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The Water and Sanitation Program is an international partnership for improving water and sanitation sector policies, practices, and capacities to serve poor people

April 2008

Field Note

Performance Improvement Planning

Designing an Effective Leakage Reduction and Management Program

Reducing nonrevenue water and maintaining it at target levels is important for any service provider looking to improve quality of service, financial soundness, and creditworthiness. In the longer term, the effectiveness of nonrevenue water programs is a function of managerial efficiency and institutional accountability.

High levels of nonrevenue water result from huge volumes of water lost through leaks or water not invoiced to customers or both, and this seriously affects financial viability of water providers.

Executive Summary

One of the principal concerns today for the deteriorating quality of water supply and sanitation services in India is the high levels of nonrevenue water (NRW)—the difference between the amount of water put into the distribution system and the amount of water billed to consumers. High levels of NRW result from huge volumes of water lost through leaks or water not invoiced to customers or both, and this seriously affects financial viability of water providers through lost revenues, increased operational costs and, eventually, increased capital costs.

Reducing nonrevenue water levels does not necessarily compromise on a service provider's ability to subsidize services for the poorer sections of the population; rather, it allows for improved transparency and accountability, and for ensuring better targeting of subsidies such that they are more equitable and actually reach poor people.

Reducing NRW and maintaining it at target levels is hence an important task for any service provider looking to improve quality of service, financial soundness, and creditworthiness. The approach to reducing NRW includes a set of activities aimed at the optimization of water supply through improved operations, maintenance, and sound management practices of distribution networks as well as governance and management reforms through specific operational and commercial strategies. However, if NRW programs are to remain sustainable in the long run, they must target institutional and organizational reform while encouraging efficiencies through technical and managerial improvements and enhancing human resource capacity.

This field note captures the core principles for the effective implementation of nonrevenue water programs through real world examples of service providers implementing such programs in India and Vietnam. The case studies demonstrate that successful leakage reduction and its effective and sustainable implementation has not been a result of erratic and irregular technical exercises to reduce physical losses.

On the contrary, these nonrevenue water programs have been successful because of the continuous effort to control physical and commercial losses while also bringing in managerial efficiency and institutional accountability.

Context

More than 40 percent of water produced in many Indian cities does not earn any revenue, be it water lost before reaching the consumer or high volumes of water not being billed for or both, therefore contributing to poor cost recovery and hence poor service quality and coverage. By no means could this estimate be considered accurate, given the absence of any meters—bulk or customer meters—in most cities. Ineffective metering is not the only cause of nonrevenue water; old and corroded pipes and fittings, poor billing, free flowing services to many, and a lack of willingness to improve upon billing and collection practices also contribute to it. Many providers also lack the ability to understand the baseline situation of NRW—a critical first step if one is to move towards effective NRW reduction.

High levels of nonrevenue water are also a result of poor institutional arrangements under which service providers currently operate. The incentives to be more accountable, to manage and perform better, and to have a revenue strategy that encourages a commercial orientation to services currently remain very poor in the country. The enabling financial incentives for encouraging service improvements are also lacking, since providers count on virtually unconditional financial support from government or from subsidies within municipal accounts.

Box 1: The Criticality of Nonrevenue Water Management

The basic aim of the performance improvement series is to help water utilities and service providers understand and adopt mechanisms that promote cost recovery and sustainable revenue strategies, as well as help achieve financially viable and sustainable improved services. The objective is to be able to focus not only on specific performance improvement areas by advancing technical, commercial, and operational efficiency—such as leak reduction, billing and collection, customer service, and tariff setting, among others—but also ensure that such improvements remain sustainable and viable in the long term through arrangements such as performance agreements, monitoring, and evaluation.

This issue, No. 3 of the series, discusses the importance of the reduction and management of nonrevenue water (NRW) as a critical step towards improving the financial soundness of any water utility. Its objective is to promote, among Indian water providers, a good understanding of the causes of NRW and ways to design and manage a system to control it. The series also showcases some real world examples of NRW management in India and East Asia.

Improving and Sustaining NRW Levels

Reducing nonrevenue water, and hence improving cost recovery, is an important task for any service provider since it is considered a crucial step towards improving its financial soundness and creditworthiness. In spite of its potential benefits, NRW reduction is not easy to implement, especially in an intermittent service environment. Reducing NRW is not technically difficult; it is, however, challenging in a governance sense: for instance, illegal connections that contribute to NRW can only be eliminated when utilities and service providers have autonomy and discipline, and when they are made accountable for keeping illegal connections under control. The approach to reducing NRW levels includes a set of technical programs and activities aimed at the optimization of water supply through improved operations and maintenance, sound commercial practices and network refurbishment, rehabilitation and management established in the managerial, organizational, and institutional environment.

The field note uses case studies to demonstrate that successful leakage reduction is not a result of sporadic and irregular technical exercises to reduce physical losses. Such programs should rather be a continuous effort and must control commercial losses since the latter helps improve the revenue stream of the water company almost immediately. These programs will, however, need to be implemented in the broader context of tackling the managerial, organizational, and institutional environment so that they remain sustainable and effective in the long run.

Box 2: Nonrevenue Water

Nonrevenue water is the difference between system input volumes and billed authorized consumption. It consists of:

- Unbilled authorized consumption (including water for fire fighting or free water distributed at standpipes or provided to religious institutions).
- Apparent losses (including unauthorized consumption and metering inaccuracies).
- Real losses (including leakages from transmission or distribution mains, leakages and overflow from utility storage and balance tanks, and leakages in reticulation systems to the point of metering).

A water balance calculates nonrevenue water into its respective components and helps identify where the main problem areas lie.

Box 3: Synopsis of Three Case Studies

Bangalore, capital of the Indian state of Karnataka, has a population of about 5.3 million (2007). The city's water needs are met by the **Bangalore Water Supply and Sewerage Board**, a publicly owned water utility. It is responsible for providing water supply, sewerage system, and sewage disposal as well as for preparing and implementing plans and water supply schemes in its service area.

The Board was losing over 40 percent of its water until it undertook some robust strategies for reducing and controlling water leakages that included a pilot nonrevenue water project. These have helped the Board in increasing service coverage and quality as well as improving the commercial viability of water services.

Jamshedpur is an industrial city in the East Singhbhum district of Jharkhand in India. It has a total population of about 0.7 million people and is home to the first private iron and steel company of the country. The **Jamshedpur Utilities and Services Company Limited** is a wholly owned subsidiary of private company Tata Steel that was created on August 25, 2003, out of Tata Steel's Town Division, to improve the quality of civic services in Jamshedpur.[1]

The service provider in Jamshedpur provides comprehensive municipal services including water and wastewater management to the township. It has recently undertaken various performance improvement measures including a proactive bulk metering practice and a pilot District Metered Area for controlling water losses in its distribution system. As a result of these initiatives the utility has been able to serve new neighborhoods with water supply through saved water from controlling nonrevenue water.

The **Haiphong Water Supply Company** is a public utility that provides water supply services to the urban population of Haiphong city—the third largest city in Vietnam—and has a population of about 1.7 million. It is owned by Haiphong Peoples' Committee and is regulated by the Department of Transport and Public Work Services. The city was receiving water supply of 325 lpcd (or liters per capita per day) but, given very high levels of nonrevenue water, the city's demands were not being met.

The company piloted its 'Phuong model' in 1993 and simultaneously instilled institutional and management changes (new utility management team, considerable changes in the organizational structure and operating rules and management style, including administrative decentralization), all of which helped achieve reduced nonrevenue water (from 70 percent in 1993 to 32 percent in 2002), increased water revenues of 5.5 times during 1993–2001 and improved quality and standards of service.

[1] Tata Steel (formerly the Tata Iron and Steel Company Limited, TISCO) is Asia's first and India's largest integrated private sector steel company that was established in 1907 in the city of Sakchi, which was originally the name of the town that came to be more famously known as Jamshedpur.

Understanding the Magnitude of the Problem

Part of the problem in understanding the magnitude of NRW lies in the lack of a meaningful standard approach to estimate and report NRW levels. Very little data is available because water utilities lack the systematic reporting and monitoring systems, such as water table calculations, for assessing water losses and NRW performance. A water balance calculates NRW into its respective components and helps identify where the main problem areas lie. A water audit helps review the water system and assesses performance by quantifying total water losses and leakages in the network as the difference between the water input to distribution and the sum of the various components of water consumed. A complete system appraisal helps arrive at a water balance calculation, through an estimation of real losses, apparent losses, and unbilled authorized consumption (Table 1).

As subsequent case studies indicate, water audits and system appraisals were undertaken so that providers could understand and analyze the magnitude of the problem, identify the areas that required specific attention and undertake technical and commercial measures to target and keep NRW under control. A water audit in Jamshedpur indicated huge water losses in one of the main trunk lines of the network which, when repaired, immediately brought down the levels of NRW. Similarly, in Bangalore, a water audit helped determine that maximum leakages were occurring at the point of service connections, which were then accordingly controlled.

Table 1: Water Balance Calculation

System input volume (measured by input meters, after checking for their accuracy)	Authorized consumption	Billed metered consumption	Billed metered consumption	Revenue water
			Billed unmetered consumption	
		Unbilled authorized consumption	Unbilled metered consumption	Nonrevenue water
			Unbilled unmetered consumption	
	Water losses	Apparent losses	Unauthorized consumption	
			Metering inaccuracies	
		Real losses	Leakages on transmission and/or distribution mains	
			Leakage overflows at utility storage tank	
			Leakage on service connections up to point of consumer metering	

Source: IWA, 2000.

Utility managers will need to understand the levels and sources of nonrevenue water through a systematic review of the network and how it is being operated.

Components of NRW

Addressing this question requires that utility managers understand the level and sources of NRW through a systematic review of the network, how it is being operated, and what the commercial practices of the service provider are (Box 4 and Table 2).

- A review of the network condition and management helps determine physical losses[2] that result from faulty, corroded, and old water transmission and distribution mains, overflowing service reservoirs, and utility storage tanks. They are a result of poor operations or maintenance, lack of active leakage control, and deteriorating or poor quality of underground assets.
- A review of commercial practices determines the nonphysical or apparent losses. This involves, among others, an analysis of completeness and accuracy of customer database, billing procedures and frequency, tariff structure and subsidies, metering policy, handling of illegal connections, and response to customer queries.
- Unbilled authorized consumption comprises water for operational purposes, firefighting, and for services to special consumer groups as may be authorized in

[2] Reviewing network conditions and management helps understand the levels of physical losses. This is done through a review of the network age, materials used, hours of supply, service pressure, valves operation, frequency of breakages, particular local characteristics influencing water loss (corrosive soil, and so on), leakage repair, attitude and level of technology available for monitoring and detecting leakages, staff capabilities, skills and awareness levels, among others.

Box 4: Understanding the Components of Nonrevenue Water

Several levels of analysis would need to be undertaken for a nonrevenue water review:

- Discussions with or among senior staff to review current management practices, financial and political constraints and influences, attitude towards leak detection and reduction, customer database recordkeeping, and so on.
- Discussions with or among operational staff on how the systems are operated, including how water leakages are detected and managed.
- Review of technical and commercial data to validate the issues discussed with management and staff and, combined with the results of the Water Audit, to get a broad picture of the situation.
- Gather more data to complement the existing ones and implement a systematic collection of key data, if that is not a current practice already.

specific tariff regimes. It also includes the difference between actual and estimated consumption where there is a volumetric tariff but no functional meters or water consumed by legal customers where billing is based not in actual or estimated terms but according to certain physical household characteristics.

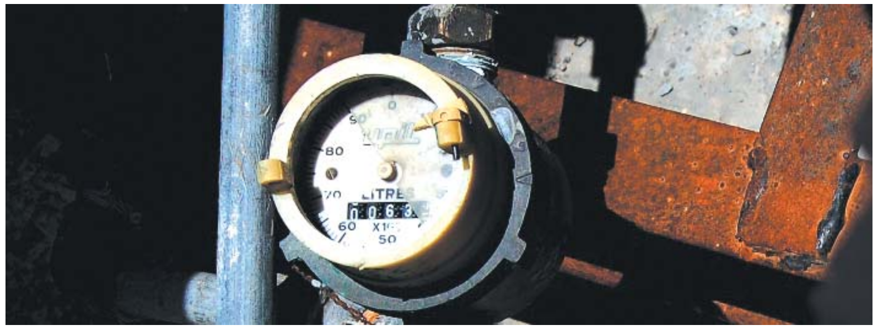

Table 2: Components and Causes of Physical and Nonphysical Water Losses

Losses	Components	Causes
Unbilled authorized consumption	Unbilled metered consumption	Water delivered to special customers that are not billed although they are metered
		Water used for operational purposes (flushing and disinfection, if metered)
	Unbilled unmetered consumption	Water delivered to special customers that are neither billed nor metered
		Difference between actual and estimated consumption
		Water used for operational purposes (flushing and disinfection, if not metered)
		Water used for firefighting
Nonphysical ('management' or 'apparent') losses	Unauthorized consumption	Illegal connections where there is no access
		Illegal connections to properties that have legal connections
		Illegal connections of vendors selling water
	Metering inaccuracies	Under-registration of customer meters
		Poor quality, inaccurate meters
		Inadequate meter maintenance or replacement policy
		Stopped meters
		Data handling errors
Physical (real) losses	Leakages on transmission and/or distribution mains	Burst pipes (sudden rupture of pipe)
		Leaking joints and fittings
	Leakage overflows at utility storage tank	Seepage from old masonry or concrete walls
		Float-valves not working
	Leakage on service connections up to point of consumer metering	Burst pipes (sudden rupture of pipe section or joint)
		Leaking joints and fittings

Source: Adapted from Leakage Management and Control: A Best Practice Training Manual. WHO, 2001, and IWA's best practice standard water balance.

Leakage management for tackling technical losses can be through: passive control; regular leakage surveys; and leakage monitoring in zones through the District Metered Area approach.

Addressing Each of the NRW Components Once They are Identified

Given that NRW is the difference between water supplied to the system and water billed to the customers, the value of these two variables is key for determining NRW levels. These could be estimated by installing meters at the system entry point and at each and every consumption point as well.

Macro-meters can be installed at the outlet of the water treatment plant and storage or distribution tanks and, normally, are also installed in every takeoff in the main conveying system.[3] Customer meters estimate consumption at the consumer end. These are sometimes not installed due to technical, economic, or political reasons.[4]

Once input and consumption figures are known or estimated (taking into account its consequences), NRW can be calculated and the search for the specific solutions can then begin.[5]

Box 5: Technical Solutions for Controlling Nonrevenue Water (Bangalore)

A study undertaken by Larsen & Toubro-Thames Water consortium on the useful life of the **Bangalore Water Supply and Sewerage Board's** pipes revealed that the pipes were in good condition and would remain so for 30 more years. The consortium, however, recommended in-situ replacements and rehabilitation, slip-lining of pipeline to improve the flow and reduce corrosion in existing pipes which, if implemented, would increase pipe life significantly two or three times more than their estimated remaining useful life. These recommendations were adopted for pipes with diameter up to 3 inches that were heavily corroded and encrusted. About 150 km of pipeline has been rehabilitated, with 700–800 km still pending.

The Bangalore Water Board also initiated a study in 2000 that indicated faulty and inaccurate meters and leakages in 30- to 40-year-old galvanized iron pipes feeding house connections as major causes for high nonrevenue water. Accordingly, the utility undertook replacement of all service pipes connected to corroded galvanized iron pipes with medium density polyethylene pipes. The Board also made it mandatory for house service connections in future to use medium density polyethylene pipes only. The costs of rehabilitation worked to US$50[6] per house connection and were to be paid by consumers through 10 monthly installments of US$5 each. The Board has replaced over 150 km of 100 mm galvanized iron pipes and 50,000 house service connection pipework with average length of between 3 and 5 meters. While the per meter cost of replacing the galvanized iron pipes worked to US$26, the per meter cost of replacement for the service pipes cost US$13.75. This has been undertaken by Larsen & Toubro and Shaw Technical Consultants, costing about US$3.75 million in all.

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[3] If not installed, the input should be estimated using other methodologies like considering hours of pumping combined with pump curves, weir constants, Parshall channels, hydraulic models, among others. If the input to the system is estimated, the possibilities are that either it is overestimated or underestimated.

[4] If customer meters are not installed, estimates are used. These can be derived using different methodologies: by means of the unit consumption per person per day, more complex calculations considering all the appliances existing in the households, conducting sample metering in pilot areas and extrapolating the results, and so on. Again, there are two possibilities. If customers' consumption is overestimated the NRW calculated will be lower than the actual and vice versa. The difference between actual and estimated consumption, if positive, contributes to the unbilled authorized consumption.

[5] Similar principles are used in the District Metering Area approach of leakage management, as discussed later.

[6] US$1 = INR 40 (as of October 2007).

Technical Solutions for Controlling NRW

Physical losses: Any NRW program must address technical solutions for tackling physical losses. Such solutions will involve network rehabilitation, refurbishment, and improved management; they also depend on how such leakages are currently detected and managed, their frequency and location, their assessment and management, how long it takes to achieve and maintain target leakage levels,[7] how expensive such an exercise is (capital and operating costs), and whether it is sustainable in the long term. The ease with which such solutions are found and implemented will depend on whether network drawings are in place, how old the network is, and on the existence of continuous water supply in the target area for facilitating detection and repair of leaks.

Leakage management for tackling technical losses is categorized into three groups: passive control; regular leakage surveys; and leakage monitoring in zones through the District Metered Area approach.

Passive control is undertaken in response to visible leakages in the system that arise due to bursts or drops in pressure, typically reported by customers or by linesmen. These are sometimes part of the day-to-day controls that are undertaken by the staff of water utilities in response to registered complaints.

Regular surveys are a method of inspection undertaken for a distribution system where leakages are looked for with listening devices[8] on pipelines and fittings, or by reading and analyzing metered inflows to temporarily isolated areas as leakages may be indicated by high night flow rates. These are undertaken on a more regular basis and form part of most leakage management strategies undertaken by water utilities.

Leakage monitoring in zones is a more advanced, focused, and comprehensive strategy that monitors leakages by creating a hydraulic supply system divided into operational zones defined on the basis of service reservoirs, pumping stations, pressure zones or other operational considerations. These operational zones are further divided into District Metered Areas within which leakage levels are constantly watched and monitored.

The District Metered Area approach is a way to study an intricate problem affecting a large (unmanageable) area by dividing it into smaller (more manageable) ones. In a sense, it means breaking down a big network into more numerous but smaller areas, the District Metered Areas. Then, for each area the total net inflows and the volume of water billed are measured and the NRW is calculated as the difference between the two figures. Once this is done, areas where NRW levels are higher than desired are analyzed to determine the appropriate solutions and implement them according to a prioritized program.

District Metered Areas are discrete hydraulic areas created within the supply zones or service stations of the city or town with a defined and permanent boundary that typically cover about 500 to 3,500 connections. The establishment of District Metered Areas includes preliminary design, detailed site survey and data collection and an understanding of the feeder mains, networks valves and meters in the area, and the supply pattern. Depending on its supply scheme, each District Metered Area is installed with one or more district meters, which should be read and recorded regularly (ideally it would either have a data logger or it would be linked to a central control station for continuous data recording). For each area, the service provider can:

- Produce a water balance;
- Monitor night flow-rates;
- Perform ‘Step Tests’;
- Monitor pressure levels; and
- Verify consumption anomalies.

These actions allow the service provider to define the relevance of each NRW component (physical and apparent losses and unbilled authorized consumption), locate leaks,

[7] Target leakage levels are often based on the Bursts and Background Estimates, which were developed from a review of international literature and consideration of the many parameters that influence losses. The original Bursts and Background Estimates leakage management concepts and software were developed in 1992–94, during the United Kingdom’s National Leakage Initiative. Such techniques are developed on four principal leakage management issues, namely logging and analysis of Minimum Night Flows, the economics of leakage and leakage control, pressure management and benchmarking of leakage, and auditing of nonrevenue water. More details on this concept are found in *Leakage Management: Introduction to WRC Tools to Manage Nonrevenue Water*, by R. S. McKenzie and J. N. Bhagwan.

[8] Some of them are (a) sounding sticks that are simple acoustic or electronically amplified instruments used for sounding on all fittings, valves, and hydrants and confirming the position of a leak; (b) ground microphones that involves placing the microphone on the ground at intervals along the line of the pipe and noting changes in sound amplification as the microphone nears the leak position; (c) leak noise correlator is the most sophisticated of the acoustic leak location instruments. It relies on the velocity of sound made by the leak as it travels along the pipe wall towards each of two microphones placed on conveniently spaced fittings. The latest versions of correlators have the capability for frequency selection and filtering and some have a noise detection head that is inserted in the pipe for increased accuracy.

When invisible leaks are suspected, monitoring night flow-rates allows estimating leakage volume from distribution mains, service connections and fittings, after subtracting legitimate customer night use.

Box 6: Using District Metered Areas and Bulk Metering to Control for Nonrevenue Water (Jamshedpur)

The drive to reduce water loss levels comes from **Jamshedpur Utilities and Services Company Limited's** realization that every m^3 of water lost has resulted in huge revenue losses for the company. Given total potable water production of 180 million liters per day, a percent reduction in Nonrevenue Water per day amounts to a saving of 1,800 m^3 per day or 54,000 m^3 per month which, cost at US$0.20 per m^3, amounts to a monthly saving of US$0.01 million. Accordingly the utility created a District Metered Area with 24-hour supply in its Circuit House Area. The network spans over 1.83 km^2, is over 75 years old and serves 350 households. The District Metered Area is constantly monitored to see if pressure and leakage levels through 24-hour water supply are maintained at optimal levels. It took the company about six months to design and implement the District Metered Area.

The utility is also undertaking a systematic bulk metering program of all system inlet connections, large consumers, and industrial connections and outlets. Bulk meters are periodically read and the data downloaded for analysis and calculation of losses in the distribution system. The bulk metering program was undertaken in two phases, costing an estimated US$1 million, where Phase I was undertaken over a period of 13 months and involved the installation of 41 bulk meters at the supply end and up to water treatment including metering of all inlets and outlets at its pump houses and water treatment plants as well as metering of branch networks and water tower inlets. Phase II involved installation of 89 meters over eight months including metering tower outlets and connections to associated companies and industrial units.

Bulk metering and constant monitoring of its mains has enabled the utility in analyzing leakages and in surveying pipelines for illegal and unknown connections. This has helped the utility in identifying two extra line connections in the central network which, when metered, brought about reduced unaccounted-for water.

These initiatives have brought about impressive results in reduced leakages. While it is difficult to get appropriate data for NRW given the absence of consumer metering, unaccounted-for water in the rising mains and the industrial water network has fallen; unaccounted-for water in the rising mains fell from 23 percent in 2004 to 10 percent in 2006.

Thus, new neighborhoods have been now served with water that was saved through these initiatives. The utility is now working on implementing customer meters for all 40,000 household connections in order to reduce leakages in house connections as well. So far the majority of the domestic consumers were paying a fixed monthly rate of US$3.5. The utility feels that metering of all domestic connections will minimize leakage and promote efficient use of water, while allowing it to divert surplus water to other areas of the city.

illegal connections and changes in customer categories and detect other problems like pressure increases beyond desirable levels, among others. It is assumed that, as part of the regular operations of the service provider, customer meters are read on a monthly basis for billing purposes (its accuracy checked according to a metering policy) and the data also used for the water balance for each District Metered Area.

When invisible leaks are suspected, monitoring night flow-rates allows estimating leakage volume from distribution mains, service connections and fittings, after subtracting legitimate customer night use. Best practice analysis of District Metered Area flows requires the estimation of leakage when the flow into the District Metered Area and customer demand is at its minimum, occurring between 12 midnight and 4 am. Analysis of night flow-rates determines whether consumption in any District Metered Area is much higher than expected or if it has increased over time, indicating bursts or undetected leakage. Suspected areas can be inspected more thoroughly using the 'step testing' procedure in which pressure in the network is monitored while sequentially closing valves until pressure rises significantly, showing that the leak in the last line is closed.

Detection of leakage in each District Metered Area is also carried out using equipment such as basic or electronic listening sticks, ground microphones and leak noise correlators. Water pressure levels within a District Metered Area are also continuously monitored through pressure loggers deployed at district meter points, elevated zones and major branching points in the network.

Leakages, once identified, must be brought to controllable 'target' levels, through a mix of pressure management, and repairs or rehabilitation of distribution mains and house connections. These target leakage levels are formulated on estimated losses from calculating individual components of losses in the distribution systems and on the customers' pipework, either as part of an annual water balance or from a night flow-rate analysis. Target leakage levels vary on a case-by-case basis and are determined by the type of leakage control policy, the size and number of District Metered Areas, the optimal pressure levels to be maintained, and the staffing policy. Typically, leakage targets are based on an 'economic' level defined as a point of minimum total costs when costs of both leaking water and leakage control are taken into account.

For successful functioning and long term sustainability of the District Metered Area approach, leakage and NRW levels must be continuously monitored and staff awareness, capacity, and motivation kept at the highest possible levels. All the information generated through this approach is optimal for feeding a hydraulic model of the network that, in turn, will provide feedback to the NRW management program.

Unbilled authorized consumption is a result of certain legal, institutional, and other social considerations that are not always sufficiently justified or compensated. As indicated in Table 2, there are mainly four reasons for unbilled authorized consumption. They are discussed here, together with some ideas on how to tackle them.

Box 7: Using a Pilot District Metered Area to Control Leakages (Bangalore)

The **Bangalore Water Supply and Sewerage Board** piloted a nonrevenue water reduction and control program in May 2003. The project, funded by the Japanese Bank for International Cooperation, spans across 32,000 connections and 270 km of pipeline (of diameter 50–600 mm and age five to 70 years) in central Bangalore.[9] Cost at US$12 million, it was awarded to the Larsen & Toubro-Thames Water consortium. Thames Water provided technical inputs while Larsen & Toubro was responsible for ground-level pipeline rehabilitation work. The project was implemented in two phases, with Phase I focusing on NRW reduction, establishment and maintenance of target NRW levels in each District Metered Area and staff training, and Phase II focusing on maintaining pressure and NRW levels at target levels as determined in Phase I.[10]

Phase I involved the formation of 21 District Metered Areas within five service stations in the pilot area.[11] The District Metered Areas covered about 1,000 to 3,500 consumer connections, with the exact number of consumers based on established boundaries and a network analysis. Once District Metered Areas were created, levels of NRW were regularly monitored. Leakage detection was undertaken through noise logging, leak noise correlators, and ground microphones, especially during the night hours. Repair work including rehabilitation and replacement of pipes using medium density polyethylene pipes was undertaken. The project controlled for apparent losses through a robust check of meters for accuracy in terms of functionality, water tightness and security and their subsequent replacement.[12] Physical losses were measured using the net night flow method and were monitored on a monthly basis. These calculations also took into consideration the impact of pressure as monitored in a few identified locations through data loggers. Ideal target leakage level rates were also established based on international best practice data estimates of water service providers in the United Kingdom in the 1980s.[13]

Phase II involved constant monitoring, leak detection surveys, repair of leaks and rehabilitation of pipelines, and retesting of leakage levels in the District Metered Area till water loss levels were reduced and maintained at target levels. The pilot project has improved water service standards and quality. It is proposed that this pilot will be extended to all areas of the city. The Japanese Bank for International Cooperation has extended its loan component to US$100 million. The project is designed to cover the balance 0.36 million consumer connections that were outside the pilot zones.

[9] This covered areas of High Grounds, Coals Park, Johnson Market, Ulsoor, and Clive Lines Reservoir.
[10] Each phase was for 18 months, with a three or four month overrun for complete implementation of Phase I.
[11] Initially the plan was for 16 District Metered Areas, which was later increased to 21.
[12] The project tested 5 percent or a minimum of 100 working meters per District Metered Area for accuracy. Faulty consumer meters were identified through customer complaints, billing data and a physical survey of meters in each District Metered Area. Of about 31,808 consumer meters surveyed during the pilot, about 30 percent meters were of a specific make; 69 percent of these meters were in good condition and 31 percent of them were either not working or were not readable. All nonworking meters of that make were replaced. In July 2004, about 3,124 meters were replaced.
[13] These estimates were inferred through a graph iteration based on a typical situation of leakage management in the United Kingdom, deducing what should be the target leakage level for each District Metered Area given a baseline Net Night Flow.

Not only can poor people afford to pay for water services but most of them would prefer to have a reliable service so that they can avoid buying water from vendors to cover for shortcomings in the public supply.

Water delivered to special customers that are not billed: Certain institutions could be regarded as deserving special treatment and, therefore, it may have been decided that these institutions should not pay for their water consumption. However, without making any judgment on the adequacy of this kind of decision, it is desirable that they are based on a predetermined and sound policy applied objectively. In any case it is also desirable that the number of cases should be kept to a minimum. It is advisable that these users are metered and sent the bill that indicates their consumption and gives them an estimate of how many people could have been supplied with the water that they are using. This could lead them to pay attention to any anomaly in their consumption that could indicate wastage and/or internal water losses that could be fixed. Another option could be to send crew to search for losses inside the premises if the billing system detects an abnormality in the consumption of any of these special users. Yet another means could be to provide coupons to certain consumer groups such as government institutions, with the coupons allowing for budgeted consumption.

Certain service providers opt for delivering a relatively limited volume of water to poor people for free or service them through public standposts on the understanding that they cannot afford any other kind of service. In fact, not only can poor people afford to pay for water services but most of them would prefer to have a reliable service that would allow them to avoid buying water from vendors to cover for shortcomings in the public supply. As discussed in Box 8, the Bangalore Water Board, over a period of five years, experimented with providing services to poor people and found that they willingly paid to connect to a reliable service. Similarly, other Indian cities of Baroda, Kerala, and Dehradun as well as Kathmandu in Nepal indicated through various surveys that consumers were willing to pay more for reliable, safe, and adequate water supply services.[14] In many cases, paying for water service allows poor people to get other services as they have a proof of residency and solvency. For service providers, *connecting poorer sections of the population* improves both revenue and service quality, as often the public standpost taps are removed and the water flows uninterruptedly during supply hours, thus lowering pressure and increasing wastage. Some service providers have resolved this through innovative means like rationalized or subsidized water connection fees and subsidized monthly rates, simplified procedures and application rules for a new connection so that poor people are indeed encouraged to apply for it, providing jobs to community members on network construction and administration of applications for new connections, and so on.

Many times, when the service provider is a public entity, government institutions are not billed nor do they pay for the water service as this is regarded as money that goes from one

Box 8: Connecting Poor People to the Network (Bangalore, India)

The **Bangalore Water Supply and Sewerage Board** has undertaken some commendable work in connecting the city's poor people to piped water services. The Board found innovative ways to connect them through subsidized connection fees, options for group connections, and simplified and easy methods for applying for a new connection. The program was jointly partnered with AusAID during 2000–02 wherein the project's Community Development Component examined and tested options for improved service delivery to urban poor people in three pilot slums: Cement Huts, Sudhamanagar, and Chandranagar.

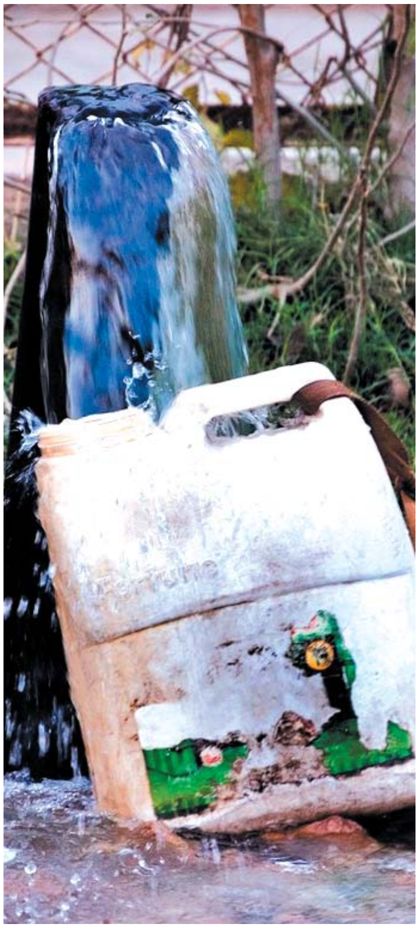
A total of 850 connections (individual and shared) were installed during the pilot phase. After successful implementation of these pilots, the Bangalore Water Board decided to replicate the results in other slums. The Board's Social Development Unit undertook extension of water supply and sewerage services through a 'Package Program' in coordination with nongovernmental organizations and community-based organizations, whereby slum dwellers were allowed to legally connect to services, provided they paid for the connection. Today there are about 6,000 connections across 46 slums in the city. Households in poor settlements are willingly paying regular water charges. By connecting all slums to piped water, the Board is reducing nonrevenue water and hopes to slowly phase out the over 15,000 public taps within city limits.

[14] (a) WSP-SA. June 1999. *Willing to Pay but Unwilling to Charge—Do Willingness-to-Pay Studies Make a Difference?*; (b) Chetan. 1995. Study on *Willingness to Pay for Water and Sanitation Services—Case Study of Baroda*; (c) Whittington, Dale, S.K. Pattanayak et al. 2001. *Willingness to Pay for Improved Water Supply in Kathmandu Valley, Nepal*, Research Triangle Institute, Final Report.

pocket to another. However, even though there may be no physical transfer of the money, the payment should be accounted for to ensure that the revenue and the cash are available to the service provider. Of course, this requires that the accounts of the service provider are clearly separated from those of other public entities.

Difference between actual and estimated consumption: There are two ways to reduce this element of nonrevenue water: improving the quality of the estimates (which could be very difficult), and installing and reading customer meters, recording the readings in a database and calculating the difference between readings and actual consumption. This is important to capture, especially in cases where billing is not based on meter-based charging practices and where a flat rate has been imposed. In such cases it would be good to be able to estimate consumption and see the difference between the two since the imposition of a flat rate also encourages ill practices of no water conservation. This estimate may also be able to indicate that the meters are not in working condition.

Water used for operational purposes: Unbilled authorized consumption also results from water being used for operational purposes such as flushing and disinfection functions. In such cases it would be important to at least keep track of the volume of water used so that it is kept within reasonable limits and the utility can inculcate some habits of controlled use. More efficient flushing and disinfection operations can help reduce this component. Measuring the volume of water used for these kinds of operations can help if



combined with incentives to the crews that can perform these operations successfully with lower volumes of water.

Water used for firefighting: The ways to reduce this component are beyond the scope of this series. However, the service provider could help authorities find ways to reduce the number of fires or to extinguish them more rapidly and effectively.

Apparent losses include unauthorized consumption (basically, illegal connections) and metering inaccuracies (under-registration, stopped or defective meters, and data handling errors).

Illegal connections: Can only be reduced if water providers have in place policies to convert them into legal connections. An efficient tariff regime with appropriately targeted subsidies is vital to address special cases of households lacking the resources to pay for the service. As a last resort, a service provider should have credible measures for disconnecting those who deliberately do not want to regularize their situation despite the opportunities given to them. Illegal connections can be tackled through a careful analysis of the customer database and comparing it to municipal registers or, if existing, combining geographic information system data with that used by the municipality or other service providers. In Bangalore, the Water Board has a disconnection policy whereby connections are initially clamped off at the street level, after which legal notices are sent. In the event that still no action is taken, the Board resorts to disconnection.

In many cases, poor settlements resort to illegal connections because the service provider refuses to connect them due to many reasons (lack of land ownership titles, uncertainty on whether they will become regular customers and pay their bills, and so on.) The best solution for this problem would be to find ways to connect poor people and get them to pay their bills. Again, as demonstrated in the case of Bangalore (Box 8), the water utility mobilized slums and successfully helped them connect to the network. These customers continue to be served with water, receive bills, and make payments. Earlier, the Water Board's policy was that a connection could not be approved unless the resident provided a proof of residence. Rules were subsequently eased so that the

Water utilities will need to incentivize their staff to undertake better billing practices, not only checking for illegal or bypass connections but also for connections with meter inaccuracies.

requirement for formal tenure proof was replaced with a simple proof of residence such as a ration card, election identity card or even an identity card.

Sometimes, existing legal customers using large volumes of water install illegal, or bypass, connections to reduce their water bill. Analyzing the customer database, billing history, and visiting the customers are ways to tackle this problem. Meter readers can play a very important role detecting this kind of situation. In Bangalore, meter readers and utility staff played an important role in improving commercial efficiencies. The Water Board incentivized utility staff and meter readers through healthy competition to undertake better billing practices, not only for checking illegal or bypass connections, but also of connections with meter inaccuracies (as discussed later). Monthly billing targets were set and reviewed, after which the best performing zone for revenue targets was rewarded.

Metering inaccuracies can be divided into two main categories:

Meter problems: These could be related to procuring meters of inadequate class or poor quality, premature wear or corrosion due to aggressive water, low flows and customers tampering with the meters, among other reasons. Careful attention on selecting the meters to procure is the best way to avoid the first three causes mentioned, while dedicated customer service and education policies could help to deal with the fourth one. Ultimately, a sanctions policy could be implemented to deal with the most difficult cases. As Box 9 indicates, Bangalore resorted to using only high quality meters that were more reliable, accurate, and durable.

Data handling problems: For providers who do bill according to actual consumption, taking readings, recording and then handling data by meter readers is another potential source of nonrevenue water.

There is a wide range of options for recording readings and producing the bills, from manual recording in a table containing only the account number and address, to remote centralized automatic reading. Deciding on one option for handling the data will depend on the particular circumstance for each service provider.

However, as a practical consideration, it is advisable to avoid copying the data from one table to another as much as possible.

Recording readings through a handheld data entry device could be especially helpful as preloading previous readings could warn the meter-reader of any data entry mistake beyond a certain threshold so that he can correct it immediately.

Some utilities in India, in Hyderabad for instance, have been using handheld data entry devices for recording meter readings. The Board has witnessed improved billing efficiencies as a result of these initiatives. Initially the Board outsourced this function to a specialized firm that had relevant experience in this function. It is simultaneously also training its own meter readers so that they can take over this function in due course.[15]

If these devices cannot be provided to the meter readers and they have to record the readings manually, then including the previous reading and an indication of the expected new reading could be helpful. However, the last option would also induce the meter reader to record an 'educated guess' of the new readings instead of the actual ones.

In summary, inadequate/no measurement facilities, inadequate calibration of bulk meters, under-registration, poor quality and inaccuracy of customer meters, faulty and stopped meters, inadequate meter maintenance and replacement policy, inadequate meter reading practices and under-estimation of water for free supplies and operational use are problems that can be corrected only if the water service provider has a robust metering policy in place for its own facilities and all the water connections that it serves. This will mean checking bulk meters, replacing customer meters at the end of their useful life and also actively checking them through regular tests and repairs. Monthly meter reading and billing, together with other measures, may help monitor and prevent customers from tampering with their meters. A proactive metering policy is also a prerequisite for the effective implementation of the District Metered Area approach.

Box 9: Metering Practices (Bangalore)

Bangalore is one of the few cities in India that has all its 0.4-million connections metered, with the metering program being in practice since 1966. Previously all household connections were installed with 'Class A' meters that had an approximate life of three to five years. Costing US$11.2 (as of 2004), the meter dials were prone to moisture and air and were less accurate.

Under the nonrevenue water project 15,000 meters were replaced with 'Class B' meters that are more accurate and durable. Costing US$30, these meters are multi-jet meters, tamper-proof, and robust in nature, having an approximate life span of seven to 10 years. They are air resistant—they measure air to a lesser extent, since the magnetic drive inside the meter gets disengaged once air passes through the meter. These meters also capture very low water flows in case of low pressure supply.

The utility has also been actively encouraging regular testing and repair of consumer meters. Initially it was itself undertaking all meter testing and repair work, repairing and testing approximately 1,500 meters on average in a month. In October 2003, it outsourced meter repairs work to a private agency. It charges its consumers a meter maintenance fee for undertaking these repairs.

[15] More details on this initiative are found in Series 2, on billing and collection practices.

Reducing nonrevenue water is achievable but it remains challenging because the approach to reducing and managing NRW goes beyond technical solutions.

Addressing the Institutional, Organizational, and Regulatory Arrangements for Creating a Suitable Environment for Controlling NRW

Other policies for keeping NRW at target levels relate to the internal organizational structure, regulatory framework for triggering NRW control, staff capacities and training, as well as customer care and information campaigns. These are important because they ensure that NRW management programs become a sustainable practice.

NRW reduction will only be successful if there is an adequate enabling environment and a proper incentive structure for performance improvements. The current inherent institutional deficiencies in the Indian context would need to be resolved through appropriate institutional arrangements that incentivize service providers to be more accountable and, at the same time, clarify roles and responsibilities of all stakeholders in the water supply and sanitation sector so that the appropriate stakeholder can be held accountable for performing its specific functions properly.[16]

Any NRW management program should hence ensure that the incentives are duly aligned with the objectives of developing an efficient and reliable service provider that meets the needs of all consumers. As demonstrated in Box 10, institutional arrangements in the Vietnamese city of Haiphong were designed such that NRW management was targeted at the ward level. The creation of strong local units delivering decentralized services at the ward level demonstrated an innovative way to reorganize the institutional arrangements for increased accountability. Similarly, appropriate employee incentive schemes were set up in both Bangalore and Haiphong to reward staff for improved performance through bonuses, rewards, certificates, and recognition. Such initiatives incentivized staff sufficiently such that it resulted in improved services.

Internal Organizational Structure: Regarding internal organizational structure, traditionally, service providers have—besides the regular administrative, finance, and human resources departments—technical and commercial departments.

The technical department is usually responsible for water production, pumping, storage and distribution, network operation and repair, and may include the engineering department that would deal with planning, designing and construction of new assets. The commercial department would produce and distribute bills, collect payments, and receive customer complaints. However, this kind of organizational structure does not always lead to a strong awareness of NRW levels and makes effective NRW reduction and management more difficult.

An alternative way of internal organization takes into consideration the different functions or processes that take place in what one could call the vertical flow within the service provider. In this sense one could identify production, transmission (involving main pumping stations, reservoirs and trunk mains) and retail distribution and selling to the end user.

This organizational structure resembles a clear supplier-customer chain where each department produces or receives water and has to deliver it to its customer. The number of production and transmission departments is determined by the number of facilities and the way the service provider wants to bundle them, while the number of retail departments would be ideally determined by the number of District Metered Areas. In this type of organization it is very easy to focus on NRW levels and management as the manager of each department is responsible for its own NRW, considering that the production and transmission departments are selling the water they receive to their customer downstream the vertical flow within the service provider.

The Haiphong case demonstrates how institutional arrangements could be rearranged such that each ward was made responsible for its own water supply functions.

Technical and administrative unbundling proved to be an innovative way for ensuring that service delivery improvements were indeed recorded at the individual ward level by making every local staff more accountable for every unit of water produced. Employees felt increased job responsibility because they were bound by trust to the community and, at the same time, monitored by them.

[16] The issue of improving upon the current institutional deficiencies is beyond the scope of this paper and has been addressed in the Performance Improvement note, Series I.

Box 10: Decentralizing Service Delivery (Haiphong, Vietnam)

The nonrevenue water (NRW) program in Haiphong targeted the reduction of water losses through rehabilitation and reconstruction work of the water network at the '*phuong*' or ward level. [17] The aim was to redistribute recovered 'lost water' to areas of poor supply through a two-phase program. The first phase was a pilot in one *phuong*—Lam Son ward—that would demonstrate to consumers how improvements in water supply services were going to be implemented subsequently in the remaining 37 *phuongs*. Lessons from the pilot would then be expanded during Phase II to remaining *phuongs* starting in 1994, with all 38 *phuongs* achieving NRW improvements by 2000. The model would work through unbundling of the water supply network for both technical and administrative aspects (refer Box at right) such that each ward unit could perform its own water supply services. It cost approximately $1 million per ward to fully improve the ward's water supply delivery. While ward-level infrastructure improvements were paid for by the Haiphong Water Supply Company through various means,[18] the customer had to pay for the service connection and for the meter, total cost for which ranged between $30 and $60 per household, depending on the length of the service pipe.

Technical and Administrative Unbundling

Technical Unbundling involved enforcing good technical standards at the ward level. The utility's ward offices connected all customers within their ward to distribution lines through branch connections, installing a meter on every connection, and signing a customer contract that detailed the company's and consumers' rights and responsibilities. Metering customers all at the same time helped prevent illegal connections. In addition, the practice of installing a master meter in each ward helped in reconciling ward billing with the amount of water the ward received from the water treatment plant. This helped monitor the points for distributional losses and its estimate and hence water bill collection efficiency. Improved services were not going to result only from construction of more infrastructure or replacement of water mains, but from ward-by-ward diffusion of distribution network improvements and from careful network management.

Administrative Unbundling involved the creation of ward level local Haiphong Water Supply Company consumer service sub-offices, staffed with five or seven members of the community, including a manager, two water meter readers, two bill collectors, and a technician for minor repairs of pipes and meters and for overall operation and maintenance of the *phuong*. These offices undertook meter reading, maintenance and revenue collection once the network was rehabilitated and established.

Ward-level work began by improving all distribution, branch, and household pipeworks in the ward, complete metering of the wards' consumers, and implementing a reliable monthly billing and collection system. The company also put in place a disconnection policy for disconnecting consumers if bill payments were delayed by more than 20 days. An office with employees selected from ward residents was also set up and made responsible for all operation and maintenance of the *phuong* network. This helped provide constant and immediate communication between the utility and consumer, facilitating quick responses to consumer needs and tailoring services according to consumer expectations. At the same time, the employees were privy to information on residents, being familiar with characteristics of the households in their ward.

These local staff were incentivized to not cheat the system[19] through an employee incentive system where ward level staff salaries were tied to a variety of yearly performance targets as well as a system of rewards (certificates, awards, and financial bonuses) and punishment (written and verbal warnings and salary deductions). For example, if NRW achieved was 1 percent lower than the set performance rate then a bonus of VND 20 million (approximately US$1,200)[20] was awarded, 40 percent of which was given to the employee directly responsible and 60 percent for the remaining functions of the utility. Employee performance was evaluated at the department level on a quarterly basis and sent to management for a review. A contract was also signed between the Haiphong Water Company and the ward for defining ward level obligations (consumer level and overall Haiphong Water Company). Consumers were also made aware of the ward's responsibilities through a billboard, displayed outside the ward office, which detailed both consumer and ward office obligations and responsibilities. Monthly ward People's Committee meetings were also held for reporting and addressing community water supply service delivery needs as well as to provide feedback on utility performance given the implementation of the ward model.

[17] The ward or *phuong* is the smallest local unit of socialist government in Haiphong, with 1,500 to 3,000 households (10,000 to 16,000 people).
[18] In Haiphong this cost was covered not only by company revenues, but also through a Finish International Development Agency grant and a credit from the World Bank for the Socialist Republic of Vietnam's Water Supply Project.
[19] By drawing local staff into ward offices, the risk existed that there could be collusion between the ward employees and the ward consumers. This was countered sufficiently.
[20] US$1 = VND 16,216 (as of April 19, 2008). Conversion rates are from www.xe.com; all conversions in the text are approximations.

Any nonrevenue water management program should ensure that incentives are aligned with the objectives of developing an efficient and reliable service provider that meets the needs of all consumers.

Incentives for improved accountability: Within an improved institutional and operating structure, water service providers also need to be encouraged to demonstrate improved accountability of functions and responsibilities.

In some international good practices as well, as detailed in Box 11, service providers have used performance contracts for incentivizing staff to better services.

This is also demonstrated in both the Bangalore and Haiphong cases where employee incentive schemes rewarded staff for improved performance through bonuses, rewards, certificates, and recognition. Employees were also given disincentives to under-perform, since they were penalized when performance was not up to the mark. Both cases also set up clearly defined performance standards that had to be achieved by employees if they wanted to be rewarded for performance improvements.

In Haiphong, a particularly transparent incentive scheme encouraged performance of the line managers at the ward level, where staff and company shared benefits of any efficiency gains achieved.

Regulatory framework: The regulatory framework and, especially, the tariff regime in place are also key issues, particularly when it comes to fulfilling the regulatory objectives of setting, monitoring, and enforcing principles of efficient tariffs and improved service quality and standards.

Enforcing NRW programs that eventually meet these objectives would need to put in place regulatory mechanisms, institutional responsibilities, and accountability frameworks involving suitable incentives and sanctions, and also clearly define the assignment of roles and responsibilities at various levels of government. Such arrangements would also need to deal with wastage and proper assessment of investment projects by providing reference regarding the proportion of subsidy (if any) included in the tariff and allow a correct allocation of costs and benefits from eventual projects to be implemented.

For instance, regulatory frameworks can be designed such that the impact of an NRW program can be monitored. The service provider's NRW performance can be reviewed through a memorandum of understanding that clearly establishes the various service delivery related regulatory objectives to be achieved over a specified timeframe, with related incentives or disincentives for their achievement or non-achievement. The actual performance of the service provider against these targets could be evaluated through third party assessments, financial audits, and beneficiary analysis through consumer feedback to ensure transparency. In some cases the provider could also be made to comply with disclosure requirements that would enhance accountability in service delivery.

Staff training and capacity building: Equally important for sustainability of NRW measures is training of staff in new skills and techniques. Any effective NRW management program would require a range of skills at all levels, starting from managers and professional engineers to technicians and plumbers.

Staff members need to be motivated and skills in techniques and technology need to be transferred to them for

Box 11: Incentive-Based Performance Contracts

In some countries water service providers have used performance contracts for incentivizing staff to undertake sustainable service delivery improvements. For instance, in **Senegal**, the contract included specific and time-bound targets covering areas of operational efficiency including reduced water losses and improved billing and collection. The contract effectively incentivized the private operator to achieve these set targets, by rewarding the private operator not for the water that it produced but for water sold and paid for.

Another example can be found in Uganda's **National Water and Sewerage Corporation**, which signed performance contracts with its respective operation areas, using an internal incentive contracting mechanism with financial incentives for encouraging managerial efficiencies. A detailed set of performance targets for each area were devised and included, among others, improvements in billing and collection and reduced water losses. The performance contracts incentivized staff to meet these performance targets through bonuses over and above their regular salaries.
A set of penalties were also imposed in case of poor performance.

effective leakage management and system operation and maintenance.

The NRW management plan would need to be accepted along with an understanding of its challenges and advantages through improved awareness and motivation of staff to adopt such strategies.

Staff members need to be trained adequately so that they have hands-on experience with such strategies and can sustain the efforts of keeping NRW at acceptable levels in the long run.

This was kept in mind while designing the NRW reduction programs in Bangalore and Haiphong. In Bangalore, particularly, Phase II of the project focused in part on training utility staff for specializing in NRW management such that they could control the system once the pilot project was over.

Asset management: Although it is not a specific action related to NRW reduction programs, an adequate asset management plan would also need to be maintained by staff as it is a very useful tool to help maintain NRW at the desired level by triggering all the rehabilitation and renewal actions required to keep the assets in normal working condition.

Such a plan would also help in making sure that network rehabilitation is being undertaken in an economical manner. This is important since many times the piped network may be very old and damaged and may also not be designed to take into account management aspects and revenue collection practices for the provider, especially in the absence of metering practices, missing network maps, and so on.

A periodic and systematic monitoring procedure must be in place to ensure that performance standards and targets are being met within the specified timeframes.

Monitoring Target NRW Levels

The first step of any follow-up strategy is to implement a periodic and systematic monitoring procedure. This comprises reading of all bulk, district, and customer meters at least once a month and calculating the NRW for each zone in which the system is divided (ideally District Metered Areas). In all three case studies explored in this note, regular monitoring was undertaken to ensure that performance standards and targets were being met within the specified timeframe. This is

Table 3: Performance Indicators for Water Loss Management

Component	Type	Basic Performance Indicator	Detailed Performance Indicator
Nonrevenue water	Financial	Volume of NRW as % of system input volume	Value of NRW as % of cost of running system
Real losses	Water resources	Volume of real losses as % of system input volume	
Real losses	System operational	Liters/service connection/day [For systems with 20 or more services/km of mains]	The Infrastructure Leakage Index = ratio of Current Annual Real Losses/Unavoidable Annual Real Losses (see Box 12 for details)
		Use m^3/km mains/day [For systems with fewer than 20 services/km of mains]	
Apparent losses	Operational		m^3/service connection/ year
Water losses	Operational	m^3/service connection/year	

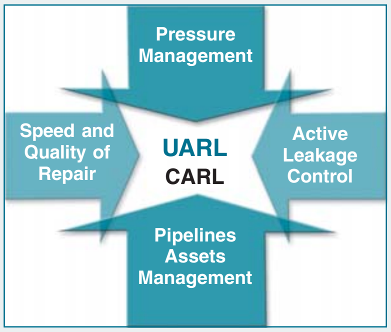
Source: Manual of Best Practice (PIs for Water Supply Services), IWA.

specially demonstrated in the Haiphong case where monthly ward level meetings were held for reporting and addressing community water supply service delivery needs as well as for providing feedback on the ward's performance as per the specific service standards that were set. Providers need to find appropriate NRW performance indicators (see Table 3 and Box 12) that could be monitored and evaluated on a regular basis. Suitable indicators need to be drawn up for monitoring all components of water loss. The use of various performance indicators as opposed to using only one percentage indicator for NRW allows water providers to properly baseline, track and target, various components of water loss including financial, operational and water resources aspects.

The second step would be to prepare a table for comparing the different zones or District Metered Areas and prioritizing future actions. Many service providers that have been successful in reducing NRW have a team looking after service quality, NRW, billing, and collection for each District Metered Area. Usually, there would be a monthly meeting where management and team leaders would discuss the success and failure stories, derive lessons and best practices, and award prices for successful teams.

These practices create a sound competitive environment and lead all teams to come up with their own ideas about what to do in their own District Metered Area to improve NRW levels, how much supply they need and what their target NRW could be. The proposed actions would be assessed using a cost benefit approach, prioritized and presented as the plan for that District Metered Area. Once approved by management, it will be implemented and, later on, it will be assessed regarding its actual cost and effectiveness. In broader terms, the policies and processes of producing and delivering water should be reviewed and rethought about, in case there is scope for improvement. Some policies to be reviewed periodically relate to network management, pumps, reservoirs and valve operations, construction materials and specifications, rehabilitation and maintenance practices and connection of new customers, especially those that may have difficulties paying the full cost of the new connection.

Box 12: The Infrastructure Leakage Index



The Infrastructure Leakage Index[21] measures how effectively a utility or water service provider is managing its distribution network for controlling real losses at current operating pressure levels. However, this does not imply that pressure management is optimal, and it may be possible to reduce the volume of real losses (but not the Infrastructure Leakage Index) by improved active pressure management. It is a measure of how well repairs, pipelines and asset management and active leakage control are controlled, as indicated in the diagram alongside.

Infrastructure Leakage Index is defined as the ratio of Current Annual volume of Real Losses (CARL) to Unavoidable Annual Real Losses (UARL). While this is an indicator with no units and thus facilitates comparisons between providers using different measurement units, it requires attention when calculating Unavoidable Annual Real Losses, computed as:

UARL (liters/day) = (18 x Lm + 0.8 x Nc + 25 x Lp) x P

where Lm = mains length (km); Nc = number of service connections; Lp = total length of private pipe, property boundary to customer meter (km); P = average pressure (m).

The length of mains and number of service connections are usually known, but the distance between the property line and the meter may not be available. Customer meters are usually located close to the property line and hence 'Lp' is 0; for the remaining cases, the average and total length of underground pipe from the property line to customer meters could be estimated by inspecting a small random sample of connections.

Source: Best Management Practice 3: 'System Water Audits and Leak Detection', Review and Recommendations for Change, California Urban Water Conservation Council, Thornton International, April 2005.

[21] This index is one of the most recent performance indicators for NRW and was designed at the IWA Leakage Conference in Cyprus, Liemberger, 2002.

> Any successful nonrevenue water management program will need to address technical issues within the overall institutional, organizational, and managerial environment, if it is to remain sustainable in the long run.

Conclusion

For developing an efficient strategy for NRW management, it is hence key to gain a better understanding of the reasons for NRW (as analyzed through a water balance) and the factors that influence its various components. Then techniques and procedures can be developed to suit specific local characteristics of the network, the consumers and the provider, to address and control each of the loss components. As discussed through the course of the field note, planning and implementing an NRW reduction strategy requires a diagnostic approach to understand and estimate how much is being lost, where and why is it happening, how to reduce losses and improve performance and how to sustain such a strategy (as detailed in Table 4).

All three case studies demonstrate that successful leakage reduction is not a result of sporadic and irregular technical exercises to reduce physical losses. Such programs should be a continuous effort and must control commercial losses since the latter helps improve the revenue stream of the water company almost immediately. In the longer term, the effectiveness of NRW programs is a function of managerial efficiency and institutional accountability.

Technical solutions are generally not easy to implement, since the network may be very old and damaged, with many illegal connections and high NRW levels. The network may also not be designed to take into account management aspects and revenue collection practices of the provider such as an absence of metering (bulk or consumption), missing network maps, and so on. Hence, while technical solutions are essential and may be time consuming and not easily result in quick successes, their long

Table 4: Designing a Nonrevenue Water Management Strategy

Key Questions	Techniques
How much is being lost?	*Water audit:* Measure components, check production or consumption, recalculate Measure components water balance, review records, operating procedures, skills
Where is it happening? Quantify leakage Quantify apparent losses	*Pilot studies:* Quantify total losses, that is, how much the leakage is in the distribution network, transmission mains and reservoirs and how much is non-physical loss; refine the water balance calculation
Why is water being lost?	*Review of network operating practices:* Investigate reasons for loss, that is, old/corroded pipes and fittings, poor practices, poor quality assurance, local influences as well as cultural, financial, social, and political factors
How can performance be improved? Design a strategy and action plan	*Development of an action plan:* Update records systems, introduce zoning/District Metered Areas; monitor water leakage; prioritize areas; address nonphysical losses; detect and locate leaks; initiate repair/rehabilitation policy, hydraulic modeling, develop geographic information systems
How can the strategy be maintained?	*Training/awareness:* Improve awareness and increase motivation; train staff with hands-on experience; monitor the loss management program; implement asset management systems

Source: Adapted from Leakage Management and Control: A Best Practice Training Manual, 2001. WHO.

term sustainability depends on effective institutions and finances. Technical solutions, thus, ultimately have to be commercially feasible and should be planned for, such as proactive and robust metering plans, checking for unauthorized connections, unbilled quantities, and volumes of free water.

Any NRW management program will therefore need to address technical issues and become part of the culture within the overall institutional, organizational, and managerial environment if it is to remain sustainable in the long run. It will need to also build relevant capacity so that local staff can keep the program going and, at the same time, develop an effective monitoring system that enables tracking whether target NRW levels are being maintained or not. Selecting the most appropriate approach for NRW management will depend on the level of leakage, the cost of leakage, and the cost-effectiveness of each method.

Reducing NRW is achievable but it remains challenging because the approach to reducing and managing NRW goes beyond technical solutions. Although it is not feasible to eliminate all NRW in a water utility, reducing it to efficient levels will be required to bring about some quick performance improvements in terms of both increased cash flows and improved services, that is, more water available to serve consumers.

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April 2008

WSP MISSION:
To help the poor gain sustained access to water and sanitation services.

WSP FUNDING PARTNERS:
The Governments of Australia, Austria, Belgium, Canada, Denmark, France, Ireland, Luxembourg, the Netherlands, Norway, Sweden, Switzerland, the United Kingdom, the United States of America; the United Nations Development Programme, The World Bank, and the Bill and Melinda Gates Foundation.

AusAID provides WSP-SA programmatic support.

ACKNOWLEDGMENTS:
This field note was peer reviewed by Mario Alejandro Suardi, Cyril Wear, Chris Heymans, Mathew Kurian, and Vandana Mehra

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Pronita Chakrabarti Agrawal
(research carried out in 2005 and 2006)

Editor: Anjali Sen Gupta
Pictures by: Sajid Darokhan
Created by: Write Media
Printed at: Thomson Press (India) Ltd