RATs in the House – How Little Rock Water Reclamation Authority Moved From a Time-Based to a Condition-Based Sewer Cleaning Strategy

Authors: Tim Harrison[1*], Alex Churchill[2]

Affiliation: [1]Little Rock Water Reclamation Authority, Arkansas [2]InfoSense, Inc., North Carolina

*timothy.harrison@lrwra.com

Keywords: acoustic pipe inspection, asset management, collection system cleaning, condition-based maintenance, pipe blockage assessment, sewer line inspection

ABSTRACT

Little Rock Water Reclamation Authority, Arkansas (LRWRA) manages ~1929 km (1100 mi) of small diameter (up to 30cm or 12 in) gravity sanitary sewer mains. In January 2017, they implemented an acoustic inspection technology as a preliminary assessment tool to help prioritize cleaning operations. They successfully transitioned from a time-based to condition-based sewer maintenance program, improving their annual maintenance contact with the small diameter gravity system from 40% to 90%. In just their first year, LRWRA inspected 1555 km (966 miles), or ~70% of their collection system, reducing non-capacity sanitary sewer overflows by ~35%, without hiring additional personnel.

Discussed are LRWRA's change management process used to successfully integrate acoustic inspection technology, the Sewer Line Rapid Assessment Tool (SL-RAT®), into their sewer maintenance program, both operationally and organizationally. LRWRA's transformation to a condition-based preventative maintenance program was nationally recognized as a *Utility of the Future Today.*

INTRODUCTION

Little Rock Water Reclamation Authority (LRWRA) Background

The City of Little Rock, located near the geographic center of Arkansas, is the state's capital and largest city. Little Rock Water Reclamation Authority (LRWRA), formerly Little Rock Wastewater, provides wastewater service to its 200,000 residents. With an organizational staff of 219 employees, the Authority operates and maintains 3 water reclamation facilities, 30 pump stations, and 2253 km (1400 mi) of collection system, of which 1770 km (1100 mi), or 80% are appropriate for acoustic inspection – that is 15-30cm (6-12 in) in diameter. The Collection System Maintenance department is staffed with 90 employees, who work together to provide a reliable collection system to protect the environment and serve customers.

LRWRA's Decision to Implement Acoustic Technology – Limitations of Time-based Collection System Maintenance Program

Prior to implementing the Acoustic Inspection program, LRWRA utilized a time-based preventive maintenance program to deploy its collection system maintenance resources. Using a time-based program limited decision-making factors to age of pipe, type of pipe, depth of pipe, and historical stoppage and overflow data. Because of these limitations, LRWRA was only able to annually perform maintenance on 40% of its small diameter pipes (up to 30 cm or 12 in diameter).

One of the major goals of the Collection System Maintenance department is to annually reduce the stoppage and overflow occurrences from the previous year. However, a time-based maintenance strategy made it difficult to continually improve collection system performance aimed at reducing stoppages and overflows. This was evident by the unchanging number of non-capacity sanitary sewer overflows for five consecutive years, as depicted in Table 1.

Table 1. *Before implementing acoustic technology in 2017, LRWRA utilized a time-based preventative maintenance program that limited their annual maintenance to 40% of their collection system. As a result, LRWRA saw no reduction in the occurrence of non-capacity sanitary sewer overflows over a five-year period (2012-2016).*

Year	Number of Non-Capacity Sanitary Sewer Overflows
2012	57
2013	50
2014	43
2015	49
2016	60

A time-based program proved limiting in showing how or where to deploy resources in a manner that would prevent stoppages or overflows. This compelled LRWRA to explore acoustic inspection technology, as a means of developing a preventative maintenance program for collection system maintenance. In 2017, LRWRA shifted to a condition-based program by introducing an acoustic inspection program utilizing the Sewer Line Rapid Assessment Tool.

Condition-Based Maintenance Integrating Transmissive Acoustic Inspection Technology

While reducing sanitary sewer overflows (SSOs) is an important function of maintenance programs, effectively deploying resources daily to achieve that objective can be a tricky challenge for wastewater collection system managers. If cleaning and inspection resources are deployed to pipes that are functioning properly, then time and money is wasted. But, if a pipe that is blocked is overlooked, serious consequences can result- such as sewer overflows, damage to the environment, damage to property, bad PR, or even sanctioning by a regulator.

Current maintenance strategies are commonly comprised of a combination of time-based maintenance and reactive maintenance. A time-based, or fixed interval, maintenance program is effective in areas that require a periodic cleaning schedule that can be appropriately estimated – such as areas with high grease restaurants. But overflows occurring from unpredictable events or blockages are unlikely to be addressed by a time-based maintenance program and force operators toward reactive maintenance.

Furthermore, there are limitations to expanding a time-based maintenance program. Howitt's (2012) comparison of overflows and percentage of system cleaned annually in 16 municipalities showed a clear, and unsurprising, correlation between cleaning and overflow reduction. Meaning, utilities that clean more, have fewer overflows. But simply increasing the percentage of system cleaned is not a cost or time effective method for improving operations since over 50% of pipes in the average utility are clean prior to maintenance (Howitt, 2012; Crabtree, 2015). Furthermore, there is likely diminishing return with more cleaning, meaning that increasing the percentage of system cleaned generally results in a larger proportion of wasted resources.

A condition-based maintenance program for collection systems aims to effectively alleviate "cleaning clean pipe" by allowing operators to target maintenance to locations with suspected issues, prior to an overflow or failure. Until recently, generating the assessment information to establish a condition-based maintenance program was cost prohibitive. The Sewer Line Rapid Assessment Tool, or SL-RAT, introduced acoustic technology as a tool that reduces time and costs associated with generating blockage assessment information. This allows acoustic inspection to be a viable option in implementing a cost and time effective condition-based collection system maintenance strategy.

To enable condition-based maintenance of gravity sewer lines, an acoustic inspection technology was developed in the mid-2000's through a multiyear partnership between Charlotte Water, The University of North Carolina – Charlotte, and the National Science Foundation. The patented product, called the Sewer Line Rapid Assessment Tool, or SL-RAT®, uses transmissive acoustics – or in other words, "yelling" and "listening" – to screen 15-30 cm (or 6-12 in) gravity-sewer lines for blockage conditions. The technology has been gaining traction with utilities since

2012, as it enables conditioned-based maintenance of a collection system – line by line. Acoustic technology is typically used to help prioritize deployment of cleaning and CCTV inspection resources - helping utilities to avoid “cleaning clean pipe”. At this point, well over 30 million meters (~100 million feet) of pipe have been inspected with transmissive acoustics, and hundreds of utilities are consistently finding that 70-90% of the pipes they were planning to clean do not need it (Figure 1).

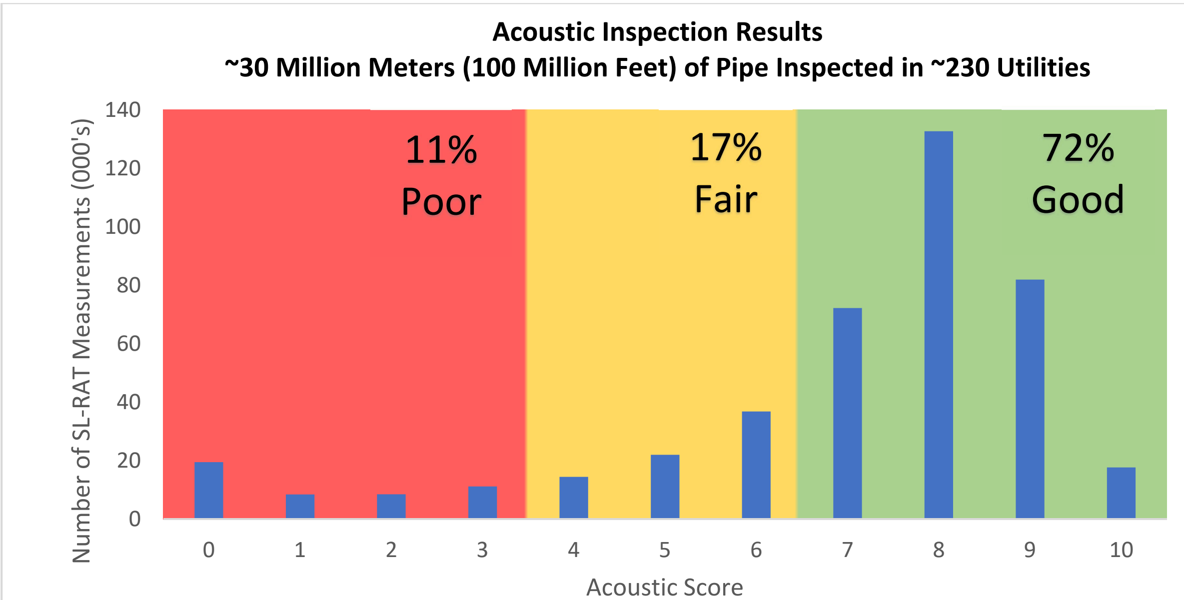

Figure 1. *Over 30 million meters (100 million feet) have been inspected with transmissive acoustics by more than 230 utilities. The cumulative acoustic inspection scores show that more than two-thirds of pipes in the average utility do not need to be cleaned – therefore, cleaning without pre-emptive cause will likely result in wasted time, cleaning resources, and water. An acoustic score ranges from 0 to 10 (0 means sound signal was completely blocked, 10 indicates a pipe with plenty of flow capacity).*

Transmissive Acoustic Pipe Inspection – How Does it Work?

The SL-RAT device is comprised of two portable components – a transmitter (TX) – that “yells” and a receiver (RX) – that “listens”. The TX and RX are placed on top of adjacent manholes, requiring no flow contact or confined space entry. The TX component then generates a known range of audible tones from a low bass to a high treble, which transmit through the free space above the flow in the pipe. The RX component listens for this known message and based on what it hears, the RX interprets the sound signal into a blockage condition assessment. Obstructions in the pipe, such as roots, grease, significant structural anomalies, and debris will all influence the sound energy, and effectively, the acoustic score.

Within three minutes, the RX provides a score ranging from 0-10 to the operator in real time. Where a “zero” means the sound signal was completely blocked and a “ten” indicates a pipe with plenty of flow capacity. The scores can be thought of as providing the system operator with a RED LIGHT 0-3; YELLOW LIGHT 4-6; or GREEN LIGHT 7-10 (Figure 2).

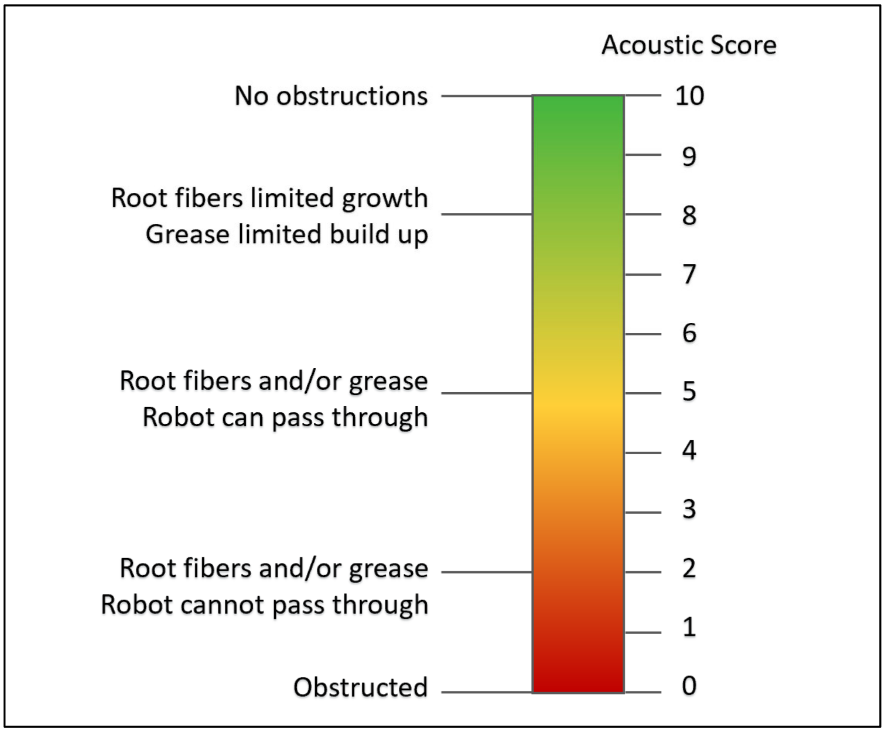

Figure 2. *Acoustic scores generated by the Sewer Line Rapid Assessment Tool, or SL-RAT®, range from 0 to 10, where 0 means the sounds signal was completely blocked, and a ten indicates a pipe with plenty of flow capacity.*

The associated software, the Sewer Line Data OrGanizer or SL-DOG®, enables quality control and archiving of SL-RAT data. Pipe segment location and length can be verified with the integrated GPS, and acoustic scores can be integrated with GIS data. The full standard practice for prioritizing sewer pipe cleaning operations using transmissive acoustic technology can be found in the F3220-17 ASTM Standard Guide (ASTM International).

Why It Makes Sense to Integrate Acoustic Inspection

Acoustic technology provides a very low-cost, very fast, but low-resolution view of blockage condition in the utility's collection system. Because an acoustic assessment takes less than three minutes, the operating cost can be a small fraction of the cost of CCTV or cleaning. Therefore, the time invested to acoustically assess pipes results in saved time and resources later in the cleaning workflow.

For instance, LRWRA used the SL-RAT to acoustically inspect ~1.6 million linear meters (5.3 linear feet) at \$0.12/unit. This information was attained more quickly, and at a much lower cost, than alternatives such as CCTV (\$0.86/unit) or hydro-cleaning (\$0.67). Therefore, acoustic blockage assessments became an effective preliminary tool for understanding general blockage conditions, and helping operators to determine where to target more expensive resources such as cleaning or CCTV in an impactful way (Table 2).

Table 2. *Acoustic inspection scores are generated in three minutes or less, giving users a very fast, but low-resolution view of blockage conditions. Therefore, acoustic inspection can be a helpful tool for attaining preliminary information at low-cost, to help target more-expensive cleaning assets such as CCTV ($0.86/unit) or hydro-cleaning ($0.67/unit) to only areas that may have blockages.*

Activity	2017 Production	2017 Unit Costs (per foot)
Acoustic Inspection	1,615,000 linear meters (5,300,000 linear feet)	$0.12
Closed-Circuit Television	217,000 linear meters (712,000 linear feet)	$0.86
Hydro-Cleaning	427,000 linear meters (1,400,000 linear feet)	$0.67

Overall, over 230 utilities have inspected over 30 million meters (~100 million ft) of sewer pipe using transmissive acoustics, which has allowed them to avoid cleaning approximately two-thirds of the lines inspected. This enables utilities to target their cleaning resources on the 10-30% of their systems with significant issues. That being said, the SL-RAT technology is simply another tool in the operator's tool kit. It is not meant to replace CCTV or cleaning activities, but it can act as a preliminary inspection tool and effectively assist in prioritizing where these much more expensive assets are allocated.

METHODOLOGY

LRWRA Pilot Study - Validating Transmissive Acoustic Inspection

LRWRA was introduced to the Sewer Line Rapid Assessment Tool (SL-RAT®) in 2013. Prior to implementing acoustic inspection technology in 2017, LRWRA relied primarily on a time-based preventative maintenance program. Since conditions in sewer mains are ever-changing and the collection system is large, it is challenging for collection system managers to maintain the proper cleaning intervals. Time-based cleaning intervals at LRWRA typically ranged from 1 to 48 months between scheduled cleanings and achieved cleaning 35-40% of Little Rock's collection system annually. In 2016, twenty-two employees were allocated to cleaning the collection system. Ten employees made up 5 two-person crews assigned to hydro-cleaning and twelve employees made up 4 three-person crews assigned to hand cleaning (Table 3).

LRWRA initially conducted acoustic inspection technology research and benefit analysis before launching a 2-year pilot study, beginning in early 2015 and concluding in late 2016 (Figure 3). The pilot study focused on performing acoustic inspections on gravity sewer mains up to 30 cm (12 in) in diameter scheduled to be cleaned every 6 months. When the pilot study began, there were approximately 1300 sewer mains being cleaned on 6-month intervals. The pilot study crew would perform acoustic inspections one month prior to the upcoming scheduled cleaning. This process allowed an assessment of the condition within the sewer main prior to performing scheduled maintenance. If acoustic inspection score results were above 6, the scheduled cleaning was postponed for 6 months; however, if acoustic inspection score results were 6 or below, the scheduled cleaning was completed in the upcoming month.

At the end of the two-year pilot study, the amount of sewer mains scheduled to be cleaned on 6-month intervals had been reduced by 50%. Under a time-based preventive maintenance strategy, the factors used to structure the maintenance program proved inadequate to properly schedule cleaning intervals. In addition, the pilot study results proved that valuable resources such as staff and fleet were not being deployed in an optimal manner.

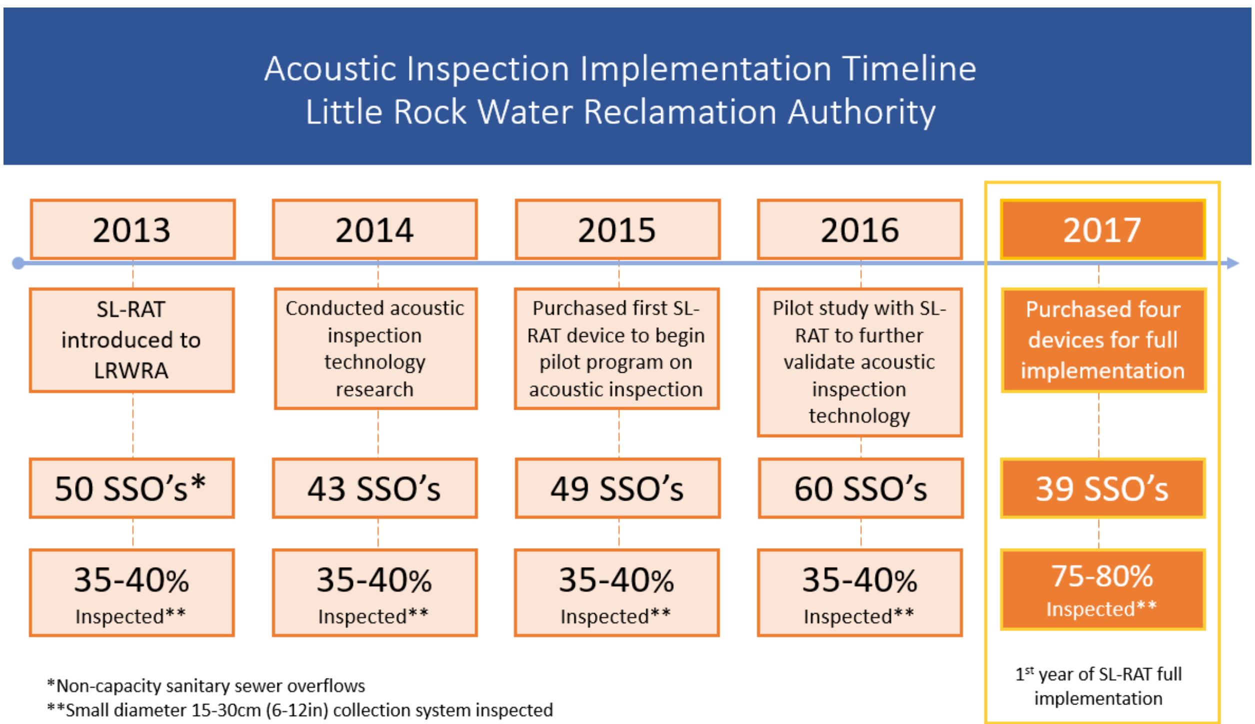

Figure 3. *LRWRA was first introduced to acoustic technology in 2013 and conducted a two-year pilot program (2015-2016) before fully launching a condition-based assessment program based on the Sewer Line Rapid Assessment Tool. In the first year of implementation, LRWRA increased their maintenance of small diameter gravity mains from 35-40% to 75-80%, resulting in a ~35% reduction in sanitary sewer overflows (SSO's).*

Implementing Acoustic Inspections Without Hiring Additional Personnel

To effectively transition from a time-based to a condition-based preventative maintenance program, it was imperative for LRWRA to ensure that integrating acoustic inspection did not require hiring of additional personnel. Collection system managers evaluated the need of staff allocated to cleaning the collection system. Based on pilot study results, many sewer mains were being cleaned too frequently. The pilot study results aligned with other reports within the industry that 70-80% of collections system pipes did not require immediate cleaning. Additionally, LRWRA wanted to move away from hand cleaning since it was so physically demanding, and less effective than alternatives such as hydro-cleaning. Based on these facts, collection system managers decided to reallocate 6 employees from hand cleaning to form three two-person crews to perform acoustic inspection. In addition to reallocating hand cleaning staff, another two-person crew previously responsible for conducting the pilot study was assigned to acoustic inspection. The reallocation of hand cleaning and staff performing the pilot study provided the necessary four two-person crews to conduct acoustic inspections on the 1929 km (1100) miles of gravity sewer mains up to 30 cm (12 in) in diameter annually (Table 3).

In addition to structuring the field staff with necessary acoustic inspection crews, the collection system managers had to provide for the administration of the acoustic inspection activity and downstream workflows. The forecasted workflows projected each acoustic inspection crew would complete 50-60 inspections per day. The failure rate for acoustic inspections was projected to be as high as 30%. To administer the workflow, 3 newly staffed Maintenance Planner positions were created. In total, the Collection System Maintenance department reclassified 8 positions. The new structure relied upon the remaining 5 hydro-cleaning and 2 hand cleaning crews to manage the collection system cleaning demand. Once the restructuring and reclassifying of positions within the department was complete the goal of not adding any staff to implement acoustic inspection into the preventive maintenance program was achieved (Table 3).

Table 3: *LRWRA was able to transition from a time-based to a condition-based assessment through restructuring personnel, so that no additional personnel needed to be hired to implement acoustic inspections. However, the restricting and introduction of the Sewer Line Rapid Assessment Tool had significant impact of percentage of collection system covered annually (improved from 35% to 80%) and reduction in non-capacity sanitary sewer overflows.* * From 2015-2016, two walking line crew members were conducting a pilot study on acoustic inspection technology.

	2016 (Prior to Acoustic Inspection)	2017 (After Acoustic Inspection)
Total Collection System	2253 km (1,400 mi)	
Small Diameter Gravity Portion	1770 km (1,100 miles)	
Percentage of collection system covered annually	~35%	~70%
Acoustically inspected pipes annually	0	1463 km (900 mi)
Non-Capacity SSOs	60	39
Department Headcount	90	90
# of Hand cleaning crews (total # of people)	4 (12)	2 (6)
# of Hydro cleaning crews (total# of people)	5(10)	5(10)
Acoustic inspection crews (# of people)	1* (2)	4 (8)
Maintenance Planners	0	3
Secretary	1	0
Dispatcher	2	2
Other Staff Headcount	63	61

Designing an Organization Structure for Acoustic Inspection Work Flow – Transitioning from Time-Based to Condition-Based Assessment

The City of Little Rock is comprised of 2253 km (1400 mi) of collection system, of which 1770 km (1100 mi), or 80% are appropriate for acoustic inspection – that is 15-30cm (6-12 in) in diameter. The goal for the newly formed acoustic inspection crews was to annually inspect the entire 1770 km (1100 miles) fitting this criterion. A daily production goal for each crew was set at 10,000 linear feet. This equates to between 50-60 acoustic inspections per day for each crew.

The collection system is divided into four major areas. The major areas are: Central, East, South and West. Each area is comprised of sub-basins. The sub-basins within each area were researched for stoppage and overflow data to aid in developing a starting point for prioritizing acoustic inspection deployments. Sub-basins within each area having the highest occurrences of stoppages and overflows over the previous 5-year period were targeted as the starting point. The priority for acoustic inspection within each area was to inspect sub-basins in descending order of stoppage and overflow occurrence.

LRWRA also established a standard for what acoustic inspection scores should initiate cleaning work orders. The acoustic inspection equipment generates a score of zero to ten for each pipe segment, where a zero indicates that a pipe is fully blocked and a ten indicates a very clear pipe. Maintenance Planners reviewed and evaluated closed-circuit television video on acoustically inspected sewer mains to aid in determining the proper score for initiating the cleaning work orders. Considering that LRWRA's goals aimed at revisiting the 1770 km (1100 mi) of collection system on an annual basis, Maintenance Planners established that an acoustic inspection score of 4 or lower should initiate a cleaning work order. This score appropriately accounted for projected failure rates of acoustic inspections and additional given resources. Once a cleaning work order is created, the segment is cleaned and undergoes reinspection acoustically. If the acoustic score does not improve upon re-inspection, the segment is scheduled for evaluation with CCTV.

Once the organizational structure for condition-based acoustic inspection was in place, consideration was given to how the maintenance program would shift from a time-based to condition-based preventive maintenance program. There was no clear method on easing out of one strategy to adopt another, so the decision was made to abort the time-based program for all scheduled cleaning intervals that exceeded 3 months. Acoustic inspection would replace any cleaning intervals that exceeded a 3-month schedule. Ultimately, there were fewer than 75 sewer mains being cleaned at fewer than 3-month intervals.

RESULTS

Acoustic inspection of the 1770 km (1100 mi) of gravity sewer mains up to 30 cm (12 in) in diameter was fully implemented into the preventive maintenance program beginning in 2017. In the 18 months since implementation, acoustic inspection crews have inspected 2.3 million meters (7.5 million feet). To date, cleaning work orders are initiated on 20% of sewer mains receiving an acoustic inspection. Cleaning crews can improve repeat acoustic inspection scores above 4 on roughly 50% of lines. The remaining 50% of lines cleaned following a failed repeat acoustic inspection score are due to structural defects within the sewer main and scheduled for closed-circuit television inspection. To date, 8% of sewer mains acoustically inspected require closed-circuit inspection and an estimated 2% of sewer mains acoustically inspected require more substantial maintenance such as repair or replacement (Figure 4).

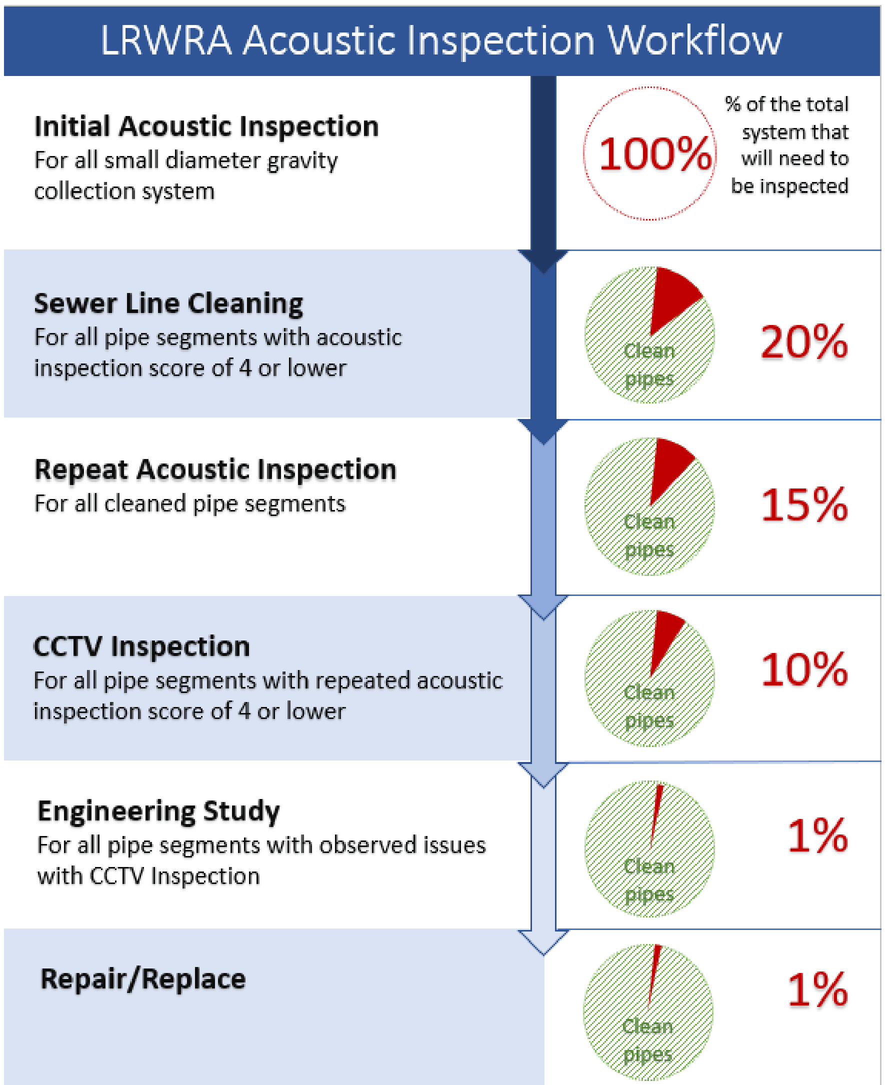

Figure 4. *In the 18 months that LRWRA has integrated acoustic inspection technology, they have acoustically inspected over 2.3 million meters (7.5 million feet). Of this total, ~ 20% of scores have been 4 or lower, initiating a cleaning order. To date, of all acoustically assessed sewer mains, 8% require CCTV, and only 2% require more substantial maintenance.*

The amount of debris removed from the collections has increased from an average of 3 cubic yards per month in 2016 to an average of 6.5 cubic yards in 2017. This increase in debris removed from the collection system is attributed to cleaning the appropriate 20% of the collection system in need of immediate cleaning. Furthermore, LRWRA has been able to reduce non-capacity overflows significantly since implementing acoustic inspection into the preventive maintenance program (Figure 5).

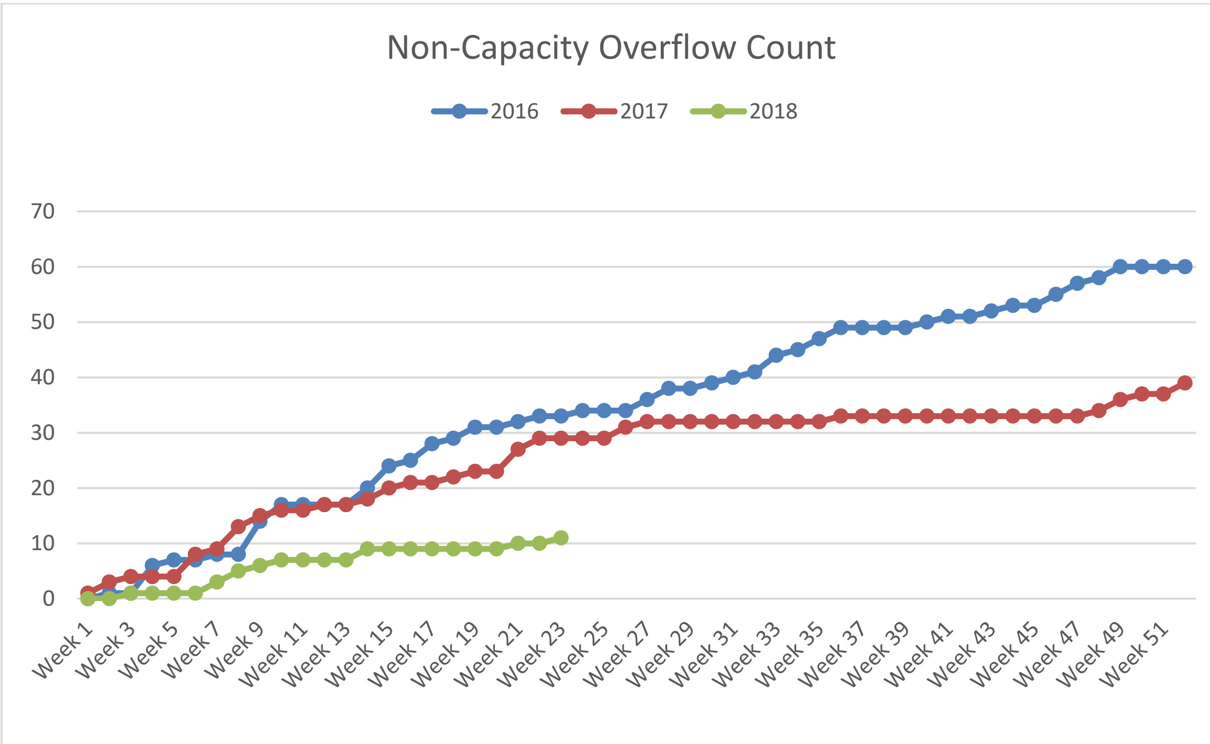

Figure 5. *The total number of sanitary sewer overflows since initiating the acoustic inspection preventative maintenance program in 2017 has reduced non-capacity sanitary sewer overflows by ~35% from 2016 and are projected to show a ~64% reduction in 2018.*

During the 1st year of implementation, the acoustic inspection crews adjusted to the workflow processes without experiencing any major difficulties. The minor difficulties were associated with conducting inspections on portions of the collections system with no previous maintenance history and having to locate sewer manholes, access properties, and coordinate right-of-way maintenance prior to inspections. These contributed to acoustic inspection crews being slowed down from achieving targeted production goals. Mailers detailing the purpose of acoustic inspections and what to expect were distributed through the postal service to homeowners and businesses located within sub-basins scheduled for upcoming acoustic inspection. The mailers aided in educating and alerting the residents to upcoming work and many times when the acoustic inspection crews arrived onsite the public was anticipating their arrival.

In 2017, the acoustic inspection activity was submitted as part of LRWRA's application to be recognized as a "Utility of the Future Today". LRWRA received national recognition as a Utility of the Future Today recipient for its forward-thinking and innovative programs. LRWRA is one of 25 utilities from around the nation receiving the award, which is presented by the National Association of Clean Water Agencies, Water Environment Federation, Water Environment and

Reuse Foundation, WaterReuse, and the U.S Environmental Protection Agency. There are approximately 16,000 utilities in the United States. The acoustic inspection activity was submitted as part of the Operational Optimization section for the award. It is LRWRA's hope to aid other public utilities looking to improve collection system performance and reliability through implementing acoustic inspection technology.

CONCLUSION

LRWRA's successful transition from a time-based to a condition-based cleaning strategy by utilizing acoustic inspection technology is evident from their 50% increase in percentage of collection system receiving maintenance contact annually and reduction of SSO's, without increasing headcount. Transmissive acoustic inspection has established a quality assurance measure for cleaning, developed new workflow processes and reduced non-capacity overflows by ~35% in just LRWRA's first year of integration. The projected overflow count for 2018 is 22, which represents a 64% reduction from overflow occurrences versus the baseline of 2016. These overflow reductions are possible through conducting acoustic inspection of sewer mains at $0.12 per linear foot. These accomplishments were all part of the implementation goals LRWRA established for utilizing the Sewer Line Rapid Assessment Tool or SL-RAT.

Today, cleaning operators know when they receive a work order to clean the sewer main has received a failing acoustic inspection score and has been deemed dirty. The condition-based cleaning strategy has added meaning to their daily tasks. Knowing a repeat acoustic inspection is scheduled when the cleaning work order is completed provides the operator with an extra incentive to clean the sewer main in a manner that is likely to cause the inspection score to pass. The amount of debris removed from the collections has increased from an average of 3 cubic yards per month in 2016 to an average of 6.5 cubic yards in 2017. This increase in debris removed from the collection system is attributed to cleaning the appropriate 20% of the collection system in need of immediate cleaning. Overall, use of acoustic inspection technology as a preliminary screening tool can result in more directed maintenance activity that substantially improves collection system performance without additional headcount.

References

ASTM International. (2017). *Standard Practice for Prioritizing Sewer Pipe Cleaning Operations by Using Transmissive Acoustic Inspection* (ASTM F3220 - 17). West Conshohocken, PA: ASTM International

Crabtree, J., Joyner, K., Churchill, A., (2015) Implementation of Acoustic Inspection Technology at the City of Augusta, GA. *Proceedings of the Water Environment Federation*, WEFTEC 2015: Session 210 through Session 219, p.1026-1036.

Howitt, I., Fishburne, J., (2012) Rethinking Collection System Cleaning Using Acoustic Inspection. *Proceedings of the Water Environment Federation*, WEFTEC 2012: Session 114