Appendix C

City of Guelph Water Loss Management Strategy Review by AECOM

AECOM
200 Indiana Avenue
Stevens Point, WI 54481
www.aecom.com

To: Tara Roumeliotis; Heather Yates; Dave Belanger, City of Guelph

From: Richard Hope

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Project #: 60612820

Technical Memorandum

Subject: City of Guelph Water Loss Management Strategy Review

1. Purpose

The purpose of the technical memorandum (TM) is to summarize the of existing water audit information provided by the City of Guelph (Phase I) and to provide opinions on the following:

1. Water Audit Process
2. Economic Level of Leakage (ELL)
3. Leakage Management Strategy
4. Level of Real Losses to be used in Water Supply Master Plan Update Water Demand Projections

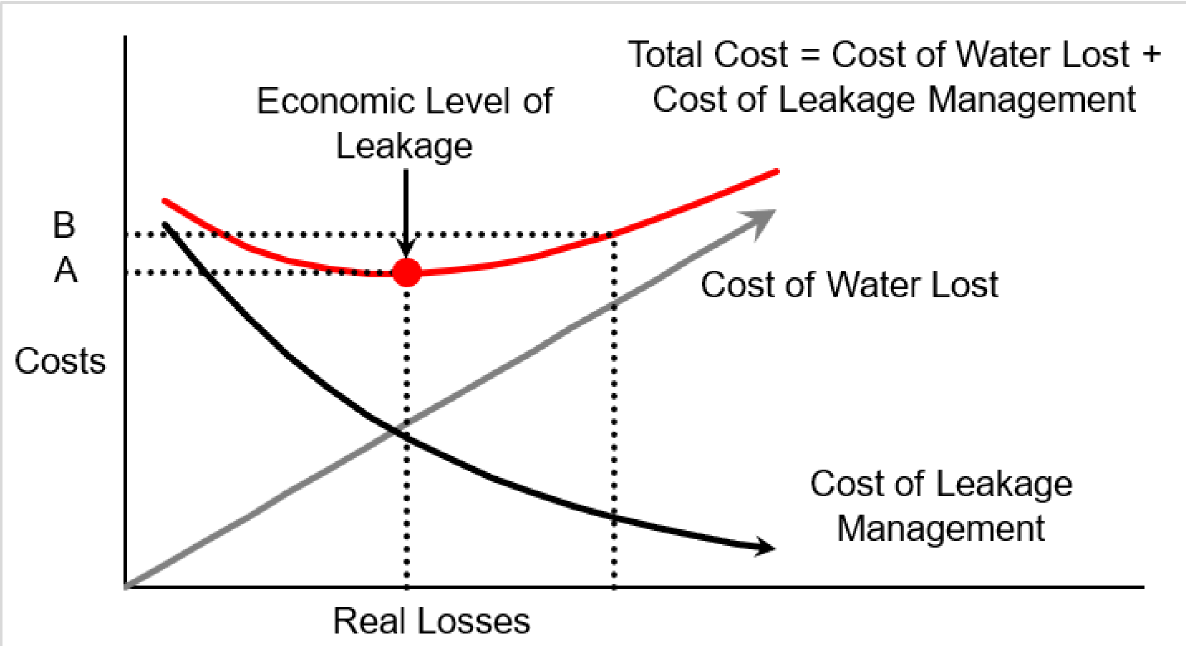
Phase II (if required) will develop the implementation plan for the agreed Water Loss Management Strategy identified in Phase I.

Attachment B provides definitions for several terms and concepts that are used to evaluate the water losses within a water system as a reference.

2. Introduction

As a steward of water resources, the management of real losses is an important activity for all water utilities. A goal of managing real losses is to implement strategies that result in achieving the ELL or close to the ELL. The ELL is the point when the cost of the annual real losses is equal to the cost of the leakage strategy. The ELL concept is illustrated in Figure 1. As illustrated, the cost of water lost increases as real losses increases and the cost of leakage management increases to reduce real losses. Therefore, the total cost is the sum of the cost of water lost plus the cost of leakage management. This cost is a minimum when the ELL is achieved.

Figure 1: Economic Level of Leakage (Real Losses)



The ELL can also be influenced by the availability of water and the infrastructure needed to provide, treat and distribute the water. If capital expenditure can be deferred, reduced or even eliminated by the reduction in water losses, additional expenditure can be justified to support the leakage management strategy.

3. Water Audit Review

The American Water Works Association (AWWA) recommended water balance which is discussed in the following sections is illustrated in Figure 2 for reference.

Figure 2: Water Balance

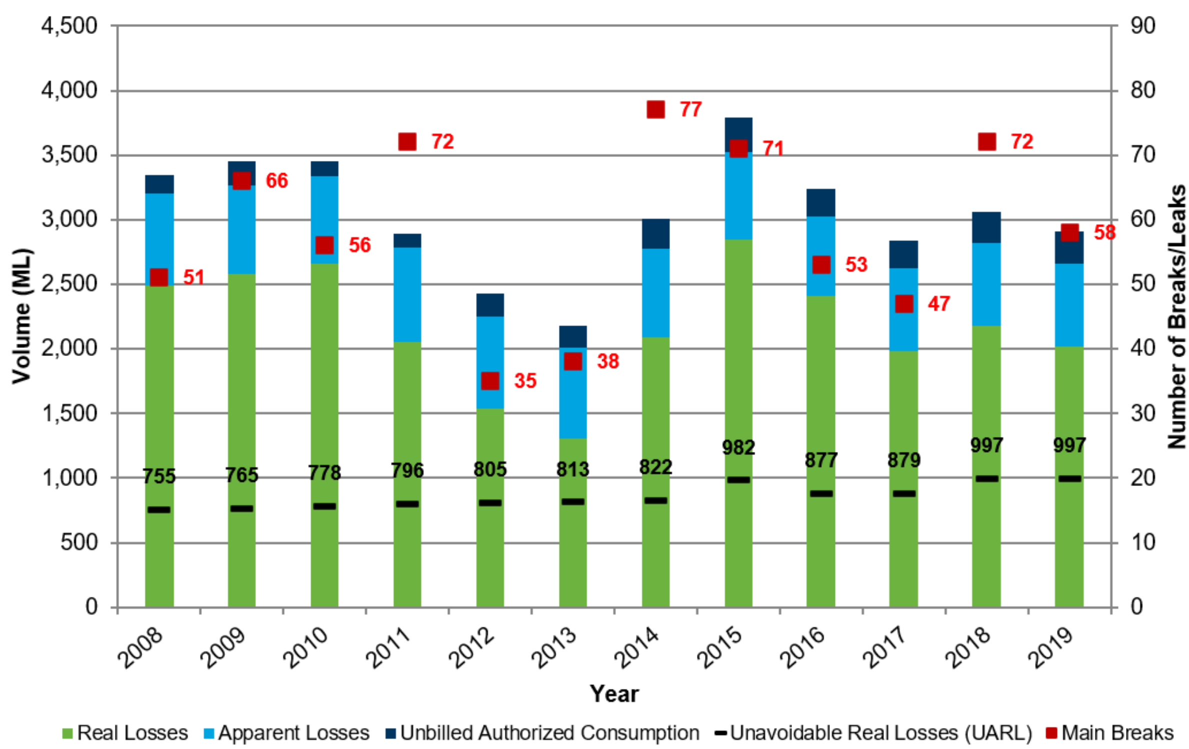
System Input Volume	**Authorized Consumption**	Billed Authorized Consumption	Billed Metered Consumption	Revenue-Generating Water
			Billed Unmetered Consumption	
		Unbilled Authorized Consumption	Unbilled Metered Consumption	Non-Revenue Generating Water
			Unbilled Unmetered Consumption	
	Water Losses	Apparent Losses	Unauthorized Consumption	
			Metering Inaccuracies	
		Real Losses	Leakage on Transmission and/or Distribution Mains	
			Leakage and Overflows at Utility's Storage Tanks	
			Leakage on Service Connections up to Point of Customer Metering	

3.1 Historical Water Losses

The City of Guelph has been completing a water audit following an industry-wide standard approach presented in the AWWA Manual M36 for over 10 years. To assist in the water audit, the City of Guelph has been using the Water Audit software developed by AWWA. The following section provides a summary of the information from the water audits since 2008.

As can be seen from Figure 3, annual water losses have varied between approximately 2,009 megalitres (ML) in 2013 to approximately 3,521 ML in 2015 with an average of approximately 2,865 ML over the 14-year period. The decline in water losses from 2011 to 2013 is attributed to the leak detection program implemented in 2010 and the two extreme cold winters occurring in 2014 and 2015 resulted in increased leakage along with an increase in unbilled authorized consumption as customers were asked to run their taps to prevent freezing. As illustrated in this figure, the annual real losses have generally declined from 2015 to 2019.

Figure 3: Historical Non-Revenue Water



For evaluating the ELL, the 2019 water audit data was used.

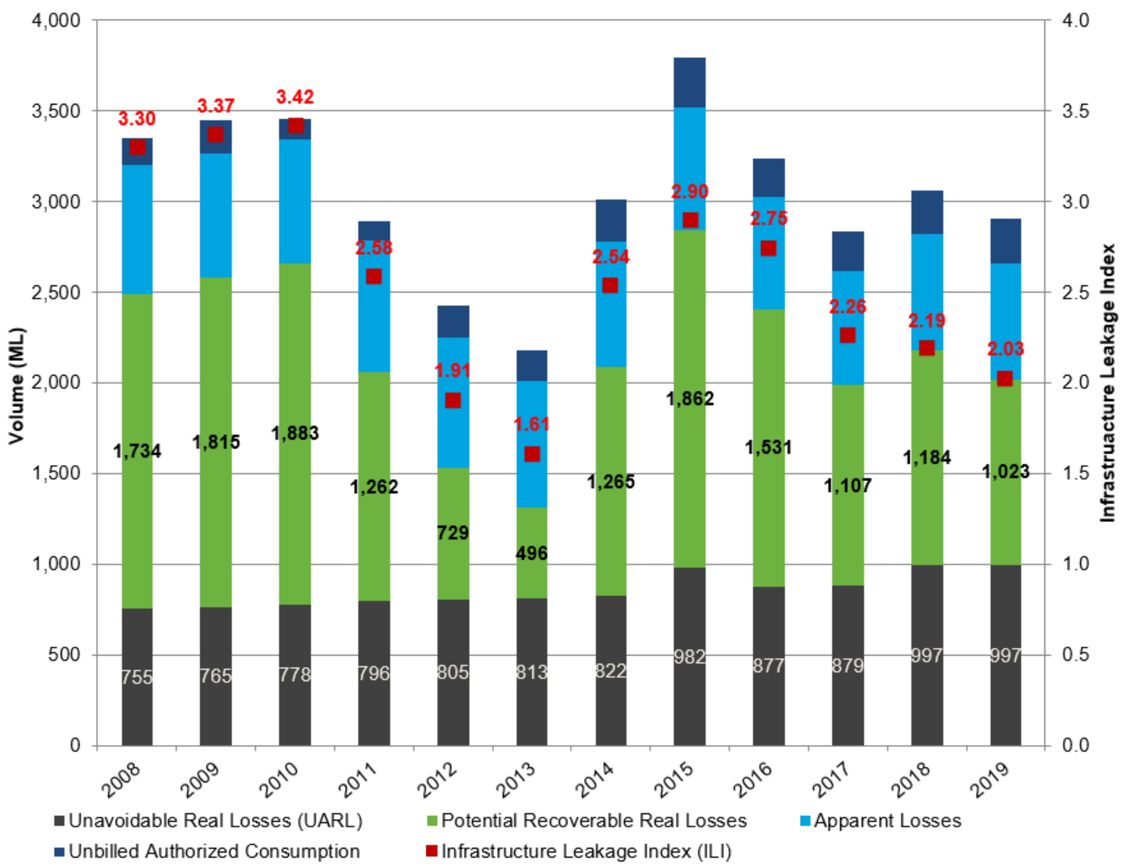
A key concept in the analysis of real losses is that all water systems have a level of leakage that cannot be economically prevented or recovered which is referred to as the

"Unavoidable Annual Real Losses" (UARL) and is dependent on a number of parameters that are specific to each water system, including length of water main, number of service connections, average length of service connection, and system pressure.

A key performance indicator (KPI) referred to as the Infrastructure Leakage Index (ILI) has been introduced in the water industry to help compare water system with respect to leakage. The ILI is the ratio of real losses and UARL. An ILI of one (1) means that the current real losses are equal to the UARL and further reduction in real losses is unlikely to be economically achieved. The ELL is typical between the current value of annual real losses and the UARL.

The ILI for the City of Guelph over the period 2008 through 2019 is illustrated in Figure 4 along with the historical components of NRW. Note the UARL is lower in 2016 and 2017, as the number of service connections was estimated as one per service address and historical values were estimated based on the number of meters. It is AECOM's understanding that Water Services is in the process of determining the number of service connections through a GIS/billing system cross reference and field verification. It is believed that the number of addresses was reflective of those entered in the billing system and is an underestimate. If the UARL was underestimated, that would result in a lower ILI.

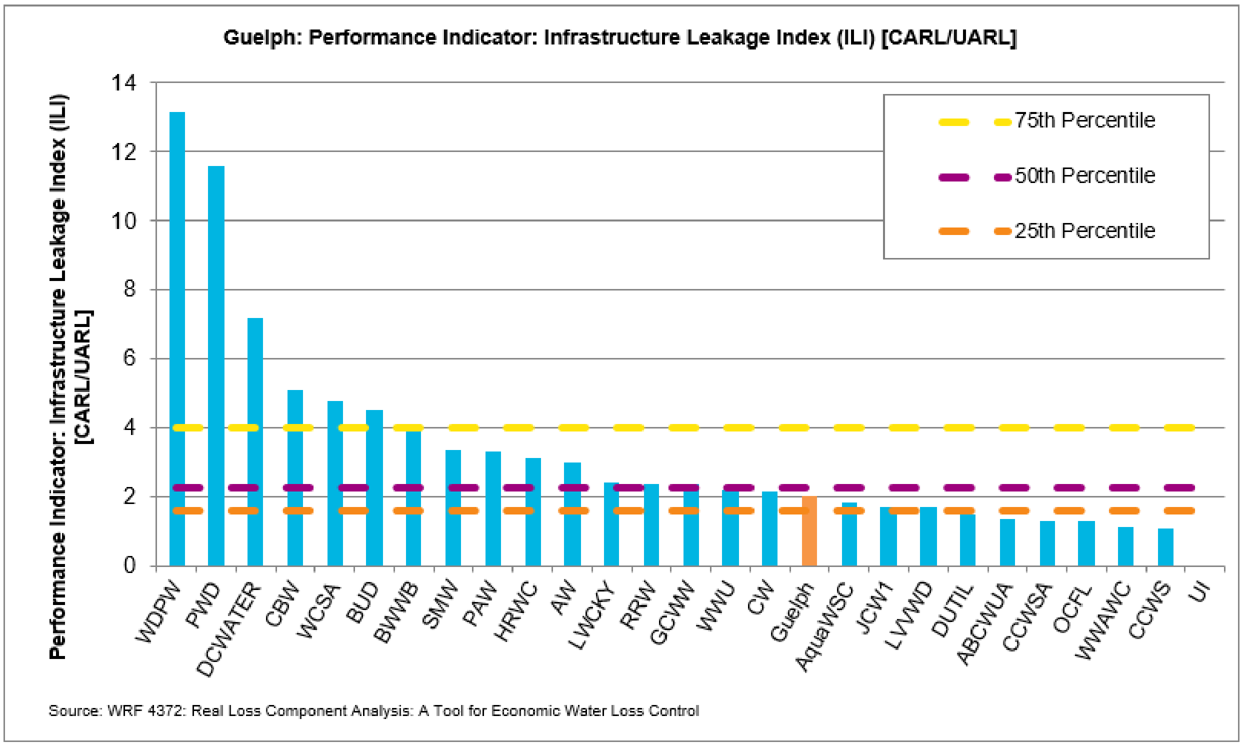
Figure 4: Historical Infrastructure Leakage Index for City of Guelph



As can be seen the ILI has ranged from approximately 1.61 (2013) to approximately 3.42 (2010). More recently, the ILI was at 2.54 in 2014 and has declined to approximately 2.03 in 2019.

Figure 5 illustrates the 2019 City of Guelph ILI compared to other communities based on the data in the Water Research Foundation (WRF) report 4372, Real Loss Component Analysis: A Tool for Economic Water Loss Control. Based on this set of data the City of Guelph ILI is between the 25th percentile and 50th percentile in the data.

Figure 5: Benchmarking of Infrastructure Leakage Index



3.2 Review of Water Audit Process

One task of this project included a review of the water audit process which has been completed annually by the City of Guelph for over ten years. AECOM reviewed the data provided and had discussions with the City personnel responsible for completing the audit to review the process and data used. The completion of a water audit annually, is one of the first steps in developing a leakage management strategy and evaluating the economic level of leakage.

A review meeting was held in April 2021 to discuss the water audit with the City of Guelph stakeholders to ensure validity and accuracy of the data (refer to Attachment C for the slides from the presentation). Another item discussed was the significance of the uncertainty of the data. For example, some components of the water audit include unmetered data; therefore, the volume is estimated. However, the volume may be small compared to the system input volume which although the volume is estimated it has little impact on the water losses.

For the review, AECOM developed a rating system for the data review and potential actions as summarized in Table 1.

Table 1: Rating Criteria for Water Audit Data Review

Rating	Description
● (red)	Improvement, recommend additional effort to improve water audit data.
● (orange)	Potential improvement, may have impact on water audit; therefore, consider change.
● (yellow)	Potential improvement, small impact on overall water audit; therefore, no change recommended.
● (green)	Good practice, continue with same effort/approach going forward.
● (black)	Not applicable.

The only component of the water audit that was rated as "red", needing improvement, is the customer meter accuracy. In 2017, 200 residential meters were sampled, targeting meters installed 15 or more years ago with higher volumes of water and 20 high volume mid-size meters. The meter testing program resulted in a weighted average of 3.8 percent under-registration which was used in the 2019 water audit to estimate apparent losses associated with customer meter inaccuracies. The estimated 2019 apparent losses associated with customer metering inaccuracies is approximately 564 ML which is approximately 20 percent of the water losses. Note that if the estimated meter accuracy is higher than actual, the real losses would be higher leading to a higher potential recoverable leakage.

The meter accuracy data is based on data from 2017 and may not be representative of the meter accuracy for all meter sizes/ages; therefore, AECOM recommends refining the meter accuracy going forward to get a better understanding of real losses and apparent losses. The WRF study Guidance on Implementing an Effective Water Loss Control Plan, 2019, states the generally accepted factors affecting customer meter accuracy include:

- Mechanical wear over time, excess cumulative volume, poor water quality, damage and vandalism
- Incorrect installation or lack of maintenance
- Incorrect sizing

- Incorrect meter type for the application
- Spinning or jetting
- Environmental problems (freezing, overheating)
- Low flow rates due to evaporative coolers and basement/rooftop storage tanks
- Changing flow patterns due to water conservation changes in building codes and pluming fixture design.

The WRF study states that proper meter sizing, selection and installation; routine testing; and optimal meter replacement mitigates most of the accuracy degradation issues.

It was noted that the City has continued to improve its methods to meter more of the NRW to have a good handle on the actual volumes instead of estimating. The values that are estimated are typically small volumes which do not have a significant impact on water losses.

A summary of the review, which is detailed in Attachment C, includes:

- The City should continue with the good industry practice of completing the AWWA audit and consider using the latest version (Version 6 released in December 2020) along with completing the validation questions and the revised methods for estimating unbilled unmetered authorized consumption, unauthorized consumption, and system data handling errors.
- The City has continued to improve the data for the water audit process including metering additional volumes of water over the years.
- The City should consider a detailed list of the meters used and the accuracy of each meter to determine the volume of water input into the system. The volume in the audit should be adjusted based on the accuracy of the meters.
- The City has a residential meter program with the goal to replace approximately 26,000 meters which was started before the pandemic in 2018. The confidence in the water audit results can be improved through a better understanding of the volume of real and apparent losses and an understanding of the meter accuracy is key. It is recommended that the City develop a meter testing program and continue with the meter replacement program.
- The City should work toward completing the water audit by pressure zone or district metering area (DMA). One step toward this is the completion of the linking of the customer billing data with the GIS.

3.3 Cost of Water Losses

The cost of water losses depends on the type of losses as follows:

- Apparent Losses – Customer retail unit charge (volumetric portion of the charges, not the fixed charges)
- Real Losses – Variable production cost of water

The variable production cost of water is used to determine the cost of leakage (water losses) as discussed in the following section.

3.3.1 Variable Production Cost of Water

The variable production cost of water is the marginal cost of water supplied to the distribution system or the cost to supply the next unit volume of water.

The variable production cost of water is important as it is used to determine the cost to the Utility of leakage (real losses) and is used in the evaluation of the ELL.

Typically, the variable cost of leakage (water) is comprised of the following two main items:

1. Electrical Cost (treatment and pumping)
2. Chemical Cost

Additional costs can be included, if appropriate, and can include:

1. Deferred capital cost
2. Reduction in maintenance/repair/replacement (equipment lasts longer and not being used as much)
3. Cost of wastewater treatment (some of the water losses reaches the wastewater treatment facility)

For the City of Guelph, electrical and chemical costs are tracked annually. Based on the 2019 data summarized in Table 2, the chemical and electricity costs are estimated at \$0.095 per m^3 (cubic metre).

For this analysis consideration was given to the three items that can be part of the variable cost of leakage. No deferred costs for capital have been included in this analysis.

Since the amount of water for wastewater treatment is hard to define, the variable cost of wastewater was not available to AECOM, and the reduction in maintenance/repair/replacement is also challenging to define; AECOM used a band of the variable cost of leakage from approximately \$0.095 per m^3 to \$0.114 per m^3 (approximately \$95 to \$114 per ML). This is based on a 20 percent increase in variable cost of water to account for some of the additional items.

Table 2: 2019 Variable Production Cost of Water

Description	2019 Expenditures	2019 Water Production (m^3)	Cost per Cubic Metre (\$/m^3)
Annual Cost of Operating Water System	\$32,168,822	-	-
721-6450 removed (full expense budget)	(\$791,627)	-	-
Total Annual Cost of Operation Water System	**\$31,377,195**	**17,160,653.96**	**\$1.83**
Operating	**-**	**-**	**-**
Hydro (2301/2302)	\$1,542,368	-	-
Treatment Chemicals (2405/2429/2431)	\$79,467	-	-
721-3450 removed (for above expenses)	\$0	-	-
Materials and Supplies (sum 24 Operating)	\$442,261	-	-
Maintenance Costs (sum 31 Repairs and Maintenance)	\$460,211	-	-
721-6450 removed (for above expenses)	(\$29,123)	-	-
Capital	\$1,261,398	-	-
Variable Cost (Unit Cost of Leakage)	\$1,621,835	17,160,653.96	\$0.095
Fixed Cost	\$2,134,747	17,160,653.96	\$0.124
Total Operational and Maintenance Costs	\$3,756,582	17,160,653.96	\$0.22

Source: City of Guelph O&M Cost Breakdown from Water and Wastewater Financial Specialist, Annette Indoe.

3.3.2 Economic Analysis

The following information was provided from the 2019 Water Audit for determining the cost of annual real losses (leakage).

Total Water Supplied: ....17,160 ML

Total Annual Real Losses (TARL): ....2,020 ML

Unavoidable Annual Real Losses (UARL): ....997 ML

Potential Annual Recoverable Real Losses (TARL-UARL): ...1,023 ML

Cost of Potential Annual Recoverable Real Losses: ....\$97,200 to \$116,600

The City of Guelph has an active leakage control program initiated in 2010 that consists of annual leak detection of the entire system at a cost of approximately \$80,000 to \$100,000 per year.

3.3.3 Summary

The City of Guelph reduced their ILI from 2.54 in 2014 to 2.03 in 2019 which indicates that the management of real losses is good. This has been achieved through an active leakage control program of annual leak detection survey at a cost of approximately $80k to $100k per year. It is anticipated that over the last six years the backlog of leaks has been eliminated and current leak detection is locating new leaks or small leaks that have increased in size. AECOM believes that continuing the annual leak detection will keep water losses at the current level but may not achieve substantial further reduction. An additional expenditure of $97k to $116K per year for water loss management is available for additional active leakage management to reduce annual real losses to be equivalent to the UARL (ILI = 1).

4. Economic Level of Leakage (ELL) and Water Supply Projections

The City of Guelph has managed and controlled real losses well which is reflected in an ILI of 2.03 (reduced from 2.54 in 2014).

In the AwwaRF report Evaluating Water Loss and Planning Loss Reduction Strategies, 2007, it was reported that in a study, ILI data was collected from utilities operating at or near ELL in UK and Australia, showing that the economic ILI for utilities are normally below 3.

The current active leakage control (ALC) of regular leak detection survey appears sufficient to keep real losses under control. This history of active leak detection along with the decline in ILI indicates that the backlog of leaks that might have existed in 2014 have been fixed and a stable condition exists with respect to leaks.

With the relative low unit cost of leakage and the low ILI, the potential cost saving ($97,200 to $116,600) of reducing the annual real losses to the UARL is small in comparison with the implementation of more extensive leakage control strategies. For example, if the full $97,200 to $116,600 could be recovered by using DMA/step testing etc. the annual cost of implementation (capital and operations) would have to be less than $97,200 to $116,600 per year. However, it is doubtful if the entire potential recoverable real losses could be recovered.

It is AECOM’s opinion that the City of Guelph could already be at or close to the ELL with an ILI of approximately 2.0.

5. Leakage Management Strategy

The purpose of the leakage management strategy is to reduce and maintain leakage to an acceptable level agreed upon considering the ELL.

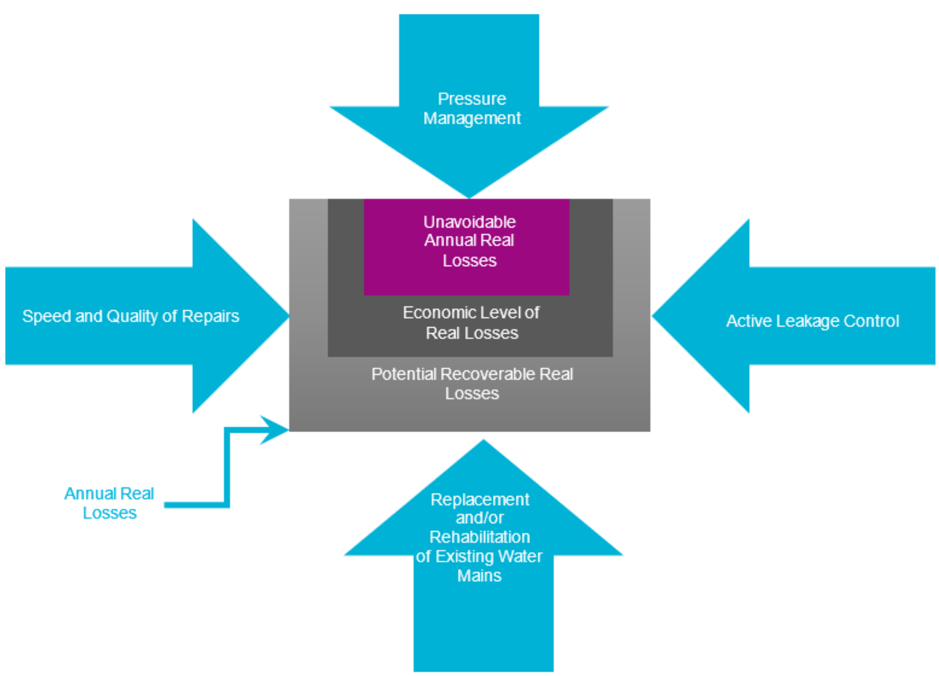
5.1 Introduction

The four pillars of a successful leakage management strategy are illustrated in Figure 6 and are summarized as:

- Pressure management seeks to optimize system pressure to minimize losses, while maintaining adequate levels of service.
- Replacement and/rehabilitation of existing water mains is the replacement/rehabilitation of key infrastructure to reduce water main breaks/leaks and water loss.
- The speed and quality of repairs reduces the time it takes to repair the leak once it is found. Reducing the time it takes from locating the leak to repairing it reduces the water lost.
- ALC is the proactive approach to search for hidden (non-surfacing) leaks and includes such things as leak detection acoustic surveys and sounding.

A brief description of each is provided in the following sections along with how each may be incorporated into an overall leakage management strategy for the City of Guelph.

Figure 6: Four Pillars of Successful Leakage Management Strategy



5.2 Pressure Management

Pressure management is typically the cheapest and easiest approach to decrease annual real losses; however, it does not find and repair the leaks. In addition, the minimum system pressure needs to be maintained in the water distribution system to provide adequate service to the customers. The 2019 water audit reported the average system pressure of 49.4 metres of head. For comparison, Ten State Standards specifies normal working pressure in the distribution system should be approximately 42 to 56 metres of head.

The system is segmented into pressure zones to address pressure/topography; therefore, pressure management is not considered a cost-effective option for the City of Guelph leakage management strategy.

5.3 Replacement and/or Rehabilitation of Existing Water Mains

The City of Guelph continues to replace water mains and while this will over time reduce leakage; it is unlikely in the short-term to have a dramatic impact on real losses. The following quote is from the American Water Works Association Research Foundation (AwwaRF) report, Evaluating Water Loss and Planning Water Loss Reduction Strategies:

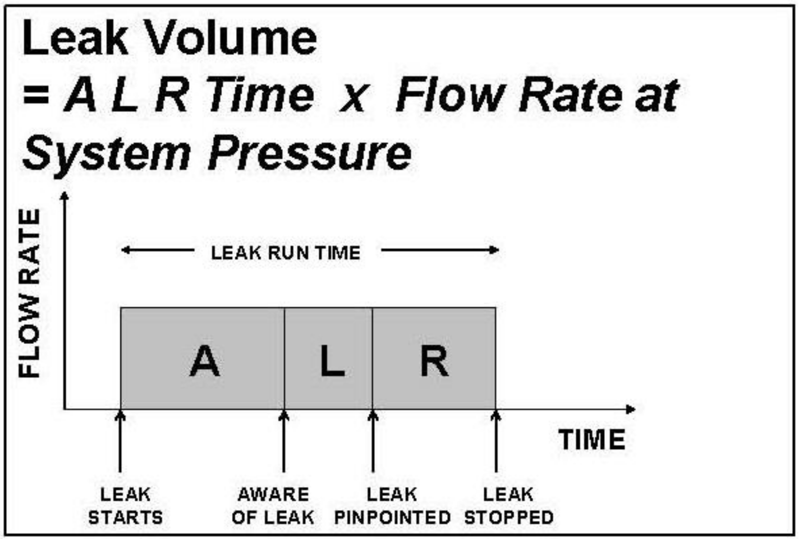
> *"From an economic perspective, it is rarely possible to justify mains replacement purely on the basis of the reduction in leakage anticipated, except in a few of the worst performing mains in the utility. In reality, mains are replaced for many other different reasons such as inadequate capacity, growth in demand, cost of continued repairs, water quality problems and good asset management."*

As water mains age, the pipe will need to be replaced and a proactive water main replacement/rehabilitation program should be implemented by the City if not currently in place. However, replacement and/or rehabilitation of existing water mains is not considered a cost-effective option for the leakage management strategy.

5.4 Speed and Quality of Repairs

The time between the pinpointing of the leak and its repair also affects the volume of water lost. The shorter the repair time, the lower the water loss, as illustrated in Figure 7. The challenge of repairing leaks in a timely manner may increase as a more proactive approach is adopted by the City of Guelph to identify and repair the non-surfacing leaks. Sufficient staff should be available to repair leaks as soon as possible after the leaks are identified and leaks of higher volume should be prioritized over smaller leaks.

Figure 7: Leakage Volume – Speed and Quality of Repairs



Source: AwwaRF report, Evaluating Water Loss and Planning Loss Reduction Strategies

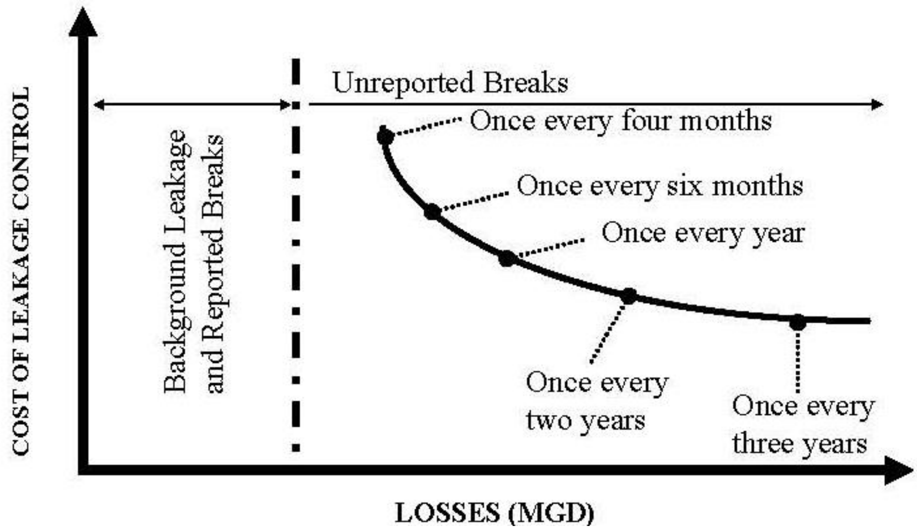
5.5 Active Leakage Control

A number of ALC approaches are available to assist in the detection and location of leaks. The following are the more common approaches as summarized in Table 3:

- Sounding
- Noise Mapping
- Acoustic Survey
- Acoustic Loggers
- AMR/Meter Acoustic Loggers
- Satellite Leak Detection

To address the non-surfacing leaks, the most proactive approach is to increase the level of effort in sounding, noise mapping, acoustic survey, etc. To identify the appropriate level of effort in leak detection, it is necessary to establish the intervention period. In principle, it is a cost beneficial relationship between the cost of intervention (leak detection survey) and the cost of the volume of water lost through leakage. This concept is illustrated in Figure 8.

Figure 8: Leakage Reduction Cost Curve for Regular Acoustic Surveys



It appears that a main contributor to real losses in the City of Guelph may be non-surfacing leaks/breaks; therefore, an initial goal should be to proactively identify and repair the non-surfacing leaks.

Acoustic loggers, satellite leak detection, and customer meter loggers are effective at identifying areas to prioritize leak detection. The greatest benefit of these technologies typically occurs once a steady state of leaks has been reached which is believed to be the case for the City.

Table 3: Summary of Active Leakage Control Measures

Methodology	Description	Advantages	Limitations	Most Appropriate For
Reactive Leakage Control	■ Response to leaks discovered through visual observation.	■ Lowest cost of detection	■ Only locates leaks reaching the ground surface	■ Small systems with a poor maintenance history and large number of leaks
Regular Sounding	■ Identifies areas of high noise and potential non-surfacing leaks by listening at system fixtures such as valves, hydrants, etc.	■ Low cost and easy to implement	■ Does not pinpoint leak ■ Background noise can mask leak noise ■ Sounding may need to be performed during night period	■ All systems
Noise Mapping	■ Expands on regular sounding by tracking, documenting, and mapping the location of system noise to improve prioritization of leak detection.	■ Low cost and easy to implement ■ Helps prioritize of leak detection	■ Does not pinpoint leak ■ Background noise can mask leak noise ■ Sounding may need to be performed during night period	■ All systems

Methodology	Description	Advantages	Limitations	Most Appropriate For
Leak Detection Survey	■ Identification and location of leaks using acoustic equipment.	■ Equipment and operators readily available ■ Relatively inexpensive ■ Preferred method for pinpointing leaks	■ Large leaks can mask smaller leaks ■ Less effective on non-metallic water mains	■ All systems to pinpoint non-surfacing leaks
Acoustic Logger	■ Acoustic loggers attached to system fixture, either permanently or temporarily, that semi-continuously listen for noise that could be associated with a leak.	■ Reduces awareness time ■ Helps prioritize leak detection	■ Does not pinpoint leak ■ High number of acoustic loggers needed to cover system (expensive)	■ All systems
Acoustic Logger on Customer Services	■ Permanent acoustic loggers attached to AMR that semi-continuously listen for noise that could be associated with a leak.	■ Reduces awareness time ■ Helps prioritize leak detection	■ Does not pinpoint leak ■ Expensive unless installed with an AMR system	■ All systems
Satellite Leak Detection	■ Identification of points of interest (POI) on GIS reports using satellite images and patented algorithm	■ Helps prioritize leak detection ■ No equipment required, low cost	■ Does not pinpoint leak/not all POI have leak	■ All systems

The City of Guelph has an ALC program that consists of annual leakage detection of the entire distribution system (both plastic and metallic pipe) at a cost of approximately $80,000 to $100,000 per year which was started in 2010. This is a contributing factor in maintaining the current ILI of 2.0 and has likely removed the backlog of leaks in the system.

The following sections discuss some additional enhancements that the City of Guelph may want to explore to enhance their current ALC program.

5.5.1 Acoustic Loggers

An acoustic logger is a small sound logging device that is attached to suitable existing fittings by means of a strong magnet. Acoustic loggers are designed to be deployed across a network at close enough intervals to ensure that any leak noise between two loggers can be detected. Once deployed, the acoustic loggers monitor leak noise during the quietest part of the night and indicate if a leak noise has been detected. The acoustic loggers are downloaded the next day to indicate if a leak noise has been detected. The leak than can be detected using leak noise correlators.

Acoustic loggers may be used in permanent locations that may historically have had a high number of leaks/breaks and/or may be used in temporary locations which allows them to be relocated in the system.

It is recommended that the City consider budgeting approximately $20,000 to $30,000 to implement a pilot program with acoustic loggers which would include purchasing and installing approximately 15 to 20 acoustic loggers that can be temporarily located in areas of the system to help prioritize areas for leak detection.

5.5.2 Satellite Leak Detection

An interesting recent development in ALC is the use of satellite imagery to help identify areas of potential leaks. The satellite takes a series of spectral aerial images over a subject area and by use of an algorithm technicians can identify soil saturated by treated water to a depth of approximately 12 feet in the ground by detecting its spectral signature. The points of interest (POI) are provided in a geographical information system (GIS) report to allow the field crew to search specific areas and pinpoint the previously undetected leaks. This technology has been adapted from the search for water on other planets, which underscores the high reliability and outstanding capability here on Earth. Further information on satellite leak detection is provided in Attachment E.

The benefits of satellite leak detection include:

- No equipment required, no upfront investment.
- Significant reduction in field labour effort.
- Entire system is surveyed as often as bi-weekly.
- Leaks can be targeted before surfacing, reducing potential damage/additional costs of repairs.
- Reduction in water losses/NRW.
- Provides a good solution for large water networks.

Based on discussions with Utils, the cost is approximately $60 to $65 per kilometre. Using 565 kilometres for the total length of the City of Guelph system, it is estimated the cost for the satellite leak detection (one delivery) for the entire system would be approximately $34,000 to $37,000.

5.5.2.1 Case Study 1

As documented in the AWWA Opflow, January 2020, New Braunfels Utilities (NBU), located in the greater San Antonio area, was able to significantly reduce its NRW because of the satellite leak detection program. The performance and value metrics comparisons of the traditional leak detection program and the satellite pre-locating program for NBU are summarized in Table 4.

Table 4: Satellite Leak Detection Case Study 1: Performance and Value Metrics Comparison

Parameter	Fiscal Year 2018 Traditional Program	Fiscal Year 2019 Satellite Pre-Locating Program
Leaks per Day Found	0.06	4.1
Number of Leaks Found	16	229
Cost per Leak Found	$14,130	$678
Crew Labour Days	249	56
Crew Labour Costs	$173,650	$42,900
Overall Operating Budget	$210,900	$155,500
Capital Costs	$24,000	$0

Source: AWWA, Opflow, January 2020.

5.5.2.2 Case Study 2

According to a March 2021 article in the Journal of New England Water Works Association, the Green Bay Water Utility has lowered water losses in 2019 by approximately 91 million gallons per year (MGY) resulting in lowering their unaccounted-for water from approximately 7 percent to 6.3 percent (a 10 percent reduction) using two satellite surveys and subsequent field inspections. The Utility, which includes approximately 510 miles of transmission and distribution mains and approximately 35,600 service connections, found approximately 1.4 leaks per crew day and 1.0 leaks per mile physically inspected at a total cost of approximately $103,000 (U.S. dollars). Based on the cost of water production, this equates to a $37,400 (U.S. dollars) savings per year with a simple payback period of 2.7 years.

5.5.3 Historical Water Main Breaks and Leaks

A preliminary review of the water main break and leak location history indicates there are areas of the water system that may be more prone to breaks and leaks as illustrated in Attachment D. The areas more prone to breaks and leaks may include geographical areas of the water system with particular pipe diameters, particular pipe materials, and/or based on soil corrosivity/pipe material, etc. For example, approximately 95 percent of the leaks and breaks in the GIS layer were likely on cast iron pipes which comprise approximately 33 percent of the pipes in the water system. Potentially, the City could consider more frequent leak detection on cast iron mains versus other pipe materials in the system. It is recommended that the City of Guelph conduct a focused review of leak and break historical data and use the historical data evaluation to help prioritize areas for leak detection efforts going forward.

5.5.4 District Metered Area (DMA) Program

According to the Final Draft of the Water Loss Management Strategy, November 4, 2020, the City began the DMA program in 2013 with the installation of flow meters and pressure sensors across the water distribution system. However, as the report indicates, the DMA program requires a one-time $2M to $4M capital expenditure to update valving and dead-end infrastructure, a $200K to $600K one-time expenditure to complete necessary telemetry, approximately $70K annual operating budget in cellular charges, batteries, spares, server licenses, server updates, and server support contract, and a $250K annual operating budget for maintenance and additional staff time.

Reducing the ILI from 2.03 to 1.0 (which may be difficult to achieve) would result in a cost savings of approximately $97K to $116K annually; therefore, the additional cost for the DMA program is not cost-effective solely from a water loss perspective.

5.5.5 Summary of Active Leakage Control

It is recommended that the City of Guelph continue with the current ALC program of leak detection to help maintain the current level of real losses and consider exploring the addition of satellite leak detection, acoustic loggers, and/or prioritizing areas for leak detection based on historical leak/break data and/or other means. For example, the City may consider surveying cast iron water mains that have a higher historical leak/break frequency more often than PVC mains that have a lower leak/break frequency.

5.6 Summary of Leakage Management Strategy

The leakage management strategy summarized in the draft Water Loss Management Strategy dated November 2020 along with the recommendations from this evaluation are summarized in Table 5.

Table 5: Recommended Water Loss Management Strategy Programs

Apparent Losses	Real Losses
Residential Meter Replacement Contract	Leak Detection Program Consider exploring the following enhancements: • Satellite Leak Detection • Acoustic Loggers • Prioritizing leak detection survey based on satellite leak detection, acoustic loggers, or historical data
Automatic Meter Reading/ Infrastructure (AMR/AMI)	~~District Metering Areas (DMA) Program~~

Apparent Losses	Real Losses
Industrial, Commercial, Institutional (ICI) and Large Residential Maintenance and Replacement Program	Develop an annual private-side fire hydrant audit program
Construction Development Water Use	Complete retroactive fire suppression metering for tracking and input into the water audit/balance

Key: ~~Not Recommended~~
Recommended
Included in Draft Water Loss Management Strategy, City of Guelph, November 2020

Note: Refer to Draft Water Loss Management Strategy, City of Guelph, November 2020 for additional details regarding the programs.

6. Non-Revenue Water Projections

Typically, projections of water demands are based on per-capita water use with an allowance for NRW which is usually a percentage of the total water supplied. Therefore, NRW projections are assumed to increase proportionately to the population/employment rate growth.

Because the City of Guelph has completed a good deal of work regarding NRW, it is possible to provide a more detailed estimate of NRW in future.

AECOM is proposing that each of the NRW components can be estimated as noted in Table 6.

Table 6: Estimation of NRW Component for Water Demand Projections

Parameter	Approach to Estimate	Notes
Real Losses	Use target ILI of 2 to estimate	Need to estimate projected UARL which may change based on length of water main and number of customer services.
Apparent Losses ▪ **Unauthorized Consumption**	Same as estimate for water audit	
Apparent Losses ▪ **Customer Meter Inaccuracies**	1 to 2% of billed consumption	Assume meters are under-registering
Apparent Losses ▪ **Systematic Data Handling Errors**	Same as estimate for water audit	
Authorized Unbilled Metered Consumption	Similar to water audit method	Increase based on growth
Authorized Unbilled Unmetered Consumption	Same as estimate for water audit	

Assuming an ILI of 2.0 is maintained, the real losses can be estimated from the ILI multiplied by the UARL. The volume of UARL will increase as the growth of the population/ employment forecast (approximately 40 percent by 2051) and the water distribution system expands. The following assumptions were used to estimate the 2051 UARL:

- Length of main in distribution system – increase by 20 percent
- Number of service connections – increase the same percent as the population/employment rate
- Assume average system pressure remains constant (49.5 m of head).
- Assumes average length of services remains constant.

Using these assumptions, the 2051 UARL is estimated to be approximately 3,790 m^3 per day (1,380 ML) which results in the projected 2051 annual real losses of approximately 7,585 m^3 per day (2,770 ML) and total 2051 projected NRW of approximately 9,982 m^3 per day. The current NRW projection for 2051 is approximately 12,342 m^3 per day.

AECOM also suggests the City consider that real losses are typically constant and do not vary daily or seasonally with changes in water use; therefore, real losses should be kept constant when determining the maximum day demand. Currently the maximum day demand is assessed based on total system water production by comparing peak days to average days (e.g. Water Supply Master Plan, etc.); this approach does not consider variable and separate maximum day factors by sector (i.e. residential, ICI and NRW). With more consumer data available on a real time basis, this assessment may be feasible in future studies.

7. Conclusions and Recommendations

7.1 Water Audit

It is recommended that the City continue to complete the water audit using the current version of the AWWA software and recommendations for estimating components if not other data is available.

The City should consider documenting the supply meters used for the volume water input into the system for the water audit along with adjusting the data based on the annual accuracy testing performed.

In addition, the City has a residential meter replacement program to replacement approximately 26,000 meters which was started before the pandemic in 2018; however, was placed on hold during the COVID-19 pandemic. It is recommended that the City develop a meter testing program and continue with the meter replacement program. The water audit accuracy may potentially be improved with a more accurate estimate of accuracy based on meter type and size.

In the longer-term, the City should work toward completing the water audit by pressure zone and/or DMA. One step toward this is the completion of the linking of the customer billing data with the GIS which AECOM understands is in progress.

7.2 Economic Level of Leakage and Active Leakage Control

The current ALC policy (regular leak detection survey and repair) has been effective in reducing real losses and should be continued. AECOM believes the leak detection program has removed the backlog of leaks in the City and has reduced the ILI to approximately 2.03 which based on the low unit cost of water is considered close to, if not at, the ELL. The potential annual recoverable real losses for 2019 are approximately 1,023 ML, assuming an ILI of 1.0. The potential annual recoverable real losses represent approximately 6.0 percent of the total water supplied and an annual cost of approximately $97K to $116K.

The following enhancements to the current leakage management strategy are recommended to be explored further:

- Satellite leak detection
- Acoustic loggers
- Focused leak detection based on strategies above and history of leak locations and pipe materials/diameters with higher leak frequency

This approach should allow the typical rate of rise of leakage to be controlled and leakage to be held constant or potentially reduced.

7.3 Non-Revenue Water Projections

For future water supply planning exercises, it is recommended that the City consider projecting NRW based on the various components and maintaining an ILI of 2.0. The City should also consider that real losses typically are constant and do not vary daily or seasonally.

7.4 General

While DMAs are not recommended solely based on savings due to the reduction in real losses, DMAs have other advantages for the operation and maintenance of a water system. If DMAs are implemented as part of an improvement strategy to the overall operation, they should be used to also support the overall leakage control strategy.

As mentioned earlier, the replacement of water mains is not a cost-effective approach to reduce real losses; however, as water mains age they need to be replaced and a proactive water main replacement/rehabilitation program should be implemented.

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- represents AECOM's professional judgement in light of the Limitations and industry standards for the preparation of similar reports;
- may be based on information provided to AECOM which has not been independently verified;
- has not been updated since the date of issuance of the Report and its accuracy is limited to the time period and circumstances in which it was collected, processed, made or issued;
- must be read as a whole and sections thereof should not be read out of such context;
- was prepared for the specific purposes described in the Report and the Agreement; and
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AECOM: 2015-04-13

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Attachment A

List of Abbreviations and Acronyms

Attachment A: List of Abbreviations and Acronyms

ALC ....Active Leakage Control

AWWA...........American Water Works Association

AwwaRF........American Water Works Association Research Foundation

DMAs.............District Metering Areas

ELL................Economic Level of Leakage

ILI ....Infrastructure Leakage Index

KPI ....Key Performance Indicator

m^3..................cubic metres

ML ....Megalitres

NRW..............Non-Revenue Water

POI ....Points of Interest

psi..................pounds per square inch

TARL ....Total Annual Real Losses

UARL.............Unavoidable Annual Real Losses

WRF ....Water Research Foundation

Attachment B

Glossary of Terms

Attachment B: Glossary of Terms

Term	Definition
Real Losses	Physical water losses from the pressurized system (water mains and customer service connections) and the utility's storage tanks, up to the point of customer consumption. In metered systems this is the customer meter, in unmetered situations this is the first point of consumption (stop tap/tap) within the property. The annual volume lost through all types of leaks, breaks and overflows depends on frequencies, flow rates, and average duration of individual leaks, breaks and overflows. Also referred to as Total Annual Real Losses (TARL) and Current Annual Real Losses (CARL)
Apparent Losses	Losses in customer consumption attributed to inaccuracies associated with customer metering, systematic data handling errors, plus unauthorized consumption (theft or illegal use of water). Apparent losses represent nonphysical (paper) losses that result in uncaptured revenue for the Utility and distortion of customer consumption data. Note: Over-estimation of Apparent Losses results in under-estimation of Real Losses. Under estimation of Apparent Losses results in over-estimation of Real Losses.
Unavoidable Annual Real Losses (UARL)	The UARL is a theoretical reference value representing the technical low limit of leakage that could be achieved if all of today's best technology could be successfully applied. It is a key variable in the calculation of the Infrastructure Leakage Index (ILI). Striving to reduce system leakage to a level close to the UARL. The UARL calculation is based on leakage data gathered from well-maintained and well-managed systems.
Potential Recoverable Real Losses	The difference between real losses and the unavoidable annual real losses is considered the recoverable annual real losses. If the ILI is 1, recoverable annual real losses would be zero. Recoverable Real Losses = TARL – UARL
Infrastructure Leakage Index (ILI)	The ratio of the Total Annual Real Losses (Real Losses/TARL) to the Unavoidable Annual Real Losses (UARL). A performance indicator quantifying how well a distribution system is managed (maintained, repaired, rehabilitated) for the control of real (leakage) losses at the current operating pressure. A low ILI value indicates the Utility has managed its leakage down toward the UARL, or the theoretical low limit of leakage technically achievable.
Variable Cost of Water (Cost of Water Losses)	The cost to produce and supply the next unit of water. This cost is determined by calculating the summed unit costs for ground and surface water treatment and all power used for pumping from the source to the customer. It may also include other miscellaneous unit costs that apply to the production of drinking water. It should also include the unit cost of bulk water purchased as an import if applicable. It is common to apply this unit cost to the volume of Real Losses. However, if water resources are strained and the ability to meet future drinking water demands is in question, then the water auditor can be justified in applying the Customer Retail Rate to the Real Loss volume, rather than applying the Variable Production Cost.
Economic Level of Leakage (ELL)	The level found by determining the level (volume) of real (leakage) losses at which the sum of the cost of the real loss reduction and the cost impact of the real losses is at a minimum. Reducing leakage levels below the ELL is not cost-effective because the cost of the leak abatement activities exceeds the value of water saved. ELL is used for leakage reduction target-setting and setting the frequency of leak survey investigations.

Attachment C

Water Audit Review Summary

Stakeholders - Water Audit
Water Loss Management Strategy

City of Guelph

April 7, 2021

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Background

Project Purpose

- Objective: Provide a recommended path forward for the Water Loss Management Strategy including economic level of leakage base on a review of water audits, draft Water Loss Management Strategy and Water Efficiency Strategy.

- Tasks:
  - Planning and Data Review
  - Water Audit Review
  - Water Loss Management Strategy Review
  - Reporting

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Economic Level of Leakage

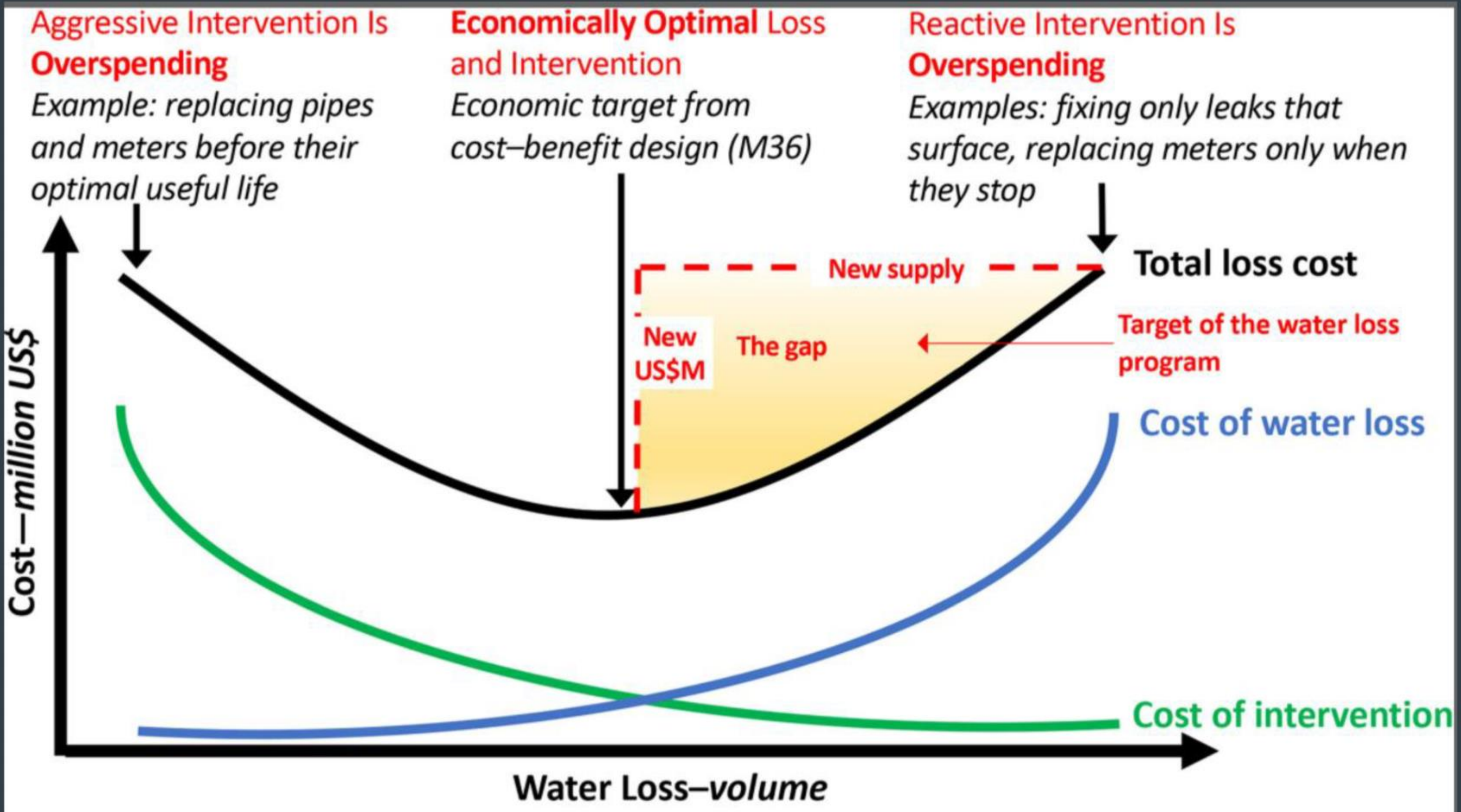

Figure by Cavanaugh & Associates

CWWMG—Catawba-Wateree Water Management Group, M36—AWWA Manual of Water Supply Practices M36, *Water Audits and Loss Control Programs*

Purpose of Meeting

- Discuss water audit input data with stakeholders

- Why are you on this call?
  - You own some of information that goes into the water audit.
  - Important to engage stakeholders to obtain input.
  - One of the key items for the water audit is to ensure validity/accuracy of data.
  - Another key item is to determine significance of uncertainty of data on the water audit.

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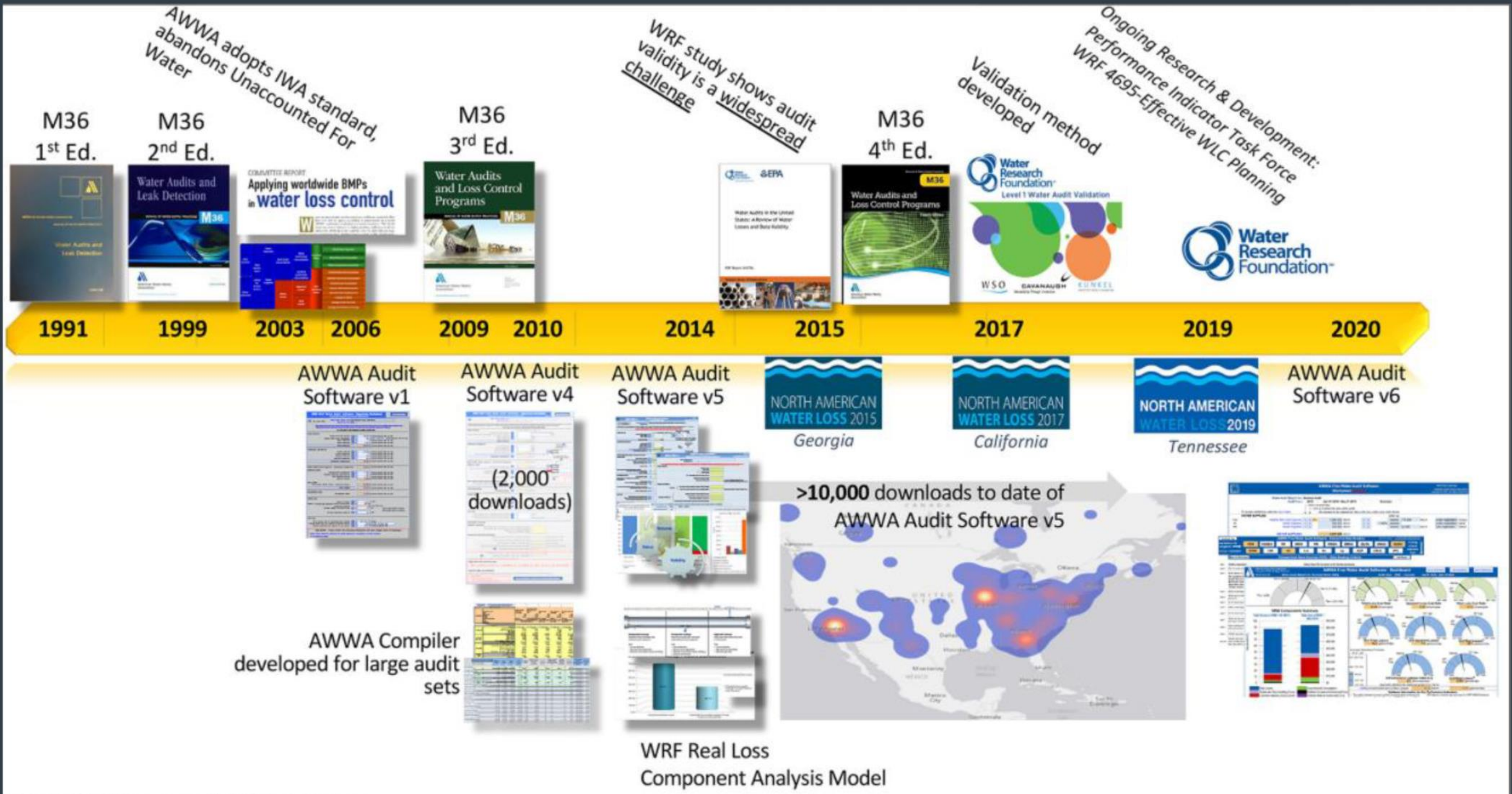

Figure by Cavanaugh & Associates

IWA—International Water Association, M36—AWWA Manual of Water Supply Practices M36, *Water Audits and Loss Control Programs,* WLC—water loss control, WRF—Water Research Foundation

AWWA Water Audit

System Input Volume	Authorized Consumption	Billed Authorized Consumption	Billed Metered Consumption	Revenue-Generating Water
			Billed Unmetered Consumption	
		Unbilled Authorized Consumption	Unbilled Metered Consumption	Non-Revenue Generating Water
			Unbilled Unmetered Consumption	
	Water Losses	Apparent Losses	Unauthorized Consumption	
			Metering Inaccuracies	
		Real Losses	Leakage on Transmission and/or Distribution Mains	
			Leakage and Overflows at Utility's Storage Tanks	
			Leakage on Service Connections up to Point of Customer Metering	

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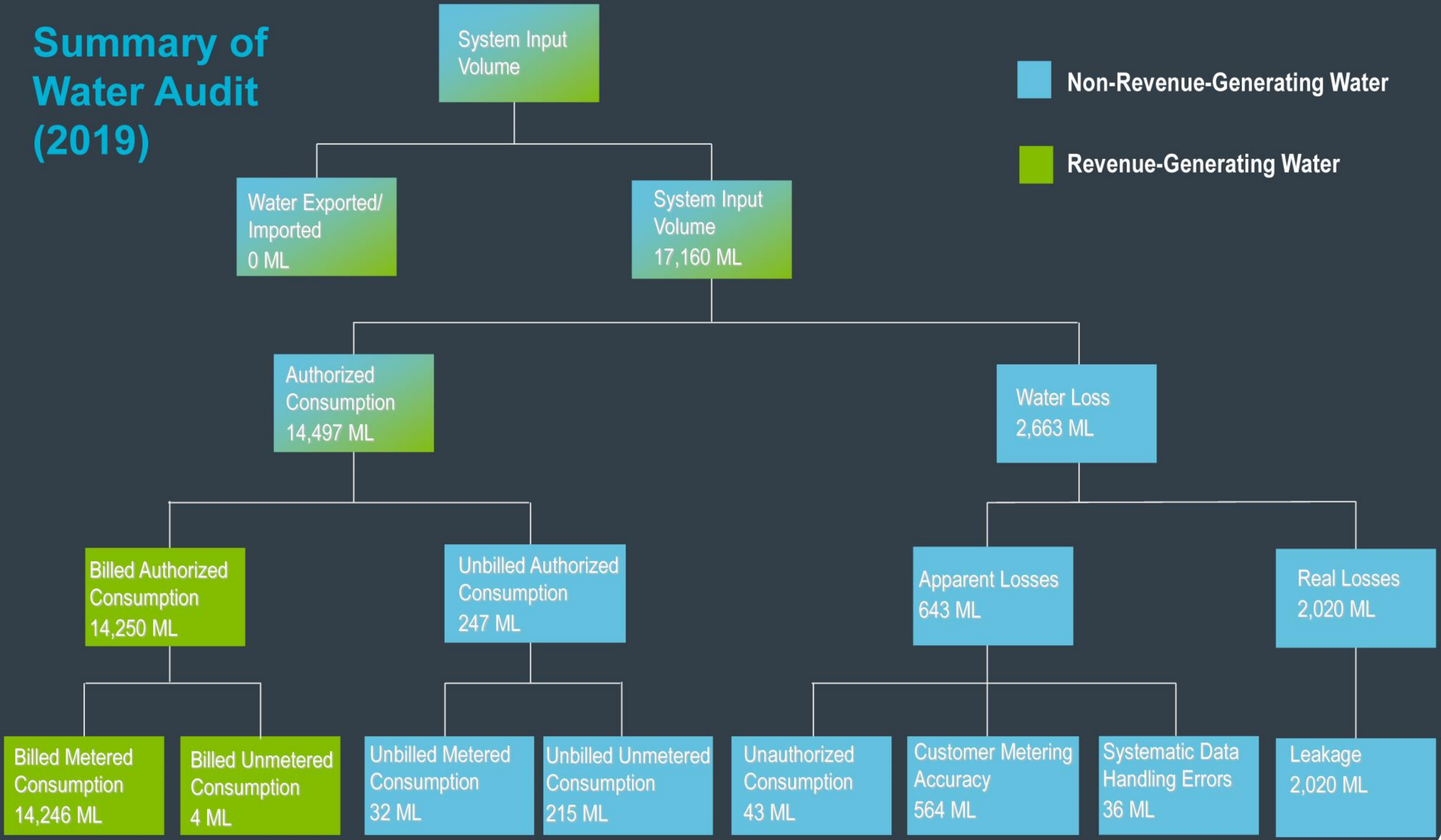
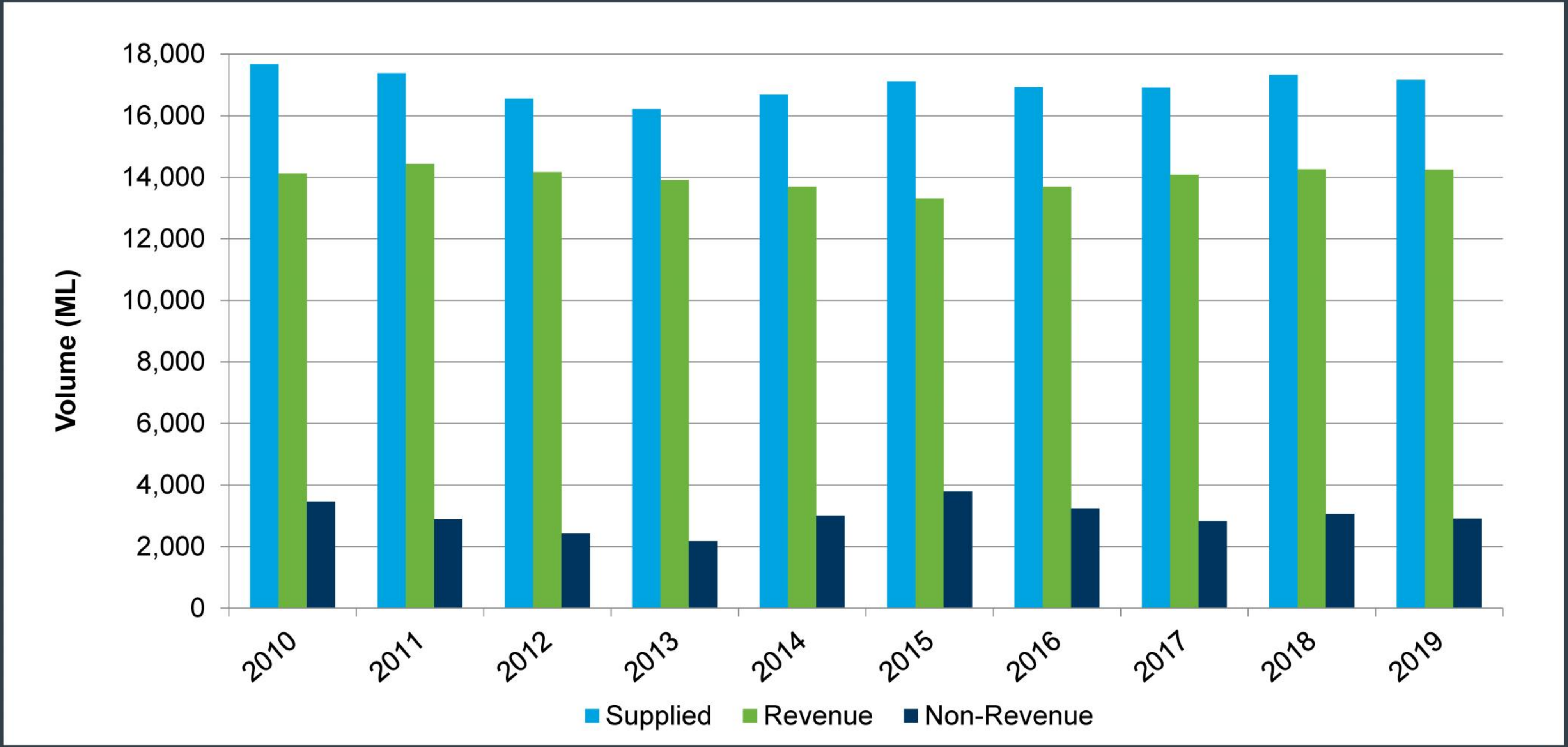
Summary of Water Audit (2019)



Historical Water Supplied Compared to Revenue and Non-Revenue Water



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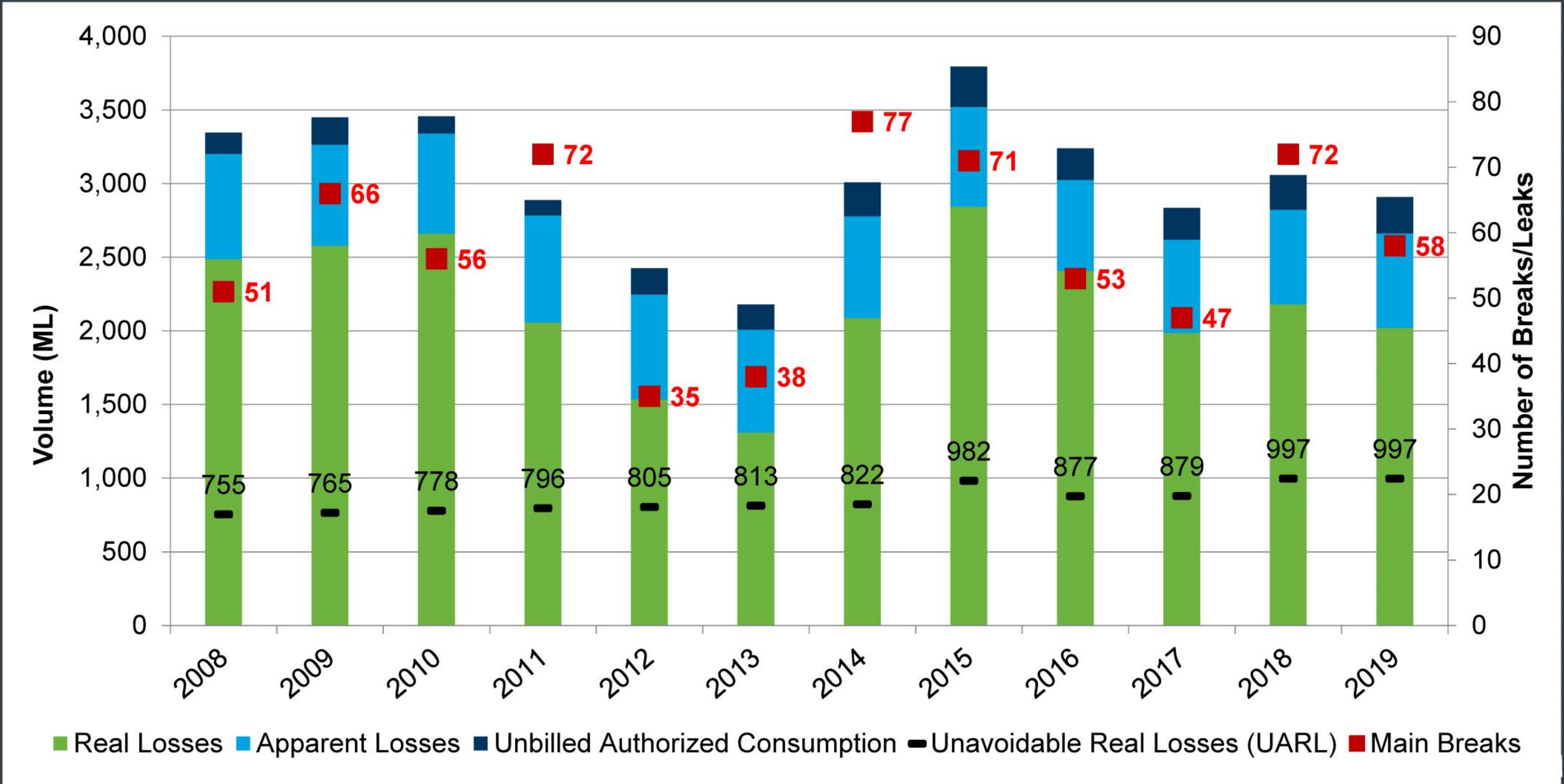
Historical Non- Revenue Water (Volume)



Water Audit Data

Rating Criteria for Data Review

Rating	Description
	Improvement, recommend additional effort to improve water audit data.
	Potential improvement, may have impact on water audit; therefore, consider change.
	Potential improvement, small impact on overall water audit; therefore, no change recommended.
	Good practice, continue with same effort/approach going forward.
	Not applicable.

Water Supplied

Category	Component	Water Use Category	Source of Water Audit Information	Rating	Comments
Water Supplied	Volume from Own Sources	Daily Production	SCADA	●	• No adjustments made for meter accuracy. • Annual meter validation. • Not all point of entry (POE) meters as other meters in flow process believed to be more accurate. • Review of 2020/2019 records indicate meters accuracy within 0.2% (Clythe Creek Booster). • Compared to Annual Report for verification. • Water Audit results – sensitive to volume/accuracy.
		Net Change in Storage	SCADA	●	• Adjustment for change in storage. • Good practice, small impact on Water Supplied.
	Water Imported			●	• City of Guelph does not import/export bulk water supply.
	Water Exported			●	• City of Guelph does not import/export bulk water supply.

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Authorized Consumption - Billed Metered

Category	Component	Water Use Category	Source of Water Audit Information	Rating	Comments
Authorized Consumption	Billed Metered	2020 Consumption from Hydro	Third Party Billing (Hydro)	●	• Inactive Accounts with Consumption, Credited Water Volume due to Leak Forgiveness Program, and Credited Water Volume due to Frozen Services needs to be removed and included in Unbilled Metered if included in Hydro data. • Confirming if adjustments are made for calendar year. • City is working on linking billing data with GIS.
		Bulk Water	Designated Fill Locations, Meter Data	●	• Clair Tower (noted in spreadsheet)
		Seasonal (parks) + Temporary Meters	Temporary Meters, Meter Data	●	• Parks Seasonal - Summer, list of individual locations • Parks Seasonal - Winter, billed unmetered • Temporary Meters - Admin (temporary hydrant meters)
		City Departments (i.e. Public Works)	Designated Fill Locations	●	• WWTP • Street sweeper usage is now metered at 50 Municipal.

Parks - Seasonal Summer

- Lyons Pool
- Larry Pearson 1
- Larry Pearson 2
- Silvercreek
- Centennial
- Micro Valeriote
- Guelph Lake
- Sunny Acres
- Exhibition Pool
- Castleberry
- Exhibition Softball Diamond
- Hanlon Creek
- Norm Jary
- Curling Club
- Margaret Green
- Exhibition Tennis Courts
- St. George's Park
- Wilson St. Parkade Project
- Speedvale/Hanlon (XACT Drilling)
- Brockville Ave (Varcon Construction)
- Two Rivers Community Garden
- Verney St. (BGL Contractors Corp)
- Phelan Crt (Bright Water Services)
- Arrow Road (Bright Water Services)
- 530 Wellington St. (WWTP)
- Horticulture – Riverside Shop
- JF Ross
- 129 Victoria Rd N (MF Properties)
- Farquar St. Train Hot Box
- Water Services
- Parks and Rec (irrigation of trees/gardens, etc.
- 435 Stone Road (Stone Road Mall)

List from 2018 Seasonal Summer Meters.

Authorized Consumption - Billed Unmetered

Category	Component	Water Use Category	Source of Water Audit Information	Rating	Comments
Authorized Consumption	Billed Unmetered	Outdoor Ice Rinks (Parks Seasonal - Winter)	Metered at one location and estimated based on rink dimensions	🟡	
		Sewer Flushing	Need to confirm source.	🟡	

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Authorized Consumption - Unbilled Metered

Category	Component	Water Use Category	Source of Water Audit Information	Rating	Comments
Authorized Consumption	Unbilled Metered	High Water Leak Forgiveness Program	Admin	●	• Request data from Matt Newman, Meter Technician. Trackable in AMANDA (A.Indoe, Apr 2018). Credit memos (PDF format) to be saved on T drive, individually per credit. Matt Newman estimates 30 to 40 in 2018.
		Temporary Meters	Meter Shop	●	
		Inactive Accounts	Third Party Billing, Hydro	●	• Inactive Accounts: Some accounts become inactive, but the water is not turned off, so water could still be used and is not being paid for. However, Hydro continues to read these meters and this data is available. This report is going to Florence (JL, Feb.2015). This water can only be allocated into theft, if the date the account was closed occurred within the current year and the water use occurred within the current year. This water is not billed, because there is no one to bill. Policy is currently being developed to have Water Services physically turn off water at these locations (JL, Feb. 2016).
		Domestic (Not Read by Hydro Meter Readers)	Meter Reading	●	• Burkes, FM Woods, Heritage (old) Building, UV Building, and Chlorine Building
		UV Bulb Cooling	SCADA	●	• WSupply Water use for UV Bulb cool-down. Changes made at Membro, Water, Emma wells in 2017 to track reverse flows in SCADA. Water pulled from distribution system to cool down UV bulb, which is reverse flow through the POE meter. The total volume of reverse flow through the meter is the volume of water used for UV bulb cool-down (Graham Nasby, discussion, June 13, 2017).
		WSupply Blow-Off/ Bleeders (Scout Camp)	SCADA	●	
		Frozen Services	Admin	●	• Running water credited.

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Authorized Consumption - Unbilled Unmetered

Category	Component	Water Use Category	Source of Water Audit Information	Rating	Comments
Authorized Consumption	Unbilled Unmetered	Guelph Eramosa Twp - within Gazor-Mooney Subdivision Including Sewer Flushing	Township	🟡	• Unmetered; however, results not sensitive to estimate (total unbilled unmetered consumption is ~1% to 1.5% of Authorized Consumption) • Noted that water after POE meters should be included. • Discuss how the volume is estimated for each category.
		Capital Water Main Installation Flushing	Distribution/Engineering	🟡	
		Curb Stop Replacement	Distribution, Noted No Water Used.	🟢	
		Water Main Replacement / Renewal Flushing	Distribution	🟡	
		Hydrant Preventative Maintenance	Distribution	🟡	
		Hydrant Install/Repair/Replacement	Distribution	🟡	
		DMA Integrity Testing	Distribution, Noted No Water Used.	🟢	
		Hydrant - Fire Flows / Flow Testing from Hydrants	Distribution	🟡	
		Hydrant - Swabbing - Contractor	Distribution	🟡	
		Hydrant - Main Flushing - City of Guelph	Distribution	🟡	
		Hydrant - Dead End Flushing for Secondary Disinfection Residual Maintenance - City of Guelph	Distribution	🟡	
		Service Renewals and Temporary Servicing	Distribution	🟡	
		Valve Repair/Replacement	Distribution	🟡	

Authorized Consumption - Unbilled Unmetered (cont.)

Category	Component	Water Use Category	Source of Water Audit Information	Rating	Comments
Authorized Consumption	Unbilled Unmetered	Bleeders	Distribution, Distribution System has no Bleeders.	🟢	• Unmetered; however, results not sensitive to estimate (total unbilled unmetered consumption is ~1% to 1.5% of Authorized Consumption) • Noted that water after POE meters should be included. • Discuss how the volume is estimated for each category.
		Packing Glands Water Running to waste Drain Lines	Supply	🟡	
		Facility Analyzer Water Usage	Supply	🟡	
		Faculty & Distribution Sample Water Usage	Supply	🟡	
		Reservoir / Contact Chamber / Tower Draining	Supply	🟡	
		Water Used after the POE Meter for Supply Maintenance Work	Supply	🟡	
		Fire Departments Usage (Incidents and Training)	Fire Department, quarterly reports including incidents and training.	🟡	
		Stomwater Maintenance (Catch Basin Cleaning)	Volume Registered at 50 Municipal Flow Meter	🟢	
		CCTV Storm and Sewer Mains Flushing	Project Manager	🟡	
		Water Wagon	No Feeds in 2019.	🟢	

Authorized Consumption – Unbilled Unmetered

Category	Component	Rating	Comments
Authorized Consumption	Unbilled Unmetered		• Use AWWA default value of 1.25% of system input volume. • Recommended default value changes in Version 6.

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Water Losses

Category	Component	Rating	Comments
Water Losses	Unauthorized Consumption	🟡	• Per IWA Benchmark loss of 0.25% of input volume used for theft allocation. • Version 6 of the AWWA software changes to 0.25% of Billed Authorized Consumption.
	Customer Metering Inaccuracies	🔴	• In 2017, 200 residential meters sampled (targeted = >15 years and high volume, plus 20 high volume mid-size meters). Weighted average results from this work show 3.8% inaccuracy. • It was decided to use this number for the 2016 audit over the outdated 2009 study during the July 2017 validation audit with Will Jernigan (AWWA WLCC).
	Systematic Data Handling Errors	🟡	• Using default AWWA value of 0.25% of system input volume. • Version 6 of the AWWA software changes to 0.25% of Billed Authorized Consumption.

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System Data

Category	Component	Rating	Comments
System Data	Number of Service Connections		• Asset Management Extract (43316 in 2019). • Uncertainty in number of service connections as system originated in 1879 and records are limited from the early years. City is reconciling this while linking customer billing data to GIS.
	Curb Stop to House		• Legacy Value Used since 2006: 9.8 m
	Average Operating Pressure		• 49.4 m used. • All DMA meter chambers (except 15-2) have a pressure sensor that collects pressure readings and is read in the ClearSCADA server. • Proposed DMAs to be active include: 8,9,10,11,12,21,22,24,30 (confirm this with D.Mutti; R.Puskas). This will create a seasonal change in operations where zones are open part of year and closed part of year. • UARL calculation sensitive to pressure.
	Total Length of Water Main (from GIS)		• Water mains should include all mains in distribution system after treatment is applied (should include Gazor-Mooney) because total production volumes are pumped through these mains. Aquaduct not included. • Confirm includes hydrant leads.

Cost Data

Category	Component	Source of Water Audit Information	Rating	Comments
Cost Data	Customer Retail Cost	Finance	●	• Applied to Apparent Losses • 2019: $3.60 per 1,000 litres
	Variable Production cost	Finance	●	• Applied to Real Losses • 2019: $243 per Megalitre

AWWA Version 6 (December 2020)

- Defaults
  - Unbilled Unmetered Authorized Consumption (UUAC)
    - Review of validated water audit data suggests UUAC default of 1.25% results in over-estimation.
    - 0.25% of Billed Authorized Consumption (previously water supplied) recommended in short-term.
  - Unauthorized Consumption (UC)
    - 0.25% is maintained as default percent.
    - Deriving this default as a percent of Billed Authorized Consumption, rather than Water Supplied, avoids inappropriate over-stating of the UC volume for high-leakage systems.
  - System Handling Errors (SDHE)
    - 0.25% is maintained as default percent.
- Data Validity Scoring
    - Series of questions which automatically determines the data grade for the given input
- Dashboard and Performance Indicators

Summary

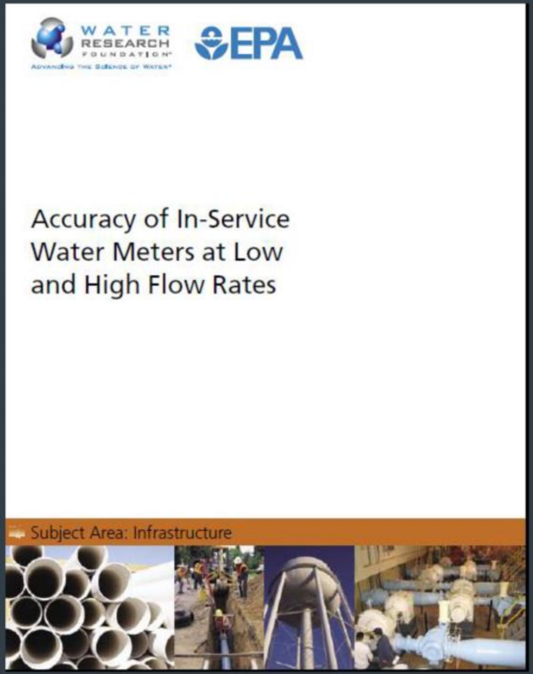
- Completing AWWA audit historically (good industry practice)
- Additional volumes metered over the years
- Have a residential meter replacement program to replace approximately 26,000 meters (started just before the pandemic)

Recommendations (preliminary)

No.	Item	Description
1	Volume of Own Sources	Document accuracy of each meter annually and include in water audit.
2	Documentation	Document calculation/source to determine value for water audit. For example, Volume of Own Sources, which meters are summed to determine the number in the audit.
3	Validation	Use AWWA Water Audit Spreadsheet (Version 6) and complete validation questions.
4	Customer Meter Accuracy	Develop a Meter Testing Program and continue with Meter Replacement Program. Potentially improve accuracy of water audit estimate based on meter type/size, etc.
5	Water Audit by Pressure Zone/DMA	Work toward completing water audit by pressure zone and/or DMA.
6	Private Mains	Industrial areas, strip malls, condos, etc. metered at individual buildings, not capturing leakage on private mains. New developments include bulk meter.

Accuracy of In-Service Water Meters at Low and High Rates, WRF, 2011

- Of the 450 new meters tested for this study, larger-than-expected number of new meters did not meet AWWA flow registry standard applicable to that meter type.
- Not all meter types are equal and some manufacturers produce a better product.
- Some meter types passed the AWWA registry standard tests more consistently than other meter types.
- Most manufacturers that publicize AWWA standard compliancy do not consistently meet AWWA metering standards.



Next Steps

- Water Audit Review
- Economic Level of Leakage
- Draft Technical Memorandum

Discussion and Questions

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Thank you

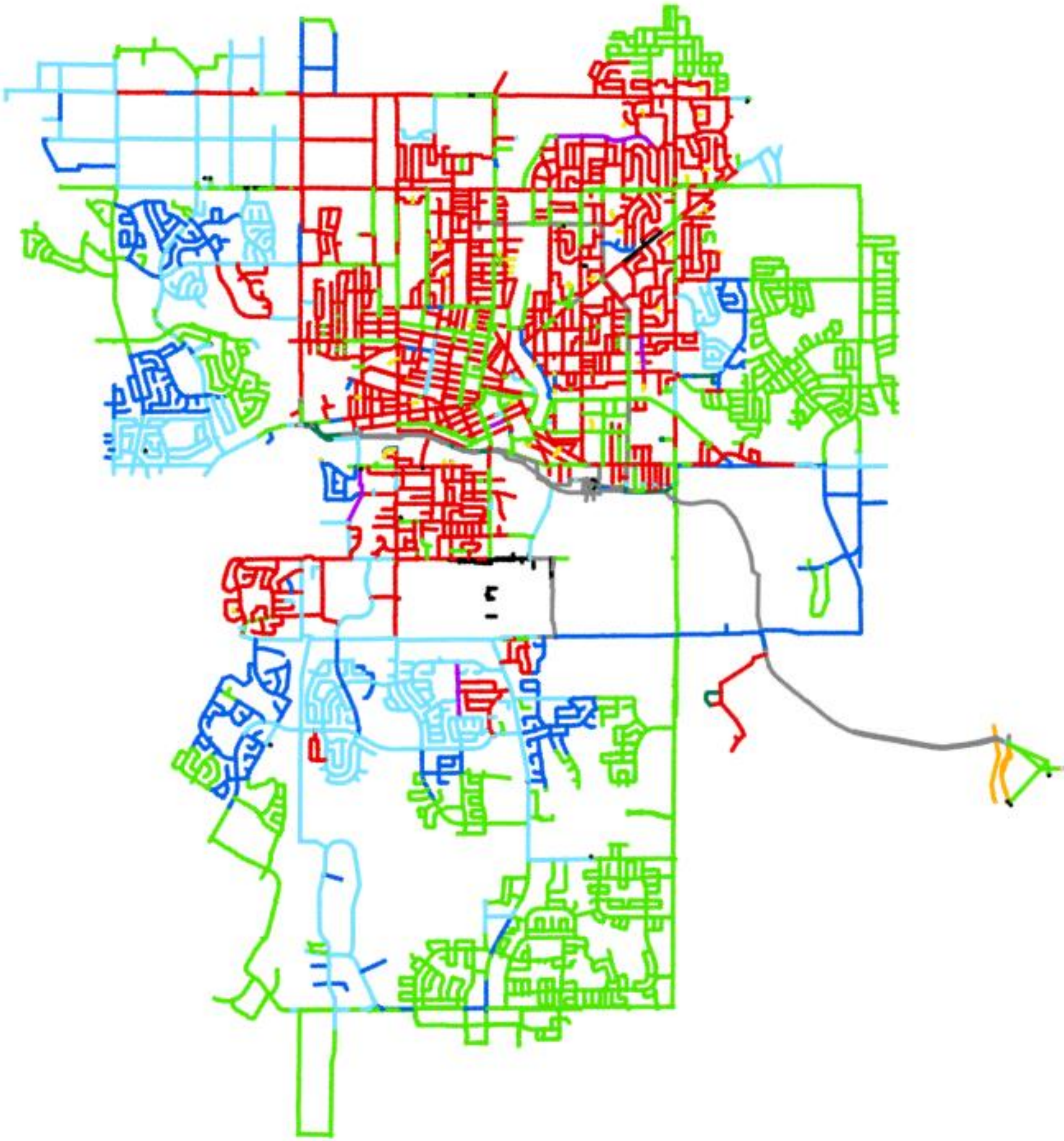
Attachment D

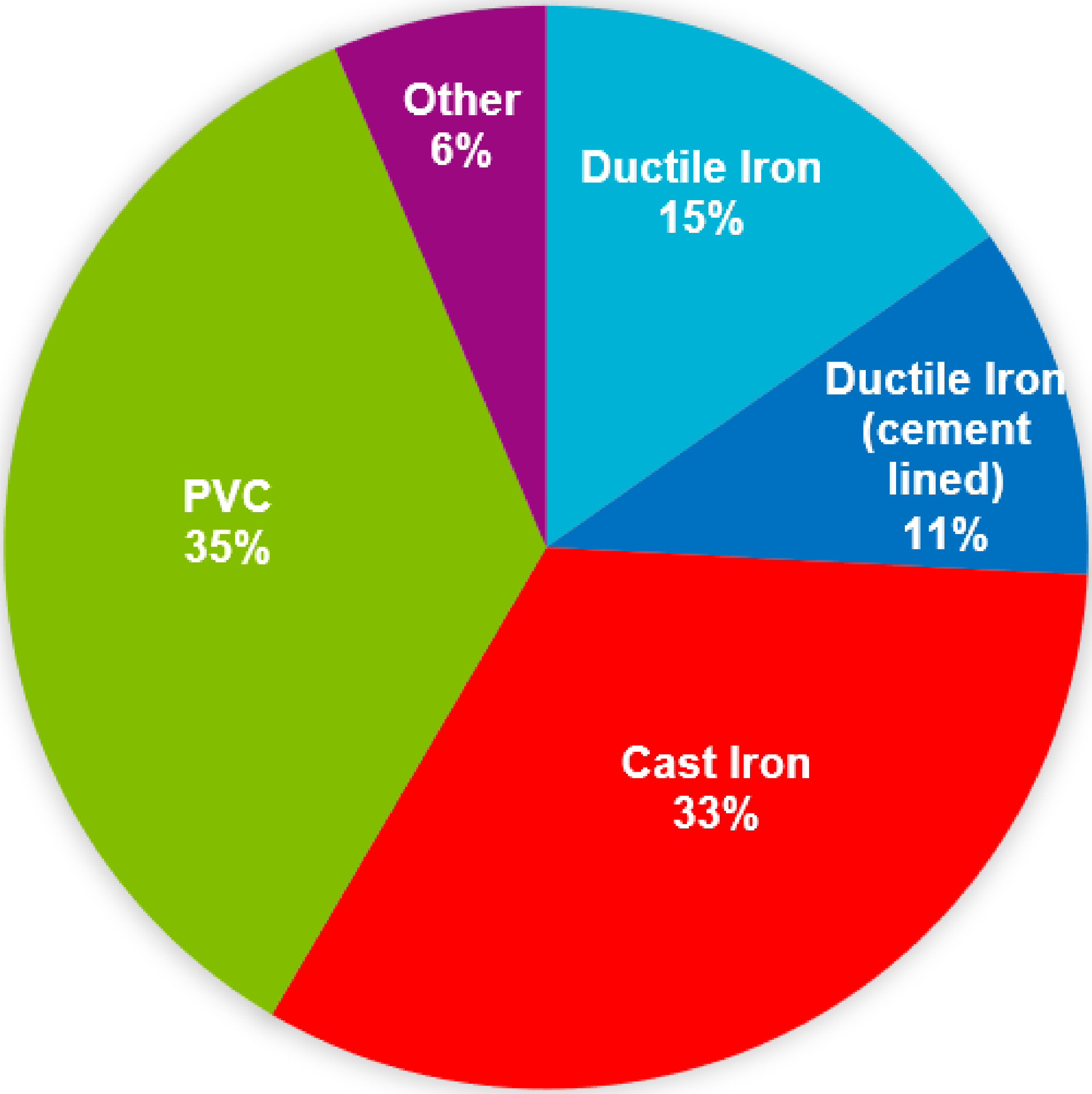
Summary of Water Main Breaks and Leaks

- D.1: Water Main Materials
- D.2: District Metering Areas

D.1: Water Main Materials

Attachment D-1: Water Main Materials

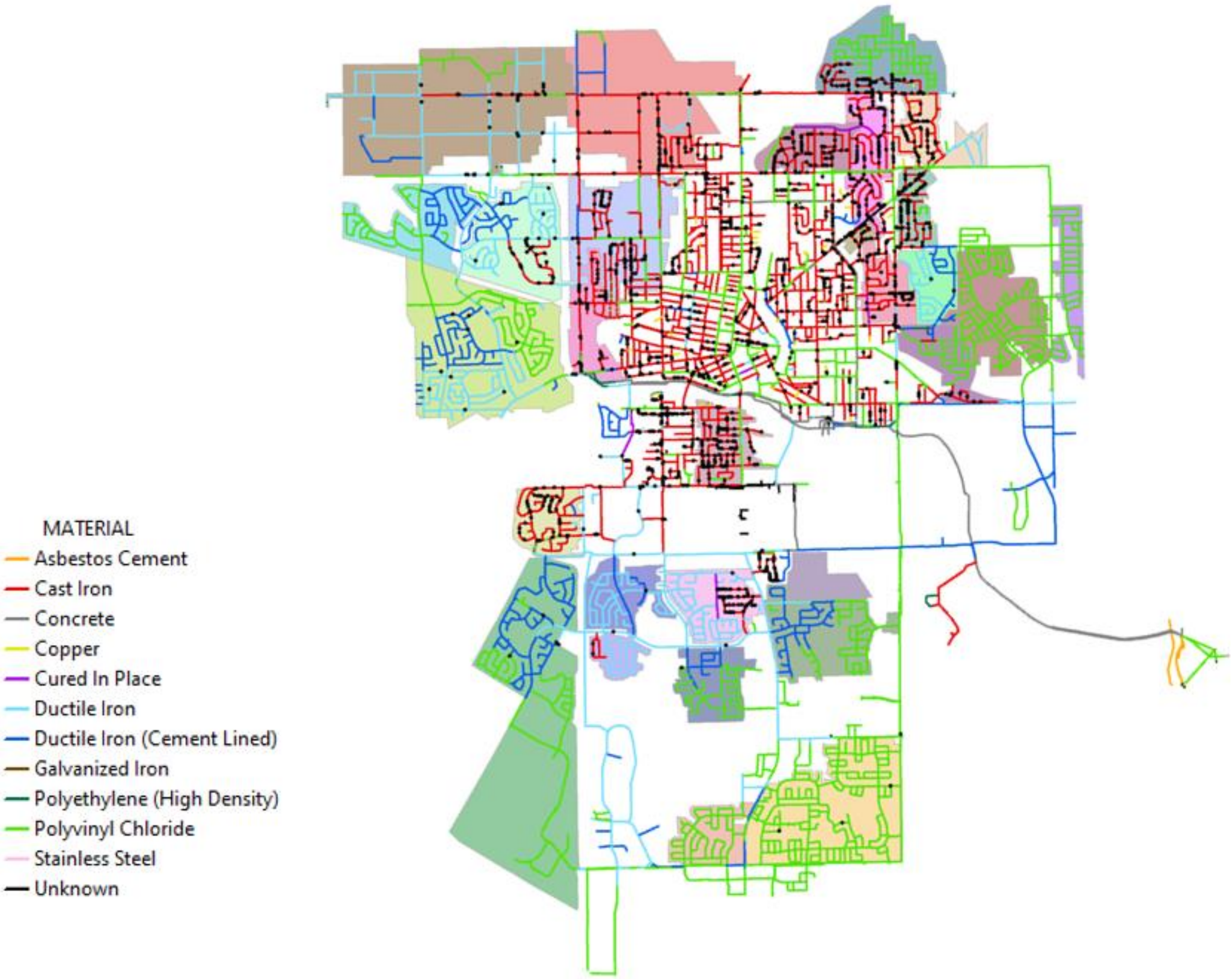




Approximately 585 km (total, GIS)

D.2: District Metering Areas

Attachment D-2: Water Main Materials



AECOM

Attachment E

Satellite Leak Detection

LEAK DETECTION

Detecting leaks from space!

The Utilis method uses satellite imagery to cover large areas and quickly narrow down the regions that contain probable leaks. How do we do this?

Specifically, L-band synthetic aperture radar (SAR) sensors are used for their day/night, cloudy/clear capabilities along with the ability to penetrate the first few meters of earth. Using a patented algorithm, Utilis can filter out the signature of drinking water and provide these zones to the customer. They are then displayed in user-friendly GIS reports, and direct the utility's preferred field crew to search within the zones in order to pinpoint the exact leak location.

This technology has been adapted from the search for water on other planets, underscoring its innovative and outstanding capability here on Earth. Utilis offers a fresh approach and a non-invasive method to the problem of urban water leakage. When compared with other leak detection methodologies, satellite-based leak detection identifies more leaks per day, saving you water, time, money and energy.

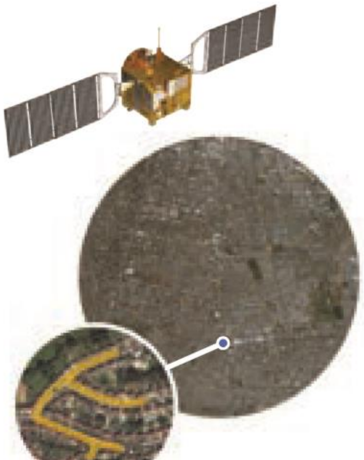
KEY BENEFITS:

- **Reduce your non-revenue water with Utilis!**
- **Maximize leaks found per day** while increasing field crew **efficiency 400%**
- Most cost-effective tool to **support regulatory compliance**
- **Identify trouble spots** for pipe replacement strategy
- **Lowest cost per leak** found on the market

UTILIS

LEAK DETECTION

FROM IMAGE TO REPAIR IN 4 EASY STEPS



Desktop

Dashboard GIS data Mobile

esri Partner Network Silver

1 Image acquisition and analysis
2 Delivery
3 Pinpointing of leak
4 Mark for excavation

UTILIS BY THE NUMBERS*

OVER **430 PROJECTS** COMPLETED IN **57 COUNTRIES**

CARBON DIOXIDE EMISSIONS REDUCED BY **14,500 METRIC TONS**

equivalent to 12.5M pounds of coal burned

21,800 MWH of **ENERGY SAVED** yearly

More than **36,000 LEAKS VERIFIED**

3.5 LEAKS FOUND PER CREW DAY

VS. 1.3 found using traditional acoustic methods (on average)

9200M GALLONS (5 million m^3) **WATER SAVED EVERY YEAR**

(EQUIVALENT TO 33% OF THE WATER USED BY A CITY OF 500K RESIDENTS)

*01/2017 - 06/2021

Rosh Ha'ayin, Israel • San Diego, USA • www.utiliscorp.com • inquiry@utiliscorp.com • +1.858.521.9442

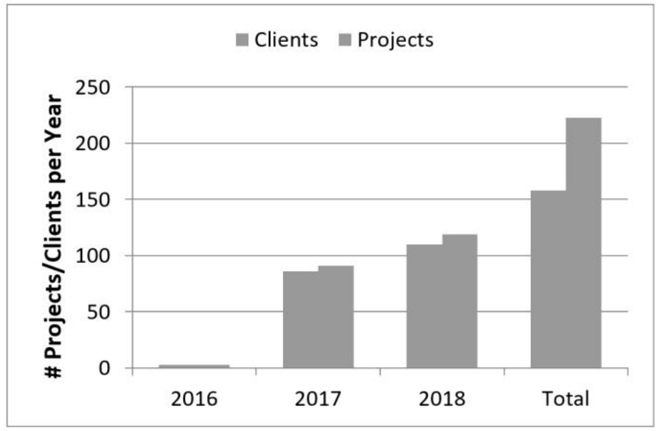
Using Synthetic Aperture Radar for Underground Leak Detection

A White Paper

July 2019

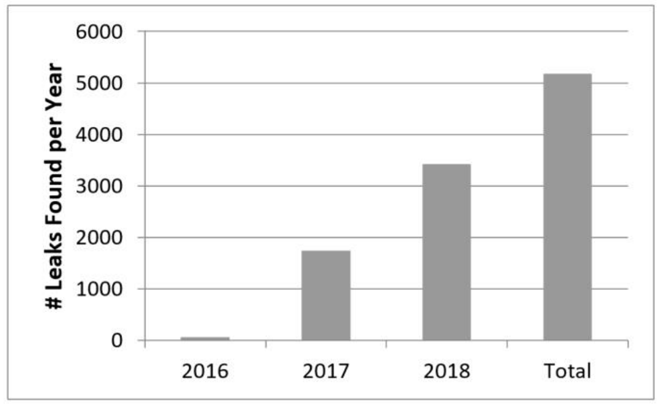
Introduction

Utilis uses satellite data to find potable water leaks underground. This technology was developed in Israel and is now deployed worldwide. The process uses synthetic aperture radar data and passes it through a proprietary algorithm along with application of filtering techniques. This paper will detail the thought behind the development of the technique and explore metrics that benchmark it against traditional leak detection methodology.

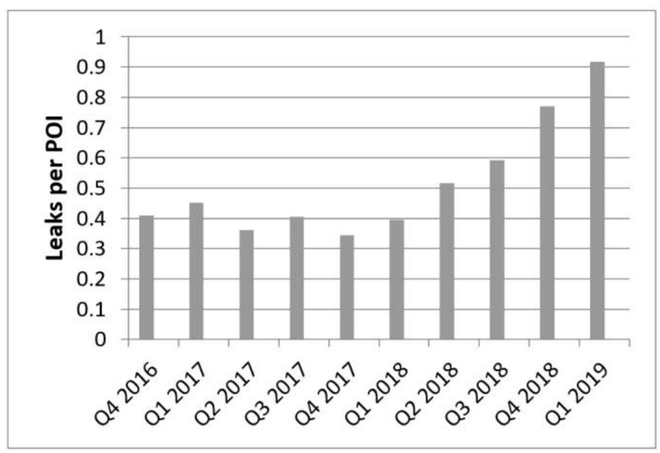


The Company

Utilis was founded in 2013 to commercialize the concept of locating subsurface, background potable water pipe leaks from space. Microwave radar is emitted from a satellite or any other airborne platform and used to detect the signature of wet soil underground with potable water indication. This technology is the same as is used to search for water on other planets such as Mars.



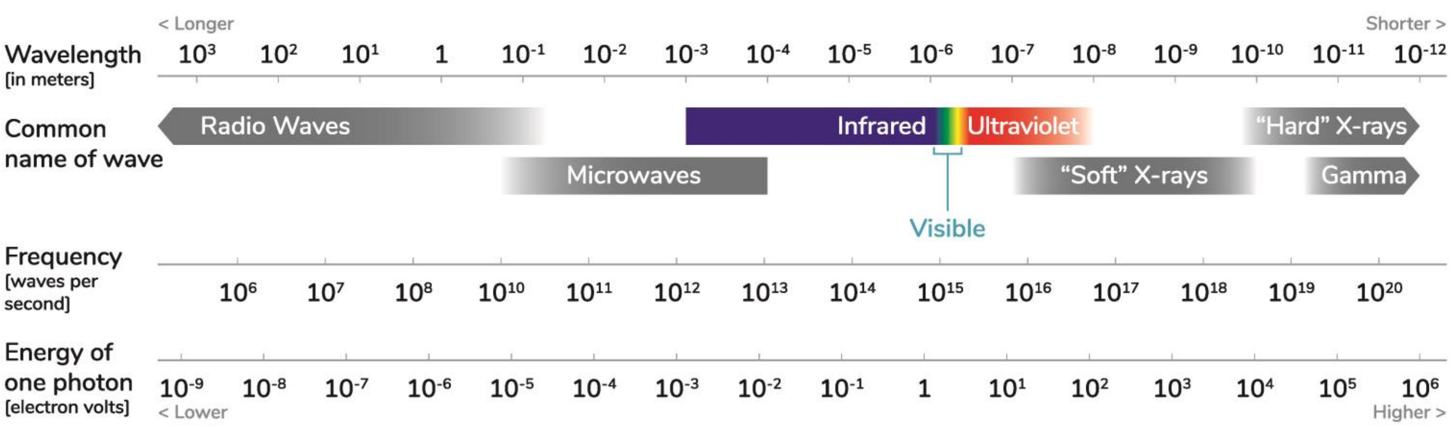
Utilis sales began in 2016. The number of projects completed has risen from three in 2016 to 110 in 2018. A total of 223 projects have been performed worldwide to date, in partnership with 158 unique clients. Over 10,700 points of interest (POI) have been identified and field verified with 5265 leaks being pinpointed in the 223 projects.



Utilis has completed projects in over 40 countries and holds three patents related to systems and methods for underground water detection using radar. Through continuous upgrades to the product, Utilis has increased the efficiency of the service over time.

The Electromagnetic Spectrum

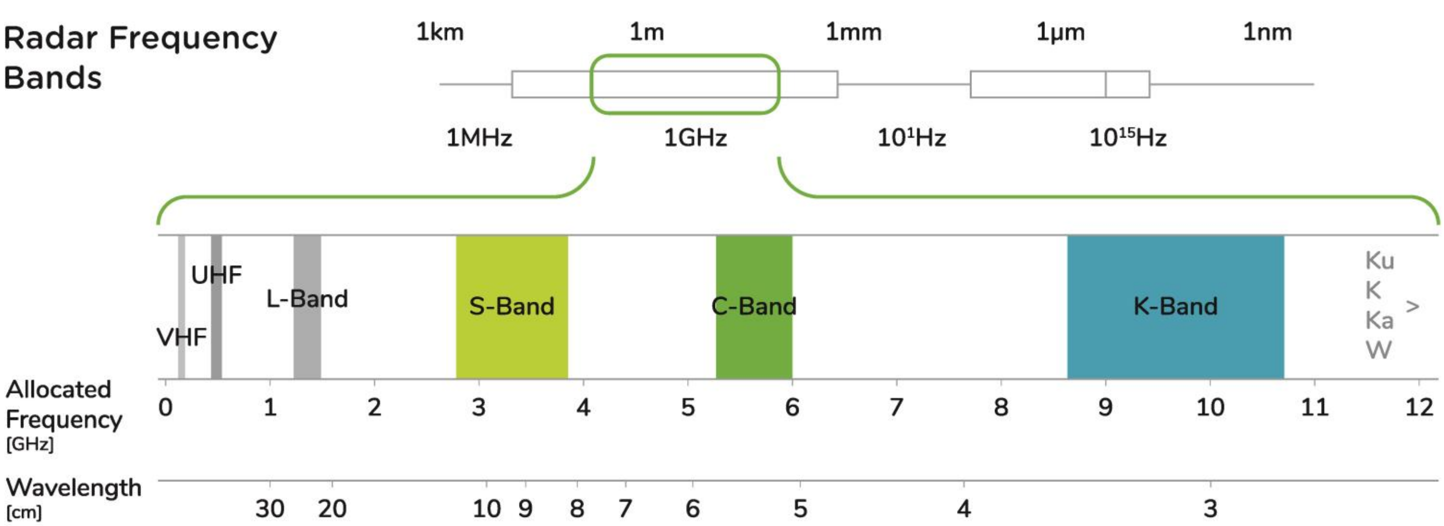
Radiation is energy that travels in the form of waves. Electromagnetic radiation (EM) can travel through empty space within the electromagnetic spectrum. Low energy EM has a long wavelength while high energy EM has short wavelength. Radio and microwaves have the longest wavelengths, and X-rays and gamma rays have the shortest wavelengths. Radar is an object detection system using EM in the microwave domain. Microwaves have a wavelength in the 0.001 to 1-meter range. Radar was developed secretly for military use before WWII. A radar system consists of a transmitter, antenna and receiver. Radar waves are sent from the transmitter and reflected off the subject object. The portion of the waves that are reflected, or backscattered, are returned to the receiver, therefore providing information about the object. Radar waves are more completely reflected by materials with high electrical conductivity including wet soil, and the reflectivity depends on the wavelength. Microwaves can penetrate ground surfaces up to 2 meters in depth, dependent on wavelength and soil type.



Radar

Traditional radar frequency band names originated as code-names during World War II and are still in military and aviation use throughout the world. Radars used to track ballistic missiles, have over-the-horizon, foliage penetrating or ground-penetrating applications, include HF (high frequency), UHF (ultra HF) and VHF (very HF) bands with frequencies in the 3 – 1000 MHz range. Radars used in weather applications, air traffic control and missile guidance have frequencies ranging from 1 – 12 GHz and include L (long), S (short), C (compromise) and X (secret in WW II) bands. Radars in the W band (75 – 100 GHz frequency range) are used in self-driving cars. These land-based applications typically use a pulsed technique whereby an area is illuminated in short bursts and echoes are received in the quiet period in between. Doppler characteristics can determine location, velocity and direction of targets. The performance of radar systems can be gauged by their range, accuracy, ability to filter noise and ability to recognize the intended target. These are greatly impacted by transmitter power and physical size of the antenna. Other systems similar to radar make use of other parts of the EM spectrum. For example, Lidar, uses ultraviolet, visible, or near infrared light from lasers rather than radio waves. Microwave imaging is a science that has evolved from older detecting/locating techniques, such as radar, in order to evaluate hidden or embedded objects in a structure or media using EM waves. Microwave imaging has a variety of applications including nondestructive testing and evaluation (NDT&E), medical imaging, concealed weapon detection at security checkpoints, structural health monitoring, and through-the-wall imaging.

Radar Frequency Bands



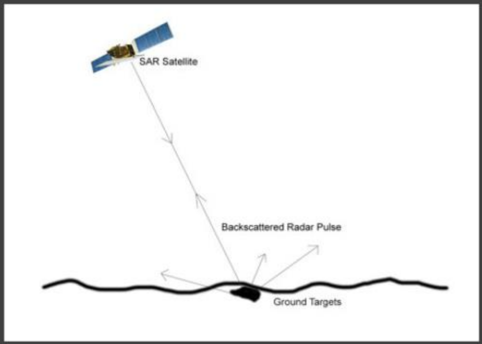
The Process

Utilis mainly, amongst others, leverages the capabilities of the Japanese Advanced Land Observing Satellite (ALOS-2) which is equipped with L-band Synthetic Aperture Radar (PALSAR-2) as an observation device for detailed examination of the earth. The satellite has a polar orbit which allows it to capture data over the same swath of the earth every 14 days. It has the capability to generate a minimum image size on the scale of 30 miles wide by 40 miles long.

SAR can be used for remote detection of underground water such as drinking water leakage from an urban water system. Water sources such as leaking pipes, lakes or swimming pools, reflect EM waves both below and above ground level. Every material has different electric properties, called the dielectric constant, creating an identifying marker that allows distinguishing between backscatter from them with SAR. Therefore, drinking water saturated soil has a specific signature in SAR data that is isolated by Utilis to find water leaks.

SAR sensors placed on an elevated platform such as a satellite or an aircraft send EM waves at a known frequency towards an area and read the EM backscatter from that area. The signals are compiled into an image of the area. This includes backscatter from water sources and other landmarks such as buildings, vegetation and topographical features of the area.

For Utilis to identify the water related backscatter, all other signals (e.g., EM noise reflection) are filtered or removed from the scan. Since different water sources (e.g., drinking water, sewage, seas, lakes swimming pools, etc.) have different dielectric constants, it is possible to distinguish one from the other. Unwanted targets are filtered out or removed from the scan thus leaving only the signal backscattered from pipeline water leakages (the signal from drinking water mixed with soil). The same image at different polarizations (called a quad-pole image) is used to further assist in reducing noise and identifying the desired material. The entire process used by Utilis is propriety and patented. The result is a GIS-based map showing points of interest (POI) where there are likely potable water pipe leaks. This map of POI's is then used to direct the boots-on-the-ground (BOTG) field inspections teams to confirm and pinpoint the leak location.



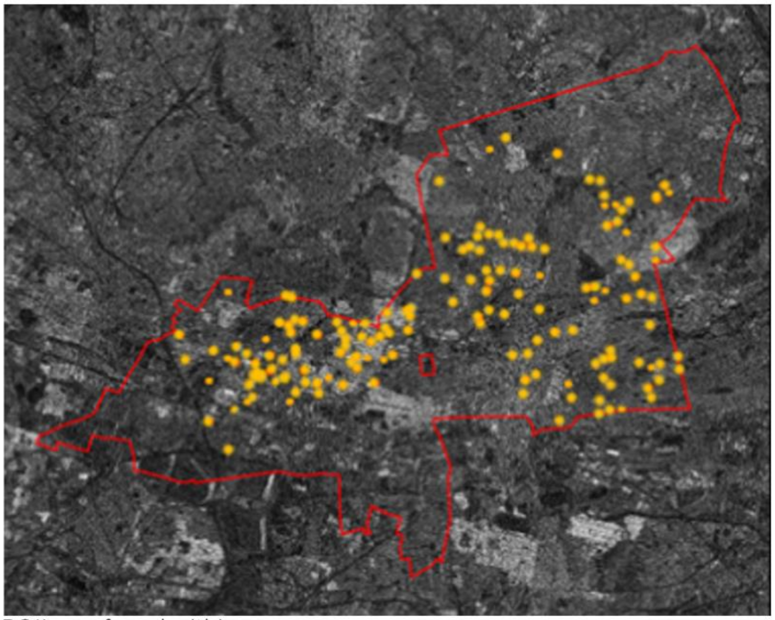
Synthetic Aperture Radar

Seasat was the first earth orbiting satellite designed for earth sensing (of the ocean) using synthetic aperture radar (SAR). SAR is a form of radar that is used to capture two or 3-dimensional images of objects such as landscapes. SAR uses the motion of the radar antenna over a target region to provide finer spatial resolution than conventional radars. SAR is typically mounted on a moving platform such as an aircraft or spacecraft.

The distance the SAR device travels over a target in the time taken for the radar pulses to return to the antenna creates a large "synthetic" antenna aperture (the "size" of the antenna). The larger the aperture the higher the image resolution will be, regardless of whether the aperture is physical (a large antenna) or "synthetic" (a moving aperture). This allows SAR to create high-resolution images with comparatively small physical antennas. To create a SAR image, successive pulses of microwaves are transmitted to "illuminate" a target scene and the echo of each pulse is received and recorded. As the SAR device moves with the aircraft or spacecraft, the antenna location relative to the target changes with time. Signal processing of the successive recorded radar echoes allows combining of the recordings from these multiple antenna positions to produce a correlated image.

The Utilis approach to finding leaks is analogous to a doctor performing triage on a patient to determine where the most acute problems are located. The entire water system is scanned and only the most likely leak locations are identified for further BOTG field inspection. This amounts to 5 -10% of the total length of pipe. The BOTG are trained in the best practices related to looking for and pinpointing leak locations.

The POI's are the centroid of a buffer zone within which the field crews are to focus their attention. The buffer zone stretches up to 300-foot radius from the POI. All pipe within that buffer zone is inspected for leak noise using state-of-art acoustic devices. Typically all of the listening points (e.g. meters, valves, curb stops, hydrants, etc.) within that buffer zone will be accessed to search for leak noises. This can be up to 140 listening points per mile of pipeline. In some cases (e.g. where meters are located inside buildings) fewer listening points are readily available for inspection and thus the field best practices protocols are altered to maximize the number of leaks found per crew day.


POI's are found within a scan area.

Pipe layers within the POI are used to narrow the search area.

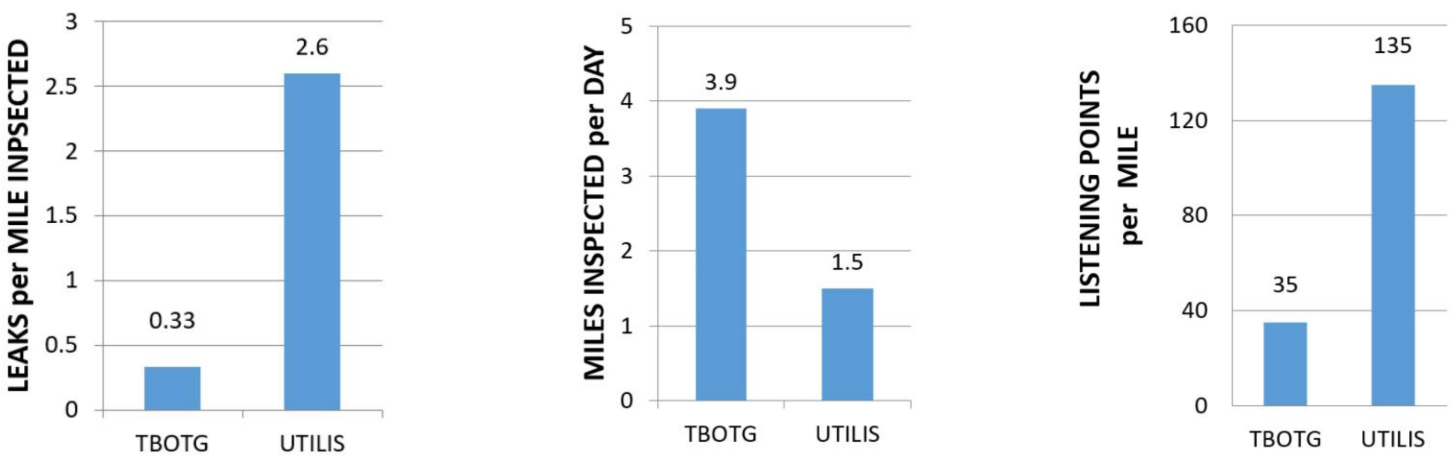
The BOTG field protocols are modified based on the conditions on the ground. The BOTG crews have a large impact on the performance of the Utilis leak detection program. The better trained and the more experience they have the more leaks they find. The Utilis imaging does not locate the point in the pipe that is leaking but senses the result of the leak; wet subsurface soil. Therefore the POI location is typically not the exact location of the leak. In addition, the type of pipe also impacts the success rate of the confirmation stage. PVC, or any plastic pipe, transmits sound less than metal pipe and thus it is harder to confirm by locating and pinpointing a leak.

THE UTILIS PROCESS

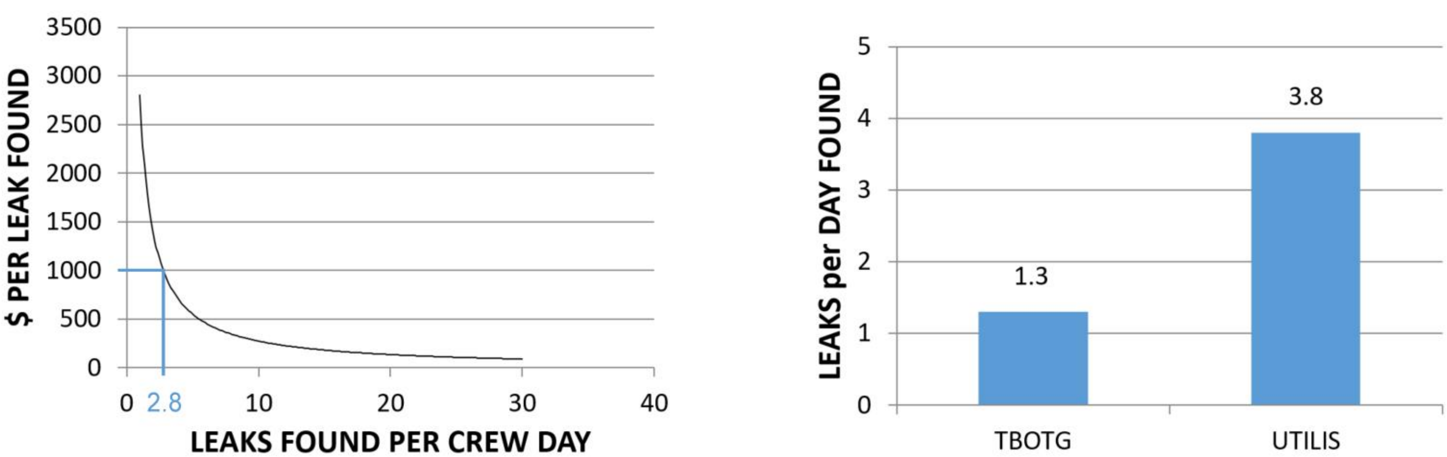
- A microwave sensor on-board a satellite acquires images.
- A corrected microwave image is processed.
- Treated water leaks are identified using a propriety algorithm.
- Data is presented graphically as a GIS data layer and within a data driven application.
- Field crews on the ground receive set of POI's to locate, confirm and repair the leaks.

Benchmarking

New technologies must always be benchmarked against existing ones to determine technical efficacy and value proposition. Performance metrics can be used to perform an apples-to-apples comparison. The best metric to measure technical efficacy of satellite leak detection is leaks found per mile physically inspected. This shows how well the Utilis satellite triage can reduce the area inspected and focus BOTG to the most likely leak locations. A meta-analysis of over 1600 traditional BOTG projects over ten years was undertaken, showing an average of 0.33 leaks found per mile versus 2.6 leaks per mile using Utilis.



Traditional boots-on-the-ground (TBOTG) vs. Utilis method.



The breakeven point between TBOTG and Utilis is 2.8 leaks per crew day. Above that, Utilis is more cost effective.

Conclusions

Value proposition can best be conveyed using the metric of leaks found per crew day. The more leaks found per day, the lower the unit cost of finding a leak since the major cost of pinpointing a leak is the BOTG labor resources. The Utilis program identifies currently 3.8 leaks per crew day (and growing every day) versus the traditional BOTG services finding an average of 1.3 leaks per day. Using average performance results, satellite survey and BOTG crew pricing, a value metric of dollars per leak found can be calculated. A typical Utilis project will result in a cost per leak found of less than $1000.

Highlights Of Satellite Imagery

- Efficient and accurate survey of a large area, covering an entire water system in a single screening.
- Using the Utilis triage methodology field leak detection crews verify almost 4 leaks per day, resulting in significant reductions in non-revenue water.
- Small leaks down to 0.1 liters per minute are detectable.
- Information generated can be used in any GIS system; the data output can be overlaid with any other data layer.
- There are no installation or capital costs associated with the Utilis program. No changes to existing infrastructure are required. Totally remote solution.
- Knowledge provided via data output is readily accessible and does not require external expertise to interpret.
- Utilis program is the most effective at reducing NRW, both economically and logistically.

Attachment F

Acoustic Loggers

CLEAN WATER

Fluid Conservation Systems

PermaNET+

Data logger

PermaNET + combines a Leak Noise Sensor and our versatile telemetry technology to create a fixed network to monitor leakage.

PermaNET+ works in conjunction with Google Maps to provide live on screen tracking, allowing leakage teams to respond quickly to problem areas and bring them under control.

Key Features and Benefits

- **Quick response:** Enables leakage teams to respond quickly to specific locations when a leak is detected
- **Secondary validation:**
  -Aqualog – detailed noise histogram to reduce 'false positives'
  -Audio – remotely listen to the noise
  -Remote correlation localize leak position
- **Leak sizes can be determined:** By matching daily alarms with flow data to enable leak alerts to be prioritized.
- **Cost effective:** Remote leakage monitoring
- **Easy set up:** Remote set up via GPRS
- **Remote Viewing:** Viewing via server hosted software
- **Precise Logging:** Ability to log noise more frequently to establish the noise profile and profile alarms for precise immediate leakage alarm
- **Fully Waterproof:** The IP68 rating has been tested at 10 m depth over a 24 hour period
- **External antennas:** To improve signal strength
- **Economic:** New communication module is smaller and more economic
- **Latest Technology:** Designed with latest mobile technology to maximize dial in and minimize cost

Applications

Once installed, leak data calculated using the proven Permalog algorithm, and secondary data, is transmitted via low cost GPRS or SMS telemetry. This removes the requirement for expensive site visits and "drive by" data retrieval.

PermaNET+ allows leakage teams to monitor the status of each logger deployed from map based host software any Internet enabled device.

Once the presence of a leak has been identified, secondary measures can be used to check and remove 'false positives' and also to localize the leak position.

MONITORING ASSETS, DELIVERING DATA, BRINGING CONTROL

PermaNET+

Data Logger

Sensor Input options

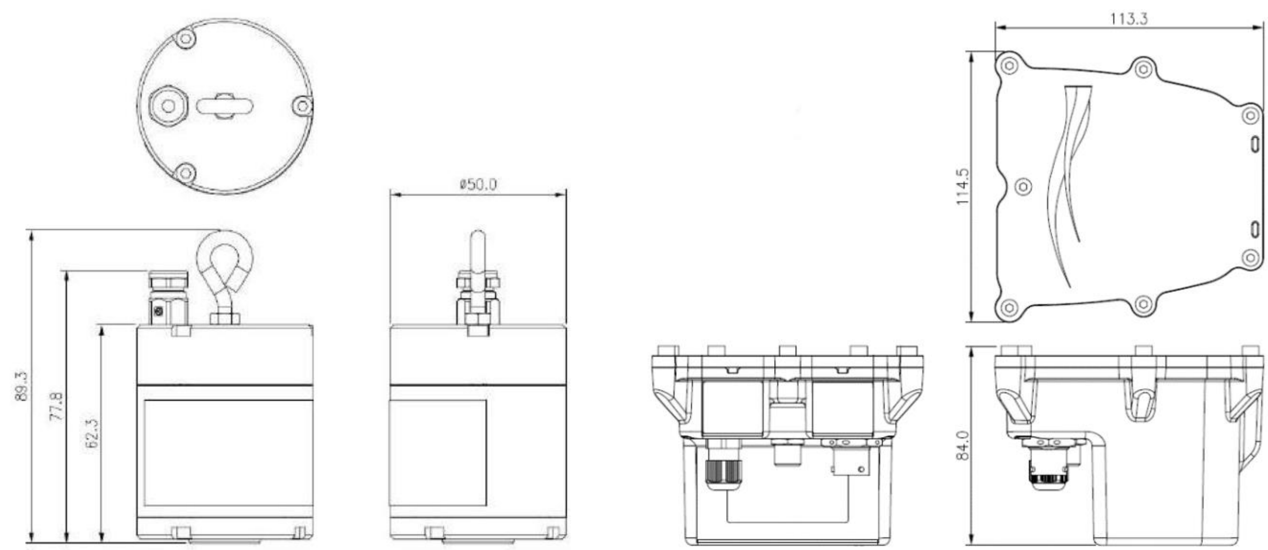
Noise	Permalog LNS Sensor

Communication and programming

Serial	USB Cable for connection to PDA hand held programming and data collection unit, laptop, or desktop PC using 9600 Baud.
Internal Cellular modem	Quad band modem supplying 850/900/1800/1900MHz bands

Logger Features

Operating temperature	Logger: -5°F to +140°F (-20°C to +60°C) Leak Noise Sensor: -5°F to +140°F (-20°C to +60°C)
Memory	Primary recording 1 million readings
Dimensions	Logger without antenna: H = 3.3", W = 4.5", D = 4.4" LNS: H = 3.5", W = 1.9", D =1.9"
Weight	Logger = 0.7 lbs Leak Noise Sensor= 1.0 lbs
Ingress protection	IP68 submersible
Clock	On board 24 hour real time clock with date facility. Automated synchronization
Logger ID	Up to 7 alphanumeric characters. Also readable factory set serial number in firmware
Alarms	Leak/no leak Signal received/not received



Fluid Conservation Systems

Fluid Conservation Systems
502 TechneCenter Drive, Suite B
Milford, OH 45150

Tel: 513-831-9335
Fax: 513-831-9336
Email: sales@fluidconservation.com

MONITORING ASSETS, DELIVERING DATA, BRINGING CONTROL

SePem® 155 – Radio Noise Loggers

The principle of noise logging

The duration of time that water leaks from the distribution network has a significant influence on “real water loss” and “non-revenue water” calculations. The goal is to quickly identify water leaks to reduce the dollars lost, reduce the impact on non-revenue water calculations, be efficient, be good stewards of the environment, and reduce potential property damage. This goal can be achieved with ***SePem® 155*** loggers.

In addition to conventional leak detection survey methods, ***SePem® 155*** loggers are an effective, permanent monitoring tool to quickly identify leaks that may never reach the surface. With its ease of reprogramming and versatility, the ***SePem® 155*** loggers can also be redeployed to other locations for shorter-term leak detection surveys. This process is often referred to as “lift and shift”.

With the aid of the ***SePem® 01 Master***, the user establishes listening times, frequency and duration, alarm levels and “Patrol Times” for the collection of data. The “listening times” are typically programmed for periods during which flow and traffic noise are at their minimum level. “Patrol Times” are typically set for “regular working hours” eliminating the need for overtime.

The compact design of the ***SePem® 155*** enables the logger to be placed in valve boxes, meter pits, and on unusual contact points. The highly sensitive microphone enables programmed monitoring of distances up to 1,600 linear feet of pipe between loggers. Spacing of the logger is dependent on the pipe size, pipe material, service density, and contact points available.

The ***SePem® 01 Master*** is portable and can be carried, or placed in the vehicle mounting bracket while patrolling for data collection.

During patrol, the result is both an audible and visual “leak/no leak” indicator, substantiated by two pieces of critical leak detection data- “minimum noise level” and “noise consistency”. Data results are cataloged by physical location, logger, patrol, date, and can be easily archived for comparison with future data. One ***SePem® 01 Master*** can accommodate up to 500 ***SePem® 155*** loggers.

SePem® Master Communicator for data backup and visualization

The ***SePem® Master Communicator*** software is freeware, which allows you to display the data managed on the ***SePem® 01 Master*** directly on a PC. The patrol lists are transmitted directly after connection and saved in a database. In logger lists you can directly access and easily manage measurements from the individual ***SePem®*** noise loggers.