Water Use Auditing:

A guide to accurately measure water use and water loss

New Mexico Rural Water Association
www.nmrwa.org

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Introduction 1

New Mexico's drinking water and wastewater systems will need to implement new administrative systems and management tools to allow them to adapt to the increased regulatory requirements and environmental complexities they face. These new tools will allow the systems to operate on a "business model" for long term sustainability to help address the issues of: new and stricter regulatory requirements, growing populations, increased service demands, limited water supplies, a highly variable climate, aging infrastructure, and limited state and federal funding.

Cost estimates for water and wastewater system needs in New Mexico are several billion dollars, while the existing state and federal funding sources can only meet a fraction of this need. These sources of funding are not expected to increase, and in many cases, are declining. Therefore, approaches to reducing the gap between what is needed and what funds are available will need to be adopted. In addition, funders want assurance that the investments they make in water and wastewater infrastructure will be adequately managed and maintained to ensure long term sustainability and security. This assurance will require water and wastewater systems to present convincing evidence that they possess adequate financial, technical, and managerial capacity to provide the service that their customers expect, to maintain the infrastructure necessary to provide that service, and to manage the organization technically and financially throughout the life expectancy of the improvements being financed.

To address these significant challenges, the 2005 New Mexico Legislature passed HJM86, which called for the State Engineer, in collaboration with the New Mexico Environment Department and other agencies, to "develop criteria for water system planning, performance and conservation as a condition of funding." The results of the HJM86 efforts indicated that requiring specific standards related to water and wastewater system operation, management, and planning is the best way to ensure that the millions of dollars in annual state and federal funding is invested in the most appropriate and cost-effective projects and is provided to systems that have adequate capacity to protect that investment. The report developed in response to HJM86 recommended that systems adopt a "business model" for managing the delivery of services that includes:

- a five-year financial plan with a fully allocated rate structure;
- an asset management plan;
- a water accounting system with full metering;
- full compliance with the Safe Drinking Water Act (SDWA), the Clean Water Act (CWA), and all of the regulations of the Office of the State Engineer and the New Mexico Environment Department;
- a governance structure adequate for proper management and oversight; and
- participation in regional efforts to collaborate on long term solutions.

In 2006, three Technical Assistance Providers[1] and the State of New Mexico teamed-up to develop guidebooks to help water and wastewater systems better manage their water resources and plan for their future. The guidebooks are titled:

- Water Use Auditing: A guide to accurately measure water use and water loss;
- Financial Planning and Rate Setting Guidebook; and
- Asset Management: A Guide for Water and Wastewater Systems.

These guidebooks address core issues regarding water system sustainability: auditing water use to reduce water losses and increase system efficiency, financial planning and management to ensure sufficient revenues to sustain operations, and asset management to allow the system to provide a sustained level of service at the lowest life cycle cost. Water and wastewater system owners, operators, managers, and board members will find that these guidebooks are useful tools for assessing the current status of their operations and for developing strategic plans for sustainable water and wastewater service.

These guidebooks are intended to be used together as integrated tools for efficient management to enable the system to meet future service demands and regulatory requirements and to provide for long-term sustainability. For example, asset management is a fundamental step in determining financial resources needed to operate the system and pay for system improvements, expansions, or replacements. The water auditing program can tie to asset management by providing information about the condition of some of the buried assets. The water auditing process also ties to water conservation and rate setting. Because of these ties, water and wastewater system personnel are encouraged to examine all three manuals before beginning their system evaluation. However, the guides can be used independently, allowing a water or wastewater system to implement the "business model" incrementally, starting with the system's most pressing needs or starting with the easiest success. No matter how the system implements the practices, the ultimate goal should be incorporating all three of these tools into the system's standard management practices.

Once initial assessments are complete, findings can and should be used by key decision makers to guide the future of the water or wastewater system. These are not "one time" activities; it will be important to reevaluate and update this information annually or whenever the system's needs change. Over time, the use of the tools can be increased and enhanced to support more complex and sophisticated operations.

Providing safe and dependable supplies of drinking water and protecting water quality through adequate wastewater treatment is critical to maintaining New Mexico's economic vitality and quality of life. These guidebooks should provide the tools needed by water and wastewater systems to actively and consistently analyze current operations and future needs in order to develop robust management systems and well-designed infrastructure to meet these growing challenges.

[1] Three technical assistance providers contributed to this project. They are the Environmental Finance Center, New Mexico Rural Water Association, and Rural Community Assistance Corporation.

How to Use This Guide 3

This guide is intended to give water utility managers, board members and operators a broad overview of water use auditing concepts and a specific method for categorizing all water use into a standard water balance. The standard water balance may be used to identify areas to increase revenue and to calculate meaningful water use performance measures for your water utility.

The next section, *Introduction to Water Use Audits*, will give readers a basis for understanding the difference between traditional methods of calculating water loss and the standard water balance method outlined in this guide. The *Standard Water Balance* section will provide the framework for conducting a water use audit, and will clearly outline the financial and managerial advantages of using this method to track water use. Step-by-step instructions to complete the water balance follow. *Performance Measures* will show you a new way to determine how well your utility is putting the water resource to use. The last sections contain supplemental worksheets and information you can use to help perform the water use audit.

It is suggested that readers familiarize themselves first with the concepts and basic method by reading the entire guide, and then plan on collecting the information required to complete the water use audit. It is important for utility personnel to understand that conducting a water use audit is not simply reporting the information you already have in a different way. A water use audit is an ongoing set of management tools that will change how you collect information and make decisions about your utility. These changes will result in more efficient water use and increased revenue for your water system.

This guide may be used by any sized water system, including very small systems managed by volunteers. It is designed to be flexible to accommodate the different levels of information and technology that are available at your system. As you begin to use and understand the water use audit, you will realize there are many improvements you can make to your utility as a result of the better information you are collecting. The guide identifies concepts, resources and ideas you can research “For More Information” on these areas.

Why perform a water use audit?

All water systems lose some amount of water for a variety of reasons. There are no accurate statistics for how much water is lost in the United States. However, it is clear that water loss is significant: based on USGS estimates, somewhere between six and seven billion gallons of water are lost *per day* by water systems in the US. Six billion gallons per day is enough water to satisfy the delivery needs of the ten largest cities in the nation.

New Mexico water systems are likely losing *at least* fifteen to seventeen billion gallons of water per year. This amount exceeds 46,000 acre-feet of water. Water resources are becoming increasingly scarce everywhere in the country, even in areas previously thought to be rich in water. New Mexico water systems primarily draw upon groundwater sources, withdrawing water that has been stored in the aquifer over thousands of years. Water system personnel are stewards of this precious resource, and must preserve it wherever possible.

Utilities cannot reduce their water loss to zero. Some water loss is unavoidable, and it is not worth the expense to try to eliminate every drop escaping your system. However, most of the loss that occurs in water systems can be better managed by using a water use audit. Water loss costs money, paid by your system and your customers. Managing a water utility is similar to managing any other business. Water is the good that you sell to the public. Losing water is like having a hole in the floor of your store that consumes fifteen percent of the goods you put out on your shelves before any customers come through the door. Inaccurate water metering or billing is like a cash register that rings up all of your sales fifteen percent under the actual price.

What is a water use audit?

Water use audits provide a rational, scientific framework that categorizes all water use in your system. A portion of the total water use is leakage, some of it is due to inaccurate metering, some of it may be unauthorized use, and some of it is water delivered to your customers. A water use audit determines where the water ends up and how much of it got there. The level of detail in the water use audit will vary based on the information your system has available. As you become more familiar with the water use audit, you will find ways to collect more and better information, making the water use audit more accurate and useful.

Traditional methods of thinking about water loss often confuse or misstate the real issues. Many utilities report a percentage of Unaccounted-for Water (UFW), or just a percentage of "water loss." There are several problems with this approach. First, there is no accepted definition of UFW – different water systems calculate it in different ways. UFW is often inaccurate no matter how it is calculated because utility personnel don't take all the factors into account. Second, there is no breakdown of the water uses contained in UFW – where is this water going? Without this information, it is very difficult to determine the best way to reduce UFW. Finally, reporting water loss as a percentage of total water use is misleading. More information on ways to report water loss is contained in the *Performance Measures* section.

What are the benefits of performing a water use audit?

Water use audits provide decision making tools to utility managers, directors, and operators. Knowing where water is being used in your system allows you to make informed decisions about investing resources such as time, labor and money. Water use audits allow managers to efficiently reduce water losses in the system. The less water your system has to pump to meet the customer demand, the less cost you incur for electricity, chemicals, and maintenance. Reducing water used at the source may even result in delaying or avoiding capital investments such as a new well, more treatment technology or additional water rights.

Water use audits also identify which water uses are earning revenue for the utility and which water uses are not. System personnel can increase revenue by ensuring all appropriate uses are being accurately measured and billed. Efficient operation occurs when system managers maximize revenue water and minimize water losses. This leads to more financial capacity in the water system, reduced cost per customer and better management of the water resource.

Water use audits allow for meaningful measurement and comparison of water use between water systems of different sizes. Customers can see and understand that the utility is taking proactive steps to manage wasted water. The standard water balance provides justification for programs and investments undertaken by the utility. Water audit information can be included in a newsletter, local papers, the annual Consumer Confidence Report, and funding applications. It is an effective educational and public relations tool for the water system.

What do I need to get started?

Read the remaining sections of this guide to understand the water use audit process. Communicate what you learn with other utility personnel and decision makers to develop support for the water use audit. One person can lead the effort to perform the water use audit, but it is ideal to form a team to help. Identify the roles of each person on the team, and be realistic about levels of expertise, time commitment, and deadlines. Refer to the *Resources* section for a list of technical assistance providers to help you with any part of the process.

Once you have identified who will help you, begin to identify what information you currently have, and what information you will need to acquire to complete a water use audit for one month at your system. These information needs will become clear when you finish reading the remaining sections of this guide. When you get the information in hand, perform the calculations to complete the standard water balance. Remember, the first water use audit you complete does not have to be perfect. Identify the areas where improved information or management will lead to a better water use audit the next time.

Water auditing is an ongoing process. Water use does not stay consistent in utilities over time. By performing a water use audit on a regular basis, you will be able to follow trends, identify problems, increase revenue, and demonstrate the effectiveness of management programs. The process will become easier and more detailed as you become familiar with it.

The standard water balance is the framework for categorizing and quantifying all water uses in the water use audit. It is called a balance because when it is completed, all uses of water in the system equal the amount of water input by the source(s). All water use is accounted for in the standard water balance (eliminating the need for the term *unaccounted-for water*). The standard water balance is really a series of simple equations. By following the four step process outlined in the next sections, utility managers will be able to complete these equations in the simplest manner possible.

You will begin by utilizing the information that you have readily available to calculate categories where information may be lacking. Next, you will use a variety of techniques to check your calculations and to break down the categories even further. This will determine actions you may need to take to refine the standard water balance and improve the performance measures.

A graphical way to think about the standard water balance is presented in Figure 1. This is the most common way to view the standard water balance. It may also be presented in the form of separate equations, or in worksheet format. Begin by reading the graphical standard water balance from the left side, starting with the **System Input** category. It is important to understand that the vertical height of each category represents a proportional amount of water. Thus, the height of the **System Input** category represents all water pumped by the system in a given time period. This amount of water can be broken down into two additional categories, **Authorized Use** and **Water Losses**. Therefore, **Authorized Use + Water Losses = System Input**. This vertical height water measurement holds true across the entire standard water balance.

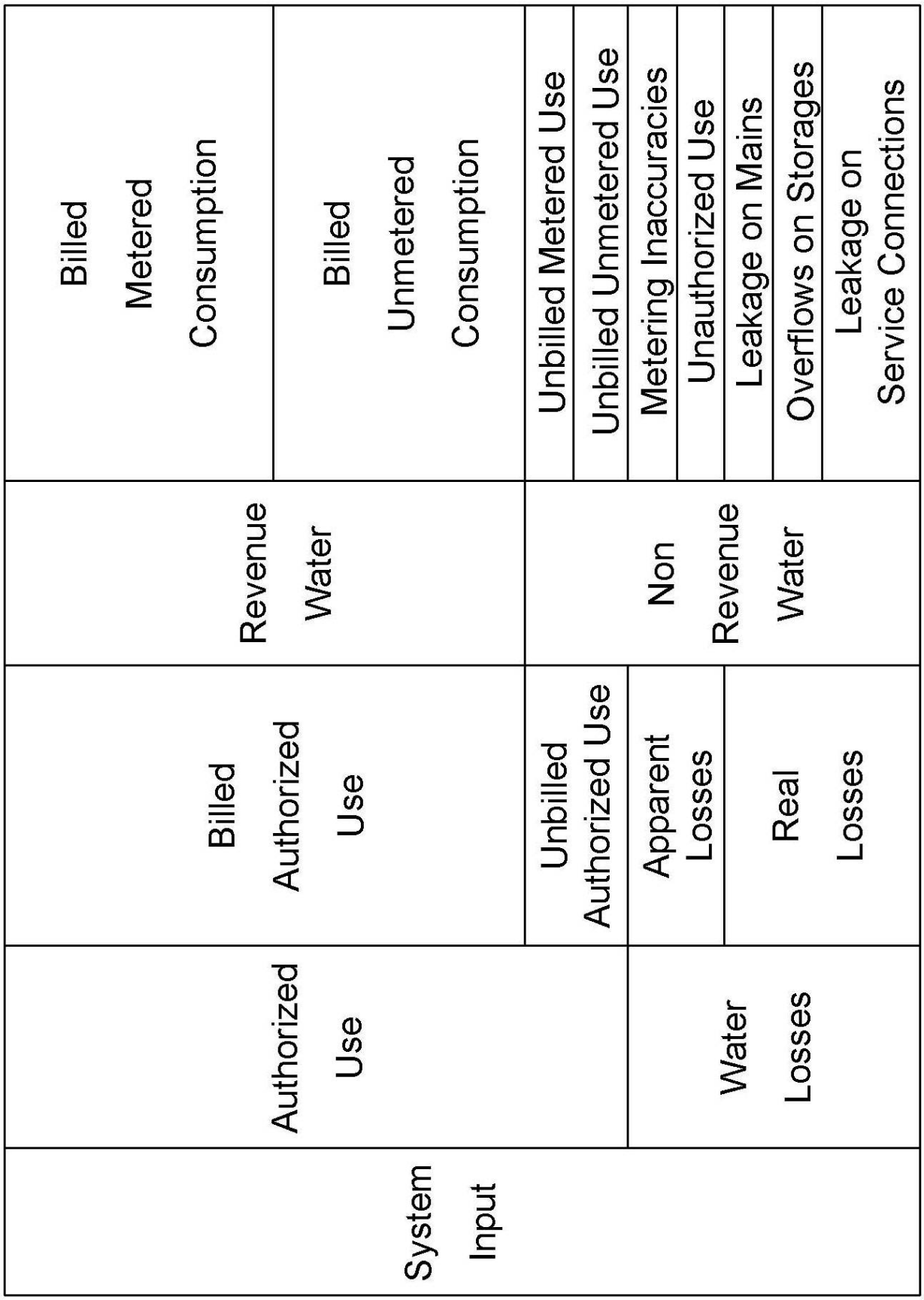
Take a moment to look over the standard water balance and familiarize yourself with the categories and the relationships between them. Don't be too concerned about the exact meaning of each category or how you will determine it. That will be covered in the following step-by-step instructions. You can identify important relationships just by glancing at the standard water balance. Practice by writing out these relationships in the form of simple equations. Remember that equal vertical measurements of categories means an equal quantity of water. This holds true even for categories that are not right next to each other. For example:

Water Losses = Apparent Losses + Real Losses
Nonrevenue Water = Water Losses + Unbilled Authorized Use
Apparent Losses = Metering Inaccuracies + Unauthorized Use

For More Information

The standard water balance has been somewhat simplified for this Manual. It is designed to take into account almost all water use situations without presenting too much detail. If you are interested in learning more about the standard water balance, check the references listed in the *Resources* section.

Figure 1:


System Input
Water Losses
Billed Authorized Use
Billed Metered Consumption
Billed Unmetered Consumption
Revenue Water
Unbilled Authorized Use
Unbilled Metered Use
Unbilled Unmetered Use
Apparent Losses
Metering Inaccuracies
Unauthorized Use
Real Losses
Leakage on Mains
Overflows on Storages
Leakage on Service Connections
Non Revenue Water

The first step in completing the standard water balance is determining **System Input**. This is a very important step, because even though it is only one category, the amount of water input to the balance is half the equation. Remember, in any type of balance, outputs must equal inputs. If this number is inaccurate, all of the remaining calculations you perform will be in error.

The amount of water input to the balance is determined by metering at the source or sources in your utility. These meters are typically called *master meters*. Master meter readings are extremely important to all water systems. Accurate master meter readings are the only reliable way to determine how much total water the utility is using. These readings affect other critical aspects of your system, such as water rights compliance, mandatory taxes (i.e., the Water Conservation Fee), and payments for any water purchased from other systems.

Master meters are larger and more expensive than customer meters. They will be subject to problems if they are not installed and maintained properly. Master meters should be tested regularly, and repaired or replaced as necessary. In order to properly maintain these meters, other appurtenances such as valves must be in good working order. It is critical that your utility has a certified water operator to perform necessary maintenance and repair, and that the operator has the tools and resources required to keep the system in good shape.

The **System Input** category may be comprised of various sources. A utility may own multiple wells, springs or surface water intakes. Some or all water may be purchased from other systems. It is possible that some of these sources are unmetered or metered less accurately than other sources. Take time to evaluate all water sources for your utility and gather all information you have about the accuracy of the master meters. This may include dates of installation, warranties, maintenance records, or verbal communication with system personnel. If you have no information available about the accuracy of your master meters, you now have the first area to improve upon for the next water use audit.

If you decide to test the accuracy of the master meters, remember that this work must be performed by a certified operator. Meter testing can be accomplished by a variety of methods, depending upon how your system is set up and how accurate you want the results to be. The simplest type of test involves running water through the meter into a container of known volume for a fixed period of time (the “bucket test”). Due to the large volume of water that can be produced at water sources, this test is often impractical. Another option is to install a test meter that is known to be accurate somewhere convenient near the master meter. Finally, the master meter can be removed entirely and tested by a certified professional. Although this can be more expensive and requires replacing the master meter with a temporary meter, it may well be worth the cost for the utility to know for certain how much water is being withdrawn from the sources.

The accuracy of master meters can also be affected by how they are installed, and what types of flow they encounter. Large meters can be sensitive to bends in pipe, valves and other equipment that is placed nearby, either upstream or downstream. These appurtenances can cause turbulence that will cause the meter to give inaccurate readings. Check with the manufacturer of

the meter to see if it is installed according to specifications. There are several types of master meters, which are designed for different flow situations. Water sources often encounter only one flow rate, for example 100 gallons per minute when the well is on, and zero when the well is off. If your water source has both high and low flow rates, it is important that the master meter is matched correctly to the flow profile. Again, the manufacturer or supplier can determine if you have the correct meters installed on the water sources.

Begin filling out the standard water balance by collecting records of master meter readings over the period of one month. Enter this information in the worksheet in this guide, directly on the graphical standard water balance, in a spreadsheet on your computer, or just in a notebook. It is usually best to start performing a water use audit in a current month. If your system has very good records, it may be possible to perform a water use audit for previous months. This is very useful to detect trends in water uses. However, it is often impossible to break down the water loss categories without specific planning to collect this information.

For More Information

If your system has no master meters and is estimating water use at the source(s), install these meters before continuing the water audit. Water utilities should have a meter repair and replacement program to ensure accurate readings. Check the *Resources* section for information on these programs. Meters require maintenance and repair like any other piece of equipment. The length of time before a meter needs replacement depends on the chemical and physical properties of the source water. The vast majority of the time, worn meters will read less water than actually passes through them.

Proper functioning of other system components like valves, telemetry systems and other electrical controls is critical to good system operation and the success of the water use audit. Valves must be exercised regularly in order to remain functional. Don't wait until an emergency to locate valves and find out if they work or not. Water system operators should have a valve maintenance program to exercise valves and schedule repairs and replacement. Properly located valves allow for more efficient leak detection and repair. Consider performing a review of your distribution system and installing new valves in advantageous locations.

The importance of qualified utility personnel cannot be over emphasized. System personnel must be properly trained, whether your water system employs an entire office of clerks, bookkeepers, managers and operators, or everything is run by volunteers. The job of a certified operator is one of the most important in the entire community. Check the *Resources* section for information on training programs for operators and managers.

Step 2: Calculate Authorized Consumption 10

This step should be fairly easy if your utility has been keeping good billing records. The first part involves calculating the category **Revenue Water**, which is made up of **Billed Metered Consumption** and **Billed Unmetered Consumption**. Since both of these categories are billed by the utility, a review of the records should give you the information you need. Make a note of any indications of billing errors when you perform this step, but don't include them yet. They will be accounted for later under a different category.

Billed Metered Consumption is usually made up of traditional water utility customers. This includes residential, commercial and industrial customers. Utilities may have different methods of billing these various customer classes. Make sure you are recording the amount of water used for each customer over the same time period. Other uses that should be placed in this category include any water that is metered and sold to other systems – this is known as *exported water*. Any other temporary or unconventional uses that are metered and billed during the month you are auditing should be accounted for in this category.

Billed Unmetered Consumption consists of any contracts the utility has to provide unmetered water for a fee. An example is a contract to provide water to a construction site from a fire hydrant to water down roads. The utility should be estimating the amount of water used in this category as accurately as possible. Examine any billed unmetered uses and determine if they can be estimated more accurately, or moved out of this category altogether by installing a meter. Sometimes the cost of metering these uses is not justified by the amount of revenue they bring in. For many utilities, the water use in this category may vary over time, or it may be zero.

After entering the information from the two categories above, simply add them together to determine **Revenue Water**. Also note that subtracting **Revenue Water** from **System Input** equals **Nonrevenue Water**. You're making progress! You already have a powerful tool as a result of your work – now you know how much of the total water produced by the system actually generates revenue. **Revenue Water** is the category that should be maximized by the utility. This is accomplished by minimizing water uses in the **Nonrevenue Water** category, either by physically reducing those uses or by moving them to **Revenue Water**. Take a moment to examine the amount of water your utility is not billing anyone for. Is it greater than, less than, or equal to what you expected?

The final part of this step is to calculate **Authorized Consumption**. This includes **Revenue Water** plus any **Unbilled Authorized Consumption**. Since water use in this category is authorized by the utility, you might expect that it will be simple to quantify. However, many utilities do not have good information on water use in this category, using an "authorize it and forget it" policy.

Unbilled Authorized Consumption is most often made up of public uses in the community. This category is further broken down into **Unbilled Metered Consumption** and **Unbilled Unmetered Consumption**. Metered uses should be easier to quantify, as long as these meters are being read and recorded. Sometimes reading these meters is not a priority for system personnel since these uses are not being billed to anyone. Quantifying unmetered consumption

will require estimation or installation of meters. Unbilled authorized consumption can be water uses like irrigation of public parks, fire flow for training or emergency use, and flushing of water lines by utility personnel. Water can also be consumed by treatment processes at the water or wastewater utility. Since much of this water use is in the public interest, and perhaps is consumed by the water utility itself, it is apparent why it is not billed to anyone. These uses should be metered if appropriate, or estimated as accurately as possible.

At this stage of the water use audit, it may be necessary to meet with other entities and educate them about the importance of estimating their water uses. It is not difficult to establish guidelines for estimating water use for fire hydrant testing and training, for example. It is important that you have a good relationship with these water users, to ensure that regular communication is occurring about estimated use. Remember, virtually all water use varies over time and estimates can be greatly improved by educating and involving people in the water audit process.

After quantifying both components of **Unbilled Authorized Consumption**, add this category to **Revenue Water**, which is also **Billed Authorized Consumption**, to determine **Authorized Consumption**. Subtract this figure from **System Input** to calculate **Water Losses**. You are ready to move on to the next section.

For More Information

Water systems that have modern, computerized billing systems will find it much easier to track water use, as well as many other kinds of financial information. Computer billing programs are not created equal – investigate billing programs thoroughly before investing in one. It's a good idea to ask neighboring or similarly sized utilities about the advantages and disadvantages of the program they use. Some manufacturers will let you try out the program for awhile at no charge, or will demonstrate the program for you using your billing information.

Automated meter reading can also make billing, financial reporting and water auditing more efficient and accurate. Automatic meter reading systems are available in various configurations and price levels. Some things to consider are whether your current billing system will work with an automatic meter reading system, and whether the meters you have now can be upgraded.

Now is the time to learn the difference between **Apparent Losses** and **Real Losses**. These two categories make up the components of **Water Losses**. The definition of these two terms is often confusing at first. Refer back to the definitions until you familiar with the concepts.

Apparent Losses of water occur as inaccuracies in water flow measurement, errors in water accounting, and unauthorized usage.

Real Losses are the physical escape of water from the distribution system, and include leakage and overflows prior to the point of end use.

Another way to think about **Apparent Losses** is that this category consists of water that is delivered to an end user – including unauthorized use – but is not properly measured or recorded. Sometimes apparent losses are called "paper losses" because they consist of water that is not properly recorded on paper. However, this term can be misleading by implying that these losses don't really involve real "wet" water. This is not the case – water theft directly removes water from a system. The best way to understand apparent losses is to memorize and use the definition above.

Studies have shown that many utilities underestimate apparent losses, which results in an overstatement of real losses. The water use audit allows you to understand the true picture of water losses in your water system. Apparent losses are more costly to the utility than real losses. The cost of apparent losses occurs at the rate charged to the utility's customers. The cost of real losses occurs at the cost of producing the water and pumping it through the distribution system.

In the standard water balance, **Apparent Losses** is made up of **Unauthorized Use** and **Customer Metering Inaccuracies**. **Unauthorized Use** is theft or otherwise illegal consumption of water. Assessing unauthorized use is like being a detective at your utility. Operators or meter readers often have a good idea how much unauthorized use is occurring. Past illegal water use may indicate the potential for continued unauthorized use. Some systems may have zero unauthorized use. Estimate how much unauthorized use exists in your utility.

High levels of frequent unauthorized use may warrant action by utility managers. Take care to protect all personnel and to obey all laws when addressing unauthorized use. Often it is necessary to involve local law enforcement for safety reasons. There are different methods to detect and deter unauthorized use. Flow measurements on distribution lines can lead you in the right direction, particularly if the measurement can be limited to a few customers. Isolation of lines using valves may also work. Physically removing illegal connections should only occur when you are fairly certain of the location. Remember to fully inform any existing customers that may be impacted by your actions, and explain what you are doing and why. Check the *Resources* section for help.

Customer Metering Inaccuracies includes inaccuracies in water flow measurement and errors in water accounting. Inaccuracies in water flow measurement occur for the same reasons

on customer meters as they do on master meters. However, customer meters are much easier to test, repair, and replace. Utilities that have a meter repair and replacement program will have a very good idea how accurate customer meters are in the system. If you don't have a meter repair and replacement program, you can create the foundation for one by testing customer meters on your system. Select a representative sample based on all the relevant factors you can think of, such as age of different meters, types of meters, types of customers, time investment, and cost. Each system will be different, and you can refine your information on customer meter accuracy over time. There are a variety of techniques and pieces of equipment that can help you test customer meters easily and quickly.

Errors in water accounting are the other piece of **Customer Metering Inaccuracies**. Errors in water accounting occur as errors in physically recording the meter reading (in the field), and errors in tabulating the meter reading in the billing system (in the office). Talk to all utility personnel to get a feel for how errors might occur, and how much error might occur in an average month. Approach these personnel positively with the goal of a producing a quality water audit, and you may get more honest responses. It is normal for some amount of error to occur. It is also possible to review field logs for meter readings and compare these with billing records. It is more difficult to determine the amount of error that occurs physically reading the meters. If you suspect there is a significant amount of these types of errors, select a sample of customer meters to check shortly after they are read in the routine manner. Estimate all of the errors in water accounting and record your assumptions.

Now that you have both components of **Customer Metering Inaccuracies**, add this figure to **Unauthorized Use** to determine **Apparent Losses**. Subtract **Apparent Losses** from **Unauthorized Use** to calculate **Real Losses**. Nearly all the categories of the standard water balance are now completed. All that remains is to assess the components of real losses.

For More Information

Testing can be performed on residential meters relatively simply. It is possible to use the bucket method if you are careful with measuring the amount and time elapsed. There are guidelines for duration and flow amounts when testing customer meters. Equipment is available that makes testing customer meters as simple as attaching the device to an outside hose bibb. Be sure to inform the customer and ensure that no water is being used in the home. Be aware that any leaks in the house will also be accounted in the difference between the two meters using this method. If you have a willing operator and good meter installations, it is often the least amount of hassle to simply replace several customer meters at a time and bench test them back at the utility office or workshop. By using this method, you have a good beginning for a meter repair and replacement program. Check the Resources section for more help.

By completing all of the steps in the previous sections, you have now calculated a total amount of water for **Real Losses**. The accuracy of this category depends upon previous assumptions and estimations. The standard water balance method uses the information that the utility is most likely to have to calculate real losses, which contains categories the utility often has little information about. By assessing the individual components of real losses using field techniques, we can cross-check our calculations and estimations. First, recall the definition of real losses:

Real Losses are the physical escape of water from the distribution system, and include leakage and overflows prior to the point of end use.

Real losses typically account for a greater volume of water lost by utilities in comparison to apparent losses. The marginal cost of real water loss occurs at the cost of production – the expenses associated with extraction, treatment, delivery, operations & maintenance. High levels of real losses require the utility to extract, treat and transport greater volumes of water. Leakage may find its way back into a storm or sewer system, requiring further costly treatment. High real losses require your water system's personnel, equipment and resources to work harder than necessary to meet customer demand.

Real water loss depends on the rate of flow and the amount of time a leak is permitted to run. Remember that all water systems will leak a certain amount of water. The amount of "normal" leakage will depend on factors like the types of pipe in the system, the quality of the installation, the soil conditions, and weather. This amount of unavoidable leakage is called *background leakage*. The amount of pressure in the distribution pipes is an important variable in real water loss, including background leakage. Pressure management is a technical topic that involves advanced calculations. Consider learning more about this topic if your utility has high levels of real losses or other problems associated with pressure management.

Leakage on Mains is the first category of **Real Losses**. Leakage on mains refers to any physical loss of water in the distribution system other than storages or service connections. This category is often mistakenly confused with "water loss" or "unaccounted-for water" by people who are unfamiliar with the standard water balance. Leakage on mains will vary over time. It is important to keep good records of leak locations, repairs, and estimated losses. Operators may have large amounts of this information stored in their heads; it's a good idea to interview them and write down what you learn.

There are many techniques for identifying and reducing leaks in utilities. The first time you perform a water use audit, your goal should be to reasonably estimate the amount of water that is used in this category. This estimate may be refined over time. In practice, it can be very time consuming to exhaustively examine your utility for leaks. The amount of effort needed to perform a leak detection survey depends heavily on the information you have available, such as system maps, inventory of pipes and fittings, and history of repairs. Good operators will have much of this information already. Industry firms will provide a leak detection survey. Be sure that the information you are paying for will meet your needs in the water use audit.

If you suspect leakages on mains at your utility, perform a visual inspection of the distribution system. Note any obvious leaks, standing water, or green patches. Isolating main lines and checking if they hold pressure is an effective method to discover leaks. This can be done only if you have working valves installed in appropriate locations. More advanced techniques involve using acoustic equipment to detect the noise created by leaks. There are many kinds of equipment to help you in this area. Check with an industry supplier to see what is appropriate for your utility.

Another technique for estimating leakages is to measure flows during the middle of the night, when very little or no water use is expected. Be aware that this technique will also account for **Leakages on Service Connections** and leakages in customer's homes. The water use audit process will help you determine how much leakage is occurring and what should be done to better estimate and control leakage at your utility.

Overflows on Storages are often overlooked as a component of real losses, and can be significant. Overflows occur at storage tanks due to lack of controls or improperly functioning controls. Overflows may occur at night when nobody is around to witness them. Examine overflow areas for signs of recent or regular flow. It is fairly straightforward to determine amount of real losses due to overflow on storages, and often this can be easily corrected. Account for any other kinds of leakage at storages in this category. Be aware that water use in this category may fluctuate over time, since it is affected by consumer demand on the system.

Leakages on Service Connections is a category that you can estimate by taking a statistical sample. In practice, you can gather information about this category during previous steps. A visual inspection for leaks can be performed while you are testing meters for the **Customer Metering Inaccuracies** category. Leaks on service connections may be revealed during leak detection efforts on mains. This is a category where many small leaks will add up to the equivalent of one large leak. When performing a leakage survey on service connections, it is a good time to educate customers about the utility's efforts to account for water use and to distribute water conservation material for use inside the home.

For More Information

There is a great deal of free information available on conservation programs for end users. Check the *Resources* section for ideas. Leak detection is a field that requires specialized skills, equipment and knowledge. Support professional training in this area for your system operator(s), contact technical assistance providers for help, or employ a qualified firm and check their customer references. Industry equipment suppliers will often provide valuable information and assistance with leak detection equipment.

Once leaks are identified, the priority shifts to reducing leaks. Good water system design, operation and maintenance will minimize real water loss. Carefully consider the potential for real water loss in any new projects and work with engineers with these goals in mind. Once the infrastructure is placed in the ground, the utility inherits any design problems.

You have now completed the standard water balance. One more step remains in the water audit process – interpreting the information you have collected. Deciding on appropriate performance measures allows the utility to track performance and improvement from one water use audit to the next. Performance measures let the system's customers understand the goals and progress made by the water use auditing process. Comparison of water efficiency between systems is straightforward if both utilities have utilized the standard water balance.

Recall that traditional methods of reporting a percentage of water loss are inadequate. After completing the standard water balance, you now have a greater understanding of the complexities of the term "water loss." But there is another problem with reporting a straight percentage of water loss out of the total system input, even if you are careful to calculate the categories correctly. A straight percentage performance measure does not account for variations in consumption or system input. Consider the following simple example:

	System Input	Total Gallons Consumed	Total Customers	Use per Capita	Total Real Losses	Percentage of Water Loss
System 1	1,000	800	10	80	200	20%
System 2	1,800	1,500	10	150	300	17%
System 3	1,300	1,000	10	100	300	23%

System 1 and System 2 serve an identical number of customers. System 2 has a higher amount of per capita use, a higher amount of total system input, and a higher amount of real losses. However, due to the ratio involved between real losses and system input, System 2 has a lower percentage of water loss.

System 2 and System 3 also serve an identical number of customers, and they have an equal amount of real losses. System 2 has a higher use per capita, and a lower percentage of water loss.

It should be clear from these hypothetical examples that a straight percentage of water loss should not be used to evaluate system water efficiency performance unless several other factors are taken into account. It is still a useful piece of information to consider, particularly when these other factors do not vary much. Other performance measures exist to help evaluate your utility's water use efficiency.

The first indicator that utility managers should consider is simply the total **Water Losses** category. This performance measure is best used to track progress over time for your water system only. Using the total number for water losses instead of a percentage eliminates the problems discussed above. Of course, the total amount of **Water Losses** will vary over time, as demand changes in your system. Tracking total amounts is most useful over time, allowing utility managers to detect trends in efficiency and determine if anything has changed in the

system. Another useful category to track in this way is **Revenue Water**. Just remember that using total amounts to assess performance also requires managers to consider some other factors.

A useful performance measure that allows for evaluation of financial performance is the percentage of **Nonrevenue Water** by **System Input**. This measure encourages system managers to focus on maximizing revenue water, not just on minimizing real losses. Decreasing this performance measure will lead to increased financial capacity at the utility. Note however that this percentage measure may have similar problems as discussed in the previous examples.

Real losses can be usefully measured as gallons per connection per day. This allows the utility to manage the amount of real losses on a per customer basis. This metric allows for meaningful comparison between systems of different sizes or rates of per capita use. Simply divide the amount of real losses for one day in gallons by the number of service connections. This performance measure may not be suitable for systems that have a low density of customers per mile of distribution line. If your utility has less than thirty customers per mile, consider using another measure.

A performance indication of the accuracy of the water use audit itself is how closely the calculated value for real losses matches the estimated amounts. Recall that **Real Losses** is determined by subtracting **Apparent Losses** from **Water Losses**. How closely does you assessment of the categories of **Real Losses** match this calculated amount? Reconciling differences in this area is an important result of the water use audit process. As you refine the water use audit in the future, keep checking your assumptions and estimates by reevaluating the **Leakage on Mains**, **Overflows on Storages**, and **Leakage on Service Connections**.

For More Information

A great deal of information exists about measuring water use efficiency by utilities. Different performance measures can account for unique situations or for more sophisticated analysis. The *infrastructure leakage index* (ILI) was recently developed to provide for better determination of a water system's control of real losses. It is a unit-less ratio of current annual real losses to unavoidable annual real losses. Check the *Resources* section to learn more about water use efficiency performance measures.

System Input	

	Billed Metered Consumption	
+	Billed Unmetered Consumption	
=	Revenue Water	

	Revenue Water	
-	System Input	
=	Nonrevenue Water	

	Unbilled Metered Consumption	
+	Unbilled Unmetered Consumption	
=	Unbilled Authorized Consumption	

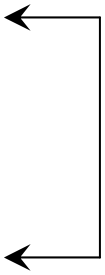
	Unbilled Authorized Consumption	
+	Revenue Water	
=	Authorized Consumption	

	System Input	
-	Authorized Consumption	
=	Water Losses	

	Unauthorized Use	
+	Customer Metering Inaccuracies	
=	Apparent Losses	

	Water Losses	
-	Apparent Losses	
=	Real Losses	

	Leakage on Mains	
+	Overflows on Storages	
+	Leakage on Service Connections	
=	Real Losses	



	Real Losses	
÷	System Input	
=	Percentage of Real Water Loss	

	Nonrevenue Water	
÷	System Input	
=	Percentage of Nonrevenue Water	

	Real Losses in Gallons per Day	
÷	Number of Connections	
=	Real Losses in Gallons/Connection/Day	

<table>
<tr><td rowspan="8">System Input
_____</td><td rowspan="5">Authorized Use
_____</td><td rowspan="3">Billed Authorized Use
_____</td><td rowspan="3">Revenue Water
_____</td><td>Billed Metered Consumption
_____</td></tr>
<tr><td>Billed Unmetered Consumption
_____</td></tr>
<tr><td rowspan="6">Non Revenue Water
_____</td><td>Unbilled Metered Use _____</td></tr>
<tr><td>Unbilled Unmetered Use _____</td></tr>
<tr><td rowspan="4">Unbilled Authorized Use _____</td></tr>
<tr><td rowspan="3">Water Losses
_____</td></tr>
<tr><td>Apparent Losses
_____</td><td>Metering Inaccuracies _____</td></tr>
<tr><td rowspan="2">Real Losses
_____</td><td>Unauthorized Use _____</td></tr>
<tr><td>Leakage on Mains _____</td></tr>
<tr><td></td><td></td><td></td><td>Overflows on Storages _____</td></tr>
<tr><td></td><td></td><td></td><td>Leakage on Service Connections
_____</td></tr>
</table>

Units = _____ per _____

Standard Water Balance

The standard water balance was originally developed by the International Water Association in the 1990's and published in 2000 in *Performance Indicators for Water Supply*. The International Standard Water Balance is being considered by the American Water Works Association for adoption in North America.

Technical Assistance Providers

New Mexico Rural Water Association	www.nmrwa.org	1-800-819-9893
National Rural Water Association	www.nrwa.org	1-580-252-0629
Rural Community Assistance Corporation	www.rcac.org	1-505-983-5074
Environmental Finance Center	efc.nmt.edu	1-505-272-7280

Water Use Audits and Meter Programs

An extremely valuable resource for learning more about every aspect of a water use audit is the book *Water Loss Control Manual* by Julian Thornton. Published by McGraw-Hill in 2002, this manual is a 645-page comprehensive work on water loss, and is highly recommended.

Certified operator resources

New Mexico operators and prospective operators can receive free training, and in some cases expense reimbursement for training. The New Mexico Rural Water Association is offering training across the state in partnership with the New Mexico Environment Department, Drinking Water Bureau and the United States Environmental Protection Agency. Call 1-800-819-9893 or visit www.nmrwa.org/erg.php for details.

Information on New Mexico's Operator Certification Program can be found with the New Mexico Environment Department, Facility Operations Team by calling 1-505-827-0108 or visiting the website www.nmenv.state.nm.us/swqb/FOT.

Water Conservation Programs

A wealth of educational materials on conservation is available from the New Mexico Office of the State Engineer. Visit the website at www.ose.state.nm.us/conservation_index.html or call 1-505-827-6691 for more information.

Acre-Foot An amount of water sufficient to cover one acre of land to a depth one foot. Equivalent to 325,851 gallons and 43,560 cubic feet.

Apparent Losses Water loss that occurs as inaccuracies in water flow measurement, errors in water accounting, and unauthorized usage. Apparent losses consist of water that is delivered to an end user – including unauthorized use – but is not properly measured or recorded. The marginal cost of apparent losses occurs at the rate charged to the utility's customers.

Background Leakage A term denoting the amount of unavoidable leakage in a water system, made up of many small leaks that are difficult or impossible to detect. The amount of acceptable background leakage will depend on factors like the types of pipe in the system, the quality of the installation, the soil conditions, and weather.

Conservation Program A conservation program is a method to encourage efficient water use by a utility's customers. Conservation programs are sometimes confused with water use audits.

Exported Water Water that is sold to other utilities. Exported water should be accounted for as *revenue water* in the *standard water balance* presented in this Manual.

Imported Water Water that is bought from other utilities. Imported water should be accounted for as *system input* in the *standard water balance*.

Infrastructure Leakage Index (ILI) A unit-less ratio of current annual real losses to unavoidable annual real losses. Provide for a better determination of a water system's control of real losses.

Leakage The physical escape of water from the system.

Master Meter Meters that measure water production at the source or sources of a utility. Accurate master meter readings are the only reliable way to determine how much total water the utility is using.

Paper Losses A term sometimes applied to *apparent losses*, because these losses consist of water that is not properly recorded on paper. Use of this term is discouraged and can be misleading by implying that these losses don't involve real "wet" water.

Purchased Water Water that is bought from other utilities. See also *imported water* and *exported water*.

Real Losses Water that physically escapes the distribution system, including leakage and overflows prior to the point of end use. Real losses typically account for a greater volume of water lost by utilities in comparison to apparent losses. The marginal cost of real water loss occurs at the cost of production – the expenses associated with extraction, treatment, delivery, operations & maintenance.

Revenue Water Consists of all billed water consumption. Equivalent to billed authorized consumption.

Standard Water Balance The standard water balance is the framework for categorizing and quantifying all water uses in the water use audit. It is called a balance because when it is completed, all uses of water in the system equal the amount of water input by the source(s). The standard water balance is a series of simple equations.

System Input The measure of water entering a utility from all sources. Allow for known metering errors when calculating system input.

Unaccounted-for Water (UFW) Many utilities report a percentage of unaccounted-for water, or just a percentage of "water loss." There is no accepted definition of unaccounted-for water. Use of this term is strongly discouraged.

Water Use Audit Water use audits provide a rational, scientific framework that categorizes all water use in a utility. A water use audit determines where and how much water is used. Water use auditing is an ongoing process that is refined over time.

Water Losses The difference between system input and authorized consumption. Water losses are comprised of *apparent losses* and *real losses*.