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Prioritising leak repair: Using acoustic sensors to determine leak flow rate

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4 Pillars of Real (Physical) Losses

Real Losses

Asset Management

ECHOLOGICS®
a MUELLER brand

Active Leakage Control

Pressure Management

i20®
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Speed/ Quality of Repairs

KRAUSZ®
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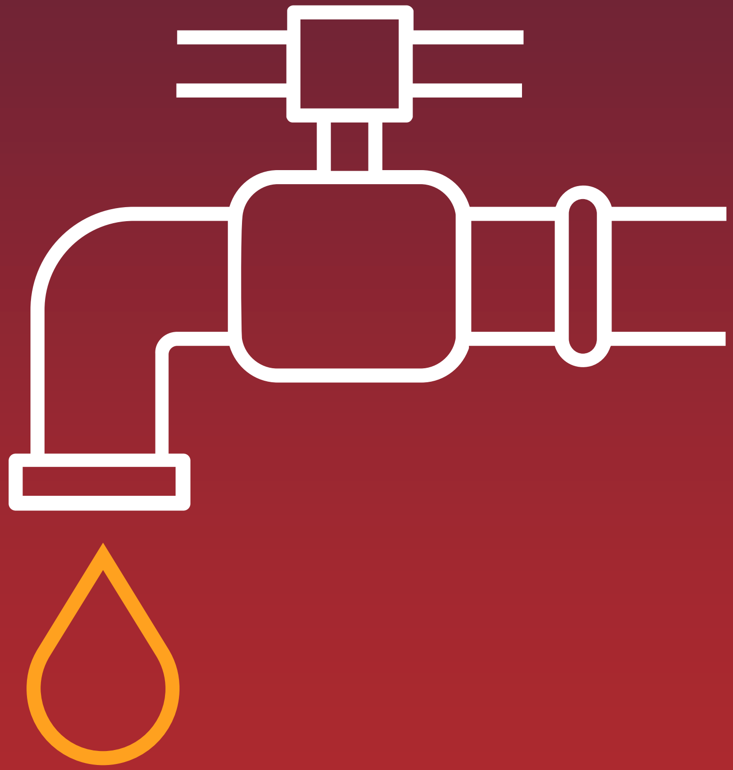
Acoustics 101

Using sound to detect anomalies on Water Networks



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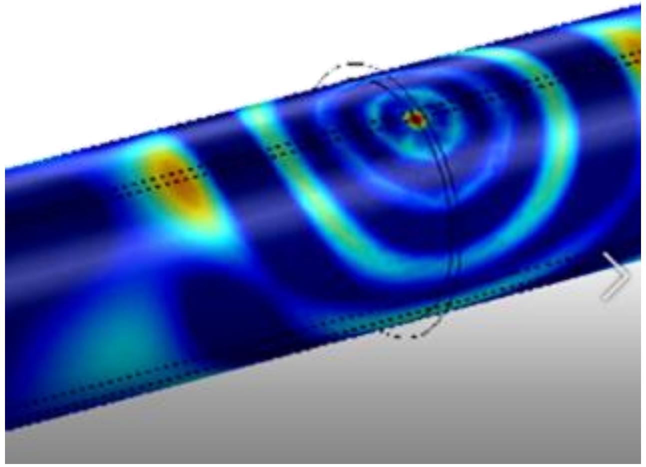
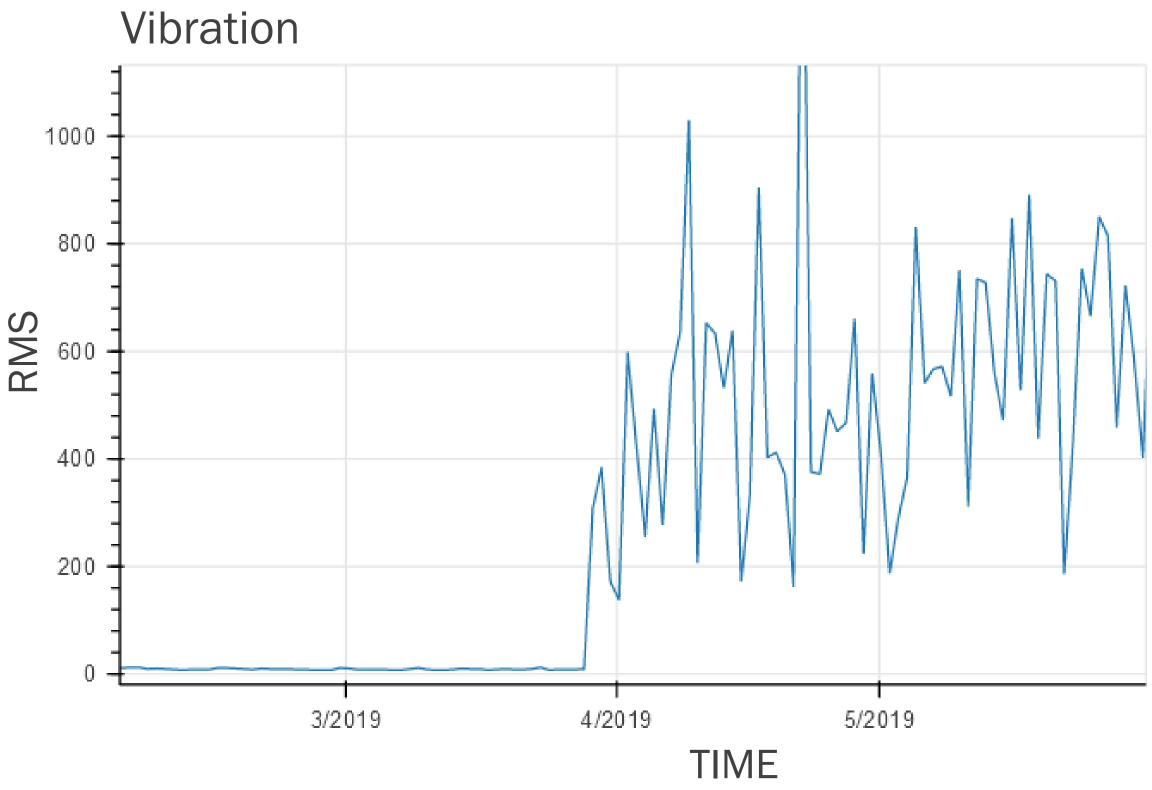
Leak detection principles

- Leaks generate acoustic noise
- Pipes are good acoustic wave guides
- Axisymmetric acoustic waves can propagate over a long distance
- Can be detected using hydrophones (sound pressure) or accelerometers (vibration)



Change in Sound Pressure



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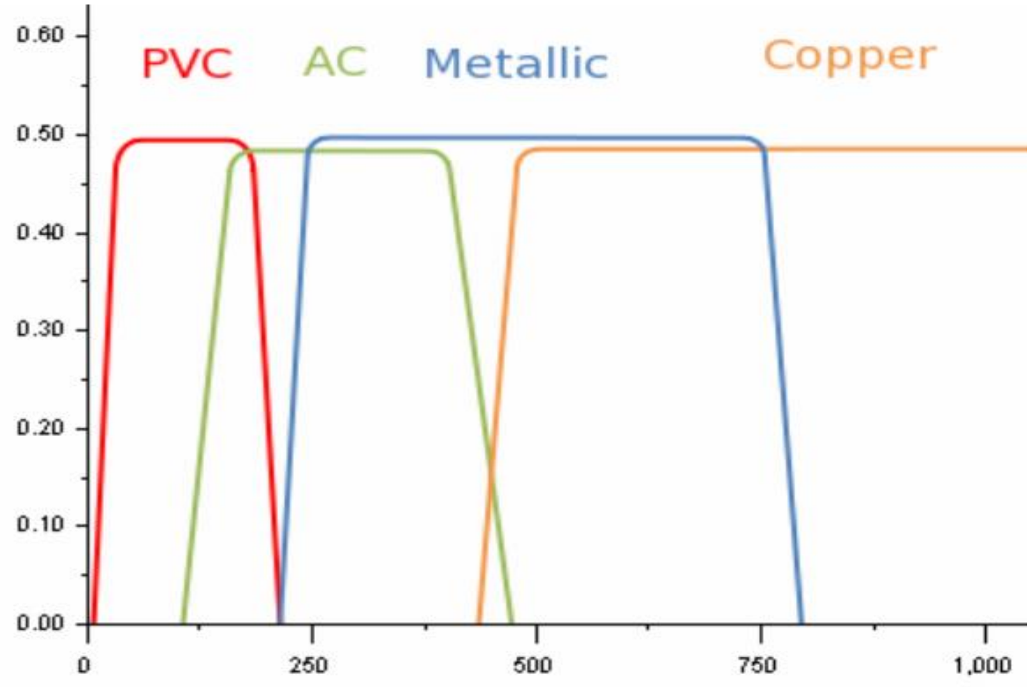
Sound propagation model

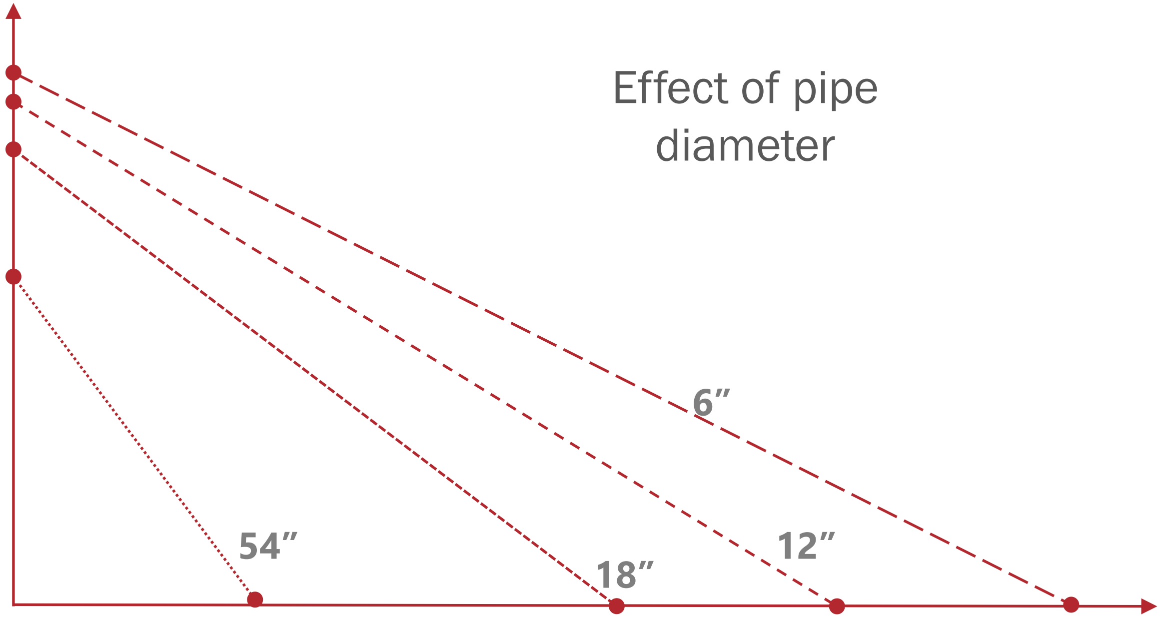
Normalised Spectrum



Frequency

Effect of pipe material

Sound Power (dB)

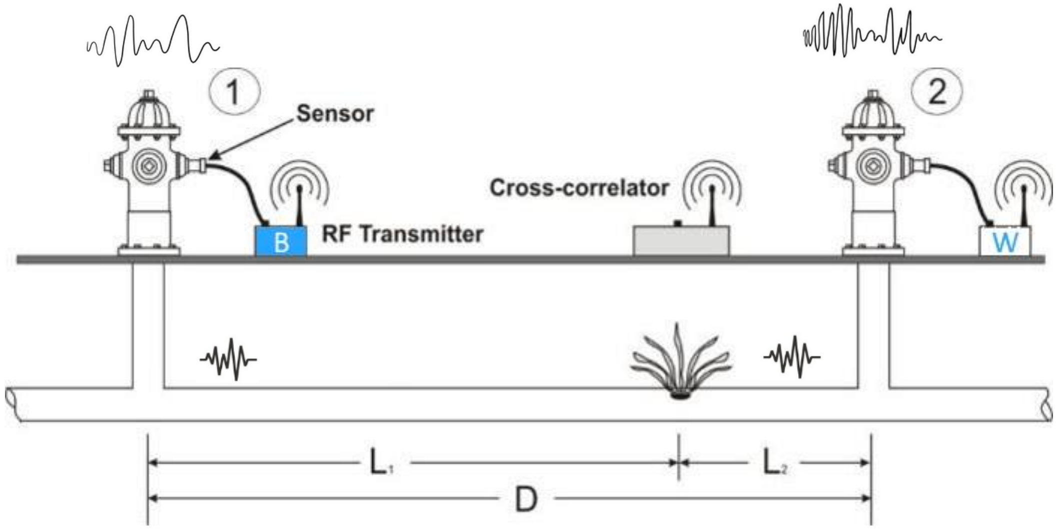


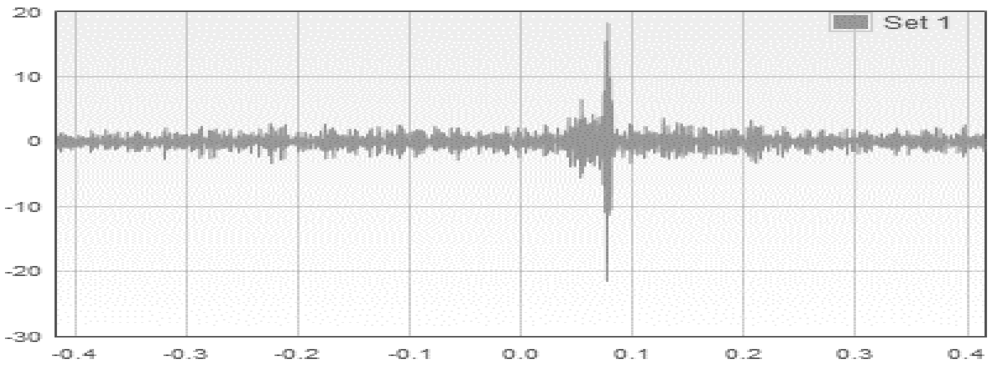
Distance

Acoustic power decreases exponentially

at 300ft	amplitude: 10 times lower
at 1000ft	amplitude: 1000 times lower
at 3000ft	amplitude: 1,000,000,000 times lower

Correlation Leak Detection





- Bracket a pipe segment with two sensors
- Leak sound propagates through the pipe reaching the two sensors
- Cross-correlation extracts the similar sound (leak) and removes ambient noise
- High processing gain: can extract signals below the noise floor
- Locate leaks by measuring the time delay between recorded acoustic waves

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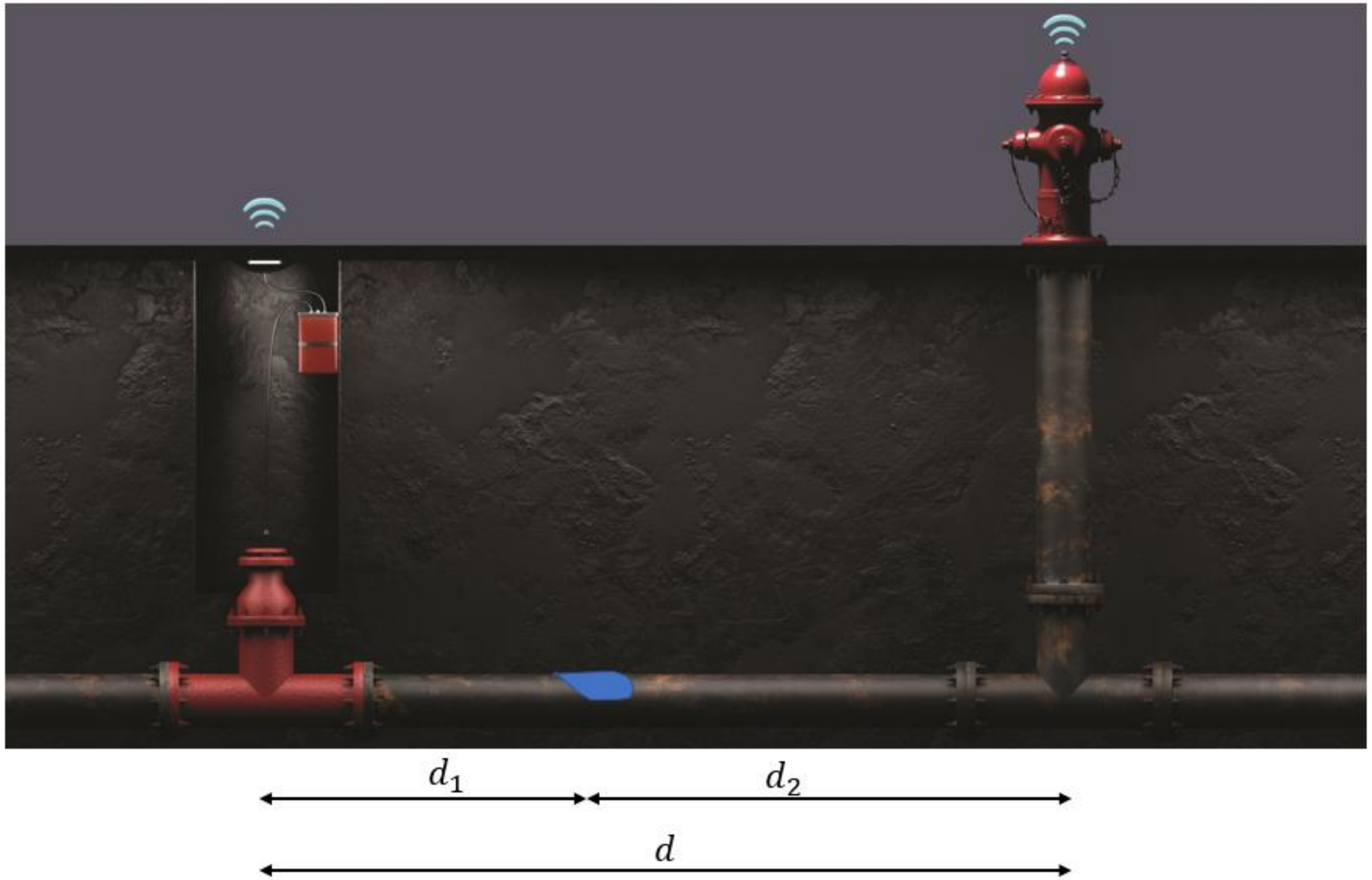
Leak location



$$d_1 = \frac{d \ - \ ct_d}{2}$$

$d_1 = distance\ to\ leak$

$d = distance\ between\ sensors$

$c = Pipe\ wavespeed$

$t_d = Time\ delay$

Sensors for leak flow rate estimation

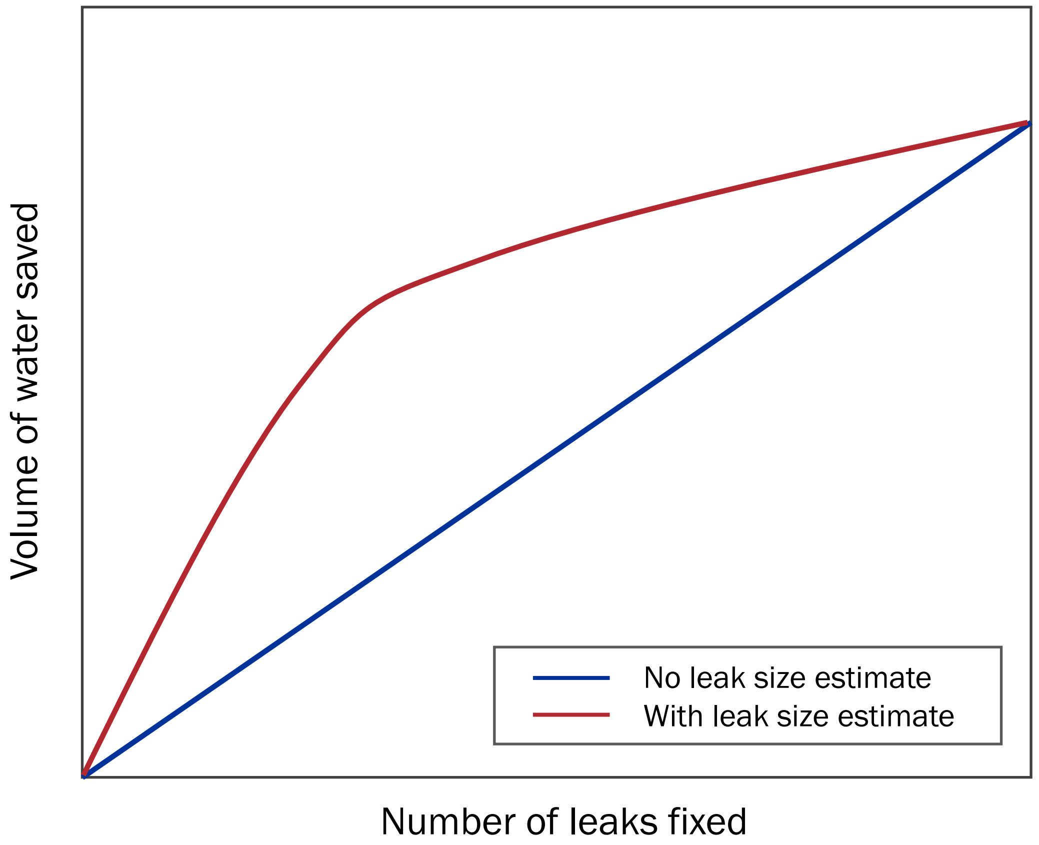
EchoShore®-DX

Leak Finder ST

Dx-e

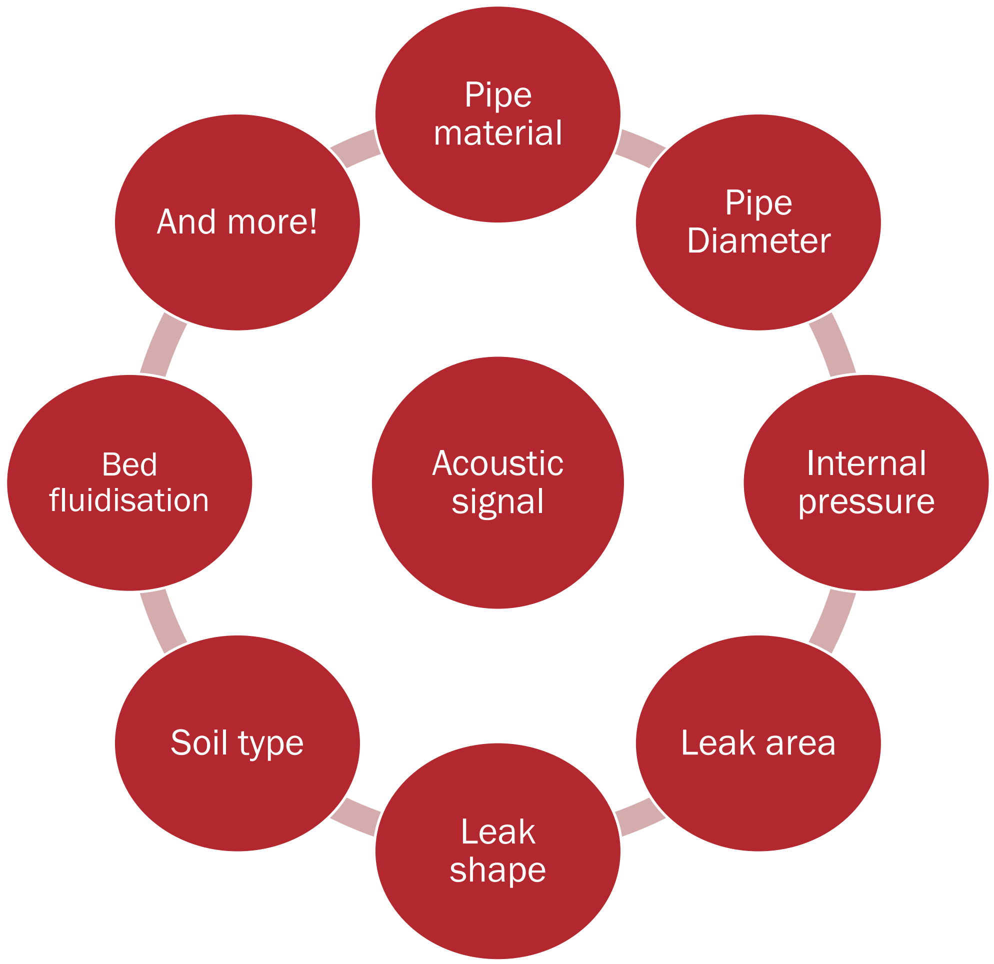
Why prioritise leak repair based on leak size?

- Reduce water loss quicker
- Repair less leaks to achieve higher reductions
- Reducing leak run times saves water
- Achieve operational/regulatory targets faster
- Reduce CAPEX/OPEX associated with leak repair
- Minimise environmental impacts



Challenges estimating flow-rate using acoustics

- Leak acoustics depends on several factors
- Large diversity of leaks
- Key factors are unknown (i.e. pressure) and they vary in time
- Ground truth: flow-rate of an exposed pipe is different than a buried pipe
- Flow-rate influences the sound level at the source, but we can measure only at access points far, away form the leak



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Methodology

Experiments to determine how variables influence acoustic signal generated by leaks

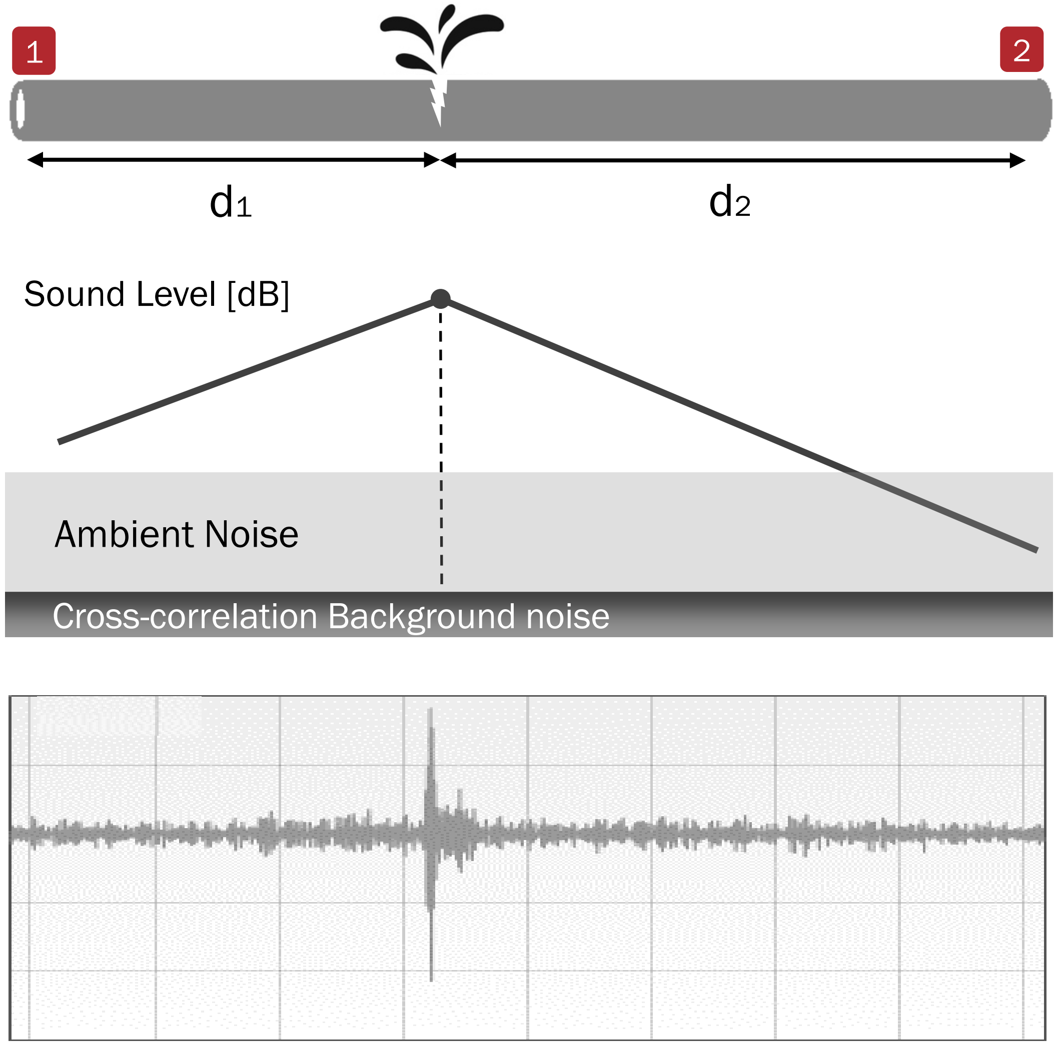
Solution:

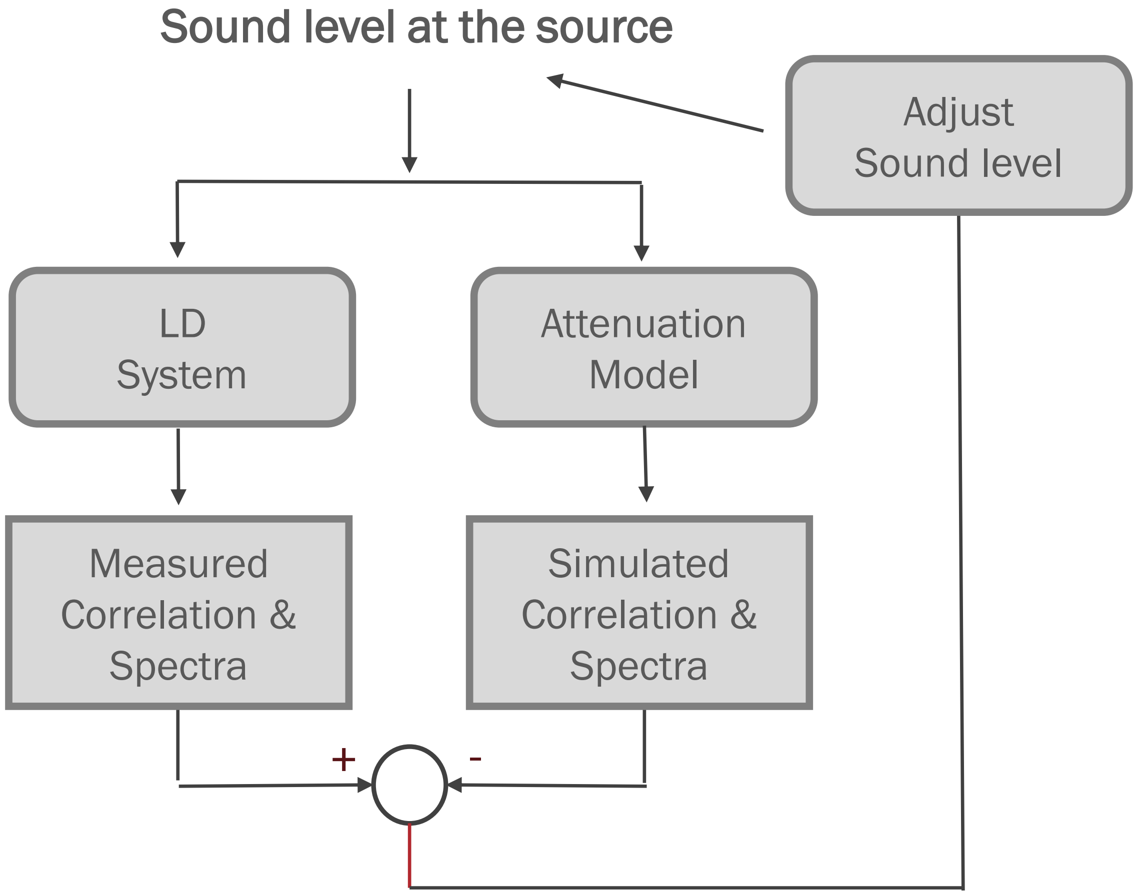
Twin model to estimate the sound at the source

Controlled experiments to relate sound levels with flow-rate

Data calibration using multiple leak observations

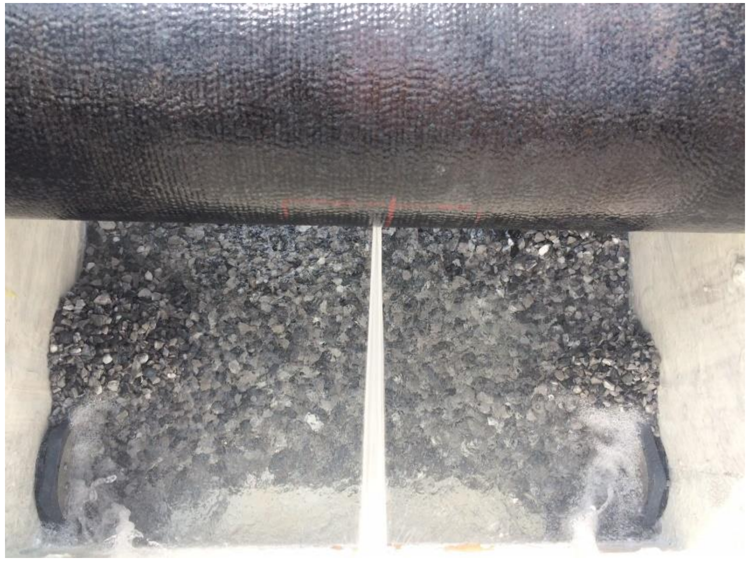
Twin Model: a simulation of pipe network acoustic





The estimated sound level is the one for which the model matches the real system.

Controlled Experiments



Controlled Experiments

Leaks of different areas and shapes :

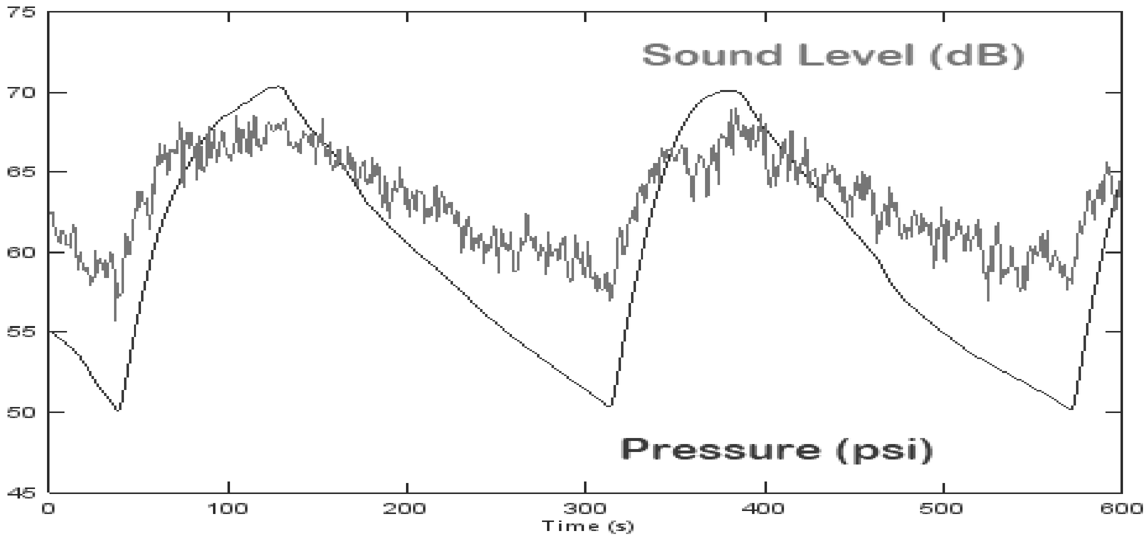
- Round holes
- Longitudinal slits
- Circumferential slits

Different medium conditions :

- Flowing in air
- Flowing in water
- Flowing in gravel
- Flowing through multiple layers of fabric
- Flowing through gravel in water

Pressure range: 50 to 70 psi

Sound level variation < 20%



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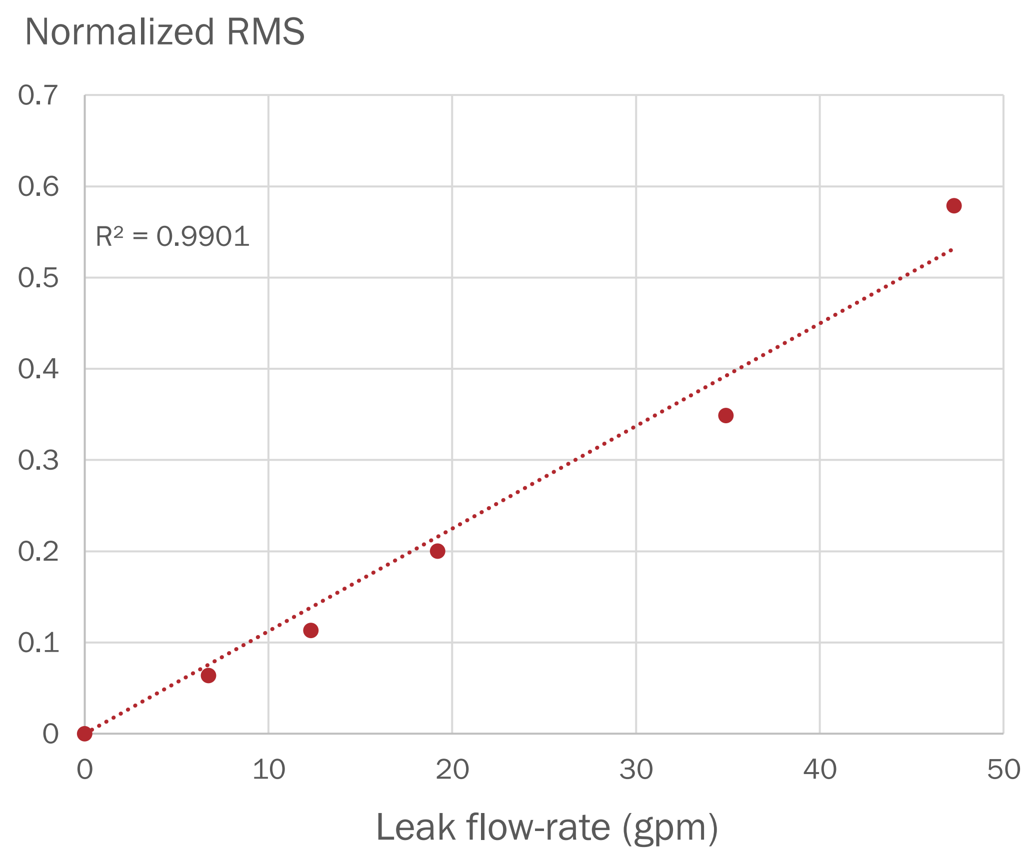
Sound level vs. Leak Flow-rate

- Flow-rate is proportional to the RMS of sound power at the source
- Empirical data collected on a 6” DI pipe at constant pressure of 50 psi
- Relationship is valid as long as the system can maintain a certain pressure in the pipe.
- At low pressure, flow becomes laminar sound level drops significantly



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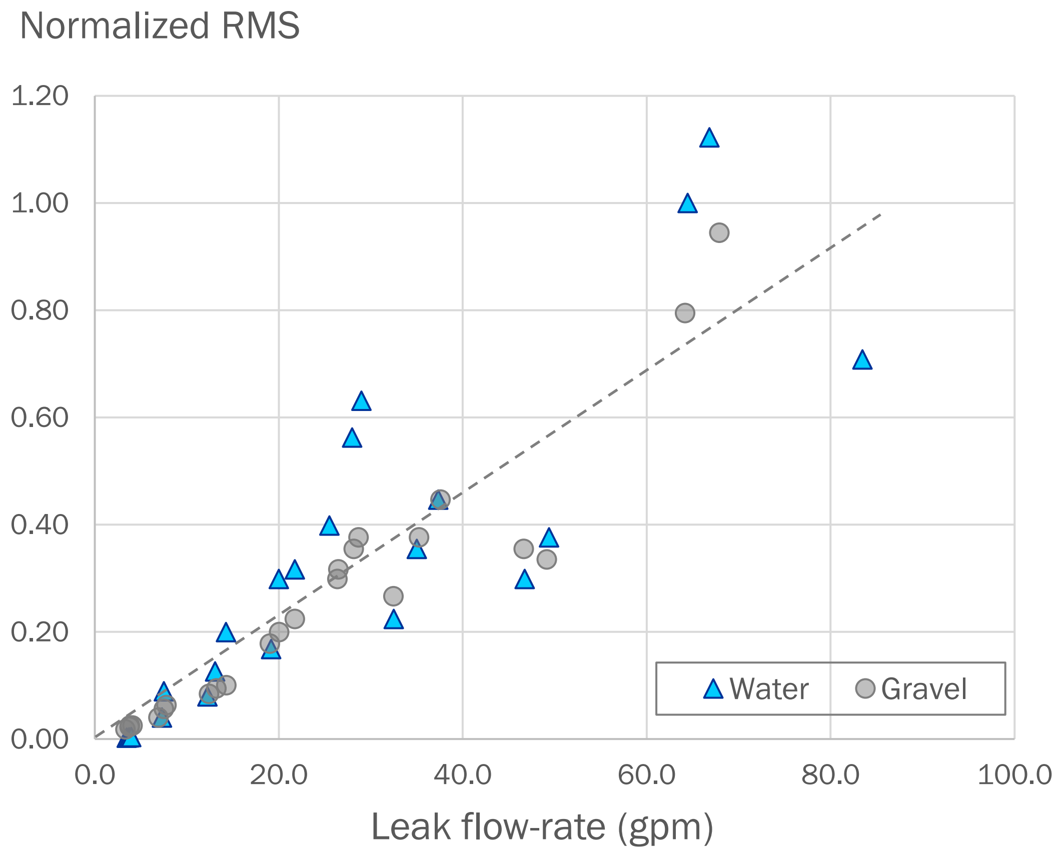
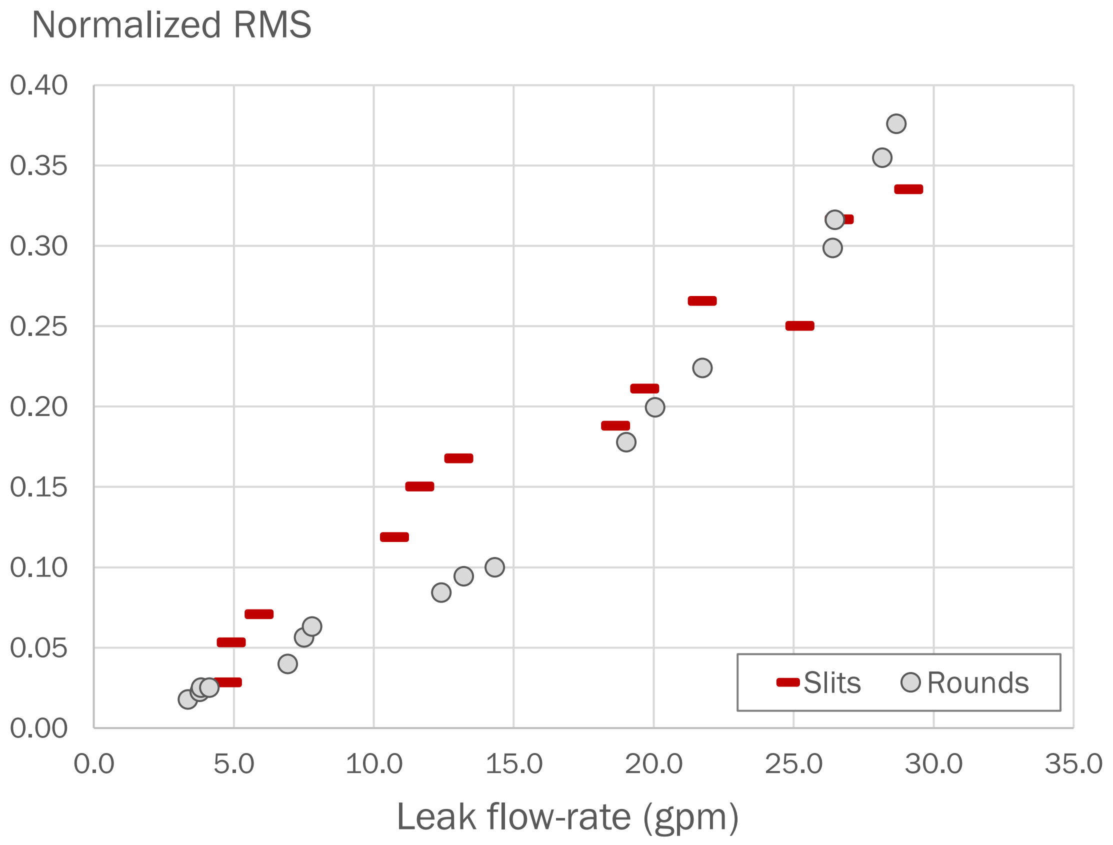
Sound level vs. Leak Flow-rate

Flow-rate vs RMS remains proportional for different surrounding mediums or leak shapes





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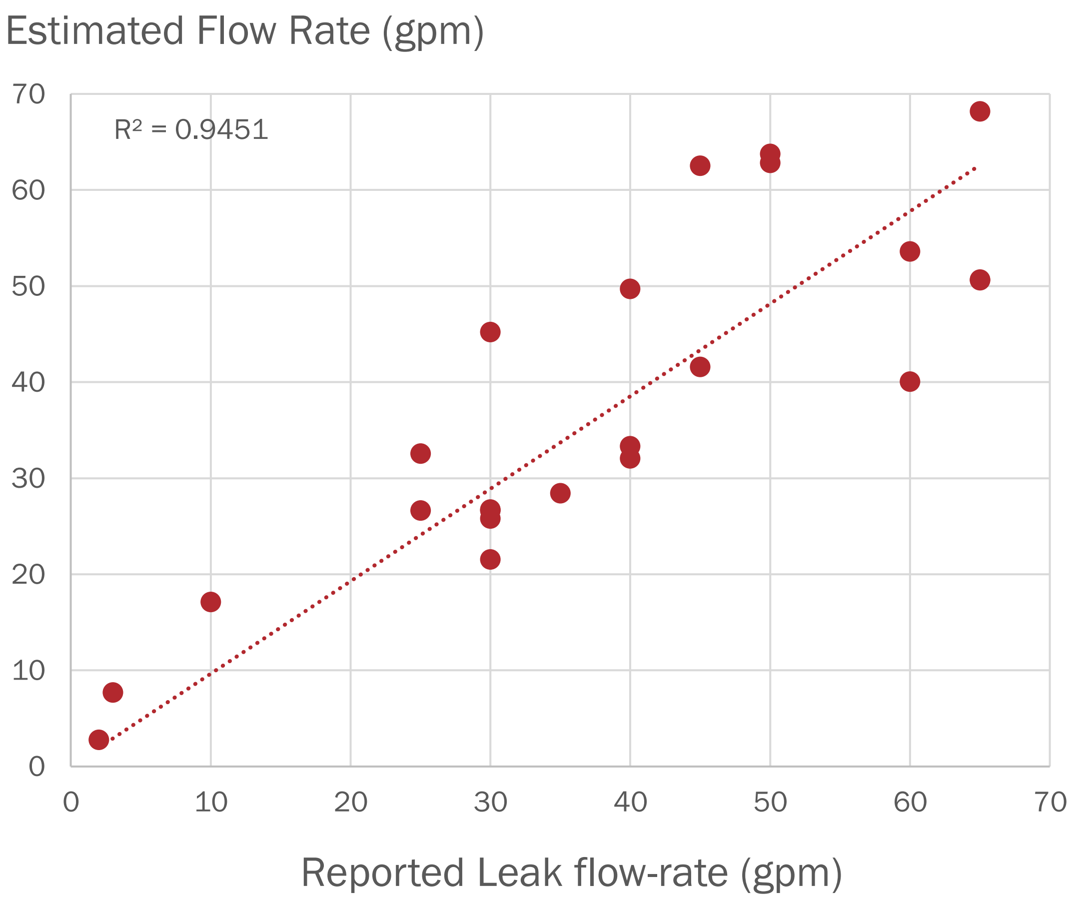
Calibration using field data

- Calibration was performed using several leaks detected by an acoustic leak detection system
- All leaks are on mains, in-bracket
- The leak location was determined using correlation and confirmed by utilities
- The flow-rate was measured and reported by the utility repair crew



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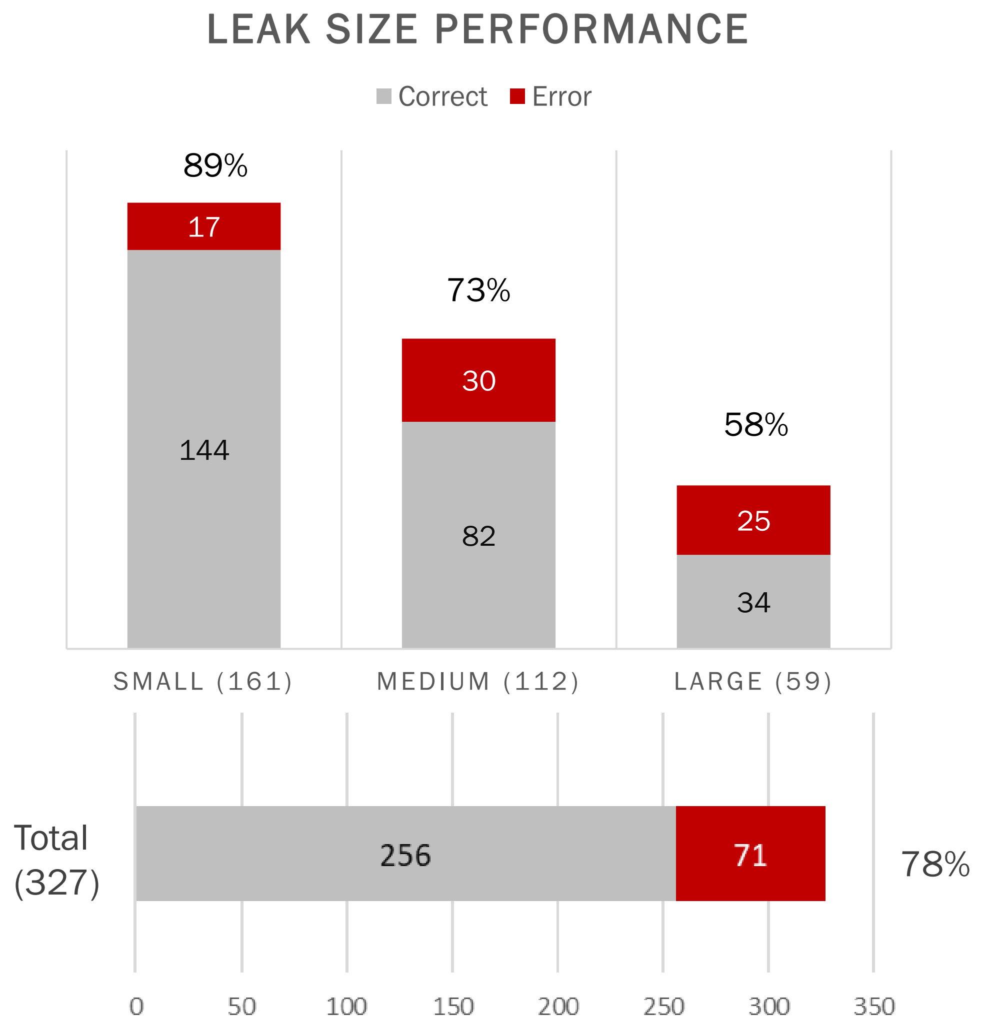
Evaluation

- Evaluated with a network of acoustic sensors installed at multiple utilities in North America
- The system monitored metallic pipes (CI & DI) with diameters ranging between 6” to 16”
- All events have been detected and located acoustically and reported to utilities
- Water utilities provided feedback on observed flow-rate following site inspection
- Leakage events included main breaks, service leaks and hydrant leaks
- Accurately estimated the flow rate for 256 leaks out of 327 (hit rate = 78%)



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Key Takeaways

Acoustic Leak Monitoring systems with flow rate estimator

- ✓ Factors influencing leak signal investigated
- ✓ Acoustic features identified to enable estimation of leak flow rate
- ✓ Twin model approach used to estimate the leak signal at the source
- ✓ System tested at scale
- ✓ Prioritise leak repair (save more water by fixing less leaks)

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