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WATER EFFICIENCY CONSULTING

REPORT ON THE EVALUATION OF 2016 VALIDATED WATER AUDIT DATA OF CALIFORNIA WATER UTILITIES

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1. INTRODUCTION

In early 2018, the California Department of Water Resources (DWR) published 2016 water audit data for over 350 of the state's urban water utilities. The data was compiled using the standard Free Water Audit Software (Software) published by the American Water Works Association (AWWA) and represents the largest dataset of validated water utility data in the United States. This effort was the result of California Senate Bill 555 (SB555), which was signed into law in October 2015. The law requires that all urban retail water suppliers annually submit to the DWR a standardized, validated water audit.

The Water Loss Technical Assistance Program (WL TAP) – funded through the State Water Resources Control Board and part of the CA-NV AWWA Section's California Water Loss Collaborative – provided training and support via consulting services for the first round of submission. This round collected and validated 2016 data during the course of 2017. The WL TAP conducted Level 1 validation for each water audit. This process is defined by the Water Research Foundation (WRF) in a guidance manual published in 2016.[1] The Level 1 validation process examines water audit data submitted by utilities to detect and remove gross inaccuracies and ensure that the quality of the data is reliably represented by a data grading system built into the software. While Level 1 validation is not sufficiently involved to correct inaccuracies in the raw data sources of the water utility, it does impart a basic level of quality control to the data and provides a strong degree of credibility to the California dataset. California is the second US state – in addition to the State of Georgia – to require Level 1 validation of water audit data.

DWR's release of the validated water audit data presented an opportunity to assess many aspects of the water and revenue loss levels occurring in California's urban water utilities. Kunkel Water Efficiency Consulting (KWEC) obtained the data to extrapolate a projection of losses occurring in *all* public water utilities in the State of California. Additionally, KWEC devised projections of the potentially recoverable losses and monetary improvements that can result from specific utility activities to reduce excessive loss.

Senate Bill 555 also requires the State Water Board to develop water loss performance standards for urban retail water suppliers between January 2019 and July 2020. The State Water Board is required to evaluate the life-cycle cost of achieving these standards. The standards will incorporate local and operational conditions to determine economically achievable water loss reduction for each urban retail water supplier. The projections established by KWEC can provide additional insight to the losses currently incurred by water utilities throughout the State of California and assist the participants and stakeholders in the process to create workable and effective standards for California water utilities.

[1] Water Research Foundation, *Level 1 Water Audit Validation: Guidance Manual*, 2016.

2. THE CALIFORNIA WATER AUDIT DATA ASSESSMENT METHODOLOGY

California DWR released data for over 350 water utilities in January 2018. Several additional water utilities are still expected to finalize and submit their 2016 water audit. KWEC obtained this data, organized it, and undertook a filtering process to remove utilities with questionable data inputs and/or output performance indicators. These steps were taken to provide consistency in the data being evaluated and to avoid including any data that could unduly skew the results of the projections created by KWEC. The steps of the data organization and filtering processes are given below:

Data Organization

1. All data was converted to units of million gallons (California utilities reported data in units of acre-feet, but million gallons units are more commonly used by water utilities in the USA).
2. Utilities that primarily sell water on a wholesale basis (wholesalers) were removed from the dataset. Only retail water utilities were required to submit water audits, but several wholesale water suppliers also submitted a water audit.
3. All data was converted to consistent numerical formats.
4. The population of the service area of each water utility was added to the dataset.

Data Filtering Process

KWEC applied the same filtering criteria as used by the WL TAP Consultant Team that conducted the training and data validation activities and issued an analysis report. The criteria are given in Table 1:

Table 1 Filtering Criteria Employed by the Water Loss Technical Assistance Program**

Water Research Foundation Water Audit Filters			
	Metric	Abbreviation	Criteria for Exclusion
Volumetric	Infrastructure Leakage Index*	ILI <1 | ILI >20	ILI less than 1 or greater than 20
	Real Losses	Real Loss < 0	Negative real losses
	Cost of Non-Revenue Water	NRW > Oper. Cost	The cost of Non-Revenue Water is greater than total operating costs
Financial	Variable Production Cost	VPC >< 2 Orders Magnitude	Variable Production Cost more than 100x or less than .01x the dataset median
	Customer Retail Unit Cost	CRUC >< 2 Orders Magnitude	Customer Retail Unit Cost more than 100x or less than .01x the dataset median
Usage	Incomplete Audit	[FIELD NAME] Blank	Reported value is either zero or blank in critical audit fields

* Not applicable to systems where the count of service connections + 32x miles of mains is less than 3,000

***Source: California Water Loss Technical Assistance Program Final Report: WSO, Cavanaugh, 2018*

In following with the criteria in Table 1, KWEC filtered (excluded) water utilities from the final dataset according to the following steps:

1. Filtered 85 utilities with an Infrastructure Leakage Index (ILI) value less than 1.0. The derivation of the ILI theoretically states that systems cannot attain an ILI value less than 1.0. While this derivation is now challenged, it was determined to remove utilities with a calculated value of ILI less than 1.0 since further validation of the source data is likely warranted.
2. Eleven systems with negative real (leakage) losses and/or negative ILI were removed. It is not possible for water utilities to have negative losses; instead this usually reflects suspect input data.
3. Two utilities (City of Stockton, Vaughan Water Company) were removed due to incomplete data.
4. No utilities were excluded based upon running any of the three filtering processes involving costs.
5. Summary statistics were calculated for each column of input data and calculated performance indicators; including totals, median, average, minimum, maximum values, and counts. These statistics were used to assist in identifying any unusual data variations and/or anomalies.

Once the above steps were executed, the remaining dataset consisted of 275 water utilities. These systems were evaluated for losses and served as the basis for projections that were undertaken.

3. WATER AND REVENUE LOSSES REPORTED BY CALIFORNIA UTILITIES

The statistical assessment conducted by KWEC summarized the loss levels incurred by the 275 water utilities in the filtered dataset. The primary assessments keyed on the levels of apparent (customer) losses in the utilities and the levels of real (leakage) losses. Additionally, the cost impacts of losses were assessed with the financial benefit from loss recovery included. Key parameters are given in Table 2.

As shown, the apparent losses reported by the 275 utilities in the filtered dataset totaled 28,153 million gallons (mg) in the reporting year, or a daily rate of 76.9 million gallons per day (mgd). When valued as uncaptured revenue at the utilities' reported retail rate, apparent losses cost the reporting utilities $143,350,000.

From the summation and analysis of real losses, seven low density systems were removed from the filtered dataset to produce a slightly smaller set of 268 utilities. Real losses reported by the 268 utilities in this filtered dataset totaled 94,390 mg in the reporting year, or a daily rate of 257.9 mgd. When valued simply at the utilities' reported variable production costs, real losses cost the reporting utilities $205,645,000. For perspective, this volume of losses equates to about 290,000 acre-feet, putting the average value of real losses at $709 per acre-foot. For the many California utilities that purchase water, real losses cost the utility significantly more that this average figure.

Table 2: Losses and Cost Impacts of California Water Utilities (2016 Data)

Apparent Loss Assessment	Value
Apparent losses reported (275 utilities)	28,153 mg (76.9 mgd)
Value of Uncaptured Revenue due to Apparent Losses (275 utilities)	$143,350,000
Apparent Loss Cost Rate, median value for 275 utilities	$12.10 /service conn/year
Estimated economically recoverable apparent losses for 137 utilities above LCR median	10,821 mg (29.6 mgd)
Estimated recoverable annual revenue from economically recoverable apparent losses (uses the Customer Retail Unit Cost of each of 137 utilities above the median loss cost rate value)	$72,660,000
Real Loss Assessment	**Value**
Real losses reported (268 utilities*)	94,390 mg (257.9 mgd)
Value of Excessive Production Costs from Real (Leakage) Losses (268 utilities)	$205,645,000
Real Loss Cost Rate, median value for 268 utilities	$16.20 /service conn/year
Estimated economically recoverable real losses for 134 utilities above LCR median	31,032 mg (84.8 mgd)
Estimated annual production cost savings from economically recoverable real losses (uses the Variable Production Cost of each of 134 utilities above the median loss cost rate value)	$113,974,000

*Seven utilities with a low density of customer service connections were not included in the analysis

Table 2 also includes an estimate of the annual volume of losses that are deemed to be economically recoverable in the 275 water utilities. The methodology to calculate economically recoverable losses uses a "loss cost rate" (LCR) performance indicator. This performance indicator is not included in the AWWA Free Water Audit Software employed by the WL TAP; however, it has been previously employed by the author in assessments of water audit data of water utilities in the states of Pennsylvania and New Jersey. The loss cost rate is calculated separately for apparent losses and real losses by multiplying the normalized loss indicator (apparent and real), in gallons/connection/day, by the respective unit cost: The Customer Retail Unit Cost (CRUC) is applied to apparent losses. The Variable Production Cost (VPC) is applied to real losses, although the CRUC might be applied to real losses where water resources are stressed. The loss cost rate is useful since it marries the rate at which losses occur in a water utility with the cost value of the loss and is normalized by dividing by the number of customer service connections. This indicator is given in units of $/service connection/year. Water utilities that have both a high rate of loss and a high value of the loss have strong incentive to better control losses. As such, it provides a lower bound to estimate the amount of losses that are likely to be economically recoverable.

The median value of the apparent loss cost rate for the 275 water utilities is $12.10 /service connection/year, while the real loss cost rate for 268 water utilities (7 low service connection density utilities cannot be included in this analysis) is $16.20 /service connection/year. KWEC determined to identify those water utilities with loss cost rates above the respective median values of the full dataset as

having a high likelihood for economically reducing those losses, down to the median level. Based upon this premise, the loss reduction volume (apparent and real) for one half of the utilities (those above the median) was calculated and loss recovery volumes totaled. Financial benefits from this loss reduction were calculated using the respective CRUC and VPC of each water utility and summed. This is a generally conservative approach for the determination of recoverable losses. Ideally, each water utility should assess its economic level of loss (apparent and real) and use this to determine their respective economic loss volumes. However, such an assessment for hundreds of water utilities requires considerable data and effort to calculate and was beyond the scope of this preliminary evaluation.

Table 2 lists economically recoverable apparent losses at 10,821 million gallons per year, with the potential of additional revenue recovery of $72,660,000 per year for the 137 water utilities in the recoverable assessment pool. The total population of the 137 utilities is 18,633,432, which is 49.95% of the total population of the State of California of 37,300,000 in 2016. The total Water Supplied Volume of the 137 water utilities is 856,832 mg, which is 45.6% of the 1,878,925 mg of total source water withdrawals in California (see Section 4).

Table 2 also lists economically recoverable real losses at 31,032 million gallons per year, with the potential reduction of excessive production costs of $113,974,000 per year for the 134 water utilities in this assessment. The total population of the 134 utilities is 16,646,092, which is 44.63% of the total population of the State of California of 37,300,000 in 2016. The total Water Supplied Volume of the 134 water utilities is 794,981 mg, which is 42.3% of the 1,878,925 mg of total source water withdrawals in California (see Section 4).

The levels of current losses and economic recoveries derived from the water audit data submitted to DWR as shown in Table 2 are significant. However, state-wide projections of losses and recoveries reveal even higher levels.

4. WATER AND REVENUE LOSS PROJECTIONS FOR CALIFORNIA UTILITIES

The methodology employed to project the levels of loss and potential recoveries for all utilities in the State of California is an extrapolation based upon the annual water withdrawal volume in the state compared to the total volume of water supplied in the Software submitted by the water utilities. As shown in Tables 3 and 4, the annual withdrawals for public water suppliers in the State of California were listed as 1,878,925 million gallons (1.879 trillion gallons) in a report assembled by the United States Geologic Survey (USGS)[2].

[2] Dieter, C.A., and Maupin, M.A., 2017, Public Supply and Domestic Water Use in the United States, 2015: U.S. Geological Survey Open-File Report, 2017–1131, 6 p., https://doi.org/10.3133/ofr20171131.

In the Software, the component 'Volume from Own Sources' typically closely aligns with the 'Water Withdrawal Volumes' reported by USGS. However, perhaps more so than any US state, California provides water to many water utilities via sizable water transfers (imports to the water utility) from large-scale infrastructure including the State Water Project and the Colorado River Aqueduct. In most US states, water volumes imported and exported are done so among water utilities. However, the large water projects in California represent entities outside of the water utilities themselves. For the filtered dataset of 275 water utilities the total 'Volume of Own Sources' is 940,946 million gallons and the 'Water Supplied Volume', which accounts for imports and exports, is 1,344,314 million gallons. For CA water audit data, the author determined that the 'Water Supplied Volume' is analogous to the 'Water Withdrawal' volume assessed by USGS, and this volume was used to conduct the state-wide projections.

Table 3 displays the calculations of projected volumes of apparent loss throughout the State of California. The proportion of apparent loss volume in the filtered dataset of 275 water utilities to the 'Water Supplied Volume' is applied proportionally to the state-wide 'Water Withdrawal' volumes to give an estimate of 36,269 million gallons of state-wide apparent loss. For the filtered dataset of 275 utilities, the economic recoverable portion of the apparent losses was determined to be 10,821 million gallons, or 0.80% of the 'Water Supplied Volume'. Applying the same percentage to the state-wide 'Water Withdrawal' volume gives projected recoveries of 15,031 million gallons of apparent loss through the entire state. The additional recoverable apparent loss volume of 4,210 million gallons (15,031 – 10,821 million gallons) was then valued using the median CRUC of $3.75 / 1,000 gallons for the 275 utilities in the filtered CA dataset. The cost impact of the 4,210 million gallons is $15,787,500. Adding this cost to $72,660,000 gives the potential uncaptured revenue grand total of $88,447,500 for the state-wide financial impact of the projected 15,031 mg of apparent losses.

Table 3 Potentially Recoverable Apparent Losses in California Utilities State-wide

Utilities	Water Supplied/Withdrawn, mg	Apparent Losses, mg	Potentially Recoverable Apparent Losses, mg	Potentially Recoverable Financial Impact
CA Dataset (275 Utilities)	1,344,315 (Water Supplied)	28,153 = 2.09% of Water Supplied	10,821 = 0.80% of Water Supplied	$72,660,000
Statewide in CA (number of utilities is unknown)	1,878,925 (Withdrawals)	(1,878,925)(0.0209) = **36,269**	(1,878,925)(0.008) = **15,031**	**$88,447,500****
**Potential additional revenue capture due to reduced apparent loss: calculated by applying median Customer Retail Unit Cost of $3.75 per 1,000 gallons to the difference of 15,031 MG minus 10,821 MG and adding this cost to $72,660,000.				

Table 4 gives calculations of projected volumes of real (leakage) loss throughout the State of California. The proportion of real loss volume in the filtered dataset of 268 water utilities to the 'Water Supplied Volume' is applied proportionally to the state-wide 'Water Withdrawal' volumes to give an estimate of 131,927 million gallons of state-wide real loss. For the filtered dataset of 268 utilities, recoverable economic losses were determined to be 31,032 million gallons, or 2.31% of the 'Water Supplied Volume'. Applying the same percentage to the state-wide 'Water Withdrawal' volume gives projected recoveries of 43,403 million gallons of real loss through the entire state. The additional recoverable real loss volume of 12,371 million gallons (43,403 – 31,032 million gallons) was valued using the median VPC of $1,418.50 / million gallons for the 275 utilities in the filtered CA dataset. The cost impact of the 12,371 million gallons is $17,548,263. Adding this cost to $113,974,000 gives the potential excessive production costs grand total of $131,522,263 for the state-wide financial impact of the projected 43,403 million gallons of real losses.

Table 4 Potentially Recoverable Real Losses in California Utilities State-wide

Utilities	Water Supplied/Withdrawn, mg	Real Losses, mg	Potentially Recoverable Real Losses, mg	Potentially Recoverable Financial Impact
CA Dataset (275 Utilities)	1,344,315 (Water Supplied)	94,390 = 7.02% of Water Supplied	31,032 = 2.31% of Water Supplied	$113,974,000
Statewide in CA (number of utilities is unknown)	1,878,925 (Withdrawals)	(1,878,925)(0.0702) = **131,927**	(1,878,925)(0.023) = **43,403**	**$131,522,263*** **
***Potential production cost savings from reduced real losses: calculated by applying median Variable Production Cost of $1,418.50 per million gallons to the difference of 43,403 MG minus 31,032 MG and adding this cost to $113,974,000.				

Since these projections are determined using group (median) values of loss cost rate, they are approximate in nature and are not as accurate as utility-specific calculations of economic loss levels.

5. DATA OBSERVATIONS

Several notable trends in the data in the filtered dataset of 275 utilities were observed by the author and are noted below for reference:

1. Water Sources:
    a. 113 utilities import no water; they obtain all water from sources that they manage
    b. 39 water utilities import all of their supply
    c. 162 import some water

2. Several trends were observed in the Variable Production Cost (VPC)

    a. Although many areas of California have experienced severe drought in recent years, only 11 of the 350 water utilities in the initial (unfiltered) dataset applied the Customer Retail Unit Cost (CRUC) to valuate real (leakage) losses, rather than applying the Variable Production Cost (VPC). AWWA notes that water utilities with stressed water supply sources can justify valuing leakage by applying the CRUC.

    b. The median VPC of the filtered dataset of 275 water utilities ($1,418.50 per million gallons) is very high relative to the VPC of $425.60 for a combined validated dataset from the State of Georgia and other North American water utilities studied by the author[3]. The median VPC ($3,046.73 per million gallons) of the 134 systems in the recoverable group of utilities is much greater yet. While it is surmised that CA experiences higher costs for imported water, additional study into the reasons why high Variable Production Costs exist in CA is warranted.

    c. The City of Arcata reported a very low VPC of only $1.14 per million gallons. While the author is suspicious that this low value is in error, it was not filtered from the analysis since its inclusion does not impart a notable impact to the results of the analysis.

The data collected by DWR provides an excellent opportunity for considerable additional analysis of data inputs, performance indicators, and groupings of utilities by cohorts of size, geographical region, and other criteria. It is likely that many studies will be conducted on this data, both to help inform the DWR process for setting performance standards in 2019/2020 and to provide greater insight to losses occurring in the drinking water industry in general.

6. SUMMARY

The State of California has taken a highly progressive approach to water efficiency by putting into place a requirement for annual water auditing for urban water utilities. More importantly, the State determined to create a robust structure for training of water utilities and Level 1 validation of the collected data. By taking these steps California has laid the groundwork for the State's water utilities to improve their operations and data, and to implement effective controls to reduce excessive water and revenue losses.

Kunkel Water Efficiency Consulting (KWEC) conducted an assessment of water audit data from California water utilities which included a projection of losses and financial impacts state-wide. The

[3] Kunkel Water Efficiency Consulting, *Report on the Evaluation of Water Audit Data for Pennsylvania Water Utilities*, February 2017.

results of this analysis include estimates of the lower bound of potential economically recoverable savings:

1. Potential recoveries in apparent (customer) losses of 15.031 billion gallons (46,000 acre-feet) per year, with potential additional revenue capture of $88,447,500 per year.

2. Potential recoveries in real (leakage) losses of 43.403 billion gallons (133,200 acre-feet) per year, with potential savings of excessive production costs of $131,522,263 per year.

The findings show significant potential for water to be saved, and production cost savings and increased revenue to be realized by water utilities. This can save water in a state that has experienced severe drought while improving the finances of water utilities. These estimates are inherently conservative, and the levels of economically recoverable losses resulting from utility-specific analysis are likely to be higher.

California has created the largest set of validated water audit data in the United States. Its work to annually collect the data and set performance standards in 2019/2020 will keep the state it at the forefront of innovations in water efficiency. California's journey to enhanced water and revenue loss control is just beginning and the state will undoubtedly continue to be a recognized leader in guiding its water utilities to a water efficient future.