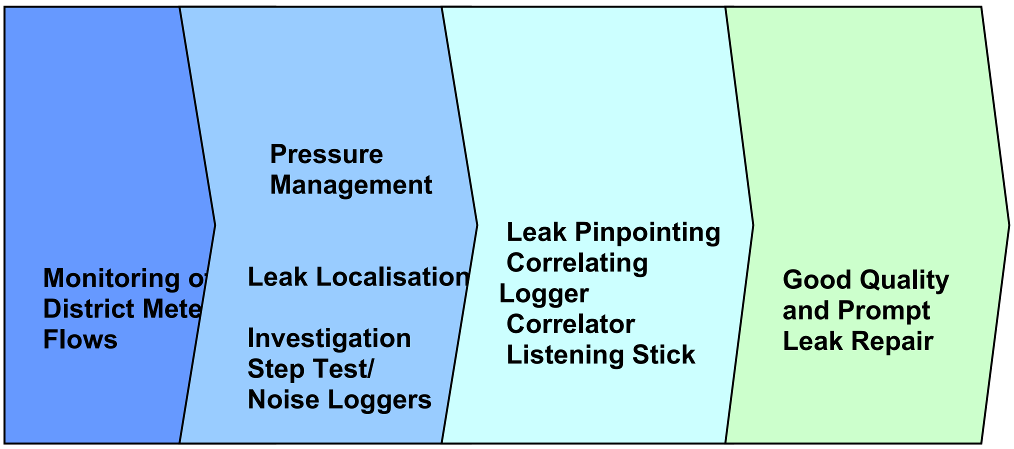


Figure 6.11 Active leakage control in Districts Meter Areas

Active leakage control is the deployment of trained and fully equipped personnel to pro-actively look for leaks that have not been reported by customers or other means i.e. leaks that are non-visible. There are two methods of Active Leakage Control, leakage monitoring and regular survey Leakage monitoring, which is the establishment of discrete areas of the network called District Meter Areas (DMAs) is more widely practised by utilities that have a reputation for good water loss management. Many utilities have recognized that this is a successful form of leakage management by implementing district meter and SCADA (supervisory control and data acquisition) projects which facilitate continuous and remote monitoring of system flows and pressures.

6.1.2 Economic Issues

There are a number of financial factors that have to be taken into consideration when developing a water loss reduction strategy. These are:

- The cost of saving the water should not exceed its value i.e. the economic level of leakage (Refer to Chapter 5.1 and 5.2).
- Each supply situation has an NRW level and it is uneconomic to reduce below this level unless it is for social or environmental reasons.
- Generally a customer meter replacement has short payback periods of 1 to 2 years (for large users this may be less). This activity has a direct impact on utility cash-flow (Figure 6.2).

- Pressure management schemes are low cost and can have a payback period measured in months rather than years.
- Operational improvements or upgrading the system to accommodate zoning or district metering often have payback periods of between 2 and 5 years.
- Capital investment programmes for rehabilitation or replacement of distribution mains have payback periods of 10 to 15 years.

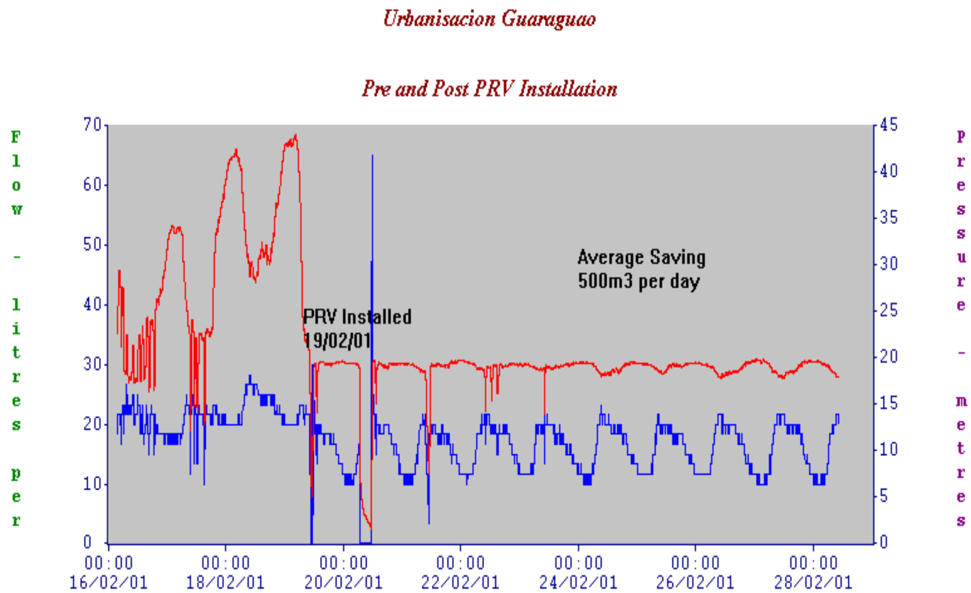
Figure 6.12 A customer meter replacement programme can have a direct impact on utility cash-flow (Liemberger, 2005)

6.1.3 General Pointers

A good water loss strategy will depend upon a cost effective mix of techniques that are appropriate to the local situation and needs of a particular utility. These are:

- Investigation of the potential for pressure management schemes
- Determine if zonal or district metering is appropriate
- Development of leak detection and location methods
- Develop a standard for speed and quality of repairs
- Determine economic intervention policy
- Examine repair or replace policies for parts of the system with high burst frequencies
- If replacing mains always replace the house connections

It is good practice to invest in pressure management schemes before considering investing in mains rehabilitation or replacement schemes because the payback is short, water is instantly saved and burst frequencies are reduced. Figure 6.3 shows the immediate impact of introducing a pressure management scheme, pressure variation is minimal (red) and flows (blue) are stabilised and reduced.



Site	Channel	Units	Min	Max	Vol
002B Guaraguao Inlet DMA F	1Min Logged Flow	Litres/Second	0.00	65.00	18176
002B Guaraguao Inlet DMA F	1Min Logged Pressure		1.47	44.13	n/a

Figure 6.13 The impact of the introduction of a pressure management scheme on flows and pressures (Source: Halcrow Group, 2002**)**

6.2 Implementation of NRW Reduction Strategy

It is of paramount importance that the activity of NRW reduction is understood and embraced at the highest level within an organisation so that the most efficient results can be achieved from the implementation of the approved programme. It is also important to appreciate, that once a NRW reduction strategy has been adopted by a utility, it becomes a 'non-stop', long term activity that can greatly contribute enormously towards more efficient and effective management of the water resources.

6.2.1 Staged Approach – First Stage

The implementation of a NRW reduction strategy is often carried out in a staged approach. This provides the opportunity to determine whether there are going to be problems with the chosen strategy and also to build up confidence in methodology. The stages involved are:

- Calculation of the water balance
- Understanding of the components of water loss
- Review of current operating and water loss control procedures
- Selection of pilot study areas, it is important that the chosen areas are representative of the overall network
- Carrying out NRW in the pilot areas
- Refinement of the strategy
- Application of the refined strategy to the whole utility
- Developing a sustainable policy for the maintenance of the improvements that have been achieved

6.2.2 Staged Approach – Main Stage

The objective of the main stage is to reduce water loss in the whole network to the appropriate target level that has been set over an agreed timescale. The target level will have been determined during the development of the strategy. It will be achieved through the application of the practices and techniques that were most successfully applied during the initial stage of water loss reduction in the pilot district or districts.

Essentially for the reduction of real losses or leakage this will be achieved through pressure management (as a priority), of district metering, leak localizing equipment, such as the acoustic or noise logger, and pinpointing tools, such as the correlating loggers or leak noise correlator.

In addition to the reduction of physical losses through the activities outlined in the previous paragraph the strategy should include the possible reduction of commercial losses and the need to have an ongoing asset renewal or rehabilitation programme.

6.2.3 Monitor and Maintain

Progress towards the target should be monitored very closely through the calculation of the top down and bottom up approaches on a regular basis. A strategy should be reviewed annually and adjusted if necessary to take account of any changes to the situation.

It will be very important for any water utility to make sure that all the advances and improvements that are made in introducing the water loss strategy are sustained. This involves the following activities:

- Ensuring appropriate staffing levels.
- Staff education and training.
- Operation and Maintenance.
- Assessing and monitoring performance

The importance of sustainability is emphasized in Chapter 10.

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7 Demand Management and Water Efficiency Plans

In Europe there is clear evidence of the environmental impact caused by over-licensed abstraction reflected in low flow in rivers and wetlands drying out. The situation is often made worse by droughts and the effects of climate change. The major international conferences on sustainable development have urges that countries develop integrated water resource management and demand management or water efficiency plans. This is commonly known as the 'twin track' approach. This chapter essentially focuses on demand management and water efficiency plans.

7.1 Demand Management

Demand management is defined as the implementation of policies which aim to control or influence the consumption of water. These policies can be considered to be part of an overall sustainable development strategy, which describes the need to use resources efficiently, influence consumption patterns and provide new advice for customers, improve the environmental performance of products and service, understand environmental limits and act to enhance the environment.

Demand management is one part of the "twin-track" approach towards seeking to optimize water resource use by aiming to balance the efficient use of water with timely proposals for appropriate resource developments. Therefore, as the need for further resource development becomes necessary there should also be an increasing effort made to use water more efficiently. Successful implementation of demand management (including leakage reduction by the utility) should allow resource developments to be deferred further into the future, which should have associate benefits for the environment. Option selection should consider developing resources only where demand management options are insufficient or too costly.

In some parts of the world, where changing weather patterns are affecting the availability of water resources, water utilities have implemented strategies with the objective to reducing water loss to an acceptable level. In recent years some of these utilities have also promoted water efficiency to their customers. In order to achieve this water efficiency, plans need to be developed that have a basic aim to encourage customers to use water more wisely.

7.2 Water Efficiency Plans

In setting out its Plan for promoting water efficiency, a utility must recognize that it has a corporate responsibility to adopt good practices and high standards in the way it operates. Water efficiency 'starts at home'. Therefore, many of the initiatives contained within the plan will be applied, as far as reasonably practicable, within the utility's own working environment, with a view to building a responsible ethos within the Company's own staff, encouraging staff to adopt similar practices in their own homes, and encouraging colleagues, friends and family to do their part too.

For many utilities water used for domestic purposes is by far the largest proportion of water supplied for consumption, often accounting for almost two thirds of the total water consumed. In that respect it offers possibly the greatest opportunities for greater water conservation and efficiency. Whilst a water efficiency plan considers the full range of water efficiency measures available both to the water utility and to the customer.

7.1.1 Water Conservation and Efficiency: Basic Principles

The main tenets of conservation generally accepted are:

- Eliminate
- Reduce
- Re-use
- Recycle
- Waste

In the context of water efficiency examples might include:

Eliminate: consider specifying equipment not requiring water, such as water-less urinals in offices.

Reduce by seeking to use less water in the way we live – active water efficiency by change of habit.

Re-use: consider the promotion of grey-water facilities in commercial developments and new housing.

Re-cycle: effluent re-use (Indirect Potable Reuse or IPR) schemes, and dual reticulation, although with care since the energy and carbon impacts can be substantial.

Waste: ultimately all used water will go to waste, for treatment, but reductions in demand and re-use options give an associated saving in the volume of wastewater.

Figure 7.14 Promoting water efficiency in the home and garden (Waterwise, 2007)

References

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8 Benefits of NRW Reduction

There are many benefits to be derived following the adoption and successful implementation of a NRW reduction programme. It will greatly contribute towards more efficient and effective management of the available water resources, especially in parts of Europe where water scarcity is a problem and there is the decreasing possibility to develop new water sources.

The more immediate benefits that will be derived from a NRW reduction programme are:

- NRW is reduced to an acceptable level
- Improved Pressure management
- Reduction in burst frequency
- Improved security of supply
- Improved levels of service
- Reduced operational costs and increased revenue
- Improved knowledge and more efficient operation of the distribution system
- Greater understanding of unauthorised water use
- Training and technology transfer

In addition to the significant financial savings that can be achieved through the implementation of an effective water loss reduction strategy/programme, water utilities can greatly benefit in several other business related activities. For example, customer service relationships can improve in areas where the security of supply has improved as a result of a successful NRW reduction programme has taken place.

The majority of customers of a utility will be aware (or should be made aware through a public relations exercise) of the improvements and will more likely support a water efficiency plan i.e. conserve water and use it more wisely in their every day life.

Once the targets have been met, it is vital to maintain the improvements that have been made and manage water loss at the reduced level. An efficient and effective set of procedures must be implemented during the period of the NRW reduction programme to ensure that once the target has been achieved, the level is maintained in future years. These procedures need to be applied at three levels, strategic, tactical and operational. More detail of these activities is given in Part 2.

Good examples of the benefits of NRW reduction are presented of the form of four case studies from Europe. The Skopje case study provides an excellent example of ‘how to get started’, develop a strategy and implement a pilot or first stage. Two other cases provide examples of ongoing NRW reduction and control strategies in locations where water is in short supply and a precious resource needs to be conserved. The fourth example is of a water company operating in a strongly regulated framework where leakage has to be reduced and maintained at an economic level. In this case the leakage performance is audited and the results are placed in the public domain.

9 Training

The need for an appropriately resourced and competently trained workforce is central to the success of any organization. In respect of NRW management this is especially true. Training encompasses the motivation of staff, transfer of skills in the techniques and technology of NRW management, and operation and maintenance of a network.

In the best managed water utilities the senior managers have an awareness and appreciation of their water loss programme and their enthusiasm and motivation is conveyed to distribution and/or to leakage control managers. They, in turn, take responsibility for training and this is often in conjunction with training providers who have the skills necessary to provide appropriate training for staff. In the 21st century this can be achieved through modern learning techniques. A training programme should include awareness seminars for senior staff and managers whilst engineers and technicians require technical training on all aspects of water loss in order to deliver a successful NRW reduction and control programme.

Training within the PROWAT project is aimed at managers by way of awareness seminars and for engineers and technicians by some innovative tools techniques that will enable them to become proficient at all of the engineering and technical issues of water loss reduction and control.

9.1 Awareness Seminars

The training in any utility should start at the top and a well organised awareness seminar aimed at the senior management should be considered as the first stage in a water loss reduction programme. The objective of such a seminar is to provide an overview of methodologies and other issues and to brief them on the aims and cost benefits of a water loss reduction policy and programme. The content should focus on financial and institutional aspects of such a programme but providing an overview of the technical issues and concluding with the benefits that enhanced operational efficiency will bring to the utility and their customers. A typical seminar would contain the following topics:

- Defining water loss or Non Revenue Water (NRW)
- Water balance, components and calculation
- Performance indicators
- Target Reduction in NRW
- Economics of leakage
- Strategy Development
- Technical aspects of leakage reduction and control
- Benefits of NRW reduction
- Training and sustainability
- EU Directives and international situation

9.2 Training for Engineering and Technical Staff

The objective of the PROWAT training programme is to provide engineers and technicians with the skills that are necessary for the implementation of international best practice on all aspects of water loss reduction and control. The training is aimed at engineers and technicians, staff with little or no experience of water loss, and gives the opportunity to update some basic skills and also provides learning opportunities for professional development through continuous discussions with other practitioner in water the sector. This non-formal learning activity will help to improve the quality of the services provided to the customers.The training pulls together the key best practice essentials and outline technical understanding behind this vital activity.

The structure of the course will be based on a modular concept, meaning that the section and units of the course can be used independently, according to the participants needs and wishes. Furthermore the learning units can be made available on paper version, electronic version on CD-ROM and on e-learning platform depending on the methodology adopted by the training providers.

The proposed teaching and learning methodology within PROWAT is based on the following adult learning principles:

- The learning is self-directed.
- It fills an immediate need and is highly participatory.
- Learning is experiential (i.e., participants and the trainer learn from one another).
- Time is allowed for reflection and corrective feedback.
- A mutually respectful environment is created between trainer/tutor and participants.
- A comfortable environment is provided.

Central in the course is therefore the participant which is an active learner who builds knowledge through social interaction with others (students and trainer) within a context driven by own motivation. The courses can be delivered with a mixture of face to face learning (in the class room or distant learning (online via the internet). This is commonly known as blended learning. The composition of which depends on the training provider.

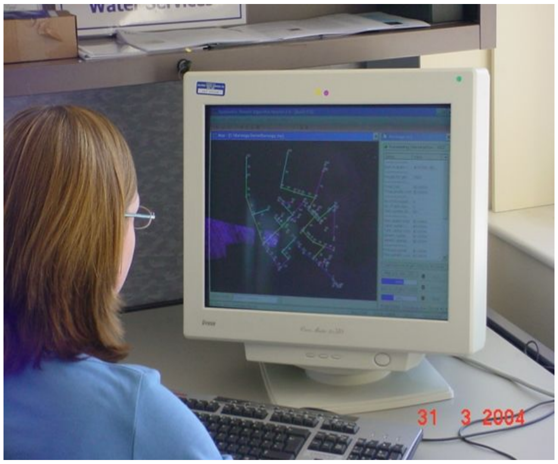

Figure 9.1 Examples of distant learning and classroom learning (Source Halcrow 2006)

Essentially the modules need to be tailor-made to suit the differing roles of the engineers and technicians. For example engineers will benefit from having an understanding of the management aspects of a NRW reduction policy and programme and also detailed modules concentrating on engineering and technical aspects. The technical and operational staff are required to have an awareness of the stages and timescale of the programme but their modules should provide an overview of facts about water and distribution systems coupled with more detail on the practical aspects of pressure management, metering, data loggers etc: This training should be in modular form and considered as a forerunner to training in out in the field. The training modules will also include examples, quizzes and exercise

10 Sustainability

Once a strategy has been successfully implemented and the target level of loss has been achieved it is essential to maintain and to sustain the improvements that have been made during the course of the NRW reduction programme. The utility must ensure that adequate funding is put in place for ongoing operation and maintenance. This funding is absolutely vital for its successful management and sustainability and should apply to all aspects of the supply and distribution system. The operation and maintenance encompasses activities as diverse as equipment selection, maintenance, purchase of spares and repair procedures. It is essential that this is built into the project at an early stage and not added as an afterthought.

The programme should include adequate staffing levels with appropriate training for all staff involved with leakage control. It is also essential to maintain the integrity of DMAs, zones, pressure management systems and the monitoring equipment such as meters and data recording devices.

Maintaining leakage at the reduced level must be considered as ‘fighting a never ending war’. Individual battles may be won in DMAs or zones but the war will go on - in other words leaks will always continue to occur. Experienced practitioners have found that the maintenance stage is more difficult than the actual reduction programme itself. Senior managers sometime consider that once the capital investment has been made, additional expenditure to maintain the position is a burden from which the utility is going to gain very little benefit.

To ensure the ongoing success of a water loss reduction control programme procedures should be developed, preferably at the strategy planning stage to monitor and maintain the achieved level of NRW. This can be done using one of the recommended Performance Indicators to monitor levels of water loss. The monitoring should be considered as having a strategic importance such that, if there is a dramatic increase in leakage caused by weather or changing ground conditions, corrective action can be taken quickly and effectively. In reality this means having a system in place whereby monthly trends can be monitored rather than waiting for the calculation of an annual water balance. This can be achieved through the monitoring of night flows.

At some stage it may be necessary for a utility to examine its current policies because of changes in legislation, regulation and enforcement or it may be that climate change requires the utility to drive water loss down to a lower level. Senior managers and engineers are recommended to have an awareness of new and interesting developments in the field of water loss. Some of these have been established whilst others are innovative techniques currently undergoing trials. The use of new technology can improve the efficiency of operational practices. Some of these techniques are:
The development of new analytical tools for determining the economic intervention level in a DMA i.e. the appropriate time to initiate a leak detection exercise
Improved leak location techniques to find ‘difficult’ leaks
Automatic meter reading of customers meters that can lead to reduction in both physical and commercial losses

The overall aim of a utility and its managers should be to maintain, or even improve its leakage performance, at an ever reducing cost. The use of new technology in addition to tried and tested techniques, may help them achieve this objective.