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Texas Water Development Board

Texas Water Loss Audit Validation Study

December 2021 **Final**

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Acknowledgements

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The Texas Water Development Board (TWDB) is responsible for preparing the state water plan every five years. Each plan is tasked with looking ahead over a 50-year horizon and strategically seeks to ensure an adequate water supply for users in the state. In order to incorporate varying geographical interests and needs, the state is divided up into 16 regional water planning areas. These regional water plans are reviewed and incorporated into the state water plan.

The TWDB commissioned this Water Audit Validation Study (hereafter referred to as the Study) due to recognizing the critical connection between water audit reliability and the State Water Plan strategic objectives.

The 2022 State Water Plan presents several challenges that Texans will need to plan for. The state's population is anticipated to increase 73 percent between 2020 and 2070. Texas' existing water supplies are projected to decline by approximately 18 percent between 2020 and 2070. If strategies are not implemented, approximately one-quarter of Texas' population in 2070 would have less than half the municipal water supplies they will require during a drought of record.

Water user groups face a potential water shortage of 3.1 million acre-feet per year in the 2020 decade and 6.9 million acre-feet per year in 2070 decade in drought of record conditions (Figure ES-1). These water user groups include municipal, mining, steam-electric, manufacturing, livestock, and irrigation. Conservation strategies, including water loss mitigation, represent approximately 29 percent of all recommended water management strategy volumes in 2070, and of that, municipal conservation strategies make up approximately 12 percent. The data supporting projected municipal water needs and the percent share of water management strategies through municipal conservation will be used to make important decisions on water supply planning. It is crucial the data is trustworthy and water loss audits play a significant role in evaluating the reliability of municipal water use data.

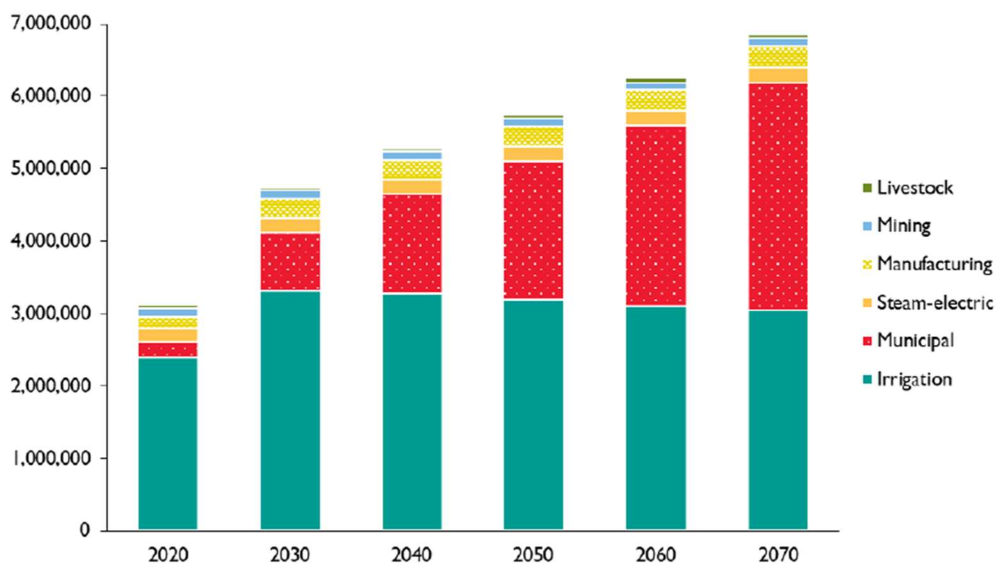


Figure ES-1 Annual water needs by water use category (acre-feet); ref 2022 State Water Plan

Water conservation plays a major role in the state water planning process. One significant role in the TWDB water conservation strategy is the collection of water loss audits. Water loss audits are required to be a component of each regional water plan and are recognized in the state water plan.

Municipal conservation strategies must consider water loss reductions. Although Texas has a regional approach to water planning, no region is immune to water loss. In fact, eight regions have established thresholds for triggering a water loss management strategy, and three of those eight regions have established voluntary thresholds for triggering water loss intervention (i.e., leak detection and repair, pipeline replacement). Figure ES-2 illustrates that the State Water Plan (which includes water loss mitigation), if effectively implemented, is structured to meet nearly all municipal water needs in 2070.

This final report for the Study presents an overview of the program background, results, findings, and recommendations for future validation activities in Texas.

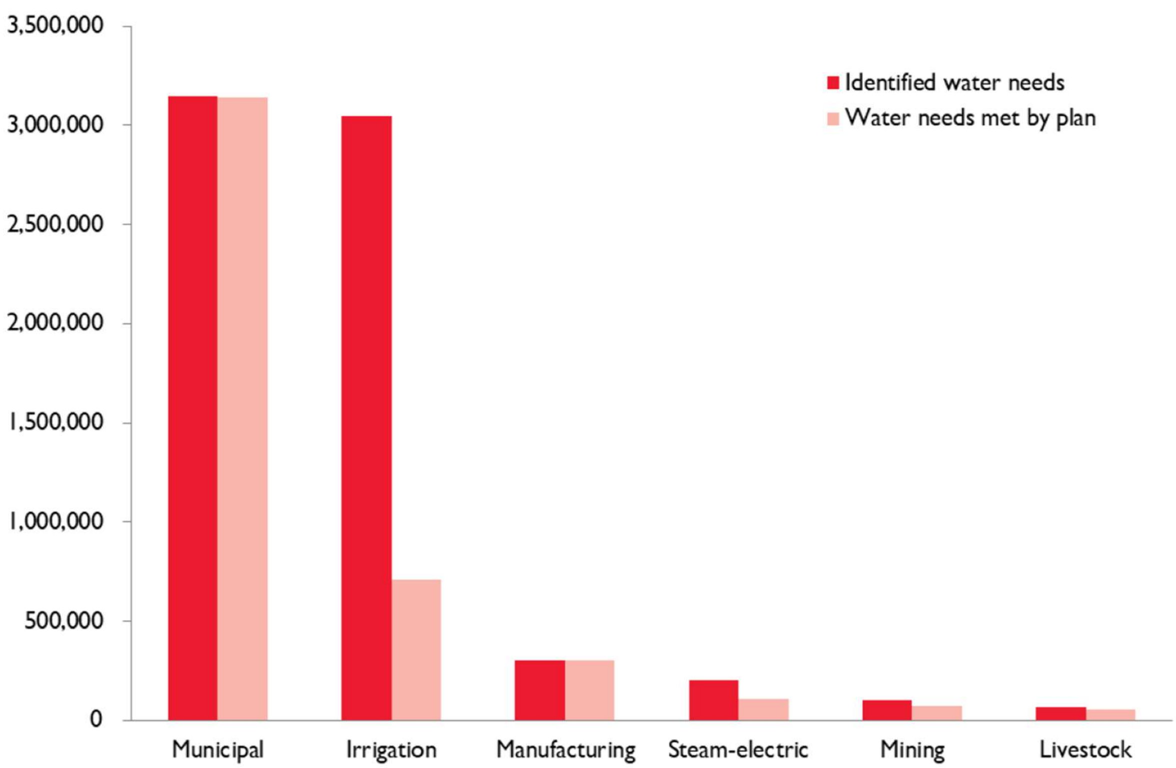


Figure ES-2 Annual water supply needs and needs met by the plan by region in 2070 (acre-feet); ref 2022 State Water Plan, *(figure 7-7)*

Program Structure

The purpose of the Study was to provide insight into reliability of water loss audits being currently reported to TWDB, and the role that validation might play in improving water loss audit reliability. For the implementation of the Study, TWDB used a qualifications-based process to select the consultant team of Cavanaugh, WSO, and Black & Veatch – hereafter referred to as the Project Management (PM) team.

The Study included 10 utilities reflecting a variety of system sizes (<10,000; 10,000-49,999; and 50,000-100,000 population) in population served and level of water loss management experience. The PM team worked with the group of participants to perform Level 1 water audit validations of their 2020 water loss audits.

Fig ES-3 Study Participants

Water audit results before and after validation were compiled and analyzed for the 10 utilities participating. Table ES 1 Table ES below shows the water audit results after Level 1 validation for all 10 participating utilities.

Table ES 1: Level 1 Validated Water Loss Audit Results (before / after Level 1 validation)

Utility	Apparent Loss (gal/conn/day)	Real Loss (gal/conn/day)	Infrastructure Leakage Index	Data Validity Assessment Score
1	6.8 / 6.8	117.3 / 117.3	3.8 / 3.8	79.5 / 75.5
2	2.4 / 2.4	23.0 / 23.0	1.0 / 1.0	84.5 / 67.0
3	16.1 / 16.1	14.6 / 14.6	1.4 / 1.0	78.0 / 70.0
4‡	blank / 7.1	blank / 74.2	blank / 3.6	blank / 47.5
5	3.6 / 3.6	73.0 / 73.0	n/a / n/a	44.0 / 35.0
6*	5.8 / 5.8	45.7 / 48.7	1.4 / 1.4	65.0 / 66.0
7*	14.4 / 4.8	92.0 / 85.6	2.0 / 2.7	81.5 / 78.5
8	6.7 / 6.7	75.6 / 75.6	n/a / n/a	79.0 / 73.0
9	19.5 / 19.4	140.0 / 138.1	6.9 / 6.8	41.5 / 51.0
10	5.3 / 5.3	15.4 / 13.9	0.9 / 0.8	71.0 / 74.0
Average:	**9.0 / 7.8**	**73.5 / 66.4**	**2.5 / 2.6**	**69.3 / 65.6**

ꜜ Utility #4 did not provide an initial version of their water loss audit, so pre-validation volumes are shown as zero. The PM team worked with Utility #4 to develop their water loss audit through the Level 1 validation process.

*Advanced validation conducted following the Level 1 validation for Utility 6 and Utility 7. See Section 5 for information on methods and results for advanced validation activities.

The validation process can often result in changes to the entries entered into the water loss audit, as well as changes to the assessment scale of those entries. As a result, changes in entries and scales cause changes to the water loss audit performance indicators. In general, all participants except for two made modifications to at least one water loss audit entry. However, all participants made modifications to the assessment scales.

There are 20 entries with their corresponding assessment scales that are reviewed during the Level 1 Validation. Figure ES 4 shows a summary of the count of water loss audit entries and assessment scales that were changed as a result of the validation. Across the study participants, all entries except for Treated Purchased Water and Treated Wholesale Water Sales were revised during validation. For systems that purchase treated water and have wholesale clients, it is expected they would have a clear understanding of those entries given that they could significantly impact their operating costs (in the case of Purchased Water) or their revenues (in the case of Wholesale Water Sales).

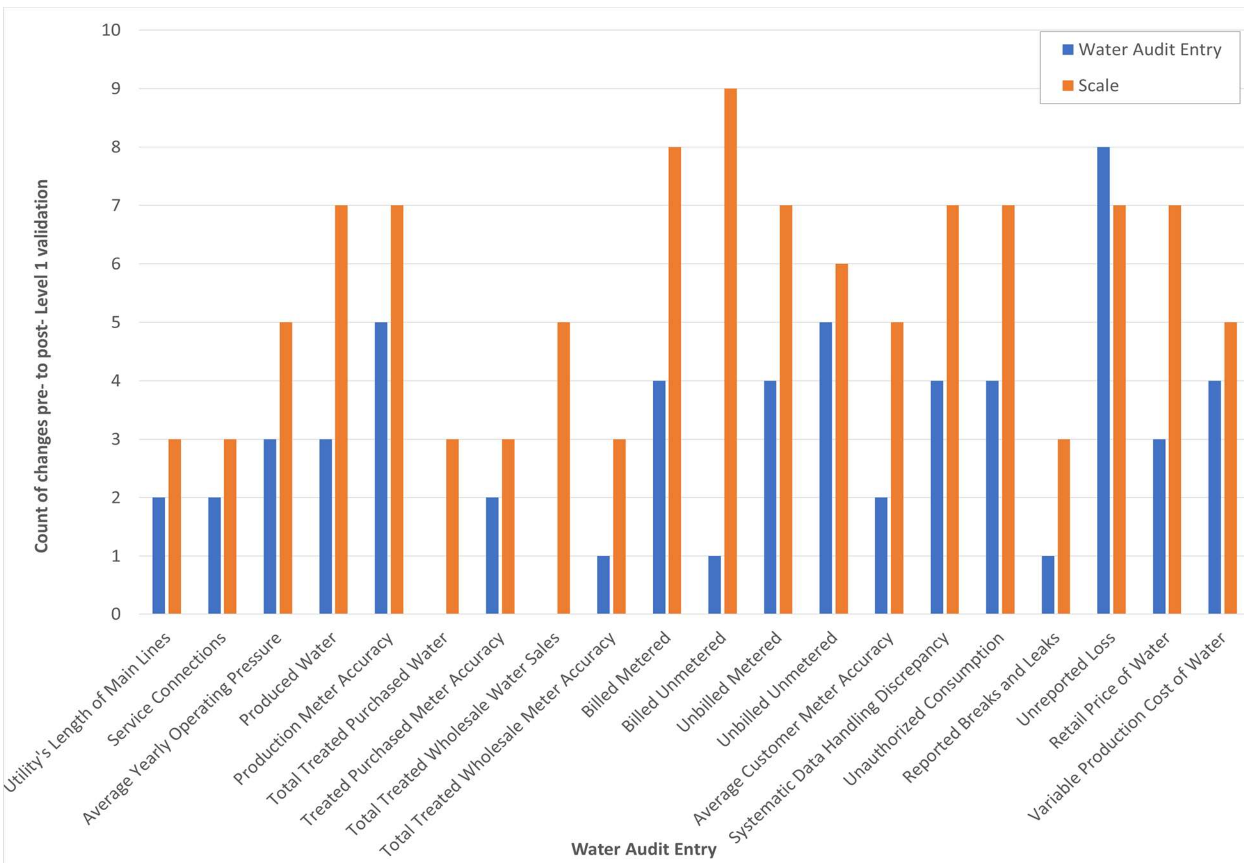


Figure ES 4: Summary of Changes to Water Loss Audit Entries and Assessment Scales from Level 1 Validation

Changes to the commonly used Performance Indicators were also evaluated to understand the impact of the validation to the water loss audit results (see Figure ES 5 below). All of the Performance Indicators evaluated changed as a result of the validation. The total Data Validity Assessment Score was the most commonly changed Performance Indicator, as expected due to the many changes that resulted to the input assessment scales.

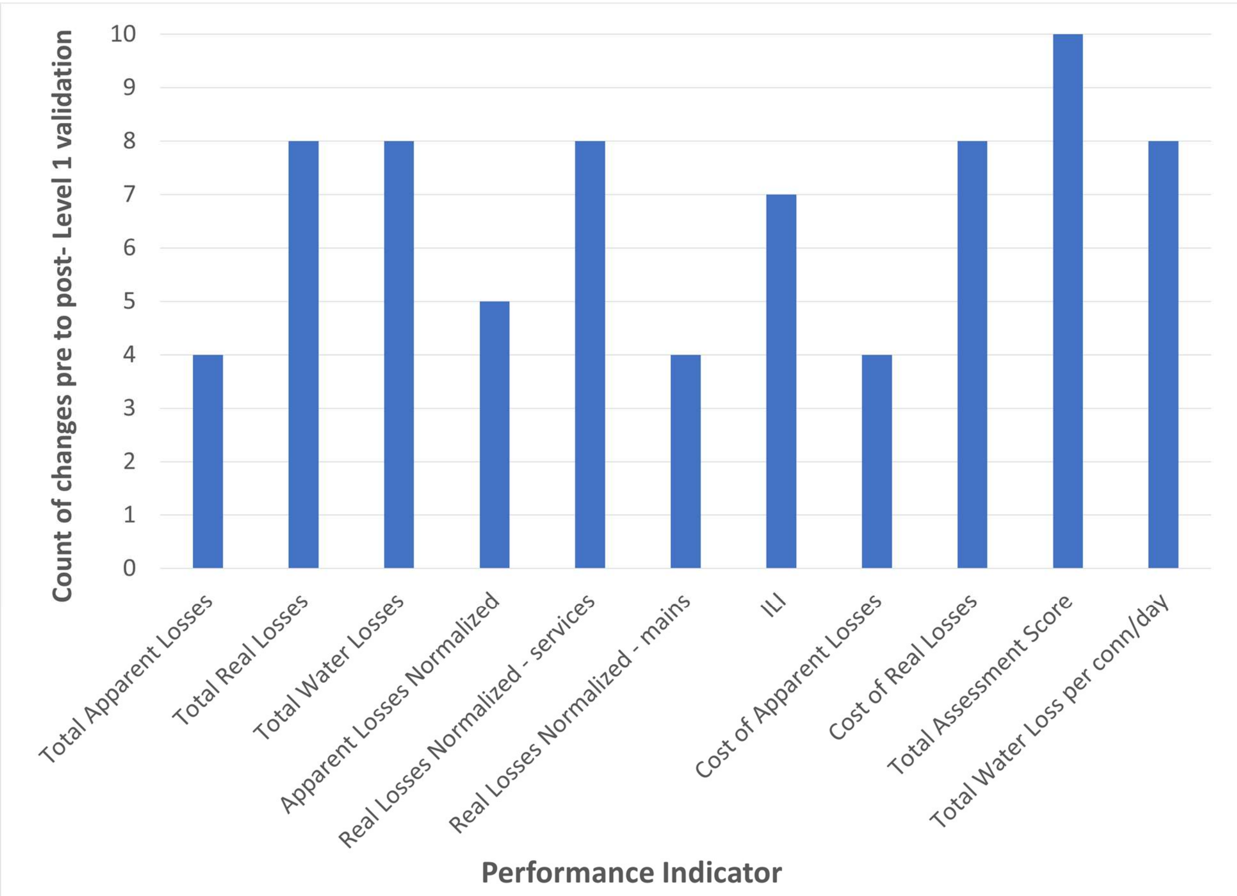


Figure ES 5: Summary of Changes to Performance Indicators from Level 1 Validation

Changes in total Data Validity Assessment Score (Assessment Score) is not uncommon as a result of the validation process. Independent validation by an experienced validator provides a uniform interpretation of the scoring assessment scale. For the Study however, all 10 of the Level 1 validations resulted in Assessment Score changes. The average change in Assessment Score per the Level 1 validation (excluding Utility #4 (see note)) was approximately minus four points. The maximum upward change in Assessment Score was 9.5 points (Utility #9), and the maximum downward change was 17.5 points (Utility #2). Figure ES 6 presents all changes in Data Validity Assessment Score resulting from the Level 1 validations, and comparisons to typical ranges in North America .

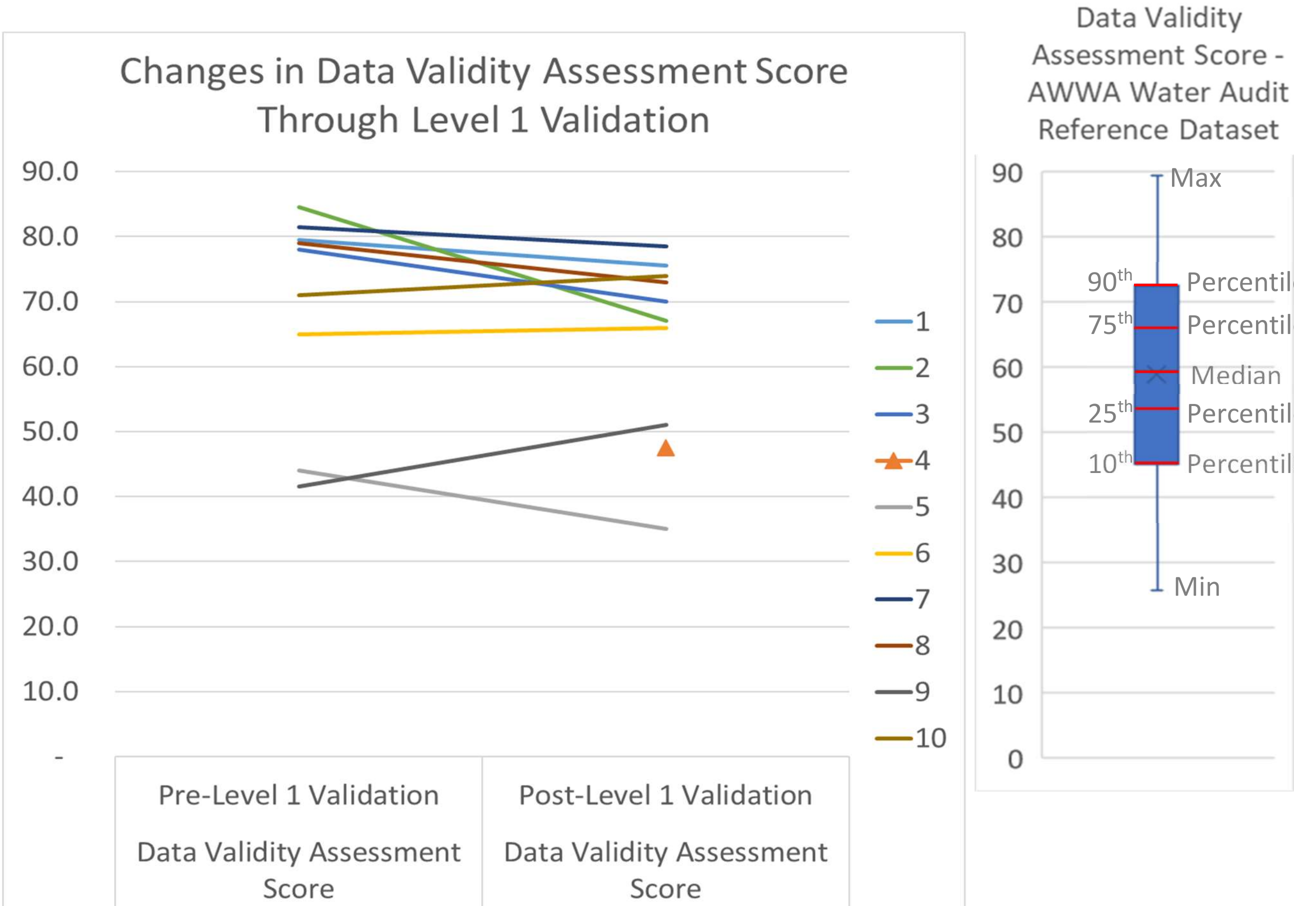


Figure ES 6: Spread of Data Validity Assessment Scores Through Level 1 Validation and Comparison to Typical Ranges in North America[1]

Program Findings

There were significant findings of the Study, as presented below:

1. **Level 1 validation results in improved reliability of self-reported water loss audit results**. The Study produced two progressive water loss estimates for each utility: first from the self-reported water loss audits and then from the Level 1 validated water loss audits. Seven of the 10 validated water loss audits resulted in volumetric corrections, yielding more representative water loss estimates. All 10 of the validated water loss audits resulted in modifications to the total Data Validity Assessment Score, yielding a more representative reliability scoring. 70% of the changes to the input Assessment Scales were decreases. The Assessment Scales were modified on the largest water balance volume inputs (*Produced Water, Billed Metered Authorized Consumption*) for at

[1]Kunkel, G. et al. AWWA Water Loss Control Committee – Water Audit Reference Dataset. 2020. AWWA. Denver, CO.

least 7 of the 10 validated water loss audits. The Study clearly shows that the accuracy of self-reported water loss audits can be improved through independent validation.

2. **Level 1 validation results in improved data management practices**. The process of gathering and providing supporting documentation for the water loss audit to an independent validator was observed to have an inherent benefit to the utility staff, *regardless* of whether the Level 1 validation resulted in changes in the water loss audit. Utility staff provided feedback that those benefits included:

    - The establishment of supporting documentation trail, making future data gathering efforts easier,
    - The Level 1 validation report which includes notes on the basis for water loss audit inputs and basis for selecting data validity assessment grades, making future audit compilation efforts easier,
    - Insights and recommendations provided by the independent validator for their specific circumstances and focus areas, and
    - Gathering the data requires increased communication across multiple departments within the utility. These exchanges increase the personnel's understanding of other aspects of the operation that are unknown to them and often result in corrections and improvements to data inputs and data validity assessment grades.

Utility staff noted these benefits will be especially valuable in scenarios where there is staff turnover or new staff gets involved in water loss auditing and validation activities in the future.

3. **Much of the supporting data needed for Level 1 validation is already tracked and reported**. Level 1 validation requires supporting documentation that includes supply volumes by month, by supply meter for the audit year. Water utilities are already providing monthly supply volumes to the TWDB Water Use Survey, so they are likely already internally tracking these volumes by supply meter by month. Authorized consumption volumes are also required for both the Water Use Survey and a Level 1 validation, though the Water Use Survey does not require this broken down by month. Further, most Study participants were able to easily provide the required information that wasn't already part of their Water Use Survey, namely a system schematic, monthly authorized consumption volumes by month, and supply meter test records (if applicable). The PM team observed that for most utilities the effort required for gathering the Level 1 validation supporting documentation was not a significant increase above their normal data management activities.

4. **Staff time availability is adequate for most utilities to participate in a Level 1 validation**. The Study was conducted during the first half of 2021. In February 2021 Texas experienced an extreme freezing event that caused widespread interruptions and emergency operations at many water utilities, including those participating in the Study. Additional time was added to the Study schedule to accommodate this unplanned event,

but the extraordinary demands on utility staff time were observed to be ongoing. Nonetheless, 7 of the 10 utilities were able to get their water loss audits and supporting documentation submitted within established timeframes. The remaining three utilities required extra time and assistance from the PM team to gather the necessary information. As noted in Section 4, one of the 10 utilities was not able to provide a self-reported water loss audit. In this case, the PM team worked with that utility to develop their water loss audit through the Level 1 validation process. Smaller systems were observed to be the most time-limited participants in the Study. The participating utilities did recognize, however, that future information gathering for them is expected to be more efficient and quicker based on protocols established in this Study (see Finding #2).

Program Recommendations

Validation is vital to **reliable water loss audits**.
Reliable water loss audits are vital to achieving **municipal conservation**.
Municipal conservation is vital in the **State Water Plan** (2022) to meet the long-range water needs in Texas.

TWDB is to be commended for recognizing these critical connections and for executing this Study to gain insights on conducting Level 1 water loss audit validations in Texas. The Significant Findings point to establishing Level 1 water loss audit validation as standard practice to ensure furthering water conservation through quantification and measurement[2]. From this, strategic plans across the 16 planning regions can be guided by reliable information.

Program recommendations for future water loss audit validation activities in Texas, based on the Significant Findings in this Study, are presented below.

Recommendation 1: Expand the Water Loss Audit Validation Study into a Regional Validation Program.

Significant Findings 1 and 2 highlight the benefits of Level 1 validation and the vital role it serves in understanding reliability of self-reported water loss audits. Without water loss audit validation, each planning region is using data of unknown reliability to make large-scale plans with large-scale implications. To build support and buy-in from the water industry, it is recommended to expand the pilot validation Study into a Regional Validation Program (RVP) in one or more planning regions with a focus on those facing the largest shortages.

[2] https://www.twdb.texas.gov/publications/reports/administrative/doc/LAR_FY2022-2023.pdf

In the short-term this would allow continued promotion of Level 1 validation in a scalable way, to match funding availability and to serve those regions with the highest needs first (see Figure ES 7). It would also allow continued building of utility case studies and testimonials in support of Level 1 validation, establishing key industry support in a region-by-region basis, and on a voluntary basis. In the long-term, it would support a pathway to Level 1 validation as standard practice across all 16 planning regions.

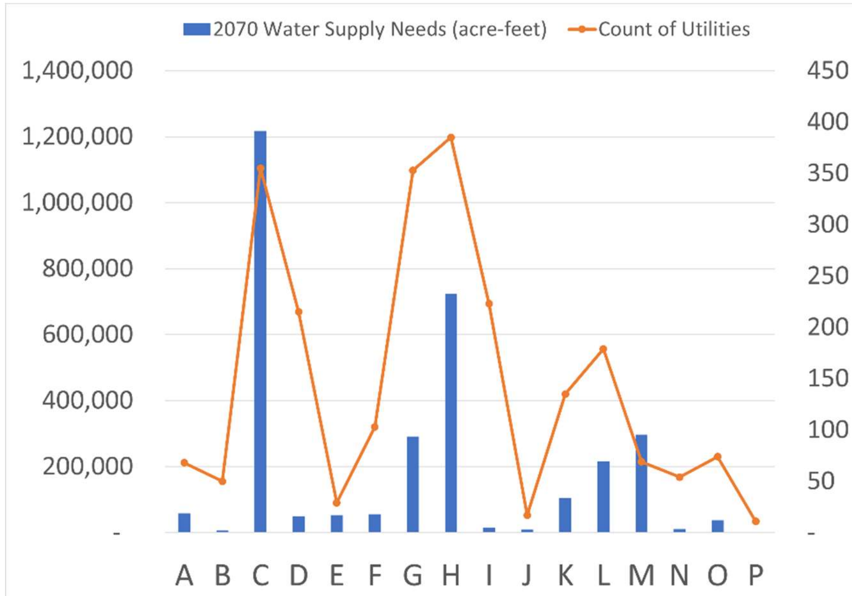


Figure ES 7: Annual water supply needs by planning region in 2070 (acre-feet); ref 2022 State Water Plan

The recommended conceptual structure for the RVP includes the following:

- Identify the region(s) that would be the focus of round 1 RVP, based on highest need (Figure ES 7) and scale of funding availability,
    - A planning budget for state funds of $6k-$8k per participating utility is recommended,
- Target the round 1 RVP towards those utilities in the selected region(s) that are currently required to conduct and submit annual water loss audits to TWDB,
- Utilizing the validation standards established in this Study, execute the round 1 RVP to complete Level 1 validations with the target participants for 2021 water loss audit year,
- Use outcomes and utility testimonials from the round 1 RVP to continue building broader support for Level 1 validations, and
- Repeat the approach to identify region(s) for round 2 RVP and subsequent RVP rounds.

Recommendation 2: Explore adopting Level 1 water loss audit validation as a required practice for all annual water loss audits.

There are approximately 750 water systems that submit a water loss audit to TWDB annually (based on size >3,300 connections or as a condition of funding from TWDB). All retail water systems (approximately 4,000) are required to submit a water loss audit to TWDB every five years, with the next submittal cycle to occur in 2026 for reported year 2025. All four Significant Findings point to establishing Level 1 water loss audit validation as standard practice for all water loss audits in Texas. As of this report, Level 1 validation is now a required standard for water loss audits in Georgia, Indiana, California, and Quebec, and is being evaluated for adoption in several other states where self-reported water loss audits are currently required.

It is recommended to explore the adoption of a Level 1 validation requirement for the approximately 750 water loss audits received annually at TWDB. Recommendation 1 (above) for expanding a Regional Validation Program would build utility support for such a requirement. In addition to utility support, however, a structured approach is necessary for success in establishing a Level 1 validation requirement based on lessons learned from the validation program rollouts in Georgia, Indiana, California, and Quebec (see Appendix 4). The requirement must come in tandem with technical assistance and support for the approximately 750 utilities subject to the requirement each year (the “target utility group”).

The recommended conceptual structure for adopting a Level 1 water loss audit validation requirement includes the following:

- Leading up to the adoption of a requirement, provide foundational training to <u>all utilities</u> in the target utility group on the concepts of water loss audit validation with focus on common errors made and how to avoid them,
- Leading up to the adoption of a requirement, provide foundational training to <u>the smaller utilities</u> in the target utility group on the concepts of completing the water loss audit,
- In the short-term (one-two years) following the adoption of a requirement, engage with a third-party subject-matter expert to conduct Level 1 validations for the target utility group each year.
    - A planning budget for state funds of $3,000 to $5,000 per participating utility per year is recommended,
- In the mid-term (two-three years) following the adoption of a requirement, develop and establish a validation certification program to create a pool of certified water loss audit validators in Texas to meet ongoing demand for Level 1 validations following similar successful models (see Appendix D).
    - A planning budget for state funds of $400,000 to $500,000 is recommended, and
- Establish one or more new FTE positions at TWDB dedicated to Level 1 water loss audit validation program administration needs.

TWDB could, alternatively, consider building out the capacity in-house to perform the Level 1 validations for the target utility group. TWDB staff currently are already providing an important high-level quality review on the water loss audit submittals received each year. The challenge, however, is scale. Performing Level 1 validations for 750 water loss audits each year in the aggregate is a massive task and not practical for any single person or small government team to accomplish. Establishing a validation certification program to get to a pool of certified validators means that both the workload and the cost of accomplishing the Level 1 validations is distributed among the target utility group. With the recommended approach, TWDB would invest in upfront costs in the short- and mid-term but would not carry the ongoing costs of annual validation efforts in perpetuity, thus making it a more sustainable model.

Recommendation 3: Explore migrating the TWDB water loss audit format to become aligned with the AWWA Free Water Audit Software version 6.0.

TWDB has long been a leader in North America on water loss auditing practices. In fact, the advent of the AWWA water loss audit data grading matrix in version 4 of the AWWA Free Water Audit Software (FWAS) came as a result of TWDB's progressive work in this field in the late 2000s. The current TWDB water loss audit format is built consistent with Version 5 of the FWAS, which was released in 2014. In December 2020, Version 6 of the FWAS was released and included significant updates in both the Assessment Scale and the Dashboard of Key Performance Indicator outputs. These updates reflect state of the art best-practices for assessing data reliability and measuring water loss performance, including the ability to benchmark against other validated water loss audit results in North America.

Audit validations conducted during this pilot program discussed the use of set questions and answers for the validations (as used in the FWAS Version 6) versus the current TWDB method of matching the auditor matching practices against a broader written matrix. Study participants that had used the TWDB method and previous FWAS Version 5 (which was less prescriptive) noted that the new "set questions" version were easier to use and more straightforward in the long-term. It is recommended for TWDB to explore transitioning its current methodology to require the set question format, following the improved method evidenced in the FWAS Version 6.

It is recognized that a significant amount of effort has been placed into the development of the existing TWDB portal. In 2012 the 83rd Legislature directed TWDB to streamline current automated and manual data entry and reporting requirements for water planning and conservation. The project combined the functionality of the Water Use Survey, Water Loss Audit, the Annual Conservation Report, and the Conservation Plan/Utility Profile into one system of applications. At the time the same data was required to be entered multiple times by the utilities. This system, now known as the Loss, Use & Conservation reporting application, allows the flow and auto-population of data between the four reports above. The outcome of the project was realization of efficiencies in reporting and consistency in data, not only by the utilities, but by TWDB as well.

The Loss, Use & Conservation reporting application combines the water use, water loss and water conservation reporting segments and there is interconnected data between the three reports.

FWAS Version 6 represents state of the art in data validity assessment, and also allows for easy comparison of water loss audit results against typical North American benchmarks. If Texas utilities want to use this tool today, then they should feel free to utilize the FWAS Version 6 and leverage its benefits. However, for TWDB data purposes it is not possible to fully utilize the FWAS on its own to report for state-required purposes. To migrate the TWDB water loss audit format for alignment with the FWAS Version 6, it is therefore likely most practical to update the portal rather than mandating use of the FWAS Version 6 directly.

It is expected that this would require some major work to the portal itself to ask each of the validation questions and then build the ensuing logic for calculation of total Data Validity Assessment Score. Coordination with and approval from AWWA would ultimately be a necessary part of the process, given the copyrighted elements of the FWAS Version 6.

In summary, it is recommended that TWDB explore ways to further align its water loss audit format to keep current with those significant updates included the AWWA FWAS Version 6. This will require additional staffing for a short- to medium-term to make the transition for the data portal. A planning budget for state funds of $50,000 to $75,000 is recommended to provide necessary assistance to TWDB’s IT Department for data portal updates associated with this recommendation.

Updating and expanding TWDB’s water loss audit training activities is also recommended to provide educational and technical support for utilities in completing the annual water loss audits. If expanded Regional Validation Programs as discussed in Recommendation 1 were implemented, it is feasible that training could be integrated to educate utilities any updates to TWDB’s portal and the water loss audit format. If training were contemplated as a stand-alone approach, it is recommended that TWDB consider developing a combination of in-person workshops, live-virtual training events, and pre-recorded training resources. Additional TWDB staff resources, beyond the current water loss program may be required.

1 Program Background

The Texas Water Development Board (TWDB) is responsible for preparing the state water plan every five years. Each plan is tasked with looking ahead over a 50-year horizon and strategically seeks to ensure an adequate water supply for users in the state. In order to incorporate varying geographical interests and needs, the state is divided up into 16 regional water planning areas (Figure 1). These regional water plans are reviewed and incorporated into the state water plan.

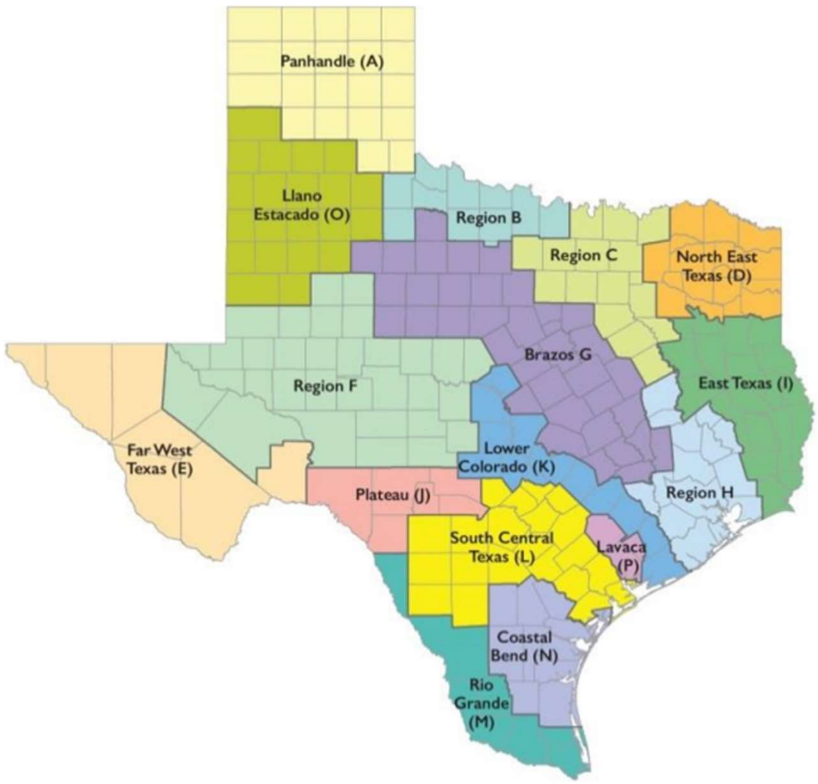


Figure 1: Regional water planning areas; ref 2022 State Water Plan *(figure ES-1)*

The 2022 State Water Plan[1] presents several challenges that Texans will need to plan for. The state's population is anticipated to increase 73 percent between 2020 and 2070. Texas' existing water supplies are projected to decline by approximately 18 percent between 2020 and 2070. If strategies are not implemented, approximately one-quarter of Texas' population in 2070 would have less than half the municipal water supplies they will require during a drought of record.

Water user groups face a potential water shortage of 3.1 million acre-feet per year in the 2020 decade and 6.9 million acre-feet per year in the 2070 decade in drought of record conditions

[1] https://www.twdb.texas.gov/waterplanning/swp/2022/index.asp

(Figure 2). These water user groups include municipal, mining, steam-electric, manufacturing, livestock, and irrigation. Conservation strategies, including water loss mitigation, represent approximately 29 percent of all recommended water management strategy volumes in 2070, and of that, municipal conservation strategies make up approximately 12 percent. The data supporting projected municipal water needs and the percent share of water management strategies through municipal conservation will be used to make important decisions on water supply planning. It is crucial the data is trustworthy and water loss audits play a significant role in evaluating the reliability of municipal water use data.

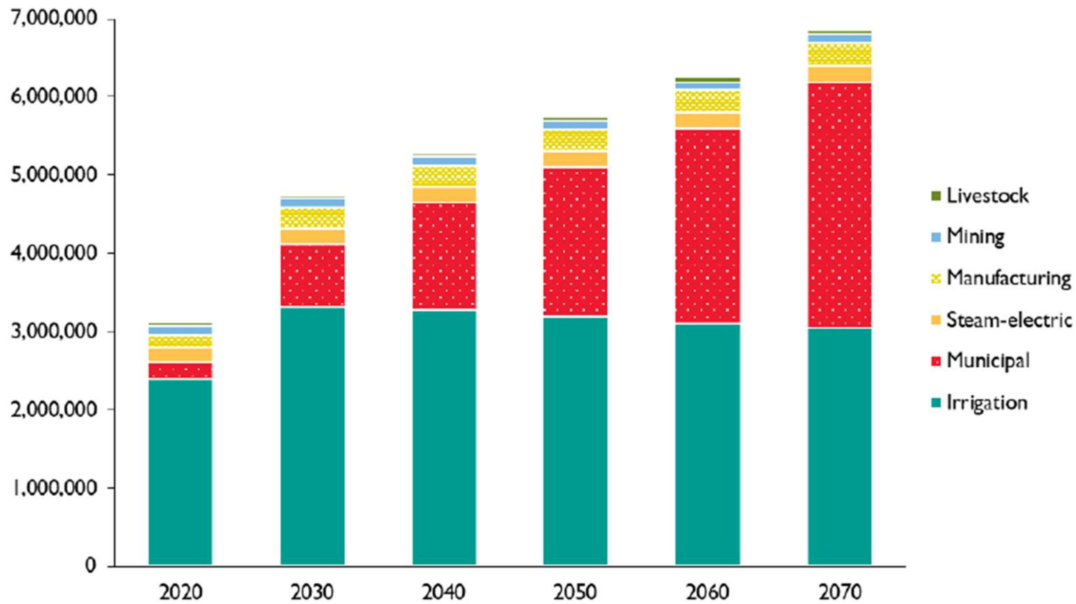


Figure 2: Annual water needs by water use category (acre-feet); ref 2022 State Water Plan, (*figure ES-4)*

Water conservation plays a major role in the state water planning process. One significant role in the TWDB water conservation strategy is the collection of water loss audits. Water loss audits are required to be a component of each regional water plan and are recognized in the state water plan. Retail public water suppliers with either an active financial obligation to the TWDB or having more than 3,300 connections are required to submit an annual water loss audit (approximately 750 systems annually). All retail public water suppliers must submit a water loss audit once every five years (approximately 4,000 systems) per Texas Administrative Code (31 TAC §358(b)(1).[2]

Municipal conservation strategies must consider water loss reductions. Although Texas has a regional approach to water planning, no region is immune to water loss. In fact, eight regions have established thresholds for triggering a water loss management strategy, and three of those eight regions have established voluntary thresholds for triggering water loss intervention (i.e., leak detection and repair, pipeline replacement). Figure 3 illustrates that the State Water Plan

2 https://texreg.sos.state.tx.us/public/readtac$ext.TacPage?sl=R&app=9&p_dir=&p_rloc=&p_tloc=&p_ploc=&pg=1&p_tac=&ti=31&pt=10&ch=358&rl=6

(which includes water loss mitigation), if effectively implemented, is structured to meet nearly all municipal water needs in 2070. The water loss audit data used to identify these water loss thresholds, however, is self-reported, without formal validation. Water loss audit validation is a process that identifies uncertainty in the water loss audit and as a result, provides more reliable data. TWDB, in recognizing the critical connection between water loss audit reliability and the State Water Plan strategic objectives, commissioned this Water Loss Audit Validation Study (hereafter referred to as the Study). Current water management strategies may be targeting on incorrect water loss audit data – which presents considerable risk to the effectiveness of current water loss mitigation plans. Bottom line - better data means better strategies.

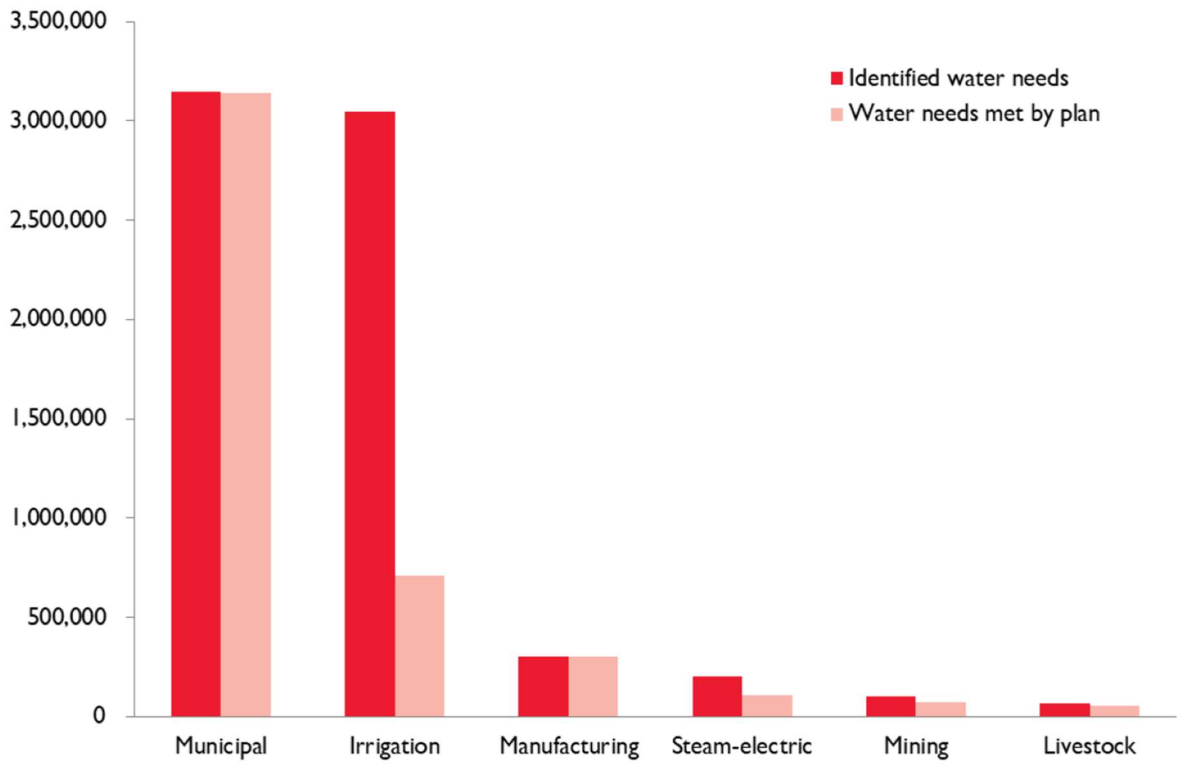


Figure 3: Annual water supply needs and needs met by the plan by water use category in 2070 (acre-feet); ref 2022 State Water Plan, *(figure ES-9)*

1.1 Scope

The purpose of the Study was to provide insight into reliability of water loss audits being currently reported to TWDB, and the role that validation might play in improving water loss audit reliability.

The TWDB's water loss audit methodology follows general industry standards and includes self-reporting of a utility's data. However, Level 1 validation[3] is not required in Texas. Level 1

[3] Water Research Foundation Project 4639A, Level 1 Water Audit Validation: Guidance Manual (2016)

validation of water loss audit data examines supporting documentation to validate methods used for input calculations and corroborates selection of the data validity assessment grades against current utility practices. This benefits the utility by identifying where best to spend limited funds and by helping to ensure that the most cost-effective water loss measures are targeted. When utilities receive financial assistance through state and federal programs, such validation can be particularly important. See Section 1.2 for additional information on Level 1 validation methodology. In some cases, advanced validation can be warranted to uncover data error that may exist within raw data (supply databases, billing databases) or in under-performing equipment and instrumentation (i.e. supply meters, SCADA systems). In this Study, advanced validation was conducted for two of the Study participants. See Section 4 for additional information on advanced validation.

For the implementation of the Study, TWDB used a qualifications-based process to select the consultant team of Cavanaugh, WSO, and Black & Veatch – hereafter referred to as the Project Management (PM) team.

The Study included 10 utilities reflecting a variety of system sizes (<10,000; 10,000-49,999; and 50,000-100,000 population) in population served and level of water loss management experience. The PM team worked with the group of participants to perform Level 1 water loss audit validations of their 2020 water loss audits.

The scope of the Study entailed:

- Task 1: Conduct Level 1 water loss audit validations
- Task 2: Develop validation questions
- Task 3: Review of historic and current water loss audit data
- Task 4: Conduct one-to-one meetings with each utility
- Task 5: Provide utility-specific validation reports
- Task 6: Provide a final report to TWDB

Figure 4: Study Participants

This final report for the Study presents an overview of the program background, results, findings, and recommendations for future validation activities in Texas.

1.2 Methods

The Texas Water Development Board's water loss audit methodology follows general industry standards for quantifying water loss.

Water Loss Audits

The industry standards for quantifying water loss provide water utilities effective tools and methods to promote accountability and efficiency in their operations.

The water loss audit is a technique that involves the review of records and data to trace the flow of water into a distribution system from its source to its destination – whether that destination is consumption by a customer or a leak through a pipe. The water balance summarizes the components of the water loss audit providing accountability since, in theory, all water into the distribution system should equal all water out of the distribution system. Figure 5 shows the components of the standard water balance.

With the water balance calculation, all water that enters the distribution system is accounted for and can be shown as either *Authorized Consumption* or *Water Loss*. Therefore, no volume of water is assumed to be unaccounted. *Water Loss* is defined as the difference between *Water Supplied* and *Authorized Consumption*. The TWDB water loss audit applies the same methodology.

Additionally, *Water Loss is* subdivided into *Apparent Loss* and *Real Loss*. *Apparent Loss is* an estimated volume that represents the volume of water that reached a customer (or its intended end-user) but was not accounted and billed for properly. The subcategories of *Apparent Loss* includes customer metering inaccuracies, unauthorized consumption, and systematic data handling errors. *Real Loss is* calculated with the water balance as the difference between *Water Loss* and *Apparent Loss* and represents the physical loss of water from the distribution system. Leakage and tank overflows are the main causes of *Real Loss*.

These key concepts were reinforced with participants during the training webinar conducted at the beginning of the Study.

Volume from Own Sources (corrected for known errors)	System Input Volume	Water Exported (corrected for known errors)	Billed Water Exported			Revenue Water
		Water Supplied	Authorized Consumption	Billed Authorized Consumption	Billed Metered Consumption	Revenue Water
					Billed Unmetered Consumption	
				Unbilled Authorized Consumption	Unbilled metered Consumption	Non-revenue Water
					Unbilled unmetered consumption	
			Water Loss	Apparent Loss	Systematic Data Handling Errors	
					Customer Metering Inaccuracies	
					Unauthorized Consumption	
				Real Loss	Leakage on Transmission and Distribution Mains	
					Leakage and Overflows at Utility's Storage Tanks	
Water Imported (corrected for known errors)					Leakage on Service Connections up to the point of Customer Metering	

Figure 5: M36 Methodology Water Balance: credit AWWA M36 Manual, 4th Ed.

Water Loss Audit Validation

Research on water loss audit data has concluded that utilities often struggle to assess the validity of their own data accurately and consistently, and a substantial portion of audit submissions have reported suspect data that produce technically impossible water loss scenarios[4]. An inaccurate water loss audit may result in an incorrect assessment of water loss performance. Without an accurate understanding of the types and quantities of water loss or the practices contributing to loss, it may not be possible to develop a cost-effective strategy to address the inefficiencies.

Water loss audit validation is the process of examining water loss audit inputs to improve the water loss audit's accuracy and document the uncertainty associated with the used data. The goals of the water loss audit validation are to:

- Identify and appropriately correct for errors in water loss audit data and misapplication of methodology.
- Evaluate and communicate the uncertainly inherit in water loss audit data.

There are three levels of validation rigor:

[4] *WRF Project #4639B - Utility Water Audit Validation: Principles and Programs. Water Research Foundation. 2016. Denver, CO.*

- *Level 1*: Water loss audits are examined for inaccuracies evident in summary data and application of methodology.
- *Level 2*: Water loss audits have been corroborated with investigations of raw data and archived reports of instrument accuracy.
- *Level 3*: Water loss audits have been bolstered by field tests of instrument accuracy and the water loss audit's estimate of Real Loss has been confirmed through other sources of field data, such as with a Component Analysis of Real Loss (see Section 4.2).

Water loss audit validation should be performed by a person proficient in current American Water Works Association (AWWA) M36 and TWDB water loss audit methodologies and the Water Research Foundation (WRF) 4639 water validation methodology[4]. The validator should not be the same person who compiled the water loss audit. Georgia, Indiana, and California – three states which require the submission of Level 1 validated water loss audits – have recognized the critical importance of water loss audit validation and over time have created state programs to certify water loss audit validators.

An example case is indicated below to illustrate the critical importance and long-term impacts of annual water loss auditing and validation (see Figure 6). The City of Asheville, North Carolina has put in place a water loss control program following the industry standards for quantifying water loss and validating water loss audits. Each year, Asheville conducts a water loss audit validation, and uses the resulting metrics to guide which field interventions are appropriate to employ for water loss reductions. Asheville has increased their Data Validity Assessment Score from 50 to 83 (on a scale 0-100) over the time period shown below. The results from their efforts have shown sustained reductions in water loss, even amidst system growth.

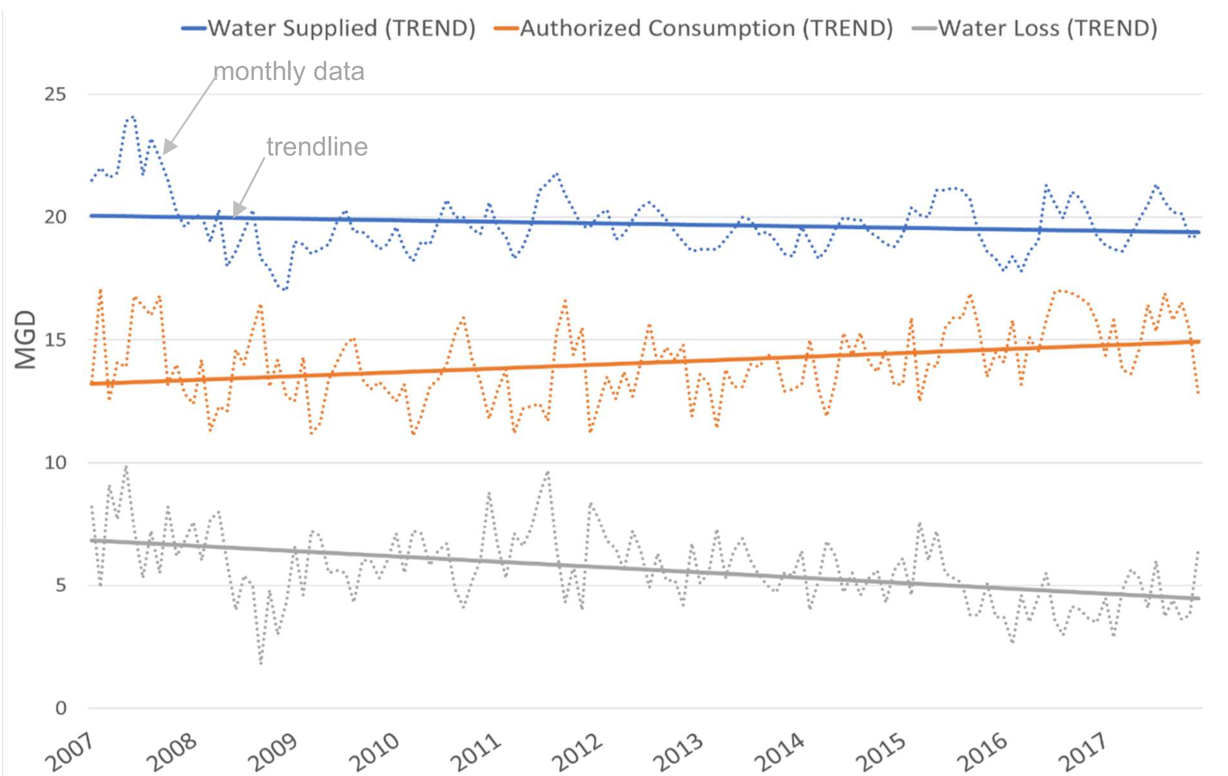


Figure 6: City of Asheville 10-Year Water Loss Reductions

2 Validation Toolkit

2.1 Level 1 Validation

A Level 1 validation was performed with each of the Study participants using their 2020 water loss audit. To facilitate this, the PM team developed a guidance document to establish standards of care for conducting a Level 1 validation in Texas. This content was built based on the principles within the WRF Project #4639A Level 1 Water Audit Validation: Guidance Manual (2016) and was adapted to the TWDB water loss audit format and specifications. These standards were then employed for the Level 1 validations performed during the Study.

The standards included specifications for supporting documents that are considered necessary and required for completing a Level 1 validation, as noted below. Parenthetical line numbers are in reference to the TWDB water loss audit worksheet.

1. ***SD1 - System Schematic*** *– depicting the water system with relative locations labeled for each of the meters used to derive the volumes entered for Produced Water (Line 13), Total Treated Water Purchased (Line 14) and Total Treated Wholesale Water Sales from Produced Water (Line 15). Does not need to be to scale, and a sketch is adequate.*
2. ***SD2.x - Produced Water*** *– volumes by month, by meter for the audit period. This should cover all volumes included in the input for Line 13 in the water loss audit form.*
3. ***SD3.x - Production Meter Accuracy*** *– documentation of accuracy testing and electronic calibration events during the audit period, if performed.*
4. ***SD4.x - Treated Water Purchased*** *– volumes by month, by meter, for the audit period. This should cover all volumes included in the input for Line 14 in the water loss audit form.*
5. ***SD5.x – Treated Wholesale Water Sales*** *– volumes by month, by meter, for the audit period. This should cover all volumes included in the input for Line 15 in the water loss audit form.*
6. ***SD6.x - Authorized Consumption*** *– volumes by month, by class or use-type, for the audit period. This should cover all volumes included in the inputs for Lines 17, 18, 19 and 20 in the water loss audit form.*

Supplemental supporting documentation is also described, that should be provided if available. This documentation may also be generated as a function of the Level 1 validation in some cases.

1. *The calculation behind the input for Average Yearly System Operating Pressure (Line 10).*
2. *The calculation behind the input for Production Meter Accuracy (Line 13a).*
3. *The calculation behind the input for Treated Purchased Water Meter Accuracy (Line 14a).*
4. *The calculation behind the input for Treated Wholesale Water Meter Accuracy (Line 15a).*
5. *The calculation behind the input for Average Customer Meter Accuracy (Line 23).*
6. *The calculation behind the input for Retail Price of Water (Line 40).*

7. *The calculation behind the input for Variable Production Cost of Water (Line 43).*
8. *Table of estimates behind the input for Reported Breaks and Leaks (Line 28).*

The guidance document also presents inventory of validation questions for inputs and additional guidance for assessment grades for each water loss audit input (see Figure 7).

Produced Water (Line 13)

Validator should frame questions that will discover answers to the following:

- Does the Line 13 volume account for all water sources owned and operated by the supplier?
- Was any volume double-counted?
- Was all non-potable water excluded?
- Does the Line 13 volume capture the whole audit period?
- Is the best fit data used for the audit input (closest to distribution, most accurate given meter history)?
- Were changes in storage calculated and properly accounted for?
- How many distinct own-source distribution inputs are there?
    - How many inputs are metered?
    - Are any of the meters in series?
    - Do the meters capture raw water or potable water?
- How are unmetered inputs estimated?
- Which own-source meters are calibrated? How often are calibrations performed?
    - What were the results of the calibrations closest to the audit period?
- Which own-source meters are volumetrically tested? How often are tests conducted?
    - What were the results of the volumetric accuracy tests closest to the audit period?

Additional DVG Assignment Guidance

In addition to the DVG criteria, consider the following when confirming the selection:

	"Accuracy testing" refers to the study of a meter's primary measuring mechanism. In volumetric accuracy testing, a meter's registered volume is compared to precise and independent volumetric measurement in-situ.
	"Electronic calibration" refers to a check on the meter's secondary instrumentation. Electronic calibration ensures the accurate communication and conversion of electronic signals.
	"% of water production" refers to percentage by volume (not by count).
2+	Manufacturer testing certificate for newly installed meter *does not qualify* as accuracy testing
2	"Occasional meter accuracy testing or electronic calibration conducted" requires that either maintenance activity occurred within the last 5 years but less than annually.
3	Accuracy testing OR electronic calibration occurs annually for at least 90% of the source flow by volume. Supporting documentation showing the most recent maintenance results required.
4+	Accuracy testing AND electronic calibration occurs for at least 90% of the source flow by volume.
5	Testing and calibration practices are closely scrutinized for adherence with the M36 Manual

Figure 7: TWDB Level 1 Water Loss Audit Validation Guidance Document (excerpt)

The full TWDB Level 1 Water Loss Audit Validation Guidance Document is provided in Appendix A.

Additionally, a template for capturing the Level 1 validation interview and review notes was developed by the PM team to establish standard of care for documenting Level 1 validation outcomes. This template is included in Appendix B.

2.2 Advanced Validation

The participating utilities had the option of conducting an advanced validation analysis of their water loss audit data. The additional analysis included either a detailed Billing Data Analysis or a Real Loss Component Analysis to further understand their leakage profile. The data request sheet provided detailed the data that would be necessary to collect for the additional analysis (see Appendix B). Both types of analysis were discussed during the training webinar.

The detailed analysis of billing data is considered a Level 2 validation, according to WRF Project 4639A (2016). The purpose of this analysis is to investigate the raw data that informs the total volume used to report the authorized consumption in the water loss audit. With this additional detailed scrutiny, any errors or anomalies in the raw data can be investigated and corrected if necessary.

With a Real Loss Component Analysis, detailed leak/break event data is analyzed to further segregate the total volume of real loss that is determined via the water loss audit into the three distinct types of leakage: background leakage, unreported leakage, and reported leakage.

This type of analysis is considered a Level 3 validation. The purpose of the analysis is to estimate the volume of leakage that could be recovered with the implementation of leakage reduction strategies while seeking a balance between the value of water saved and the cost of intervention. The Water Research Foundation[5] published an excel-based tool for conducting a Real Loss Component Analysis that is freely available.

Outcomes of advanced validation analyses are presented in Section 5.

[5] Water Research Foundation Project 4372B, Real Loss Component Analysis: A Tool for Economic Water Loss Control (2015)

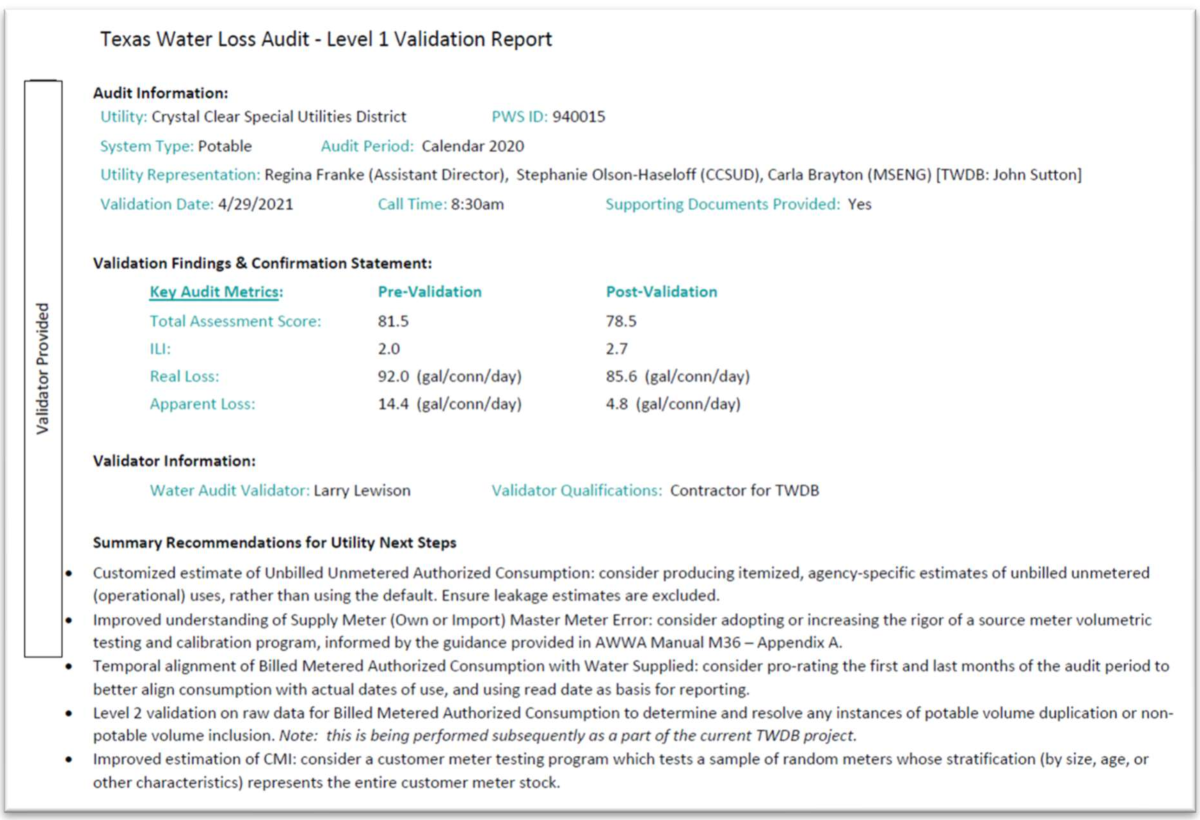
3 Level 1 Water Loss Audit Validation Results

As part of the Study, the PM team engaged the participating utilities in a Level 1 Water Loss Audit Validation. The primary objectives of a Level 1 Water Loss Audit Validation are to trace water loss audit inputs back to supporting documentation and evaluate the reliability of the data through a better understanding of practices and policies within the system and appropriately identifying those in the assessment scale.

3.1 Level 1 Validation Reports

Participants were tasked with compiling their 2020 calendar year water loss audit using the Texas Water Loss Audit format. Upon completion of the water loss audit and submittal to the TWDB, the participants provided their supporting documentation (as described in Section 3.1) to the PM team. Individual meetings between the PM team and the utilities were conducted through a shared screen web meeting to conduct the Level 1 validation interview.

Participating utilities were provided a summary of their water loss audit results, the validation process, and recommendations for improving water loss auditing practices and loss management (example excerpt shown in Figure 8). Individual utility reports are included in Appendix C.



Texas Water Loss Audit - Level 1 Validation Report

Validator Provided

Audit Information:

Utility: Crystal Clear Special Utilities District PWS ID: 940015

System Type: Potable Audit Period: Calendar 2020

Utility Representation: Regina Franke (Assistant Director), Stephanie Olson-Haseloff (CCSUD), Carla Brayton (MSENG) [TWDB: John Sutton]

Validation Date: 4/29/2021 Call Time: 8:30am Supporting Documents Provided: Yes

Validation Findings & Confirmation Statement:

Key Audit Metrics:	Pre-Validation	Post-Validation
Total Assessment Score:	81.5	78.5
ILI:	2.0	2.7
Real Loss:	92.0 (gal/conn/day)	85.6 (gal/conn/day)
Apparent Loss:	14.4 (gal/conn/day)	4.8 (gal/conn/day)

Validator Information:

Water Audit Validator: Larry Lewison Validator Qualifications: Contractor for TWDB

Summary Recommendations for Utility Next Steps

- Customized estimate of Unbilled Unmetered Authorized Consumption: consider producing itemized, agency-specific estimates of unbilled unmetered (operational) uses, rather than using the default. Ensure leakage estimates are excluded.
- Improved understanding of Supply Meter (Own or Import) Master Meter Error: consider adopting or increasing the rigor of a source meter volumetric testing and calibration program, informed by the guidance provided in AWWA Manual M36 – Appendix A.
- Temporal alignment of Billed Metered Authorized Consumption with Water Supplied: consider pro-rating the first and last months of the audit period to better align consumption with actual dates of use, and using read date as basis for reporting.
- Level 2 validation on raw data for Billed Metered Authorized Consumption to determine and resolve any instances of potable volume duplication or non-potable volume inclusion. *Note: this is being performed subsequently as a part of the current TWDB project.*
- Improved estimation of CMI: consider a customer meter testing program which tests a sample of random meters whose stratification (by size, age, or other characteristics) represents the entire customer meter stock.

Figure 8: Individual Level 1 Validation Report (excerpt)

3.2 Program Results

As part of the Level 1 validation, the project team reviewed all the submitted material to:

1. Ensure correct application of the methodology and
2. Understand the uncertainty associated with the water loss audit data

The Level 1 validation process often results in revisions to the submitted water loss audit. Through this process the project team clarified the methodology and validation concepts with the participating utility. Typical audit revisions encountered during the validation calls conducted for this Study included:

- Identification or revision of water loss audit boundary, impacting which meter(s) were to be used for reporting supply volumes. The water loss audit boundary is the starting point for the analysis. This is typically the meter that is used to measure the supply volume. Depending on the water utility setting, this could be a finished water meter at a water treatment plant or an import meter at the interconnection with a neighboring utility. Identification of the correct boundary (i.e., the correct meter) is important because any errors in the supply volume will have the largest impact on the water loss estimates obtained from the water loss audit;
- Inclusion or revision of an average source meter error if accuracy test results were available. Understanding the level of inaccuracy in the supply meter will allow for a more accurate calculation of the supply volume, which in turn will provide a more accurate estimation of water loss. This is done through in-situ accuracy tests. If accuracy test results are available, the utility may use the results to adjust the production volume. If accuracy test results are not available, this adjustment should be omitted;
- Inclusion of exported volumes in the appropriate audit inputs. If a water utility wholesales water to a neighboring utility, this is considered an export of water. The water loss audit methodology has a specific method for accounting for these kinds of sales to determine more accurate measures of water loss performance;
- Inclusion of an estimate for customer meter error. All customer meters have a certain degree of error in their volume measurements. These errors should be acknowledged and estimated, or in the best case, calculated through the analysis of customer meter accuracy test results. Estimation of this volume will allow for a more accurate estimate of apparent loss and real loss volume; and
- Refinements to the individual data validity assessment grades impacting the overall data validity assessment score (Assessment Score). The Assessment Score is a measure of the reliability in the water loss audit results. It is computed from data validity assessment grades that are assigned to each individual entry in the water loss audit. A higher numerical Assessment Score means there is a higher degree of confidence in the data used to compile the water loss audit, and thus in the resulting water loss estimates. Although there is no specific Assessment Score value that is considered universally correct or the goal, it is generally recommended that utilities that have an Assessment Score of 50 or below first improve the accuracy of their data before implementing any strategies to manage their water loss. <u>Achieving a higher degree of confidence in the</u>

water loss audit results is recommended before implementing water loss strategies because after improving their data, utilities may find that their levels of water loss may be significantly different than initially estimated. Additionally, having a good understanding of water loss levels is a crucial step to identifying the most appropriate water loss reduction strategy for any utility.

Water loss audit results before and after validation were compiled and analyzed for the 10 utilities participating. Table 1 below shows the water loss audit results after Level 1 validation for all 10 participating utilities.

Table 1: Level 1 Validated Water Loss Audit Results (before / after Level 1 validation)

Utility	Apparent Loss (gal/conn/day)	Real Loss (gal/conn/day)	Infrastructure Leakage Index	Data Validity Assessment Score
1	6.8 / 6.8	117.3 / 117.3	3.8 / 3.8	79.5 / 75.5
2	2.4 / 2.4	23.0 / 23.0	1.0 / 1.0	84.5 / 67.0
3	16.1 / 16.1	14.6 / 14.6	1.4 / 1.0	78.0 / 70.0
4ꜜ	blank / 7.1	blank / 74.2	blank / 3.6	blank / 47.5
5	3.6 / 3.6	73.0 / 73.0	n/a / n/a	44.0 / 35.0
6*	5.8 / 5.8	45.7 / 48.7	1.4 / 1.4	65.0 / 66.0
7*	14.4 / 4.8	92.0 / 85.6	2.0 / 2.7	81.5 / 78.5
8	6.7 / 6.7	75.6 / 75.6	n/a / n/a	79.0 / 73.0
9	19.5 / 19.4	140.0 / 138.1	6.9 / 6.8	41.5 / 51.0
10	5.3 / 5.3	15.4 / 13.9	0.9 / 0.8	71.0 / 74.0
Average:	**9.0 / 7.8**	**73.5 / 66.4**	**2.5 / 2.6**	**69.3 / 65.6**

ꜜ Utility #4 did not provide an initial version of their water loss audit, so pre-validation volumes are shown as zero. The PM team worked with Utility #4 to develop their water loss audit through the Level 1 validation process.

*Advanced validation conducted following the Level 1 validation for Utility 6 and Utility 7. See Section 5 for information on methods and results for advanced validation activities.

The total value of the water loss experienced by the 10 pilot participants in a twelve-month period is approximately $19.3 million. Some volume (and corresponding value) of water loss is anticipated for all utilities. However, it is likely that the participants could decrease a portion of their water loss volumes and corresponding financial loss. Informed by Level 1 validated water loss audit results, the economic balance of intervention for each utility could be analyzed to determine the most appropriate and cost-effective water loss control strategies that would provide optimum benefit.

Several of the most significant findings after evaluating pre- and post-validation water loss audit results from the Study are presented below.

Granular Changes Resulting from Level 1 Validation

The validation process can often result in changes to the entries entered into the water loss audit, as well as changes to the assessment scale of those entries. As a result, changes in entries and scales cause changes to the water loss audit performance indicators. In general, all participants except for two made modifications to at least one water loss audit entry. However, all participants made modifications to the assessment scales.

There are 20 entries with their corresponding assessment scales that are reviewed during the Level 1 Validation. Figure 9 shows a summary of the count of water loss audit entries and assessment scales that were changed as a result of the validation. Across the study participants, all entries except for *Treated Purchased Water* and *Treated Wholesale Water Sales* were revised during validation. For systems that purchase treated water and have wholesale clients, it is expected they would have a clear understanding of those entries given that they could significantly impact their operating costs (in the case of Purchased Water) or their revenues (in the case of Wholesale Water Sales).

The Unreported Loss, although not calculated by the utility, was the value that most frequently changed during the validation because of revisions to other entries. This is an important finding given that one of the main purposes of conducting the water loss audit is to understand the level of loss that could be recovered by the system. Other commonly revised entries were Production Meter Accuracy and Unbilled Unmetered Authorized Consumption. Figure 10 shows the magnitude of change for those entries that were modified as a result of the validation. As shown in the chart, there were both increases and decreases to the entries.

Every input value assessment scale was modified for at least 3 of the 10 utilities. *Produced Water* and *Production Meter Accuracy* assessment scales were modified for 7 of the 10 utilities. The most changed assessment scales were for Billed Metered and Billed Unmetered Authorized Consumption. This is impactful because these are some of the largest water balance volumes, and carry the most significance when it comes to accuracy and reliability. Over 70% of the changes to the assessment scale were decreases.

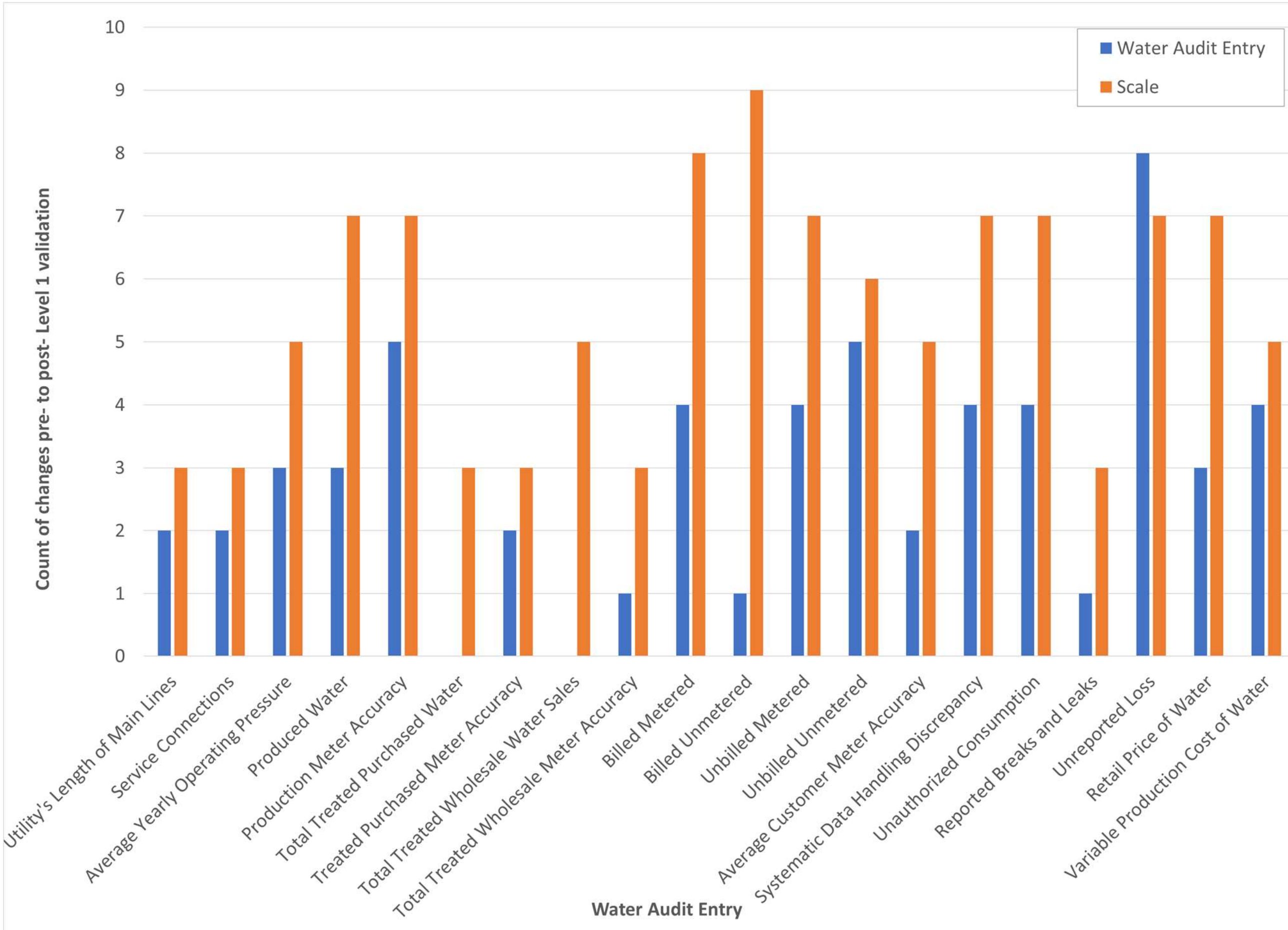


Figure 9 - Summary of Changes to Water Loss Audit Entries and Assessment Scales from Level 1 Validation

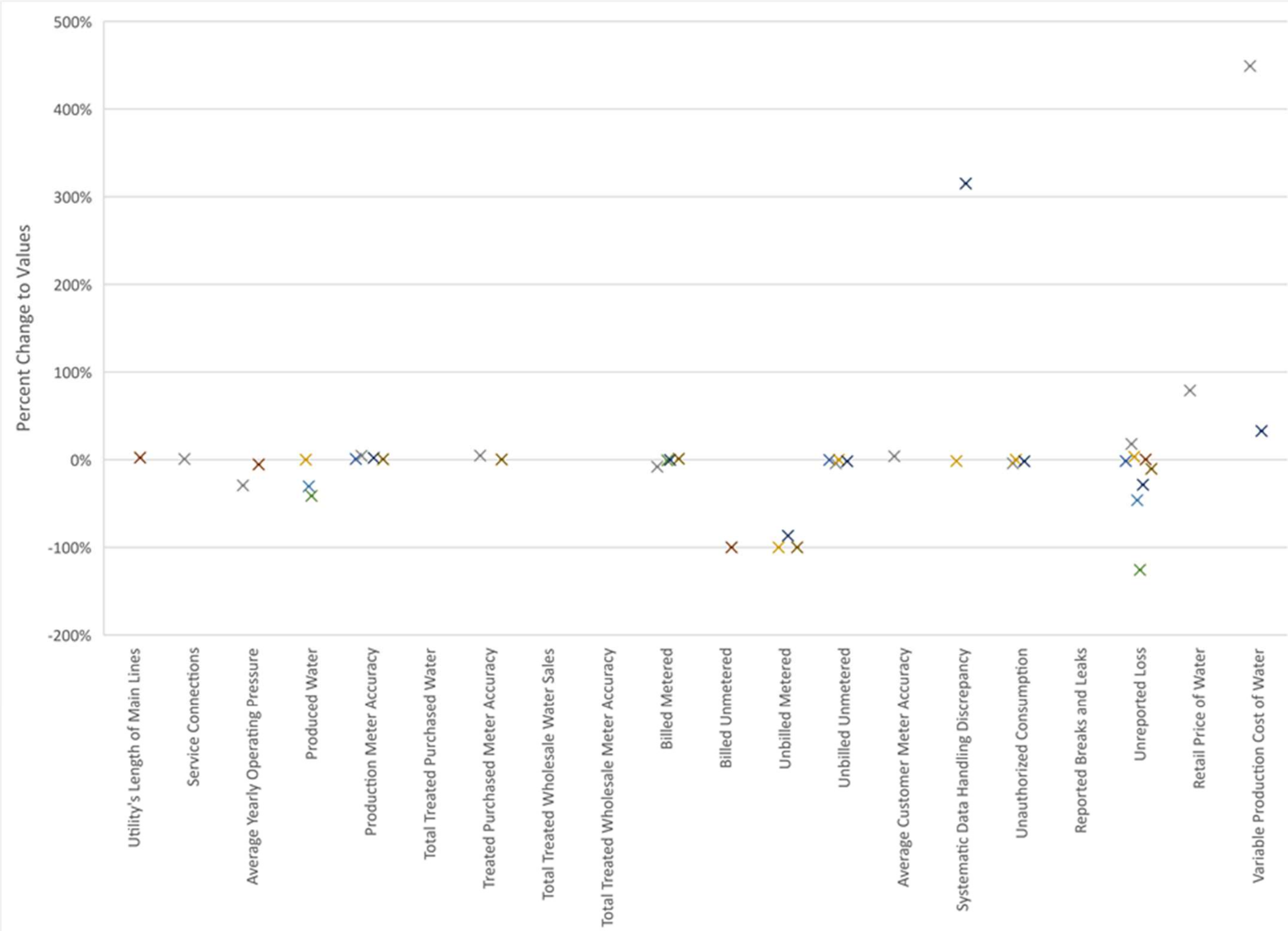


Figure 10 - Percent Change to Water Loss Audit Entry Values

Changes to the commonly used Performance Indicators were also evaluated to understand the impact of the validation to the water loss audit results (see Figure 11). All of the Performance Indicators evaluated changed as a result of the validation. The total Data Validity Assessment Score was the most commonly changed Performance Indicator, as expected due to the many changes that resulted to the input assessment scales.

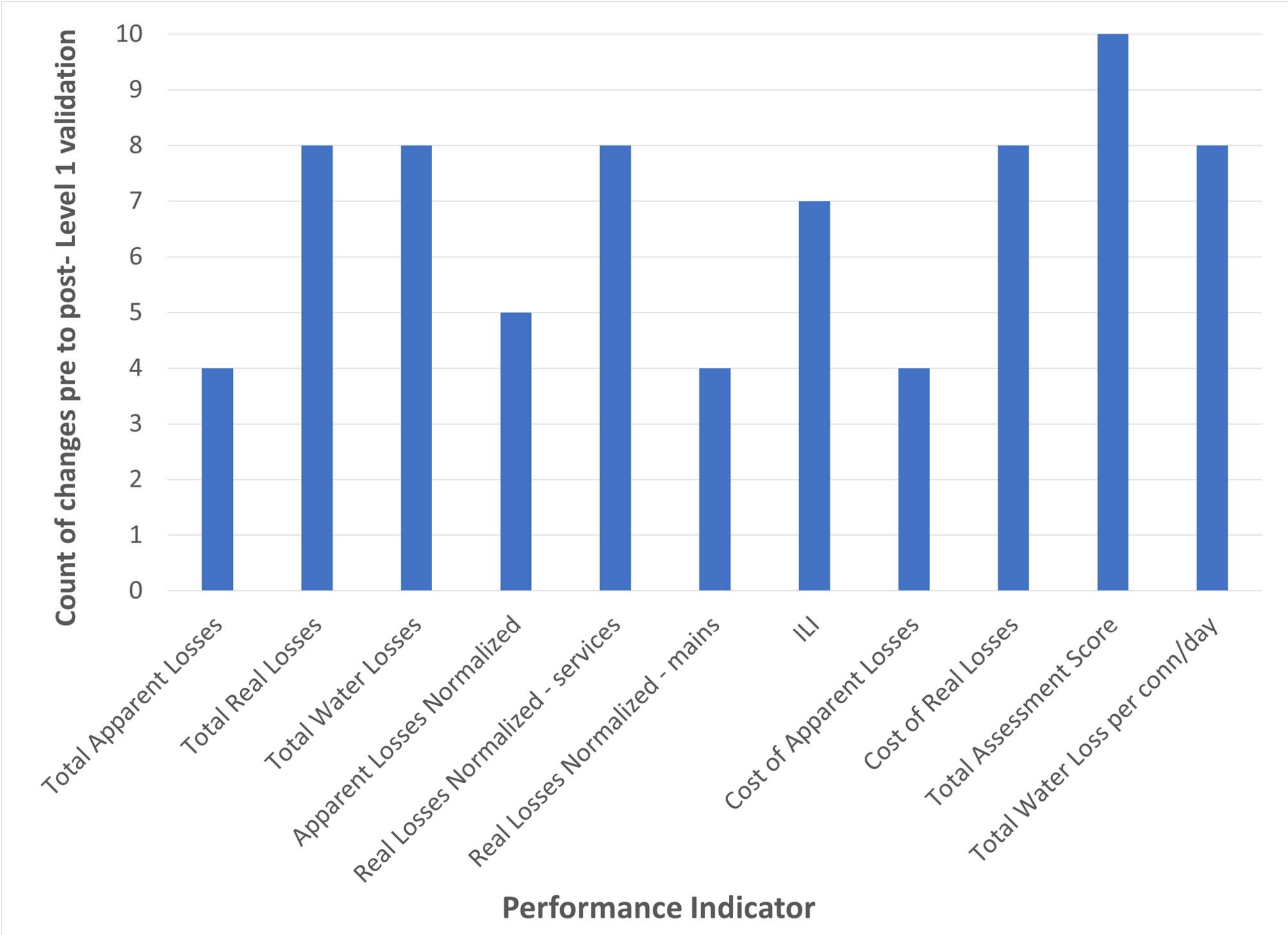


Figure 11 - Summary of Changes to Performance Indicators from Level 1 Validation

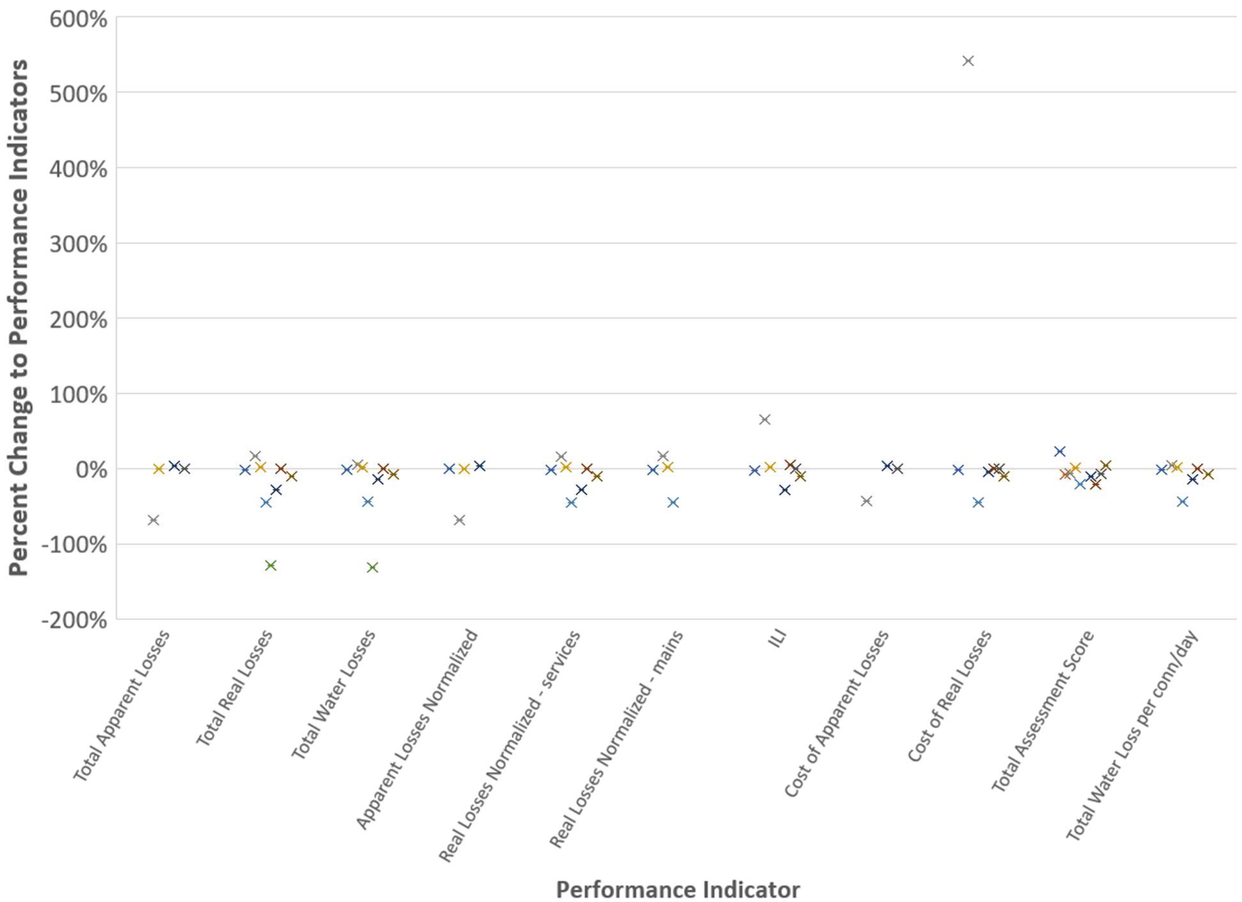


Figure 12 - Percent Change in Performance Indicators from Level 1 Validation

Changes in Water Loss Results

Though self-reported water loss audits may provide actionable insight into leakage, the accuracy of self-reported water loss audits can be and were improved through independent validation in the Study. Numeric changes based on the typical audit revisions (described above in Section 4.2) improved the estimated volume of apparent and real loss, and their subsequent performance indicators in gal/conn/day. Figure 13 displays the change in volumetric results produced from the Level 1 validations.

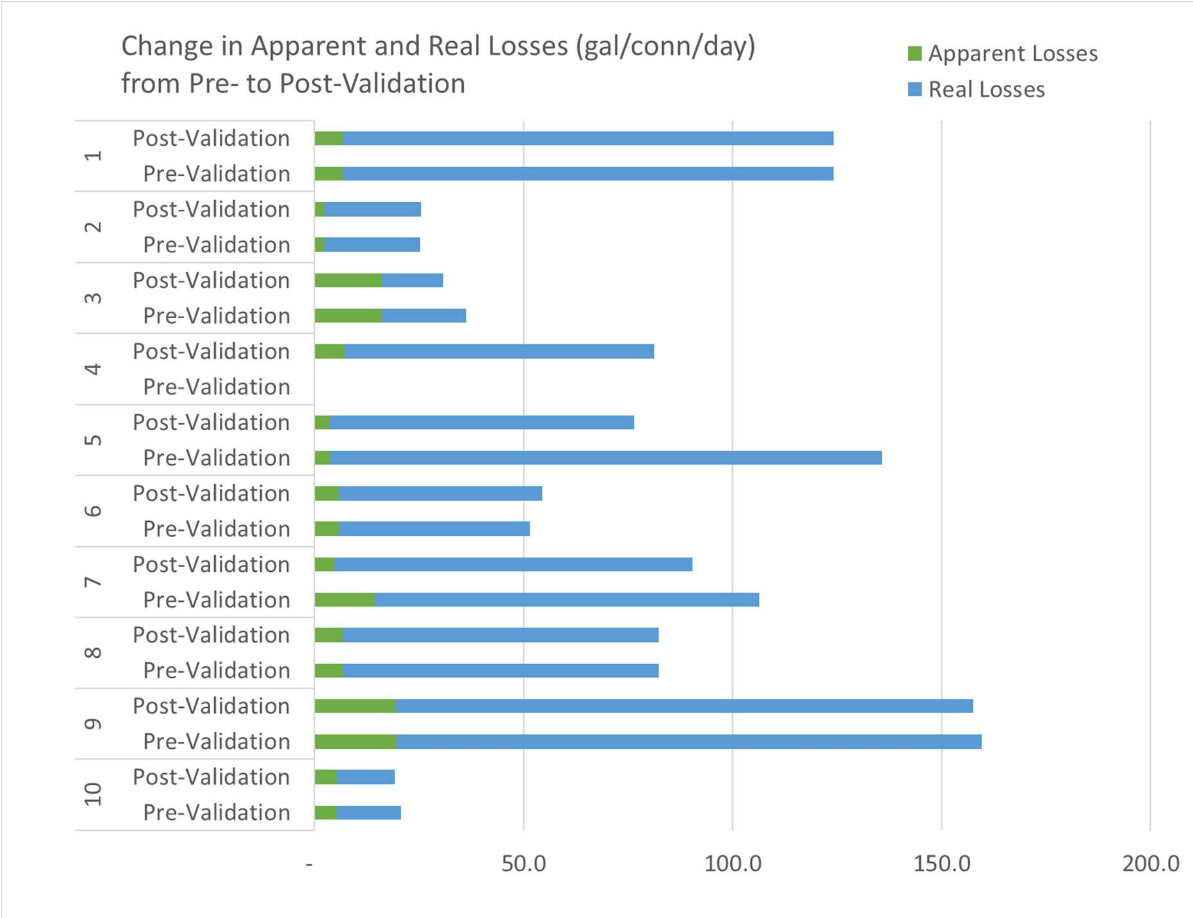


Figure 13: Change in Apparent and Real Loss Through Validation

Note: Utility #4 did not provide an initial version of their water loss audit, so pre-validation volumes are shown as zero. The PM team worked with Utility #4 to develop their water loss audit through the Level 1 validation process.

Changes in Data Validity Assessment Scores

Changes in total Data Validity Assessment Score (Assessment Score) is not uncommon as a result of the validation process. Independent validation by an experienced validator provides a uniform interpretation of the scoring assessment scale. For the Study however, all 10 of the Level 1 validations resulted in Assessment Score changes. The average change in Assessment Score per the Level 1 validation (excluding Utility #4 (see note)) was approximately minus four points. The maximum upward change in Assessment Score was 9.5 points (Utility #9), and the maximum downward change was 17.5 points (Utility #2). Figure 14 presents all changes in Data Validity Assessment Score resulting from the Level 1 validations, and comparisons to typical ranges in North America[6].

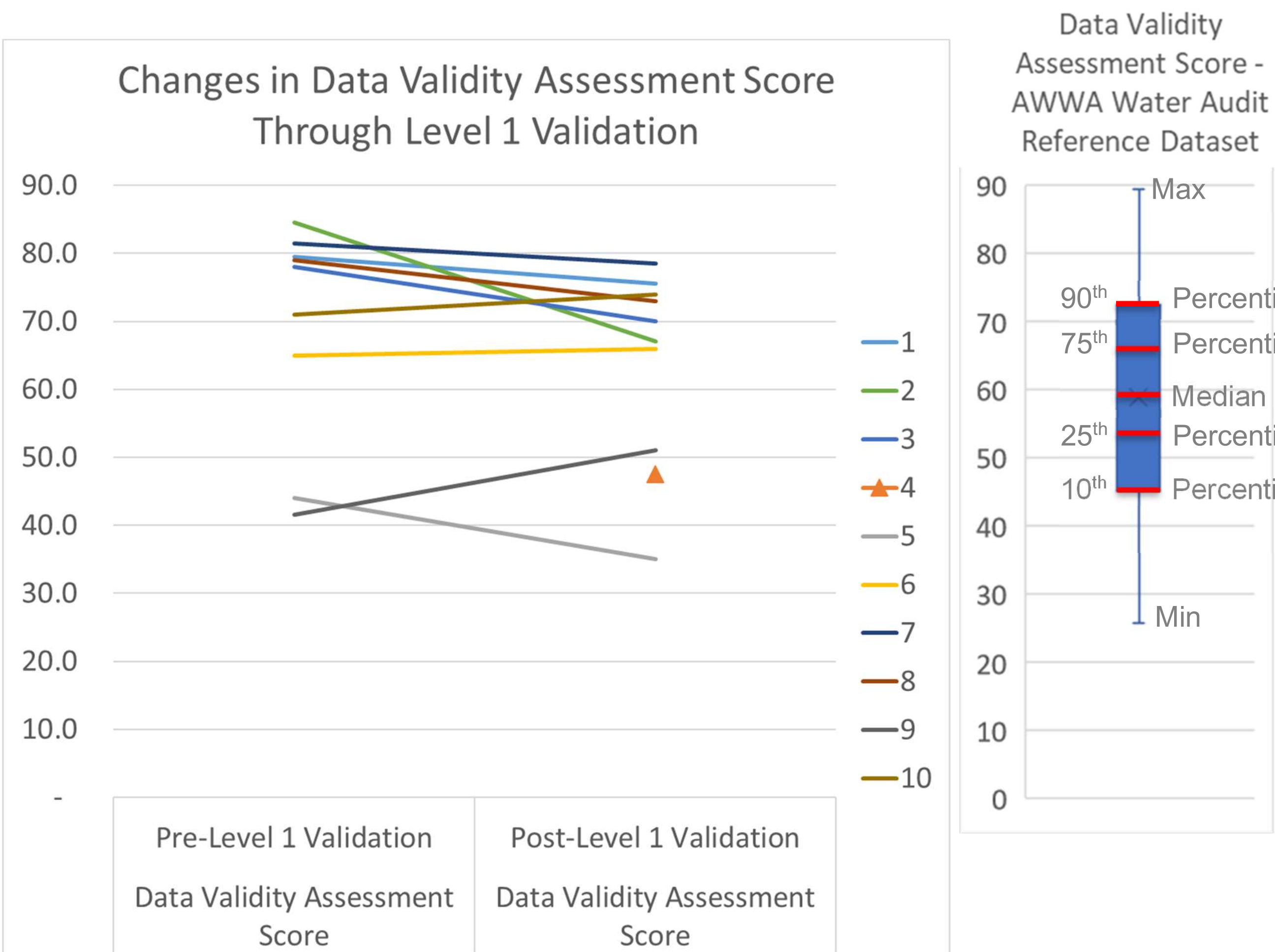


Figure 14: Spread of Data Validity Assessment Scores Through Level 1 Validation and Comparison to Typical Ranges in North America[6]

[6] Kunkel, G. et al. AWWA Water Loss Control Committee – Water Audit Reference Dataset. 2020. AWWA. Denver, CO.

Note: Utility #4 did not provide an initial version of their water loss audit, so pre-validation Assessment Score is shown as zero. The PM team worked with Utility #4 to develop their water loss audit through the Level 1 validation process.

3.3 Utility-Level Water Loss Recommendations

Most utilities in the Study have a validated Assessment Score between 50 and 80, suggesting that next steps may be focused simultaneously on improving data reliability and evaluating cost-effective interventions for water and revenue loss recovery. Individual reports documenting the water loss audit validation, results, and recommendations were provided for all participants. The most frequent opportunities among the utilities in the Study to improve the reliability of audit inputs and outputs include:

- **Improved understanding of supply meter error:** consider adopting or increasing the rigor of a source meter volumetric testing and calibration program, informed by the guidance provided in Appendix A of the AWWA M36 Manual;

- **Improved estimation of customer meter accuracy**: consider a customer meter testing program that tests a sample of random meters whose stratification (by size, age, or other characteristics) represents the entire customer meter stock.
    - Develop small meter stratification parameters, then test a random sample to gauge small meter overall accuracy performance. According to the M36 Manual, between 50 to 100 residential meters may be sufficient for an initial assessment, but the optimal number of meters to test to determine a statistically representative average accuracy will depend on utility specific conditions.
    - Test large customer meters, giving higher priority to those meters that register larger consumption volumes since those individual meters typically have a significant impact on revenue generation form their billed volume.

- **Customer retail unit cost refinement**: The customer retail unit cost is used to assign a financial value to the apparent loss. The calculated value should reflect a weighted average of all customer classes and consumption tiers. This can be accomplished by dividing the total commodity revenue by the total volume sold. Ideally, the weighted average cost should also include charges for sewer, stormwater, or biosolids processing, if these charges are based on the volume of potable water sold. This is the recommended industry approach, though it is recognized that this data may not be easy for some utilities to get. Higher refinement of this value, if available, will provide a better estimate of the revenue generation potential of reducing apparent loss;

- **Variable production cost refinement**: The variable production cost is used to assign a financial value to real loss. This value should consider direct and indirect expenses of producing one additional unit of water. Typical primary costs include the unit costs for all ground and surface water treatment and power used for pumping from the source to the customer. Other miscellaneous unit costs may also be included (e.g., residuals disposal costs) if they apply to the production of drinking water. It should also include the unit cost of bulk water purchased if applicable. An accurate understanding of the variable cost of production will provide a better estimate of the potential financial benefit of reducing real loss; and

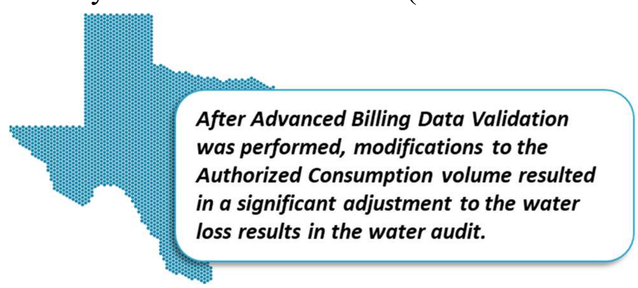
- **Lag-time corrections:** There should be a temporal alignment of Billed Metered Authorized Consumption with Water Supplied. Consider pro-rating the first and last months of the audit period to better align consumption with actual dates of use and using read date as basis for reporting. Detailed information on this process can be found in Chapter 3 of the AWWA M36 Manual, 4^{th} Ed.

4 Advanced Water Loss Audit Validation Results

As part of the Study, advanced validation was made available to three water systems, selected based on their interest and readiness. The value of advanced validation includes identifying deeper areas of uncertainty or error that cannot be brought to light in a Level 1 validation which is, by its nature, interacting with only summary level data. Advanced validation engages with granular data to understand trends, patterns, and anomalies. A total of three utilities utilized the opportunity for advanced validation. Methods and excerpt of results are presented below.

4.1 Billing Data Analysis

A Billing Data Analysis (BDA) was conducted for one utility (#7). This analysis evaluates raw billing data supporting the water loss audit to determine whether the data is accurate and comprehensive. This process required that raw billing data be extracted from a billing system and then passed through a series of integrity checks to identify and resolve anomalies (see Table 2 below). The utility provided flat-file exports from their billing systems that documented all meter reads occurring during the audit period. The file contained one row (record) per meter read. Additional fields like read date, meter totalizer, meter number, meter size, account number, and account type were also included.



The billing data was analyzed for completeness, consistency, and coherence. Figure 15 shows the count of reads by month in the data file provided. It shows that the number of records per billing cycle does not vary significantly. If significant variation is observed, it may be an indication that some data is missing from the file or duplicated in the export. Missing or duplicate data may cause an inaccurate calculation of the billed metered authorized consumption. In this case, the billing data provided was complete and consistent.

Table 2: Billing Data Analysis - Integrity Checks

Integrity Check	Purpose
Count of records per bill cycle	The number of records per billing cycle should not vary significantly. If significant variation is observed, some data may be missing from or duplicated in the export.
Exclusion of non-potable volumes	The water loss audit deals strictly with potable water volumes. Any raw, recycled, or reclaimed water should be excluded.
Duplicate records	Each water meter read, and subsequent bill should only be counted a single time in the water loss audit. Duplicate records may be introduced by meter reading and billing procedures and must be resolved into a single consumed volume for the accuracy of the water loss audit.
Negative consumption	Negative consumption may indicate a meter rollover, a billing correction, or an errant read. The reason for each negative consumption record must be determined to verify that it represents a legitimate record.
Consumption outliers	Unusually high or low consumption values for an account could indicate misreads or other data inaccuracies. However, some outlying consumption values may represent legitimate use, so the reason for significant outlying consumption must be ascertained to determine whether the consumption volume should be used in the water loss audit.
Consecutive zero consumption	Consecutive zero reads are repeated meter readings that indicate that no consumption is occurring on an active meter. Consecutive zero readings can indicate a stuck meter or other data handling issues.
Calculated consumption	Totalizer readings are used to calculate consumption based upon the start and end totalizer readings for each record in the dataset and compared the consumption volume recorded in the dataset for consistency.

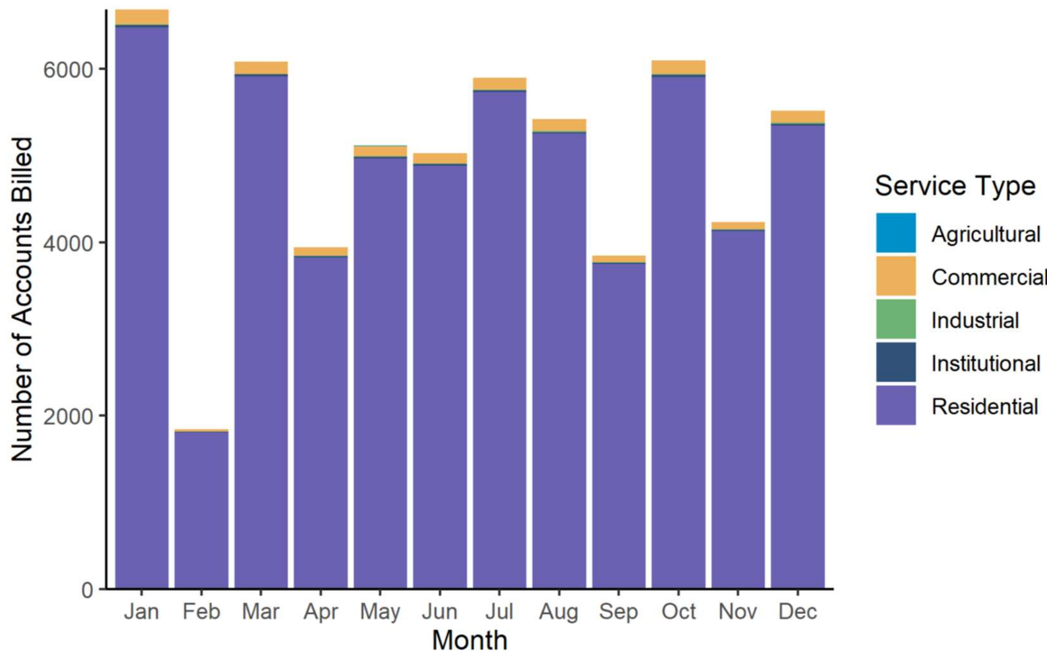


Figure 15: Distribution of Records Count by Read Month

The BDA resulted in a significant finding as shown below in Figure 16. An anomalous total volume for the month of October 2020 had already been identified during the Level 1 validation but identifying root cause analysis and correcting the error(s) required a BDA, given the nature of the error(s) in the raw data.

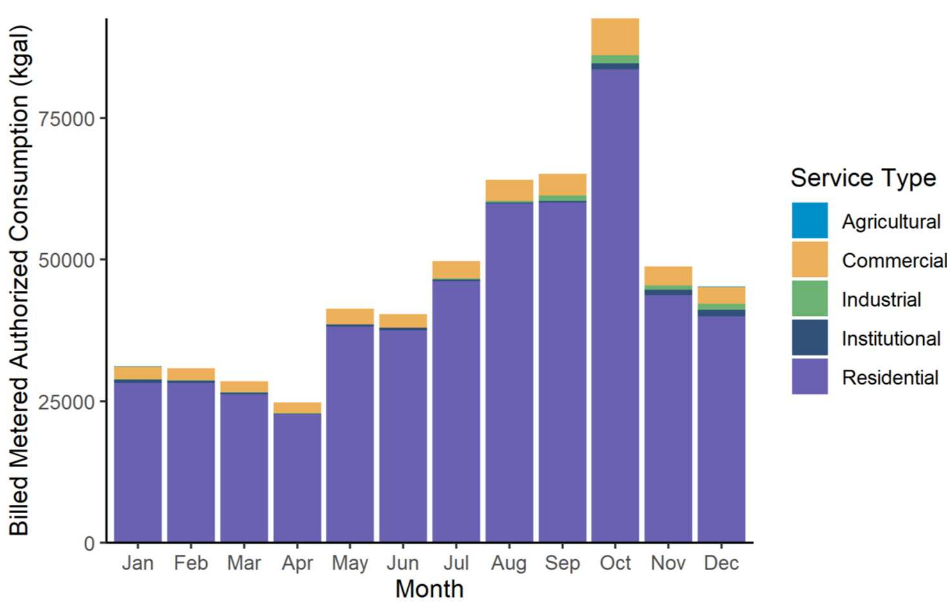


Figure 16: Uncorrected Billing Dataset – Volumes by Month with October Anomaly (Annual Total = 561 MG)

From analysis of the uncorrected dataset, it was determined that October totals were including some duplicated consumption records. The duplications were corrected, and the billing data was also prorated to better align with month of actual consumption (rather than simple assignment based on 'month of read'). The corrected consumption results are shown below (see Figure 17).

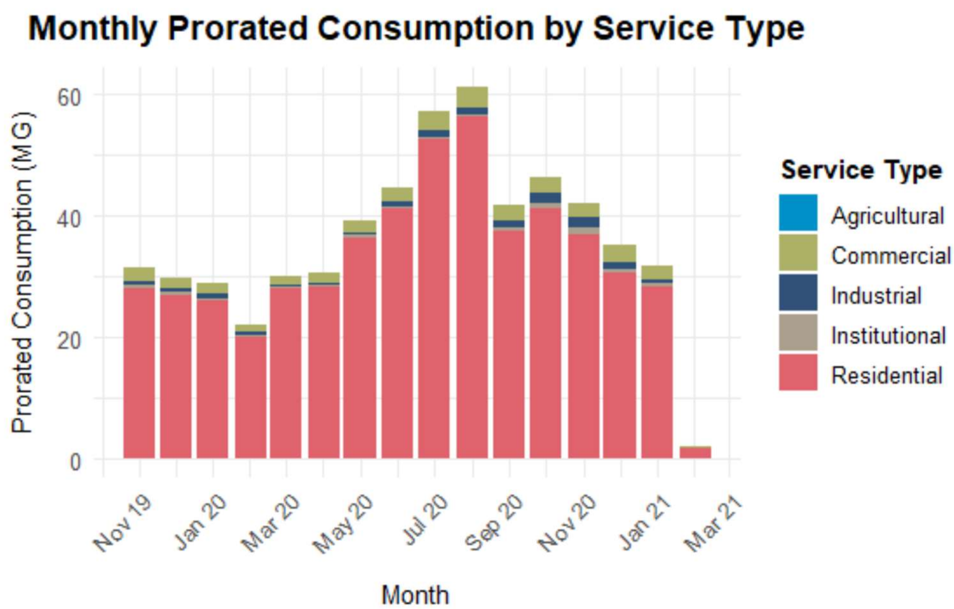


Figure 17: Corrected Billing Dataset – Volumes by Month (Annual Total = 516 MG)

After the BDA was performed, the necessary modifications to the Billed Metered Authorized Consumption volume in the water loss audit was made and resulted in a significant adjustment to the water loss results in the water loss audit. Several additional issues were identified and discussed in the detailed report which was provided directly to the utility. The report ultimately included recommendations for ongoing quality control reviews and issues to monitor in the billing volumes for future auditing efforts.

4.2 Real Loss Component Analysis

A Real Loss Component Analysis was conducted for two utilities (#6, #7). These analyses were based on the utilities' calendar year 2020 water loss audit and detailed repair records for breaks in the water pipe network. A Real Loss Component Analysis was performed to determine the volume for each real loss component as shown in Figure 18.

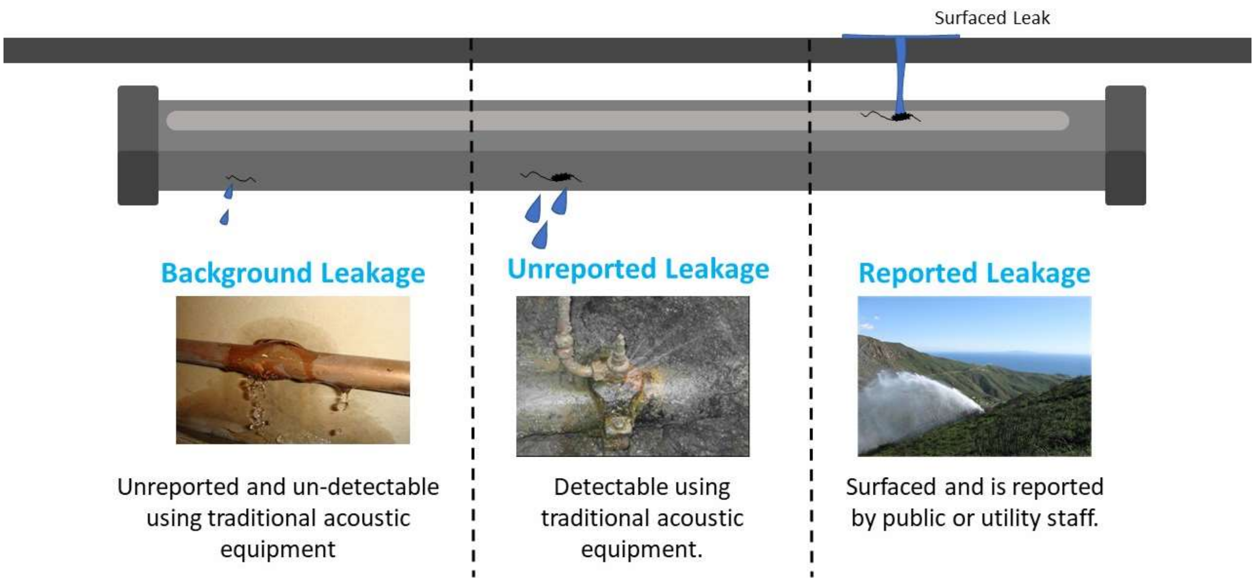


Figure 18: Primary Components of Real Loss (Adapted from AWWA M36 Manual, 4th Ed.)

- *Background Leakage*: Estimated by comparing the utilities current infrastructure condition to the theoretical minimum level of leakage for a system of similar characteristics. AWWA M36 Methodology provides standard calculations to make this comparison for system background leakage.

- *Reported Leakage*: Estimated based on the repair history data provided by the utilities and valued at their variable production cost. Methods from Water Research Foundation 4372A were utilized for leakage estimations, based on analysis of runtimes and flowrates. See Table 3 for example calculation of this component.

Table 3: Reported Leakage Summary Based on Repair Records (from Study Participant)

Type	Count	Estimated Runtime per Leak During Reporting Year (Days)	Estimated Weighted Average Flow Rate (GPM)	Total Volume Lost in Reporting Year (MG)
Mains	569	9.0	7.00	51.5
Services	128	8.0	3.00	4.4
Other	14	8.4	1.00	0.2
Total	**711**	**8.8**	**6.2**	**56.1**

- *Unreported Leakage*: Unreported leakage represents the volume of leakage discovered through proactive leak detection. Data on the two participating utilities' unreported leaks were not available, given no proactive leak detection in place. Therefore, the volume attributed to this component is zero and all potentially discoverable leakage was categorized as 'hidden loss.'
- *Hidden Loss*: The remaining volume of water after deducting reported, unreported (repaired), and background leakage from the total assessment of real loss is hidden loss (see Table 4). This is the assessment of the volume of loss currently running undetected in the distribution system that could be found using traditional acoustic leak detection equipment.

Table 4: Derivation of 'Hidden Loss' (from Study Participant)

Operation	Leakage Type	Estimated Volume (MG)
A	Background Loss	145
B	Reported Loss	56
C	Unreported Loss	0
D	Total Real Losses (from FY2018 AWWA audit)	247
= D - (A + B + C)	**Hidden Loss**	**46**

The goal in prescribing real loss intervention is to seek a balance between the value of water saved and the cost of intervention. Theoretically, the utility should not spend more resources recovering leakage than the financial value of that leakage. This balance is called the Economic Level of Leakage (ELL). This approach acknowledges that some level of loss is inevitable and will not be economically justifiable to recover.

There are three primary short to medium term intervention strategies against real loss that can be considered, because they are commonly the most cost effective:

- **Proactive Leak Detection**: The largest volume of recoverable leakage currently running in the distribution system is comprised of hidden loss. This loss is potentially recoverable using acoustic leak detection equipment.

- **Pressure Management**: Pressure management is typically the only viable intervention strategy to reduce background loss (although it is also an effective strategy for reducing all types of loss). An example of pressure management is show in Table 5.

Table 5: Pressure Management Scenarios (from Study Participant)

Pressure Management Scenarios (N1 = 1.0)			
Reductions in System Average Pressure	System Average Pressure	Volume Saved/Year (MG)	Value of Savings
1	66	3.69	$12,129
2	65	7.37	$24,258
3	64	11.06	$36,386
4	63	14.75	$48,515
5	62	18.43	$60,644
6	61	22.12	$72,773
7	60	25.81	$84,902
8	59	29.49	$97,030
9	58	33.18	$109,159
10	57	36.87	$121,288

- **Improved Repair Response Time**: Between 3 percent and 4 percent of real loss is lost to reported leakage—leaks that were called in to the utilities for repair. One avenue for recovery is to respond to and contain these reported leaks faster.

Results of the two Real Loss Component Analyses were compiled in reports and delivered directly to the participating utilities. These reports included utility-specific recommendations regarding short-term proactive leak detection, long-term proactive leak detection, data management practices, speed and quality of repairs, and pressure management.

5 Program Findings and Recommendations

The Study results as presented in Sections 4 and 5, combined with the PM team's observations and experience with similar programs across North America have been synthesized into the Significant Findings and Program Recommendations presented herein.

5.1 Significant Findings

Significant findings of the Study are presented below.

1. **Level 1 validation results in improved reliability of self-reported water loss audit results**. The Study produced two progressive water loss estimates for each utility: first from the self-reported water loss audits and then from the Level 1 validated water loss audits. Seven of the 10 validated water loss audits resulted in volumetric corrections, yielding more representative water loss estimates. All 10 of the validated water loss audits resulted in modifications to the total Data Validity Assessment Score, yielding a more representative reliability scoring. 70% of the changes to the input Assessment Scales were decreases. The Assessment Scales were modified on the largest water balance volume inputs (*Produced Water, Billed Metered Authorized Consumption*) for at least 7 of the 10 validated water loss audits. The Study clearly shows that the accuracy of self-reported water loss audits can be improved through independent validation.

2. **Level 1 validation results in improved data management practices**. The process of gathering and providing supporting documentation for the water loss audit to an independent validator was observed to have an inherent benefit to the utility staff, *regardless* of whether the Level 1 validation resulted in changes in the water loss audit. Utility staff provided feedback that those benefits included:
   - The establishment of supporting documentation trail, making future data gathering efforts easier,
   - The Level 1 validation report which includes notes on the basis for water loss audit inputs and basis for selecting data validity assessment grades, making future audit compilation efforts easier,
   - Insights and recommendations provided by the independent validator for their specific circumstances and focus areas, and
   - Gathering the data requires increased communication across multiple departments within the utility. These exchanges increase the personnel's understanding of other aspects of the operation that are unknown to them and often result in corrections and improvements to data inputs and data validity assessment grades.

   Utility staff noted these benefits will be especially valuable in scenarios where there is staff turnover or new staff gets involved in water loss auditing and validation activities in the future.

3. **Much of the supporting data needed for Level 1 validation is already tracked and reported**. Level 1 validation requires supporting documentation that includes supply

volumes by month, by supply meter for the audit year. Water utilities are already providing monthly supply volumes to the TWDB Water Use Survey, so they are likely already internally tracking these volumes by supply meter by month. Authorized consumption volumes are also required for both the Water Use Survey and a Level 1 validation, though the Water Use Survey does not require this broken down by month. Further, most Study participants were able to easily provide the required information that wasn't already part of their Water Use Survey, namely a system schematic, monthly authorized consumption volumes by month, and supply meter test records (if applicable). The PM team observed that for most utilities the effort required for gathering the Level 1 validation supporting documentation was not a significant increase above their normal data management activities.

4. **Staff time availability is adequate for most utilities to participate in a Level 1 validation**. The Study was conducted during the first half of 2021. In February 2021 Texas experienced an extreme freezing event that caused widespread interruptions and emergency operations at many water utilities, including those participating in the Study. Additional time was added to the Study schedule to accommodate this unplanned event, but the extraordinary demands on utility staff time were observed to be ongoing. Nonetheless, 7 of the 10 utilities were able to get their water loss audits and supporting documentation submitted within established timeframes. The remaining three utilities required extra time and assistance from the PM team to gather the necessary information. As noted in Section 4, one of the 10 utilities was not able to provide a self-reported water loss audit. In this case, the PM team worked with that utility to develop their water loss audit through the Level 1 validation process. Smaller systems were observed to be the most time-limited participants in the Study. The participating utilities did recognize, however, that future information gathering for them is expected to be more efficient and quicker based on protocols established in this Study (see Finding #2).

5.2 Program Recommendations

Validation is vital to **reliable water loss audits**.
Reliable water loss audits are vital to achieving **municipal conservation**.
Municipal conservation is vital in the **State Water Plan** (2022) to meet the long-range water needs in Texas.

TWDB is to be commended for recognizing these critical connections and for executing this Study to gain insights on conducting Level 1 water loss audit validations in Texas. The Significant Findings point to establishing Level 1 water loss audit validation as standard practice to ensure furthering water conservation through quantification and measurement[7]. From this, strategic plans across the 16 planning regions can be guided by reliable information.

Program recommendations for future water loss audit validation activities in Texas, based on the Significant Findings in this Study, are presented below.

[7] https://www.twdb.texas.gov/publications/reports/administrative/doc/LAR_FY2022-2023.pdf

Recommendation 1: Expand the Water Loss Audit Validation Study into a Regional Validation Program.

Significant Findings 1 and 2 highlight the benefits of Level 1 validation and the vital role it serves in understanding reliability of self-reported water loss audits. Without water loss audit validation, each planning region is using data of unknown reliability to make large-scale plans with large-scale implications. To build support and buy-in from the water industry, it is recommended to expand the pilot validation Study into a Regional Validation Program (RVP) in one or more planning regions with a focus on those facing the largest shortages.

In the short-term this would allow continued promotion of Level 1 validation in a scalable way, to match funding availability and to serve those regions with the highest needs first (see Figure 19). It would also allow continued building of utility case studies and testimonials in support of Level 1 validation, establishing key industry support in a region-by-region basis, and on a voluntary basis. In the long-term, it would support a pathway to Level 1 validation as standard practice across all 16 planning regions.

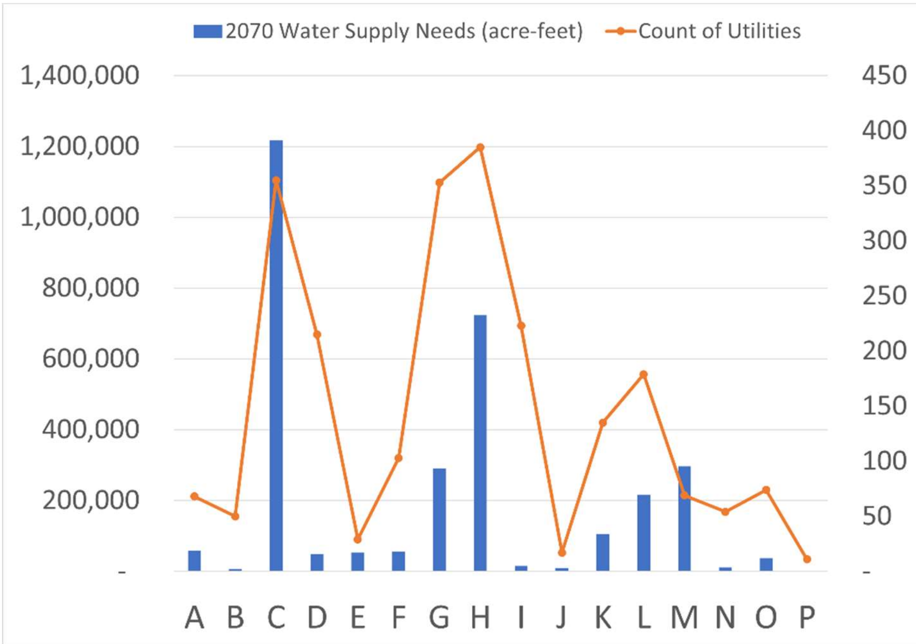


Figure 19: Annual water supply needs by planning region in 2070 (acre-feet))

The recommended conceptual structure for the RVP includes the following:

- Identify the region(s) that would be the focus of round 1 RVP, based on highest need (Figure 19) and scale of funding availability,
  - A planning budget for state funds of $6k-$8k per participating utility is recommended,
- Target the round 1 RVP towards those utilities in the selected region(s) that are currently required to conduct and submit annual water loss audits to TWDB,
- Utilizing the validation standards established in this Study, execute the round 1 RVP to complete Level 1 validations with the target participants for 2021 water loss audit year,
- Use outcomes and utility testimonials from the round 1 RVP to continue building broader support for Level 1 validations, and
- Repeat the approach to identify region(s) for round 2 RVP and subsequent RVP rounds.

Recommendation 2: Explore adopting Level 1 water loss audit validation as a required practice for all annual water loss audits.

There are approximately 750 water systems that submit a water loss audit to TWDB annually (based on size >3,300 connections or as a condition of funding from TWDB). All retail water systems (approximately 4,000) are required to submit a water loss audit to TWDB every five years, with the next submittal cycle to occur in 2026 for reported year 2025. All four Significant Findings point to establishing Level 1 water loss audit validation as standard practice for all water loss audits in Texas. As of this report, Level 1 validation is now a required standard for water loss audits in Georgia, Indiana, California, and Quebec, and is being evaluated for adoption in several other states where self-reported water loss audits are currently required.

It is recommended to explore the adoption of a Level 1 validation requirement for the approximately 750 water loss audits received annually at TWDB. Recommendation 1 (above) for expanding a Regional Validation Program would build utility support for such a requirement. In addition to utility support, however, a structured approach is necessary for success in establishing a Level 1 validation requirement based on lessons learned from the validation program rollouts in Georgia, Indiana, California, and Quebec (see Appendix 4). The requirement must come in tandem with technical assistance and support for the approximately 750 utilities subject to the requirement each year (the "target utility group").

The recommended conceptual structure for adopting a Level 1 water loss audit validation requirement includes the following:

- Leading up to the adoption of a requirement, provide foundational training to <u>all utilities</u> in the target utility group on the concepts of water loss audit validation with focus on common errors made and how to avoid them,
- Leading up to the adoption of a requirement, provide foundational training to <u>the smaller utilities</u> in the target utility group on the concepts of completing the water loss audit,
- In the short-term (one-two years) following the adoption of a requirement, engage with a third-party subject-matter expert to conduct Level 1 validations for the target utility group each year.
    - A planning budget for state funds of $3,000 to $5,000 per participating utility per year is recommended,
- In the mid-term (two-three years) following the adoption of a requirement, develop and establish a validation certification program to create a pool of certified water loss audit validators in Texas to meet ongoing demand for Level 1 validations following similar successful models (see Appendix D).
    - A planning budget for state funds of $400,000 to $500,000 is recommended, and
- Establish one or more new FTE positions at TWDB dedicated to Level 1 water loss audit validation program administration needs.

TWDB could, alternatively, consider building out the capacity in-house to perform the Level 1 validations for the target utility group. TWDB staff currently are already providing an important high-level quality review on the water loss audit submittals received each year. The challenge, however, is scale. Performing Level 1 validations for 750 water loss audits each year in the aggregate is a massive task and not practical for any single person or small government team to accomplish. Establishing a validation certification program to get to a pool of certified validators means that both the workload and the cost of accomplishing the Level 1 validations is distributed among the target utility group. With the recommended approach, TWDB would invest in upfront costs in the short- and mid-term but would not carry the ongoing costs of annual validation efforts in perpetuity, thus making it a more sustainable model.

Recommendation 3: Explore migrating the TWDB water loss audit format to become aligned with the AWWA Free Water Audit Software version 6.0.

TWDB has long been a leader in North America on water loss auditing practices. In fact, the advent of the AWWA water loss audit data grading matrix in version 4 of the AWWA Free Water Audit Software (FWAS) came as a result of TWDB's progressive work in this field in the late 2000s. The current TWDB water loss audit format is built consistent with Version 5 of the FWAS, which was released in 2014. In December 2020, Version 6 of the FWAS was released and included significant updates in both the Assessment Scale and the Dashboard of Key Performance Indicator outputs. These updates reflect state of the art best-practices for assessing data reliability and measuring water loss performance, including the ability to benchmark against other validated water loss audit results in North America.

Audit validations conducted during this pilot program discussed the use of set questions and answers for the validations (as used in the FWAS Version 6) versus the current TWDB method of matching the auditor matching practices against a broader written matrix. Study participants that had used the TWDB method and previous FWAS Version 5 (which was less prescriptive) noted that the new "set questions" version were easier to use and more straightforward in the long-term. It is recommended for TWDB to explore transitioning its current methodology to require the set question format, following the improved method evidenced in the FWAS Version 6.

It is recognized that a significant amount of effort has been placed into the development of the existing TWDB portal. In 2012 the 83rd Legislature directed TWDB to streamline current automated and manual data entry and reporting requirements for water planning and conservation. The project combined the functionality of the Water Use Survey, Water Loss Audit, the Annual Conservation Report, and the Conservation Plan/Utility Profile into one system of applications. At the time the same data was required to be entered multiple times by the utilities. This system, now known as the Loss, Use & Conservation reporting application, allows the flow and auto-population of data between the four reports above. The outcome of the project was realization of efficiencies in reporting and consistency in data, not only by the utilities, but by TWDB as well.

The Loss, Use & Conservation reporting application combines the water use, water loss and water conservation reporting segments and there is interconnected data between the three reports.

FWAS Version 6 represents state of the art in data validity assessment, and also allows for easy comparison of water loss audit results against typical North American benchmarks. If Texas utilities want to use this tool today, then they should feel free to utilize the FWAS Version 6 and leverage its benefits. However, for TWDB data purposes it is not possible to fully utilize the FWAS on its own to report for state-required purposes. To migrate the TWDB water loss audit format for alignment with the FWAS Version 6, it is therefore likely most practical to update the portal rather than mandating use of the FWAS Version 6 directly.

It is expected that this would require some major work to the portal itself to ask each of the validation questions and then build the ensuing logic for calculation of total Data Validity Assessment Score. Coordination with and approval from AWWA would ultimately be a necessary part of the process, given the copyrighted elements of the FWAS Version 6.

In summary, it is recommended that TWDB explore ways to further align its water loss audit format to keep current with those significant updates included the AWWA FWAS Version 6. This will require additional staffing for a short- to medium-term to make the transition for the data portal. A planning budget for state funds of $50,000 to $75,000 is recommended to provide necessary assistance to TWDB's IT Department for data portal updates associated with this recommendation.

Updating and expanding TWDB's water loss audit training activities is also recommended to provide educational and technical support for utilities in completing the annual water loss audits. If expanded Regional Validation Programs as discussed in Recommendation 1 were implemented, it is feasible that training could be integrated to educate utilities any updates to TWDB's portal and the water loss audit format. If training were contemplated as a stand-alone approach, it is recommended that TWDB consider developing a combination of in-person workshops, live-virtual training events, and pre-recorded training resources. Additional TWDB staff resources, beyond the current water loss program may be required.

Appendix A: Texas Level 1 Water Loss Audit Validation Guidance Document (v1.1)

Texas Water Development Board

Level 1 Water Audit Validation Guidance Document

Version 1.1

July 2021

Prepared By:

CAVANAUGH
Stewardship Through Innovation

WSO

BLACK & VEATCH
Building a world of difference.

This document was prepared for the Texas Water Development Board, to provide guidance for performing a Level 1 water audit validation per WRF 4639 specifications, adapted to the TWDB water audit format.

Required Supporting Documents – must be provided to complete the Level 1 validation

1. **SD1 - System Schematic** – depicting the water system with relative locations labeled for each of the meters used to derive the volumes entered for Produced Water (Line 13), Total Treated Water Purchased (Line 14) and Total Treated Wholesale Water Sales from Produced Water (Line 15). Does not need to be to scale, and a sketch is adequate.
2. **SD2.x - Produced Water** – volumes by month, by meter for the audit period. This should cover all volumes included in the input for Line 13 in the water audit form.
3. **SD3.x - Production Meter Accuracy** – documentation of accuracy testing and electronic calibration events during the audit period, if performed.
4. **SD4.x - Treated Water Purchased** – volumes by month, by meter, for the audit period. This should cover all volumes included in the input for Line 14 in the water audit form.
5. **SD5.x – Treated Wholesale Water Sales** – volumes by month, by meter, for the audit period. This should cover all volumes included in the input for Line 15 in the water audit form.
6. **SD6.x - Authorized Consumption** – volumes by month, by class or use-type, for the audit period. This should cover all volumes included in the inputs for Lines 17, 18, 19 and 20 in the water audit form.

Note: items 2, 3, 4 and 5 requested in Excel format

Supplemental Documentation – to be provided if available

1. The calculation behind the input for Average Yearly System Operating Pressure (Line 10).
2. The calculation behind the input for Production Meter Accuracy (Line 13a).
3. The calculation behind the input for Treated Purchased Water Meter Accuracy (Line 14a).
4. The calculation behind the input for Treated Wholesale Water Meter Accuracy (Line 15a).
5. The calculation behind the input for Average Customer Meter Accuracy (Line 23).
6. The calculation behind the input for Retail Price of Water (Line 40).
7. The calculation behind the input for Variable Production Cost of Water (Line 43).
8. Table of estimates behind the input for Reported Breaks and Leaks (Line 43).

Question Inventory for Validation Session between Validator and Audit Team

Questions should be targeted to validate inputs were derived correctly in accordance with the Texas Water Loss Audit Manual, based on AWWA M36 first principles. The Validator should present questions as open-ended and determine next questions as warranted by the audit team responses, to gather insights as described in the following section. Items are presented in the recommended order of discussion.

Schematic Understanding for Water Audit Boundary:

The Validator should first discuss the System Schematic (SD1) with the Audit team as necessary to draw the water audit boundary along each of the system input meters indicated in SD2.x, SD4.x and SD5.x. The volumes totaled from the Supporting Documents should match the water audit inputs.

Produced Water (Line 13)

Validator should frame questions that will discover answers to the following:

- Does the Line 13 volume account for all water sources owned and operated by the supplier?
- Was any volume double-counted?
- Was all non-potable water excluded?
- Does the Line 13 volume capture the whole audit period?
- Is the best fit data used for the audit input (closest to distribution, most accurate given meter history)?
- Were changes in storage calculated and properly accounted for?
- How many distinct own-source distribution inputs are there?
  - How many inputs are metered?
  - Are any of the meters in series?
  - Do the meters capture raw water or potable water?
- How are unmetered inputs estimated?
- Which own-source meters are calibrated? How often are calibrations performed?
  - What were the results of the calibrations closest to the audit period?
- Which own-source meters are volumetrically tested? How often are tests conducted?
  - What were the results of the volumetric accuracy tests closest to the audit period?

Additional DVG Assignment Guidance

In addition to the DVG criteria, consider the following when confirming the selection:

	"Accuracy testing" refers to the study of a meter's primary measuring mechanism. In volumetric accuracy testing, a meter's registered volume is compared to precise and independent volumetric measurement in-situ.
	"Electronic calibration" refers to a check on the meter's secondary instrumentation. Electronic calibration ensures the accurate communication and conversion of electronic signals.
	"% of water production" refers to percentage by volume (not by count).
2+	Manufacturer testing certificate for newly installed meter *does not qualify* as accuracy testing
2	"Occasional meter accuracy testing or electronic calibration conducted" requires that either maintenance activity occurred within the last 5 years but less than annually.
3	Accuracy testing OR electronic calibration occurs annually for at least 90% of the source flow by volume. Supporting documentation showing the most recent maintenance results required.
4+	Accuracy testing AND electronic calibration occurs for at least 90% of the source flow by volume.
5	Testing and calibration practices are closely scrutinized for adherence with the M36 Manual

Produced Meter Accuracy (Line 13a)

Validator should frame questions that will discover answers to the following:

- How are Line 13 volumes sampled and recorded?
- How often is Line 13 production data reviewed?
- Are changes in stored volume incorporated? If so, how?
- Is the adjustment correctly assigned as negative or positive?

Additional DVG Assignment Guidance

In addition to the DVG criteria, consider the following when confirming the selection:

2+	Tank levels are monitored and reviewed daily, and the net change in storage for the year is included in the MMSEA input. Daily calculations on tank storage unnecessary.

Total Treated Water Purchased (Line 14)

Validator should frame questions that will discover answers to the following:

- Does the Line 14 volume account for all water sources purchased by the supplier?
- Was any volume mistakenly double-counted?
- Was all non-potable water excluded?
- Does the Line 14 volume capture the whole audit period?
- Is the best fit data used for the audit input (closest to distribution, most accurate given maintenance history)?
- Does the Line 14 data source feature any financial adjustments?
- How many distinct import connections are there?
  - How many import connections are metered?
  - Are any of the meters in series?
  - How are unmetered imports estimated?
- How often are import meters calibrated? Which meters are calibrated?
  - What were the results of the calibrations closest to the audit period?
- How often are import meters tested for volumetric accuracy? Which meters are volumetrically tested?
  - What were the results of the volumetric accuracy tests closest to the audit period?

Additional DVG Assignment Guidance

In addition to the DVG criteria, consider the following when confirming the selection:

	"Accuracy testing" refers to the study of a meter's primary measuring mechanism. In volumetric accuracy testing, a meter's registered volume is compared to precise and independent volumetric measurement in-situ.
	"Electronic calibration" refers to a check on the meter's secondary instrumentation. Electronic calibration ensures the accurate communication and conversion of electronic signals.
	"% of water production" refers to percentage by volume (not by count).
2+	Manufacturer testing certificate for newly installed meter *does not qualify* as accuracy testing
2	"Occasional meter accuracy testing or electronic calibration conducted" requires that either maintenance activity occurred within the last 5 years but less than annually.
3	Accuracy testing OR electronic calibration occurs annually for at least 90% of the source flow by volume. Supporting documentation showing the most recent maintenance results required.
4+	Accuracy testing AND electronic calibration occurs for at least 90% of the source flow by volume.

Treated Purchased Water Meter Accuracy (Line 14a)

Validator should frame questions that will discover answers to the following:

- How are Line 14 volumes recorded?
- How often are Line 14 volumes captured, and how often are they reviewed?
- What documentation is available to describe the interagency import-export agreement?
- Is the adjustment correctly assigned as negative or positive?

Additional DVG Assignment Guidance

In addition to the DVG criteria, consider the following when confirming the selection:

2+	Processes of data review by Importer can stand in for data review by Exporter

Total Treated Wholesale Water Sales (Line 15)

Validator should frame questions that will discover answers to the following:

- Does the Line 15 volume account for all water sources purchased by the supplier?
- Was any volume mistakenly double-counted?
- Was all non-potable water excluded?
- Does the Line 15 volume capture the whole audit period?
- Is the best fit data used for the audit input (closest to distribution, most accurate given maintenance history)?
- Does the Line 15 data source feature any financial adjustments?
- How many distinct import connections are there?
    - How many import connections are metered?
    - Are any of the meters in series?
    - How are unmetered imports estimated?
- How often are import meters calibrated? Which meters are calibrated?
    - What were the results of the calibrations closest to the audit period?
- How often are import meters tested for volumetric accuracy? Which meters are volumetrically tested?
    - What were the results of the volumetric accuracy tests closest to the audit period?

Additional DVG Assignment Guidance

In addition to the DVG criteria, consider the following when confirming the selection:

	"Accuracy testing" refers to the study of a meter's primary measuring mechanism. In volumetric accuracy testing, a meter's registered volume is compared to precise and independent volumetric measurement in-situ.
	"Electronic calibration" refers to a check on the meter's secondary instrumentation. Electronic calibration ensures the accurate communication and conversion of electronic signals.
	"% of water production" refers to percentage by volume (not by count).
2+	Manufacturer testing certificate for newly installed meter *does not qualify* as accuracy testing
2	"Occasional meter accuracy testing or electronic calibration conducted" requires that either maintenance activity occurred within the last 5 years but less than annually.
3	Accuracy testing OR electronic calibration occurs annually for at least 90% of the source flow by volume. Supporting documentation showing the most recent maintenance results required.
4+	Accuracy testing AND electronic calibration occurs for at least 90% of the source flow by volume.

Treated Wholesale Water Meter Accuracy (Line 15a)

Validator should frame questions that will discover answers to the following:

- How are Line 15 volumes recorded?
- How often are Line 15 volumes captured, and how often are they reviewed?
- What documentation is available to describe the interagency import-export agreement?
- Is the adjustment correctly assigned as negative or positive?

Additional DVG Assignment Guidance

In addition to the DVG criteria, consider the following when confirming the selection:

2+	Processes of data review by Importer can stand in for data review by Exporter

Billed Metered (Line 17)

Validator should frame questions that will discover answers to the following:

- Are all customer classes appropriately included in the total Line 17 volume?
- Is all recycled or raw water consumption excluded?
- Is unbilled metered consumption excluded, such as non-paying municipal accounts?
- Is the Line 15 volume (wholesale exports to other agencies) excluded from Line 17?
- How are financial adjustments handled? Confirm that the consumption total reflects actual volumetric use and solely financial changes are disregarded.
- Is the data pro-rated to align with the audit period?
- What portion of customers are metered?
- How are customer meter reads collected?
    - What is the success rate of meter read collection?
- How many meters are replaced annually? What is the driver for selecting which meters to replace?
- How many customer meters are tested annually? What is the driver for deciding which meters to test?
- How are customer bill records maintained?
    - How often are customer bill records audited? By whom?

Additional DVG Assignment Guidance

In addition to the DVG criteria, consider the following when confirming the selection:

2 "Very limited meter accuracy testing" describes a reactive testing program wherein only complaint based or consumption flag triggered accuracy testing occurs. "Sporadic" describes testing that occurs less than annually.

3 "Limited meter accuracy testing" describes a proactive testing program wherein subsets of meters (i.e. old meters, large meters) are targeted but a representative sample of the full meter population is not involved.

Annual auditing of "summary statistics" describes monthly or annual total volumes are reviewed annually.

4 "Regular meter accuracy testing" describes a proactive testing program wherein subsets of meters (i.e. old meters, large meters) are targeted but a representative sample of the full meter population is not involved AND the results directly inform maintenance and replacement activities.

Routing auditing of "detailed statistics" involves review of billing data at least down to charge code categories.

"Third party verification" involves a sampling review on select billing accounts.

5 "Statistically significant testing and replacement" describes a proactive meter testing program that features: 1) large meter testing informed by revenue considerations and 2) small meter testing of a random and representative sample. The accuracy test results inform maintenance and replacement activities, and testing program margins of error have been analyzed.

Third party audit describes a full billing database inquiry and analysis of raw data to rebuild a corroboration of the summary volumes.

Billed Unmetered (Line 18)

Validator should frame questions that will discover answers to the following:

- How does the supplier generate revenue for the estimated consumption in Line 18?
- Is the consumption summarized in Line 18 exclusively flat rate customers? Why are these customers unmetered?
- What other billed unmetered uses are included?
- What are the utilities policies regarding which customers must be metered?
- Are metering policies clear?
- Are metering policies consistently implemented?
- How is billed unmetered consumption estimated?

Unbilled Metered (Line 19)

Validator should frame questions that will discover answers to the following:

- What uses are included in the Line 19 input?
- What is the source of information for the Line 19 input?
- If Line 19 records are included in a billing database, were these volumes excluded from the Line 18 total?
- What are utility policies regarding which customers are metered but unbilled?
- Are billing exemption policies clear?
- Are billing exemption policies consistently implemented?
- How often are unbilled meters read?
- How is unbilled metered consumption estimated in the absence of a recent meter read?

Unbilled Unmetered (Line 20)

Validator should frame questions that will discover answers to the following:

- What uses are included in the Line 20 input?
- How are unmetered, unbilled uses documented?
- How is consumption for each use estimated?

Average Customer Meter Accuracy (Line 23)

Note: Validator should reference insights gained on the Billed Metered input (Line 17) re: customer meter testing and replacement practices. Validator should then frame questions that will discover answers to the following:

- How was the Line 23 input derived / estimated?
- Was small meter inaccuracy considered separately from large meter inaccuracy?
- How are customer meter records managed?
- What is the make-up of the customer meter population? Are meter types and manufacturers homogeneous or varied?
- Were the test results used for Line 23 calculation? How?

Additional DVG Assignment Guidance

In addition to the DVG criteria, consider the following when confirming the selection:

2	Meter accuracy tests are only conducted upon customer request. CMI is estimated.
4	Meter accuracy tests are triggered by customer requests *and* consumption flags. The inaccuracy volume is *inferred* from test data. Replacement program targets old meters upon failure.
6	"Routine, but limited meter accuracy testing" describes a *proactive* customer meter testing program. The sample can be targeted (large meters, oldest meters). The input must be *calculated* for the full meter population based on this data.
8	"Ongoing meter replacement and accuracy testing" describes an annual proactive customer meter testing program. The test sample must be representative of the whole meter population, not just a sub-population of concern. The input must be *calculated* for the full meter population based on this data.
9	"Statistically significant" describes a testing program wherein the margins of error have been analyzed.
10	"Targeted and justified" meter replacement describes a program of thorough, proactive customer meter testing. Large meter testing is prioritized by revenue and a random, representative sample of small meters is tested. Test results inform maintenance and replacement activities. Testing program and input calculations have been closely scrutinized for M36 alignment.

Systematic Data Handling Error (Line 25)

Validator should frame questions that will discover answers to the following:

- If the default was not used, how did the supplier derive its estimate of Line 25? What data transmission and billing process review informed the estimate?
- What policies govern billing processes and account management?
  - How effectively are these policies implemented?
- What technologies are used in read collection and billing processes?
- How often are billing processes and billing data audited?
  - Who performs the auditing?
  - What checks and functions are built into billing data management to minimize error?

Unauthorized Consumption (Line 26)

Validator should frame questions that will discover answers to the following:

- If the default was not used, how did the supplier derive its estimate of Line 26?
- What instances of Line 26have been documented?
- What information is capture in records of Line 26?
- Are documented volumes of unauthorized consumption extensive enough to replace the default estimate?

Utility's Length of Main Lines (Line 6)

Validator should frame questions that will discover answers to the following:

- Does the length of mains only include potable water infrastructure?
- Does the length of mains include hydrant lateral pipe length?
- What is the policy for installing and documenting new infrastructure?
- How effectively are these policies implemented?
- How are pipe assets tracked?
- How often are asset records validation with field data?

Additional DVG Assignment Guidance

In addition to the DVG criteria, consider the following when confirming the selection:

5	"Random field validation" describes an effort of asset information verification that is completed for the specific purposes of asset inventory (not through the double checking that occurs through regular work order processes).

Number of Retail Service Connections Served (Line 7)

Validator should frame questions that will discover answers to the following:

- What is the policy for permitting, installing and documenting new service connections?
- How effectively are these policies implemented?
- How are service connections tracked?
- How is service connection documentation field verified?
- What margin of error does the auditor assign to the estimate of the Number of Active and Inactive Service Connections?

Average Yearly System Operating Pressure (Line 10)

Validator should frame questions that will discover answers to the following:

- Does the utility employ pressure zones?
- How does the utility manage system pressure?
- How are pressure zones defined and separated?
- Are pressure zones discrete?
- Was Line 10 based on a calculation from data, or estimated?
- If calculated, how was Line 10 derived? How were pressure zone values weighted?
- What is the range of pressures throughout the system?
- How and where is pressure data collected?

Additional DVG Assignment Guidance

In addition to the DVG criteria, consider the following when confirming the selection:

1	AOP is *estimated.*
2	"Basic coverage" describes a system that has telemetry or pressure logging at boundary points (PRVs, booster pumps, supply locations). Input is *inferred* from the data.
3	"Well-covered" describes telemetry or pressure logging beyond the boundary points, targeted in some portions of the system but not representing the full pressure profile. Input is *calculated* from the data.
4	"Full-scale" describes telemetry or pressure logging that captures data beyond the boundary points, collecting pressure information from throughout the distribution system, representing a full pressure profile. If pressure logging (instead of using telemetry), seasonal variation must also be captured.
5	Telemetry is required that captures data beyond the boundary points, collecting pressure information from throughout the distribution system. A hydraulic model is in place and has been calibrated within the last 5 years to produce a precise average pressure input.

Reported Breaks and Leaks (Line 28)

Validator should frame questions that will discover answers to the following:

- How are surfacing leak events documented, if at all?
- How was the estimated volume entered into Line 28 derived?
- What percent of the surfacing leaks are repaired?
- What is the average time from call-to-repair?
- How was the estimated volume entered into Line 28 derived?

Additional DVG Assignment Guidance

In addition to the DVG criteria, consider the following when confirming the selection:

Validator may offer guidance to the audit team on categorizing leak records as 'good' vs 'outstanding', based on the discussion, but generally the final call on this should be made by the audit team, given their firsthand knowledge of said records.

Unreported Losses (Line 29)

Validator should frame questions that will discover answers to the following:

- What is the frequency and extent of proactive leak detection performed to find non-surfacing leaks?
- How are proactive leak detection activities and results documented?
- What activities are included in the proactive leak detection efforts (basic sounding and correlation, DMAs and flow monitoring, other)?
- To what extent are a real loss component analysis and economic level of leakage assessment conducted?

Additional DVG Assignment Guidance

In addition to the DVG criteria, consider the following when confirming the selection:

3+	One or more District Metered Areas required.

Retail Price of Water (Line 40)

Validator should frame questions that will discover answers to the following:

- How was the Line 40 input calculated?
- Are sewer charges volumetric? If so, are any sewer charges included in Line 40?
- How are the utility's rates structured, and when was it last updated?
- Have all rate tiers and account classes been incorporated?
- How frequently is the rate structure reviewed by a party knowledgeable in AWWA water audit methodology?

Additional DVG Assignment Guidance

In addition to the DVG criteria, consider the following when confirming the selection:

5	*Any sewer revenues collected by the utility that are based on water meter readings must be factored into the composite rate.*

Variable Production Cost of Water (Line 43)

Validator should frame questions that will discover answers to the following:

- How was input calculated?
- Are all primary variable costs included?
- Are any secondary variable costs included?
- Are fixed costs excluded?
- How frequently are production costs audited? By whom?

Additional DVG Assignment Guidance

In addition to the DVG criteria, consider the following when confirming the selection:

2	A DVG of 2 or 2.5 is assigned when only primary Variable Product Cost (power, chemicals, and/or purchase water costs) is used.
3	Reference to "pertinent additional costs" describe that some (but not all) secondary costs have been evaluated and incorporated. Secondary costs include – but are not limited to: • wear and tear on dynamic equipment • residuals management • impending expansion of supply • damages paid from claims from line breaks If some of the secondary costs are not applicable, the basis for this should be documented.
4	All secondary costs have been evaluated and incorporated as applicable. For any deemed not applicable, the basis for this should be documented. 3rd party M36 review suggests that the input calculations have been reviewed by a water loss expert.

Appendix B: Level 1 Water Loss Audit Validation Report Template

Validator Provided

Texas Water Loss Audit - Level 1 Validation Report

Audit Information:

Utility: PWS ID:

System Type: Potable Audit Period:

Utility Representation:

Validation Interview Date(s): Supporting Documents Provided: (y/n)

Validation Findings & Confirmation Statement:

Key Audit Metrics:	**Pre-Validation**	**Post-Validation**
Total Assessment Score:		
ILI:		
Real Loss:	(gal/conn/day)	(gal/conn/day)
Apparent Loss:	(gal/conn/day)	(gal/conn/day)

Validator Information:

Water Audit Validator: Validator Qualifications:

Summary Recommendations for Utility Next Steps

- Recommendation 1
- Recommendation 2
- Recommendation 3

<System Schematic Here>

Summary of Pre- and Post-Validation Entries

#	Water Audit Input	*AWWA Code*	Assessment Scale		Post-Validation Input Revision (if applicable)
			Pre-Val	Post-Val	
Ln 6	Utility's Length of main lines	*Lm*			
Ln 7	Total Retail Metered Connections – Active and Inactive	*Nc*			
Ln 10	Average Yearly System Operating Pressure	*AOP*			
Ln 13	Produced Water	*VOS*			
Ln 13a	Production Meter Accuracy	*VOSEA*			
Ln 14	Treated Purchased Water	*WI*			
Ln 14a	WI Master Meter & Supply Error Adjustment	*WIEA*			
Ln 15	Treated Wholesale Water Sales	*WE*			
Ln 15a	WE Master Meter & Supply Error Adjustment	*WEEA*			
Ln 17	Billed metered	*BMAC*			
Ln 18	Billed unmetered	*BUAC*			
Ln 19	Unbilled metered	*UMAC*			
Ln 20	Unbilled unmetered	*UUAC*			
Ln 23	Average Customer Meter Accuracy	*CMI*			
Ln 25	Systematic data handling errors	*SDHE*			
Ln 26	Unauthorized consumption	*UC*			
Ln 28	Reported Breaks and Leaks				
Ln 29	Unreported Losses				
Ln 40	Retail Price of Water	*CRUC*			
Ln 43	Variable production cost	*VPC*			

Validation Review Notes

#	Water Audit Input	Recom Scale	Basis of Input Derivation	Basis of Data Validity Grade
Ln 6	Utility's Length of main lines	X	Input derivation: Hydrant leads included: Comments:	Mapping format: Asset management database: Map updates & field validation: Comments:
Ln 7	Total Retail Metered Connections – Active and Inactive	X	Input derivation: Basis for database query: Comments:	CIS updates & field validation: Estimated error of total count within: Comments:
Ln 10	Average Yearly System Operating Pressure	X	Number of zones, general profile: Typical pressure range: Input derivation: Comments:	Extent of static pressure data collection: Characterization of real-time pressure data collection: Hydraulic model: Comments:
Ln 13	Produced Water	X	Supply meter profile: Enter Number, Type(s), Configuration VOS input derived from: Comments:	Percent of own supply metered: Signal calibration frequency: Volumetric testing frequency: Volumetric testing method: Percent of own supply tested and/or calibrated: Comments:
Ln 13a	Production Meter Accuracy	X	Input derivation: Net storage change included in input: Comments:	Supply meter read frequency: Supply meter read method: Frequency of data review for trends & anomalies: Storage levels monitored in real-time: Comments:
Ln 14	Treated Purchased Water	X	Import meter profile: Enter Number, Type(s), Configuration, note Emergency Interties WI input derived from: Comments:	Percent of import supply metered: Signal calibration frequency: Volumetric testing frequency: Volumetric testing method: Percent of import supply tested and/or calibrated: Comments:
Ln 14a	Treated Purchased Water	X	Input derivation: Comments:	Import meter read frequency: Import meter read method: Frequency of data review for trends & anomalies: Comments:

#	Water Audit Input	Recom Scale	Basis of Input Derivation	Basis of Data Validity Grade
Ln 15	Treated Wholesale Water Sales	X	Export meter profile: Enter Number, Type(s), Configuration, note Emergency Interties Comments:	Percent of export supply metered: Signal calibration frequency: Volumetric testing frequency: Volumetric testing method: Percent of export supply tested and/or calibrated: Comments:
Ln 15a	WE Master Meter & Supply Error Adjustment	X	Input derivation: Comments:	Export meter read frequency: Export meter read method: Frequency of data review for trends & anomalies: Comments:
Ln 17	Billed metered	X	Customer meter profile: Age profile: Enter general range & average Reading system: Read frequency: Comments:	Percent of customers metered: Small meter testing policy: Number of small meters tested/year: Large meter testing policy: Number of large meters tested/year: Meter replacement policy: Number of replacements/year: Billing data auditing: Comments:
Ln 18	Billed unmetered	X	Profile: Input derivation: Comments:	Policy for metering exemptions: Comments:
Ln 19	Unbilled metered	X	Profile: Input derivation: Comments:	Policy for billing exemptions: Comments:
Ln 20	Unbilled unmetered	5	Profile: Comments:	Comments:
Ln 23	Average Customer Meter Accuracy	X	Input derivation: Comments:	Characterization of meter testing: Characterization of meter replacement: Comments:
Ln 25	Systematic data handling errors	X	Comments:	Comments:
Ln 26	Unauthorized consumption	X	Comments:	Comments:

#	Water Audit Input	Recom Scale	Basis of Input Derivation	Basis of Data Validity Grade
Ln 28	Reported Breaks and Leaks	X	How are surfacing leak events documented, if at all? How was the estimated volume entered into Line 28 derived? What percent of the surfacing leaks are repaired? What is the average time from call-to-repair? How was the estimated volume entered into Line 28 derived?	
Ln 29	Unreported Losses	X	What is the frequency and extent of proactive leak detection performed to find non-surfacing leaks? How are proactive leak detection activities and results documented? What activities are included in the proactive leak detection efforts (basic sounding and correlation, DMAs and flow monitoring, other)? To what extent are a real loss component analysis and economic level of leakage assessment conducted?	
Ln 40	Retail Price of Water	X	Input derivation: Comments:	Characterization of calculation: Comments:
Ln 43	Variable production cost	X	Supply profile: Primary costs included: Secondary costs included: Comments:	Characterization of calculation: Comments:

Appendix C: Level 1 Water Loss Audit Validation Reports for Study Participants

Validator Provided

Texas Water Loss Audit - Level 1 Validation Report

Audit Information:

Utility: City of Alpine PWS ID: 22001

System Type: Potable Audit Period: 1/1/2020 – 12/31/2020

Utility Representation: Jess Washington, Scott Perry [TWDB: John Sutton and Daniel Rice]

Validation Date: 4/22/2021 Call Time: 1:00 pm Central Time Supporting Documents Provided: Yes

Validation Findings & Confirmation Statement:

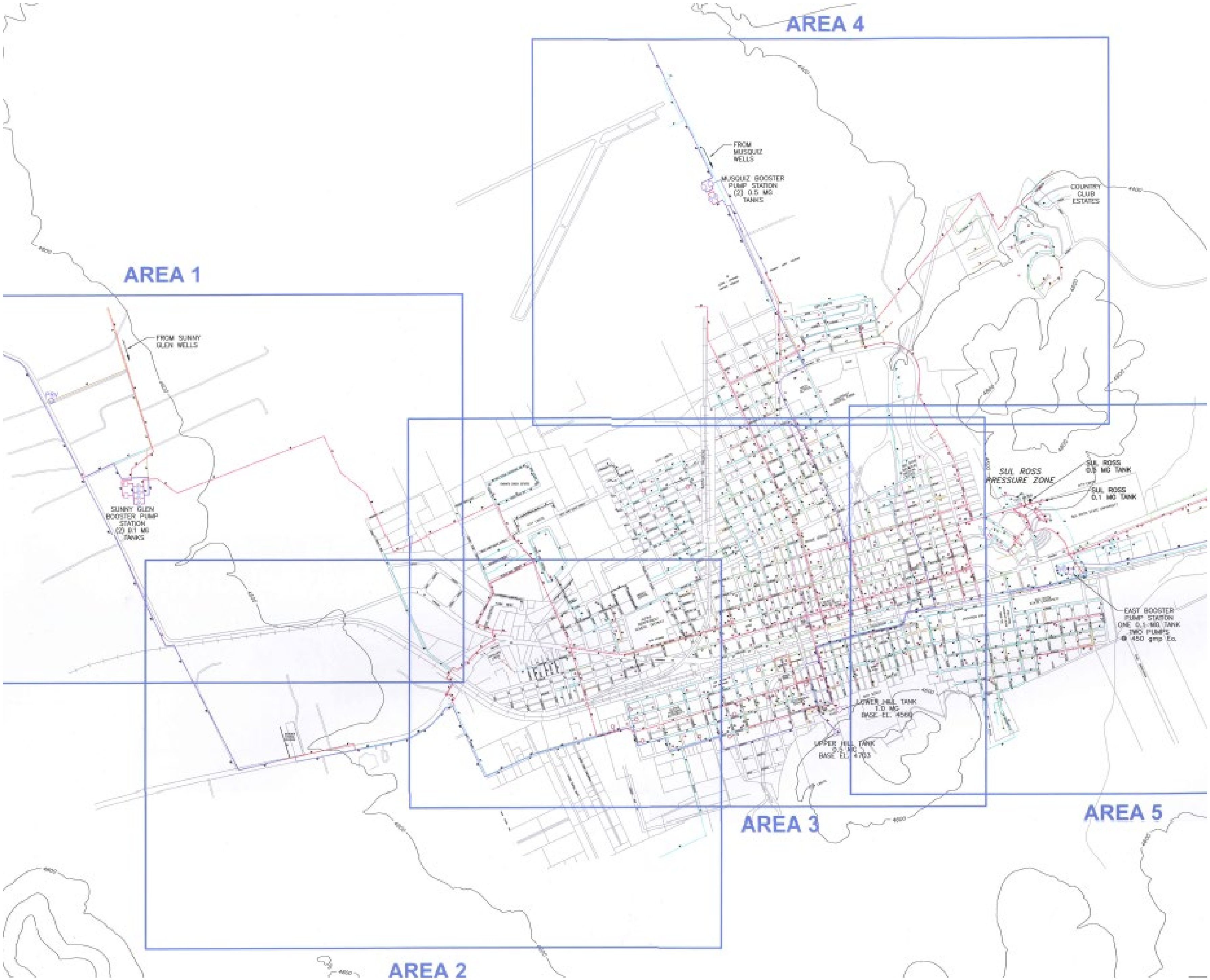
Key Audit Metrics:	Pre-Validation	Post-Validation
Total Assessment Score:	41.5	51.0
ILI:	6.94	6.78
Real Loss:	140.0 (gal/conn/day)	138.1 (gal/conn/day)
Apparent Loss:	19.5 (gal/conn/day)	19.4 (gal/conn/day)

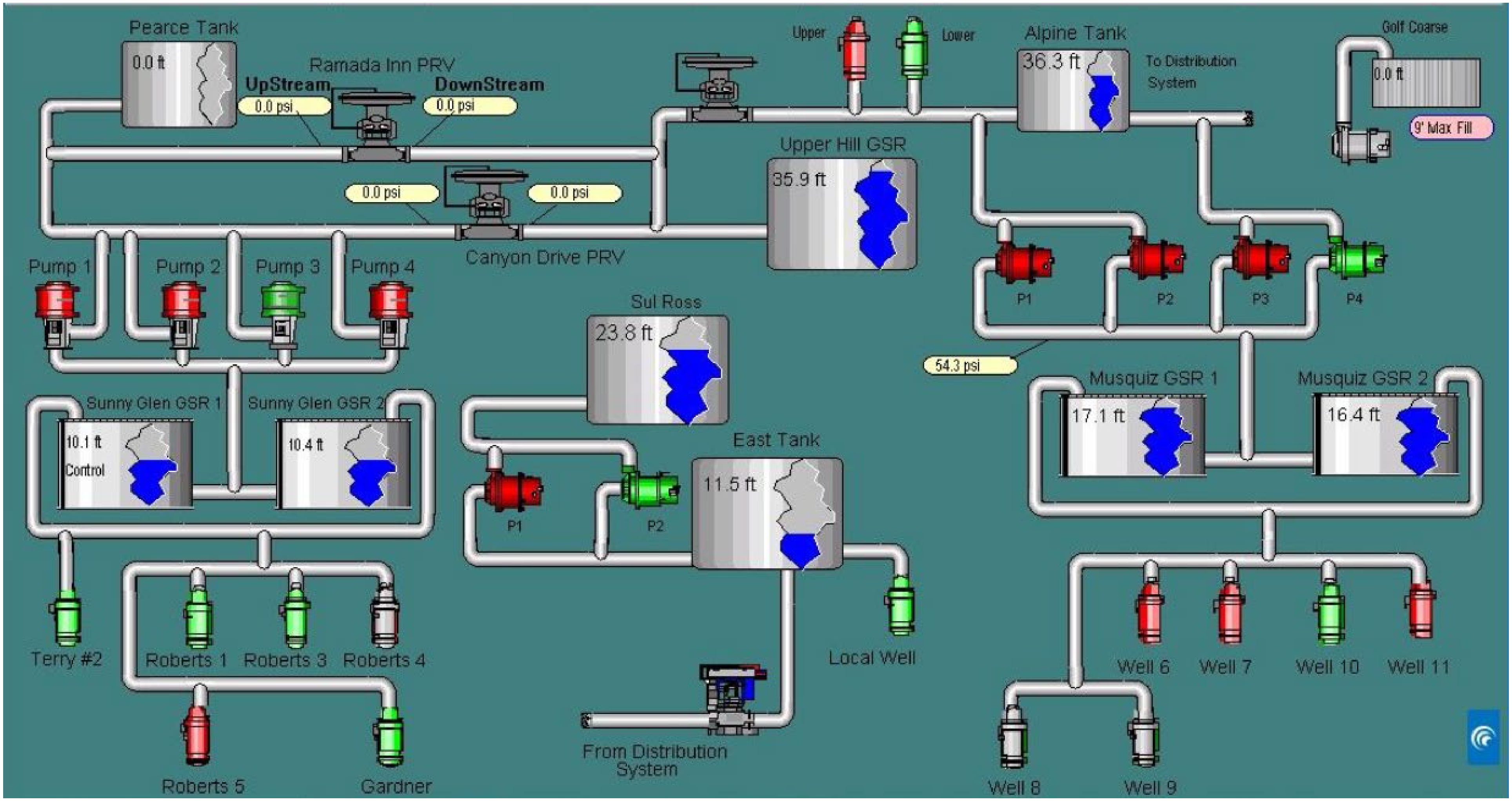
Validator Information:

Water Audit Validator: Andrew Chastain-Howley, David Sayers Validator Qualifications: Contractor for TWDB

Summary Recommendations for Utility Next Steps

- Continue to improve understanding of Supply Meter (wells) Master Meter Error: consider adopting or increasing the rigor of a source meter volumetric testing and calibration program, informed by the guidance provided in AWWA Manual M36 – Appendix A.
- Level 2 validation on raw data for Billed Metered Authorized Consumption to determine and resolve any instances of potable volume duplication or inclusion of volumes not applicable to this category.
- The meter stock is relatively old, so a dedicated retail meter testing program of 50-100 meters should be considered.
    - Improved estimation of CMI: As above - consider a customer meter testing program which tests a sample of random meters whose stratification (by size, age, or other characteristics) represents the entire customer meter stock.
- The ILI and real losses are relatively high, so additional auditing focus will be worthwhile. If the real losses continue to show elevated values a leakage detection survey should be considered.


AREA 4
AREA 1
AREA 3
AREA 5
AREA 2
FROM MUSQUIZ WELLS
MUSQUIZ BOOSTER PUMP STATION (2) 0.5 MG TANKS
COUNTRY CLUB ESTATES
FROM SUNNY GLEN WELLS
SUNNY GLEN BOOSTER PUMP STATION (2) 0.1 MG TANKS
SUL ROSS PRESSURE ZONE
SUL ROSS 0.5 MG TANK
SUL ROSS 0.1 MG TANK
EAST BOOSTER PUMP STATION ONE 0.1-MG TANK TWO PUMPS @ 450 gpm Ea.
LOWER HILL TANK 1.0 MG BASE EL. 4560
UPPER HILL TANK 0.5 MG BASE EL. 4703


Pearce Tank
0.0 ft
Ramada Inn PRV
UpStream
0.0 psi
DownStream
0.0 psi
0.0 psi
0.0 psi
Canyon Drive PRV
Upper
Lower
Alpine Tank
36.3 ft
To Distribution System
Golf Coarse
0.0 ft
9' Max Fill
Upper Hill GSR
35.9 ft
Pump 1
Pump 2
Pump 3
Pump 4
P1
P2
P3
P4
54.3 psi
Sul Ross
23.8 ft
Sunny Glen GSR 1
Sunny Glen GSR 2
10.1 ft
Control
10.4 ft
Musquiz GSR 1
17.1 ft
Musquiz GSR 2
16.4 ft
East Tank
11.5 ft
P1
P2
Terry #2
Roberts 1
Roberts 3
Roberts 4
Local Well
Well 6
Well 7
Well 10
Well 11
Roberts 5
Gardner
From Distribution System
Well 8
Well 9

Summary of Pre- and Post-Validation Entries

#	Water Audit Input	*AWWA Code*	Assessment Scale		Post-Validation Input Revision (if applicable)
			Pre-Val	Post-Val	
Ln 6	Utility's Length of main lines	*Lm*	1.5	1.5	
Ln 7	Total Retail Metered Connections – Active and Inactive	*Nc*	1	1	
Ln 10	Average Yearly System Operating Pressure	*AOP*	2	2	
Ln 13	Produced Water	*VOS*	2.5	3	
Ln 13a	Production Meter Accuracy	*VOSEA*	1.5	1.5	Changed to 95.6% utilizing consultant-derived weighted average. Subsequent volume calculations impacted from this.
Ln 14	Treated Purchased Water	*WI*	n/a	n/a	
Ln 14a	WI Master Meter & Supply Error Adjustment	*WIEA*	n/a	n/a	
Ln 15	Treated Wholesale Water Sales	*WE*	n/a	n/a	
Ln 15a	WE Master Meter & Supply Error Adjustment	*WEEA*	n/a	n/a	
Ln 17	Billed metered	*BMAC*	2.5	2	
Ln 18	Billed unmetered	*BUAC*	1	3	
Ln 19	Unbilled metered	*UMAC*	1.5	2.5	
Ln 20	Unbilled unmetered	*UUAC*	1	2.5	
Ln 23	Average Customer Meter Accuracy	*CMI*	1.5	1.5	
Ln 25	Systematic data handling errors	*SDHE*	1.5	0.5	
Ln 26	Unauthorized consumption	*UC*	0.5	2.5	
Ln 28	Reported Breaks and Leaks		1	3	
Ln 29	Unreported Losses		0.5	0.5	
Ln 40	Retail Price of Water	*CRUC*	3	1.5	Changed to $1.50 to remove base charges, sewer
Ln 43	Variable production cost	*VPC*	1.5	2.5	

Validation Review Notes

#	Water Audit Input	Recom Scale	Basis of Input Derivation	Basis of Data Validity Grade
Ln 6	Utility's Length of main lines	1.5	Input derivation: Annual additions to legacy mileage number. Hydrant leads included: No. Comments: No GIS, utilize AutoCAD currently; looking to upgrade.	Mapping format: Paper. Asset management database: Not currently in place. Map updates & field validation: Accomplished through normal work order processes. Comments: No GIS, recommend including the 8-10 ft of hydrant lead line in future estimates
Ln 7	Total Retail Metered Connections – Active and Inactive	1	Input derivation: Rudimentary estimate. Basis for database query: Meter ID - non-premise based. Comments: Number for each month are supplied and averaged. Includes an estimate for fire hydrants (about 240). Difficult to get inactive accounts, so estimated about 200 vacant or inactive. Dedicated billing system but it's old and not very sophisticated 10 years + old. Utility is looking to upgrade billing system.	CIS updates & field validation: Accomplished through normal meter reading processes. Estimated error of total count within: 3%. Comments: No additional comments.
Ln 10	Average Yearly System Operating Pressure	2	Number of zones, general profile: 2 zones Typical pressure range: 45-90 Input derivation: Calculated as simple average from analysis of field data. Comments: Pressure tests taken off hydrant tests and pump stations via SCADA. Varies between 45 and 90 psi, so 55 is an all-point average estimate. There are two distinct pressure zones – had to resolve isolation issues now have proper separation.	Extent of static pressure data collection: Hydrant pressures taken during routine system flushing and/or hydrant testing. Characterization of real-time pressure data collection: Real-time monitoring limited to pump stations. Hydraulic model: None currently in place. Comments: Utility did not grade this item prior to the first call. This was the only grading conducted this way.
Ln 13	Produced Water	3	Supply meter profile: Spreadsheet provided with monthly volumes and testing data. 23 production level meters although some pump into treatment plants – in these cases only the master meter from the relevant treatment plant was used VOS input derived from: SCADA and manual reads from production meters as archived. Comments: Monthly totals for all wells provided. Some small amounts going to the ranches where the well is located. These total to a Metered Unbilled volume. Well records are collected on a daily basis (M-F). Moving towards AMR system for the wells which will help with data collection. Both wellfields were not shown on the maps provided as they are a distance out of town. Musquiz is 13 miles to the north as an example. Pumping quite a distance from the well fields – pumping raw water. There are four treatment plants (N, S, E, W) around town. Disinfection is at the plants after the manifolds.	Percent of own supply metered: 100% Signal calibration frequency: Not applicable given no signal output from some supply meters. Volumetric testing frequency: Annual. Volumetric testing method: Not noted. Percent of own supply tested and/or calibrated: 100% Comments: All data provided, Consultant developed a weighted average

Ln 13a	Production Meter Accuracy	1.5	Input derivation: Weighted average from accuracy test results. Net storage change included in MMSEA input: No. Comments: Consultant provided weighted calculation for MMEA 4.4% (95.6%) under reporting instead of estimated 5%. Utility to change in the input field. Note that this had a number of slight changes in other values as it affects Volume from own sources	Supply meter read frequency: Daily. Supply meter read method: Manual and automatic logging. Frequency of data review for trends & anomalies: Monthly. Storage levels monitored in real-time: Yes. Comments: No additional comments.
Ln 14	Treated Purchased Water	n/a	n/a	n/a
Ln 14a	WI Master Meter & Supply Error Adjustment	n/a	n/a	n/a
Ln 15	Treated Wholesale Water Sales	n/a	n/a	n/a
Ln 15a	WE Master Meter & Supply Error Adjustment	n/a	n/a	n/a
Ln 17	Billed metered	2	Customer meter profile: Mostly small meters, only a few large meters. Age profile: Older meter stock. Reading system: Manual. Read frequency: Monthly. Comments: One person does the meter reads. Utility has a number of old Kent meters, Precision meters, Rockwell's – old ones. Many different kinds. 30% max one manufacturer, 70% mixed manufacturers.	Percent of customers metered: 100% Small meter testing policy: Reactive - complaint based or flagged-consumption testing only. Number of small meters tested/year: Not quantified, but known to be small. Large meter testing policy: None. Number of large meters tested/year: Not quantified, but known to be small. Meter replacement policy: Upon failure only. Number of replacements/year: Not quantified, but known to be small. Billing data auditing: Standard billing QC, plus review of volumes by use type each billing cycle. Comments: Not many large meters, mostly residential
Ln 18	Billed unmetered	3	Profile: Bulk water unmetered Input derivation: Rudimentary estimate standard amount times number of tanks. Comments: City gives out bulk water from tank in the yard. Not metered for sale, but tank is measured / estimated per load. Other location is a fire hydrant that is metered. 653,000 gallons tracked. So, this volume (653k gal) is included in billed metered.	Policy for metering exemptions: Limited to own facilities. Comments: confirmed all customers metered by policy and no unmetered other than controlled bulk tankers

Ln 19	Unbilled metered	2.5	Profile: Some provided to ranch customers on well sites, city buildings are not billed but are metered, some ranches have allocated amounts as part of the well contracts. Input derivation: Direct from meter readings. Comments: Value is sum of ranch use on well sites + city buildings (read every month)	Policy for billing exemptions: Limited to own facilities and small number of ranches. Comments: No additional comments.
Ln 20	Unbilled unmetered	2.5	Profile: Default grade applied Comments:	Comments: Default grade applied. Grade moved up to account for default.
Ln 23	Average Customer Meter Accuracy	1.5	Input derivation: Rudimentary estimate. Comments: City does actively test meters – only on complaints / customer issues. Planning to pull 10% of meters and test. Consultant recommends 50-100 meters would be sufficient to get a representative sample (300 for statistical sample, which is probably more than need for small utility).	Characterization of meter testing: Limited (upon request AND consumption flag only). Characterization of meter replacement: Limited (upon failure only). Comments: No additional comments.
Ln 25	Systematic data handling errors	0.5	Comments: Entered zero and graded accordingly	Comments: no analysis currently conducted
Ln 26	Unauthorized consumption	2.5	Comments: Default input applied.	Comments: Default grade applied. Moved score up accordingly.
Ln 28	Reported Breaks and Leaks	3	How are surfacing leak events documented, if at all? Has a work order management system, administered by city hall – but hard to get hold of the information. Not easy to use. Therefore, the water department has them recorded and summarized in a spreadsheet – the spreadsheet only shows the more significant leaks – not necessarily everything that is in the work order system. How was the estimated volume entered into Line 28 derived? Estimated leak rate x time accounting for pressure (using AWWA guidance). What percent of the surfacing leaks are repaired? 100% What is the average time from call-to-repair? Fixed within hours or same day.	Reasonable monitoring of leaks and breaks. Good repair history reported with most repaired in less than three days average. Increased grading to account for this reporting.
Ln 29	Unreported Losses	0.5	What is the frequency and extent of proactive leak detection performed to find non-surfacing leaks? No pro-active efforts in recent past. How are proactive leak detection activities and results documented? N/A What activities are included in the proactive leak detection efforts (basic sounding and correlation, DMAs and flow monitoring, other)? N/A	No leakage detection conducted. Consultant recommended considering in future.

			To what extent are a real loss component analysis and economic level of leakage assessment conducted? N/A	
Ln 40	Retail Price of Water	1.5	Input derivation: $7 per 1000 gallons originally input included sewer. City recalculated to just the water costs using a water only average residential usage rate ($1.50) Comments: Correction to the water cost was noted.	Characterization of calculation: Non-weighted average. Input calculations have not been reviewed by an M36 water loss expert. Comments: Weighting by usage and customer class would increase grade
Ln 43	Variable production cost	2.5	Supply profile: Own sources only. Primary costs included: Treatment chemicals and supply & distribution power. Secondary costs included: None currently included. Comments: No additional comments.	Characterization of calculation: Primary costs only. Input calculations select been reviewed by an M36 water loss expert. Comments: Primary costs included, but not secondary yet – moving towards a 3.

Validator Provided

Texas Water Loss Audit - Level 1 Validation Report

Audit Information:

Utility: Aqua WSC PWS ID: 110013

System Type: Potable Audit Period: 1/1/2020 – 12/31/2020

Utility Representation: Chuck Kellogg, James D'Souza [TWDB: Daniel Rice]

Validation Date: 4/28/2021 Call Time: 9:00 am Central Time Supporting Documents Provided: Limited

Validation Findings & Confirmation Statement:

Key Audit Metrics:	**Pre-Validation**	**Post-Validation**
Total Assessment Score:	79.0	73.0
ILI:	n/a	n/a
Real Loss:	75.6 (gal/conn/day)	75.6 (gal/conn/day)
Apparent Loss:	6.7 (gal/conn/day)	6.7 (gal/conn/day)

Validator Information:

Water Audit Validator: Andrew Chastain-Howley, David Sayers Validator Qualifications: Contractor for TWDB

Summary Recommendations for Utility Next Steps

- Improved understanding of Supply Meter (wells) Master Meter Error: consider adopting or increasing the rigor of a source meter volumetric testing and calibration program, informed by the guidance provided in AWWA Manual M36 – Appendix A.
- Level 2 validation on raw data for Billed Metered Authorized Consumption to determine and resolve any instances of potable volume duplication or inclusion of volumes not applicable to this category.
- Improved estimation of CMI: The WSC does conduct large meter testing (including both wholesale and large customer meters), however, the data was not used directly in the respective calculations. This was considered too much work to evaluate for 2020 but should be conducted for 2021 (thereby also increasing the validation scores).
  - consider a customer meter testing program which tests a sample of random meters whose stratification (by size, age, or other characteristics) represents the entire customer meter stock.
- Basic data was provided, although the auditor already knew the system. If future auditors do not have any system knowledge it would be good to get additional backup information including system mapping and well production information.

Summary of Pre- and Post-Validation Entries

#	Water Audit Input	*AWWA Code*	Assessment Scale Pre-Val	Assessment Scale Post-Val	Post-Validation Input Revision (if applicable)
Ln 6	Utility's Length of main lines	*Lm*	4.5	4.5	
Ln 7	Total Retail Metered Connections – Active and Inactive	*Nc*	4.5	4.5	
Ln 10	Average Yearly System Operating Pressure	*AOP*	4.5	3.5	
Ln 13	Produced Water	*VOS*	4.5	2.5	
Ln 13a	Production Meter Accuracy	*VOSEA*	5	3.5	
Ln 14	Treated Purchased Water	*WI*	n/a	n/a	
Ln 14a	WI Master Meter & Supply Error Adjustment	*WIEA*	n/a	n/a	
Ln 15	Treated Wholesale Water Sales	*WE*	4.5	2.5	
Ln 15a	WE Master Meter & Supply Error Adjustment	*WEEA*	2	2	
Ln 17	Billed metered	*BMAC*	4.5	3.5	
Ln 18	Billed unmetered	*BUAC*	3.5	4	
Ln 19	Unbilled metered	*UMAC*	5	5	
Ln 20	Unbilled unmetered	*UUAC*	4.5	4.5	
Ln 23	Average Customer Meter Accuracy	*CMI*	3	3	
Ln 25	Systematic data handling errors	*SDHE*	3.5	3.5	
Ln 26	Unauthorized consumption	*UC*	2.5	2.5	
Ln 28	Reported Breaks and Leaks		4.5	4.5	
Ln 29	Unreported Losses		1.5	1.5	
Ln 40	Retail Price of Water	*CRUC*	4.5	4.5	
Ln 43	Variable production cost	*VPC*	2.5	3.5	

Validation Review Notes

#	Water Audit Input	Recom Scale	Basis of Input Derivation	Basis of Data Validity Grade
Ln 6	Utility's Length of main lines	4.5	Input derivation: Totaled from GIS based map. Hydrant leads included: Uncertain. Recommend evaluation for future Comments: Confident in the size, age, material of the pipe. Mainly PVC for smaller pipe. Larger pipes 12" + are DIP. The utility turns new records of updates over to the GIS team for updating on a regular basis. In-house GIS team with some consulting help – e.g. modeling. There are a lot of mains with long runs without connections, running through open fields. Therefore, the utility needs a lot of field work to find the leaks.	Mapping format: Digital. Asset management database: In place but separate from GIS system. Planning to integrate Map updates & field validation: Accomplished through normal work order processes. Comments: No additional comments.
Ln 7	Total Retail Metered Connections – Active and Inactive	4.5	Input derivation: Standard report run from billing system. Basis for database query: Meter ID - non-premise based. Comments: 'Enhance' billing system is used – will be changed in near future. They have their own meter services group – with AMR system covering all of the network. High level of accuracy believed. Recommend comparing number of accounts and meters and make sure this is validated in future years. Looking for pressurized connections. Number used is likely to be the December number rather than an average across the year – this is okay as long as similar method is used each year.	CIS updates & field validation: Accomplished through normal meter reading processes. Estimated error of total count within: <2%. Comments: Random field validation holds back from 5.
Ln 10	Average Yearly System Operating Pressure	3.5	Number of zones, general profile: Several pressure zones – 10-15. Lot of elevation variation driving this. Tanks and PRVs are used but not sure if they are all connected to SCADA Typical pressure range: maybe up to 100 psi in some zones Input derivation: Calculated as simple average from analysis of field data. Comments: Recommend calculate/validating this value from the hydraulic model in future years.	Extent of static pressure data collection: Hydrant pressures taken during routine system flushing and/or hydrant testing. Characterization of real-time pressure data collection: Basic - telemetry or pressure logging at boundary points (supply locations, tanks, PRVs, boosters). Hydraulic model: In place and may have been calibrated within the last 5 years. Check for future years. Comments: Recommend calculate/validating this value from the model for future years.
Ln 13	Produced Water	2.5	Supply meter profile: Master meter / propeller meters. Some uncertainty on type of meters across whole system VOS input derived from: SCADA reads from production meters are recorded and archived. Comments: Meters tested on rotation – every 2 years. Not tested in 2020 due to covid. Well meters are tested. Utility reported calibration is included in the final SCADA number – automatically rolled into the reported number so no adjustment is needed. Additional focus on annual testing recommended. The utility has 30 wells. Pumping to treatment plants. Metering is at the wells and also some at the treatment facilities. As an example, there are 8 wells into one plant (South plant) – chlorination. Camp swift and 5 McDade:	Percent of own supply metered: 100% Signal calibration frequency: Within last 5 years but less than annually. Volumetric testing frequency: Within last 5 years but less than annually. Volumetric testing method: Unknown Percent of own supply tested and/or calibrated: 100%, but on a rolling basis over two years.

			also incorporate 2 wells, some with one well. Under 10 treatment plants in total. Discharge is measured at some treatment plants. The SCADA system is connected to all the wells.	Comments: Recommend annual calibration to drive up grade
Ln 13a	Production Meter Accuracy	3.5	Input derivation: Weighted average from accuracy test results. Net storage change included in MMSEA input: No, but system run very consistently, so expect only minor volume change between beginning and end of year. Comments: Accuracy results factored directly into Produced water volume. Not sure about what happens if there is a data outage – recommend making sure these are accounted for and estimated appropriately when needed in future audits.	Supply meter read frequency: Continuous. Supply meter read method: Automatic logging via SCADA telemetry. Frequency of data review for trends & anomalies: Automatic daily, manually likely weekly and as needed when issue arises. Storage levels monitored in real-time: Yes. Comments: Select
Ln 14	Treated Purchased Water	n/a	n/a	n/a
Ln 14a	WI Master Meter & Supply Error Adjustment	n/a	n/a	n/a
Ln 15	Treated Wholesale Water Sales	2.5	Export meter profile: Limited information – 7 wholesale meters Comments: Possibly test every 2 years – but unsure. Large mechanical meters generally only warrantied for one year – so recommend annual testing. Some correction was thought to be needed due to industrial use component, but after discussion with TWDB, it is suggested that no change was necessary and it was not double counted.	Percent of export supply metered: 100 Signal calibration frequency: Not applicable given no signal output from supply meters. Volumetric testing frequency: Reportedly 2-year cycle, although data not available for this audit. Volumetric testing method: n/a. Percent of export supply tested and/or calibrated: n/a. Comments: Recommend review testing program and develop weighted average for future audits
Ln 15a	WE Master Meter & Supply Error Adjustment	2	Input derivation: Contracts in place with wholesale entities Comments: N/A	Export meter read frequency: Monthly. Export meter read method: Manual and automatic logging. Via AMR Frequency of data review for trends & anomalies: Monthly. Comments: Recommend annual accuracy testing and development of weighted average.
Ln 17	Billed metered	3.5	Customer meter profile: Age profile: transition to AMR resulted in meter upgrades – so most are 10 years or newer	Percent of customers metered: 100% of regular customers

			Reading system: AMR. Read frequency: Monthly. Comments: No additional comments.	Small meter testing policy: Reactive - complaint based or flagged-consumption testing only. Number of small meters tested/year: small Large meter testing policy: Targeted testing is conducted annually for high volume meters. Number of large meters tested/year: estimated 15 Meter replacement policy: Upon failure only. Number of replacements/year: Estimated 22 Billing data auditing: Standard billing QC, plus review of volumes by use type each billing cycle. Comments: No additional comments.
Ln 18	Billed unmetered	4	Profile: Precincts – measured by truck load volume Input derivation: Good estimate using number of truck loads multiplied by size of truck tanks. Comments: No additional comments.	Policy for metering exemptions: Limited to own facilities only, no unsupervised hydrant fill ups. Comments: No additional comments.
Ln 19	Unbilled metered	5	Profile: Plant backwash and one fire department meter Input derivation: Direct from meter readings. Comments: No additional comments.	Policy for billing exemptions: Own facilities plus other exemptions including one fire department. Comments: No additional comments.
Ln 20	Unbilled unmetered	4.5	Profile: Includes flushing, flow multiplied by time is the basis of the estimates for flushing, Fire Department is based on their own reporting. Comments:	Comments: DVG based on all uses generally tracked by event using site-specific estimation methods.
Ln 23	Average Customer Meter Accuracy	3	Input derivation: Inferred from reference data (manufacturer, anecdotal test results) but not derived from test data analysis & calculation. Comments: Some data from large meter tests, but not yet used in calculations. Recommend developing weighted average from large meter tests, then conducting more small meter tests.	Characterization of meter testing: Limited (upon request AND consumption flag for small meters, regular for large high use meters. Characterization of meter replacement: Limited (upon failure only). Comments: No additional comments.
Ln 25	Systematic data handling errors	3.5	Comments: Value provided by billing department. Billing activation is reportedly sound, billing consumption flags and alerts are in place and provided as inputs to audit if appropriate.	Comments: No additional comments.
Ln 26	Unauthorized consumption	2.5	Comments: Default is used	Comments: Default is used
Ln 28	Reported Breaks and Leaks	4.5	How are surfacing leak events documented, if at all? Work order management system in place	

			How was the estimated volume entered into Line 28 derived? Not clear – but estimation of loss is done by field crews. What percent of the surfacing leaks are repaired? >90% What is the average time from call-to-repair? Call to repair times between 3 days and one week and likely average less than 3 days.	
Ln 29	Unreported Losses	1.5	What is the frequency and extent of proactive leak detection performed to find non-surfacing leaks? Some pro-active leak detection performed but utility not yet found these surveys to be very productive. How are proactive leak detection activities and results documented? None recently What activities are included in the proactive leak detection efforts (basic sounding and correlation, DMAs and flow monitoring, other)? Basic sounding, No DMAs To what extent are a real loss component analysis and economic level of leakage assessment conducted? N/A	
Ln 40	Retail Price of Water	4.5	Input derivation: Based on weighted system rates Comments: No additional comments.	Characterization of calculation: Weighted average but possibly not composite of all rates (ICI). Utility to review for 2021, but keep grading as initially recorded for 2020. Input calculations have not been reviewed by an M36 water loss expert. Comments: Review weighting calculation for 2021
Ln 43	Variable production cost	3.5	Supply profile: Own sources only. Primary costs included: Treatment chemicals and supply & distribution power. Secondary costs included: Some additional costs currently added to cost. Comments: No additional comments.	Characterization of calculation: Primary costs and some basic secondary costs only. Input calculations have not been reviewed by an M36 water loss expert. Comments: No additional comments.

Validator Provided

Texas Water Loss Audit - Level 1 Validation Report

Audit Information:

Utility: Crystal Clear Special Utilities District PWS ID: 940015

System Type: Potable Audit Period: Calendar 2020

Utility Representation: Regina Franke (Assistant Director), Stephanie Olson-Haseloff (CCSUD), Carla Brayton (MSENG) [TWDB: John Sutton]

Validation Date: 4/29/2021 Call Time: 8:30am Supporting Documents Provided: Yes

Validation Findings & Confirmation Statement:

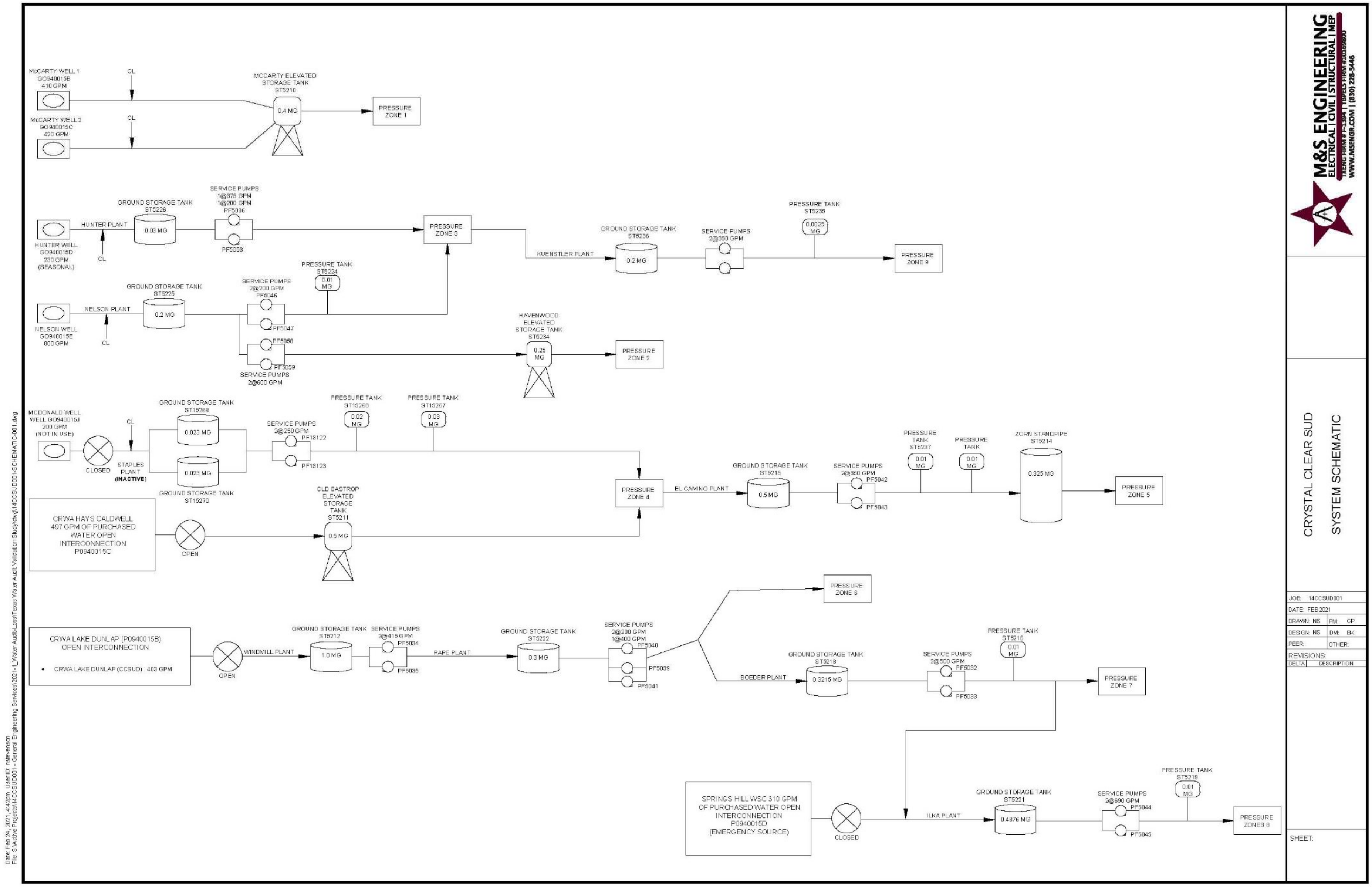
Key Audit Metrics:	Pre-Validation	Post-Validation
Total Assessment Score:	81.5	78.5
ILI:	2.0	2.7
Real Loss:	92.0 (gal/conn/day)	85.6 (gal/conn/day)
Apparent Loss:	14.4 (gal/conn/day)	4.8 (gal/conn/day)

Validator Information:

Water Audit Validator: Larry Lewison Validator Qualifications: Contractor for TWDB

Summary Recommendations for Utility Next Steps

- Customized estimate of Unbilled Unmetered Authorized Consumption: consider producing itemized, agency-specific estimates of unbilled unmetered (operational) uses, rather than using the default. Ensure leakage estimates are excluded.
- Improved understanding of Supply Meter (Own or Import) Master Meter Error: consider adopting or increasing the rigor of a source meter volumetric testing and calibration program, informed by the guidance provided in AWWA Manual M36 – Appendix A.
- Temporal alignment of Billed Metered Authorized Consumption with Water Supplied: consider pro-rating the first and last months of the audit period to better align consumption with actual dates of use, and using read date as basis for reporting.
- Level 2 validation on raw data for Billed Metered Authorized Consumption to determine and resolve any instances of potable volume duplication or non-potable volume inclusion. *Note: this is being performed subsequently as a part of the current TWDB project.*
- Improved estimation of CMI: consider a customer meter testing program which tests a sample of random meters whose stratification (by size, age, or other characteristics) represents the entire customer meter stock.


McCARTY WELL 1
GO940015B
410 GPM
McCARTY WELL 2
GO940015C
420 GPM
CL
McCARTY ELEVATED STORAGE TANK
ST5210
0.4 MG
PRESSURE ZONE 1
HUNTER WELL
GO940015D
200 GPM
(SEASONAL)
HUNTER PLANT
GROUND STORAGE TANK
ST5226
0.03 MG
SERVICE PUMPS
1@375 GPM
1@200 GPM
PF5036
PF5053
PRESSURE ZONE 3
KUENSTLER PLANT
GROUND STORAGE TANK
ST5236
0.2 MG
SERVICE PUMPS
2@350 GPM
PRESSURE TANK
ST5235
0.0025 MG
PRESSURE ZONE 9
NELSON WELL
GO940015E
800 GPM
NELSON PLANT
GROUND STORAGE TANK
ST5225
0.2 MG
SERVICE PUMPS
2@200 GPM
PF5046
PF5047
PRESSURE TANK
ST5224
0.01 MG
PF5058
PF5059
SERVICE PUMPS
2@600 GPM
HAVENWOOD ELEVATED STORAGE TANK
ST5234
0.25 MG
PRESSURE ZONE 2
MCDONALD WELL
WELL GO940015J
200 GPM
(NOT IN USE)
CLOSED
STAPLES PLANT
(INACTIVE)
GROUND STORAGE TANK
ST15269
0.023 MG
GROUND STORAGE TANK
ST15270
0.023 MG
SERVICE PUMPS
2@250 GPM
PF13122
PF13123
PRESSURE TANK
ST15268
0.02 MG
PRESSURE TANK
ST15267
0.03 MG
CRWA HAYS CALDWELL
497 GPM OF PURCHASED WATER OPEN INTERCONNECTION
P0940015C
OPEN
OLD BASTROP ELEVATED STORAGE TANK
ST5211
0.5 MG
PRESSURE ZONE 4
EL CAMINO PLANT
GROUND STORAGE TANK
ST5215
0.5 MG
SERVICE PUMPS
2@350 GPM
PF5042
PF5043
PRESSURE TANK
ST5237
0.01 MG
PRESSURE TANK
0.01 MG
ZORN STANDPIPE
ST5214
0.325 MG
PRESSURE ZONE 5
CRWA LAKE DUNLAP (P0940015B)
OPEN INTERCONNECTION
• CRWA LAKE DUNLAP (CCSUD) : 403 GPM
OPEN
WINDMILL PLANT
GROUND STORAGE TANK
ST5212
1.0 MG
SERVICE PUMPS
3@415 GPM
PF5034
PF5035
PAPE PLANT
GROUND STORAGE TANK
ST5222
0.3 MG
SERVICE PUMPS
2@200 GPM
1@400 GPM
PF5040
PF5039
PF5041
PRESSURE ZONE 6
BOEDER PLANT
GROUND STORAGE TANK
ST5218
0.3215 MG
SERVICE PUMPS
2@600 GPM
PF5032
PF5033
PRESSURE TANK
ST5216
0.01 MG
PRESSURE ZONE 7
SPRINGS HILL WSC 310 GPM
OF PURCHASED WATER OPEN INTERCONNECTION
P0940015D
(EMERGENCY SOURCE)
CLOSED
ILKA PLANT
GROUND STORAGE TANK
ST5221
0.4876 MG
SERVICE PUMPS
2@690 GPM
PF5044
PF5045
PRESSURE TANK
ST5219
0.01 MG
PRESSURE ZONES 8
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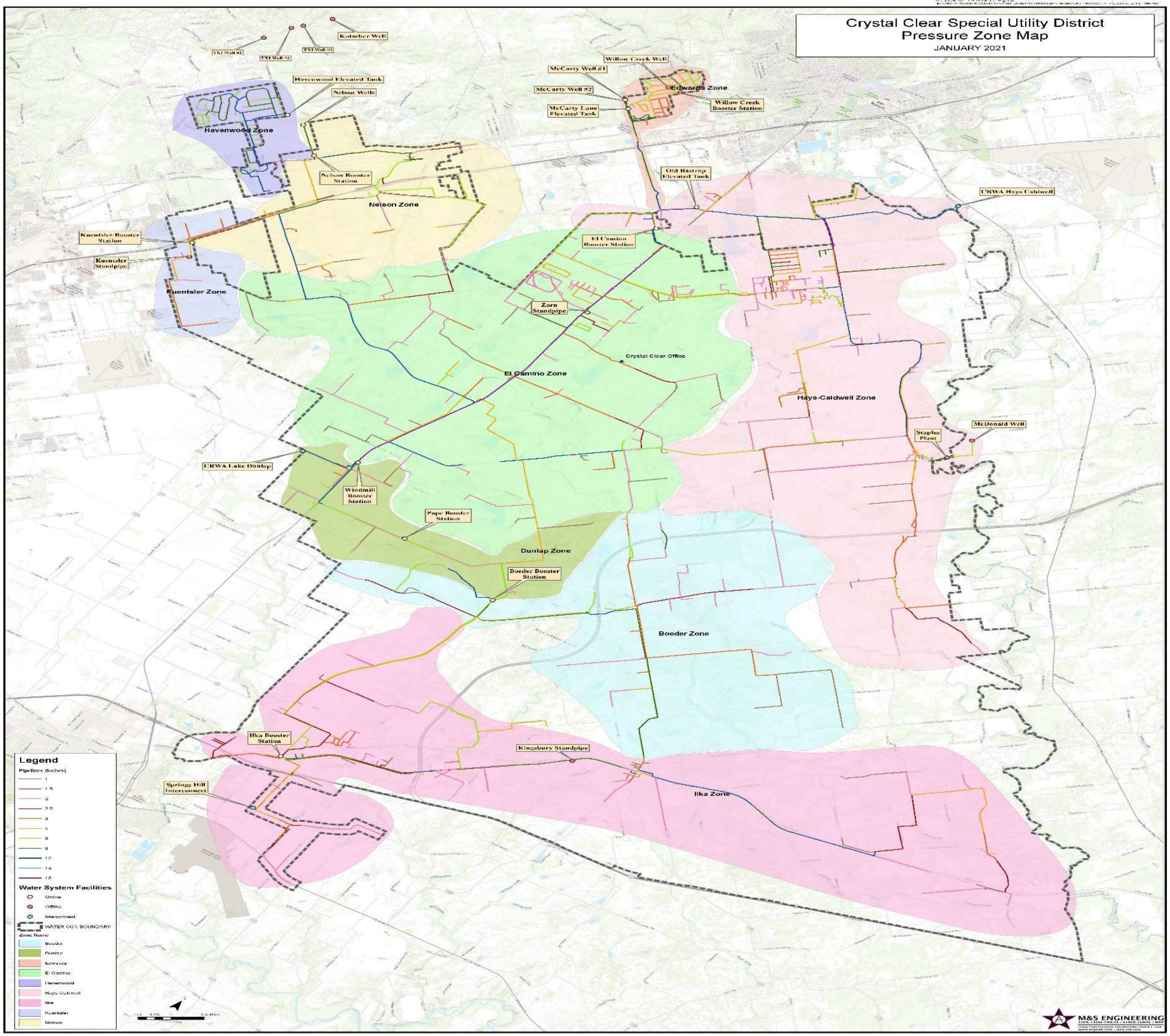
CRYSTAL CLEAR SUD
SYSTEM SCHEMATIC
JOB: 14CCSUD001
DATE: FEB 2021
DRAWN: NS
PM: CP
DESIGN: NS
DM: BK
PEER:
OTHER:
REVISIONS:
DELTA
DESCRIPTION
SHEET:


Crystal Clear Special Utility District
Pressure Zone Map
JANUARY 2021
Kutscher Well
TXI Well #1
TXI Well #2
TXI Well #3
Havenwood Elevated Tank
Nelson Wells
Havenwood Zone
Nelson Booster Station
Nelson Zone
Willow Creek Well
McCarty Well #1
McCarty Well #2
McCarty Lane Elevated Tank
Edwards Zone
Willow Creek Booster Station
Old Bastrop Elevated Tank
CRWA Hays Caldwell
Kuentsler Booster Station
Kuentsler Standpipe
Kuentsler Zone
El Camino Booster Station
Zorn Standpipe
Crystal Clear Office
El Camino Zone
Hays-Caldwell Zone
McDonald Well
Staples Plant
CRWA Lake Dunlap
Windmill Booster Station
Pape Booster Station
Dunlap Zone
Boeder Booster Station
Boeder Zone
Ilka Booster Station
Kingsbury Standpipe
Springs Hill Interconnect
Ilka Zone
Legend
Pipelines (Inches)
1
1.5
2
2.5
3
4
6
8
12
14
16
Water System Facilities
Online
Offline
Interconnect
WATER CCN BOUNDARY
Zone Name
Boeder
Dunlap
Edwards
El Camino
Havenwood
Hays-Caldwell
Ilka
Kuentsler
Nelson
M&S ENGINEERING

Summary of Pre- and Post-Validation Entries

#	Water Audit Input	*AWWA Code*	Assessment Scale		Post-Validation Input Revision (if applicable)
			Pre-Val	Post-Val	
Ln 6	Utility's Length of main lines	*Lm*	4.5	4.5	
Ln 7	Total Retail Metered Connections – Active and Inactive	*Nc*	4.5	4.5	6,081
Ln 10	Average Yearly System Operating Pressure	*AOP*	4.5	4.5	67 psi
Ln 13	Produced Water	*VOS*	5	4.5	
Ln 13a	Production Meter Accuracy	*VOSEA*	4	2.5	99%
Ln 14	Treated Purchased Water	*WI*	5	4.5	
Ln 14a	WI Master Meter & Supply Error Adjustment	*WIEA*	4	2.5	94.4%
Ln 15	Treated Wholesale Water Sales	*WE*	n/a	n/a	
Ln 15a	WE Master Meter & Supply Error Adjustment	*WEEA*	n/a	n/a	
Ln 17	Billed metered	*BMAC*	3	3.5	
Ln 18	Billed unmetered	*BUAC*	3	n/a	
Ln 19	Unbilled metered	*UMAC*	3	n/a	
Ln 20	Unbilled unmetered	*UUAC*	3	2	9,660,539 gal
Ln 23	Average Customer Meter Accuracy	*CMI*	4	3	98.7%
Ln 25	Systematic data handling errors	*SDHE*	3	2.5	Default of 0.25%
Ln 26	Unauthorized consumption	*UC*	3	3	
Ln 28	Reported Breaks and Leaks		4	4	
Ln 29	Unreported Losses		3	3	178,819,001 gal
Ln 40	Retail Price of Water	*CRUC*	5	4.5	$9.10/kgal
Ln 43	Variable production cost	*VPC*	5	3	$3,290/MG

Validation Review Notes

#	Water Audit Input	Recom Scale	Basis of Input Derivation	Basis of Data Validity Grade
Ln 6	Utility's Length of main lines	4.5	Input derivation: Totaled from GIS based map. Hydrant leads included: Yes. Comments: 249 Fire Hydrants at 10 ft Average lead length = 2490 ft. Thus, 367.6 Total Length of Mains (mi)	Mapping format: Digital. Asset management database: In place but separate from GIS system. Map updates & field validation: Accomplished via specific efforts for asset inventory, outside of normal work order processes. Comments: Monthly GIS updates
Ln 7	Total Retail Metered Connections – Active and Inactive	4.5	Input derivation: Standard report run from billing system. Basis for database query: Meter ID - non-premise based. Comments: No additional comments.	CIS updates & field validation: Accomplished through normal meter reading processes. Estimated error of total count within: 2%. Comments: Assessment Scale (AS) of 4.5 based well-managed CIS, error margin within 2%.
Ln 10	Average Yearly System Operating Pressure	4.5	Number of zones, general profile: 8 Typical pressure range: 60-80 Input derivation: Calculated as simple average from analysis of field data. Comments: The average pressure derived throughout the entire system based on the pressure readings coming into the existing facilities was 67 psi. The updated average pressure derived from the EPS water model was determined to be 75 psi. The pressure of 67 psi will be used. Recommend evaluating the HGL to the model and reconcile the points that do not agree.	Extent of static pressure data collection: Hydrant pressures taken during routine system flushing and/or hydrant testing. Characterization of real-time pressure data collection: Well-covered - telemetry or pressure logging beyond the boundary points, targeted in some portions of the system but not representative of the whole. Hydraulic model: In place and calibrated within the last 5 years. Comments: AS limited by lack of agreement between model and field data.
Ln 13	Produced Water	4.5	Supply meter profile: 4 wells, 3 turbine meters, 1 mag VOS input derived from: Manual reads from production meters as archived. Comments: Input derivation from supporting documents confirmed. Exclusion of non-potable volumes confirmed. McCarty Well WP1 test results were not provided. Meter tests for the MMEA derived from Nelson, Hunter and McCarty Well WP2. It is recommended to acquire test results directly from the effluent meter(s) at the plant discharge. This is the recommended point to start the water audit boundary for flow and system data.	Percent of own supply metered: 100% Signal calibration frequency: Not applicable given signal output from supply meters is not utilized in system operations or tabulation of VOS. Volumetric testing frequency: Annual. Volumetric testing method: Comparative apparatus. Percent of own supply tested and/or calibrated: 90% Comments: Limiting criteria for AS is missing some supply meter test results. Recommend testing all supply meters. Also, M36

#	Water Audit Input	Recom Scale	Basis of Input Derivation	Basis of Data Validity Grade
				recommends 3 rates of flow (within normal operating range) per meter (if available) to establish a composite accuracy for each meter.
Ln 13a	Production Meter Accuracy	2.5	Input derivation: Weighted average from accuracy test results. Net storage change included in MMSEA input: No. Comments: 2020 CCSUD Meter Calibrations have been provided for most supply meters. The composite accuracy for production meter has been included in the revised spreadsheet.	Supply meter read frequency: Daily. Supply meter read method: Manual. Frequency of data review for trends & anomalies: Weekly. Storage levels monitored in real-time: Yes. Comments: Net storage change as limiting criteria for AS.
Ln 14	Treated Purchased Water	4.5	Import meter profile: 2 primary sources, 1 emergency connection. 5 meters total, mix of turbine and static meters. WI input derived from: Totalization of volumes per redundant meter reads by utility. Comments: Input derivation from supporting documents confirmed. Exclusion of non-potable volumes confirmed. Meter tests for the MMEA derived from 2 downstream CCSUD booster stations (Windmill and El Camino). While using meter test results from downstream booster stations may be practical, it is recommended to acquire test results directly from the effluent meter at the plant discharge. This is the recommended point to start the water audit boundary for flow and system data.	Percent of import supply metered: 100% Signal calibration frequency: Not applicable given signal output from supply meters is not utilized in system operations or tabulation of VOS. Volumetric testing frequency: Annual. Volumetric testing method: Comparative apparatus. Percent of import supply tested and/or calibrated: 90% Comments: Limiting criteria for AS is obtaining test results from interconnection points. Recommend adherence to M36 best practices for accuracy testing. Only 1 rate of flow was used to derive test result. M36 recommends 3 rates of flow (within operating range, if possible) per meter to establish a composite accuracy
Ln 14a	WI Master Meter & Supply Error Adjustment	2.5	Input derivation: Weighted average from accuracy test results.* Comments: * Accuracy test results not all from the direct purchase meters at the purchase points however test results from meters downstream booster stations were used to adjust the purchase water volume.	Import meter read frequency: Continuous. Import meter read method: Manual and automatic logging. Frequency of data review for trends & anomalies: Weekly. Comments: Purchase agreement in place. AS limited by test results from downstream location other than interconnection point.
Ln 15	Treated Wholesale Water Sales	n/a		

#	Water Audit Input	Recom Scale	Basis of Input Derivation	Basis of Data Validity Grade
Ln 15a	WE Master Meter & Supply Error Adjustment	n/a		
Ln 17	Billed metered	3.5	Customer meter profile: Age profile: 2 years old, Reading system: AMI. Read frequency: Monthly. Comments: Lag-time correction is not employed in input derivation. Input derivation from supporting documents confirmed. Exclusion of non-potable volumes confirmed. Includes SF Residential, MF Residential, Commercial, and Municipal uses. TWDB portal worksheet would not accept a revised value for BM. Value is auto-populated from WU Survey. Therefore: the revised total of 537,448,405 gallons was not uses. The revised amount incorporated subtraction for "NO USE CODES" The monthly reports used to generate the Water Use Survey are different and do not query for this erroneous consumption. Recommend updating monthly reports to include this query to provide the most accurate BMAC value. Also recommended to investigate anomalous volumes showing for October. Advanced validation may be required for resolving any issues if those exist at the raw data level.	Percent of customers metered: 100% Small meter testing policy: Reactive - complaint based or flagged-consumption testing only. Number of small meters tested/year: Not quantified, but known to be small. Large meter testing policy: No testing program in place, but meter conversion project serving as proxy for testing criteria. Number of large meters tested/year: Not quantified, but known to be small. Meter replacement policy: Ongoing via meter conversion project at ~15% each year. Number of replacements/year: Not quantified, but known to be small. Billing data auditing: Standard billing QC, plus review of volumes by use type each billing cycle. Comments: Currently in a meter changeout project. AS derived at 3.5 based on limitation of an established meter testing program.
Ln 18	Billed unmetered	n/a		
Ln 19	Unbilled metered	n/a		
Ln 20	Unbilled unmetered	2	Profile: Operational flushing, FD usage, street cleaning & sewer jetting. Comments: Default input of 1.25% was used.	Comments: Default grade 2.5 applied. Recommend establishing an itemized tracker for UU uses. Some utilities build the uses directly into a WOMS to make it convenient for operations to manage.
		3		

#	Water Audit Input	Recom Scale	Basis of Input Derivation	Basis of Data Validity Grade
Ln 23	Average Customer Meter Accuracy	2.5	See BMAC comments regarding meter testing & replacement activities. Input derivation: Inferred from reference data (manufacturer, anecdotal test results) but not derived from test data analysis or test data calculation. Comments: CMI Estimation calculations have been included.	Characterization of meter testing: Limited (upon request AND consumption flag only). Characterization of meter replacement: Routine (proactive), but limited. Comments: AS of 2.5 derived from using estimated inaccuracy percentage. Meter accuracy tests are triggered by customer requests and consumption flags. The composite inaccuracy is inferred from manufacturer data. Replacement program targets old meters upon failure.
Ln 25	Systematic data handling errors	3	Comments: Default input of 0.25% was used. Pursue custom volume. Each month a report is ran after readings are imported into our billing software. It is called our High/ low report to be able to check accounts that are reflecting higher usage than 'normal' for their account.	Comments: Default grade of 2.5 applied. Recommend establishing an itemized tracker for volumetric adjustments, multiplier errors and others data handling volumetric errors.
Ln 26	Unauthorized consumption	4	Comments: Default input of 0.25% applied.	Comments: Default grade of 2.5 applied.
Ln 28	Reported Breaks and Leaks	3	Surfacing leaks are documented via service order and linked to a customer's account if applicable. The estimated volume in line 28 was derived from the data that was input by our crews when making repairs to a leak. They use their best judgement and estimate the gallons per minute and multiply that by the length of time it has been leaking.	
Ln 29	Unreported Losses	4.5	Typically, every three years a third-party agency is hired to come and conduct a full-scale leak detection audit, SAMCO leak detection. Also have own in-house leak detection equipment to pin-point leaks in our system with sounding equipment. Working on developing a routine schedule to use this equipment to locate leaks faster. But currently as it stands, using the equipment reactively to pinpoint leaks in a known location where there is little to no water surfacing.	AS of 3.5 based on limitation of no real loss component analysis (RLCA) data. Recommend performing this analysis to evaluate the different real loss components.
Ln 40	Retail Price of Water	3	Input derivation: Total consumptive revenue divided by Billed Metered Authorized Consumption. Sewer charges are based on water meter readings. Sewer revenues are incorporated into calculation. Comments: Value was adjusted to match up with actual retail rates.	Characterization of calculation: Weighted average composite of all rates. Input calculations have not been reviewed by an M36 water loss expert. Comments: No additional comments.
Ln 43	Variable production cost	4.5	Supply profile: Own sources and import supply. Primary costs included: Treatment chemicals, supply & distribution power, and purchase costs.	Characterization of calculation: Primary costs only. Input calculations have not been reviewed by an M36 water loss expert.

#	Water Audit Input	Recom Scale	Basis of Input Derivation	Basis of Data Validity Grade
			Secondary costs included: None currently included. Comments: No additional comments.	Comments: AS based on primary costs only. Recommend evaluation to determine if some secondary costs may apply in your system.

Validator Provided

Texas Water Loss Audit - Level 1 Validation Report

Audit Information:

Utility: Johnson County SUD PWS ID: 1260018

System Type: Potable Audit Period: Calendar Year 2020

Utility Representation: Danny Armstrong, Cindy Curley (Billing), Kelly Holloway

Validation Date: 4/26/2021 Call Time: 3:30 pm CT Supporting Documents Provided: Yes

Validation Findings & Confirmation Statement:

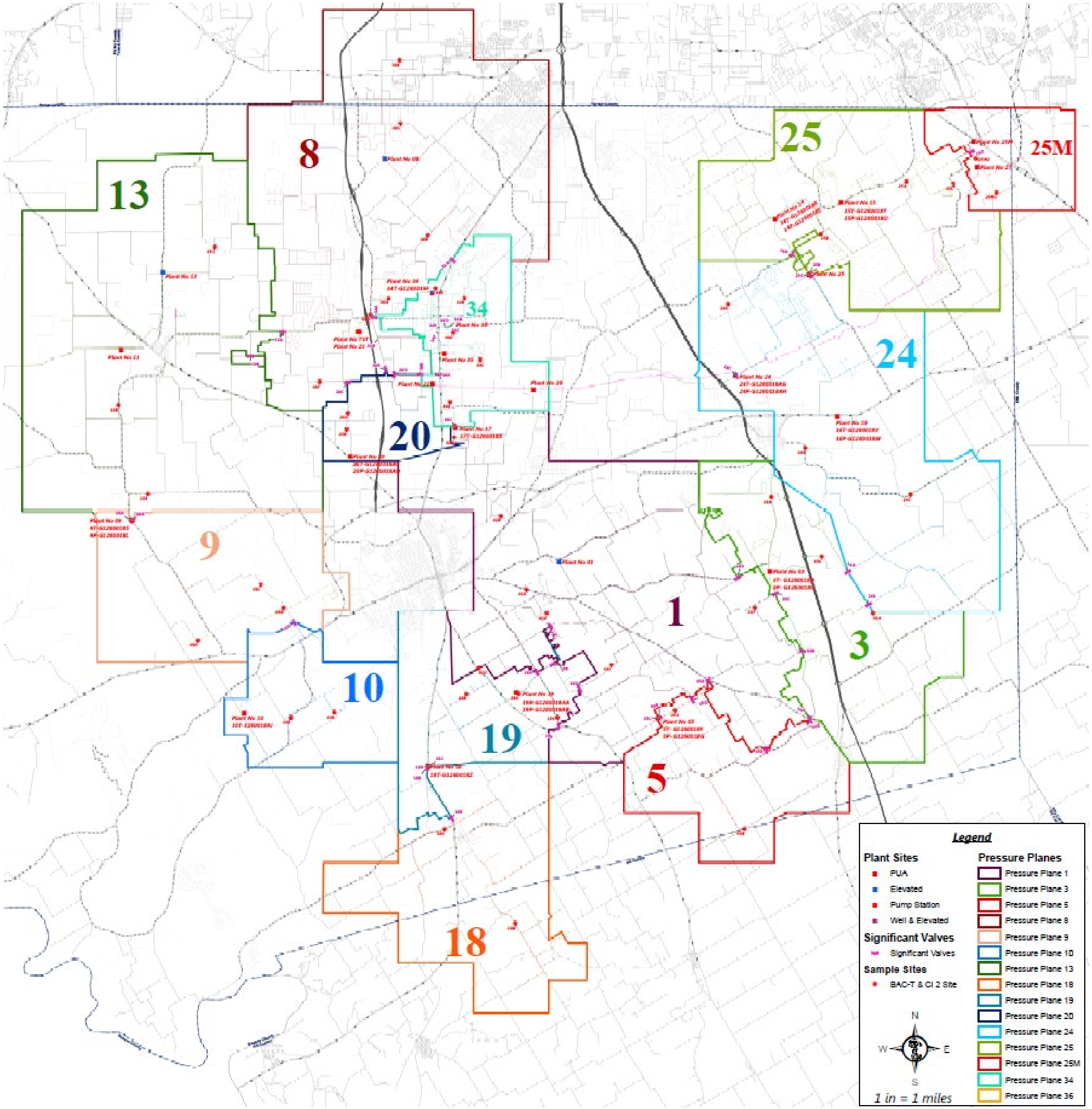
Key Audit Metrics:	Pre-Validation	Post-Validation
Total Assessment Score:	65	66
ILI:	1.4	1.4
Real Loss:	45.7 (gal/conn/day)	48.7 (gal/conn/day)
Apparent Loss:	5.8 (gal/conn/day)	5.8 (gal/conn/day)

Validator Information:

Water Audit Validator: Drew Blackwell Validator Qualifications: Contractor for TWDB

Summary Recommendations for Utility Next Steps

- Customized estimate of Unbilled Unmetered Authorized Consumption: consider producing itemized, agency-specific estimates of unbilled unmetered (operational) uses, rather than using the default. Ensure leakage estimates are excluded.
- Improved understanding of Supply Meter (Own or Import) Master Meter Error: consider adopting an electronic calibration program, informed by the guidance provided in AWWA Manual M36 – Appendix A. Calculate volumetric accuracy test results as a weighted average based on the percent of source flow at each supply meter to give a more accurate error adjustment.
- Temporal alignment of Billed Metered Authorized Consumption with Water Supplied: consider pro-rating the first and last months of the audit period to better align consumption with actual dates of use, and using read date as basis for reporting.
- Improved estimation of CMI: consider a customer meter testing program which tests a sample of random meters whose stratification (by size, age, or other characteristics) represents the entire customer meter stock.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Well & Elevated
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Significant Valves
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Pressure Planes
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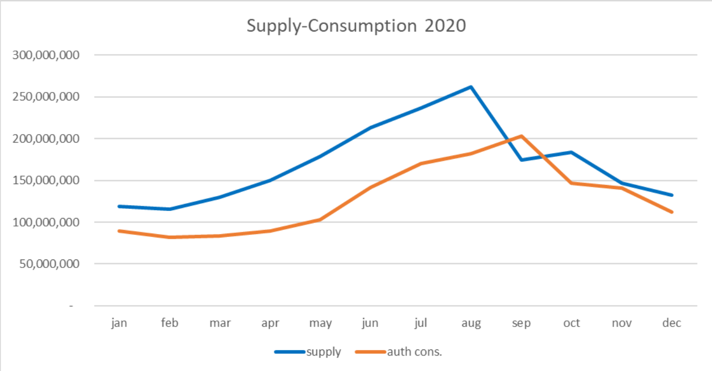
Summary of Pre- and Post-Validation Entries

#	Water Audit Input	*AWWA Code*	Assessment Scale		Post-Validation Input Revision (if applicable)
			Pre-Val	Post-Val	
Ln 6	Utility's Length of main lines	*Lm*	4	4	
Ln 7	Total Retail Metered Connections – Active and Inactive	*Nc*	3.5	3.5	
Ln 10	Average Yearly System Operating Pressure	*AOP*	3	3	
Ln 13	Produced Water	*VOS*	5	3.5	673,764,000 gal
Ln 13a	Production Meter Accuracy	*VOSEA*	5	5	
Ln 14	Treated Purchased Water	*WI*	5	3.5	1,370,501,000 gal
Ln 14a	Treated Purchased Water Meter Accuracy	*WIEA*	5	5	
Ln 15	Treated Wholesale Water Sales	*WE*	4	3.5	
Ln 15a	WE Master Meter & Supply Error Adjustment	*WEEA*	3.5	3.5	
Ln 17	Billed metered	*BMAC*	3.5	2.5	
Ln 18	Billed unmetered	*BUAC*	5	5	
Ln 19	Unbilled metered	*UMAC*	4	n/a	0 gal
Ln 20	Unbilled unmetered	*UUAC*	2	2.5	
Ln 23	Average Customer Meter Accuracy	*CMI*	2.5	2.5	
Ln 25	Systematic data handling errors	*SDHE*	2.5	2.5	3,862,570 gal
Ln 26	Unauthorized consumption	*UC*	2	1.5	11,591,464 gal
Ln 28	Reported Breaks and Leaks		3.5	3.5	
Ln 29	Unreported Losses		2	2.5	
Ln 40	Retail Price of Water	*CRUC*	0	4.5	
Ln 43	Variable production cost	*VPC*	0	2.5	

Validation Review Notes

#	Water Audit Input	Recom Scale	Basis of Input Derivation	Basis of Data Validity Grade
Ln 6	Utility's Length of main lines	4	Input derivation: Totaled from GIS based map. Hydrant leads included: Not included. Recommend including in input derivation for next audit. Comments: Just distribution. No transmission lines. Updated with new development.	Mapping format: Digital. Asset management database: In place and integrated with GIS system. Map updates & field validation: Accomplished through normal work order processes. Comments: No additional comments.
Ln 7	Total Retail Metered Connections – Active and Inactive	3.5	Input derivation: Standard report run from billing system. Basis for database query: Meter ID - non-premise based. Comments: Harris product. Switching to Emco – Isis. Uncertain of frequency, but believed to be more frequently than annually.	CIS updates & field validation: Accomplished through normal meter reading processes. Estimated error of total count within: 3%. Comments: No additional comments.
Ln 10	Average Yearly System Operating Pressure	3	Number of zones, general profile: 11 zones Typical pressure range: 35 psi to 120 psi Input derivation: Output from hydraulic model. Comments: Just put in Mueller meter – For future audits investigate capability of pressure data logging at residential meters.	Extent of static pressure data collection: Not collected currently. Characterization of real-time pressure data collection: Well-covered - telemetry or pressure logging beyond the boundary points, targeted in some portions of the system but not representative of the whole. Hydraulic model: In place and calibrated within the last 5 years. Comments: collecting at every supply point, most connected to SCADA
Ln 13	Produced Water	3.5	Supply meter profile: 18 active GW wells in 2020. Different makes right now, but all will be ultrasonic in 2022. VOS input derived from: Manual reads from production meters as archived. Comments: Input derivation from supporting documents confirmed. Exclusion of non-potable volumes confirmed.	Percent of own supply metered: 100% Signal calibration frequency: None. Volumetric testing frequency: Semi-annual. Volumetric testing method: Transit-time ultrasonic. Percent of own supply tested and/or calibrated: 100% Comments: No additional comments.
Ln 13a	Production Meter Accuracy	3.5	Input derivation: Simple average from calibration results. Net storage change included in MMSEA input: No. Comments: For future audits, it is recommended to use the weighted average based on percent of source flow rather than a simple average.	Supply meter read frequency: Daily. Supply meter read method: Automatic logging via SCADA telemetry. Frequency of data review for trends & anomalies: Monthly. Storage levels monitored in real-time: Yes. Comments: No additional comments.
Ln 14	Treated Purchased Water	3.5	Import meter profile: Mansfield and BRPUA WI input derived from: Totalization of volumes per redundant meter reads by utility.	Percent of import supply metered: 100% Signal calibration frequency: None. Volumetric testing frequency: Semi-annual. Volumetric testing method: Transit-time ultrasonic. Percent of import supply tested and/or calibrated: 100%

#	Water Audit Input	Recom Scale	Basis of Input Derivation	Basis of Data Validity Grade
			Comments: Input derivation from supporting documents confirmed. Exclusion of non-potable volumes confirmed. Difference in purchased wat er volume in SDs from water use survey.	Comments: No additional comments.
Ln 14a	Treated Purchased Water Meter Accuracy	3.5	Input derivation: Simple average from calibration results. Comments: For future audits, it is recommended to use the weighted average based on percent of source flow rather than a simple average.	Import meter read frequency: Daily. Import meter read method: Automatic logging via SCADA telemetry. Frequency of data review for trends & anomalies: Monthly. Comments: No additional comments.
Ln 15	Treated Wholesale Water Sales	3.5	Export meter profile: 9 export connections/customers Comments: Input derivation from supporting documents confirmed. Exclusion of non-potable volumes confirmed. Exclusion from BMAC input confirmed.	Percent of export supply metered: 100% Signal calibration frequency: None. Volumetric testing frequency: Annual. Volumetric testing method: Transit-time ultrasonic. Percent of export supply tested and/or calibrated: 100% Comments: No additional comments.
Ln 15a	WE Master Meter & Supply Error Adjustment	3.5	Input derivation: Simple average from accuracy test results. Comments: For future audits, it is recommended to use the weighted average based on percent of source flow rather than a simple average.	Export meter read frequency: Daily. Export meter read method: Automatic logging via SCADA telemetry. Frequency of data review for trends & anomalies: Monthly. Comments: No additional comments.
Ln 17	Billed metered	2.5	Customer meter profile: Age profile: Conversion to AMI less than a year ago Reading system: AMI. Read frequency: Monthly. Comments: Lag-time correction is not employed in input derivation. Input derivation from supporting documents confirmed. Exclusion of non-potable volumes confirmed. 	Percent of customers metered: 100% Small meter testing policy: Reactive - complaint based or flagged-consumption testing only. Number of small meters tested/year: Not quantified, but known to be small. Large meter testing policy: Reactive - complaint based or flagged-consumption testing only. Number of large meters tested/year: Not quantified, but known to be small. Meter replacement policy: Upon failure only. Number of replacements/year: Not quantified, but known to be small. Billing data auditing: Standard billing QC, plus review of volumes by use type each billing cycle. Financial auditor performs sampling review on select accounts each year. Comments: anything 2” is large meter

#	Water Audit Input	Recom Scale	Basis of Input Derivation	Basis of Data Validity Grade
Ln 18	Billed unmetered	n/a	n/a	n/a
Ln 19	Unbilled metered	n/a	Profile: It is believed that some flushing is metered, but not quantified in supporting data or verified on call. Input derivation: Direct from meter readings. Comments: For future audits, track and report any unbilled metered consumption	Policy for billing exemptions: No policy established at this time. Comments: No additional comments.
Ln 20	Unbilled unmetered	5	Profile: Operational flushing and fire department usage. Comments: Compared to 2019 unbilled unmetered consumption, 2020 volume seems low.	Comments: Default grade applied.
Ln 23	Average Customer Meter Accuracy	2.5	See BMAC comments regarding meter testing & replacement activities. Input derivation: Rudimentary estimate. Comments: No additional comments.	Characterization of meter testing: Limited (upon request AND consumption flag only). Characterization of meter replacement: Limited (upon failure only). Comments: No additional comments.
Ln 25	Systematic data handling errors	2.5	Comments: Default input applied.	Comments: Default grade applied.
Ln 26	Unauthorized consumption	5	Comments: Default input applied.	Comments: Default grade applied.
Ln 28	Reported Breaks and Leaks	3.5	How are surfacing leak events documented, if at all? Work order issued. How was the estimated volume entered into Line 28 derived? Visual estimate. Main breaks – measuring cups to estimate run time, mobile app for field crew as well. What percent of the surfacing leaks are repaired? >90% What is the average time from call-to-repair? Undetermined How was the estimated volume entered into Line 28 derived? Undetermined	
Ln 29	Unreported Losses	2.5	What is the frequency and extent of proactive leak detection performed to find non-surfacing leaks? Undetermined How are proactive leak detection activities and results documented? Undetermined	

#	Water Audit Input	Recom Scale	Basis of Input Derivation	Basis of Data Validity Grade
			What activities are included in the proactive leak detection efforts (basic sounding and correlation, DMAs and flow monitoring, other)? Undetermined To what extent are a real loss component analysis and economic level of leakage assessment conducted? Undetermined	
Ln 40	Retail Price of Water	4.5	Input derivation: Total consumptive revenue divided by Billed Metered Authorized Consumption. Sewer charges are not based on water meter readings. Sewer revenues are not incorporated into calculation. Comments: No additional comments.	Characterization of calculation: Weighted average composite of all rates. Input calculations have not been reviewed by an M36 water loss expert. Comments: No additional comments.
Ln 43	Variable production cost	2.5	Supply profile: Own sources and import supply. Primary costs included: Treatment chemicals, supply & distribution power, and purchase costs. Secondary costs included: None currently included. Comments: total water produced (chemical and electrical)	Characterization of calculation: Primary costs only. Input calculations have not been reviewed by an M36 water loss expert. Comments: No additional comments.

Texas Water Loss Audit - Level 1 Validation Report

Validator Provided

Audit Information:

Utility: City of Ladonia PWS ID: 740004

System Type: Potable Audit Period: 1/1/2020 – 12/31/2020

Utility Representation: Dana Burkett

Validation Date: 7/22/2021 Supporting Documents Provided: Yes

Validation Findings & Confirmation Statement:

Key Audit Metrics:	Pre-Validation	Post-Validation
Total Assessment Score:	44	35
ILI:	Not calculated	Not calculated
Real Loss:	132.18 (gal/conn/day)	73.0 (gal/conn/day)
Apparent Loss:	3.5 (gal/conn/day)	3.5 (gal/conn/day)

Validator Information:

Water Audit Validator: Drew Blackwell Validator Qualifications: Contractor for TWDB

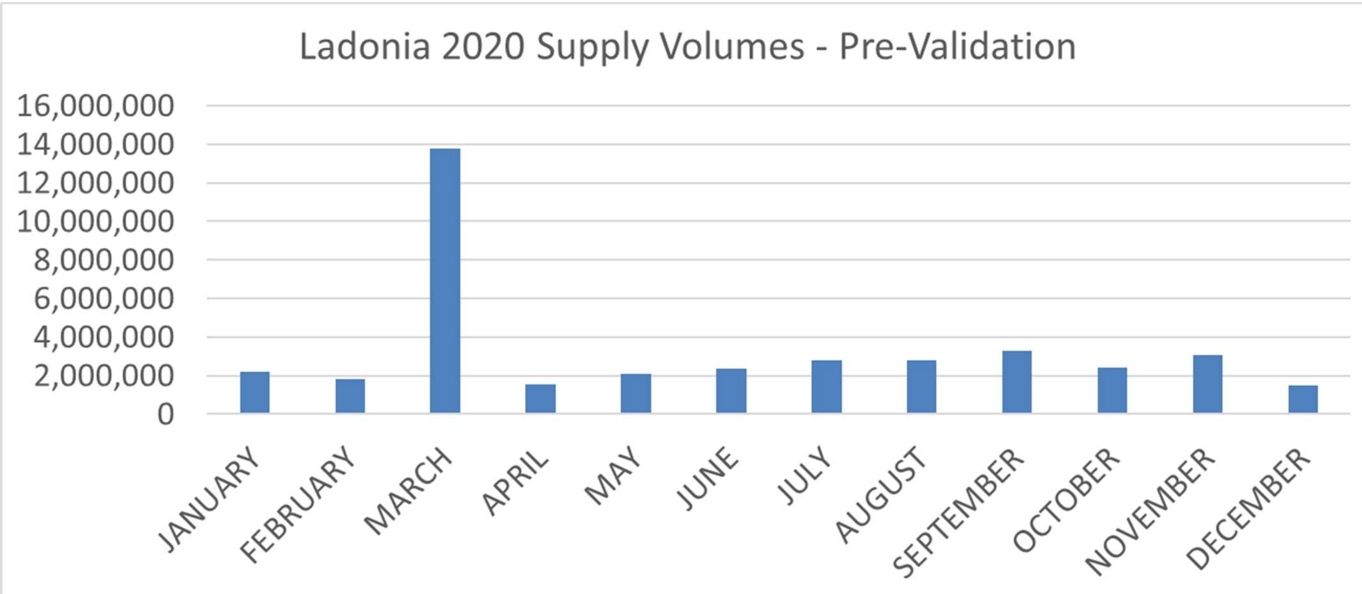
Summary Recommendations for Utility Next Steps

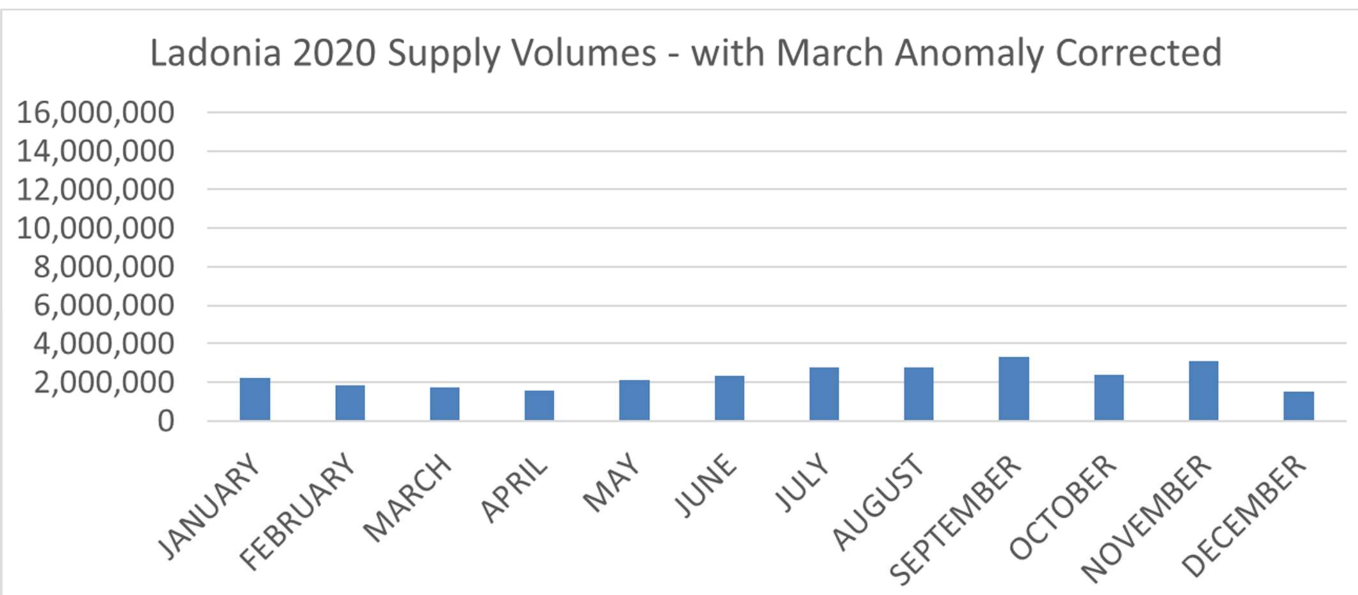
- Continue to improve understanding of Supply Meter (wells) Master Meter Error: consider adopting the rigor of a source meter volumetric testing and calibration program, informed by the guidance provided in AWWA Manual M36 – Appendix A.
- Level 2 validation on raw data for Billed Metered Authorized Consumption to determine and resolve any instances of potable volume duplication or inclusion of volumes not applicable to this category.
- The real losses are relatively high, so additional auditing focus will be worthwhile. The calculation of the variable production cost (the cost in which real loss value is determined) should be reviewed. If the real losses continue to show elevated values a leakage detection survey should be considered.

Summary of Pre- and Post-Validation Entries

#	Water Audit Input	*AWWACode*	Assessment Scale		Post-Validation Input Revision (if applicable)
			Pre-Val	Post-Val	
Ln 6	Utility's Length of main lines	*Lm*	2	2	
Ln 7	Total Retail Metered Connections – Active and Inactive	*Nc*	2	2	
Ln 10	Average Yearly System Operating Pressure	*AOP*	2	2	
Ln 13	Produced Water	*VOS*	3.5	1	It was confirmed that volumetric accuracy testing has not been performed on supply meters. An anomaly was identified in the March 2020 data which improbably overstated the supply volume. An estimated supply volume for March was used based on typical supply patterns, resulting in a Produced Water volume of 27.5958 MG (12.027 MG lower than the pre-validation volume). See next page for detail.
Ln 13a	Production Meter Accuracy	*VOSEA*	2.5	2.5	
Ln 14	Treated Purchased Water	*WI*	2	n/a	
Ln 14a	Treated Purchased Water	*WIEA*	2	n/a	
Ln 15	Treated Wholesale Water Sales	*WE*	2	n/a	
Ln 15a	WE Master Meter & Supply Error Adjustment	*WEEA*	2	n/a	
Ln 17	Billed metered	*BMAC*	2.5	2.5	
Ln 18	Billed unmetered	*BUAC*	2	2	
Ln 19	Unbilled metered	*UMAC*	2	2	
Ln 20	Unbilled unmetered	*UUAC*	2.5	2.5	
Ln 23	Average Customer Meter Accuracy	*CMI*	2.5	2.5	
Ln 25	Systematic data handling errors	*SDHE*	2	2	
Ln 26	Unauthorized consumption	*UC*	0.5	0.5	
Ln 28	Reported Breaks and Leaks		1	1	
Ln 29	Unreported Losses		2	2	
Ln 40	Retail Price of Water	*CRUC*	2	2	
Ln 43	Variable production cost	*VPC*	5	2.5	Initial variable production cost is high for a system producing its own water. The

#	Water Audit Input	*AWWACode*	Assessment Scale		Post-Validation Input Revision (if applicable)
			Pre-Val	Post-Val	
					calculated rate should be reviewed to at least power and chemical treatment costs.





Texas Water Loss Audit - Level 1 Validation Report

Validator Provided

Audit Information:

Utility: City of Marshall

PWS ID: 1020002

System Type: Potable

Audit Period: CY2020

Utility Representation: James McClendon

Validation Dates: 4/28/2021; 6/15/2021

Supporting Documents Provided: Yes

Validation Findings & Confirmation Statement:

Key Audit Metrics:	Pre-Validation	Post-Validation
Total Assessment Score:	0	47.5
ILI:	0	3.59
Real Loss:	0 (gal/conn/day)	74.21 (gal/conn/day)
Apparent Loss:	0 (gal/conn/day)	7.10 (gal/conn/day)

Validator Information:

Water Audit Validator: Isabel Szendrey, P.E.

Validator Qualifications: Contractor for TWDB

Summary Recommendations for Utility Next Steps

- Improved understanding of Supply Meter (Own or Import) Master Meter Error: consider adopting or increasing the rigor of a source meter volumetric testing and calibration program, informed by the guidance provided in AWWA Manual M36 – Appendix A.
- Investigate the Fire Hydrant and Other categories of the authorized consumption to confirm the appropriate categories for these volumes.
- Level 2 validation on raw data for Billed Metered Authorized Consumption to determine and resolve any instances of potable volume duplication or inclusion of volumes not applicable to this category.
- Improved estimation of CMI: consider a customer meter testing program which tests a sample of random meters whose stratification (by size, age, or other characteristics) represents the entire customer meter stock.
- Recommend to calculate the Customer Retail Unit as total consumptive revenue for water (and sewer if applicable) divided by BMAC, converted for units as needed.
- Recommend for next audit to calculate the Variable Production Cost by determining the annual expenses for expense categories that may vary with water production (usually electric power, treatment chemicals) and dividing by the total production.

Summary of Pre- and Post-Validation Entries

#	Water Audit Input	*AWWA Code*	Assessment Scale		Post-Validation Input Revision (if applicable)
			Pre-Val	Post-Val	
Ln 6	Utility's Length of main lines	*Lm*	0	2.5	
Ln 7	Total Retail Metered Connections – Active and Inactive	*Nc*	0	3	10,762
Ln 10	Average Yearly System Operating Pressure	*AOP*	0	1.5	75 psi
Ln 13	Produced Water	*VOS*	0	2.5	1,400,869,200 gal
Ln 13a	Production Meter Accuracy	*VOSEA*	0	1.5	98
Ln 14	Treated Purchased Water	*WI*	0	n/a	
Ln 14a	WI Master Meter & Supply Error Adjustment	*WIEA*	0	n/a	
Ln 15	Treated Wholesale Water Sales	*WE*	0	1.5	
Ln 15a	WE Master Meter & Supply Error Adjustment	*WEEA*	0	0.5	98
Ln 17	Billed metered	*BMAC*	0	1.5	1,054,996,000 gal
Ln 18	Billed unmetered	*BUAC*	0	5	
Ln 19	Unbilled metered	*UMAC*	0	4	9,553,000 gal
Ln 20	Unbilled unmetered	*UUAC*	0	2.5	
Ln 23	Average Customer Meter Accuracy	*CMI*	0	1.5	2%
Ln 25	Systematic data handling errors	*SDHE*	0	2.5	
Ln 26	Unauthorized consumption	*UC*	0	2.5	
Ln 28	Reported Breaks and Leaks		0	3.5	24,689,050
Ln 29	Unreported Losses		0	0.5	
Ln 40	Retail Price of Water	*CRUC*	0	0.5	$8.92 / kgal
Ln 43	Variable production cost	*VPC*	0	0.5	$410 / MG

Validation Review Notes

#	Water Audit Input	*Recom Scale*	Basis of Input Derivation	Basis of Data Validity Grade
Ln 6	Utility's Length of main lines	2.5	Input derivation: GIS data exists, but a lot of information comes from index cards. Hydrant leads included: Uncertain. Comments: Most of the information for GIS was obtained from plans.	Mapping format: Combination of paper and digital Asset management database: Unknown Map updates & field validation: Accomplished through normal work order processes. Comments: No additional comments.
Ln 7	Total Retail Metered Connections – Active and Inactive	3	Input derivation: Standard report run from billing system. Basis for database query: Meter ID - non-premise based. Comments: Audit showed 9,302, but a higher number of 'meters' indicated on the supporting documentation. Value was revised to number of meters: 10,762.	CIS updates & field validation: Accomplished through normal meter reading processes. Estimated error of total count within: 3%. Comments: No additional comments.
Ln 10	Average Yearly System Operating Pressure	1.5	Number of zones, general profile: One pressure zone Typical pressure range: 40-93 psi Input derivation: Inferred from observations of pressure readings in field or review of pressure measurements. Comments: Data is collected at 3 pressure gages.	Extent of static pressure data collection: Pressure is measured in the field based on complaints. Characterization of real-time pressure data collection: Real-time monitoring limited to WTP and two storage tanks. Hydraulic model: Uncertain Comments: No additional comments.
Ln 13	Produced Water	2.5	Supply meter profile: One effluent meter at the Water Treatment Plant. VOS input derived from: SCADA reads from production meters as archived. Comments: Input derivation from supporting documents confirmed. Supporting data was used to compute a revised supply volume. Details on the computation provided below. Exclusion of non-potable volumes confirmed. The Water Audit Report had a *Produced Water* value of 2,388,333,000 gallons. This was significantly greater than the reported *Volume of Water Intake* at 1,517,205,000 gallons. Not determined where the reported *Produced Water* value came from. SWMOR data was provided after the validation call. The SWMOR showed daily values of treated and raw water as well as monthly summaries. Several anomalies were identified: • Treated water was greater than raw water during the months of June, July, and August. • No production was reported from September 26 to October 16 (total of 21 days). Total reported volumes for these months were not adjusted to account for production volumes during this period. Raw water volumes remained within similar ranges as the other months, so production appears to have stayed within usual volumes.	Percent of own supply metered: 100% Signal calibration frequency: Annual. Volumetric testing frequency: None. Volumetric testing method: n/a. Percent of own supply tested and/or calibrated: 100% Comments: Limiting criteria for DVG is availability of testing/calibration documentation.

#	Water Audit Input	*Recom Scale*	Basis of Input Derivation	Basis of Data Validity Grade

- Lower than average production was reported from October 17 to November 30 (total of 45 days).

A revised supply volume was calculated to mitigate the data anomalies. The following table presents the reported and the revised values. The recommended value for **Produced Water** for 2020 is **1,400.869 MG**.

	As reported			REVISED
Month	**Raw Water Pumpage (MG)**	**Treated Water Pumpage (MG)**	**Treated Water Pumpage Average (MGD)**	**Treated Water Pumpage (MG)**
January	142.228	137.053	4.421	137.053
February	116.851	116.623	4.021	116.623
March	114.195	98.235	3.169	98.235
April	107.400	101.405	3.380	101.405
May	148.108	112.271	3.622	112.271
June	124.872	126.387	4.213	126.387
July	126.183	127.353	4.108	127.353
August	128.544	128.921	4.159	128.921
September	119.591	100.406	4.016	***120.487***
October	153.691	35.357	2.357	***120.933***
November	108.366	79.595	2.653	***95.075***
December	127.176	116.126	3.746	116.126
Total	**1,517.205**	**1,279.732**		**1,400.869**

A revised production data was estimated for the months of September, October, and November. Revisions were computed as follows:

- Assumed an average production of 4.016 MGD (average daily flow for September) for 5 days in September for an additional monthly volume of 20.08 MG.
- Assumed a daily average production of 3.901 MGD (daily average from January to September) for 16 days in October for an additional volume of 62.416 MG.
- Calculated the difference between the average production of 3.901 MGD and the under-reported average production for 15 days in October. The estimated additional monthly volume was 23.16 MG for October.
- For November, the assumed average daily production was 3.169 MGD – the average production for March 2020, a rainy month similar to November. The under-reported volume was then calculated as the difference between 3.169 MGD and the under-reported average production for 30 days in November. The estimated additional monthly volume was 15.48 MG for November.

#	Water Audit Input	*Recom Scale*	Basis of Input Derivation	Basis of Data Validity Grade
			The total estimated under-reported production volume for 2020 was 121.14 MG. This represents about 9% increase from the annual total of the reported values. And, the estimated annual production is 40% less than the production value originally reflected in the water audit.	
Ln 13a	Production Meter Accuracy	1.5	Input derivation: Assumed same accuracy as last year's report. Net storage change included in MMSEA input: No. Comments: No additional comments.	Supply meter read frequency: Daily. Supply meter read method: Automatic logging via SCADA telemetry. Frequency of data review for trends & anomalies: Each business day. Storage levels monitored in real-time: Yes. Comments: Net storage change as limiting criteria for DVG.
Ln 14	Treated Purchased Water	n/a	Import meter profile: No treated water purchases	n/a
Ln 14a	WI Master Meter & Supply Error Adjustment	n/a	n/a	n/a
Ln 15	Treated Wholesale Water Sales	1.5	Export meter profile: A total of 6 wholesale connections. Comments: Input derivation from supporting documents confirmed. Exclusion of non-potable volumes confirmed. Exclusion from BMAC input confirmed.	Percent of export supply metered: 100% Signal calibration frequency: Not applicable given no signal output from supply meters. Volumetric testing frequency: Unknown Volumetric testing method: n/a. Percent of export supply tested and/or calibrated: Unknown Comments: No additional comments.
Ln 15a	WE Master Meter & Supply Error Adjustment	0.5	Input derivation: Assumed same value as last year's report. Comments: No additional comments.	Export meter read frequency: Monthly. Export meter read method: Manual. Frequency of data review for trends & anomalies: Monthly. Comments: No additional comments.
Ln 17	Billed metered	1.5	Customer meter profile: Age profile: 20 years old on average Reading system: Mixture of AMR and Manual (most of them)	Percent of customers metered: 100% Small meter testing policy: Unknown. Number of small meters tested/year: Unknown

#	Water Audit Input	*Recom Scale*	Basis of Input Derivation	Basis of Data Validity Grade
			Read frequency: Monthly. Comments: Lag-time correction is not employed in input derivation. Input derivation from supporting documents confirmed. Exclusion of non-potable volumes confirmed. Value excludes Hydrant category. It was assumed this was unbilled and unmetered. Recommending confirming correct category for this value for future. Derivation notes: The total Authorized Consumption reported in the water audit was 1,063,453,000 gallons – all in the *Billed Metered* category. Not determined where that value came from. The following billing summary data was provided in a scanned pdf file. Several of the total values shown in the scan were not equivalent to the calculated total of the values that were being summed, but the differences were not significant. The table below shows the correct total addition for all categories. The total ***Billed Metered Authorized Consumption*** is calculated at **1,054,996,000** gallons by subtracting the wholesale volume and Fire Hydrant Volume from the total billed volume in the table below. The Fire Hydrant volume is assumed to be part of the Unbilled Unmetered Authorized Consumption, but this category should be further investigated for future reports. It should be confirmed that all other categories of the table apply to the BMAC.	Large meter testing policy: Unknown Number of large meters tested/year: Unknown Meter replacement policy: Unknown Number of replacements/year: Unknown Billing data auditing: Unknown Comments: No additional comments.

Month	Billed/ Rts	Norit	BICC	*Wholesale customers*						Fire Hydrants	*Subtotal Wholesale*	*Billed Subtotal Excluding Wholesale, Fire Hydrants*	Total (all billed water, Excluding Fire Hydrants)
				Leigh	Talley	Cypress	Blocker	Gill	Scotts ville				
Jan	58,185	39,258	1,120	1,911	0	0	0	0	0	0	*1,911*	*98,563*	100,474
Feb	49,802	50,876	882	2,858	337	0	0	0	0	0	*3,195*	*101,560*	104,755
Mar	53,212	35,058	882	1,820	0	0	0	54	0	0	*1,874*	*89,152*	91,026
Apr	46,470	21,281	976	1,234	0	0	0	0	0	20	*1,234*	*68,727*	69,961
May	51,493	21,517	865	1,342	471	33	0	0	0	20	*1,846*	*73,875*	75,721
Jun	64,974	23,182	1,193	2,949	1	0	0	0	0	31	*2,950*	*89,349*	92,299
Jul	77,404	20,849	1,783	2,700	0	0	0	69	0	915	*2,769*	*100,036*	102,805
Aug	73,966	22,447	1,703	351	333	0	0	0	0	498	*684*	*98,116*	98,800
Sep	78,330	25,587	1,234	327	0	7	0	137	0	62	*471*	*105,151*	105,622
Oct	60,912	25,223	1,333	88	29	54	0	0	0	63	*171*	*87,468*	87,639
Nov	57,884	12,017	1,737	309	84	0	0	0	0	448	*393*	*71,638*	72,031
Dec	58,949	11,291	1,121	252	1,300	0	0	0	0	15	*1,552*	*71,361*	72,913
Total	731,581	308,586	14,829	16,141	2,555	94	0	260	0	2,072	*19,050*	*1,054,996*	1,074,046

#	Water Audit Input	*Recom Scale*	Basis of Input Derivation	Basis of Data Validity Grade
Ln 18	Billed unmetered	5	Profile: None	n/a
Ln 19	Unbilled metered	4	Profile: City and own facilities. The billing report included an "Other" category. Input derivation: Direct from meter readings. Comments: Input derivation from supporting documents confirmed. Recommendation to investigate what uses are included in the "Other" category to confirm the correct category for this volume. Input recommended to be 9,553,000 as totaled on the supporting documentation.	Policy for billing exemptions: Limited to own facilities. Comments: No additional comments.
Ln 20	Unbilled unmetered	2.5	Profile: Default input applied Comments: No additional comments.	Comments: Default grade applied.
Ln 23	Average Customer Meter Accuracy	1.5	See BMAC comments regarding meter testing & replacement activities. Input derivation: Rudimentary estimate. Assumed same value as last year's report. Comments: No additional comments.	Characterization of meter testing: Limited (upon request AND consumption flag only). Characterization of meter replacement: Limited (upon failure only). Comments: No additional comments.
Ln 25	Systematic data handling errors	2.5	Comments: Default input applied.	Comments: Default grade applied.
Ln 26	Unauthorized consumption	2.5	Comments: Default input applied.	Comments: Default grade applied.
Ln 28	Reported Breaks and Leaks	3.5	How are surfacing leak events documented, if at all? How was the estimated volume entered into Line 28 derived? Monthly reports estimate this volume. What percent of the surfacing leaks are repaired? Close to 100% What is the average time from call-to-repair? Assumed to be about or less than a week. How was the estimated volume entered into Line 28 derived?	Monthly reports estimate this value, but uncertain on the method. And no computerized maintenance management system used to document leak repair trends.
Ln 29	Unreported Losses	0.5	What is the frequency and extent of proactive leak detection performed to find non-surfacing leaks? No active leak detection How are proactive leak detection activities and results documented? What activities are included in the proactive leak detection efforts (basic sounding and correlation, DMAs and flow monitoring, other)? To what extent are a real loss component analysis and economic level of leakage assessment conducted?	Active leak detection not currently conducted

#	Water Audit Input	*Recom Scale*	Basis of Input Derivation	Basis of Data Validity Grade
Ln 40	Retail Price of Water	0.5	Input derivation: Assumed same value as last year since rates have not changed. Sewer charges are assumed to be based on water meter readings, but not incorporated to this input. Comments: Recommend for next audit to derive as total consumptive revenue for water (and sewer if applicable) divided by BMAC, converted for units as needed.	Characterization of calculation: Estimate. Input calculations have not been reviewed by an M36 water loss expert. Comments: Lowest grade assigned since there was not data to support the value used.
Ln 43	Variable production cost	0.5	Supply profile: Own sources only. Primary costs included: Assumed same value as last year since there has not been significant changes to the operation. Secondary costs included: N/a - input is estimated. Comments: Recommend for next audit to calculate this value by determining annual expenses for variable expense categories (usually electric power, treatment chemicals) and dividing by the total production.	Characterization of calculation: Primary costs only. Input calculations have not been reviewed by an M36 water loss expert. Comments: Grade by lack of data to determine this value.

Texas Water Loss Audit - Level 1 Validation Report

Validator Provided

Audit Information:

Utility: City of Plainview PWS ID: TX0950004

System Type: Potable Audit Period: 1/1/2020 – 12/31/2020

Utility Representation: Paul Kite

Validation Date: 6/23/2021 Call Time: 1:00 pm Central Time Supporting Documents Provided: Yes

Validation Findings & Confirmation Statement:

Key Audit Metrics:	**Pre-Validation**	**Post-Validation**
Total Assessment Score:	78	70
ILI:	1.35	0.97
Real Loss:	20.25 (gal/conn/day)	14.62 (gal/conn/day)
Apparent Loss:	16.09 (gal/conn/day)	16.14 (gal/conn/day)

Validator Information:

Water Audit Validator: Drew Blackwell Validator Qualifications: Contractor for TWDB

Summary Recommendations for Utility Next Steps

- Provide supply data per meter per month. Supply data at this detail allows for a weighted average for supply meter test results per percent of source flow at each meter.
- Confirm if backwash meter (Fuji Time Delta – C, Serial Number: NBF1265) is reporting flow after the water has entered the distribution system. If so, it should be accounted for as Unbilled Metered Authorized Consumption.
- Develop a customized estimate of Unbilled Unmetered Authorized Consumption: consider producing itemized, agency-specific estimates of unbilled unmetered (operational) uses, rather than using the default. Ensure leakage estimates are excluded.
- Develop and improved estimation of CMI: consider a customer meter testing program which tests a sample of random meters whose stratification (by size, age, or other characteristics) represents the entire customer meter stock.

Industrial Blvd
E 34th St
1767
Quincy Tower
87
N Columbia St
E 24th St
T
Andy Taylor Rd
Kokomo Pump Station
Holiday Tower
Treatment Plant Pump Station
2286
Smythe Tower
Well #22
194
Marshall Formby Memorial Hwy
Ennis St
W 5th St
70
27
N Date St
Well #20
Prison Tower
400
SW 3rd St
SW 3rd Street Pump Station
S Date St
US Hwy 70
789
US 87 Bus
Google Earth
N
1 mi

Summary of Pre- and Post-Validation Entries

#	Water Audit Input	*AWWA Code*	Assessment Scale		Post-Validation Input Revision (if applicable)
			Pre-Val	Post-Val	
Ln 6	Utility's Length of main lines	*Lm*	4.5	X	
Ln 7	Total Retail Metered Connections – Active and Inactive	*Nc*	4.5	X	
Ln 10	Average Yearly System Operating Pressure	*AOP*	4	X	
Ln 13	Produced Water	*VOS*	4	3.5	
Ln 13a	Production Meter Accuracy	*VOSEA*	4	2.5	Changed from 98% to 100%. Meter accuracy inconclusive without understanding percent of source flow attributed to each meter.
Ln 14	Treated Purchased Water	*WI*	n/a	n/a	
Ln 14a	Treated Purchased Water	*WIEA*	n/a	n/a	
Ln 15	Treated Wholesale Water Sales	*WE*	n/a	n/a	
Ln 15a	WE Master Meter & Supply Error Adjustment	*WEEA*	n/a	n/a	
Ln 17	Billed metered	*BMAC*	4	4	Changed 1,083,061,000 gal to 1,079,245,000 gal based on supporting documentation.
Ln 18	Billed unmetered	*BUAC*	3	n/a	
Ln 19	Unbilled metered	*UMAC*	3	3	Changed from 4,961,167 gal to 650,000 gal. 4961167 could not be traced in supporting documentation but presumed to be backwash meter at plant.
Ln 20	Unbilled unmetered	*UUAC*	2.5	2.5	
Ln 23	Average Customer Meter Accuracy	*CMI*	3	1.5	
Ln 25	Systematic data handling errors	*SDHE*	4	2.5	Changed from 0 gallons to 0.25% of revised BMAC volume: 1,079,245,000 X 0.0025 = 2,698,112 gallons
Ln 26	Unauthorized consumption	*UC*	2.5	2.5	
Ln 28	Reported Breaks and Leaks		4	4	
Ln 29	Unreported Losses		2	2	
Ln 40	Retail Price of Water	*CRUC*	4.5	4.5	
Ln 43	Variable production cost	*VPC*	4.5	4.5	

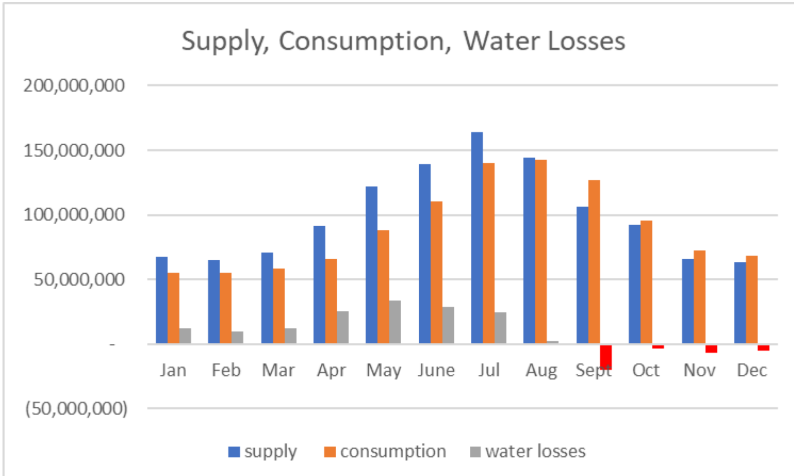
Validation Review Notes

#	Water Audit Input	Recom Scale	Basis of Input Derivation	Basis of Data Validity Grade
Ln 6	Utility's Length of main lines	4.5	Input derivation: Totaled from GIS based map. Hydrant leads included: Uncertain. Comments: No additional comments.	Mapping format: Digital. Asset management database: In place and integrated with GIS system. Map updates & field validation: Accomplished through normal work order processes. Comments: No additional comments.
Ln 7	Total Retail Metered Connections – Active and Inactive	4.5	Input derivation: Standard report run from billing system. Basis for database query: Undetermined Comments: No additional comments.	CIS updates & field validation: Accomplished through normal meter reading processes. Estimated error of total count within: Undetermined Comments: No additional comments.
Ln 10	Average Yearly System Operating Pressure	4	Number of zones, general profile: Undetermined Typical pressure range: 50-56 Input derivation: Inferred from observations of pressure readings in field or review of pressure measurements. Comments: No additional comments.	Extent of static pressure data collection: Undetermined Characterization of real-time pressure data collection: Undetermined Hydraulic model: Undetermined Comments: No additional comments.
Ln 13	Produced Water	3.5	Supply meter profile: Wells 4, 19, 20, 21, and 22 feed to distribution system (Wells 4 and 19 out of service) Remaining wells feed to ground storage or booster stations. Raw water also purchased and treated at WTP (from Canadian) at plant considered Produced Water. VOS input derived from: Undetermined if well volumes are from manual or automatic reads. Monthly well volumes combined. Un determined if there is a single effluent meter at WTP or multiple. Comments:	Percent of own supply metered: 100% Signal calibration frequency: None. Volumetric testing frequency: Annual. Volumetric testing method: Transit-time ultrasonic. Percent of own supply tested and/or calibrated: Not determined. Recommended to determine for next audit submittal. Comments: Wells 11, 13, 16, 18, 20, 21, and 22 volumetrically tested in 2020. Remaining well tests in reporting year did not produce results or deemed untestable. No record of electronic calibration is limiting factor.
Ln 13a	Production Meter Accuracy	2.5	Input derivation: Not computed. Undetermined what percent of source flow attributed to each meter. Net storage change included in MMSEA input: No. Comments: No additional comments.	Supply meter read frequency: Presumed daily Supply meter read method: Undetermined Frequency of data review for trends & anomalies: Presumed at least monthly Storage levels monitored in real-time: Undetermined. Comments: No additional comments.

<table>
<tr><td>Ln 14</td><td>Treated Purchased Water</td><td>n/a</td><td>n/a</td><td>n/a</td></tr>
<tr><td>Ln 14a</td><td>Treated Purchased Water</td><td>n/a</td><td>n/a</td><td>n/a</td></tr>
<tr><td>Ln 15</td><td>Treated Wholesale Water Sales</td><td>n/a</td><td>n/a</td><td>n/a</td></tr>
<tr><td>Ln 15a</td><td>WE Master Meter & Supply Error Adjustment</td><td>n/a</td><td>n/a</td><td>n/a</td></tr>
<tr><td>Ln 17</td><td>Billed metered</td><td>4</td><td>Customer meter profile: Significant portion of meter population at 20+ years
AGE OF METERS BASED ON INSTALL DATE
<table>
<tr><th>SIZE</th><th>1-3 YEARS OLD</th><th>4-6 YEARS OLD</th><th>7-10 YEARS OLD</th><th>11-15 YEARS OLD</th><th>16-20 YEARS OLD</th><th>20+ YEARS OLD</th><th>UNKNOWN YEARS OLD</th></tr>
<tr><td>IRRIGATION</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>12</td><td>11</td><td>3</td><td>26</td><td>6</td><td>2</td><td>24</td></tr>
<tr><td>3/4"</td><td>13</td><td>9</td><td>7</td><td>6</td><td>17</td><td>98</td><td>9</td></tr>
<tr><td>1"</td><td>22</td><td>37</td><td>28</td><td>37</td><td>61</td><td>63</td><td>16</td></tr>
<tr><td>1 1/2"</td><td>4</td><td>4</td><td>4</td><td>12</td><td>8</td><td>7</td><td>4</td></tr>
<tr><td>2"</td><td>5</td><td>8</td><td>2</td><td>4</td><td>6</td><td>14</td><td>3</td></tr>
<tr><td>3"</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>2</td><td>0</td></tr>
<tr><td>4"</td><td>2</td><td>2</td><td>3</td><td>1</td><td>1</td><td>3</td><td>1</td></tr>
<tr><td>6"</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td></tr>
<tr><td>TOTAL</td><td>59</td><td>71</td><td>47</td><td>86</td><td>99</td><td>190</td><td>57</td></tr>
<tr><td>WATER</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>15</td><td>4</td><td>50</td><td>38</td><td>21</td><td>94</td><td>35</td></tr>
<tr><td>3/4"</td><td>477</td><td>830</td><td>571</td><td>1531</td><td>1208</td><td>6373</td><td>1165</td></tr>
<tr><td>5/8"</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>11</td><td>0</td></tr>
<tr><td>1"</td><td>46</td><td>110</td><td>72</td><td>131</td><td>159</td><td>335</td><td>40</td></tr>
<tr><td>1 1/2"</td><td>17</td><td>22</td><td>12</td><td>36</td><td>76</td><td>64</td><td>44</td></tr>
<tr><td>2"</td><td>20</td><td>33</td><td>17</td><td>21</td><td>46</td><td>48</td><td>24</td></tr>
<tr><td>3"</td><td>5</td><td>3</td><td>1</td><td>6</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>4"</td><td>7</td><td>3</td><td>7</td><td>5</td><td>9</td><td>4</td><td>1</td></tr>
<tr><td>6"</td><td>4</td><td>1</td><td>5</td><td>1</td><td>3</td><td>3</td><td>3</td></tr>
<tr><td>8"</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>TOTAL</td><td>592</td><td>1006</td><td>735</td><td>1770</td><td>1524</td><td>6933</td><td>1312</td></tr>
<tr><td></td><td>651</td><td>1077</td><td>782</td><td>1856</td><td>1623</td><td>7123</td><td>1369</td></tr>
</table>
Age profile:
Reading system: Manual or mix of manual and AMR/AMI.
Read frequency: Monthly.
Comments: Some minor discrepancies between the data in the Water Use Survey and the supporting documentation provided. Supporting data will be used to update WUS and Water Audit = 1,079,245,000 gallons.</td><td>Percent of customers metered: 100%
Small meter testing policy: Undetermined.
Number of small meters tested/year: Not quantified, but known to be small.
Large meter testing policy: Undetermined.
Number of large meters tested/year: Not quantified, but known to be small.
Meter replacement policy: Undetermined
Number of replacements/year: Not quantified, but known to be small.
Billing data auditing: Undetermined.
Comments: Practices and policies should be reviewed to ensure assessment grade is appropriately evaluated.</td></tr>
</table>

Audit Input	Plainview data (gal)	WUS (gal)
BMAC		
Residential - Single	592,392,000	591,236,000
Residential - Multi	76,784,000	76,326,000
Institutional	48,921,000	175,753,000
Commercial	275,380,000	133,368,000
Industrial	0	0
Ag	85,768,000	106,378,000
Total	1,079,245,000	1,083,061,000

Consider performing a lag-time correction to bring consumption volumes into the same timeframe as supply volumes for audit year.



Ln 18	Billed unmetered	4	n/a	n/a
Ln 19	Unbilled metered	3	Profile: Consumption data reports 650,000 gallons Unbilled consumption and no unmetered consumption. Backwash meter indicated in meter test results. But not volume provided. Confirm if this meter (Water Meter Type: Fuji Time Delta - C Serial Number: NBF1265) is reporting flow after the water has entered the distribution system. If so, it should be accounted for as Unbilled Metered Authorized Consumption.	Policy for billing exemptions: Undetermined but presumed to be municipal building and own facilities Comments: No additional comments.

<table>
<tr><td></td><td></td><td></td><td>
<table>
<tr><td>1000</td><td>650,000</td></tr>
<tr><td>Month</td><td>Unbilled Consumption</td></tr>
<tr><td>Oct</td><td>134</td></tr>
<tr><td>Nov</td><td>132</td></tr>
<tr><td>Dec</td><td>31</td></tr>
<tr><td>Jan</td><td>169</td></tr>
<tr><td>Feb</td><td>80</td></tr>
<tr><td>Mar</td><td>56</td></tr>
<tr><td>Apr</td><td>33</td></tr>
<tr><td>May</td><td>43</td></tr>
<tr><td>June</td><td>26</td></tr>
<tr><td>Jul</td><td>68</td></tr>
<tr><td>Aug</td><td>43</td></tr>
<tr><td>Sept</td><td>33</td></tr>
<tr><td>Oct</td><td>21</td></tr>
<tr><td>Nov</td><td>61</td></tr>
<tr><td>Dec</td><td>17</td></tr>
<tr><td>Jan</td><td>67</td></tr>
</table>

Discrepancy in unbilled metered supporting documentation 650,000 gallons versus audit entry 4,961,167 gallons

Input derivation: Direct from meter readings.
Comments: Confirm if this meter is reporting flow after the water has entered the distribution system.</td><td></td></tr>
<tr><td>Ln 20</td><td>Unbilled unmetered</td><td>2.5</td><td>Profile: Default grade applied
Comments: No additional comments</td><td>Comments: Default grade applied. Grade moved up to account for default.</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Ln 23</td><td>Average Customer Meter Accuracy</td><td>1.5</td><td>Input derivation: Rudimentary estimate.
Comments: Provide calculation of meter accuracy as supporting documentation as supplemental documentation.</td><td>Characterization of meter testing: Undetermined
Characterization of meter replacement: Undetermined
Comments: No additional comments.</td></tr>
<tr><td>Ln 25</td><td>Systematic data handling errors</td><td>2.5</td><td>Comments: Default applied in absence of data to suggest initial input of 0 gallons. 0.25% of BMAC. Used revised BMAC Volume from supporting data. 1,079,245,000 * 0.0025 = 2,698,112.500 gal</td><td>Comments: No additional comments.</td></tr>
<tr><td>Ln 26</td><td>Unauthorized consumption</td><td>2.5</td><td>Comments: Default applied</td><td>Comments: Default applied</td></tr>
</table>

Ln 28	Reported Breaks and Leaks	4	How are surfacing leak events documented, if at all? Not determined. Recommended to determine for next audit submittal. How was the estimated volume entered into Line 28 derived? Not determined. Recommended to determine for next audit submittal. What percent of the surfacing leaks are repaired? Not determined. Recommended to determine for next audit submittal. What is the average time from call-to-repair? Not determined. Recommended to determine for next audit submittal.	
Ln 29	Unreported Losses	2	What is the frequency and extent of proactive leak detection performed to find non-surfacing leaks? Not determined. Recommended to determine for next audit submittal. How are proactive leak detection activities and results documented? Not determined. Recommended to determine for next audit submittal. What activities are included in the proactive leak detection efforts (basic sounding and correlation, DMAs and flow monitoring, other)? Not determined. Recommended to determine for next audit submittal. To what extent are a real loss component analysis and economic level of leakage assessment conducted? Not determined. Recommended to determine for next audit submittal.	
Ln 40	Retail Price of Water	4.5	Input derivation: Check calc using total commodity revenue ($) divided by billed metered volume: CRUC (assuming base fees not included): 0.00511828 per gal $ 5.12 per kgal suggests that base fees may be included in revenue data and confirmed in rate fee structures. $2.18/kgal in audit appears to be composite weighted value. Comments: Sewer revenues ($1.83/kgal) are tied to water meter reads but are not incorporated in the retail price of water.	Characterization of calculation: Weighted average composite of all rates. Input calculations have not been reviewed by an M36 water loss expert. Comments: Include sewer in calculation to accurately value apparent losses since revenue is tied to water meter reads.
Ln 43	Variable production cost	4.5	Supply profile: Own sources only. Primary costs included: Treatment chemicals and supply & distribution power. Secondary costs included: pumping equipment wear & tear. Comments: Removed O&M costs and just included cost for chemical and power, debt service, and depreciation -> $907,080.15 / 1,191,465,900 = $0.000761/gal	Characterization of calculation: Primary costs plus some but not all applicable secondary costs. Input calculations have not been reviewed by an M36 water loss expert. Comments: No additional comments.

Texas Water Loss Audit - Level 1 Validation Report

Validator Provided

Audit Information:

Utility: City of San Marcos

PWS ID: 1020002

System Type: Potable

Audit Period: CY2020

Utility Representation: Jodie Jones

Validation Date: 4/27/2021 Call Time: 10:00 am

Supporting Documents Provided: Yes

Validation Findings & Confirmation Statement:

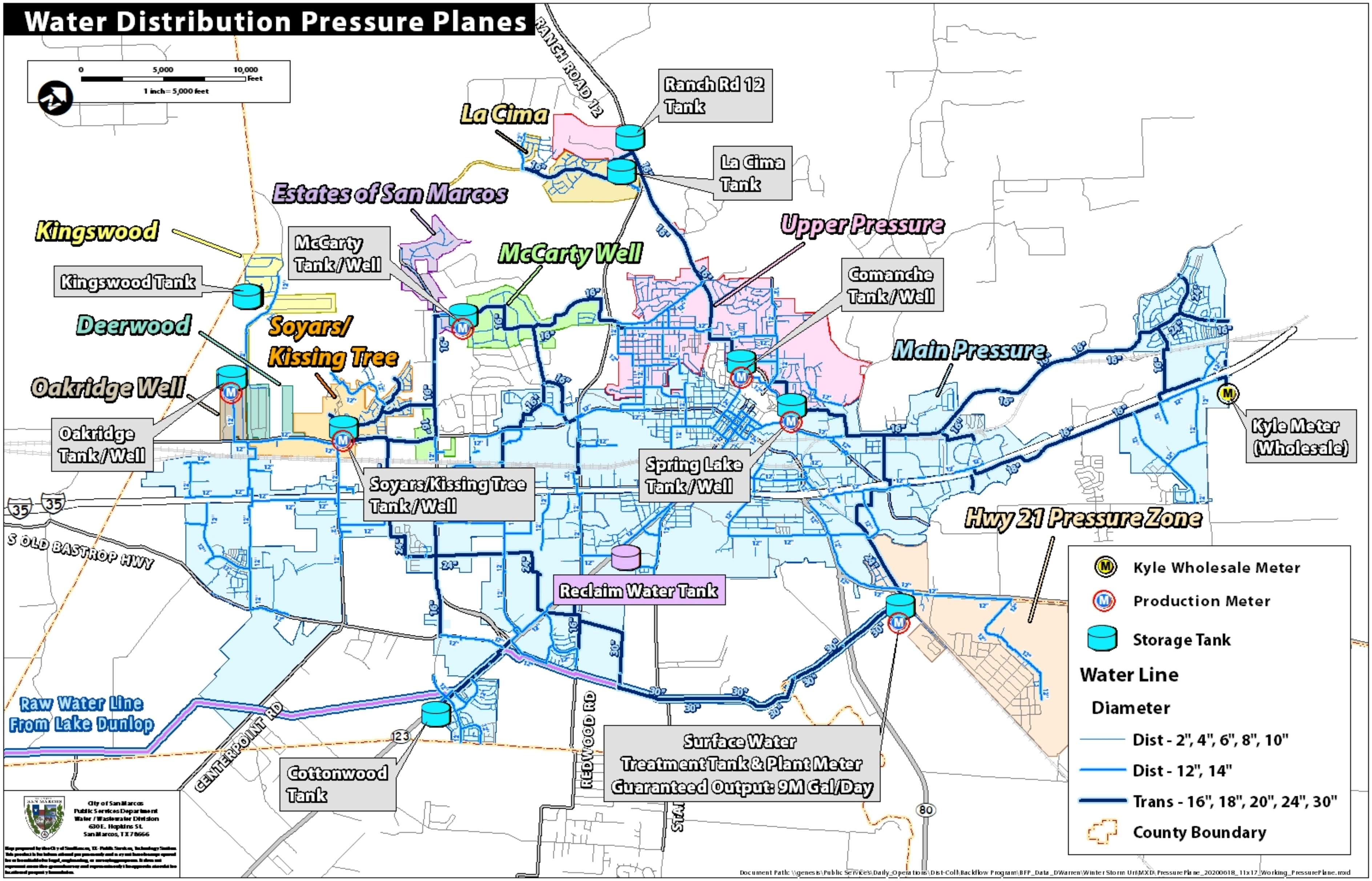
Key Audit Metrics:	Pre-Validation	Post-Validation
Total Assessment Score:	84.5	67.0
ILI:	0.99	1.04
Real Loss:	22.98 (gal/conn/day)	23.03(gal/conn/day)
Apparent Loss:	2.37 (gal/conn/day)	2.37(gal/conn/day)

Validator Information:

Water Audit Validator: Isabel Szendrey, P.E. Validator Qualifications: Contractor for TWDB

Summary Recommendations for Utility Next Steps

- Improved understanding of Supply Meter (Own or Import) Master Meter Error: consider adopting or increasing the rigor of a source meter volumetric testing and calibration program, informed by the guidance provided in AWWA Manual M36 – Appendix A.
- Calculated a weighted average for production meter accuracy. Production volumes vary significantly depending on the source of water, so differences in the production meter accuracy could have significant impact on the overall average accuracy.
- Level 2 validation on raw data for Billed/Unbilled Metered/Unmetered Authorized Consumption to determine and resolve any instances of potable volume duplication and to confirm volumes are included in the appropriate categories.
- Improved estimation of CMI: consider a customer meter testing program which tests a sample of random meters whose stratification (by size, age, or other characteristics) represents the entire customer meter stock.
- Recommend for next audit to calculate a Customer Retail Unit Cost as total consumptive revenue for water (and sewer if applicable) divided by BMAC (cell G23), converted as needed.
- Recommend for the next audit to calculate the Variable Production Costs by adding the annual expenses for expense categories that vary with water production volumes (usually electric power, treatment chemicals) and divide by the total production.


Water Distribution Pressure Planes
0
5,000
10,000
Feet
1 inch = 5,000 feet
La Cima
Ranch Rd 12 Tank
La Cima Tank
Estates of San Marcos
Kingswood
McCarty Tank/Well
McCarty Well
Upper Pressure
Kingswood Tank
Comanche Tank/Well
Deerwood
Soyars/ Kissing Tree
Main Pressure
Oakridge Well
Kyle Meter (Wholesale)
Oakridge Tank/Well
Spring Lake Tank/Well
Soyars/Kissing Tree Tank/Well
Hwy 21 Pressure Zone
Reclaim Water Tank
Raw Water Line From Lake Dunlop
Surface Water Treatment Tank & Plant Meter Guaranteed Output: 9M Gal/Day
Cottonwood Tank
RANCH ROAD 12
S OLD BASTROP HWY
CENTERPOINT RD
REDWOOD RD
35
123
80
Kyle Wholesale Meter
Production Meter
Storage Tank
Water Line
Diameter
Dist - 2", 4", 6", 8", 10"
Dist - 12", 14"
Trans - 16", 18", 20", 24", 30"
County Boundary
City of San Marcos
Public Services Department
Water / Wastewater Division
630 E. Hopkins St.
San Marcos, TX 78666

Summary of Pre- and Post-Validation Entries

#	Water Audit Input	AWWA Code	Assessment Scale		Post-Validation Input Revision (if applicable)
			Pre-Val	Post-Val	
Ln 6	Utility's Length of main lines	*Lm*	5	4.5	309.9698 miles
Ln 7	Total Retail Metered Connections – Active and Inactive	*Nc*	5	3	
Ln 10	Average Yearly System Operating Pressure	*AOP*	3.5	2.5	85 psi
Ln 13	Produced Water	*VOS*	4.5	2.5	
Ln 13a	Production Meter Accuracy	*VOSEA*	4.5	1.5	
Ln 14	Treated Purchased Water	*WI*	n/a	n/a	
Ln 14a	WI Master Meter & Supply Error Adjustment	*WIEA*	n/a	n/a	
Ln 15	Treated Wholesale Water Sales	*WE*	4	4.5	
Ln 15a	WE Master Meter & Supply Error Adjustment	*WEEA*	4	1	
Ln 17	Billed metered	*BMAC*	3.5	2.5	
Ln 18	Billed unmetered	*BUAC*	3	5	0
Ln 19	Unbilled metered	*UMAC*	3	4.5	
Ln 20	Unbilled unmetered	*UUAC*	4	5	
Ln 23	Average Customer Meter Accuracy	*CMI*	4	1.5	
Ln 25	Systematic data handling errors	*SDHE*	4.5	2.5	
Ln 26	Unauthorized consumption	*UC*	3	2.5	
Ln 28	Reported Breaks and Leaks		4.5	4.5	
Ln 29	Unreported Losses		5	2.5	
Ln 40	Retail Price of Water	*CRUC*	5	2.5	
Ln 43	Variable production cost	*VPC*	4.5	4.5	

Validation Review Notes

#	Water Audit Input	Code	Assessment Scale		Basis of Input Derivation	Basis of Data Validity Grade
			Original	Validated		
Ln 6	Utility's Length of main lines	*Length of main*	5	4.5	Input derivation: Totaled from GIS based map. Hydrant leads included: Originally not included, miles of main will be revised to include this length. Comments: No additional comments.	Mapping format: Digital. Asset management database: In place and integrated with GIS system. Map updates & field validation: Accomplished through normal work order processes. Comments: Maximo software for Asset Management.
Ln 7	Total Retail Metered Connections – Active and Inactive	*Number of service connectio ns*	5	3	Input derivation: Value from Water Use Survey. This value is computed through a formula. Source of the data for the calculation is the billing database. Basis for database query: Meter ID - non-premise based. Comments: Meter count is adjusted to compute this value since more than one meter can be connected to a single service. It includes all distinct customer service piping connections including fire protection lines but not hydrant laterals.	CIS updates & field validation: Accomplished through normal meter reading processes. Data and GPS coordinates are collected for every new service/meter that is installed. Estimated error of total count within: 3%. Comments: No additional comments.
Ln 10	Average Yearly System Operating Pressure	*Average operating pressure*	3.5	2.5	Number of zones, general profile: 10 pressure zones, most with storage tanks Typical pressure range: 60 – 140 psi Input derivation: Calculated as simple average from analysis of field data. Comments: This value was updated after the validation review.	Extent of static pressure data collection: Hydrant pressures taken during routine system flushing and/or hydrant testing. Characterization of real-time pressure data collection: Basic - telemetry or pressure logging at boundary points (supply locations, tanks, PRVs, boosters). Hydraulic model: In place and calibrated within the last 5 years. Comments: No additional comments.
Ln 13	Produced Water	*Volume from Own Sources*	4.5	2.5	Supply meter profile: One WTP effluent volume through one meter. 8 wells all individually metered, 6 of the wells active during the audit period. VOS input derived from: SCADA reads from production meters as reviewed and reported on a daily basis. Comments: Input derivation from supporting documents confirmed. Exclusion of non-potable volumes confirmed.	Percent of own supply metered: 100% Signal calibration frequency: Uncertain. Volumetric testing frequency: Annual. Volumetric testing method: Comparative apparatus. Percent of own supply tested and/or calibrated: 100% Comments: All production meters are tested annually. Accuracy test results provided for some wells (~15% of production). Accuracy test of WTP not provided limiting the assessment score.
Ln 13a	Production Meter Accuracy	*VOS MMSEA*	4.5	1.5	Input derivation: Straight average of the meter test results. Net storage change included in MMSEA input: No. Comments: No additional comments.	Supply meter read frequency: Daily. Supply meter read method: Automatic logging via SCADA telemetry.

#	Water Audit Input	Code	Assessment Scale Original	Assessment Scale Validated	Basis of Input Derivation	Basis of Data Validity Grade
						Frequency of data review for trends & anomalies: Each business day. Storage levels monitored in real-time: Yes. Daily Comments: Net storage change as limiting criteria for DVG.
Ln 14	Treated Purchased Water	*Water Imported*	n/a	n/a	Import meter profile: n/a WI input derived from: n/a Comments: No water purchased.	n/a
Ln 14a	WI Master Meter & Supply Error Adjustment	*WI MMSEA*	n/a	n/a	Input derivation: n/a Comments: No additional comments.	n/a
Ln 15	Treated Wholesale Water Sales	*Water Exported*	4	4.5	Export meter profile: One wholesale meter to the City of Kyle used on "as needed" basis. Comments: Input derivation from supporting documents confirmed. Exclusion of non-potable volumes confirmed. Exclusion from BMAC input confirmed.	Percent of export supply metered: 100% Signal calibration frequency: Not applicable given no signal output from supply meters. Volumetric testing frequency: Annual. Volumetric testing method: Comparative apparatus. Percent of export supply tested and/or calibrated: 100% Comments: No additional comments.
Ln 15a	WE Master Meter & Supply Error Adjustment	*WE MMSEA*	4	1	Input derivation: Simple average from accuracy test results. Comments: There is only one export meter, so a weighted calculation is not necessary.	Export meter read frequency: Monthly. Export meter read method: Manual. Frequency of data review for trends & anomalies: Annually Comments: No additional comments.
Ln 17	Billed metered	*BMAC*	3.5	2.5	Customer meter profile: Age profile: Meters are replaced at 10-years Reading system: Mostly is AMI. Some are manually read. Read frequency: Monthly. Comments: Lag-time correction is not employed in input derivation. Input derivation from supporting documents confirmed. Exclusion of non-potable volumes confirmed.	Percent of customers metered: 100% Small meter testing policy: Reactive - complaint based or flagged-consumption testing only. Number of small meters tested/year: 5 Large meter testing policy: Reactive - complaint based or flagged-consumption testing only. Number of large meters tested/year: Not quantified, but assumed to be small. Meter replacement policy: Based on an age threshold per manufacturer guidelines. Number of replacements/year: 4,300 in 2020 Billing data auditing: Standard billing QC, plus review of volumes by use type each billing cycle.

#	Water Audit Input	Code	Assessment Scale		Basis of Input Derivation	Basis of Data Validity Grade
			Original	Validated		
						Comments: No additional comments.
Ln 18	Billed unmetered	*BUAC*	3	5	Profile: The City originally included the volume of water from trouble codes related to customer meter repair and maintenance. After discussions it was determined this volume should be zero. Input derivation: Not applicable. Comments: The City does not have any flat rate or unmetered customers.	Policy for metering exemptions: All connections require metering. Comments: No additional comments.
Ln 19	Unbilled metered	*UMAC*	3	4.5	Profile: Users under this category include: City facilities, CIP construction projects, street sweepers, Vac-Trucks Input derivation: The City has two sources of data for this volume. The volumes used by City facilities and CIP construction accounts are derived from the Northstar system as the difference between the total metered consumption and the total billed consumption. The volumes used by street sweepers and Vac-Trucks are obtained from Maximo. The uses are tracked by individual work order and the street sweepers and Vac-Trucks have meters. Comments: Input derivation from supporting documents confirmed.	Policy for billing exemptions: Limited to own facilities. Comments: No additional comments.
Ln 20	Unbilled unmetered	*UUAC*	4	5	Profile: Main/hydrant flushing, construction/engineering projects, fire department, storage tank draining, main and service relocation. All tracked through work orders. Maximo system has good record keeping of estimates. Comments: No additional comments	Comments: DVG based on all uses tracked by event using site-specific estimation methods.
Ln 23	Average Customer Meter Accuracy	*Customer metering inaccuracies*	4	1.5	See BMAC comments regarding meter testing & replacement activities. Input derivation: Inferred from reference data (manufacturer, anecdotal test results) but not derived from test data analysis & calculation. Comments: No additional comments.	Characterization of meter testing: Limited (upon request AND consumption flag only). Characterization of meter replacement: Ongoing (proactive), annual. Comments: No additional comments.
Ln 25	Systematic data handling errors	*SDHE*	4.5	2.5	Comments: Default input applied.	Comments: Default grade applied.
Ln 26	Unauthorized consumption	*UC*	3	2.5	Comments: Default input applied.	Comments: Default grade applied.

#	Water Audit Input	Code	Assessment Scale		Basis of Input Derivation	Basis of Data Validity Grade
			Original	Validated		
Ln 28	Reported Breaks and Leaks		4.5	4.5	How are surfacing leak events documented, if at all? Work orders for repairs are tracked in Maximo. How was the estimated volume entered into Line 28 derived? Repairs are tracked in Maximo with certain codes. Field personnel estimate the water lost for each individual event. The estimated volumes of the repair codes are then summed. What percent of the surfacing leaks are repaired? 100% What is the average time from call-to-repair? Within a day or two.	All reported breaks and the corresponding repairs are tracked.
Ln 29	Unreported Losses		5	2.5	What is the frequency and extent of proactive leak detection performed to find non-surfacing leaks? Annual survey of 25% of the system by contractors. How are proactive leak detection activities and results documented? Leaks are reported and the repair tracked in Maximo. What activities are included in the proactive leak detection efforts (basic sounding and correlation, DMAs and flow monitoring, other)? Basic sounding and correlation. To what extent are a real loss component analysis and economic level of leakage assessment conducted? None	No DMA are defined in the system.
Ln 40	Retail Price of Water	*Customer retail unit cost*	5	2.5	Input derivation: Single rate class selected, with some rate classes excluded. Sewer charges are based on water meter readings. Sewer revenues are not incorporated into calculation. Comments: Recommend for next audit to derive as total consumptive revenue for water (and sewer if applicable) divided by BMAC (cell G23), converted as needed.	Characterization of calculation: Estimate. Input calculations have not been reviewed by an M36 water loss expert. Comments: No additional comments.
Ln 43	Variable production cost	*VPC*	4.5	Not reviewed	Supply profile: Own sources only. Primary costs included: Uncertain of the costs included in calculation. Secondary costs included: Uncertain of the costs included in the calculation Comments: Recommend for the next audit to calculate this value by adding annual expenses for expense categories that vary with water production (usually electric power, treatment chemicals) and divide by the total production.	Characterization of calculation: Derivation of value unknown. Input calculations have not been reviewed by an M36 water loss expert. Comments: No additional comments.

Texas Water Loss Audit - Level 1 Validation Report

Validator Provided

Audit Information:

Utility: Southern Utilities PWS ID: 2120063

System Type: Potable Audit Period: 1/1/2020 – 12/31/2020

Utility Representation: Sigi West (KSA Consultants), Scott Pope (Utility)

Validation Date: 4/14/2021 Call Time: 9:00 am (Central) Supporting Documents Provided: Yes

Validation Findings & Confirmation Statement:

Key Audit Metrics:	Pre-Validation	Post-Validation
Total Assessment Score:	79.5	75.5
ILI:	3.8	3.8
Real Loss:	117.3 (gal/conn/day)	117.3 (gal/conn/day)
Apparent Loss:	6.8 (gal/conn/day)	6.8 (gal/conn/day)

Validator Information:

Water Audit Validator: Andrew Chastain-Howley & David Sayers Validator Qualifications: Contractor for TWDB

Summary Recommendations for Utility Next Steps

- Improved understanding of Supply Meter (wells) Master Meter Error: consider adopting or increasing the rigor of a source meter volumetric testing and calibration program, informed by the guidance provided in AWWA Manual M36 – Appendix A. The Utility does conduct production meter testing, and all the data for 28 wells was provided, however the error adjustments were estimates and the available data was not used directly in the respective calculations.
- System pressure appeared high so this probably needs to be validated through use of the hydraulic model in 2021.
- Level 2 validation on raw data for Billed Metered Authorized Consumption to determine and resolve any instances of potable volume duplication or inclusion of volumes not applicable to this category.
- Improved estimation of CMI: consider a customer meter testing program which tests a sample of random meters whose stratification (by size, age, or other characteristics) represents the entire customer meter stock. Initially start with developing a weighted average from current metering testing information.
- Recommend to calculate the Customer Retail Unit Cost as a weighted average.
- Recommend for next audit to calculate the Variable Production Cost by including secondary costs

Summary of Pre- and Post-Validation Entries

#	Water Audit Input	*AWWA Code*	Assessment Scale		Post-Validation Input Revision (if applicable)
			Pre-Val	Post-Val	
Ln 6	Utility's Length of main lines	*Lm*	4.5	4.5	
Ln 7	Total Retail Metered Connections – Active and Inactive	*Nc*	4.5	4.5	
Ln 10	Average Yearly System Operating Pressure	*AOP*	4	2.5	
Ln 13	Produced Water	*VOS*	4.5	4.5	
Ln 13a	Production Meter Accuracy	*VOSEA*	4.5	3.5	
Ln 14	Treated Purchased Water	*WI*	5	4	
Ln 14a	WI Master Meter & Supply Error Adjustment	*WIEA*	5	4	
Ln 15	Treated Wholesale Water Sales	*WE*	4	3.5	
Ln 15a	WE Master Meter & Supply Error Adjustment	*WEEA*	4.5	3.5	
Ln 17	Billed metered	*BMAC*	5	3.5	
Ln 18	Billed unmetered	*BUAC*	1	5	
Ln 19	Unbilled metered	*UMAC*	1	5	
Ln 20	Unbilled unmetered	*UUAC*	4	3	
Ln 23	Average Customer Meter Accuracy	*CMI*	4	4	
Ln 25	Systematic data handling errors	*SDHE*	3.5	2.5	
Ln 26	Unauthorized consumption	*UC*	3.5	2.5	
Ln 28	Reported Breaks and Leaks		4.5	4.5	
Ln 29	Unreported Losses		3.5	2.5	
Ln 40	Retail Price of Water	*CRUC*	4.5	3.5	
Ln 43	Variable production cost	*VPC*	4.5	3.5	

Validation Review Notes

#	Water Audit Input	Assessment Scale-post	Basis of Input Derivation	Basis of Data Validity Grade
Ln 6	Utility's Length of main lines	4.5	Input derivation: Totaled from CAD-based map. Hydrant leads included: Utility to review for 2021 submittal, assuming not for 2020 Comments: Utility provided an updated length of mains based on new data available	Mapping format: Digital. Asset management database: CAD system – constantly updating – last major update in late 2020, they also integrate with a Water Model Map updates & field validation: They run the model 1-2 times / month which reflects the frequency that Southern adds new neighborhoods etc. (which are then included in the model) Comments: Random ground truthing in field is the only thing holding back from a 5.0
Ln 7	Total Retail Metered Connections – Active and Inactive	4.5	Input derivation: Standard report run from billing system. Basis for database query: Meter ID - non-premise based. Comments: Has an approved tariff which covers the policies around new connections / customers. Consultant for utility gets a monthly count of active connections. Feels they are within around 2% accuracy	CIS updates & field validation: Accomplished through normal meter reading processes. Estimated error of total count within: 2%. Comments: Correspondents not sure what the billing system is. Would be good to cross-reference with other data sources
Ln 10	Average Yearly System Operating Pressure	2.5	Number of zones, general profile: Single zone – with variations Typical pressure range: 70-110psi Input derivation: Calculated as simple average from analysis of field data. Comments: Average of all readings	Extent of static pressure data collection: Annual hydrant pressures taken during routine system flushing and/or hydrant testing. Characterization of real-time pressure data collection: Real-time monitoring limited to tank levels. Also includes some pump station monitoring in the distribution system. Scott also uses pressure loggers (x3) out in the field (distribution system) to get reference values for making operational adjustments Hydraulic model: One exists and is actively updated but has not been calibrated within the last 5 years. Comments: Recommend utilizing hydraulic model for validation (with calibration as appropriate in future years).
Ln 13	Produced Water	4.5	Supply meter profile: 28 x prop / turbine meters with annual calibration, SCADA on each well 24/7 VOS input derived from: SCADA reads from production meters and is archived.	Percent of own supply metered: 100%

#	Water Audit Input	Assessment Scale-post	Basis of Input Derivation	Basis of Data Validity Grade
			Comments: Input derivation from supporting documents confirmed (well meter tests). Exclusion of non-potable volumes confirmed by utility. Southern is an Investor owned utility and has an approved tariff (approved by the Public Utility Commission). System is basically fully interconnected. All the wells are run into ground storage and then line pumps feed the system including elevated tanks. Approximately 30 ground storage tanks and 5 elevated storage tanks. Metering is at the wells. Flushing of the wells upon startup happens before the well meters. Staff still tries to estimate the volume of the flushing by calculating pump x run time.	Signal calibration frequency: Not applicable given no signal output from mechanical supply meters. Volumetric testing frequency: Annual. Volumetric testing method: Transit-time ultrasonic. Percent of own supply tested and/or calibrated: 100% Comments: Ultrasonic meter test rig – tested at a single flow rate. Test meter may be a little close to the actual meter device – don't know the specific details. Ultrasonic might perform better with a dual beam sensor. Less than 10% of meters outside 3% inaccuracy.
Ln 13a	Production Meter Accuracy	3.5	Input derivation: Simple average from accuracy test results. Net storage change included in MMSEA input: Partial. Comments: Utility runs tanks at relatively constant levels so expected very minor variation between start and end of year. Need to review in 2021 but expect that it will be a negligible adjustment.	Supply meter read frequency: Continuous. Supply meter read method: Automatic logging via SCADA telemetry. Frequency of data review for trends & anomalies: Each business day. Storage levels monitored in real-time: Yes. Comments: Recommend doing a weighted averaging by volume for the aggregate test accuracy. Also recommend another review of direction of adjustment (+ve or -ve)
Ln 14	Treated Purchased Water	4	Import meter profile: Turbine meter – but was damaged in the freeze (Feb 2021) so looking to replace. Annual testing performed by the City of Tyler. During the review the Utility considered refining the purchased and wholesale treated dataset, but after discussion this was deemed to leave as-is for this year and revisit during the next audit. WI input derived from: Totalization of volumes per invoices received from exporter. Comments: Input derivation from supporting documents confirmed. Exclusion of non-potable volumes confirmed by utility.	Percent of import supply metered: 100% Signal calibration frequency: Not applicable given no signal output from supply meters. Volumetric testing frequency: Annual. Volumetric testing method: Unknown? Percent of import supply tested and/or calibrated: 100% Comments: 4 as do not have data from purchase agency, but will ask for in future years
Ln 14a	WI Master Meter & Supply Error Adjustment	4	Input derivation: Simple average from accuracy test results. Comments: Recommend getting the actual accuracy % data from the City	Import meter read frequency: Continuous. Import meter read method: Automatic logging via SCADA telemetry. Frequency of data review for trends & anomalies: Each business day.

#	Water Audit Input	Assessment Scale-post	Basis of Input Derivation	Basis of Data Validity Grade
				Comments: No contract for import inspected.
Ln 15	Treated Wholesale Water Sales	3.5	Comments: John Soules Foods and City of Tyler were included in this volume. The John Soules Foods meter might not be included in future years. Recommend reviewing for future years and reduced grading by 0.5 as reminder to evaluate (due to additional uncertainty).	Percent of export supply metered: 100% Signal calibration frequency: Annual. Volumetric testing frequency: Less than annual Volumetric testing method: Not noted. Percent of export supply tested and/or calibrated: Not noted. Comments: No additional comments.
Ln 15a	WE Master Meter & Supply Error Adjustment	3.5	Input derivation: Left at 100% in absence of analyzed test data. Comments: Recommend reviewing for future years and reduced grading to 3.5 as well as a reminder to evaluate (in future years due to additional uncertainty). Used 100% meter accuracy assuming new meter and annual testing until data evaluated in 2021.	Export meter read frequency: Monthly. Export meter read method: Manual and automatic logging. Frequency of data review for trends & anomalies: Monthly. Comments: Initially used N/A as grading score and 0% accuracy for meters. There should be a flag on TWDB online to make sure cannot use N/A if data in previous input and should not be able to use 0% accuracy.
Ln 17	Billed metered	3.5	Customer meter profile: Age profile: 8 year average or so driven by replacement of 15% /year Reading system: Manual. Read frequency: Monthly. Comments: Lag-time correction select employed in input derivation. Input derivation from supporting documents confirmed. Exclusion of non-potable volumes confirmed.	Percent of customers metered: 100% Small meter testing policy: Reactive and Proactive based on age and usage and anomalies Number of small meters tested/year: 60-100 Large meter testing policy: Same as small meter Number of large meters tested/year: Not noted. Meter replacement policy: Ongoing via meter conversion project at ~15% each year. Number of replacements/year: 15% (non-Covid avg.) Billing data auditing: Not noted. Comments: testing not regular in audit year. This is partially due to regular new meter installations, so do expect good meter accuracy, but also need test results to document.
Ln 18	Billed unmetered	5	Profile: Confirmed none	Comments: All customers have a water meter, no unmetered accounts intended

#	Water Audit Input	Assessment Scale-post	Basis of Input Derivation	Basis of Data Validity Grade
Ln 19	Unbilled metered	5	Profile: Confirmed none	Policy for billing exemptions: Policy for no unbilled accounts at this time.
Ln 20	Unbilled unmetered	3	Profile: Operational flushing and fire department usage. Comments: Used flushing charts (time based).	Comments: DVG based on some uses tracked and estimated by event with formula, while other known uses not tracked.
Ln 23	Average Customer Meter Accuracy	4	See BMAC comments regarding meter testing & replacement activities. Input derivation: Inferred from reference data (manufacturer, anecdotal test results) but not derived from test data analysis & calculation. Comments: Data is recorded but not kept in electronic format	Characterization of meter testing: Routine (proactive), but not fully representative. Characterization of meter replacement: Ongoing (proactive), annual. Target is 15% change / year, but limited during COVID Comments: They have their own Ford test bench. During summer test 6-8 meters / month, so 60-100 per year. Mix of reactive and proactive testing
Ln 25	Systematic data handling errors	2.5	Comments: Applied default values	Comments: Default grade applied.
Ln 26	Unauthorized consumption	2.5	Comments: Default grade applied	Comments: Default grade applied.
Ln 28	Reported Breaks and Leaks	4.5	How are surfacing leak events documented, if at all? How was the estimated volume entered into Line 28 derived? What percent of the surfacing leaks are repaired? What is the average time from call-to-repair? How was the estimated volume entered into Line 28 derived? Breaks and leaks fixed >90%. Call to repair less than 3 days. Work order management system tracks the leakage repairs. Leakage is identified through the SCADA system – looking for anomalies. But this will not identify some of the small leaks. The volume is calculated using the break size / psi hole / split – estimate from chart – estimated from amount of disturbance on sandy soil. They use a 48 hr. run estimate based on a recommendation heard during water audit training.	
Ln 29	Unreported Losses	2.5	What is the frequency and extent of proactive leak detection performed to find non-surfacing leaks? Occasional, not annual How are proactive leak detection activities and results documented? Reports from vendors What activities are included in the proactive leak detection efforts (basic sounding and correlation, DMAs and flow monitoring, other)?	They don't have leak detection equipment, have not observed it to be effective. Over 700 miles of pipe to monitor. Occasional leakage detection, but no DMA's etc.

#	Water Audit Input	Assessment Scale-post	Basis of Input Derivation	Basis of Data Validity Grade
			To what extent are a real loss component analysis and economic level of leakage assessment conducted?	
Ln 40	Retail Price of Water	3.5	Input derivation: Sewer charges are not based on water meter readings. Sewer revenues are not applicable. Comments: Investor owned utility – rates are a little higher than many municipalities: inside and outside City of Tyler has different rates / Tiered rates structure in use as well.	Characterization of calculation: Non-weighted average. Input calculations have not been reviewed by an M36 water loss expert. Comments: Recommend 3.5 due to no weighted average this time – recommend weighting for future – weighting should look at inside / outside city customers and tiered block usage
Ln 43	Variable production cost	3.5	Supply profile: Own sources and import supply. Primary costs included: Treatment chemicals, supply & distribution power, and purchase costs. Secondary costs included: None currently included. Comments:	Characterization of calculation: Primary costs only. Input calculations have not been reviewed by an M36 water loss expert. Comments: Recommend 3.5, if can't get purchase costs then should be 2.5.

Validator Provided

Texas Water Loss Audit - Level 1 Validation Report

Audit Information:

Utility: City of Stephenville PWS ID: 720002

System Type: Potable Audit Period: 1/1/2020 – 12/31/2020

Utility Representation: Karen Wilkerson, Jeremy Jennings, Nick Williams [TWDB: John Sutton and Daniel Rice]

Validation Date: 3/24/2021 Call Time: 2:00 pm Central Time Supporting Documents Provided: Yes

Follow up Call: 4/16/2021 2pm Central Time

Validation Findings & Confirmation Statement:

Key Audit Metrics:	**Pre-Validation**	**Post-Validation**
Total Assessment Score:	71.0	74.0
ILI:	0.9	0.8
Real Loss:	15.4 (gal/conn/day)	13.9 (gal/conn/day)
Apparent Loss:	5.3 (gal/conn/day)	5.3 (gal/conn/day)

Note: *While this system may experience low volumes of leakage, the ILI after level 1 validation indicates that advanced validation is warranted before conclusions can be made regarding the system's leakage and overall water losses. At least one of the following scenarios may contribute to this result:*

- ***Water Supplied (both Own Source and/or Imported Water) may be understated**. This can occur if supply meters are under-registering more significantly than is currently reflected in the Master Meter Error & Supply Adjustment (MMSEA). This can also occur if the supply volumes include uncorrected inaccuracies in the data archives due to data gaps or SCADA formula errors.*
- ***Authorized consumption may be overstated.** This can occur if sales volumes have not been pro-rated to align consumption with dates of actual use instead of the dates of meter reads. This can also occur if the BMAC input includes any non-potable volumes or duplication/exclusion of potable volumes.*
- ***The estimate of average operating pressure may be too high**, thereby overestimating the technical minimum volume of leakage for the system.*

Validator Information:

Water Audit Validator: Andrew Chastain-Howley, David Sayers Validator Qualifications: Contractor for TWDB

Summary Recommendations for Utility Next Steps

- Improved understanding of Supply Meter (Own or Import) Master Meter Error: consider adopting or increasing the rigor of a source meter volumetric testing and calibration program, informed by the guidance provided in AWWA Manual M36 – Appendix A. The City does conduct production and large meter testing (including both wholesale and large customer meters), however, the data was not used directly in the respective calculations. This was considered too much work to evaluate for 2020 but should be conducted for 2021.
- Investigate the Fire Hydrant and Other categories of the authorized consumption to confirm the appropriate categories for these volumes.
- Level 2 validation on raw data for Billed Metered Authorized Consumption to determine and resolve any instances of potable volume duplication or inclusion of volumes not applicable to this category.
- Improved estimation of CMI: consider a customer meter testing program which tests a sample of random meters whose stratification (by size, age, or other characteristics) represents the entire customer meter stock.
- Recommend for next audit to calculate the Variable Production Cost by including secondary costs.
- The production and Import meter accuracy changes brought the utility into an ILI range lower than 1. This is expected to not be correct, but the data evaluation from 2019 used for 2020 was deemed worthwhile in order to understand the process. The data gradings were not changed to accommodate this. It's expected that ILI will be above 1 in 2021, but the suggestions in the previous section should be considered for reasons for a low ILI.

Summary of Pre- and Post-Validation Entries

#	Water Audit Input	*AWWA Code*	Assessment Scale		Post-Validation Input Revision (if applicable)
			Pre-Val	Post-Val	
Ln 6	Utility's Length of main lines	*Lm*	5	4.5	
Ln 7	Total Retail Metered Connections – Active and Inactive	*Nc*	5	4.5	
Ln 10	Average Yearly System Operating Pressure	*AOP*	4	4.5	
Ln 13	Produced Water	*VOS*	4	4	
Ln 13a	Production Meter Accuracy	*VOSEA*	3.5	3.5	99% to 99.5%
Ln 14	Treated Purchased Water	*WI*	4	4	
Ln 14a	WI Master Meter & Supply Error Adjustment	*WIEA*	3.5	3.5	99% to 99.2%
Ln 15	Treated Wholesale Water Sales	*WE*	n/a	n/a	
Ln 15a	WE Master Meter & Supply Error Adjustment	*WEEA*	n/a	n/a	
Ln 17	Billed metered	*BMAC*	4	3.5	6,496,016 moved from unbilled metered
Ln 18	Billed unmetered	*BUAC*	3	5	
Ln 19	Unbilled metered	*UMAC*	2	5	6,496,016 moved to billed metered
Ln 20	Unbilled unmetered	*UUAC*	3	3	
Ln 23	Average Customer Meter Accuracy	*CMI*	4.5	3.5	
Ln 25	Systematic data handling errors	*SDHE*	2	1.5	
Ln 26	Unauthorized consumption	*UC*	2	2.5	
Ln 28	Reported Breaks and Leaks		1.5	4	
Ln 29	Unreported Losses		1.5	1	
Ln 40	Retail Price of Water	*CRUC*	5	4.5	
Ln 43	Variable production cost	*VPC*	2	2	

Validation Review Notes

#	Water Audit Input	Recom Scale	Basis of Input Derivation	Basis of Data Validity Grade
Ln 6	Utility's Length of main lines	4.5	Input derivation: Totaled from GIS based mapping. Hydrant leads included: Not included. Recommend including in input derivation for next audit. Comments: Use of Asset management – they have high confidence in diameter and material and age. Rigorous review confirmed.	Mapping format: Digital. Asset management database: In place and integrated with GIS system. Map updates & field validation: Accomplished through normal work order processes. Comments: Need random field validation to get to 5.
Ln 7	Total Retail Metered Connections – Active and Inactive	4.5	Input derivation: Standard report run from billing system. Basis for database query: Meter ID - non-premise based. Comments: Encode billing system. New customers get 911 address and Utility to check this gets added to GIS for 2021 audit.	CIS updates & field validation: Accomplished through normal meter reading processes. Estimated error of total count within: 2%. Comments: No additional comments.
Ln 10	Average Yearly System Operating Pressure	4.5	Number of zones, general profile: 2 different PZs, confident they are discrete due to valves and operational understanding Typical pressure range: ~65 Input derivation: Calculated as simple average from analysis of field data. Comments: Lots of data (including hydraulic model). Suggested use this for next audit. Pressure monitoring on pump stations and ground and elevated storage tanks – 5 ground and 2 elevated storage tanks. Pressure sustaining valves – they have gauges on them – checked to make sure they are working correctly. Monthly dead-end mains flushing – they check pressure during these times too.	Extent of static pressure data collection: Hydrant pressures taken during routine system flushing and/or hydrant testing. Characterization of real-time pressure data collection: Real-time monitoring limited to SCADA systems at tanks and Pump Station. Hydraulic model: In place and calibrated within the last 5 years. Comments: Have all data for 5 grade, but not all utilized in 2020 for input value. Suggested utilizing all for next audit
Ln 13	Produced Water	4	Supply meter profile: 8 production meters in total. 5 ultrasonic (Eastech and Fuji) meters, 3 propeller (McCrometer and Sparling) at Pump stations. VOS input derived from: SCADA reads from production meters as archived. Comments: Input derivation from discussions with City staff, no supporting documents confirmation. The value is a basic average. Exclusion of non-potable volumes confirmed by City staff. 30 active water wells. Meters on all of them. Meters at influent of pump stations too. Some wells used and some unused. The wellfields include: 10 wells in airport | Route 914 – wells in a line | Bowman Ridge. Meters on the GW wells also, so a mass balance is possible. Three/four main pump stations: Lillian PS on south side from Bowman Ridge and 914 Alexander + SW purchased water (from Upper Leon WD) which is metered at the Dublin	Percent of own supply metered: 100% Signal calibration frequency: Not noted. Volumetric testing frequency: Within last 5 years but less than annually. Not done in 2020 due to COVID Volumetric testing method: Not sure – will review for 2021. Percent of own supply tested and/or calibrated: 100% Comments: Testing conducted in 2019. Due again in 2021

			PS. This goes on to the Lillian PS [possible double counting here, although reported that it is not. Schematic of this part of system could help]. Airport PS – utilizes a propeller meter (Sparling). Garfield PS in town. Eastech Badger Ultrasonic x1. Paddock: Prop meter (McCrometer). 8 Pump Station meters in all confirmed by utility. Meter testing was last conducted in 2019 – 3rd party does testing. Planning to get them all tested again in 2021. 6 MG of storage which are run at similar levels throughout the year. Negligible but should be accounted for to maximize grading. 4 Ground storage, 2 Elevated. "Recycled" water in the City's water use spreadsheet is reported to go through the Chlorine analyzers at the Pump Stations it is not recycled/reuse/reclaimed water (purple pipe) as normally associated with this term.	
Ln 13a	Production Meter Accuracy	3.5	Input derivation: Simple average from accuracy test results. Net storage change included in MMSEA input: No, recommended for 2021, but run tanks at similar levels all year so expect very minor. Do have tank level information. Comments: City conducted additional data analysis to improve accuracy input from 99% to 99.5%. Data from 2019, so not changed validation.	Supply meter read frequency: Continuous. Supply meter read method: Automatic logging via SCADA telemetry. Frequency of data review for trends & anomalies: Each business day. Storage levels monitored in real-time: Yes. Comments: City received additional data to improve accuracy input to 99.5%
Ln 14	Treated Purchased Water	4	Import meter profile: Upper Leon, through Dublin Pump Station WI input derived from: No data from supplier available for review in 2020. Recommended for City to ask (Upper Leon) for test records each year. Comments: No supporting documents, so Input derivation not confirmed, but reported as correct. Exclusion of non-potable volumes confirmed. Mag meters – so likely just getting pass / fail. After review, City received additional data to improve accuracy input from 99% to 99.2%.	Percent of import supply metered: 100% Signal calibration frequency: Annual. Volumetric testing frequency: Within last 5 years but less than annually. Usually annually, but not in 2020 due to COVID Volumetric testing method: City not sure – will get test results in 2021. 99% was assumed. City received additional data to improve accuracy input to 99.2% Percent of import supply tested and/or calibrated: 100% Comments: Recommend asking for Upper Leon for their test data in 2021.
Ln 14a	WI Master Meter & Supply Error Adjustment	3.5	Input derivation: Simple average from accuracy test results. Comments: No written data from wholesale provider at time of review. After review, City received additional data to improve accuracy input from 99% to 99.2%.	Import meter read frequency: Continuous. Import meter read method: Automatic logging via SCADA telemetry. Frequency of data review for trends & anomalies: Each business day. Comments: Verbally reported information, but no data paper trail from wholesale provider in 2020.

Ln 15	Treated Wholesale Water Sales	n/a	n/a	n/a
Ln 15a	WE Master Meter & Supply Error Adjustment	n/a	n/a	n/a
Ln 17	Billed metered	3.5	Customer meter profile: Age profile: Changeout of all smaller meters in 2015. Using Sensus iPerl with AMI Reading system: AMI. Read frequency: Continuous, with bill frequency of Monthly. Comments: Lag-time correction is employed in input derivation. Input derivation from supporting documents confirmed. Exclusion of non-potable volumes confirmed. Changed volume from 704,804,005 to 711,300,021 due to Unbilled metered alteration (is billed)	Percent of customers metered: 100% Small meter testing policy: Reactive - complaint based or flagged-consumption testing only. Number of small meters tested/year: Not quantified, but known to be small. Large meter testing policy: Targeted testing is conducted annually for high volume meters. Number of large meters tested/year: 10+ Meter replacement policy: Upon failure only. Number of replacements/year: Not quantified but known to be small. Billing data auditing: Standard billing QC, plus review of volumes by use type each billing cycle. Comments: No proactive testing. Meter stock relatively new and so expect very accurate. However, no testing and meters could be degrading, so reduced grade.
Ln 18	Billed unmetered	5	Profile: No unmetered connections. Input derivation: n/a Comments: Stated that all customers are metered and sent a bill (even City departments and city parks)	Comments: confirmed all customers metered by policy and no unmetered
Ln 19	Unbilled metered	5	Profile: None. Input derivation: n/a Comments: City moved the volume input here back to billed metered, no unbilled metered usage, no hydrant meters etc. 6,496,016 gallons	Policy for billing exemptions: n/a Comments: All reported billed, even City facilities.
Ln 20	Unbilled unmetered	3	Profile: Operational flushing and fire department usage. Comments: Count of events x flow rate	Comments: DVG based on some uses tracked and estimated by event with formula, while other known uses not tracked.
Ln 23	Average Customer	3.5	See BMAC comments regarding meter testing & replacement activities. Input derivation: Inferred from reference data (manufacturer, anecdotal test results) but not derived from test data analysis & calculation.	Characterization of meter testing: Limited (upon request AND consumption flag only).

	Meter Accuracy		Comments: City does reportedly have test data for large meters only. Recommended including weighted average for future years. Small meters tested if there are any customer complaints. 2015 Sensus iPerls for all smaller meters. Some of the larger meters were tested and recommend accuracy data from this is used going forward	Characterization of meter replacement: Ongoing (proactive), annual. Comments: Do reportedly have test data, but not applied to 2020 value (and therefore grading lowered)
Ln 25	Systematic data handling errors	1.5	Comments: 0 value entered. Tracking will be performed going forward, e.g., for leak credits.	Comments: Utility find this difficult to do.
Ln 26	Unauthorized consumption	2.5	Comments: Default input applied.	Comments: Default grade applied.
Ln 28	Reported Breaks and Leaks	4	How are surfacing leak events documented, if at all? Workorders How was the estimated volume entered into Line 28 derived? Estimates added to workorder with respect to failure type and size What percent of the surfacing leaks are repaired? 100% What is the average time from call-to-repair? 3 Hours How was the estimated volume entered into Line 28 derived?	Monthly report – based on size of hole and type of break x duration. Approx. 20-30 leaks – about average based on WRF. Not many visible leaks therefore able to move quickly. Estimated 3 hours from report to shut off flow from main. They have acoustic leak detection equipment, but don't often use it pro-actively Have not brought in 3rd party for leak detection.
Ln 29	Unreported Losses	1	What is the frequency and extent of proactive leak detection performed to find non-surfacing leaks? None, do have acoustic leak microphone, but old and rarely used How are proactive leak detection activities and results documented? N/A What activities are included in the proactive leak detection efforts (basic sounding and correlation, DMAs and flow monitoring, other)? None To what extent are a real loss component analysis and economic level of leakage assessment conducted? None	
Ln 40	Retail Price of Water	4.5	Input derivation: Simple rate structure with only a single volumetric rate. Sewer charges are based on water meter readings with winter quarter average on residential. Sewer revenues are not incorporated into retail price calculation. Comments: There is a summer surcharge that will increase the average price slightly – a more complete analysis would include a weighted average of the usage.	Characterization of calculation: Non-weighted average (but simple rate structure). Input calculations have not been reviewed by an M36 water loss expert. Comments: Weighting by usage would increase grade
Ln 43	Variable production cost	2	Supply profile: Own sources and import supply. Primary costs included: Treatment chemicals, supply & distribution power, and purchase costs. Secondary costs included: None currently included. Comments: Cost calculation needs to be performed.	Characterization of calculation: Primary costs only. Input calculations have not been reviewed by an M36 water loss expert. Comments: Primary costs included, but not secondary

Appendix D: Water Research Foundation Project 5057 Task 3 Memo

WATER RESEARCH FOUNDATION PROJECT #5057

Task 3 Memo: Review Existing Validator Credentialing Programs

August 2020

Background

The Water Research Foundation (WRF) Project #4639A "Level 1 Water Audit Validation: Guidance Manual," published in 2017, is the North American standard adopted by all states requiring Level 1 validation. To date there are 5 states/provinces (Hawaii, California, Indiana, Georgia, and Quebec) requiring a Level 1 validation prior to the submittal of the AWWA water audit to their respective regulatory agencies.

Project #4639A "Level 1 Water Audit Validation: Guidance Manual" was developed to provide guidance on Level 1 validation for audits prepared using AWWA's Free Water Audit Software (v5). The next version of the AWWA Free Water Audit Software (v6) is being published in 2020, concurrent with the development of WRF Project #5057, which provides an updated Level 1 validation guidance manual that sets the industry standard for Level 1 validation for audits prepared using AWWA's Free Water Audit Software v6. In addition to cataloguing differences in v5 and v6 integrating changes into the guidance manual, WRF Project #5057 also presents the opportunity to solicit industry feedback on the existing manual, review results of current Level 1 validation efforts, and review existing validator credentialing programs. **The focus of this technical memorandum is Task 3: Review existing validator credentialing programs.**

Task 3

As of 2020, four formal programs for credentialing Level 1 validators exist in North America (Figure 1). In 2016, the Georgia Association of Water Professionals developed the first validator credentialing program, call the Qualified Water Loss Auditor program, which trained and certified individuals who successfully completed course work and passed an examination testing their competence to perform Level 1 water audit validations. Since then, California, Quebec, and Indiana have initiated similar credentialing programs, each with local adaptations. Key parameters were examined for each of these programs and are presented in Table 1.

TABLE 1: KEY PARAMETERS EXAMINED FOR LEVEL 1 VALIDATION CREDENTIALING PROGRAMS

FIGURE 1: LEVEL 1 VALIDATION CREDENTIALING PROGRAM IN NORTH AMERICA

Key Program Parameter	Georgia	California	Quebec	Indiana
Year of Program Establishment	2016	2018	2019	2020
Precipitating Rule or Policy	Water Stewardship Act (2010) 391-3-33 Rules for Public Water Systems To Improve Water Supply Efficiency (2016)	SB555 (2015) CA Water Code Section 10608.34 (2018, amended in 2019) and CA Code of Regulations Title 23, Section 638.5 (2018)	Québec Water Efficiency Strategy for 2019-2025 (2019)	SEA4 (2019)
Applicability of water systems under regulatory requirement	Public water systems -- a system for the provision to the public of piped water for human consumption -- serving over 3,300 in population	CCR Section638.5(c) requirements apply to all potable water systems associated with an urban retail water supplier (URWS); URWS defined as a water utility with at least 3,000 service connections or 3,000 Acre-Feet of source water withdrawal annually	All municipal water systems	Each Community Water System that supplies water to its users via meters is required to complete a water audit annually. Validated water loss audits are required on every even-numbered year cycle for the most recently completed water audit year
Hosting Entity	Georgia Association of Water Professionals	California-Nevada Section AWWA	Reseau Environment (Quebec Section AWWA)	Indiana Section AWWA
Incorporation of WRF 4639A Manual (2016)	Curriculum and supporting documents requirements are generally based on WRF 4639A Manual but are not directly cited; guidance on validation methods incorporated into course workbook	Curriculum and supporting documents requirements are specifically based on WRF 4639A Manual with citation; guidance on validation methods incorporated into CA validator manual (2018)	Curriculum and supporting documents requirements are specifically based on WRF 4639A Manual with citation; no additional validator guidance manual created	Curriculum and supporting documents requirements are generally based on WRF 4639A Manual with citation; no additional validator guidance manual created
Eligibility and pre-requisite knowledge requirements for trainees	Proof of prior attendance to a basic water audit training is required. Extensive knowledge of the AWWA M36 water audit methodology marketed as necessary for participants, with attendees responsible for this determination	Extensive knowledge of the AWWA M36 water audit methodology marketed as necessary for participants, with attendees responsible for this determination	Trainees limited to small number of staff on Quebec government team of engineers	Proof of prior attendance to a basic water audit training is required. Extensive knowledge of the AWWA M36 water audit methodology marketed as necessary for participants, with attendees responsible for this determination
Allows credentials from other programs to meet requirements	None	None	None	Georgia, California

Key Program Parameter	Georgia	California	Quebec	Indiana
Rigor of program instructional content	Moderate: ~1.5-day duration; 50% lecture, 50% exercise; exercises incorporating 1 system example; student-led exercises with instructor-led reflections; no full mock validation scenario conducted	High: ~1.5-day duration; 20% lecture, 80% exercise; exercises incorporating 4 system examples; student-lead exercises with instructor-led reflections; full mock validation scenario conducted	High: ~1.5-day duration; 20% lecture, 80% exercise; exercises incorporating 4 system examples; student-lead exercises with instructor-led reflections; full mock validation scenario conducted	Moderate: ~1.5-day duration; 50% lecture, 50% exercise; exercises incorporating 3 system examples; instructor-led exercises only; no full mock validation scenario conducted
Rigor of the examination to acquire validator credential	~0.5 day duration; Part 1 multiple choice section for examination of general water audit knowledge; Part 2 practical section for examination of validation knowledge and application	~0.5 day duration; Part 1 multiple choice and Part 2 short answer sections for examination of general water audit knowledge; Part 2 practical section for examination of validation knowledge and application	~0.5 day duration; Part 1 multiple choice and Part 2 short answer sections for examination of general water audit knowledge; Part 2 practical section for examination of validation knowledge and application	~0.5 day duration; Part 1 multiple choice and Part 2 short answer sections for examination of general water audit knowledge; Part 2 practical section for examination of validation knowledge and application
Method of instructor selection	Based on availability of local Water Loss Committee volunteers, with consent of host Association	Service hired through qualifications-based selection process	Service hired through qualifications-based selection process	Service hired through qualifications-based selection process
Number of credentialed validators publicly posted (Aug 2020)	270	92	5	91
Period before credential renewal required	Not limited	3 years	Not limited	4 years
Structured checks and balances for ongoing quality control in the program	Broad filtering of validated water audit submittals and specific outlier review by regulatory agency staff; no continuing educational requirements for credentialed validators	Broad filtering of validated water audit submittals and specific outlier review by regulatory agency staff; continuing educational requirements for credentialed validators limited to 8 hours or 1 webinar attendance	Broad filtering of validated water audit submittals and specific outlier review by regulatory agency staff; no continuing educational requirements	Broad filtering of validated water audit submittals and specific outlier review by regulatory agency staff; credentialed validators required to either complete 1) two water loss audit validations and two hours of Continuing Education Credits four years from the date of issuance or 2) eight hours of continuing education
Restrictions on performing self-validation of a water loss audit	Validator and auditor can be same individual, though this is discouraged	Validator must be an individual who was not involved in preparing the audit	N/A - Validators are limited to Quebec government team of engineers	Validator must be an individual who was not involved in preparing the audit

Level 1 Validated Water Audits are also required in the Hawaii for County-owned water systems and Large Capacity and Water Management Areas, however a formal validation certification program does not presently exist like those described in Table 1. Instead, staff with the Hawaii Department of Land and Natural Resource's Commission on Water Resource Management (CWRM) completed a training program to become proficient in the water audit validation process, excluding a course examination or formal credentialing. Hawaii water audit validations are conducted similarly to those in Quebec, in that they are performed only by government staff.

Summary

Each of the four Level 1 validation credential programs presented here are anchored in the WRF 4639A Level 1 Water Audit Validation Guidance Manual. Only one program, California, formally developed written methodology for performing a Level 1 validation in greater detail than the WRF 4639A manual, which primarily offered standardization for data validity grade language interpretations relative to the AWWA Free Water Audit Software version 5 data grading matrix. As the AWWA Free Water Audit Software version 6 has addressed the issue of standardizing data grade assignments (see Task 4 memo), incorporation of lessons learned from the California program has been largely accommodated. The California material should be further cross-referenced, to glean specific questions from the Input Derivation and Data Practices Inquiry Guidance sections for each water audit input, to carry forward to the WRF 4369A manual update as appropriate.

Some data practices questions previously asked by the validator will now be answered by the auditor in the course of completing the audit, with the advent of an Interactive Data Grading function in AWWA Free Water Audit Software version 6 (see Task 4 memo). This means certain answers will be available to the validator prior to the validation interview, as a function of the water audit and supporting documents review. Supporting documentation requirements was generally similar among the validation credentialing programs. The WRF 4369 manual update should provide detailed update to the minimum standard for supporting documentation as well as value-added documentation guidelines.

The AWWA Free Water Audit Software version 6 updates will allow for an improved focus of the Level 1 validation on methodology verification, supporting documentation detail and forward-looking validity improvements. At the same time, existing validator credentialing programs will need to update course materials, in-class exercises, and examination materials to stay consistent with the WRF 4369A manual update.