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An Essential or Neglected Part of the Water Conservation Strategy for Los Angeles County Water Retailers?

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Executive Summary

The water governance system in Los Angeles County is complex and fragmented. Potable water supply in metropolitan Los Angeles County relies on over 100 water retailers, both public and private. It is unclear how the current system with many small water retailers will succeed in promoting integrated water resource management. Among other changes, there will need to be a shifting of water supply sources from predominantly imported to more local resources through conservation, recycled water usage, stormwater capture and groundwater management. The institutional capacity of water retailers to instigate this transition will depend heavily on their capacity to maintain reliable water deliveries without significant losses from leakage and failing infrastructure. Additionally, with drought conditions prevalent in eleven of the last fourteen years in California, and increasing evidence of climate change impacts on all water resources in California, it is crucial that water retailers minimize water losses through their distribution systems to match the increasingly stringent conservation efforts required of their customers, and to efficiently utilize scarce supplies.

Until this year, existing regulations for water agencies in California only requested information about system losses for potable water systems with more than 3000 connections. These numbers were reported through Urban Water Management Plans every five years. However, loss estimates through breaks and leaks have not been separated out from other non-revenue uses of water. To date, the most effective efforts to monitor water losses in California are voluntary and limited to members of the California Urban Water Conservation Council. To understand water distribution efficiency in urban Los Angeles County, we developed a questionnaire regarding leakage monitoring, system-wide water losses, and the implementation of pre-emptive best management practices. We surveyed 10 of the approximate total of 100 water retailers. The sample was representative of retailers of many types, sizes, and geographical locations in metropolitan Los Angeles and divided into tiers of size (small, mid-sized and large) based on the number of connections served. The survey questionnaire also addressed other metrics including per capita water consumption, leakage volumes, water loss estimation methodology, water loss estimates and infrastructure monitoring and replacement.

The survey indicated several findings. First, the *percentage* of water loss due to breaks and leaks, though possibly misrepresentative, is still a widely used metric to measure water losses. Sixty percent of the agencies sampled still monitor only ‘unaccounted for water’ and not ‘real losses’. Retailers that do measure real losses reported them to be between 3-4% of total water supplied, which is an improbably low compared to international estimates as elaborated in the literature review section. Different water retailers were divided on the efficacy of leak detection technologies, which demands more education on available leak detection technology and their usage.

Larger retailers reported greater use of most of the best management practices addressed by our survey to maintain storage and distribution systems. Most small retailers did not report prioritizing adoption and implementation of best management practices to minimize water loss. Also, small Mutual Water Companies that we contacted did not have information on distribution water losses available publicly. To improve water efficiency, small retailers could pool resources and expertise to better detect, monitor and reduce distribution water losses. Investor-owned utilities and special water districts serve a large customer base, but as a group, they were least responsive of all the sample water retailers we contacted. . In summary, California water regulations should aim at recommending crucial best management practices, ensuring accurate and verifiable water loss monitoring and prescribing an effective water loss metric and maximum acceptable standard as a roadmap for water retailers.

Contents

Introduction

The largely varying precipitation and large population of Los Angeles County renders it dependent on imported water for majority of its water supply. The County of Los Angeles imports more than 60% of its water supply from three major sources, the Los Angeles Aqueduct supplied by the Eastern Sierra watershed, the Colorado River Aqueduct, and the California Aqueduct supplied by the Sacramento-San-Joaquin River Delta (Bay Delta). Groundwater forms 35% of the total water supply in the region (Los Angeles Department of Public Works, 2014).

Twelve of the last sixteen years have been drier than normal for California.[1]. The Sierra snowpack has been reduced to a historically low 5% (California Department of Water Resources, 2015). For the Eastern Sierras, global climate models predicted a temperature rise of 2 to 5 °Celsius, leading to an increase in the mean fraction of precipitation falling as rain (Costa-Cabral, Roy, Maurer, Mills, & Chen, 2013). Recent work by Diffenbaugh (2014) finds that anthropogenic warming has increased the risk of severe drought in California. Such warming outweighs the increased soil-water availability due to early runoff during the cooler low evapotranspiration period (Diffenbaugh, Swain, & Touma, 2014). Global climate models have consistently predicted that runoff in the Colorado Watershed will reduce by 10-30% and have already translated as reduced storage levels in Lake Mead and Lake Powell. (Barnett & Pierce, 2009). The Bay Delta is threatened by future rise in sea levels as predicted by climate models, which might lead to restrictions in water allocations to southern California via the State Water Project. Additionally, dramatic increases in "permanent" versus "annual crop" irrigated agriculture (United States Department of Agriculture, 2011), all have increased water demand, creating a potentially chronic water shortage across a state with widely variable precipitation.

Because of the drought emergency, California has quickly moved into a new era of water management. The Governor issued an executive order on April 1, 2015 that will require every water user, from farm to industry to urban users to cut back on water use (Governor of California, 2015). The State Water Board is preparing to issue emergency regulations for mandatory cutbacks averaging 25% to all urban water suppliers (State Water Resources Control Board, 2015). In response, the Metropolitan Water District of Southern California which serves region of 18 million people, passed a mandatory allocation reduction on April 14, 2015, averaging 15% to all of their member agencies, with heavy fines for excess delivery (Metropolitan Water District, April 2015).

While some of these drastic cuts will be reduced when the drought abates, major changes in water use will be expected and water suppliers will need to pay new attention to their distribution efficiency as well as customer conservation. Retail water systems in Southern California can lose a significant amount of water and thus, revenue through leaks and breaks in their distribution systems. Large main breaks can also cause severe property damage. For instance, in July 2014, the 93 year old main on Sunset Boulevard in Los Angeles not only lost

[1] Personal Communication, William Patzert, Climatologist, NASA's Jet Propulsion Laboratory

10 million gallons[2] (2% of the daily use of 3.4 million customers in Los Angeles city), but also caused tremendous damage to university property and hundreds of parked vehicles at the University of California Los Angeles campus. Based on an assessment of over 11,000 miles of water mains, the deterioration in the potable water infrastructure in evident across Los Angeles County (American Society of Civil Engineers, 2012). As part of conservation efforts, water retailers need to monitor their distribution systems to manage them for efficiency.

The Environmental Protection Agency describes water efficiency as the "long term ethic of saving water resources through the use of water-saving technologies and practices" (United States Environmental Protection Agency, 2015). The state of a retail water distribution system determines the retailer's efficiency in conveying it to their customers. The water distribution efficiency of a given water retailer can be evaluated by their competence in maintaining, operating and monitoring the storage and distribution system, and developing their financial resources to rehabilitate infrastructure. This capacity can be as significant a determinant in the retailers' contribution to water conservation as consumer efforts are. The 2007 US Conference of Mayors assessed that revenues collected by city departments, account for about 80-90% of the capital required to replace their sewer and water infrastructure. This backlog combined with the financial implications of regular rehabilitation and maintenance of old infrastructure can lead to a high increase in monthly service charges to customers (Sedlak, 2014). Retailers should gauge their water distribution efficiency by measuring the loss of water during conveyance to their customers and take steps to reduce revenue losses via water leakages.

In this study, we investigated the water distribution efficiency of a sample of water retailers in metropolitan Los Angeles County. The study consists of reviewing prior research, developing a survey for water retailers, and analyzing results. Much work exists regarding water efficiency. To inform the interpretation of our survey results, we surveyed the literature on water efficiency and the development of best management practices related to losses from breaks and leaks, as well as practices to manage systems to minimize losses. The American Water Works Association releases a manual on best management practices to reduce water loss reduction. In this study we considered recommendations such as monitoring breaks, leak detection, infrastructure testing and replacement. In particular, we overview the existing reporting requirements for the State of California and voluntary reporting solicited by the California Urban Water Conservation Council.

The entire agglomeration of water retailer jurisdictions that we sampled from in urban Los Angeles County are shown in Figure 1. Thus, water service in urban Los Angeles County is highly fragmented and involves many small retailers (Cope & Pincetl, 2014; Cheng & Pincetl).We developed a stratified sample survey, including in depth interviews with approximately 10% (10 out of about 100) of the water retailers in urban Los Angeles County. We examined how they measure water losses from leakages or breakages in their systems, as well as technical expertise and financial investments to reduce leakage. We have considered leakages as subsurface water losses, whereas breaks are water losses above the ground surface. The survey was designed to obtain a balanced stratified sample. The stratified sample ensured

[2] Main break near UCLA: http://ktla.com/2014/07/29/water-main-break-in-westwood-prompts-flooding-of-streets-strands-people/ (Accessed 06/18/2015)

that the number of participants in each category based on size, type and geographic location of water retailers, was proportional to those in the corresponding categories of the population. The survey was designed to collect information on the estimation and reporting of typical water loss, existing infrastructure maintenance and replacement strategies and distribution system failures.

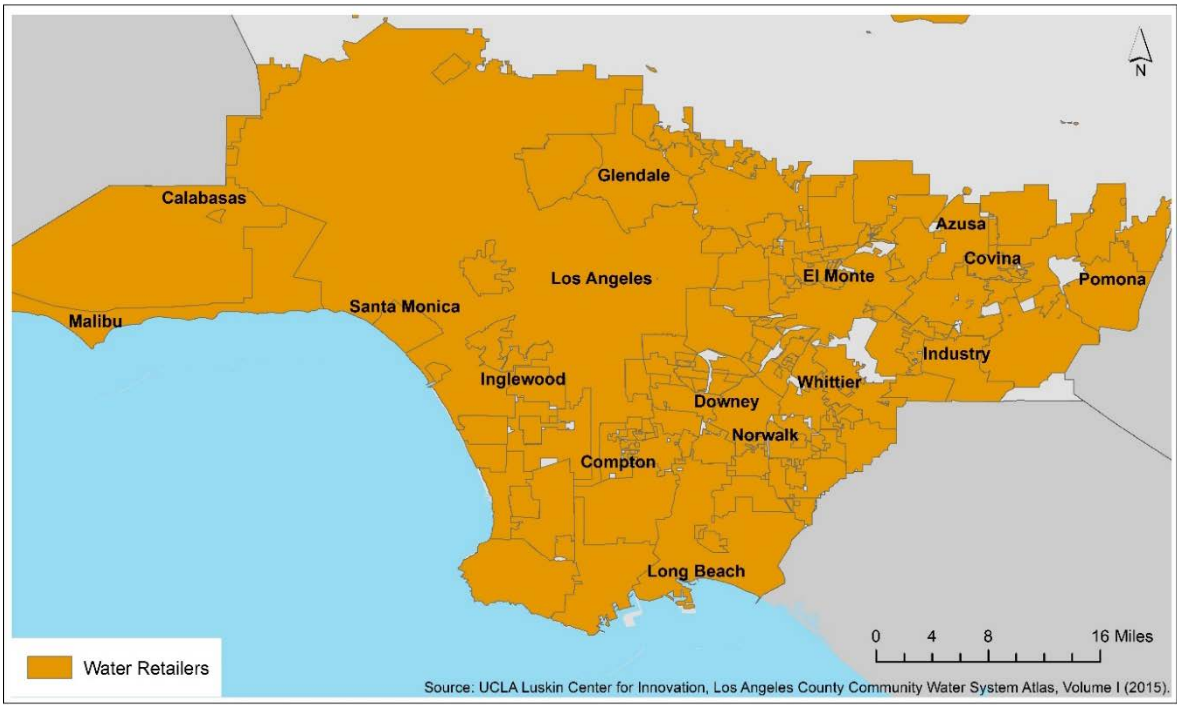

Figure 1 Study area and potable water retailers in metropolitan Los Angeles County (Deshazo & McCann, 2015)

Literature Review and Background

Emergence of Global Water Efficiency Standards and Practices

Water loss through distribution systems is a global issue. In 1987, the American Water Works Association (AWWA) addressed the issue of loss of revenue for agencies via water distribution leakages. Dr. L.P. Wallace and his students from Brigham Young University, overviewed techniques of monitoring and minimizing losses in an AWWA Research Foundation report (Wallace, 1987). In the early 1990s, AWWA released Water Audits and Leak Detection manuals after which it joined the International Water Association (IWA) Water Loss Task Force in 1996. AWWA released manuals of water supply practices in 1991, 1999, 2009 describing benefits of water balance audits, their water audit method and recommended measures for water loss control (Fanner, et al., 2007).

The IWA Water Loss Task Force (WLTF) was a small group of water utility professionals from around the globe which was formed in 1996, Allan Lambert from the United Kingdom was the Chair. The American Water Works Association (AWWA) was one of its members from 1997 to 2000 (American Water Works Association, 2009). The goal of the WLTF was to create a common global framework for water loss performance indicators using common terminology and a standardized water balance equation[3]. The IWA published Performance Indicators for Water Supply Service which described this global methodology developed by the IWA WLTF (Alegre, 2000).

The IWA methodology was based on the original Water Audits and Leak Detection Manual published by the AWWA in 1990 (American Water Works Association, 1990). The IWA WLTF published a series of 8 articles on a 'Practical Approach' for global best management practices in water loss assessment and reduction strategies in the Water21 magazine in through June 2003 to December 2004. In this second article, they separated various water loss components and proposed this as 'best practice' standard water balance as shown in Fig. 2. (Lambert A. , 2003).

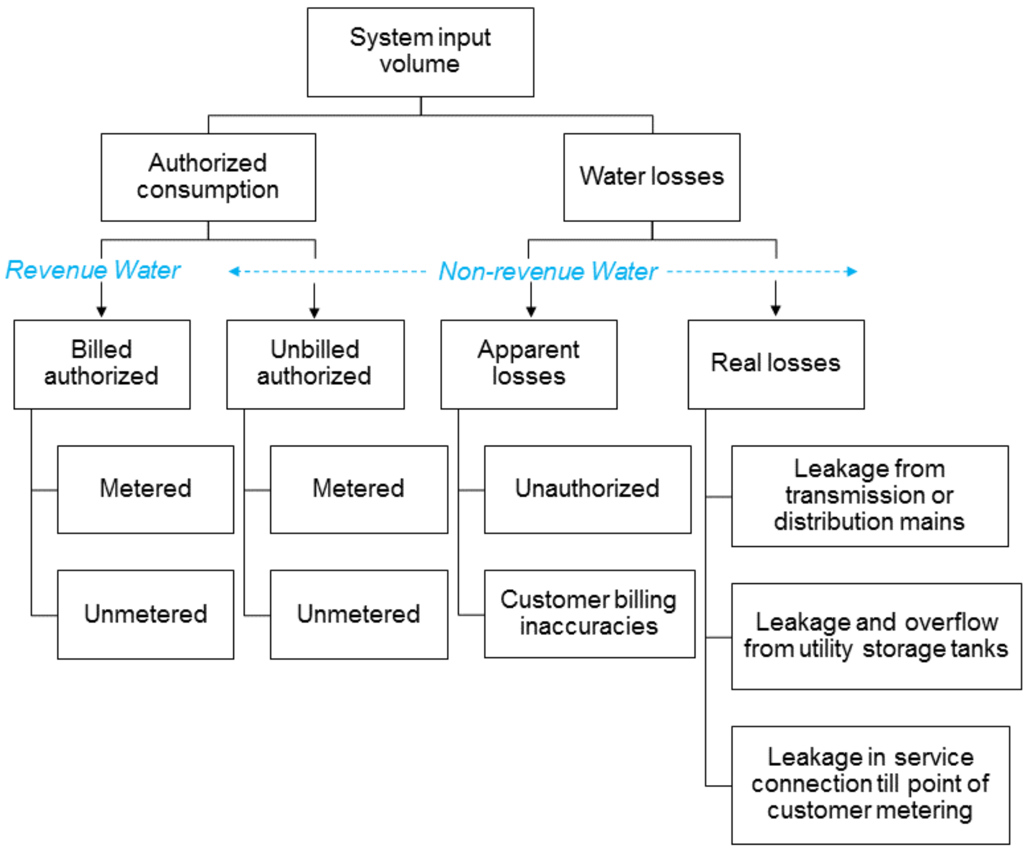

Figure 2 IWA water balance *(Lambert A. , 2003)*

The IWA conducted surveys across many geographic regions to gather data from water retailers to develop a framework for determining water losses. The primary motivation for this study was to reduce losses in revenue from water losses. They compared water retailers across England, Wales, California, the Nordic[4] countries, Japanese and German cities, Australia, Singapore and Malta in terms of water losses. The data from various nations was collected by the IWA Water Loss Task Force in the form of an International Dataset and was presented in

[3] Water Ideas 2014 – Committees, http://www.waterideas2014.com/?page_id=65 (Accessed 3/23/2015)
[4] Denmark, Norway, Sweden, Iceland, Finland

their report from 2001 (Lambert A. O., Water Losses Management and Techniques, 2001). They discouraged using the term “unaccounted for water” to designate losses from a distribution system due to its varying interpretations globally. They discussed that real losses represented as percentage can be ambiguous. They observed that an equivalent real loss volume expressed as percent appears higher for regions with lower water consumption per connection. The percent water loss reported was about 15% for Australia and 6% for California, which may be heavily skewed by the difference in their daily water consumption per connection. Lambert (2002) summarized the motivation behind this study, resulting conclusions and recommendations by the IWA Task Force.

The AWWA Water Loss Control Committee adopted the updated Best Management Practices for water loss prevention recommended by the IWA WLTF based on their international study and dataset and published and endorsed their conclusions on Best Management Practices in their 2003 committee report (American Water Works Association, 2009).

Many global efforts exist regarding improved water auditing technology. McKenzie et al (2005) overviewed standard water audit software in South Africa, Australia and New Zealand and the methodology. Soon, after its joint efforts with the IWA, AWWA Water Loss Committee Control launched a free Water Audit Software in 2006 followed by several updated versions. The latest version available now is version 5 released in 2014. The software uses a top-down approach to calculate the real losses, that is, the actual leakage from the system- what is left after all other losses are accounted for (American Water Works Association, 2009). Real losses are defined as the volume lost “the annual volumes lost through all types of leaks, bursts and overflows on mains, service reservoirs and service connections, up to the point of customer metering” (Lambert A. , 2003). The AWWA Water Audit Software can be a good indicator of water distribution system losses if used accurately. The model used in the software includes certain assumptions for the user, such as, an ability to extricate different kinds of authorized and unauthorized usage from the supply volume and a high confidence level in reporting unmetered usage. The end product grades the water distribution system with the corresponding Infrastructure Leakage Index value, which represents the condition of the distribution system as compared to a system in “perfect” condition (American Water Works Association, 2009).

The software lists recommendations for overall and immediate measures to improve the system’s condition and reduce water losses based on the “Infrastructure Leakage Index” which is a “grade” that the system receives based on its water losses and efforts such as efficiency of repairs, leakage control and upgrades calculated in the AWWA Water Audit. This methodology then formed the backbone of many water audit software packages globally. Fantozzi et al. (2006) discussed the common approach for leak detection and control efforts in North America, Canada, Australia and Europe. The observations in this study were based on the authors’ experience in these regions.

The AWWA released a report in 2007 to provide guidelines on how to use appropriate performance indicators for losses, conduct a water audit, determine leakage and formulate and execute loss reduction programs (Fanner, et al., 2007). The IWA WLTF has now evolved into the Water Loss Specialist Group, a consulting firm offering software and other tools aims at reducing water losses from urban water systems.

Studies on Infrastructure Rehabilitation Strategies

Simultaneously, several studies focused on the cost-effectiveness of infrastructure replacement and influential factors. Colombo and Karney (2002) determined the economic consequences of leakages in a system and deduced that energy costs increase with increasing leakage volumes. Southern California Edison conducted a study to determine water and energy savings through leak detection and repairs for three utilities and demonstrated the economic significance of minimizing water losses[5]. They used the AWWA methodology for water auditing and field leakage measurement to obtain data on water losses. The engineering consulting organization implementing the study, selected suitable cost-effective leakage intervention tools for each water utility, while an independent team evaluated the water and energy savings. These intervention tools were based on the guidelines to calculate the 'Economic Level of Leakage', provided by this consulting organization and Alliance for Water Efficiency (Sturm, Gasner, Wilson, Preston, & Dickinson, 2014). They estimated cumulative water savings of 83 million gallons per year (255 acre-feet per year) and cumulative energy savings of about 500 Mega Watt-hours per year for the three utilities via this leak detection study. Engelhardt et al. (2000) discussed physical causes for deterioration of pipes, such assoil and water corrosivity, traffic loading and high alkalinity in pipe material in the United Kingdom. They described the regulatory process for the privatized water industry in the U.K., which consists of an external agency that regulates the economic and water supply performance. They reviewed distribution system rehabilitation decision models adopted in the U. K.

Several studies proposed optimization models for strategizing rehabilitation. Dandy and Engelhardt (2001) proposed using the Genetic Algorithm to optimally schedule replacement of water mains in a distribution system. They optimized with respect to available funds and applied it to a pressure zone in metropolitan Adelaide in Australia. Nafi and Kleiner (2010) used the Genetic Algorithm to optimize for economies of scale and road improvements and applied it to a community in Ontario, Canada as an example. Dandy and Engelhardt (2006) followed up their study in 2001 by suggesting a multi-objective genetic algorithm approach for constraints such as replacement and repair cost and reliability (lack of interruptions). Bogardi and Fulop (2012) used a space-time probabilistic model to minimize cost and pressure drops in the distribution system. Roshani and Filion (2014) optimized the timing of water main rehabilitation and replacement using a sorting genetic algorithm. Li et al. (2015) developed a decision-making algorithm based on a sorting genetic algorithm for pipeline replacement minimizing cost and service interruptions.

Global Evaluation of Water Distribution Efficiency

The U.S. Environmental Protection Agency and the Water Research Foundation jointly funded a study by an engineering consulting firm, Water Loss Optimization to review of water loss reporting guidelines for state agencies, and organizations in Austria, New Zealand and Australia. The study also reviewed guidelines and standards for nine North American state agencies and organizations (including California). According to the review, Austria and

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[5] Southern California EDISON Water Leak Detection Program and Water System Loss Control Study, by Water Systems Optimization (2011)

Australia achieved very low levels of real losses in their distribution systems. They also reviewed literature for frequency of breaks in the system and observed large variance in the collected data. The study found a weighted average annual frequency for main breaks in North America of 25 failures for every 100 miles of pipeline. Nine North American utilities participated in this study to demonstrate the use of AWWA's Component Analysis Tools. For California, the understanding of the usage of the tool and the quality of collected data was less than satisfactory. About 35% of the water audits from member water agencies of the CUWCC shows implausible results, out of which 28% of the utilities claimed that their distribution system was in better condition than the 'theoretically perfect condition' prescribed by the water audit. (Sturm, Gasner, Wilson, Preston, & Dickinson, 2014).

National Water Efficiency Standards and Regulations

Beecher obtained information on water loss policies for forty-three states in the U.S.A. addressing the existence of policies, terminology defining water loss, monitoring methodology, targeted maximum losses, planning and technical assistance, data collection and performance incentives. From the seventeen jurisdictions defining "unaccounted for" water, only three state agencies provided a method of calculating it. Twenty-three states and three regional authorities reported the use of a standard for water losses which varied from 7.5-20%; most commonly 15%. Only fifteen state agencies required some form of auditing to enforce standards. (Beecher, 2002).

Recommendations regarding water loss targets are scarce. The only target or recommendation for maximum water losses found in literature dates back to an article published by AWWA in 1957 (American Water Works Association, 1957). It noted that the water losses from well-maintained systems with a consumption of 100-125 gallons per capita per day (GPCD) can vary from 10-15% (Liston, et al., 1996). AWWA later refuted this value in their committee report in 1996, deeming the loss value obsolete due to significant changes in operating costs and technological resources. The average losses from a system depend on system age, size, material and population density, which calls for a more customized cost-benefit analysis (Alegre, 2000). We observed in our interviews of water retailers in urban Los Angeles County, that this standard has been followed by most of these retailers who practice leakage monitoring and use the AWWA software. According to Beecher's survey in 2002, the California Urban Water Conservation Council (CUWCC) mandates that the member agency conduct the complete Water Audit if their unaccounted for water exceeds 10% of the total volume supplied. (Beecher, 2002).

In 2002, US EPA completed seventeen case studies of water conservation and efficiency by urban water utilities across the country, and in Canada (United States Environmental Protection Agency, 2002). Of those seventeen case studies, leak detection and repair is named as a key strategy in six locations: Ashland, Oregon; Gallitzin, Pennsylvania; Houston, Texas; the Massachusetts Water Resources Authority; New York City and Seattle, Washington. 46% of the utilities studied outside California reported leak detection and repair as a major strategy, while none of the five utilities studied in California had this focus.

In 2012, The Alliance for Water Efficiency[6] conducted a survey of all states to collect information on State regulations for water efficiency and conservation. While the study mostly targeted conservation policies, one of the twenty questions asked if "the state has regulations or policies for water utilities regarding water loss in the utility distribution system" (Alliance for Water Efficiency, 2012). They concluded that though most states have regulations for monitoring utility distribution water loss, some states do not rely on state-of-the-art methodologies for water auditing, whereas others lack in legal foundation for their requirements. For California, the Department of Water Resources is the agency authorized to require water retailers to submit distribution water loss estimates.

Existing Measures for Water Loss Monitoring in California

The California Department of Water Resources (DWR) released a workbook in 1986, which contained a manual and a guidance tool for estimating the value of the leak volume[7]. The latest version of the Workbook was in released in 2002. The overall goal of this project was to prepare a comprehensive guidance document which can be used by water utilities to: (1) ensure accurate measuring of supplied water and meter and billing accuracy, (2) prepare an accurate water audit (and water balance), (3) evaluate the economic implications of leakage, plan and (4) suggest water loss-reduction programs (Fanner, et al., 2007). This guidebook is different from the new AWWA Water Audit, as the main focus of the Workbook is to guide the utility in accurately estimating the total water supplied subject to meter and billing inaccuracies. The Guidebook does not specify methods to estimate all these values, but suggests general measures to correct leak issues. It also overviews leak detection techniques.

Since 1990, DWR has collected Urban Water Management Plans (UWMP) from Urban Water Suppliers every five years. Urban water suppliers are defined by the most recent amendment of the Urban Water Management Act[8] as "a supplier, either privately or publicly owned, providing water for municipal purposes either directly or indirectly to more than 3000 customers or supplying more than 3000 acre-feet of water annually". The aim of the UWMP is to help urban water suppliers plan for a 20 year horizon of water supply and include a reliability study for existing and planned water sources for normal, dry, multiple dry years.

The Water Act of 2009 adds deliverables such as a map of the water supply area, methods for estimating conservation targets and baseline water usage, population estimation methods and sources, metered or measured flows, groundwater management plans, description of the groundwater basins and an report on the location, amount and sufficiency of the groundwater pumped by the supplier in the past five years and a schedule of implementation for water management measures. To comply with the Water Act of 2009, agencies included plans to decrease per capita water usage by 20% by 2020 in the 2010 UWMPs. DWR assesses these plans based on the Urban Water Management Planning Act.

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[6] Alliance for Water Efficiency, http://www.allianceforwaterefficiency.org/, a nonprofit organization focused on the efficient and sustainable use of water

[7] California Department of Water Resources Website, http://www.water.ca.gov/wateruseefficiency/leak/ (Accessed 3/23/2015)

[8] California Water Code Division 6, Part 2, Section 10610-10610.4

Up to this year, the Water Code required reporting "system losses" in the UWMP. The term system losses has not been defined, except as the general loss of water through any method from the supplier's distribution system. In California and elsewhere, water losses from potable distribution systems are primarily being measured by many utilities as "unaccounted for water", which represents the deficit between the purchased and metered supplied water volumes. This term encompasses various types of water losses in addition to actual leakages, such as demand for fire-fighting water, fire training, routine testing and maintenance of fire hydrants, street cleaning or municipal parks, billing errors, meter errors and water theft. Losses from storage leaks, pipe leaks and breaks have been hard to isolate with current approaches.

The Water Act of 2009 required an Independent Technical Panel (ITP) to advise the DWR on new demand management measures, technologies and approaches to improve water use efficiency every five years after 2010 (Senate Bill AB 1420, California Water Code 10631.7). The DWR convened the ITP in May 2013. The ITP recommended reporting of distribution water loss by urban water suppliers supported by water loss audits based on past ten years as part of the UWMPs. They also recommended a standardized reporting system for the UWMPs (Independent Technical Panel, 2014).

This recommendation became law this year. SB 1420 (Wolk)[9] was effective on January 1, 2015, requiring that all water retailers submitting 2015 Urban Water Management Plans use the American Water Works Association Water Audit Methodology (AWWA) to specifically report on pipe leaks and breaks. This methodology and the method of interpreting its results and estimates are described in the AWWA M36 Manual with their recommended Best Management Practices. SB 555 (Wolk)[10] was introduced in February 2015 and then amended in April 2015 for water loss management. This bill would require each urban water supplier to submit completed water audit reports based on the AWWA water audit methodology and provide information on measures adopted toward water loss reduction. These reports would need to be validated and posted on their website for public viewing and comparison. It would also require the DWR to provide technical assistance for water loss detection programs conducted by urban water suppliers. The DWR would also require to develop rules for performance standards, validation process and metrics for the reporting of annual water loss reduction by urban water suppliers with the State Water Resources Board. After 2015, water loss from leaks and breaks would have to be reported on for each year and included in the next five year update.

California Urban Water Conservation Council: An Independent Approach

The California Urban Water Conservation Council (CUWCC) is a membership organization of water retailers and suppliers that has developed Best Management Practices for water usage efficiency. The CUWCC has three groups of members, water suppliers, businesses and public advocacy organizations. Water retailers that are members are required to report their Best Management Practices (BMPs) for water conservation and loss with AWWA water audits every two years. Reclamation Contractors or members of Bureau of Reclamation are required

[9] Ch. 490, California Water Code, amending Sections 10631 and 10644
[10] Ch. 490, California Water Code, amending Section 10608.34

to submit these BMPs annually[11]. California's Urban Water management Plan (UWMP) Act allows urban water suppliers that are CUWCC members and that comply with CUWCC's BMPs can submit audits in addition to the Demand Management Measures suggested by the DWR.

Member water retailers include an assessment of real (leaks and breaks) and "apparent" losses and the economic value of real loss value of real loss recovery in terms of avoided cost of water. The CUWCC adopted the AWWA Water Audit Software based the AWWA/IWA methodology and requires members to use it for their analysis. The estimated losses require data validation by methods recommended by the AWWA methodology. The CUWCC also requires a Component Analysis every four years which analyzes the estimated losses and their causes[12].

These BMPs were formulated using the 10% maximum standard for unaccounted for water recommended by the AWWA Leak Detection and Water Accountability Committee (Dickinson, 2005). The above mentioned full-scale water audit is mandated by the CUWCC for the member utilities, provided the deficit or unaccounted for water exceeds 10% of the total distributed volume. The conditionality of the full-scale audit is not stated on the CUWCC website, but it is stated in the original BMP Retail Coverage Report input sheets used by the member utilities[13]. The full scale audit using the AWWA audit methodology would provide clear leak and break loss estimates.

To summarize, the most advanced efforts toward water loss reduction in California are voluntary (by CUWCC members). Water auditing relies on the method of data collection and accuracy in reporting and water retailers are not required to report on other best management practices to reduce water loss from their distribution system. There are no regulatory standards for maximum allowance of water loss and high quality data to create a benchmark.

Survey of Real Water Losses for Water Retailers in Urban Los Angeles County

Current regulatory and reporting standards in California raised certain issues on their effectiveness which are described as follows.

1. Are real water losses measured by water retailers, and if so, are these verifiable?
2. Are crucial Best Management Practices followed by water retailers to minimize water losses?
3. How regularly do water retailers monitor and maintain their distribution system for water loss reduction?

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[11] http://www.cuwcc.org/Resources/Reporting-Database/Reporting-101, (Accessed 9/25/2014)
[12] http://www.cuwcc.org/Resources/Memorandum-of-Understanding/Exhibit-1-BMP-Definitions-Schedules-and-Requirements/BMP-1-Utility-Operations-Programs (Accessed 9/25/2014)
[13] The Long Beach Department of Water BMP Coverage Report (2009-2010) http://www.water.ca.gov/urbanwatermanagement/2010uwmps/Long%20Beach%20Water%20Department/Attach_K.pdf

4. How publicly accessible are data and measurements of water losses from a distribution system made by the water retailer?
5. How do water retailers of different sizes and types compare in addressing the above issues?
6. What is a reliable and accurate metric for real water losses for a water retailer irrespective of its size and type that can be validated via available data?
7. Do California's legal and regulatory requirements under the Urban Water Management Act ensure accuracy in reporting and accomplish real water loss reduction?

Improving water distribution efficiency relies on aspects such as an effective water loss metric and standard, accuracy and frequency of monitoring and reporting, and data quality. The currently available literature, and collected data from the CUWCC and DWR were not sufficient to address these issues. We conducted this survey aiming to answer these questions and provide a snapshot of the current practices in urban Los Angeles County.

Methodology

Study area and Sample set

The Urban Los Angeles Region includes all areas south and west of the Angeles National Forest in Los Angeles County, as shown in Figure 1. It includes approximately 100 retail water systems (serving water to customers) with between 15 and approximately 680,000 connections[14] (Cope & Pincetl, 2014; Cheng & Pincetl). Many types of water retailers exist in the county, including city water departments and city water utilities, county water districts, county waterworks districts, municipal water districts, irrigation districts, nonprofit mutual water companies and private independently owned water utilities (IOU). Each has its own authorizing legislation, state oversight, governance, and customer accountability. Within the study area, water retailers include 41 Cities, 26 Mutual Water Companies, 10 County Water Districts, 8 Investor Owned Utilities, 3 Irrigation Districts, 3 County Waterworks District, 1 Municipal Water District (uniquely, also retailers), and 1 California Water District (Cope & Pincetl, 2014; Cheng & Pincetl). We based our sample selection on this population of retailers and the geospatial database cited above.

The number of connections that each retailer serves in this population follows a Gaussian distribution in the logarithmic form. The population has a large number of smaller retailers in our study area, and a portion of them are not urban water suppliers (serving more than 3000 users), and thus, are not required to submit UWMPs. We used percentile ranking to bin the population into three size-based categories depending on the number of service connections: Retailers ranking below 50 percentile in size as small, between 50 and 75 percentile as mid-sized and above 75 percentile as large retailers.

To represent the population of water retailers accurately, we developed a stratified sample set based on type, size and location of the retailers. We considered a sample size of 10 retailers, that is, 10% of the statistical population for our analysis. We offered the choice of anonymity

[14] We were not able to contact water retailers which served under 200 connections.

and confidentiality to the participating agencies. We only report results and not names to protect confidentiality of survey respondents. To accommodate and correctly represent all types of retailers, we did not include the type ‘California Water District’, as there exists only one such retailer in our study area. We represented Irrigation Districts, County Waterworks District and Municipal Water Districts as ‘Special Districts’ (SD) to maintain anonymity.

We contacted 20 retailers and received responses from 10, indicating a 50% response rate. When water retailers decided to not participate in the study, we substituted with other similar retailers to maintain the unbiased distribution in size, location and type. We contacted three mid-sized retailers, while sustaining our requirement for different types and locations of retailers, but did not receive a response from these mid-sized retailers. Hence our analysis will reflect performance of small and large retailers only. We had a low response rate from Special Districts, hence the low representation. Figure 3 shows the final sample set after the replacements. The two tables on the bottom-left show the categorization in our sample. The percentages in the parentheses are the percent representation of such retailers from the entire population in our sample. The pool of participants was dependent on the will for participation and legal binding of the water retailers that we contacted.

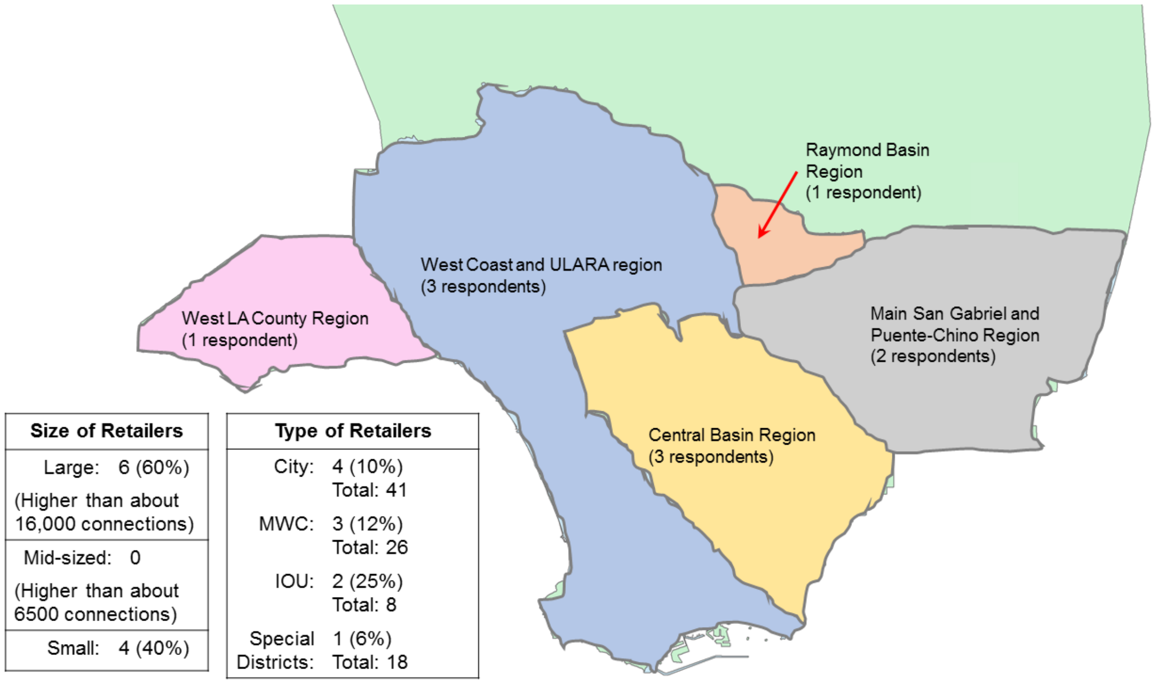

Figure 3 Final sample set for study

Data Collection and Analysis

We conducted reconnaissance interviews with the local water system experts who manage, work with or oversee water retailers to better understand how to develop the interview instrument. Through literature research and these preliminary interviews, we determined that performance of retailers is dependent on monitoring of their distribution system and planning of investments in infrastructure maintenance and replacement. We hypothesized that the institutional capacity and competency of a water retailer can be indicated by their ability to management its water distribution system efficiently, without excessive loss of water due to leaks and breaks and other system defects. We also concluded that maintaining public data is necessary for each retailer to develop an effective strategy for water distribution efficiency improvement. Based on these conclusions, we formulated a set of interview questions to collect data from water retailers in our sample. The interview questions are presented in Appendix A.

We evaluated the retailers' responses using the following criteria and allotted performance indices to each sample retailer:

Table 1 Performance indices allotted for Best Management Practices for water distribution

Best Management Practices	Indices allotted
Monitor GPCD	1
Awareness and regularity of usage of AWWA Water Audit Methodology	3
Existing or future programs for smart meters	1
Preventive maintenance (exercising of valves and flow testing of meters)	2
Infrastructure replacement (for pipes, valves and meters)	3
Monitoring of annual number and location of pipe breaks and implementation of leak detection programs	2
Monitoring of age and material usage on GIS	1

We also assessed the participating water retailers based on their own target parameters. In addition to prescribing to any of above measures, their proposed and achieved targets reflect their efficiency in water distribution. We also conducted a statistical t-test between each type and size of retailer with the rest of the sample.

- Water losses
    - Annual Real Losses in volume or percent i.e., true losses or leakages from transmission and distribution mains, leakage and overflows at utility storage tanks up to customer meters
    - Annual Unaccounted for water in volume or percent
- Percent of distribution pipeline replaced annually
- Number of main breaks for every ten miles of distribution pipeline

During data collection, we asked participating retailers for information that would verify the data, such as reports, monitoring charts and urban water management plans. We awarded points to retailers that provided us with documentation that verified the data. The documentation was either directly provided by the retailer or obtained from the website, urban water management plan, or water master plan. We also examined the accessibility of information through responses to the interview and follow-up questions and available or provided documentation and awarded the retailers points.

Since some respondents did not respond to all of the questions, we followed up with the individual respondents via, email and phone. In case of a lack of response from a retailer after several attempts, we were compelled to remove that retailer from the sample for this particular analysis of overall performance. Owing to this process we could assess the overall performance for 8 water retailers.

Results and Discussion

The survey results yielded findings regarding the responsiveness of different types of entities to participate in the survey public availability of data on distribution system water loss, infrastructure replacement standards, adoption of best management practices and water loss estimates and metrics. All the following results and discussion are based on our sample of water retailers. Any reference to entire population is included explicitly.

Responsiveness and Public Water Losses Reporting

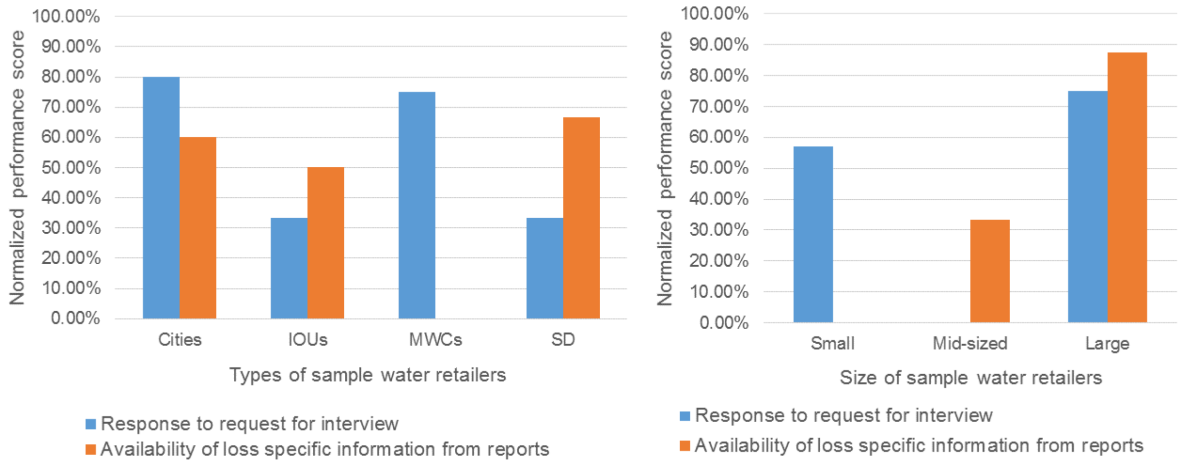

Figure 4 Accessibility and verifiability of water retailers of various types and sizes

To determine the transparency, accessibility and verifiability of various types and sizes of retailers, we assessed the retailers that we contacted, including the ones not participating, based on their responsiveness to the interview and follow-up questions. *Figure 4* depicts the accessibility of these 20 water retailers that we contacted to researchers or citizens seeking information, without the use of the Right to Information Act.

There significant differences in the willingness of retailers to respond to survey request as shown in *Figure 4*. Three large IOUs that we contacted refused to participate in the study declared legal issues. Together, these IOUs serve a large number of consumers in Los Angeles County, but out of the 6 we contacted, only 2 participated in the survey. It was also very difficult to verify the information that large IOU A (from our sample) provided due to lack of responsiveness to follow-up questions. On the contrary, Large IOU B (from our sample) was very responsive and was transparent about its methods of monitoring breaks, impediments and current infrastructure status, and has also formulated its own water audit tool to determine real losses. Overall, IOUs as a group were not responsive to requests for information.

Large retailers serving cities were very responsive and provided documentation to verify their data. Small City B provided incomplete information and showed a lack of responsiveness to follow-up questions. Small City B also discussed several economic issues and political hurdles with respect to infrastructure maintenance and replacement. Another small city did not respond to our several requests for participation.

The MWCs were responsive to attempts of contacting them, but could not provide validating documentation to verify information. Small MWC A could not provide us with complete data and small MWC B could not verify the data they provided on the number of main breaks, reflecting their poor monitoring practices. Thus, though two out of the three MWCs were responsive in this study, due to lack of verifiability, it was difficult to rely on the data that all three MWCs provided. The Large SD (from our sample) was very responsive and provided verifiable information promptly. Other smaller retailers that we contacted included two special districts, an MWC and a City which were not responsive to our request of interview. Overall, we had a 50% success rate in obtaining information from the retailers we contacted, not including the ones unresponsive to follow-up questions.

Infrastructure Replacement Schedule

Most of the participating retailers allocate annual budget funds for replacing a fixed number of miles of distribution pipeline. In our sample set, six out of ten retailers allotted some budget for the same, whereas the other four replaced their distribution pipeline ‘as needed’. Figure 4 shows the number of years it will take to replace the entire distribution pipeline based on their current targeted rate of pipe replacement for 2013.

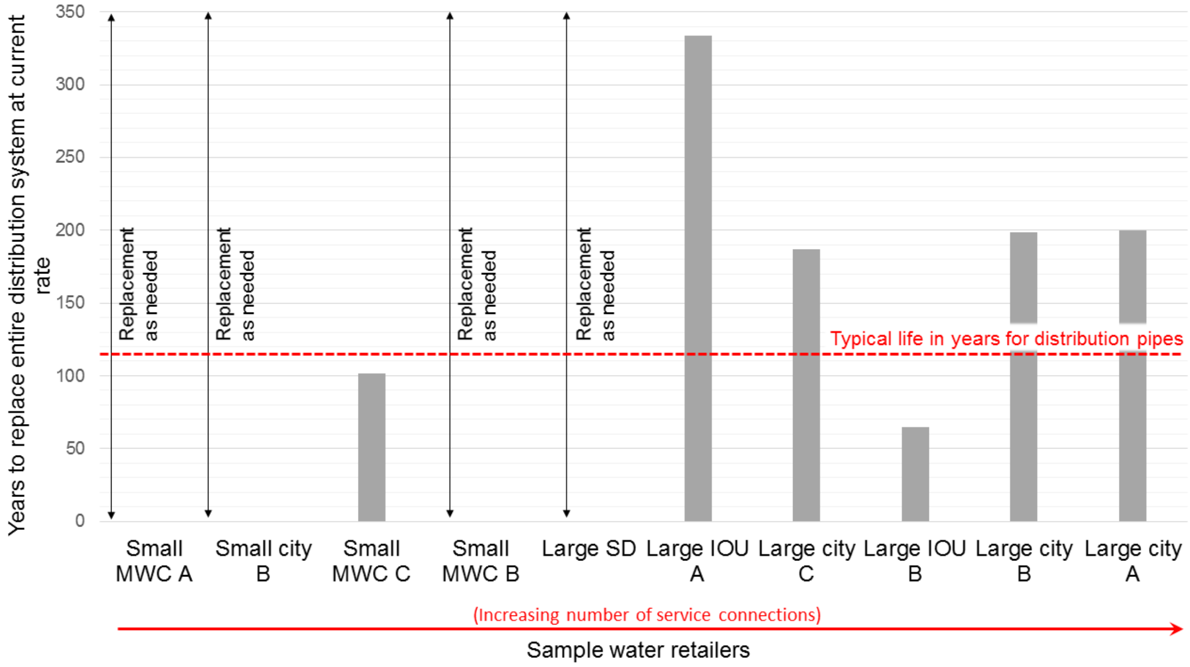

Figure 5 Number of years to replace distribution system for participating retailers

The timelines for replacing current systems are long. Four out of six retailers that replace a fixed number of miles every year will take about 190-330 years to replace their entire distribution pipeline. The typical life in years of the pipes used in their systems was reported to be 100-120 years. For very highly maintained pipes using state-of-the-art materials (e.g. ductile iron), they report the maximum lifespan to about 140 years. Only two participating retailers successfully replacing their pipelines by estimated pipe lifespan. With reliance on pipes potentially beyond their usage life, the water distribution system in urban Los Angeles is susceptible to further pipe failures with tremendous amounts of water loss and significant property damage.

Figure 5 shows the number of breaks for all 10 water retailers. We normalized the number of main breaks for each sample water retailer by the water distribution length of the system, which makes them comparable. Factors such as age of pipes and storage facilities, the pipe materials and construction quality, the valves, meter accuracy, soil acidity, high operational pressure and variation due to undulating topography or acute diurnal variation can strain distribution system components. According to some water suppliers from the study sample, the longevity of distribution system components is also determined by overlying traffic density.

Small MWC A and small MWC C claimed to have zero and one break in the entire year of 2013. The other small retailers had 22-26 main breaks every 100 miles of pipeline, which is high compared to large retailers had 3-16 main breaks every 100 miles. Sturm et al. (2014) estimated the weighted average of failure frequency in main and distribution lines for North American water utilities from previous literature as 24.68 failures every 100 miles per year. The estimates by our sample water retailers are lower than the national average as these do not include sub-surface leaks.

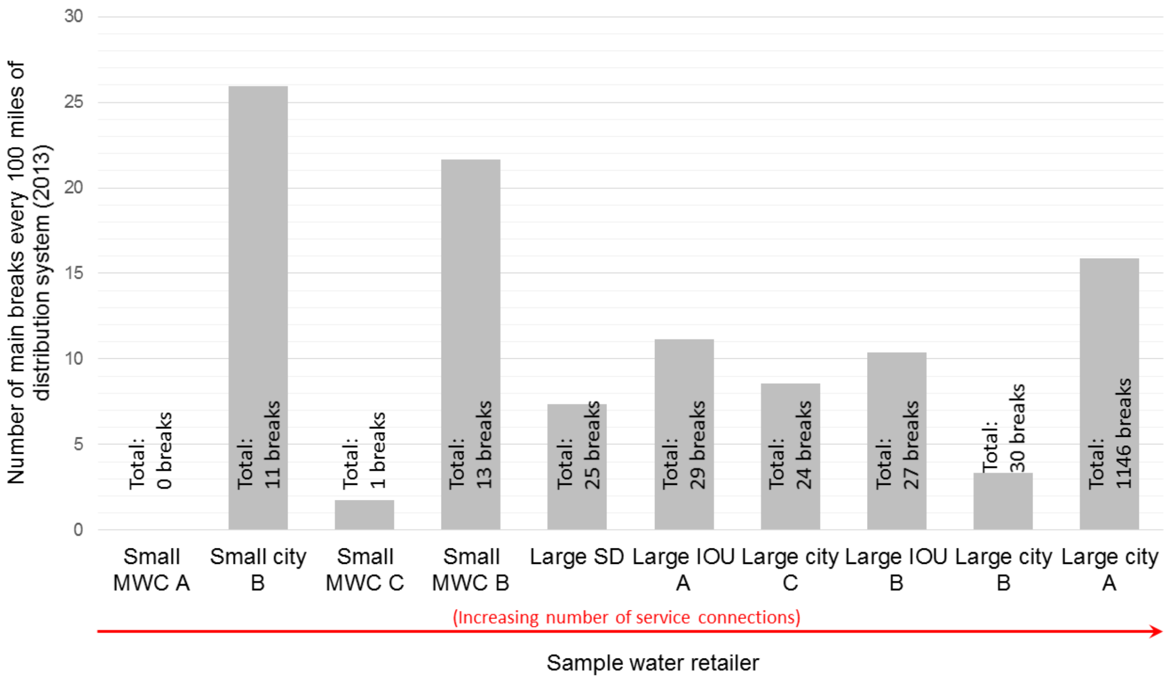

Figure 6 Number of main breaks every 10 miles of distribution system for sample water retailers in 2013

Age of pipes and storage facilities, the pipe materials and construction quality, the valves, meter accuracy and pumps all matter, Soil types also affect system efficiency, as corrosive soils reduce pipe life. High operational pressure and variation in hillside areas can further strain distribution system components. According to some water suppliers from the study sample, the longevity of distribution system components is also determined by overlying traffic density.

Small MWC A and small MWC C claimed to have zero and one break in the entire year of 2013. The other small retailers had 2-3 main breaks every 10 miles of pipeline, whereas large retailers had 0.3-1.1 main breaks every 10 miles. The largest retailer had higher number of breaks.

We asked the sample water retailers for their estimates of real water losses. Table 1 shows water loss estimates and the verifiability of these estimates. Only four out of the ten sample water retailers estimated real losses for their distribution system. All the retailers that measured real losses were large. These retailers reported having 3-4% of real water losses, which are improbably low as compared to estimates all over the nation (United States Environmental Protection Agency, 2010). The rest still use the metric of 'unaccounted for water' to assess their distribution system efficiency. The nation-wide average estimate for "unaccounted for" water for Israel was 10-12% in 2011 (Planning Department of the Israeli Water Authority, 2011). The national average for Australian water utilities with more than 100,000 connections is 18 gallons per connection per day in 2011. (Real Loss Component Analysis: A Tool for Economic Water Loss Control, 2014).

Table 2 Estimates for water losses by sample water retailers

Sample Retailer	**Real Losses (%)**	**Unaccounted for water (%)**	**Verification**
Large City C	Not measured	2.8 % (18.1 gal/connection/day)	No
Large City B	3.4 % (19.9 gal/connection/day)	4.5 %	Yes
Large City A	4.1 % (31 gal/connection/day)	Measures real loss	Yes
Small MWC A	Not measured	3 % (16.7 gal/connection/day)	No
Small MWC B	Not measured	11.35 % (67.4 gal/connection/day)	No
Large SD	4 % (40.5 gal/connection/day)	Measures real loss	Yes
Large IOU A	No response	1 % (5.6 gal/connection/day)	No
Small City B	No response	6.5 % (32.3 gal/connection/day)	No
Large IOU B	4.02 % (11.6 gal/connection/day)	Measures real loss	Yes
Small MWC C	No Response	No Response	No
Responders	7 out of 10	9 out of 10	**4 out of 10**

Overall Performance - Best Management Practices

We used survey results to develop an index of performance based on the criteria described in the Methodology section: monitoring per capita water consumption, awareness and usage of the AWWA water audit tool or equivalent analysis, usage of smart meters, infrastructure testing and replacement, leak and break detection and monitoring, age and material of infrastructure on Geographic Information Systems.

Figure 6 summarizes the performance of different types of retailers from our sample set in these categories.

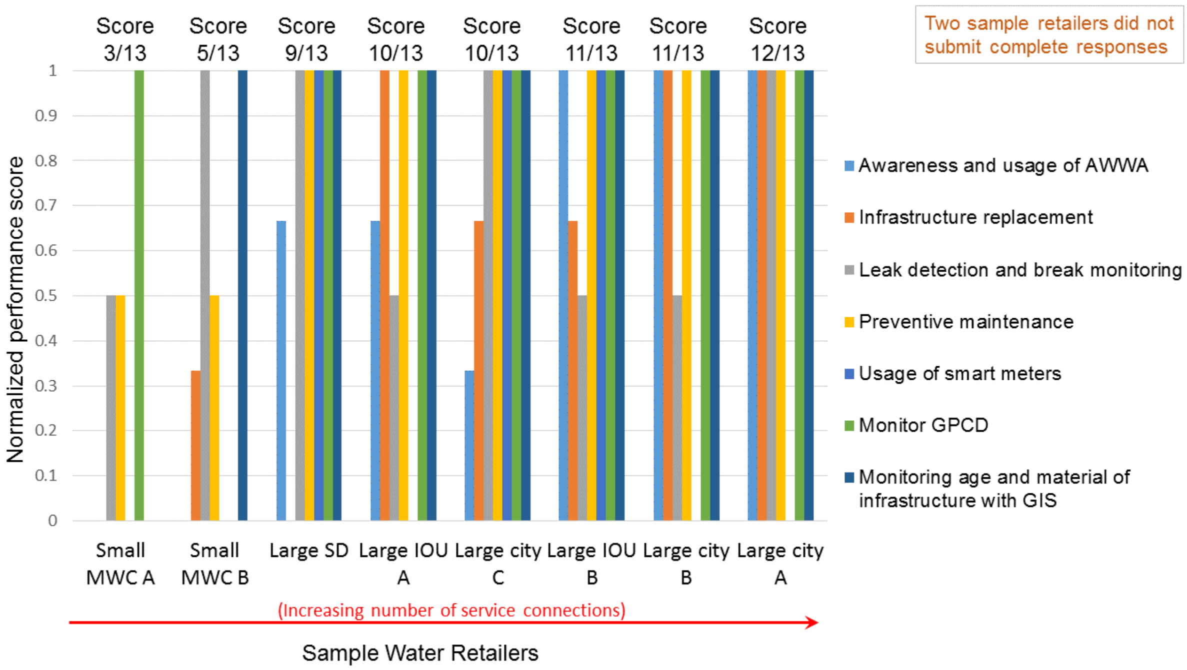

Figure 7 Scoring of participating retailer with respect to best management practices followed

Large cities in our sample reported adhering to most of the best management practices, but their targeted pipe replacement is low. Small city B lags in these practices and also had a high number of main breaks in 2013. The IOUs were almost at par with the cities in implementing these Best Management Practices. The California Public Utilities Commission requires IOUs that are Class A utilities[15] to conduct and submit the results of a water loss audit in their General Rate Case applications (CPUC, 2006). The IOU respondents conducted water audits as they are members of the CUWCC but did not share information about this CPUC rulemaking. The MWCs had a low performance in preventive maintenance, awareness and usage of the AWWA Water Audit and infrastructure replacement. The performance score for the sample increases as the number of service connections increases.

Table 3 T-test results for performance based on size and type

Criteria	Size	Type
Overall performance	Large retailers (high, p=0.0034)	MWCs (low, p=0.0035)

[15] Utilities serving 10,000 customers or more

Main breaks	Not significant	Not significant

Statistical analysis indicates that the large retailers had a significantly higher overall performance with respect to following best management practices (p=0.0034). The MWCs had a lower overall performance than the rest of the sample (p=0.0035). It is difficult to isolate the performance by type in this reduced sample, as there were not sufficient number of MWCs with complete information and monitoring. The t-tests were conducted with a significance of 5%.

Monitoring and Quantifying Real Water Loss

The AWWA M36 Manual (American Water Works Association, 2009) calculates that underground leakages, which are usually undetected, can lose more water than surface main breaks if not repaired over a period of several days. Leak detection to locate small underground leaks is necessary to reduce continuous, undetected water losses. Yet, only 4 out of the 10 water retailers in our sample invest in installing or leasing leak detection technology. Moreover, one city commented that small leaks do not lose as much water as large main breaks. Based on our interviews, water retailers in our sample who cannot afford to buy leak detection equipment find it more suitable to lease basic equipment (of high quality), which provide an accurate location of the underground leak within a few feet.

Recommendations and Discussion

Out of the 10 in our sample, 6 water retailers still used the term ‘unaccounted for water’, which is now an obsolete term to quantify water losses as it lumps real losses together with other non-revenue water. Only 3 out of 10 regularly use the AWWA Water Audit to determine real losses. They cited several reasons for their inability to estimate real losses: (1) Monitoring consumption over uncoordinated billing cycles among their connections (2) Lack of metering for non-revenue water uses (for instance, parks and fire hydrants) (3) Difficulty in tracking water volumes in interconnected networks with other retailers. One solution for estimating non-revenue water is to install meters at locations using non-revenue or unbilled water and avoid under-reporting.[16]

The AWWA Water Audit relies heavily on self-reported data, which is subject to non-standardized data collection, especially for non-revenue water volumes. For example, in 2014, 35% of the audits submitted to the CUWCC were invalid, whereas in our survey, two small MWCs reported to have had zero and one main break in year of 2013 in their distribution system. Mandating submission of the completed AWWA Water Audit without verification of data may provide us with underestimated water loss values, thus pre-empting any vigorous attempts to improve water infrastructure in Los Angeles. For effective auditing and distribution efficiency, it is practical to verify the submitted data of randomly selected water suppliers with monitored data records, similar to the functioning of the CUWCC or the privatized water industry of the United Kingdom (Engelhardt, Skipworth, Savic, Saul, & Walters, 2000).

[16] Personal communication, Mary Ann Dickinson

Further, in the current CUWCC procedures, the detailed AWWA Water Audit is not required if the non-revenue water is less than 10% of the total supplied volume based on a preliminary audit. Since this is an obsolete recommendation, we suggest and prescribing realistic maximum water loss standards for retailers. Post Senate Bill 555, the data collected from valid water audits should be used to develop a benchmark for the average real water losses across California. This database can also be used to recommend a more realistic maximum real water loss standard. All the sample retailers measured real losses as a percent of total supply. For large retailers, expressing water loss as a percent of the total volume supplied can mask the actual volume of water lost. While comparing a large and small retailer, a similar percent water loss for a larger retailer implies a large volume of loss, as shown in Table 2. Measuring the losses in volume units, such as 'gallons per connection per day' is a more representative measure, especially for a stringent conservation framework as California's.

Auditing water losses, while an improvement on current practices of many retailers, is not a complete solution to planning systematic allocation of resources for different parts of the distribution system. It is equally important to strategize infrastructure replacement based on these independent factors affecting the distribution system. The occurrence of a leak or break can be caused by the age of pipeline or peripheral infrastructure such as valves and meters, wear and tear due to traffic and pressure and flow variation at that location. We suggest developing a compendium of the best management practices to reduce water losses that pertain to various deficiencies in distribution systems from which water retailers can adopt measures crucial to their system.

The AWWA M36 Manual (American Water Works Association, 2009) estimates that undetected subsurface leakages can lose more water than surface main breaks if not repaired over a period of several days. Leak detection technology is necessary to reduce continuous, undetected water losses. Yet, only 4 out of the 10 of our sample water retailers invest in installing or leasing leak detection technology. The sample water retailers were divided on the validity of leak detection equipment. In case of restricted budgets, small retailers could pool resources to buy leak detection equipment, and set up a regular schedule based on the size of the distribution system. Leak detection needs to be an ongoing process with water auditing, subject to the cost-effectiveness of repairing specific leakages, to obtain returns in revenue on the water saved[17].

Last, water retailers with less than 3000 connections are now exempt from submitting an urban water management plan to the state, which is now the reporting vehicle for real water loss. Similarly, the PUC exempts IOUs under 3000 connections from their water loss analysis. However, in large urban areas, there are many small retailers and many small irrigation districts that now serve water, as do mutual water companies and small IOUs. In fact, in Los Angeles County, over 46,000 connections are served by retailers with less than 3000 connections. Currently, these retailers are exempt from the requirements imposed on larger systems, including reporting on losses from leakage and breaks. The state needs to think about how retailers who cumulatively serve a large number of customers in an urban area can pool

[17] Personal Communication, Reinhard Sturm

resources and receive technical assistance to do water audits, and to use best management practices to replace old pipe, clean and repair inaccurate meters and monitor breaks and leaks, thus reducing real water losses.

Conclusions

To support intensifying conservation requirements in California, minimizing water losses from infrastructure is crucial. Some recent and upcoming legislation in California is looking to prioritize this issue. For instance, state Senate Bill 1420 mandating the use of the AWWA Water Audit aims to reduce water losses from infrastructure. After interviewing several types and sizes of water retailers distributed across various geographical locations in urban Los Angeles, we conclude that assessing the efficiency of a water distribution system only via the AWWA Water Audit will be insufficient and may underestimate actual losses. Sixty percent of our sample still relies on monitoring only “unaccounted for” water to control water losses. Using an external authority to validate data and metering for non-revenue water can improve the efficacy of the AWWA water audit methodology. Another effective metric of infrastructure quality is consistency in following prescribed best management practices customized to the size and type of retailers.

Water retailers should invest regularly in water infrastructure to avoid loss in revenue and damage claims. Decision-making for rate increases can be more informed with detailed knowledge of the state of the distribution system and the investments and practices necessary to minimize water, losses and economize water distribution. In Los Angeles, many pipelines are past their useful life, with leakages or points of imminent failures, potentially causing tremendous water loss.

As suppliers of potable water to the public, the Investor-Owned Utilities must be responsible to provide more accessibility and transparency to information about their respective distribution systems. This can also facilitate proposing capital improvements to the CPUC as more transparency can garner public support. The MWCs can bolster their cooperation in water conservation by maintaining verifiable information on water losses in their system in the form of reports or monitored data. The MWCs are organized in the state, and could develop a mutual assistance and cost sharing agreements with other mutual or with adjacent retailers. Such verifiability will aid them in addressing concerns from the State and water quality authorities, as well as in monitoring their system efficiently. Smaller retailers can improve their performance by coordinating their efforts in leak detection and minimization.

In conclusion, strategizing best management practices and assessing cost-effectiveness of leakage repairs based on the accurate infrastructure assessment for retailers can improve management of water infrastructure and reduce water losses. These strategies have been made available by AWWA M36 Manual (American Water Works Association, 2009) and other literature reviewed in this study. Transparency and verifiability in information is crucial to implement such a system. With this paper, we have provided a glimpse of the current status water loss reporting state wide, of water retailers in urban Los Angeles County and have thrown light on their deficiencies while outlining their strengths. This paper also provides a context for upcoming policy decisions to reduce water losses through infrastructure, thus supporting conservation efforts.

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Appendix

Document of Interview Questions for Study

In this interview, we are asking you to respond to questions about water distribution efficiency and related measures in your water agency, company or department.

[At this point, read and sign consent form and begin responding]

Urban Water Supplier: According to the Urban Water Management Act, it is "a supplier, either privately or publicly owned, providing water for municipal purposes either directly or indirectly to more than 3000 customers or supplying more than 3000 acre-feet of water annually."

1. Which service does your water agency provide? *Indicate all options that apply.*

    a. Water Distribution to End Users

    b. Raw Water Treatment to Drinking Water Standards

    c. Water Reclamation or Ground Water Replenishment

    d. Stormwater Treatment

    e. Power

2. What is your agency's **annual** water distribution volume for potable/recycled water in **acre-feet**, as most recently monitored?

3. What is the residential population in your service area? If your service area is geographically divided into isolated segments, please give totals for each segment.

4. How many residential service connections do you have?

5. How many business service connections do you have?

6. How do you measure/calculate the **volume of water in acre-feet** that is being brought **into** your system, either through local or imported sources? How do you measure this?
7. Do you know your agency's average **per capita per day** usage for **potable** water for **residential** users in your service area? (Y/N) *If yes, please answer Q8, if not go to Q9.*

8. What is the per capita per day use for **residential** customers? (GPCD) How do you calculate it?

9. What is the **per capita equivalent usage** for **businesses**? How do you calculate the usage? *If you don't know, please indicate and move to the next question.*

10. Are you a member of the California Urban Water Conservation Council (CUWCC)? (Y/N)

11. Have you used the **AWWA** tool for estimating all real losses? (Y/N) If yes, **when** was the last time you used it? *If not, skip to Q14*

Real Water Losses are defined by the AWWA Water Audit Tool as "true losses of water from the utility's system, up to the point of customer metering. They consist of leakage on transmission and distribution mains, leakage and overflows at utility storage tanks, and leakage on service connections up to the point of customer metering"

12. What is the **current** estimate of the **Real Water Losses** associated with your distribution network for the 2013-14 year? (July 1st 2013 to June 30th 2014). *If you don't know please indicate and move to Q15.*

13. Can you give an estimate in volume or percent, the **real losses** in various **parts** of your agency's distribution system? *If you don't know, please indicate below and move to Q15.*

	Estimated Volume	Estimated Percent
a. Transmission/distribution mains		
b. Overflows at storage tanks		
c. Service connections		
d. Don't know		

14. If you have **not** used the AWWA tool, do you calculate your real losses? (Y/N) If so, how? Can you give an estimate of your real losses? *If you can't estimate losses, please indicate and move to the next question.*

15. How much of your agency's distributed volume is **metered**? (Volume or percentage of total) Do you have **smart meters**?

16. Does your agency have a regular **schedule** for water distribution system **replacement** and **upgrades**? (Y/N)

17. If so, do you have a **standard number of miles** of distribution system that you **replace/repair each year**?

18. Do you have a **schedule** for checking and replacing **valves**? Do you have a schedule for checking **meters** for accuracy and replacing them?

19. Does your agency have a Leak Detection Program? (Y/N) If yes, can you describe it?

    If yes then go to Q20 and skip Q21; if not, go to Q21.

20. If you do have a leak detection program, do you use it to plan **budgets** and **investments** in pipe and other distribution system replacement? (Y/N)

21. If you don't have a leak detection program now, do you think that you will be developing one in the next year? (July 2014-June 2015)? (Y/N)

22. Do you keep records of the number of **line breaks per year**? (Y/N)

23. Do you keep records of the **material** and **age by location** of various parts of your distribution system? (Y/N) What is the pipe material that your system uses?

24. What is the **average life** in years for pipes in your system? Which specific **factors** affect pipeline life in your system? (E.g. corrosion, material, earth movement, etc.)

25. Do you report your system losses from water supply to any **government agency** in addition to the DWR? If yes, what parameters pertaining to system losses do you report?

    If yes, please name the agencies below:

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26. What other **current** or **past measures** has your agency implemented to prevent or reduce real losses?

27. Can you tell us if your agency is thinking about new **future measures** to prevent or reduce real losses?

28. Are you able to secure enough revenues out of your annual resources to prevent or reduce real system losses? (Y/N) If not, what kind of assistance would you need to minimize system losses through monitoring, rapid response and replacement?

29. In your opinion, what requires to be done to improve water distribution efficiency across various agencies in urban Los Angeles?

List of Figures