Water Use Audit Analysis

City of Las Vegas, New Mexico

Prepared for
New Mexico Office of the State Engineer
City of Las Vegas

Prepared by

HYDROSPHERE
Resource Consultants

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Abbreviations

AWWA = American Water Works Association
GPM = flow rate, in units of gallons per minute
IWA = International Water Association
MG = million gallons
NMOSE = New Mexico Office of the State Engineer
PSI = pressure, in units of pounds per square inch
WTP = water treatment plant

1. Introduction

The New Mexico Office of the State Engineer (NMOSE) contracted Hydrosphere Resource Consultants ("Hydrosphere") to complete a water use accounting and consumption analysis for the City of Las Vegas, New Mexico ("the City"). This analysis was done in cooperation with the City of Las Vegas Utilities department. The American Water Works Association (AWWA) Water Loss Control Committee Water Audit methodology was the basis for this work.

The overall purpose of this study was to implement a water use accounting project using the International Water Association/American Water Works Association (IWA/AWWA) water audit methodology in order to provide useful information to the City of Las Vegas for their ongoing water planning efforts. In addition, the study will provide NMOSE with data and experience for developing a statewide methodology for water demand and conservation planning. The specific tasks performed by Hydrosphere for this analysis included:

- **Water use questionnaire:** Hydrosphere reviewed the answers to a questionnaire provided to the City of Las Vegas by the NMOSE that requested detailed information about the City's water supply system, water use records and other data needed to complete a water audit (i.e. information regarding water meters or other measurement devices including locations, models, specifications, age, and accuracy testing methodology and schedules, among other details). After reviewing the questionnaire response, Hydrosphere requested follow-up information from the City in several areas.

- **Pre-production/withdrawal data quality control –** Hydrosphere reviewed the quality and evaluated the accuracy of treated water production data provided by the City. This included an assessment of the accuracy of the City's treated water production meters.

- **End use data quality control and evaluation –** Hydrosphere obtained copies of the City's monthly utility billing and consumption summary reports for 2006, as well as a copy of relevant portions of the City's billing database covering that period. Hydrosphere reviewed those data and worked with the City to understand the details of

the City's billing process and associated database management system. Hydrosphere categorized the City's end uses into billed metered, unbilled metered, billed unmetered, and unbilled unmetered amounts through discussions with City utilities staff, visual and statistical analyses of the data, and review of industry research literature.

- **Preliminary water balance –** Hydrosphere developed a preliminary water balance for revenue and non-revenue water for calendar year 2006 utilizing the AWWA water audit methodology. This involved a significant amount of processing of treated water production and end use data necessary for calculations.

- **Detailed breakdown of non-revenue water** – As part of the development of the preliminary water balance, Hydrosphere developed a detailed breakdown of non-revenue water use.

- **Study report –** Hydrosphere prepared this project report including descriptions of the data, assumptions and methods used and calculations made, obstacles encountered in completing the water audit, recommended action steps for the City to minimize non-revenue water and implement water conservation, and discussion of the AWWA water audit methodology and software, and how it could be used by Las Vegas.

2. Description of Las Vegas' Water Supply System

2.0. Mission Statement

The mission of the City of Las Vegas Water Department is to provide the finest and most proficient service in the City of Las Vegas and surrounding areas. It is the Department's intention to continue providing the best quality water and to be ready to respond to any concerns our customers may have in regards to the City's Water System. The City of Las Vegas water supply system has 7,189 residential, commercial, and industrial accounts.

2.1. Service Area and Population

The City's water utility provides water supply to a range of residential, commercial and livestock customers located within the City's incorporated area (about 4,600 acres) and certain adjoining areas outside the City's boundaries. According to 2000 census data, Las Vegas had a service area population of approximately 14,600 people. Assuming a 1% average annual growth rate since 2000, the City's 2006 service area population is estimated to have been about 15,500 people. The NMOSE recommends that service area population be calculated as follows.

(#SFR accounts + #MFR units) x HHS x VR

where:
#SFR accounts = number of single-family residential accounts in the service area
#MFR units = number of multi-family residential units in the service area
HHS = mean household size (persons/household), from Census data for the service area
VR = vacancy rate (expressed as a percentage), from Census data for the service area

We could not use this methodology to calculate the City's service area population because data on multifamily residential units in the service area were not available.

The City's service area population fluctuates during the year due to seasonal changes in student enrollments at Highlands University, Luna Community College and the Armand Hammer United World College of the American West. The fall/spring student enrollment at these institutions is

about 3,500, 2,060 and 100 students, respectively (totaling 5,660), with less than half of these students being residents of Las Vegas. During the summer the combined enrollment at these institutions drops to about 800 students. This constitutes a seasonal fluctuation of more than 2,400 people in the City's service area population, which should be considered when evaluating the City's water use patterns. For example, Section 2.6 (below) discusses Las Vegas' outdoor watering ban in 2006 and Figure 3 shows that the City's monthly in-City residential consumption was essentially flat throughout the year. Our comparison of irrigation season vs. non-irrigation season consumption for a sample of individual residential accounts (as described in Section 2.6 below) showed that summer water consumption by some residences rose significantly, suggesting that the outdoor watering ban was not universally complied with. However, reduced water demands caused by the summer reduction in student population probably masked this non-compliance from the perspective of total residential water use.

2.2. Raw Water System

The primary water supply source for the City is surface water diverted from the Gallinas River, supplemented with water from the Taylor well field, as shown in Figure 1. Water from the Gallinas River is diverted by a 27" raw water line and metered at a 27" raw water meter pit. A 16" raw water line then transports Gallinas River water to Bradner and Peterson Reservoirs or directly to the water treatment plant (WTP). Water in Bradner and Peterson Reservoirs can be conveyed to the City's WTP or to Storrie Lake. Under an agreement with the owners of Storrie Lake, the City can store excess surface diversions in Storrie Lake for later municipal use. Water flows by gravity to Storrie Lake via a 16" raw water line. The City's stored water in Storrie Lake is then metered and pumped back to Peterson Lake through the same 16" raw water line for water quality blending purposes before going to the WTP. Treated water from the WTP either flows directly into the main distribution line, or into a 5 million gallon (MG) storage tank adjacent to the WTP (the Cabin Site storage tank). All treated water leaving the WTP is metered via an 18" electromagnetic meter.

During 2006, Taylor Well #4 was the only producing well in the Taylor well field. This well was shut down from August through December 2006 while Taylor Well #7 was being finished

(Well #7 is not yet in service pending NMOSE permitting). Water pumped in 2006 from the Taylor Well #4 is metered at the wellhead via an 8" DanFoss type flow meter and treated with a mixed-oxidant chlorination system. Water pumped from the City's wells is blended with water from the treatment plant in the 400,000 gallon Valencia tank (via a new 8" P.V.C. pipe).

2.3. Distribution System

According to updated information provided by City utilities staff, the City's treated water distribution system has 91 miles of 3" to 18" water mains, 10.2 miles of 2" to 2½" mains, and 23 miles of ½" to 2" individual service lines between its points of treated water production and its end use meters. More than 75% of the city's service lines have been updated to copper pipe; the rest is galvanized pipe. The City's water distribution system is currently divided into three pressure zones: Zone 1 ranges from 50 to 100 psi, Zone 2 ranges form 45 to 100 psi, and Zone 3 ranges from 40 to 90 psi. According to the City's questionnaire responses, there are a total of 6,445 metered connections to the City's treated water distribution system. A summary of the City's water distribution system data is shown in Table 1. The distribution of metered connections among customer classes is shown in Table 2.

Table 1: Summary of Las Vegas Distribution System Data
(Source: City of Las Vegas)

Length of Mains, miles	124.2
Number of Active and Inactive Service Connections	6445
Connection Density, connections per mile of main	52
Average Length of Private Pipe, feet	50.0
Average Operating Pressure, psi	75

It should be noted that the City's monthly billing and consumption reports show an average of 6,338 connections during calendar year 2006. The discrepancy amounts to 1.7%, which can be reasonably attributed to inactive accounts associated with vacant residences and businesses; this compares to the US Census calculated vacancy rate of 1.2%. According to an estimate provided by the City, the average length of line from the meter to the place of use is 50 feet.

Table 2: Number of Connections by Customer Sector and Meter Size
(Source: Las Vegas responses to MNOSE questionnaire)

Sector	Number of Connections in City	Number of Connections out of City	Meter Size
Residential	4562	1023	5/8" - 3/4"
Residential	43	26	1"
Small Commercial	504	29	5/8" - 3/4"
Large Commercial	71	16	1"
Large Commercial	131	13	2"
Large Commercial	20	3	4"
Large Commercial	0	2	6"
Large Commercial	2	0	8"
Total	**5333**	**1112**	
All meters are either a Mueller, Neptune or Badger brand, and 90% of the 5/8"-3/4" meters have been replaced with Neptune brand.			

2.4. Production Meters

All water leaving the City's WTP is measured by an 18" electromagnetic meter that is approximately 1 year old. The WTP production meter is has a remote totalizing read-out that is read by operating staff and meter readings are recorded every day. The City provided us with monthly flow volumes through this meter for 2006, as well as the daily meter readings for the end of each month. According to the treatment plant supervisor, the minimum flow rate through this meter in 2006 was about 800 GPM, which occurred during the night when most of the produced water was being used to refill the City's treated water storage tanks. No estimate of the maximum daily flow rate was provided. We estimated the maximum daily flow as 2.0 times the maximum recorded monthly flow volume in 2006, or approximately 2,800 GPM. We consider this estimate to be conservative given that little or no outdoor watering occurred in 2006.

The WTP meter is an 18" Endress & Hauser Promag 53F. A review of technical data for his meter indicates maximum measured errors of 0.8% and 0.2% at the corresponding estimated low and high flows of 800 to 2,800 GPM, with the maximum error increasing to approximately 2.5% as the flow drops to 400 GPM. This is somewhat consistent with the City utility staff's estimate that the WTP production meter is "accurate down to 400 GPM". Endress & Hauser's technical information specifies that Promag meters should be installed with several considerations in mind

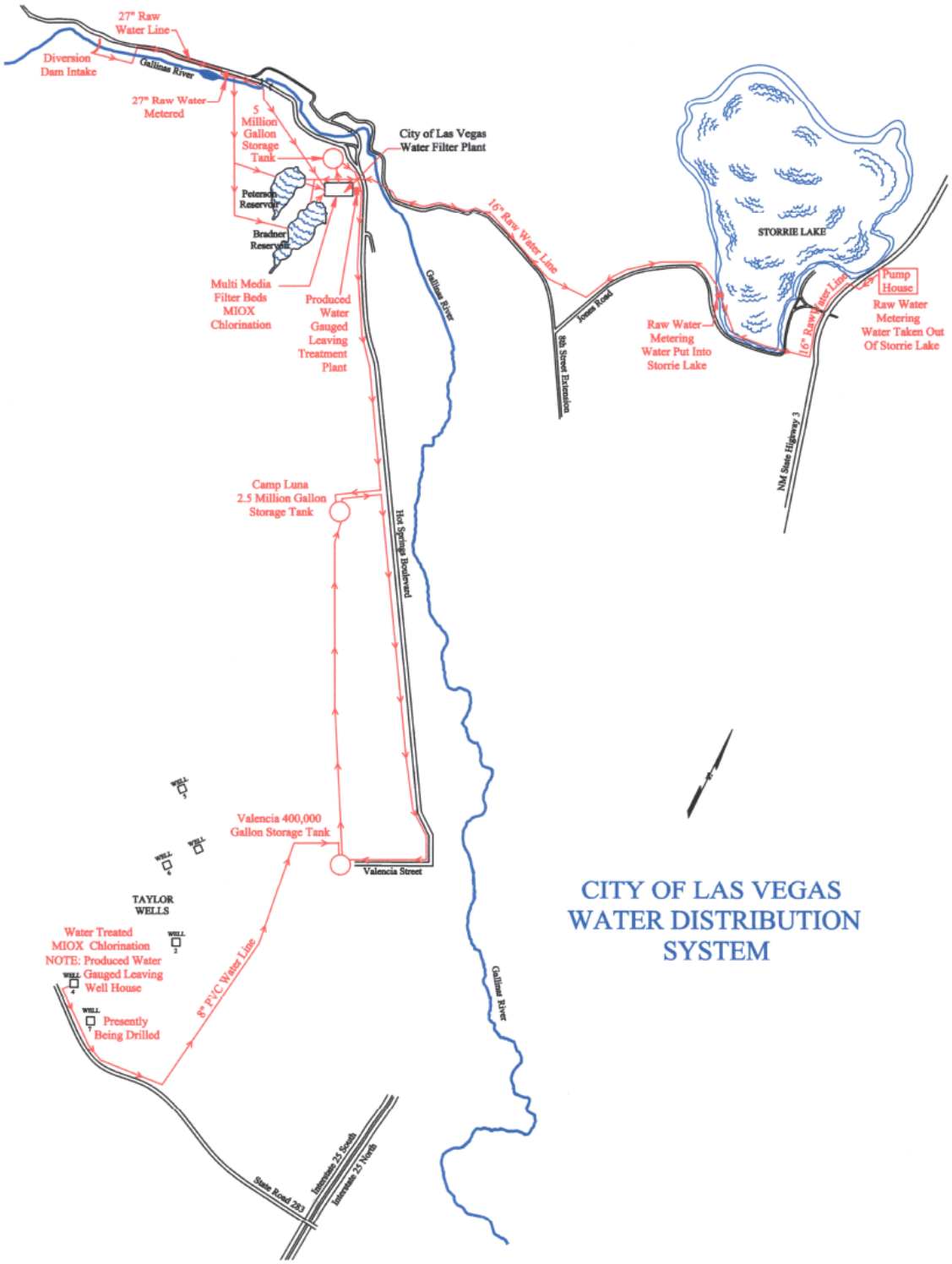

Figure 1: Schematic of City of Las Vegas Water Supply and Distribution System.
(Source: City of Las Vegas)

to avoid entrained air, pump suction, partially filled pipes, etc. The City provided photos of the meter, but Hydrosphere did not make a visual inspection of this meter as City staff indicated that the meter is located in an underground vault. Therefore, we were not able to assess whether the WTP production meter was installed in a manner to optimize its accuracy.

According to the City's responses to the questionnaire, water pumped from Taylor Well #4 is measured by an 8" DanFoss MAGFLO 5100 meter that is approximately 2 years old. According to the City utility staff, this well meter is has a totalizing read-out that is read by operating staff every day. The City provided us with monthly flow volumes through this meter for 2006. During 2006, the Taylor Well #4 was used for raw water supply only during the months of January through August. Monthly production volumes during those months ranged from 1.35 to 11.56 MG. No daily or sub-daily flow records were provided, so no estimates of minimum and maximum flow rates through the well meter could be developed. A DanFoss Magflo Model 5100 meter has an accuracy of 0.2% of the total flow passing through the meter.

According to the City utility staff, neither meter has been tested since being installed (both meters are less than 2 years old), but the City is planning on implementing an annual testing program for both meters beginning in 2007.

2.5. End Use Meters

As previously discussed there are approximately 6,445 metered connections to the City's water supply system. According to the City's billing database approximately 88% of these connections are residential and 12% are commercial. Approximately 98.3% of the meters were associated with active accounts in 2006.

As a normal aspect of operating and maintaining its water supply system, the City has had an ongoing meter replacement program that operated primarily in response to reported problems or meter failures. According to the City's billing database, the city replaced an average of 5% of its end use meters annually from 1990 through 2002. In 2003, the City purchased 6,000 new Neptune model T-10 positive displacement meters and began an expedited meter replacement program that has continued to date. The age distributions of the City's end use meters at the

beginning and end of 2006 are shown in Table 3. Based upon the information shown in Table 3, the weighted mean age of the City's end use meters in 2006 was 6.98 years, and about 33% of the City's end use meters are more than 10 years old.

The City reported that it does not have a system for testing residential meter accuracy, and that meters are sent to the manufacturer for testing when needed.

Table 3: Age Distribution of Las Vegas' End Use Meters in 2006
(Source: City of Las Vegas water utility billing database)

January 2006			December 2006		
Year Meter Installed	Count	Percent of Total	Year Meter Installed	Count	Percent of Total
1989	1316	20.4%	1989	1080	17.0%
1990	163	2.5%	1990	124	2.0%
1991	276	4.3%	1991	236	3.7%
1992	198	3.1%	1992	157	2.5%
1993	208	3.2%	1993	172	2.7%
1994	180	2.8%	1994	141	2.2%
1995	79	1.2%	1995	68	1.1%
1996	108	1.7%	1996	97	1.5%
1997	86	1.3%	1997	74	1.2%
1998	82	1.3%	1998	63	1.0%
1999	116	1.8%	1999	91	1.4%
2000	103	1.6%	2000	79	1.2%
2001	116	1.8%	2001	77	1.2%
2002	170	2.6%	2002	141	2.2%
2003	449	7.0%	2003	430	6.8%
2004	1886	29.2%	2004	1849	29.1%
2005	820	12.7%	2005	779	12.3%
2006	96	1.5%	2006	695	10.9%
Total	6452	100.0%		6353	100.0%

2.6. Landscaping

Weather conditions in 2006 were severe with a very dry spring and early summer, followed by record breaking flooding in August. Flow rates in Gallinas Creek (Figure 2), the main water source for the City, dropped to almost zero in June. Stage 2 water conservation measures were in force on January 1, 2006 and were raised to Stage 3 on March 27. There was a complete ban on outdoor watering of both residential and city landscaping during 2006. The exception to the irrigation ban was the City's golf course, which was irrigated with reclaimed wastewater. The

effect of this ban can be seen in Figure 3, which shows monthly in-city residential consumption and total treated water production. In years with no watering restrictions, there is a pronounced spike in summer residential consumption due to irrigation of lawns and other landscaping.

Compliance with the outdoor watering ban does not appear to have been universal. We reviewed the 2006 billing and consumption records for a sample of 96 in-city residential accounts for which there was no change in owner or occupant during the year. For 25 of those 96 accounts, the average May-July consumption was more than 20% greater than the average January-April consumption. This trend was not apparent from a total consumption perspective because some residences used significantly less water in the summer, which may be attributable to the summer decline in student enrollment at the local colleges, as previously discussed.

The City also reported that, during normal watering conditions, irrigation of City parks is metered and included in the city's billed consumption database.

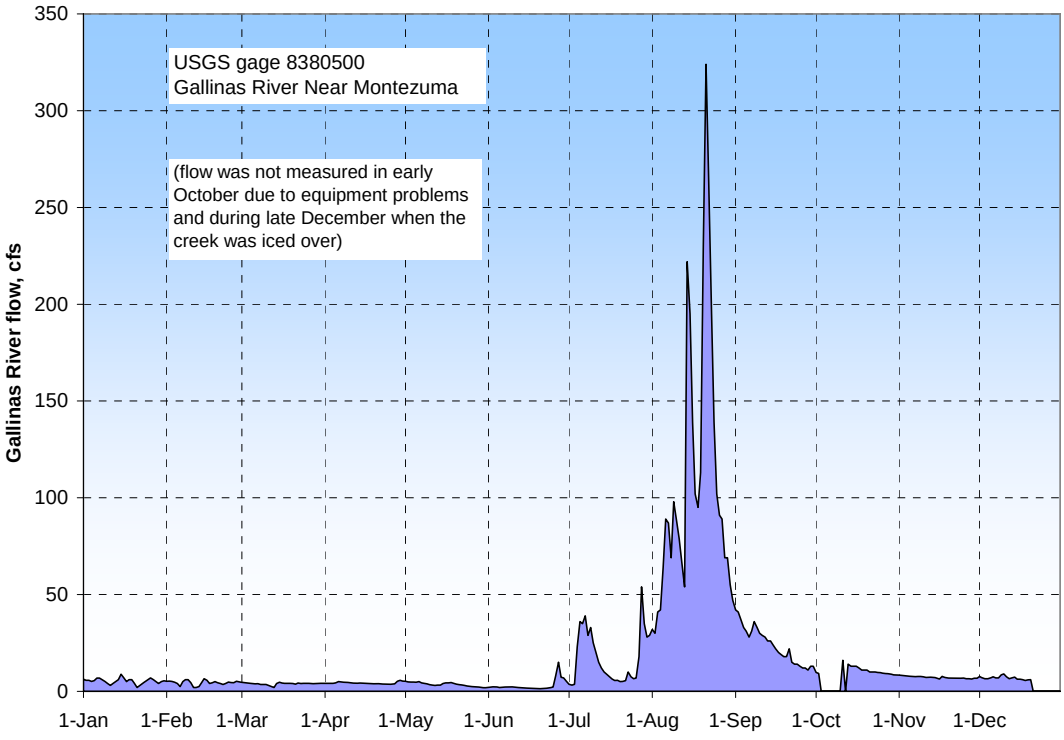

Figure 2: Gallinas River stream flow from 1/1/2006 through 12/31/2006.
(Source: USGS National Water Information System)

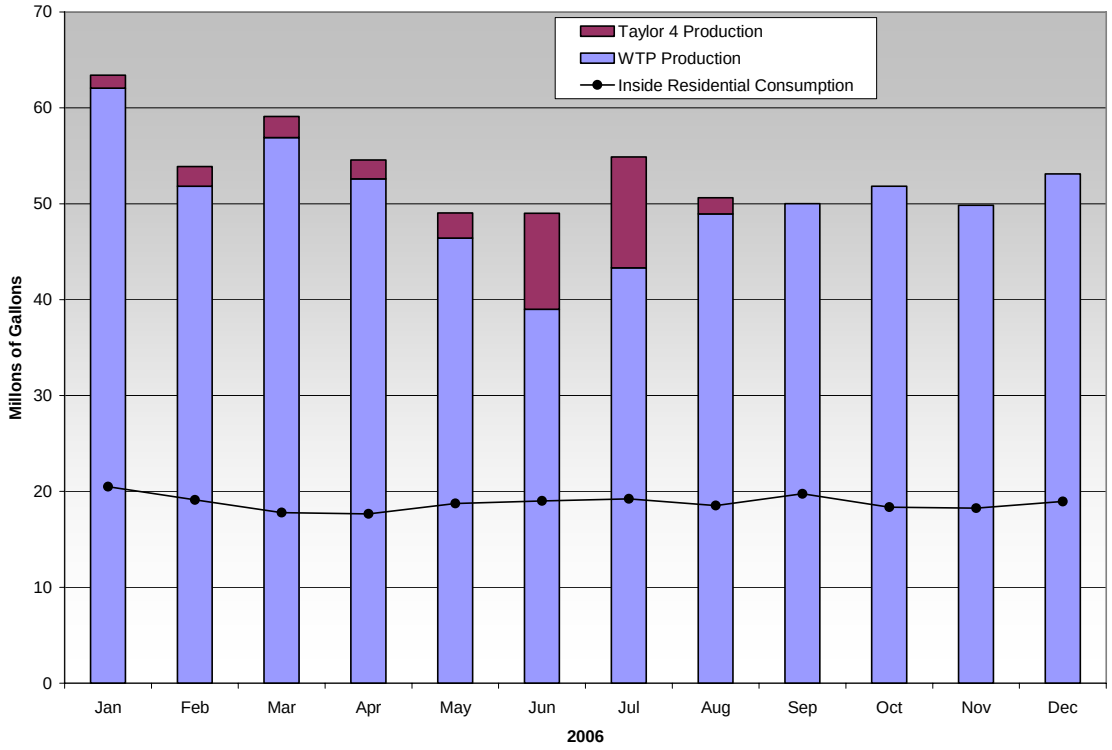

Figure 3: Residential Consumption (inside city limits) vs. Treated Water Produced.
(Source: City of Las Vegas)

2.7. Miscellaneous Water Uses

Street sweepers and construction companies normally obtain water from fire hydrants using temporary meters. During 2006, no street sweeping occurred, and water for construction purposes was supplied from reclaimed wastewater. Bulk one-time sales of potable water, typically to water tanker trucks, occurs at one location referred to as the "standpipe meter". Such sales are metered and the water is purchased at the time of pumping. Because this water use is paid for immediately, this consumption is not included in the City's billing database. Standpipe meter sales totaled 245,000 gallons in 2006.

Water usage at the City Public Pool is metered, and the Public Pool was operated during 2006.

2.8. Reclaimed and Reused Water

The City has 5,383 residential sewer accounts. As well as treating wastewater from within the city limits, approximately 30,000 to 35,000 gallons of septic sewage per month are treated from outside the service area. The City's total monthly wastewater discharge volumes for 2006 are summarized in Table 4. The major users of the reclaimed wastewater include construction companies, which average 57,000 gallons per month, and the City golf course, which uses approximately 558,000 gallons per month. Water purchased from the wastewater treatment plant is not included in the billing database.

Table 4: 2006 Wastewater Treatment Plant Discharge.
(Source: City of Las Vegas)

Wastewater Discharge in Million Gallons	
January	41.97
February	40.81
March	54.07
April	53.25
May	56.62
June	55.77
July	52.18
August	54.04
September	52.02
October	53.46
November	45.37
December	43.60

3. Water Audit Analysis

3.1. Water Supplied

As previously discussed, in 2006 the City obtained its water supply from surface water from the Gallinas River, and ground water from the Taylor Well #4. A monthly summary of the City's treated water production is shown in Table 5. Water use by customer class is shown in Figure 4.

Table 5: City of Las Vegas Treated Water Production in 2006, (million gallons)
(Source: City of Las Vegas)

Month	Water Treatment Plant	Taylor Well #4	Total Treated Water
Jan	62.06	1.35	63.41
Feb	51.83	2.05	53.88
Mar	56.91	2.20	59.11
Apr	52.58	1.97	54.56
May	46.43	2.62	49.05
Jun	39.00	9.99	48.99
Jul	43.31	11.56	54.87
Aug	48.94	1.68	50.62
Sep	50.01	0.00	50.01
Oct	51.84	0.00	51.84
Nov	49.84	0.00	49.84
Dec	53.12	0.00	53.12
Year	605.86	33.43	639.29

A review of available information for the City's two treated water production meters indicates that both meters are less than three years old. The manufacturer's reported maximum error rates for meters similar to the City's WTP meter range from 0.2 to 0.7%, with no reporting as to the nature of that error (over- vs. under-report). While we did not inspect the production meters' installation, there is no basis to assume that there are any problems with the installations in terms of meter accuracy. Therefore, no adjustment for production meter error is warranted at this time.

According to City utility staff, Las Vegas does not import water from other providers nor does it export water to water users outside of its service area. Therefore, the total treated water supplied by the City in 2006 is assumed to be 639.29 MG. We compared the volumes of produced water reported in the questionnaire (and shown in Table 5) to meter readings recorded at the end of

each month by the City's operators on their daily water reports. While we could not exactly reproduce the provided numbers, the discrepancy was less than 0.05%.

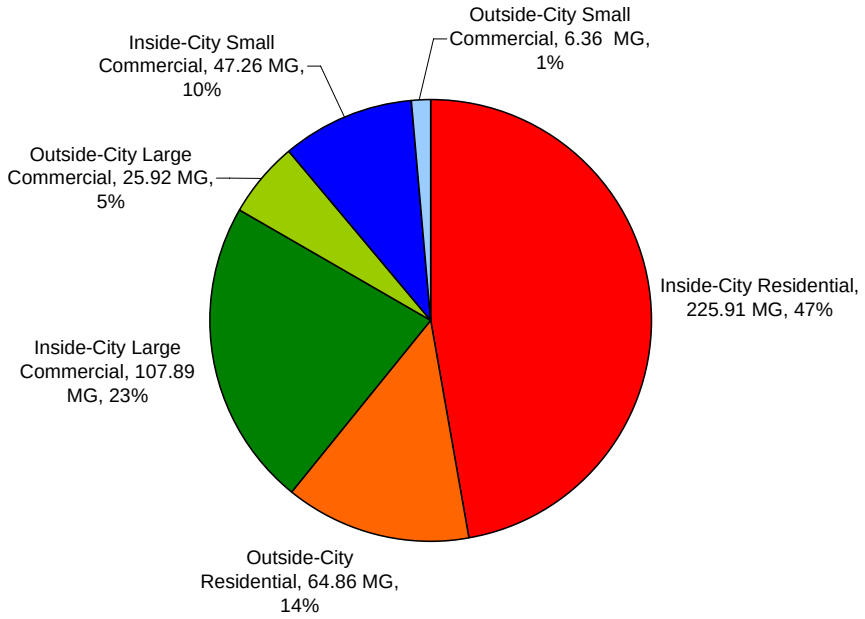

Figure 4: Water Use by Customer Class for Both Inside and Outside City Limits.

(livestock consumption was less than 1% and is not shown in this chart)
(Source: City of Las Vegas water utility billing database)

3.2. Authorized Consumption

Authorized consumption is the sum of billed metered consumption, billed unmetered consumption, unbilled metered consumption, and unbilled unmetered consumption. As discussed below, authorized consumption in 2006 totaled about 478.67 MG, which is the sum of the four authorized consumption components listed above.

3.2.1. Billed Metered Consumption

According to the City's billing database, billed metered consumption during 2006 was 478.34 MG. The City's standpipe meter sales, which were not included in the database, were reported

to total 245,000 gallons in 2006. Thus, the City's total billed metered consumption in 2006 was approximately 478.58 MG. A breakdown of use by customer class is shown in Figure 4; categories include residential and large and small commercial (both shown as inside and outside city limits). The difference between large and small commercial is meter size, where small commercial users have meters less than 1" in diameter. Combined residential usage is 61% of the total billed consumption for the City, equal to 290.77 MG.

3.2.2. Billed Unmetered Consumption

This category includes estimated consumption in cases of meter malfunction. As discussed below, such estimated consumption appears to be reasonably calculated and included in City's billing database and was not separately quantified as part of this study.

3.2.3. Unbilled Metered Consumption

According to City utilities staff, there is no unbilled metered delivery of water in Las Vegas' system. All metered uses are billed, including uses by municipal departments such as irrigation of parks and medians, the public swimming pool, and street sweeping.

3.2.4. Unbilled Unmetered Consumption

This component of water usage typically includes fire fighting, flushing of water mains and sewers, street sweeping, etc.

Water used by the City Fire Department is not metered. Neither the City's utility staff nor the City's Fire Captain, Steve Tafoya, recalled any large or significant fires during 2006. Aside from actual fire fighting uses, the Fire Department also uses unmetered water during training sessions which occur 2 to 3 times a year, but which only use water for about half an hour. Fire Department staff is attempting to quantify the number of fire responses in 2006, but we did not receive those data prior to the publication of this report.

Fire hydrant flushing is the responsibility of the City Utilities department and not the Fire Department. Fire hydrant flushing is typically not metered. Due to the extensive drought and water conservation restrictions, almost no fire hydrant flushing occurred in 2006. Any water

used for hydrant flushing 2006 was collected in tanker trucks and recycled into the City's raw water reservoirs rather than allowing the flush water to run down the street.

According to the City's utility staff, water main flushing, sewer flushing and street sweeping did not occur in 2006 because the City was under severe water use restrictions.

Based on information that there was some water use for fire training and minor fire fighting, we estimate that unbilled unmetered consumption in 2006 was approximately 90,000 gallons and was entirely attributed to fire training and minor fire responses. This estimate is based upon the following assumptions:

- 2 fire training sessions, 2 hoses operated for 30 minutes each per session, at flows of 500 GPM per hose
- 30 minor fire responses, average of 1,000 gallons water use per response

Based upon the previous discussion, authorized water consumption in Las Vegas in 2006 equaled approximately 478.67 MG.

3.3. Water Losses

The AWWA methodology calculates total water losses by subtracting total authorized consumption (478.67 MG) from total water produced (639.29 MG), which results in a total of 160.62 MG of water losses in 2006. Water losses are then accounted for as being either apparent losses or real losses as discussed in the following sections.

3.4. Apparent Water Losses

Apparent losses do not represent actual physical losses from the water distribution system, but are instead water deliveries that are not recognized by the City's customer metering and billing systems. They include unauthorized consumption, customer metering inaccuracies, and data handling errors. As discussed below, apparent losses totaled about 29.94 MG in 2006, which is the sum of the three apparent loss components listed above.

3.4.1. Unauthorized Consumption

This category of water loss includes water illegally withdrawn from hydrants, illegal connections, meter bypasses or meter tampering. The City utility staff was not aware of any such water losses in 2006.

3.4.2. Customer Metering Inaccuracies

This category of water loss includes apparent water losses caused by end use meter inaccuracies. The primary source of end use meter inaccuracy under-reporting of low flows (less than 0.25 GPM). The primary sources of low flows are leaks from faucets and toilets, leaks from the private service line (between the meter and the house), and low, steady end uses such as swamp coolers. Leaks and steady low flow end uses can be a significant source of apparent loss since the low flow rates at which they occur are very difficult to accurately measure, especially when such leaks and steady low flow end uses represent the only water used, which typically occurs for most of the hours in each day.

According to the City utility staff, unlike other areas in New Mexico, Las Vegas has relatively little swamp cooler use due to the City's relatively high elevation (approximately 6,400 ft) and the relatively large percentage of adobe and thick walled homes in its service area.

The accuracy curves of most end use meters tend to diminish significantly as flows drop below 0.25 GPM, especially as they become older. It is likely that the meters the City was replacing over the last four years were underreporting usage compared to the newly installed meters. Without a study of end use rate frequency curves specific to each customer sector in Las Vegas' service area and a regular program of meter accuracy testing, the amount of water lost to meter under-reporting can only be estimated in a general manner. A study by Westerling and Hart (1995) of meters ranging in size from 5/8" to 1" derived the following empirical formula to estimate meter accuracy based on age:

Accuracy (%) = -0.466%* (Age of meter in years) + 97.4%

Using this formula and the age distribution of meters given in Table 3, we estimate that under-reporting in 2006 due to meter age was 5.71% of billed metered use, or 28.98 MG. It should be noted that this formula was based upon the end use rate frequency curve shown in Table 6, which shows a relatively small percentage (2.6%) of flows less than 0.25GPM.

Table 6: End Use Rate Frequency Curve Used by Westerling and Hart
(Source: Westerling and Hart, 1995)

flow rate, gpm	% of time
0-0.25	2.6
0.25-0.50	1.5
0.50-1.0	10.4
1.0-2.0	21.9
2.0-4.0	33.5
4.0-20.0	30.1

Such a curve is generally indicative of a service area that has implemented an effective household leak reduction program. Household leaks from dripping faucets and running toilets can amount to significant volumes of water that are difficult to measure with standard flow meters. A leak of 1/16th GPM (1 cup per minute) will waste 90 gallons per day, which can be as much as 2,700 gallons per month. The City has a large percentage of older and historic homes, which are more likely to contain leaky fixtures and private service lines. It is possible that Las Vegas' apparent losses from meter inaccuracies could be significantly larger than our estimate.

3.4.3. Data Handling Errors

In 2006, the City's end use meters were visually read by City utility staff, and the readings recorded with handheld PDA devices. The PDA data are downloaded to the City's database every evening and were run through software that screens for anomalies in the data. The City's database also has algorithms that check for erroneous and outlier readings, and the City's billing staff also visually scan the data for potential inaccuracies.

We reviewed the consumption records in the City's billing database for potential anomalies, errors or outliers through a series of consumption data distribution analyses, read type counts, and detailed reviews of record samples for the major customer classes. Our review showed that,

while approximately 22% of the City's service locations had "non-regular" reads in their records (zero reads, blank reads, partial month reads, etc.) at some point during 2006, the vast majority of these "non-regular" reads were associated with changes in customer ID or meter replacement at a given location, or a combination of both. The City often uses the occasion of a change in customer to replace the meter at a location. Partial month reads are typically associated with final and initial reads due to customer or meter change. While monthly meter readings are occasionally missed during periods of bad weather or other circumstances when inspection of meters was impossible, in these cases estimated reads and subsequent corrected reads are employed to determine actual consumption.

In nearly all of the cases of meter change or customer ID change examined, the City's consumption records appeared to be reasonable, and the zero reads, blank reads or partial month reads are explained by other read records. In cases where a property changed hands and water service at the location was inactive for extended periods of time, the City's billing database generally appears to adequately handle changes in customer ID and subsequent resumption in water service.

In our detailed review of a sample of 112 in-city residential accounts, the only cases of probable under-reads encountered were associated with meter failure where estimated consumption for the period of meter outage appeared to be questionable (1 occurrence), or where there was a change in customer but the initial read for the new customer appeared to have been made at least several days after the new customer was recorded at that location (4 occurrences). In each of these cases we compared the recorded consumption to the range of previous or subsequent consumption for the same customer in other months. In those instances where the disparity was greater the observed range in other months, we assumed that the disparity was an under-read. No occurrences of over-reads were noted that were not already flagged in the database as needing a reading adjustment. We compared the total amount of under-reads to the total consumption for the sample and calculated that suspected under-reporting due to database or data entry errors constituted approximately 0.2% of billed consumption for those accounts in 2006. For the purpose of estimating apparent losses due to data handling errors, we assumed that this same rate of under-reporting due to database error was representative of all of the City's customer classes.

Based upon our review and evaluation of the City's utility billing database, we estimate that apparent losses due to data handling errors in 2006 were equivalent to 0.2% of billed consumption, or approximately 960,000 gallons.

3.5. Real Water Losses

Real losses represent physical distribution system losses due to spills at treated water storage tanks, main breaks, and leaks in water mains and service lines. Based upon information provided by the City and our estimates of individual water audit components as described above, real water losses in 2006 totaled about 130.68 MG, which is the total water supplied (639.29 MG) minus total authorized consumption (478.67 MG) minus total apparent losses (29.94 MG).

3.5.1. Overflows or Leaks from Treated Water Storage Tanks

City utility staff did not recall any overflows or leaks from treated water storage in 2006. We therefore assumed that real losses from treated water storage were zero in 2006.

3.5.2. Main Breaks

The City provided detailed estimates of main breaks in 2006 based upon the City's records for "line locates". The City's estimates of losses due to known main breaks during 2006 are detailed in Table 7, and totaled 1.24 MG.

Table 7: Estimates on the Timing and Volume of Main Line Breaks During 2006.
(Source: City of Las Vegas)

Size of Main	Date	Duration of Leak	Approximate Loss
6" Cast Iron Main	1/20/2006	4.5 hrs.	115,000 Gallons
6 " Cast Iron Main	2/21/2006	3 hrs.	15,000 Gallons
8" Cast Iron Main	4/3/2006	6 hrs.	126,000 Gallons
4" Cast Iron Main	4/9/2006	2 hrs.	20,000 Gallons
8" Cast Iron Main	5/16/2006	4 hrs.	204,000 Gallons
6" Cast Iron Main	6/13/2006	5 hrs.	140,000 Gallons
8" Cast Iron Main	7/21/2006	3 hrs.	136,000 Gallons
8" Cast Iron Main	7/23/2006	5 hrs.	255,000 Gallons
6" Cast Iron Main	9/14/2006	4.5 hrs.	102,000 Gallons
6" Cast Iron Main	11/4/2006	6 hrs.	126,000 Gallons
Total			1.239 Million Gallons

3.5.3. Leaks

Given the assumptions that losses from treated water storage were zero and that losses from main breaks were 1.24 MG, the remainder of real losses is attributed to leaks in water mains and service lines, which amounted to about 129.44 MG and comprised virtually all of the real water losses in 2006.

An earlier study of water losses for the City (CDM, 1985) found the "incidence of leakage in the system is considered moderately high, and is related to the deteriorated condition of the system when acquired by the City in 1983." The City currently does not have a leak detection program in place but is working on implementing one.

Discussions with City staff noted that the pressure in the water mains varied greatly in the past and was as high as 130 psi in some locations. This high pressure was causing excessive leaking until pressure regulators were replaced in the fall of 2003. It is highly likely that there are still remaining leaks in the distribution system due to the high pressure in the past.

3.6. Non-Revenue Water

In the AWWA methodology, non-revenue water is the sum of unbilled metered and unbilled unmetered consumption, apparent losses and real losses. In Las Vegas' case, non-revenue water totaled about 160.71 MG in 2006, equivalent to about 25.14% of total water supplied. Non-revenue water was comprised of 130.68 MG of real losses, 29.94 MG of apparent losses, and 0.09 MG unbilled consumption.

4. Conclusions

Using the information described above, the AWWA water audit methodology was used to quantify real and apparent losses of treated water produced by Las Vegas in 2006. Selected performance indicators from this methodology are shown in Table 8. A summary of the methodology and calculations is shown in Table 9. Screen captures of the actual AWWA water audit software calculation spreadsheet and water balance are shown in Figure 5 and Figure 6.

Table 8: Summary AWWA Water Audit Performance Indicators

Apparent Losses, gallons/service connection/day	**11.80**
Real Losses, gallons/service connection/day	**56.32**
Real Losses, gallons/service connection/day per PSI pressure	**0.16**
Infrastructure Leakage Index (ILI)	**2.31**

Total losses from were about 160.62 MG, or about 25.12% of total water supplied. Apparent losses and real losses made up about 29.94 MG and 130.68 MG of this total, respectively. Apparent and real losses are also shown in terms of losses per connection per day in Table 8. Non-revenue water was about 160.71 MG, or about 25.14% of total water supplied. Most of the total losses and the non-revenue water is attributed to distribution system leaks and end use meter inaccuracies (probably caused primarily by household and private service line leaks).

Another performance indicator is the Infrastructure Leakage Index (ILI), which is calculated as the ratio of annual real losses to unavoidable real losses. The lower the amount of leakage and real losses that exist in the system, the lower the ILI value will be. The ILI value calculated for Las Vegas is 2.31 (see Table 8). An ILI value approaching 1.0 is almost never seen and would indicate extremely efficient leakage control. The ILI is designed as an approximate guideline for leakage reduction target-setting. The best means of setting such a target is to perform an economic assessment of loss control options that is specific to a water provider's financial, operational and water resources circumstances.

Overall, Las Vegas' water customers are well metered, with very little unmetered water consumption (the largest source of unmetered water appears to be the fire department, which is

Table 9: Results of AWWA Water Audit Methodology for Las Vegas, New Mexico for 2006

City of Las Vegas Water Audit	Gallons	% of total
Water Supplied		
Metered Treated Water Production	639,290,000	100.00%
Production Meter Error	0	0.00%
Imported Water	0	0.00%
Exported Water	0	0.00%
Total Water Supplied	***639,290,000***	***100.00%***
Authorized Consumption		
Billed Metered, Commercial (Inside City limits)	155,141,354	24.27%
Billed Metered, Commercial (Outside City limits)	32,279,566	5.05%
Total Billed Metered Commercial	***187,420,920***	***29.32%***
Billed Metered, Residential (Inside City limits)	225,907,106	35.34%
Billed Metered, Residential (Outside City limits)	64,860,753	10.15%
Total Billed Metered Residential	***290,767,859***	***45.48%***
Billed Metered, Livestock	149,530	0.02%
Total Billed Metered All Uses in Database	***478,338,309***	***74.82%***
Metered, "Standpipe" Sales (not included in billing database)	245,000	0.04%
Total Billed Metered All Uses	***478,583,309***	***74.86%***
Billed Unmetered	0	0.00%
Unbilled Metered	0	0.00%
Unbilled Unmetered, Fire Department*	90,000	0.01%
Total Authorized Consumption	***478,673,309***	***74.88%***
Apparent Losses		
Unauthorized Consumption (illegal connections and theft)	0	0.00%
Customer Metering Inaccuracies**	28,980,000	4.53%
Data Handling Errors	960,000	0.15%
Total Apparent Losses	***29,940,000***	***4.68%***
Real Water Losses		
Storage Overflow Losses	0	0.00%
Estimated Loss During Main Breaks	1,239,000	0.19%
Leaks	129,437,691	20.25%
Total Real Water Losses***	***130,676,691***	***20.44%***
Non-Revenue Water		
Total Authorized Unbilled Unmetered	90,000	0.01%
Total Apparent Losses	29,940,000	4.68%
Total Real Water Losses***	130,676,691	20.44%
Total Non-Revenue Water	***160,706,691***	***25.14%***

*Estimated Fire Dept. usage
**Based on meter inaccuracy due to age
***Adjusted Production – Authorized Consumption – Apparent Losses

AWWA WLCC Water Audit Software: Reporting Worksheet

Back to Instructions

? Click to access definition

Water Audit Report for: Las Vegas, New Mexico
Reporting Year: 2006

Please enter data in the white cells below. Where possible, metered values should be used; if metered values are unavailable please estimate a value. Indicate this by selecting a choice from the gray box to the left, where M = measured (or accurately known value) and E = estimated.

ALL VOLUMES TO BE ENTERED AS ANNUAL QUANTITIES

WATER SUPPLIED				
Volume from own sources:	?	M	639.3	million gallons (US) per year
Master meter error adjustment:	?	E	0.0	million gallons (US) per year
Water Imported:	?	M	0.0	million gallons (US) per year
Water Exported:	?	M	0.0	million gallons (US) per year
WATER SUPPLIED:			639.3	million gallons (US) per year
AUTHORIZED CONSUMPTION				
Billed metered:	?	M	478.6	million gallons (US) per year
Billed unmetered:	?	M	0.0	million gallons (US) per year
Unbilled metered:	?	M	0.0	million gallons (US) per year
Unbilled unmetered:	?	E	0.1	million gallons (US) per year
AUTHORIZED CONSUMPTION:			478.7	million gallons (US) per year
WATER LOSSES (Water Supplied - Authorized Consumption)			160.6	million gallons (US) per year
Apparent Losses				
Unauthorized consumption:	?	E		million gallons (US) per year
Customer metering inaccuracies:	?	E	29.0	million gallons (US) per year
Data handling errors:	?	E	1.0	million gallons (US) per year
Apparent Losses:			29.9	million gallons (US) per year
Real Losses				
Real Losses (Water Losses - Apparent Losses):			130.7	million gallons (US) per year
WATER LOSSES:			160.6	million gallons (US) per year

Figure 5: AWWA Water Audit Calculation Spreadsheet

NON REVENUE WATER

NON-REVENUE WATER:			160.7	million gallons (US) per year

SYSTEM DATA

Length of mains:	?	M	124.2	miles	
Number of active AND inactive service connections:	?	M	6,445		
Connection density:			52	conn./mile main	
Average length of private pipe:	?	E	50.0	ft	(pipe length between curbstop and customer meter or property
Average operating pressure:	?	M	75.0	psi	

COST DATA

Total annual cost of operating water system:	?			$/Year
Customer retail unit cost (applied to apparent losses):	?			
Variable production cost (applied to real losses):	?			$/million gallons (US)

DATA REVIEW - Please review the following information and make changes above if necessary:

- Input values should be indicated as either measured or estimated. You have entered:
  - **9 as measured values**
  - **6 as estimated values**
  - **3 without specifying measured or estimated**
- It is important to accurately measure the master meter - you have entered the measurement type as: measured
- Cost Data: None to evaluate

Figure 5: AWWA Water Audit Calculation Spreadsheet (continued)

PERFORMANCE INDICATORS

Financial Indicators

Non-revenue water as percent by volume:	25.1%	
Non-revenue water as percent by cost:		
Annual cost of Apparent losses:		
Annual cost of Real Losses:		

Operational Efficiency Indicators

Apparent losses per service connection per day:	12.73	gallons/connection/day
Real losses per service connection per day*:	55.55	gallons/connection/day
Real losses per length of main per day*:	N/A	
Real losses per service connection per day per psi pressure:	0.74	gallons/connection/day/psi
? Unavoidable Annual Real Losses (UARL):	0.16	million gallons/day
? **Infrastructure Leakage Index (ILI) [Real Losses/UARL]:**	**2.28**	

* only the most applicable of these two indicators will be calculated

Figure 5: AWWA Water Audit Calculation Spreadsheet (continued)

AWWA WLCC Water Audit Software: Water Balance

Water Audit Report For:	Report Yr:
Las Vegas, New Mexico	2006

Own Sources (Adjusted for known errors) 639.3	Water Exported 0.0	Billed Water Exported			
	Water Supplied 639.3	Authorized Consumption 478.7	Billed Authorized Consumption 478.6	Billed Metered Consumption (inc. water exported) 478.6	Revenue Water 478.6
				Billed Unmetered Consumption 0.0	
			Unbilled Authorized Consumption 0.1	Unbilled Metered Consumption 0.0	Non-Revenue Water (NRW) 160.7
				Unbilled Unmetered Consumption 0.1	
		Water Losses 160.6	Apparent Losses 29.9	Unauthorized Consumption 0.0	
				Customer Metering Inaccuracies 29.0	
				Data Handling Errors 1.0	
Water Imported 0.0			Real Losses 130.7	Leakage on Transmission and/or Distribution Mains Not broken down	
				Leakage and Overflows at Utility's Storage Tanks Not broken down	
				Leakage on Service Connections Not broken down	

Figure 6: AWWA Water Balance

probably not a significant amount). The billing database also appears to very complete, with few obvious errors, in spite of over 600 meter replacements occurring in 2006.

Our application of the AWWA water audit methodology did not address operating costs and retail units costs for Las Vegas' water supply system. Las Vegas should consider incorporating such cost data into the AWWA water audit methodology, because the methodology can calculate the annual costs to Las Vegas of non-revenue water, apparent losses and real losses. Such cost data can be very useful to the City in prioritizing additional loss control and demand management measures designed to reduce such losses. The AWWA methodology software is available from the NMOSE, and has been implemented in an easy-to-use spreadsheet format that can be readily operated on a personal computer using most versions of spreadsheet software.

5. Recommendations

1. Las Vegas should implement an annual testing program for its treated water production meters with a standardized method of testing. The NMOSE recommends a volumetric testing approach. The results of each year's annual testing program should be stored in the City's database to tracking of any trends in meter error.

2. Las Vegas should complete its expedited program for replacing its end use meters, with a goal of eliminating end use meters that are more than 10 years old. The City should then implement a regular and ongoing end use meter testing program.

3. Las Vegas should investigate the incidence and magnitude of low flow rate end use leaks in its service area, which are typically caused by faucet and toilet leaks and leaks from private service lines (between end use meters and the place of use). Such low flow rate end use leaks are typically not accurately measured, even by the latest generation of end use meters, and can represent a significant revenue loss. They can be remedied effectively by targeted water conservation programs and line replacement programs.

4. Las Vegas should seasonally track its water consumption by customer sector (an example of which is shown in Figure 3), which can provide useful information on the effectiveness of water conservation programs and drought response watering restrictions.

5. Las Vegas should track and identify the number of individual multifamily units in its service area for the purposes of better characterizing its water use by customer class and estimating its service areas population.

6. References

Camp Dresser and McKee (CDM). November 8, 1985. Water System Leakage and Loss Survey (Draft Report).

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