Reduction of Non-Revenue Water through Continuous Acoustic Monitoring

November 5, 2015
Sustainable Seminar Series
Webinar Presentation

• Setting the table
  ▪ How to find hidden leaks
  ▪ Recent technology developments

• The Waycinden Project

• Cost modeling

• Update

• Your questions
American Water

47,000 miles of main
Over 80 billion gallons NRW/year
Pipe Leakage and Water Loss

- Leaks represent significant waste of water and money with the cost for chemicals, power, and wear on the pumping and process equipment.
- Leaks add a cost for repair with excavation and restoration costs.
- Leaks can weaken other infrastructure, damage private and public property.
- Pipe failures can jeopardize the quality of water.

Most water loss comes from slow long running small leaks that are undetected, not from the large main breaks that last a few hours.
Water System Leak Detection Strategies

- **Conventional Leak Surveys**
  - Usually performed at night, using consultants or staff

- **District Metering**
  - Increases in minimum night flow provides an alert

- **Continuous Acoustic Monitoring**
  - Continuous Leak Detection

*Glen Jean Zone Flow October 24 - November 1, 2015*
Continuous Acoustic Monitoring

- Devices placed “permanently” to listen for leak “noise” every night. By extending the monitoring time, distinguishing leak noise from background noise becomes more reliable.

- American Water has worked with vendors since 2005 to develop and improve a monitoring program that sends leak vibration data on a daily basis directly to the field office.

- The product in use for this project began with initial testing in 2009.
How Does Continuous Acoustic Monitoring Work?

• Monitor identifies the minimum sound it hears usually an overnight time segment.

• The data monitors leak frequencies noise and performs analytics against the leak frequencies for ferrous and plastic pipe.

• The software interprets changes and magnitude of sounds to rate the location as a possible source of a leak and displays it graphically on FTP site (cloud).

• Field staff looks in vicinity of suspected leak noise and pinpoints if found.
• Connellsville is located along the hilly Youghiogheny River valley about 40 miles south of Pittsburgh.

• System dates back to 1880’s. Mostly cast iron and galvanized steel but also AC, ductile, & plastic. 80% of 57 miles of main are over 100 years old.

• NRW was over 25% and the cost of water (purchased) is $1,900 (US) per million gallons.
Initial Results (480 units)

- From June to December 2005 46 leaks were reported in Connellsville (compared to 18 in 2003, 12 in 2004).

- 24 of the 46 leaks were identified by acoustic monitors and repaired without ever coming to the surface.

- Another 10 leaks were identified but surfaced before repair was made. The 12 others were undetected but surfaced and were repaired.

- Flow substantially reduced by over 250,000 gallons per day in 2005.
Piloting Results Connellsville 2006-2008

NRW Volume and Leak Flow Connellsville, 2006-2008

- Stopped leaks 691 gpm
- Non-surfacing leaks stopped 1394 gpm
- Stopped leaks 270 gpm
Piloting Results Connellsville 2006-2008

• COVERAGE 172 leaks occurred during period of which 131 (76%) were detectable. 33 leaks (19%) could not be detected because they surfaced and were repaired before overnight monitoring. Others were outside the range of the original deployment.

• EFFICIENCY Of the 131 coverage leaks, 51 (39%) were detected and repaired before surfacing and 34 (26%) were detected acoustically and surfaced before repairs were made.

• The major cause for not detecting overnight leaks (34%) is believed to be the use of plastic and repair clamps for ferrous pipe main repairs that reduce leak noise transmission.
Understanding the Economics of Leakage

- Leaks cost money but the equipment investment to find hidden leaks with monitoring should save money.
  - Requires a proper assessment of how finding leaks faster saves money.
  - Requires a proper assessment of the cost of water.
  - Requires an reasonable projection of how much water can be found through the method selected.

- Effectiveness relates to nature of leaks
  - Acoustic monitoring most effective where leaks run hidden for extended time periods.
  - American Water has found that a leaky system that is surveyed commonly has a second (and third) wave of leaks as the system becomes more pressurized.
Benefits of Fixed Leak Monitoring

- Saves water treatment and pumping costs by reducing lost water with early leak detection
  - Average leak goes undetected for unspecified periods
  - Note there is an estimated 2%-5% of water generated loss that cannot be detected
- **May prevent catastrophic bursts** by fixing leaks early
  - Liabilities including collateral damage for transmission mains
  - Avoid bad publicity and customer dissatisfaction
- **Saves repair costs** by planning out repairs instead of emergency repairs and fixing leaks sooner
- **May help prioritize limited capital and maintenance spending**
- Could help pay for AMI communication system for reading meters
Echo Shore DX

- Pilots put in place in 2014 after development stage
  - Minimum 50 Hydrants
  - Required components
    - Leak Loggers, typically 7 per mile
    - Repeaters/Collectors – propagation analysis
    - Cloud technology allows utility data access
- Must obtain GIS data or create GIS data for the geographic area of interest
  - **REQUIRED DATA**: Pipe type, pipe size, hydrant locations
  - Will take a few months to convert data, install, initialize system (Waycinden July 1 start, operational in September)
A new device to be tested - Echo Shore DX

- RF transceiver with Echologics’ high sensitivity sensor

The sensor potted in standard hydrant cap
How Echo Shore DX Works

1. Sensors generate a report containing acoustic data it collects from the pipeline along with alerts of leaks, bursts, unauthorized flow, hydrant tampering.

2. On a daily basis, sensors transmit the report through RF signals to the host software through a mesh AMI network.

3. Client analyzes the findings using ESRI GIS mapping software, which is integrated with the interface, to view and locate detected leaks.

4. If a leak is detected, correlation confirms the presence of the leak and determine its location.
What is Leak Noise Correlation

- Vibration travels at known speeds in pipes of specific material and size (important to know distances, diameters and materials of pipe).
- Place sensors on either side of suspected leak location. If a leak is not between sensors, the instrument will help you move to right place.
- Sensors listen simultaneously and deliver the data to a receiving microprocessor (PC)
- PC displays a profile of the leak noise and provides a location for the leak
Correlation Tools

- The closer to one sensor, the greater the time delay from the second sensor

\[ L_1 = L_2 + V \times T_d, \quad L_1 = \frac{(D - V \times T_d)}{2} \]

- Correlation requires precise timing for simultaneous measurement.
Distribution Leak Detection Testing  Uniontown PA

- First site for field trial; deployed since June 2013
- Daily data collection and site monitoring
- Leak discovered on Friday, January 10, 2014

Correlation graph

Suspected Pipe Leak Location

Identified Hydrant Locations
Confirmed leak at nearby location after utility site visit

Actual site
- Near an unmonitored hydrant
- 1700 ft distance, greater than 1500 ft expected
- Heard via a pipe not on original map

Site location is in inactive customer area which would never have been discovered

After pipe was fixed, leak correlation was gone
Mi.ECHO Leak Detection

- First leak detected acoustically but was already surfacing and repair scheduled
  - Noise dissipated with repair
- Second leak detected acoustically
  - Correlated by hydrants 930 feet apart
  - Leak not surfacing, not detected initially by ground microphones
- Second leak persists and increases in volume after 3 weeks
  - Ground microphone detects increasing noise
  - Decision to excavate and correlate at excavation if necessary
Mi.ECHO Leak Detection in Liberty, PA

- Leak excavation initially a dry hole but water then appears when hand digging reaches pipe invert
- Pipe removed reveals longitudinal crack from invert on bell
Metro Chicago District Illinois American Water

- Waycinden system serves about 750 customers (Mt. Prospect, IL)
- About 12 miles of water main, water loss between 12-15 MG/Y
- Water supply is purchased water so leaks are costly
- Averages about 12 leaks per year; corrosion is often the cause
- Highways tend to make finding leaks more challenging
Savings Analysis of Leak Detection

- **Water loss nonsurfacing**
  - experience suggests 90 day run time underground
  - subject to details of break on case by case basis
- **Reduction in restoration materials**
  - paving, sidewalk, backfill
- **Reduction in repair materials**
  - repair parts, pipe
- **Reduction in repair labor**
  - faster repair, overtime reduction
  - History suggests all repairs average 3 overtime hours
- **Reduction in secondary damage**
  - to private property, other utilities, impact of outage
Kincaid Court Leak

- Leak detected September 12 and repaired September 24
- Leak ran into storm sewer manhole, unlikely to surface
- Leak repair was simple clamp on 6” cast iron pipe
- Leak occurred in grass area, minimal restoration
Savings Analysis of Kincaid Court Leak

- **Water loss nonsurfacing**
  - Projected 90 day run time underground
  - SCADA and on site flow estimated at 25 gpm \( (90 \times 1440 \times 25 = 3.24 \text{ MG}) \)
  - Potential for violent break at end (20 minutes 500 gpm) \( (20 \times 500 = .01 \text{ MG}) \) = 3.25 MG x $5342/MG = $17350

- **Reduction in restoration materials** – none anticipated

- **Reduction in repair materials**
  - Possible entire pipe length and extra clamps $250

- **Reduction in repair labor**
  - average 3 overtime hours x 50% differential rate + 1 hour if repair & restoration was more complex x crew rate $625

- **Reduction in secondary damage** – none anticipated

- **TOTAL ESTIMATED SAVINGS** $18,255
Linneman Street Leak

- Friday October 31, work on a service line to an apartment triggered a leak on a shutoff valve at the meter pit.
- Leak ran through the night but was reduced on Saturday and repaired.
- Leak started at known time and ran for known duration (not hidden).
- Echologics was not aware of the leak until the following week.
- Closest leak monitor was inactive with a dead battery!
Echologics - Linneman Street Leak

- Echologics able to look at other sensors to see if they had any indication.
- Leak was confirmed and time and duration matched using units 850 and 1450 feet away.
- Only one of these sensors was the primary correlation unit. So this did not register as a point of interest (POI).
- **Echologics response is recognition of a software problem that can cause battery rundown so entire network of 79 units to be replaced with system upgrade to official units.**
Leak Analysis Integrated with Cloud Technology

- Automatic display of system and results for the users
- Display probable leaks in the context of the water infrastructure
Service line leaks

- Malmo Street
- Running about 1 gpm out of box and on to adjacent road curb area
- Leak not initially found by Echologics but they are capable of tracking (and can check to see if it grows.)
- **Because this is a customer service leak (who are responsible for repair), the acoustic monitoring system provides a way to check on leak status without dispatching a truck.**
SCADA – Minimum Night Flow

- A reporting system has been set up to monitor night flow between 3 AM and 4 AM
  - Takes into account change in tank volume
  - Takes into account supply feed flow from water sources

- System works best when only factor is Linneman tank
  - Need to improve granularity
  - 0.1 foot = 1500 gallons
  - Flow accuracy of pump meters are questionable
  - Consistent about 115 gpm or 6900 gallons per hour
  - Uncertainty with flow meters
Additional water main leaks ISTC project

- **9 Additional Leaks**
  - 359 West Dempster Street – unit failed battery
  - 501 Carboy Avenue – short term leak
  - 1181 Stark Place – duplicate serial number, short term leak
  - 1101 Elmhurst Road – units not fully activated, short term leak
  - 183 West Walnut Street – duplicate serial number, short term leak
  - 963 Leahy Circle – short term leak
  - 724 Algonquin Road – short term leak
  - Malmo Drive and Algonquin Road – short term leak
  - 998 Wilson Drive – short term leak

- *In six cases Echologics did re-enact a leak to verify that if the leak was full overnight, it would have been detected even from secondary units.*
Final “Leak” of Project

- June 26, 2015 Illinois American Water sends out email at 5:30 AM
  - Severe water loss slowly draining system for about 7 hours
  - Can Echologics find the leak?
  - Leak found on 12” service main on private property within an hour after the email.
  - Metered Leak 1800 gpm or about 800,000 gallons
Lesson Learned

- Echologics did not hear leak because of absence of hydrant sensors in the area.
- Hydrants on private property eliminated need for public hydrants along road
- Chicago metro will consider strategic placements on private hydrants
Savings Analysis of Leak Detection – winter

- **Water loss nonsurfacing leaks**
  - Experience suggests 90 day run time underground if corrosion related (corrosion leaks anytime of year)
  - Winter circumferential breaks largely surface quickly
- **Reduction in restoration materials**
  - paving, sidewalk, backfill – sudden breaks have similar costs and higher costs in cold weather
- **Reduction in repair labor**
  - Ice as hazard tends to magnify overtime
  - Faster repair, overtime reduction negated if leak is sudden
- **Reduction in secondary damage**
  - Quick response tends to negate private property damage
Savings Analysis for 10 Month Study Period

- Savings $18,500 in 10 months
- Expense of system roughly $1000 per unit x 79 units = $79,000
- Prorated Return on Investment 60 month life of units $111,000
- Operating Expense to Manage System
Cost Analysis of Leaks

- 359 West Dempster Street – questionable ability to reduce cost as leak started over holiday period
- 1181 Stark Place - incorrect numbering led to possible miss of this leak of perhaps one week
- 1101 Elmhurst Road - Savings not realized as a few days of leak reduction potential could not be confirmed
- Linneman Road south of Dempster – major eruption – suggests potential to find large leaks at night might add value
- No savings in others confirmed as short term leaks

*Prior history does suggest that there is more potential for short term leaks than exhibited over the past eight months*
Work continues

• Large American Water deployment in Charleston, WV system
  ▪ Over 400 units deployed along river valley
  ▪ found over a dozen leaks include leak on connected 36” PCCP pipe reducing NRW by over 4 MGD
  ▪ Savings maintained over 8 months with a total exceeding 60 leaks (most nonsurfacing) repaired
Work continues

• Competitive comparison with 3 other acoustic systems in Pittsburgh neighborhoods
• Strengthen model for exploring economics to be further refined based on experiences from other systems.
• Echologics working with WV American to make software more user friendly
• Development of dead end sensor
Final Project Report

• Establish criteria to be used to analyze individual systems for acoustic monitoring feasibility

• Provide cost model outline

• Update Echologics in other areas (system now commercially available)
Conclusions on Equipment

- System able to reconstruct scenarios to validate equipment
- Issues with prototype addressed
  - Programming/battery issue, duplicate numbering issues resolved
- Less false positives (90%) is confirmed
- Correlation adds benefit
  - Within 25 feet of leak instead of 500 feet
- Still will miss some leaks
  - Must wait for initial period, hydrant limits, dead ends, transitions
Conclusions on Project

- Although a leaky system, leaks do tend to surface and only high cost of water makes this a viable location
- Leaks appeared during trial more related to cold weather
- Crews very responsive to any leaks at any time
- Chicago Metro willing to install in another system indicating local recommendation and recognition of speed of repair
- Value of projects like this better validated with longer study
- Economic model highly valuable but ways to gauge length of time leaks are hidden are limited