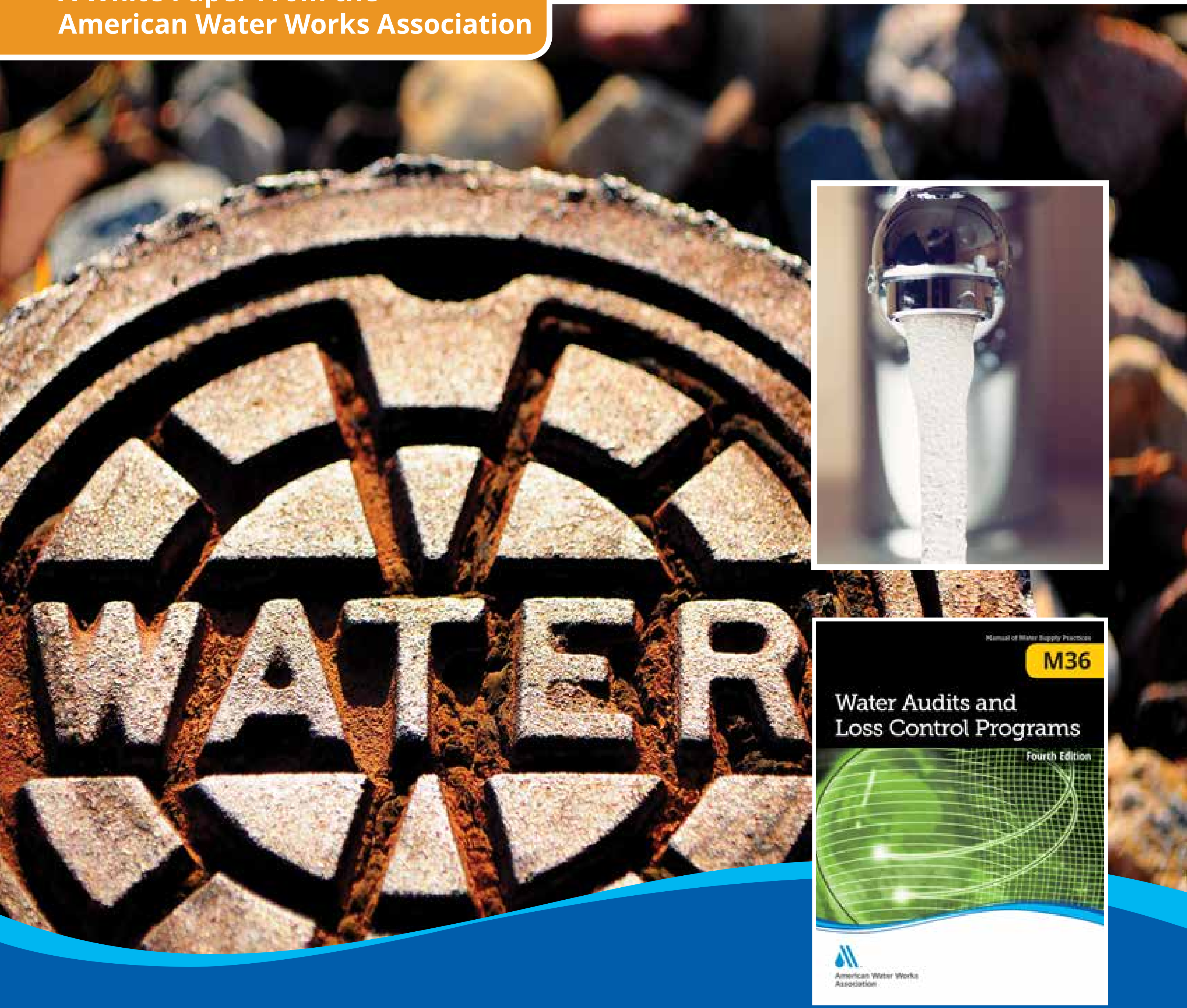
The State of Water Loss Control in Drinking Water Utilities

A White Paper From the
American Water Works Association



American Water Works
Association

Dedicated to the World's Most Important Resource®

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Safe drinking water plays a crucial role by promoting good health, food production, and manufacturing and support of virtually all aspects of life. Drinking water utilities have done an outstanding job of meeting these needs by providing safe water directly to homes, businesses, institutions, and industrial facilities. Yet, today's water utilities encounter numerous challenges in providing safe drinking water for human consumption. By improving efficiencies in supply and revenue recovery, utilities can better serve their customers, improve a utility's financial standing, and be better positioned to make vital upgrades to the vast and aging water infrastructure in community water supply systems.

Throughout the history of North America, abundant water resources could be readily and reliably tapped to supply communities. Unfortunately, that condition no longer exists in many regions due to a changing climate and other environmental stress, growing and shifting populations, financial constraints, and evolving regulatory programs. For many of today's water utilities, the amount of water they have today is likely the greatest volume they will ever have. Today's water managers must ensure they are accountable in their practices and highly efficient in their operations.

All drinking water utilities have water losses, however, the extent varies from system to system. Unfortunately, most water utilities do not regularly account for (or audit) their supplies to quantify these losses or identify the cost burdens the losses impart upon the system. The cost impacts, such as the quantities of losses, are hidden from utilities and their customers. The paying customers ultimately bear the financial burden of a utility's inefficiencies, whether or not water rates are set to cover all costs.

This paper provides water utilities with background, facts, and resources to help them understand and communicate the occurrence of water and revenue losses in utility operations and the means to cost-effectively control them. Fundamentally, this paper describes the availability of reliable methods to audit the water distribution and utility revenue stream and innovative technologies to control leakage losses, metering and accounting errors, and other losses that are common in all water utilities.

What Is Water Loss? What Is "Non-revenue" Water? What Are the Impacts to Utility Finance and Water Supply?

What Is Water Loss? What Is Non-revenue Water?

Water utilities typically withdraw water from an available water resource such as a river, lake or groundwater source. Water is then treated to regulatory standards, pumped through an underground piping distribution system, and finally supplied to customers. Water utilities may also purchase treated water from neighboring systems. Most North American water utilities include a water meter on the customer service line to measure the supply of water and record a quantity that is the basis for the monetary charge included on the regular customer water bill. Unfortunately, all utilities incur inefficiencies, or losses, in both supply- and customer-related functions of their operations.

Losses in utilities include the physical escape of water from the pressurized piping system as leakage—an occurrence known as real losses. Losses also occur due to inaccurate metering of customer consumption, theft of service, and the utility's own errant billing and accounting practices; all of which are collectively known as apparent losses. Non-revenue Water (NRW) includes the real plus apparent losses, along with unbilled authorized consumption, which represents water used in miscellaneous activities such as fire-fighting. In other words, NRW comprises the volume utilities lose from their water supply infrastructure and the unbilled volumes associated with lost revenue from a portion of the supply that reaches the customer, plus the authorized unbilled usage.

The AWWA Water Balance diagram shown in ***Figure 1*** portrays all component volumes of water supplied, delivered to customers, or lost during the course of a reporting year. Each box represents an annual volume of water, and each column totals to the same amount of water. Thus, all columns "balance" as water moves across the system, and all water is accounted for. Accordingly, there is no "unaccounted-for" water, and AWWA recommends against use of the term "unaccounted-for water." Instead, AWWA recommends use of the term NRW, as defined above and shown in ***Figure 1***. The water balance diagram provides accountability for water utilities by defining a clear path to quantify the loss volumes and demonstrate how those losses affect utility operations.

Volume from Own Sources *(corrected for known errors)*	System Input Volume	Water Exported *(corrected for known errors)*	Billed Water Exported			Revenue Water
		Water Supplied	Authorized Consumption	Billed Authorized Consumption	Billed Metered Consumption	Revenue Water
					Billed Unmetered Consumption	
				Unbilled Authorized Consumption	Unbilled Unmetered Consumption	Non-revenue Water
					Unbilled Metered Consumption	
			Water Losses	Apparent Losses	Customer Metering Inaccuracies	
					Unauthorized Consumption	
					Systematic Data Handling Errors	
Water Imported *(corrected for known errors)*				Real Losses	Leakage on Transmission and Distribution Mains	
					Leakage and Overflows at Utility's Storage Tanks	
					Leakage on Service Connections up to the point of Customer Metering	

NOTE: *All data in volume for the period of reference, typically one year.*
Figure 1 *AWWA Water Balance (Source: AWWA M36 Manual, 4th Ed.)*

What Are the Impacts to Utility Finances and Water Supply?

Uncontrolled NRW results in numerous negative impacts to water utilities and communities. Where water resources are limited, leakage represents a waste of precious water and energy resources when water is produced, but not delivered to a customer. Constrained water resources could result in limits being placed on new commercial or residential development in water-short regions. Damaging water leaks and large breaks are increasingly visible, can be very costly, and can compromise the confidence that communities, elected officials, and the media place in the water utility. Fortunately, leakage management practices and technologies can be used to help recover treated drinking water that may have been going to waste for many years. Apparent losses mean water utilities do not realize all of the revenue needed to reinvest in system upkeep and renewal. By minimizing apparent losses, however, utilities can bring in additional revenues that help fund system renewal—one of the greatest needs confronting water utilities today.

The cost of producing drinking water varies from utility to utility due to the quality and availability of the source water, size of the system, geography, energy costs, and other factors. Likewise, water utilities set customer rates and charges that are specific to their own cost of doing business, and these charges vary widely. When a utility experiences leakage in its water distribution system, the losses drive up production costs while forcing the water utility to withdraw more water from its sources than its customers need. When utilities encounter apparent losses because of inaccurate customer meters, theft, or billing issues, the cost of these losses occurs at the retail rate charged to the customer for water service. Thus, utilities with relatively high water rates and charges suffer a relatively greater impact due to uncaptured revenue from their apparent losses. The combined annual financial impact of real and apparent losses in utility operations can reach millions of dollars for large water utilities, as reported in a dataset compiled by the AWWA Water Loss Control Committee *(see reference to WADI in next section).*

Best Management Practices for Water Loss Control

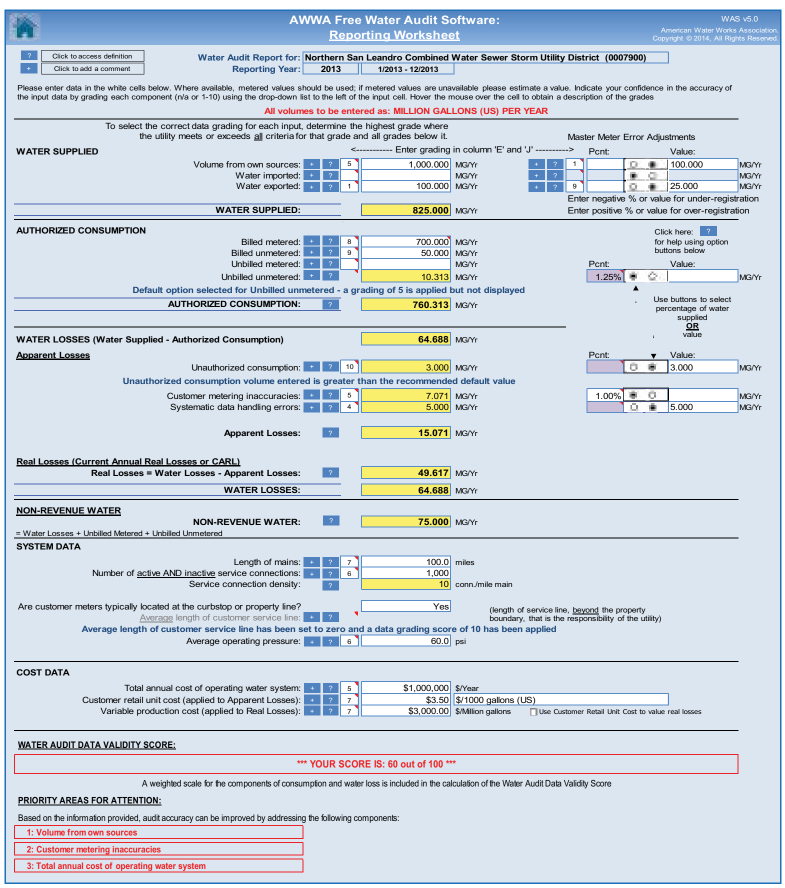
The Water Audit

Water utilities should track the annual volumes of water they manage, measuring not only the amount of water supplied to their customers, but also the water lost. The foundation of a water loss control program is the annual water audit. An audit is a systematic examination of records and financial accounts to check their accuracy and ensure the viability of the company or agency being audited. Audits are common in the world of finance and accounting. Similarly, a utility water audit involves a review of records and data that traces the flow of water from its source, through the treatment process, into the water distribution system, and delivered to customer properties. The water audit usually exists in the form of a worksheet or spreadsheet that details the volumes of water supplied, customer consumption, and loss volumes that occurred in a community water system annually.
The standard water audit also tracks various costs and calculates a variety of performance indicators to assess the efficiency of the water utility.

An assessment of validated water audit data from 2013 for 246 water utilities found that the utilities collectively incurred apparent (customer) losses equivalent to 29.4 billion gallons of water, translating into uncaptured revenue of over $151 million for the year.

Additionally, the same utilities incurred 130.1 billion gallons of water lost to system leakage. This loss added over $77 million of excessive treatment and pumping expenses to utility ledgers. The number of utilities included in this assessment is a small portion of more than 50,000 water utilities in the United States, meaning water losses across all water utilities in the United States exist at a staggering level.

AWWA's water audit methodology is the best practice approach recommended for North American water utilities to employ, which provides consistent and reliable performance tracking and benchmarking for and among water utilities. This methodology is embodied in the AWWA guidance manual, M36, *Water Audits and Loss Control Programs (4th Ed; 2016)*, [1] which gives detailed instruction on the water audit process, best practice methods to control real (leakage) losses and apparent losses, and helpful case studies on the benefits of these practices for a utility.



Additionally, AWWA provides a free spreadsheet software tool—the AWWA Free Water Audit Software (FWAS)—utilities can use to compile a standardized water audit. First released in 2006, this Excel®-based tool has been upgraded several times, with the current Version 5.0 released in 2014.[2] Since its release, thousands of water utilities and industry practitioners have downloaded the FWAS to compile a water audit. The FWAS includes inputs for volumes of water supplied by the utility, water consumed by customers, and the difference between these two numbers, which amounts to water losses. Other inputs include data about the water system and the pertinent costs. All of these data are used to calculate a series of performance indicators which give an effective rating of the system efficiency.
The FWAS also includes a unique data grading capability that allows the user to rate, or grade, the trustworthiness of the data that are input into the audit. A Data Validity Score (DVS) calculated by the FWAS represents the overall trustworthiness of the water audit.

The audit is only as good as the data available. Aside from the FWAS Grading Matrix, third-party validation is beneficial. In 2011, the AWWA Water Loss Control Committee launched the Water Audit Data Initiative (WADI) that enlists several dozen volunteer water utilities to submit their annual water audit for posting to the AWWA website.[3] These audits must first undergo a validation process conducted by Committee members in order to ensure quality control of the data. Only audits with validated data are posted. The state of Georgia followed this practice by implementing a data validation requirement, and all audits in Georgia have been validated since 2011 (see Georgia case study on page 14). The state of California is following suit, and utility water audit data will be fully validated by 2017. Over the past several years, assessments of validated water audit data found that water utilities are reporting substantial volumes of real and apparent losses with significant cost impacts *(see sidebar)*.

Establishing a Water Loss Control Program

With the development of the AWWA methodology and implementation tools, water utilities have available to them all they need to reliably audit their supply and distribution systems and assess their water loss standing. The water audit also provides the foundational data needed by the water utility to plan a cost-effective strategy to control excessive losses. In establishing a water loss control program, utilities can follow the approach shown in ***Figure 2*** for real losses and ***Figure 3*** for apparent losses.

Figures 2 and 3 on page 8 are known as the 4-Pillars diagrams. The structure is the same for each diagram with an outer rectangle that represents the annual volume of loss as quantified in the annual water audit. The outer rectangle is surrounded by 4 pillars, or arrows, representing the activities that a water utility can undertake to exert control of specific occurrences of loss and "shrink" the square representing losses. Within the square of the diagram are two reduced loss volume levels—the economic level and the unavoidable level. For most water utilities, targeting the economic level of loss is appropriate. In this approach, the utility does not spend more on loss control activities than the value of the benefit it expects to recover from the loss reduction. Because losses (apparent and real) can never be expected to be totally eliminated, the unavoidable level attempts to define the absolute minimal level that could be attained if all efforts could be exerted to contain losses, regardless of cost. At this time, the unavoidable annual apparent loss (UAAL) level exists in concept only because there is no equation to rigorously calculate this value. An equation exists to calculate the unavoidable annual real losses (UARL), and it is programmed into the FWAS. Because each utility has a unique level of losses (real and apparent) and unique costs (production, retail), the economic evaluation of loss control is unique to each system.

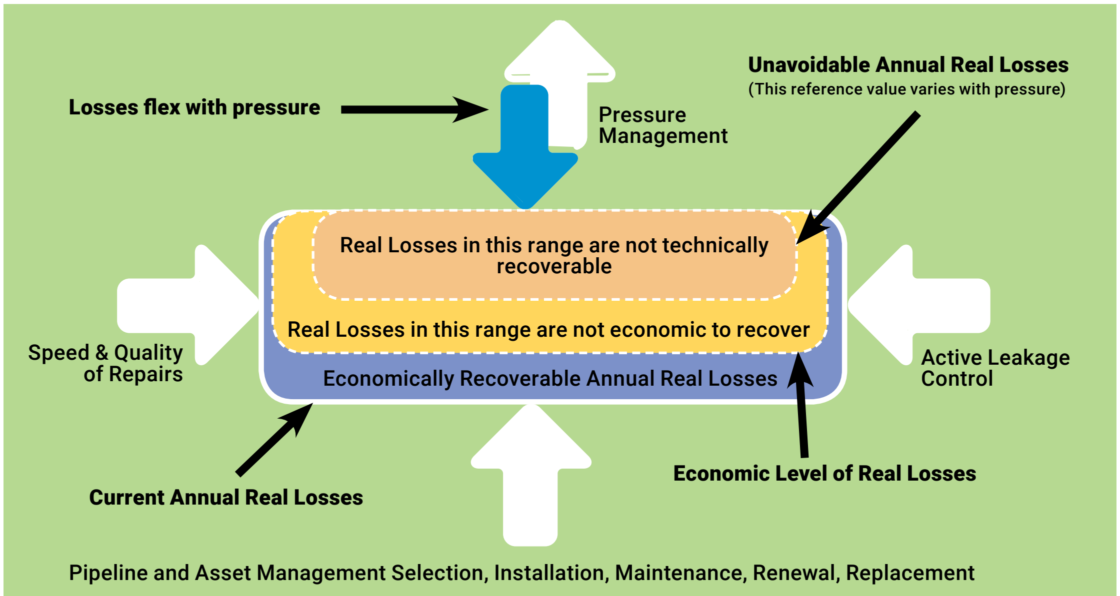


Figure 2 *The "4 Pillars" of Real Loss Control*

Controlling Real Losses

Guidance on controlling real (leakage) losses is shown in ***Figure 2***. Each pillar in this diagram identifies actions to contain leakage. In planning a proactive leakage management program to control real losses, the water utility should determine the nature of leaks and breaks occurring in its system by carefully documenting information on the leaking asset (water main piping, fire hydrants, customer service lines, etc.), the nature of repairs, and related information such as damages caused by leaks or breaks. Other information, such as average system pressure and costs to conduct leak detection work, better manage excessive pressure, and to renew water piping, should also be collected. With all of this data, the right combination of the 4-pillars activities can be determined in striving to bring leakage down toward the economic level of leakage. As part of a project administered by the Water Research Foundation (WRF), a free spreadsheet software tool[4] was developed that allows a utility to enter data and conduct a leakage component analysis. This analysis provides the utility with a slate of cost-effective leakage management

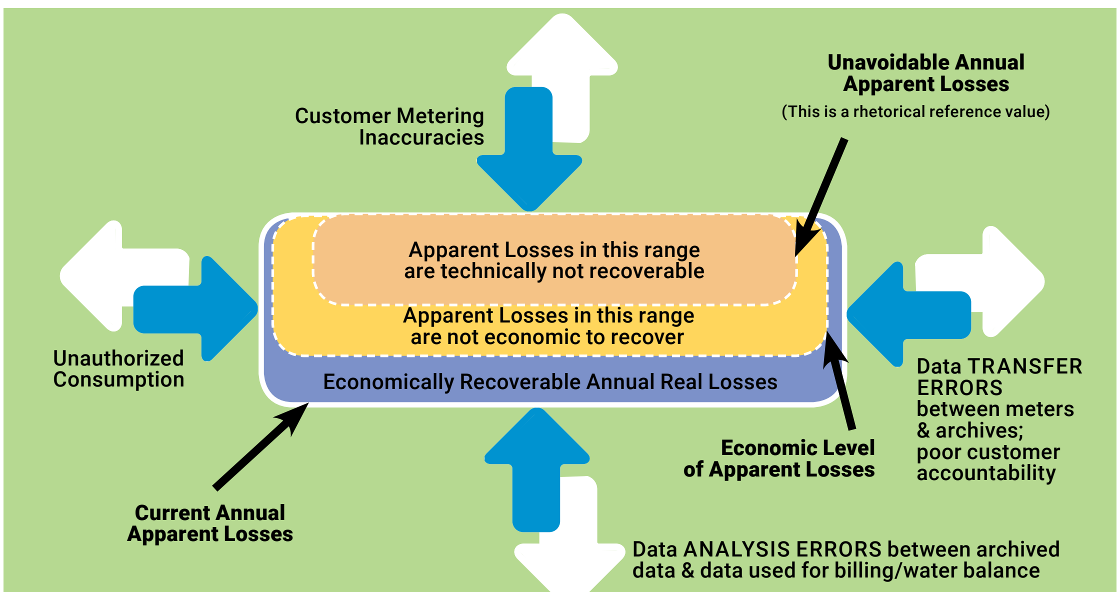


Figure 3 *The "4 Pillars" of Apparent Loss Control*

options that are tailored to the utility's leakage management needs. Water utilities should operate a proactive leakage management program as an ongoing means to combat the always occurring new leaks, many of which are hidden from view. Utilities that merely respond to visible leaks and breaks are addressing leakage reactively and will find it difficult to control system leakage; and they may find the leakage continues to increase.

Utilities should also review their effectiveness in executing timely, lasting repairs of leaks and water main breaks and evaluate their policies that require their customers to arrange for repairs on leaking water service connection piping supplying homes and businesses. Some utilities place the responsibility on customers to arrange for repairs of these lines, but these repairs are not always conducted in a timely and effective manner. This is an important consideration because often the majority of hidden leaks occur on customer service lines, rather than water mains.

Finally, water utilities should have an effective asset management program that provides for water distribution system renewal and rehabilitation at an appropriate interval to ensure the ongoing viability of the system. Such programs should explicitly recognize the monetary and resilience-related benefits derived from the activities that reduce real losses.

Controlling Apparent Losses

Guidance for organizing efforts to control apparent losses, creating what is labeled a revenue protection program by some utilities, is shown in ***Figure 3***. As with the leakage management program, the approach of the revenue protection program is to determine the appropriate combination of the 4 pillars shown in ***Figure 3*** to reduce the annual volume of apparent loss as represented by the outer rectangle. Apparent loss control can often result in a faster financial payback to the water utility by expeditiously injecting additional revenue into utility accounts.
Thus, the revenue protection program must consider activities occurring in a wide range of utility functions and customer interactions. Utilities can undertake a billing system flow-charting process to trace the flow of billing activities in the hope of identifying data transfer errors (from the meter-reading process) or data analysis errors (such as errant billing adjustment protocols) that inadvertently result in missed customer billings or underbillings of certain customer accounts. The revenue protection program should also look at the management of the customer water meter population to see if it is current, technologically robust, and well documented. Effective management of the customer meter population is needed to ensure that water meters and billings are accurate.

Provision of water service is not immune to the occurrence of unauthorized consumption. Some members of every community are willing to tamper with water meters or meter-reading equipment or find other ways to obtain water service without paying (fully) for it. It is up to water utilities to review their policies for provision of water service to make certain that they are clear about what uses of service are proper. Utilities should also have a means to detect unauthorized consumption. Today's Advanced Metering Infrastructure (AMI) has outstanding capabilities to monitor customer water consumption and to detect tampering and unusual water usage patterns. Water utilities should have in place appropriate enforcement mechanisms to address offenders' behavior in a way that can recover revenue and disincentivize continued inappropriate use of water service.

Benefits of Effective Water Loss Control

Effective water loss control offers many benefits. At the broadest level, efficient water utilities better sustain water resources, manage energy, and plan for future water supply infrastructure. For example, a water utility whose water resources are marginally adequate to meet existing demands would do well to incorporate a water loss control plan within its strategy for sustaining water resource adequacy. Such approaches can be integrated with traditional water conservation programs to reduce or stabilize source water withdrawals going into the future. This can allow the utility to defer or downsize planned expansions of source and treatment capacity and maximize efficient use of water supply. Revenue recovered from apparent loss control activities can be re-allocated to fund supply, infrastructure, or additional water loss control activities.

At the community level, water loss control results in fewer disruptions attributable to leaks and water main breaks, better payment equity among customers because fewer customers obtain unintentionally discounted or free water, improved public relations, and reduced liability.

The 2016 Standard & Poor's Rating Services issued updated rating methodology in its report U.S. Public Finance Waterworks, Sanitary Sewer, and Drainage Utility Systems: Rating Methodology and Assumptions.[5] The report notes that water audits based on industry-accepted performance standards must be compiled on a regular basis to receive a good or strong rating under the Operational Management Assessment.

The value of progressive water loss control is being recognized by the bond rating agencies in the financial market. This revised rating methodology clearly indicates that water loss control is a factor in determining the appropriate rating to be assigned for a pending debt issue needed to finance infrastructure improvements. Thus, better management of NRW can help to achieve better financial ratings and lower financing costs. Drinking water utilities now have outstanding means to audit their supplies, quantify and value their losses, and devise effective programs to economically control losses.

Getting Started on Water Loss Control

Just as a proactive water utility carefully tracks its finances, effective utilities should also track the water supply and distribution system that they manage. Historically, the motivation for a water utility to compile the annual water audit was strictly voluntary. However, since 2005, several American states have enacted requirements for annual water audits, and the number of water utilities routinely compiling water audits is growing. For most water utilities, getting started is the largest hurdle. However, outstanding publications, software tools, and guidance to launch a water loss control program are now available to utilities. The most important step is to just get started and then build on the results!

Utilities instill accountability in their operations by compiling the annual water audit. Utilities can improve the efficiency of their operations by implementing combinations of the activities shown in the 4-pillars diagrams in ***Figure 2*** and ***Figure 3***. It is important to recognize water utilities must have strong accountability by compiling the annual water audit before they can assess their level of efficiency. It is simply not possible for a utility to know how efficient it is without first having reliable data from the water audit. The water audit quantifies the volume and cost impacts of utility losses, which are the basis used to devise a water loss control program. Water audit data can then be tracked from year-to-year, with the hope of reporting steady reductions in losses. However, compiling the water audit is the important first step in the water loss control process.

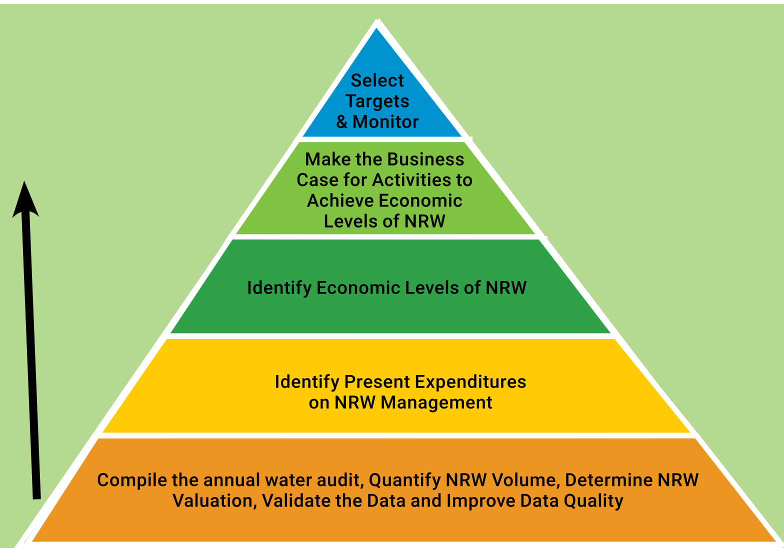


Figure 4 *Building an Effective Water Loss Control Program*

Water utilities getting started on the process of water loss control can consult the references and information sources *(see Table 1)* to launch a program. Although many water utilities will be aware of "low hanging fruit" that can be addressed in the short term with little additional planning, it is wise to follow the sequence shown in ***Figure 4*** when building an effective water loss control program.

Depending on utility size, the utility should also assign a Water Loss Control team that will "champion" each activity (data gathering, analysis, and water loss reduction).

Once launched, the team should do the following:

- Assess their "As-Is" water loss status;
- Determine the monetary valuation of existing water losses and the current level of expenditure to manage them;
- Identify opportunities (candidate activities) to improve their NRW management performance;
- Establish performance targets for the desired "To-Be" condition;
- Formulate a strategy and implementation plan by analyzing current conditions, influences, and monetary and other related costs;
- Assess and allocate resources for implementation;
- Implement strategies;
- Monitor progress; and
- Adjust their management plan as needed.

Water systems come in all shapes and sizes. The vast majority of North American water utilities are considered "small systems," serving a population of 10,000 or less. Small systems reliably meet the water supply needs of smaller communities with relatively fewer ratepayers to support meeting the revenue goals of the utility. Many of these systems encounter challenges different from their large-system counterparts. Small systems typically don't have the financial, managerial, or human resource capacity that large systems typically have, however, the approaches and tools described in this paper work for small systems as well as large systems. Certain performance indicators included in the AWWA FWAS are specifically tailored for small systems with a low density of customer service connections. Although the mechanisms of water loss control work as well for small systems as for large systems, the delivery of knowledge and assistance to small systems may require additional outreach. The Rural Community Assistance Partnership (RCAP) is an example of an organization that provides excellent assistance in terms of training in water loss control methods. RCAP has assembled the training program Controlling Water Loss in Small Drinking Water Systems[6] to educate small systems on the methods included in this paper and in alignment with the content found in the AWWA M36 guidance manual. The Environmental Finance Center Network is another organization that creates training materials geared toward small water systems.

Current Regulatory Trends

What Is Happening at the State level?

Regulatory entities in North America increasingly consider water loss control performance within their water supply management programs, primarily requiring demonstration of "satisfactory" water loss performance, or submittal of plans to achieve same, as a condition of granting permits for additional water supplies, or continuation of permits for existing water supplies. These entities are generally reluctant to explicitly consider the financial implications of thresholds they establish for "satisfactory" performance when determining the viability of such permit requests. Exceptions are public service commissions charged with overseeing rate-making processes for regulated utilities (private and, in some states, public as well), requiring in-depth submittal of supporting justification for recovery of expenditures for activities related to water loss control.

A growing number of regulatory entities are requiring annual water auditing using the methodology presented in AWWA M36, together with proactive technical guidance for validating the underlying data inputs. Some agencies are also implementing remedial activities to improve control of water losses and priority point scoring-based funding mechanisms (e.g., a state revolving fund for low-interest loans to help finance capital investments that focus on non-growth related projects for water loss control). These programs and the underlying enabling legislation are being developed through collaborative efforts among elected officials, regulators, water utilities, and other involved parties such as consultants, service providers, and non-government organizations.

The California Water Loss Control Collaborative (CWLCC) is a leading initiative that is transforming water loss assessments in California. With funding obtained from USEPA via the Drinking Water Revolving Loan Fund, the Collaborative is coordinating the work that is implementing the requirements under legislation enacted under SB1420 and SB555,[7] which passed in 2015. The initiative is based on the successful program developed in Georgia. The following are key features of the CWLCC:

- Commitments by urban potable retail water systems to participate in a series of training sessions in water audits and loss control (tailored to the needs of three classes of relative water system proficiency)
- Validation of water audits (with provision for designation of certified internal validators after receiving training)
- Submittal of water audits to the California Department of Water Resources (CDWR) by milestone dates in 2016 and 2017, depending on the assigned proficiency class

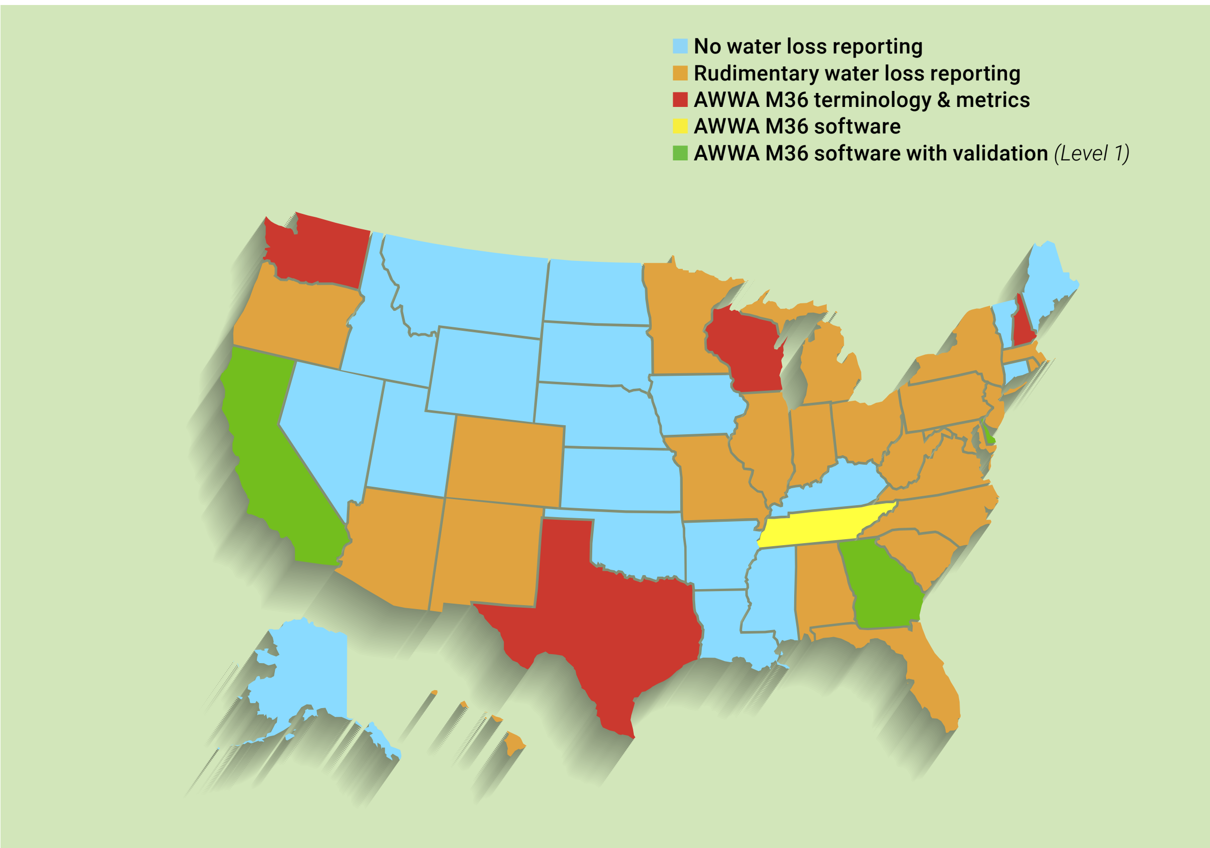


Figure 5. Status of Water Auditing and Reporting Programs in the US *(Adapted from NRDC, June 2016)*

Comparison of Current Regulatory Requirements

A summary of state/provincial regulatory agencies that have water loss control programs with requirements based on the AWWA Water Audit Methodology is shown in Table 2-1 of AWWA M36. This is not necessarily a complete listing because other regulatory agencies may since have developed or intend to develop water loss control requirements substantially based on the AWWA Water Audit Methodology. The most recent additions to the list of regulatory agencies that will be employing the AWWA Water Audit Methodology are Indiana (March 2016 legislation) and Hawaii (May 2016 legislation). Similar legislation has been proposed in Colorado but is presently on hold. ***Figure 5*** on page 12 is a "50-State Map" that indicates the current status of water loss audit and reporting programs of the AWWA Water Audit Methodology as of mid-2016.

Such programs may have different justifications for being implemented. In some cases, the requirements are imposed as part of a broader water use efficiency context that includes more conventional water conservation programs intended to aid in managing water resources in areas experiencing water shortages. In other cases, requirements may focus on operational concerns or issues of financial viability. Regardless of the program objectives, the essential elements of an effective water audit and loss control regulatory program should include the following:

- A stakeholder participation for the rule-making process
- A statement of desired objectives, policies, and approaches for achieving the objectives
- Appropriate application of the best practice water audit performance indicators and Data Validity Score (DVS) of the FWAS
- Appropriate caution in target-setting for water loss control interventions
- Definition of compliance/noncompliance provisions of prospective water auditing and loss control rules
- Guidance for compliance with prospective water auditing and loss control rules
- Obtaining financial support for relevant projects proposed by water utilities
- Investigating the availability of State Revolving Fund monies as a possible source for funding such regulatory programs for water efficiency purposes

Case Studies/Illustrative Examples of Successful Water Loss Control Programs

State of Georgia—Water Stewardship Act Program Requirements[8]

In 2010, the state of Georgia enacted the Water Stewardship Act (WSA), a landmark bill that established mandatory statewide water conservation practices for the water industry, including the annual collection of utility water audit data using the AWWA FWAS. After the initial data collection found gross mistakes, anomalies, and systematic errors in water audit data, the state realized that validation of audit data was necessary before publication. To achieve this, the state of Georgia embarked upon water audit training, technical assistance, and data validation efforts, funded through the Georgia State Revolving Fund. A Level 1 validation program was required, consisting of two phases: initial third-party validation of data submission followed by a transition to a self-sustaining model in which utilities validate their own data.

In the first phase of audit data validation, third-party experts were contracted to conduct level 1 validation of all water audits from 2011 to 2013. After data was collected, these contractors conducted a teleconference with each utility to examine the derivation of audit inputs and document the policies and practices in-place to support or amend the data grading selected for each input. The contractors modeled protocols for conducting data review and validation after those of the AWWA Water Audit Data Initiative (WADI).

Phase two of audit data validation evolved from the state's desire to move to a self-sustaining model that does not rely in perpetuity on state-funded third-party validation. To this end, Georgia again engaged a third-party expert, this time to design and execute a validation certification program to train and certify water industry professionals in level 1 validation of water audit data. The program, titled the Qualified Water Loss Auditor (QWLA) program, was also designed to provide the state with checks and balances for quality assurance. Any individual taking the required training and passing the accompanying examination could be qualified as a QWLA, allowing for utility employees and other water professionals to achieve this qualification and validate utility water audits. The contractor executed the first year of QWLA training in January 2016, and 170 individuals were qualified as QWLAs.

In addition to the comprehensive structure for water audit data collection, the state of Georgia has also investigated water efficiency improvements in utilities by funding and conducting a series of projects that have inspected water production flowmeter installations throughout the state and tested them for accuracy where possible. The state also piloted innovative leak detection and pressure management technologies in certain utilities. These projects are going beyond the water audit requirement and address the efficiency traits of the state's water utilities.

The state of Georgia has taken a highly progressive and structured stance toward implementation of the requirements of the WSA. Consequentially, Georgia publishes well-vetted water audit data for more than 200 water utilities on an annual basis. This data is allowing for analysis that is revealing notable trends in utility efficiency across the state. This data stands as the largest and most trustworthy water audit dataset existing at this time, and Georgia's innovative approach is being modeled by a number of other states.

Halifax Water, Halifax, Nova Scotia, Canada

Halifax Water was the first water utility in North America to employ the water audit methodology now advocated by AWWA. The utility has also become the North American leader in leakage management by innovating and employing extensive leakage and pressure management controls across its water distribution system. With a strong philosophy of customer-centered management and a focus on continuous improvement, Halifax Water made water loss control the centerpiece of its integrated services.

Halifax Water took a strong focus on leakage control and greatly advanced it by gaining training on the most progressive leakage control methods being employed across the world and implementing them in its system. Its water distribution system is now largely sectored into many District Metered Areas (DMAs) with supply flows monitored continuously and newly emerging leakage quickly detected and abated. Advanced pressure management has been employed to the extent possible, and the system is upgraded at an appropriate rate. Consequently, Halifax has driven down leakage by over 10 MGD, worth $600,000 annually, to near the technical low limit and has been successful in maintaining this state. Halifax has focused on apparent losses by installing commercial bulk watering stations and disallowing use of fire hydrants for retail supply purposes. Additionally, Halifax is launching installation of an Advanced Metering Infrastructure (AMI) system that will be fully online in 2017.

Philadelphia Water Department, Philadelphia, Pennsylvania

Philadelphia Water Department is one of the largest water utilities in the United States, serving a population of over 1.5 million via a water distribution system of more than 3,000 miles of pipeline. Philadelphia Water Department became the first water utility in the United States to employ the AWWA water audit methodology and compiles a highly detailed water audit on an annual basis. The utility installed the then largest water utility Automatic Meter Reading (AMR) system in the US by 1999 and has piloted a number of projects to demonstrate innovative leakage control. Its involvement in WRF projects has helped to greatly focus the importance of water loss control. One WRF project included the construction of a full-scale DMA with advanced pressure management, which serves as a continuing research undertaking. Philadelphia Water Department has employed services that use acoustic leak detection sensors inside of large-diameter transmission pipelines to accurately detect leaks flowing at very low volumes. As a result of its continuous efforts, volumes of NRW exist at one-third less than they stood at the outset of Philadelphia's water loss control efforts. Philadelphia Water Department continues to be a leading utility that has brought water loss control to the forefront of industry concerns and has proven that reliable water auditing and consistent use of innovative technologies promote a more accountable and efficient water utility.

Birmingham Water Works, Birmingham, Alabama

Birmingham Water Works has progressively pursued NRW management for over a decade, creating a structured in-house program that addresses both challenging leakage conditions and revenue recovery opportunities. Birmingham's leadership is open to new approaches and has sought alternatives to distribution system management beyond outright pipe replacement, which is an expensive undertaking. The water distribution system serves over 600,000 persons through nearly 4,000 miles of main and traverses many hills and valleys comprising the mountainous terrain of the Birmingham region, requiring that the system be divided into many pressure zones with very high water pressure in much of the system. Birmingham has sectored the system to monitor flows, manage system pressures, and identify emerging leakage with the aid of portable acoustic noise loggers and location-pinpointing via correlating equipment. Supply flows recorded by its SCADA system are compared with metered consumption to determine water loss in each pressure zone. This helps to prioritize its NRW management activities and further informs its long-range asset management (system renewal) program. Birmingham has also piloted the use of a variety of production flow-meters that measure bulk supply and flows into DMAs and other zones. Ongoing testing of customer meters is conducted by in-house staff with its test bench apparatus along with truck-mounted testing equipment for larger meters, resulting in a relatively high overall customer meter accuracy. Birmingham Water Works operates a large water system with challenging conditions, but has taken a proactive stance to better manage its water infrastructure, save water, and manage its revenue base to the betterment of the utility and its community.

Water and Wastewater Authority of Wilson County, Tenn. (WWAWC)

The Authority is a small system that supplies water to 7,000 service connections through just over 320 miles of pipeline in a rural county near Nashville, Tenn. WWAWC purchases its entire supply of water at a high cost and has focused extensively on leakage control to prevent wasting this expensive resource. The water distribution system is made up almost entirely of plastic (polyvinyl chloride) pipe, which challenges traditional acoustic leak detection because this material does not emit strong noise when leaks occur. Consequently, WWAWC established a comprehensive system of DMAs to monitor flows and respond to alerts of flow increases above normal customer demand, that typically signify emerging leakage. Using this approach, WWAWC has been very successful in managing leakage, initially recovering $70,000 worth of lost water, then bringing it down to the unavoidable level of leakage. This experience shows that innovative leakage management approaches are applicable—and perhaps the only successful—options for small utilities with challenging leakage conditions to pursue.

Summary

North American water utilities are instrumental in providing health and vitality to our communities by providing safe drinking water on a continuous basis and at an affordable cost. All water utilities lose a portion of their treated water to leakage and fail to fully recover all revenues due from their customers. These inefficiencies of water and revenue loss—collectively known as non-revenue water—create a number of problems including wasted water and energy resources, damage from rupturing underground water distribution piping, additional financial hardships for cash-strapped systems, and many other negative impacts.

Water utilities have traditionally lived with losses, knowing intuitively that they exist, but viewing them as a seemingly unavoidable additional cost of doing business. Unfortunately, by not quantifying these losses and the cost impacts they cause, utility managers have often failed to portray the justification they need to convince executive management, governing board members and/or elected officials to undertake programs to directly address losses.

Research Opportunities

Fortunately, this condition has changed for the better in the new millennium as innovative methods and technologies for auditing water supplies and controlling real (leakage) losses and apparent (customer) losses have been developed and are greatly assisting water utilities in controlling losses to economic levels. AWWA, the Water Research Foundation, and other organizations have produced a number of low- or no-cost software tools and publications to assist and guide utilities in employing these new best practice approaches to effective water loss control. Utilities now have at their disposal all of the capabilities that they need to launch a reliable water audit process and apply effective efficiency controls.

Although considerable technological progress has been made, several research opportunities exist for

- advancing understanding and determining the significance of underlying root causes of water loss (such as negative effects of excessive operating pressure and occurence of pressure transients);
- quantifying the benefits of water loss control for improving operational efficiency, e.g., managing the "water-energy nexus;"
- identifying the most meaningful performance indicators and their relationship to water loss control practices and setting of reliable goals for economic control of apparent and real losses;
- identifying how these performance indicators can be incorporated by regulatory agencies in an effective oversight process while avoiding a "one size fits all" approach;
- developing guidance for business case planning and associated analytical approaches (i.e., "strategic thinking") to be used when developing water loss implementation programs.

Emerging Regulatory Trends

A number of state, provincial, and regional regulatory agencies have implemented requirements for utilities to submit annual water audit data and begin to move their losses downward. It is certain that additional state agencies in the United States will implement such requirements knowing that realistic auditing assessments exist, as well as effective loss control technologies. The value of these efforts will be enhanced if a rating system comprising these performance indicators is not only technically sound, but is also easily grasped and understood by both technical (water utility) and non-technical (customers, elected officials, financial, public relations, media) stakeholders. The ability of a water utility to communicate the status of its NRW performance and garner support for water loss control programs from all stakeholders is essential for demonstrating effective utility management and stewardship of water resources.

Water Loss Control at a Crossroads

The North American drinking water industry stands at an important crossroads regarding non-revenue water. Many utilities are greatly challenged by water resources that are threatened by a changing climate, cost constraints and pressures to keep water affordable, while undertaking renewal of vast, aged water supply infrastructure. Water loss control can assist utilities in addressing all of these issues. The figurative "fork in the road" presents two pathways to possible future scenarios for utilities: a status quo approach from past years that leads water utilities further into declining water resources, crumbling infrastructure, inadequate metering, and a cash-starved existence; or a future of efficiency with accurate metering, timely billing, and low-leakage systems that help preserve available supplies, better sustain water infrastructure, and maintain solvent water utilities with water rates that are affordable for communities. Which future scenario will your water utility choose?

Glossary

Active Leakage Control—A proactive program that a water utility implements to control unreported (hidden) leaks in water distribution systems. Active leakage control includes traditional acoustic leak detection or non-acoustic leak detection. Active Leakage Control can also include permanent flow monitoring in small zones of the water distribution system known as district metered areas to infer changing leakage rates and identify emerging leakage.

Apparent Losses—Apparent Losses involve systematic data-handling error (in the customer billing process), all types of customer metering inaccuracies, and unauthorized consumption.

Authorized Consumption—Authorized Consumption is the annual volume of metered and/or unmetered water taken by registered customers, the water supplier, and others who are authorized to do so.

Customer Metering Inaccuracies—Apparent Losses caused by the collective under-registration or malfunction of customer water meters, which can occur from meter wear, improper sizing or type of meter for the customer usage, or improper installation, aggressive water quality, malfunction, and other causes. Mechanical meters wear as volumes of water are passed through them over time, eventually under-registering the flow.

Non-revenue Water—This is the sum of Unbilled Authorized Consumption, Apparent Losses, and Real Losses. This value can also be derived by calculating the difference between System Input Volume and Billed Authorized Consumption.

Pressure Management—An effective method for optimizing pressures in a water distribution system to minimize losses and surge impacts while maintaining adequate water service, including firefighting flows. Pressure management is particularly effective in minimizing background losses or widespread small leaks across the system, and is also a valuable strategy to inhibit water main breaks from occurring, thereby better sustaining the life of the water distribution system infrastructure.

Real Losses—Real Losses are the annual volumes lost through all types of leaks, breaks, and overflows on mains, distribution reservoirs, and service connections up to the point of customer metering.

Revenue Water—Revenue Water pertains to those components of System Input Volume that are billed and have the potential to produce revenue.

System Input Volume—System Input volume is the annual volume input to the water supply system. This equals the Volume From Own Sources plus the Water Imported volume as measured and reported by master supply meters, corrected for metering error. Meters require regular accuracy testing and specified installation.

Systematic Data-Handling Error—pertains to customer consumption and billing data error that occurs in the water utility's business processes as a result of lax oversight, poor procedure, or gaps in information programming and archiving. These are apparent losses caused by structural or random errors existing in the meter reading, data transfer, accounting, or archival function of customer consumption management. Examples include inaccurate estimates, extended periods during which no meter readings are obtained, poor account adjustment protocols, and poor accountability allowing some consumers to exist without an account in the billing system.

Unauthorized Consumption—water taken from the water distribution system without the authorization of the water utility. This may include (unpermitted) water withdrawn from fire hydrants, illegal connections, bypasses to customer meters, meter or meter reading equipment tampering, or similar actions. Unauthorized consumption is one of the components of apparent losses.

Volume From Own Sources—This is the volume of water withdrawn from water resources (rivers, lakes, streams, wells, etc.) controlled by the water utility, and then treated for potable water distribution.

Water Exported—The Water Exported volume is the bulk water conveyed and sold by the water utility to neighboring water systems that exist outside of their service area.

Water Imported—The Water Imported volume is the bulk water purchased to become part of the Water Supplied volume. Typically, this is water purchased from a neighboring water utility or regional water authority.

Water Losses—This is the difference between System Input Volume and Authorized Consumption, consisting of Apparent Losses plus Real Losses.

Water Supplied—The Water Supplied volume is the annual volume of treated water delivered to the retail water distribution system. This equals System Input Volume minus the Water Exported volume.

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AWWA Water Loss Control Products and Additional Resources

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