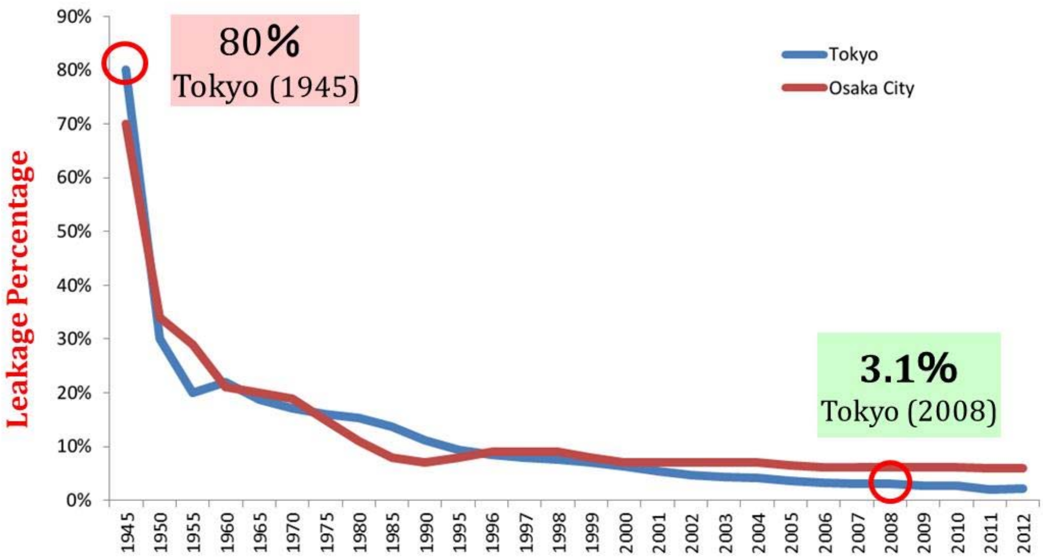
Theme 5. Reducing Non-Revenue Water

Contents

1. Introduction

The average water leakage rate of the water supply systems of the utilities in Japan in 2014 was only 4.69 %. This was not the case many years ago. Major cities in Japan suffered from high leakage rate after World War II (WW II). Tokyo, the capital city, had a leakage rate of 80 %. With persistent efforts, this was eventually brought down to 3 % in 2008.



Source: Modified from Bureau of Waterworks, Tokyo Metropolitan Government and Osaka Municipal Waterworks Bureau

Figure 1. Improvement in the Water Leakage Rate of Tokyo and Osaka City

This module describes Japanese experience in reducing non-revenue water and provides examples of effective control measures and will answer questions frequently asked by the participants of water supply training courses.

Q1. How did Japan reduce leakage from 80% to 3% in some large cities?

Q2. What are the effective measures for reducing Non-Revenue Water (NRW)?

Column: Definition of Non-Revenue Water (NRW) and Leakage

Japanese utilities use the water balance table system developed by Japan Water Works Association (JWWA) which is slightly different from that of the International Water Association (IWA) used by many utilities all over the world (Figure 2a). Many of them use “effective water rate” instead of “NRW rate” as the target performance indicator (Figure 2b). The effective water rate is made up of water consumption by customers, water used during the water treatment process, and unbilled consumption for public use. The “in-effective rate” is leakage and minor adjustments to customer billing such as discounts for the poor, or leakage or water quality deficiencies. Utilities are mainly looking at leakage for NRW reduction.

<table>
<tr><td rowspan="10">System Input Volume</td><td rowspan="2">Authorized Consumption</td><td rowspan="2">Billed Authorized Consumption</td><td>Billed Metered Consumption</td><td rowspan="2">Revenue Water</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="8">Water Losses</td><td rowspan="2">Unbilled Authorized Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="8">Non-Revenue Water (NRW)</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="3">Apparent (Commercial) Losses</td><td>Unauthorized Consumption</td></tr>
<tr><td>Customer Metering Inaccuracies</td></tr>
<tr><td>Systematic Data Handling Errors</td></tr>
<tr><td rowspan="3">Real Losses</td><td>Leakage on Transmission and Distribution Mains</td></tr>
<tr><td>Leakage and Overflows at Utility's Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to point of Customer metering</td></tr>
</table>

Figure 2a. Water Balance Table of IWA

<table>
<tr><td rowspan="8">Supplied Water</td><td rowspan="4">Effective water</td><td rowspan="2">Revenue Water</td><td>Billed Water</td><td rowspan="2">Revenue Water</td></tr>
<tr><td>Bulk Sales/Emergency</td></tr>
<tr><td rowspan="2">Effective Non-Revenue Water</td><td>Consumption by Utilities</td><td rowspan="6">Non-Revenue Water (NRW)</td></tr>
<tr><td>Customer Metering Inaccuracies (Apparent/Commercial Losses)</td></tr>
<tr><td rowspan="4">Ineffective water</td><td colspan="2">Adjustment (discounted customer billing for poor services caused by leakage or water quality deficiencies)</td></tr>
<tr><td rowspan="3">Real Losses (Ineffective Non-Revenue Water)</td><td>Leakage on Transmission and Distribution Mains</td></tr>
<tr><td>Leakage and Overflows at Utility's Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to point of Customer metering</td></tr>
</table>

Figure 2b. Water Balance Table in Japan

2. Status of Non-Revenue Water

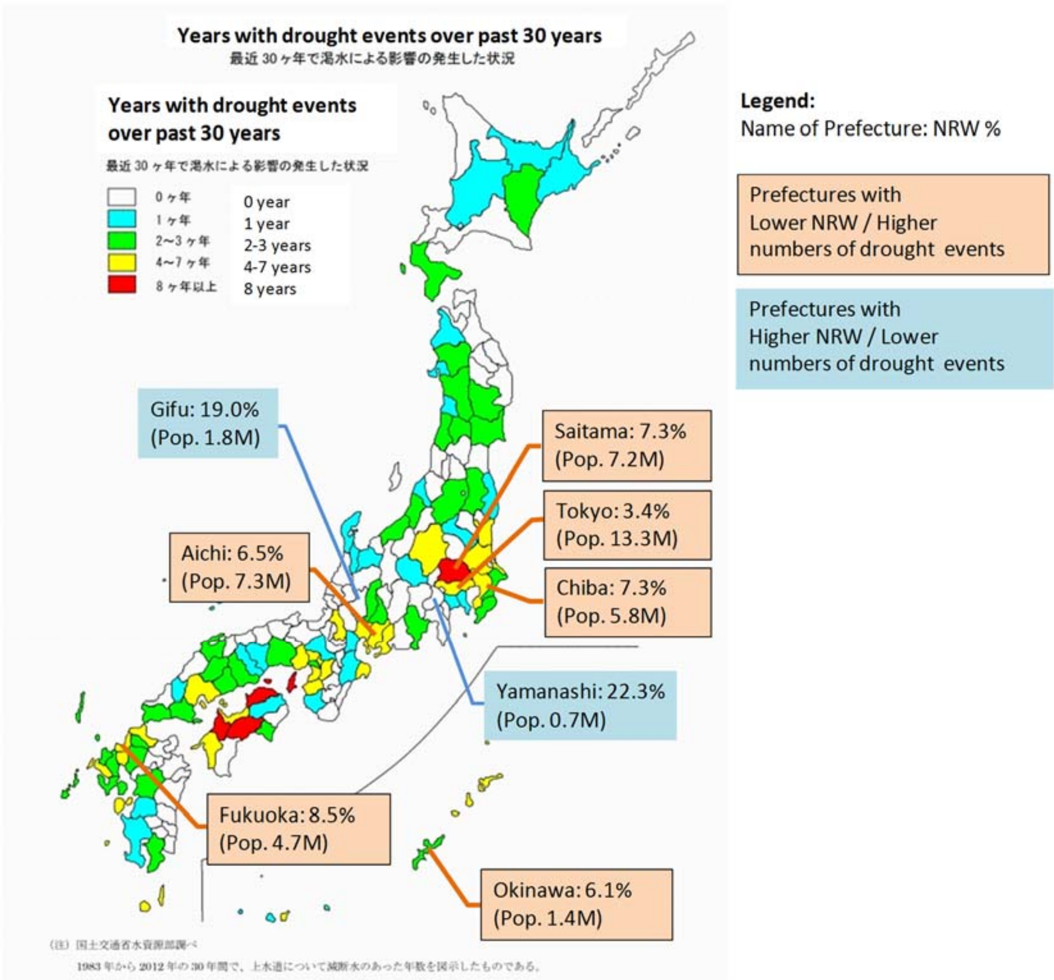
(1) Non-Revenue Water Rates across the Country

The average NRW rate in Japan was only about 9.82% in 2013 and the rate in Tokyo metropolitan area is less than 4%. However, the rates vary depending on the location, conditions of water demands, limited water sources and drought conditions.

NRW rates range widely in Japan. The Tokyo metropolitan area has a rate of < 4% and the rate for Okinawa, Aichi, Osaka, and Fukuoka is less than 9% (Figure 3). Where population density is low and distribution pipe length per connection relatively long, the rate exceeds 30%. Mountainous areas with abundant good water resources tend to have non-revenue water rate of > 20%, as in Yamanashi, doubling the national average of 9.82%. Social and natural conditions seem to have considerably impact on non-revenue water.

The areas with very low non-revenue water rates appear to be: (1) major metropolitan areas where population density, water demand and cost of water resource development are very high (e.g. Tokyo, Aichi, Osaka); (2) areas with limited water resources that often experience drought conditions (e.g. Okinawa, Fukuoka). This suggests that the availability of water resources affects the NRW rate. Not all utilities have low NRW, they mainly maintain NRW at an acceptable level.

As a benchmark for performance, the 2004 “Water Vision” published by the Ministry of Health, Labour and Welfare sets the effective water rate target of > 98% (≒ 2% leakage) for large-scale water utilities, and > 95% (≒ 5% leakage) for small- and medium-scale water utilities. This is quite low but the utilities are making their best effort to achieve the target leakage rates.



Source: Statistics on Water Supply (2014), the Ministry of Land, Infrastructure, Transport and Tourism website

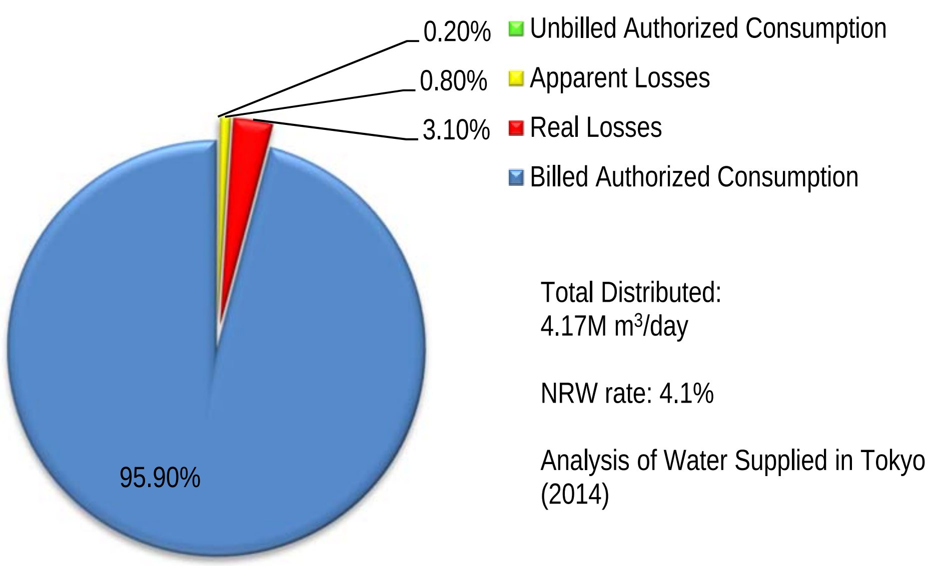
(Years with drought events over past 30 years)

Figure 3. Differences in Non-revenue Water Rates in Japan (by Prefecture)

(2) Components of Non-Revenue Water

Leakage from water service pipes (real losses) and metering inaccuracy (commercial or apparent losses) are the major components of non-revenue water in Japan. There are very few illegal connections. Control measures to reduce leakage are of top priority.

Figure 4 shows the rates of revenue and non-revenue water, and the components of non-revenue water in Bureau of Waterworks, Tokyo Metropolitan Government (BWTMG**)**. The largest component of non-revenue water is real losses which consist of leakage and the second is metering inaccuracy, also known as "commercial losses." These two components made up the overwhelming majority of the losses and illegal connections do not show up on the statistical figures because the cases are few. Other water utilities in Japan have similar non-revenue water composition. The utilities are committed to reduce in-effective water and implement control measures to reduce leakage.



Source: Materials by Shozo Yamazaki

Figure 4. Apparent and Real Losses in Water Supply in Tokyo

3. Causes and Control Measures for Non-Revenue Water

(1) Importance of Reducing Non-Revenue Water

NRW is a waste of resources and an unnecessary economic loss, taken seriously by management. Furthermore, contamination of the water supply can occur through leakage points and associated pressure reduction in the pipelines. National notices were issued to emphasize the need for water leakage control. Utilities form networks to develop and implement measures.

Non-Revenue consists of unbilled consumption and water losses which is “water not generating revenue”. Therefore, it affects the financial viability of utilities through lost revenues and increased operational costs. The major causes of commercial or apparent losses are mal-functioning or broken meters, meter reading errors, and illegal connections. If these problems are left unaddressed, the utility would lose the customers’ trust and with the flat rate system this can reduce the likelihood of customers taking water conservation seriously.

Real losses mostly from aging or rusting pipes and drop in water pressure in distribution networks can result in the degradation of water quality. This can affect customer satisfaction and willingness to pay. Utilities cannot afford to waste scarce resources through leakage, given the high cost of water resources development and the risk of having to impose water restriction in the event of water shortage.

NRW affects the performance of the supply system and financial conditions of the utilities. Utilities across the country have dealt with NRW successfully with the help of JWWA since they could communicate with one another how to get to it utilizing the network. Repeatedly issued national notices also accelerated the measures by disseminating the importance of NRW. The timely publication of technical documents such as the *Water Supply Facilities Maintenance Manual* and *Guidelines for Water Leakage Prevention* which contains specific methods for leakage prevention has been very helpful for the utilities.

(2) Causes and Preventive Measures for Leakage

Measurement of water flow in distribution networks is the crucial first step in the investigation of non-revenue water. Construction quality, leakage detection and repair, good quality equipment, are required to control real loss (leakage). Minimizing metering errors is also essential.

It is necessary to measure water flow in distribution networks when investigating the causes of non-revenue water. A pilot project in a selected distribution block can be carried out to obtain the base line values for water flow and the night time minimum flow. Then the leakage location can be confirmed and the leak repaired, or if necessary water meters can be installed or replaced, or illegal connections removed. Monitoring the water flow after the implementation of control measures, would indicate if the problems have been corrected.

Table 1. Water Leakage Control

Category	Item	Measures
Basic measures	Preparation for leakage prevention	Arrangement of financial and human resources
		Preparation of documents (Drawings of pipe network, distribution blocks, etc.)
		Information management system for pipe network
		Arrangement of areas and measuring devices
	Survey on current conditions	Analysis of water supply and leakage, measurement of water pressure
		Analysis of leakage and its causes
	Research and development of pipe materials	Materials for distribution and service pipes, joints and attachments
	Technological development	Measurement of leakage, investigation of underground pipes
Symptomatic measures	Responsive work	Immediate repair of visible leakage
	Planned work	Early detection and repair of leakage detected underground
Preventive measures	Water supply plan	Planning in consideration of leakage prevention
	Water network analysis and evaluation	Water pressure, aging pipes and joint types, etc.
	Design and construction	Earthquake resistance, durability, anti-corrosion characteristics, water tightness
	Replacement of aging pipes	Replacement of distribution pipes and service pipes (including material upgrade)
	Improvement of structures of water service devices	Integration of road-crossing pipes
	Pipe protection	Installation of meters to places closer to public-private border
		Devices for anti-corrosion and leakage prevention, strengthening of pipe bend
	Proper treatment of out-of-service pipes	Clearance of old pipes at interconnecting part
		Management of water service devices
	Patrol	Supervision to avoid damages by companies carrying construction near water supply facilities
	Adjustment of water pressure	Arrangement of distribution area, installation of pressure reducing valves

Source: JWWA "*Guidelines for Water Leakage Prevention*"

Measures against real losses include proper installation and high quality material, leakage detection and repair, and quality control of water supply equipment. Minimizing metering errors would reduce commercial losses.

1) Proper installation and high quality materials

Making the pipe connections in the distribution networks must be carried out with proper technical know-how and high quality material. Looking back the history in Japan, pipe technologies largely contributed to the leakage reduction. Until the 1950s, most of the pipelines were gray cast iron pipe with lead-caulked bell-spigot joints which used the hemp yarn and lead for making the connection. This type of pipeline has low ductility and flexibility and the joints can become loose causing leakage problems. In the 1960s, utilities began to use T-type push-on joints and A-type mechanical joints with rubber seals. K-type mechanical joint which uses rounded rubber joint to improve the water tightness was introduced later; this is the technology developed in Japan and has been used until today. Advanced pipe joining technology also contributed to leakage prevention. In addition to technological improvements, utilities also have strengthened construction supervision such as using a detailed check-list to ascertain uniform construction quality.

House connections are also one of the most important causes of leakages. Nowadays in Japan, most water leaks are found on house connections. To ensure proper installation the supervisory personnel would check that (1) the soil cover is not too thin, because the pipe wall can be damaged if there is lack of protection from external pressure or by construction material left in the ground unintentionally; (2) there is adequate service branch connections, and (3) the pipe material can withstand surrounding conditions. Construction qualities of house connections are quite important because these problems, especially for (1) and (2), could be solely prevented by quality control of the construction.

The official certification system, the establishment of the Plumbing Constructor's Association and the registration system of plumbing constructors, all help to ensure that the installation of the pipelines is carried out properly and competently. Utilities have a good archival system for drawings of pipe installations prepared for house connections. This enables them to respond quickly to reported problems and minimize leakage.

2) Detection and repair

The detection for and repair of water leaks have been carried out routinely so that the utilities stay on top of any potential problems. Most leaks found on water service pipes and could be detected by listening for leaking sounds around water meters and at service connections.

Measuring night time minimum flow at distribution blocks helps to pinpoint areas that are vulnerable to leakage, and identify priority areas for detection and repair. 24-hour water supply and well-controlled water pressure makes it easier to locate water leaks. Persistent effort and well-trained staff are essential for conducting the daily routine which can involve night inspections.

3) Good quality water service devices

The quality of water service devices are assured by a) laws and regulations, b) technical standards, and certification and inspection by a third party organization, and c) the use of high quality materials.

a) Laws and regulations

Structural design and materials of water service devices and a registration system for the contractors installing service connections, are prescribed in the Water Supply Act (Article 16). More detailed specifications can be found in the ministerial ordinance by the Ministry of Health, Labour and Welfare (MHLW).

b) Technical standards, certification and inspection by the third party organizations

In Japan, most of the water supply equipment is manufactured domestically. The equipment has to comply with the Japanese Industrial Standard (JIS) and JWWA standards. JWWA also performs certification and inspection.

c) Pipe materials

Pipe materials such as lead and galvanized steel, commonly used in Japan, lack earthquake resistance and are vulnerable to corrosion causing leakage. Elution of lead or rusting of steel pipes affects the quality of potable water. Bureau of Waterworks, Tokyo Metropolitan Government is switching to stainless steel for water service pipes. Yokohama City uses three types of pipe material: PVC lined steel, stainless steel and dual-layer polyethylene.

d) Metering errors (commercial or apparent loss)

In Japan, the Measurement Law prescribes the required accuracy and replacement period for water meters. These requirements contribute to maintaining the required level of accuracy. The water meter is protected in a box and is on loan to the customer by the water utility. It cannot be arbitrarily removed or intentionally destroyed. Meters must be installed properly and appropriately maintained to reduce NRW.

Column: Illegal connections

Illegal connections are rare in Japan. Deeply buried pipeline and continuous flow (24-hour water supply) with appropriate water pressure makes it difficult for untrained persons to install unauthorized connections. In addition, customers usually have high ethical standards. Some water utilities made strong efforts to persuade illegally connected households to apply for the service legally. Illegal connections can be detected from the changes in consumption pattern shown in the meter logs. Therefore, the metering system is very important for the detection of illegal connections.

Phnom Penh Water Supply Authority is widely known for its success with administrative improvement. They reduced NRW from over 70% to 6% in 2011. They identified illegal connections and leakage using distribution flow monitoring, introduced by Japanese experts in JICA technical cooperation projects. Electromagnetic flow meters were installed in each distribution block. On one occasion, water theft was caught by a patrol unit following up on suspicious high water flow recorded during the night. PPWSA's reforms and successes are credited to the leadership shown by the utilities and the technical capabilities acquired from technical cooperation with Japan.

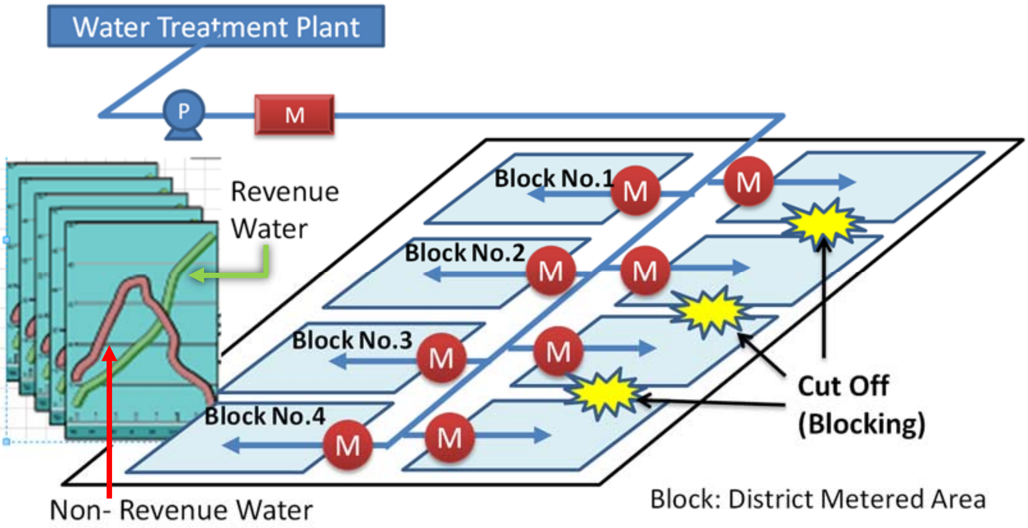


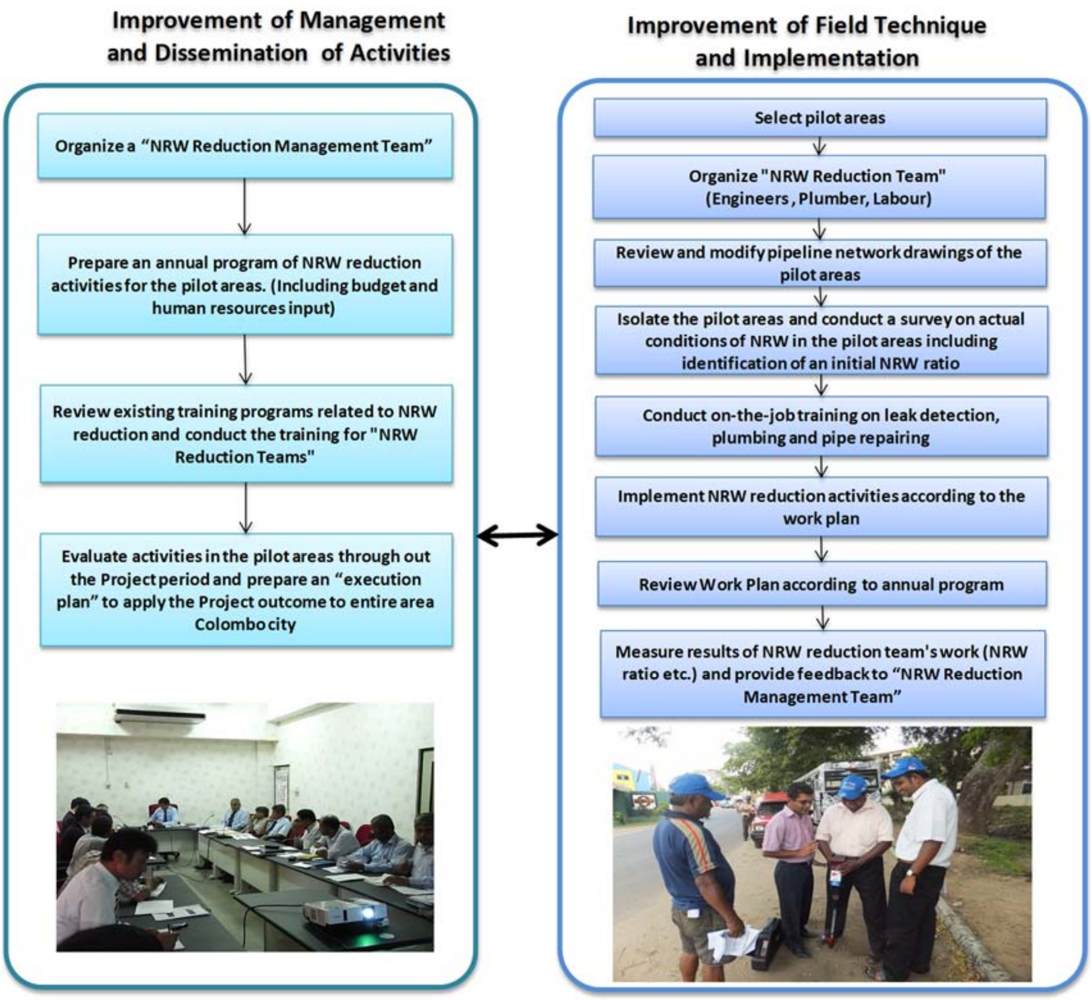
Figure 5. Distribution Monitoring System by PPWSA under Technical Cooperation with Water and Sewer Bureau, City of Kitakyushu

Column: JICA projects

JICA implemented several non-revenue water projects in developing countries and shared the experience and know-how of Japanese water utilities.

These projects emphasized: (1) identification of a responsible or lead department/division; (2) setting realistic and achievable goals; (3) employing quantitative indicators and monitoring to assess the effectiveness of preventive measures; (4) developing arms-length process for monitoring and assessing results; (5) preparing action plans for non-revenue water reduction; (6) offering incentives for improvements, bestowing rewards based on performance and (7) learning techniques by implementation of pilot project.

In the “Capacity Development Project for Non-Revenue Water (NRW) Reduction in Colombo City”, JICA experts started with building the management and technical teams. The latter was given technical training. The management team received assistance with the preparation of the annual program, including budgeting, procurement and human resource plan. The experts also facilitated the development of the strategic plan for sustainable operation, including cost-benefit analysis of NRW reduction activities. The project included a training program in Tokyo. NRW reduction was not introduced as a short-term exercise but was emphasized as a core activity to be carried out consistently in an on-going basis.



Source: Project Completion Report: The Capacity Development Project for Non-Revenue Water (NRW) Reduction in Colombo City (JICA)

Figure 6. Outline of the Capacity Development Project for NRW Reduction in Colombo City (JICA Project)

4. Leakage Control

In Japan, commercial or apparent losses due to illegal connections and metering errors had been small compared to real losses from leakage. In the post war era, water utilities had to reduce leakage in their water supply systems to conserve scarce resources as it faced a rapid increase in water demand and suffered severe droughts.

Commercial or apparent losses due to illegal connections and metering errors are small compared to real losses from leakage. Leakage inflates the water utility's production costs and stresses water resources since they represent water that is extracted and treated, yet never reaches beneficial use. Water utilities, which have to bear high costs for water resources development or to suffer from water scarcity, tend to mount more vigorous efforts in tackling leakage. This accounts for their success in keeping the non-revenue water rate low. Other utilities with high non-revenue water also need to focus on reducing leakage as a means to limit the waste of water resources and curb lost revenue.

(1) Metering

Excessive consumption by customers paying flat rate tariffs has been widely recognized among Japanese utilities. Tariff setting based on meter consumption is widely used in Japan because the utilities are aware of its importance for reducing waste. The Measurement Act outlines the term of validity, accuracy, periodic inspection, replacement cycle and use of certified water meters. This highly developed metering practice contributes to low commercial losses thereby allowing utilities to more easily identify and effectively reduce leakage.

The Measurement Act specifies the terms of validity and accuracy of water meters, the requirement for the use of certified water meters, their periodic inspection and replacement. This has been very effective in contributing to the control of commercial losses.

Nagoya City had to manage a surge of water demand in the second half of the 1910s. Its open water supply based on a flat rate encouraged indiscriminant water use. From 1921 to 1924, 30,000 water meters were installed. Metering and volumetric tariffs were introduced, with other cities following suit. The use of water meters, hence the demand, brought improvements to the manufacturing of the product. The first made-in-Japan water meter was manufactured in 1913. By 1926, the share of national products in the water meter market expanded to 42% in Osaka City and 35% in Tokyo. Product inspection and certification for water meters was established in

1928 and the recommended replacement cycle was six years (revised to eight years in 1944). In addition, a licensing system was introduced for meter manufacturers. These developments contributed to the quality assurance of Japanese water meters even in the early days of modern water supply system development in the country. The importance of metering and metering accuracy is well recognized in major cities, therefore commercial or apparent loss due to metering error is usually low.

"Make your kitchen better: A household that values water prospers. A household that wastes water suffers."

Source: Nagoya City Waterworks and Sewerage Bureau

Photo 1. A Poster to Promote Water-Conservation (1912 - 1926)

(2) WWII Destruction and Post War Recovery

Major cities in Japan suffered from high leakage from the destruction caused by aerial attacks during WW II. Intensive restoration efforts supported by national subsidies helped to rapidly rebuild major water supply infrastructure.

Water supply infrastructures of major cities such as Tokyo, Hiroshima, Osaka and Nagoya, were badly damaged by aerial attacks during the war. Water distribution networks in Osaka reported a leakage rate greater than 70%. In 1945, the national government subsidized half of the restoration costs of water supply systems and implementation of leakage prevention measures; and one third of the costs for installation of distribution networks in the following year. Osaka City mended broken water taps with non-stop water flows and repaired or replaced distribution pipes and reduced the leakage rate to 30% in 10 years.

Column: Water supply reconstruction after the war

After WW II, the Japanese economy and major infrastructures were devastated. Water supply facilities were in a state of disrepair. There was a lack of manpower and shortage of materials, making the reconstruction very difficult.

According to the survey of 90 cities by JWWA, 53% of the water service pipes were destroyed (1.67 million out of a total of 3.13 million connections). 16.8% of the water supply facilities were damaged with an estimated cost of replacement or repair reaching 366 million yen. Lead pipes were the most seriously damaged because they were easily destroyed by fire.

A rapid recovery of water supply facilities was needed to restore good public health conditions in the cities. In 1945 the national government provided subsidies to cover half of the restoration costs and for measures to control leakage. In 1946, national subsidies covered one third of the cost for the installation of water distribution pipes.

The first task of the water utilities was to remove broken water taps to stop the continuous flow of water. This activity alone achieved a significant improvement in a short period.

The water supply capacity of the utilities was greatly increased just by reducing leakage. The increased capacity allowed the utilities to cope with the population growth around 1950. Population returned to the level of the pre-war period and the water demand barely exceeded the capacity of water supply facilities. By the mid-1950s, with the continuous rise of the urban population, water supply capacity could no longer meet the demand. Water utilities started to expand supply capacity and develop water resources. The number of water supply facilities increased from 357 to 485 between 1945 and 1955. The water supply coverage rose from 26% to 32%.

Source: Ministry of Internal Affairs and Communications

Photo 2. Situation After WWII (Ichinomiya City, Aichi Prefecture)

(3) Water Demand Increase and Water Shortage

Water demand driven up by rapid economic growth together with severe water shortage brought the country together to address the urgent need for leakage reduction.

Rapid post-war economic development and population growth drove the water demand in urban areas up by 10% annually between 1955 and 1975. Surface water resources were developed extensively to meet the demand. Severe drought conditions made the situation worse. Water restrictions were imposed over a wide area in Tokyo from 1961 to 1965 (during the Tokyo Olympic Games in 1964). National media suggested grave concerns for the future of the country. A nationwide water shortage occurred in 1973 and more water supply restrictions followed (Table 2). A call for water conservation began to spread in the Tokyo area. Leakage prevention was recognized as an effective alternative to the development of new water resources. The history of water shortages gave the impetus to leakage prevention across the country.

Destruction in WWII, demand increase and water shortages were severe mostly in larger cities such as Tokyo, Osaka Fukuoka but it was widely broadcasted throughout the country. Therefore, all utilities are well aware of the priority and importance of leakage reduction.

Table 2. Severe Drought Events and Long Periods of Water Restrictions from 1960 to 1975

1961～65	4-year long water supply restriction and drought in Tokyo
1964	More than 8-month water supply restriction in Nagasaki
1967	Water supply restriction in 278 water utilities west of Kanto region
1973	Water supply restriction in 393 cities due to water shortage

Source: Bureau of Waterworks Tokyo, Metropolitan Government website

Photo 3. Emergency Water Supply During Severe Drought from 1961 to 1964

(4) National Policy for Leakage Control

The national government issued notices to promote leakage control. JWWA prepared the guidelines for leakage prevention. A nationwide effort was underway to implement leakage prevention activities.

Water utilities carried out leakage prevention measures, while the Japanese government and JWWA played a crucial role in promoting the initiative throughout the country. The Ministry of Health and Welfare (MHW)[1] tasked JWWA to prepare the "*Water Leakage Prevention Guidelines*," and announced the "*Measures to prevent leakage in water supply systems*" in 1950.

The leakage control initiative was launched across the country. For example, the Bureau of

[1] The Ministry of Health and Welfare was merged with the Ministry of Labour to form the Ministry of Health, Labour and Welfare in 2001.

Waterworks, Tokyo Metropolitan Government took the following measures:

1950 -1958	Leakage detective survey and repairs
1959-1965	Replacement of old deteriorated distribution pipes
1966-1979	Introduction of DCIP as well as preventive maintenance works by well-trained technicians and establishment of dedicated research department
1980-	Continuation of the above and completion of service pipe replacement

The leakage rate was reduced from 17.2% (NRW 27.9%) in 1970 to 10.2% (NRW 14.6%) in 1990. Similar efforts at other utilities also reduced the average NRW rate from 26.0% to 14.3% for the same period.

In 1990, MHW decided to strengthen leakage prevention. Utilities with less than 90% effective water rate were instructed to implement further leakage prevention to raise their effective water rate to 90% as soon as possible. Utilities with an effective water rate ≥ 90% had to set a higher target (such as 95%) and continue to work on systematic leakage prevention. The 2004 "Water Supply Vision" published by MHW prescribes the target effective water rate of > 98% for large-scale water utilities, and > 95% for small- and medium-scale water utilities.

Column: Improvement in living standard and soaring water demand

There was a significant increase in water demand during the post-war period of rapid economic growth. Increase in purchasing power and improved living standard led to increased domestic water use. Water consuming household fixtures such as washing machines, private baths, and flush toilets became common items in Japan from 1955 to 1975, while the family size dropped from 4.68 in 1955 to 3.35 in 1975.

Water consumption per capita per day grew rapidly from 194 liters in 1960, to 216 liters in 1965 and 302 liters in 1975; an increase of 1.5 times from 1955 to 1975. Served population increased by 2.5 times in 15 years, from 39.68 million people in 1960, to 68.24 million people in 1965 and 98.4 million people in 1975. The amount of water supplied more than tripled in 20 years.

5. Best Practices at the Bureau of Waterworks, Tokyo Metropolitan Government

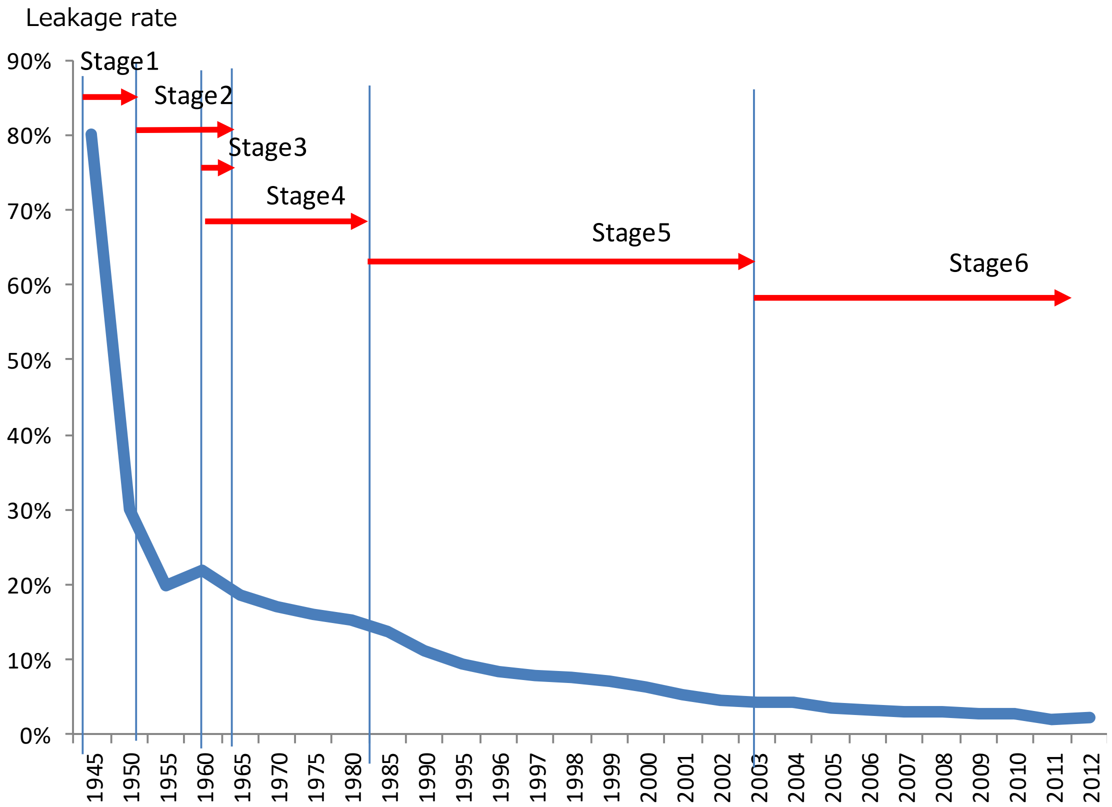
The important factors that contribute to leakage reduction include: early detection and repair of leaks, selective measurement, better pipe materials, and systematic replacement of aging pipelines.

(1) Progressive Approach to Leakage Management

In the early days when leakage rate was high, repairs were made when water was visible on the surface of the ground from leaks. Utilities gradually shifted to early detection and then to systematic pipe replacement together with the use of better pipe materials.

BWTMG lowered its leakage rate from 80% in 1945 to 3.1% by 2008. The improvements came about gradually. During the first few years (Stage 1) by fixing the leaks detected above ground with intensive input of manpower and building repair teams, the leakage rate was reduced to approximately 30%. In the next phase (Stage 2) the effort shifted to sub-surface leak detection using high quality water leak detectors, establishment of distribution blocks, and preparing accurate pipe network drawings. The leakage rate was further reduced to 20% by 1955. By this time the need for pipeline repairs became overwhelming. When a leak was repaired in one area, another would be found somewhere else. The leakage rate went up. The decision was made in the 1960s to replace aging pipes with ductile iron pipes instead of traditional cast iron pipes (Stage 3), bringing the leakage rate to < 20%. The activities for leakage prevention, pipe replacement, adoption of advanced technologies and staff training were accelerated. By 1979, the leakage rate was reduced to 15.5% (Stage 4). Then stainless steel became the material of choice for water service pipes, because of its strength and corrosion resistance. At that time more than 95 percent of water leaks were on service pipes (Stage 5). When the leakage rate fell below 5%, the emphasis was shifted from detection and repair to the more cost effective measure of systematic pipe replacement (Stage 6).

The progression the BWTMG went through in tackling leakage in the water supply system is typical for most water utilities in Japan.



Stage	Leakage ratio	Leakage control work	Method
1	>30%	Decrease aboveground visible leakage	Intensive repair activities
2	30%-20%	Decrease underground leakage	Zoning, accurate piping maps, training & utilizing good quality equipment for detection
3	25%-20%	Prevent recurrence of leakage	Increase in leakage control work, starting replacement of deteriorated pipes, use of DCIP
4	20%-12%	Carry out thorough leakage control work	Revision of working method & acceleration of pipe replacement work
5	12%-5%	Improve service pipes	Introduction of stainless steel service pipes which are strong and durable
6	<5%	Maintain low NRW	Systematic pipe replacement and leakage control work based on cost and benefit analysis

Source: Materials by Shozo Yamazaki

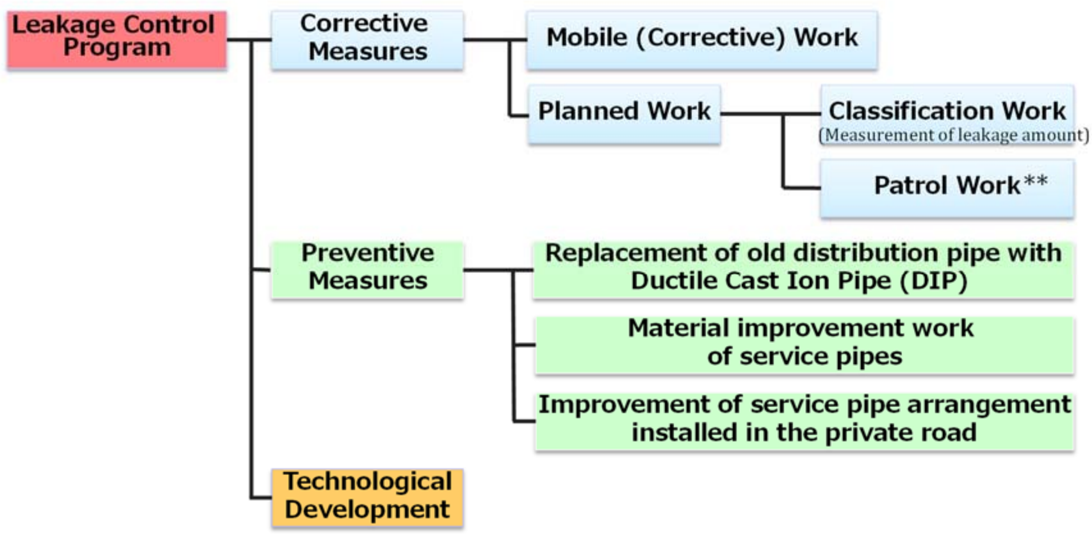
Figure 7. BWTMG Leakage Control Experience

(2) Early Detection and Repair: Planned and Corrective Maintenance

In Tokyo, fixing leaks detected or reported above ground makes up a large number of leakage control activities. However, 60% of leakage reduction is achieved by planned systematic leakage investigation. Both corrective and preventive measures are necessary to reduce leakage.

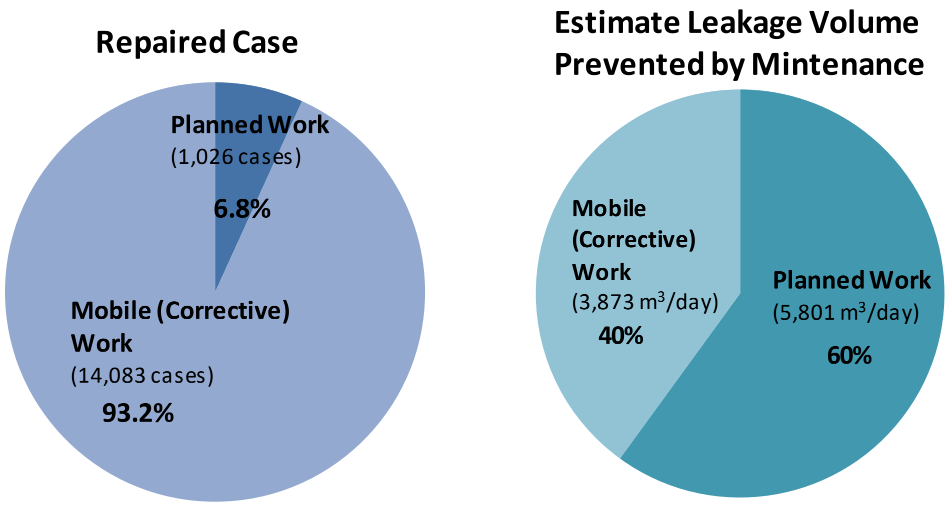
BWTMG has a 24-hour service to respond to customer calls about leakage as well as city-wide site inspections looking for signs of leakage. 93% of the repairs are carried out in response to leakage detected above ground. BWTMG also carries out scheduled inspections of each distribution block for leakage, which accounts for the balance (7%) of the leakage repairs. While reactive and planned preventive maintenance are both necessary for leakage control, an estimated 60% of the leakage reduction is credited to the latter.

Planned preventive maintenance can deal with below ground leakage at an earlier stage, significantly reducing the delay between the start of the leak and its repair.



Source: Training materials for JICA Technical Cooperation Projects

Figure 8. Leakage Prevention Measures



Source: Training materials for JICA Technical Cooperation Projects

Figure 9. BWTMG Corrective and Planned Maintenance for Water Leakage

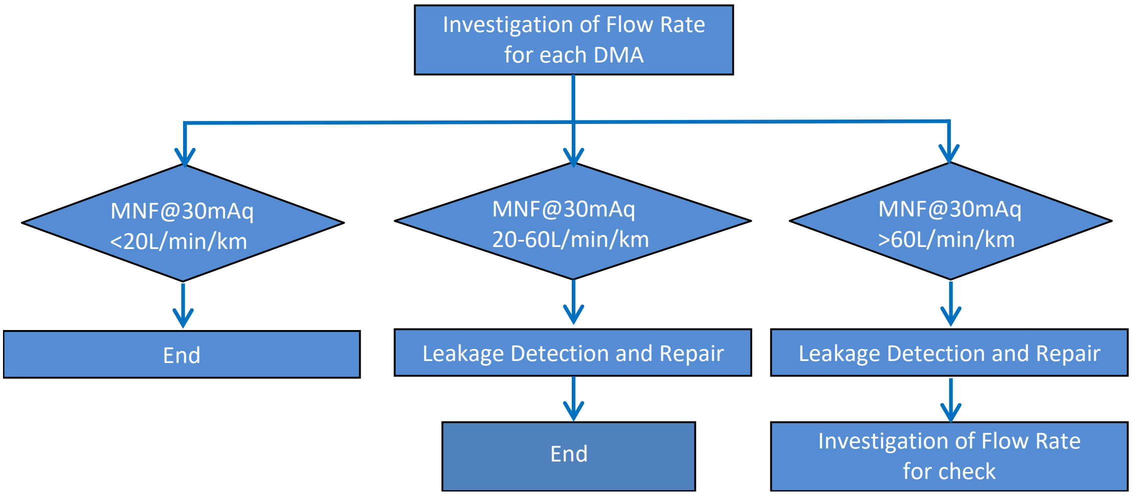
(3) Selective Measurement

Monitoring of night flows in distribution blocks is an effective tool for identifying water loss. The average minimum night flow data is used to determine the priority areas for leakage detection.

Most of the water supply networks in Japan are designed as block distribution systems. A network is divided into small manageable distribution blocks.

A BWTMG distribution block has about 1,100 households. Each distribution block is hydraulically isolated as the flow can be measured in each block at night time (minimal consumption) by a mobile meter installed in a concrete block chamber. Water loss is calculated from the minimum night flow.

BWTMG successfully conducted selective measurements from 1978 to 2005 to detect and repair leaks not visible on the surface. Distribution blocks are screened based on minimum night flow as shown in Figure 10. Selected distribution blocks are then targeted for leakage reduction activities.

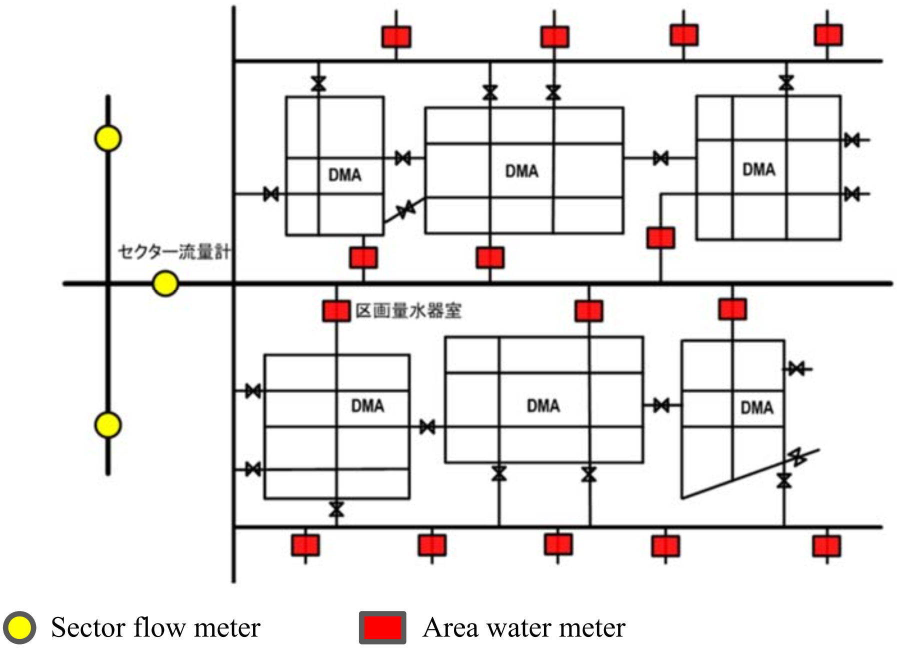


Note: MNF (Minimum Night Flow), mAq (meter Aqua≒0.1MPa)

If MNF is greater than 20 L/min/km at 30 mAq by investigation as part of routine planned work, implement more detailed leakage detection and repair work. Then measure again to check the impact of repairs.

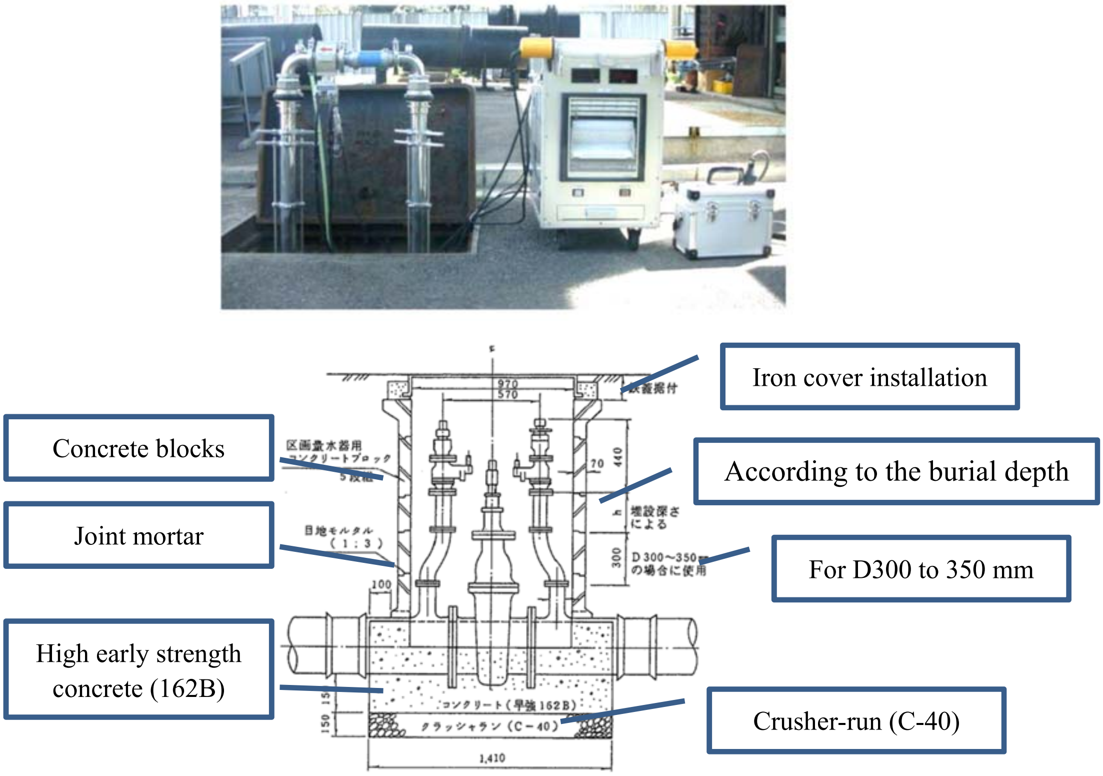
Source: Training materials for JICA Technical Cooperation Projects

Figure 10. Selective Measurement



Source: Training materials for JICA Technical Cooperation Projects

Figure 11. Conceptual Design of Distribution Blocks in BWTMG



Source: Training materials for JICA Technical Cooperation Projects

Figure 12. Mobile Block Meter for Measurement of Minimum Night Flow

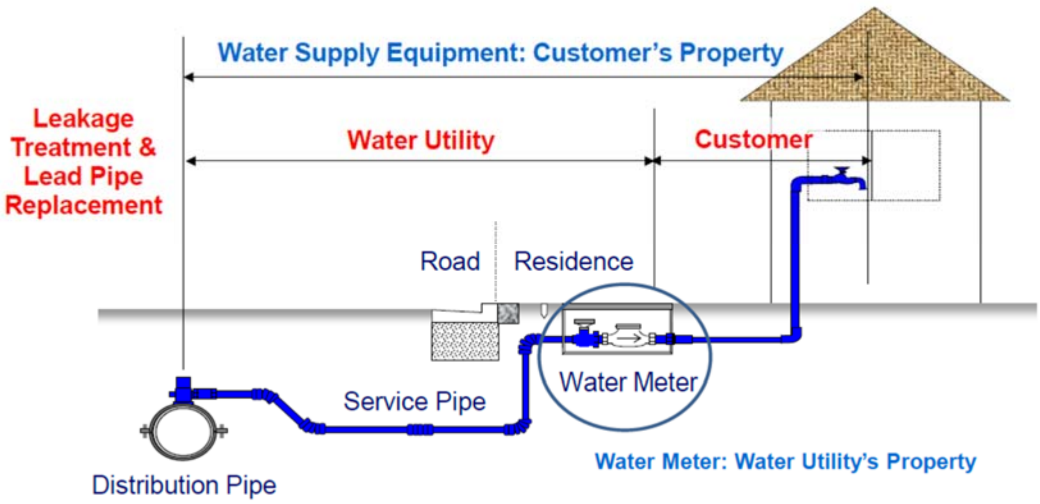
(4) Better Pipe Materials

Most water leaks occur at water service pipes. BWTMG significantly reduced leakage by switching to stainless steel pipes, which have high durability.

97.5% of the leakage experienced by BWTMG occurred at service pipes. On the other hand, there are fewer leakage from distribution pipes in Japan because utilities have implemented planned renewal of them. BWTMG customers are responsible for installation and replacement of water service pipes. Since replacement of these pipes is crucial to reducing leakage, BWTMG takes the initiative to do so instead of leaving it to the customers. Labor cost is usually higher than material cost. It is therefore more cost effective to use stainless steel (SUS316) pipes which have a longer service life and require less frequent replacement. BWTMG has a committee with members from the Water Service Devices Division in the Sales Department and various other departments to study and standardize the pipe materials. The committee visits pipe manufacturers, and inspected the materials at the test center. Stainless steel pipes have the additional advantage of being earthquake resistance.

There is a historical background why BWTMG adopted stainless steel for service pipes. Nowadays, there are other reliable and inexpensive options of pipe materials such as HDPE (PE100). PE100 is a relatively new material put into use after 1989. Some utilities hesitate to adopt HDPE because of reports of breakage and peeling of inner lining. In other words, such inexpensive options are not available in 1980s when BWTMG determined their measures. Therefore, looking at the cost effectiveness in their life cycle and better leakage prevention, BWTMG adopted stainless steel for its service pipes.

Utilities work together and with private companies to establish the causes of leakages and implement effective measures. They cooperate and coordinate on various issues in the process, such as setting priorities, budgetary appropriation, and confirmation on availability of materials and work experience and capability of local contractors. Their joint efforts are very effective and always produce remarkable results.



Source: JWWA

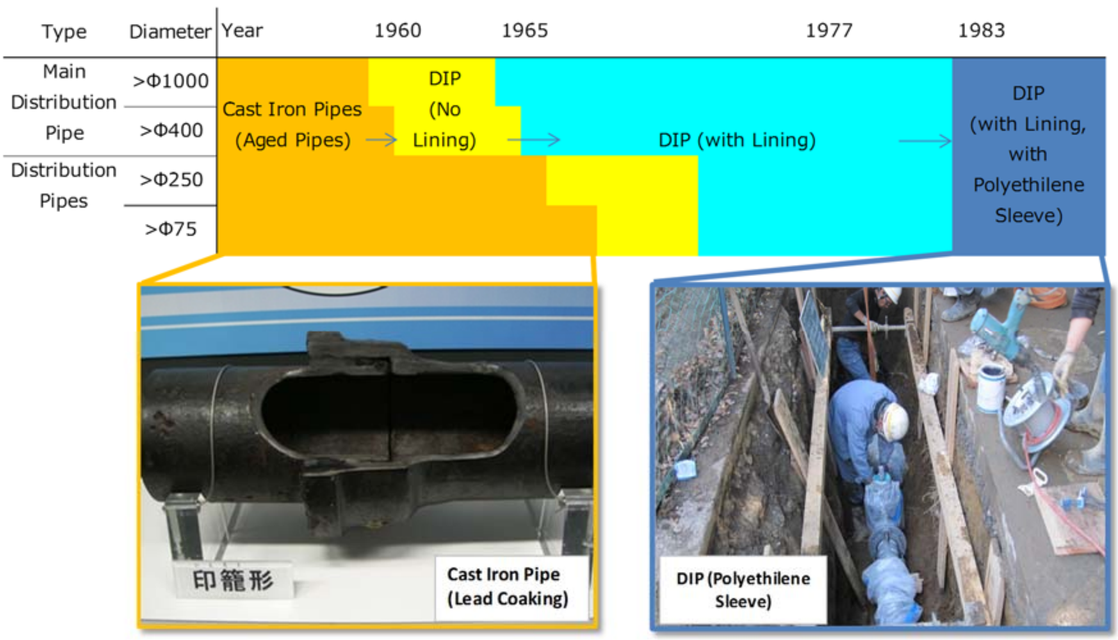
Figure 13. Responsibility of the Customer vs that of Utility at House Connections

(5) Systematic Pipe Replacement

> Many leaks were found in aging pipes, installed based on old standards. BWTMG has been continuously and systematically replacing old pipes, with pipes made of better materials developed by manufacturers.

Asbestos cement pipes with low durability were commonly used from 1950s to 1970s. There were many technical innovations from the 1950s to 1970s during the period of significant expansion of water supply systems. Most water distribution pipes in Japan are ductile cast iron, steel or polyethylene.

BWTMG started using ductile iron pipes in water distribution networks since 1960. Some new methods applied gradually; an inner lining and polyethylene sleeve to prevent corrosion, and seismic resistant joint. The aging cast iron pipes are being replaced at about 300 to 400 km per year. With a total of 24,000 km distribution pipes, all water distribution pipes will be replaced in 60 to 80 years.



Source: Training materials for JICA Technical Cooperation Projects
Sources of Photo: (Left) Water Partners Jp Co., Ltd. (Right) Japan Ductile Pipe Association

Figure 14. Replacement of Cast Iron Pipe

6. Lessons Learned

The following Japanese experience could be useful for other countries.

- **(Need for Leakage Prevention)** Water supply systems in Japan's major cities, such as Tokyo or Osaka, suffered from high leakage after WW II. Today the leakage rate is as low as 3% in Tokyo. Japan has historically used the water leakage rate rather than the non-revenue water rate in managing water supply system efficiency. Japanese water utilities recognize the importance of leakage control and prevention because of their experience with infrastructure destruction during the war, severe droughts, and water restrictions.

- **(Leakage Control for Reducing NRW)** The major cause of NRW in Japan is leakage. Utilities have dramatically improved NRW by reducing leakages. Utilities in Japan could identify the major cause of NRW because most of water supply was metered. It is important to install meters and analyze water flow, locate leaks and develop control measures. This requires a coordinated effort among various work units within the utility.

- **(Accuracy of Meters)** The Measurement Act requires replacement of water meters every 8 years and utilities are obliged to keep them in good working order under the Water Supply Act. Metering errors can be kept to a minimum with a strong legislative framework.

- **(Progressive Leakage Control)** An active leakage control program can start with improved response to repairing visible leaks. Then the activities can shift to early detection of leaks not yet visible above ground, and eventually to systematic planned replacement of aging pipes. Planned pipeline replacement and improved pipe materials is very effective for NRW reduction.