Draft

Water Conservation Plan Update

City of Lamar

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Prepared by:
Sustainable Practices
Swarthmore, PA

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Introduction and Purpose

The City of Lamar is a legally and regularly created, established, organized and existing home rule city, municipal corporation and political subdivision under the provisions of Article 20 Section 6 of the Constitution of the State of Colorado and the Home Rule Charter of the City. Lamar was incorporated on May 24, 1886, and operates under a City Charter. Lamar is located in eastern Prowers County and serves as the County seat. The City sits on the south banks of the Arkansas River, and serves as a transportation hub for trucking traffic and rail service both east west and north south. Lamar is also home to the County facilities, including the Court House, the fairgrounds and the local community college.

At the end of 2014, the City's water utility served a full-time population of about 8,200 and the City boundaries encompassed about 4.2 square miles. Lamar began operating a municipal water system in 1887 which currently provides potable water to customers contained within the City and adjacent to the City over a 4.5 square mile service area (see Figure 1).

The City of Lamar has been diligent in preparing and implementing water conservation plans in the past, having submitted plans for State review and approval in 2002 and 2010. These past planning efforts focused on promoting improved customer demand efficiencies with low-flow fixtures and appliances, and native and natural landscaping. The City also established regulatory measures and drought responses that helped to reduce water waste and manage water demand in periods of reduced water availability. Finally, the City developed and maintained proactive water loss management measures related to leak detection and aggressive system repair and replacement.

Table 1
Summary of City Water Use and Population

Year	Population Served[1]	Total Water Production (gallons)	Total Water Sold (gallons)	Per Capita Water Use (gpcd)[2]
2010	8,605	698,301,000	601,764,544	191.59
2011	8,567	692,540,000	601,970,983	192.51
2012	8,509	684,695,499	642,755,709	206.95
2013	8,429	578,637,000	564,511,968	183.49
2014	8,261	557,060,600	529,830,036	175.72

However, the nature of water conservation and water use efficiency has changed significantly over the past 15 years, as the City's population has dropped by about 14% since 2000, including more than 4% since 2010 (see Table 1). Although per capita water use has fluctuated over the past 5 years, total water production has steadily decreased from nearly 700 million gallons in 2010 to about 560 million gallons in 2014. Water production in 2015 is projected to be even less due to the shrinking population and the amount of precipitation that has fallen. To this point, customer demand management has become less important to the City's utility operations and financial health than accurate customer metering and billing,

[1] Based on US Census as reported at https://www.google.com/?gws_rd=ssl#q=lamar+colorado+population plus 653 persons to account for water provided to customers outside of the City limits.

[2] Per capita water use is reported in gallons per capita per day (gpcd) based on system wide water sold divided by population served.

improved water production metering and water loss management, and the development and use of appropriate water billing rates to promote efficient use without negatively impacting utility revenues.

Two key projects were implemented at substantial cost by the City since the last water conservation planning effort – the installation of improved water treatment plant master meters in 2011 and the installation of automated meter reading (AMR) and advanced meter infrastructure (AMI) in 2013. These two projects, costing the City about $3.5 million, greatly improved the accuracy of its measurement capabilities of the utility thus providing the opportunity for much better opportunities to track customer water use behaviors and characterize system water loss. Therefore, the updated water conservation plan will focus on those components of the regulations that will support utility financial security and performance, while encouraging overall water use efficiency.

Covered Entity Status

In 2010, the City produced nearly 700 million gallons of water, which equates to about 2,150 acre-feet (AF) which would place the City into the status of a covered entity, as per the definition provided in the State regulations[3]. However, due to changes in the City's population and overall water demand management, including improved water loss management, the City now produces about 1,700 AF of water to meet demand, which is below the 2,000 AF threshold.

Upon a more explicit read of the regulatory definition, the City's domestic, commercial, industrial, or public facility customers had a combined demand of about 1,670 AF in 2010, varying from about 1,880 to 1,625 AF over the last five years. Although customer demand in 2000 was greater, it is currently below the 2,000 AF threshold and, based on customer demand, has been since the last water conservation plan was developed and submitted to the CWCB for approval.

Nonetheless, meaningful water conservation[4] is vital to the health and sustainability of the City and its customers; therefore, the City will continue its efforts in keeping with the State's regulations and the needs of the local and regional community.

Water Conservation Planning Approach

The City will be conducting the Water Conservation Plan update to not only make current its existing plan with regarding to the water conservation and water use efficiency efforts that have been implemented locally by the City in the past 4 years, but to also incorporate regional water management and water use efficiencies programs that compliment and coordinate with the work of the Southeastern Colorado Water Conservancy District ("Southeastern District") and its partners working in and along the

[3] Covered entities are those municipal water providers that have a legal obligation to supply, distribute or provide water at retail to domestic, commercial, industrial, or public facility customers with a total annual demand of 2,000 acre-feet of water or more.

[4] The CWCB defines meaningful water conservation as those measures and programs that provide for measurable and verifiable permanent water savings – which may include measures and programs that are being implemented for political reasons and/or to improve customer satisfaction. Although cost-effectiveness is one metric to evaluate and select meaningful water conservation efforts, other selection criteria may be used by planning entities; however, not all water conservation measures and programs can be considered meaningful.

Lower Arkansas River basin to the extent practical. Although the City is not technically a covered entity, it will utilize the CWCB's guidelines and guidance documents related to the development of a water conservation plan. The City will also adhere to the requirements of the State Regulation CRS 37-60-126 (see Appendix A).

In addition, the City will utilize the Southeastern District's Best Management Practices (BMP) Tool Box, which is a web-based water conservation planning tool that contains a wide variety of relevant information regarding best practices that water utilities can use to improve water use efficiency and support smart water use. The Tool Box contains categories of measures and programs that address the five different operational areas that all utilities perform regarding water supply, distribution and sales including system wide management, water production and treatment, water distribution, delivery of water to customers and customer demand management.

Water Supply System Characteristics

Water Source Information

The City of Lamar's water supply source is comprised of one hundred percent (100%) ground water, which is extracted from a series of production wells that tap the Clay Creek Aquifer, which is surface water influenced groundwater such that production must be offset by augmentation and/or replacement water. The City uses Fryingpan-Ark Project water and ditch and canal water to recharge the ground water in the well field for augmentation purposes. Table 2 summarizes some of the relevant attributes of the water system utilized by the City.

Table 2
Summary of Water System Attributes

Water Sources	28 groundwater production wells	Chlorination and fluoride addition prior to distribution
Master Meter	1 master meter prior to treatment plant	12-inch master meter tested annually for accuracy; Meter replaced in 2011
Meter Readings	Monthly (20th of the month)	AMR with AMI; currently matching production days to billing days to assist with water loss management (entire system read in one day using AMR/AMI)
Billings	Monthly (1st of the month)	Was month plus one month delay (i.e., January bill was November use); now billing is month after use (i.e., December bill is end of November and most of December use)

AMR – automated meter reading devices; AMI – advanced meter reading infrastructure (e.g., telemetry)

The City of Lamar owns 3,200 shares of the Fort Bent Ditch Company and 360 shares of the Lamar Canal Company. The amount of water available from these shares can vary drastically from year to year due to calls on the river that influence the amount of water senior and junior water rights owners can utilize. Water from the shares is used as replacement water for the well pumping and to recharge the Clay Creek Aquifer. In 2010, groundwater pumping depletions were replaced with 466 AF (386 shares) of the Fort Bent Ditch pursuant to the City's existing augmentation plan in case # W-4015, and an additional 907 AF of pumping was replaced by recharge from 933 shares of the Fort Bent Ditch and Fryingpan-Arkansas Project replacement water under the City's current Rule 14 plan. 1,246 AF of pumping was replaced by accretion to the river from return flows of all pumped waters, stream channel, and ditch transit losses. Table 3 summarizes the decrees for the Fort Bent Ditch and Lamar Canal.

Table 3
Decree Dates for Ditch and Canal Rights

Fort Bent Ditch	Cubic Feet per Second	Lamar Canal	Cubic Feet per Second
4/1/1886	27.77	Prior to 1886	15.75
3/10/1889	32.77	11/4/1886	72.09
9/11/1889	11.7	4/16/1887	13.64
8/12/1890	26.77	7/16/1890	184.27
1/1/1893	50		
12/31/1900	80		

The City of Lamar is a benefactor of the Fryingpan-Arkansas Project (Fry-Ark Project) operated by the US Bureau of Reclamation and administered by the Southeastern District. The Project is a trans-mountain diversion that diverts water from the Fryingpan River near Basalt, CO, on the western slope, to the

Arkansas River Valley to be used by agriculture and municipal entities. The Southeastern District's boundaries extend from Buena Vista to Lamar. The City of Lamar purchases Fry-Ark Project water to recharge the City's ground water supplies. Over the last 5 years the City has requested 2,000 acre feet to be allocated from the Fry-Ark Project, but has typically received a lesser amount (see Table 4).

Potable Water Treatment and Storage

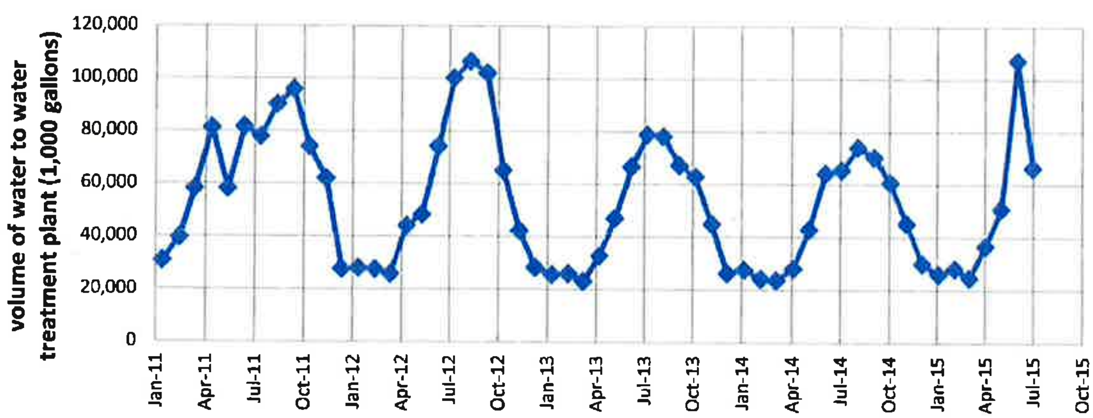
Table 4
Allocated Water Received By the City From the Fry-Ark Project (in acre-feet)

	2009	2010	2011	2012	2013
Requested	2,000	2,000	2,000	2,000	2,000
Received	2,000	1,600	1,600	176	1,077

Water from the well field is pumped to the Lamar Water Treatment Facility (WTF). The WTF is located at 8502 County Road DD.8. The WTF has 5.76 million gallons per day (MGD) peak capacity (or 4,000 gallons per minute). The City's current peak and average daily demand are 4.76 MGD and 2.4 MGD respectively. The City's finished water supply, which is chlorinated and fluoridated groundwater, is stored in two tanks, a six million gallon tank and a two million gallon tank, for a combined eight million gallons of finished water storage. The two million gallon tank was installed in 2002.

Figure 2 presents monthly water production over the period January 2011 to July 2015. Note that in May 2011 a new master meter was installed to measure the water coming into the WTF including SCADA. For this reason, WTF flows prior to May 2011 are of questionable accuracy, especially when compared to post-May 2011. This issue is further explored in the discussion of non-revenue water presented later in this Plan.

Figure 2 - Water Treatment Plant Monthly Flows



Two key points to note related to the data shown in Figure 2. The first relates to the produced water volumes presented for January through April 2011. It is unclear how these volumes compare to those after April 2011, however, the trend in later years illustrates that some anomalies appear to occur in these early months of 2011, with volumes registered by the master meter in this time frame are likely higher than actual. The replacement of the master meter in May 2011 relates to this suspected inaccuracy. The lack of master meter accuracy prior to May 2011 justified not using 2010 production data to support development of this Plan.

Also noteworthy is the produced water volume in June 2015 is high based on two major water main breaks that occurred in that month. Volumes of water lost related to the main breaks is estimated to be in the 50-55 million gallon range, as will be discussed in additional detail in the following sections.

Otherwise, the trend of water production appears to mimic expected customer demand trends with low production in the winter months and high production in summer months.

Waste Water Treatment and Storage

The Lamar wastewater treatment facility (WWTF) is located at 1221 Century Drive. It consists of evaporative lagoons. The only discharge is to ground water, hence there is no discharge to the river. Lamar's National Pollutant Discharge Elimination System (NPDES) permit number CO 0023671 was reissued in 1990 and amended in 1993. The WWTF has a capacity of 1.5 MGD average and 3.0 MGD peak, and the average use is 0.95 MGD and the maximum use is 3.0 MGD. Presently there are no planned changes to the WWTF.

Water Use – Current and Future

City Demographics and Current Water Use

As of the 2000 census, the median income for a household in the city was $28,660, and the median income for a family was $32,560. Males had a median income of $24,145 versus $20,133 for females. The per capita income for persons living in the City was about $13,900. About 14.4% of families and 19.7% of the population are identified as living below the poverty line, including 29.5% of those under age 18 and 12.2% of those ages 65 or over.

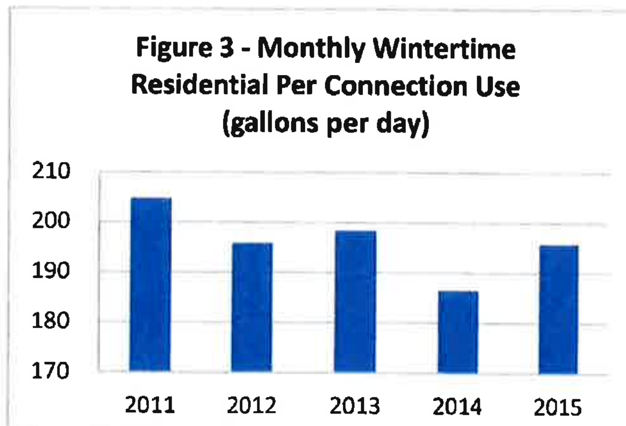
Customer water use is tracked and billed monthly in accordance with the following customer categories:

- Residential (inside and outside of town)
- Commercial (inside and outside of town)
- Government (inside and outside of town)
- Non-Profit (inside and outside of town)
- Car Washes

Table 4, shown on the next page, presents a summary of the monthly water use. Based on these data, the following observations can be made:

- Total production, as indicated earlier, is trending downward, except for 2015, when the annualized production based on January through July data would be almost 658 million gallons. Adjusting for the major line breaks in June by a factor of 55 million gallons[5], total annualized production in 2015 which is estimated to be about 606 million gallons, would have be about 551 million gallons if the leak had not occurred. This value is in line with the customer demand data and estimated evapotranspiration (ET) for 2015.

- Total customer demand is also trending downward during the period 2011 to 2015. This may be due to the increasing number of wet years in 2014 and 2015, however, it may also be a function of reduced population served or a general improvement of customer water use efficiency. One indicator which helps to characterize the trend of decreasing customer demand is the average wintertime monthly use per residential connection, as shown in Figure 3.



[5] 55 million gallons is the approximate difference between the June 2015 non-revenue water and the average June non-revenue water in the previous years (excluding 2012 when June had a negative volume of non-revenue water).

Table 4
Summary of Water Sold by Customer Category (in gallons)

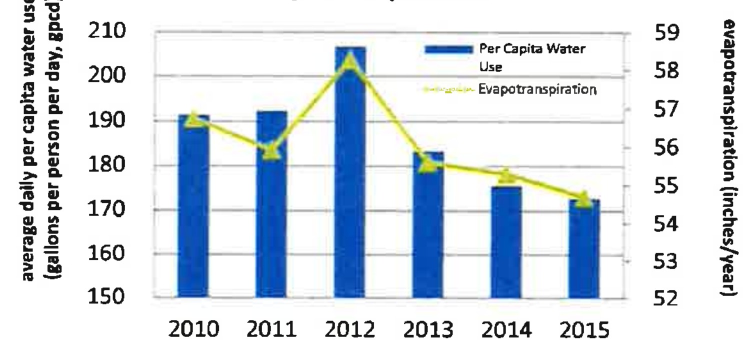
	Total Production	Residential	Commercial	Government	Non-Profit	Car Washes	Total Water Sold	Non-Revenue Water	% Non-Revenue	ET (inches/yr)
2010	698,301,000	353,761,099	117,642,024	116,846,254	6,196,923	7,318,245	601,764,544	96,536,456	13.8%	56.77
2011	692,540,000	369,544,166	116,662,796	102,552,561	7,042,023	6,169,438	601,970,983	90,569,017	13.1%	55.94
2012	684,695,499	394,634,309	117,393,940	116,470,697	7,573,767	6,682,996	642,755,709	41,939,790	6.1%	58.29
2013	578,637,000	346,192,745	109,061,247	96,833,853	5,392,109	7,032,014	564,511,968	14,125,032	2.4%	55.62
2014	557,060,600	330,651,438	105,215,162	82,410,484	4,953,879	6,599,073	529,830,036	27,230,564	4.9%	55.32
2015[a]	340,011,400	172,280,890	52,921,104	36,507,959	3,105,148	4,296,238	269,111,339	70,900,061	20.9%	54.72[a]

[a] data from period January through July only, with the exception of ET, which was annualized based on calculated January through July ET
ET estimated based on Blaney-Criddle method as provided by the State of Colorado Climatologist, 2014

Since wintertime use is comprised entirely of indoor uses, the downward trend illustrated in Figure 3 may indicate that passive water conservation savings[6] have been occurring within the City's residential customer base as a result of the natural, ongoing replacement of toilets, showerheads, dishwashers and clothes washers with high efficiency models now available in the marketplace. The reduction in wintertime indoor water use within the residential sector is estimated to be in the range of about 5% collectively over the last 5 years, which is in line with estimates developed by the CWCB for passive water savings in 2010. Commercial per connection wintertime use also exhibits the downward trend, decreasing by more than 10% over this same period of time.

- Figure 4 provides a comparison of average daily per capita water[7] in gallons per person per day (gpcd) for each of the last 5 years with ET, included an estimated ET for 2015. Clearly there is a direct correlation

Figure 4 - Per Capita Water Use versus Evapotranspiration



[6] Passive water conservation relates to those water demand reductions that occur naturally independent of the active conservation encouraged and facilitated by the City.
[7] Average daily per capita water use is calculated as total water sold divided by population served for each year of interest.

between ET and water use within the City, as seasonal use varies depending on rainfall and daily temperature (given that wintertime water use is declining as discussed above). Warmer, drier summers bring increased outdoor irrigation and water use for cooling. This is especially true for residential and commercial customers which constitute over 80% of the City's water demand.

- Customer connections have changed with changes in population although not at as rapid a rate, as indicated in Table 5. Residential connections have dropped almost 1% over 5 years (versus population which has dropped by about 4% in that same time frame), whereas some customer categories (e.g., government, non-profit) have seen little change.

Table 5
Summary of Active Customer Connections in July of Each Year
(all active, non-zero consumption connections)

	Residential	Commercial	Government	Non-Profit	Car Washes
2011	2,771	361	81	29	3
2012	2,775	361	84	29	3
2013	2,736	353	78	26	3
2014	2,737	355	79	30	4
2015	2,748	354	78	28	3

- Government per connection use is down by about 25% comparing annual per connection demand in 2014 to 2012[8]. This observed reduction may be indicative of both weather related factors and improvements in the efficiency of public water use, especially in outdoor applications.

Overall, water use is down for the community, both in terms of total water produced and total water sold. Although a reduced population has impacted overall water demand, per connection and per person water demand has also dropped in recent years. The reduction in water use has detrimentally impacted City revenues, and as such future water conservation efforts must rectify improvements in customer water use efficiency with utility cash flow.

Future Water Supply and Demand

As indicated in Table 1, the City of Lamar has observed a loss in population fairly consistently since the turn of the century, including over 4% since 2010. Although projections have been developed for Prowers County that indicate some growth should be expected over the next 5 to 7 years, the same sources projected growth from 2010 to 2015, which has not occurred. To this point, projections of future water demand for this Plan are focused on the variations in demand related to weather rather than changes due to expected shifts in population served. Said another way, this Plan assumes that the population served by the City over the next 5 to 7 years will not change appreciably. Therefore, the characterization of future demands will be based on statistical variations in past per connection rates and

[8] As compared to a 20% decrease in residential per connection use and a 11% decrease in commercial per connection use over the same period of time.

current numbers of connections. This model is expected to reasonably reflect the range of likely future demands, at least for the planning period. Also note, that since the variability of per connection usage includes the effects of passive savings over the period of record, it is anticipated that the future impacts of passive savings should be accurately depicted using the characteristic parameters developed using the last five years of customer use data.

Variations in water demand based on weather influences are expected, as illustrated in Figure 4. Per connection variation over the last five years has therefore been a function of varying wet and dry years, as well as a slight reduction in indoor use, at least for the residential customers. Table 6 presents the characteristic parameters developed based on the five years of record (i.e., 2011 through 2015).

Table 6
Per Connection Characteristic Parameters for 2011 through 2015 by Customer Category
(gallons per connection per day)

	Average	Standard Deviation	Coefficient of Variation[9]
Residential	359	46	13%
Commercial	847	75	9%
Car Wash	5,770	674	12%
Government	3,258	499	15%
Non-Profit	576	100	17%

Using these characteristic parameters, average and dry year condition usage can be predicted. For the purposes of this Plan, dry year is defined by the natural variations in weather and other factors that will create customer demand that is equal to or exceeded only once every 9 out of 10 years. Average conditions, by definition, are those demands that are equal to or exceeded 5 out of every 10 years.

Table 7 presents the results of the estimated future customer demands. This table also includes the estimated water production rates, based on 7.5% and 15% water loss (real plus apparent). Note that based on these estimates, it is likely that without any additional growth, future water production will exceed 2,000 AF as a result of natural variations in weather and other factors, on a regular basis without additional water conservation measures and programs.

Table 7
Estimated Future Water Demand and Water Production Annually for Each of the Next Five Years (millions of gallons per year and AF in parenthesis)

	Customer Demand	Water Production (by Percent Water Loss)	
		7.5%	15%
Average Conditions	574 (1,761)	621 (1,904)	675 (2,072)
Dry Year[1]	666 (2,043)	720 (2,210)	784 (2,405)

[1] a dry year is defined as the typical dry year 1 out of every 10 years under current conditions

[9] Coefficient of variation is the standard deviation divided by the average.

Non-Revenue Water and Water Loss

Non-revenue water is calculated as the difference between water produced and water sold. Non-revenue water can then be segmented into authorized, unbilled uses (such as hydrant flushing) and apparent and real losses. This section describes the data that is available to characterize non-revenue water as well as those relevant components of non-revenue water.

The City of Lamar has made substantial improvements in its water loss management programs over the past five years, focused on reducing non-revenue water and better understanding real and apparent water loss. As previously indicated, the City committed to improved data collection and handling methods, investing over $3.5 million in meters and meter-related equipment.

Prior to the investments, the City had non-revenue water in the range of 100 million gallons per year, or about 13-14% of production. It was unclear how accurate the meters were that supported this estimate, for the production meters were not read consistently, and were not regularly tested for accuracy. In addition, the City's customer meters were aging, with some more than 10% low in their measurement of individual customer use, noting that when customer meters read low, non-revenue water is under estimated.

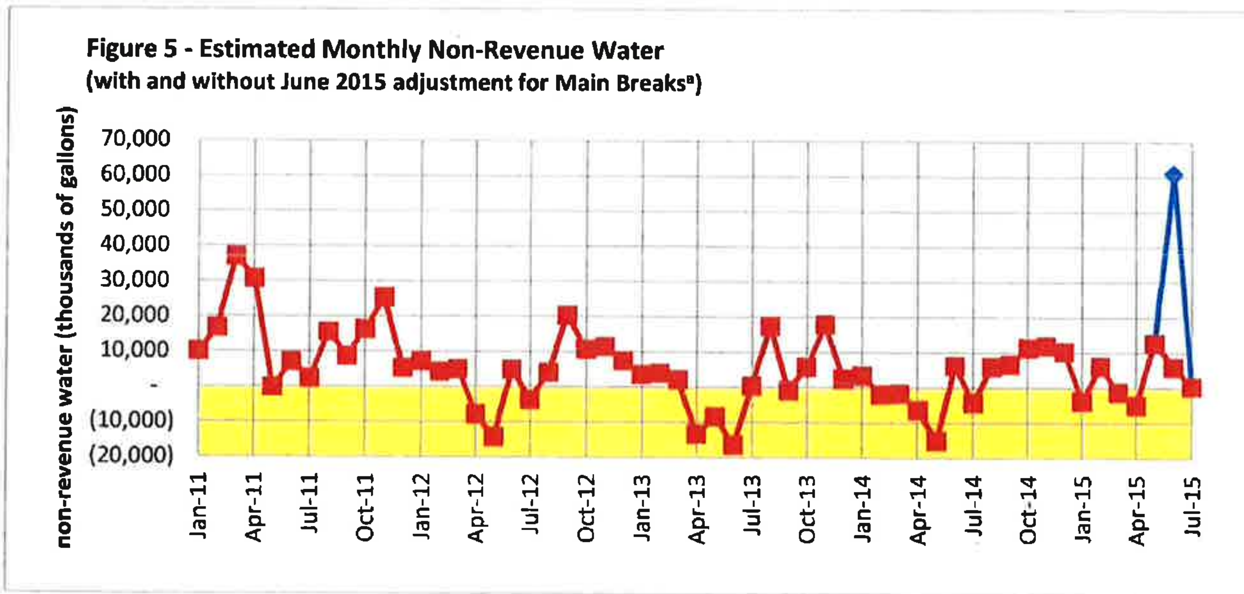
However, most confounding to the City's efforts to characterize water loss was the complicated configuration of production well piping, the location and manner of raw and treated water line connections to customers, and the manner in which meter reading data was provided to the finance department. For example, the public works department read a select group of meters in the field manually, including a number of meters that monitored authorized unbilled water uses (e.g., lift station flow dilution meter) and/or raw water use (e.g., Fairmont Cemetery irrigation, Stulp's Booster Pump). These readings were typically included in tallies of water sold, which over estimated water sold, and therefore, caused non-revenue water to be under estimated.

The recent improvements that have helped the City improve its water loss management program include the following:

- City financial staff have been able to focus on tracking down and resolving systematic data handling errors that have existed in the past related to tracking and appropriately accounting for inactive and abandoned meters, and the resolution of false meter readings in the field (much of which did not happen prior to 2011);
- City billings have been conducted based on a consistently gathered customer meter reading database;
- Customer meters have been replaced to improve overall water billing accuracy by perhaps as much as 5 to 7%, including obtaining readings from approximately 700 meters during the winter that did not have adequate flow in the past to measure with the old meters; and
- Some, if not all, raw water sales have been identified and segregated from treated water sales such that the total water sold is better estimated, which improves the accuracy of the estimated amount of non-revenue water.

Through the implementation of these improved best management practices, the billing data base has substantially reduced anomalies in the records, and now more accurately reflect actual water deliveries to the City's customers. In addition, the City can more easily bill its customers with meter readings that are accurate and timely; helping customers to better understand their individual water use behaviors and in some cases identify leaks. Finally, the City, which used to bill 4 to 6 weeks after customers used a particular volume of water, can bill for water used in the month that the bill arrives[10].

With the combined improvements, the City has reduced non-revenue water from about 20% in 2010 to less than 10%. In fact, the City has data indicating non-revenue water in 2014 was less than 5%. There is reason to question this low of an amount of non-revenue water; however, since the City does not have an overly aggressive water loss management program, and is in the process of improving its overall water loss efforts, it is unlikely that the City would have such low losses[11].



[a] see footnote 5

Figure 5 presents the monthly trend for non-revenue water over the past 5 plus years, showing that the trend in generally downward. The figure also shows how many estimates of non-revenue water are negative, meaning that more water is sold than is placed into distribution. Negative non-revenue water is possible if substantial water is being removed from system storage during any particular period of time; however, demand for the City is much greater (20 to 25 million at its lowest) versus 8 million gallons of

[10] Billings for November water usage were included in the January bill. November usage is now billed on December 1st.

[11] Based on the American Water Works Association Manual 36, Water Audits and Water Loss Control Programs, the City's unavoidable annual real losses (UARL), which are only a portion of the City's non-revenue water, should be in the range of about 22 million gallons of water per year. However, the City's unavoidable annual real losses are greater than the non-revenue water calculated for 2013 (i.e., 14 million), and slightly less than the non-revenue water calculated for 2014 (i.e., 27 million). For this reason, it appears that the City has not fully characterized its non-revenue water, since it is reasonable to expect, based on joint industry research, substantially higher losses in a system as large and complex as the one operated by the City of Lamar.

system storage such that having water removed from storage in back to back months totaling more than 30 or 40 million gallons is not possible (see April and May 2012, or February through May 2014). Therefore, there is some question as to the accuracy of the master meter used to estimate flows into the distribution system, for it is possible that this meter is reading lower than actual, which would explain the negative non-revenue water, especially after the new customer meters were installed in late 2013. A review of meter calibration methods indicate that the mag meters are not calibrated to a range of flows, but rather to a single, average flow rate. Although mag meters are known for being able to accurately measure flows across a broad spectrum, low flows made be occurring during off peak daily demands that are not registering.

Other possible explanations include erroneous customer meters and/or systematic data handling issues with water sold. Given that non-revenue water "goes negative" during the summer, meaning that the amount of water sold is greater than the amount of water produced, it may well be that some irrigation and/or seasonal accounts that are including in the potable billing accounting are actual non-potable water accounts that inflate the actual volume of potable water sold. A closer review of customer accounts included in the billing summaries is therefore warranted.

Noteworthy is that two major leaks occurred in June of 2015 – both on main water distribution lines. The result of these leaks is illustrated on Figure 5 with the blue line showing the actual readings and the red line showing the readings that would have been expected had the two main line breaks not occurred (based on measured non-revenue water in previous Junes during the period of record). It was estimated (as presented in Footnote 5) that approximately 55 million gallons of water were lost as a result of these two leaks. The value of the monthly tracking of non-revenue water is illustrated through this example.

It will be one of the key foci of the City is to better understand and characterize non-revenue water as a result of this Plan update. To that point, monthly tracking of non-revenue water and performing regular water audits using those methods described by the American Water Works Association will be considered by the City as a component of future water conservation efforts to help improve the City's understanding of real and apparent water loss and to improve overall water loss management.

Current Water Utility Budget

Two key attributes of the City's water utility budget are important to the development of this water conservation plan update – the utility's operating budget for water production, treatment and distribution; and the utility's capital improvement budget. Table 8 presents the relevant expenses related to these accounts.

Table 8
Summary of Pertinent Water Utility Expenses

	2013	2014	2015 (budget)
Water Purchased (for augmentation)	$ 53,534	$ 60,150	$ 65,000
Power Purchased			
Supply and Pumping	165,897	153,000	135,000
Treatment	13,451	15,698	12,540
Distribution	23,944	18,540	20,085
Chemicals	3,020	4,100	5,280
Maintenance of Meters	2,931	1,500	1,500
Maintenance of Hydrants	6,022	10,000	20,000
Water Conservation Programs	0	0	0
Debt Service on Bonds and Loans	183,995	631,162	867,586
Water into Distribution (1,000 gallons)	578,637	557,060	340,011 (est)
Cost Per 1,000 Gallons for Power and Chemicals	$ 0.36	$ 0.34	n/a

Water Rates

Currently the City uses a flat rate for water sales – one for inside the City limits ($1.925/1,000 gallons) and one for outside ($3.85/1,000 gallons). For a residential customer inside the City limits, a base fee of $11.05 per month is charged. The base fee includes 500 cubic feet of treated water (which is equivalent to 3,740 gallons), after which the flat rate is charged for all water usage. All customers inside the City limits pay the same flat rate; however, the amount of treated water included within the base fee, and the base fee, increase for larger taps. A complete listing of water rates, and base fees, is provided in Appendix B.

Past Water Conservation Goals and Practices

In the City's 2010 water conservation plan, it set forth a goal of reducing City water demand by 1% per year on average over ten years. The water use reduction were expected to be realized through improvements in metering (through metering unmetered uses), and reductions in residential use over time. Active water conservation measures and programs that the City selected to implement included park and residential irrigation improvements, residential rebates for HE toilets and washing machines, water rate increases, and improved water loss management. Through 2015, few of these programs were implemented successful, given changing priorities and available resources.

One important change made by the City as part of improved water loss controls occurred in 2011 when the City replaced its water treatment plant master meters – installing magnetic meters in place of older mechanical meters. This change improved the accuracy of measuring water production. In addition, in 2012, the City invested over $3.2 million on the installation of an AMR/AMI system[12], which became fully operation in August 2013. The impact of that investment has not been fully realized at this time, as the City has been changing its procedures to collect data and estimate water loss. Nonetheless, the City has improved its billing programs and protocols, eliminating systematic data handling errors associated with tracking and accounting for closed and inactive accounts. Recent modifications to billing protocols have helped to remove non-potable accounts from potable water accounts, improving the nature and accuracy of water loss accounting for the City.

The City has implemented day of the week watering restrictions starting in May 2013. The watering restrictions, which are considered Stage 2 watering restrictions, result in no more than three times a week watering allowed for any single parcel or home, and define those practices that are deemed wasteful by the City (see Appendix C). The effect of the watering restrictions is not entirely clear, based on the data presented in Figure 4 and Table 4, since customer demand peaked in 2012 after the restrictions were put into place, and have decreased since, presumably in response to changes in weather and ET. Some warnings have been posted by City staff to individual property owners; however, no fines have been levied to date.

Finally, the City has supported the Southeastern District in its efforts to plan for and implement regional water conservation planning. As part of this effort, Lamar participated in water audits conducted by the District in 2013. Based in part on the District's efforts and the City's recent investment in new metering infrastructure, the City decided to update its Plan.

As indicated previously in the Plan, the future water conservation measures and programs that the City is most interested in pursuing relate to improved water loss management and the development of water rate structures that encourage efficient customer water use while maintaining appropriate levels of water sales revenue for the utility and the City. Educational programs will also be of interest, especially those that promote native and Xeriscape planting, and wide outdoor water use. The City is also interested in promoting general awareness of water issues in the area through K-12 water education

[12] The $3.2 million included all new customer meters, Aclara software and telemetry, and SCADA system for remote meter reading and tracking..

programs. All of these components of future water conservation planning and implementation will be discussed in detail in the remainder of this Plan.

Updated Water Conservation Goals

Water production volumes and water sales have been dropping in Lamar over the past 5 years due in part to reductions in population served, as well as impacts related to weather and perhaps even customer water use behaviors. To this point, current levels of water use demand are below 2,000 AF and have been for some time. However, statistical analyses of the variability of water use demand indicate that future year demands may exceed 2,000 AF (see Table 7). For this reason, the City will continue to plan for and implement water conservation measures and programs that make fiscal sense to the organization.

Noting that per unit power and chemical costs appear to be fairly consistent in 2013 and 2014; however, it is anticipated that power and chemical costs will increase in the future. It is also possible that future years could see water sales revenue impacted by either wet periods (when water sales may drop due to reductions in outdoor irrigation) or by dry years (when water sales may drop due to increased use of watering restrictions). For this reason, the City will expend resources to develop customer water rates that help to promote responsible seasonal water use without detrimentally impacting overall utility cash flow and viability.

Noteworthy is that current peak daily demand is about 80% of water treatment plant capacity. Appropriately constructed water rates will help provide customer incentives and motivations to manage seasonal water use, such that additional infrastructure capacity can be avoided to the extent practical, at least during the current planning horizon.

Water loss management, and apparently losses related to lost water sales revenues, will also be a priority for the City with particular emphasis on leveraging the benefits of the new AMR/AMI customer metering system. For example, rededication of utility staff to hydrant and valve exercising, and system flushing, as staff time becomes available post-AMI installation, will help to reduce water line breaks and leaks reducing real water loss. Apparent water loss has been improving as the finance department improves record keeping and error correction of customer account information; however, additional work may be need to continue the trend to further reduce apparent water loss and increase the accuracy of overall water loss management.

One challenge for the City relates to developing a water conservation goal for improved water loss management, when current levels of water loss management are in the 5% of production range. Although it is anticipated that this value of water loss, represented by the volume of non-revenue water, is artificially low, goals for future water loss management will focus on improving the accuracy of monitoring and verification efforts, as opposed to lowering the volume of non-revenue water and water loss. Nonetheless, measures and programs will be needed to assist the City in its efforts to improve water loss management.

Notwithstanding the City's requirements to operate without a deficit, the City is also mindful of the benefits of water conservation, both from the view point of the City's own uses (parks, etc.) and of its customers. Therefore, the City will support those programs that effectively promote water use efficiency institutionally, as well as seasonally.

With these points all in mind, the City's updated water conservation goals are as follows:

- Promote customer awareness related to efficient water use through improved, tiered water rates, and customer educational programs.
- Promote improved water loss management through the planning and implementation of annual water audits and improved data handling and management practices.
- Promote institutional water use efficiency enhancements through the technical assessment of outdoor and indoor water use at all City facilities.
- Link drought response management to the implementation of City mandated watering restrictions and water rates.

The combination of these efforts will create some water demand reductions under average conditions (e.g., in the range of 20 AF), the combination of the programs will strive to reduce the variability of future water demands by 15 to 20% from average to dry years, which translates into a planned demand reduction in the range of 45 to 60 AF by 2022.

Identification and Evaluation of Candidate Water Conservation Measures and Programs

Identification

Identifying candidate water conservation and efficiency measures and programs has its roots in two key resource areas. First is the State of Colorado Revised Statute 37-60-126 (4)(a) which addresses water conservation planning for municipal water providers (see Appendix A). This statute is directly applicable to the City[13] and as such it requires that "at a minimum, [the planning entities should] consider" a list of water-saving measures and program types that may be used by a water provider for water conservation and improved water use efficiency. The second is the Southeastern Colorado Water Conservancy District's (Southeastern's) Best Management Practices (BMP) Tool Box, which is a web-based water conservation planning tool that contains a wide variety of relevant information regarding BMPs that water utilities can use to improve water use efficiency and support smart water use. The Tool Box contains categories of measures and programs that address the five different operational areas that all water utilities conduct - system wide management, water production and treatment, water distribution, delivery of water to customers and customer demand management.

Table 9 presents a discussion of how each of the State's "to be considered" water conservation measures and programs were considered and incorporated into the City's evaluation of candidate water conservation and water use efficiency programs. In general, Lamar has determined that customer demand management techniques may provide some benefit in terms of outdoor water use; otherwise the City is looking to improve its overall water management programs that will improve its ability to track use, maintain appropriate levels of water sales revenue, and reduce water loss.

For these reasons, Lamar will choose to focus its resources on maintaining and upgrading the water system infrastructure – managing data collection, water loss, and revenue generation – over providing incentives and financial support for customer demand management. The City will also evaluate those programs that will address seasonal water use by the City itself (e.g., in parks) and by its customers (e.g., residential, commercial, etc.). The City will also look to strengthen its customer education and engagement programs recognizing the importance of reaching and engaging the City's residential and commercial customers and improving their understanding of water supply, wise water use, and the cost of providing reliable, potable water.

Note that a broader range of customer demand management programs such as those listed by the State for consideration under CRS 37-60-126 (4)(a) may become more applicable to the needs of the City and its customer base in the future. However, for the current planning period, there is limited utility of some of those measures and programs contained in Table 9, as noted.

[13] Although the City of Lamar is not currently a covered entity under the definition provided by statute (see Appendix A), for the City water demand may exceed 2,000 acre-feet of water for municipal and industrial uses in the future if appropriate water conservation measures and programs are not planned for and implemented. As a covered entity, the City would be required to create and maintain an approved water conservation on file with the CWCB.

Table 9

Review of State Required Measures and Programs for Consideration Under CRS 30-67-126 (4)(a)

Measure or Program	Relevance to Lamar	Applicability	Status for Further Evaluation
Water-efficient fixtures and appliances, including toilets, urinals, clothes washers, showerheads, and faucet aerators	Customer Indoor Water Use (chiefly residential, but can be for some commercial (e.g., hotels and bars) and industrial customers)	Customer efforts to replace aging water using fixtures and appliances will create water demand reductions over the planning period. Lamar could benefit from expanding its Rules and Regulations to address new construction indoor plumbing fixtures (including retrofits) however the State is currently moving forward with this effort, and the City does not expect much, if any growth over the planning period. More customer education related to indoor water efficiency will be considered (see below).	No further evaluation necessary
Low water use landscapes, drought-resistant vegetation, removal of phreatophytes, and efficient irrigation	Customer Outdoor Water Use	The City will consider efforts to improve the planting of low water use landscapes in its parks and open spaces, and will promote Xeriscape and native plant materials with its educational programs/materials	Include for further evaluation
Water-efficient industrial and commercial water-using processes	Customer Commercial and Industrial Process Water Use (including laundries, cooling systems, etc.)	The City has commercial customers which are chiefly bars and restaurants, but includes some industrial users and comercial laundries. These facilities may benefit from improved water use efficiency; however the cost for new commercial equipment is beyond the scope of this planning effort at this time.	No further evaluation necessary
Water reuse systems	Potential Reuse of Return Flows	The City does not have any reusable water supplies in its portfolio at this time. Project water return flows are not reusable for locations east of John Martin Reservoir.	No further evaluation necessary
Distribution system leak identification and repair	Distribution System Water Loss Management (and System Wide BMPs to collect and manage data to support decision-making)	The City has a number of opportunities to improve the accuracy of its measurements to support a better understanding of water loss. Potential areas of improvement include: • Master Metering • Customer Water Use Tracking (and differentiation of potable from non-potable) • System Wide Water Audits	Include for further evaluation
Dissemination of information regarding water use efficiency measures, including by public education, customer water use audits, and water-saving demonstrations	Customer and Elected Official Education	The City will continue its efforts to educate and to diseminate water education information through local and regional programs, through means such as: • Educational Forums and Workshops • Participation in Regional Collaborations	Include for further evaluation
Water rate structures and billing systems designed to encourage water use efficiency in a fiscally responsible manner	Customer Billing and Utility Finances	The City has a flat water rate structure. It will consider evaluating tiered rates and linking rate changes to drought responses and other water conservation programs. New water rates may be needed to keep up with increased cost of energy, chemicals and system maintenance requirements.	Include for further evaluation
Regulatory measures designed to encourage water conservation	City Ordinanaces to Improve Customer Water Use Efficiency	The City will consider updating its water waste ordinance.	Include for further evaluation

Table 9 (continued)
Review of State Required Measures and Programs for Consideration Under CRS 30-67-126 (4)(a)

Measure or Program	Relevance to Lamar	Applicability	Status for Further Evaluation
Incentives to implement water conservation techniques, including rebates to customers to encourage the installation of water conservation measures	Customer Indoor and Outdoor Water Use	The City's customer base is currently replacing older fixtures and appliances as retrofits occur and aging fixures and appliances are updated. Incentives are not considered to be as high a priority as water loss management and improved data collection at this time.	No further evaluation necessary

Components of each of these programmatic areas that the City will consider for implementation are described in more detail below.

Improved Overall Water Loss Management

Although the City has a good track record regarding tracking and managing system wide water loss, with a number of notable substantial improvements[14], there are still some unqualified irregularities in the accounting for non-revenue water, as noted in one of the previous sections. Most notably, since the start of 2013, over 30% of the months have negative amounts of non-revenue water (meaning that more water is sold than produced), and that occurrence has been increasing, rather than otherwise, in 2014 and 2015.

It is likely that the issue for the City is some type of systematic data error, that can be found through the implementation of BMPs that will help the City better characterize non-revenue water and real and apparent losses, which in turn will support more rigorous economic assessments of future capital expenditures and operating expenses related to water loss management and infrastructure investment. The improvements, which consist of various BMPs, will also help to support more accurate tracking of customer water use behaviors, which in turn may support decisions regarding customer demand management program investments in the future.

The BMPs related to improved overall water loss management include those that:

- Improve customer water use data collection;
- Improved master meter testing and assessment;
- Improve data use and management; and
- Continue real loss management.

Improved Customer Water Use Data

The City may consider developing a more rigorous assessment of customer accounts that are tracked within the billing software, such that double counting and/or potable and non-potable customers are identified and segregated. Previous work conducted as part of the Plan development exercise helped to identify some non-potable accounts that were previous included in the non-revenue accounting. Given that negative non-revenue months tend to occur in the spring and summer, it is possible that some irrigation accounts and/or seasonal accounts are included erroneously within the potable water accounts.

Another consideration for the City is to differentiate institutional uses such as schools from commercial uses and/or government uses. Improvements in customer categorization will help the City to better understand customer water use patterns. In addition, the City will benefit from reviewing commercial, industrial and institutional accounts as a means to identify authorized, unbilled water uses that may help

[14] The City has invested in a new master meter in 2011; new customer meters and AMR/AMI technology in 2013 and has created a number of customer water use tracking and billing record improvements over the last 3 years.

to better characterize apparent and real water loss. Recharacterization of customer categorization may also support future water rate studies – including setting tap fees and customer use rates.

The City may also consider creating wholesale water customer categories to track deliveries to those entities with separate retail billing systems that may become prevalent in the future. Placing these organizations into a separate customer category will help to better characterize these types of deliveries and may help to support future program developments and assessments. For example, water loss related to wholesale deliveries tends to be less than retail customers since real losses associated with service connections are limited. Understanding wholesale deliveries more explicitly will also help to assess meter replacement programs for these customers, since large meters tend to require replacement more often than small meters.

Finally, the City should consider continuing its meter replacement and upgrade program. More accurate customer meters will help to reduce apparent water losses, and use of AMR radio-read based data collection can help to reduce systematic data handling errors, as well as free up staff time to allow for more distribution system preventive maintenance programs (e.g., valve exercising, hydrant flushing, leak detection). Increased preventive maintenance has been shown to reduce real losses and improve the quality of water deliveries.

Improved Data Management and Assessment

The City should consider implementing annual system wide water audits, continuing to perform audits in a manner consistent with the audit performed for the City by the Southeastern Colorado Water Conservancy District in 2013. The water audit is based on the American Water Works Association (AWWA) M-36 Manual on Water Loss Control and Management. Conducting the water audit using this methodology will help to maintain a consistency in data collection and use, and will support benchmarking and comparative analyses with other similar utilities that the City may wish to perform in the future. Given that the M-36 methodology is focused on supporting economic decision-making by utilities related to water loss management, it fits nicely with the current and expected future needs of the City.

Continued Real Loss Management

The City has various programs that address real water loss including leak identification and repair, replacement of aging water lines and service lines, and various preventive maintenance routines. The City should continue these programs and look for ways to enhance those preventive maintenance programs that improve distribution system water quality and reduce water loss.

Improve Utility Cash Flow while Promoting Wise Water Use

The City has struggled in 2015 with decreased water sales due to the prevailing wet weather pattern. For this reason, the City has been strapped with less cash in its water enterprise fund than had been budgeted. In addition, increases in debt service have increased operating expenses for the utility. Understandably, overall cash flow is a key issue for the City's water utility.

Improvements in water loss management, including characterizing and finding both apparent and real losses, and then reducing them through programs and BMPs, will directly benefit the utility's bottom line. However, the City's water rate structure could be formulated in a manner that more explicitly connects base rates to fixed costs and use rates to variable costs. In addition, the City may consider developing tiered water rates to promote customer seasonal water use efficiency, and provide for water sales revenues at an increased rate during summer time peak use, when the water supply system is at its most stressed.

With respect to water rates, the City may consider more explicitly connecting changes in water rates, even if only temporarily, to drought triggers that may be defined by limits in water supply, augmentation water, project water deliveries, or some combination thereof.

Other Relevant Programs

Educational

The City has long invested in student education programs supporting water fairs and providing classroom content. The City also is active in educational programs that relate to its position and standing in the local and regional water community. By keeping involved with regional and state wide water programs and initiatives, the City can be prepared for and understand new and upcoming changes in water availability, regulations and funding programs. The City can also influence processes that run counter to the City's interests.

The City will continue its efforts in this area, adding one new program initiative to its list of key programs to track and support – the Lower Arkansas Valley Water Quality Working Group. This group has been established as a result of unmet compliance orders from the State Health Department to local private water companies that operate in close proximity to the City. The Working Group's objectives include identifying and developing solutions to allow local private water companies to come into compliance with state and federal regulations, in collaboration with local and regional water utilities and water providers, as well as county, state and federal governmental entities. The City has a clear role in monitoring these proceeding and potentially lending support in those areas that coincide with City interests and benefits.

Water Waste

An extension of the City's educational programs may include expanding on its current water restriction ordinance to a broader water waste ordinance. The water waste ordinance may not only allow the City to call out the misuse of water, but also helps to impress upon the community the importance of efficiency water use. A list of potential components of a water waste ordinance which that City may consider includes:

- Developing more prescriptive and in some cases (e.g., during drought) restrictive water irrigation practices that define time of day and day of the week watering restrictions; overspray restrictions; and water waste enforcement practices.

- Establishing more pronounced drought triggers and drought response programs for control of seasonal water use in times of water shortage.
- Continuing and enhancing customer water education programs to create more awareness and engagement as it relates to seasonal water use and water waste.

Timeframe

Water conservation and/or efficiency measures and programs that the City may choose to implement have been identified using the template presented in Southeastern's BMP Tool Box. The results are listed in Table 10. Table 10 is organized by each of the five areas that define water utilities operations (as indicated in the BMP Tool Box) and the time frame during which implementation of the candidate measures and programs may occur. The table has been segregated in into the three key time periods as follows:

- Short-term (1 to 2 years)
- Mid-term (3 to 5 years)
- Long-term (> 5 years)

These time frames have been developed to differentiate those activities that the utility will initiate shortly after plan acceptance and approval from those activities that will occur in future years, still within the 7-year planning horizon, depending on:

- The results of the short-term implementation activities;
- The applicability and relevance of the mid-term and long-term measures and programs; and
- The changing needs of the City and its customers.

Overall, the City will look to select programs that will do the following throughout the planning horizon:

- Improve overall water loss management;
- Improve utility cash flow while promoting customer water use efficiency; and
- Support improved customer educational and outreach programs.

There is a basic logic to how the various components of future water conservation measures and programs that the City will consider for implementation are structured with respect to implementation. For example, most improvements to data collection and management are considered important and appropriate in the short-term (1 to 2 years from Plan approval). This is due to the fact that improved data collection and management BMPS are the basis for future program selection and development. In addition, the City is planning to conduct a water rate assessment within the short-term leverage its new customer metering and billing systems.

In the mid-term (i.e., the next 3 to 5 years), the City will continue to implement BMPs that enhance its current water conservation and efficiency programs leveraging better and more accurate data collection, improved data assessment and evaluation programs. Of particular importance will be the City's efforts to utilize information collected that more accurately characterizes water loss such that more rigorous economic assessments can be made regarding leak detection, repair and prevention. For example, the

City should consider expanding its testing and/or replacement of the meters on its largest water customers on a regular basis – perhaps as often as every other year. This effort would reduce apparent losses associated with typical meter inaccuracies that occur more readily on large meters, and would support improved water loss management.

Table 10
Summary of Water Conservation and Efficiency Measures and Programs Under Consideration

System Wide Management	Process and Treatment	Distribution System	Customer Water Delivery	Customer Demand Management
Short-Term (1-2 years)				
Improve data management for water loss assessment, water utility management, and SECWCD and CWCB Reporting	Join Lower Ark Working Group dealing with radionuclides and other water quality issues	Continue water line repair and replacement, as needed	Continue meter repair and replacement, as needed	Continue current customer education supporting local and regional programs
Initiate annual system-wide water audits (based on AWWA M-36 methodology)		Initiate improved water loss control program including improved data tracking and assessment; improved preventive maintenance programs of valve and hydrant exercising and replacement	Continue service line repair and replacement, as needed (on Utility side of connection)	
Evaluate changes to water rates and customer billing structure to include more rigorous conservation pricing and to prepare for drought-related pricing when needed			Develop improved customer water use tracking esp. for wholesale water sales[15] and to differentiate raw water (non-potable) uses from finished water (potable) uses.	
Mid-Term (3 – 5 years)				
Same as above	Same as above	Same as above	Same as above	Same as above
Update and improve water waste ordinance and drought response planning.	Plan for AVC operations	Evaluate Regional Water Supply Options	Develop customer meter testing and/or replacement program including prioritized replacement of older and larger meters.	
Long-Term (>5 years)				
Same as above	Same as above	Same as above	Same as above	Same as above
Evaluate changes/updates to water waste ordinance/drought response			Initiate planning for AMR device upgrades/battery replacement program	Evaluate water use training and/or audit program for City Parks and other outdoor uses.
			Expand current "red-flag" monitoring of billing data to help identify customer-side leaks and abnormal water use conditions	

[15] Includes treated water sales to those entities that maintain separate customer billing now and into the future.

In addition, the City will continue to benefit from the more sophisticated characterization of customer water use behavior afforded by the AMR/AMI systems. The AMR and AMI systems allow the City to collect more customer water use readings, helping to better parse water use behaviors into smaller time segments as well as allowing for the synoptic collection of both master meter flows and customer water use. These improvements will help to support more rigorous water loss management efforts and allow for a more explicit understanding of changes in water rates and other customer water policies (e.g., watering restrictions).

Another component of water use efficiency that the City may wish to consider during the mid-term period, after data collection methods are improved and standardized and the impact of changes to water rates are assessed, will be the more explicit definition of the City's water waste and drought response policies. More accurate and consistent data will allow policies to be developed that work hand in glove with the revised water rate structures devised to support improved cash flow and more efficient water use behaviors in the City.

Another mid-term program that the City may consider implementing relates to the training and/or auditing of its largest outdoor water users – its irrigation only customers (which includes the City parks) and its largest commercial and industrial water users (which includes schools). This may involve holding meetings to discuss irrigation practices, or it may involve conducting onsite visits to review past water use and current irrigation methods and practices.

The City may find that the mid-term period is a good time to evaluate regional alliances related to overall water supply and water resources management, in part due to the ongoing planning for the AVC (see next section). There is the potential for regional water efficiencies afforded by regional alliances that may benefit the City, the regional water resources picture, or both. One noteworthy regional alliance that the City may want to consider during the next seven year period is the options and opportunities to collaborate with its nearest neighbors to the north and west (i.e., The Town of Wiley and May Valley Water). There may be various business justifications for the City to entertain providing potable water to these entities wholesale as a means to expand the City's customer base and support more sustainable and efficient regional water resources management[16]. Other alliances may also avail themselves as work is conducted on the design and operational planning for the AVC. It is therefore of substantial importance that the City remains engaged in these regional efforts associated with the AVC project implementation.

In the long-term, the City may plan to utilize improved water loss management data collection and tracking methods to reduce both apparent and real losses – by directing capital improvements and focusing day-to-day operational activities. Other long-term conservation programs may include updating and revising the City's Rules and Regulations as needed, updating and replacing customer meter reading

[16] May Valley and Wiley both have groundwater supplies impacted by naturally occurring radionuclides and iron. Treatment for these materials reduce water use efficiency as backwash flows from treatment facilities are pumped to waste.

device batteries and equipment, and considering updating the City's web site to include more water conservation and water education content.

Other water conservation measures and programs may be included in the implementation of this Plan in support of achieving the specified goals, since the City may choose alternative actions in response to changing conditions and customer needs. However, the basis for changing direction and making revisions to planned water conservation and water use efficiency measures and programs will be those data that are collected as a result of the early phases of Plan implementation.

Issues Regarding AVC Implementation Planning

An important aspect of improved water use efficiency for the City relates to its connection to the AVC in the future. As previously indicted, the City utilizes local alluvial wells for water supply. Pumping these wells requires that the City utilize its water rights portfolio to augment the City's return flows to prevent downstream injuries. Use of AVC deliveries, in general, and Fry-Ark project water, in particular, for its primary water supply when allocations permit eliminates the need for the City's augmentation sources, potentially saving the City the cost for the augmentation water, as well as decreasing the power consumption required to pump production wells. Perhaps more importantly for the City is the improvement of the City's use of its Fry-Ark project water deliveries. Past Fry-Ark deliveries from Pueblo Reservoir to the City for augmentation use suffered from 60% or more transit loss over the 120 mile journey through the Arkansas River below Pueblo. The AVC will all but eliminate the transit losses, greatly improving future transmission efficiencies.

Finally, the AVC will afford the City with other options for water management in the future, as regional collaborations occur leveraging improved water infrastructure, enhanced water exchanges and coordinated water resources management. Therefore, it is imperative from the City's perspective, that it continues to work with regional groups to prepare for the use and operation of the AVC and other regional water management programs.

Evaluations

The City has real limitations related to available cash associated with the implementation of new water conservation programs, in part due to the size of the City's customer base and current need to commit funds to addressing debt service (which has been developed in recent years to improve water loss management and the accuracy of customer billings). Beyond these recent customer metering and data handling improvements, the City has had no real resources to apply to other water conservation programs, and that trend is likely to persist, at least until such time as the City is able to increase water rates. The focus of the City is therefore to be more efficient with the management of the utility infrastructure such that water loss is reduced, hinged on improved water use tracking, water auditing, and standard operating procedures related to preventive maintenance programs.

Overall concerns exist related to customer irrigation practices and end user water waste, especially as it relates to periods of scarce water supplies. To this point, the City has instituted a time of day and day of the week watering schedule which limits how customers can use water for outdoor irrigation. These water restrictions will continue to be utilized in the future, in accordance with the wishes of City management.

Therefore, future water conservation programs that can be complimentary to the City's ongoing needs must not require the reprogramming of funds or the appropriation of new funds, but rather must fit within the current budgets developed for the utility by the City. To this point, new educational programs or customer technical support is not viable in the short to mid-term planning for the City. Rather the City will focus its efforts on those measures and programs that are affordable within the planning horizon including those listed in Table 10.

Overall, the City will perform the following tasks, as summarized in Table 10:

- Utilize current public works and finance staff to improve master metering and customer metering data handling practices to better categorize potable and non-potable water deliveries, as well as other potential systematic errors in data handling (such as implement the AWWA M-36 Water Audit methodology – see Appendix D), such that non-revenue water accounting is improved and better supports future economic assessments and decision-making;
- Direct public works staff to continue to improve preventive maintenance procedures and practices related to valves and hydrants to improve safe and efficient distribution system operation (see Appendix E);
- Commit the resources needed to establish new water rates that not only increase rates to address increasing operational costs, but to protect the City from periods of decreased water sales revenues that accompany periods of abnormal weather conditions (either wet periods or dry periods when water sales revenues drop);
- Evaluate efficacy of tiered water rates, as well as more prescriptive water waste ordinances, to promote more efficient customer water use behaviors;
- Develop a more explicit understanding of the link between water rates and watering restrictions, as well as the potential impact of changing customer water use in periods of abnormal weather conditions on water sales revenue;
- Continue public works programs related to ongoing water line repair and placement, meter repair and replacement, and customer service line repair and replacement, as needed;
- Continue to commit resources, as appropriate, to important regional water management programs, such as the AVC, to prepare for future water supply needs and support regional and local improvements in water uses efficiency; and
- Continue to support local water educational efforts, as conditions dictate and resources allow.

Impact of Water Conservation on Future Water Sales and Water Use

Water Sales Revenue

The City is understandably concerned with future cash flow and sustainability of financial resources. To this point, water conservation which occurs without consideration of the impacts of reduced customer demand on water sales revenue does not support responsible business practices. The City has therefore focused its efforts on reducing and/or better characterizing non-revenue water related to City infrastructure and metering, as opposed to customer demand reduction over the short- to mid-term. The City will also commit resources to better connecting water rates to services provided, in an effort to link customer water billings to the costs of production, treatment and delivery, as well as the cost of the water itself.

Given the City's focus – water loss management and water rates – improvements in water use efficiency are not expected to create substantial changes to future water sales in and of themselves. Water loss improvements will reduce the overall system wide demands year round, such that production and treatment volumes decrease assuming no population growth occurs during the planning horizon. The combination of the various water loss improvement efforts will therefore reduce operating expenses and improve overall cash flow and utility profitability, which will in turn allow for more investments to be made in infrastructure.

Increasing water rates would also help the City's cash flow, especially in light of retiring its debt service and in providing financial resources to create increased preventative maintenance budgets and operating reserves. Given that increasing water rates can reduce discretionary customer water use, it is possible that increasing rates will be offset to some extent by reduced customer water use demands. However, customer water use demands are directly linked to prevailing weather patterns such that periods of wet or dry conditions will likely have a greater influence on future water sales revenue than increasing water rates, even though the City has voluntary watering restrictions in place. For this reasons, future water sales are not expected to change dramatically unless water rates are raised substantially (e.g., greater than 15%) over current rates.

If the City chooses, or is forced to choose, more draconian water waste ordinances and/or watering restrictions in times of drought, water sales revenues could be dramatically impacted. La Junta, for example, links substantial increases in water rates to declarations of drought to offset reduced customer water use in times of water scarcity. The City of Lamar should consider updating its drought ordinances to include this kind of language to protect against future water sales shortfalls if, and when, drought conditions occur. Water sales revenue drops of 15 to 20 percent or more have been recorded in Colorado when drought conditions limit municipal supply availability. For Lamar, this could mean a reduction of $100,000 to $150,000 per year in water sales revenue during periods of drought.

Water Use Reductions

The programs that the City has selected to implement will help to reduce water production and treatment by the City, and will reduce customer demand during summertime peak water use periods, especially during periods of drought. Although the programs focus on managing water use during dry periods, water loss management will reduce water production and treatment during all ranges of operating conditions.

With respect to water loss reduction, the City's efforts to better characterize water loss through the application of the AWWA M-36 methodology will likely increase the amount of non-revenue water measured by the City in the short-term, as the reasons for the City's current negative non-revenue water circumstances are understood and rectified. The best management practices that the City uses to better characterize non-revenue water will not cause water loss to increase, but will have the effect of increasing the amount of non-revenue water measured by the City. Once this occurs, the City will have the tools to understand more accurately its non-revenue water, as well as its apparent and real water loses, which in turn will allow the City to make better informed decisions on improving its water loss management – including for example, what resources to commit to maintaining valves and hydrants, etc.

In the short-term, non-revenue water may increase from 30 million gallons to perhaps 90 million gallons annually (see Figure 5) as periods of negative non-revenue water are reversed. Once this occurs, the City can better characterize apparent and real water losses, and make appropriate investments. One such investment – the focused improvement of the City's valve and hydrant maintenance program – is expected to reduce real loss by 15 to 20% - which would result in a reduction of water loss by perhaps 20-25 AF per year by the end of the planning period.

As for customer demand reduction, the City will leverage improved water rates and water rate structures with more explicit water waste and drought management ordinances and protocols to reduce seasonal water use, especially during periods of dry weather and water scarcity. These reductions are expected to reduce dry period summertime water use by 10 to 15%, or about 10 to 15 million gallons, which would create reduced treatment and production requirements by 36 to 54 AF[17]. Note that the City currently has Stage 2 watering restrictions in place (see Appendix D). Although these restrictions effectively address most forms of customer water waste, and make the water restrictions mandatory, there are no provisions for non-compliance such as warnings and/or fines. Other stages of watering restrictions should also be considered for use in times of water supply shortages.

Table 11 presents a summary of the estimated impacts of the proposed water conservation programs on future water production and demand based on the forecasted demands presented in Table 7.

Table 11
Effect of Proposed Water Conservation on Future Water Demands and Water Placed into Distribution (millions of gallons per year) (assuming 15% combined real and apparent losses in 2016)

	Water to Distribution (without conservation)		Water to Distribution (with conservation)		Water Demand (without conservation)		Water Demand (with conservation)	
	Average	Dry Conditions	Average	Dry Conditions	Average	Dry Conditions	Average	Dry Conditions
2015	675	784	**675**	**784**	574	666	**574**	**666**
2020	675	784	**665**	**729**	574	666	**574**	**635**

[17] Assuming 15% apparent plus real water losses.

2022	675	784	**655**	**710**	574	666	**574**	**620**

Implementation Plan

Implementation Tasks

Based on the needs of the City and its customers, Lamar will implement those selected water conservation and water use efficiency programs listed in Table 12, with the intention of achieving the water conservation goals listed previously. Implementation will occur over a number of years as ongoing programs are continued and new programs are phased in. Funding levels are always a consideration, as operating expenses and water sales income change seasonally and from year to year. However, the programs that have been selected for implementation are those that the City believes are best for the organization in the short-term and mid-term; helping to improve processes, enhance business practices, and support customer needs.

The focus of the implementation plan is on the 1 to 2-year planning horizon, for during the short-term it is possible to identify expenditures that can be used to implement those selected measures and programs without the substantial uncertainty that occurs when planning for 3 to 5 years into the future. To this point, the implementation plan provides a detailed accounting of planned expenditures for those programs selected for implementation in the short-term; and less detailed accounting of those that have been selected for implementation 3-years and further out.

Programs related to the implementation of improved processes such as tracking water use and water loss, enhanced customer education, etc. will be conducted as appropriate during the normal course of business once the proper infrastructure is in place. Once initiated, it is anticipated that these practices will be conducted on a regular and consistent basis into the future.

Other long-term water conservation and water use efficiency measures and programs that have been identified for consideration in Table 10 presented in the previous section will be evaluated and characterized further for implementation based on the outcome of the short-term and mid-term implementation efforts.

Table 12

Summary of Selected Water Conservation and Water Use Efficiency Measures and Programs for Short-Term (1-2 years) and Mid-Term (3-5 years) Implementation by the City of Lamar

Selected Measure/Program	BMP Category(ies)	Key Attributes	Description	Estimated Cost
Customer Water Use Tracking				
Improve customer water use tracking including wholesale and non-potable water sales	Customer Water Delivery	Supports more accurate characterization of water use and water loss	Requires separating non-potable water sales from potable water sales. Also includes developing wholesale water use categories.	City Finance Dept. Labor Only
Water Loss Management				
Continue Best Management Practice (BMP) related to data collection and management in support of water loss management	System Wide Management	Supports more accurate characterization of water loss through distribution to customers	City will strive to develop and link BMPs based on a more rigorous accounting of non-revenue water, authorized unbilled water, and estimates of real and apparent water loss in accordance with AWWA standards (i.e., M-36). BMPs will include improving the collection and tracking of water placed in distribution, unbilled water uses, and customer water use.	City Utility and Finance Dept. Labor Only
Enhance current "red flag" system for identifying (and correcting, if possible) high water use by customers and false readings in the billing database	Customer Water Delivery	Supports the identification of customer side leaks and over water use; and errors in data collection	Requires making selected adjustments to billing software and/or billing data processing to allow for comparisons of water use to previous months and tracking back into historical use to be able to differentiate high use from differences between normal seasonal increases.	City Finance Dept. Labor Only
Conduct annual system wide water audits	System Wide Management	Supports more accurate characterization of water loss through both water treatment and distribution to customers	Utilize City resources to conducted annual system-wide water audits using the AWWA M-36 methodology (see Appendix D). City will consider conducting third party audit every 3 to 5 years to support data checking and to evaluate BMPs and/or coordinating tri-annual audits with the Southeastern District.	City Utility Labor Only (except for 3rd party audit which will be provided by the Southeastern District triannually)
Continue water line repair and placement projects based on results of improved water loss management BMPs	Distribution System/Customer Water Delivery	Supports reduced water loss through installation of improved distribution piping and new valves and appurtenances	Utilizes resources which are budgeted and expensed annually, then makes adjustments based on the audit results and improved data collection efforts, such that funding can be funneled to those areas of greatest benefit	$25-50,000/yr
Continue service line repair and replacement	Distribution System/Customer Water Delivery	Supports reduced water loss through installation of improved service line/metering couplings	Utilizes resources which are budgeted and expensed annually to replace service lines when water mains are replaced.	(included in water line replacement and repair)
Continue meter repair and replacement	Customer Water Delivery	Supports improved accuracy of tracking customer water use which improves organization's water sales revenues and reduces water loss	Utilizes resources which are budgeted and expensed annually to replace existing under-performing customer meters. Revise program to be more aggressive in the future based on results of the audits and improved data collection efforts.	$2-5,000/yr
Develop enhanced valve and hydrant maintenance program	Distribution System/Customer Water Delivery	Supports reduced water loss through improved valve and hydrant exercising and preventative maintenance	Utilizes resources which are budgeted and expensed annually leveraging utility staff which have had other responsibilities in the past (see Appendix E).	City Utility Labor Only

Table 12 (continued)

Summary of Selected Water Conservation and Water Use Efficiency Measures and Programs for Short-Term (1-2 year) and Mid-term (3-5years) Implementation by the City of Lamar

Selected Measure/Program	BMP Category(ies)	Key Attributes	Description	Estimated Cost
Seasonal Demand Management				
Revise and Update City's Rules and Regulations related to water waste, outdoor irrigation restrictions, enforcement options, and drought triggers.	System Wide Management/Customer Demand Management	Defines requirements for operation of irrigation systems and how drought will influence different actions by the City to limit and improve the efficiency of seasonal water use.	Updating the Rules and Regulations involves reviewing and revising components of the existing ordinances and codes to incorporate new technology, to identify penalties for non-compliance, and make more direct connections between water waste and improved seasonal water use efficiency.	City Utility and Management Labor Only
Evaluate changes to water rates and fee structures (may need to occur every 3-5 year depending on water sales revenues)	System Wide Management	Supports improving revenue generation to support more aggressive leak detection and water loss management through capital projects, improved metering; and enhanced BMPs	Develop water rates based on changing customer demand characteristics, need for conservation rate structures (tiered rate structures), and increasing operational costs. Include connection between drought response and rate structures.	$15,000 (one time cost)
Other Educational Efforts				
Continue Customer Educational Efforts	Customer Demand Management	Supports customer engagement and understanding of changing water rates, policies and programs		
Join Lower Arkansas Water Quality Working Group	System Wide Management/Water Production and Treatment	Allows the City to remain abreast of regulations and policies that may impact utility operations and future water use efficiencies	Maintaining connection with the progress of the AVC design and construction, as well as stay current with changing and evolving State Health Department regulations related to drinking water and solid waste management that may impact City operations.	City Utility Labor Only

Plan Monitoring and Assessment

Many of the measures and programs that have been selected for implementation have imbedded within them data collection and evaluation BMPs that constitute plan monitoring and assessment practices. For example, the goal associated with reductions in system wide water loss will be assessed through the deliberate use of the AWWA M-36 water accounting methodology described in Appendix D. Similarly, the goal associated with reduced summertime water demand will be characterized and tracked as customer water use and total distribution system demanded are measured. A summary of the data collection and assessment that will occur to monitor and assess the benefits of the various selected measures and programs is presented in Table 13.

Table 13
Summary of Monitoring and Assessment Data Collection

Type of Data	Timing			Uses		
	Hourly	Daily	Monthly	Distribution System Water Loss Metrics[1]	System Wide Water Use Metrics[2]	Customer Demand Management
Water to Distribution		X	X	X	X	
Metered Unbilled Water Use			X	X	X	
Metered Customer Water Use			X	X	X	
Unmetered Authorized Water Use (bulk water sales, construction water, etc.)			X	X		
Estimates of Other Authorized or Known Uses (e.g., losses due to leaks, line flushing, etc.)			X	X		
Individual and Categorized Water Customer Water Use (through tracking of financial data)			X	X	X	X
Number of Leaks Found/Repaired			X	X		
Number of Customer High Use Accounts Identified			X			X

[1] Includes: (all are monthly) water to distribution, water sold, non-revenue water, authorized unbilled consumption, estimated apparent losses, estimated current monthly water loss (see Appendix D)

[2] Includes: (all are monthly) water sold per single residential connection, water sold per multi-tap residential connection, water sold per commercial connection, number of connections, highest water use connections (top 50)

Updating the Plan

The City's Water Conservation and Efficiency Plan will be reviewed and updated informally throughout the planning period (i.e., until the end of 2022). The City may choose to formally update the Plan whenever it is valuable to the organization dependent on financial needs, and/or substantial changes to its current operating conditions. At the very least, the Plan will be updated in 7 years, or by the end of 2022.

Plan Public Review and Comment

Lamar's Water Conservation and Efficiency Plan Update has undergone public review in accordance with the requirements of the State regulations for a period of 60 days – from _____ 2019 to _____ 2019. A notice of the public review will be printed in the local newspaper. A copy of the draft Plan will be made available to the public at the City's offices and online. Public comments were received and the comments will be attached on completion.

Appendix A – Letter Report Including Supplemental Data, Calculations and Analysis - Prepared by Helton & Williamsen, P.C.

HELTON & WILLIAMSEN, P.C.
CONSULTING ENGINEERS IN WATER RESOURCES
7353 S. ALTON WAY, SUITE A-125
CENTENNIAL, CO 80112
PHONE (303) 792-2161

June 28, 2019

Mr. John Sutherland
Administrator, City of Lamar
102 E. Parmenter St.
Lamar, CO 81052

Subject: Supplement to Draft Water Conservation Plan Update, City of Lamar

Dear John,

This letter has been prepared to supplement the *Draft Water Conservation Plan Update* for the City of Lamar (Lamar), which was prepared by Sustainable Practices in December, 2015. Lamar has requested that we, Helton & Williamsen, P.C., review and comment on the *Draft Water Conservation Plan Update* (hereinafter, the "draft Water Conservation Plan"). Certain aspects of the plan need to be updated, expanded upon, or corrected. This letter highlights some of the principal items we have identified. As a supplement to the draft Water Conservation Plan, this letter shall control if any inconsistencies exist between the two documents. This letter may be refined or added to if/as we conduct further review.

This letter covers mainly the "Water Supply System Characteristics" and "Water Use—Current and Future" sections of the draft Water Conservation Plan. Page numbers, tables and figures referred to herein correspond to the draft Water Conservation Plan. In preparing this Supplement we have also relied upon the City of Lamar's *Comprehensive Water Plan – Final Report* (September 2007)[1], the decrees and engineering reports in Lamar's various water court actions, and our knowledge of Lamar's water system, water rights, and plans for augmentation, which we have gained by representing Lamar for the past twenty-plus years.

WATER SUPPLY AND WATER RIGHTS

This section offers additional detail, and in some cases, corrects details, over the draft Water Conservation Plan. The City of Lamar provides potable water supplies to customers located in and near the city from groundwater pumped by wells in the Clay Creek Alluvial Well Field. Non-potable water supplies are provided from other alluvial wells and surface water sources for irrigation of city parks, golf course, ball fields, and cemeteries and construction/ industrial purposes. The Clay Creek Alluvial Well Field is recharged from water delivered by the

[1] Prepared by Felt, Monson, & Culichia, LLC; Helton & Williamsen, P.C.; and The Engineering Company, September, 2007.

Fort Bent Ditch to a recharge site (the "Clay Creek Recharge Site") centered near the wells. This recharge site has been in operation since 1973 and ground water levels are monitored to document effectiveness of the recharge site. Annually Lamar removes sediment from the Clay Creek Recharge Site to maintain effectiveness of the site. Surface water in the recharge site can be pumped from the recharge site to the Spreading Antlers Golf Course and Fairmont Cemetery for irrigation. **Map 1** shows the location of the Clay Creek Recharge Site, water supply, treatment, storage, wastewater disposal, and other pertinent structures and landmarks.

The City of Lamar owns 3,199.6 shares of Fort Bent Ditch Company stock out of 11,651.2 shares outstanding, 350 shares of Lamar Canal Company stock out of 26,127 shares outstanding, and 129.2 preferred shares of Lower Arkansas Water Management Association (LAWMA) stock. The Fort Bent Ditch and Lamar Canal divert native flows and stored water regulated in John Martin Reservoir from the Arkansas River near Lamar. LAWMA provides water supplies for augmentation of depletions caused by wells and other structures in the lower Arkansas River basin and has a portfolio of changed water rights and decrees. The decrees and plans for augmentation have been established and used for the maximum utilization of Lamar's water rights and water supplies.

Following are descriptions of Lamar's significant water rights and plans for augmentation:

Civil Action No. 418 – This case adjudicated the water rights on April 21, 1959 for 20 wells constructed in the Clay Creek Alluvial Well Field.

Case Nos. W-1051, W-706, W-1609, and W-4014 – These decrees adjudicated the water rights for 12 wells in the Clay Creek alluvial Well Field and 3 Dakota and Cheyenne bedrock aquifer wells.

Case No. W-4015 – On May 28, 1978, a plan for augmentation was approved in Case No. W-4015 for 21 of Lamar's wells located in the Clay Creek aquifer. The plan involves recharging the Clay Creek alluvial aquifer with deliveries of water from the Fort Bent Ditch and pumping the wells for potable water supplies. The decree changed the use of 386 Fort Bent Ditch Company shares from irrigation to recharge purposes and approved the use of Lamar's allocation of Fryingpan-Arkansas Project water for recharge purposes. The decree limits the use of the identified wells to the volume of water delivered to the recharge area less an allowance for evaporation.

Case No. 02CW181 – In Case No. 02CW181, the Lower Arkansas Water Management Association (LAWMA) obtained a decree approving a change of water rights and plan for augmentation involving water rights in 7 irrigation canals. Included were 923 Fort Bent Ditch Company shares owned by Lamar and formerly used on 2 irrigated farms and 50 Lamar Canal Company shares owned by Lamar and formerly used on 1 farm.

Case No. 05CW107-A – This decree authorizes 1) a change of use from irrigation to municipal, recharge, augmentation and replacement purposes for 1,890.6 shares of Fort Bent Ditch Company stock owned by Lamar; 2) a change of use to include recharge use of the 923 shares of Fort Bent Ditch Company stock owned by Lamar and included in LAWMA's decree; and 3) an augmentation plan to replace depletions caused by the use of 4 wells for irrigation of cemeteries and parks and 1 well used for construction and maintenance activities. Water that is recharged but not pumped through a well returns to the Arkansas River. The decree authorizes Lamar to quantify the amount of recharged water returned to the river and receive a credit to replace historical return flow obligations or depletions caused by Lamar's wells. Also treated wastewater effluent, septic return flows, and lawn irrigation return flows that are quantified as fully consumable may be credited against historical return flow obligations or depletions caused by Lamar's wells. The decree also authorizes the use of water pumped from the Fort Bent Ditch for irrigation of the approximately 7 acres of ball fields winthin Lamar.

Case No. 05CW107-B – This decree involves an exchange of water available to Lamar's use of their interests in the Fort Bent Ditch Company from several points of delivery on the Arkansas River below the headgate of the Fort Bent Ditch upstream to: 1) the Fort Bent Ditch headgate, 2) John Martin Reservoir, and 3) Pueblo Reservoir. Lamar is cooperating with CWCB officials in attempting to establish a storage account in John Martin Reservoir for this purpose. Also Lamar is participating with the Southeastern Colorado Water Conservancy District in the promotion and development of the conduit from Pueblo Reservoir to Lamar. All of these measures would allow Lamar to use their water supply more efficiently by providing means to recapture Lamar's excess water that has returned to the Arkansas River for later use in its water system, for augmentation, or for recharge.

Case No. 13CW3060 - The plan for augmentation in this case uses water derived from the use of Lamar's Fort Bent Ditch water supplies to replace depletions caused by evaporation from three recreational ponds, formerly gravel mines, in Lamar and near the Arkansas River. Alternatively, Lamar may augment these depletions pursuant to LAWMA's decree in Case No. 17CW3000 using LAWMA preferred and common shares.

Annual Rule 14 Plans – Lamar has 32 wells diverting from the Clay Creek aquifer which qualify to be included in a Rule 14 Plan pursuant to the State Engineer's Amended Rules and Regulations Governing the Diversion and Use of Tributary Groundwater in the Arkansas River Basin. Annually Lamar transmits a detailed operating plan to the State Engineer for approval to show that the projected depletions caused by the wells will be replaced in time and amount by water supply sources available to Lamar. Lamar submits monthly detailed records to show that the net depletions caused by the 32 wells are replaced by net recharge accretions, treated wastewater effluent, lawn irrigation return flows, and direct deliveries from the Fort Bent Ditch through an augmentation station to the Arkansas River.

WATER USE

This section describes the volume of water Lamar's customers have used over the past several years. As described above, Lamar obtains water for its potable water system from groundwater (Clay Creek alluvium), and also irrigates several parks, baseball fields, two cemeteries, and a golf course with raw (untreated) water[2].

We were unable to replicate many of the annual pumping totals in the draft Water Conservation Plan. Therefore, the pumping and usage data described below are based on 1) customer billing data provided by Lamar, and 2) water rights accounting records, which are in turn based on monthly meter records provided by Lamar. We understand that the master meter, which measures all water coming into the water treatment plant from the Clay Creek Wellfield, was replaced in 2011, and the accuracy of the old meter was in question. Therefore, our analysis covers 2012-2018.

Table A is similar to Table 1 in the draft Water Conservation Plan. It displays Lamar's total raw water diversion, total water deliveries (billed potable and raw irrigation water), average numbers of customers (i.e., number of accounts or taps—throughout this Supplement, "Customers" means "Accounts" or "Taps", not population), and average daily use per account for 2012-2018. **Figure A** shows the water deliveries and the number of customer accounts graphically.

Table B displays the total water diverted for potable use, potable deliveries to customers, daily deliveries per customer, and apparent system losses on annual and seasonal (winter) bases. The winter, or non-irrigation season months, are December through February. The use during these months is the base or in-building use for the rest of the year; all usage greater than this base used is considered outdoor irrigation use in Lamar's monthly water rights accounting report. **Table B,** Column 5 shows that the annual average daily demand ranged from 356 gallons per customer per day in 2017 to 491 gallons per tap per day in 2012 (dry year); base in-building per-capita use was more steady, ranging between 56 and 61 gallons per capita per day (Column 12). **Figure B** demonstrates the average daily in-building use and the annual total potable use per customer/tap graphically. (**Figure B** is an update and revision of Figure 3 in the Water Conservation Plan; however, we do not know the origin of the data behind Figure 3.) It is noted that these data indicate very low *annual* system losses, but high *winter* system losses ranging from 35 to 45 percent. This is somewhat similar to the findings in the draft Water Conservation Plan. Also in our experience, inflow and infiltration into Lamar's sewer lines are high, with deliveries to the wastewater treatment facility reaching over twice the calculated indoor water use at times during the summer months. More effort is needed to identify any anomalies or errors in the annual vs. winter diversion and delivery data.

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[2] It is not clear whether the Water Conservation Plan includes the use of raw water for irrigation.

Finally, **Table C** is a condensed update of Table 4 in the draft Water Conservation Plan for 2012-2018. Sustainable Practices apparently obtained full billing records to identify the Government, Non-Profit, and Car Wash data in Table 4. The currently available data from Lamar includes only Residential and Commercial categories, where Commercial consists of all non-Residential water use (including raw water irrigation).

The drought year of 2012 was a high-demand year, demonstrated by **Tables A-C** and **Figures A** and **B**. Notwithstanding, it appears that demands may be trending downward slightly, as noted in the draft Water Conservation Plan. We understand that water sales have decreased over the past few years, due in part to the institution of a tiered water rate structure in 2016. The water rates appear to be encouraging conservation by Lamar's customers. We also understand that water sales continue to cover the costs of water treatment[3]. **Figure B** does not appear to show a significant trend in per-customer indoor use. Rather, the downward trend in overall use may be due to a combination of wetter years since 2012 (excepting 2018, which was somewhat hot and dry), fewer customers (active taps), and conservation in outdoor irrigation (possibly due to a combination of attention to irrigation by customers, changes in type and extent of irrigated landscaping, and the tiered water rate structure).

Discussion of Outdoor Water Demand

The draft Water Conservation Plan also describes consumptive use of outdoor landscaping (generally, lawns, gardens, trees, and shrubs). Figure 4 compares annual per capita daily water use with "Evapotranspiration". Evapotranspiration (ET) is the process by which plants consume water. Both natural (i.e., rainfall) and applied (i.e., irrigation) water contribute to ET. The Consumptive Water Requirement (CWR) is the total amount of water that a fully irrigated crop would consume (in this case, bluegrass and other plants commonly used in urban landscaping). The Consumptive Irrigation Requirement (CIR) is the net water demand by a crop after the contribution of rainfall. Figure 4 generally demonstrates that Lamar's overall water demand tends to increase in hot, dry years due to lawns and gardens needing more water (e.g., 2012).

We calculated the CWR and CIR for Kentucky bluegrass at Lamar[4] for the years 2011-2018. Our CIR values range from 25 inches in 2015 to about 28.5 inches in 2012, and are essentially the same shape as Figure 4 in the draft Water Conservation Plan. The ET values in Figure 4 are evidently related to lake evaporation, but the concept is accurate: both methods relate temperature and rainfall to water demand and demonstrate greater overall water demands in hot, dry years than in cooler, wetter years.

Finally, **Table D** shows the volumes of nonpotable water produced for irrigation, commercial, and industrial uses. These are the total volumes from various sources: 1) Fort Bent

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[3] This is an improvement over the condition described in the 2015 draft Water Conservation Plan, pg. 9.

[4] Climate data obtained for the Lamar NOAA climate station.

Ditch water used directly and through the Clay Creek Recharge Site for irrigation, 2) alluvial well water used for irrigation, and 3) alluvial well water sold in bulk for commercial and industrial uses. **Figure C** displays 1) CWR and CIR for Kentucky bluegrass at Lamar, and 2) annual raw water irrigation for 2012-2018 from **Table D**. We understand that raw water irrigation of parks, cemeteries, and the golf course has been discussed among City departments as an area for potential conservation. It should also be noted that less raw water was applied to irrigation in the 2012 drought year than in any year since, including 2018, indicating that the operators may have exercised more care that year due to the short water supply.

AUGMENTATION AND RECHARGE

In addition to the conservation measures recommended and/or highlighted in the draft Water Conservation Plan that Lamar has implemented, several factors have contributed to the successful operation of Lamar's plans for augmentation over the past few years. Successful management of augmentation and replacement supplies is an important aspect of the management of Lamar's overall water portfolio.

First, Lamar has taken advantage of the better water supplies since the droughts of 2002 and 2012, and generally dry conditions over the past 18 years. Total recharge at the Clay Creek Recharge Site has been greater than 2,000 acre-feet per year for the past three years. Due to the lagged nature of recharge accretions, the benefits of this effort are becoming evident in Lamar's plans for augmentation: at the time of the submittal of the 2019 Rule 14 Plan, we projected that recharge accretions alone will begin to replace monthly well depletions this year, whereas sewage and lawn irrigation return flows, LAWMA shares, and special augmentation releases from the Fort Bent Ditch have been relied upon heavily in past years to make up shortfalls. Recall also that one of the principal reasons for the recharge site was originally to *recharge* the aquifer from which Lamar pumps its water. The concerted effort to maximize recharge in the good water supply years will help Lamar have reliable water supply and recharge accretion credits to carry the city through drier years.

After the completion of Case No. 13CW3060 and Case No. 17CW3000, Lamar converted its LAWMA common shares to "preferred" shares. LAWMA endeavors to manage its water rights portfolio and pumping allocations so as to provide 1 acre-foot of depletion credit for each preferred share, each year. LAWMA requires preferred shares for un-interruptible depletions, such as pond and reservoir evaporation; this conversion made it possible for Lamar to fully augment the North Gateway Park Ponds with either LAWMA shares, return flows and recharge accretions, or both.

Lamar has re-piped two of its wells located near the Clay Creek Recharge Site into the water line that provides irrigation to the golf course and Fairmount Cemetery. This allows Lamar to use previously recharged, raw water for irrigation early in the season before surface water is delivered to the recharge site. In the past, Lamar had to provide higher-quality water from the southern wellfield for irrigation of these areas in the early season. This change allows the higher-quality water to be conserved for blending into the potable water supply for better overall drinking water quality.

CONCLUSION

This letter report provides additional information that we believe is lacking in the City of Lamar's draft Water Conservation Plan, as well as providing corrections to various statements or data in that report that we are unable to corroborate. Rather than editing the draft Water Conservation Plan (prepared by another consultant), we have prepared this Supplement to that report.

The City of Lamar has made numerous improvements over the last decade in its water distribution system. Lamar instituted its tiered water rate structure in 2016, which appears to be encouraging its residents and customers to conserve water in their outdoor irrigation practices. Both of these efforts appear to be successful in decreasing the annual volume of potable water used, as population over the past 4 years has held relatively steady (Column 11 of **Table B**).

Lamar has become more proactive in managing its surface water supplies to maximize recharge of the Clay Creek aquifer in recent years. This is benefitting the aquifer by "storing" water in the aquifer that can be withdrawn through the Clay Creek Wellfield later. Stated another way, Lamar is replacing its withdrawals from the aquifer—even over-replacing in the last few years—thereby preserving the aquifer from being depleted and providing water to be pumped in future, drier years when recharge supplies will be less. The success of this recharge is measured in 1) the depths to water in the Clay Creek aquifer wells, and 2) in the accretions to the Arkansas River of recharged water that offset depletions from past well pumping.

In the area of water rights, Lamar has assembled a portfolio of surface water rights, groundwater augmentation credits (LAWMA preferred shares), and plans for augmentation over the years that provide the water it needs to divert for recharge and irrigation as well as a more firm, flexible augmentation supply. Lamar is also active on the Fort Bent Ditch Board of Directors, meaning it has a voice in the ditch's operations and is aware of water rights and water supply issues affecting the ditch.

Lamar should continue to locate and repair leaks and faulty flow meters in order to more accurately assess the efficiency of its water distribution system. Water conservation in park, golf course, and cemetery irrigation should continue to be encouraged. Lamar should continue to support and promote the completion of the Arkansas Valley Conduit, which will provide clean, fully consumable Fryingpan-Arkansas Project water for potable and recharge uses at Lamar. Finally, Lamar should continue to promote the establishment of a special storage account in John Martin Reservoir for Colorado water users and explore other opportunities to obtain storage and change its unchanged water rights to municipal, augmentation, and recharge uses; all of which have the potential to firm and provide more flexibility in Lamar's water supplies.

Please contact us with any questions.

Sincerely yours,

HELTON & WILLIAMSEN, P.C.

Daniel J. Gillham, P.E.

Thomas A. Williamsen, P.E.

DJG/djg

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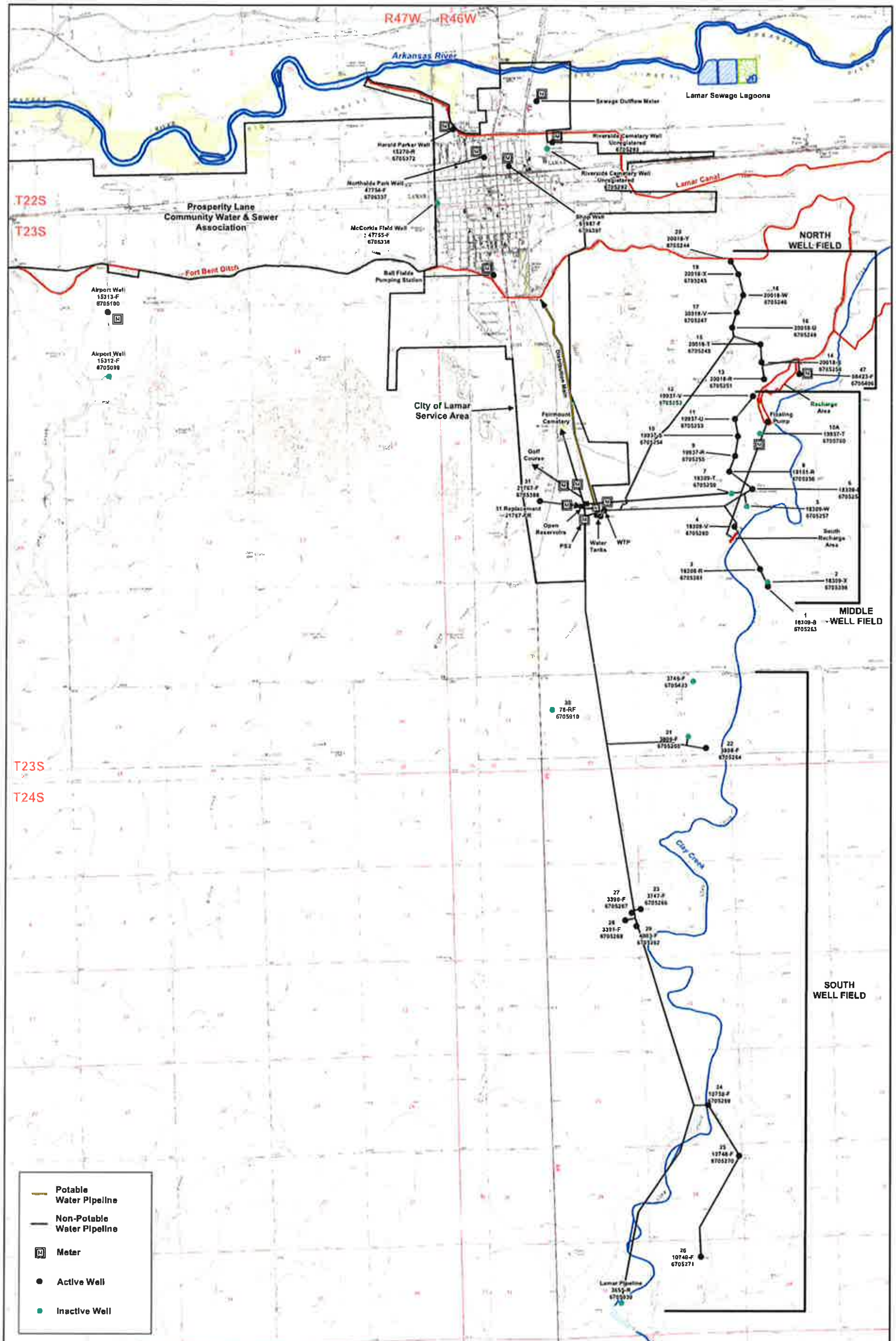


MAP 1

City of Lamar Water Service Area and Well Location Map

0 1,500 3,000 6,000

Scale in Feet

N

Helton & Williamsen, P.C.

Drawn by: Andy Olson

Checked by:

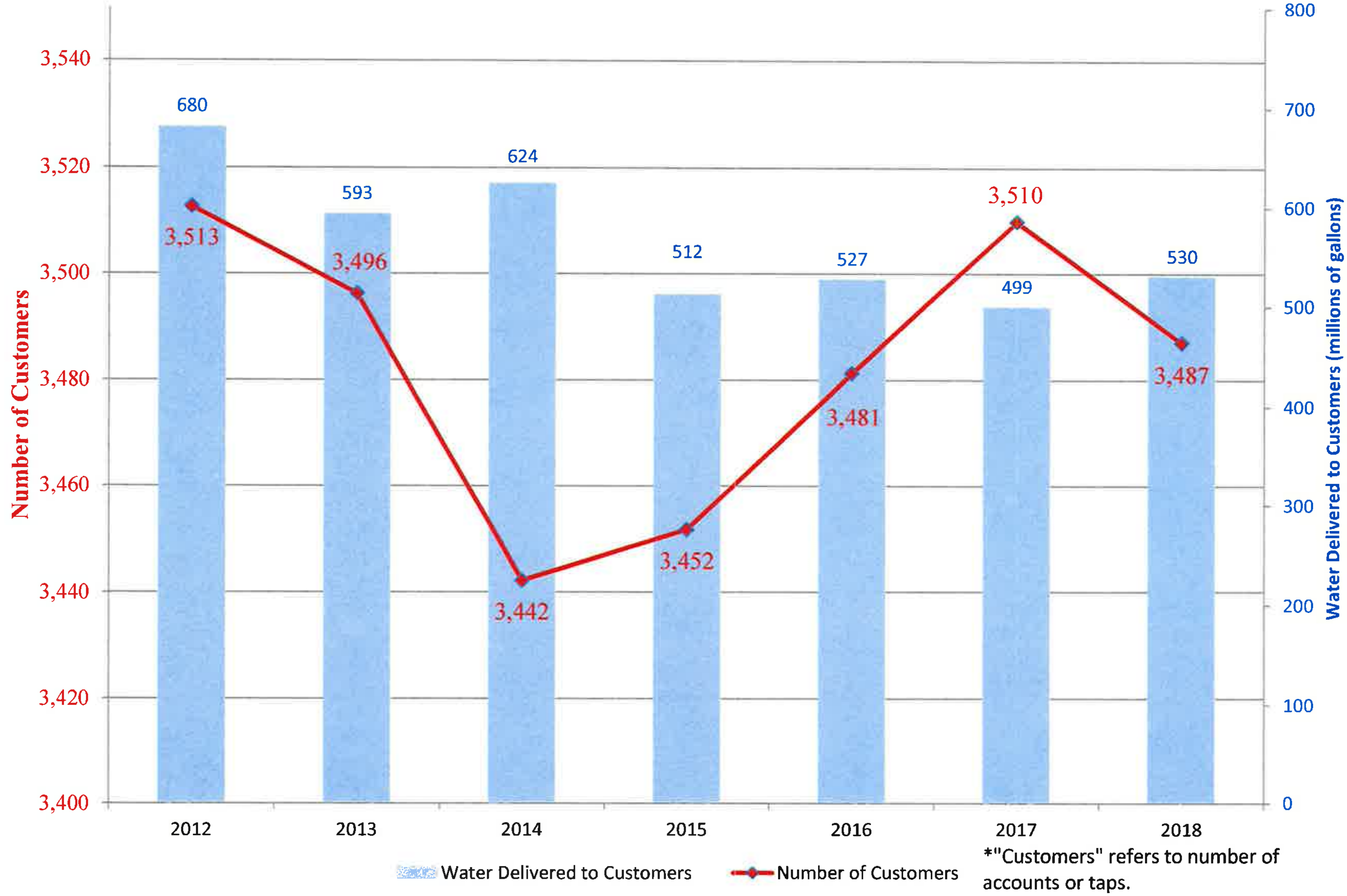
Job No. L1002

Date: 6/18/2008

File: Service_Area_Map1.mxd

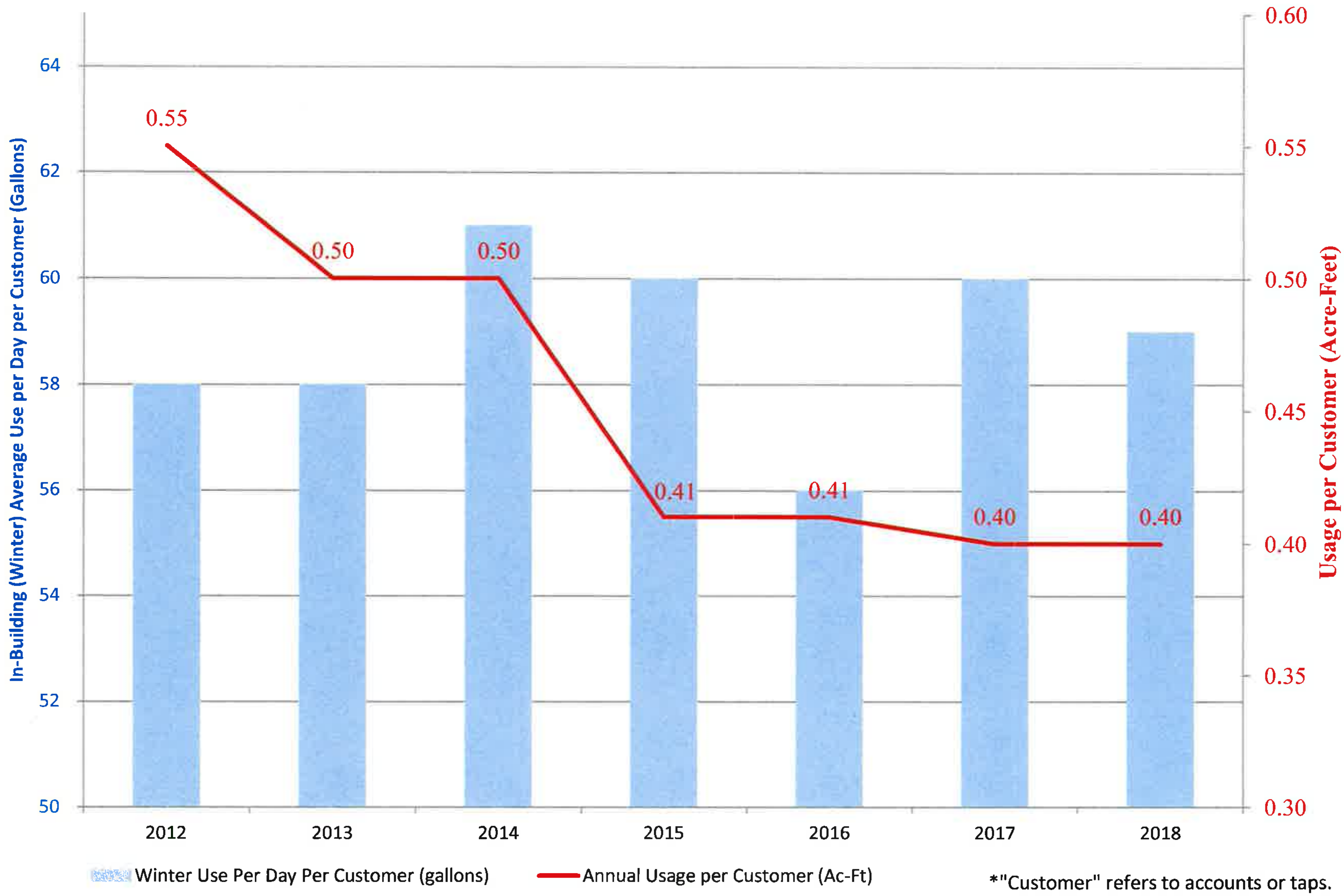
Rev. Date: 6/27/2018

Figure A
City of Lamar Water - Production & Customer Base*



*"Customers" refers to number of accounts or taps.

Figure B
Average Daily and Annual Potable Usage Per-Customer*



*"Customer" refers to accounts or taps.

Figure C

Lamar NOAA Station - Bluegrass Water Requirements and Raw Irrigation Water Used

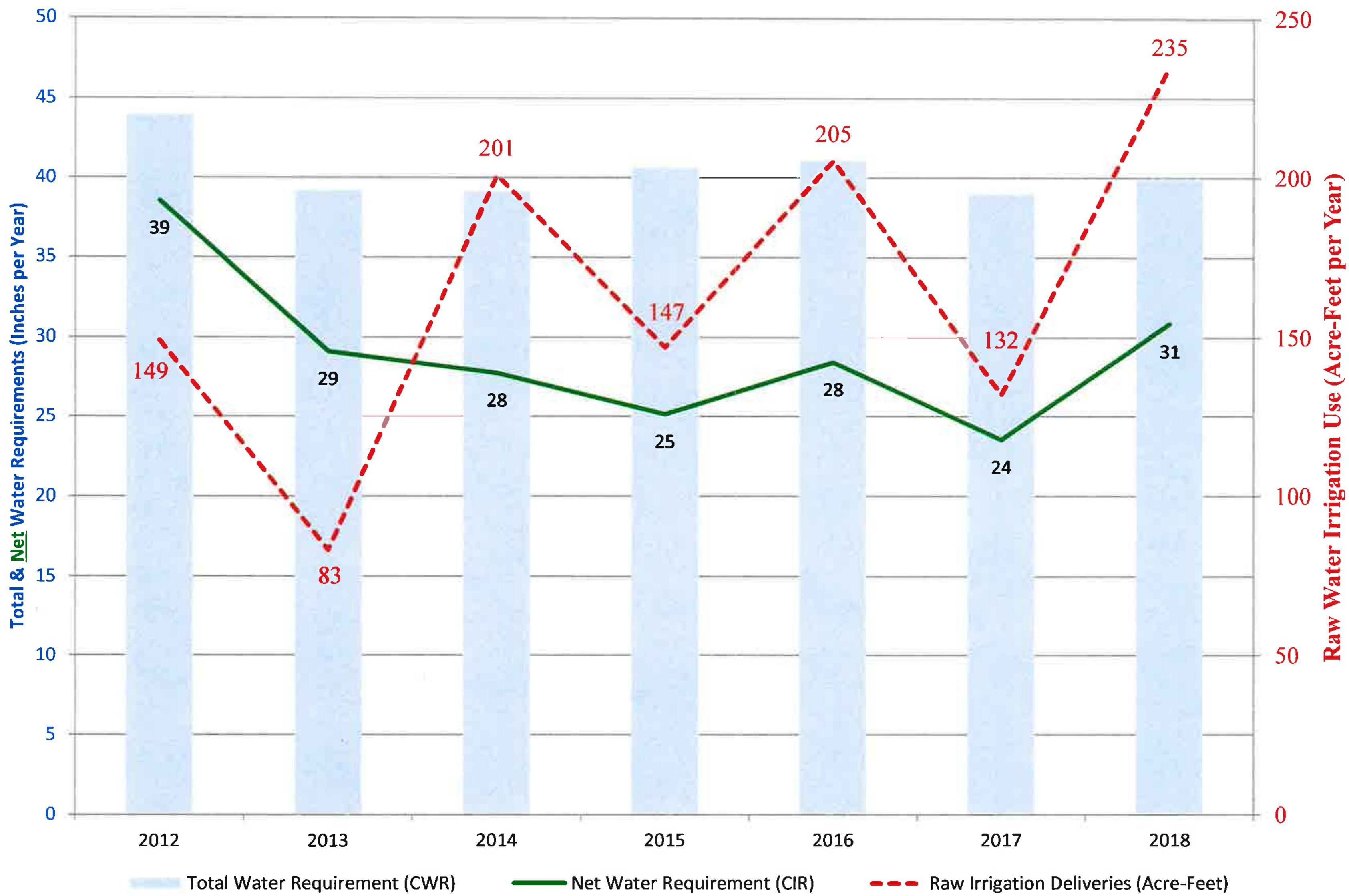


Table A
City of Lamar Water Usage Data
(Values in Acre-Feet)

Year (1)	Total Raw Water Diverted (2)	Total Water Delivered to Customers (3)	Avg. No. of Customers (4)	Annual Avg. Daily Delivery per Customer (GPD/Cust) (5)
2012	2,270	2,086	3,513	529
2013	1,869	1,821	3,496	465
2014	1,906	1,914	3,442	496
2015	1,804	1,570	3,452	406
2016	1,844	1,618	3,481	414
2017	1,679	1,531	3,510	389
2018	1,920	1,626	3,487	416

Column Notes:
2. Includes groundwater and surfacewater diverted for potable and nonpotable uses.
3. Includes non-potable water used for irrigation of parks, cemeteries, and golf course, and for bulk water sold for commercial and industrial uses.
4. "Customers" refers to accounts or taps.
5. Total Use ÷ Number of Customers ÷ days per year, converted to gallons.

Table B
City of Lamar Potable Water Usage
(Values in Acre-Feet)

	Annual (January-December)					Winter (December-February)						
Year	Raw Water Diverted for Potable Uses	Potable Water Delivered to Customers	Avg. No. of Customers	Avg. Daily Potable Delivery per Customer (GPD/Cust)	Apparent Annual System Loss	Winter Potable Production	Winter Potable Water Delivered	Avg. No. of Customers In Winter	Winter Avg. Daily Use per Customer (GPD/Cust)	Approximate Population Served	Average Daily Use per Capita (GPC/day)	Apparent Winter System Loss
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
2012	2,121	1,937	3,513	491	9%	250	139	2,913	171	8,509	58	45%
2013	1,786	1,738	3,496	444	3%	230	135	2,898	169	8,429	58	41%
2014	1,705	1,714	3,442	444	-1%	232	139	2,896	174	8,261	61	40%
2015	1,657	1,423	3,452	368	14%	243	137	2,897	171	8,199	60	44%
2016	1,639	1,412	3,481	361	14%	230	127	2,904	157	8,216	56	45%
2017	1,547	1,399	3,510	356	10%	213	138	2,915	171	8,254	60	35%
2018	1,684	1,391	3,487	356	17%	233	135	2,921	167	8,254	59	42%

Column Notes:
1. Calendar Year
2. Total Clay Creek Wellfield Pumping measured by master meter.
3. Treated water delivered. Calculated as Lamar's records of total water deliveries, minus water produced for raw irrigation and raw commercial uses.
4. Average monthly number of customers (aka, accounts or taps) provided by City of Lamar.
5. Col. 3 ÷ Col. 4 ÷ Days in Year, converted to gallons.
6. (Col. 2 - Col. 3), ÷ Col. 2.
7. Same as Col. 2 for December-February. (Consecutive months: December of previous year through February of year of Col. 1)
8. Same as Col. 3 for December-February.
9. Same as Col. 4 for December-February.
10. Same as Col. 5 for December-February.
11. Approximate population obtained from Water Conservation Plan (2012-2014) and http://worldpopulationreview.com/us-cities/lamar-co-population/ (2015-2018). 2015-2018 is population plus approximately 653 persons living outside the city limits but served by Lamar's water system, as in the Water Conservation Plan. 2018 set equal to 2017, the last year of available data.
12. Col. 3 ÷ Col. 4 ÷ Days Dec.-Feb., converted to gallons.
13. (Col. 7 - Col. 8), ÷ Col. 7.

Note on Columns 6 and 13: more information is needed to better understand system losses and non-revenue water. These data suggest that the volumetric loss rates in Lamar's potable water distribution system are higher in December-February than for the other 9 months of the year, which is likely not the case.

Table C
City of Lamar Water Usage Data by Customer Type
(Values in Acre-Feet)

Year	Total Raw Water Diverted	Total Water Delivered	Avg. No. of Customers	Water Delivered to Residential Customers	Avg. No. of Residential Customers	Average Delivery per Residential Customer	Water Delivered to Commercial Customers	Avg. No. of Commercial Customers	Average Delivery per Commercial Customer
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
2012	2,270	2,086	3,513	1,253	2,919	0.43	833	594	1.40
2013	1,869	1,821	3,496	1,015	2,905	0.35	806	591	1.36
2014	1,906	1,914	3,442	1,022	2,889	0.35	893	553	1.61
2015	1,804	1,570	3,452	964	2,891	0.33	606	561	1.08
2016	1,844	1,618	3,481	987	2,920	0.34	630	561	1.12
2017	1,679	1,531	3,510	919	2,946	0.31	611	564	1.08
2018	1,920	1,626	3,487	990	2,918	0.34	636	569	1.12

Column Notes:

(Data obtained from the City of Lamar for Cols. 3-8.)

2. Includes water diverted by the Clay Creek Wellfield for potable uses; from the Fort Bent Ditch directly and through the Clay Creek Recharge Site for ballfield, cemetery, and golf course irrigation; from individual wells for park and cemetery irrigation; and from an individual well for bulk water sales (commercial and industrial uses).
3. Includes all water delivered for potable and nonpotable uses.
4. Average monthly number of customers (aka accounts or taps) during the year.
5. Potable water delivered to Residential Customers.
6. Average monthly number of Residendial Customers (aka accounts or taps).
7. Col. 5 ÷ Col. 6.
8. Potable water delivered to Commerical Customers. Includes all non-Residential customers of potable and nonpotable water.
9. Average monthly number of Commercial Customers (aka accounts or taps).
10. Col. 8 ÷ Col. 9.

Table D
City of Lamar Water Production for Nonpotable Uses
(Values in Acre-Feet)

Year	Raw Water Diverted for Nonpotable Uses	Raw Water Irrigation	Commercial/ Industrial/ Bulk Water Sales
(1)	(2)	(3)	(4)
2012	149	144	5
2013	83	76	7
2014	201	197	3
2015	147	142	5
2016	205	203	3
2017	132	129	3
2018	235	232	4

Column Notes:

2. Includes raw water diverted from the Fort Bent Ditch directly and through the Clay Creek Recharge Site for ballfield, cemetery, and golf course irrigation; from individual wells for park and cemetery irrigation; and from an individual well for bulk water sales (commercial and industrial uses).

3. Includes raw water diverted from the Fort Bent Ditch directly and through the Clay Creek Recharge Site for ballfield, cemetery, and golf course irrigation; and from individual wells for park and cemetery irrigation.

4. Includes raw water from an individual well for bulk water sales (commercial and industrial uses).

Appendix B – CRS 37-60-126

COLORADO REVISED STATUTES

*** This document reflects changes current through all laws passed at the First Regular Session
of the Sixty-Ninth General Assembly of the State of Colorado (2013) ***

TITLE 37. WATER AND IRRIGATION
WATER CONSERVATION BOARD AND COMPACTS
ARTICLE 60.COLORADO WATER CONSERVATION BOARD
PART 1. GENERAL PROVISIONS

C.R.S. 37-60-126 (2013)

37-60-126. Water conservation and drought mitigation planning - programs - relationship to state assistance for water facilities - guidelines - water efficiency grant program - repeal

(1) As used in this section and section 37-60-126.5, unless the context otherwise requires:

(a) "Agency" means a public or private entity whose primary purpose includes the promotion of water resource conservation.

(b) "Covered entity" means each municipality, agency, utility, including any privately owned utility, or other publicly owned entity with a legal obligation to supply, distribute, or otherwise provide water at retail to domestic, commercial, industrial, or public facility customers, and that has a total demand for such customers of two thousand acre-feet or more.

(c) "Grant program" means the water efficiency grant program established pursuant to subsection (12) of this section.

(d) "Office" means the office of water conservation and drought planning created in section 37-60-124.

(e) "Plan elements" means those components of water conservation plans that address water-saving measures and programs, implementation review, water-saving goals, and the actions a covered entity shall take to develop, implement, monitor, review, and revise its water conservation plan.

(f) "Public facility" means any facility operated by an instrument of government for the benefit of the public, including, but not limited to, a government building; park or other recreational facility; school, college, university, or other educational institution; highway; hospital; or stadium.

(g) "Water conservation" means water use efficiency, wise water use, water transmission and distribution system efficiency, and supply substitution. The objective of water conservation is a long-term increase in the productive use of water supply in order to satisfy water supply needs without compromising desired water services.

(h) "Water conservation plan", "water use efficiency plan", or "plan" means a plan adopted in accordance with this section.

(i) "Water-saving measures and programs" includes a device, a practice, hardware, or equipment that reduces water demands and a program that uses a combination of measures and incentives that allow for an increase in the productive use of a local water supply.

(2) (a) Each covered entity shall, subject to section 37-60-127, develop, adopt, make publicly available, and implement a plan pursuant to which such covered entity shall encourage its domestic, commercial, industrial, and public facility customers to use water more efficiently. Any state or local governmental entity that is not a covered entity may develop, adopt, make publicly available, and implement such a plan.

(b) The office shall review previously submitted conservation plans to evaluate their consistency with the provisions of this section and the guidelines established pursuant to paragraph (a) of subsection (7) of this section.

(c) On and after July 1, 2006, a covered entity that seeks financial assistance from either the board or the Colorado water resources and power development authority shall submit to the board a new or revised plan to meet water conservation goals adopted by the covered entity, in accordance with this section, for the board's approval prior to the release of new loan proceeds.

(3) The manner in which the covered entity develops, adopts, makes publicly available, and implements a plan established pursuant to subsection (2) of this section shall be determined by the covered entity in accordance with this section. The plan shall be accompanied by a schedule for its implementation. The plans and schedules shall be provided to the office within ninety days after their adoption. For those entities seeking financial assistance, the office shall then notify the covered entity and the appropriate financing authority that the plan has been reviewed and whether the plan has been approved in accordance with this section.

(4) A plan developed by a covered entity pursuant to subsection (2) of this section shall, at a minimum, include a full evaluation of the following plan elements:

(a) The water-saving measures and programs to be used by the covered entity for water conservation. In developing these measures and programs, each covered entity shall, at a minimum, consider the following:

(I) Water-efficient fixtures and appliances, including toilets, urinals, clothes washers, showerheads, and faucet aerators;

(II) Low water use landscapes, drought-resistant vegetation, removal of phreatophytes, and efficient irrigation;

(III) Water-efficient industrial and commercial water-using processes;

(IV) Water reuse systems;

(V) Distribution system leak identification and repair;

(VI) Dissemination of information regarding water use efficiency measures, including by public education, customer water use audits, and water-saving demonstrations;

(VII) (A) Water rate structures and billing systems designed to encourage water use efficiency in a fiscally responsible manner.

(B) The department of local affairs may provide technical assistance to covered entities that are local governments to implement water billing systems that show customer water usage and that implement tiered billing systems.

(VIII) Regulatory measures designed to encourage water conservation;

(IX) Incentives to implement water conservation techniques, including rebates to customers to encourage the installation of water conservation measures;

(b) A section stating the covered entity's best judgment of the role of water conservation plans in the covered entity's water supply planning;

(c) The steps the covered entity used to develop, and will use to implement, monitor, review, and revise, its water conservation plan;

(d) The time period, not to exceed seven years, after which the covered entity will review and update its adopted plan; and

(e) Either as a percentage or in acre-foot increments, an estimate of the amount of water that has been saved through a previously implemented conservation plan and an estimate of the amount of water that will be saved through conservation when the plan is implemented.

(4.5) (a) On an annual basis starting no later than June 30, 2014, covered entities shall report water use and conservation data, to be used for statewide water supply planning, following board guidelines pursuant to paragraph (b) of this subsection (4.5), to the board by the end of the second quarter of each year for the previous calendar year.

(b) No later than February 1, 2012, the board shall adopt guidelines regarding the reporting of water use and conservation data by covered entities and shall provide a report to the senate agriculture and natural resources committee and the house of representatives agriculture, livestock, and natural resources committee, or their successor committees, regarding the guidelines. These guidelines shall:

(I) Be adopted pursuant to the board's public participation process and shall include outreach to stakeholders from water providers with geographic and demographic diversity, nongovernmental organizations, and water conservation professionals; and

(II) Include clear descriptions of: Categories of customers, uses, and measurements; how guidelines will be implemented; and how data will be reported to the board.

(c) (I) No later than February 1, 2019, the board shall report to the senate agriculture and natural resources committee and the house of representatives agriculture, livestock, and natural resources committee, or their successor committees, on the guidelines and data collected by the board under the guidelines.

(II) This paragraph (c) is repealed, effective July 1, 2020.

(5) Each covered entity and other state or local governmental entity that adopts a plan shall follow the entity's rules, codes, or ordinances to make the draft plan available for public review and comment. If there are no rules, codes, or ordinances governing the entity's public planning process, then each entity shall publish a draft plan, give public notice of the plan, make such plan publicly available, and solicit comments from the public for a period of not less than sixty days after the date on which the draft plan is made publicly available. Reference shall be made in the public notice to the elements of a plan that have already been implemented.

(6) The board is hereby authorized to recommend the appropriation and expenditure of revenues as are necessary from the unobligated balance of the five percent share of the severance tax operational fund designated for use by the board for the purpose of the office providing assistance to covered entities to develop water conservation plans that meet the provisions of this section.

(7) (a) The board shall adopt guidelines for the office to review water conservation plans submitted by covered entities and other state or local governmental entities. The guidelines shall define the method for submitting plans to the office, the methods for office review and approval of the plans, and the interest rate surcharge provided for in paragraph (a) of subsection (9) of this section.

(b) If no other applicable guidelines exist as of June 1, 2007, the board shall adopt guidelines by July 31, 2007, for the office to use in reviewing applications submitted by covered entities, other state or local governmental entities, and agencies for grants from the grant program and from the grant program established in section 37-60-126.5 (3). The guidelines shall establish deadlines and procedures for covered entities, other state or local governmental entities, and agencies to follow in applying for grants and the criteria to be used by the office and the board in prioritizing and awarding grants.

(8) A covered entity may at any time adopt changes to an approved plan in accordance with this section after notifying and receiving concurrence from the office. If the proposed

changes are major, the covered entity shall give public notice of the changes, make the changes available in draft form, and provide the public an opportunity to comment on such changes before adopting them in accordance with subsection (5) of this section.

(9) (a) Neither the board nor the Colorado water resources and power development authority shall release grant or loan proceeds to a covered entity unless the covered entity provides a copy of the water conservation plan adopted pursuant to this section; except that the board or the authority may release the grant or loan proceeds notwithstanding a covered entity's failure to comply with the reporting requirements of subsection (4.5) of this section or if the board or the authority, as applicable, determines that an unforseen emergency exists in relation to the covered entity's loan application, in which case the board or the authority, as applicable, may impose a grant or loan surcharge upon the covered entity that may be rebated or reduced if the covered entity submits and adopts a plan in compliance with this section in a timely manner as determined by the board or the authority, as applicable.

(b) The board and the Colorado water resources and power development authority, to which any covered entity has applied for financial assistance for the construction of a water diversion, storage, conveyance, water treatment, or wastewater treatment facility, shall consider any water conservation plan filed pursuant to this section in determining whether to render financial assistance to such entity. Such consideration shall be carried out within the discretion accorded the board and the Colorado water resources and power development authority pursuant to which such board and authority render such financial assistance to such covered entity.

(c) The board and the Colorado water resources and power development authority may enter into a memorandum of understanding with each other for the purposes of avoiding delay in the processing of applications for financial assistance covered by this section and avoiding duplication in the consideration required by this subsection (9).

(10) Repealed.

(11) (a) Any section of a restrictive covenant or of the declaration, bylaws, or rules and regulations of a common interest community, all as defined in section 38-33.3-103, C.R.S., that prohibits or limits xeriscape, prohibits or limits the installation or use of drought-tolerant vegetative landscapes, or requires cultivated vegetation to consist wholly or partially of turf grass is hereby declared contrary to public policy and, on that basis, is unenforceable. This paragraph (a) does not prohibit common interest communities from adopting and enforcing design or aesthetic guidelines or rules that require drought-tolerant vegetative landscapes or regulate the type, number, and placement of drought-tolerant plantings and hardscapes that may be installed on the unit owner's property or property for which the unit owner is responsible.

(b) As used in this subsection (11):

(I) "Executive board policy or practice" includes any additional procedural step or burden, financial or otherwise, placed on a unit owner who seeks approval for a landscaping change by the executive board of a unit owners' association, as defined in section 38-33.3-103, C.R.S., and not included in the existing declaration or bylaws of the association. An "executive board policy or practice" includes, without limitation, the requirement of:

(A) An architect's stamp;

(B) Preapproval by an architect or landscape architect retained by the executive board;

(C) An analysis of water usage under the proposed new landscape plan or a history of water usage under the unit owner's existing landscape plan; and

(D) The adoption of a landscaping change fee.

(II) "Restrictive covenant" means any covenant, restriction, bylaw, executive board policy or practice, or condition applicable to real property for the purpose of controlling land use, but does not include any covenant, restriction, or condition imposed on such real property by any governmental entity.

(II.5) "Turf" means a covering of mowed vegetation, usually turf grass, growing intimately with an upper soil stratum of intermingled roots and stems.

(III) "Turf grass" means continuous plant coverage consisting of nonnative grasses or grasses that have not been hybridized for arid conditions which, when regularly mowed, form a dense growth of leaf blades and roots.

(IV) "Xeriscape" means the application of the principles of landscape planning and design, soil analysis and improvement, appropriate plant selection, limitation of turf area, use of mulches, irrigation efficiency, and appropriate maintenance that results in water use efficiency and water-saving practices.

(c) Nothing in this subsection (11) precludes the executive board of a common interest community from taking enforcement action against a unit owner who allows his or her existing landscaping to die or go dormant; except that:

(I) No enforcement action shall require that a unit owner water in violation of water use restrictions declared by the jurisdiction in which the common interest community is located, in which case the unit owner shall water his or her landscaping appropriately but not in excess of any watering restrictions imposed by the water provider for the common interest community;

(II) Enforcement shall be consistent within the community and not arbitrary or capricious; and

(III) In any enforcement action in which the existing turf grass is dead or dormant due to insufficient watering, the unit owner shall be allowed a reasonable and practical opportunity, as defined by the association's executive board, with consideration of applicable local growing seasons or practical limitations, to reseed and revive turf grass before being required to replace it with new sod.

(d) This subsection (11) does not supersede any subdivision regulation of a county, city and county, or other municipality.

(12) (a) (I) There is hereby created the water efficiency grant program for purposes of providing state funding to aid in the planning and implementation of water conservation plans developed in accordance with the requirements of this section and to promote the benefits of water efficiency. The board is authorized to distribute grants to covered entities, other state or local governmental entities, and agencies in accordance with its guidelines from the moneys transferred to and appropriated from the water efficiency grant program cash fund, which is hereby created in the state treasury.

(II) Moneys in the water efficiency grant program cash fund are hereby continuously appropriated to the board for the purposes of this subsection (12) and shall be available for use until the programs and projects financed using the grants have been completed.

(III) For each fiscal year beginning on or after July 1, 2010, the general assembly shall appropriate from the fund to the board up to five hundred thousand dollars annually for the purpose of providing grants to covered entities, other state and local governmental entities, and agencies in accordance with this subsection (12). Commencing July 1, 2008, the general assembly shall also appropriate from the fund to the board fifty thousand dollars each fiscal year to cover the costs associated with the administration of the grant program and the requirements of section 37-60-124. Moneys appropriated pursuant to this subparagraph (III) shall remain available until expended or until June 30, 2020, whichever occurs first.

(IV) Any moneys remaining in the fund on June 30, 2020, shall be transferred to the severance tax operational fund described in section 39-29-109 (2) (b), C.R.S.

(b) Any covered entity or state or local governmental entity that has adopted a water conservation plan and that supplies, distributes, or otherwise provides water at retail to customers may apply for a grant to aid in the implementation of the water efficiency goals of the plan. Any agency may apply for a grant to fund outreach or education programs aimed at demonstrating the benefits of water efficiency. The office shall review the applications and make recommendations to the board regarding the awarding and distribution of grants to applicants who satisfy the criteria outlined in this subsection (12) and the guidelines developed pursuant to subsection (7) of this section.

(c) This subsection (12) is repealed, effective July 1, 2020.

HISTORY: Source: L. 91: Entire section added, p. 2023, § 4, effective June 4.L. 99: (10) repealed, p. 25, § 3, effective March 5.L. 2003: (4)(g) amended and (11) added, p. 1368, § 4, effective April 25.L. 2004: Entire section amended, p. 1779, § 3, effective August 4.L. 2005: (11) amended, p. 1372, § 1, effective June 6; (1), (2)(b), and (7) amended and (12) added, p. 1481, § 1, effective June 7.L. 2007: (1)(a), (2)(a), (5), (7), and (12) amended, p. 1890, § 1, effective June 1.L. 2008: IP(4) amended, p. 1575, § 30, effective May 29;

(12)(a) amended, p. 1873, § 14, effective June 2.L. 2009: (12)(a) amended, (HB 09-1017), ch. 297, p. 1593, § 1, effective May 21; (9)(a) amended, (SB 09-106), ch. 386, p. 2091, § 3, effective July 1.L. 2010: (4)(a)(I) and (9)(a) amended and (4.5) added, (HB 10-1051), ch. 378, p. 1772, § 1, effective June 7; (12)(a)(III), (12)(a)(IV), and (12)(c) amended, (SB 10-025), ch. 379, p. 1774, § 1, effective June 7.L. 2013: (11)(a), (11)(b)(III), IP(11)(c), (11)(c)(I), and (11)(c)(III) amended and (11)(b)(II.5) and (11)(d) added, (SB 13-183), ch. 187, p. 756, § 1, effective May 10; (6) and (12)(a)(IV) amended, (SB 13-181), ch. 209, p. 873, § 24, effective May 13.

Editor's note: Subsection (12) was originally enacted as subsection (13) in House Bill 05-1254 but was renumbered on revision for ease of location.

Cross references: (1) In 1991, this entire section was added by the "Water Conservation Act of 1991". For the short title and the legislative declaration, see sections 1 and 2 of chapter 328, Session Laws of Colorado 1991.

(2) For the legislative declaration contained in the 2004 act amending this section, see section 1 of chapter 373, Session Laws of Colorado 2004.

Appendix C – Current Water Rates

15. The City of Lamar shall impose and collect the following fees for Water and Wastewater to be charged at the rates set forth in the schedules provided below

2019

Water Usage Rates	Monthly Minimum Use (in cf)	2018 Fixed Fee
In City		
Residential 3/4" and 1" Meters	500	11.40
Commercial:		
3/4" Meter	510	12.40
1" Meter	840	20.50
1-1/4" Meter	1,150	28.45
1-1/2" Meter	1,590	39.00
2" Meter	2,665	65.00
3" Meter	5,330	130.05
4" Meter	8,333	204.00
6" Meter	16,607	405.00
Outside City		
Residential 3/4" Meter	500	22.80
Commercial 3/4" Meter	510	24.80
1" Meter	840	41.00
1-1/4" Meter	1,150	56.90
1-1/2" Meter	1,590	78.00
2" Meter	2,665	130.00
3" Meter	5,330	260.10
4" Meter	8,333	408.00
6" Meter	16,607	810.00

CHARGES FOR USE ABOVE THE MONTHLY MINIMUM USAGE (PER CUBIC FOOT)

Residential 3/4" and 1" Meter

Charges for use greater than Minimum Use and not more than 1,300 cubic feet per month

	Fee per 1,000 Cubic Feet
In City	18.00
Outside City of Lamar Boundary	36.00

Charges for use greater than 1,300 cubic feet in one month

	Fee per 1,000 Cubic Feet
In City	21.90
Outside City of Lamar Boundary	43.80

Rates for usage greater than the Minimum in a month

	Fee per 1,000 Cubic Feet
Commercial 3/4" Meter	24.30
1" Meter	17.50
1-1/4" Meter	17.00
1-1/2" Meter	17.00
2" Meter	17.00
3" Meter	17.00
4" Meter	17.00
6" Meter	17.00

Wastewater Collection & Treatment Rates

Residential

In City (no volume charge)	10.32
Outside City of Lamar Boundary (no volume charge)	20.64

Commercial

Volume charge is calculated as the rate ($)/1,000 cubic feet for usage exceeding 900 cf.

In City (Same monthly fixed fee as above + a volume charge)	5.67
Outside City Boundary (Same monthly fixed fee as above + a volume charge)	11.34

FACILITY INVESTMENT FEE	2019 WATER	2019 SEWER
Customers with a 3/4" Meter shall pay per month	11.50	9.00
1" Meter	18.59	9.00
1-1/4" Meter	22.32	9.00
1-1/2" Meter	37.82	9.00
2" Meter	38.82	9.00
3" Meter	68.14	9.00
4" Meter	100.67	9.00
6" Meter	192.83	9.00
Master Meter-where water is sold to a District the fee shall be $9.00 per month times the number of District water customers.	15.00	9.00

Appendix D – Relevant City Water Regulations

RESOLUTION No. 19-04-02

A RESOLUTION OF THE CITY OF LAMAR, COLORADO ADOPTING MODIFIED STAGE 1 MANDATORY WATER RESTRICTIONS

Whereas, pursuant to LMC § 13-2-70(a)(b) the City Administrator, Public Works Director, Water & Wastewater Department Superintendent and the Water Board for the City of Lamar, Colorado have determined that water availability and quality conditions in southeast Colorado have improved over the past two years, but that water remains a scarce and precious resource; and

Whereas, the City Council of the City of Lamar, Colorado has through previous action, implemented new water rates that are intended to send a clear pricing signal to users of the real cost of procuring water in southeast Colorado; and

Whereas, faced with a continuing need to use its water resources wisely, the City Administrator, Public Works Director, Water & Wastewater Department Superintendent, the Water Board and the Lamar City Council all finds that it is prudent at this time to ask our citizens to continue to use basic water conservation practices; and

Whereas, it is hereby found and determined that the meeting at which this Resolution is adopted to be open to the public as required by law.

NOW, THEREFORE, BE IT RESOLVED BY THE CITY COUNCIL OF THE CITY OF LAMAR, COLORADO THAT:

1. The following Modified Stage 1: Mandatory Water Use Restrictions are hereby implemented for all users of the municipal water system:

    Restricted days: Watering of landscape (i.e. flowers, flower beds, lawns, trees, shrubs, vegetable gardens and plants) shall be permitted on every day of the week.

    Restricted Hours: Landscape watering shall be permitted only before 11:00 a.m. and after 6:00 p.m.

    Restricted Water Uses: Property owners shall be required to monitor their irrigation systems to limit over-spray of landscape water onto impervious concrete surfaces such as sidewalks, driveways, streets or alleyways.
    No washing of impervious surfaces such as parking lots and driveways.

Limited Water Uses: **(1)** Washing of private vehicles is permitted only by use of a hose with a positive shutoff nozzle or by use of a bucket.

2. The within Stage 1 mandatory water use restrictions are effective as of the date of adoption, by the City of Lamar City Council.

3. The within Stage 1 mandatory water use restrictions shall remain in effect until modified by subsequent resolution adopted by the City Council pursuant to LMC § 13-2-70.

INTRODUCED, PASSED AND ADOPTED this 22nd day of April, 2019.

CITY OF LAMAR, COLORADO, a
Home Rule Municipal Corporation

By: ______________________
ROGER STAGNER, Mayor

CITY OF LAMAR SEAL STATE OF COLORADO

Attest:

By: ______________________
LINDA WILLIAMS, City Clerk

Appendix E – AWWA M-36 Methodology

Chapter **2**

Conducting the Water Audit

This chapter details the best practice IWA/AWWA Water Audit Method published in *Performance Indicators for Water Supply Services* in 2000 for quantifying customer consumption and volumes of real and apparent losses.[1] This method allows the operator to reveal the destinations of water supplied throughout the distribution system and to quantify volumes of consumption and loss. AWWA's Water Loss Control Committee recommends that drinking water utilities employ this method to conduct a water audit. The auditing process occurs at three levels, each adding increasing refinement.

1. Top-down approach: the initial desktop process of gathering information from existing records, procedures, data, and other information systems.

2. Component analysis: a technique that models leakage volumes based on the nature of leak occurrences and durations. This technique can also be used to model various occurrences of apparent losses by looking at the nature and duration of the occurrence.

3. Bottom-up approach: validating the top-down results with actual field measurements such as leakage losses calculated from integrated zonal or district metered area (DMA)* night flows. Similarly, physical inspections of customer properties can uncover apparent losses from defective or vandalized customer meters, or unauthorized consumption. Process flowcharting of customer billing systems can be used to identify systematic billing errors.

The top-down approach is the recommended starting point for water utilities compiling their initial water audit, and it is described in this chapter. Descriptions of bottom-up approaches and component analysis are given in Chapters 3 and 5.

* A DMA is a small zone of the distribution system—typically encompassing between 500–3,000 customer service connections, with measured supply input flow of sufficiently small volume that individual leakage events can be quantified, thereby guiding leak detection deployment decisions. See Chapters 4 and 5 for details.

The water audit addresses the questions "How much water is being lost?" and "How much are these losses costing the water utility?" With relatively modest effort, the top-down method can provide a good preliminary assessment of water loss standing and insight to the quality of available water supply data. The top-down audit also helps to identify components that require further validation. Ultimately, the water auditor can better validate and improve the accuracy of the water audit when it is augmented by component analysis, bottom-up field measurements, or both.

THE WATER AUDIT

The water auditing process is an effective tool available to utilities to quantify consumption and losses that occur in the distribution system and the management processes of the water utility. The auditing process is a revealing undertaking that provides great insight to the auditor on the type and amounts of loss occurring in the utility. Launching a water audit also often begins the culture change necessary to focus utility employees on water efficient practices. The top-down water audit is assembled in two steps: (1) quantifying, via measurement or estimation, individual water consumption and water loss components, and (2) undertaking the water balance calculation. This chapter explains a recommended water audit approach, which includes example data from the fictitious water utility—County Water Company (CWC). Step-by-step instruction is given to compile the water audit, including the required information, how to get that information, how to enter it on the worksheet, and how to calculate the performance indicators. The user may instead employ the AWWA Water Loss Control Committee's free Water Audit Software described in Appendix C to quickly compile a preliminary water audit and then augment it via the methods in this chapter.

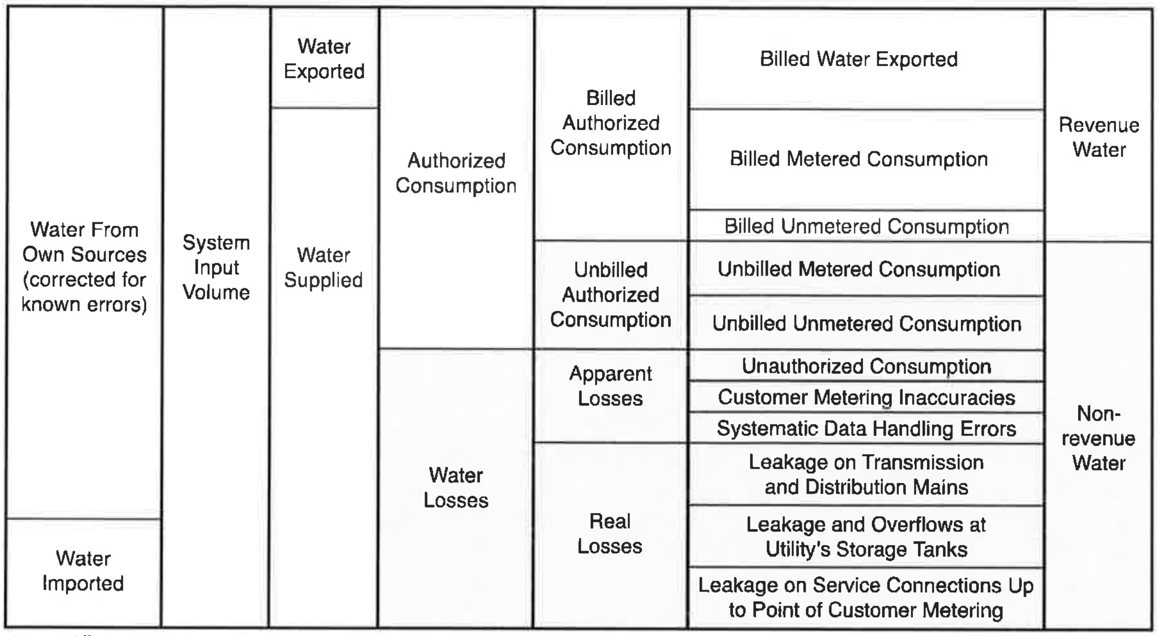
THE WATER BALANCE CALCULATION

A preliminary assessment of water loss can be obtained by gathering available records and placing data into the water audit worksheet. The summary data from the water audit is shown in the water balance, which compares the distribution system input volume with the sum of customer consumption and losses (estimated or known). The sum of all components in each column of the water balance are equal, and therefore *balance* as shown in Figure 2-1. The water balance for CWC is given in Figure 2-2. Most water utilities have readily available data on production, water imported from or exported to, other utilities, and customer consumption. Utilities often have less data available to quantify leakage, meter error, and unauthorized consumption. The water balance provides a guide as to how much water is lost as a result of customer meter inaccuracy, systematic data handling error, and unauthorized consumption (apparent losses), as well as leakage (real losses).

The two most powerful features of the best practice water audit methodology are its rational terms and definitions (Table 2-1) and standard set of performance indicators (as shown later in Table 2-19). On the broadest level, water system input volume goes to two places: authorized consumption or losses. The method advances the concept that all water should be quantified, via measurement or estimate, as either authorized consumption or losses. Hence, no water is *unaccounted-for*.

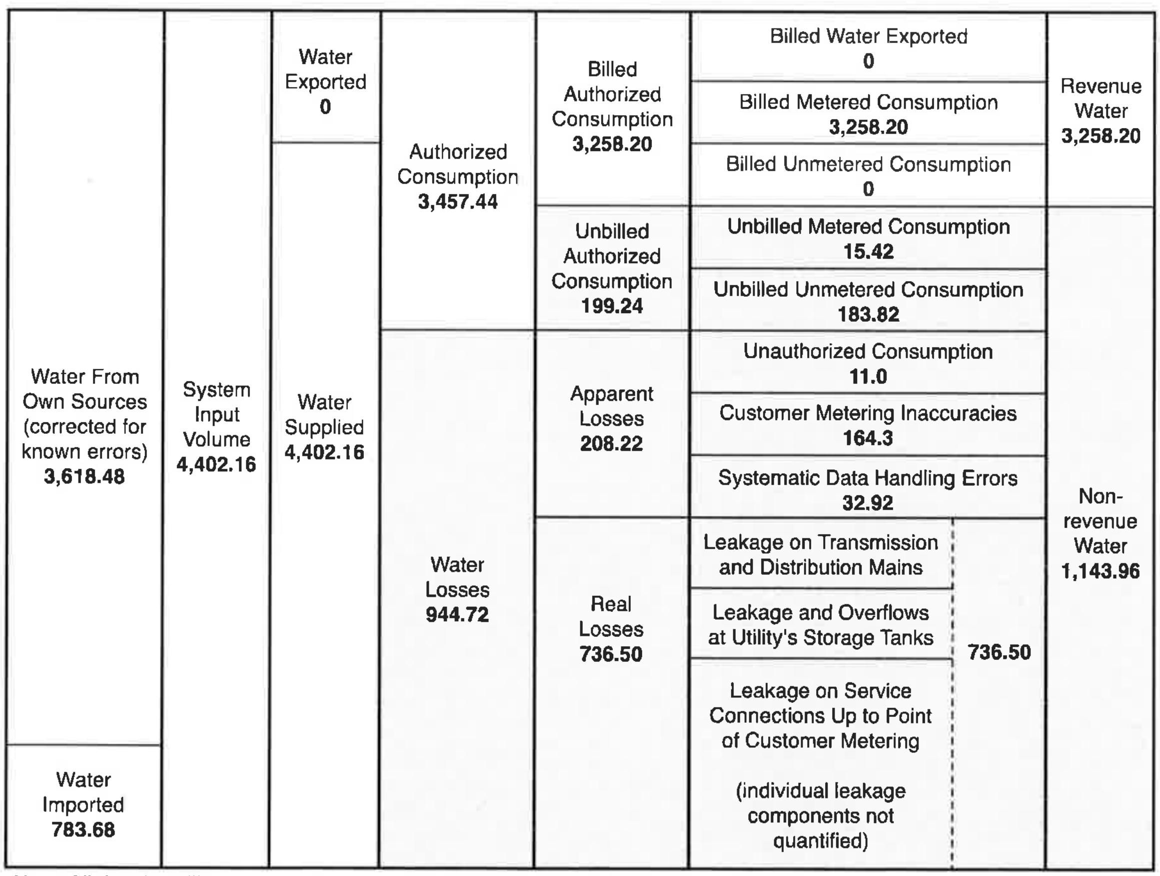
It is recommended that water utilities, state agencies, and drinking water stakeholders avoid use of the imprecise term *unaccounted-for water*. See instead the term *nonrevenue water* (NRW) defined in Table 2-1.

The performance indicators give a reliable assessment of water loss standing from water resources management, financial, and operational perspectives. They are effective in evaluating current standing, benchmarking with other utilities, and for loss reduction target setting.



NOTE: All data in volume for the period of reference, typically one year.

Figure 2-1 Water balance



NOTE: All data in million gallons volume for the period of reference, calendar year 2006.

Figure 2-2 Water balance for County Water Company—2006 calendar year

Table 2-1 Water balance terms and definitions

Water Balance Component	Definition
System Input Volume	The annual volume input to the water supply system
Authorized Consumption	The annual volume of metered and/or unmetered water taken by registered customers, the water supplier, and others who are authorized to do so
Water Losses	The difference between System Input Volume and Authorized Consumption, consisting of Apparent Losses plus Real Losses
Apparent Losses	Unauthorized Consumption, all types of customer metering inaccuracies and systematic data handling errors
Real Losses	The annual volumes lost through all types of leaks, breaks, and overflows on mains, service reservoirs, and service connections, up to the point of customer metering
Revenue Water	Those components of System Input Volume that are billed and produce revenue
Nonrevenue Water	The sum of Unbilled Authorized Consumption, Apparent Losses, and Real Losses. Also, this value can be determined as the difference between System Input Volume and Billed Authorized Consumption

COMPILING THE TOP-DOWN WATER AUDIT DATA

This section provides step-by-step instructions on the means to compile the top-down water audit. Major tasks are listed as well as individual steps, under these tasks.

Before Starting the Water Audit

At the outset of the water audit, it is important to define several key parameters for the water audit.

Identify the system boundaries. The auditor must clearly define the system boundaries for the audit noting where water is launched into supply and where it leaves the system. The water audit can be performed for treated or untreated water transmission (wholesale) systems, distinct treated water distribution systems, or sectors of distribution systems, such as pressure districts or district metered areas. Illustrations of such example configurations are given in Figures 2-3a, 2-3b and 2-3c. It is important that the system boundaries be identified to match the justification put forward for compiling the water audit. Water audits are most commonly performed on distinct treated water distribution systems (Figure 2-3b), and the example given in this chapter follows this configuration. Appendix B discusses water resources considerations that might justify expanding or isolating the audit to include water transmission systems, water use/loss through water treatment plants, or more detailed evaluations of customer consumption. When identifying the system boundaries, it is important that accurate measurement of the water input is obtainable from existing meters or new meters that are proposed for installation at the input location.

The boundary limits should be defined by points of metering of the water supply. Typical metering locations for drinking water supply and distribution are given in Table 2-2. A water audit of the raw water system utilizes metering data of the source water withdrawals as the system input and the water metered at the treatment plant influent or effluent (where the water improves in quality and value) as the end point.

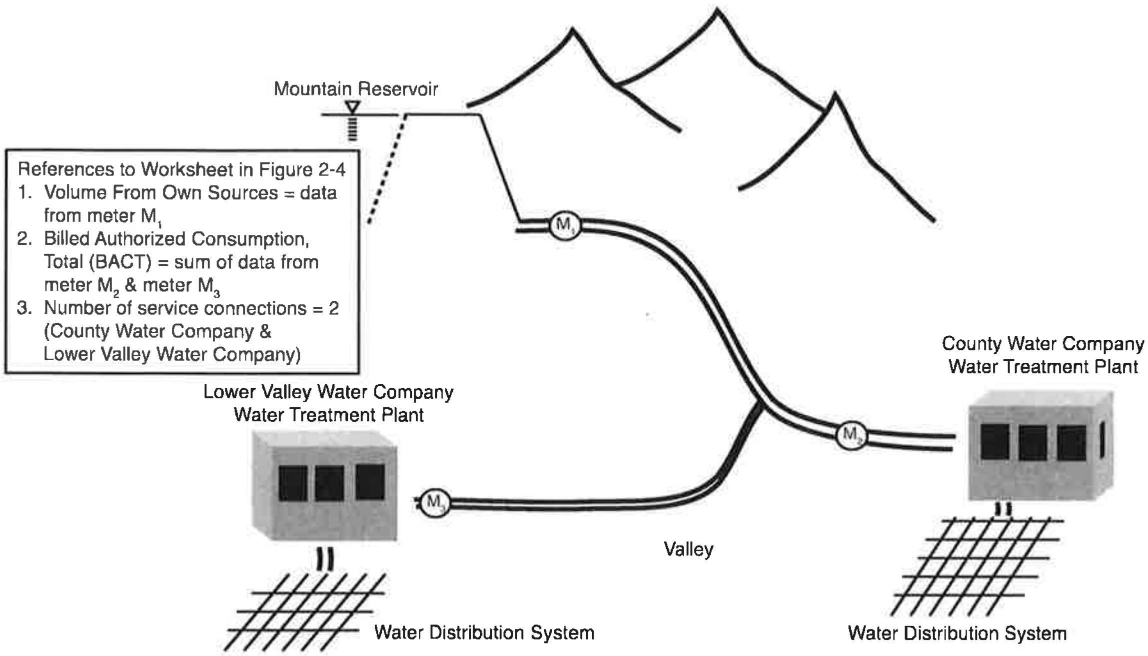


Figure 2-3a Identifying system boundaries for a water audit conducted on a wholesale transmission water supply system

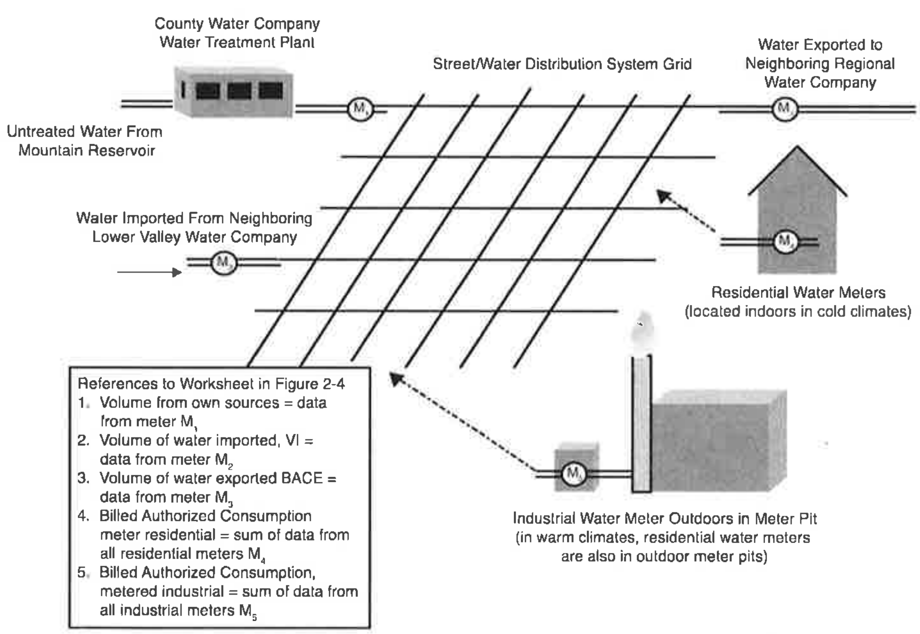


Figure 2-3b Identifying system boundaries for a treated water distribution system

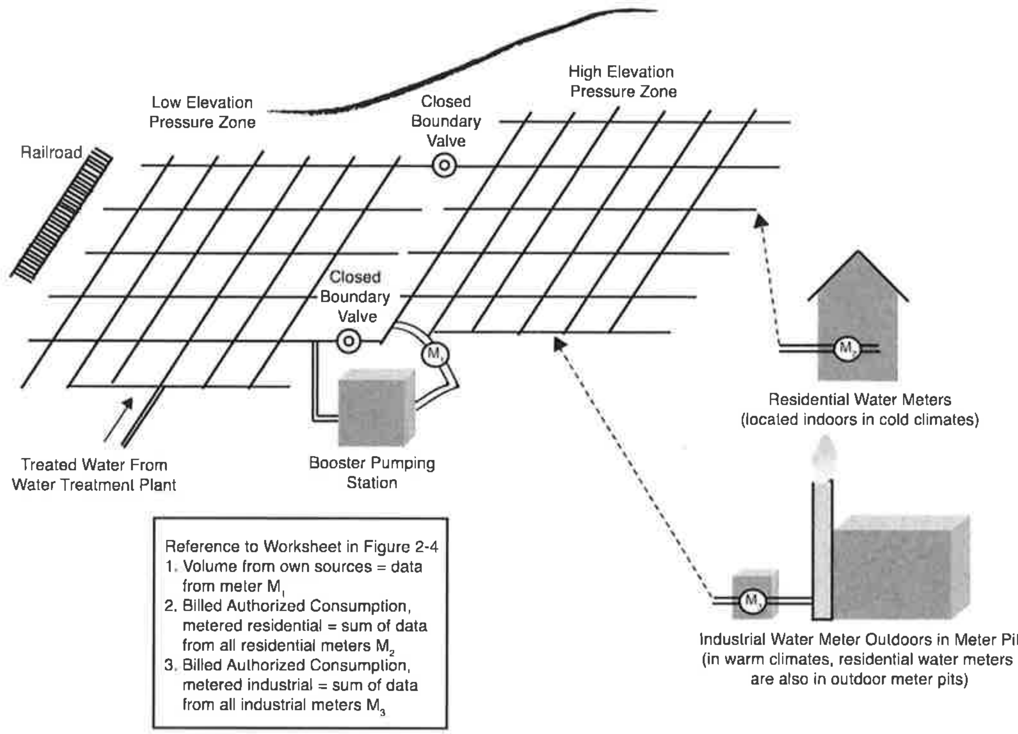


Figure 2-3c Identifying system boundaries for a discrete pressure zone or DMA

Table 2-2 Metering locations in drinking water supply systems

Location	Function
Water Source (untreated water)	Measure withdrawal or abstraction of water from rivers, lakes, wells, or other raw water sources
Treatment Plant or Works	Process metering at water treatment plants; metering may exist at the influent, effluent, and/or locations intermediate in the process
Distribution System Input Volume	Water supplied at the entry point of water distribution systems; either at treatment plant, treated water reservoir, or well effluent locations
Distribution System Pressure Zones	Zonal metering into portions of the distribution system being supplied different pressure. Also includes metering at major distribution facilities such as booster pumping stations, tanks, and reservoirs.
District Metered Areas	Discrete areas of several hundred to several thousand properties used to analyze the daily diurnal flow variation and infer leakage rates from minimum-hour flow rates
Customers	Consumption meters at the point-of-end use
Bulk Supply	Import/Export meters to measure bulk purchases or sales
Miscellaneous	Capture use of water from fire hydrants, tank trucks, or other intermittent use

For water audits conducted on treated water distribution systems (the typical example in this manual), metered water at the water treatment plant effluent is taken as the starting point for system input and customer metered consumption is the end point.

Set a time period. A water audit is a study over time. Choose a time period that allows analysis and evaluation of total system water supply. One month or even six months is too short a time to give an overall picture of water flow through the system. A 12-month study period is recommended as it is long enough to include seasonal variations and reduces the effects of lag time in customer meter reading. Most utility records are kept by the calendar or business (fiscal) year; either schedule makes 12 months of data available. The calendar year is illustrated in this chapter.

Units of measure. The units of measure must also be chosen and standardized so that supply and customer consumption units are the same. In many water utilities, treatment and distribution operations use one unit of measure (e.g., gallons) while metering and billing systems often use a different unit (e.g., cubic feet). While a variety of units are used by North American water utilities (million gallons, acre-feet, cubic feet, megaliters), million gallons will be used in the examples in this manual. Because the time period is one year, the unit of measure (million gallons) is presented as a volume for the year. If the auditor desires, an additional column can be added in the worksheet in Figure 2-4 to show the data in daily average units of million gallons per day (mgd).

Assemble records and data. One of the auditor's greatest challenges is to assemble records and data from a wide variety of operations in the water utility. Information is required on production metering, distribution system pressures, leak detection and repair, customer metering and billing, authorized consumption from flushing, fire-fighting and related activities, water conservation activities, the cost of water (water rates and production costs), infrastructure rehabilitation, and a host of related data. Distribution system maps or geographical information systems, customer billing systems, maintenance management information systems, and supervisory control and data acquisition (SCADA) systems are some of the information management systems that can be accessed to assemble the needed data.

Establishing procedures and contacts for the routine, annual collection of this data is an important function. The auditor should be cognizant during the auditing process of the caliber of information sources: who provides the data, in what format and what degree of confidence does the data exist? If new information sources are uncovered during the auditing process, the new information streams should be documented so that the desired data is available for the next year's water audit. Because similar data is gathered on a yearly basis, routine data collection processes greatly ease the amount of work needed to assemble this information each year after the initial water audit is conducted.

Starting the Water Audit

Figure 2-4 provides a standard water audit worksheet. The figure provides an example of the fictitious County Water Company, and the means to complete the worksheet is explained throughout Chapter 2. A blank form for this figure is given in Appendix A. In the first section, the name of the person compiling the audit (auditor) should be listed, as well as the reference time period that the audit covers, along with the other required information. (Note: while Figure 2-4 serves as the example in Chapter 2, the auditor may alternatively use the AWWA Water Loss Control Committee's free Water Audit Software, which is described in Appendix C.)

WATER AUDIT FOR THE PERIOD	January 1, 2006	TO	December 31, 2006
UTILITY NAME & ADDRESS	County Water Company, Anytown, USA	POPULATION SERVED	37,000
COMPILED BY	John Smith, Manager	DATE COMPILED	March 23, 2007
DATA TO BE ENTERED SHOWN IN WHITE, CALCULATED VALUES SHOWN IN DARK GRAY, SUGGESTED DEFAULT VALUES IN MEDIUM GRAY			

DISTRIBUTION SYSTEM DESCRIPTION INFORMATION

SYSTEM CONFIGURATION TYPE (underline your selection)	Raw Water Transmission	Bulk Treated Transmission	Retail Treated Distribution	Pressure Zone or DMA (specify)

INFRASTRUCTURE DATA		FINANCIAL DATA	
250	Miles of Transmission & Distribution Mains, Lm	$9,600,000	Total costs to operate the water supply system
11,490	Number of service connections, residential accounts, Nr	$4,142	*Customer retail unit rate—residential accounts—applied to Apparent Losses ($/mil gal)
706	Number of service connections, commercial, industrial & agricultural accounts, Ni	$3,627	*Customer retail unit rate—industrial, commercial & agricultural accounts—applied to Apparent Losses ($/mil gal)
12,196	Total number of service connections, Nc = Nr + Ni	$3,945	*Customer retail unit rate—composite unit rate—applied to Apparent Losses ($/mil gal)
18	Average length of customer service connection from curb stop to customer meter, Lp, ft	$190	Short-term variable cost to produce the next unit of water—applied to Real Losses ($/mil gal)
2,750	Number of fire hydrants, Nf	OPERATIONAL DATA	
12	Average length of fire hydrant leads, Lh, ft	365	Days in water audit period
65	Average operating pressure, P, psi	100%	Percent of time that system is pressurized

*Be certain to calculate the retail customer rate charges in dollars/million gallons to keep units of measure consistent.

WATER BALANCE CALCULATIONS			Water Volume Unit	Water Volume Mil Gal	Costs Rate Applied & Total: Currency	Costs Rate Applied & Total: US$
1.	Volume From Own Sources (raw data)			3,480.76		
1A.	Adjustment: Sources meter error (+/–)	+136.89				
1B.	Adjustment: Changes in reservoir and tank storages (+/–)	+0.83				
1C.	Other Adjustments (specify)	0				
1D.	Total Adjustments = Lines 1A +1B + 1C	+137.72				
2.	VOS: Volume From Own Sources (adjusted) = Lines 1 +/– 1D			3,618.48		
3.	VI: Volume of Water Imported (adjusted)			783.68		
4.	SIV: System Input Volume = VOS + V1			4,402.16		
5.	BACE: Volume of Water Exported (adjusted)			0		
6.	WS: Water Supplied = SIV – BACE			4,402.16		
7.	BACM1: Billed Authorized Consumption: Metered (uncorrected) Type 1 (specify)	Residential Accounts		2,318.80		
8.	BACM2: Billed Authorized Consumption: Metered (uncorrected) Type 2 (specify)	Industrial Accounts		488.60		
9.	BACM3: Billed Authorized Consumption: Metered (uncorrected) Type 3 (specify)	Commercial Accounts		97.20		
10.	BACM4: Billed Authorized Consumption: Metered (uncorrected) Type 4 (specify)	Agricultural Accounts		353.40		

Figure 2-4 Water audit worksheet: Top-down approach

	WATER BALANCE CALCULATIONS				Water Volume		Costs Rate Applied & Total	
					Unit	Mil Gal	Currency	US$
11.	BACT = (BACM1 + BACM2 + BACM3 + BACM4) (uncorrected)			3,258.00				
11A.	Adjustment due to customer meter reading lag time (+/–)			+0.20				
12.	BACTAD = BACT +/– Line 11A					3,258.20		
13.	BACU: Billed Authorized Consumption: Unmetered					0		
14.	NRW: NONREVENUE WATER = WS – (BACTAD + BACU)					1,143.96	= Lines 15 + 16A + 17 = $1,764,296	
15.	UACM: Unbilled Authorized Consumption: Metered					15.42	@ $3,945/mil gal = $60,831	
16.	UACU: Unbilled Authorized Consumption: Unmetered	Estimated as	1.250%	of WS		(55.03)		
16A.	UACU: Unbilled Authorized Consumption: Unmetered	Use instead of Line 16 if greater than Line 16				183.82	@ $3,945/mil gal = $725,170	
17.	WL: WATER LOSSES = NRW – (UACM + UACU)					944.72	= Lines 24 + 25 = $978,295	
18.	ALMUR1: Apparent Loss – residential meter under-registration					134.33	@ $4,142/mil gal = $556,395	
19.	ALMUR2: Apparent Loss – industrial/commercial/agricultural meter under-registration					29.97	@ $3,627/mil gal = $108,701	
20.	ALDHE1: Apparent Loss – systematic data transfer error (specifiy)					12.57	@ $3,945/mil gal = $49,589	
21.	ALDHE2: Apparent Loss – systematic data analysis error (specifiy)					8.72	@ $3,945/mil gal = $34,400	
22.	ALDHE3: Apparent Loss – data policy/procedure impacts					11.63	@ $3,945/mil gal = $45,880	
23.	UC: Unauthorized Consumption	Estimated as	0.250%	of WS		11.00	@ $3,945/mil gal = $43,395	
23A.	UC: Unauthorized Consumption	Use instead of Line 23 if greater than Line 23				–		
24.	AL: Sum of Apparent Losses = ALMUR1 + ALMUR2 + ALDHE1 + ALDHE2 + ALDHE3 + UC					208.22	Sum = $838,360	
25.	CARL: Current Annual Real Losses = WL – AL (In the top-down water audit approach, Real Losses are taken as the losses remaining after Apparent Losses are subtracted from the Total losses)					736.50	@ $190/mil gal = $139,935	
26.	Normalized CURRENT ANNUAL REAL LOSSES: CARL per day					2.02		

WATER AUDIT—PERFORMANCE INDICATORS

Category	Description	*IWA Code	Expressed as:	Calculation	Indicator Value
Financial	Financial: Nonrevenue water by volume	Fi36	Volume of Nonrevenue Water as % of System Input Volume	= (1,143.96/4,402.16)% = 25.9%	25.9%
	Financial: Nonrevenue water by cost	Fi37	Value of Nonrevenue Water as % of annual cost to operate the water supply system	= ($1,764,296/$9,600,000)% = 18.3%	18.3%
Operational	Water Losses		mil gal	= WL	944.72
	Apparent Losses		mil gal	= AL	208.22
	Current Annual Real Losses		mil gal	= CARL	736.50
	Apparent Losses Normalized	Op23	[gal/service connection/d]	= (AL/Nc/D) = (208,220,000/12,196/365)	46.8
	Real Losses Normalized (1)	Op24	[gal/service connecion/d] or [gal/mi of mains/day] (only if service connection density is less than 32/mi)	Service connection density = (12,196/250) = 48.8/mile Op24 = (736,500,000/12,196/365)	165.4

Figure 2-4 Water audit worksheet: Top-down approach (continued)

WATER AUDIT—PERFORMANCE INDICATORS					
Category	Description	*IWA Code	Expressed as:	Calculation	Indicator
Operational	Real Losses Normalized (2)		[gal/service connecion/d/psi] or [gal/mil of mains/d/psi] (only if service connection density is less than 32/mi)	Service connection density = 48.8 connections/mile Real Losses Normalized (2) = (736,500,000/12,196/365/65)	2.54
	Unavoidable Annual Real Losses	UARL	UARL (gal/d) = (5.41Lm + 0.15Nc + 7.5Lc) × P, where: Lm = length of water mains, miles (including hydrant lead length) Nc = number of service connections Lc = (Nc × Lp)/5,280, mi Lp = average service connection piping length, ft (See Figures 2-9–2-11 for guidance) P = average pressure in the system, psi	Lm = miles of main + total hydrant lead length (miles) = 250 + [(2,750 × 12)/5,280] = 256.25 Lc = (12,196 ×18)/5,280 = 41.6 UARL = [(5.41 × 256.25) + (0.15 × 12,196) + (7.5 × 41.6)] × 65 = 229,300 gal/d = 83.69 mil gal/yr	83.69
	Infrastructure Leakage Index (ILI)	Op25	CARL/UARL (dimensionless)	= 736.50/83.69 = 8.80	8.80

* Descriptors assigned to the performance indicators are from the International Water Association publication *Performance Indicators for Water Supply Services*, 2000.

Figure 2-4 Water audit worksheet: Top-down approach (continued)

Task 1—Collect Distribution System Description Information

This section of the worksheet provides for the entry of pertinent distribution system characteristics that are necessary to describe the utility and calculate the performance indicators. The information is provided under three headings: infrastructure data, financial data, and operational data. The operational data includes default values that assume that the utility distribution system is operated 365 days per year and is continually pressurized during these operations. This is true for North American systems; however, in many developing countries, intermittent supply systems are typical, providing pressurized water supply for only a portion of each day or only for certain days of the week.

Most of this information should be readily available to utility managers. Several of the requested parameters will be new to many water utilities, however, including the average length of customer connection piping from the curb stop to the customer meter or property boundary if customers are unmetered (see later in Figures 2-9–2-11). This parameter, labeled Lp, separates the repair responsibilities for customer service connection piping leaks; that is, the delineation of water utility responsibility vs. repairs arranged by the customer. Policies that require the utility to implement repairs result in faster repair times and shorter leak run times than repairs arranged by customers using contractors or plumbers. The average length needed for this parameter, as well as the average length of fire hydrant leads, can be approximated if they are not known.

Three levels of costs from the utility should be entered to generate a cost assessment of losses in the system. First, the total costs to operate the water supply system should be entered. These costs include those for operations, maintenance, and long-term upkeep of the system. They include employee salaries and benefits, materials, equipment, insurance, fees, other administrative costs, and all other costs that exist to maintain the water supply. These costs should not include any costs to operate wastewater, biosolids, or other systems outside of drinking water.

Next, the retail rate charged to customers for water supplied should be tabulated. These unit costs will be applied to the components of apparent loss, because these losses represent water reaching customers but not (fully) paid for. It is important to compile these costs per the same unit cost basis as the volume measure included in the water audit. For example, if all water volumes are measured in million gallons, the unit cost should be dollars per million gallon ($/mil gal). This usually requires a conversion because most water utilities bill customers in cubic feet or gallons. A single retail rate can be used, or separate retail rates for different customer rate classes (residential, industrial, etc.) can be employed. Charges for wastewater and stormwater may also apply. If these additional costs apply, an aggregate unit cost will also likely be needed (an estimate between the previous values can be used) to value those apparent losses where the breakdown of customer consumption categories is unknown.

Lastly, real losses should be valued at an appropriate rate. The cost rate, which depends on the local economic and water resource considerations of the utility, can vary from

- At lowest, the short-term variable production costs or bulk supply purchase cost, plus variable treatment and pumping costs;
- At highest, the customer retail rate, in situations where water resources are very constrained and every drop of abated leakage can be projected as water sales to a customer.

This variable, or marginal, cost includes the basic costs to provide the next unit (mil gal) of water, typically the costs of treatment and power for pumping to convey the water through the distribution system. If water is purchased from another water utility, the unit purchase cost is used. Some systems may supplement internal sources with purchased water. Most drinking water utilities compile all of these costs, and this data is readily available. If any costs are missing, an estimate can be used until a separate cost assessment can be performed at a later time.

The data requested in the Distribution System Description Information section of the water audit worksheet shown in Figure 2-4 should be provided.

Task 2—Measure Water Supplied to the Distribution System

Proceed to the section of the worksheet in Figure 2-4 labeled Water Balance Calculations. This task demonstrates how much water enters the distribution system and where it originates.

Step 2-1. Compile the volume of water from own sources. All water sources should be identified that are owned or managed by the water utility to supply water into the distribution system. Such sources can include raw water that is treated adjacent to sources such as wells, rivers, streams, lakes, reservoirs, or aqueduct turnouts. However, most water audits are performed on the potable water distribution system (see Figure 2-3b) so that the "source" is often the location where *treated* water enters the distribution system. The effluent water supplied from a water treatment plant is a primary example. This also represents the point where the water increases in value by virtue of being treated and energized for delivery. All volumes from such sources should be metered with routine meter testing and calibration conducted so that volumes of water taken from all sources are registered accurately. Data from these meters should also be archived in a computerized format that allows for easy retrieval and analysis. Data should be available on a daily, weekly, or monthly basis to compile into an annual volume of water supplied from each source. Meter information can be kept in a table similar to Table 2-3.

Perhaps one or more water sources are unmetered, or have meters that are not routinely monitored. In such cases the following situations apply:

- *No meters at a water source.* A portable meter should be used or the flow estimated. Portable meters can be insertion types or strap-on types and can be installed on source piping just downstream of the treatment plant effluent or other source. A minimum of 24 hours of continuous metering should be obtained. If portable metering is not feasible, one way to infer an estimate is to utilize treated effluent water pumping records. If the water pump performance characteristics are known, a volume estimate can be derived by multiplying the number of hours that the pump was operated during the year by the average pumping rate. If water is taken from a large reservoir, an estimate of the withdrawal can be formulated by accounting for the amount of drawdown of the reservoir level, adjusted by the amount of inflow from streams and rainfall. Such methods give an approximate volume measurement, and unmetered sources should ultimately be designated for metering when possible.

- *Source water meters have not been routinely calibrated.* An inspection of the source structures should be conducted. The type of metering device that exists should be noted (e.g., Venturi flowmeter, magnetic flowmeter, ultrasonic flowmeter, Parshall flume, weir, or stream gauge). Basic information about the measuring device should be noted: type, identification number, frequency of reading, type of recording register, unit of measure (and conversion factor, if necessary), multiplier, date of installation, size of pipe or conduit, frequency of testing, and date of last calibration. Using that information, a table similar to Table 2-3 should be constructed.

A record should be obtained on how much water was produced by each source during the period of the audit. Most meters have some type of register or totaling device. Registers may be round-reading or direct-reading. Round-reading registers have a series of small dials with pointers, registering cubic feet, or gallons, in tens, hundreds, thousands, and ten thousands. Direct-reading registers have a large sweep hand for testing and a direct-reading dial that shows total units of volume. If the meter has not been routinely read, tested, or calibrated, there should be an effort initiated to calibrate the meter and institute routine reading or polling of the meter. Currently, many drinking water utilities link source meters with SCADA systems that convey data in real time to centralized computers, where the flow data is totaled and archived for easy retrieval. Again, a portable meter can be utilized to obtain measurements to compare during any master meter calibration or verification activities.

Tables 2-3 and Table 2-4 illustrate the example of CWC with two meters on sources that it owns: "aqueduct turnout 41" and "well field," as well as water imported (purchased) from a neighboring water utility, "City Intertie." These tables illustrate how source meter and flow data can be arranged and adjusted for the water audit period.

Accurately measured source or production flows are critical to the efficient operations of water utilities and wise resource management as overseen by regulatory agencies and other stakeholder groups. Therefore, utility managers and regulators should give high priority to the use of accurate metering at all sources. All water sources should include flowmeters that are technologically current, accurate, reliable, well-maintained, and—ideally—continuously monitored by a SCADA system or similar monitoring system.

Enter the volume of water (3,480.76 mil gal) from own sources (raw data) on Line 1 of the worksheet in Figure 2-4.

Table 2-3 Source water measuring devices for County Water Company

Characteristics	Water From Own Sources: Source 1 Turnout 41	Water From Own Sources: Source 2 Well Field	Water Imported: Source 3 City Intertie
Type of measuring device	Venturi	Propeller	Venturi
Identification number (may be serial number)	0000278-A	8759	OC-16
Frequency of reading	Daily	Weekly	Daily
Type of recording register	Dial	Dial	Builder type M
Units registers indicate	100,000 gal	Gal	Ft^3
Multiplier (if any)	1.0	1.0	100.0
Date of installation	1974	1990	1978
Size of conduit	24 in.	8 in.	11.5 in.
Frequency of testing	Annual	Every 2 years	Every 4 months
Date of last calibration	4/1/2006	8/21/2005	1/15/2006

Table 2-4 Total water supply in million gallons for County Water Company (uncorrected)

2006 by Month	Source 1 Turnout 41	Source 2 Well Field	Subtotal Own Sources (unadjusted)	Source 3 City Intertie (water imported)	Total for All Sources 1, 2, and 3 (unadjusted)
January	0	130.34	130.34	104.27	234.61
February	0	195.51	195.51	65.17	260.68
March	130.83	130.34	261.17	0	261.17
April	160.18	260.68	420.86	0	420.86
May	326.53	97.76	424.29	0	424.29
June	368.62	0	368.62	81.46	450.08
July	372.64	0	372.64	84.72	457.36
August	400.89	0	400.89	89.61	490.50
September	360.72	32.59	393.31	32.59	425.90
October	160.18	32.59	192.77	97.76	290.53
November	160.18	0	160.18	130.34	290.52
December	160.18	0	160.18	97.76	257.94
Annual Total	2,600.95	879.81	3,480.76	783.68	4,264.44
Daily Average, mil gal/d					11.68

Step 2-2. Adjust figures for total supply. Once a volume is established for each source for the year, the measured amounts should be reviewed and corrected for known systematic or random errors that may exist in the metering data. Figures for the total water supply, based on readings from source meters and measuring devices, are raw data. The raw data must be adjusted for a number of factors, including

1. Meter inaccuracies.

2. Changes in reservoir and storage levels.

3. Any other adjustments such as losses that occur before water reaches the distribution system. One example would be losses incurred during the treatment process (filter backwashing, etc.) if the source meter is located influent to a water treatment plant.

These adjustments are made in the following steps, and they are aggregated into the Volume from Own Sources (VOS) on Line 2 of the worksheet in Figure 2-4.

Step 2-2A. Verify meter accuracy. Although most source flows are measured by meters, some are measured by other devices, such as Parshall flumes or weirs. Water supply data (like those used in Table 2-4) are based on readings of these measuring devices. **Any unreasonable degree of error in a measuring device must be discovered and corrected; incorrect supply data compromises the water audit because any error in the source or production meters carry throughout the audit.**

To be sure that meters are accurate, the results of meter tests should be compared to applicable AWWA standards and guidance manuals. If a meter measures incorrectly and the error exceeds the standard for its category, the meter should be repaired and recalibrated to function within standard limits. If the meter has not been tested within the past 12 months, the meter should be tested immediately.

Possible causes of meter error. If source meters are inaccurate, inspect each one in the field. Normal wear is not the only cause of inaccurate meter readings. Check to be sure that the meter is the right type and size for the application and that it is installed correctly. See AWWA Manual M33, *Flowmeters in Water Supply*, for guidance on typical source meter types and applications.[2] The size should be checked against manufacturers' recommended ranges. The meter should be level; most meters are not designed for sloped or vertical operation. The meter should be inspected to see if hard-water encrustation is interfering with the measurement.

Also it should be verified that the proper registers were selected and installed correctly. Finally, the register should be read to see that the signal from the meter is properly transmitting through the SCADA system. An employee familiar with metering instrumentation should perform the calibration of the instrument and should make a special reading of the source meter, or an employee should accompany the meter reader to verify sample readings. It should be verified that the meter is read and recorded correctly and that the correct conversion factor is used.

Checking Venturi meters. Venturi meters should be checked for blockages in the throats of the meters or in the sensing lines. The primary device should be tested by comparing it with a measurement taken from a pitot rod or other insertion-type meter. Testing the meter with a pitot rod shows whether or not the installation is adequate for nonturbulent flows. The meter's primary device should be tested at different flow ranges. If pressure deflection for appropriate flows is adjusted without checking the Venturi itself, the meter may still record flows erroneously.

Testing meters. There are four ways meters may be tested. The following meter testing methods are listed in order of effectiveness, with the most effective first.

1. Test the meters in place. Some pipes may need to be replaced to make this possible.

2. Compare meter readings with readings of a calibrated meter installed in series with the original meter.

3. Record meter readings for a given flow over a specified time period. Remove the meter and replace it with a calibrated meter. Record readings from the calibrated meter using the same flow rate for the same duration; compare the readings.

4. Test the meter at a meter testing facility.

Meters can be tested with portable equipment. Pump efficiency flow testing can be used to check meters; it is sometimes provided free of charge by electric utilities. Some utilities use an averaging rod meter or anubar to test meters, but results may be off by as much as 10 percent. A standard single-point pitot rod gives more accurate results, generally ±2 percent.

Meter testing may be done by an outside agency. Consultants, meter manufacturers, and special testing laboratories offer testing services.

Step 2-2B Adjust supply totals. The monthly and annual supply data should be adjusted from Table 2-4 for meter error. To do this, the uncorrected metered volume (UMV) should be divided by the measured accuracy of the meter (a percentage expressed as a decimal) and subtract the UMV as follows:

$$\frac{\text{uncorrected metered volume}}{\text{percent accuracy}} - \text{uncorrected metered volume} = \text{corrected metered volume} \qquad \text{(Eq. 2-1)}$$

Table 2-5 shows how to adjust the supply totals from Table 2-4 to yield the adjusted measurements. *Enter the net meter error adjustment (±) on Line 1A of the worksheet in Figure 2-4. For County Water Company, this is +136.89 mil gal.*

Step 2-2C. Adjust reservoir and tank storage. If source meters are located upstream of reservoirs and storage tanks, stored water must be accounted for in the water audit. Generally, water flowing out of storage is replaced; as the replacement water flows from the source into storage, it is measured as supply into the system. If the reservoirs have more water at the end of the study period than at the beginning, the increased storage is measured by the source meters but not delivered to consumers. Such increases in storage should be subtracted from the metered supply. Conversely, if there is a net reduction in storage, then the decreased amount of stored water should be added to the metered supply. Table 2-6 shows how to figure the change in storage volume.

It should be noted that *decreases* in storage are *added* to the supply; storage *increases* are *subtracted* from the supply. *Enter the net reservoir and tank storage adjustment (±) of Line 1B of the worksheet in Figure 2-4. For County Water Company this is +825,580 gal or +0.83 mil gal.*

Large open reservoirs may require volume adjustments as a result of the effects of evaporation (water lost) and rainfall (water gained). See Task 5, Step 5-2E, for approaches to quantify such adjustments.

Step 2-2D. Other adjustments. Some water suppliers may be subject to other types of contributions or losses. For example, there may be an additional source that enters the water system between the source meter and the finished water system. This could result from infiltration into an open channel. Likewise, losses may be introduced through an unlined or open channel. These additions or losses should be accounted for as "other contributions or losses" on the worksheet. *Enter the net adjustment (±) for all other adjustment categories on Line 1C of the worksheet in Figure 2-4. For County Water Company, no such adjustments exist, so a value of zero is entered.*

Step 2-2E. Total all adjustments. *The worksheet totals Lines 1A + 1B + 1C to give the sum of all adjustments (±) as shown on Line 1D. Here Line 1D = +137.72 mil gal.*

Table 2-5 Volume of water from own sources in mil gal for County Water Company (adjusted for meter error)

Source	Yearly Total: Uncorrected Metered Volume (UMV)*	Meter Accuracy (MA), percent	Meter Error Calculation UMV/MA† – UMV	Meter Error	Adjusted Metered Volume‡
1 Turnout 41	2,600.95	95	(2,600.95/0.95) – 2,600.95	+136.89	2,737.84
2 Well field	879.81	100	(879.81/1.00) – 879.81	+0.0	879.81
				+136.89	

* Based on Table 2-4.

† A percentage, written as a decimal (95 percent = 0.95).

‡ The corrected meter volume for sources 1 and 2 is 3,617.65 mil gal; note that this is 136.89 mil gal greater than the total supply given for these sources in Table 2-4. This is a way to double-check the arithmetic. The new total is not recorded on the worksheet—the "total adjustment due to meter error" is. This is only one of three adjustments that must be made to the raw data given in Table 2-4.

Table 2-6 Changes in reservoir storage for County Water Company

Reservoir	Start Volume, gal	End Volume, gal	Change in Volume, gal
Apple Hill	32,350	36,270	+3,920
Cedar Ridge	278,100	240,600	–37,500
Monument Road	978,400	318,400	–660,000
Davis	187,300	55,300	–132,000
Total change in reservoir storage			–825,580

Step 2-2F. Determine the adjusted volume of water from own sources. *The worksheet calculates Line 2 = Line 1 ±1D to give the adjusted Volume from Own Sources listed as 3,618.48 mil gal.*

Step 2-3. Compile the volume of water imported from outside sources or purchased from other water utilities. Tables 2-3 and 2-4 include Source 3, which is an interconnection flowmeter on the "City Intertie." This meter registers water purchased from a neighboring water utility by County Water Company. Interconnections between water utilities usually include flowmeters that are carefully maintained and monitored because the metered data provides the basis for billing large water volumes. Both the water utility supplying the water and the system purchasing the water have a strong motivation to keep this bulk measurement accurate because significant costs are at stake for each water utility. As with the data from "own sources," the data derived from "import" meters should be adjusted accordingly during the water audit. Often, however, these meter totals require no end-of-year adjustment because most water utilities monitor the data carefully and correct any inaccuracies as they are discovered throughout the year. A separate line is therefore not included for adjustments to the Volume of Water Imported on the worksheet in Figure 2-4. If this is desired, an adjustment can be created for "City Intertie" in the same manner as shown in Table 2-5. *Enter the Water Volume Imported (VI) on Line 3 of the worksheet in Figure 2-4. From Table 2-4, obtain the value of 783.68 mil gal for the City Intertie imported volume to County Water Company and enter it on Line 3.*

Step 2-4. Calculate system input volume. *The System Input Volume (SIV) is the total amount of water supplied into the distribution system and is obtained by adding the water Volume from Own Sources (VOS) to the water Volume Imported (VI). This calculation is Line 2 + Line 3 = Line 4 on the worksheet in Figure 2-4. The SIV for County Water Company is 4,402.16 mil gal.*

Step 2-5. Compile the volume of water exported to outside water utilities or jurisdictions. Any water volumes sent outside of the distribution system to a neighboring water utility should be monitored and adjusted with the same scrutiny given to imported water, for the same revenue implications exist. As with Volume of Water Imported, a separate line for adjustments is not included on the worksheet in Figure 2-4. *Enter this volume on Line 5 (BACE) on the worksheet in Figure 2-4. County Water Company exports no water to neighboring water utilities, so the value entered on Line 5 is zero.*

Step 2-6. Calculate the volume of water supplied into the distribution system. *The volume of water supplied to the distribution system is then calculated as Water Supplied (WS) which equals System Input Volume (SIV) minus Water Exported (BACE) and is included on Line 6 of the worksheet in Figure 2-4. Because Water Exported (BACE) equals zero, the worksheet calculation gives the same value of 4,402.16 mil gal as WS on Line 6.*

Task 3—Quantify Billed Authorized Consumption

Authorized consumption is any water delivered for consumptive purposes that are authorized or approved by the water utility, thereby providing a benefit to the community. TASK 3 and TASK 5 both describe how to quantify authorized consumption. TASK 3 deals with *billed* authorized consumption while TASK 5 details *unbilled* authorized consumption.

Billed authorized consumption represents the collective amounts of water delivered to individual customers that have accounts in a customer billing system. Billed authorized consumption is the basis for revenue generation for the water utility. Billed accounts are customer properties served by permanent customer service connection piping. Most of the water supplied into the distribution system should go to this type of consumption. In North America, most water utilities require customer meters on service connections and bill based on metered consumption on a monthly or quarterly basis. Metered water can be categorized as residential, industrial, commercial, agricultural, governmental, and other uses. Not all water utilities, however, meter their customers, instead charging a flat billing rate per consumption period, or a charge based on property or other characteristics. Therefore, billed authorized consumption may be metered or unmetered. AWWA recommends that all customers with permanent service connection piping be metered with billing based on measured consumption.

Unbilled authorized consumption describes water taken irregularly in a variety of manners from nonaccount connections that typically do not supply permanent structures. Withdrawing water from fire hydrants is the most common example of such nonaccount consumption. Water utilities often allow water to be taken from fire hydrants for fire fighting (their primary purpose), flushing, testing, street cleaning, construction, and other purposes. These uses should be metered to the extent possible, with usage policies in force to protect water quality and public safety. Water utilities often utilize water from the distribution system at their own plants and facilities in uses that include backwash water, internal building use, and sampling. Sometimes unbilled water supplied to government properties is also included in this category although it is recommended that all water continuously supplied to permanent structures be metered and be tracked in a billed account in the customer billing system. In this way, water consumption is monitored even though the property is issued a "no-charge" bill.

Remember: To be accurate, the water audit period must be consistent. Be sure to use the same 12-month study period and the same units of measure when evaluating consumption as was used to quantify the water supplied.

Step 3-1. Compile the volume of billed authorized consumption—metered water. Modern metering, automatic meter reading (AMR), and customer billing management technologies offer outstanding capabilities to water utilities to gather and utilize accurate customer consumption and billing data. It is strongly recommended that water utilities measure individual customer consumption via water meters and utilize computerized customer billing systems to store customer account data. AMR systems are being implemented by a growing number of water suppliers because of their cost effectiveness in gathering metered consumption data. For water utilities that utilize these technologies, consumption data is typically accessed via a variety of reports from the customer billing system. Examples of typical reports are shown in Tables 2-7 and 2.8, where consumption is summarized by meter size and customer consumption category, respectively.

Caution: Chapter 3 discusses the potential impacts to the integrity of consumption data caused by customer billing system operations (see p. 72). The auditor should develop a sound understanding of the customer billing system workings in order to ascertain the true amount of customer consumption and identify any billing system functions that unduly modify consumption data.

Step 3-1A. Maintain customer accounts data. If computerized billing records or reports do not exist, the water auditor must assemble customer account information from available records. Start by identifying all customer users from permanent structures who should have meters. Accounts should be identified by several descriptors such as account number, property street address, meter size, meter serial number, connection size, assessor's parcel number, and the name and address of the property owner as well as any tenants. In order to track customer consumption patterns and water conservation impacts, it is important to list the consumption category for each account: residential, industrial, commercial, agricultural, governmental, etc.

Step 3-1B. Maintain customer meter and AMR data. All active accounts should include the meter identification number, meter size, and meter type. If an AMR system exists, the automatic meter reading device number and meter reading route number should also be included in the customer billing system, along with any other pertinent information. If the AMR system is compatible, readings should be collected from connected meters at times that coincide with the beginning and end of the water audit.

Step 3-1C. Compile metered consumption volumes for the water audit period. First, assemble the total (uncorrected) water consumption for all accounts and connections for each size of meter by month (or other billing period) and for the entire study period, as shown in Table 2-8. The same unit of measure as supply should be used—this may require performing a conversion, for example, from cubic feet to million gallons.

Enter the total value for residential, industrial, commercial, and metered agricultural consumption shown in Table 2-8 into Lines 7, 8, 9, and 10, respectively, in Figure 2-4. The worksheet calculates the sum of these four values in Line 11 as total Billed Authorized Consumption: Metered.

Step 3-1D. Adjust for lag time in meter readings. Corrections must be made to metered use data when the source-meter reading dates and the customer-meter reading dates do not coincide with the beginning and ending dates of the water audit period.

Table 2-7 Number of customer accounts and metered consumption by meter size for County Water Company: January 1, 2006–December 31, 2006

Meter Size, in.	Number of Accounts	Percent of Total Accounts	Percent of Metered Consumption
⅝	11,480	94.1	71.2
¾	10	0.08	0.1
1	338	2.8	2.8
1½	124	1.0	2.8
2	216	1.8	11.7
3	15	0.12	6.6
4	7	0.05	2.2
6	6	0.05	2.6
Total	12,196	100.00	100.0

Table 2-8 Total metered water consumption by category for County Water Company (uncorrected)

2006 by Month	Residential, mil gal	Industrial, mil gal	Commercial, mil gal	Metered Agriculture, mil gal	Total for All Meters, mil gal
January	146.6	35.8	8.1	0	190.5
February	162.9	35.8	8.1	0	206.8
March	162.9	35.8	8.1	0	206.8
April	179.2	39.1	8.1	24.4	250.8
May	211.8	42.4	8.1	57.0	319.3
June	228.1	48.9	8.1	74.9	360.0
July	260.3	48.9	8.1	57.0	374.3
August	266.5	48.9	8.1	74.9	398.4
September	228.1	45.6	8.1	65.2	347.0
October	162.9	35.8	8.1	0	206.8
November	162.9	35.8	8.1	0	206.8
December	146.6	35.8	8.1	0	190.5
Annual Total	2,318.8	488.6	97.2	353.4	3,258.0
Daily Average, mil gal/d	6.35	1.34	0.27	0.97	8.93

Adjusting for one-meter route. For example, a utility studies one calendar year, January 1 through December 31. Source meters are read on the first day of each month and customers' meters are read on the 10th day of each month. The goal is to calculate the amount of water supplied and consumed for the calendar year:

- Source meters. No lag time correction is made for source meters, because their reading usually occurs on the days that the water audit period begins and ends. If the last reading (December 31) was a day late (January 1), then the water supplied for January 1 should be subtracted from the total water supply reading.

- Customer meters. Because customer meter readings do not coincide neatly with the study period, a correction must be made. The best way to account for changes in the number of customers and in consumption patterns is to prorate water consumption for the first and last billing periods within the water audit period.

  The first billing period has only 10 days that actually occur in the water audit period. Yet the billing information represents 31 days of consumption. If consumption for December 11 through January 10 is 33.204 mil gal, the amount applicable to the water audit period is

$$33.204 \text{ mil gal} \times \frac{10 \text{ days}}{31 \text{ days}} = 10.711 \text{ mil gal} \qquad \text{(Eq. 2-2)}$$

  Thus, 10.711 mil gal of the consumption read on January 10 applies to the water audit period.

  At the end of the water audit period, there are 21 days not included in the billing data collected on December 10. Consumption for the last 21 days in December is obtained from the following month's billing. If sales for that month are 36.66 mil gal, the amount applicable to the water audit period is

$$36.66 \text{ mil gal} \times \frac{21 \text{ days}}{31 \text{ days}} = 24.83 \text{ mil gal} \qquad \text{(Eq. 2-3)}$$

  Thus, 24.83 mil gal is added to the consumption read on December 10.

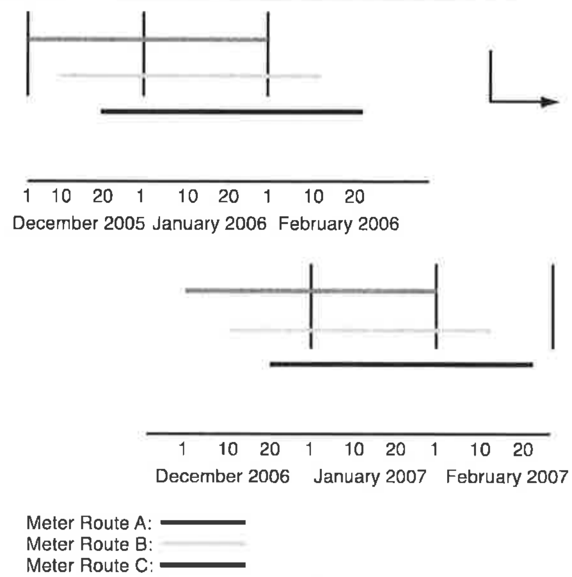
Adjusting for many-meter routes. The preceding discussion describes the basic method for correcting lag time in meter reading when all customers' meters are read on the same day. That seldom happens, however. Usually, meters are assigned to different routes and read on different days. Therefore, a meter lag correction should be used for each meter reading route, particularly if each customer's meter is read on the same date each month. Figure 2-5 gives an example of this.

A meter lag correction can involve a number of steps. In the example, County Water Company has three meter routes, each with its own reading date. The water audit period is one calendar year, and the consumption is prorated for each meter route or book. Meters are read bimonthly: route A on the first of the month, route B on the 10th of the month, and route C on the 20th of the month (see Figure 2-5).

The uncorrected total metered use (from step 3-1C, Table 2-8) is based on bills issued during the water audit period. However, because of the bimonthly billing schedule, these bills would not include all water consumed during the year. Some water shown as used in the first billing period (issued in February) actually occurred in the preceding December. The last set of bills, issued in November and December, would not include water consumed in December. Two corrections need to be made. First, water consumed in the month proceeding the water audit period must be subtracted from consumption figures. Second, water consumed in the final month of the water audit period must be added. The more frequent (monthly as opposed to quarterly) the readings, the smaller the adjustment and the less likely the estimated use will be prone to error.

Figure 2-5 shows how to adjust sales figures for meter lag time. Many utilities combine accounting and billing procedures into a computerized format to make this procedure easier and quicker.

Prorate water sales figures to adjust for lag time in meter reading. Enter the net adjustment of +0.20 mil gal on Line 11A of the worksheet in Figure 2-4. The worksheet adds the net adjustment (±) in Line 11A to the total Billed Authorized Consumption:



The December through January billing period is 62 days long.

Route	Date Read	Sales	Adjustment
A	2/1/2006	4.0 mil gal	31/62 = 2.0 mil gal
B	2/10/2006	3.3 mil gal	21/62 = 1.1 mil gal
C	2/20/2006	3.6 mil gal	11/62 = 0.6 mil gal

Total adjustment to eliminate 2005 consumption from the water audit period equals –3.7 mil gal. This amount appears on the February billing, but the water was consumed during the previous December.

Route	Date Read	Sales	Adjustment
A	2/1/2007	4.2 mil gal	31/62 = 2.1 mil gal
B	2/10/2007	3.3 mil gal	21/62 = 1.1 mil gal
C	2/20/2007	3.9 mil gal	11/62 = 0.7 mil gal

Total adjustment to add December 2006 sales to the water audit period equals +3.9 mil gal. This amount did not appear on the final bill for the year; it is prorated from the bill on which it appears.

Net adjustment..+0.20 mil gal

Figure 2-5 Detailed meter lag correction

Metered in Line 11 to give the adjusted Billed Authorized Consumption: Metered in Line 12. This value is 3,258.20 mil gal.

Step 3-2. Compile the volume of billed authorized consumption—unmetered water. The majority of North American drinking water utilities meter their customers and bill based on measured consumption. This is standard practice recommended by AWWA. However, not all utilities meter their customers; instead these water utilities bill customers a flat fee per billing period. Others meter a portion of their customer accounts. This latter scenario can occur if

- The utility is in transition to a fully metered customer population;
- Utility policies dictate that certain accounts, such as municipal properties or fire connections, need not be metered; or
- Some of the meters are known to be nonfunctional, highly inaccurate, or readings are unobtainable; in which case estimates of consumption are used in place of measured consumption.

Without functional meters in place, the water auditor must devise an estimate of the water consumed by the unmetered population. A number of means exist to develop reasonable estimates. For instance, in an unmetered system, water meters could be installed in a small, representative sample of accounts (50 or 100) based on consumption category or meter size. Data from these meters could be used to develop average consumption trends that could be inferred for the entire population in each category. Any estimating process that is developed should be fully documented and based on current conditions. Unmetered accounts require the use of estimation that interjects a degree of error into the measure of customer consumption. For this reason, it is highly recommended that all customers be properly metered, read, and archived.

Include the total estimate of Billed Authorized Consumption: Unmetered on Line 13 of Figure 2-4. For County Water Company, this value is zero since the company meters and reads all accounts.

Task 4—Calculate Nonrevenue Water

Nonrevenue water is the portion of the water that a utility places into the distribution system that is not billed and, therefore, recovers no revenue for the utility. Nonrevenue water consists of the sum of Unbilled Authorized Consumption (metered and unmetered), Apparent Losses, and Real Losses. In the top-down approach demonstrated in this chapter, nonrevenue water is calculated inversely as the remaining water into supply that is not recovered in Billed Authorized Consumption.

Step 4-1. Calculate nonrevenue water: *The worksheet in Figure 2-4 calculates nonrevenue water as the volume of water supplied minus the sum of the adjusted Billed Authorized Consumption: Metered and the Billed Authorized Consumption: Unmetered. This is shown on Line 14 in Figure 2-4. In this case, nonrevenue water = 4,402.16 – 3,258.20 = 1,143.96 mil gal.*

At this point in the worksheet, the cost impacts of the various loss components and nonrevenue water shall be calculated. The cost for nonrevenue water is the sum of the cost impacts for Unbilled Authorized Consumption plus Apparent Losses plus Real Losses. In this approach, the cost impacts of these components must be determined first and then summed to give the total cost impact of nonrevenue water. The calculation is given as Nonrevenue Cost = Cost of Line 15 + Line 16 (or 16A) + Line 17 = $1,764,296.

Task 5—Quantify Unbilled Authorized Consumption

As discussed previously, *unbilled* authorized consumption describes water taken irregularly in a variety of manners from nonaccount connections that do not typically supply permanent structures. Water utilities often allow water to be taken from fire hydrants for firefighting (their primary purpose), flushing, testing, street cleaning, construction, and other purposes. Rarely is such consumption metered or directly billed although sometimes revenue is recovered via flat fees paid by fire departments or other users. Unfortunately, many water utilities do not employ clearly written policies that include procedures for safely supplying such unbilled water consumption. Similarly, good accounting often does not exist for the types and volumes of such consumption occurring throughout the year. It is recommended that the auditing process review utility policies and practices and improve them as needed to ensure that such water consumption is not unsafe or wasteful and can be accounted for to the extent practical.

It should also be recognized that unbilled authorized consumption is usually a small portion of the volume of WS. Based on the findings of numerous water audits worldwide, the worksheet in Figure 2-4 defaults to a value of 1.25 percent of the volume of WS for the water audit period for unmetered, unbilled authorized consumption. To quickly quantify this category, the default value can be used rather than attempting to quantify numerous minor water uses that are authorized by the utility. Generally, the auditor's time will be better served if dedicated to the quantification and control of real and apparent losses. However, under conditions such as severe drought, publicly visible use of water for flushing or other operations could generate negative public perceptions for the water utility. In such cases, auditing should review all instances of unbilled authorized consumption and ensure that they are efficiently managed.

Step 5-1. Compile the volume of unbilled authorized consumption—metered water. Any unbilled consumption that is metered can be quantified by obtaining meter readings at the beginning and end of the consumption period(s) throughout the year of the water audit. If a permanent meter exists and supplies a permanent structure (such as a municipal building or a water treatment plant), it is best if the property is eventually assigned an account in the customer billing system and is read and billed regularly—even if the billing charge is zero. This would shift such consumption into the category of Billed Authorized Consumption: Metered. Metered properties should exist in the customer billing system to the greatest extent possible.

Certain uses of water—such as fire flow tests—are measured by using portable instruments. In such cases the flow should be averaged over the period of time that the fire hydrant was opened. Volumes of water from such tests should be totaled for the entire water audit period.

Include the total of all metered Unbilled Authorized Consumption documented for the water audit period on Line 15 of Figure 2-4. For illustration, the manager of County Water Company tabulates a total of 15.42 mil gal valued at the composite customer retail rate of $3,945 for a total cost impact of $60,831.

Step 5-2. Compile the volume of unbilled authorized consumption—unmetered water: The most common occurrences of Unbilled Authorized Consumption: Unmetered include

- Fire fighting and training
- Flushing water mains, storm inlets, culverts, and sewers
- Street cleaning
- Landscaping/irrigation in public areas, landscaped highway medians, and similar areas
- Decorative water facilities
- Swimming pools
- Construction sites: water for mixing concrete, dust control, trench setting, others
- Water consumption at public buildings not included in the customer billing system

Water consumed in water supply operations, such as water quality testing, filling tanks and reservoirs, and loading water mains would also fall into this category. Process water at treatment plants should be metered and exist in a billed account because water treatment plants are permanent structures. In most water utilities, a variety of unmetered, unbilled authorized consumption exists. In medium to large systems, such occurrences can be numerous, yet their total consumption is still likely to be a small portion of the volume of water supplied to the distribution system. For expediency, the auditor may choose to use the default value of 1.25 percent of water into supply (WS) to represent this category of consumption. In this case *the worksheet in Figure 2-4 calculates the volume of Unbilled Authorized Consumption: Unmetered as 1.25 percent of the WS or (4,402.16 mil gal) (0.0125) = 55.03 mil gal valued at the composite customer retail rate of $3,945 for a total cost impact of $217,093. However, the manager of County*

Water Company suspects that Unbilled Authorized Consumption is greater than the value that the default percentage gives and decides to perform an analysis of this consumption, as described in the following section.

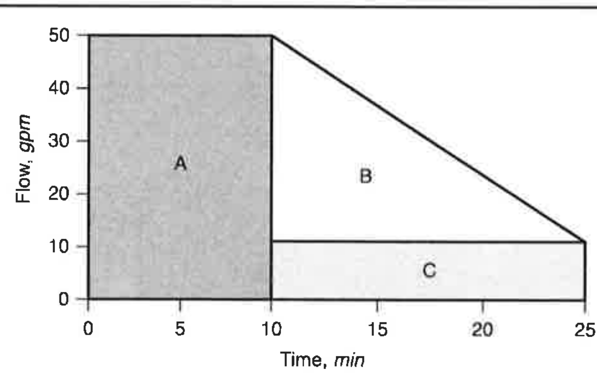
If the auditor feels that this consumption is notably greater than the default value, he or she can work to obtain detailed estimates of these components. This work can be time-consuming, and the auditor should use good judgment to determine whether the extra effort to analyze many undocumented occurrences of consumption is likely to lead to a consumption level greater than the default value. In most cases, the extra effort to document this consumption is not worthwhile. It is recommended that the default value be applied unless the auditor has documented evidence of Unbilled Authorized Consumption: Unmetered greater than this amount.

To obtain reasonable estimates of Unbilled Authorized Consumption: Unmetered, the auditor can apply the most appropriate of the three estimating methods described in the following sections.

Batch procedure. When water is transported in a tank truck or container of some sort, the batch procedure should be used. The volume of the tank or other container should be multiplied by the number of times it is filled from the distribution system. This yields the volume of water delivered from the distribution system. Careful record keeping is necessary for accurate estimates.

Discharge procedure. When water is applied directly from a pipe, as in a sprinkler system, the discharge procedure should be used. The rate of water discharge is multiplied by the total time it flows. This yields the volume of water delivered. The discharge rate may vary and the application period will vary in length and frequency, as shown in Figure 2-6. Discharge is calculated as the area of the shapes in the graphic. Again, careful record keeping is necessary for accurate estimates.

Comparison procedure. For some facilities and areas, such as schools, swimming pools, construction sites, and golf courses, consumption figures may be adapted from similar facilities, provided that they are alike in size, hours of operation, type of use,



The discharge flow was constant for 10 min at 50 gpm, then uniformly reduced to 10 gpm over the next 15 min, and then was shut off.

Volume A = 50 × 10 = 500 gal
Volume B = 0.5 × (50 –10) × (25 – 10) = 300 gal
Volume C = 10 × (25 – 10) = 150 gal

Total Volume = 950 gal

Figure 2-6 Calculation of water volume from variable-rate discharge

landscaping, and most other details. Any differences must be accounted for. For example, at a construction site, work habits are important. If the crew at a metered site turns off water between uses while the crew at an unmetered site lets the water run continuously, the borrowed consumption figures will have to be adjusted considerably.

Additional guidance on estimating likely occurrences of Unbilled Authorized Consumption: Unmetered is given in the following step.

Step 5-2A. Fire fighting and training. This includes water taken from fire hydrants, fire-sprinkler systems, and other unmetered water drawn for such uses from the water distribution system. It may be used for fire suppression, testing fire equipment, flushing sprinkler systems, or hazardous-materials reduction performed by public safety crews. It also includes water for fire-fighter training, airport personnel, and other public safety employees and volunteers. This category does *not* include water drawn from ponds, rivers, or any water sources not connected to a piped water distribution system. It also excludes water used in separate, nonpotable fire distribution systems that are not considered under the water audit.

Usually the water utility must rely on fire department records of hydrant operations during fire events or training operations. The water utility must coordinate with the fire department to establish reliable reporting procedures requiring documentation of water quantities used in fire-related operations. Additional coordination is required of water utilities whose service area includes multiple fire departments.

Again, a cautionary note is offered to the auditor. Water used for firefighting and training is typically a small component in the annual water audit, and a reasonable estimate of this consumption can be included in the use of the default value described under Step 5-2 earlier in this chapter. If the auditor has strong reason to believe that this consumption is significantly greater than that quantified by the default value, work can be conducted to obtain detailed estimates of these components. Establishing procedures for reporting fire volumes can be very time-consuming, and the utility manager must ultimately rely on the efforts of fire department personnel to obtain reliable data. Therefore, the auditor should use good judgment to determine whether the extra effort to collect actual fire-related consumption data is likely to lead to a consumption level greater than the default value.

If the auditor believes that fire-fighting water volumes must be tracked in detail, the following methods can be employed. To estimate water volumes consumed in fire-fighting activities, fire department records should be checked for training, flushing, and fire suppression. Many fire departments use more water for training than for fighting fires. Where flowmeters on standby fire systems show water use, the maintenance superintendent of the building may have fire or test records. In some municipalities, fire departments also conduct routine inspections of fire hydrants, usually flushing the hydrant in the process. A measure or estimate of this water consumption should also be gathered.

Many fire departments issue a *run report* after a unit responds to a call. A survey of all run reports from the water audit period in the water service area should yield a good estimate of the water volume used by the fire department. Calls to locations where the water used came from water supplies not connected to the distribution system should be eliminated.

Estimates of other fire-fighting uses, such as sprinkler systems (including their testing), require calculations of the flow of the system and the duration of operation. For this calculation, the discharge procedure is used. To acquire the raw data needed for the calculation, meters should be surveyed and inspected at schools, stores, apartments, industrial sites, lumberyards, warehouses, and other similar locations. The more compete the survey, the more accurately the final estimate will reflect water used in testing, and in leaky or incorrectly connected sprinkler systems. However, the

Table 2-9 Sum of individual estimates of unbilled authorized consumption: unmetered

Item No.	Item Description	Volume, mil gal
5-2A	Fire fighting and training	9.70
5-2B	Flushing water mains, storm inlets, culverts, and sewers	2.55
5-2C	Street cleaning	1.75
5-2D	Landscaping/irrigation in large public areas	162.89
5-2E	Decorative water facilities	1.75
5-2F	Swimming pools	0.42
5-2G	Construction sites	0.56
5-2H	Water quality and other testing	1.2
5-2I	Water consumption at public buildings not included in the customer billing system	2.15
5-2J	Other	0.85
	Total unbilled authorized consumption: unmetered	183.82

auditor should be mindful to ascertain the time to conduct such a detailed survey; it should be well justified.

In the example of County Water Company, there are four fire companies in the service area. None of them make run reports. However, their logs show a total of 10 structural fires and a 5-day wildfire (for which water was airlifted from an open reservoir), plus 8 days (48 work hours) of training in which water was used. Estimates of water consumption are 6.5 mil gal for fire fighting and 3.2 mil gal for training. Water used for fighting the wildfire is not included because it was not drawn from the distribution system.

Add fire fighting and related consumption to determine the total consumption for fire fighting and training. Enter the sum of 9.7 mil gal on the first line in Table 2-9.

Step 5-2B. Flushing water mains, storm inlets, culverts, and sewers. Many water utilities operate flushing programs to maintain good water quality in the distribution system. Water flow rates from these flushing operations should be measured with portable instruments, such as a pitot blade, or estimated and applied over the period of time that the flushing occurs. Quantifying water used in flushing operations not only improves accountability but also helps utilities balance water quality needs with any water resource limitations that may confront the water utility, particularly during drought or shortage conditions. Flushing is also often used to clean or maintain storm inlets, storm sewers and culverts, or sanitary sewers. Procedures should be employed to quantify and document this water consumption.

The County Water Company's manager estimates that the amount of water used to flush water mains, storm inlets, and sewers is 2.55 mil gal. Enter this amount on the second line in Table 2-9.

Step 5-2C. Street cleaning. Water is often used to clean roadways, walkways, boat ramps, bus stops, parking areas, bike paths, and similar areas. It may be released directly from fire hydrants for which case logs should be kept indicating estimated flow and cleaning duration that may be used to calculate volumes used in street cleaning. Water may also be sprayed from trucks, sweepers, or other equipment. Knowing the volume of tanks on such equipment and the number of fillings will allow calculation of a reliable measure of water consumed in such practices. Table 2-10 shows how to calculate total street cleaning estimates using the batch procedure.

Table 2-10 Estimate of water volumes used by tank trucks for street cleaning

Vehicle	Capacity, gal	Number of Refills per Day	Number of Days Used per Year	Volume per Vehicle per Year, gal
A	200	× 5	× 200	= 200,000
B	500	× 10	× 150	= 750,000
C	2,000	× 2	× 200	= 800,000
		Total annual consumption, gal		1,750,000

The manager for County Water Company estimates the amount of water consumed in street cleaning to be 1.75 mil gal. Enter the sum of 1.75 mil gal on the third line in Table 2-9.

Step 5-2D. Landscaping irrigation in public areas. This water is used to irrigate parks, golf courses, cemeteries, playgrounds, community gardens, highway median strips, and similar areas. For landscaped areas watered by tank trucks, the batch procedure should be used for estimating volume. For unmetered sprinkler systems, the discharge method can be used. Essential factors are (1) the discharge rate at each supply pipe to an irrigated area, and (2) the total amount of time water is supplied at each area. Time or moisture controlled irrigation systems make the calculation easier. When figuring the amount of time water is applied, the total time the service is discharging should be used, rather than the period for one lateral. Figure 2-7 demonstrates how to estimate the volume used for landscape irrigation.

The manager for County Water Company estimates the amount of water consumed in public landscaping irrigation to be 162.89 mil gal. Enter this value on the fourth line in Table 2-9.

Step 5-2E. Decorative water facilities. This water is used for filling, cleaning, and maintaining water quality in pools, fountains, and other decorative facilities. The major causes of water loss from open-air, standing bodies of water are evaporation, water drained from a pool during maintenance, water used for cleaning, bleed-off water used to maintain chemical balance of the water, and leaks. Because decorative water facilities are typically fixed structures, the best way to account for water supplied to these facilities is to meter the water supply connection piping and gather routine meter readings. This would place these facilities in the category of billed metered consumption. Otherwise the following estimation methods can be used.

Evaporation is appreciative generally only in large, standing bodies of water. In most cases, decorative fountains, waterfalls, and similar facilities are relatively small, and therefore no calculation for evaporative loss is necessary. If large, standing bodies of water, such as large open water supply reservoirs, exist in warm climates with plenty of sunshine, evaporative losses should be determined. The auditor should consult an appropriate text on evaporation, conservation, or irrigation to obtain a method for this calculation. If the effects of evaporation are taken into account for a large open reservoir, measures of appreciable rainfall providing water to the reservoir over the course of the water audit period should also be calculated. An appropriate textbook on hydrology should be consulted in order to determine this calculation.

Pool drainage. To estimate water loss from pool drainage, the following equation should be used:

$$V \times F = V_w \qquad \text{(Eq. 2-4)}$$

Where:

$V =$ volume of pool at the time it is drained
$F =$ frequency of pool draining
$V_w =$ volume of water loss due to drainage

Bleed-off water. The volume of any bleed-off water can also be calculated similarly to the previous equation:

$$Q_b \times T = V_b \quad \text{(Eq. 2-5)}$$

Where:

$Q_b =$ average bleed-off flow rate, (volume/time, e.g., gpd)
$T =$ total time that bleed-off is operated during the audit period (e.g., days)
$V_b =$ volume of water loss due to bleed-off

Cleaning. To estimate the water lost in cleaning, maintenance workers should be consulted about pool volumes and the frequency of cleaning and flushing. For an unmetered source, ask how much time is required for maintenance work after the pool

Example Estimate of Landscape Watering in a Public Area

A single 2-in. service provides irrigation water to 4½-acre Sunnyslope Park at the rate of 160 gpm. Each of three laterals provides equal amounts of water and is controlled by a common timer.

Lateral A operates from 1:00 a.m. to 3:00 a.m. Lateral B operates from 3:00 a.m. to 5:00 a.m. Lateral C operates from 5:00 a.m. to 7:00 a.m. The system irrigates according to the following schedule:

May and September	Every third day
June	Every second day
July and August	Daily

How much water is applied from May through September? The following shows how this is estimated:

The service supplies 160 gpm or 9,600 gph (160 × 60). It operates 6 hours each day the park is watered. During those 6 hours, 9,600 gph × 6 hr = 57,600 gal of water applied.

The number of watering days must now be calculated:

Month	Days in Month	Frequency of Watering	Number of Days Watered
May	31	Every third day	11
June	30	Every second day	15
July	31	All days	31
August	31	All days	31
September	30	Every third day	11
		Total	99

The total amount of water applied during the five-month period is

57,600 gpd × 99 days = 5,702,400 gal
= 762,353 ft^3
= 5.7 mil gal*

* The final answer must be given in the audit's official unit of measure.

Figure 2-7 Estimating landscape irrigation is drained. Also, it should be determined whether the hose or refill pipe is left running during that time. Flow rates should be determined for the appropriate outlet, refill pipe, or hose, and the volume used should be calculated. If the source is a hose bib from a metered facility, no further calculation is needed because the consumption will be included in the billed account data.

Leaks. To estimate leakage, the inlet supply should be closed for 24 hours, and any decline in the water level of the pool should be measured. Knowing the dimensions of the pool, the drop in level should be converted to a volume. The average amount that should be lost to evaporation (if any) is subtracted from the normal water volume. The difference is leakage. Water lost to evaporation, drainage, cleaning, and leaks should be added. The losses by type of facilities (e.g., parks, buildings) should be added within the service area.

The manager for County Water Company estimates the amount of water consumed in managing decorative water facilities to be 1.75 mil gal. Enter the sum of 1.75 mil gal on the fifth line in Table 2-9.

Step 5-2F. Swimming pools. Swimming pools require considerable water to maintain volume and water quality, including cleaning filters, as well as maintenance water to clean decks and walkways, and to operate sanitary and drinking water facilities associated with swimming pools. Concessionaires may also be served from a branch supply connection pipe from the pool water supply. Many swimming pools are served via metered supply connections, and this is the recommended practice for pools and related water appurtenances. In such cases, their consumption is already counted as part of metered billed authorized consumption.

If supply lines to swimming pools are unmetered, the consumption should be estimated from information provided by operations and maintenance staff, carefully noting the volume of the pool and number of fillings. Generally, the batch estimating procedure can be applied. Comparing water consumption with metered pools of similar size and function is also a viable approach. In addition to the recommendation to establish metering on pool supply lines, it is strongly recommended to monitor pool structures, linings, and plumbing for leaks. It is not uncommon to hear of public swimming pools being filled continuously throughout the warm weather season with no overflow of the pool, as a result of heavy leakage that is left unchecked. Leakage volumes can be estimated in the same manner as described for decorative water facilities.

The manager for County Water Company estimates the amount of water consumed in swimming pool management to be 0.42 mil gal. Enter this sum on the sixth line in Table 2-9.

Step 5-2G. Construction sites. Water is often delivered through fire hydrants to tank trucks for road dust control, site preparation, landscaping, temporary domestic use, and materials processing (e.g., mixing concrete). Fire hydrants may also be permitted to supply new building construction sites until such time that permanent water service connections are installed. Meters can be required for such use in order to obtain the volumes consumed during this work.

In the absence of meters, one way to estimate total use is to obtain consumption data from metered construction sites for similar projects. Data might also be obtained from regulatory water agencies. The practice of shutting off supply at unmetered sites should be compared with the practices at metered sites and compensated for the difference. Establishing bulk water stations to provide water for such use should be considered to assist accountability, efficiency, and positive revenue stream for the water utility (see sidebar on page 37).

The manager for County Water Company estimates the amount of water consumed at construction sites to be 0.56 mil gal. Enter this sum on the seventh line in Table 2-9.

Step 5-2H. Water quality and other testing. This water is used to test distribution system output to meet public health standards and to test meters and new mains. Operations to disinfect new water mains, or repairs in existing water mains, can use reasonable quantities of water for filling and flushing. Water consumption can be estimated by contacting operations staff to determine testing frequency as well as duration and volumes of water used. Amounts probably vary with each user.

The manager for County Water Company estimates the amount of water consumed during water quality and other testing to be 1.2 mil gal. Enter this sum on the eighth line in Table 2-9.

Step 5-2I. Water consumption at public buildings not included in the customer billing system. It is recommended that water service connections to all permanent structures be metered and included in the water utility customer billing system. Many municipal water utilities have policies not to bill their own municipal and government buildings. However, establishing accounts in the billing system and regularly reading meters ensures that water consumption is measured and archived. This is essential to provide accountability and tracking to confirm conservation improvements and detect leaks or other wasteful consumption.

Unfortunately, many water utilities do not meter or track consumption at public buildings. Typical facilities can include municipal offices, schools, government buildings, institutional buildings, water and wastewater buildings (treatment plants and pumping stations), park buildings, and recreational facilities. Estimates can be formulated by comparing buildings to metered locations of similar size and function. Water consumption at water or wastewater treatment plants—which require considerable volumes of water in their operations—can be estimated by assessing water using processes such as filter backwashing and chemical process applications. By noting the pumping rates through individual processes and their duration of operation, reasonable estimates can be obtained.

The manager for County Water Company estimates the amount of water consumed at public buildings to be 2.15 mil gal. Enter this sum on the ninth line in Table 2-9.

Step 5-2J. Other. An unmetered but verifiable use may not fit any of the categories previously described. In that case, the best means for estimating the total volume used should be determined and included in the "Other" category.

The manager for County Water Company estimates the amount of water consumed at a variety of miscellaneous uses to be 0.85 mil gal. Enter this sum on the ninth line in Table 2-9.

Step 5-2K. Sum of all components of unbilled authorized consumption: unmetered. Each of the individual estimates obtained under 5-2A through 5-2J as shown in Table 2-9 should be added.

The total estimate of Unbilled Authorized Consumption: Unmetered is 183.82 mil gal. Because this amount is greater than the default calculation of 55.03 mil gal on Line 16 of the worksheet, the manager enters 183.82 mil gal on Line 16A. The worksheet therefore uses the larger of these two values—183.82 mil gal from Line 16A in the further calculations. This water volume is valued at the composite customer retail rate of $3,945 for a total cost impact of $725,170.

The following are several insights regarding Unbilled Authorized Consumption: Unmetered. First, careful policy considerations should be employed regarding water withdrawn from fire hydrants (see sidebar on page 37). Also, how unmetered consumption instances can eventually become metered accounts should be considered. Over time, water utility managers should attempt to establish permanent metering at unmetered sites, particularly if they are permanent structures, such as municipal buildings. Finally, while these types of consumption may not provide revenue to the water utility, they should not be wasteful. There should be consideration for how water efficiency

Fire Hydrant Usage Policy: Does the Utility Have Control of Its Fire Hydrants?

An important question for water utility managers: Are the fire hydrants under control?

The primary purposes of fire hydrants are fire fighting and water distribution system testing and maintenance, including flushing water mains. In many water utilities, however, the use of fire hydrants—for both authorized and unauthorized purposes—goes far beyond these basic functions. Unauthorized consumption from fire hydrants, which is classified under Apparent Losses, occurs when hydrants are illegally used to fill tank trucks for landscaping or construction purposes, to wash cars, or to use recreationally such as for personal cooling in hot weather. Many water utilities have policies that permit water to be drawn from fire hydrants for a variety of community-spirited purposes. This water typically falls under Unbilled Authorized Consumption: Unmetered in the water audit and includes street cleaning, filling public swimming pools, providing transient supplies (such as nonpotable supply to a traveling circus), community gardens, and constructions sites. Some allow hot weather cooling relief from fire hydrants using spray caps. These varied uses of fire hydrants pose potential problems for water utilities and customers, including

- Water taken from fire hydrants is often unmetered. The more hydrants that are opened, the greater the amount of water that must be estimated in the water audit.
- Water taken continuously from fire hydrants should include backflow protection to prevent contaminants from entering the distribution system during a negative pressure event. Often no backflow protection is used.
- Water drawn from a fire hydrant could pose a health risk if used for human consumption because water quality degradation can occur as the water passes through the barrel of the hydrant.
- Using the spray of a fire hydrant to cool off is a significant safety risk as fire hydrants are usually configured to face the street. The public (often children) is pushed by water under high pressure into the roadway to compete with traffic.
- Widespread unauthorized openings of fire hydrants can result in greatly reduced pressure in the distribution system, crippling fire fighting capability, and greatly increasing the risk of backflow contamination.
- Allowing multiple uses of fire hydrants sends a poor public relations message that water is free for the taking to those who can manage to open a hydrant. This is a precarious position particularly because of the need to secure drinking water systems.

For the reasons previously stated, it is recommended that water utilities keep the number of permitted uses of fire hydrants to a minimum. Utility managers should maintain strong control of fire hydrants and resist requests for sundry uses of hydrants. It is important that utility managers establish a sound policy for fire hydrant usage that is supported by fire departments and political leaders. Procedures for permitting and tracking allowable uses should be put in place and enforced. Many water utilities are establishing bulk water sales stations to supply tank trucks rather than allowing the use of fire hydrants. This is one step of a good policy on fire hydrant use. Water utility managers should work to educate public officials, contractors, customers, the media, and other stakeholders on the need to maintain strict utility control over fire hydrants.

improvements (the need for which often becomes evident once meters are installed) could be implemented to ensure that no more water is going toward these uses than needed.

Task 6—Quantify Water Losses

Water losses are made up of apparent and real losses. In the top-down water audit approach, water losses are determined as nonrevenue water minus the sum of Unbilled Authorized Consumption: Metered and Unmetered.

The worksheet in Figure 2-4 calculates the volume of water losses as: water losses (WL) = NRW – (UACM + UACU). For County Water Company, WL = 1,143.96 – (15.42 + 183.82) = 944.72 mil gal. The cost impact of water losses can be calculated by summing the costs of Apparent Losses and Real Losses (Line 24 + Line 25) and equals $978,295.

Task 7—Quantify Apparent Losses

Apparent losses are the nonphysical losses that occur when water is successfully delivered to the customer but is not measured or recorded accurately. Apparent losses distort customer consumption data and cost water utilities revenue when accounts are underbilled. Apparent losses are comprised of

- Customer meter inaccuracy,
- Systematic data handling error, and
- Unauthorized consumption.

The top-down approach relies on the operator to devise estimates or measures of apparent losses to include in the audit. Methods to quantify apparent losses are given in the following steps.

Step 7-1. Estimate customer meter inaccuracy. In Chapter 3, the Customer Meter Inaccuracy section gives background information on customer metering. For water utilities with unmetered customer consumption, there is no amount of apparent loss caused by customer meter inaccuracy, and this component does not apply. Most drinking water utilities in North America, however, provide meters on all or most of their customer service connection piping to measure consumption. This is good industry practice supported by AWWA. Meters are subject to wear and loss of accuracy with continued use. Another common source of meter inaccuracy occurs when meters are oversized for the flow profile that they encounter. Many meter types fail to accurately measure low flow rates, therefore meters frequently experiencing low flows will be less accurate than appropriately sized meters. Historically, meter sizing calculations have been based on conservative techniques, which resulted in a significant percentage of oversized meters in many water utilities. Changing building uses, such as a factory converted to office space, can result in an oversized meter if the original meter that passed high flows remains in place after the low-flow office setting is established. The degree of inaccuracy in the meter population at any point in time depends on the amount of cumulative flow that meters have registered, whether the meters are appropriately sized and installed, the aggressiveness of the water in creating internal corrosion, and the degree of upkeep of the meter population by the water utility management. Taking these factors into account, the water auditor can determine an estimate of the amount of water lost to the inaccuracy of customer meters.

Because there are typically many thousands of customer meters in any drinking water utility, it is not practical to inspect and test every one each year. Instead, annual inspections and testing should consider large meters sized 2 in. and larger, along with a random sample of smaller meters. As a minimum, it is important to ensure that

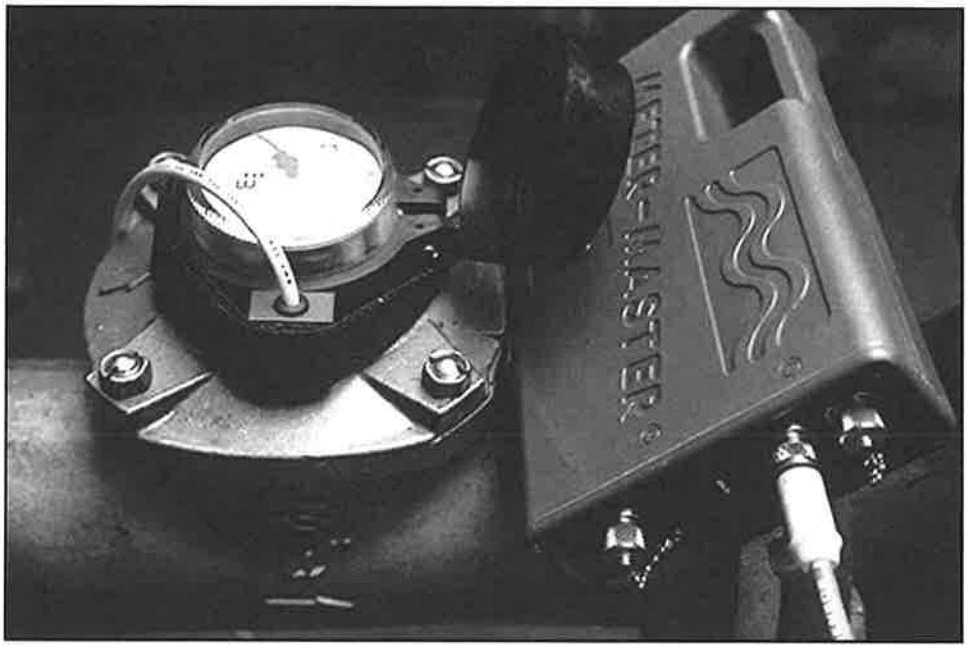


Figure 2-8 Customer meter flow recorder (Courtesy of F.S. Brainard and Co.)

the meters serving the largest users are sized properly and maintained on a regular basis.

Step 7-1A. Check for proper installation. The utility's practices on meter selection, sizing, and installation should be reviewed to determine whether or not present practices permit accurate operation. If they do not, the practices should be revised as necessary so that meters will operate correctly. Refer to AWWA Manual M6, *Water Meters—Selection, Installation, Testing, and Maintenance*, and AWWA Manual M22, *Sizing Water Service Lines and Meters*.[3]

Industrial, commercial, and agricultural meters register a much larger portion of consumption and produce a much larger share of revenue per account than do residential meters. Industrial and commercial accounts should be inspected for proper selection, sizing, and installation. In addition, all large meters should be inspected and tested before they are used. Not all new meters are sufficiently accurate.

Meter right-sizing programs. Traditional meter sizing approaches were conducted conservatively basing the size of the meter on the peak flow it might encounter; despite the high likelihood that the peak would be experienced only on rare occasions. Meters sized in this way are usually larger than they need to be, resulting in substantial meter inaccuracy at low flows. Meter right-sizing programs can recoup much of that loss with significant gains in billed consumption. Flow recorders, such as shown Figure 2-8, can provide accurate flow rate data and meter sizing decisions.

Step 7-1B. Test residential meters. A random sample of residential meters should be tested; 50 to 100 is a sufficient number, but the optimal number to be tested depends on the size of the customer meter population, the degree of confidence required in the test results, and the variance in the actual test results observed. Residential meters may be tested on a test bench or sent to the factory or a consultant for testing. (For more information see AWWA Manual M6, *Water Meters—Selection, Installation, Testing, and Maintenance*.)

Table 2-11 Weighting factors for flow rates related to volume percentages for ⅝-in. and ¾-in. water meters*

Percent of Time	Range, gpm	Average, gpm	% Volume†
15	Low 0.50–1.0	0.75	2.0
70	Medium 1–10	5.00	63.8
15	High 10–15	12.50	34.2

* Based on information from Tao, Penchin, "Statistical Sampling Technique for Controlling the Accuracy of Small Meters," *Journal AWWA*, 6:296 (1982).

† Percent volume refers to the proportion of water consumed at the specified flow rate, as compared to the total volume consumed at all rates. In this example, only 2.0 percent of the total water consumed occurs at the low-flow range of approximately 0.5–1.0 gpm.

Instead of using the percentage of volumes shown here, the utility may compute its own percentage volume data. Using special dual-meter yokes and recording meters, the utility can determine the actual flow rates for their water meters.

Table 2-12 Meter testing data from a random sample of 50 meters for County Water Company

Test Flow Rates, gpm	Mean Registration, %
Low (0.25)	88.8
Medium (2.0)	95.0
High (15.0)	94.0

Meter testing and replacement programs. Many utilities operate meter testing and replacement programs. Particularly for small meters, it has become more cost-effective to replace meters than to repair them. Random or specific testing to determine the accuracy of installed customer meters can be conducted to monitor the wear of meters. A representative sample of newly purchased residential meters can also be tested to confirm the acceptability of the delivered meters. This test data represents a good source of information to infer the overall degree of inaccuracy existing in the customer meter population. Large meter replacement programs offer an excellent opportunity to ensure that older meters are replaced with the correct type and size new meters. Flow recorders can assist with this selection process by recording the daily variation of flows and ensure that low-flow regimes are identified and included in the meter sizing determination. Both compound and turbine meters offer advantages for specific flow profiles. However, the potential inaccuracy of older meters and any flow data recorded from them should be considered if they have not been maintained properly.

Step 7-1C. Calculate total customer consumption meter error. Total customer consumption meter error includes meter errors from all meter sizes, including residential, industrial, commercial, agricultural, and others. In general, meter error can be assessed for small meters (⅝ and ¾ in.) considered residential use and all other (large) meters, which include industrial, commercial, agricultural, and others.

Calculate residential (small) meter error. Residential meters are tested for low, medium, and high flows. The results, shown as a percentage of accuracy, are used to calculate the total meter error at average flow rates. Tables 2-11 through 2.13 demonstrate how to use existing meter test data to calculate total residential meter error. The data in the tables are based on Table 2-8.

Table 2-13 Calculation of residential water meter error

Percent Volume* (%V)	Total Sales Volume† (Vt), mil gal	Volume at Flow Rate (Vf) (%V × Vt), mil gal	Meter Registration (R)‡, %	Meter Error (ME) ME = Vf/(0.01R) – Vf, mil gal	Meter Error (ME), mil gal
2.0	2,318..8	46.38	88.8	[(46.38/0.888) – 46.38]	5.85
63.8	2,318.8	1,479.39	95.0	[(1,479.39/0.95) – 1,479.39]	77.86
34.2	2,318.8	793.03	94.0	[(793.03/0.94) – 793.03]	50.62
		Total residential meter error (Line 18 of Figure 2-4)			134.33

* Data from Table 2-11.
† Based on residential water sales data in Table 2-8.
‡ Data from Table 2-12.

Table 2-14 Volume percentages for large meters for County Water Company*

Flow Rates	% Volume Delivered
Low	10
Medium	65
High	25

* For this example, assume flow recordings were made for 24 hr in July and February to indicate the percent of volume delivered by large meters at low-, medium-, and high-flow rates.

Enter the resulting residential meter error from Table 2-13 on Line 18 of the worksheet shown in Figure 2-4. For County Water Company, this is 134.33 mil gal with a cost impact at $4,142 per mil gal or a total of $556,395.

Calculate industrial/commercial (large) meter error. Tables 2-14 through 2.16 show how to use existing meter test data to calculate total large meter error. The mean registration data in Table 2-14 are used to calculate the meter error for large meters. One of the benefits of a water audit is the potential increase in revenue resulting from testing, repairing, or right-sizing large meters (performed as part of the water audit). The auditor can estimate the amount of revenue to be gained by improving the function of large meters by applying the appropriate cost factor.

Enter the resulting commercial/industrial meter error from Table 2-16 on Line 19 of the worksheet shown in Figure 2-4. For County Water Company, this is 29.97 mil gal with a cost impact at $3,627 per mil gal or a total of $108,701.

Step 7-2. Estimate systematic data handling error. The reader is directed to Chapter 3, section Systematic Data Handling Errors for background information. For water utilities that meter customer consumption, integrity must exist not just with the accuracy of the meter but also with the processes to transmit, archive, and report customer consumption totals as derived from the meter population. An error at any point in this process potentially represents an apparent loss by distorting the ultimate documented value of customer consumption, causing a portion of the consumption to be understated and possibly missing a portion of revenue. Systematic data handling error can therefore occur anywhere from the time that the meter reading is registered to the final reporting and use of the consumption data.

Table 2-15 Meter test data for large meters for County Water Company

Meter ID Number	Size, in.	Meter Type	Date of Installation	Manufacturer	Test Date	Mean Registration at Various Flow Rates: (designated as percent of registration)		
						Low	Medium	High
XYZ001	3	Turbine	June 1991	Sensus	Oct 2006	89	93	100
X00ZAA	3	Turbine	June 1993	Sensus	Oct 2006	70	95.2	98
NB123	4	Displace	July 1980	Sparling	Oct 2006	95	99	102
NB456	6	Compound	Sept 1977	Sparling	Oct 2006	98	96.5	102
AA002	6	Propeller	May 1966	Hersey	Oct 2006	98	99	103
				Sum of mean registrations		450	482.7	505
				Mean registration for five meters tested		90	96.54	101

Table 2-16 Calculation of large water meter error

Percent Volume* (%V)	Total Sales Volume† (Vt), mil gal	Volume at Flow Rate (Vf) (%V × Vt), mil gal	Meter Registration (R)‡, percent	Meter Error (ME) ME = Vf/(0.01R) – Vf, mil gal	Meter Error (ME), mil gal
10	939.2	93.92	90.0	[(93.92/0.90) – 93.92]	10.43
65	939.2	610.48	96.54	[(610.48/0.9654) – 610.48]	21.86
25	939.2	234.80	101.0	[(234.80/1.01) – 234.80]	–2.32
		Total meter error for large meters (Line 19 of Figure 2-4)			29.97

* Data from Table 2-14.
† Data from Table 2-8 sum of industrial, commercial, and agricultural metered consumption.
‡ Data from Table 2-15.

Step 7-2A. Systematic data transfer errors: Customer meter reading. Considerable error can occur in the customer meter reading process. Meters are typically read in two manners: manual meter reading or automatic meter reading (AMR). Manual meter reading, with meter reading personnel visiting individual meters to collect readings, is the traditional approach and, as of the final draft of this publication, still used by more than 60 percent of water utilities in North America. In many systems, however, manual reading is being supplanted by AMR, which is usually more accurate, less labor intensive, safer, and typically more cost effective than manual meter reading. AMR has a strong history in the gas and electric utility industry, with implementation in the water industry growing in the past 15 years. Many very successful case studies in water utility AMR have occurred; an example of which is given in the sidebar on page 44. AMR has greatly reduced the accessibility and safety problems that have plagued manual meter reading programs. Radio signals transmit the current meter reading to a device outside of the building or meter pit in which the meter is located. With mobile AMR systems, readings can be collected by meter readers with hand-held devices, or more economically, via vans patrolling scheduled meter reading routes, in which multiples readings are gathered almost simultaneously. Fixed-network AMR is starting to emerge as the more comprehensive and effective means of data collection. Fixed networks typically include permanently installed data collector units located strategically across the service area. While the traditional AMR systems gather single meter readings every 30 days or more, fixed-network or data logging AMR systems generate detailed customer consumption profiles by obtaining readings as frequently as every 15 minutes. By collecting more granular data in this manner, fixed-network or data logging AMR systems can utilize capabilities to reduce and more quickly resolve customer billing complaints, quickly identify plumbing leaks, and assist water conservation and loss control efforts. The metering and meter reading industry are creating greatly expanded capabilities at the customer end point and label this new functionality under the heading *Advanced Metering Infrastructure (AMI)*. In addition to the above capabilities, AMI includes functions such as backflow detection and tamper detection, and more end-point capabilities are likely to be developed in the future.

While AMR is less susceptible to data handling error, both forms of meter reading can incur errors. Meter reading attempts can fail for many reasons. Manual meter reading has encountered a growing number of pitfalls, particularly in gaining access to meters located inside customer premises, the typical location of water meters in colder climates. With growing numbers of working couples in families, many properties have no one at home during business hours to let a meter reader into the house. Indoor water meters are often located in hard-to-reach corners of basements, boiler rooms, or other subterranean areas. Often, owners store items that block access to the meters. Outdoor meters in pits can have access difficulties, such as flooding and snow cover in colder climates. Meter readers entering private properties often encounter safety risks from aggressive dogs, dark or poorly maintained spaces, or hostile customers. For these reasons manual meter reading success rates have declined in recent years for many water utilities. AMR attempts can fail due to a malfunction of the automatic meter reading device from causes such as battery failure. Billing system analysts should evaluate billing data to detect accounts with successive cycles of "zero consumption" to identify potential AMR failure, or possible tampering of metering or meter reading equipment.

When a meter reading attempt is unsuccessful in obtaining an actual meter reading, most water utilities bill customers based on an *estimated* volume that reflects the customer's consumption based on their recent past history. While this is a reasonable approach, multiple cycles of meter readings without an actual reading greatly increase the prospect of inaccurate estimates. Over periods of time, buildings are sold and new owners with vastly different water consumption habits may be the permanent occupants. An estimate generated for a household of two may be fine until the house is sold to a family of seven. Water consumption could triple, but understated billings based on the outdated estimate could continue for some time. When an actual meter reading is eventually obtained, a large billing adjustment will confront the new property owner, a scenario that commonly creates customer ill will toward the water utility. Clearly, obtaining routine, accurate meter readings is key in maintaining sound oversight of customer consumption patterns and maintaining stable billing and revenue collection functions.

The water auditor should review records to gain a general sense of the meter reading success rate for both residential and industrial/commercial categories of accounts. The number of estimates assigned should also be tracked and an approximation of the error due to poor estimation should be attempted. Accounts that register zero consumption for several successive meter reading cycles should be sampled and investigated to determine if the zero consumption is valid (which could occur in unoccupied buildings) or whether AMR failure or tampering has occurred. Other sources of systematic data transfer error can exist in any given water utility. Depending on the time and resources available to the auditor, investigations can be conducted to assess

The Benefits of Automatic Meter Reading Systems

Prior to the start of AMR installation in 1997, Philadelphia's Water Department and Water Revenue Bureau encountered such poor meter reading success that only one out of every seven water bills issued was based upon an actual meter reading; six were based on estimates. With the installation of over 425,000 residential AMR units by 2000, the city witnessed a meter reading success rate of over 98 percent in its monthly billing process. A system of mostly estimates was replaced with a system of mostly actual meter readings. This has greatly improved the confidence of customer consumption data, lessened the number of customer billing complaints and aided the detection of systematic data handling error and unauthorized consumption in the City of Philadelphia.

any errors that are unique to the utility. The auditor should attempt to quantify the major components of apparent loss due to data transfer error and include them in the water audit.

Enter the quantity attributed to data transfer errors on Line 20 of the worksheet shown in Figure 2-4. For County Water Company, the manager analyzes Apparent Losses related to several different meter data collection functions including meter reading error, estimating error, and computer programming error. The manager estimates the total of error identified in these areas to be 12.57 mil gal with a cost impact at $3,945/mil gal for a total of $49,589.

Step 7-2B. Systematic data analysis errors. Typically meter readings are transferred to customer billing systems where they are used to calculate the volume of customer consumption occurring since the previous reading. In the United States, consumption is most often recorded in units of cubic feet or thousand gallons. Billing systems often include programming algorithms that assign estimates of consumption if an actual meter reading cannot be obtained. These algorithms often base the estimate on the recent trend of customer consumption, or they may use another method. If a poor or outdated estimation algorithm exists in the customer billing system, underestimation or overestimation of customer consumption can occur, either of which could distort consumption data needed for operational purposes. The water auditor should understand the method used to estimate consumption and consider programming refinements if it is determined that the existing method creates inaccuracies. A quantity representing the amount of missed customer consumption as a result of this occurrence should be included in the water audit.

A significant error can also occur by billing adjustments that distort registered consumption data. An important question is: Are billing adjustments triggered by modifying actual consumption volumes? As described in the sidebar on page 72, billing systems designed with good revenue collection intention may corrupt the operational integrity of customer consumption volumes when generating a credit.

Distortions in customer consumption as a result of billing adjustments can occur when billing systems do not distinguish between *registered* consumption (from meter readings) and *billed* consumption, listed on the customer bill and archived in the billing records. Billed consumption can differ from registered consumption when the customer is due a monetary credit. If the billing system creates the credit (negative revenue to the utility) by creating negative consumption values, actual consumption data becomes distorted. Billing systems that include separate fields for registered and billed consumption avoid this problem.

Table 2-17 gives an example of a residential customer account that incurred estimates for a 23-month period, during which time the property was temporarily vacant and then sold to a new owner who consumes less water than his predecessors. Beginning in October 2002, the water utility was unable to obtain a reliable meter reading at this property. This may have been caused by blocked access to the meter, a failure of AMR equipment, or another cause. Unfortunately, the water utility was unable to correct this condition and obtain an accurate meter reading until August 2004. During the period without readings, the water utility assigned an estimate of the consumption based on the customer's recent history, in this case 885 ft^3/month. This estimate, shown in Column D, closely matched the actual consumption (shown in Column G for illustrative purposes) until April 2003, when the property was vacated and placed for sale. The property was vacant until August 2003 and experienced only minimal water consumption during periodic caretaker visits from April to August 2003. Upon sale to a new owner in August 2003, a regular pattern of water consumption resumed but at a slightly lower rate than the previous owner.

Between April 2003 and August 2004 (17 months), the assigned estimate (885 ft^3) notably overestimated the consumption for this account. When the water utility was once again able to gain an accurate meter reading, it found that its estimate of the July 2004 meter reading (42477) was overstated by a total of 4,132 ft^3 since the last accurate meter reading in September 2002. This resulting cumulative overestimation error was compounded by

- The lengthy duration (23 months) of the period with no meter readings,
- The four-month period of vacancy of the property, and
- The lower water consumption habits of the new property owner.

When an accurate meter reading was obtained in August 2004, an adjustment of negative 4,132 ft^3 cubic feet was necessary and a credit due to the customer in the dollar amount commensurate with the volume of adjusted consumption.

How the customer billing system awards this credit has bearing on both the billing (*financial*) and operational (*engineering*) functions of the system. While money can flow to and from the drinking water utility—via charges and credits, respectively—water flows in only one direction, being supplied *by* the utility *to* the customer. If the billing system contains only a single field for customer consumption, the billed consumption value for August 2004 is *negative* 4,132 ft^3. While a negative consumption number is acceptable for use for billing (financial) reasons as it translates into a monetary credit, a negative consumption number is unacceptable for operational (engineering) purposes because the actual consumption for August 2004 was 825 ft^3 (Column G), not negative 4,132 ft^3 as shown in Column D.

The distortion of the consumption data is further reflected in the estimated vs. actual consumption based on yearly periods. Water utility analysts reviewing the account data shown in Table 2-17 for conservation or loss control purposes would be in error by 3,840 ft^3 (10,620 – 6,780) over the actual consumption in 2003. Conversely, the analysis would be understated for this account by 3,967 ft^3 (8,915 – 4,948) in 2004. Some may reason that the periods of estimation and adjustment ultimately balance with no net difference over the long term; therefore, using a single consumption value is acceptable. However, many analytical and reporting functions are performed over the course of a calendar or business year. If a given account has been poorly estimated for many years, the use of a huge multi-year adjustment in the last year will greatly distort the consumption for that final year. Additionally, in any given drinking water utility, many hundreds or thousands of accounts could utilize estimates for varying periods of time. Reliably estimating the net impact of the aggregate overestimation or underestimation of these accounts in a given year is unnecessarily complex. Clearly,

Table 2-17 Distorted customer consumption data due to customer billing adjustments triggered by the use of negative consumption values (Example data for a ⅝-in. residential meter account)

A Year	B Month	C Meter Reading (estimates shown in gray)	D Billed Consumption (current minus previous meter reading, estimated consumption shown in gray), ft^3	E Cumulative Billed Water Consumption (per year), ft^3	F Actual Meter Reading	G Actual Consumption, ft^3	H Cumulative Actual Consumption, ft^3
2001	Dec	15004			15004		
2002	Jan	15838	834	834	15383	834	834
	Feb	16654	816	1,650	16654	816	1,650
	Mar	17496	842	2,492	17496	842	2,492
	Apr	18304	808	3,300	18304	808	3,300
	May	19220	916	4,216	19220	916	4,216
	Jun	20162	942	5,158	20162	942	5,518
	Jul	21130	968	6,126	21130	968	6,126
	Aug	22105	975	7,101	22105	975	7,101
	Sep	23007	902	8,003	23007	902	8,003
	Oct	23892	885	8,888	23867	860	8,863
	Nov	24777	885	9,773	24722	855	9,718
	Dec	25662	885	10,658	25535	813	10,531
2003	Jan	26547	885	885	26360	825	825
	Feb	27432	885	1,770	27184	824	1,649
	Mar	28317	885	2,655	28021	837	2,486
	Apr	29202	885	3,540	28433	412	2,898
	May	30087	885	4,425	28513	80	2,978
	Jun	30972	885	5,310	28578	65	3,043
	Jul	31857	885	6,195	28633	55	3,098
	Aug	32742	885	7,080	29255	622	3,720
	Sep	33627	885	7,965	30059	804	4,524
	Oct	34512	885	8,850	30836	777	5,301
	Nov	35397	885	9,735	31592	756	6,057
	Dec	36282	885	10,620	32315	723	6,780
2004	Jan	37167	885	885	33032	717	717
	Feb	38052	885	1,770	33740	708	1,425
	Mar	38937	885	2,655	34462	722	2,147
	Apr	39822	885	3,540	35150	688	2,835
	May	40707	885	4,425	35884	734	3,569
	Jun	41592	885	5,310	36686	802	4,371
	Jul	42477	885	6,195	37520	834	5,205
	Aug	38345	–4,132	2,063	38345	825	6,030
	Sep	39113	768	2,831	39113	768	6,798
	Oct	39811	698	3,529	39811	698	7,496
	Nov	40515	704	4,233	40515	704	8,200
	Dec	41230	715	4,948	41230	715	8,915
2005	Jan	41951	721	721	41951	721	721

while a negative consumption value can be acceptable for billing (*financial*) purposes, it is quite harmful to the integrity of the data for operational (*engineering*) purposes.

For the reasons previously explained, it is recommended that water utility customer billing systems include two separate fields for customer consumption: one for *registered* consumption and a separate field for *billed* consumption. Using the same data from the example in Table 2-17, the form of the data with separate fields is shown in Table 2-18.

Table 2-18 includes separate columns for billed consumption (Column D) and registered consumption (Column G). When actual meter readings resumed in August 2004, the consumption adjustment of negative 4,132 ft^3 appears as billed consumption in Column D and is used to generate the monetary credit to the customer. However, Column G reflects the revised estimate of consumption for the prior 30-day period, which is based on the difference between the two most recent actual meter readings (September 2001 and August 2003). This one-time estimate is determined as

$$(38345 - 23007)/23 \text{ months} = 667 \text{ ft}^3 \qquad \text{(Eq. 2-6)}$$

By September 2004, the second consecutive actual monthly meter reading was obtained, estimates are no longer utilized, and billed consumption once again matches registered consumption. The benefit to the operational integrity of data using separate billed and registered consumption fields is shown by comparing the cumulative consumption for 2004 in Column E and Column H, or 4,948 and 9,747 ft^3, respectively. If only a single field is used for consumption, the billed value of 4,948 greatly understates the actual consumption for the year. The registered consumption value of 9,747 ft^3 is a much more representative value of the water consumed by this account during 2004.

In determining the amount of data analysis error occurring in billing system operations, the water auditor should determine how billing adjustments are calculated. If adjustments are triggered by changes in consumption, then an approximation of the number of adjustments—both overstating and understating actual consumption—should be attempted. If a significant understating of customer consumption has occurred, an estimate of this difference should be included as an apparent loss and entered onto Line 21 of the worksheet shown in Figure 2-4.

Enter the quantity attributed to systematic data analysis errors on Line 21 of the worksheet shown in Figure 2-4. For County Water Company, the manager estimates this to be 8.72 mil gal with a cost impact of $3,945/mil gal or a total of $34,400.

Step 7-2C. Policy and procedure shortcomings. Apparent losses can occur because of policies and procedures that are shortsighted or poorly designed, implemented, or managed. Such occurrences can be subtle and numerous. Chapter 3 illustrates how flowcharting the customer billing process—with a focus on impacts to customer consumption values—gives insight to the likelihood of these types of apparent losses. Some of the common occurrences to consider are

- Despite company goals to meter all customers, the installation of meters in certain customer classes is ignored; this is common for municipally owned buildings in water utilities run by local governments.
- Provisions allowing customer accounts to enter *nonbilled* status, a potential loophole often exploited by fraud or poor management.
- Bureaucratic regulations or inefficiencies that cause delays in permitting, metering, or billing operations.
- Poor customer account management: accounts not initiated, lost, or transferred erroneously.

Table 2-18 Utilizing separate fields for registered and billed consumption in the customer billing system. Example data for a ⅝-in. residential water meter account (see Table 2-17)

A Year	B Month	C Meter Reading (estimates shown in gray)	D Billed Consumption (current minus previous meter reading, estimated consumption shown in gray), ft^3	E Cumulative Billed Water Consumption (per year), ft^3	F Actual Meter Reading	G Registered (actual) Consumption, ft^3	H Cumulative Registered (actual) Consumption, ft^3
2001	Dec	15004			15004		
2002	Jan	15838	834	834	15383	834	834
	Feb	16654	816	1,650	16654	816	1,650
	Mar	17496	842	2,492	17496	842	2,492
	Apr	18304	808	3,300	18304	808	3,300
	May	19220	916	4,216	19220	916	4,216
	Jun	20162	942	5,158	20162	942	5,518
	Jul	21130	968	6,126	21130	968	6,126
	Aug	22105	975	7,101	22105	975	7,101
	Sep	23007	902	8,003	23007	902	8,003
	Oct	23892	885	8,888	Unknown, No Readings	885	8,888
	Nov	24777	885	9,773		885	9,773
	Dec	25662	885	10,658		885	10,658
2003	Jan	26547	885	885		885	885
	Feb	27432	885	1,770		885	1,770
	Mar	28317	885	2,655		885	2,655
	Apr	29202	885	3,540		885	3,540
	May	30087	885	4,425		885	4,425
	Jun	30972	885	5,310		885	5,310
	Jul	31857	885	6,195		885	6,195
	Aug	32742	885	7,080		885	7,080
	Sep	33627	885	7,965		885	7,965
	Oct	34512	885	8,850		885	8,850
	Nov	35397	885	9,735		885	9,735
	Dec	36282	885	10,620		885	10,620
2004	Jan	37167	885	885		885	885
	Feb	38052	885	1,770		885	1,770
	Mar	38937	885	2,655		885	2,655
	Apr	39822	885	3,540		885	3,540
	May	40707	885	4,425		885	4,425
	Jun	41592	885	5,310		885	5,310
	Jul	42477	885	6,195		885	6,195
	Aug	38345	–4,132	2,063	38345	667	6,862
	Sep	39113	768	2,831	39113	768	7,630
	Oct	39811	698	3,529	39811	698	8,328
	Nov	40515	704	4,233	40515	704	9,032
	Dec	41230	715	4,948	41230	715	9,747
2005	Jan	41951	721	721	41951	721	721

The degree to which such shortcomings in billing account management exists is largely dependant on the accountability "culture" that exists in the water utility. If accountability is only casually emphasized, it is likely that numerous opportunities for missed consumption exist. If sound accountability is trumpeted by the utility's leaders and managed down to all levels of staff, then such occurrences are likely to be isolated and of minor significance. The water auditor should consider including an estimate of apparent loss that represents the collective policy and procedure shortcomings of the water utility. During the top-down audit, perhaps only a rough approximation can be ventured. During subsequent audits, bottom-up investigations can give greater insight to such problems, and corrections can be identified.

Enter the quantity attributed to policy and procedure shortcomings on Line 22 of the worksheet shown in Figure 2-4. For County Water Company, the manager estimates this to be 11.63 mil gal with a cost impact of $3,945/mil gal or a total of $45,880.

Step 7-3. Estimate unauthorized consumption. Unauthorized consumption includes water that is taken against the policies of the water utility and can include

- Illegal connections;
- Open bypasses;
- Buried or otherwise obscured meters;
- Misuse of fire hydrants and fire-fighting systems (unmetered fire lines);
- 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; or
- Illegally opening intentionally closed valves to neighboring water distribution systems designed for emergency or special use.

Water utilities sometimes allow a spacer pipe to be installed in place of a water meter in new building construction, with the intention to install a water meter at a later time in the occupancy process. Unfortunately, water utilities sometimes forget to install the meter and, although the customer may be aware that they are not being billed for water use, continue to consume water without notifying the water utility. Policies that allow water service to be established in this manner without a meter are discouraged. However, if such a policy is required, a periodic audit should be conducted to verify that each property has a meter and occupied buildings show positive water consumption.

The potential for unauthorized consumption exists in any drinking water utility but varies from system to system. In large, urban systems, occurrences of unauthorized consumption are likely to be more numerous than that of medium or small systems in suburban or rural settings. Yet, in most cases for systems of all sizes, the total annual volume of water lost to unauthorized consumption is likely to be a small portion of the utility water into supply volume. For expediency during the top-down water audit, the auditor may choose to use the default value of 0.25 percent of WS. This percentage has been found to be representative of this component of loss in water audits compiled worldwide. In this case, *the worksheet in Figure 2-4 calculates the volume of Unauthorized Consumption in Line 23 as 0.25 percent of the WS. For County Water Company, the manager determines that he does not have sufficient time to fully investigate the occurrence of unauthorized consumption, although he knows that a certain amount of such consumption occurs. He therefore uses the default estimate calculation of (WS) (.0025) = (4,402.16) (.0025) = 11.00 mil gal with a cost impact of $3,945/mil gal for a total of $43,395.*

For small systems, the occurrence of unauthorized consumption may be a larger portion of distribution system input flow. If the auditor believes that this consumption is significant and has the time and resources to investigate, he or she can conduct work to examine the occurrences of unauthorized consumption and obtain quantities for these components. This work can be tedious, however, and the auditor should use judgment to determine whether the extra effort to obtain specific estimates of unauthorized consumption is worthwhile compared to merely applying the default value.

If an actual quantification of unauthorized consumption is obtained, this value can be entered in Line 23A and used in place of the default estimate listed in Line 23.

Step 7-4. Calculate total apparent losses. The total apparent losses are determined by adding all apparent loss components for customer meter inaccuracy, systematic data handling error, and unauthorized consumption.

The worksheet in Figure 2-4 calculates the total volume of apparent losses in Line 24 as AL: Sum of Apparent Losses = ALMUR1 + ALMUR2 + ALDHE1 + ALDHE2 + ALDHE3 + UC. For County Water Company, the total volume of apparent losses calculates to be 208.22 mil gal with a cost impact of $838,360 of lost revenue.

Task 8—Quantify Real Losses

Water losses consist of the apparent losses plus the real losses occurring in the drinking water utility operations and management. While practical methods to quantify leakage in distribution systems exist (see Chapter 5), the top-down water audit approach mathematically calculates real losses simply as water losses minus apparent losses.

The worksheet in Figure 2-4 calculates the volume of Real Losses in Line 25 as Real Losses (RL) = Water Losses (WL) – Apparent Losses (AL), or (944.72 – 208.22) mil gal = 736.50 mil gal; at a cost impact of (736.50 mil gal) ($190/mil gal) = $139,935. Once the value of Real Losses is calculated, the value of Real Losses per day that the system is pressurized (default days = 365) is calculated in Line 26 as (736.50 mil gal)/(365) = 2.02 mgd.

While this straightforward approach makes the real losses calculation easy to determine mathematically, care should be taken in the interpretation of the volume of real losses determined in this manner. By this method of calculation, real (leakage) losses are a "catch-all" quantity, basically the amount of water leftover after consumption and apparent losses have been quantified. The reliability of the amount of leakage losses is therefore only approximate because

- The accumulated errors from the other components will be associated with the estimate of real losses;
- The catch-all nature of this estimate of leakage losses gives no indication of the breakdown of individual leakage components, particularly unreported leaks and background losses; and
- A water balance normally covers a completed (retrospective) 12-month period, so it has limited value as an early warning system for identifying new leaks.

For these reasons, leakage losses should also be assessed by additional bottom-up methods, namely

- Component analysis of real losses, and
- Quantification of leakage components via field measurements and minimum hour flow analysis.

These methods are discussed in Chapters 4 and 5.

Task 9—Assign Costs Of Apparent and Real Losses

The process of compiling a water audit is effective in tracing the water supplied by a drinking water utility to its various destinations, including losses. Of equal importance, however, the method detailed in this publication also assesses the cost impact of all water audit components. Water utilities, like any business entity, cannot operate efficiently without knowing their costs and impacts on budgeting, operations, revenue collection, capital financing, and all other financial aspects of utility management. The worksheet in Figure 2-4 provides for costs for each of the pertinent components in the water audit to be assigned in the column shown on the right side of the worksheet.

The nature of the valuation process of the water audit is compelling in the stark difference between apparent and real losses. Because apparent losses are quantified by the amount of water improperly recorded at the customer's delivery point, this water is valued at the retail cost that is charged to the customer. Apparent losses cost water utilities a portion of their revenue. Often, the cost impact of apparent losses is higher than that of real losses, which are typically valued at the variable production costs to treat and deliver the water. (If water resources are constrained, the utility might also be justified in valuing real losses at the customer retail rate.) For most water suppliers, the retail rate charged to customers is notably higher than the variable production costs to provide the water. Therefore, apparent losses can have a dramatic financial impact to the water utility's revenue stream.

Step 9-1. Determine cost impact of apparent loss components. Because apparent losses represent water supplied but not paid for, these losses should be valued at the prevailing retail rate charged to customers. Many water utilities, however, have multiple rates in place for different customer classes such as residential, commercial, or industrial. Also, many utilities include wastewater charges based on the volume of water consumption. Various rate structures are also used: increasing block (conservation) structures, decreasing block structures, as well as surcharges, discounts, and waivers. The auditor should review the rate structure to gain familiarity with the cost impact of apparent losses. For practicality, however, various sub-rates should likely be grouped into only two to four categories to avoid having too many cost categories involved in the water audit. Even a single composite rate can be used for simplicity. The water audit shown in Figure 2-4 lists three rates: a small meter (residential) charge, a large meter (industrial/commercial) cost, and a composite cost (between these two values).

Step 9-2. Determine cost impact of real loss components. Assessing costs for real losses can be complex, but the methods included in this publication recommend keeping the evaluation simple. Real losses include water that has been extracted from a water resource source, treated, energized, and transported a distance before being lost from the distribution system. Because these quantities of loss occur in addition to the water successfully supplied to customers, real losses effectively impose on the water utility excess extraction, treatment, and delivery charges, and/or excess imported water purchase charges. Treatment and delivery costs include the variable costs to produce the water, or the costs to produce the next million gallons (or other standard increment) of water. If the water supplied is purchased from a neighboring water utility, the purchase unit cost should be applied. Generally, unit costs for treatment (chemicals, power) and delivery (pumping power costs) can be readily determined, and these costs will suffice for the water audit.

While not recommended for inclusion in the top-down water audit, it is worth noting that other long-term costs also exist for real losses. The cost of wear and tear on treatment and pumping equipment might be taken into account in the supply costs, particularly if real losses are high. Additionally, because real losses represent volumes of water taken from a source that do not generate a benefit, these losses could also be assessed costs relating to their environmental, economic, and social impacts. Reducing leakage could mean smaller withdrawals from a river, which could improve instream flows, benefiting aquatic life, recreation (boating, fishing), or economic development (waterfront amenities). Clearly, in the long term, such impacts exist. Because these impacts are difficult to quantify, they are not included in this manual. Work is underway to devise user-friendly ways to quantify such impacts.

Another situation for consideration is that of a water utility facing constrained water resources with water restrictions in effect. In this case, real losses might be valued at the retail rate (same as apparent losses) because the reduction of these losses could result in the sale of like volumes of water to customers, thereby allowing new development to occur without increasing water withdrawals.

The worksheet in Figure 2-4 provides for entry and summation of costs for all components of the water balance, as shown in the column on the far right. As listed, the cost impact to County Water Company caused by apparent losses is $838,360, and the cost impact caused by real losses is $139,935.

Task 10—Calculate the Performance Indicators

The IWA/AWWA Water Audit Method published in *Performance Indicators for Water Supply Services* (2000)[1] includes a highly useful array of performance indicators, which represent one of the greatest strengths of the method. With this publication, multiple indicators of varying detail became available to water utilities, allowing a realistic assessment of water loss standing. The performance indicators published in 2000 are defined in Table 2-19 and are endorsed by the AWWA Water Loss Control Committee. In 2006, the second edition of the IWA/AWWA publication was published with changes to the structure of several of the performance indicators.[4] The Water Loss Control Committee has not undertaken a review of these changes and remains in support of the performance indicators published in the first edition. These performance indicators appear throughout this manual and the AWWA Water Loss Control Committee's Free Water Audit Software.

Prior to 2000, the sole performance indicator used in many parts of the world had been the imprecise unaccounted-for water percentage, which usually took some form of the amount of water losses over system input volume. A number of flaws existed in this approach, including

- Practices to define the volume of unaccounted-for water varied widely; therefore the calculation of this percentage has been widely inconsistent, eliminating any meaning for reliable performance comparisons.
- This indicator is highly sensitive to the level of customer consumption in the water utility. If consumption increases or decreases noticeably, the percentage can change, despite the fact that no change in loss levels may have occurred.
- This indicator does not segregate apparent and real losses. Also, it includes no information on water volumes and costs, the two most important parameters in assessing water loss.

Some have used the inverse of the unaccounted-for water percentage or the *metered water ratio* as the amount of billed water over the system input volume. Even the name of this *indicator* is misleading, as some drinking water utilities do not meter their customers. The concept behind both of these expressions was applied in the development of the IWA/AWWA method to specifically define the nonrevenue water by volume indicator. This new indicator has value but only as a high-level financial indicator, and it is not sufficiently detailed to be useful as an operational indicator.

The method includes performance indicators in financial and operational areas of water supply functions. The performance indicators were also established in three levels of detail, labeled 1, 2, and 3; representing high level, broad indicators (1) down to very detailed indicators (3). The method includes performance indicators at each of these levels as shown in Table 2-19.

The full array of performance indicators can be calculated on completion of the water audit. Individually, these indicators give good insight to the loss standing in particular functional areas. Collectively, they give a very realistic, objective assessment of overall loss standing and are viewed as the current best practice means to assess water loss standing in water utilities.

Step 10-1. Calculate the financial performance indicators. The water audit method includes two financial performance indicators that are useful in assessing a water utility's fiscal standing regarding water losses. The first indicator is expressed as a percentage of the volume of nonrevenue water over the system input volume and labeled as Fi36 on Table 2-19. This performance indicator is closest in its definition to

Table 2-19 IWA/AWWA Water Audit Method—Performance indicators

Function	Level*	Code*	Performance Indicator	Comments
Financial: Nonrevenue water by volume	1 Basic	Fi36	Volume of nonrevenue water as a percentage of system input volume	Easily calculated from the water balance, has limited value in high-level financial terms only; it is misleading to use this as a measure of operational efficiency
Financial: Nonrevenue water by cost	3 Detailed	Fi37	Value of non-revenue water as a percentage of the annual cost of running the system	Incorporates different unit costs for nonrevenue components, good financial indicator
Operational: Apparent Losses	1 Basic	Op23	[gal/service connection/d]	Basic but meaningful performance indicator for apparent losses. Easy to calculate once apparent losses are quantified
Operational: Real Losses	1 Basic	Op24	[gal/service connection/d] or [gal/mi of mains/d/psi] (only if service connection density is less than 32/mi)	Best of the simple "traditional" performance indicators, useful for target setting, limited use for comparisons between systems
Operational: Real Losses	2 Intermediate		[gal/service connection/d]/psi or [gal/mi of mains/d/psi] (only if service connection density is less than 32/mi)	Easy to calculate this indicator if the Infrastructure Leakage Index (ILI) is not yet known, useful for comparisons between systems
Operational: Unavoidable Annual Real Losses	3 Detailed	UARL	UARL (gal) = (5.41Lm + 0.15Nc + 7.5Lc) × P, (Eq. 2-7) Where: Lm = length of water mains, mi Nc = number of service connections Lc = total length of private service connection pipe, mi = Nc × average distance from curb stop to customer meter, Lp (see Figures 2-9 through 2-11 to determine L_p) P = average pressure in the system, psi	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. A key variable in the calculation of the ILI. The UARL calculation is not valid for systems with less than 3,000 service connections.
Operational: Real Losses	3 Detailed	Op25	ILI (dimensionless) = CARL/UARL	Ratio of Current Annual Real Losses (CARL) to Unavoidable Annual Real Losses (UARL); best indicator for comparisons between systems

* Descriptors assigned to the performance indicators are from the IWA publication *Performance Indicators for Water Supply Services*, 2000.

the conceptual unaccounted-for water percentage used inconsistently in the past. However, by employing the specifically defined *nonrevenue* water in the numerator, this performance indicator avoids the inconsistencies that have crippled the interpretation of unaccounted-for water. This indicator has some usefulness but only on a high-level financial basis to assess overall water supply management. Because it does not provide specific insight to the level of apparent loss or real loss management, it is not useful as an operational performance indicator.

As shown in Figure 2-4, the Fi36 financial performance indicator for County Water Company is calculated to be 25.9 percent.

The second financial performance indicator is very revealing by quantifying the financial impact to the water utility from losses. This indicator is expressed as the cost of nonrevenue water over the total annual cost of running the water supply system (Fi37). These costs include those for operations, maintenance, and any annually incurred costs for long-term upkeep of the system, such as repayment of capital bonds for infrastructure expansion or improvement. Typical costs include employee salaries and benefits, materials, equipment, insurance, fees, administrative costs, and all other costs that exist to sustain the drinking water supply. These costs should not include any costs to operate wastewater, biosolids, or other systems outside of drinking water. This indicator gives important insight to water utility managers, the financial community, regulators, customers, and advocacy groups about the overall financial impact of losses on the water utility. It is an important indicator that could be used when issuing bonds, setting water rates, or employing other financial functions typically undertaken by water utilities.

For County Water Company, the Fi37 financial performance indicator is calculated to be 18.3 percent. Because the Fi37 (Level 3) indicator is a more detailed indicator than Fi36 (Level 1), its value of 18.3 percent is a better reflection of the financial impact of losses occurring in County Water Company. On its own, the Fi36 indicator appears to overstate the impact of losses on this utility.

Step 10-2. Calculate the operational performance indicators. The method also includes five operational performance indicators, the greatest number of indicators in any of the three functional areas. These indicators range in levels of detail from 1 (high level) to 3 (detailed). As shown in Table 2-19, one performance indicator exists for apparent losses and four indicators exist for real losses.

Step 10-2A. Apparent losses normalized. This performance indicator (Op23) measured in gallons of apparent loss per service connection per day is effective is assessing apparent loss standing and is useful to monitor as apparent loss controls are implemented. It is important to recognize that the cost impact of apparent losses is also an important parameter to track, particularly because the valuation of apparent losses at the retail customer rate is typically substantial. Apparent loss costs represent revenue to be recovered, a portion of which can often occur with very modest recovery effort.

For County Water Company, the Op23 performance indicator is calculated to be 46.8 gallons per service connection per day. The cost impact of apparent losses for 2006 is $838,360.

Step 10-2B. Real losses normalized. Two normalized performance indicators exist for real losses; a basic indicator and an intermediate indicator. The basic indicator (Op24) is measured in gallons of real loss per service connection per day. However, for water utilities with a low density of service connections (such as rural systems), the indicator is measured in gallons per mile of main per day. Those systems that have a system-wide average density of less than 32 service connections per mile of main should apply the latter indicator.

For County Water Company, the Op24 performance indicator is calculated to be 165.4 gallons per service connection per day. The cost impact of real losses for 2006 is $139,935.

The intermediate version of the Op24 performance indicator for real losses is expressed in gallons per service connection per day per psi. For low density of connections, the units are gallons of real loss per miles of main per day per psi. The value for pressure is the average distribution system pressure across the system boundaries from in the water audit. The sidebar on pages 56–58 offers guidance on calculating the average system pressure. The same delineation of 32 service connections per mile of main distinguishes low-density systems.

For County Water Company, the intermediate version of the Op24 performance indicator is calculated to be 2.54 gallons per service connection per day per psi of average system pressure.

These performance indicators are effective for trending the status of real losses in a water utility and for basic target setting. As leakage management controls are successfully implemented, the downward trend in these measures should be observed.

Step 10-2C. Infrastructure leakage index (ILI). The infrastructure leakage index (ILI) is a performance indicator designed for benchmarking of leakage standing among water utilities. The ILI is the ratio of the level of current annual real losses (CARL), from the water audit, to the unavoidable annual real losses (UARL). The UARL is a reference minimum level of leakage that is calculated in a system-specific manner for a water utility. It represents the theoretical low limit of leakage that could be achieved if all of the current best leakage management efforts could be exerted. Equation 2-7 calculates the UARL and is shown in Table 2-19. The data needed to calculate the UARL are typically available to water utility staff and include

- The total length of water main piping in the distribution system, mi
- The total number of fire hydrants and average hydrant lead length (from water main to hydrant barrel), ft
- The average pressure across the distribution system, psi (The sidebar on pages 56–58 offers guidance on calculating average system pressure)
- The number of customer service connections
- The miles of service connection piping maintained by the water utility (taken as the average length of a service connection piping under utility responsibility multiplied by the total number of service connections and converted from feet to miles). This value is determined based on the water utility's policy for leak repair responsibility and the delineation point of this responsibility, such as the curb stop or customer water meter. As shown in Figure 2-4, this parameter is calculated by multiplying the value of Lp by the number of service connections, Nc. Figures 2-9 through 2-11 show the definition of the Lp value in various customer service connection piping and metering configurations.

It can be seen that the structure of the UARL calculation is specific to the individual water utility. Hence, the UARL for a relatively large system with high pressure will be higher than a small system with moderate or relatively low pressure. This system-specific approach portrays the utility's real loss standing in an objective manner, rather than a "one level fits all" approach.

The derivation of the UARL calculation is given in Tables 2-20 and 2-21. The UARL calculation was devised by the IWA Water Loss Task Force during its development of the water audit methodology. In conducting work to develop a reliable benchmarking performance indicator (the ILI), the task force determined to devise a means to evaluate the technical low limit of leakage that could be achieved in a given water distribution system. It is recognized that leakage in any water

DETERMINING AVERAGE SYSTEM PRESSURE IN A WATER UTILITY DISTRIBUTION SYSTEM

Water utility managers need to understand the variation of water pressure across their distribution systems in order to assess the potential for improved pressure management, and to calculate their level of UARL using Equation 2-7 in Table 2-19.

The UARL is typically calculated for the entire water distribution system, and the average pressure across the network is one of the inputs into Equation 2-7. It is recognized that, while a mathematical average of the pressure throughout the water distribution system can be calculated, pressures can vary considerably from one part of the system to another, particularly if the system exists in hilly or mountainous terrain. In such cases, the utility manager should become familiar with those regions where static system pressures are notably lower or higher than the average level, and the impact of these regional pressures on leakage rates and levels of customer service. Chapters 4 and 5 discuss pressure management.

Calculating Average Pressure Across a Water Distribution System

Several means exist to determine the average system pressure with accuracy sufficient to calculate the UARL. These methods include

- The use of a calibrated hydraulic model, which can provide pressures at nodes across the water distribution system under various water demand conditions. The average of pressures across the system can easily be calculated by the data from this model. If a hydraulic model does not exist for the water distribution system, one of the following methods should be selected to approximate the average pressure.
- For water distribution systems existing across a relatively flat service area, the average pressure can be determined by gathering static pressure readings from approximately 30 fire hydrants spaced proportionally across the system. The mathematical average of these readings should be calculated. Because fire hydrants in North America are typically located aboveground, water pressure in the underground pipelines is slightly higher (1–2 psi, depending on depth) than the level measured at the fire hydrant.
- For water utilities whose distribution system extends across hilly or mountainous terrain, the distribution system should be sectioned into several distinct zones that represent different pressure regimes. In each zone, topographical data (ground-level elevations) should be gathered, and a weighted average technique should be used to determine the location of the average elevation. Water pressure can be measured at the average elevation site from a fire hydrant or other system appurtenance to give a good approximation of the average pressure in the specific zone. The average pressure values from individual zones can then be averaged to obtain the average pressure across the entire distribution system.

An example calculation from the last of the method methods is shown on page 57. The example focuses on one region of County Water Company's service area: the downtown region. The water piping grid for this region is shown on page 58. Fire hydrant locations are shown as well as ground-elevation contours, at 10-ft contour intervals. The ground elevation of this region varies from 850 ft above sea level to more than 910 ft above sea level.

DETERMINING AVERAGE SYSTEM PRESSURE IN A WATER UTILITY DISTRIBUTION SYSTEM (continued)

County Water Company—Downtown Region Listing of Fire Hydrants and Ground-Level Elevation

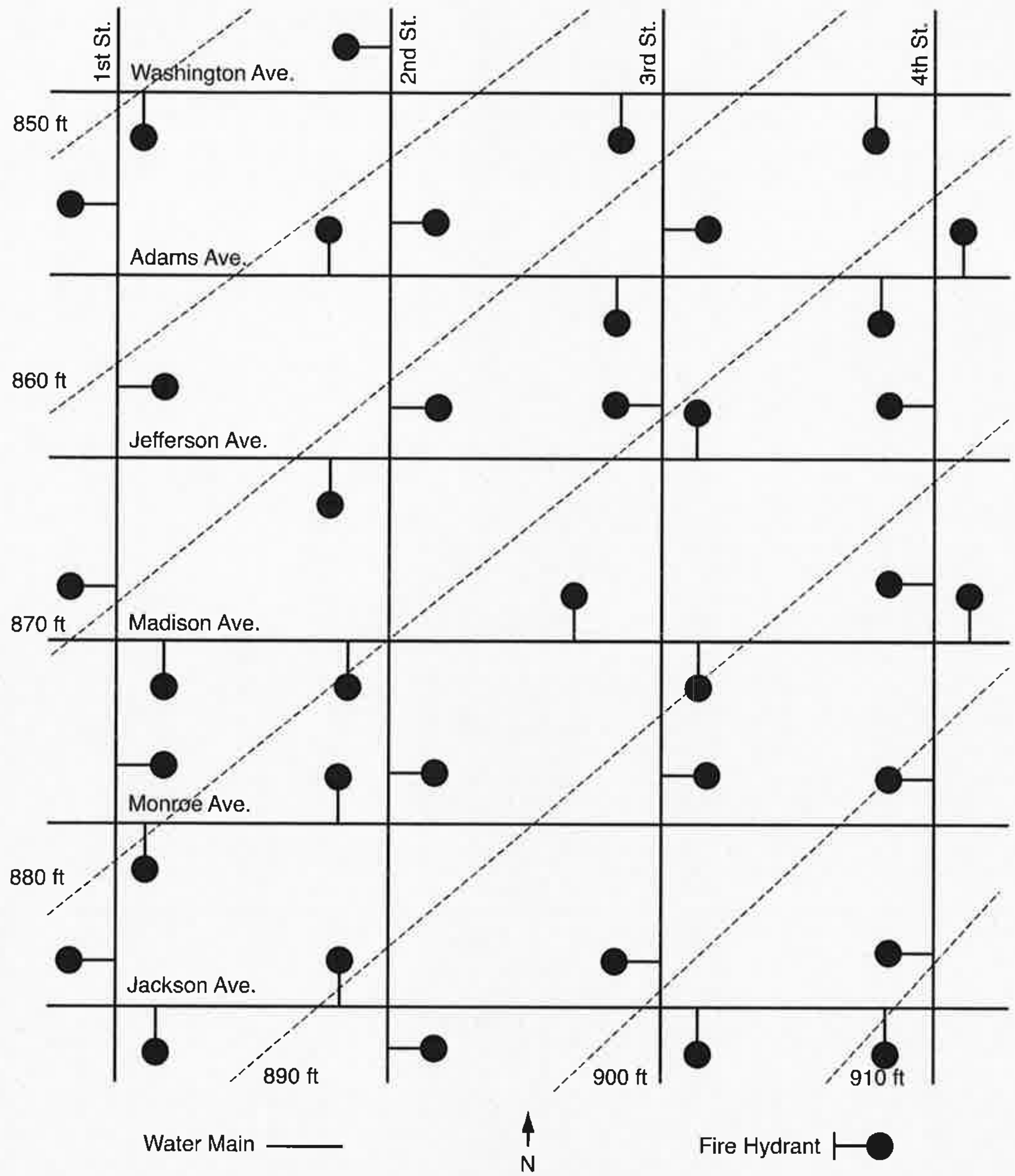
Street	Cross Street	Elevation	Street	Cross Street	Elevation
Washington	1st	850	Washington	W. of 3rd	865
1st	N. of Adams	854	3rd	N. of Adams	872.5
1st	N. of Jefferson	861.5	Adams	W. of 3rd	873
1st	N. of Madison	869	3rd	N. of Jefferson	879.5
Madison	1st	872.5	Jefferson	E. of 3rd	882
1st	N. of Monroe	877.5	Madison	W. of 3rd	885
Monroe	1st	879.5	Madison	E. of 3rd	888.5
1st	N. of Jackson	883	3rd	N. of Monroe	892.5
Jackson	1st	886	3rd	N. of Jackson	899
2nd	N. of Washington	854.5	Jackson	E. of 3rd	902
2nd	N. of Adams	863	Washington	W. of 4th	874.5
Adams	W. of 2nd	862	Adams	E. of 4th	883
2nd	N. of Jefferson	871	Adams	W. of 4th	882
Jefferson	W. of 2nd	871	4th	N. of Jefferson	887
Madison	W. of 2nd	879	4th	N. of Madison	893
2nd	N. of Monroe	885	Madison	E. of 4th	898
Monroe	W. of 2nd	884.5	4th	N. of Monroe	902
Jackson	W. of 2nd	890.5	4th	N. of Jackson	909.5
2nd	S. of Jackson	893.5	Jackson	W. of 4th	910

Weighted Average Calculations

Lower Limit	Upper Limit	Mid-point	Count	Count times Mid-Point	
850	860	855	3	2,565	Weighted Average Ground Elevation = 33,480/38 = 881.0 ft
860	870	865	5	4,325	Nearest location of Average Zone Point = 881.0 ft Adams, W. of 4th = 882.0 ft **Measured pressure at this fire hydrant = 58 psi; for underground piping, take as 57 psi**
870	880	875	10	8,750	
880	890	885	10	8,850	
890	900	895	6	5,370	Nearest location of zone Critical Point = 910 ft Jackson, W. of 4th = 910 ft **Measured pressure at this fire hydrant = 45 psi; for underground piping, take as 44 psi**
900	910	905	4	3,620	
		Total	38	33,480	

NOTES: The average zone point (AZP) in a zone is defined as the location of the average static water pressure. The critical point (CP) in a zone is defined as the location of the lowest static water pressure. In this example, the AZP and CP are taken as the location of the average and highest elevations, respectively. It is recognized that the locations of the AZP and CP are influenced by both elevation and the level of head loss in the distribution system. Identifying these locations is therefore most accurate when using a hydraulic model. However, the method shown in this example gives a reliable way to identify the AZP and CP with limited data collection needs.

DETERMINING AVERAGE SYSTEM PRESSURE IN A WATER UTILITY DISTRIBUTION SYSTEM (continued)



distribution system can never be totally eliminated; and there is no reasonable expectation that such is possible. However, a number of water utilities have been successful in driving leakage down to extremely low levels and maintaining low-loss operations.

The Water Loss Task Force obtained data from dozens of world class systems and observed the rate at which new leaks arise despite having comprehensive leakage controls in place. From this, data allowances were created for various leak types according to response times typical of strong leakage management operations. The allowances were developed for the three leak types: background leakage, reported leakage, and unreported leakage. These types are defined in Chapters 4 and 5. An allowance for each leakage type was assigned for key infrastructure components; such as water mains, customer service connection piping maintained by the water utility, and customer service piping typically maintained by the customer.

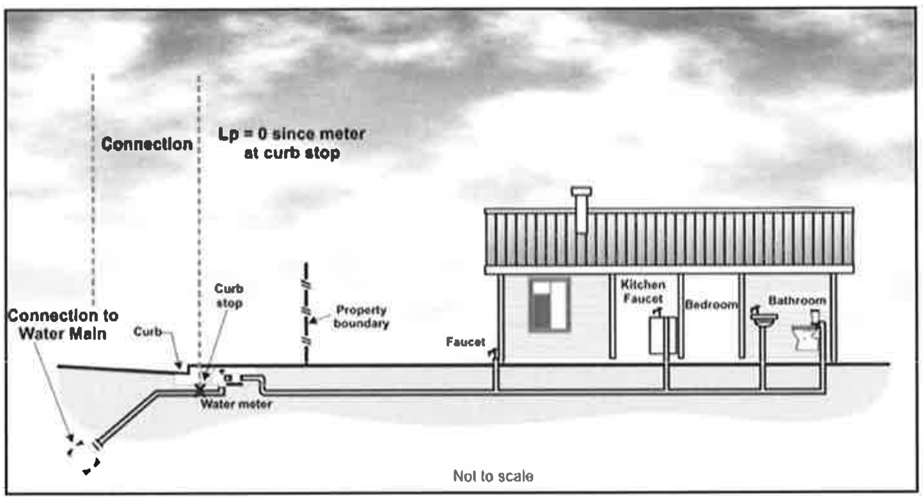


Figure 2-9 Determining the Lp distance for customer meter located at the curb stop[5] (Courtesy of Ronnie McKenzie, WRP Pty Ltd.)

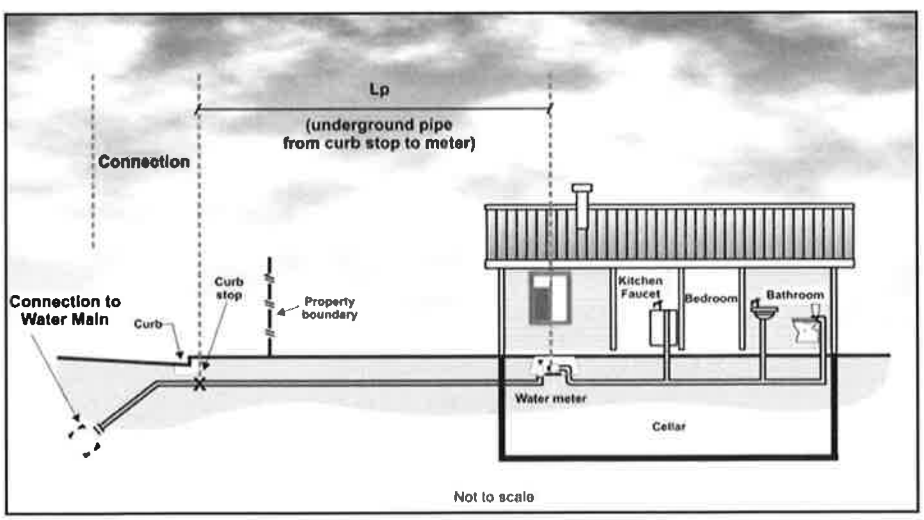


Figure 2-10 Determining the Lp distance for customer meter located inside customer premises[5] (Courtesy of Ronnie McKenzie, WRP Pty Ltd.)

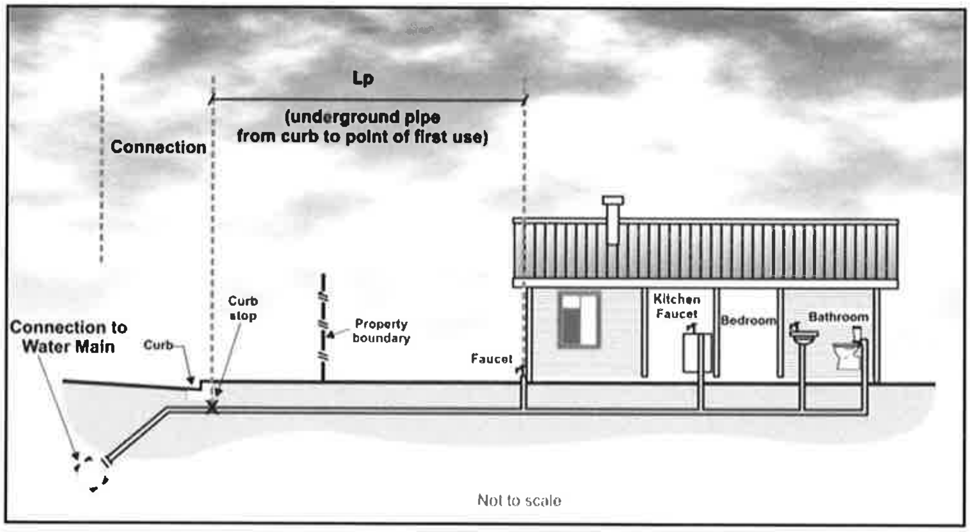


Figure 2-11 Determining the Lp distance for unmetered customer properties[5] (Courtesy of Ronnie McKenzie, WRP Pty Ltd.)

Table 2-20 Component values of the UARL calculation[6]

Infrastructure Component	Background (undetectable) Leakage	Reported Leaks and Breaks	Unreported Leaks and Breaks
Mains or pipelines	8.5 gal/mi/hr	0.20 breaks/mi/yr at 50 gpm for 3 days' duration	0.01 breaks/mi/yr at 25 gpm for 50 days' duration
Service connections, main to curb stop	0.33 gal/service connection/hr	2.25 leaks/1,000 service connections at 7 gpm for 8 days' duration	0.75 leaks/1,000 service connections at 7 gpm for 100 days' duration
Service connections, curb stop to meter or property line (for 50 ft average length)	0.13 gal/service connection/hr	1.5 leaks/1,000 service connections at 7 gpm for 9 days' duration	0.50 leaks/1,000 service connections at 7 gpm for 101 days' duration

NOTE: All flow rates are specified at a reference pressure of 70 psi.

Leakage events serving as the basis for these allowances are shown in Table 2-20. The equivalent leakage rates that occur under the conditions in Table 2-20 are shown in Table 2-21. As shown in Figure 2-4, the system specific data for County Water Company (miles of water main, average pressure, Lp value, and number of customer service connections) are used to calculate the UARL value.

Note: The UARL calculation has not yet been sufficiently proven valid for small systems with less than 3,000 service connections or a service connection density of less than 16 connections per mile of pipeline. Systems at or below these levels can rely on the real losses Op24 (gallons per mile of main per day) performance indicator as a measure of real loss standing.

The ILI is the ratio of CARL over UARL. The ILI is structured as a benchmarking performance indicator, allowing reliable comparisons of real loss standing among water utilities. For water utilities that are just starting to audit their supply, the ILI can also be used as a preliminary target-setting mechanism (see Chapter 5). Setting

Table 2-21 Standard unit values used for the UARL calculation[6]

Infrastructure Component	Background Leakage	Reported Leaks and Breaks	Unreported Leaks and Breaks	UARL Total*	Units
Mains, gal/mi of main/d/psi	2.87	1.75	0.77	5.4	Gal/mi of main/d/psi
Service Connections, main to curb stop, gal/service connection/d/psi	0.112	0.007	0.030	0.15	Gal/service connection/d/psi
Service Connections, curb stop to meter, gal/mile of service connection/d/psi	4.78	0.57	2.12	7.5	Gal/mil of service connection/d/psi

* The UARL values give the following equation:

$$\text{UARL (gal)} = (5.4L_m + 0.15Nc + 7.5Lc) \times P$$

Where:

Lm = length of water mains, mi (including hydrant lead length)
Lc = Nc × Lp (average length of private pipe)
Nc = number of service connections
P = average pressure in the system, psi

targets via the ILI carries a caveat, however. Because average pressure is included in the UARL and ILI calculations, changes in pressure (as might be performed in pressure management strategies) will alter the UARL and ILI. It is possible that leakage reductions might be achieved via improved pressure management, yet the ILI may remain unchanged, or even rise. Once a water utility has moved past its initial water auditing and loss control efforts, the ILI should serve only as a benchmarking indicator. Real loss reduction can then be tracked via the Op24 performance indicator.

For County Water Company, the CARL is 736.50 mil gal, and the UARL is calculated to be 83.69 mil gal for the year. The ILI is calculated as the ratio of CARL over UARL and is determined to be 8.8, or a current level of real losses 8.8 times greater than the technical low level that could be achieved, in theory, if all possible leakage interventions were successfully applied.

During the first several years since the publication of the IWA/AWWA method, the ILI has become the most recognizable performance indicator quoted by water utilities applying this method. Perhaps one of the most important features for water utilities in performing a water audit is the ability to compare their water loss standing with peer utilities in the industry. The ILI is designed to effectively serve this purpose. Water audit data and findings are reported for several water utilities in case study accounts included in Appendix D. The ILI allows for a reliable method of comparison among these utilities.

Task 11—Compile The Water Balance

Once the worksheet shown in Figure 2-4 has been completed, quantities from the key consumption and loss components can be shown on the water balance. The completed water balance for County Water Company is shown in Figure 2-2. It can be seen that the summation of the component volumes in each column moving left to right is 4,402.16 million gallons, hence all flows balance. The water balance reflects that all water managed by the drinking water utility is accounted for in the various categories of consumption and loss. Hence, no water is *unaccounted for*, and no such term exists in the recommended water audit method.

It is recognized that by quantifying the amount of real losses as a "catch-all" volume by subtracting authorized consumption and apparent losses from water supplied, the data is forced to balance. The discussion under Task 8 notes that this does necessarily represent a wholly accurate quantification of the real losses because errors in the water supplied, authorized consumption, or apparent losses could induce a degree of error in the real loss value. Statistical methods have been devised to assign values representing the likely degree of error in each of the categories, thereby identifying those components of the water audit that are less reliable than others. These methods are beyond the scope of this manual but are offered as services by various consultants. Ultimately, the reliability of the top-down water audit is improved by incrementally incorporating bottom-up approaches as described in Chapters 3 and 5.

An Important Final Word About Data Validation

The top-down audit is highly useful—particularly for water utilities doing a first-time water audit—because it is quick to assemble using readily available data. The downside to the top-down approach is that, for many first-time auditors, the quality and completeness of readily available data may be questionable. While the audit can be completed and the performance indicators calculated, how confident can the water utility manager be in those results if it is believed that much of the data entered into the water audit is of marginal quality?

This is the question of data validation. The IWA/AWWA Water Audit Method now exists to give water utilities a highly robust and reliable structure for water auditing. However, as with computer systems, the quality of the output of the water audit (performance indicators) is only as reliable as the quality of the data entered into the water audit.

No water utility has perfect data, and all data are subject to some degree of error. If the water auditing process is instituted as a standard, annual business practice—as it should be—a two-fold goal should exist to both compile the water audit and incrementally utilize bottom-up activities to improve the completeness and quality of the data.

Many methods currently exist to display the quality of data in water audits. Many consultants use auditing software that assigns statistical confidence levels to each component of the water audit. A composite degree of error can then be stated for the audit. The AWWA Water Loss Control Committee's free Water Audit Software, described in Appendix C, includes a data grading capability to weigh the validity of the water audit data. Rather than applying statistics, it uses a process-based approach to assign a validity score for the audit and provides specific guidance for water utilities. Regardless of the data validity assessment method used, it is important that water utilities assess both the output data and the degree of confidence of the data. The higher the level of confidence or validity of the data in a water audit, the greater is the level of confidence in devising the particular loss reduction strategies.

As water auditing becomes incorporated into the water industry, and perhaps the regulatory environment, the greater will be the need to state the degree of error existing in the water audit. This will be necessary to make fair comparisons among water utilities. The best course of action is for water utilities to perform regular water auditing and consistently improve their data via the bottom-up approaches detailed in Chapters 3 and 5.

SUMMARY

Water utility managers can assemble the top-down water audit by gathering records, data, and procedures from various operations routinely occurring in their provision of drinking water. The top-down water audit is largely a desktop exercise, with minimal field testing or investigations required. The advantage is that the top-down audit can be assembled relatively quickly and give a reasonable sense of the utility's accountability status and the nature and extent of its losses. It is extremely important that the water utility verify the accuracy of its production meters and correct any gross malfunctions of these devices as part of the top-down process. To refine the top-down water audit and formulate strategies to cut losses, work should then shift to the bottom-up approach. Over time, bottom-up activities should be pursued to better audit apparent losses (described in Chapter 3) and real losses (described in Chapter 5).

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