Indiana Water Loss Audit Guidance Manual

January 2020

Acknowledgments

The Indiana Finance Authority would like to acknowledge Water Systems Optimization ("WSO") as the author of the *California Department of Water Resources: Water Audit Manual* (WSO, 2016) upon which most of this manual is based. We appreciate the California Department of Water Resources for sharing this important resources with Indiana utilities.

The IFA would also like to acknowledge the Indiana Section of the American Water Works Association ("AWWA"), Indiana Rural Water Association, Indiana Rural Community Assistance Program, M.E. Simpson Co., Inc., and Wessler Engineering for further developing the materials, and the AWWA for its development of the free Water Audit Software and Manual 36, Water Audits and Loss Control Programs.

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Preface

In 2015, Indiana utilities produced an estimated 50 billion gallons of water that did not generate revenue, resulting in a loss of approximately $54.6 million (IFA, 2016). To better understand Indiana's non-revenue water, the Indiana Legislature enacted Senate Enrolled Act 4 (2019). The resulting state statute, IC 8-1-30.8, obligates water utilities to complete annual water audits. In addition, in every even-numbered year, starting in 2020, the legislation requires these water loss audits to be validated by a certified, third party water audit validator ("Certified Validator"). Water utilities must then submit these validated water loss audits to the Indiana Finance Authority ("IFA") for compilation into a biennial report to the Indiana General Assembly. The first validated water loss audit is due to the IFA by August 1, 2020, and by August 1 in every subsequent even-numbered year thereafter.

This guidance was prepared specifically as a reference for Indiana water suppliers to provide guidance on preparing a distribution system water loss audit in accordance with the American Water Works Association ("AWWA") Manual 36 Water Audits and Loss Control Programs ("M36") (AWWA, 2016). While useful, this guide is not a substitute for M36.

Water loss audits are a valuable tool in maintaining the managerial, financial, and technical integrity of a water utility. Implementing a water loss audit program can improve the efficiency of water production and delivery for all water suppliers.

Contents

1 INTRODUCTION

1.1 What is the AWWA Water Audit?

The water audit is an accounting exercise that is conceptually similar to a financial audit. Whereas a financial audit tracks all sources and uses of funds for an organization, a water audit tracks all sources and uses of water within a water system over a specified period. By answering the following questions, the exercise can help reveal and clarify inefficiencies in water delivery and revenue generation:

- How much water entered the system?
- How much water was used?
- For what purposes was water used?
- How much water was lost?
- What types of water loss occurred?
- What was the financial cost of water losses?
- What was the volume of *non-revenue* water?
- What was the financial cost of *non-revenue* water?

The AWWA Water Audit methodology is consistent with that developed by the International Water Association (IWA) Water Loss Task Force, of which AWWA was a participating member. The effort drew from the best practices of various approaches to water auditing to develop a universal, standardized methodology that can be applied to any water distribution system.

Key concepts:

Non-Revenue Water: Water that fails to generate revenue for the water supplier for any reason. Non-Revenue Water includes Apparent Losses (paper losses), Real Losses (leakage), and Unbilled Authorized Consumption. See Glossary of Terms on page 63.

Most utility operators recognize leakage as a form of water loss. Less widely appreciated are water losses due to metering inaccuracies, unauthorized consumption, and data handling errors, which are collectively termed "**Apparent Losses**," also known as paper losses.

"**What about Unaccounted-for-Water**?" The concept of unaccounted-for-water has been formally abandoned by AWWA as an effective tool for managing system losses due to its unreliable application and inconsistent definition. As you will see throughout the process of completing the AWWA water audit, you can account for all volumes of water, including water losses. Upon doing so, you can refer to valuable performance indicators that more accurately describe system performance. These are discussed in detail in Section 6.

1.2 Why Perform a Water Audit?

1.2.1 Utility Motivations

A water audit evaluates the quality and efficiency of operations. It can answer questions such as:

- How much water fails to generate revenue? How much revenue is lost as a result?
- What are the volumes of the various components of non-revenue water—how much is attributable to leakage, customer meter error, unbilled consumption, and data handling errors?
- How much leakage does your system experience, and how does that compare to what could be expected from your system? What is the cost of leakage?
- How accurate are the master meters upon which your water production and import volumes are based? What is the cost of such inaccuracy?

An AWWA audit is an excellent way to understand your water losses. Once you understand your water losses, you can devise and implement strategies that result in the following improvements:

- Water resources management—by reducing water waste, thereby maximizing the value of existing sources and reducing the need for new sources.
- Financial performance—by optimizing revenue recovery, improving ratepayer equity, reducing wasteful operating expenses, and reducing the need for costly capital expansion.
- Operational performance—by improving understanding of the distribution system, reducing service disruptions, and generating reliable performance data.

The benefits above can improve relations with the public—both ratepayers and members of the financial community, such as rating agencies. In sum, a water audit and the management of water losses can facilitate a broader adoption of more goal-oriented, metric-driven, financially-sensible, and publicly-accountable practices.

1.2.2 Statewide Context

Beyond the internal reasons to perform a water audit, there is increased regulatory pressure to manage water efficiently, including the following developments:

- **Senate Enrolled Act 347** (2016) required all public water utilities in the State of Indiana to provide the IFA with a Non-Revenue Water Audit, as identified in the AWWA M36. The act also required the IFA to conduct a study and analysis of infrastructure needs for all water utilities in the State of Indiana. The final report, representing 552 utilities, discovered over 50 billion gallons of annual non-revenue water loss valued at approximately $54.6 million. The report is available at the IFA website.

- **Senate Enrolled Act 4**: Building off SEA 347, Senate Enrolled Act 4 (2019) requires all community water systems that supply water to its users via meters to complete an annual water audit. In addition, in every even-numbered year, starting in 2020, SEA 4 requires water audits to be validated by a certified, third party water audit validator and submitted to the IFA by August 1 for compilation into a biennial report to the General Assembly.

1.3 How to Use This Manual

This manual is intended to help Indiana drinking water utilities complete the AWWA Water Audit. The manual is meant to be clear, logical, and consistent with AWWA water audit methodology. The manual proceeds as follows:

- Chapters 2 and 3 introduce the concept of the water audit and how to approach it.
- Chapters 4 and 5 show you how to complete the water audit using the AWWA Water Audit Software.
- Chapter 6 provides information on how to interpret the results of the water audit, including performance indicators.

It is recommended that you proceed in the order that the manual is written, which follows the general flow of the water audit methodology

2 INTRODUCTION TO THE WATER AUDIT METHODOLOGY

2.1 The Water Balance

The heart of the water audit is the water balance, which is a graphical and intuitive representation of the water audit. Figure 1 presents a simplified version of the AWWA water balance.

For the time being, do not worry about the definitions of all the terms in the water balance, which will be discussed later. For now, the important thing is to grasp the methodology behind the water balance.

Each box represents a specific category, or volume, of water. For example, Water Supplied represents the total volume of water that entered the water system over a particular audit period for use within the distribution system. In the example shown in Figure 1, Water Supplied is 100 million gallons (MG).

By definition, boxes of smaller heights may be summed together to find the total of neighboring boxes with greater heights. For example, Water Supplied = Authorized Consumption + Water Losses (100 MG = 88 MG + 12 MG). Similarly, Revenue Water = Billed Metered Consumption + Billed Unmetered Consumption (84 MG = 82 MG + 2 MG). Boxes need not be next to each other to make comparisons. For example, Water Supplied = Revenue Water + Non-Revenue Water (100 MG = 84 MG + 16 MG).

Keep in mind that the sizes of the boxes in the water balance do not correspond to the actual volumes they represent.

<table>
<tr><td rowspan="8">Water Supplied
100 MG</td><td rowspan="4">Authorized Consumption
88 MG</td><td rowspan="2">Billed Authorized Consumption
84 MG</td><td>Billed Metered Consumption
82 MG</td><td rowspan="2">Revenue Water
84 MG</td></tr>
<tr><td>Billed Unmetered Consumption
2 MG</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption
4 MG</td><td>Unbilled Metered Consumption
1 MG</td><td rowspan="6">Non-Revenue Water
16 MG</td></tr>
<tr><td>Unbilled Unmetered Consumption
3 MG</td></tr>
<tr><td rowspan="4">Water Losses
12 MG</td><td rowspan="3">Apparent Losses
4 MG</td><td>Unauthorized Consumption
0.25 MG</td></tr>
<tr><td>Customer Metering Inaccuracies
3.50 MG</td></tr>
<tr><td>Systematic Data Handling Errors
0.25 MG</td></tr>
<tr><td colspan="2">Real Losses
8 MG</td></tr>
</table>

Figure 1. AWWA water balance example.

The exercise below helps you understand the methodology behind the water balance without yet having to consider the complexities of your own system.

> **Exercise:** Based on the information provided in Figure 2, determine the volumes for the missing categories. *(Hint: Water Losses = Water Supplied – Authorized Consumption)*

<table>
<tr><td rowspan="8">Water Supplied
40 MG</td><td rowspan="4">Authorized Consumption
__ MG</td><td rowspan="2">Billed Authorized Consumption
__ MG</td><td>Billed Metered Consumption
27 MG</td><td rowspan="2">Revenue Water
___ MG</td></tr>
<tr><td>Billed Unmetered Consumption
2 MG</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption
__ MG</td><td>Unbilled Metered Consumption
0 MG</td><td rowspan="6">Non-Revenue Water
__ MG</td></tr>
<tr><td>Unbilled Unmetered Consumption
1 MG</td></tr>
<tr><td rowspan="4">Water Losses
__ MG</td><td rowspan="3">Apparent Losses
__ MG</td><td>Unauthorized Consumption
0.50 MG</td></tr>
<tr><td>Customer Metering Inaccuracies
3 MG</td></tr>
<tr><td>Systematic Data Handling Errors
0.50 MG</td></tr>
<tr><td colspan="2">Real Losses
__ MG</td></tr>
</table>

Figure 2. AWWA water balance for exercise. Answers are provided in Section 2.1.1.

2.1.1 The Process of Deduction

As you may have noticed, some volumes are simply sums of other volumes. For instance, Authorized Consumption is the sum of Billed Authorized Consumption and Unbilled Authorized Consumption. However, Water Losses and Real Losses are deduced, or derived, volumes—in other words, volumes that are calculated through a process of elimination:

- Water Losses are calculated by subtracting Authorized Consumption from Water Supplied.
- Real Losses are calculated by subtracting Apparent Losses from Water Losses.
- Since Water Losses and Real Losses are derived volumes, they are not entered by the auditor. The AWWA software will automatically calculate them based on the information entered in other portions of the water balance. (The software will be discussed in detail at a later point).

A primary outcome of the water audit is the determination of the volume of Water Losses and Real Losses. However, since these are derived volumes, they are only as accurate as the accuracy of the other volumes informing the calculation.

For example, the volume of Water Losses and Real Losses in Figure 2 were respectively determined to be 10 MG and 6 MG. However, if the volume of Water Supplied was not 40 MG but actually 42 MG due to source meter inaccuracy, then the respective volumes of Water Losses and Real Losses respectively be would be 12 MG and 8 MG.

This is all to say that an accurate determination of Water Losses and Real Losses relies upon the accuracy of the other volumes of the Water Balance.

<table>
<tr><td rowspan="8">Water Supplied
40 MG</td><td rowspan="4">Authorized Consumption
30 MG</td><td rowspan="2">Billed Authorized Consumption
29 MG</td><td>Billed Metered Consumption
27 MG</td><td rowspan="2">Revenue Water
29 MG</td></tr>
<tr><td>Billed Unmetered Consumption
2 MG</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption
1 MG</td><td>Unbilled Metered Consumption
0 MG</td><td rowspan="6">Non-Revenue Water
11 MG</td></tr>
<tr><td>Unbilled Unmetered Consumption
1 MG</td></tr>
<tr><td rowspan="4">Water Losses
10 MG</td><td rowspan="3">Apparent Losses
4 MG</td><td>Unauthorized Consumption
0.50 MG</td></tr>
<tr><td>Customer Metering Inaccuracies
3 MG</td></tr>
<tr><td>Systematic Data Handling Errors
0.50 MG</td></tr>
<tr><td colspan="2">Real Losses
6 MG</td></tr>
</table>

Figure 3. Answers to AWWA water balance exercise

2.2 Performance Indicators

As discussed in the previous section, a complete water balance provides the following pieces of important information:

- Volume of Water Losses: The difference between Water Supplied into the system and Authorized Consumption.
- Volume of Apparent Losses: "Paper losses," the non-physical losses associated with water delivered but not measured or recorded accurately.
- Volume of Real Losses: Physical leakage.
- Volume of Non-Revenue Water: Water that fails to generate revenue to the utility.

While this information is certainly helpful, the water balance in itself is of limited value for comparing management of water losses between systems and over time. You may ask why you could not simply calculate percentages for each volume (e.g. Real Losses as percent of Water Supplied) as a means of evaluating performance. The reason is that percentages can be very misleading as measures of performance, particularly with respect to evaluating leakage. (See Appendix B: Limits of the Use of Percentages as Performance Indicators for a discussion of this.)

For this reason, the AWWA water audit utilizes specific performance indicators that provide additional meaning to the water balance. These performance indicators are presented in Section 6.

2.3 Applicability of the Water Audit to Wholesale Water Agencies

Wholesalers face distinct operating conditions from retail agencies. For example, the instance of water theft experienced by a wholesaler is presumably less than a retail utility, because a wholesaler has only a limited number of customer connections and has infrastructure that is less vulnerable to theft. Nonetheless, the methodology of the water balance, which is based on a simple mass-balance framework, remains applicable.

However, the performance indicators referenced in the previous section were designed for retail distribution systems, and are of limited value when evaluating performance of wholesale supply systems, in particular:

- **Real Losses per Service Connection per Day:** This performance indicator is meaningful only in systems that feature a service connection density of greater than 32 connections per mile, and thus is deemed not applicable in systems of 32 connections per mile or fewer. Since wholesale suppliers typically feature a small number of service connections, it is expected that this performance indicator would not apply. Consequently, Real Losses per Service Connection per Day per PSI would also not apply. Instead, Real Losses per Length of Main per Day would be the more appropriate indicator.

- **Infrastructure Leakage Index:** This performance indicator is based on a calculated allowance of leakage designed for retail distribution systems. It is not a useful metric for evaluating wholesale water systems.

3 HOW TO APPROACH THE WATER AUDIT

While the water audit is at its basic level a formulaic procedure, the quality of the water audit – and therefore its usefulness—is entirely dependent on the quality of data. Anybody can fill out a water audit, but to complete a water audit that is meaningful and useful typically requires particular habits. The following recommendations are valuable for the compilation of a high-quality audit.

3.1 Responsibility

It is advised that there be a dedicated person who is responsible for completion of the water audit. This person should be someone who has a general understanding of how the utility operates and, most importantly, is able to work with the appropriate people from all relevant departments to gather the necessary information. This person should have at least basic proficiency with Microsoft Excel and data management, since the water audit will be completed using Excel-based software and requires compilation of data.

While it is recommended that one person be responsible for the completion of the water audit, it is also advised that all pieces of submitted information be subject to scrutiny from multiple sets of eyes. This will ensure that information is complete, relevant, and accurate. Additionally, such sharing of information will often raise important questions that may have been overlooked by any one person. It is recommended that the utility set up an internal water audit task force or working group that includes knowledgeable staff from the relevant departments responsible for providing audit data.

3.2 Transparency

By definition, an audit sheds light on organizational practices. As such, utilities will often discover aspects of their operations that had previously gone unnoticed. Sometimes these findings will be discouraging. Nonetheless, the completion of an accurate and meaningful audit requires an organizational commitment to a culture of transparency. Without such a commitment, the quality of data is questionable and the accuracy of the audit suffers. Thus, it is important that the utility facilitate an open environment where data and operations can be discussed critically and candidly.

3.3 Continuous Improvement

Water auditing is not a one-time event, but a continual process. The important thing is not that the water audit be perfect—no audit ever will be—but that the process of performing the audit be treated as an opportunity for continuous organizational improvement. As mentioned previously, utilities may encounter previously unknown issues or run into the limits of their own knowledge of the system. For instance, utilities may ask themselves questions like “How do we know how accurate our customer meters are if they haven’t been thoroughly tested in the last 10 years?” or “What master meter testing procedures does our wholesaler follow?”

The water audit should not be seen as a one-time exercise to find errors and faults, but rather as an important means by which a utility may continually assess and improve upon current practices.

3.4 Skepticism

In order to achieve the highest possible degree of accuracy of the audit, those involved in its completion should ask the following questions with respect to the information that is gathered:

Is it relevant/representative? Does the information reflect what is actually being requested? For instance, when calculating Billed Metered Consumption, a utility should make sure to exclude consumption of recycled water by customers, since recycled water does not belong in a potable water audit.

Is it complete? Does the data fully answer what is being requested? For instance, does a customer consumption report include consumption by all accounts, even if those accounts were marked as inactive?

Is it accurate/reliable? How trustworthy is the data, and how do you know? For instance, a utility may calculate the volume of water entering the system based on an input meter (also known as a source meter or master meter) with known accuracy issues. If that is the case, the data should be corrected for known error or qualified. Even if a utility is not able to correct for specific volumes that have known accuracy issues, it is important that such issues be documented for data validity evaluation and guidance of future improvement efforts.

3.5 Pragmatism

While data accuracy is essential in the completion of any audit, you should be pragmatic about how you focus your time. The use of staff time should be prioritized in accordance with the potential impact of inaccuracy for a particular volume or category. In other words, inaccuracies for the larger volumes of water such as Water Supplied and Billed Authorized Consumption will have a far greater impact than inaccuracies for presumably smaller volumes such as Unauthorized Consumption (water theft). Here are a few ordinary examples of pragmatism at work:

- Given limited staff resources, it would be of greater value to spend time evaluating master meter accuracy than to try to perfectly account for consumption by the local fire department, since the former volume will have a potentially large impact on the water balance, while the latter presumably will not.

- Given limited staff resources, it would probably be of greater value to spend time conducting customer meter tests for the sake of calculating customer meter error than to deploy staff in search of water theft, since the former volume will have a potentially large impact on the water balance, while the latter presumably will not.

3.6 Time

Lastly, a water audit can take time. Even though the audit requires only a limited number of fields to be completed, the process of compiling, validating, and analyzing information can take a significant amount of time, particularly in complex water systems. For this reason, it is advised that you start early and tackle the audit in manageable parts.

4 OVERVIEW OF AWWA WATER AUDIT SOFTWARE

4.1 The AWWA Water Audit Software

To facilitate user-friendly and consistent water auditing practices, AWWA has developed the AWWA Free Water Audit Software, which is based on the principles of the AWWA M36 Water Audit methodology. Indiana drinking water utilities will use this software to complete the water audit. The software uses Microsoft Excel and is available at: https://www.awwa.org/Resources-Tools/Resource-Topics/Water-Loss-Control. At the time of writing, the most current version of the software is Version 5.0. Because the instructions and graphics in this guide are based on Version 5.0, it is recommended that utilities also use this version.

Upon opening the AWWA Free Water Audit Software Excel spreadsheet, the user will notice that there are 12 worksheets**.** Don't be overwhelmed—only three of these worksheets require data entry, and two of those three require little information (the sheets titled "Instructions" and "Comments"). The other nine sheets serve a variety of functions, including presentation of performance indicators, the automatically-populated water balance, and helpful background information and definitions.

Sections 4 and 5 provide a guide to completing the sheets that require data entry. Other sheets will be discussed later in this manual.

4.2 Instructions Worksheet

The worksheet titled "Instructions" provides a general orientation to the software. This is also where basic audit information should be entered. Figure 4 shows the worksheet filled out for a hypothetical water utility, the Green Country Water District ("GCWD"). This example utility will be used throughout this guide for illustrative purposes.

Cells within the software are color-coded in the following manner:

A value to be entered by the user

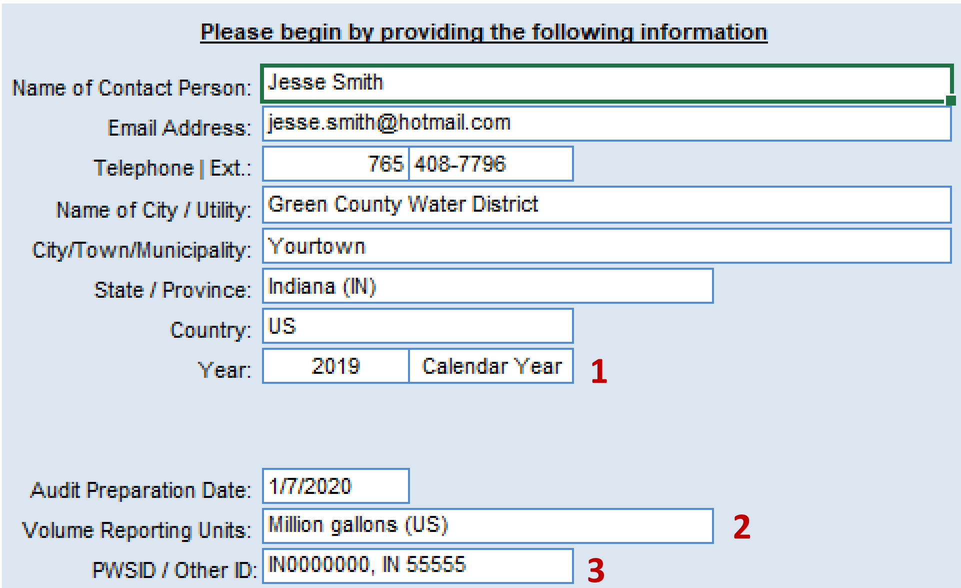
A calculated value based on data from other cells

Contains a recommended default value

1 **Year, Start Date, End Date**: Enter the appropriate water audit reporting period ("audit period") here. In the example, the utility has selected Calendar Year as the audit period.

2 **Volume Reporting Units:** This is where you should select the units that your utility will be reporting in with respect to volumes of water. In the example, the utility has selected "million gallons" as the volumetric reporting unit.

3 **PWSID:** Each audit should reference a single PWSID but, if your system has special circumstances and needs to include multiple PWSIDs, multiple PWSIDs may be entered.


Please begin by providing the following information

Name of Contact Person: Jesse Smith
Email Address: jesse.smith@hotmail.com
Telephone | Ext.: 765 408-7796
Name of City / Utility: Green County Water District
City/Town/Municipality: Yourtown
State / Province: Indiana (IN)
Country: US
Year: 2019 Calendar Year 1
Audit Preparation Date: 1/7/2020
Volume Reporting Units: Million gallons (US) 2
PWSID / Other ID: IN0000000, IN 55555 3

Figure 4. Screen shot of the "Instructions" worksheet from the AWWA Water Audit Software

4.3 Reporting Worksheet

This worksheet is where you should complete the water audit. The worksheet follows the general flow of the water balance methodology.

Remember that the water audit pertains exclusively to the potable portion of a water system. Therefore, non-potable water volumes such as raw water and recycled water must be excluded. To produce accurate results, this needs to be consistently followed for all steps of the water audit, including determination of billed customer volumes.

There are three types of entries in the Reporting Worksheet:

- Entries that represent or impact volumes of water. These are discussed sequentially, beginning with Section 5. They are indicated in Figure 5 by the **red box.**

- Entries that pertain to **Data Validity Scoring**. The concept of Data Validity Scoring is introduced immediately below and is remarked upon in further detail with respect to particular volumes of water in the ensuing sections. Data Validity entries are indicated in Figure 5 by the **green box.**
- Buttons that redirect you to the **Comments** Worksheet, where you can add comments with respect to specific pieces of data that you have entered. Comments can take note of sources of data and methodology to ensure consistency in future audits. You can click on the "+" button to make a comment, as indicated by the **orange box** in Figure 5.

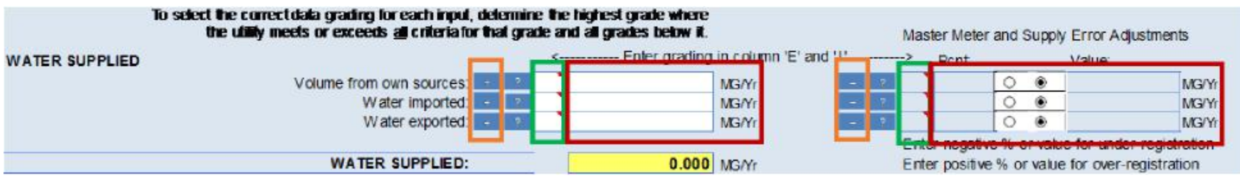


Figure 5: Screen shot of the Reporting worksheet from the AWWA Water Audit Software

4.3.1 Data Validity Grading: An Introduction

The AWWA Free Water Audit Software helps you evaluate the validity of the audit by allowing you to grade each component of the water balance. The data validity scoring system describes the level of accuracy and reliability of each data entry contributing to the audit.

A detailed guide on how to grade each component is provided in the worksheet titled "Grading Matrix," and you should review this worksheet before assigning grades. Additionally, you can hover over individual data validity cells to reveal a shorthand guide to data validity grading for the respective category. While the Grading Matrix is very helpful, it cannot account for all of the particularities of individual Indiana water utilities. As such, you will need to use a degree of discretion in assigning grades. Remember that the purpose of the grading system is for utilities to be able to reflect upon their own practices in order to identify opportunities for improvement. Thus, you should approach the data validity evaluation with a critical mind.

To select the correct data grading for each input, determine the highest grade where the utility meets or exceeds all criteria for that grade and all grades below it.

5 COMPLETING THE WATER AUDIT

5.1 Water Supplied

The determination of Water Supplied is the first step and the foundation of the water balance. Because Water Supplied is the largest volume in the water balance, error can have a large impact. Thus, it is critical that you be as thorough as possible in determining this volume.

> ***Water Supplied***: The volume of treated and pressurized water input to the retail water distribution system. Mathematically: *Water Supplied = System Input Volume – Water Exported*

It is advised that you collect Water Supplied data from meters that are located immediately at or prior to entry into the distribution system. For example, if faced with the choice of using flow data from either a water treatment plant influent or effluent meter, the effluent meter would be preferable (insofar as it is in good working order, because the effluent meter captures only the water that enters the distribution system whereas the influent meter may also capture water used for operational purposes at the treatment plant, which is upstream of the distribution system).

An excerpt of the water balance is presented in Figure 6 below to illustrate the relationship between Water Supplied and other key volumes. Water Supplied is highlighted.

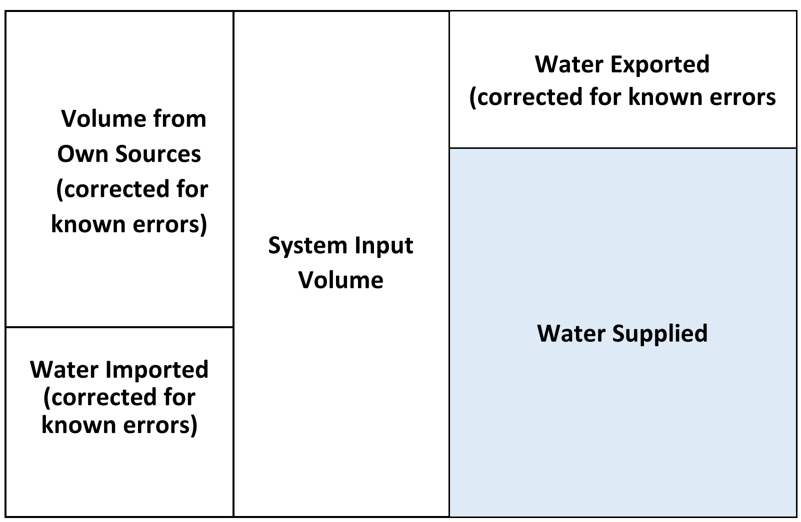


Figure 6: AWWA Water Balance highlighting Water Supplied.

Volume from Own Sources: The volume of water withdrawn from water resources (rivers, lakes, wells, etc.) controlled by the water utility and then treated for potable water distribution.

Water Imported: Bulk water typically purchased from a neighboring water utility or regional water authority, which is metered at the custody transfer point of interconnection between the two utilities. Water Imported is also known as import, purchased or wholesale water.

System Input Volume: The volume of water that is introduced to the water distribution system over the audit period. According to the AWWA M36 Manual, it is "the volume of water input to that part of the water supply system to which the water balance relates."

Mathematically: *System Input Volume = Volume from Own Sources (incl. net changes in storage) + Water Imported*

Water Exported: Bulk water sold to neighboring water systems that exist outside the service area.

Figure 7 shows the Green Country Water District water system. GCWD's potable water comes from two wells, surface water, and treated imported water. Well water and surface water go to the water treatment plant prior to entering the distribution network. Flow volumes are metered as effluent from the treatment plant. Imported water enters the distribution network directly and is metered at the interconnection between the GCWD system and the neighboring system. GCWD exports some water to a neighboring utility, which is metered at the system interconnection.

As such, Volume from Own Sources consists of water from wells and surface water, which is cumulatively metered as treated effluent at the water treatment plant. Water Imported consists of imported water. Water Exported consists of export water to the neighboring utility. GCWD's auditor collected data for the audit period from the three relevant meters, indicated by the letter "M."

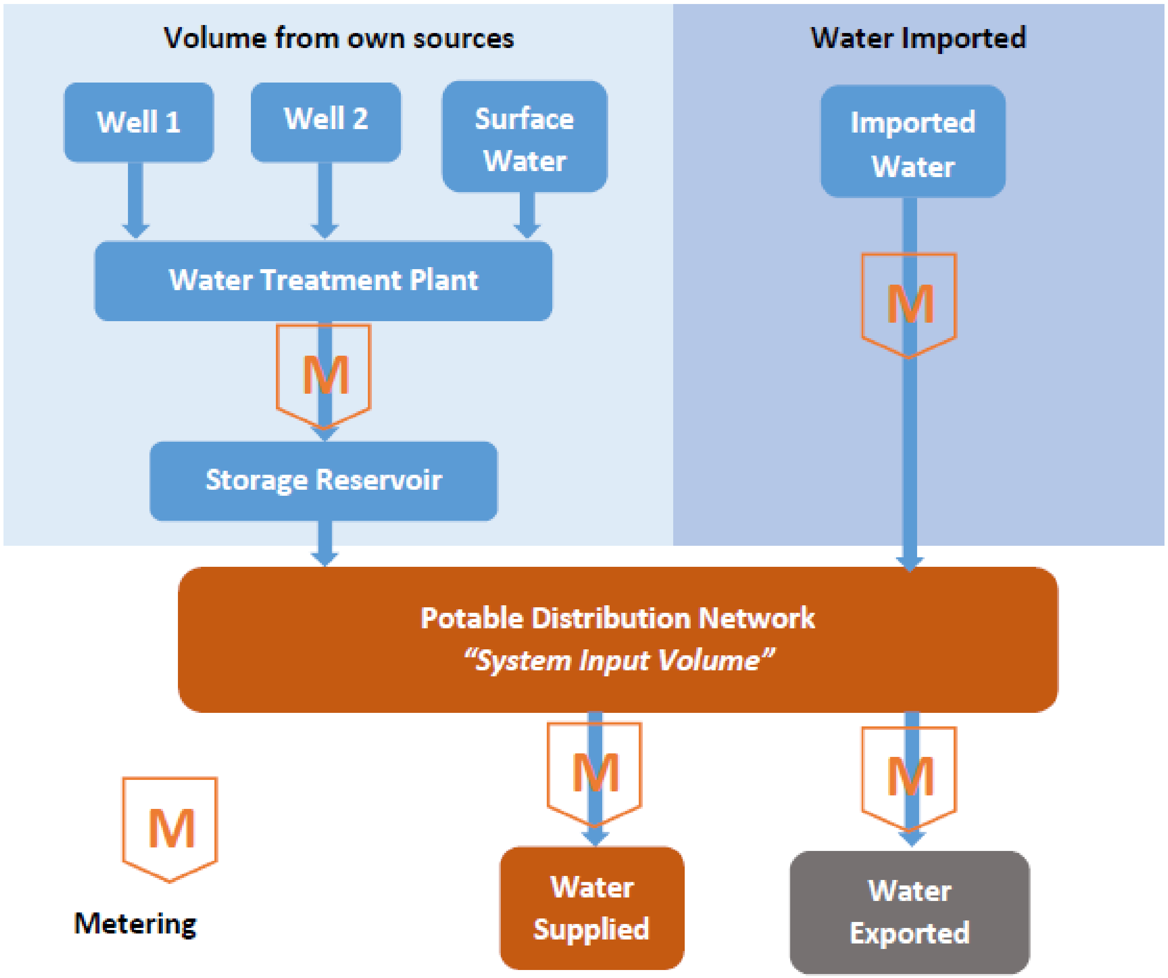


Figure 7: Green Country Water District water system.

You may turn to a number of different sources for Water Supplied data. For example, your utility may have information from any number of the following sources:

- Monthly water purchases on bills from wholesalers
- Monthly groundwater extraction volumes on statements from groundwater-regulating agencies
- Manual meter readings
- SCADA meter readings

Ultimately, you will need to determine which data sources most accurately reflect the actual volume of water entering the distribution system and leaving as exports. This step can be challenging, and often requires the collaboration of a number of staff to devise the best approach. However, a thorough approach will pay off in the accuracy of the audit.

5.1.1 Accounting for Changes in Storage

Best practice is to account for changes in reservoir storage levels over the course of the audit period. If the volume of stored water increased between the first and last day of the audit period, then the change in storage represents a withdrawal of water from the distribution system. In other words, the increase in storage represents water that was supplied into the system but then temporarily withheld from customer use. In this case, the absolute value of the volumetric change should be *subtracted* from the calculation of Water Supplied. The inverse is similarly true: if stored volume decreased between the first and last day of the audit period, then the change represents an additional supply of water to distribution system, and the absolute value of the volumetric change should be *added* to the calculation of Water Supplied.

The AWWA Free Water Audit Software does not provide a separate field for Changes in Storage. As such, Changes in Storage must be applied to either Volume from Own Sources or Water Imported, depending on the setup of the system. For GCWD, storage was calculated to have decreased by 18.850 MG between the first and last days of the audit period based on reservoir levels. Therefore, the auditor should *add* 18.850 MG to Volume from Own Sources, since it represents an additional supply to the distribution system. It is important to make a note of the specific volume of Changes in Storage that was applied to Volume from Own Sources, using the Comments feature in the AWWA software.

Changes in Storage should only be accounted for if storage is located downstream of the metering points that are relied upon for Water Supplied data. If storage is upstream of those meters, then changes in storage will already be accounted for by the meters and will not need to be accounted for separately.

5.1.2 Compiling & Entering Water Supplied Volumes

Table 1 lists GCDW water supplied data for the audit period:

Table 1: GCWD Water Supplied

Input	Volume (MG)
Effluent from Water Treatment Plant	20,714.690
Decrease in Storage	18.850
Imported Water	17,975.104
Exports to Neighbor Utility	385.586

Some utilities keep monthly records of changes in storage, in which case the storage changes over the course of the year-long audit period can be added together. Make sure that “+” and “–” signs are properly taken into account.

At this point, do not take metering inaccuracies or data errors into account – these will be covered in the following section. From the data, the auditor has calculated the following volumes:

$$\textit{Volume from own sources} = 20{,}714.690 + 18.850 = 20{,}733.540 \text{ MG}$$
$$\textit{Water imported} = 17{,}975.104 \text{ MG}$$
$$\textit{Water exported} = 385.586 \text{ MG}$$

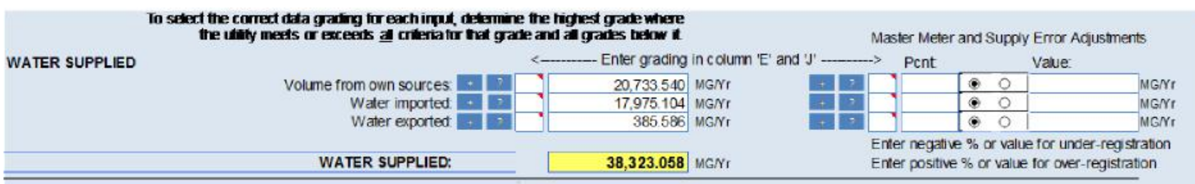


Figure 8 shows the Reporting Worksheet given the information stated in the example.

Every water system is unique, so you will have to consider the distinct setup of your own system when determining how to appropriately calculate Water Supplied. Nonetheless, this checklist can help you make sure that Water Supplied is accurately calculated:

- ✓ Did you account for all sources of water?
- ✓ Did you ensure that no water was mistakenly double-counted?
- ✓ Did you account for all exports of water?
- ✓ Did you make sure to exclude all non-potable water?
- ✓ Did you properly incorporate changes in storage, if applicable?

5.1.3 Master Meter and Supply Error Adjustments

This is where you should account for any known errors in master meters. Sources of error include meter inaccuracy (under- or over-registration) and data gaps caused by outages of the meter instrumentation.

Because every utility has a unique combination of master metering setup, testing and calibration procedures, and data management processes, there is no uniform method for calculating master meter and supply error. You will have to use the available information and your best judgment. For example, GCWD has made the following adjustments, based on the available information:

- The effluent meter at the water treatment plant under-registered by an average of 1.2% in a test performed during the audit period. Using this percent error, the auditor determined the appropriate volume to enter into Master Meter Supply and Error Adjustments (see the sidebar “Calculating Meter Error Volumes”).

- The imported water meter passed instrumentation calibration tests on two separate occasions, but staff is not aware of any volumetric or comparative tests that have been performed (see the note under the “Data Validity Grading” portion of this section for an explanation of the difference between instrumentation calibration and meter testing). In the absence of specific quantitative information, the auditor did not assign any volumes to Master Meter Supply and Error Adjustments, but took these uncertainties into account when assigning a data validity grading.

- The export meter over-registered by 0.5% in the most recent test. Using this percent error, the auditor determined the appropriate volume to enter into Master Meter Supply and Error Adjustments.

Because the AWWA Free Water Audit Software includes a single data field for the error associated with each component of Water Supplied (Volume from Own Sources, Water Imported, and Water Exported), it is recommended that the auditor calculate the error adjustments on a separate spreadsheet, as shown in Table 2 for GCWD below. This is especially true when data from multiple meters must be added together to determine a particular component of Water Supplied.

Calculating Meter Error Volumes:
Given a known meter percent error, use the formula below to calculate the meter error volume:

$$u - \frac{u}{x}$$

Where u is the original, uncorrected metered volume and where x is the tested percent accuracy of the meter (e.g. 98.8% means 98.8% accurate). Note that the formula in this manual produces a value of opposite sign from the formula in the M36 manual. This is due to the particular setup of the AWWA software.

Table 2: GCWD Master Meter and Supply Error Adjustments Example

		Uncorrected Metered Volume (MG)	Master Meter Accuracy	Master Meter Error and Supply Adjustment Volume (MG)
a	Effluent from Treatment Plant	20,714.690	98.8%	-251.595
b	Decrease in Storage	18.850	NA	NA
c	Imported Water	17,975.104	NA	NA
d	Exports to Neighbor Utility	385.586	100.5%	1.918
A = a+ b	Volume from Own Sources	20,733.540		-251.595
B = c	Water Imported	17,975.104		0.000
C = d	Water Exported	385.586		1.918

In the AWWA software, a positive value or percentage entered in the Master Meter and Supply Error Adjustments section indicates over-registration, while a negative value or percentage indicates under-registration. Be careful not to overlook this key aspect of the software methodology—an oversight could have significant consequences on the accuracy of the audit. In the example, the auditor calculated the meter error adjustment volumes on a separate spreadsheet to ensure that the software would be filled out properly.

The auditor then filled in the AWWA Free Water Audit Software accordingly, as shown in Figure 9. Because the auditor calculated specific error volumes—not percentages—the "Value" button was selected, as noted in the red box.

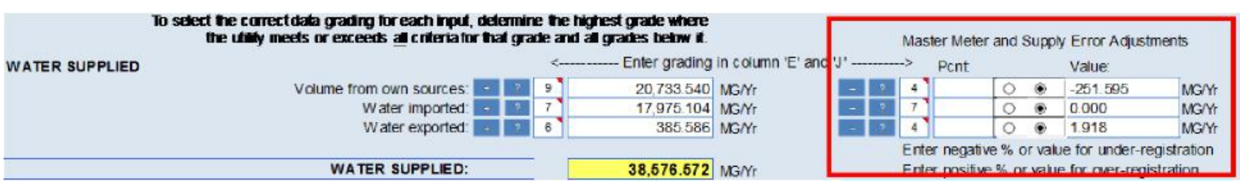


Figure 9 shows how to enter Master Meter and Supply Error Adjustments.

5.1.4 Data Validity Grading

It is recommended that you thoroughly review the Grading Matrix included in the AWWA Free Water Audit Software when assessing data validity associated with the various volumes making up Water Supplied. Below are some of the key considerations:

- Are sources of water metered?
- If so, are master meters tested and calibrated? How often? When was the nearest test and/or calibration with respect to the audit period?
- How accurate are the master meters (specifically, in percent error terms)?
- Were comparative or volumetric tests conducted, or solely calibration of the meters?
- In what format are the production volumes associated with Volume from Own Sources logged? By hand or electronically?
- How frequently is production data reviewed and, if necessary, corrected?
- How are changes in storage taken into account, if applicable? In what format are they logged, and how frequently?
- Is there a computerized system (i.e., SCADA) that automatically balances flows from all sources and storage? Is the computerized system calibrated with master meters to ensure minimal data transfer error?

There is a notable difference between accuracy testing of the primary metering device and calibration of related instrumentation (e.g. a pressure differential cell). A meter test compares the test meter reads to either a reference meter or a fixed volume, while instrument calibration ensures accurate communication of the electronics of certain types of meters. While calibration of instrumentation is critical, it does not guarantee meter accuracy in itself.

5.2 Authorized Consumption

The determination of the volume of Authorized Consumption is the second major component of the AWWA water balance.

> **Authorized Consumption:** The volume of metered and/or unmetered water taken by registered customers, the water supplier, and others who are authorized to do so.

Figure 10 below shows the position of Authorized Consumption and its sub-components within the simplified water balance. (This manual uses the term "simplified water balance" to refer to the portion of the water balance that begins with Water Supplied, thereby excluding the presentation of Water Exported.)

As shown below, Authorized Consumption consists of Billed Authorized Consumption and Unbilled Authorized Consumption, which can be further divided into the following components:

Billed Metered Consumption*:* Consumption that generates revenue, the volume of which is determined by a water meter.

Billed Unmetered Consumption*:* Consumption that generates revenue, the volume of which is determined by estimation or is not known.

Unbilled Metered Consumption: Consumption that does not generate revenue, the volume of which is determined by a water meter.

Unbilled Unmetered Consumption: Consumption that does not generate revenue, the volume of which is determined by estimation or is not known.

<table>
<tr><td rowspan="8">Water Supplied</td><td rowspan="4">Authorized Consumption</td><td rowspan="2">Billed Authorized Consumption</td><td>Billed Metered Consumption</td><td rowspan="2">Revenue Water</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="6">Non-Revenue Water</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="4">Water Losses</td><td rowspan="3">Apparent Losses</td><td>Unauthorized Consumption</td></tr>
<tr><td>Customer Metering Inaccuracies</td></tr>
<tr><td>Systematic Data Handling Errors</td></tr>
<tr><td colspan="2">Real Losses</td></tr>
</table>

Figure 10 highlights the Authorized Consumption portion of the AWWA water balance.

It is important to accurately distinguish amongst these categories because they directly inform your utility's understanding of revenue and non-revenue water. Additionally, the process of categorization can lead to valuable insights as to how to improve the reliability of data.

This guide proceeds by describing how to calculate the volumes associated with the four types of Authorized Consumption and provides examples to clarify how particular uses of water should be categorized.

5.2.1 Billed Metered Consumption

Billed metered consumption consists of all uses that generate revenue and are metered. In a utility where most of or all customers are metered, consumption by retail customers will comprise the majority of billed metered consumption, so it is imperative that you be thorough in the determination of this volume. Any errors introduced at this step will have a relatively large impact on the accuracy of the water balance and the calculation of real losses.

> It is best practice to keep track of the particular parameters and procedures that are followed to generate data, so that you can replicate the process year-to-year.

Work with your billing department to generate a customer consumption report that includes all classes of potable customers that provide revenue to the utility. It is important to include temporary meters that generate revenue, such as meters used for construction sites. Make sure that the parameters of the report are established such that the consumption data best reflects consumption as it actually occurred within the audit period, so that your comparison of "water in" from source meters to "water out" to customers makes sense. Although every utility conducts billing in a unique manner, here are some guidelines that most utilities will find applicable:

1. If your billing system utilizes Advanced Metering Infrastructure ("AMI"), you probably have access to actual daily consumption data, which allows you to very accurately capture consumption over the audit period. This is ideal.
2. If your billing system does not utilize AMI—if your utility uses either Automatic Meter Reading or manual readings—then run a consumption report in which the meter read date falls within the audit period.
3. If your billing system does not allow you to run a report by meter read date, then run a report in which the bill date falls within the audit period. For the purpose of capturing consumption as it actually occurred in the audit period, this method is less accurate than using meter read date because bills are sent out later than the meter read date and less accurately reflect the actual timing of customer consumption.

> Do not confuse exports to other agencies with billed metered consumption, even if such volumes are billed and metered! Exports should be treated as Water Exported in the determination of Water Supplied. Some customer billing systems include records of sales to outside agencies—if so, make sure to exclude them from the calculation of Authorized Consumption.

The following checks can help ensure that the consumption report accurately reflects the parameters of the water audit:

- ✓ Does the data include all billed metered customers and exclude unbilled metered customers such as non-paying municipal accounts (or at least identify those accounts so that you may account for them separately)?
- ✓ Did you make sure that any sales to outside agencies were excluded (or at least identified so that you may account for them separately)?
- ✓ Did you make sure that any non-potable water sales were excluded (or at least identified so that you may exclude them yourself)?
- ✓ Are you sure that the consumption data reflects actual volumetric use, and not changes that may have been made to billed consumption for the sole purpose of making financial adjustments to the bill?

5.2.1.1 Consistency of Units

Make sure that volumetric units within the billing database are consistent. Some utilities have meters that are read in different units—some may be read in CCF (hundred cubic feet), while others may be read in KGAL (thousand gallons). If the billing database features more than one volumetric unit, make sure to make the necessary conversions to standardize the data.

5.2.1.2 Correct for Misalignment between Billing Period and Audit Period

If you used Option 2 or 3 above to generate a consumption report, it is best practice to correct for the misalignment between the meter reading / billing cycles and the audit period. This is applicable when meter reading / billing cycles do not perfectly coincide with the audit period.

The following example introduces the concept of correcting for misalignment in a simple situation—where customer meters are read on a single day every month. However, the exercise can become quite complex with utilities that have a high number of meter reading / billing cycles. The example below does not show the specific calculations that were performed to make the corrections for misalignment. Those calculations are presented in Appendix A: Correcting for Misalignment between Meter Reading / Billing Cycles and Audit Period.

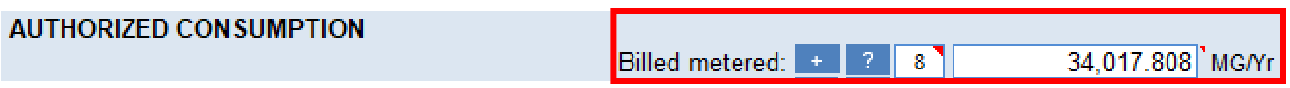
> Correcting for billing period misalignment using the pro-rating method is especially important in utilities that bill at less frequent intervals, such as on a bi-monthly or quarterly basis.

Green Country Water District reads customer meters on the same day every month. The GCWD auditor compiled billed metered sales data relevant to the audit period (01/01/2019 - 12/31/2019), as detailed in Table 3 below, plus an extra meter read on either side of the audit period in order to correct for misalignment. This data is shown in the column titled “Customer Sales.” The final column of Table 3 shows the volume of sales after correcting for misalignment.

Table 3: GCWD Correcting for Billing Period Misalignment Example

Read Date	Customer Sales (MG)	Customer Sales – Corrected for Misalignment (MG)
12/10/2018	2,418.661	0
1/10/2019	2,278.897	735.128
2/10/2019	2,233.471	2,233.471
3/10/2019	2,278.897	2,278.897
4/8/2019	2,877.013	2,877.013
5/10/2019	2,952.724	2,952.724
6/9/2019	3739.260	3,739.260
7/10/2019	3,471.978	3,471.978
8/10/2019	3,439.905	3,439.905
9/11/2019	3,068.071	3,068.071
10/12/2019	2,865.882	2,865.882
11/10/2019	2,460.604	2,460.604
12/10/2019	2,422.748	2,422.748
1/10/2020	2,281.797	1,472.127
Total	**34,089.450**	**34,017.808**

The GCWD auditor filled out the Reporting Worksheet accordingly:



The example above shows the value of correcting for misalignment. Without doing so, billed metered consumption would have been 33,642.876 MG, which is 1.1% less than the corrected volume. If left uncorrected, this 1.1% difference would have been carried through the remaining steps of the water balance and been accounted for as real losses. The resulting volume of real losses would have been calculated to be 3,244 MG instead of 2,858 MG – overstated by 13.5**%. In other words, make sure to get this step right, because it will impact your understanding of water losses, real losses, revenue and non-revenue water, and the resulting performance metrics for your system.**

5.2.1.3 Data Validity Grading

It is recommended that you thoroughly review the Grading Matrix included in the AWWA Free Water Audit Software when assessing data validity associated with billed metered consumption. Below are some of the key considerations:

- Are billing records maintained on paper or electronically?
- What is the meter read success rate?

- What is the frequency and scale of estimates?
- Are billing records audited, by whom, and at what frequency?
- What is the frequency and scale of meter testing?
- What portion of meters are read using AMI or AMR?
- What factors inform the decision to replace a customer meter?

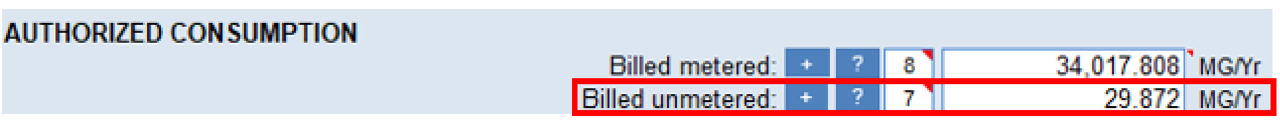
5.2.2 Billed Unmetered Consumption

Billed unmetered consumption consists of consumption that generates revenue but is not metered. These accounts are often referred to as flat rate or flat fee customers, since they are assessed a fixed charge based on an estimated volume of use.

There are a number of means by which consumption can be estimated, such as using a sample of *metered* accounts similar in characteristics (e.g. customer category, meter size) and extrapolating consumption habits from those accounts to the non-metered population. However, even such an approach contributes a great deal of uncertainty to the determination of consumption volumes. Because of the difficulty in accurately determining consumption through estimation, the AWWA M36 manual highly recommends that all customers be properly metered, read, and archived.

In the example of GCWD, all customers are metered, with the exception of some unmetered condominium developments. These unmetered accounts are billed an assumed monthly usage of 8 CCF per housing unit, which is based on an approximate average monthly consumption for metered multi-family housing units. These accounts are included in the customer billing database and uniquely identified as flat fee. The total audit period consumption for these accounts was 29.872 MG. When calculating *billed metered* authorized consumption, the auditor made sure to exclude those accounts.

The GCWD auditor filled out the Reporting Worksheet accordingly:



5.2.2.1 Data Validity Grading

It is recommended that you thoroughly review the Grading Matrix included in the AWWA Free Water Audit Software when assessing data validity associated with billed unmetered consumption. Below are some of the key considerations:

- What portion of billed customers in the system are unmetered?
- What is the degree of thoroughness with which consumption volumes are estimated?

Revenue and Non-Revenue Water

You've just completed the necessary information to be able to determine an important metric: the volume of revenue (and non-revenue) water. As shown in the water balance in Figure 10, revenue water is simply the volume of Billed Authorized Consumption (the sum of billed metered consumption and billed unmetered consumption). Non-revenue water can then be calculated by subtracting Billed Authorized Consumption from Water Supplied. In the AWWA Software, refer to the line titled "Non-Revenue Water" or go to the sheet titled "Water Balance" to see the calculated volumes of revenue and non-revenue water for your system.

5.2.3 Unbilled Metered Consumption

Unbilled metered consumption includes all uses that are metered but do not generate revenue for the utility. In Indiana, such use is typically associated with metered operational uses by the water utility, such as flushing programs that utilize temporary meters to track usage. Unbilled metered uses may be tracked in the billing system, on operational records, or a combination of the two, depending on utility practices (see sidebar). Keep in mind that consumption volumes that are *calculated* rather than *metered*—such as the filling of a fixed-volume water truck—should be categorized as unbilled unmetered consumption, as described in Section 5.2.4.

> There may be accounts located within the billing database that do not generate revenue, such as metered operational uses by the water utility. Such consumption should be classified as unbilled metered consumption. Make sure to exclude such uses in the determination of billed metered consumption.

The auditor for GCWD has identified the following unbilled metered uses and consumption volumes for the audit period, and performed the appropriate lag time correction:

Table 4: GCWD Unbilled Unmetered Use

Type of Use	CY19 Pro-rated Consumption (MG)
Water Utility Facilities – Indoor	41.464
Water Utility Facilities – Irrigation	2.588
Total Unbilled Metered Consumption	44.052

The auditor has filled out the relevant section of the Reporting Worksheet accordingly:

AUTHORIZED CONSUMPTION					
Billed metered:	+	?	8	34,017.808	MG/Yr
Billed unmetered:	+	?	7	29.872	MG/Yr
Unbilled metered:	+	?	7	44.052	MG/Yr

5.2.3.1 Data Validity Grading

It is recommended that you thoroughly review the Grading Matrix included in the AWWA Free Water Audit Software when assessing data validity associated with unbilled metered consumption. Below are some of the key considerations:

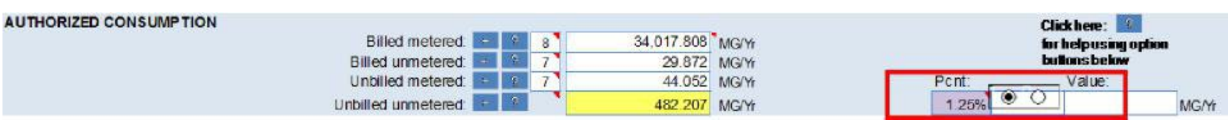
- To what degree are the policies pertaining to unbilled accounts codified and adhered to?
- What is the quality of available information on the number of unbilled metered accounts?
- What is the frequency of meter reading and level of meter upkeep?
- In what manner are consumption volumes determined (estimation, meter reading)?

5.2.4 Unbilled Unmetered Consumption

Unbilled unmetered consumption consists of those uses that are neither metered nor revenue-generating. Most often, this includes operational uses by the water utility. Because the volumes associated with these forms of consumption can be challenging to compile and accurately quantify, AWWA provides a default value that can be used until better information within the utility becomes available. The default value equates to 1.25% of the volume of Water Supplied. AWWA recommends using the default value unless you have reason to believe that the actual volume may be significantly different than 1.25% of Water Supplied. You should be aware that tracking down such consumption volumes can be time-consuming and potentially not worth the expense given the relatively small volume of water typically in question.

The AWWA default value for Unbilled Unmetered Consumption is provided in the model because many utilities do not have accurate records of Unbilled Unmetered Consumption. That said, it is best practice to develop a system for tracking such uses. Many utilities have begun doing this as part of their drought response. Some utilities find that their volume of unbilled unmetered consumption differs significantly from the AWWA default value.

The GCWD auditor used the default percentage because GCWD does not keep thorough documentation of unbilled unmetered consumption, as shown below. However, the auditor suspects that the actual consumption volume is less than the default value and has initiated a utility-wide review of all unbilled unmetered uses so that future audits can more accurately estimate consumption.



If you choose to quantify unbilled unmetered uses rather than use the default value, the following types of uses commonly fall into this category:

- Reservoir draining
- Water use at water utility facilities (if unmetered)
- Water quality testing
- Water treatment plant operations (if within boundaries of water audit, i.e. downstream of the source meters relied upon for Water Supplied data)
- Flushing water mains (hydrant flushing), storm inlets, culverts and sewers
- Firefighting and training
- Fire flow tests performed by the utility
- Street cleaning
- Landscaping/irrigation in public areas
- Construction sites (should be billed metered, but sometimes not enforced by utilities)

5.2.4.1 Data Validity Grading

It is recommended that you thoroughly review the Grading Matrix included in the AWWA Free Water Audit Software when assessing data validity associated with unbilled unmetered consumption. If you choose to use the AWWA default value, the data validity grade is automatically assessed a "5." If you calculate unbilled unmetered consumption on your own, here are some of the key considerations:

- To what degree are unbilled unmetered uses known?
- To what extent are there procedures in place to track unbilled unmetered consumption?
- To what extent are unbilled unmetered consumption volumes actually quantified in practice?
- In what manner are unbilled unmetered consumption volumes quantified (time by flow rate formulae, known fixed volumes, other methods of estimation)?
- What is the quality of record-keeping?

Water Losses

You've just completed the necessary information to be able to determine an important metric: the volume of water losses. Water losses, which include apparent losses (paper losses) and real losses (leakage) can be thought of simply as "Water In minus Water Out." As shown in the water balance in Figure 11, water losses is the volume of Water Supplied minus Authorized Consumption. In the AWWA Software, refer to the line titled "Water Losses" on the Reporting Worksheet or go to the sheet titled "Water Balance" to see the calculated volume of water losses for your system.

5.3 Water Losses

Water Losses consists of Apparent Losses and Real Losses, as shown in Figure 11. First, you will determine the volume of Apparent Losses, which will in turn determine the volume of Real Losses— which is simply the remainder after the volume of Apparent Losses has been subtracted from the volume of Water Losses.

<table>
<tr><td rowspan="8">Water Supplied</td><td rowspan="4">Authorized Consumption</td><td rowspan="2">Billed Authorized Consumption</td><td>Billed Metered Consumption</td><td rowspan="2">Revenue Water</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="6">Non-Revenue Water</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="4">Water Losses</td><td rowspan="3">Apparent Losses</td><td>Unauthorized Consumption</td></tr>
<tr><td>Customer Metering Inaccuracies</td></tr>
<tr><td>Systematic Data Handling Errors</td></tr>
<tr><td colspan="2">Real Losses</td></tr>
</table>

Figure 11 shows the different types of water losses on the water balance.

5.3.1 Apparent Losses

Apparent Losses is one of the two primary components of Water Losses. The determination of the volume of Apparent Losses is the third major step in assembling the AWWA water balance. According to the AWWA M36 manual:

> ***Apparent Losses:*** The nonphysical losses that occur when water is successfully delivered to the customer but is not measured or recorded accurately.

<table>
<tr><td rowspan="8">Water Supplied</td><td rowspan="4">Authorized Consumption</td><td rowspan="2">Billed Authorized Consumption</td><td>Billed Metered Consumption</td><td rowspan="2">Revenue Water</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="6">Non-Revenue Water</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="4">Water Losses</td><td rowspan="3">Apparent Losses</td><td>Unauthorized Consumption</td></tr>
<tr><td>Customer Metering Inaccuracies</td></tr>
<tr><td>Systematic Data Handling Errors</td></tr>
<tr><td colspan="2">Real Losses</td></tr>
</table>

Figure 12 below shows the position of Apparent Losses and its sub-components within the simplified water balance.

As shown above in Figure 12, Apparent Losses consists of Unauthorized Consumption, Customer Metering Inaccuracies, and Systematic Data Handling Errors:

Unauthorized Consumption: Consumption that is not explicitly or implicitly authorized by the utility, commonly known as water theft.

Customer Metering Inaccuracies: Inaccuracies in registering water consumption by retail customer meters.

Systematic Data Handling Errors: Errors caused by accounting omissions, errant computer programming, data gaps, and data entry; inaccurate estimates used for accounts that fail to produce meter readings; billing adjustments that manipulate billed consumption so as to generate a rightful financial credit in such a way that billed consumption does not reflect actual consumption.

Controlling Apparent Losses can offer substantial opportunities for revenue recovery, since such water is valued at the customer retail cost. In other words, Apparent Losses represent water that is being delivered but not being billed for—the recovery of which can have significant financial benefits. Thorough investigation of Apparent Losses not only has revenue recovery potential, but can also shed light on opportunities for improving operational practices with respect to meter reading, customer billing, account management, and meter testing and replacement.

It is important to develop an accurate understanding of Apparent Losses because its relationship with Real Losses is zero-sum, due to the deduced determination of Real Losses. Any under-estimation of Apparent Losses will result in an over-estimation of Real Losses, and vice versa.

This guide proceeds by describing how to calculate the volumes associated with the three types of Apparent Losses.

5.3.1.1 Unauthorized Consumption

Unauthorized consumption, also known as water theft, can include:

- Illegal connections
- Open bypasses
- Buried or otherwise obscured meters
- Misuse of fire hydrants and fire-fighting systems
- Vandalized or bypassed consumption meters (meter tampering)
- Tampering with meter reading equipment
- Illegally opening intentionally closed valves or curb stops on customer service piping that has been discontinued or shut off for nonpayment.

While Unauthorized Consumption varies from system to system, the total volume of water lost is typically a very small portion of the volume of Water Supplied. AWWA has found a default estimate of 0.25% of Water Supplied to be suitable in most cases.

Because investigating Unauthorized Consumption can be challenging and tedious, and because the volume of water at stake is typically very small, it is recommended that you use the default estimate unless you have reason to believe that your system experiences significantly different levels of theft. That said, investigation of water theft has value beyond the sake of the water audit, so the availability of the AWWA default estimate should not be a reason to neglect proper oversight of water theft.

In our example of Green Country Water District, the auditor has selected the AWWA default estimate of 0.25% of Water Supplied, which translates to 96.441 MG. Nonetheless, the auditor has started a working group with colleagues to evaluate water theft oversight, including a systematic review of policies, procedures, and practices.

5.3.1.1.1 Data Validity Grading

It is recommended that you thoroughly review the Grading Matrix included in the AWWA Free Water Audit Software when assessing data validity associated with Unauthorized Consumption. If the default estimate is selected, the data validity grading will automatically be assessed at a "5." If you choose to determine the volume yourself, you should consider the following when grading data validity:

- Level of awareness of extent of theft
- Coherence of policies and procedures to prevent and punish theft
- Thoroughness of estimation procedures

5.3.1.2 Customer Metering Inaccuracies

Customer metering inaccuracies (also called customer metering error) account for the fact that all meter populations feature a certain degree of inaccuracy in registering customer consumption volumes. Inaccuracies typically reflect meter under-registration due to wear-and-tear and inappropriate meter sizing (usually over-sizing). Meter over-registration is possible, though less common.

It is simply not practical to inspect and test every single customer meter. Large, high-revenue meters are typically associated with industrial, commercial, and agricultural customers that produce a much larger share of revenue per account than small meters, which tend to be associated with residential uses. As such, it is recommended that the utility annually inspect and test high-revenue meters and a random sample of small meters.

The purpose of this section is to introduce key concepts with respect to the determination of customer metering error. For a more comprehensive guide for meter testing, refer to the AWWA Manual M6, *Water Meters— Selection, Installation, Testing, and Maintenance.*

Testing before installation

Best practice is to inspect and test all large meters prior to use. While this is practical for large meters, it would be practicably challenging to test every meter in a large set of small meters, so it is advised that the utility test a random sample of meters (stratified by relevant criteria, such as meter manufacturer, model, and size) prior to installation.

5.3.1.2.1 Small Meter Testing

Utilities should test a random sample of small meters (see sidebar on the meaning of random). Ideally, the utility would stratify its small meter population into different groups, based on any combination of manufacturer, model, and size, and randomly test meters within each group. Information on meter age and/or total throughput (cumulative water volume passed through the meter over its lifespan) could be included for additional analysis. Keep in mind that any given sample of a particular meter group should be sufficiently large to be meaningful—for example, three tests of 3/4" Badger meters is not sufficiently large to confidently represent the actual performance of the entire population of 3/4" Badger meters. The level of specificity to which the analysis goes should be informed by your utility's capacity to test meters and perform data analysis.

Small meters are typically tested at a number of flow rates because meter accuracy varies with flow rate.

What is a random meter sample?
A random meter sample means that meters are selected entirely by chance and not for any particular reason. This can be achieved by labeling all of the meters with a unique ID code and using a random-number generator such as that offered by Microsoft Excel. Here are a few examples of samples that are **not** random:

- Test results from meters that were removed due to customer complaints
- Test results from meters that were removed due to age
- Test results from meters located in a particular geographic area

Table 5 summarizes test results for GCWD, which randomly selected 100 small meters for testing.

Table 5: GCWD Meter Testing Example

Test Flow Rate	Mean Accuracy
Low (0.25 gpm)	94.60%
Medium (2.0 gpm)	97.20%
High (15.0 gpm)	99.20%

The next step is to identify the volume of consumption registered at different flow rates. Sometimes, utilities will have system-specific data showing the breakdown of consumption by flow rates, but this is rare. For utilities that do not have such information at hand, it is advised that the AWWA volume-weighted standards be applied. These values are shown in Table 6, under column A. The GCWD auditor used the combination of AWWA volume-weighted standards, consumption data, and meter test results to calculate meter error, as detailed in Table 6. The determination of customer meter error applies to metered consumption only, so any unmetered consumption should be excluded from this analysis.

Investigate how meters are tested:

- Using a bench test?
- Portably, in the field?
- Sent to certified third party?

Assess the reliability of these testing forms. For example, how do you know that the meter test bench produces accurate results? Has the test bench been tested or calibrated?

Stuck meters, or "dead" meters—where the register does not turn at all when water is passed through—should be excluded from this analysis insofar as there are policies and procedures in place to identify dead meters promptly, to replace them, and to bill the customer accordingly.

Table 6: GCWD Meter Testing: AWWA Volume-Weighted Standards Example

	A	B	C = A * B	D	E = (C/D) - C
Flow Rate	Consumption Volume Distribution[1]	GCWD CY19 Small Meter Total Consumption (MG)[2]	GCWD CY19 Small Meter Consumption at Flow Rate (MG)	Mean Accuracy	Meter Error (MG)[3]
Low (0.5 – 1.0 gpm)	2.0%	26,946.454	538.929	94.60%	30.763
Medium (1 – 10 gpm)	63.8%	26,946.454	17,191.838	97.20%	495.238
High (10 - 15 gpm)	34.2%	26,946.454	9,215.687	99.20%	74.320
Total	**100.0%**	**26,946.454**	**26,946.454**	**97.82%[4]**	**600.322**

[1]In other words, an estimated 2.0% of total consumption by small meters is registered at low flows.
[2]Based on sales data.
[3]The formula for meter error produces a value of opposite sign to the formula that was used to calculate meter error for source meters in Section 5.1.3. That is because the AWWA software is set up such that negative values mean under-registration for source meter error, while negative values mean over-registration for customer meters.
[4]The total mean accuracy of 97.82% is a composite accuracy calculated by comparing the total uncorrected volume of small meter consumption to the total corrected volume [(26,946.454 / (26,946.454 + 600.322)].

5.3.1.2.2 Large Meters

A similar analysis described above for small meters above can be performed for large meters. However, there is no reliable industry standard for consumption volume distribution by flow rate, since large meter use is much more unpredictable and variable. If your utility has reliable information on the breakdown of large meter consumption volumes by flow range, that is ideal. If such information is not available, then you can equally weight accuracy at all flows by utilizing a simple average. Table 7 shows large meter accuracy results for GCWD from tests that were performed during the audit period. GCWD tests approximately half of its large meters every year.

Table 7: GCWD Large Meter Test Example

	Test Flow Rate	Mean Accuracy
A	Low	91.40%
B	Medium	96.90%
C	High	99.90%
(A + B + C)/3	Average	96.07%

The GCWD auditor used the average accuracy of 96.07% and billing data to calculate large meter error, as shown in Table 8.

Table 8: GCWD Large Meter Error Example

A	B	C = (B / A) - B
Meter Accuracy	GCWD CY19 Large Meter Total Consumption (MG)	Meter Error
96.07%	7,071.354	289.528

For GCWD, total customer metering inaccuracies for CY19 were 889.95 MG, as shown in Table 9.

Table 9: GCWD Total Customer Metering Inaccuracies Example

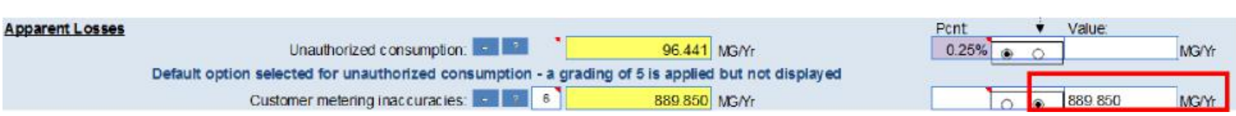
	Meter Error (MG)
Small Meters	600.322
Large Meters	289.528
Total	**889.850**

What if my utility does not have any meter testing documentation?

If your utility does not have any reliable, representative meter test data available, you should nonetheless estimate meter accuracy. You should speak with those in your utility who are most knowledgeable about the customer meter stock, and consider the following factors when estimating accuracy:

- Age distribution of the meter stock
- Meter installation quality
- Any miscellaneous test results (e.g. tests on retired meters)

The auditor then filled out the Reporting Worksheet accordingly by selecting the "Value" function for Customer Metering Inaccuracies:



5.3.1.2.3 Data Validity Grading

It is recommended that you thoroughly review the Grading Matrix included in the AWWA Free Water Audit Software when assessing data validity associated with Customer Metering Inaccuracies. Below are some of the key considerations:

- Quality of recordkeeping on customer meter population
- Extent and frequency of meter testing
- Extent of meter replacement program, and degree to which the program is strategically designed
- Means by which accuracy levels are determined
- Whether third party review of customer meter management is utilized.

5.3.1.3 Systematic Data Handling Errors

Systematic Data Handling refers to the processes that "transmit, archive, and report customer consumption totals as derived from the meter population." In other words, it consists of the various processes from the point of the meter read to the use of the consumption data.

To determine the Apparent Losses volume attributable to Systematic Data Handling Errors, you can either rely upon the AWWA default estimate of 0.25% of Billed Metered Authorized Consumption or perform a rigorous review of data handling. Your utility can benefit from the latter option, since such an exercise not only contributes to a more accurate audit but is an essential part of quality control. That said, the AWWA default estimate is useful when time and resources are limited.

If you choose to determine the volume yourself, rather than rely upon the default estimate, the paragraphs below can help get you started.

5.3.1.3.1 Meter Reading

Meter reading can introduce errors or inaccuracies into the billing system in a number of ways.

Regardless of the type of meter reading system employed (manual reads, AMR, AMI), a certain number of reads will fail to successfully register. The frequency of **failed reads** (the positive equivalent would be the meter read success rate) should be investigated, particularly in settings where meters are read manually.

When a successful read is not obtained, estimates are typically made. The frequency of **estimates** should be evaluated, as well as the volumetric impact of such reads (e.g. 2.5% of volumetric sales were associated with estimated reads.) Additionally, you should look into the means by which consumption is estimated, and assess whether such methodology is appropriate. Sometimes estimates are based on outdated information that poorly reflects actual consumption.

"Zero reads"—reads where consumption is zero—should be investigated. Sometimes these reads will reflect genuine zero-consumption—for example, on an account where the customer has been on extended vacation—but other times they can indicate failed reads, meter tampering or theft, or a stuck meter. Accounts that feature strings of consecutive zero reads should be given close attention.

5.3.1.3.2 Billing Adjustments

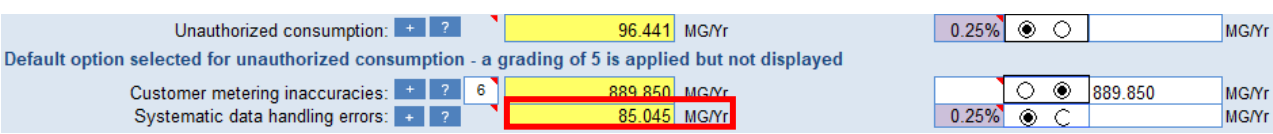
Billing adjustments, which are made in order to resolve financial concerns, can sometimes interfere with the accurate calculation of consumption. Many utilities will modify billed consumption volumes to trigger a financial adjustment, in the process distorting consumption data. Ideally, utilities will either issue financial adjustments without changing consumption volumes, or will keep two distinct fields for customer consumption: one for *registered* consumption (actual water use), and another for *billed* consumption. In the absence of such practices, you as the auditor would need to thoroughly review adjustments to get a sense of their volumetric impact. One place to start would be to examine negative billed consumption volumes, which would presumably reflect a credit issued to the customer.

5.3.1.3.3 Policy and Procedure Shortcomings

Policy and procedure shortcomings can contribute to Apparent Losses, including but not limited to:

- Inefficiencies or delays in permitting, metering, or billing, allowing water use to occur without proper tracking.
- Poor customer account management, such as accounts that were not initiated, lost, or transferred erroneously.

The GCWD auditor determined that such a thorough review was beyond the scope of the CY19 water audit and relied upon the AWWA default estimate. It is the auditor's goal to perform a manual review of Systematic Data Handling Errors for the next audit in conjunction with the customer billing department. As such, the auditor has filled out the Reporting Worksheet accordingly. The worksheet automatically calculated the volume of Systematic Data Handling Errors to be 85.045 MG.



5.3.1.3.4 Data Validity Grading

It is recommended that you thoroughly review the Grading Matrix included in the AWWA Free Water Audit Software when assessing data validity associated with Systematic Data Handling Errors. If the default estimate is selected, the data validity grading will automatically be assessed at a "5." If you choose to determine the volume yourself, you should consider the following when grading data validity:

- Coherence and rigor of policies and procedures governing account activation and billing operations
- Recordkeeping system (computerized, paper records)
- Relationship between billing adjustments and measured consumption volumes, and understanding of that relationship
- Frequency and rigor of internal checks on billing accuracy
- Utilization of third party auditing
- Coherence of policies and procedures to prevent and punish theft

- Thoroughness of estimation procedures

Upon completing the three categories of Apparent Losses, the AWWA Software will automatically sum them to determine a total volume of Apparent Losses, as shown below using the example of GCWD:

Apparent Losses

Unauthorized consumption:	+ ?	96.441	MG/Yr
Default option selected for unauthorized consumption - a grading of 5 is applied but not displayed			
Customer metering inaccuracies:	+ ? 6	889.850	MG/Yr
Systematic data handling errors:	+ ?	85.045	MG/Yr
Default option selected for Systematic data handling errors - a grading of 5 is applied but not displayed			
Apparent Losses:	?	**1,071.336**	MG/Yr

5.3.2 Real Losses

At this point, you have entered all of the necessary information to be able to determine the volume of Real Losses (leakage). As discussed in Section 2.1.1, in a top-down water audit such as this one, Real Losses are derived using a process of deduction or process of elimination. Now that you have calculated the volume of Water Supplied, Authorized Consumption, and Apparent Losses, the volume of Real Losses is simply what is left over.

In the case of GCWD, the volume of Real Losses is 2,931.297 MG, as shown in the excerpt from the Reporting Worksheet below. (This can also be seen in the "Water Balance" worksheet).

It is important to distinguish between the top-down method of calculating Real Losses and the bottom-up, or "Component Analysis," method. The bottom-up method seeks to quantify volumes of leakage using a combination of leak-break documentation and engineering modeling. This approach is very helpful for breaking down leakage into discrete categories and designing targeted leakage mitigation strategies. For more information, see "Further Resources."

Real Losses (Current Annual Real Losses or CARL)

Real Losses = Water Losses - Apparent Losses:	?	**2,931.297**	MG/Yr

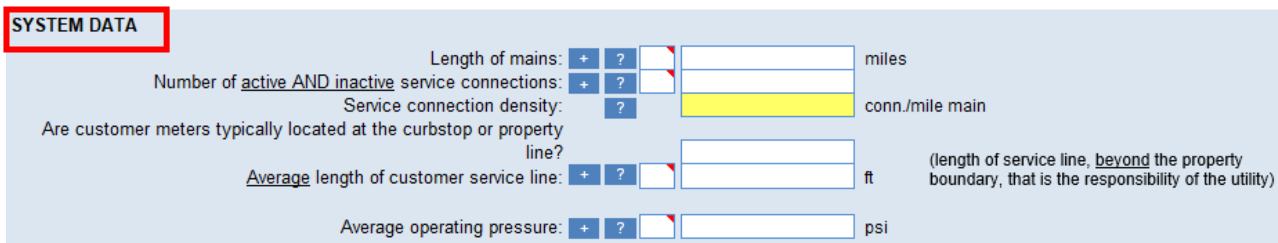
Congratulations, you now have a complete *water balance* in place! At this point, you do not quite yet have a complete *water audit*—the following sections discuss the necessary pieces of system information and cost data that are necessary to complete the water audit, which provides useful performance metrics beyond the water balance itself.

5.4 System Data

To complete a water audit, it is essential to provide key information about the water system to which the audit pertains. This information informs the calculation of key performance metrics. Specifically, system data determines the “leakage allowance” for your system. All systems—even brand new ones— will inevitably leak. The leakage allowance represents the baseline volume of leakage that is deemed unavoidable given current operating conditions. In technical terms, this leakage allowance is referred to as the volume of Unavoidable Annual Real Losses (“UARL”).

System Data is not used solely for informational purposes, but is critical to the development of a meaningful audit.

The UARL is determined by length of piping, density of service connections, and average operating pressure. Figure 13 below shows the System Data section within the Reporting Worksheet of the AWWA Software.



Please note that the UARL has not been proven fully valid for systems that are very small and/or operate at a low pressure. As described in the “Definitions” tab of the AWWA Software, if...

A) (Lm x 32) + Nc < 3,000
Where Lm is the length of mains, in miles
Where Nc is the number of service connection

OR

B) Pressure < 35 PSI

then the calculated UARL value may not be valid. In this case, the AWWA Water Audit Software does not calculate the UARL and the Infrastructure Leakage Index (ILI) and instead displays an “N/A” message.

5.4.1 Length of Mains

This is the total length of transmission and distribution pipelines in the potable water system to which the audit pertains. It does not include the length of service lines, but it does include fire hydrant lateral pipe—the segment of pipe between the water main and the hydrant. If the actual length of fire hydrant lateral pipe is not known, an average length can be estimated, and then multiplied by the number of hydrants in the system.

5.4.1.1 Data Validity

You should consider the following when grading data validity:

- Quality of procedures to document new water main installations
- Type of recordkeeping (paper records, GIS, asset management database)
- Quality of recordkeeping
- Frequency of field validation

5.4.2 Number of Active and Inactive Service Connections

This includes the total number of customer service connection laterals, which are located between the water main and the customer. It does not include fire hydrant lateral pipe, which should be accounted for in “Length of Mains.” It is important to note that this statistic reflects distinct piping connections, including fire connections, regardless of whether the respective account is active or inactive. This number may be different from the number of customers or accounts.

5.4.2.1 Data Validity

You should consider the following when grading data validity:

- Strength of permitting policy for new service connections
- Strength of enforcement and oversight of permitting
- Quality of recordkeeping
- Type of recordkeeping (paper records, GIS, asset management database)
- Frequency of field validation
- Results of field validation

5.4.3 Are Customer Meters Typically Located at the Curbstop or Property Line?

This field requires a yes/no response. The point of this question is to determine the length of customer-owned pipe that is upstream of the meter. If your customer meters at located at the curbstop or the property line, then this length is zero, and you should select "Yes." However, if your customer meters are typically located beyond the customer property line, you will need to select "No," and then estimate the average length of customer service line. If most of your customers are unmetered, then you should select "No" and estimate the average length of customer service line between the point of ownership transfer and the building line.

In Indiana, most utilities' customer meters are located at the property line (typically on or adjacent to the sidewalk).

For a helpful visual display of the various metering setups, refer to the "Service Connection Diagram" worksheet in the AWWA software, as well as the definition under the "Definitions" worksheet.

5.4.3.1 Data Validity

If the response to this question was "Yes," then an automatic grading of 10 is applied. If the response was "No," then you will need to assign a data validity score, in which case you should consider the following:

- Clarity of policy governing delineation of water utility ownership and customer ownership of service connection piping
- Basis for estimate of average length of piping (number of field measurements, statistical validity of sample)
- Quality of recordkeeping system

5.4.4 Average Operating Pressure

The average operating pressure for the potable distribution network plays a critical role in determining the leakage allowance volume (Unavoidable Annual Real Losses). Thus, it is important to be as thorough as possible in determining this value.

There are a number of ways to determine this value:

- If your utility utilizes a hydraulic model, an average of the nodes can be taken. Ensure that the model has been recently calibrated with actual field pressures and that the nodes are geographically distributed throughout the system.
- If you do not have a calibrated hydraulic model, use one of the following three methods:
    - If the water distribution system is relatively flat and/or consists of a single pressure zone, you should take a representative sample of pressure readings, and then simply average those values.

- If the water distribution system features significant elevation changes, and/or consists of multiple pressure zones, the average pressures for each zone should be taken, and then weighted according to either the number of service connections or miles of mains within each zone, depending on the following:

    - If there are >32 service connections per mile of main for the entire system, use number of service connections as the basis for weighting.

    - If there are ≤ 32 service connections per mile of main for the entire system, use miles of main as the basis for weighting.

The service connection density for your system is automatically calculated by the AWWA software on the Reporting Worksheet, under "System Data."

- If you are compiling the audit for the first time and do not have the ability to conduct such testing, the average pressure can be approximated, but with a low data validity grading.

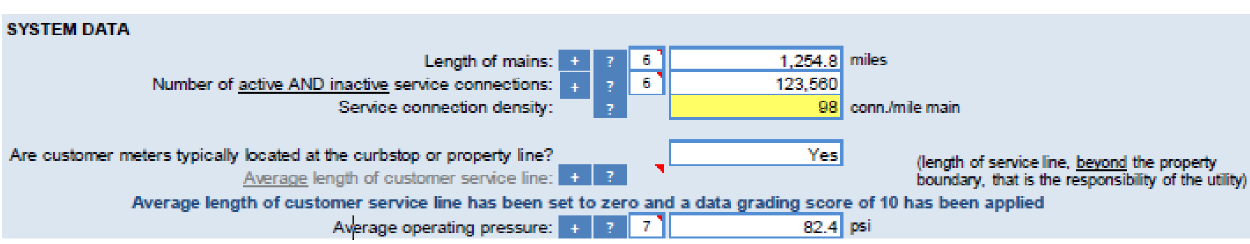
Regardless of which method is used above, do your best to gain a representative sample of average system operating conditions. Consider the level of demand throughout the day—it would not be advisable to use pressure data from the middle of the night, when demand is at its lowest and pressure is highest, or in the early morning, when demand peaks and pressure is at its lowest. Also take into account tank operations and how they impact pressure throughout the day.

5.4.4.1 Data Validity

You should consider the following when grading data validity:

- Means of gathering pressure data
- Representativeness of pressure data
- Pressure management setup
- Pressure monitoring system
- Quality of pressure zone management/discreteness of pressure zones (extent of breaches)

In the case of GCWD, the auditor has assembled system data and filled out the Reporting Worksheet accordingly:



5.5 Cost Data

A water audit provides more than just an accounting of water over a given period. It also provides meaningful *financial* information that can inform forward-looking management decisions.

The AWWA software provides financial performance indicators based on three different pieces of information entered by the auditor, discussed in the following sections.

Cost Data is not just for informational purposes, but is critical to the development of a meaningful audit.

You can find additional guidance on calculating cost data in Appendix C: Cost Data Guidance.

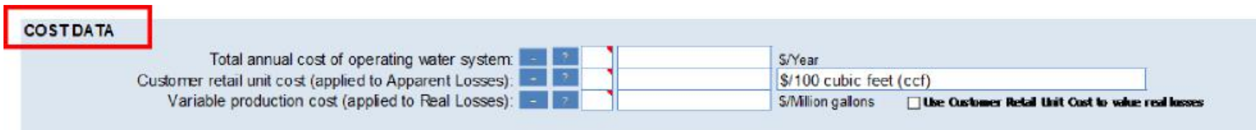


Figure 14 below shows the Cost Data section within the Reporting Worksheet of the AWWA Software.

5.5.1 Total Annual Cost of Operating Water System

The total cost of operating the potable water system, including, but not limited to:

- Operations and maintenance (O&M)
- Financing costs (debt service)
- Salaries and benefits
- Insurance and administrative costs

Make sure to include *only* costs pertaining to the potable water system. Costs associated with wastewater, biosolids, and recycled water should be excluded.

5.5.1.1 Data Validity

You should consider the following when grading data validity:

- Type of accounting system (paper, electronic)
- Reliability of accounting system
- Frequency and rigor of auditing

5.5.2 Customer Retail Unit Cost

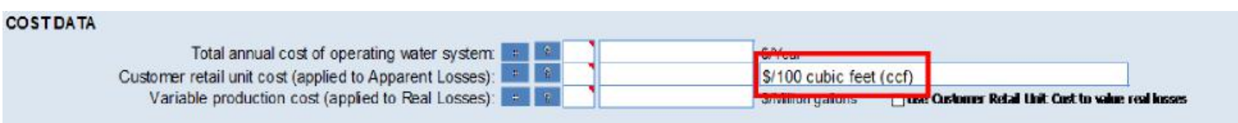
Customer Retail Unit Cost: This represents the charge that customers pay for water and serves as the unit cost that is applied to Apparent Losses, since such water is delivered to customers but not billed for. Additional charges for sewer, storm water, and/or biosolids processing may be included, insofar as those charges are directly based on the volume of potable water consumed.

To determine the appropriate cost, you should ask yourself, “If we fail to collect payment for a unit of water consumed by a retail customer, how much revenue is lost?” Because every utility has a unique rate structure, often featuring a mix of fixed service fees, variable use charges, tiers, and base allocations, you will have to come up with the most reasonable way to determine a composite cost for the audit period. A simple approach would be to divide total volume-based revenues by the total volume of potable water delivered.

If your utility employs the services of a professional rate consultant, they can be a valuable resource in calculating the customer retail unit cost.

AWWA M36 states that additional charges for sewer, storm water, and/or biosolids processing may be included, *insofar as those charges are directly based on the volume of potable water consumed*. Otherwise, such costs should be excluded.

Finally, make sure that you select the appropriate volumetric unit in the field shown below in red.



The GCWD auditor determined the customer retail unit cost to be $2.55/CCF, based on the following information:

Table 10: GCWD Retail Unit Cost Calculation Example

A	CY19 Billed Metered Consumption (MG)	34,017.81
B = A * 1,000,000 / 748	FY15 Billed Metered Consumption (CCF)	45,478,352.98
C	FY15 Volume-Based Water Sales	$115,969,800.00
D = C / B	Customer Retail Unit Cost	$2.55

5.5.2.1 Data Validity

You should consider the following when grading data validity:

- Degree to which billing operations accurately reflect rate structure
- Means by which the composite rate is calculated
- Auditing procedures

5.5.3 Variable Production Cost

Real Losses (leakage) are typically valued at the Variable Production Cost. In other words, the Variable Production Cost represents the value associated with leakage (and its recovery).

> **Variable Production Cost:** The cost to supply the next unit of water to the system. This cost is determined by calculating the summed unit costs for ground- and surface water treatment and all power used for pumping from the source to the customer. It may also include other miscellaneous unit costs that apply to the production of drinking water. It should also include the unit cost of bulk water purchased as an import, if applicable.

Determining the cost of providing water can be quite complex, depending on the degree of detail that you choose to go into.

According to the M36, the cost rate "depends on the local economic and water resource considerations of the utility." Ultimately, you will need to determine the most accurate means of assessing the cost to your utility of providing water. The five common approaches below can help inform your determination:

1. **Power & Chemicals:** This is a present-oriented approach that could be used in a utility where 100% of supply comes from groundwater and/or surface water, and the sole cost of production is power and chemicals. It does not consider the value of future-oriented benefits of real loss reduction, such as avoided expansion of supply (e.g. drilling new wells).
2. **Cost of Imports:** This would be appropriate in a utility that imports 100% of its water. Alternatively, it could be used in a utility that features a mix of local and imported sources but where leakage reduction would translate directly to reduced imported water purchases.

> The AWWA software is set up such that **the reporting of Variable Production Cost will be in whichever unit was selected for volumetric reporting at the beginning of the audit.** Make sure that volumetric units are properly taken into account when performing calculations.

3. **Cost of Most Expensive Source:** This approach is appropriate in a utility where leakage reduction would translate directly to reduced supply of the most expensive source of water, whatever that may be (e.g., desalinated water).

4. **Composite/Average Cost:** This approach averages the cost to supply water from the various sources (e.g., ground- surface, and import water). This approach would be appropriate in a utility that does not know how leakage reduction would impact the use of different water sources.

5. **Cost of Avoided Expansion of Supply:** This is the most future-oriented approach, as it assesses the value of leakage reduction at the avoided cost of future expansion of supply. It could be appropriate in a utility where leakage reductions translate directly to avoided expansions such as new wells and treatment plants.

Additionally, the AWWA software offers the auditor the option of valuing real losses at the Customer Retail Unit Cost instead of the Variable Production Cost.

Please provide commentary on how you determined the Variable Production Cost. You can do so using the "Comments" feature of the software. The information will be helpful when completing future audits.

As an example of a starting point, you can add up the direct variable costs associated with water production and wholesale purchases, and then divide by the total volume of Water Supplied (if applicable to your utility).

The following costs should be included, where known:

- Treatment costs (chemicals)
- Energy costs for pumping, treatment
- Wholesale (i.e., bulk or import) purchase costs

For example, the GCWD auditor determined the Variable Production Cost to be $2,240.87/MG, based on the following calculation:

Table 11: GCWD Variable Production Cost Calculation Example

	Category	Cost
A	Water Purchases	$55,722,822
B	Chemicals	$4,146,708
C	Energy - Treatment	$9,330,093
D	Energy - Pumping	$17,245,376
E = A + B + C + D	Total Cost	$86,445,000
F	Water Supplied (MG)	38,576.57
G = E / F	Variable Production Cost ($/MG)	$2,240.87

AWWA software versions 5.0 and newer include an optional check box that allows you to value Real Losses at the Customer Retail Unit instead of the Variable Production Cost. This option can be appropriate in times of constrained water resources such as drought, where the value of reducing leakage should be compared to conservation programs that reduce billed customer consumption. Because reduction of leakage does not reduce customer sales, it can be assessed at the value of "revenue not lost."

5.5.3.1 Data Validity

You should consider the following when grading data validity:

- Reliability of accounting system
- Thoroughness of cost allocations (whether indirect or secondary costs are included)
- Auditing procedures

6 HOW TO INTERPRET THE RESULTS OF THE WATER AUDIT

Based on the information that you have entered into the Reporting Worksheet, the AWWA software produces a number of helpful metrics. To varying degrees, these metrics can help improve water audit validity, inform water loss control planning efforts, and compare performance over time and with that of other utilities.

Of the metrics presented within the AWWA software, the following six are particularly important.

6.1 Water Audit Data Validity Score (Reporting Worksheet)

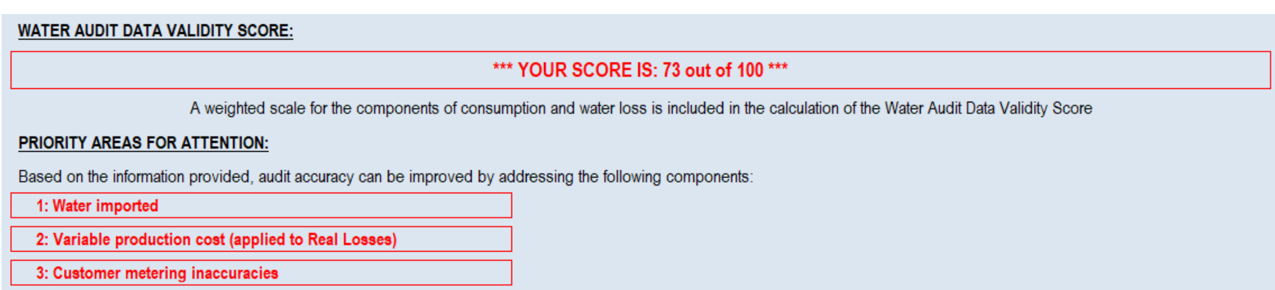
- This is a composite score that reflects the quality of the data entered into the audit, as determined by your self-reported data validity scores for individual fields. The score is a volumetrically-weighted average, in which a lower score reflects less confidence in the accuracy of data, and a higher score reflects greater confidence.
- The AWWA software offers general water loss control guidance on the worksheet titled "Loss Control Planning" based on the results of the Data Validity Score.

> The only criteria for a "good" data validity score is whether the score accurately reflects the quality of data. In other words, a low data validity score is not in itself a bad thing. **It is better to have a lower score that accurately reflects the quality of data than a higher score that is less accurate.** That said, once you have established a trustworthy data validity score, you should continually work to improve upon it through concrete steps.

6.2 Priority Areas for Attention (Reporting Worksheet)

- The audit software identifies priority areas for data validity improvement based on the data validity scores that you entered when completing the audit. These suggestions offer opportunities to improve the overall data validity score and the reliability of the performance indicators produced by the audit. *It is important to note that improvement of these priority areas will result in higher data validity, but not necessarily improved system performance in managing water losses.*

Figure 15 shows these two metrics for the Green Country Water District. GCWD's composite data validity score of 73 out of 100 could be increased by improving the reliability of data that informs Water Imported, Variable Product Cost, and Customer Metering Inaccuracies.


WATER AUDIT DATA VALIDITY SCORE:

*** YOUR SCORE IS: 73 out of 100 ***

A weighted scale for the components of consumption and water loss is included in the calculation of the Water Audit Data Validity Score

PRIORITY AREAS FOR ATTENTION:

Based on the information provided, audit accuracy can be improved by addressing the following components:

1: Water imported

2: Variable production cost (applied to Real Losses)

3: Customer metering inaccuracies

While the previous two metrics shed light on the *quality* of the audit, the following performance indicators ("PI"s) speak to the *performance of the system* during the audit period. They are calculated solely according to the actual data that you entered into the water audit and are not impacted by the data validity scores associated with those entries. These PIs can be located on the Performance Indicators worksheet.

Remember that the quality of water audit results is only as good as the data going into the audit. Thus, the following performance metrics should be considered in context of the level of data validity of your audit.

6.3 Non-Revenue Water as Percent by Cost of Operating System

- This PI is *financial* in nature, as it tells you the value of Non-Revenue Water as a percentage of the total cost to run the water system. It should not be deemed an *operational* indicator, as it does not *specifically* speak to the level of Real Losses or Apparent Losses. Remember that Non-Revenue Water includes Real Losses (leakage), Apparent Losses (paper losses), and Unbilled Authorized Consumption.
- For example, the value of Non-Revenue Water in GCWD's system was 5.9% of the total cost to operate the system for the audit period, as shown in Figure 16 below.

6.4 Infrastructure Leakage Index (ILI)

- The ILI indicates how well a distribution system controls Real Losses (leakage), taking into account its key characteristics, namely the length of water mains, number of service connections, and average system operating pressure. The ILI is a leading benchmark standard for evaluating system performance over time and in comparison to other utilities.

Changes in performance metrics over time can reflect changes in the quality of data, and not necessarily actual changes in system performance. For this reason, you are encouraged to promptly improve data validity as much as possible, so that performance metrics can best reflect actual system performance.

- Mathematically, it is the ratio of the *actual* annual volume of Real Losses to the *lowest possible volume* of Real Losses that can be technically achieved for that water system given current operating conditions (Current Annual Real Losses ("CARL") divided by Unavoidable Annual Real Losses). For example, an ILI of 2.5 indicates that the volume of Real Losses within a distribution system is 2.5 times the technical minimum, while an ILI of 1.0 indicates that the volume of Real Losses approximates the technical minimum.
- The ILI does not serve as a valid performance indicator for systems that are very small and/or operate at a low pressure. For additional detail on these thresholds of calculation, please refer to Section 5.4, where UARL requirements (necessary for the calculation of ILI) are introduced in the context of system data entry.

- For example, the ILI for GCWD for the audit period was 3.85, as shown in Figure 16 below.

The calculation of the ILI is largely dependent on average system pressure, which determines the leakage allowance (Unavoidable Annual Real Losses or UARL). As such, changes over time in average system pressure can impact the ILI in a way that can sometimes be misleading. For example, imagine a scenario where a utility reduces its average system pressure substantially. Because of the direct relationship between pressure and leakage, the volume of leakage is thereby reduced. However, in spite of the overall improvement in leakage management, the ILI could remain the same, or even increase, because of the decrease in the leakage allowance!

Given an appreciation for the ILI's sensitivity to pressure, it is an extremely helpful performance indicator – especially when a system's key characteristics are stable.

6.5 Apparent Losses per Service Connection per Day

- This PI normalizes Apparent Losses so that you can evaluate performance over time even as the number of service connections changes. It is expressed in gallons per service connection per day. It is helpful as a means of comparing performance across utilities.
- For example, GCWD experienced Apparent Losses of 23.75 gallons per service connection per day for the audit period, as shown in Figure 16 on the following page.

6.6 Real Losses per Service Connection per Day

- This PI normalizes Real Losses so that you can evaluate performance over time as the number of service connections changes. It is expressed in gallons per service connection per day. It is of limited value as a means of comparing performance across utilities, since systems operate at different pressures. A higher pressure system can be expected to leak more, and vice versa, due to the direct relationship between pressure and leakage. As such, Real Losses per Service Connection per Day *per PSI of Pressure* is a more useful metric for comparing performance across utilities.
    - If your system's service connection density is less than 32 service connections per mile of pipeline, then the more appropriate PI is Real Losses per Length of Main per Day. The AWWA Software will automatically present the appropriate indicator based on the service connection density of your system.
- For example, GCWD experienced Real Losses of 65.00 gallons per service connection per day for the audit period, as shown in Figure 16 on the following page.

Performance Indicators:

Financial:	Non-revenue water as percent by volume of Water Supplied:	11.7%	
	Non-revenue water as percent by cost of operating system:	5.9%	Real Losses valued at Variable Production Cost
Operational Efficiency:	Apparent Losses per service connection per day:	23.75	gallons/connection/day
	Real Losses per service connection per day:	65.00	gallons/connection/day
	Real Losses per length of main per day*:	N/A	
	Real Losses per service connection per day per psi pressure:	0.79	gallons/connection/day/psi
	From Above, Real Losses = Current Annual Real Losses (CARL):	2,931.30	million gallons/year
	? Infrastructure Leakage Index (ILI) [CARL/UARL]:	3.85	

Figure 16 shows GCWD's Performance Indicators

"Where do I find Unaccounted-for-Water?"

As discussed in detail in Section 1.1, the concept of unaccounted-for-water has been formally abandoned by the industry because it has been deemed inconsistent and unreliable for the management of system losses. As you have seen, **you have accounted for all volumes of water** through the water audit, leaving no water unaccounted-for. Even better, you have broken down water losses into the more specific components of Apparent Losses and Real Losses, which is far more useful than simply writing off losses as unaccounted-for.

"Where do I find percent losses?"

Most people intuitively want to know what percent of water in the system is lost. However, the use of percentages can be misleading because they do not allow for proper comparisons of performance between utilities or within the same utility over time. The PIs mentioned in this section are superior to percentages in these respects. For specific examples of the limitations of percentages, refer to Appendix B: Limits of the Use of Percentages as Performance Indicators.

REFERENCES:

Water Systems Optimization, 2016, California Department of Water Resources: Water Audit Manual.

Indiana Finance Authority, 2016, Evaluation of Indiana's Water Utilities Report.

Senate Enrolled Act 4, Indiana General Assembly, (2019 Session).

Indiana Code, Title 8, Article 1, Chapter 30.8. Non-Revenue Water Audits.

American Water Works Association, 2016, Manual 36 Water Audits and Loss Control Programs (4th edition).

APPENDIX A: CORRECTING FOR MISALIGNMENT BETWEEN METER READING/ BILLING CYCLES AND AUDIT PERIOD

To properly correct for misalignment between meter reading/billing cycles and the audit period, the auditor should first determine billed metered consumption for every meter reading cycle (by date). For small utilities, there may be just a few meter reading cycles; for large utilities, there could be many.

The example below introduces the concept with a very simple meter reading schedule: where meters are read on the same day each month.

Green Country Water District staff read customer meters on the same day every month. The GCWD auditor compiled billed metered sales data relevant to the audit period (1/1/19 - 12/31/19), as detailed in Table 12 below, plus an extra meter read on either side of the audit period in order to correct for misalignment.

Table 12: GCWD Monthly Sales Example

Read Date	Customer Sales (MG)
12/10/2018	2,418.661
1/10/2019	2,278.897
2/10/2019	2,233.471
3/10/2019	2,278.897
4/8/2019	2,877.013
5/10/2019	2,952.724
6/9/2019	3739.260
7/10/2019	3,471.978
8/10/2019	3,439.905
9/11/2019	3,068.071
10/12/2019	2,865.882
11/10/2019	2,460.604
12/10/2019	2,422.748
1/10/2020	2,281.797
Total CY19	**34,089.450**

The auditor then made adjustments to billed metered sales on both ends of the audit period, based on the pro-rated share of consumption actually falling within the audit period. This is shown in Table 13.

Table 13: GCWD Prorated Consumption Example

	Read Date	1/10/2019	1/10/2020
	Previous Read Date	12/10/2018	12/10/2019
A	Customer Sales	3,471.98	4,169.55
B	Days in Audit Period	10	21
C	Days of Consumption	31	31
D = A * (B/C)	**Customer Sales - Corrected**	**1,119.993**	**2,824.533**

Table 14 below shows monthly customer sales after correcting for misalignment. The shaded cells indicate which dates were added to calculate the total calendar year value.

Table 14: GCWD Monthly Misalignment Example

Read Date	Customer Sales (MG)	Customer Sales - Corrected for Misalignment (MG)
12/10/2018	2,418.661	0.000
1/10/2019	2,278.897	735.128
2/10/2019	2,233.471	2,233.471
3/10/2019	2,278.897	2,278.897
4//2019	2,877.013	2,877.013
5/10/2019	2,952.724	2,952.724
6/9/2019	3739.260	3,739.260
7/10/2019	3,471.978	3,471.978
8/10/2019	3,439.905	3,439.905
9/11/2019	3,068.071	3,068.071
10/12/2019	2,865.882	2,865.882
11/10/2019	2,460.604	2,460.604
12/10/2019	2,422.748	2,422.748
1/20/2020	2,281.797	1,472.127
Total CY 19	**34,089.450**	**34,017.808**

In reality, most utilities have more complex reading cycles. Therefore, a meter lag correction should be used for each meter reading route. This will require that the auditor determine the volume of billed consumption for each meter reading route, and then making the correction in the manner as described above.

APPENDIX B: LIMITS OF THE USE OF PERCENTAGES AS PERFORMANCE INDICATORS

The use of percentages as performance indicators can be misleading because they are "highly sensitive to the level of customer consumption...despite the fact that no change in loss levels may have occurred." (The level of leakage in a system is unrelated to the volume of customer consumption.)

For example:

As shown in Table 15 below, Utility A had a Water Supplied volume of 100 MG for Year 1. Authorized Consumption was 90 MG. Water Losses were 10 MG, consisting entirely of Real Losses (no Apparent Losses). Thus, Utility A had Real Losses of 10.0% for Year 1.

Year 2 was especially dry, and witnessed increased irrigation use. As a result, customers used 10 MG more water, while the leakage volume remained the same. Thus, Utility A had a Water Supplied volume of 110 MG and Authorized Consumption of 100 MG for Year 2. Just like Year 1, Water Losses (all Real Losses) were 10 MG. However, the percent losses decreased to 9.1%—suggesting that the utility's performance improved—when in fact, the volume of Real Losses did not actually change at all.

Table 15: Limits of Percentages as Performance Indicators Example

		Year 1	Year 2
A	Water supplied	100 MG	110 MG
B	Authorized Consumption	90 MG	100 Mg
C = A – B	Water Losses (all Real Losses)	10 MG	10 MG
D = C / A	Water Losses (all Real Losses)	10.0 %	9.1%

APPENDIX C: COST DATA GUIDANCE

This guide provides additional information about the three pieces of financial data required by the drinking water loss audit:

1. Total Annual Cost of Operating a Drinking Water System
2. Customer Retail Unit Cost
3. Variable Production Cost

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1. Total Annual Cost of Operating a Drinking Water System

What is the Total Annual Cost of operating a drinking water system?

- The Total Annual Cost includes all expenses related to keeping the water system up and running.

Why is this number important?

- Estimating annual operating expenses has many practical uses. Utility staff and other stakeholders can better plan budgets and manage rates when they know all the costs involved in running the utility. Additionally, expressing water loss costs as a percent of the total cost helps prioritize financial investments.

How do I find the Total Annual Cost of operating a drinking water System?

- The Total Annual Cost includes all expenses related to operating only the drinking water system. It does not include any costs associated with wastewater or other non-drinking water systems.

Costs may include, but are not limited to:

Employee salaries and benefits	Facility rent and mortgage
Supplies and equipment	Insurance
Electricity	Chemicals and analysis
Purchased water costs	Loan repayments
Equipment rental and repair	Legal fees
Phone and internet	Depreciation transfers

Example 1: Calculating Total Annual Cost of Operating a Drinking Water System

Expense Categories	**2018 Year End Expended**
Salaries & Wages	$ 225,978
Employee Benefits	$ 78,314
Power Purchase	$ 10,528
Water Purchase	$ 333,828
Materials & Supplies	$ 71,963
General & Misc.	$ 169,011
Contract Services	$ 116,460
New Equipment	$ 37,040
Depreciation Transfers	$ 15,616
Capital Improvements	$ 5,272
Bond & Loan Transfers	$ 74,041
Total Annual Cost of Operating a Drinking Water System	$1,138,051

2. Customer Retail Unit Cost

What is the Customer Retail Unit Cost?

- The Customer Retail Unit Cost (CRUC) is the average price a customer pays for a unit of water.

Why is this number important?

- The Customer Retail Unit Cost values the amount of water a customer receives, but is not billed for due to metering errors. This difference between the amount billed and the amount received is part of the utility system's apparent losses.

How do I find the Customer Retail Unit Cost?

- A utility can use several methods to find the Customer Retail Unit Cost. One option is as follows:

$$CRUC = \frac{variable\ (volume\ based)\ revenue}{total\ volume\ billed}$$

Where do these numbers come from?

- Volume based revenue (e.g., income from selling water) can be found by subtracting fixed revenue (e.g., meter charges) from total revenue:

Total revenue = fixed revenue + variable revenue

- The total volume billed is the amount of water the utility billed customers.

What if I cannot separate out fixed revenues?

- If your billing system does not allow you to separate out fixed revenues, you can estimate based on the number of meters and the meter size rate schedule.

Other Tips:

- Make sure you track the units your billing software provides (e.g., gallons or 1,000 gallons or million gallons)

- Average range of Customer Retail Unit Costs is $4 - $18. If you are outside of this range, double-check your math or sources to verify your result.

- If you do not remove fixed costs, indicate this on your notes/documentation

Example 2: Calculating Customer Retail Unit Costs

Total revenue = fixed revenue + variable revenue

Variable revenue = total revenue – fixed revenue

$$CRUC = \frac{variable\ (volume\ based)\ revenue}{total\ volume\ billed} = \frac{\$}{1000\ gallons}$$

Code	Meter count	Annual Rate by Meter Size 5/8"	Annual Rate by Meter Size 1"	Fixed Annual Revenue ($)	Annual Units (gallons)	Annual Units (1000 gallons)	Variable Annual Revenue ($)	Total Annual Revenue
	Fixed Revenue				*Variable Revenue*			
Residential	1,095	$ 89.40	$ -	$ 97,870.65	58,075,000	58,075	$ 949,231.25	$ 1,047,101.90
Shop	67	$ 89.40	$ -	$ 6,027.05	3,244,000	3,244	$ 53,791.05	$ 59,818.10
Commercial	103	$ 89.40	$ -	$ 9,193.30	36,080,000	36,080	$ 550,226.42	$ 559,419.72
Government	23	$ -	$ 135.72	$ 3,132.87	5,942,000	5,942	$ 77,401.49	$ 80,534.36
School	11	$ -	$ 135.72	$ 1,436.37	4,666,000	4,666	$ 64,981.73	$ 66,418.10
Religious	17	$ 89.40	$ -	$ 1,519.80	704,000	704	$ 13,895.93	$ 15,415.73
Total	1,316			$ 119,180.04	108,711,000	108,711	$ 1,709,527.85	$ 1,828,707.89

CRUC = $15.73 per thousand gallons

3. Variable Production Cost

What is Variable Production Cost?

- The Variable Production Cost is the cost to produce one more additional unit of water than you are producing right now.

Why is this number important?

- The Variable Production Cost puts a value on the real water losses in your system (i.e. the water lost through leaks/breaks/theft).

How do I find the Variable Production Cost?

- You can find the Variable Production Cost by adding all the costs to treat and pump water, and then dividing that sum by the total annual volume of water pumped.

  Note: the total volume of water pumped will be different from the total volume of water billed.

$$\text{Variable Production Cost} = \frac{electricity + chemicals + purchased\ water + residuals\ disposal}{annual\ volume\ of\ water\ pumped}$$

Other Tips:

- Utilities supplying their own water will likely be in the $200 - $800 range. Utilities purchasing most of their water may have higher variable production costs, up to the $4,000 range.

Example 3: Calculating Variable Production Cost

$$\text{Variable Production Cost} = \frac{electricity + purchased\ water}{annual\ volume\ of\ water\ pumped}$$

$$= \frac{\$10{,}528 + \$333{,}828}{108.711\ \text{million gallons}}$$

$$= \$3{,}168\ \text{per million gallons}$$

(Numbers from Examples 1 and 2)

GLOSSARY OF TERMS

Apparent Losses: The nonphysical losses that occur when water is successfully delivered to the customer but is not measured or recorded accurately. Apparent Losses can result from customer metering inaccuracies, unauthorized consumption (theft), or systematic data handling error. Often referred to as "paper losses."

Apparent Losses per Service Connection per Day: A performance indicator that describes the volume of Apparent Losses in a normalized fashion (gallons per service connection per day), for means of assessment over time and between systems.

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

Billed Authorized Consumption: All water, metered and unmetered, that is taken for authorized purposes and generates revenue to the water supplier.

Billed Metered Consumption: Water that is taken for authorized purposes that is both metered and generates revenue for the water supplier.

Billed Unmetered Consumption: Water that is taken for authorized purposes that is not metered and generates revenue for the water supplier.

Changes in Storage: The annual volumetric change in stored water that is located within the bounds of the water audit.

Current Annual Real Losses (CARL): The volume of water lost to all forms of leakage or spillage. The ratio of the CARL to the Unavoidable Annual Real Losses (UARL) is the Infrastructure Leakage Index (ILI).

Infrastructure Leakage Index (ILI): A performance indicator that indicates how well a distribution system controls Real Losses (leakage), taking into account its key characteristics, namely the length of water mains, number of service connections, and pressure. The ILI is a leading benchmark for evaluating system performance over time and in comparison to other utilities. Mathematically, it is the ratio of Current Annual Real Losses (CARL) to Unavoidable Annual Real Losses (UARL).

Non-Revenue Water: Water that fails to generate revenue for the water supplier for any reason. Non-Revenue Water includes Apparent Losses (paper losses), Real Losses (leakage), and Unbilled Authorized Consumption.

Non-Revenue Water as Percent by Cost of Operating System: A financial performance indicator that assesses the value of non-revenue water relative to the annual cost of operating the water system. It should not be deemed an operational indicator, as it does not specifically speak to the level of Real Losses or Apparent Losses.

Real Losses: Physical loss of water from the system as a result of leaks, breaks, or spillage that occurs prior to the point of customer consumption (the customer meter in metered systems; in unmetered systems, it is the point of transfer of responsibility). Customer-side leaks are not considered Real Losses.

Real Losses per Service Connection per Day: A performance indicator that indicates the level of leakage in the water system in a normalized fashion (gallons per service connection per day), for means of assessment over time.

Real Losses per Service Connection per Day per PSI: The same as Real Losses per Service Connection per Day, except that it is normalized for pressure, allowing for more appropriate comparison between systems of different operating pressures.

Revenue Water: Water that generates revenue for the utility. It consists of Billed Authorized Consumption (and Billed Water Exported in the expanded version of the Water Balance).

System Input Volume: The volume of water that is introduced to the water distribution system over the audit period. It is equal to the water produced by the water supplier's own source waters (Volume from Own Sources), plus Water Imported, plus or minus the net change in applicable water storage (Changes in Storage).

Systematic Data Handling Errors: A form of Apparent Loss pertaining to "customer consumption and billing data error in the water utility's business processes as a result of lax oversight, poor procedures, or gaps in information programming and archiving." Specifically, it can be error caused by accounting omissions, errant computer programming, data gaps, and data entry; inaccurate estimates used for accounts that fail to produce meter readings; and billing adjustments that manipulate billed consumption so as to generate a rightful financial credit in such a way that billed consumption does not reflect actual consumption.

Unauthorized Consumption: Any water that is taken in an unauthorized fashion; water theft. This may include "unpermitted water withdrawn from fire hydrants, illegal connections, bypasses to customer meters, meter or meter reading equipment tampering, or similar actions." A form of Apparent Loss.

Unavoidable Annual Real Losses (UARL): The UARL is a theoretical reference value representing the technical low limit of leakage that could be achieved if all of today's best technology could be successfully applied, given the pipeline mileage, service connection density, and average operating pressure of the system. It serves as the denominator in the ratio that determines the Infrastructure Leakage Index.

The formula for calculating the UARL is:

UARL (gallons/day) = $(5.41Lm + 0.15Nc + 7.5Lc) \times P$

Where Lm is the length of mains in miles

Where Nc is the number of active and inactive service connections

Where Lc is the average length of customer piping

Where P is the average system operating pressure

Multiply the result by 365 to determine the annual volume.

Unbilled Authorized Consumption: All water, metered and unmetered, that is taken for authorized purposes and does not generate revenue for the water supplier.

Unbilled Metered Consumption: Water that is taken for authorized purposes that is metered and does not generate revenue for the water supplier.

Unbilled Unmetered Consumption: Water that is taken for authorized purposes that is not metered and does not generate revenue for the water supplier- e.g., system flushing.

Volume from Own Sources: The volume of water withdrawn from water resources (rivers, lakes, wells, etc.) controlled by the water utility, and then treated for potable water distribution.

Water Exported: Bulk water sold to neighboring water systems that exist outside the service area.

Water Imported: Bulk water typically purchased from a neighboring water utility or regional water authority, which is metered at the custody transfer point of interconnection between the two utilities. Also known as “import,” “purchased,” or “wholesale” water.

Water Losses: Consists of Real Losses (leakage) plus Apparent Losses (paper losses). Can also be derived by subtracting Authorized Consumption from Water Supplied.

Water Supplied: The volume of treated and pressurized water input to the retail water distribution system.