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WSO

TO: **Mark Graham, Keith Nobriga, Timothy Schaadt**
FROM: **WSO**
DATE: **January 16, 2013**
RE: **Metropolitan Water District – Water Balance Validation & Component Analysis Feasibility Study**

I. Introduction

Water loss assessment is the focus of the Best Management Practice (BMP) 1.2 in the California Urban Water Conservation Council (CUWCC)'s Memorandum of Understanding (MOU). As a signee of this MOU, the Metropolitan Water District (MWD) is required to submit standard water balances annually and complete a component analysis of real losses every four years. Beyond compliance with the CUWCC BMP 1.2 requirements, regularly assessing water loss provides an opportunity for MWD to realize efficiency improvements and water savings.

Water Systems Optimization (WSO) was hired to validate MWD's water balance and investigate the feasibility of a component analysis of real losses for a transmission system. The standards used in the water balance and component analysis assumptions are geared toward distribution systems with significantly smaller pipe sizes and lower pressures; it is important to evaluate whether this methodology can provide useful insight for a transmission system.

II. Treated Water Balance Findings

The following outlines the findings from the water loss assessment and highlights important assumptions applied to present a realistic water balance for MWD.

For the treated water system, WSO compiled a basic water balance for the calendar year of 2012. First, the inputs into the treated water system were totaled from MWD's master meter data. Next WSO inventoried all of the treated water service connections. Reviewed and confirmed by MWD staff, WSO tabulated the total volume of water deliveries – or authorized consumption – for the potable water system. Non-revenue water is the difference between these two volumes (Total Water Supplied minus Billed Metered Consumption).

Table 1 presents the non-revenue water determination for the treated water system.

Table 1: Non-Revenue Water Determination for Treated Water System

TOTAL WATER SUPPLIED (A)	891,434.20	AF
BILLED CONSUMPTION (B)	886,370.10	AF
NON-REVENUE WATER (A-B)	5,064.10	AF
NON-REVENUE WATER *as a % of supply*	0.57%	

The non-revenue water determination shows that MWD successfully delivered and generated revenue for nearly all of the treated water it produced in CY 2012.

To satisfy the AWWA Water Balance requirements, non-revenue water must be broken down into its three components: 1) Unbilled Consumption, 2) Apparent Losses consisting of meter under-registration and water theft and 3) Real Losses - physical water losses from infrastructure failures.

The assumptions outlined in Table 2 were applied to address these volume of non-revenue water for MWD. It is important to note that many of the AWWA Free Water Audit Software's suggested default values were changed to account for the unique nature of MWD's transmission-only system.

Table 2: Assumptions Used in Treated Water Balance

Non-Revenue Water	**Value Used for MWD**	**Notes on Assumption**
Unbilled Unmetered Consumption	0.1% of Water Supplied	*This is the volume of water used for operational purposes throughout the year (neither billed nor metered). Though the default value for distribution systems is 1.25% of Water Supplied, a much lower value is applied here.*
Meter Under-Registration	0.25% Meter Under-Registration	*This is the assumed inaccuracy of customer meters. Though Venturi meters are quoted at +/-0.75% accuracy, a lower under-registration is applied to accommodate for the low total of non-revenue water.*
Unauthorized Use (Theft)	Zero	*MWD staff reported that water theft in the system is negligible if it exists at all.*

With these assumptions, a complete water balance – including the real loss volume estimation - was produced. Table 3 presents the finalized water balance for the MWD treated water system

(additionally, the free AWWA Water Audit Software which outlines the same volumes is included in Appendix A).

Table 3: Water Balance for MWD Treated Water CY 2012

WATER BALANCE COMPONENT	CY 2012 VOLUME
	(AF)
WATER SUPPLIED	**891,434.20**
Billed Metered Authorized Consumption	886,370.10
Billed Un-metered Authorized Consumption	NA
BILLED AUTHORIZED CONSUMPTION	**886,370.10**
Un-billed Metered Authorized Consumption	NA
Un-billed Un-metered Authorized Consumption	891.43
UN-BILLED AUTHORIZED CONSUMPTION	**891.43**
AUTHORIZED CONSUMPTION	**887,261.53**
WATER LOSSES	**4,172.67**
Unauthorized Consumption	NA
Meter Error	2,215.93
APPARENT LOSSES	**2,215.93**
REAL LOSSES	**1,956.74**

It is expected for a system exclusively composed of transmission lines to experience low losses: a large diameter pipe network with low service connection density has few points of infrastructural vulnerability.

Non-Revenue Water by Zone

To take a closer look at the treated water system, WSO divided MWD's treated water system into five zones. Examining separate water balances for each of these zones allowed for a more detailed picture of water loss throughout the system. Table 4 describes the parameters for each zone's boundaries.

It is important to note that a number of these zones are overlapping. The combination of Zone A and Zone D capture the total treated water system. Zones, B, C, and E are all within the bigger Zone A.

Table 4: Zone Boundary Designations

ZONE	BOUNDARY DETAILS
A	The total treated water zone, excluding the portion off of Skinner Lake
B	Exclusively the Allan McColloch Pipeline ("AMP")
C	Exclusively the West Valley Feeder #2 and the Calabasas Feeder
D	Treated water off of Skinner Lake
E	"Los Angeles Central Zone" refers to the the zone where different sources of treated water overlap, boundaries defined as: *Inputs into the Los Angeles Central Zone:* • PVF-0 serves as one of the northern boundaries • MF-1 serves as one of eastern boundaries • 2LF-4W serves as one of the eastern boundaries • MFBP-0 serves as one of the eastern boundaries • WC-0 serves as one of the eastern boundaries • LF-2W serves as one of the eastern boundaries • SC-OS serves as one of the eastern boundaries • SF-V serves as the western boundary *Outputs from the Los Angeles Central Zone (distinct from customers):* • LF-2E serves as an outlet on the eastern boundary • 2LF-3E serves as an outlet on the eastern boundary • 2LF/WOCS serves as an outlet on the eastern boundary • SC-ON serves as an outlet on the eastern boundary

For each zone, WSO determined the non-revenue water volume for the calendar year of 2012. First, the inputs into each zone - metered by one or many of the MWD's master meters – were totaled. Next WSO inventoried all of the service connections by zone. Reviewed and confirmed by MWD staff, WSO tabulated the total volume of water deliveries – or authorized consumption – for each zone. Non-revenue water is the difference between these two volumes (Total Water Supplied minus Billed Metered Consumption).

Table 5 presents the non-revenue determinations for MWD's treated system by zone alongside the number of service connections and mileage for each zone.

Table 5: Non-Revenue Water Determinations by Zone

ZONE		A	B	C	D	E
Mileage	(miles)	485.29	22.96	17.95	42.08	152.09
Service Connections		284	28	4	12	117
TOTAL WATER SUPPLIED:	(AF)		99,722.30	124,294.60	153,329.70	231,175.50
BILLED CONSUMPTION	(AF)		100,590.60	123,618.20	152,790.60	232,513.80
NON-REVENUE WATER:	(AF)	4,525.00	(868.30)	676.40	539.10	(1,338.30)
NON-REVENUE WATER *as a % of supply*		0.61%	-0.87%	0.54%	0.35%	-0.58%

Examining the non-revenue water determinations by zone confirms that MWD experiences very low water loss levels across its treated water system. The calculations in Zones B and E show that more consumption was billed than entered the particular zone. This implausible scenario likely suggests the impact of meter inaccuracy in the master meter, the customer meters, or both. It is important to note that when non-revenue water is so low, any metering inaccuracy will have significant impacts in the water balance.

III. Recommendations for Improved Water Loss Assessment

For future water balances, it is recommended to replace any assumptions applied here with documentation of use specific to MWD's practices. Going forward it will be useful to keep track or actively estimate the following volumes:

- Unbilled Unmetered Authorized Consumption: all operational uses for flushing, maintenance, etc.
- Unauthorized Consumption: documentation of any water theft

It is also recommended to calculate non-revenue water for the whole treated water system – and by zone – on a frequent basis. After inventorying the appropriate inputs and outputs, the designation of zones will serve to highlight smaller areas of attention if the non-revenue water determinations vary. Ongoing attention to the trends of non-revenue water throughout the year will allow for further investigation if it increases and presents a larger problem.

Lastly, it is recommended to continue the current maintenance and testing schedule of all input meters and wholesale customer meters.

IV. Component Analysis Feasibility and Results

Transmission mains have long been a challenging component to address effectively in water network audits and modelling of real losses. The lack of reliable methods for assessing this component of real water loss has forced the use of educated guesses and assumptions (Laven and Lambert, 2012).

It is important to note that The Bursts and Background Estimates (BABE) Concept was developed for component analysis of Real Losses on distribution systems (Lambert, 1994; Lambert and Morrison, 1995). It classifies leakage events into three different categories – undetectable background leakage, unreported bursts and reported bursts – each with different characteristics in terms of typical frequencies, flow rates and run-times. Because of this methodology's focus on distribution systems, it becomes challenging to use it to produce a reliable real loss component analysis for a transmission system. The results need to be interpreted in the context of the limitations of conducting a real loss component analysis for a transmission system. A Real Loss component analysis separates the leak and break volumes of real loss into the following categories (see Figure 1).

- **Reported leaks**: those leaks that are called in during the normal course of the day. Reported leaks may be called in by the public, meter readers or by other utility personnel.
- **Unreported leaks**: are those leaks that are not called in and have to be located by proactive leak detection methods.
- **Background Leakage:** the collective weeps and seeps in pipe joints and connections. They have flow rates that are typically too small (1gpm or less) to be detected by conventional acoustic leak detection equipment. They run continuously until they gradually worsen to the point when they can be detected. The only ways of reducing background leakage is through pressure management or infrastructure replacement.

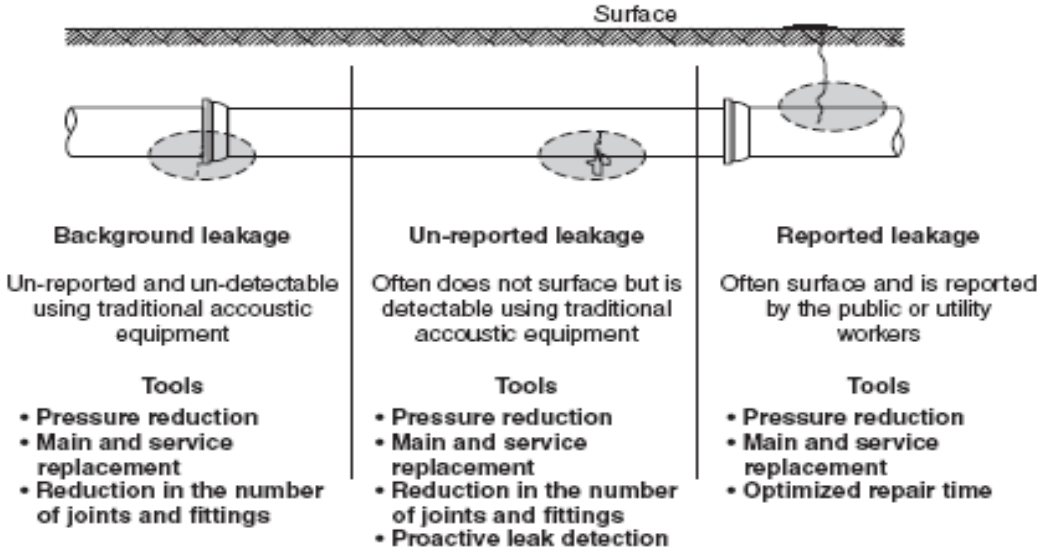


Figure 1: Components of Real Losses and Tools for Intervention

IV. a – Background Leakage

The total volume of estimated background leakage on MWD's treated water transmission system was calculated using an Infrastructure Condition Factor (ICF) of 1.5, which assumes that background leakage is 1.5 times higher than the technical minimum. This assumption was informed by the transmission's high operating pressure and the generally very good condition of the infrastructure. Under this assumption, the total volume of background losses for MWD's treated water transmission system was calculated to be 1,318 AF. This background losses volume accounts for about 67% of the total volume of real losses calculated for CY 2012 (see Figure 2 for the calculation details). Given the high average pressure in the transmission system and the nature of the transmission system infrastructure it appears reasonable that two thirds of the total real loss volume is caused by background leakage, which comprises of weeps and seeps in pipe joints and connections.

Step 2: BACKGROUND LEAKAGE ON MAINS AND SERVICES

Instructions: The background leakage volume from mains and service connections will be automatically calculated after selecting one of the default Infrastructure Condition Factors (ICF) based on infrastructure age or after a utility specific ICF has been selected and entered in cell P43. The level of background leakage tends to increase with infrastructure age and is higher for systems with higher pressure. The volume of background losses is generally a significant component of the total real loss volume, at times up to 50% of the total volume of real losses. Overestimating (ICF used in model is too high) or underestimating (ICF used in model is too low) the background leakage volume might lead to a real loss control strategy that is not truly optimized. Selecting the ICF based on general age of the distribution network should only be seen as a starting point. It is strongly recommended that over time a utility specific ICF is assessed and confirmed through field tests using one of the recommended approaches outlined in the AWWA M36 manual.

						Pressure Corrected Calculation	
System Component	Units	Quantity	Component UARL Values (g/unit/d/psi)	Infrastructure Condition Factor	Average Pressure (psi)	N1 (Leakage-Pressure Exponent) Value	Annual Volume Acre-feet
Mains	miles	527.4	2.87	1.5	261.6	1.5	1,289.68
Services - Main to Curb-Stop	number	296	0.112	1.5	261.6	1.5	28.25
Services - Curb-Stop to Meter	miles	-	4.78	1.5	261.6	1.5	-
					Total Background Leakage on Mains and Services		**1,317.93**

Select Infrastructure Condition Factor (ICF) based on age of distribution network

○ ICF 1 for System Age <50 years	1.0
◉ ICF 1.5 for System Age 50 - 70 years	1.5
○ ICF 2.5 for System Age >70 years	2.5
OR	
○ Enter ICF values assessed through implementing the approaches outlined in the AWWA M36 manual	

Figure 2: Calculation of Background Leakage for MWD Treated Water Transmission System

IV. b – Reported Leakage/Failures

There were no reported leaks/failures during CY 2012. Therefore the total volume from reported leakage for 2012 is zero.

IV. c – Un-Reported Leakage/Failures

There were no un-reported leaks/failures during CY2012 identified through proactive leak detection efforts. Therefore the total volume from un-reported leakage for 2012 is zero.

IV. d – Real Loss Component Analysis Summary

Figure 3 provides a summary of the real loss component analysis for MWD's treated water transmission system. As mentioned in the introduction to this section the results need to be interpreted in the context of the limitations of conducting a real loss component analysis for a transmission system. The results would indicate that about two thirds of the total real loss volume are due to background leakage, which can only be reduced through pressure reduction or infrastructure replacement. The component analysis model indicates that about 639AF are

due to unreported leaks that are currently running undetected and could possibly be detected by utilizing in-line leak detection technologies. However, given the cost for in-line leak detection services there does not appear to be an economic incentive for MWD to change their current leakage control strategy.

SUMMARY: REAL LOSS COMPONENT ANALYSIS				
System Component	Background Leakage (Acre-feet)	Reported Failures (Acre-feet)	Unreported Failures (Acre-feet)	Total (Acre-feet)
Reservoirs	-	-	-	-
Mains and Appurtenances	1,289.68	-	-	**1,289.68**
Service Connections	28.25	-	-	**28.25**
Total Annual Real Loss	**1,317.93**	-	-	**1,317.93**
Real Losses as Calculated by Water Audit				**1,956.74**
Hidden Losses/Unreported Leakage Currently Running Undetected				**638.81**

Figure 3: Real Loss Component Analysis Results

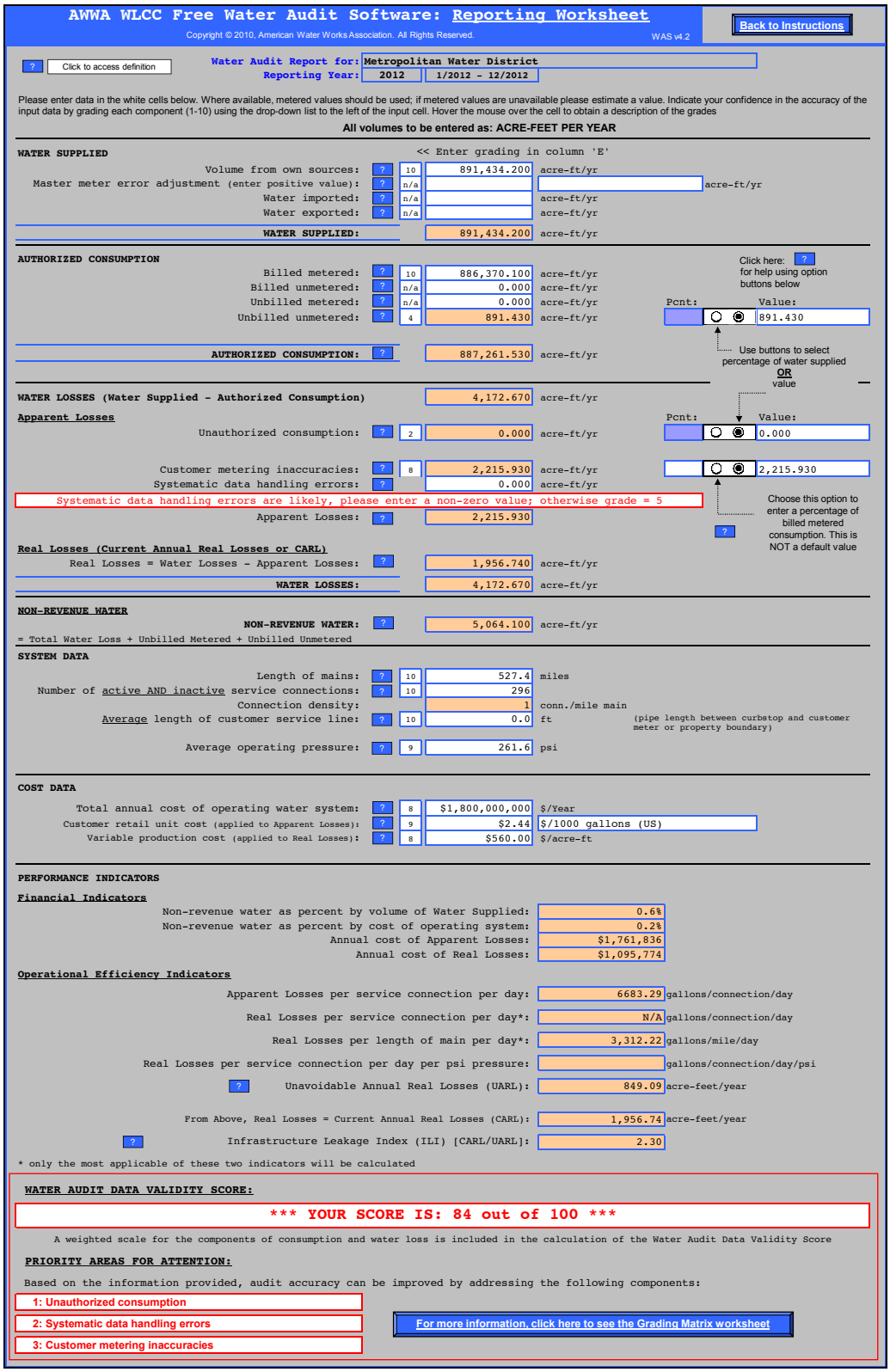
References

Laven, K. and A.O. Lambert. 2012. What Do We Know About Real Losses on Transmission Mains? Presented at IWA Water Loss Conference, Manila, Philippines, February 22 – 26, 2012.

Lambert (1994). Accounting for Losses: The Bursts and Background Concept. Journal of the Institution of Water and Environmental Management, 1994, Volume 8 (2), pp 205-214.

Lambert, A.O and J.A.E Morrison (1996). Recent Developments in Application of 'Bursts and Background Estimates' Concepts of Leakage Management. J.CIWEM, 1996, 10, April, 100-104

APPENDIX A: AWWA Free Water Audit Software



AWWA WLCC Free Water Audit Software: Reporting Worksheet

 WAS v4.2

Back to Instructions

Click to access definition

Water Audit Report for: Metropolitan Water District
Reporting Year: 2012 1/2012 - 12/2012

Please enter data in the white cells below. Where available, metered values should be used; if metered values are unavailable please estimate a value. Indicate your confidence in the accuracy of the input data by grading each component (1-10) using the drop-down list to the left of the input cell. Hover the mouse over the cell to obtain a description of the grades

All volumes to be entered as: ACRE-FEET PER YEAR

WATER SUPPLIED << Enter grading in column 'E'

Volume from own sources:	10	891,434.200	acre-ft/yr	
Master meter error adjustment (enter positive value):	n/a		acre-ft/yr	
Water imported:	n/a		acre-ft/yr	
Water exported:	n/a		acre-ft/yr	
WATER SUPPLIED:		891,434.200	acre-ft/yr	

AUTHORIZED CONSUMPTION

Click here: for help using option buttons below

				Pcnt:	Value:
Billed metered:	10	886,370.100	acre-ft/yr		
Billed unmetered:	n/a	0.000	acre-ft/yr		
Unbilled metered:	n/a	0.000	acre-ft/yr		
Unbilled unmetered:	4	891.430	acre-ft/yr		891.430
AUTHORIZED CONSUMPTION:		887,261.530	acre-ft/yr		

Use buttons to select percentage of water supplied **OR** value

WATER LOSSES (Water Supplied - Authorized Consumption) 4,172.670 acre-ft/yr

Apparent Losses

				Pcnt:	Value:
Unauthorized consumption:	2	0.000	acre-ft/yr		0.000
Customer metering inaccuracies:	8	2,215.930	acre-ft/yr		2,215.930
Systematic data handling errors:		0.000	acre-ft/yr		

Systematic data handling errors are likely, please enter a non-zero value; otherwise grade = 5

Apparent Losses: 2,215.930

Choose this option to enter a percentage of billed metered consumption. This is NOT a default value

Real Losses (Current Annual Real Losses or CARL)

Real Losses = Water Losses - Apparent Losses: 1,956.740 acre-ft/yr

WATER LOSSES: 4,172.670 acre-ft/yr

NON-REVENUE WATER

NON-REVENUE WATER: 5,064.100 acre-ft/yr

= Total Water Loss + Unbilled Metered + Unbilled Unmetered

SYSTEM DATA

Length of mains:	10	527.4	miles	
Number of active AND inactive service connections:	10	296		
Connection density:		1	conn./mile main	
Average length of customer service line:	10	0.0	ft	(pipe length between curbstop and customer meter or property boundary)
Average operating pressure:	9	261.6	psi	

COST DATA

Total annual cost of operating water system:	8	$1,800,000,000	$/Year
Customer retail unit cost (applied to Apparent Losses):	9	$2.44	$/1000 gallons (US)
Variable production cost (applied to Real Losses):	8	$560.00	$/acre-ft

PERFORMANCE INDICATORS

Financial Indicators

Non-revenue water as percent by volume of Water Supplied:	0.6%
Non-revenue water as percent by cost of operating system:	0.2%
Annual cost of Apparent Losses:	$1,761,836
Annual cost of Real Losses:	$1,095,774

Operational Efficiency Indicators

Apparent Losses per service connection per day:	6683.29	gallons/connection/day
Real Losses per service connection per day*:	N/A	gallons/connection/day
Real Losses per length of main per day*:	3,312.22	gallons/mile/day
Real Losses per service connection per day per psi pressure:		gallons/connection/day/psi
Unavoidable Annual Real Losses (UARL):	849.09	acre-feet/year
From Above, Real Losses = Current Annual Real Losses (CARL):	1,956.74	acre-feet/year
Infrastructure Leakage Index (ILI) [CARL/UARL]:	2.30	

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

WATER AUDIT DATA VALIDITY SCORE:

*** YOUR SCORE IS: 84 out of 100 ***

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

PRIORITY AREAS FOR ATTENTION:

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

1: Unauthorized consumption
2: Systematic data handling errors
3: Customer metering inaccuracies

For more information, click here to see the Grading Matrix worksheet