Establishing the First Validated Dataset of North American Water Utility Water Audit Data

Chastain-Howley*,G. Kunkel, and W. Jernigan*****

*Black & Veatch, Arlington, Texas, USA : Chastain-howleya@bv.com

**Philadelphia Water Department, Philadelphia, Pennsylvania, USA : George.Kunkel@phila.gov

***Cavanaugh & Associates, Winston-Salem, NC, USA ; will.jernigan@cavanaughsolutions.com

Keywords: Water Audit; Validated Data Set; North American Benchmarking

Abstract

The American Water Works Association's (AWWA) Water Loss Control Committee (WLCC)assembled in 2011 an initial dataset of Water Audit data from 26 water systems from the United States and Canada. This effort represents the initial phase of a project that ultimately aims to establish North American water industry benchmarks for water loss control, while promoting the use of standardized water loss accounting practices.. In early 2011, the committee embarked upon an effort to collect and validate an initial pool of water utility water audit data. Data validationis an integral part of the IWA/AWWA Water Audit employed as the best practice tool for data collection. It is important to input accurate and meaningful data into the Water Audit, in order to yield accurate and meaningful performance indicators. Accuracy of information promotes effectiveness in water loss management and revenue recovery in utility systems. Inaccuracy of information promotes misalignment of resources and utility system inefficiencies.

This paper describes the WLCC's data collection efforts and outlines the data validation process and where utility systems should generally focus initial efforts for improvement of data validity. The utility-specific dataset from a group of utility systems in North America was compiled by using the AWWA Free Water Audit Software© (latest version, 4.2, June 2010) and the associated Compiler software which was created by the AWWA Water Loss Control Committee. Each Water Audit in this dataset was peer reviewed for analysis of data validity. Results and discussion of this analysis are presented.

Introduction

The routine compilation of standardized water audits by water utilities is a relatively new practice in North America. The IWA water audit methodology was approved as standard practice through the AWWA in 2001. As the education of utilities has improved and other tools have been made available (such as the AWWA Free Water Audit Software ©) validation has improved. However, with more than 50,000 utilities it is a long and complex process.

The major emphases of this paper are 1) the validity of the data reported by the water utilities and 2) the range of operational and financial performance indicators calculated from the input data. Data Validity is a measure of the accuracy of the audit. There are many terms that may be interchanged, including data confidence, integrity, correctness, accuracy, quality and reliability. All of these terms are synonymous with Data Validity. AWWA developed and published a means for quantifying Data Validity as part of the AWWA Free Water Audit Software© (Chastain-Howley, 2010). Each data input is assigned a grading value of 1 – 10, based on how a utility's policies and practices match up to a set of grading criteria for a particular data input. An example grading criteria is shown in Figure 1. This is not meant to be as detailed as a statistical or component analysis. It is a first analysis of validation to discover poor validation and data errors.

The Water Audit Data Validity Score (DV) is calculated based upon the gradings of all of the entered components and this value it displayed near the bottom of the Reporting Worksheet of the software. For data inputs that do not apply, a grading of "n/a" is assigned, and the data input is removed from the calculation of the DV. The DV is then rebased such that the maximum possible score is always 100.

In the context of the water utility's water supply and customer billing operations, certain quantities have greater impact on the water audit than others. Water Supplied (Volume from Own Sources, imported and exported water), Billed Metered Consumption, and Customer Metering Inaccuracies are significant inputs, as any degree of error in these three inputs will more heavily skew accuracy of the Water Audit results versus an equal degree of error in other data inputs. As a result, the most effective efforts for improvement of Data Validity often involve one or more of these three inputs. The software includes a mechanism to recognize the importance of the above components.

The importance of Data Validity is that water audit data provide the basis upon which water utility managers and governing boards make decisions for investment or deferment of resources for the management of nonrevenue water. Accuracy of information promotes effectiveness in water loss management and revenue recovery in utility systems. Inaccuracy of information promotes misalignment of resources and utility system inefficiencies.

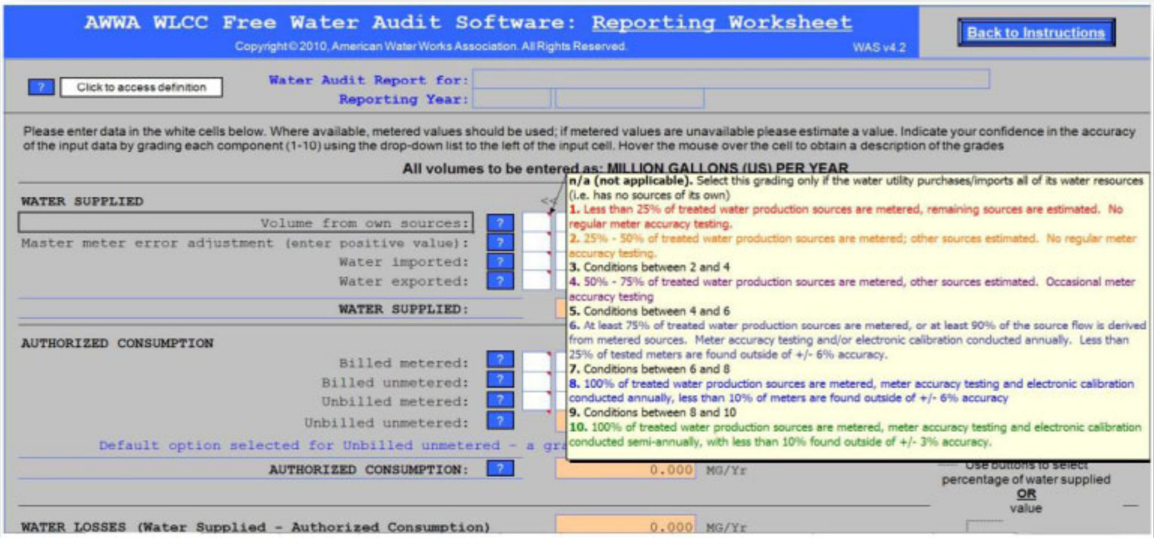


Figure 1. Screenshot of Example DV Scoring Criteria from Free Water Audit Software©.

Methodology

The WLCC Water Audit Software Subcommittee (WASS) requested Water Audit (audit) data from 26 utilities in the United States and Canada. Twenty-three utilities replied with data, and the WASS conducted validation interviews within a scheduled timeline for 21 of those utilities. Data was provided by the utilities for a recent fiscal year (2009 or newer) in the latest version of the software (Version 4.2, June 2010). Each utility also completed a Water System Practices Survey which provided system background information. A matrix of reviewers was developed to assign two committee members to each audit. A validation checklist was developed to guide review of the audits (Figure 2).

II. Water Supplied

a) Volume from own sources

2. List the number of water source pipelines supplying water to the system (pipelines that convey water from a river, lake, stream, well-field or other source)	
3. List the number of the water source pipelines that are metered?	
4. What is the typical frequency that the source meters are verified? **This information is provided in the Water Utility Practices Survey**. (Remember: meter verification is more than simply calibrating the meter instrumentation and includes steps to confirm the accuracy of the meter's flow measuring capability).	
5. How many meters were found to be with inaccuracy greater than +/- 3% during the past year?	

Figure 2. Example from Validation Checklist.

Committee reviewers first evaluated the data inputs and their corresponding gradings, looking for abnormalities or inconsistencies in the data. Telephone interviews were then conducted, ranging from 1 to 2 hours, with one or more representatives from each utility to further discuss and scrutinize the data submitted. The primary focus of each telephone interview was evaluation of data sources and grading values, with review of data inputs to determine consistency of reporting. Interviewers questioned the specific policies and practices of the water utility in order to gain a fuller understanding of how data are collected and what quality control measures are in place. Any resulting amendments to data values or their gradings were documented and incorporated into a revised water audit. Once this process was completed for a given audit, the audit was considered 'validated'. Pre and post validation audits were physically assembled for comparison and analysis via a database compiler which was also developed by the WASS for the purpose of facilitating water audit data management. A map of locations of utilities with validated water audits is provided below (Figure 3).

Figure 3. Map of Validated Audit Locations.

Out of the 26 audits submitted, 21 had been validated at the time of publication of this paper.

Key performance indicators (KPIs) were statistically reviewed and trends analysed. The basis for trend analysis included the following:

- Total system size – KPIs were compared between systems with greater than and less than 50,000 connections.
- Temperature – KPIs were compared between systems with greater than and less than an average annual temperature of 50°F or 10°C.
- Rainfall – KPIs were compared between systems with greater than and less than an average annual rainfall of 30”.
- Number of connections – KPIs were compared between systems with greater than and less than a connection density of 60 connections / mile of main (40 connections / kilometre).

Results

Thedata validity scores for the water utilities in the validated dataset ranged from 52 to 90, and are shown in Figure 4.In addition to the assessment of the composite scores for the water utilities, grading’s for individual components can be compared.

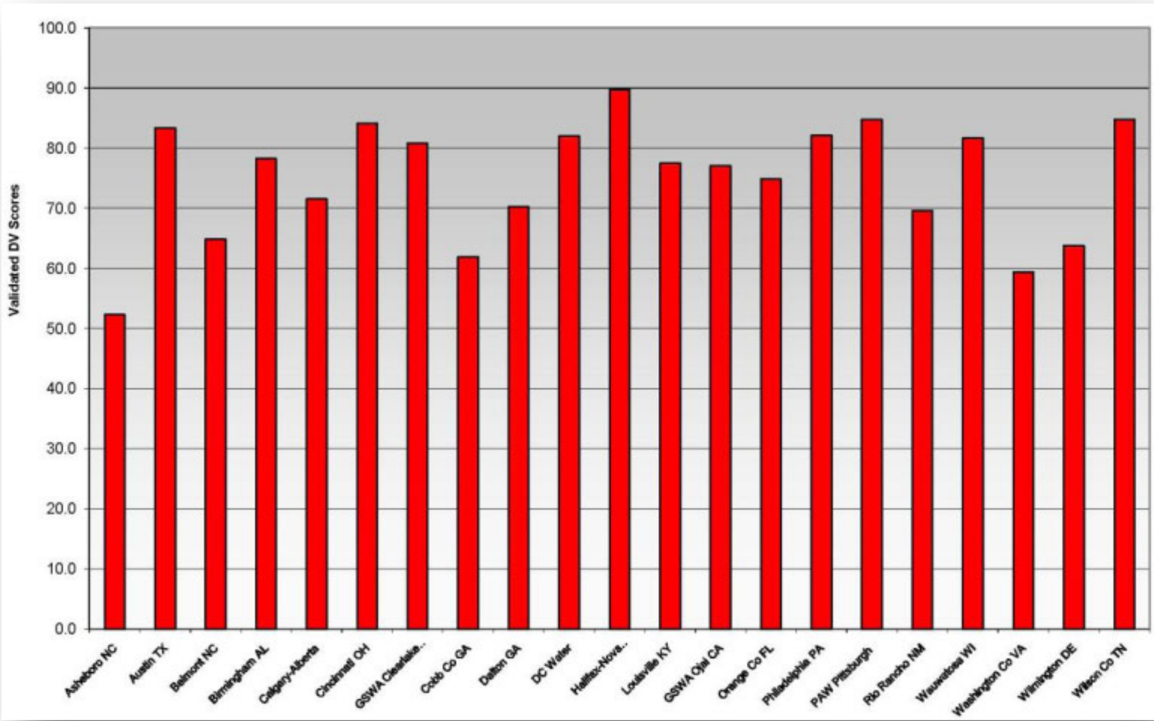


Figure 4. Validated Scores.

Utilities who import all water do not enter an input for ‘Volume from Own Sources’ and these appear as a “0” on Figure 5. There is an average of 7.44 (see Table 1) for the utilities surveyed. This outlines that most of the utilities conduct electronic calibration of their source meters, but do not conduct any additional flow testing on these meters to prove the flow data.

Table 1. Pre- vs. post-validation data input statistics.

Data Input	Pre-Validation					Post-Validation				Change
	Utilities	Average	Range			Average	Range			
Volume from own sources	16	8.39	2	-	10	7.44	2	-	10	(0.95)
Master meter error adjustment	16	6.33	1	-	10	5.81	2	-	10	(0.52)
Water imported	12	8.33	2	-	10	7.75	2	-	10	(0.58)
Water exported	10	8.85	7	-	10	8.60	6	-	10	(0.25)
Billed metered	21	8.35	3	-	10	8.24	4	-	10	(0.11)
Billed unmetered	7	8.91	3	-	10	9.29	6	-	10	0.38
Unbilled metered	16	7.94	1	-	10	7.88	1	-	10	(0.07)
Unbilled unmetered	21	6.58	3	-	10	6.24	3	-	9	(0.34)
Unauthorized consumption	21	5.58	5	-	8	5.43	5	-	8	(0.15)
Customer metering inaccuracies	21	7.08	3	-	10	6.81	3	-	10	(0.27)
Systematic data handling errors	21	6.00	3	-	10	6.05	3	-	10	0.05
Length of mains	21	8.38	3	-	10	8.33	3	-	10	(0.05)
Number of active AND inactive service connections	21	8.38	5	-	10	7.95	5	-	10	(0.43)
Average length of customer service line	21	8.15	3	-	10	9.00	5	-	10	0.85
Average operating pressure	21	7.38	2	-	10	7.05	2	-	10	(0.34)
Total annual cost of operating water system	21	8.62	3	-	10	8.71	5	-	10	0.10
Customer retail unit cost (applied to Apparent Losses)	21	8.69	6	-	10	8.52	6	-	10	(0.17)
Variable production cost (applied to Real Losses)	21	8.31	4	-	10	8.05	4	-	10	(0.26)
Water Audit Data Validity Score	**21**	**78.41**	**52**	**-**	**94**	**74.97**	**52**	**-**	**90**	**(3.44)**

Table 2 presents the calculated Key Performance Indicators and Cost Data from the overall validated dataset.

Table 2. Calculated Key Performance Indicators - Overall

Key Performance Indicator	#	Average	Range		
NRW as a % by Volume	21	22.6%	6.8%	-	45.5%
NRW as a % by Cost	21	10.0%	1.7%	-	23.0%
NRW - Total Annual Cost (Million $)	21	$5.81M	$0.04M	-	$42.97M
Apparent Losses (litres/conn/day)	21	***57***	***9***	-	***249***
Real Losses (litres/conn/day)	18	***240***	***65***	-	***567***
Real Losses (litres/km of main/day)	3	***4,283***	***1,518***	-	***8,159***
Infrastructure Leakage Index (ILI)	21	3.57	1.15	-	12.68
Water Audit Data Validity Score	21	74.97	52.28	-	89.72
Cost Data	**#**	**Average**	**Range**		
Annual operating cost (Million $)	21	$51.22M	$1.36M	-	$224.43M
Annual operating cost [$ per m^3]	21	$ ***0.88***	$ ***0.30***	-	$ ***2.15***
Customer retail unit cost [$ per m^3]	21	$ ***1.21***	$ ***0.29***	-	$ ***2.21***
Variable production (or import) cost [$ per m^3]	21	$ ***0.19***	$ ***0.05***	-	$ ***0.57***

The following Tables (3 through 5) outline so basic variations and data trends. The number of connections, average temperature, and connection density are analysed.

Table 3. Comparison of Key Performance Indicators among systems with greater than and less than 50,000 connections

	# connections <50,000					# connections >50,000				
Key Performance Indicator	**#**	**Avg**	**Range**			**#**	**Avg**	**Range**		
NRW as a % by Volume	10	24.1%	12.2%	-	45.5%	11	21.4%	6.8%	-	39.6%
NRW as a % by Cost	10	9.3%	3.1%	-	17.5%	11	10.6%	1.7%	-	23.0%
Apparent Losses (litres/conn/day)	10	*39*	*9*	-	*78*	11	*72*	*24*	-	*249*
Real Losses (litres/conn/day)	7	**222**		-		9	**250**	**30**	-	**567**
Real Losses (litres/km of main/day)	10	*4,283*	*1,518*	-	*8,159*	11			-	
Infrastructure Leakage Index (ILI)	10	3.51	1.24	-	12.68	11	3.62	1.15	-	9.89
Water Audit Data Validity Score	10	70.44	52.28	-	84.79	11	79.08	61.92	-	89.72
Cost Data	**#**	**Avg**	**Range**			**#**	**Avg**	**Range**		
Annual operating cost (Million $)	10	9.16	1.36	-	29.08	11	89.45	24.77	-	224.43
Annual operating cost [$ per m^3]	10	*1.12*	*0.49*	-	*2.15*	11	*0.65*	*0.30*	-	*1.15*
Customer retail unit cost [$ per m^3]	10	*1.34*	*0.84*	-	*2.21*	11	*1.08*	*0.29*	-	*2.08*
Variable production (or import) cost [$ per m^3]	10	*0.26*	*0.09*	-	*0.57*	11	*0.13*	*0.05*	-	*0.47*

Table 4. Comparisonof Key Performance Indicators among systems with greater than and less than average annual temperature of 50°F or 10^{o}C.

	average annual temp >50°F/10^{o}C					average annual temp <50°F/10^{o}C				
Key Performance Indicator	**#**	**Avg**	**Range**			**#**	**Avg**	**Range**		
NRW as a % by Volume	14	20.9%	6.8%	-	45.5%	7	26.2%	14.4%	-	42.9%
NRW as a % by Cost	14	10.7%	3.1%	-	23.0%	7	8.7%	1.7%	-	19.1%
Apparent Losses (litres/conn/day)	14	*60*	*10*	-	*249*	7	*50*	*24*	-	*116*
Real Losses (litres/conn/day)	11	*203*	*65*	-	*470*	7	*297*	*120*	-	*567*
Real Losses (litres/km of main/day)	3	*4,283*	*1,518*	-	*8,159*	0			-	
Infrastructure Leakage Index (ILI)	14	2.75	1.15	-	7.54	7	5.21	2.24	-	12.68
Water Audit Data Validity Score	14	72.62	52.28	-	84.79	7	79.66	63.79	-	89.72
Cost Data	**#**	**Avg**	**Range**			**#**	**Avg**	**Range**		
Annual operating cost (Million $)	14	38.77	1.36	-	168.25	7	76.12	5.88	-	224.43
Annual operating cost [$ per m^3]	14	*0.92*	*0.30*	-	*2.15*	7	*0.78*	*0.47*	-	*1.27*
Customer retail unit cost [$ per m^3]	14	*1.26*	*0.72*	-	*2.21*	7	*1.10*	*0.29*	-	*2.08*
Variable production (or import) cost [$ per m^3]	14	*0.30*	*0.05*	-	*0.57*	7	*0.12*	*0.05*	-	*0.33*

A comparison of Key Performance Indicators and Cost Data based on system connection density is presented in Table 5.

Table 5. Comparisonof Key Performance Indicators among systems with greater than and less than connection density of 40 connections/kilometre.

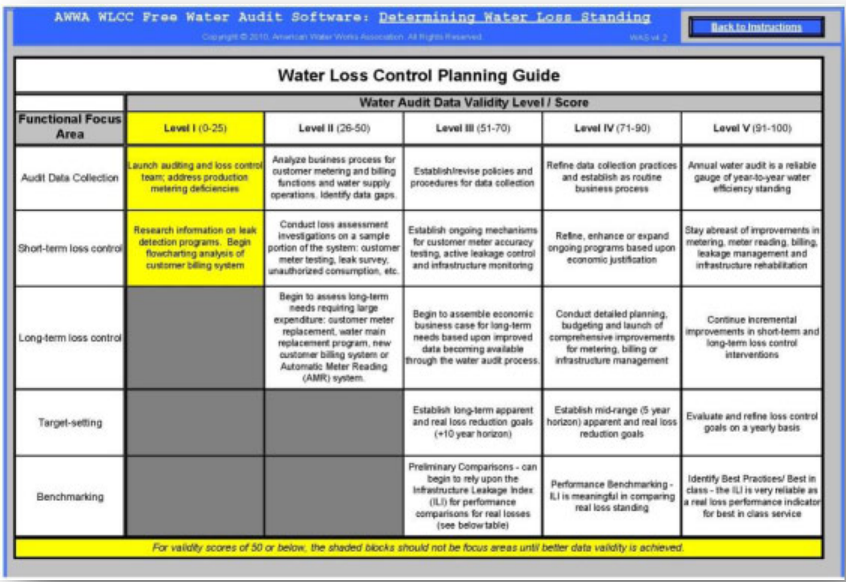
	connection density <40/km					connection density >40/km				
Key Performance Indicator	**#**	**Avg**	**Range**			**#**	**Avg**	**Range**		
NRW as a % by Volume	9	20.9%	6.8%	-	45.5%	12	24.0%	12.5%	-	42.9%
NRW as a % by Cost	9	11.0%	3.2%	-	17.5%	12	9.3%	1.7%	-	23.0%
Apparent Losses (litres/conn/day)	9	***43***	***10***	-	***88***	12	***67***	***9***	-	***249***
Real Losses (litres/conn/day)	6	***190***	***65***	-	***470***	12	***265***	***113***	-	***567***
Real Losses (litres/km of main/day)	3	***4,283***	***1,518***	-	***8,159***	0			-	
Infrastructure Leakage Index (ILI)	9	2.28	1.15	-	4.27	12	4.53	1.70	-	12.68
Water Audit Data Validity Score	9	69.98	52.28	-	84.79	12	78.71	63.79	-	89.72
Cost Data	**#**	**Avg**	**Range**			**#**	**Avg**	**Range**		
Annual operating cost (Million $)	9	43.82	1.36	-	168.25	12	56.77	1.38	-	224.43
Annual operating cost [$ per m^3]	9	***0.87***	***0.30***	-	***2.15***	12	***0.88***	***0.35***	-	***2.07***
Customer retail unit cost [$ per m^3]	9	***1.41***	***1.01***	-	***2.21***	12	***1.05***	***0.29***	-	***2.08***
Variable production (or import) cost [$ per m^3]	9	***0.26***	***0.06***	-	***0.57***	12	***0.23***	***0.05***	-	***0.57***

Discussion

Twenty-one of the 26 submitted audits were validated at the time of publication of this paper. The remaining audits will be incorporated into the next phase of data initiative, which will be in 2012. It is the intention of the WLCC to update the audits currently in the database on an annual basis, as well as to add new utilities to the database each year.

Analysis of DV Scores in Dataset

The DV scores for the initial dataset largely fall into Levels III and IV of the water loss control planning guide within the AWWA Free Water Audit Software©(Figure 5); utilities with a DV score in the range of Level III and above represent those with at least basic data collection policies and procedures in place, and have sufficient validity to begin short- and long-term loss control efforts, set long-term reduction targets and utilize the relevant performance indicators.



AWWA WLCC Free Water Audit Software: Determining Water Loss Standing

Back to Instructions

Water Loss Control Planning Guide

Functional Focus Area	Water Audit Data Validity Level / Score: Level I (0-25)	Level II (26-50)	Level III (51-70)	Level IV (71-90)	Level V (91-100)
Audit Data Collection	Launch auditing and loss control team; address production metering deficiencies	Analyze business process for customer metering and billing functions and water supply operations. Identify data gaps.	Establish/revise policies and procedures for data collection	Refine data collection practices and establish as routine business process	Annual water audit is a reliable gauge of year-to-year water efficiency standing
Short-term loss control	Research information on leak detection programs. Begin flowcharting analysis of customer billing system	Conduct loss assessment investigations on a sample portion of the system: customer meter testing, leak survey, unauthorized consumption, etc.	Establish ongoing mechanisms for customer meter accuracy testing, active leakage control and infrastructure monitoring	Refine, enhance or expand ongoing programs based upon economic justification	Stay abreast of improvements in metering, meter reading, billing, leakage management and infrastructure rehabilitation
Long-term loss control		Begin to assess long-term needs requiring large expenditure: customer meter replacement, water main replacement program, new customer billing system or Automatic Meter Reading (AMR) system.	Begin to assemble economic business case for long-term needs based upon improved data becoming available through the water audit process.	Conduct detailed planning, budgeting and launch of comprehensive improvements for metering, billing or infrastructure management	Continue incremental improvements in short-term and long-term loss control interventions
Target-setting			Establish long-term apparent and real loss reduction goals (+10 year horizon)	Establish mid-range (5 year horizon) apparent and real loss reduction goals	Evaluate and refine loss control goals on a yearly basis
Benchmarking			Preliminary Comparisons - can begin to rely upon the Infrastructure Leakage Index (ILI) for performance comparisons for real losses (see below table)	Performance Benchmarking - ILI is meaningful in comparing real loss standing	Identify Best Practices/ Best in class - the ILI is very reliable as a real loss performance indicator for best in class service

For validity scores of 50 or below, the shaded blocks should not be focus areas until better data validity is achieved.

Figure 5. Planning Guide for Ranges of DV Scores.

Average gradings for ‘Volume from Own Sources’, ‘Billed Metered Consumption’, and ‘Customer Metering Inaccuracies’ for the initial data set were strong. This may stem from the fact that the utilities willing to participate in the initial phase of the project were inherently early adopters of the Water Audit method, and more likely to have already made headway on these three most important aspects of water utility operations. Those utilities in the dataset with lower gradings in these three categories, such as Asheboro and Belmont, reported during the audit interviews about specific improvements to finished-water metering and testing that will result in a significant increase in their grading for ‘Volume from Own Sources’, and accordingly the DV score in the coming year’s audit, which will be included in the next phase of the WLCC data initiative.

Average gradings for ‘Customer Metering Inaccuracies’ were slightly below those of ‘Volume from Own Sources’ and ‘Billed Metered Consumption’, with over one third of the participating utilities at a score of 5 or less for this category. This may be a reflection on the variability of meter testing and replacement programs among utilities in general. Some of the utilities in the dataset had regular testing or replacement programs, but few had both.

The greatest positive and negative adjustments to gradings were observed for ‘Volume from Own Sources’ (-0.95 points on average) and ‘Average Length of Service Line’ (+0.85 points on average). For ‘Volume from Own Sources’, the driving cause for utilities to overstate Data Validity for this input was a general misconception that accuracy testing for finished water meters need only test electronic registration. In many of the utilities, flow verification is not performed in conjunction with testing electronic registration. Both flow and electronics testing must be conducted in order to achieve the highest degree of confidence in finished water meter output, and therefore the highest grading for same.

For ‘Average Length of Service Line’, the driving cause for utilities to under-grade this input was a general misconception of the basis for how this distance is measured. For systems who locate customer meters inside the customer’s building line (typically for colder climates), this distance is calculated from curb stop to meter. For the majority of the systems in the initial dataset, however, customer meters are typically located at the customer’s property line. The distance is therefore “0”, and a grading of 10 is assigned by the software.

The averages of the utility DV scores saw a -3.44 point decrease after validation. The fact that there was any change indicates that general understanding of the Data Validity scoring process is still requiring education, even among those utilities who are early-adopters.

Trend Review

Comparisons can be made among systems in the dataset, on the basis of certain operational and environmental conditions. These comparisons are discussed below, with the caveat that the initial validated dataset is comprised of only 21 utilities, and future expansion of this dataset will more soundly reveal trends among different utilities based on different factors.

System Size

On the basis of system size, smaller systems (those with <50,000 connections) showed a slightly higher nonrevenue water (NRW) as a % by volume (24.1%) as compared to larger systems (21.4%). This is to be expected given smaller systems will have lower system inputs than larger systems. Smaller systems, however, showed a lower actual volume of loss, both real and apparent, on a normalized basis (gal/connection/day). This shows why percentages should not be used to measure water losses. The larger utilities generally have higher use per connection and so any loss percentage appears to be lower than a smaller system. The gallons per connection indicator appears to be much more reliable as a benchmark indicator. Interestingly, the average ILI for smaller and larger systems were very similar, or 3.51 and 3.62, respectively. Since this indicator is determined by the internal dynamics of the individual systems (connections, pressure and miles of main) it is not as susceptible to changes in usage characteristics. It can therefore be used across all systems (although it is not generally used for systems under 3,000 connections). Data Validity scores for smaller systems averaged about 70, as compared to about 79 for larger systems, which may reflect the trend of advanced data collection and management systems in larger utilities.

Climate

On the basis of system climate, specifically temperature, warmer climates (those with average annual temperature of greater than 50°F or 10°C) showed a lower real loss per connection (203 litres/connection/day) as compared to colder climates (297 litres/connection/day). Apparent Losses were slightly higher in the warmer utilities (60 to 50 litres/connection/day). Likewise, the ILI for colder climates (5.21) was almost double that of warmer climates (2.75). This may be a reflection of harsher ambient ground conditions in colder climates and the propensity for system breaks and leaks. Also, utilities in warmer climates generally put greater emphasis on water conservation which often leads to more proactive leak detection and water loss reduction programs.

On the basis of rainfall (table not shown), drier climates (those with total annual rainfall of greater than 750 millimetres, or 30-inches) apparent losses were about half the amount and Real Losses were about two-thirds of the amount in drier climates as compared to wetter climates. All these data differences are probably due to the propensity of water conservation efforts in the drier climates and the need for water loss reductions to balance out the fact that these utilities are also asking their customers to reduce water usage. ILI and Data Validity scores were comparable between these two climates.

Connection Density

On the basis ofconnection density, less dense systems - those with connection density of less than 40 connections per kilometre, (60 connections per mile) showed slightly less real loss per connection (190 litres/connection/day) as compared to more dense systems (265 litres/connection/day). Since one of the main locations for real water losses are at the service connection, this appears logical. Normalized Apparent Losses (litres/connection/day) were about 57% higher and normalized Real Losses were about 40% higher in more dense systems, as compared to less dense systems. Less dense systems showed an ILI of about half (2.28) that of more dense systems (4.53). Data Validity score was about 12% higher in more dense systems.

Cost Data

A review of cost data (Table not shown) reveals, as expected, a notably higher average variable production cost *\$0.34 per* m^3(\$1.29/1,000 gallons) among systems who purchase (import) 100% of water supplied, versus those who produce some or all of their water supplied *\$0.15 per* m^3(\$0.55/1,000 gallons). Average customer retail unit cost between these 2 groups was comparable *\$1.17 to \$1.30/*m^3(\$4.46 and \$4.92/1,000 gallons).

Improving Data Validity

Improving Data Validity comes from a combination of top-down (records analysis and calculations) and bottom-up (field measurement) efforts. Ultimately, the reliability of the top-down Water Audit is improved by incrementally incorporating bottom-up approaches to field-verify assumptions and estimations (Thornton et al., 2009). As mentioned above, certain components exert a stronger effect than others in the water audit. Initial bottom-up efforts for improving Data Validity should be focused on these significant components. For 'Volume from Own Sources', focus should first be that all finished-water inputs to the distribution system are metered with meter readings digitally archived, and second that those meters are tested for accuracy of both flow measurement and electronic registration at least annually. Data should be reviewed regularly and adjusted to account for any data gaps that can occur if instruments are out of service for periods of time. For 'Billed Metered Consumption' and 'Customer Metering Inaccuracies', focus should be on the minimization of estimated billings, utilization of billing software that can be electronically queried for meter data, and the development of a routine testing program that dictates a meter replacement protocol based on cumulative consumption and meter age.

Conclusions

Ranges and averages for Data Validity as presented in this paper can be utilized for reference.However, this is an initial dataset intended for annual updating. It is also expected that the initial dataset will be expanded with additional participating utilities. At least three years of data compilation and analysis will be needed to represent a robust data set for stronger benchmarking. More utilities will be invited to participate in future phases, but only to the extent that the reported utility data can be validated.

Data Validity scores are generally strong in this initial dataset, but the dataset represents early-adopters so the effect of expanding the dataset on the average Data Validity Score may be difficult to predict.

References

Chastain-Howley, A., Goff, D., Kunkel, G., Lalonde, A., Sayers, D. (2010) AWWA Free Water Audit Software©, version 4.2.

Thornton, Julian et al. (2009).*Manual of Water Supply Practices - M36, Water Audits and Loss Control Programs*. 3rd Edition. American Water Works Association, Denver CO.

Jernigan, W., Chastain-Howley, A., Cobb, M., Goff, D., Kunkel, G., Lalonde, A., Sayers, D. (2011) Assembling Validated Water Audit Data for Reliable Utility Benchmarking. AWWA Distribution System Symposium, Nashville, TN.

Acknowledgements

Members of the WLCC Software Subcommittee: Andrew Chastain-Howley (chair), Mike Cobb, David Goff, Will Jernigan, George Kunkel, Alain Lalonde, and David Sayers.

Thanksto all the utilities who submitted water audits and participated in the validation interviews leading to the first published and validated dataset of water audit data in the IWA/AWWA format.