



**MARYLAND DEPARTMENT OF THE ENVIRONMENT**  
**Water Supply Program**

**Guidance for Preparing Water Audits and Water Loss Reduction Plans**

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## **WATER AUDITING**

### **What is a water audit?**

A water audit is conducted to determine the amount of water lost from a distribution system due to leakage, storage overflow, meter malfunctions, and theft. Audits are also used to estimate the cost associated with these losses to the water system by balancing the amount of water produced with the amounts billed. Comprehensive audits can provide the water system with a detailed profile of the distribution system and water users, allowing for more effective management of resources and improved reliability. Water auditing serves as an important step towards improved water conservation and, linked with the implementation of a water loss reduction plan, can save the water system a significant amount of money and time.

Elements of a water audit include:

- A record of the amount of water produced
- A record of the amount of water delivered to metered users
- A record of the amount of water delivered to unmetered users
- A record of the amount of water loss (balance of water, including leaks)

### **What are the benefits of conducting a water audit?**

Benefits of an audit include improved knowledge and documentation of the distribution system including the identification of problem or risk areas. By providing a better understanding of what happens to the water after it leaves the treatment plant, an audit can be a valuable tool to manage resources.

According to the American Water Works Association, water audit programs ultimately lead to reduced water losses, financial improvement, increased knowledge of the distribution system, more efficient use of existing supplies, increased safety for public health and property, improved public relations, reduced legal liability, and reduced disruption to customers.

### **What is water loss?**

There are two types of water losses, real and apparent. Real water loss includes water lost through leakage in distribution systems, service connections, and storage tanks (including overflow). Apparent loss includes meter and record inaccuracies and unauthorized water uses such as theft or unauthorized connections. Authorized unmetered uses are a special type of water loss, and should be carefully estimated as these losses can represent a significant source of lost revenue.

Water loss most commonly occurs due to leakage caused by a variety of factors, including:

- Corrosion
- Excess pressure
- Temperature variations
- Seismic activity
- Lack of regular maintenance
- Excessive traffic loading
- Poor design/installation
- Inappropriate backfill
- Pressure transients/fluctuations

Additionally, some of the primary reasons that meters fail over time include:

- General wear

- Impacts due to water quality and chemical build-up
- Poor design/installation
- Temperature variations
- Tampering
- Lack of regular maintenance

### **When is a water audit required?**

Water audits are generally required for all Maryland public drinking water systems that serve greater than 10,000 people. This requirement is frequently listed as a condition in Water Appropriation and Use Permits. Water audits required by permit condition must be conducted annually and submitted by the end of the State fiscal year for review by MDE. All systems are encouraged to conduct water audits as a means to increase system efficiency and reduce water loss. If a system is unsure whether it is required to submit an audit, the system should contact the Water Supply Program.

### **Conducting a water audit**

Audits are completed by calculating the difference between the amount of water produced and the amount sold (metered sales), and then addressing the difference. Metered sales are compiled and the remaining difference between produced water represents water lost. An audit records the amounts of water produced, the amount delivered to metered users, the amount delivered to unmetered users, and water loss, along with likely causes for the unaccounted water. Finally, the results are analyzed and estimates are made for recoverable leakage.

General steps for conducting a water audit are as follows:

1. Set an evaluation period –usually the previous calendar year
2. Modify the attached worksheet provided in Appendix A, if needed, to meet the system’s needs
3. Compile water production, water purchased (if any), and sales (metered) data
4. Make adjustments to the metered amounts, as necessary
5. Complete the summary sheet provided in Appendix B for submission
6. Determine whether water loss exceeds 10% of the total amount produced. If so, follow up by developing a water loss reduction plan.

An evaluation period should be set to allow an evaluation of the complete water system. A one year time period is recommended because it includes each of the seasons and provides enough time to eliminate the effect of meter reading lags. Shorter periods might not give a complete picture of the water system, and longer periods can be difficult to manage.

Appendix A of this guidance document includes a model water audit worksheet and instructions. This model worksheet is based on a worksheet developed by the Texas Water Development Board. This worksheet is simple, but it is sufficient to account for water usage and quantify lost water. Since distribution system characteristics vary, each water system will be presented with different challenges in performing the water audit. Individual systems will need to determine the most appropriate method to perform the audit while taking cost and accuracy into consideration.

It is possible to complete a water audit in one day if meter reading records are readily available and if significant adjustments to the records are not necessary. The audit should use existing records to the extent possible to produce the most accurate results. Unmetered uses should be documented along with the methods to quantify them. An attempt to account for water loss should be made.

### ***Adjustments to records***

All adjustments to metered amounts should be documented in the submission along with the calculations. All records should reflect any adjustments and should be verifiable. If adjustments are made for significant amounts of water, the system should make any necessary changes to eliminate need for adjustments in the future. Adjustments may be made to account for known production meter inaccuracy, or the difference between finished reservoir storage at the beginning and end of the study period. Difficulties may arise in adjusting existing records to fit the period of evaluation, when meter reading periods overlap. Also, some flow records might have to be pro-rated so that all flow measurements reflect the same time period. This should be done carefully to insure the accuracy of the audit.

### ***Comprehensive Audits***

In addition to the above guidelines, a more thorough audit may include the following subsequent steps:

- A meter inventory
- An evaluation of meter accuracy
- An analysis of water lost

To conduct a meter inventory, a list of the different types, sizes, and ages of meters in the distribution system should be compiled. The list is useful for estimating the accuracy of the meters on a system-wide scale and may complement the water usage information and help to identify usage patterns in the distribution system. This list could also serve as a guideline for developing meter replacement and cross-connection control programs.

Once meters have been inventoried, they should be tested for accuracy and checked to ensure that they are the proper size and type. Records should be checked carefully to make sure that the units and calculations are correct, all measurements are included, and that all measurements represent the same time period.

## **WATER LOSS REDUCTION PLANS**

### **What is a water loss reduction plan?**

A water loss reduction plan is a plan for reducing water losses and usually targets the losses identified by an audit (or several audits). Once potential options are developed to reduce water loss, cost benefit analyses should be performed to choose the best options for the system. The finalized plan must outline the measures that will be taken to further identify and reduce both real and apparent water losses and include an implementation schedule. The goal in implementing a loss reduction plan is to reduce the system's water losses as much as possible.

Elements of a water loss reduction plan typically include:

- The results of one or several recent water audits
- A plan for improved water accounting
- A plan for improved metering
- A plan for improved loss control
- A plan for improved pressure management
- A plan for improved overflow prevention
- A plan for improved consumer education
- An implementation schedule

## **What are the benefits of implementing a water loss reduction plan?**

The water system could experience several benefits from the implementation of a water loss reduction plan including the reduction of lost commodity, reduced leak-associated risks, and limiting the liability resulting from the failure to address leaks. Lost commodity is easy to quantify, as it is typically found on the bottom line of an audit worksheet.

Risks associated with not implementing a loss reduction plan include the potential for the following to occur:

- Small problems that eventually cause major outages and the need for emergency repairs
- Excessive wasted capacity
- Water theft (or dead meters),
- Roadway or foundation collapse
- Personal property damage
- Threats from cross connections as they are a direct conduit into the distribution system when fluctuations in pressure occurs

## **When is a water loss reduction plan required?**

Maryland Water Appropriation and Use Permits typically require that a loss reduction plan be submitted when an annual audit for a system serving more than 10,000 indicates unaccounted for or unmeasured water loss of greater than 10 percent. Permit conditions usually require the plan to be submitted by the end of the calendar year in which the audit was performed. For example, if the audit evaluation period is for January through December of 2050, the audit must be submitted by June 30, 2051 and if the loss is greater than 10 percent, a loss reduction plan should then be submitted by December 31, 2051.

If future annual audits continue to show water loss greater than 10%, the plan for reducing water losses should be updated and re-submitted.

## **Developing a water loss reduction plan**

General steps for developing a water loss reduction plan are as follows:

1. Evaluate previous water audits to determine where known and unknown losses occur
2. Develop a list of potential corrective measures to address audit findings
3. Perform a cost-benefit analysis to determine which measures to take
4. Develop a plan to carryout each of the measures to be taken
5. Identify the intended outcomes of each measure
6. Develop an implementation schedule for completing the chosen measures

There are many different corrective measures that can be taken and each should be considered when developing a water loss reduction plan. Factors to be considered include when and where the losses occur, the magnitude of the loss in each problem area, what possible solutions exist, and the amount of time required to implement the solutions.

Cost benefit analyses also help to determine which corrective measures should be taken. For example, costs of recovering leakage include the personnel and the equipment required to make improvements.

Corrective measures for addressing real water losses include the following:

- Leak detection
- Timely response to visible maintenance issues
- The development of system zones

- Pressure management
- Replacement or repair of service connections and water mains
- Corrosion control
- Storage level (overflow) control

Corrective measures for addressing apparent water losses include the following:

- Testing of production and sales meters
- Re-specifying, re-sizing and replacement of meters
- Improvements to meter reading methods
- Billing improvements
- Identification of unauthorized connections

### ***Water Accounting***

An improved water accounting system is the basis for a loss reduction strategy. Water accounting helps to track water throughout the system and identify “nonaccount water”. “Nonaccount water” includes water that is metered but not billed, as well as unmetered water. Unmetered water may include authorized and unauthorized uses.

### ***Metering***

Accurate and complete metering is fundamental to a loss reduction program. Illegal or unregistered connections must be eliminated and installation of meters at unmetered connections should be considered a priority. Meter testing should be conducted to determine the accuracy of metering systems and meter inaccuracies should be resolved through calibration, repair, or replacement. Additionally, upgrades to newer metering technologies should be considered for ease of detecting necessary repairs and changes in water use patterns and for ease of gathering metered data.

### ***Loss Control***

In addition to wasting water, water loss produces no revenue for the system and therefore should be eliminated. Loss control includes leak detection, repair, and prevention; improved response times for pipeline ruptures and leak repair; and pipeline inspection and maintenance. Pipeline maintenance could include corrosion control, pipe cleaning, pipe lining, and pipe repair.

### ***Pressure Management***

Many systems operate at pressures in excess of those required. Water loss through leakage is related to pressure to a large extent. Optimization of pressure within the distribution system can reduce wear on supply lines, prevent pipe damage, and improve the efficiency of the water supply. Pressure management can be achieved through flow and valve control devices, sectorization (dividing the distribution system into separate sectors), pump control (activating or deactivating pumps based on system demand), and leakage control.

### ***Overflow Prevention***

Water losses can occur through improper management of reservoir and tank levels. Overflows usually occur at night when pressure conditions are at their highest (due to lack of demand) and may go unnoticed or are deemed insignificant. Loss reduction strategies should evaluate the frequency and magnitude of overflow events. Overflow can be prevented by installing or repairing automated water level controls.

## ***Consumer Education***

Customer education is critical to the success of water conservation efforts. For auditing and loss reduction purposes, the system can aid consumers by producing an understandable and informative water bill and by providing water bill inserts with information on water use and costs. Water bills should clearly identify volume of usage, rates and charges, and other relevant information. Systems can promote plumbing retrofits and replacements, including meter replacement programs.

## ***Implementation Schedule***

All water loss reduction plans should include a realistic schedule for the implementation of loss reduction measures. Implementation should begin as soon as possible once results of the water audit are realized. The implementation schedule should identify measures that will be taken within the upcoming calendar year to reduce losses in the subsequent audit as well any measures that will be taken further in the future. Reasoning should be provided for measures that are projected to take longer to implement. Minimum long-term follow up measures should include updates to the water audit, further reducing water loss, and on-going meter evaluations.

## **SUBMISSION OF WATER AUDITS AND WATER LOSS REDUCTION PLANS**

### **Water audit documentation for submission**

When submitting a water audit, please include the following:

- The completed worksheet from Appendix A
- The Annual Water Audit Summary sheet (Appendix B)
- Any supporting documentation to explain losses or adjustments

Appendix A includes a spreadsheet that utilities are encouraged to use; however, utilities may develop their own worksheet, if necessary, to provide more detail. A more detailed worksheet will provide a better understanding of the water usage and could be a useful tool for the water system. The worksheet, similar to an accounting spreadsheet, should make the computations clear and simple and allow the water system to balance water produced with water used. Water produced represents the commodity/assets (in gallons water produced) and will be balanced with liabilities (gallons sold) to determine the loss of commodity.

The Water Audit Summary sheet included as Appendix B should also be submitted and should be filled in to indicate whether the audit represents the calendar year or another timeframe, such as a State or federal fiscal year.

### **Water loss reduction plan documentation for submission**

When submitting a water loss reduction plan, please include the following:

- An evaluation of previous water audits
- Identification of measures to address losses identified by the audit
- Explanation of how measures will be taken
- An analysis of the intended outcomes of each measure
- An implementation schedule of measures to be taken



## **How to submit water audits and loss reduction plans**

Mail Water Audits and Water Loss Reduction Plans to:

Water Supply Program  
Water Management Administration,  
Maryland Department of the Environment  
1800 Washington Blvd., Ste. 450  
Baltimore, Maryland 21230-1708

## **MORE INFORMATION**

A copy of this guidance can be found online at: [Conducting a Drinking Water Distribution System Water Audit \(.pdf\)](#).

The following websites and manuals are additional sources of information pertaining to water audits and water conservation:

- Maryland Department of the Environment Water Conservation Guidance: [Guidance for Water Conservation Best Management Practices](#)
- U.S. Environmental Protection Agency guidelines and information: <http://www.epa.gov/WaterSense/pubs/guide.html> and <http://www.epa.gov/region9/waterinfrastructure/water-conserv.html>
- American Water Works Association manual: *M36 Water Audits and Leak Detection*
- International Water Association: *Losses from Water Supply Systems: Standard Terminology and Recommended Performance Measures*.

## **Questions?**

Contact the Water Supply Program: • 410-537-3590 • Fax 410-537-3157 • <http://www.mde.state.md.us>

## **APPENDIX A**

### **Water Audit Instructions and Worksheet**

**Note: Units should be reported in millions of gallons.**

#### Line 1 – Total Water Supply to Distribution System

This is the total volume of all water supplied to the system as measured by the master meter(s) and interconnections with other sources of supply. If water is purchased from an interconnected system, please include detailed quantities in the spreadsheet.

#### Line 2 – Adjustments to Water Delivery

Adjustments may be an increase or a decrease in storage capacity from the beginning to the end of the study period, or adjustments for known broken, or inaccurate master meters.

#### Line 3 – Net Water Produced

This is the net adjusted water produced and/or measured through the master meters, from plants and interconnections, after adjustments.

#### Line 4 – Gallons of Metered Water Sold

This lists the total amount of water that is sold through meters in the system. This includes residential, commercial, industrial, institutional, and other metered sales such as standpipes for water haulers. It is important to evaluate when the meters are read so that the readings can be adjusted to reflect the time it takes to actually read the meters. To assure that the production/purchase records are comparable to the customers' meter readings, consumption during the meter reading period must be adjusted to match the production/purchase period.

#### Line 5 – Billed Unmetered Sales

These are sales to customers that are not metered. They include connections that are not metered and any bulk sales (e.g., through hydrants). These amounts should be detailed in the spreadsheet.

#### Line 6 – Unbilled Authorized Consumption

Provided on the chart is a general listing of potential uses that are frequently not metered, however, if these facilities are metered they should be included in Line 4. You may use this list or make your own estimates of unmetered users and accounts. Please include detailed amounts with documentation in the spreadsheet.

#### Line 7 – Apparent Water Losses

These consist of unauthorized consumption and meter inaccuracies. Meter inaccuracy includes production meters and customer meters. These amounts should be documented in the spreadsheet.

### Line 8 – Real Water Losses

These losses are generally those that cannot be metered. They primarily include leaks and tank overflow. Any water that has not been documented in other categories should be listed as other lost and included in one of these three categories.

### Line 9 – Net Lost Water

Net lost or unmeasured water is determined by subtracting the sum of Lines 4, 5, and 6 from Line 3. This should be the same value as the sum of Lines 7 and 8.

- Net lost or unmeasured water = (line 3 – (line 4 + line 5 + line 6)).
- Net lost or unmeasured water = line 7 + line 8

### Line 10 – Percentage of Lost Water

The percentage of lost or unmeasured water is calculated by dividing Line 9 by Line 3.

- Net lost or unmeasured water = line 9 / line 3

**WATER AUDIT WORKSHEET FOR TREATED WATER\***  
(units should be reported in millions of gallons)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
<b>WATER DELIVERED</b>													
1. Total Water Supply to Distribution System													
2. Adjustments to Water Delivery													
3. Net Water Produced													
<b>WATER USED</b>													
4. Gallons of Metered Water Sold													
<i>Residential</i>													
<i>Commercial</i>													
<i>Industrial</i>													
<i>Institutional</i>													
<i>Other (please specify)</i>													
<b>Total</b>													
5. Billed Unmetered Sales													
6. Unbilled Authorized Consumption													
<i>Water Main Flushing</i>													
<i>Sewer/Storm Drain Flushing</i>													
<i>Parks/Playgrounds/Swimming Pools</i>													
<i>Golf Courses</i>													
<i>Cemeteries</i>													
<i>Road Medians</i>													
<i>Schools</i>													
<i>Training/Fire Fighting</i>													
<i>Construction</i>													
<i>Storage Tank Drainage</i>													
<i>Sewer Plant Uses</i>													
<b>Total</b>													
7. Apparent Water Losses													
<i>Water Meter Malfunction</i>													
<i>Theft</i>													
<i>Other (please specify)</i>													
<b>Total</b>													
8. Real Water Losses													
<i>Leaks</i>													
<i>Storage Overflow</i>													
<i>Other (please specify)</i>													
<b>Total</b>													
9. Net Lost or Unmeasured Water													
10. Percentage of Lost or Unmeasured Water													

Source: Adapted from the Texas Water Development Board  
\* Worksheet is also available as an Excel spreadsheet

**APPENDIX B**

**ANNUAL WATER AUDIT SUMMARY**

**SYSTEM INFORMATION**

SYSTEM NAME: \_\_\_\_\_

SYSTEM ID: \_\_\_\_\_

**WATER AUDIT INFORMATION**

A. Total Water Produced (Line 3): \_\_\_\_\_

B. Total Lost or Unmeasured Water (line 3 – (line 4 + line 5+ line 6)) or (Line 7 + Line 8): \_\_\_\_\_

C. Percentage of Water Lost or Unmeasured to Total Water Produced (line 9 / line 3): \_\_\_\_\_

*Note: If greater than 10 percent, a water loss reduction plan should be prepared.*

**WATER AUDITOR**

Name of person completing this report: \_\_\_\_\_

Audit time period: \_\_\_\_\_ to \_\_\_\_\_

Signature: \_\_\_\_\_ Date Completed: \_\_\_\_\_

Phone Number: \_\_\_\_\_ E-mail Address: \_\_\_\_\_

Please mail this summary page, the worksheet, and supporting documents to:

Maryland Department of the Environment  
Water Supply Program  
1800 Washington Boulevard, Ste. 450  
Baltimore, Maryland 21230-1708

For questions, please call (410) 537-3702