EPA United States Environmental Protection Agency

WATER AUDITS AND WATER LOSS CONTROL FOR PUBLIC WATER SYSTEMS

This document provides an introduction to water loss control and information on the use of water audits in identifying and controlling water losses in public water systems. **Water audits** are the first step in a three-step process for controlling water loss. A water audit is followed by **intervention** to identify losses and implement solutions and then by an **evaluation** of intervention measures and the needs for further improvement. This document is intended for small and medium-sized water systems, as well as state programs and technical assistance providers that regulate or support these systems.

Introduction

The Water Loss Problem

Public water systems face a number of challenges including aging infrastructure, increasing regulatory requirements, water quantity and quality concerns and inadequate resources. These challenges may be magnified by changes in population and local climate. It has been estimated that:

- The United States. will need to spend up to $200 billion dollars on water systems over the next 20 years to upgrade transmission and distribution systems.[i]
- Of this amount, $97 billion (29 percent) is estimated to be needed for water loss control.[ii]
- Average water loss in systems is 16 percent - up to 75 percent of that is recoverable.[ii]

A water loss control program can help water systems meet these challenges. Although it requires an investment in time and financial resources, management of water loss can be cost-effective if properly implemented. The time to recover the costs of water loss control is typically measured in days, weeks, and months rather than years.[ii] A water loss control program will also help protect public health through reduction in potential entry points for disease-causing pathogens.

Understanding Water Use and Water Loss

Much of the drinking water infrastructure in the United States has been in service for decades and can be a significant source of water loss through leaks. In addition to leaks, water can be "lost" through unauthorized consumption (theft), administrative errors, data handling errors, and metering inaccuracies or failure. The International Water Association (IWA) and the American Water Works Association (AWWA) have developed standard terminology and methods to assist water systems in tracking water losses and in performing water audits. The standard terminology includes the terms authorized consumption, real loss, apparent loss and non-revenue water that are used in this document.

- **Authorized Consumption** is water that is used by known customers of the water system. Authorized consumption is the sum of billed authorized consumption and unbilled authorized consumption and is a known quantity. It also includes water supplied to other water systems.

- **Real Losses,** also referred to as physical losses, are actual losses of water from the system and consist of leakage from transmission and distribution mains, leakage and overflows from the water system's storage tanks and leakage from service connections up to and including the meter.
- **Apparent losses**, also referred to as commercial losses, occur when water that should be included as revenue generating water appears as a loss due to unauthorized actions or calculation error. Apparent losses consist of unauthorized consumption, customer metering inaccuracies, and systematic data handling errors in the meter reading and billing processes.
- **Non-Revenue Water** (NRW) is water that is not billed and no payment is received. It can be either authorized, or result from apparent and real losses. Unbilled Authorized Consumption is a component of NRW and consists of unbilled metered consumption and unbilled un-metered consumption.

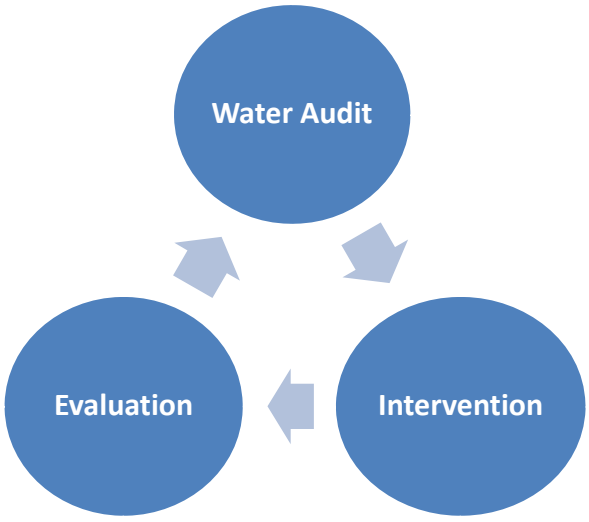
What are the Benefits of a Water Loss Control Program?

A water loss control program helps to identify real or physical losses of water from the water system and apparent losses, the water that is consumed but not accounted for. Real losses represent costs to a water system through the additional energy and chemical usage required to treat the lost water. Apparent losses represent a loss of revenue because the water is consumed but not accounted for and thus not billed. Once a water system identifies these real and apparent losses through a water loss control program, it can implement controls to reduce them. This can reduce the need for costly upgrades and expansions due to population growth and increased demand. By reducing the amount of water lost, the recovered water can be sold to consumers, generate revenue and meet water demands. In some cases this can reduce the need to find additional sources. *Water loss control programs are often the most economical solution to increasing demand, especially in the short term*.[i]

What Does a Water Loss Control Program Look Like?

A water loss control program consists of three major steps (see Figure 1). The critical first step is the ***water audit***. A *water audit* identifies and quantifies the water uses and losses from a water system. The ***intervention*** process addresses the findings of the *water audit* through implementation of controls to reduce or eliminate water losses. The ***evaluation*** step uses performance indicators to determine the success of the chosen intervention actions. Utilizing the standard terminology and the three steps of a water loss control program, systems can determine their baseline water use and loss, prioritize and implement water efficiency projects and operational changes, and evaluate and continuously improve their water loss

Figure 1. Components of a Water Loss Control Program



management.
Figure 2 provides a summary of the main data needs, action items and performance indicators for each step of a water loss control program. The following sections will go into more detail for each step.

Step 1 - Water Audit Data Needs	Step 2 - Intervention Action Items	Step 3 - Evaluation Performance Indicators
•Gathering information. •Determining flows into and out of the distribution system based on estimates or metering. •Calculating the performance indicators. •Assessing where water losses appear to be occurring based on available metering and estimates. •Analyzing data gaps. •Considering options and making economic and benefit comparisons of potential actions. •Selecting the appropriate interventions.	•Gathering further information, if necessary. •Metering assessment, testing, or a metering replacement program. •Detecting and locating leaks. •Repairing or replacing pipe. •Operation and maintenance programs and changes. •Administrative processes or policy changes. •No further action is necessary.	•Were the goals of the intervention met? If not, why not? •Where does the system need more information? •How often should the system repeat the *audit, intervention* and *evaluation* process? •Is there another performance indicator the system should consider? •How does the system compare to the last *audit, intervention* and *evaluation* process? •How can the system improve performance?

Figure 2. Summary of Data Needs, Action Items, and Performance Indicators of a Water Loss Program

The Importance of Metering

Water meters, both at the source and the service connection, are very important for all aspects of the water supply operations and make accurate water auditing possible. They make it possible to charge customers based upon the quantities of water that the customers consume. They record usage and make billing fair for all customers. They can encourage conservation by making customers aware of their usage as well as help detect leaks and establish accountability. Meter records provide historic demand and customer use data that is used for planning purposes to determine future needs. Unmetered water systems will need to consider some level of system metering to address water loss in the system.

A variety of meters exist and each type has its advantages and disadvantages. There is no single type of meter that will accurately measure flow for all applications. To select the proper meter for a specific application, a variety of factors should be considered in order for the meter to satisfy the location requirements and conditions where it will be installed. More information about the types and applications of meters can be found in EPA's *Control and Mitigation of Drinking Water Losses in Distribution Systems,* EPA 816-R-10-019, November 2010. The document is available at: http://water.epa.gov/type/drink/pws/smallsystems/technical_help.cfm.

Step 1 – How to Complete a Water Audit

A *water audit* is an accounting of all of the water in a water system resulting in a quantified understanding of the integrity of the water system and its operation. It is the first step in formulating an economically sound plan to address water losses. A preliminary water audit begins with the following information and simple calculations :[i]

1. Determine the amount of water added to the system, typically for a one year period,
2. Determine authorized consumption (billed + unbilled), and
3. Calculate water losses (water losses = system input – authorized consumption)
    a. Estimate apparent losses (unauthorized consumption + customer meter inaccuracies + billing errors and adjustments)
    b. Calculate real losses (real losses = water losses – apparent losses)

These steps are an example of a **top down audit**, which starts at the "top" with existing information and records. It may also be known as a desktop audit or paper audit since no additional field work is required. Water systems are dynamic. The water audit process and calculation of the water balance, when routinely performed, is a useful guide for a system's water loss control program. Water systems can get started using the data that is readily available, identify any data gaps and then work towards improving their data.

After performing an initial top down audit it may become evident that some of the numbers are rough estimates. The next action in the audit process is to improve any initial estimates and begin reducing non-revenue water losses. A **bottom up audit** is often implemented after several top down audits have been completed and can better quantify loss volumes that were not revealed by the top down audit. A bottom up audit will help find apparent and real losses and begins by looking at components or discrete areas in the utility's operations. A bottom up audit assesses and verifies the accuracy of the water loss data associated with individual components of the water system. A bottom up audit could include estimates of water used in municipal operations such as fire fighting, distribution system flushing and street cleaning, as well as metering of all authorized uses.[iii]

Bottom up audits are more costly since they are more labor and staff intensive. The top down audit can help to identify areas where bottom up audit efforts should be concentrated. There are several techniques and methods used to perform a bottom up analysis. They are described in detail in *Control and Mitigation of Drinking Water Losses in Distribution Systems,* EPA 816-R-10-019, November 2010, which can be found at: http://water.epa.gov/type/drink/pws/smallsystems/technical_help.cfm.

Additional data often needs to be collected to perform a *water audit*. Additional data collection can occur during the audit or intervention phase and may include the following: [i]

- ***Locating leaks and losses*** can be accomplished through an examination of billing records, flow monitoring, visual inspection or leak detection equipment (e.g., acoustic, thermal, electromagnetic, tracer). Through an examination of billing records, a water system may identify sudden changes in water usage at particular locations in the water system, which could indicate the need to investigate further for possible leaks or theft. Flow monitoring can be conducted by examining individual customer meter records, metered districts or through placement of temporary meters in suspect locations. These temporary meters clamp onto pipes and do not sacrifice the integrity of the pipelines.

- ***Condition assessment*** tools include traditional external visual inspections (e.g., periodic walk-over and opportunistic inspections of exposed mains), internal visual inspection technologies (e.g., closed circuit television (CCTV) camera inspections), pit depth measurements, destructive testing (e.g., test coupons) and non-destructive testing (e.g., ultrasonic testing).
- ***Hydraulic modeling*** can be used to predict locations of leaks in a water system based on physical and operating data of the water system. Calibration of these models to actual field data is essential to obtain realistic and usable results.

Water Audit Resources

- AWWA provides Free Water Audit Software©, available at: http://www.awwa.org/Resources
- Georgia Department of Natural Resources, *Georgia Water System Audits and Water Loss Control Manual*, Version 1.0 (2011), available at: http://www.gaepd.org/Files_PDF/GaWaterLossManual.pdf.
- The Maryland Department of the Environment's *Developing and Implementing a Water Conservation Plan*, includes water audit worksheets and describes the development of a water conservation plan. The information is available at: http://www.mde.state.md.us/programs/Water/WaterConservation/Documents/www.mde.state.md.us/assets/document/water_cons/WCP_Guidance2003.pdf.
- The Texas Water Development Board's *Water Loss Audit Manual* (2008) includes a water audit worksheet. The manual and worksheets are available at: http://www.twdb.state.tx.us/conservation/municipal/waterloss/.
- The New Mexico Office of the State Engineer provides examples of water audits of public water systems using the IWA/AWWA process. Information is available at: http://www.ose.state.nm.us/wucp_accounting.html.

Step 2 – The Intervention Phase

Interventions are actions taken by a water system to identify the specific sources of water loss and implement solutions. These actions can include :[i]

- Preventive measures such as design standards and effective maintenance
  - Reliable construction and design standards allow a water system to maintain maximum structural integrity throughout its operating life. Once a water system has been constructed according to appropriate design standards, effective maintenance can help to ensure the system operates at optimal performance throughout its lifespan and ensure that repairs are made proactively.
- Meter installation, testing and replacement
  - Accurate metering is important for all phases of a water audit. Meters record usage and monitor demand, encourage conservation, help detect leaks and make it possible to charge customers for the water they use.

- Leakage management

    - Detecting, pinpointing and repairing leaks generates event data that refines and confirms the water losses identified in the water audit.
    - Pressure management evaluates areas of excessive pressure and implements controls that reduce pressure to cut pressure-sensitive background leakage and reduce rupture rates.
- Pipe repair and replacement
    - Once a leak has been detected and located, the pipe can be repaired or replaced. Repairing and replacing pipes requires trained personnel, the right tools and the proper inventory of parts and materials.

Step 3 – The Evaluation Phase

The *evaluation* phase is important for ensuring an efficient and effective water loss control program. Comparison of the water system to industry benchmarks or past audits can document improvements in water loss control and allow a water system to track its progress. Use of performance indicators such as those mentioned above can help to ensure meaningful interpretations of the evaluation and to encourage continuous improvement. The evaluation will answer questions such as:

- Were the goals of the intervention met? If not, why not?
- Where do we need more information?
- How often should we repeat the *Audit, Intervention and Evaluation* process?
- Is there another performance indicator we should consider?
- How did we compare to the last *Audit, Intervention and Evaluation* process?
- How can we improve performance?

Benchmarking for Small Systems

Conducting a water audit allows a system to monitor its water loss performance over time and compare itself to other systems. This process is known as benchmarking and uses a collection of performance indicators to numerically evaluate different aspects of the water system. Performance indicators need to be consistent, repeatable and presented in meaningful standardized units. Some examples are breaks per mile of distribution main per year, gallons of water lost per service connection, and gallons of leakage per mile of distribution main per year. Because conditions at small systems can vary so greatly, benchmarking can become a difficult practice as many performance indicators may not be consistent or comparable across small systems. However, the basic steps of top-down water audits, metering and water loss control efforts can help small systems conserve their resources and improve their long term sustainability.

Resources

Performing a *water audit* and developing a complete water loss control program does not have to be overwhelming. By beginning with the basic steps and principles outlined in this document, any water system can begin the process of identifying and mitigating water losses. Additional resources available to assist water systems in performing *water audits* include the following:

- EPA Office of Ground Water and Drinking Water. http://www.epa.gov/drink/
- EPA Office of Water, Water Infrastructure*: Moving Toward Sustainability.* http://water.epa.gov/infrastructure/sustain/index.cfm
- Association of State Drinking Water Administrators. http://www.asdwa.org
- The Alliance for Water Efficiency . http://www.allianceforwaterefficiency.org
- American Water Works Association. http://www.awwa.org

Resources are also available to assist water system customers in conducting a water audit of their premises. These resources include the following:

- The Maryland Department of the Environment provides instructions on how to conduct a home water audit as well as a spreadsheet that calculates current use using customer entries. http://www.mde.state.md.us/programs/Water/WaterConservation/WaterAuditing/Pages/Programs/WaterPrograms/Water_Conservation/Water_Auditing/index.aspx
- Broward County Florida Water Services provides a worksheet for plumbing fixtures and appliances to calculate residential water use and provides average use for comparison. http://www.cob.org/documents/pw/environment/water-conservation/home-water-audit-worksheet.pdf
- The City of Corvallis, Oregon, Utilities Division provides information for residential customers on checking for leaks using the water meter, measuring or estimating flows in plumbing fixtures and measuring water used in landscaper irrigation. http://www.ci.corvallis.or.us/index.php?option=content&task=view&id=443&Itemid=384

[i] U.S. Environmental Protection Agency. 2009. Drinking Water Infrastructure Needs Survey Fact Sheet , EPA 816-F-09-003. http://water.epa.gov/infrastructure/drinkingwater/dwns/factsheet.cfm.

[ii] Thornton, J., Sturm, R., Kunkel, G., *Water Loss Control Manual (2nd Edition)*, McGraw-Hill, 2008.

[iii] Texas Water Development Board, Water Conservation Task Force, *Water Conservation Best Management Practices Guide*, November 2004. http://savetexaswater.org/bmp/.