Using Acoustics to Prioritize Sewer Cleaning Activity in Hillsborough County

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Municipal wastewater utilities struggle to effectively manage the vast underground network of pipes that handle the transportation of raw sewage in cities and towns throughout the United States. Operators must constantly balance a variety of competing challenges that include aging infrastructure, increasing operation and maintenance costs, regulatory pressure, and the need to reduce sanitary sewer overflows (SSOs). Current maintenance operations typically target system cleaning based on past performance and system knowledge.

Recently, an acoustic inspection device called the Sewer Line Rapid Assessment Tool (SL-RAT®), has been developed for rapidly assessing sewer line blockages in three minutes or less. The patented technology is based on measuring the signal received from an active acoustic transmission within a sewer line segment; from the received signal, an acoustic profile is obtained. Commonly encountered sanitary sewer defects, such as roots, grease, and breakages, naturally obstruct acoustic energy, which changes the pipeline's acoustic properties and produces a measurable impact on the acoustic profile. An algorithm is used to exploit these variations and provide a real-time evaluation of the segment's blockage condition.

As part of an effort to improve the efficiency and effectiveness of cleaning operations and to maximize the utilization of available staffing, Hillsborough County Public Utilities Department has recently implemented the acoustic inspection tool across both its north yard and south yard locations.

The utility was founded in 1967 when it made its first acquisition of a franchise system and currently has 2,417 mi of sewer, with 1699 mi of small-diameter gravity-fed lines that are applicable for acoustic inspection. The collection system includes a broad mix of materials (75 percent polyvinyl chloride, 20 percent vinyl chloride, and 5 percent ductile iron) and serves just over 173,000 accounts, tallying close to 500,000 residents out of Hillsborough County's total population of just over 1.3 million.

Approximately 70 percent of the system has not yet been inspected via closed-circuit television (CCTV). The SL-RAT will help focus those efforts as part of its capacity, management, operation, and maintenance (CMOM) program. The public utilities field maintenance services group has established a CCTV and inspection team that utilizes the SL-RAT on a daily basis, focusing on the reduction of SSOs and a proactive analysis of the county's wastewater system. The same team cleans, evaluates, and rates the condition of manholes and gravity lines in the system. It uses a high-resolution digital CCTV side-scanning camera designed for rapid and detailed condition assessment of the wastewater system, as well as combination vacuum/jet trucks to perform the cleaning operations.

This article focuses on the county's experiences and lessons learned in successfully integrating acoustics into its overall maintenance program. It will provide details of implementation plans, challenges faced, and successes realized so far.

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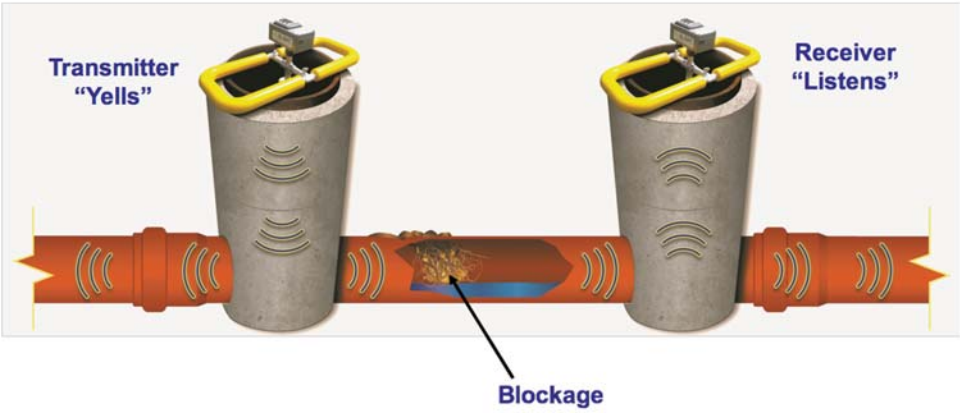

Figure 1. Concept and Operation of the Sewer Line Rapid Assessment Tool Acoustic Inspection System

Assessment Tool Overview

Acoustic Inspection Technology

The SL-RAT is a patented methodology (Howitt, 2009) and exploits the similarities and differences between water and sound transmission through a sewer line segment in order to diagnose the extent of the pipe's blockage. Figure 1 depicts the general configuration of the SL-RAT device. The acoustic transmitter generates sound waves just below the entrance to the manhole, which naturally couple into the connecting sewer line segments, whether the depth of the manhole is 3 ft or greater than 30 ft. The sound wave propagates in the air gap above the wastewater flow from the speaker to the receiving microphone located at the adjacent manhole; segment lengths exceeding 750 ft have been successfully evaluated. The acoustic receiver measures the acoustic plane wave from the transmitted signal in order to evaluate the condition of an entire segment and provides an onsite assessment in less than three minutes. An important practical aspect of this technology is that both the speaker and the microphone are placed just within the opening of the manhole and never come in contact with the wastewater flow, and the operators have no requirement for confined-space entry.

The acoustic inspection system provides a blockage assessment (a score ranging from 0 to 10) in less than three minutes. A scale of the acoustic score and description of typical blockage conditions are provided in Figure 2. The device is inherently conservative in its rating of the blockage condition; anomalies that absorb or reflect sound in the air space of the pipe will result in a lower score.

Technology Deployment and Implementation

The county initially evaluated the SL-RAT acoustic inspection technology in February 2013 in a pilot study with Inframetrix, a Florida-based contractor. The contractor assessed over 500 line segments totaling approximately 135,000 ft over seven work days. The equipment's speed, durability, practicality, and ease of use were noted, as well as the fact that only 8 to 10 percent of the segments tested were identified to have significant blockage or structural issues. This study highlighted the potential of the technology to focus cleaning activity and to help save the county significant time and resources.

The acoustic inspection system was determined to fit in with the county's desire to enhance its existing proactive maintenance strategy, which focuses on cost-effective asset deployment and the use of technology to efficiently manage a large and complicated wastewater collection system. The county also found that the SL-RAT's focus on small-diameter gravity-fed lines aligned well with the composition of its overall system, and that using it to evaluate lines slated for CCTV inspection prior to cleaning could assist in optimizing pre-CCTV cleaning activity. By reducing the cleaning resources required to complete CCTV inspections, the SL-RAT technology could enhance the county's ability to meet its goal of visually inspecting its wastewater collection system on a five-year cycle.

Over many years, the county has developed a culture of proactive maintenance and investment in its infrastructure that has led to an aggressive pipe-lining program, proactive cleaning, and excellent system performance as measured by low SSOs and low discharge volumes. County field maintenance crews are organized into two separate departments: north and south. Each department maintains its own separate management infrastructure and its own equipment, with interdivision support happening on an "as needed" basis. The north department operates its own cleaning, CCTV, and SL-RAT inspection crews, and the south department operates similarly. Both operating units rely heavily on contracted resources to perform grouting, manhole rehabilitation, pipe relining, and supplemental CCTV inspection activities.

Two acoustic inspection devices were purchased by the county in early June 2015 to be used independently by both the north and south divisions as part of the county's comprehensive collection system maintenance and inspection program. Two-person teams have been deployed and are inspecting approximately 1,500 to 2,000 ft per operating hour, for daily totals of approximately 5,500 to 11,000 ft per day. This inspection speed allows SL-RAT crews to easily outpace both the cleaning and CCTV operations that nominally target production of 3,000 ft per day for each. The acoustic inspection teams proceed from grid to grid systematically through the collection system and they typically operate out of a Ford F-350 pickup with enough tools to handle routine maintenance issues, as well as to conduct paper-based manhole inspections during the course of their work. The

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Table 1. Acoustic Inspection Result Maintenance Protocol

Acoustic Score	Maintenance Action
0 – "BLOCK"	Immediate Response – Clean and CCTV
1-3 – "POOR"	Field Crew Situation Analysis – Look for possible surcharge or dips in roadway, evaluate upstream/downstream flow. Schedule for cleaning within 24 hours – then CCTV after
4-6 – "FAIR"	Field Crew Situation Analysis – If no issues identified, leave on normal precleaning and CCTV schedule
7-10 – "GOOD"	Skip precleaning and maintain on schedule for CCTV

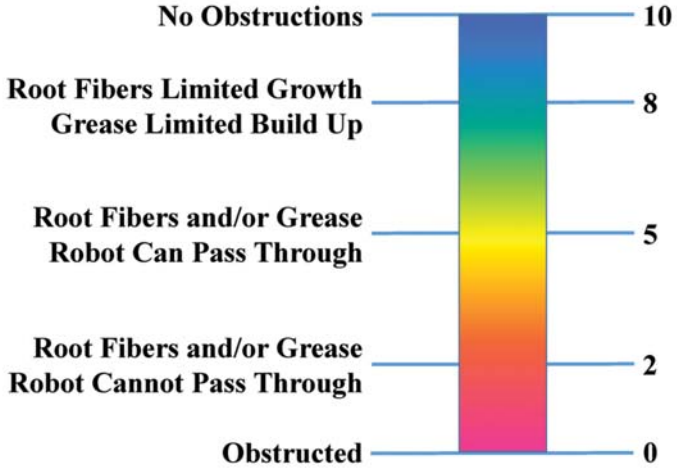

Figure 2. Acoustic Inspection Scoring System

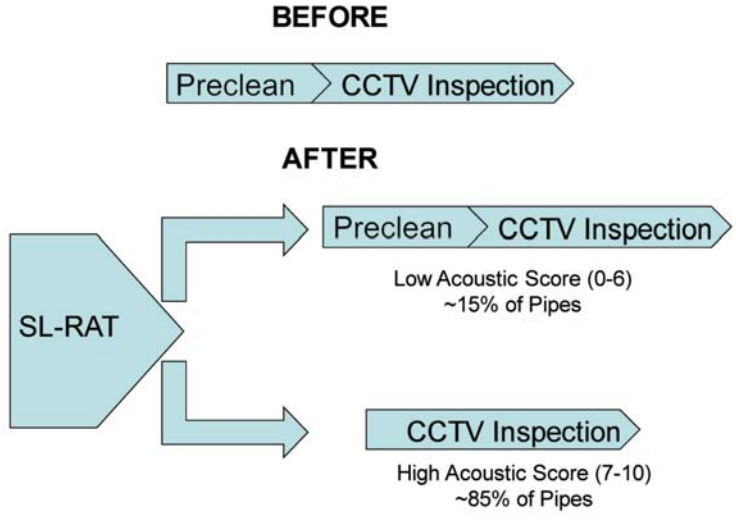

Figure 3. Precleaning Process Prior to and After Implementation of Acoustic Inspection

Table 2. Inspection Statistics by Device Identification

SL-RAT ID	Number of Segments Inspected	Estimated Feet of Pipe Inspected
312	2284	512,000
320	1729	399,000
Total	4013	910,000

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acoustic inspection crews also act as backup resources in assisting the cleaning and CCTV crews when emergencies or other significant needs dictate.

Condition-Based Maintenance Protocol

The county field maintenance team has developed a protocol for prioritizing the deployment of cleaning and CCTV resources based on the acoustic assessment of each pipe segment, as shown in Table 1.

Cleaning and Inspection Process

Deployment of the acoustic inspection technology has changed the county's process for CCTV inspection by allowing for the elimination of a significant proportion of precleaning activity. Pipe segments that receive high acoustic scores indicating a largely clean pipe are eliminated from the precleaning program, as seen in Figure 3. This allows for the targeted elimination of "cleaning clean pipe" and consequent resource reallocation, as well as significant cost savings. The cost savings result primarily from substitution of the SL-RAT's lower operating cost (approximately $0.05-0.15 per ft) for a significant portion of the precleaning costs, which are on the order of $1 per ft.

The field crews have found acoustic inspection work attractive because it is cleaner and easier than other activities, such as jetting, manhole rehabilitation, excavation, etc. The management team has found that the ease of use, speed, durability, and real-time data provided by the device allows it to prioritize the pipes that need the most attention and, again, avoid "cleaning clean pipe."

It should be noted again that the SL-RAT technology focuses on small-diameter, gravity-fed sanitary sewer lines. The recommended pipe diameter for inspection is 6 in. to 12 in. Large-diameter pipes can be inspected (up to 30 in.), although a more conservative policy must be used for triggering maintenance activity (Selembo et al., 2013). Also, the pipe does not need to be taken out of service when performing acoustic inspections. Higher flows can possibly cause lower acoustic scores (less air gap within the pipe between manholes), which is still acceptable since it will result in a more conservative preliminary assessment and may indirectly identify where potential capacity or inflow and infiltration issues may exist.

No systematic comparative evaluation of the acoustic inspection technology to CCTV was performed as part of this study. This topic has been well studied (Howitt, 2010; Kiefer, 2014; Pangulari, 2014), and so the focus of this project was on the integration of acoustic in-

spection into an overall collection system maintenance strategy and using it to prioritize resources.

Implementation Results

As of the first nine months of use, field crews at the county had inspected over 4,000 segments totaling more than 910,000 ft (172 mi) of pipe. A summary of inspection statistics by device is provided in Table 2.

This information about pipe-blockage condition and manhole condition has been provided in near real time and for a cost on the order of $100,000 to $150,000; however, acoustic inspection resolution does not approach that of CCTV and therefore should be considered a complementary preinspection and prioritization tool, rather than an outright alternative to CCTV.

Ultimately, the acoustic inspection campaign has provided a high-level snapshot of the county's system condition, as shown in Figure 4. These results allowed collection system management to focus its limited resources away from the 86 percent of the segments that scored "good" as largely unblocked, and allocate resources more effectively toward the 14 percent of segments that scored "poor" and "fair."

Data Management

The SL-RAT devices are uniquely serial-numbered and provide operators with blockage assessment results in real time on the device itself, along with a unique measurement identification (ID), a time stamp of the measurement, and map-grade global positioning system (GPS) coordinates. The combination of device ID and measurement ID serves as a key to manage the database for each customer's private web portal. The device stores up to 199 measurements locally that can be downloaded via universal serial bus (USB) cable to a Windows-based personal computer. County field crews download the data from the devices approximately twice a week to archive results and to develop work orders for future cleaning and CCTV inspection activity. The data can be viewed, edited, and analyzed using the Sewer Line Data OrGanizer (SL-DOG®) web portal (www.sl-dog.com) or exported directly in unedited form from the device into an Excel spreadsheet.

Management and scheduling staff are then able to check for measurement validity, export and view measurement data graphically in Google Earth or shapefile (SHP) format, manage crew productivity, and develop management reports. Several representative screen shots of the SL-DOG software and its features are shown in Figures 5, 6, and 7.

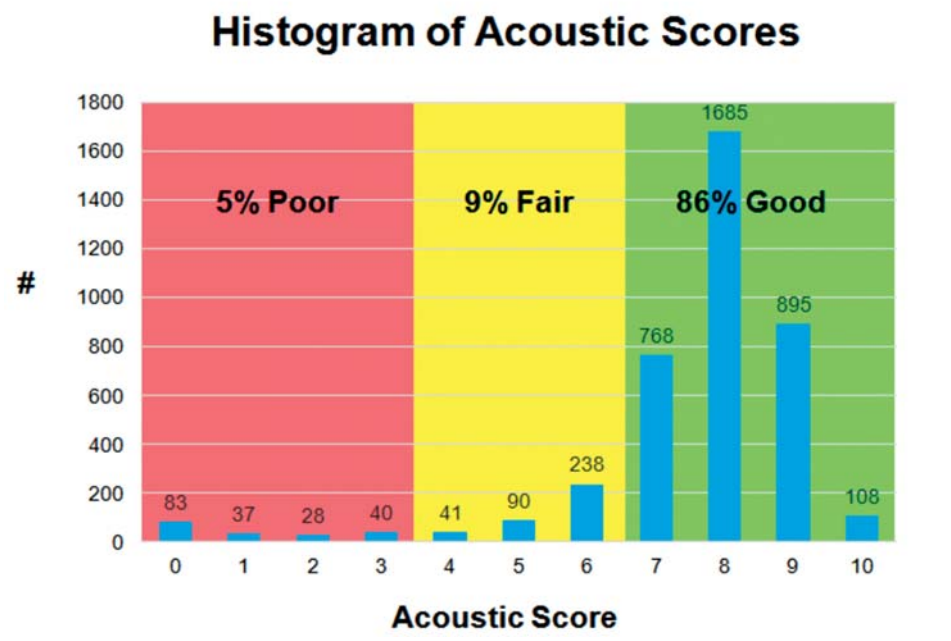

Figure 4. Distribution of Acoustic Inspection Results for 172 Mi of Sewer Lines

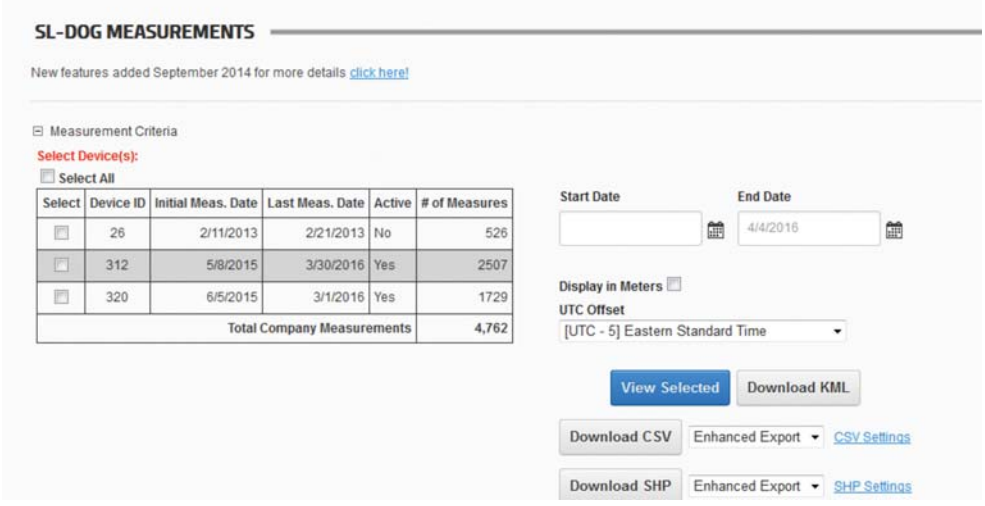

Figure 5. Device Management Summary Screen

Technology Benefits and Next Steps

The county has found the acoustic inspection device to be simple, reliable, and easy to use. These features were key to developing buy-in from the field crews, as well as for generating quality data. A large portion of the system has been inspected in a short time and for a fraction of the cost compared to alternative methods. In addition, less than 15 percent of the inspected pipes required immediate attention, resulting in a significant reallocation of valuable precleaning resources to the assets that need it most.

In the next phase of implementation, the county envisions improving the integration of the SL-DOG data output with existing work order and asset management systems. From this

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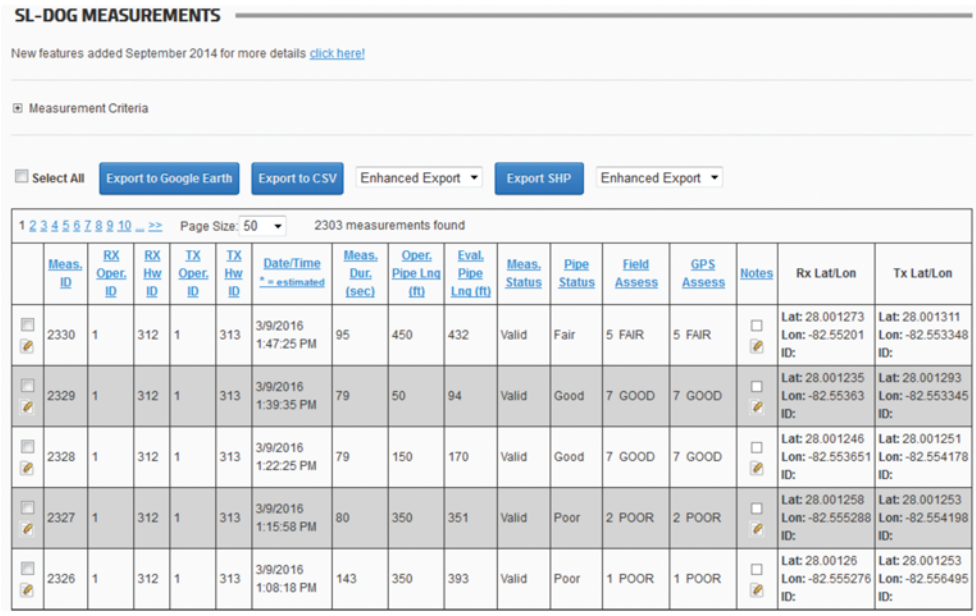


SL-DOG MEASUREMENTS

New features added September 2014 for more details click here!

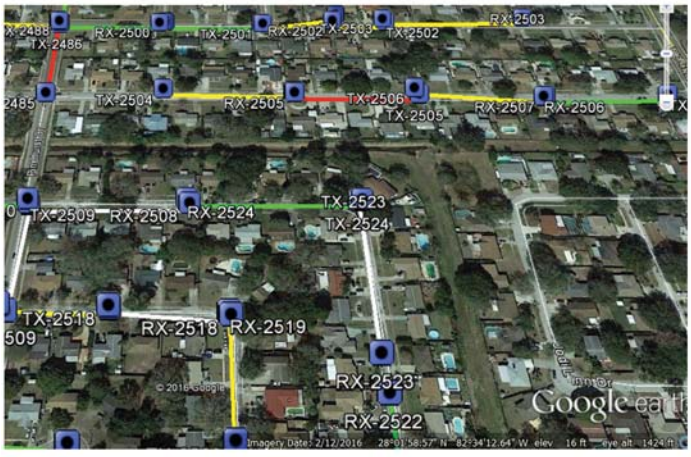
Measurement Criteria

Select All | Export to Google Earth | Export to CSV | Enhanced Export | Export SHP | Enhanced Export

1 2 3 4 5 6 7 8 9 10 ... >> Page Size: 50 2303 measurements found

	Meas. ID	RX Oper. ID	RX Hw ID	TX Oper. ID	TX Hw ID	Date/Time * = estimated	Meas. Dur. (sec)	Oper. Pipe Lng (ft)	Eval. Pipe Lng (ft)	Meas. Status	Pipe Status	Field Assess	GPS Assess	Notes	Rx Lat/Lon	Tx Lat/Lon
	2330	1	312	1	313	3/9/2016 1:47:25 PM	95	450	432	Valid	Fair	5 FAIR	5 FAIR		Lat: 28.001273 Lon: -82.55201 ID:	Lat: 28.001311 Lon: -82.553348 ID:
	2329	1	312	1	313	3/9/2016 1:39:35 PM	79	50	94	Valid	Good	7 GOOD	7 GOOD		Lat: 28.001235 Lon: -82.55363 ID:	Lat: 28.001293 Lon: -82.553345 ID:
	2328	1	312	1	313	3/9/2016 1:22:25 PM	79	150	170	Valid	Good	7 GOOD	7 GOOD		Lat: 28.001246 Lon: -82.553651 ID:	Lat: 28.001251 Lon: -82.554178 ID:
	2327	1	312	1	313	3/9/2016 1:15:58 PM	80	350	351	Valid	Poor	2 POOR	2 POOR		Lat: 28.001258 Lon: -82.555288 ID:	Lat: 28.001253 Lon: -82.554198 ID:
	2326	1	312	1	313	3/9/2016 1:08:18 PM	143	350	393	Valid	Poor	1 POOR	1 POOR		Lat: 28.00126 Lon: -82.555276 ID:	Lat: 28.001253 Lon: -82.556495 ID:

Figure 6. Sewer Line Data OrGanizer Data Summary Display



Acoustic Results are color coded

Block (0) = White
Poor (1-3) = Red
Fair (4-6) = Yellow
Good (7-10) = Green

Figure 7. Visualization of Sewer Line Rapid Assessment Tool Measurement Data in Google Earth

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integration, it is anticipated that more visibility of crew work practices, as well as a more rigorous and quantitative understanding of the financial benefits achieved through use of acoustic inspection, will be achieved. Concurrently, daily acoustic inspection production goals are being developed to aid in crew management and optimizing staffing among acoustic inspection, cleaning, and CCTV.

Based on the footage acoustically inspected so far and the maintenance protocol outlined previously, precleaning activity could have been avoided on over 3,400 segments, totaling 762,000 ft. Assuming cleaning costs of roughly $1 per ft, the initial $50,000 SL-RAT investment has had the potential to save the county approximately $575,000 in its first nine months of field implementation, using a conservative acoustic inspection operating cost of $0.15 per ft.

Conclusion

The county has significantly reduced unnecessary precleaning activity using acoustic inspection, while obtaining critical near-real-time condition assessment information in a practical and economical way. This new capability has enabled the county to focus its cleaning efforts and more effectively and efficiently achieve its goal of visually inspecting the wastewater collection system on a five-year cycle.

References

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