WATER USE AND LOSS IN WATER DISTRIBUTION SYSTEMS

A BEST PRACTICE BY THE NATIONAL GUIDE TO SUSTAINABLE MUNICIPAL INFRASTRUCTURE

National Guide to Sustainable Municipal Infrastructure
Guide national pour des infrastructures municipales durables

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Federation of Canadian Municipalities
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Water Use and Loss in Water Distribution Systems
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FOREWORD

In spite of recent increases in public infrastructure investments, municipal infrastructure is decaying faster than it is being renewed. Factors such as low funding, population growth, tighter health and environmental requirements, poor quality control leading to inferior installation, inadequate inspection and maintenance, and lack of consistency and uniformity in design, construction and operation practices have impacted on municipal infrastructure. At the same time, an increased burden on infrastructure due to significant growth in some sectors tends to quicken the ageing process while increasing the social and monetary cost of service disruptions due to maintenance, repairs or replacement.

With the intention of facing these challenges and opportunities, the Federation of Canadian Municipalities (FCM) and the National Research Council (NRC) have joined forces to deliver the *National Guide to Sustainable Municipal Infrastructure: Innovations and Best Practices*. The Guide project, funded by the Infrastructure Canada program, NRC, and through in-kind contributions from public and private municipal infrastructure stakeholders, aims to provide a decision-making and investment planning tool as well as a compendium of technical best practices. It provides a road map to the best available knowledge and solutions for addressing infrastructure issues. It is also a focal point for the Canadian network of practitioners, researchers and municipal governments focused on infrastructure operations and maintenance.

The *National Guide to Sustainable Municipal Infrastructure* offers the opportunity to consolidate the vast body of existing knowledge and shape it into best practices that can be used by decision makers and technical personnel in the public and private sectors. It provides instruments to help municipalities identify needs, evaluate solutions, and plan long-term, sustainable strategies for improved infrastructure performance at the best available cost with the least environmental impact. The five initial target areas of the Guide are: potable water systems (production and distribution), storm and wastewater systems (collection, treatment, disposal), municipal roads and sidewalks, environmental protocols and decision making and investment planning.

Part A of the *National Guide to Sustainable Municipal Infrastructure* focuses on decision-making and investment planning issues related to municipal infrastructure. Part B is a compendium of technical best practices and is qualitatively distinct from Part A. Among the most significant of its distinctions is the group of practitioners for which it is intended. Part A, or the decision making and investment planning component of the Guide, is intended to support the practices and efforts of elected officials and senior administrative and management staff in municipalities throughout Canada.

It is expected that the Guide will expand and evolve over time. To focus on the most urgent knowledge needs of infrastructure planners and practitioners, the committees solicited and received recommendations, comments and suggestions from various stakeholder groups, which shaped the enclosed document. Although the best practices are adapted, wherever possible, to reflect varying municipal needs, they remain guidelines based on the collective judgements of peer experts. Discretion must be exercised in applying these guidelines to account for specific local conditions (e.g. geographic location, municipality size, climatic condition).

For additional information or to provide comments and feedback, please visit the Guide at <www.infraguide.gc.ca> or contact the Guide team at infraguide@nrc.ca.

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The dedication of individuals who volunteered their time and expertise in the interest of the *National Guide to Sustainable Municipal Infrastructure* is acknowledged and much appreciated.

This best practice was developed by stakeholders from Canadian municipalities and specialists from across Canada, based on information from a scan of municipal practices and an extensive literature review. The following members of the National Guide's Potable Water Technical Committee provided guidance and direction in the development of this best practice. They were assisted by the Guide Directorate staff and by Delcan Corporation.

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This and other best practices could not have been developed without the leadership and guidance of the Project Steering Committee and the Technical Steering Committee of *the National Guide to Sustainable Municipal Infrastructure*, whose memberships are as follows:

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EXECUTIVE SUMMARY

Water use and loss from a potable, water distribution system are significant factors affecting water delivery to customers. It is therefore important to understand the ultimate fate of the water supplied to the system and how best to account for it.

This best practice will assist municipalities and water utility managers in understanding all the elements of their water distribution system and in properly accounting for the water supplied to the system.

In the development of this best practice, a flow chart was produced, which outlines all the potential uses of the potable water beginning with the water supplied to the distribution system. The water into the distribution system will be either *authorized consumption* or *water loss*.

Authorized consumption can be metered or unmetered consumption that is either billed or unbilled.

Water loss can be either:

- the apparent losses due to meter inaccuracies or unauthorized consumption, or
- real losses due to leakage at water service lines, breaks or leakage on mains and hydrants/laterals or at storage facilities.

Another important distinction in this best practice is the difference for metered systems between *revenue water* and *non-revenue water*. Water loss is clearly non-revenue water while authorized consumption is revenue water, with the exception of unbilled consumption.

The following strategies to identify and reduce water loss are briefly explained:

- metering;
- leak detection and repair;
- water efficiency/conservation;
- valve maintenance;
- pressure management;
- infrastructure renewal;

- pricing (water rates);
- speed and quality of repairs;
- by-law enforcement and system inspection;
- zone metering and district metered areas (DMAs);
- design standards for construction methods and materials;
- a supervisory control and data acquisition (SCADA) system;
- nighttime flow analysis; and
- distribution system modelling.

This best practice uses the concepts developed by the International Water Association (IWA) and the American Water Works Association (AWWA) to define the need to prepare a water audit. The document describes the data requirements to allow for the proper creation of the water audit.

1. GENERAL

1.1 INTRODUCTION

This best practice was initiated following a scan completed for the National Guide on reducing losses in water transmission and distribution systems. Based on the scan data, it was evident a best practice needed to be developed to guide municipalities on accounting for the water used and lost in their distribution systems.

This document provides guidance in the collection and evaluation of information required to account for all potable water supplied to the water distribution system. It will enable municipalities and water utilities to understand and improve water accountability.

1.2 SCOPE

The first objective of this best practice is to provide municipalities with a basic common method of accounting for the water used and lost in their water distribution system. The intent is to use standard terms that are recognized internationally, allowing municipalities to communicate readily and understand each other. By accounting for the water, municipalities can make operations, maintenance, and capital improvement decisions in the best interests of their water customers and the community they serve. This best practice will help municipalities prioritize their capital and operating decisions and better safeguard their systems from water loss.

Two leading organizations represent municipalities, water utilities, individuals, and other organizations, in matters related to this guide. It is recommended that municipalities get involved with the AWWA (American Water Works Association) and the IWA (International Water Association) to pursue the continuous improvement in water use and loss control in distribution systems. This, in turn, will allow their knowledge and expertise to be disseminated by these organizations for the betterment of municipalities and potable water suppliers everywhere.

It should be noted that there are many other organizations involved in infrastructure rehabilitation, including the Water Environment Federation (WEF), the American Society of Civil Engineers (ASCE), the Water Resource center (WRc), and the Drinking Water Inspectorate in the United Kingdom, as well as academia. All organizations have a role to play in the pursuit of continuous improvement initiatives for water main replacement and rehabilitation. A recent research report published in June 2002 by the National Research Council, Institute for Research in Construction (report #101), “Construction and Rehabilitation Costs for Buried Pipe with a Focus on Trenchless Technologies”, highlighted recent costs (1993–2000) for trenchless technologies.

The National Guide's Potable Water Technical Committee will continue to monitor these organizations and others to make any updates or changes to this best practice.

1.3 SUSTAINABILITY

Water loss carries a significant price tag, both economic and environmental. It is not financially cost-effective to have a product fall short of reaching its consumer. Nor is it a good use of resources to treat a raw product to a high quality only to have it lost. Proper accounting of water used and lost will help reduce the costs associated with potable water and lead to a more sustainable product.

2. RATIONALE

The operations, maintenance, and management of a potable water system are complex activities. Since much of the potable water infrastructure is underground, it is difficult to prioritize maintenance activities while continuously operating a reliable water system that meets the needs of the customers and the community. A water distribution system accounts for 50 to 80 percent of the expenses of an overall water system. As such, it should be operated, maintained, and managed in the most efficient way possible while providing high-quality potable water. A scan on reducing losses associated with water transmission and distribution systems was done during the winter of 2001–2002 to determine how municipalities across Canada were responding to water losses. The report from this scan determined that many municipalities would benefit from a best practice on how to account for the water used and lost in their distribution systems. The knowledge gained by using this best practice will allow municipalities to make better decisions with respect to operational and maintenance activities, capital investment priorities, water system security/reliability issues, and customer service levels.

3. WORK DESCRIPTION

3.1 ACCOUNTING FOR WATER

The problem of accounting for water has been studied extensively by national and international organizations that are at the forefront of the potable water industry. More specifically, the AWWA and the IWA have developed standardized methods for accounting for water use and loss in water distribution systems. This best practice draws from much of the work undertaken to date by these two organizations.

Accounting for use and loss in a water distribution system is critical. Proper accounting will allow utilities to make informed decisions on operations, maintenance, capital investment, and customer service programs. Along with the knowledge and experience of experts from across Canada who were involved with developing this best practice, two other key resources have been used: *The Manual of Water Supply Practices*, specifically “Water Audits and Leak Detection” (AWWA, 1999) and *Standard Components of Water Balance for Transmission or Distribution Systems* (IWA, 2001). Further information on these documents can be obtained from <www.awwa.org> and <www.iawq.org.uk>.

Water utility managers, operators, and other public and private water sector organizations should regularly upgrade or update their skills. Becoming a member of these and other organizations is a logical step in the successful implementation of a continuous improvement program regarding all aspects of potable water operations, maintenance, and management. Although this best practice emphasizes water use and loss in the water distribution system, these and other potable water organizations also address many other best practices that should be adopted by municipalities.

3.2 BASIC DATA AND INFRASTRUCTURE REQUIREMENTS

The first step in accounting for water used and lost in a water distribution system is appropriate data collection. There are four basic groupings of data:

- the water system infrastructure (i.e., inventory data);
- the quantity of potable water supplied into the water distribution system including water imported and own sources;
- the quantity of water metered or consumed and non-revenue water lost within the distribution system; and
- the operations and maintenance activities within the water distribution system.

3.2.1 WATER SYSTEM INFRASTRUCTURE DATA

The following infrastructure data is important in understanding the uses and losses in a water distribution system:

- production water meters (quantity, age, diameter, type, location, accuracy);
- water mains (age, material, diameter, length, location, depth, condition);
- water service lines (quantity, material, diameter, location, depth, length);
- valves (quantity, age, diameter, type, location);
- fire hydrants (quantity, age, type, location);
- customer water meters (quantity, age, diameter, type, location, accuracy);
- storage reservoirs (volume, location, type);
- district metered areas (DMAs); and
- bulk metering of water imported and water exported (quantity, age, diameter, type, location, accuracy).

It is understood that many municipalities will not have all or most of these data. Although it is not absolutely necessary to have this information to undertake this best practice, the more data a municipality has, the better informed their decisions will be regarding initiatives aimed at minimizing water losses.

3.2.2 DATA ON WATER SUPPLIED INTO THE WATER DISTRIBUTION SYSTEM

Monitoring the quantity of water supplied into the water distribution system is a critical component of data required for this best practice. There are three primary sources that supply water into a water distribution system:

- surface water delivered via a water purification/treatment plant;
- groundwater from wells delivered via a water purification/treatment plant; and
- purchased water (water imported).

Each possible water source must be metered to account for the volume supplied into the water distribution system. The meters must be in convenient locations to allow for regular reading and calibration, and for other maintenance activities. If feasible, the volume of water supplied into the distribution system should be monitored by way of data capture, or a SCADA system, on a continuous (24/7), daily, midnight to midnight basis. This metering information will lead to a more comprehensive understanding of the water supplied to the system and will give useful information in determining the non-revenue water lost throughout the day and all exports of water between systems and sub-systems. If a municipality has two or more completely separate water distribution systems (i.e., no interconnecting water mains between systems), each should be metered and monitored separately.

All water supply meters should be calibrated in accordance with the manufacturer's recommendations. As with all metering devices, water meters are not 100 percent accurate and can lose their sensitivity over time, hence the reason for regular calibration. This calibration will provide a municipality with valuable information on the accuracy of the quantity of water being supplied, leading to appropriate decisions on maintenance or replacement frequency.

3.2.3 WATER USED AND LOST IN THE WATER DISTRIBUTION SYSTEM

Metered and unmetered billed water (revenue water) and lost (non-revenue water) in a distribution system is tabulated from known and calculated volumes of water over time as shown in Figure 3–1. Where economically feasible, a municipality should meter all water used by customers. Since the metering of other uses may not always be possible, calculated volumes are recommended.

<table>
<tr><td rowspan="9">System Input Volume</td><td rowspan="4">Authorized Consumption</td><td rowspan="2">Billed Authorized Consumption</td><td>Billed Metered Consumption (including water exported)</td><td rowspan="2">Revenue Water</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="7">Non-Revenue Water (NRW)</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="5">Water Losses</td><td rowspan="2">Apparent Losses</td><td>Unauthorized Consumption</td></tr>
<tr><td>Metering Inaccuracies</td></tr>
<tr><td rowspan="3">Real Losses</td><td>Leakage on Transmission and/or 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>

Source: IWDC Ltd.

Figure 3–1: IWA Water Balance Sheet

3.2.4 DATA ON OPERATIONS AND MAINTENANCE ACTIVITIES

Operation and maintenance activities within a water distribution system can provide valuable information on how a system is operating. What effect do these activities have on the use and loss of water within a water distribution system?

When and why is water use and loss occurring? Where can the municipality effectively focus its activities? Important data related to the operations and maintenance activities that have an impact on water use and loss include:

- water system pressure readings throughout each and every day (the higher the pressure, the more water lost at every leak and the greater the frequency of new leaks each year);
- maintenance activities related to water mains (number of water main breaks/repairs each year, blow-offs for water quality or freezing concerns, water main replacement or rehabilitation programs, water main flushing/swabbing/pigging programs, discharges at pressure relief valves, etc.);
- fire hydrant use or maintenance activities (physical inspection, fire flow testing, pool filling, temporary water services from hydrants, tanker truck filling, sewer cleaning, leaks on hydrants, etc.);
- valve maintenance activities (boundary valve between two different pressure zones, pressure-reducing valves within the water distribution system, maintenance on valve stems, seats, leaks on valves, check valve maintenance and inspection);
- water service and curb box inspection and maintenance (leaks on service connections);
- active leak detection programs; and
- reservoir use (filling/emptying throughout the day, cleaning, leakage, etc.).

3.3 Completing a Water Audit

A water audit enables municipalities to determine the water supplied, consumed, and lost in the distribution system. It also allows the municipality to calculate what that lost water is costing.

Ideally, the quantity of water supplied into the water distribution system would equal the quantity of water used by all the customers connected to that system. Absolutely no losses would occur in the water distribution system and all waters consumed, and all maintenance activities, would be accurately metered. In reality, a combination of metered consumption values and calculated values monitor water used and lost. An audit can provide municipalities with the information they need to make decisions on appropriate operation, maintenance, and capital improvement programs to reduce water loss in their water distribution system.

A water audit should take place yearly for year-to-year comparisons and to prioritize operation and maintenance programs. To perform a water audit, a water distribution system balance flow chart is used, as shown in Figure 3–2. As each task is addressed, the information on water use and loss becomes more complete.

3.3.1 WATER BALANCE FLOW CHART

The water balance flow chart comprises two main components: the water supplied into the water distribution system, and the water used and lost within the water distribution system.

Total Water Supplied to Distribution System (System Input Volume)
This is the quantity of water supplied to the water distribution system throughout a one-year period, from all the municipality's sources (water plants, wells, imported water from another municipality or private company). Any errors in the source water metering data should be addressed in this tabulated value.

For any financial analysis to be carried out, it would be useful to split the total water supplied to distribution system (system input volume) into two sub-components: water imported and own sources. These 2 components typically carry very different costs per cubic metre.

Total water supplied to the distribution system = authorized consumption + water losses.

Metering the water supplied into the water distribution system is critical if a municipality wants to understand where water is used and lost in the system. The right size and appropriate calibration frequency of system input meters monitoring the flow to the water distribution system will reduce unregistered water and meter inaccuracies.

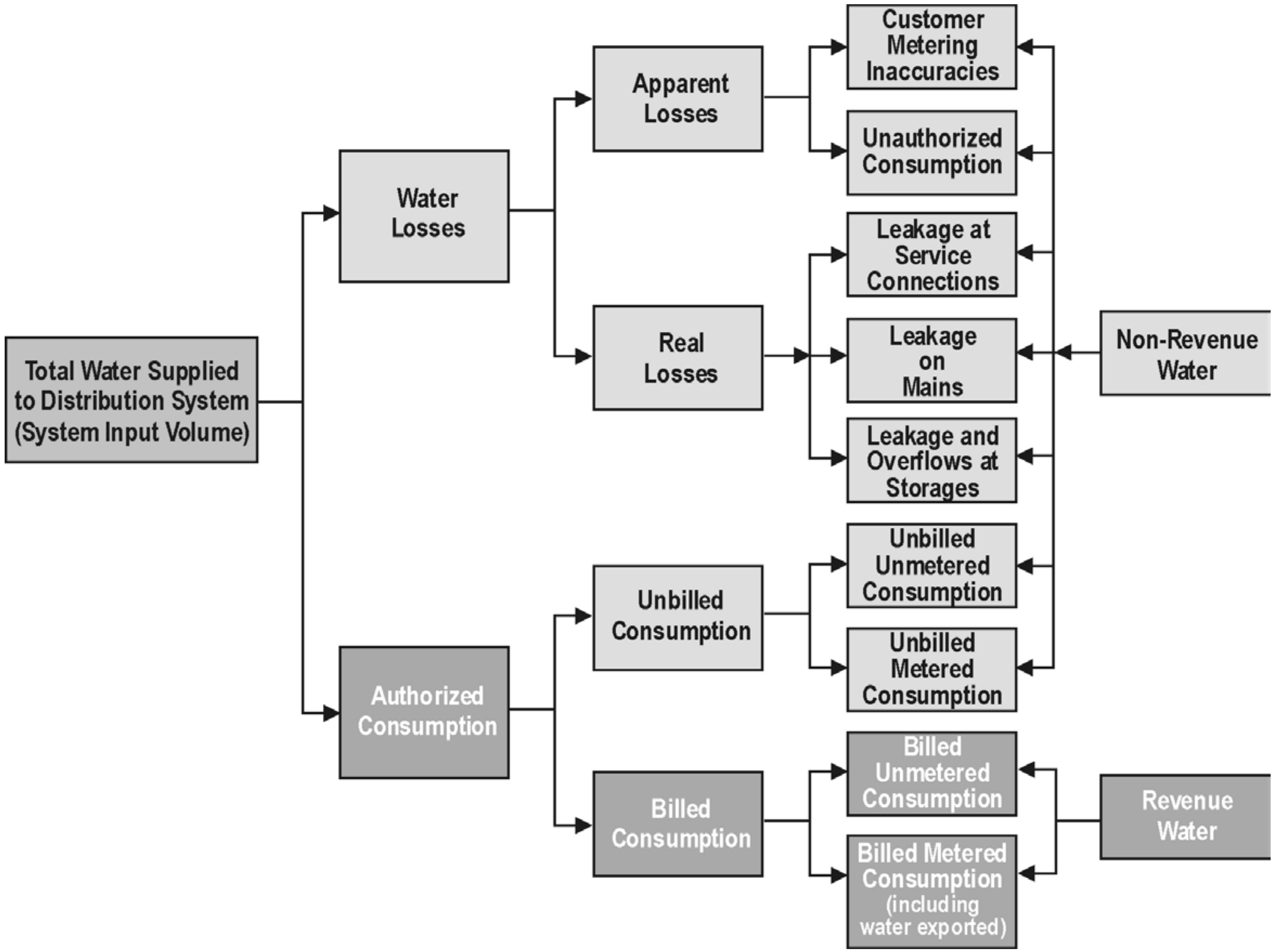
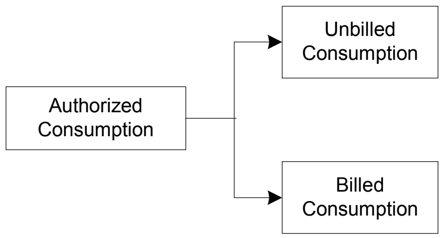


Figure 3–2: Flow Chart of Water Balance for Water Distribution Systems

Authorized Consumption
The quantity of water authorized for customers to use could be metered or unmetered. It includes all residential, commercial, industrial, institutional, fire fighting, flushing of water mains, cleaning of sewers, and any other municipal or other uses authorized by the municipality.

Authorized consumption = billed consumption + unbilled consumption

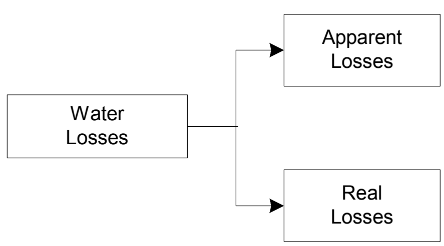


The **billed consumption** including water exported is that quantity of water consumed by customers, which is metered or unmetered. The unmetered, billed consumption is an estimate of the quantity of water consumed by the customer.

The **unbilled consumption** is that part of authorized consumption, which is not billed to customers. This applies to metered and unmetered customers. The reason for not billing these users will depend on the municipality, but could include metered (or unmetered) municipal buildings, recreation facilities, not-for-profit organization facilities, fire fighting, and hydrant flushing.

Water Losses
The quantity of water lost is the difference between the total water supplied to the distribution system less the authorized consumption. Water losses can also be broken down as follows:

Water losses = apparent losses + real losses

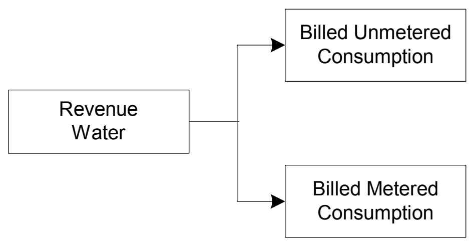


Apparent losses occur due to water meter inaccuracies at customer buildings, accounting procedure errors, and unauthorized consumption.

Accounting procedure errors may occur due to overlapping billing cycles, misread meters, improper calculations, or computer programming errors. These types of losses are mistakes that can be identified and corrected. Many errors are associated with units of measurement, such as a meter reading in cubic feet, gallons or U.S. gallons, and converting this to cubic metres. The entire billing procedure should be reviewed to make certain all issues are addressed.

Real losses occur in the water distribution system due to water main breaks/leaks, water service line leaks, storage tank leaks and storage tank overflow occurrences.

Revenue Water
This is the water billed to customers, which includes metered and unmetered consumption.



Non-Revenue Water
Non-revenue water includes all apparent losses, all real losses, and all unbilled consumption.

3.3.2 DETERMINATION OF LOST WATER

To determine the quantity of lost water, first determine the quantity of water supplied to the water distribution system. This will equal all metered data over the year, adjusted (plus or minus) for any meter inaccuracies based on calibration information on each water supply input meter.

Non-revenue water losses comprise real (leakage) and apparent (paper losses or accounting inaccuracies) losses. Non-revenue water losses could result from meter error/inaccuracies, unauthorized consumption, distribution system leaks, and storage reservoir leakage or overflow.

Meter Error and Inaccuracies
All meters are designed and made to meet given accuracy requirements. However, accuracy varies with the type, use, and age of the meter. Important factors when assessing meter accuracy include meter error, under-registration, and the selection criteria for system input and customer meters.

Unauthorized Consumption
Identifying unauthorized consumption in a water distribution system is no easy task. Activities, such as meter bypasses, abandoned service lines still in use,

illegal connections, illegal hydrant use and meter tampering, all contribute to unauthorized consumption.

Estimating unauthorized water use requires documentation of the activities that typically occur in the distribution system. Most unauthorized water use occurs at fire hydrants with the theft of water by contractors and illegal tanker truck filling. Good community involvement and reporting mechanisms can assist utilities in reducing this non-revenue water component. By-laws with enforcement mechanisms may also prove useful.

Distribution System Leaks

Real water loss includes distribution system leakage. Water leakage can be reported or unreported. A reported leakage arises when customers call in a report of a water leak in the system. Unreported water losses are discovered through active leak detection programs or system investigation by utility staff. It is not necessarily the number of water leaks that occur, but the run time of the leaks that contributes to the quantity of water lost. Once the leak is discovered, the speed and quality of the repair reduces the overall quantity of water lost. To use IWA performance measures, the distribution system ends at the point of customer metering (or equivalent point for an unmetered service line or fire connection).

Storage Reservoir Leakage

Leakage typically occurs from cracks in tank linings, and in the floors and walls of the storage reservoirs. To estimate the storage reservoir leakage, it is suggested the inflow and outflow of the reservoir be isolated over several days, so the change in water level can be monitored. The change in water level over a specific period will provide the quantity of water lost. It is recommended this procedure be performed at different water levels in the storage reservoir, since water may only leak at certain levels.

Storage Reservoir Overflows

This often occurs due to faulty altitude control valves. This value will be an estimate in many cases and will be based on the rate of filling the storage reservoir less the discharge rate from the reservoir during the overflow period. An ultrasonic level sensor/alarm should be installed in the tank to monitor water levels. A sensor device installed in the overflow pipe linked directly to an alarm system may be another economical and practical solution.

4. STRATEGIES TO REDUCE WATER LOSS

There are numerous ways to reduce the loss of water. Deciding which program to use will depend on the condition of the local water infrastructure and the areas where water loss is occurring. Municipalities can consider one or all of the following programs to help in the reduction of water loss in their distribution system:

- metering;
- leak detection and repair for both public and private water systems;
- water efficiency/conservation;
- valve maintenance;
- pressure management including surge suppression;
- infrastructure renewal;
- pricing (water rates);
- speed and quality of repairs;
- by-law enforcement and system inspection;
- zone metering and district metered areas (DMAs);
- design standards for construction methods and pipe material;
- a supervisory control and data acquisition (SCADA) system;
- nighttime flow analysis;
- distribution system modelling.

4.1 METERING

A water-metering program for all customers is one of the first programs that should be undertaken to account for water used in a distribution system.

Fully implementing a metering program can take years. It is suggested that a municipality begin metering large volume users first, such as industrial, commercial, and institutional facilities. A planned approach to residential metering can begin with multiple residential units, and the requirement for any new homes or developments to have meters. Implementing a residential metering program in existing homes will be a concern to many residents with “finished” basements. A good communication strategy and community involvement are key to the acceptance of water meters. Financial reserves should also be put aside to fund and maintain such a program.

4.2 LEAK DETECTION AND REPAIR

Active leak detection is instrumental in finding unreported water leakage and losses within the distribution system. The water distribution system is surveyed to pinpoint water losses from buried infrastructure. Finding the leak is only the start, as the speed (utility responsiveness) and quality of the leak repair are also critical in reducing water loss and preserving the water infrastructure. Finding and repairing water losses through an active leak detection program will reduce the water loss and, in many cases, save the municipality substantial money, because of having a planned process to find and repair leaks. Without a leak detection program, leaks may only be found when they become visible at the surface, or when major infrastructure collapses. Active leak control will reduce expensive emergency overtime repairs and the associated liability costs. The impact on customers is also greater in emergency repair situations as is the possible impact on other infrastructure (roads, sewers, utilities) and on the environment due to possible discharges of chlorinated water.

A leak detection program is normally undertaken by the municipality for publicly owned water distribution systems. It should also be remembered that there can be many private water infrastructures in many municipalities (e.g., condominium complexes, federal lands, shopping centres, private lands, service laterals, etc.), and water loss on these properties can be substantial. If a municipality does not meter the water entering these private systems at the property line, substantial, unmetered water may be lost within these systems. The impact of private water systems on the overall water loss within a municipality should be assessed before undertaking (or requiring the private water system owner to undertake) a leak detection program on private infrastructure.

4.3 WATER EFFICIENCY/CONSERVATION

Water efficiency/conservation programs are extremely beneficial in an unmetered municipality, as leaks (or other forms of wasting water) in building plumbing systems can be substantial. In a fully metered municipality, the water meter should account for all water use in facilities and, as such, water efficiency or conservation programs may have a minimal impact on water losses in the distribution system.

However, there are many other benefits to a water efficiency or conservation program, including the delay of major water plant expansions and reduced water use, which benefits the environment.

4.4 VALVE MAINTENANCE

An appropriate frequency of main line valve inspections and a planned operating program are recommended to ensure that water main valves are accessible and operational. System valve operation will allow utility staff to isolate leaks quickly for repair, and provide for system shutdowns, metered sectorization, and other system tie-ins.

Predictable access and operation will facilitate leak detection activities and system sectorization to enhance leak detection activities. It will also support annual main line valve inspection and systematic valve cycling programs to ensure valve operating status. Boundary valves and check valves should have special attention paid to them especially if zone metering or district metering is being utilized.

4.5 PRESSURE MANAGEMENT

Pressure management can be an effective tool to reduce water loss in a water distribution system. Maximum pressures (including the influence of surges) can significantly affect the rates at which new breaks occur. Water losses through leaks are directly related to the water pressure within the water main. Pressure management allows municipalities to reduce the water pressure in parts or all of the distribution system, thereby reducing the quantity of water lost through leaks. Pressure management can be simple or complex, but must meet the needs of the customers and the community. It should be noted that low water pressure can affect fire protection and, possibly, water quality; expert advice should be sought before undertaking a pressure management program. Such a program can also be used to reduce nighttime pressure increases. This would lower the water lost from leakage and reduce the frequency of water main re-leakage from pressure increases.

Pressure control valves are also part of malfunctioning distribution system controls, and can have a large impact on water loss. Pressure control valves should be regularly maintained and their settings recalibrated as recommended by the manufacturer and as determined by their use. Similarly, pressure relief valves should have their pressure set points regularly verified to ensure they do not open prematurely, thus wasting water.

Water pressure has a substantial impact on water loss, as the higher the system pressure, the more water is lost through leaks. Typically a 1 percent reduction in pressure should reduce existing system leak flow rates by between 0.5 percent and 1.5 percent, depending upon pipe materials and type of leak. Pressure rise and system pressure variations and surges can increase the frequency of water leakage. System operators should be aware of system pressure variations and attempt to mitigate the operational root causes creating this condition. Some pressure management strategies include looping within the system and use of elevated storage, which also provides many other functions.

4.6 INFRASTRUCTURE RENEWAL

Replacing or rehabilitating leaky water mains and appurtenances can also reduce water losses. The renewal of water infrastructure includes all components of a water system: water mains and services, valves, and fire hydrants. This requires a planned and focused approach. Infrastructure renewal should be undertaken with other renewal projects, whenever possible (roads, sewers) to reduce the inconvenience to customers and to share the overall renewal cost with the other projects and thus minimize the overall cost to consumers and taxpayers.

4.7 PRICING

Full cost accounting and water pricing are necessary to generate adequate funds to operate and replace system infrastructure. Full cost recovery provides a business case to support rates and charges for water supplied and services for both metered and unmetered customers in a system.

The effect of water pricing on water loss within a system depends on a number of factors including any price increases and whether the customer base is metered or unmetered. Water loss is only one small component of any water pricing policy, as the overall revenues and expenditures of operating, maintaining, and managing the water system are the major reasons to review and update water pricing. Water pricing can reduce water loss by making customers more aware of the water they use and lose within their homes and buildings. This leads to customers making repairs to their plumbing which, in turn, leads to reduced water loss and consumption.

4.8 SPEED AND QUALITY OF REPAIRS

Prioritizing maintenance activities by having water loss repairs completed immediately can be a substantial benefit to municipalities. Responsiveness to repair leaks will minimize the length of time the leak is flowing. It is important to remember that the total quantity of water lost is directly proportional to the flow rate of the leak and the leak duration time. And in doing the repair, utility staff can also assess the condition of the pipe. Utilities should endeavour to prioritize and respond quickly to water leakage.

4.9 BY-LAW ENFORCEMENT AND SYSTEM INSPECTION

By-law enforcement is required to reduce the illegal use of water from fire hydrants and tapped water lines. The community is encouraged to assist by-law enforcement and inspection activities to reduce the theft of water. Illegal access to the water system may pose a water quality, cross-connection, or other health situation through improper connections to the municipal potable water system.

4.10 Zone Metering or District Metered Areas

Zone metering, also referred to as district-metered area (DMA), allows utilities to evaluate water losses. DMAs could be used to define various types of metered areas, either by client usage (i.e., industrial, commercial, and residential) or by function (i.e., reservoir or pressure). A DMA typically occurs within a distinct pressure zone of the system (a pump system or pressure-reduced area). Zone metering allows a utility to analyze water use and determine water loss within a specific DMA of the distribution system. It also provides utility operators with a better understanding of water use and overall system input into the area. Water loss prevention programs and priority maintenance activities can be assessed from DMA analysis by comparing water loss rates among the zones to determine priorities for repairs. DMAs can also be effective in capturing the positive benefits of a proactive pressure management strategy and allowing utilities to conduct a water loss management audit.

4.11 Design Standards

Good (and enforced) design standards for the construction and selection of water infrastructure are critical in reducing future water loss in the water system. Municipalities should ensure staff members are adequately trained in the inspection and installation of new infrastructure. Competent inspection practices, good documentation of infrastructure, suitable backfill material and compaction including appropriate thrust restraint will mitigate future water leakage in the distribution system over a long period.

4.12 SCADA System

Supervisory control and data acquisition systems provide a municipality with a real-time look at water flow, pressures, and quality. A SCADA system also tabulates the water supplied into the water distribution system and can be automated to turn pumps on and off, regulate pressure, and maintain storage reservoir levels as required. The proper use and operation of a SCADA system can have tremendous benefits for a municipality, not only in the reduction of water loss, but also in regards to water quality management, system reliability, and efficient system operation.

4.13 Nighttime Flow Analysis

Nighttime flow analysis can be used to determine the differences in nighttime use and water loss for a defined area. Differences in nighttime flow rates between 2:00 a.m. and 4:00 a.m. can assist the operator in determining the quantity and potential size and number of water leaks in a sector (DMA). Nighttime flow analysis in conjunction with district-metered areas will provide the municipality with functional metering information to assess system water use and leakage flow rates. The utility can prioritize its active leak control program in areas that experience sudden or elevated nighttime flow rates within a DMA.

4.14 DISTRIBUTION SYSTEM MODELLING

The computer modelling of a municipality's water distribution system can be a great aid in understanding what is occurring in the system. Calibrating a distribution system model with actual data collected in the field, and through data received from a SCADA system can provide a municipality with the tools to understand water use, loss, and pressures across the system. Modelling can also be used to determine the impacts of various scenarios before implementing a water loss prevention program.

Two types of modelling should be considered: Network Analysis Models (Hydraulic) and Component Analysis of Real Losses.

5. APPLICATIONS AND LIMITATIONS

5.1 FREQUENCY

This Water Use and Loss in Water Distribution Systems best practice should be undertaken on a yearly basis, as a minimum. Since so many operational and maintenance activities are required, a review of the undertaking of this best practice is advisable on a seasonal schedule, to allow appropriate planning of seasonal activities within the municipality.

5.2 DATA COLLECTION LIMITATIONS

The limitations of data collection completely depend on the municipality. The quality, frequency, and method of data collection on the water system infrastructure and on the water use and loss within the water distribution system play an important role in the development of this best practice. A municipality must consider how it will collect, store, and evaluate the data to allow it to make the most informed decisions.

5.3 RISK OF NOT UNDERTAKING THIS BEST PRACTICE

Not undertaking this best practice may indicate that a municipality has decided there is little value to water or to the infrastructure that delivers it. The utility should consider the long-term water source availability in the region and the cost of treatment, pumping, and operation and maintenance of control valves in the system. The cost of real and apparent loss should be calculated, which will provide a business case for the priority and extent of water loss initiatives that should be undertaken by the utility. Significant water loss may have significant short-term operating costs and long-term sustainability issues that may affect the ability of the water utility to meet the long-term water requirements of the community.

It is recommended that municipalities avail themselves of the current water accountability practices and procedures through water organizations, such as the American Water Works Association, and the International Water Association in applying best practices to reduce water loss.

5.4 EXPECTED OUTCOMES

A municipality applying this best practice will benefit through reduced water loss and reduced costs to the utility. The importance of prioritizing active leak control practices and procedures in the identification of water loss and the corresponding strategies to reduce leakage cannot be understated. The municipality will also benefit through the extension of sustainable water supplies, reduced operating costs, improved system hydraulics and utility efficiency, and improved environmental stewardship. This methodology will also allow more rational performance measures to be calculated for sub-systems, systems and utilities for realistic national and international performance comparisons of water loss management.

REFERENCES

AWWA (American Water Works Association), 1999. "Water Audits and Leak Detection," *The Manual of Water Supply Practices.* Second edition.

IWA (International Water Association), 2001. *Standard Components of Water Balance for Transmission or Distribution Systems.*