

 A close-up, black and white photograph of a water tap handle and spout, positioned on the left side of the cover. The tap is partially open, with water droplets visible. The background is a solid teal color.

The Issues and Challenges of Reducing Non-Revenue Water

Asian Development Bank



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Asian Development Bank

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Abbreviations

- DMA – District Metered Area
- ILI – Infrastructure Leakage Index
- IWA – International Water Association
- NRW – non-revenue water
- PBC – performance-based contract
- WLTF – Water Loss Task Force

Foreword

Chronic water losses have been the hallmark of urban Asia's water management over the decades. This may not have mattered much during an era of assumed plenty. But the rapid growth of Asia's towns and cities, coupled with increased volumes of water for irrigated agriculture, energy, and industry, has meant that there is much less water to go around in the urban centers. The loss of an estimated 29 billion cubic meters of treated water every year, valued conservatively at \$9 billion, is no longer something that Asia's urban water managers can ignore.

Reducing these water losses is critical to efficient resource utilization, efficient utility management, enhanced consumer satisfaction, and postponement of capital-intensive additions to capacity. Wherever active water loss reduction programs have been initiated and sustained, the gains to consumers and utilities alike have been significant. In fact, as Frauendorfer and Liemberger point out, the costs of improved service delivery are much lower when undertaken through investments in non-revenue water reduction rather than through investments in capital projects to augment supply capacities.

This report has arrived not a moment too early. At a time of blistering economic growth in Asia and rising competition for scarce freshwater resources, Frauendorfer and Liemberger remind us of the enormity of the urban water challenge in Asia, the critical role of non-revenue water management, its constituent elements, and measures to address it. This is a "must read" for urban water practitioners, policy makers, owners of water companies, investors, and those of us in the development business who can, hopefully, induce changes in Asia's urban water management, armed with the new insights that this paper provides.


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Introduction

Facing ever-increasing urban populations and expanding service areas, many water utilities in Asia and the Pacific continue to struggle with providing clean drinking water to their consumers. Common water supply problems in Asian cities are related to the sources and use of raw water, intermittent supply, and the quality of tap water at the consumer’s end.

One of the major challenges facing water utilities is the high level of water loss in distribution networks. If a large proportion of water that is supplied is lost, meeting consumer demands is much more difficult. Since this water yields no revenue, heavy losses also make it harder to keep water tariffs at a reasonable and affordable level. This situation is common in many Asian cities. “Non-Revenue Water” (NRW)—defined as the difference between the amount of water put into the distribution system and the amount of water billed to consumers—averages 35% in the region’s cities and can reach much higher levels.

NRW is a good indicator for water utility performance; high levels of NRW typically indicate a poorly managed water utility. In addition, published NRW data are often problematic, suspicious, inaccurate, or provide only partial information. Some utilities invent “creative” definitions of NRW, use wrong or misleading performance indicators, and fail to quote important information, such as average pressure and supply time.

Conversely, successful utilities actively address NRW by controlling physical losses, ensuring customer meter accuracy and making all efforts to keep the number of illegal connections within limits. Taking these measures can boost revenue by increasing the amount of water that can be billed while reducing wastage of the product. This increases profitability and improves the return on investment. With larger profits, the utility can then reinvest retained earnings and improve its productivity.

While the benefits of reducing NRW are well known, decades of effort have not delivered much improvement in the developing world. While there are many explanations and excuses, much of the failure is due to underestimating the technical difficulties and complexity of NRW management, along with the potential benefits of taking action.

As long as utility owners are not sufficiently aware they are “sitting on a goldmine,” they will continually fail to incentivize or oblige their chief executive officers to take action (for example, by paying or withholding subsidies). On the other hand, if utility leaders are not sufficiently informed about the level, causes and cost of NRW, along with the potential for improvement, they will not be able to convince their owners to provide funding for NRW management activities and investments. Further, lack of support for comprehensive NRW management by utility owners and chief executive officers makes it difficult to motivate utility staff and provide them

One of the major challenges facing water utilities is the large proportion of water loss in distribution networks

Expanding water networks without addressing water losses will only lead to a cycle of waste and inefficiency

with the means (funding, training, and technology) to successfully and sustainably reduce NRW.

As a consequence, billions of cubic meters of treated water will continue to be lost, and water utilities will continue to lose a substantial amount of revenues. To meet growing demand, new resources will be developed, more water will be pumped into the leaking networks, and the vicious cycle will continue.



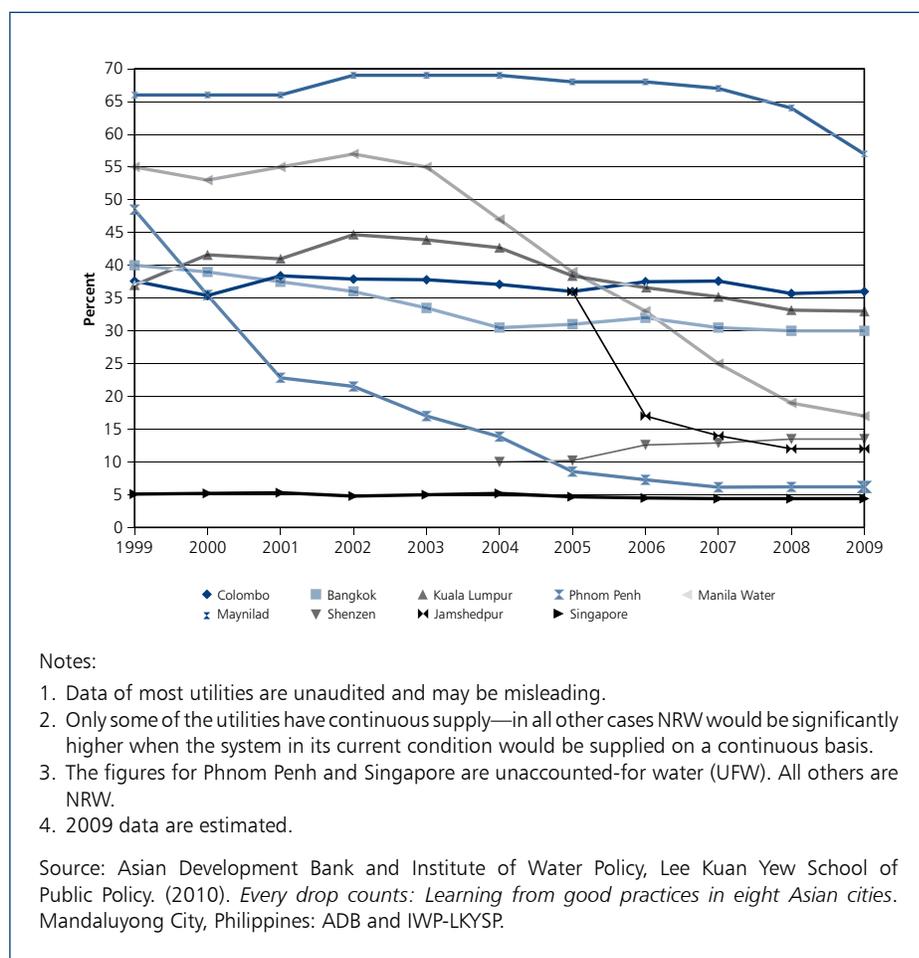
Maynilad Water Services, Inc.

Physical losses are the main problem

The need for NRW management in general, and in Asia in particular, is so obvious that it is hard to understand why efforts to improve the situation have been so limited. There are, however, a few successful examples of utilities reducing NRW to below 20% (e.g., Singapore, Phnom Penh, Manila [East Zone]) and some places where serious actions have at least started. However, the vast majority of water utilities in Asia are not engaging in serious and professional NRW management.

For many cities, reducing NRW should be the first option to pursue when addressing low service coverage levels and increased demand for piped water supply. Expanding water networks without addressing water losses will only lead to a cycle of waste and inefficiency. Also, a high rate of NRW is closely related to poor energy efficiency, since water transported in networks is "loaded" with energy poor through the distribution and treatment processes. Thus, energy is lost along with the water. Therefore, reducing NRW is important to overall efficiency and financial sustainability, since it provides additional revenues and reduces costs.

Figure 1 Non-Revenue Water Levels of Asian Cities



In its urban water supply projects, ADB pursues NRW reduction as a key strategy along with increasing production capacity and expanding networks. It acknowledges that reducing NRW cannot be solved through a single project. Long-term engagement and dialogue with governments and water companies are required, as institutional changes take time and pipe replacements alone will not suffice. Rather, NRW reduction requires further effort to maintain low levels once initial progress is made. While ADB promotes utilities to consider private sector involvement (e.g., through performance-based contracts), this needs to be assessed on a case-by-case basis. Along the way, it is important that utilities develop in-house capacity to deal with this core issue.

The main objective of this discussion paper is to provide the basis for a substantive dialogue on NRW between key decision makers at the municipal level, including local government officials, management of water utilities, civil society, and other stakeholders. It aims to raise awareness on key issues surrounding NRW, including the magnitude of the NRW problem in Asian cities, reasons why NRW management is often not practiced, international terminologies and methodologies for improving NRW management, and the importance of using appropriate performance indicators.

Non-Revenue Water: Definition, Terminology, and Approach

A precondition for calculating internationally comparable performance indicators is a standardized terminology and water accounting methodology

Until the early 1990s, there were no reliable and standardized methods for accounting for water losses. Leakage management performance was measured in terms of “unaccounted-for water.” Since this term had no generally accepted definition, there was wide room for interpretation. Unaccounted-for water was typically expressed as a percentage of system input, which is already problematic. Given this situation, utility performance could not be measured or compared, realistic targets could not be defined, and performance against targets could not be tracked reliably.

While this situation still exists in many countries, significant progress has been made to address these past shortcomings. Over the last 20 years, a number of organizations from around the world have developed a suite of tools and methodologies to help utilities evaluate and manage water losses in an effective manner.



Roland Liemberger

Box 1 Tales of Mystery and Imagination The misleading world of publicly available NRW data

The amount of publicly available NRW data is limited—but even worse, data are sometimes wrong and misleading. There are number of reasons for this:

In countries where the legal situation requires water utilities to keep their level of NRW below a certain level, there is a strong tendency to report lower than actual numbers to meet legal or regulatory requirements. For example, this was common in the former Soviet Union, where utilities were required to keep NRW below 18%. All utilities reported such low levels, even when their actual levels often exceeded 50%.

Many water utilities in Asia are not used to producing a water balance; therefore, the split between physical and commercial losses is rarely known. The other problem is that information on average supply time, average pressure, and the number of service connections is often not known and rarely published. This makes calculating meaningful NRW performance indicators nearly impossible.

In general, most of the published water utility data, especially from low- and middle-income countries are unaudited, resulting in sometimes significantly incorrect data being included in databases and publications, which can be very misleading.

Source: Authors.

Perhaps most significantly, the International Water Association (IWA) has developed and refined a comprehensive range of performance indicators for water supply utilities.¹ As a part of an initiative started in the late 1990s, IWA established a Water Loss Task Force (WLTf) to examine international best practices and to develop performance indicators related to water loss. A precondition for calculating internationally comparable performance indicators is a standardized terminology; consequently, the task force developed an International Water Balance with clear definitions.

Following this initial IWA initiative, members of the WLTf were, in the last 10 years, developing the concepts further, publishing countless papers, articles, and books, and contributing to conferences around the world. The fruits of this work are the most advanced water loss management concepts, tools, and strategies available today.

One recommendation of the WLTf was to use the term “non-revenue water” instead of “unaccounted-for water.” NRW has a precise and simple definition. It is the difference between the volume of water put into a water distribution system and the volume that is billed to customers. NRW comprises three components as follows:

Physical (or real) losses comprise leakage from all parts of the system and overflows at the utility’s reservoirs. They are caused by poor operations

One recommendation of the WLTf was to use the term “non-revenue water” instead of “unaccounted-for water”

¹ This work was initially triggered by an initiative in the then newly privatized UK water industry, which led to the publication of the “Managing Leakage” series of reports.

and maintenance, the lack of active leakage control, and poor quality of underground assets.

Commercial (or apparent) losses are caused by customer meter under-registration, data handling errors, and theft of water in various forms.

Unbilled authorized consumption includes water used by the utility for operational purposes, water used for firefighting, and water provided for free to certain consumer groups.²

Although it is widely acknowledged that NRW levels in developing countries are often high, actual figures are elusive. Most water utilities do not have adequate monitoring systems for assessing water losses, and many countries lack national reporting systems that collect and consolidate information on water utility performance. The result is that data on NRW is usually not readily available. Even when data is available, it is not always reliable, as some poorly performing utilities are known to practice “window dressing” in an attempt to conceal the extent of their own inefficiency.

² Contrary to physical and commercial losses, unbilled authorized consumption does not reflect operational inefficiencies but a public policy decision to allocate water without monetary compensation.

Non-Revenue Water Estimates for Asia

The estimated annual volume of NRW in urban water utilities in Asia is in the order of 29 billion cubic meters (m^3). Assuming a value of water of \$0.30 per m^3 , Asia's water utilities are losing nearly \$9 billion per year. By cutting physical losses to half the present level (which is technically feasible), 150 million people could be supplied with already-treated water.

Reducing total NRW (not only physical losses) to half the present level and assuming an average reduction cost of \$500 per m^3 per day (m^3/d) NRW reduction, the total investment needed would be around \$20 billion. Spread over a 10-year period, \$2 billion would have to be invested annually in water loss reduction projects. When this reduction is achieved, the revenues of Asia's urban water utilities will increase by an estimated \$4.3 billion annually.

150 million people could be supplied by cutting Asia's water losses to half the present level



Roland Liemberger

Poor infrastructure condition is a major problem

Table 1 NRW Estimates and Values in Asia

Region ^a	Urban Population with Service Connections (in millions)	System Input Volume l/c/d	m ³ /d	Non-Revenue Water %	(m ³ /d)	Physical Losses ^b	Commercial Losses	NRW	Value ^c
						(billion m ³ /year)			billion \$/year
Central and West Asia	29	450	13,050,000	40	5,220,000	1.4	0.5	1.9	0.6
East Asia ^d	605	230	139,150,000	25	34,787,500	9.5	3.2	12.7	3.8
Middle East ^e	167	250	41,750,000	30	12,525,000	3.4	1.1	4.5	1.4
South Asia ^f	202	180	36,360,000	35	12,726,000	3.5	1.2	4.7	1.4
Southeast Asia	133	280	37,240,000	35	13,034,000	3.6	1.3	4.9	1.5
Total Asia	1,136		267,550,000		78,292,500	21.4	7.3	28.7	8.6

^a Regions are slightly different from ADB's regions.

^b A 75%/25% split was assumed.

^c Water was valued with \$0.3/m³.

^d Including Japan.

^e Excluding Egypt.

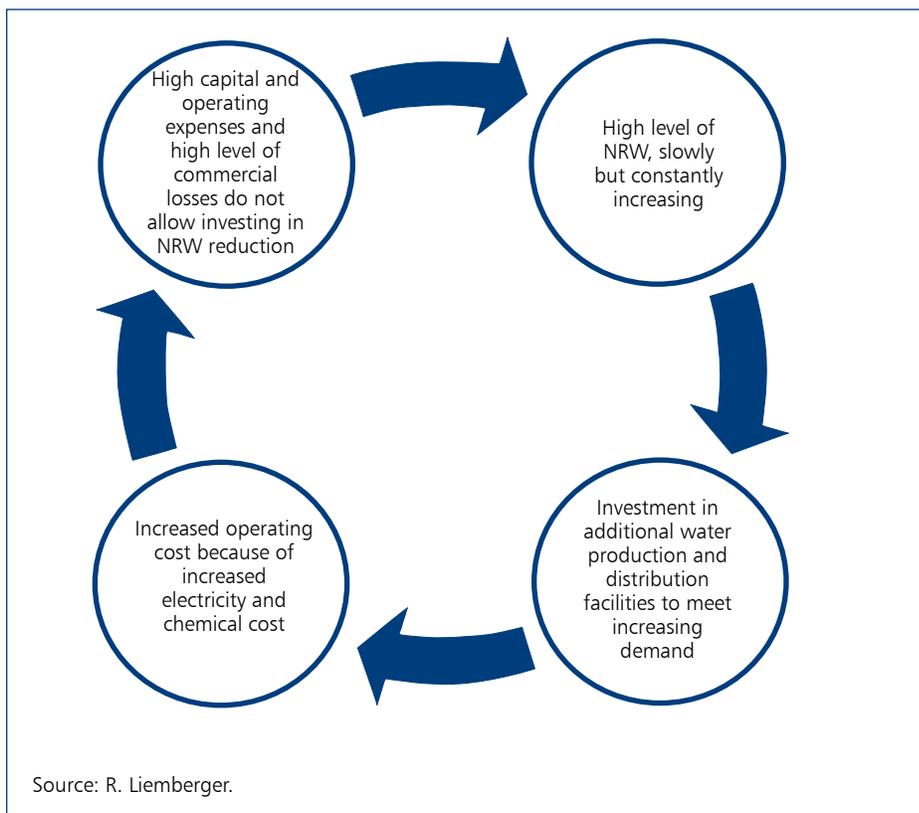
^f Including Pakistan.

Source: Urban Population: WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation 2006 data. NRW estimates: Roland Liemberger.

Non-Revenue Water Impact on Water Utility Efficiency

No business can survive for long if it loses a significant portion of its marketable product, but that is exactly what is happening with many water utilities. High levels of NRW lead to low levels of efficiency. When a utility's product (treated water) is lost, water collection, treatment and distribution costs increase, water sales decrease, and substantial capital expenditure programs are often promoted to meet the ever-increasing demand. In short, the utility enters into a vicious cycle that does not address the core problem.

Figure 2 The Vicious NRW Cycle

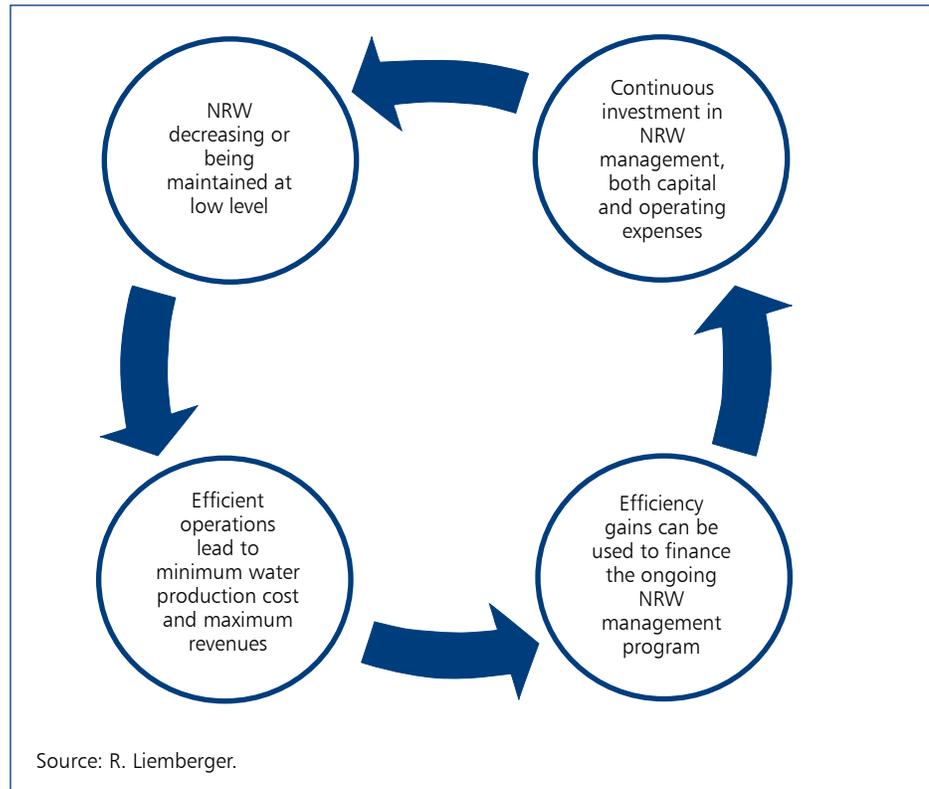


No business can survive for long if it loses a significant portion of its marketable product, but that is exactly what is happening with many water utilities

The challenge for these utilities is to turn this vicious cycle into a virtuous cycle, which will lead to low levels of NRW and therefore substantially improved efficiency (Figure 3). To make such a transformation, political will and the full support of top management is vital. In most cases, technical know-how at the utility level

must also be improved. Some utilities may require assistance from outside experts, either through standard technical assistance or more innovative methods, e.g., performance contracts.

Figure 3 The Virtuous NRW Cycle



Reducing physical losses will not only help postpone capital investments for developing new water sources, it will also help reduce a utility's electricity bill

Sufficient up-front funding and budgetary provision, both capital and recurrent expenditure, is also important. NRW reduction costs vary widely, but a rule of thumb is to assume that reducing NRW by one cubic meter per day will cost roughly \$500.³ For instance, if the present volume of NRW is 200,000 m³/d and the goal is to reduce that by 50%, some \$50 million will be required to achieve this target.

In addition to the general reluctance to invest in NRW reduction, there is also a lack of financial incentives. Average tariffs are usually too low and do not encourage water utilities to expand coverage and to reduce commercial losses. Also, raw water is in many cases free of charge and environmental costs are not taken into account. If water utilities were forced to pay abstraction charges, the reduction of physical losses would be high on the agenda.

Reducing physical losses will not only help postpone capital investments for developing new water sources, it will also help reduce a utility's electricity bill. Water delivered to customers' taps has a large amount of embedded energy.

³ Kingdom, W., R. Liemberger, and P. Marin. 2006. *The Challenge of Reducing Non-Revenue Water (NRW) in Developing Countries – How the Private Sector Can Help: A Look at Performance-Based Service Contracting*. WSS Sector Board Discussion Paper #8. World Bank.

Before it reaches its final destination, the water may have been pumped from the source to a treatment plant, where further energy is used in the treatment process. It will then be pumped to a treated water reservoir and may require further pumping in the distribution system. Since water is heavy, all of these processes require significant amounts of energy.

For reasons stated above, the level of NRW is one of the best indicators of water utility efficiency. A utility with a high level of NRW either has a management who is not aware of the benefits of NRW reduction or is simply not capable of introducing and managing these complex and interrelated activities. A utility with a low level of NRW obviously must be well managed, as NRW management is one of the most complex and difficult tasks of a water operator.

Non-Revenue Water Impact on Customers

High levels of leakage cause intermittent supply and therefore pose a significant public health risk

The main objective of a water utility is to satisfy customer demand. A high level of NRW has a severe and direct impact on the ability of utilities to meet this objective and therefore has a negative impact on customers. High physical losses often lead to intermittent supply, either because of limited raw water availability or because of water rationing, which may be needed to reduce supply hours (and therefore hours of water leakage) per day.

In addition to substandard service, intermittent supply poses a significant health risk, as contaminated groundwater, or even sewerage, can enter the leaking pipes during supply interruptions and very low pressure periods. The avoidance of this significant public health risk should be reason enough to reduce leakage to enable continuous supply. High leakages also increase flow rates in the pipe network, which can cause unnecessarily high pressure losses that affect customers and often lead to supply interruptions during peak demand hours.



Roland Liemberger

Poor coverage because of high water losses

Yet another problem is that intermittent supply will leave customers unsatisfied, resulting in low willingness to pay for improved service. This will discourage local governments to approve tariff increases that could help improve the situation, and the vicious NRW management cycle will be reinforced.

In the long run, high levels of NRW may lead to unnecessarily high tariffs (if tariffs are properly set). In these cases, high water tariffs can, in effect, represent a subsidy borne by paying customers to cover NRW. If tariffs are not high enough, the water utility will remain financially weak and will not be able to provide appropriate service to its customers.

In water systems characterized by unsatisfied demand and limited coverage, a high level of NRW is often the main reason why the system cannot be improved. In many cases, the population is then forced to use alternative water sources, which are often of poor quality and high in cost. There are two reasons for this situation. First, where raw water is limited, the volume of water that is physically lost is often required to supply unserved areas. Second, poor financial performance that results from high NRW makes it difficult to finance distribution network expansion.

Non-Revenue Water and the Urban Poor

Reducing physical losses will also make more water available and enable water utilities to increase coverage, including to poor communities

The urban poor are often blamed for high levels of NRW, especially due to illegal connections. On the other hand, the poor are significantly affected by high water losses. While theft of water in low-income communities is certainly a reality in many Asian cities, its impact must be put in the proper perspective.

The volume of water that is illegally consumed by a poor household is normally quite small, because of the lack of washing machines, flush toilets, garden irrigation, etc. Furthermore, this low level of consumption would nearly always be in the lowest tariff category (if such category exists). Therefore, the financial impact is even less than the volumetric impact. Experience in many countries shows that water theft by higher income households, and commercial and industrial users can be much more of a problem.

Case studies from various Asian cities also indicate that there is very often a high willingness to pay for piped water supply among the poor, as this is nearly always cheaper than water purchased from water vendors. Unfortunately, in many cities, it is illegal to supply water to informal settlements, which automatically leads to the construction of illegal connections. These are nearly always built of inferior quality and at the tapping points the main pipes are damaged, so the physical losses in such areas often exceed the commercial losses caused by the theft of water.



Women carrying metal water container

ADB Photo Library

In the case of intermittent supply, which is frequently caused by excessive leakage, the urban poor often suffer most, as they cannot afford proper storage facilities and pumps and often have to buy water from vendors during non-supply hours. Reducing physical losses will also make more water available and enable water utilities to increase coverage, including to poor communities.

The Importance of Establishing a Water Balance

Twenty years ago, NRW management was based more on guesswork than on precise science. This has changed dramatically in many industrialized countries, kick-started by the regulatory pressure on UK water companies to cut leakage. Yet, despite some encouraging success stories, most water supply systems worldwide continue to have high levels of water losses.

Part of the problem is the lack of a standard approach to defining and quantifying the components of NRW. Surprisingly, few water utilities in developing countries establish a water balance. Even if they do, no standard approach or terminology is used, so they all differ from each other. To address this situation, a number of national associations have adopted the International Water Association's (IWA) standard international water balance structure and terminology.

The first step in reducing NRW is to establish current levels of water losses through a water audit

Figure 4 The International Water Balance

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	Commercial Losses	Unauthorized Consumption	
			Metering Inaccuracies and Data Handling Errors	
		Physical Losses	Leakage on Transmission and/or Distribution Mains	
			Leakage and Overflows at Utility's Storage Tanks	
Leakage on Service Connections up to Point of Customer Metering				

Source: International Water Association.

The first step for any utility aiming to reduce water losses is to prepare a baseline to establish current levels of water losses. This is done by carrying out a water audit that leads to a water balance, which is a prerequisite for designing a NRW reduction strategy. This first step is critical, yet it is often overlooked in the development of many urban water supply projects. A standard template⁴

⁴ Similar water balance templates have become (or are becoming) national reporting standards in a growing number of countries (for example, Australia, Canada, Germany, New Zealand, and South Africa) and in the United States in selected states (for example, Texas and California), and they are promoted by the American Water Works Association (AWWA) Water Loss Control Committee.

Box 2 Water Balance in Ancient Rome

Almost 2,000 years ago, 95 AD, Sextus Julius Frontinus was appointed Curator Aquarum (Water Commissioner) of Rome. One of his concerns was the water lost from the aqueducts. Throughout his professional career, he tried (and failed) to achieve a meaningful balance between the quantity of water entering and leaving the aqueducts which served the city. His failure was not due to lack of diligence, he was simply using a wrong methodology. The accepted Roman method was to compare areas of flow, but because flow velocity was not taken into account, the calculations never worked out.

Source: R. Liemberger.

and terminology for categorizing and quantifying NRW, based on IWA's initial version, is shown in Figure 4.

The components of the water balance can be measured, estimated, or calculated using a number of techniques. Ideally, all of these important components will be measured, but this is often not the case. Sometimes even key data, such as the total system input, are not really known, so determining water balances is usually inexact to start. However, it is always worth trying to establish a water balance, even if main elements are based on estimates. By doing this, it will be possible to produce a catalogue of required actions that are needed to improve the accuracy of the water balance.

After all the groundbreaking work done by the IWA, there is no reason for a utility to develop different water balance forms and definitions. Thus, national associations should consider making the International Water Balance a national reporting requirement and make an audited water balance a precondition for any water supply improvement or expansion project. In addition, water utilities should publish the water balance in their annual reports and on their webpage.



Temporary flow measurement to collect initial data

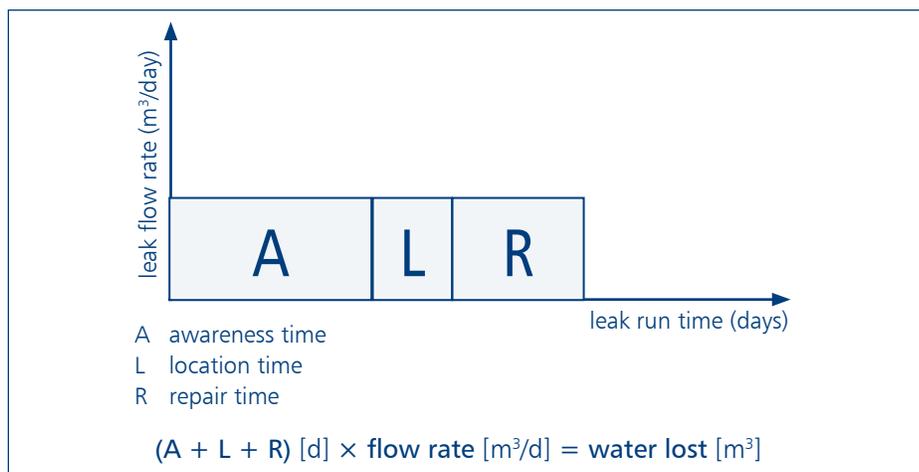
What You Should Know about Physical Losses

Physical losses can occur along the entire distribution system, from storage reservoirs and the primary network to the smallest service connections. When people think about leakage, they normally think of big and spectacular pipe bursts. These often cause a lot of damage but are insignificant in volume compared to all the other leaks that do not come to the surface.

Normally around 90% of water that is physically lost from leaks cannot be seen on the surface. These leaks might eventually become visible after many years, but until then, large volumes of water are lost every year. Sometimes, undetected leaks can be quite large, such as those that run directly into a sewer or a drain. Therefore, a water utility that does not practice a policy of efficient and intensive active leakage control will always have a high level of leakage, except if the infrastructure is new and/or in excellent condition.

The water volume lost from a pipe burst depends on both the flow rate and the leak run time

Figure 5 The Impact of Leak Run Time



The volume of water lost from an individual pipe burst does not only depend on the flow rate of the event, but is also a function of run time. This is often overlooked. The leak run time consists of three components:

- Awareness time: time until the utility becomes aware that there is a leak
- Location time: time spent to precisely locate the leak so that a repair job order can be issued
- Repair time: time between issuing of repair job order and completion of the repair

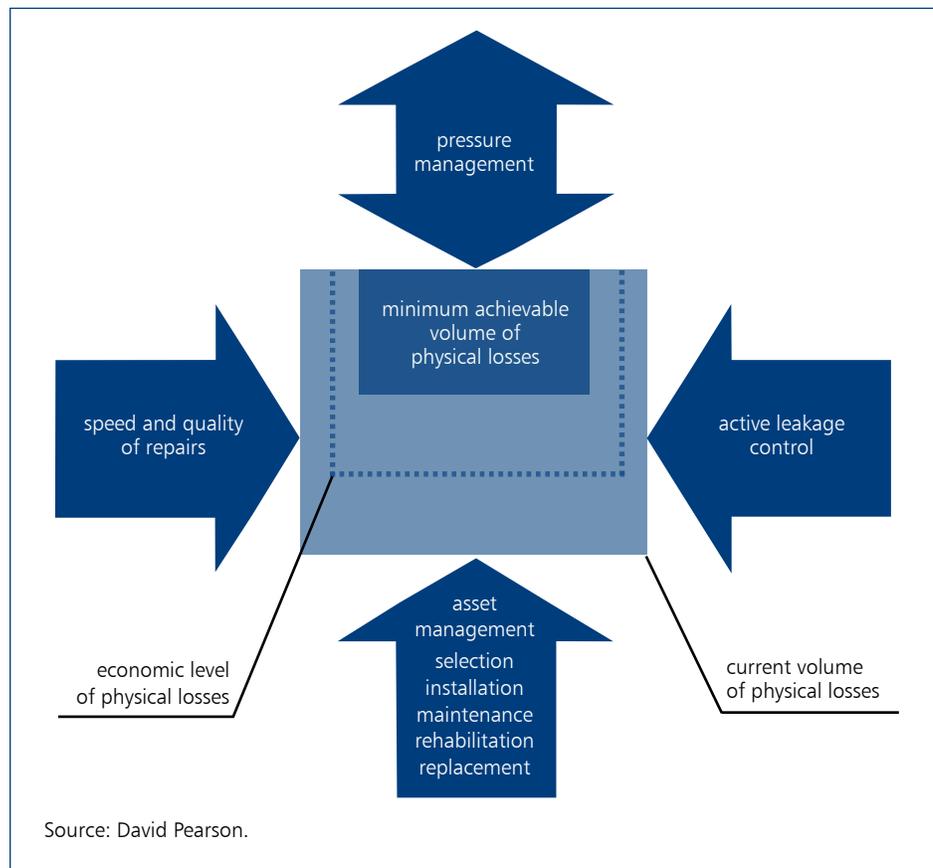
For example, a spectacular burst on a water main, running at 10 m³/h (240 m³/d) would often be repaired on the same day. The total water lost would be 240 m³. In comparison, a small leak on a service connection of only 10 m³/day may run all year if there is no active leakage control. In this case, the volume of water lost would be 3,650 m³.

All four elements of the “Four Arrows Chart” must be implemented to reduce physical losses

The “Four Arrows Chart,” which can be found in every book on NRW management, visualizes the entire physical loss management issue. The big box represents the current annual volume of physical losses and the small dark box represents the minimum achievable annual volume. In order to reduce the current level of physical losses, all four elements must be implemented as follows:

- Active leakage control must be introduced in order to detect all present and future leaks.
- Known leaks must be repaired as soon as possible to keep leak run times low, and good quality of the repairs will make the efforts sustainable (in poorly run water utilities, even visible leaks are often not repaired).
- In the long run, pipes must be rehabilitated or replaced using good quality materials and installation (asset management).
- Pressure management must be exercised, as explained below.

Figure 6 The “Four Arrows Chart”



While the first three elements are self-explanatory, the fourth (the only one represented by a bidirectional arrow) must be explained further. Leakage is directly related to pressure. The higher the pressure, the higher the volume of water lost from any given leak. Pressure leakage relationships are a complex issue, but a utility can assume a roughly linear relationship between the two. This means that when the pressure increases by 10%, the volume of leakage also increases by 10%. However, if pressure can be reduced, this will lead immediately to a leakage reduction—without repairing a single leak. Therefore, the arrow is bidirectional.

Pressure management is also the only element that can shrink (or expand) the small box, which represents the minimum achievable volume of physical losses. In the past, pressure reduction was only considered in systems with excessively high pressures. Presently, pressure management is considered essential to sustain leakage reduction efforts, especially in deteriorated distribution networks with relatively low pressures. For example, in a system with an average pressure of only 15 m (not uncommon in Asia), a 3 m pressure increase (which will hardly be noticed) will increase the volume of leakage by 20%. In addition to having an immediate positive impact on the volume of water lost, pressure management will also dramatically reduce burst frequency and therefore extend the lifetime of assets and reduce repair and maintenance costs.

Pressure management in its simplest form requires zoning by elevation, but the trend is towards more sophisticated pressure management, where marginal pressure reductions and the avoidance of pressure fluctuations are the main objectives. This trend is relatively new and hence there is a substantial lack of

Pressure management is the only element that can shrink or expand the minimum achievable volume of physical losses



Maynard Water Services, Inc.

Pressure management requires a lot of expertise

understanding in water utilities around the world. Therefore, specialized outside advice will often be required when a water utility starts to engage in pressure management. While there is an initial technological barrier to overcome, advanced pressure management will play an important role in solving Asia's massive leakage problems.

What You Should Know about Leakage Reduction

Many water utilities in Asia practice passive leakage control, meaning that they repair only those leaks that are visible. This is clearly not enough since 90% of the leaks are usually not visible on the surface. This means it takes far too long, often many years, until the utility is even aware that there is a leak. Since awareness time largely determines the volume of water lost from a pipe burst, utilities need a strategy to reduce awareness time.

The most traditional and basic method is to have a team of leak detection specialists who check all pipes on a regular basis. Since leak noise can be detected, this work is done with a wide range of listening devices, ranging from simple mechanical listening sticks to electronic ground microphones or even leak noise correlators.⁵ Leakage inspectors use this equipment to listen to the network and identify problems, much like doctors use stethoscopes. If every part of the network

By computing the volume of leakage in each hydraulically discrete zone, leak detection specialists can better target their efforts



Trunk main inspection in Manila

Maynilad Water Services, Inc.

⁵ Computerized devices which can determine the exact leakage point between two microphones which are placed on the pipe or any accessible point (e.g., valve spindles).

Water losses from larger diameter pipes can be quite significant, especially in the Asian context with predominantly low-pressure systems

Box 3 Leakage Reduction Used to Supply More Households

Technically, it is no problem to reduce leakage from urban water supply systems in Asia by 50% from the current levels of physical losses. This would mean that annually some 10 billion cubic meters of water could be saved and used to supply the yet unserved part of the population.

Assuming a per capita consumption of 150 liters and an average household size of five persons, 36 million additional households in Asia could be supplied.

Source: Authors.

is surveyed once a year, the average leak run time (awareness time) is 6 months.⁶ To reduce awareness time, the survey frequency can be increased. However, leak detection efforts will still not be well targeted.

To be able to determine how much water is lost in specific parts of the network, the network must be split in hydraulically discrete zones and the inflow to these zones must then be measured. By computing the volume of leakage in each zone, leak detection specialists can better target their efforts. Clearly, the smaller the zone, the better the information and the efficiency of leak detection.

The smallest zones are called District Metered Areas (DMAs). A DMA is hydraulically discrete and ideally has only a single inflow point. The inflow and corresponding pressure is measured and monitored on a continuous basis. Ideally, when the entire distribution network is split into DMAs, the utility has several advantages. For instance:

- The volume of NRW (the difference between DMA inflow and billed volume) can be calculated on a monthly basis.
- The components of NRW (physical and commercial losses) can be quantified by analyzing flow and pressure data.
- Leak detection works can be prioritized.
- New pipe bursts can be identified immediately by monitoring the minimum night flow, and therefore awareness time will be reduced from several months to several days (or even less).
- When leakage is eliminated, utilities can better gauge the existence of illegal connections or other forms of water theft and can take action.

Furthermore, DMAs can be helpful in managing pressure. At the inflow to the DMAs, pressure reducing valves can be installed, and the pressure in every DMA can be adjusted to the required level.

⁶ As some of the leaks may occur the moment before they are detected and others just after the leakage inspector passed the location, the average run time is 6 months when the system is completely surveyed every 12 months. As a consequence, checking the system twice a year will reduce the average leak run time to 3 months.

There is no ideal size for a DMA. The size, whether it is 500 or 5,000 service connections, is always a tradeoff. The decision has to be made on a case-by-case basis and depends on a number of factors (e.g., hydraulic, topographic, practical and economic).

The size of DMAs has an impact on the cost of creating them. The smaller the DMA, the higher the cost. This is because more valves and flow meters will be required and maintenance is costlier. However, the benefits of smaller DMAs are that:

- new leaks can be identified earlier, which will reduce awareness time;
- location time can be reduced because it will be faster and easier to pinpoint the leak; and
- as a by-product, it is easier to identify illegal connections.

Topography and network layout also play an important role in DMA design and size. Therefore, there will always be DMAs of different sizes in a distribution network. An important influencing factor is the condition of the infrastructure. If mains and service connections are fragile, then bursts will be more frequent and the optimal DMA will be relatively small. On the other hand, in areas with brand new infrastructure, DMAs can be larger and still manageable.

According to the recommendations of the International Water Association's (IWA) Water Loss Task Force,⁷ if a DMA is larger than 5,000 connections, it becomes difficult to discriminate small bursts (e.g., service connection bursts) from variations in customer night use. In networks with very poor infrastructure conditions, DMAs as small as 500 service connections might be warranted. A calibrated hydraulic model should always be used for DMA design irrespective of the size of the DMAs.

Water losses from larger diameter pipes can be quite significant, especially in the Asian context with predominantly low-pressure systems, where leaks will not come to the surface and remain unnoticed for many years. Leaks on large diameter pipes are always difficult to detect and often specialized equipment is required (e.g., inside pipe inspection and leak detection). These techniques are costly but might be economically well justified where water availability is limited and every cubic meter of water recovered can be sold to existing or new customers.

A calibrated hydraulic model should always be used for DMA design irrespective of the size of the DMAs

⁷ In its DMA guidance notes: www.iwaom.org/datosbda/Descargas/45.pdf

What You Should Know about Commercial Losses

Commercial losses are nearly always less in volume than physical losses, but this does not mean that commercial loss reduction is any less important

Commercial losses are nearly always less in volume than physical losses, but this does not mean that commercial loss reduction is any less important. Commercial loss reduction has the shortest possible payback time, as any action immediately results in an increase in billed volume and an increase in revenues.

Commercial losses consist of three main elements:

- customer meter under-registration;
- illegal connections and all other forms of water theft; and
- problems and errors in metering, data handling, and billing.

Metering: Minimizing customer meter under-registration⁸ requires substantial technical expertise, managerial skills, and upfront funding. Customer meter management should be undertaken holistically, best described by the term “integrated meter management.”



Roland Lemberger

Deteriorated customer meters

⁸ Depending on the type of customer meter and the water quality, meters can often under-register due to wear and tear. After a number of years, customer meters have to be replaced. The ideal time should be determined by an economic analysis.

Box 4 Integrated Meter Management

In the past, the responsibilities for metering-related activities were scattered throughout the organization of Maynilad Water Services Inc. As a result, metering efforts and resources (e.g., data loggers, service vehicles, and meters) were often uncoordinated and insufficient.

With the establishment of the integrated meter management (IMM) department and its integration in the Central NRW Division, Maynilad now has a one-stop-shop for all metering issues. The IMM department is a young team of highly specialized engineers responsible for all metering related issues—from the smallest customer meters to the largest raw water bulk meters.

Source: Authors.

In this effort, utilities should seek to select appropriate meter types and prepare tailored specifications. This can prove difficult, especially where procurement laws and regulations encourage purchasing the cheapest products on the market. A number of meter manufacturers produce meters that “on paper” meet the specifications but deteriorate at an amazing rate in the field. This is one of the major obstacles for sustained improvement of customer meter accuracy.

Contributing to this problem is the lack of good quality meter testing facilities, especially when it comes to larger diameter meters, and the lack of experience in how to best utilize such facilities. This makes it easy for manufacturers to supply meters from second class quality manufacturing batches with little risk that the utility would ever find out.

Another common problem is the reluctance to invest in high quality but more costly meters for large customers. Normally, the top accounts of a utility generate such a large portion of their revenues that any investment in more advanced meters can be economically justified. The payback time is often just a matter of months. Yet, many water utilities opt to maintain and calibrate old meters over and over again instead of taking appropriate action and installing new meters.

Billing system issues: The billing system is the only source of metered consumption data that can help determine the volume of NRW through an annual water audit. However, most billing systems are not designed to retain the integrity of consumption data. Rather, they are designed to deliver accurate bills to customers and correctly account for the bills. However, there are many day-to-day processes in operating a billing system that have the potential to corrupt the integrity of the consumption data, depending on the design of the particular system.

Issues that can affect consumption volumes include

- meter reading practices
- handling of reversals of over-estimation
- processes used for dealing with complaints about high bills
- customer leaks

A number of meter manufacturers produce meters that “on paper” meet the specifications but deteriorate at an amazing rate in the field. This is one of the major obstacles for sustained improvement of customer meter accuracy



Roland Liemberger

Illegal connections

- estimation of consumption
- meter change-outs
- tracking inactive accounts, and
- the processes for the identification and rectification of stuck meters.

Reducing water theft requires making difficult and unpleasant managerial decisions that may be politically unpopular

Water theft: While meter under-registration is more of a technical problem, water theft is a political and social issue. Reducing this part of commercial losses is neither technically difficult nor costly, but it requires making difficult and unpleasant managerial decisions that may be politically unpopular. The reason is that illegal connections are nearly always wrongly associated with only the urban poor and informal settlements. However, water theft by high-income households and commercial users, sometimes even large corporations, often accounts for sizable volumes of water lost and even higher losses of revenue.

In addition to illegal connections, other forms of water theft include meter tampering and meter bypasses, meter reader corruption, and illegal hydrant use. Another common problem is “inactive accounts.” In cases where a customer’s contract has been terminated, the physical service connection, or at least the tapping point on the main, still exists and is easy to re-connect illegally. A stringent inactive account management and verification program can easily solve this problem.

The Need for Appropriate Performance Indicators

To allow for inter-utility comparison and to measure changes in NRW performance over time, it is important to have standardized performance indicators, calculated according to a clearly defined methodology and using standard definitions.

Unfortunately, the most widely used performance indicator for water loss is still the percentage of NRW.⁹ This is calculated by dividing the total volume of NRW by the total system input. Although this figure is important for a utility to measure, many practitioners tend to overlook its shortcomings in properly assessing water losses.

Published NRW data are in many cases problematic, suspicious, inaccurate, or provide only partial information. First, as shown in Box 5, the percentage of NRW is completely unsuitable to compare water utilities with different consumption

Although the percentage of NRW is important for a utility to measure, many practitioners tend to overlook its shortcomings in properly assessing water losses



Stuart Hamilton

Service connections are a major source of leakage

⁹ For years international and national associations have discouraged the use of percentage of NRW (% NRW) as a performance indicator—with limited success, as most utilities still used percentages when talking about water losses. However, there are exceptions such as the Water Services Association of Australia (WSAA) which publishes three real loss performance indicators (ILI, I/conn./day, and I/km/day) but not % NRW or % real losses.

Box 5 Important Determinants of NRW—Consumption, Pressure, and Supply Time

NRW and consumption

Systems with high consumption can easily indicate lower levels of NRW. A city with considerable commercial or industrial consumption may have an average daily customer consumption of 1.5 m³. When average quality leakage management is practiced, NRW would be around 20%. Similar leakage management efforts in a small town with low per customer consumption (0.7 m³/d) would result in an NRW level of 40%.

NRW and pressure

Leakage is directly proportional to pressure. Thus, without knowing the corresponding average pressure, a utility will not be able to understand the level of NRW and the room for potential improvement. A utility that has an NRW level of 20% at an average pressure of 20 m is performing substantially better than a utility that also has an NRW level of 20% but an average pressure of only 10 m.

NRW and supply time

The volume of water lost from existing leaks at a given pressure depends on the leak run time. A system that is operated intermittently will automatically have lower leakage levels. A 20% leakage in a system with 6 hours supply per day means that the leakage level of the system, assuming 24/7 service, would be 80%. Thus, in systems with significant intermittent supply, NRW quoted in percent is very misleading.

Source: Authors.

levels, pressures and supply times (parameters that can vary widely across in the developing world). Network characteristic (length of mains, number of service connections) also significantly influence NRW levels. Also, this indicator does not indicate the ratio between physical and commercial losses.

In addition, “creative definitions” for NRW are often used to reduce the reported numbers (e.g., “minimum leakage” or unbilled consumption is deducted to wrongly reduce the volume of NRW). Wrong numbers are sometimes also reported to meet regulatory requirements.

To address these shortcomings, and to properly understand and compare the NRW situation of water utilities, four water loss performance indicators are recommended, as shown in Table 2.

Establishing these performance indicators requires the availability of a water balance, along with four other parameters: length of mains; number of service connections; average supply time; and average pressure. Measuring these parameters should become common practice and be required by regulators, national associations, and funding institutions.

Unfortunately, many utilities in low- and middle-income countries do not keep records on the number of connections. In these cases, the number of connections

Table 2 Recommended Performance Indicators for NRW

Performance Indicator	Measure	Notes
NRW	Liters/Service Connection/Day (w.s.p.) ¹	<ul style="list-style-type: none"> – A service connection is the small diameter pipe between the main pipe and location of water consumption (e.g., a building). – The number of physical service connections is nearly always less than the number of customers, because one location can have multiple customers.
Physical Losses (basic)	Liters/Service Connection/Day (w.s.p.)	<ul style="list-style-type: none"> – Calculated by dividing the average daily volume of physical losses by the number of service connections and adjusting this value to the supply time.² – For this indicator, it is important to take the supply time into account.
Physical Losses (advanced)	Infrastructure Leakage Index (ILI)	<ul style="list-style-type: none"> – ILI is the ratio between the current annual volume of physical losses (CAPL)³ and the minimum achievable annual volume of physical losses (MAAPL).⁴ – As a truly meaningful inter-utility comparison, it indicates how well a distribution network is being managed and maintained at the current operating pressure.
Commercial Losses	Percentage of authorized consumption	– Both billed and unbilled should be measured (see water balance).

¹ w.s.p. stands for when the system is pressurized. This means that the indicator is adjusted as if the system would have continuous supply.

² For example, if the daily volume of physical losses divided by the number of service connections is 200 l/conn/d but the average supply time is 12 hours per day, the physical loss performance indicator is 400 l/conn/d (w.s.p) (400 = 200 / 12h × 24h). Only now it can be used for comparisons with a system with a different supply time.

³ The corresponding IWA term is current annual volume of real losses (CARL).

⁴ The corresponding IWA term is unavoidable annual volume of real losses (UARL).

Source: International Water Association.

must be estimated based on the number of customers, along with the average number of customers per connection, the estimated number of illegal connections, and the estimated number of connections with inactive accounts.

The Infrastructure Leakage Index (ILI) is the ratio between the actual volume of physical losses and the minimum (unavoidable) level of leakage. The International Water Association's (IWA) Water Loss Task Force analyzed water distribution network data from around the world and developed a "user-friendly" pressure-dependent format for practical use:

$$\text{MAAPL (liters/day)}^{10} = (18 \times L_m + 0.8 \times N_c + 25 \times L_p) \times P$$

where MAAPL = minimum achievable annual volume of physical losses; L_m = mains length (km); N_c = number of service connections; P = average pressure (m); and L_p = small correction factor.¹¹

¹⁰ MAAPL must be adjusted to the average supply time. For example, if the result from this equation for a given system is 1,000,000 liters, it must be reduced if the average supply time is only 18 hours/day: MAAPL (18h) = 1,000,000 / 24 × 18 = 750,000.

¹¹ This is relevant only if water meters are deep inside the property. It is the total length of service connections between the property boundary and the customer meter (km). It is by no means the total length of all service connections. In most Asian urban situations, where the customer meter is at the property boundary, this factor is simply zero.

In most water utilities in Asia, the water loss levels are so excessively high that they should at least be reduced by 50% before any economic analysis is needed

A water utility with an ILI of, or close to, 1 is practicing excellent and efficient leakage management. As the ILI formula was developed, the available data sets showed values between 1 and 10. It was assumed that 10 is the worst possible, but when the ILI was later used to assess the leakage management performance in water utilities in low- and middle-income countries, much higher values were observed—up to extremes of over 200 in Central Asia.

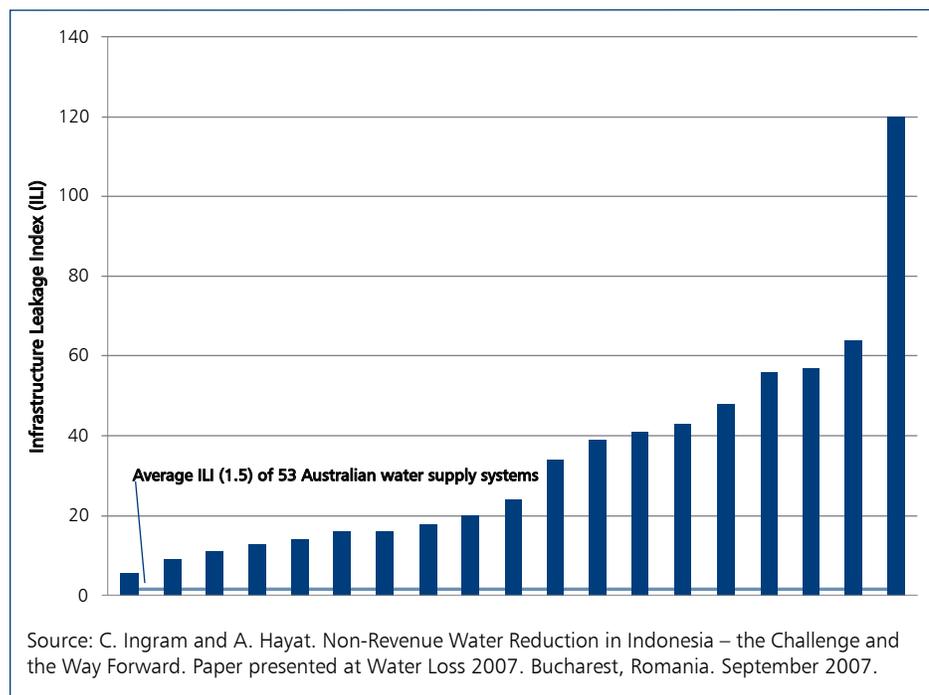
Figure 7 provides a good indication of the quality of leakage management in Indonesia and shows the significant differences between individual systems. The general conclusion is that leakage levels are extraordinarily high and the vast majority of utilities do not practice active leakage management. This is apparent when comparing the ILI values between Indonesian and Australian utilities.

Deciding what level of water loss is “acceptable” is not a simple task, because it depends on the specific conditions of each utility, both operational (network length, connection density, service pressure) and commercial. However, in most water utilities in Asia, the water loss levels are so excessively high that they should at least be reduced by 50% before any economic analysis is needed.

Based on extensive experience, a simple physical loss matrix was published in 2005¹² that provides some insights into typical values for different situations. This approach classified the leakage levels for utilities in developed and developing countries into four categories.

A split was introduced between “developed” and “developing” countries because the current gap in performance is such that setting targets for developing countries

Figure 7 ILI Values from 19 Indonesian Water Utilities (2006)



¹² R. Liemberger and R. McKenzie. Accuracy Limitations of the ILI: Is It an Appropriate Indicator for Developing Countries? In Conference Proceedings, IWA Leakage 2005 Conference in Halifax, Nova Scotia, Canada.

based on the performance of the best utilities in the developed world could easily be counterproductive. When setting goals, one must be realistic and take into consideration the difficult environment in which water utilities in the developing world are operating.

The problem with this matrix is that the volume of physical losses must be known. Therefore, it is not suitable for an initial assessment prior to the availability of a water balance. In response, the International NRW Assessment Matrix (Figure 8) was created to allow for a basic initial assessment of NRW (as a simple alternative to the commonly used percentages).

Figure 8 The International Non-Revenue Water Assessment Matrix

NRW Management Performance Category		Non-Revenue Water in liters/connection/day when the system is pressurized at an average pressure of:				
		10 m	20 m	30 m	40 m	50 m
High Income Countries	A1		< 50	< 65	< 75	< 85
	A2		50–100	65–125	75–150	85–175
	B		100–200	125–250	150–300	175–350
	C		200–350	250–450	300–550	350–650
	D		> 350	> 450	> 550	> 650
Low and Middle Income Countries	A1	<55	<80	<105	<130	< 155
	A2	55–110	80–160	105–210	130–260	155–310
	B	110–220	160–320	210–420	260–520	310–620
	C	220–400	320–600	420–800	520–1000	620–1200
	D	> 400	> 600	> 800	> 1000	> 1200

Source: R. Liemberger. Recommendations for Initial Non-Revenue Water Assessment. IWA Water Loss 2010. Sao Paulo, Brazil. June 2010.

This matrix is based on an extreme simplification. Commercial loss allowances are based on an assumed average billed consumption per connection of 1,000 liters per day. This means that in systems with substantially higher average consumption, the values might be difficult to achieve, especially in the “A” categories.

- **Category A1:** World-class NRW management performance; the potential for further NRW reductions is small, unless there is still potential for pressure reductions or the accuracy improvement of large customer meters.
- **Category A2:** Further NRW reduction may be uneconomic, unless there are water shortages or very high water tariffs; a detailed water audit is required to identify cost-effective improvements.
- **Category B:** Potential for marked improvements; establish a water balance to quantify the components of NRW; consider pressure management, better active leakage control practices, and better network maintenance; improve customer meter management, review meter reading, data handling and billing processed, and identify improvement potentials.
- **Category C:** Poor NRW record; tolerable only if water is plentiful and cheap; even then, analyze level and causes of NRW and intensify NRW reduction efforts.
- **Category D:** Highly inefficient; a comprehensive NRW reduction program is imperative and high priority.

The International NRW Assessment Matrix has the potential to lead Asia’s water utilities to a more realistic assessment of their water loss situation

Addressing Community Behavior

Water loss is not just an engineering problem but also reflects a sociocultural situation that requires changes in community behavior and attitudes toward water usage

Many utilities that have been successful in addressing NRW have gone beyond technical measures to address community behavior that drives illegal connections and pilferage. This is done with the understanding that water loss is not just an engineering problem but also reflects a sociocultural situation that requires changes in community behavior and attitudes toward water usage.

In response to this challenge, for example, Manila Water Company Inc. used an engineering solution—District Metered Areas (DMAs)—as the basis of a decentralized field operations structure. The structure went all the way down to informal street leaders, who helped provide information about pipe bursts, leaks, and water outages.

Other Asian cities are also harnessing communities to reduce NRW. For instance, in Jamshedpur, India, technical measures have been complemented by efforts to address illegal connections by walk-through surveys and authorizing illegal connections by legitimizing them and adding them to the network.



Maynilad Water Services, Inc.

Clustering of customer meters

Box 6 Community Organization to Reduce NRW in Manila

In the east sector of Metro Manila, Manila Water Company Inc. is organized into 247 territories, each headed by a territory manager who oversees anywhere from three to five DMAs. Each territory has from 1,500 to 5,000 connections. In addition, DMAs are broken up into meter reader units, with each meter reader having up to 200 connections to monitor and service.

Within the organizational setup, a DMA is a business unit. DMA managers must be entrepreneurial and meet business targets. This means that they can propose additional investment but must have a business plan to justify full-cost recovery and the profitability of the new pipe investment. The principal concern of a territory and DMA manager is both to reduce NRW and increase billable water.

The Manila Water structure is designed to allow DMAs to have a direct relationship with every customer within the metering area. Once an area's demographics reach a certain density or the character of the area changes, a DMA is reorganized or a new one formed.

Outside of the DMA managers and meter readers, a critical part of the structure is the identified *kasanggas* (street leaders) in the community. The DMA managers have to develop anywhere from five to seven (sometimes more) of these relationships in their areas. They help communicate problems on the ground and broadcast local plans and news to communities.

Source: Asian Development Bank and Institute of Water Policy, Lee Kuan Yew School of Public Policy. (2010). *Every drop counts: Learning from good practices in eight Asian cities*. Mandaluyong City, Philippines: ADB and IWP-LKYSP.

In Phnom Penh, the public utility was able to reduce NRW by 91% in 15 years through strong commitment and a comprehensive network replacement and physical loss reduction program. On top of that, simple but unique measures were taken to reduce commercial losses. For example, if a meter reader of an area did not, or could not, find an illegal connection, but one of his colleagues did, the colleague received a reward and the meter reader was penalized.¹³

The public was also made aware of the problem of illegal connections. Those customers found to have illegal connections were heavily penalized, and anyone who reported an illegal connection was rewarded. Inspection teams were set up to search for, find, and eliminate illegal connections. As a result of these and other actions, the number of illegal connections discovered dropped from an average of one per day to less than five per year by 2002. At present, it is highly unusual to find even one illegal connection.

The public was also made aware of the problem of illegal connections

¹³ Asian Development Bank and Institute of Water Policy, Lee Kuan Yew School of Public Policy. (2010). *Every drop counts: Learning from good practices in eight Asian cities*. Mandaluyong City, Philippines: ADB and IWP-LKYSP.

Outsourcing of Non-Revenue Water Management Activities

Contract models and level of performance-based payments can vary widely from one utility to another

Many water utility managers argue that NRW management is an integral part of good utility management and should not be outsourced. While this is a valid point, utilities that have struggled for years to reduce their NRW level may well consider this option.

Outsourcing of certain water loss reduction activities is not a new practice. Many water utilities in Europe, the United States, and even in developing countries (for example, SABESP in Brazil) use private leak detection contractors to periodically survey their distribution network. This is usually done through the most basic form of outsourcing, where the contractor gets paid on a schedule of rates (e.g., per day or per km pipeline checked) regardless of the achievements made.

However, during the last 10 years, more utilities throughout the world are using contracts with performance-related payments. These are commonly referred to as performance-based contracts (PBCs), not to be confused with target contracts. Under a PBC, a private firm is contracted to implement a NRW reduction program, and contract payments are (to varying degrees) linked to performance achievements. Contract models and level of performance-based payments can vary widely from one utility to another.

Box 7 Performance Contracts versus Target Contracts

Often, target contracts are confused with performance-based contracts. A target contract is a contract where, for example, NRW has to be reduced by a certain, pre-determined volume and penalties/bonuses apply for not achieving/surpassing the target. These are often problematic, as the targets are frequently arbitrary. If the targets are too high, the private sector will not be interested to bid or the risk premium will be substantial. If they are too low, the contract might be disadvantageous for the utility. True performance contracts have no contractual target and the performance fee is directly proportional to NRW reduction.

Source: R. Liemberger, P. Fanner, Didier Carron. 2009. Performance Based Contracts for Non-Revenue Water Management. *Water21*. April. IWA Publishing.

In practice, the applicability of PBCs depends on the level of risk that the private sector is willing or able to take. Although this is a relatively new concept for the water sector in the developing world, it is increasingly implemented in other sectors as a way to improve efficiency and accountability of contracts with private providers.

With the proper balance of government oversight and private sector initiative, PBCs can provide an enabling environment and the right incentives to help reduce NRW, with immediate operational and financial benefits. It has the potential to bring rapid improvements for a public water utility, in terms of both increased cash flows and more water available to serve the population, by efficiently harnessing the know-how of the private sector.

This could in turn generate enough momentum to push for the institutional and governance reforms that are necessary to establish sustainable water utilities so that they can more effectively serve the need of the growing population in developing countries.

However, it is important to note that, despite its obvious potential, using PBCs for NRW reduction should not be viewed as a new magic formula for solving the many woes of public water utilities in developing countries, which most often are a result of more fundamental institutional problems.

International funding institutions are considering the model (e.g., a PBC funded by the World Bank is in progress in Ho Chi Minh City, Viet Nam), and the market for PBCs will likely become more mainstream. However, design of NRW reduction contracts is not simple, and very few specialists currently have enough experience to properly design such contracts. Some of the main issues are mentioned below.

Selecting a contractor: In the past, PBCs were often driven by the private sector and rarely competitively tendered. This has often led to contracts that were too much in favor of the contractor.¹⁴ To avoid this situation, public utilities should drive the process.

There are no blueprints for PBCs—every situation is different and needs a tailored approach. After the initial NRW assessment, one of the first steps for a utility is to develop a tailor-made NRW reduction strategy and decide what elements the private sector can implement (e.g., reduction of physical losses, commercial losses, or both).

Next, they should pursue a competitive bidding process. Ideally, bid evaluation would not only be based on the contract price but also take the quality of the technical proposal into account. This might not always be possible under applicable procurement rules, but at a minimum, there should be a strict prequalification process and pass/fail criteria to ensure that all compliant bidders are capable of successfully undertaking the contract.

Developing a contract: Contract documents should be well balanced and fair to both parties. There must be a clear delineation between contractor and utility rights and responsibilities. Also, while the contract documents for a PBC must be sufficiently comprehensive, it is advisable to keep things as simple as possible. This applies to the legal language, performance monitoring and measurement mechanism, and reporting and dispute resolution process.

Despite its obvious potential, using PBCs for NRW reduction should not be viewed as a new magic formula for solving the many woes of public water utilities in developing countries

¹⁴ Kingdom, W., R. Liemberger, and P. Marin. 2006. *The Challenge of Reducing Non-Revenue Water (NRW) in Developing Countries – How the Private Sector Can Help: A Look at Performance-Based Service Contracting*. WSS Sector Board Discussion Paper #8. World Bank.

Flexibility to accommodate future modifications of the contract is also an important issue, especially for larger contracts with a long duration

Allowing a certain proportion of the payments as fixed fee will reduce the total cost of the contract, as the risk for the contractor will be reduced. The mix of fixed fee, performance payments, and payments for materials and civil works has to be well balanced.

There are many ways of paying for the actual repair works, meter replacement, and civil works and materials. Options range from including everything in the performance fee to having everything reimbursed at a cost-plus basis. Both extremes are problematic and in most cases expensive. Other methods to be considered include: paying unit rates (bill of quantities) for supply and installation for pipe laying and other civil works; or the utility providing materials to the contractor. Advantages and disadvantages have to be carefully evaluated and an appropriate mix has to be found. This is even more important if large-scale infrastructure renewal forms part of the contract.

Flexibility to accommodate future modifications of the contract is also an important issue, especially for larger contracts with a long duration. Changes might become necessary in the course of the contract and the contractual provisions should allow modifications.

It is also worth noting that the development of tender documents for PBCs is not an easy task, and public procurement laws in many countries make the development of such contracts very difficult. Thus, water utilities should always consider engaging a specialist advisor to develop the contract and sometimes even to support contract management.

Ensuring sufficient data collection and management: A lack of understanding of the magnitude and sources of NRW is one of the main reasons for insufficient NRW reduction efforts around the world. This issue has to be addressed when designing a PBC. Only by quantifying NRW and its components and calculating appropriate performance indicators can the NRW situation be properly understood, cost estimates be made, and a fair contract model be developed. It is also of utmost importance to have good pressure and supply time data, as those have a fundamental impact on leakage levels and its reduction/increase potential.

The contractor must also have appropriate information systems since, as explained above, NRW management requires collecting a good deal of data. Also, because much of this data is invaluable for the utility over the long term, the contractor must share access to the systems during the contract, and all the systems and data must be handed over at the end of the contract.

Planning for beyond the contract: A utility should consider what will happen after the PBC has been completed. NRW management is not a one-time effort but a never-ending, ongoing activity. For instance, while the contractor under a PBC can remove the backlog of leaks, new leaks will appear afterwards. It is therefore essential that the utility have plans after the PBC expires.

If the utility intends to take over NRW management, they must build staff capacity and make all the necessary provisions to enable them to continue in a successful manner. This includes transfer of technology, availability of managerial capacity, sufficient human resources, and long-term budgetary provisions.

Another possibility is to continue outsourcing NRW management (or parts of it). This might be done under a subsequent performance contract, but the contractual provision, and the performance assessment and payment mechanism may be substantially different for a contract that only intends to keep NRW at a certain level.

In most cases, the utility will want to keep all options open and leave this decision until a later time. Therefore, the development of in-house capabilities should always be pursued to allow maximum flexibility at the end of the PBC.

The Future

One of the problems that can be addressed is the lack of NRW management in engineering curricula at colleges and universities

The NRW problems of water utilities around the world are substantial, and enormous efforts are needed to address them. In addition to implementing NRW management projects, many other measures can be taken.

Through a wealth of specialized publications, it is now well understood that NRW management is technically difficult, contradicting a common belief that the issue was not overly complicated. With current technologies, software systems, and highly specialized equipment, this is simply not the case anymore.

One of the problems that can be addressed is the lack of NRW management in engineering curricula at colleges and universities. Engineering students learn how to design new systems but not how to manage and improve existing ones. Classes on efficient water utility management and NRW management classes should be included in water and sanitary engineering departments, and these will ideally include masters or post-graduate classes. While this would help ensure that future generations of engineers have good background knowledge, such changes will not happen soon. To effect this change, proponents should promote such changes at conferences around the world and try to convince academia to start discussing relevant changes. Another good approach would be to develop national and regional NRW management training programs, ideally combined with standardized certification schemes.

Water utilities will also need to practice appropriate design of system expansions (e.g., new network parts already constructed as DMAs) and use higher quality works, materials, and equipment. In addition, regulators and policy makers should require water utilities to do periodic water audits and regularly publish detailed NRW data, which can then be independently audited.

Again, NRW management is not a one-time activity. Although an intense and comprehensive NRW reduction program is suitable to reduce the backlog of required NRW reduction measures, it will not lead to a sustainable low level of NRW unless NRW management becomes part of the normal day-to-day activities of the water utility.

Annex 1: Water Balance Definitions

In the following, all terms used in the water balance are listed in hierarchical order—as one would read the water balance form from left to right. Some of the terms are self-explanatory, but are still listed and briefly explained.¹

- **System Input Volume:** The volume of treated water input to that part of the water supply system to which the water balance calculation relates. It may come from a utility's own sources and treatment facilities or from external bulk suppliers. It is important to note that water losses at raw water transmission schemes and losses during the treatment process are not part of the annual water balance calculations. In case the utility has no distribution input meters, or they are not used and the key meters are the raw water input meters, the system input has to be based on the raw water meters but must be adjusted by treatment plant water use. In either case, the measured volume has to be corrected for known systematic bulk meter errors.
- **Authorized Consumption:** The volume of metered and/or unmetered water taken by registered customers, the water utility, and others who are implicitly or explicitly authorized to do so for residential, commercial, and industrial purposes. This also includes water exported across operational boundaries. Authorized consumption may include items such as firefighting and training, flushing of mains and sewers, street cleaning, watering of municipal gardens, public fountains, frost protection, building water, etc. These may be billed or unbilled, metered, or unmetered.
- **Water Losses:** The difference between system input 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 physical losses and commercial losses.²
- **Billed Authorized Consumption:** Those components of authorized consumption that are billed and produce revenue (also known as revenue water or billed volume). This is equal to billed metered consumption plus billed unmetered consumption.
- **Unbilled Authorized Consumption:** Those components of authorized consumption that are legitimate but not billed and therefore do not produce revenue. This is equal to unbilled metered consumption plus unbilled unmetered consumption.

¹ A detailed description of performance indicators and definitions is provided in Alegre, H., et al. 2006. Performance Indicators for Water Supply Services. *IWA Manual of Best Practice*. 2nd Edition. IWA Publishing.

² The International Water Association uses the terms “real” and “apparent” losses.

- **Commercial Losses:** Includes all types of inaccuracies associated with customer metering as well as data handling errors (meter reading and billing), plus unauthorized consumption (theft or illegal use).
- **Physical Losses:** Leakage and other physical water losses from the pressurized system and the utility's storage tanks, up to the point of customer use. In metered systems, this is the customer meter. In unmetered situations, this is the first point of use (stop tap/tap) within the property.³
- **Billed Metered Consumption:** All metered consumption that is billed. This includes all groups of customers, such as domestic, commercial, industrial and institutional, and also includes water transferred across operational boundaries (water exported) that is metered and billed.
- **Billed Unmetered Consumption:** All billed consumption that is calculated based on estimates or norms but is not metered. This might be a very small component in fully metered systems (for example, billing based on estimates for the period a customer meter is out of order) but can be the key consumption component in systems without universal metering. This component might also include water transferred across operational boundaries (water exported) that is unmetered but billed.
- **Unbilled Metered Consumption:** Metered consumption that is for any reason unbilled. For example, this might include metered consumption by the utility itself or water provided to institutions free of charge, including water transferred across operational boundaries (water exported) that is metered but unbilled.
- **Unbilled Unmetered Consumption:** Any kind of authorized consumption that is neither billed nor metered. This component typically includes items such as firefighting, flushing of mains and sewers, street cleaning, frost protection, etc. In a well-run utility, it is a small component that is very often substantially overestimated. Theoretically, this might also include water transferred across operational boundaries (water exported) that is unmetered and unbilled (although this is an unlikely case).
- **Unauthorized Consumption:** Any unauthorized use of water. This may include illegal water withdrawal from hydrants (for example for construction purposes), illegal connections, bypasses to consumption meters, or meter tampering and under-reading of customer meters because of meter reader corruption.
- **Customer Metering Inaccuracies and Data Handling Errors:** Apparent water losses (water that is only "apparently" lost but causes a loss in revenues) caused by customer meter inaccuracies and data handling errors in the meter reading and billing system.
- **Leakage on Transmission and/or Distribution Mains:** Water lost from leaks and breaks on transmission and distribution pipelines. These might either be small leaks that are not visible at the surface (e.g., leaking joints) or large breaks that were reported and repaired but did leak for a certain period before that and contribute therefore to the annual volume of physical losses in a particular year.

³ Although physical losses, after the point of customer use do, by definition, not form part of the volume of physical losses in the water balance; this does not necessarily mean that they are not significant or worthy of attention for demand management purposes.

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- **Leakage and Overflows at Utility's Storage Tanks:** Water lost from leaking storage tank structures or overflows of such tanks caused, for example, by operational or technical problems.
 - **Leakage on Service Connections up to Point of Customer Metering:** Water lost from leaks and breaks of service connections from (and including) the tapping point until the point of customer use. In metered systems, this is the customer meter; in unmetered situations, this is the first point of use (stop tap/tap) within the property. Leakage on service connections might sometimes be visible but will predominately be small leaks that do not surface and run for long periods (often years).
 - **Revenue Water:** Often called billed volume, includes those components of authorized consumption that are billed and produce revenue (also known as billed authorized consumption). This is equal to billed metered consumption plus billed unmetered consumption.
 - **Non-Revenue Water:** Those components of system input that are not billed and do not produce revenue. This is equal to unbilled authorized consumption plus physical and commercial losses.
 - **(Unaccounted-for Water)** Because of the widely varying interpretations and definitions of the term "Unaccounted-for Water," it is strongly recommended that this term no longer be used.

Annex 2: List of Key Publications

- Alegre, H., et al. 2006. *Performance Indicators for Water Supply Services*. IWA Manual of Best Practice. 2nd Edition. IWA Publishing.
- American Water Works Association (AWWA) Water Loss Control Committee. 2003. Applying Worldwide Best Management Practices in Water Loss Control. *AWWA Journal*. August.
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- Farley, M., G. Wyeth, Z. Ghazali, A. Istandar, and S. Singh. 2008. *The Manager's NRW Handbook*. USAID.
- Kingdom, W., R. Liemberger, and P. Marin. 2006. The Challenge of Reducing Non-Revenue Water (NRW) in Developing Countries – How the Private Sector Can Help: A Look at Performance-Based Service Contracting. *WSS Sector Board Discussion Paper #8*. World Bank.
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- Lambert, A., T.G. Brown, M. Takizawa, and D. Weimer. 1999. A Review of Performance Indicators for Real Losses from Water Supply Systems. *AQUA*. 48(6).
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- . 2010. Recommendations for Initial Rapid Non-Revenue Water Assessment. Paper to the IWA Water Loss 2010 Conference. Sao Paulo, Brazil.
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- South African Bureau of Standards Code of Practice: SABS 0306:1999. The management of potable water in distribution systems.
- Thornton, J., R. Sturm, and G. Kunkel. 2008. *Water Loss Control*. 2nd edition. McGraw-Hill Professional.
- Wide Bay Water Corporation and Queensland Environmental Protection Agency. 2005. *Managing and Reducing Losses from Water Distribution Systems*, Manual 10 – Executive Summary.

The Issues and Challenges of Reducing Non-Revenue Water

Improving the efficiency of water utilities and reducing water losses are becoming top priorities in Asia, with its often-limited water resources and rapidly increasing urban population. This publication provides an up-to-date introduction to the subject matter, highlights the complexity of managing non-revenue water (NRW), offers guidance on NRW assessment, and recommends appropriate performance indicators. It is, to a large extent, based on the work of the Water Loss Specialist Group of the International Water Association in the last decade, and is amply complemented by the authors' practical experiences in Asia and in other countries around the world.

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