Water Infrastructure Efficiency Pilot

Advanced Leak Detection and System Monitoring

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1. THE PROBLEM

Water utilities lose significant volumes of treated water through leaks and distribution inefficiencies. These losses, known as Non-Revenue Water (NRW), increase operating costs, waste water resources, and accelerate wear on aging infrastructure. At the same time, many utilities must identify and replace lead service lines under regulatory and public health pressure.

2. PROPOSED SOLUTION

This pilot uses acoustic sensors, pressure monitoring, and data analytics to detect leaks earlier and improve system visibility. The system is designed to integrate with existing utility operations and support—not replace—current engineering and maintenance workflows.

3. FOCUS AREAS

- Real-time and near-real-time leak detection using acoustic and pressure data
- District Metered Area (DMA) analysis for targeted response
- Improved prioritization of repair crews and field teams
- Data support for lead service line replacement planning
- Integration with existing SCADA, GIS, and maintenance systems

4. PILOT OBJECTIVES

- Reduce time from leak occurrence to detection and repair
- Lower NRW levels within the pilot area
- Improve visibility into hidden system losses
- Demonstrate measurable gains in operational efficiency
- Evaluate integration feasibility and organizational fit

5. PILOT STRUCTURE

The pilot begins with a baseline assessment of a defined service area, followed by sensor deployment, system integration, performance monitoring, and field validation. It is intentionally scoped to deliver clear operational results while remaining manageable for utility staff.

6. EVALUATION CRITERIA

Success will be measured by:

- Time to detect and respond to likely leaks
- Number of validated actionable detections
- Estimated reduction in avoidable water loss
- Improvement in maintenance prioritization
- Practical value for infrastructure planning and lead service line replacement

7. NEXT STEPS

A phased 12-month pilot is recommended. Successful results would provide the foundation for broader deployment across additional service areas.

Technical Appendix

1. Executive Summary

Water utilities increasingly face the dual pressures of enhancing operational efficiency and modernizing aging infrastructure, all while navigating limited staffing and constrained capital budgets. Two of the most persistent challenges in this domain are addressing **non-revenue water (NRW)** caused by systemic leaks, and prioritizing **lead service line replacement** in a manner that is technically defensible, operationally viable, and aligned with available funding.

This brief outlines a practical framework leveraging **sensor-based monitoring, acoustic leak detection, pressure and flow analysis, and AI-assisted analytics** to facilitate earlier leak identification and strategic infrastructure planning. This approach equips utilities with improved visibility into hidden system conditions, reduces avoidable water losses, and enables better-informed decisions regarding repair sequencing and replacement schedules.

Rather than relying on speculative technology, this concept serves as an operational decision-support model designed to fortify existing utility workflows. By enhancing the quality, timeliness, and actionability of infrastructure data, this approach helps utilities transition from a reactive posture to a proactive, data-informed system management model.

A focused pilot program is the recommended next step. Implementing a limited deployment within a defined service area allows utilities to evaluate detection accuracy, operational utility, integration feasibility, and the overall value of analytics-supported prioritization prior to broader adoption.

2. Problem Statement: NRW and Lead Service Line Challenges

Modern water distribution systems confront overlapping pressures, including aging assets, incomplete infrastructure visibility, deferred maintenance, escalating replacement costs, and heightened expectations for public health protection. Consequently, utilities must make critical decisions on allocating limited operational and capital resources.

A primary operational challenge is **non-revenue water**. NRW encompasses treated water that is produced but not billed due to leaks, main breaks, service line failures, or metering inaccuracies. Often, a significant portion of water loss occurs below the threshold of immediate visibility, allowing leaks to persist undetected for extended periods. This results in avoidable production costs, added stress on treatment and pumping facilities, and diminished network efficiency.

Concurrently, utilities are actively managing **lead service line replacement programs**. These initiatives are frequently complicated by incomplete historical records, partial field verifications, and the need to balance replacement efforts with public health priorities, regulatory mandates, and community expectations. Utilities require superior methodologies to determine where intervention is most urgent and where supporting data is most reliable.

Ultimately, utilities face the shared challenge of making critical infrastructure decisions despite incomplete visibility into asset conditions and localized risks. Without robust monitoring and analytic support, organizations may continue relying on fragmented records and reactive response models that fail to optimize field resources or long-term capital planning.

The fundamental need is therefore not merely for better technology, but for an improved **operational framework**—one that assists utilities in identifying problem areas sooner, validating issues effectively, prioritizing interventions consistently, and documenting decisions transparently.

3. Operational Context and Utility Need

Utilities operate within practical constraints that dictate planning and operational decisions. These constraints typically include aging networks, limited staff capacity, budget pressures, fragmented software environments, and competing capital priorities. Furthermore, asset information often evolves over decades across multiple platforms and reporting formats, complicating efforts to establish a unified, reliable operational picture of system losses and priority assets.

In routine operations, leak detection and field investigations are frequently driven by customer complaints, visible failures, or incident-based maintenance. While these traditional approaches remain necessary, they often fail to capture low-visibility losses early enough to allow for optimal intervention. Similarly, infrastructure replacement decisions are heavily influenced by engineering judgment, historical records, funding stipulations, and program deadlines rather than a continuously updated understanding of network behavior.

Therefore, utilities require tools that enhance situational awareness without imposing additional operational burdens. An effective modernization strategy must integrate seamlessly into existing workflows, complement current staff capabilities, and generate outputs that are readily interpretable by operations, engineering, finance, and leadership teams.

A robust decision-support model should address critical questions, including:

- Where is water most likely being lost within the distribution system?
- Which network anomalies require immediate field investigation?
- Which pipe segments or service areas represent the highest combined operational and public health priority?
- How can system data better inform leak response, maintenance schedules, and replacement sequencing?

- How can utilities produce clearer records to support funding applications, compliance reporting, and executive decision-making?

The operational need is highly tangible: utilities require a more efficient, defensible method to connect system behavior and asset data with field response, ensuring that maintenance and capital decisions are both well-targeted and thoroughly documented.

4. Technical Approach

The proposed technical approach synthesizes multiple forms of system monitoring and data interpretation to enhance infrastructure visibility and support utility decision-making. The core concept involves pairing **data inputs from the distribution system** with **AI-assisted analytic methods** to detect likely anomalies, support prioritization, and drive operational action.

4.1 Data Inputs

A comprehensive implementation may utilize a combination of the following inputs, tailored to utility readiness and data availability:

- acoustic monitoring data indicative of potential leak signatures,
- pressure monitoring data,
- flow data from district metering areas or relevant network points,
- historical repair and maintenance records,
- GIS and asset registry data,
- service line and material composition records,
- meter and billing exception data where appropriate,
- customer complaint patterns,
- replacement program datasets relevant to lead service line planning.

These inputs do not need to be flawless at the outset. Significant value can be generated simply by improving how existing data is organized and interpreted, with data quality and asset consistency iteratively refined over time.

4.2 Analytic Methods

The analytic layer emphasizes practical decision support over technological complexity. Appropriate methods may include:

- anomaly detection,
- time-series analysis,
- acoustic signal pattern recognition,
- risk-based asset prioritization,
- machine learning for event classification or ranking,
- rule-based scoring tied to defined operational thresholds,
- combined indicators merging infrastructure condition, observed anomalies, and program priorities.

Within this framework, AI serves to process extensive, mixed datasets efficiently, highlighting actionable patterns and prioritizing probable issues based on available evidence. AI-assisted outputs are structured recommendations intended to guide, rather than replace, field validation and engineering review.

4.3 Operational Outputs

A successful technical system must produce actionable outputs for utility teams, including:

- likely leak alerts or anomaly flags,
- ranked investigation lists,
- priority maps or service area summaries,
- asset risk dashboards,
- recommended sequences for inspection or repair,
- support material for lead service line replacement planning,
- executive and operational reporting views.

The overarching objective is to translate fragmented technical signals into operationally coherent information, reducing uncertainty and enabling utilities to respond efficiently to conditions impacting water loss, infrastructure performance, and public health outcomes.

5. Pilot Design

The recommended implementation pathway is a carefully defined pilot program rather than an immediate full-scale deployment. A pilot provides a controlled environment to evaluate usefulness, integration compatibility, operational adoption, and measurable value.

5.1 Pilot Objective

The primary goal of the pilot is to determine whether AI-assisted monitoring and prioritization demonstrably improve utility decision-making regarding NRW reduction, leak detection, maintenance targeting, and lead service line replacement planning.

5.2 Pilot Scope

The pilot should target a clearly defined operating environment, such as:

- a specific service district,
- a pressure zone,
- a high-priority neighborhood,
- an area with historically documented leakage concerns,
- a zone slated for active or planned lead service line replacement work.

The scope must be manageable yet sufficiently broad to yield meaningful operational insights.

5.3 Pilot Duration

A realistic evaluation period typically ranges from 90 days to six months, depending on procurement, installation timelines, and field validation requirements. This duration provides ample time to establish baseline conditions, monitor anomalies, execute field checks, and compare outcomes against standard practices.

5.4 Pilot Activities

A practical pilot execution involves the following steps:

1. define the target area and operational objectives;
2. establish baseline metrics for leak detection, response timing, or relevant replacement planning indicators;
3. identify available data sources and monitoring infrastructure;
4. deploy additional sensing where needed and feasible;
5. configure analytics and alert thresholds;
6. validate selected outputs through utility staff review and field investigation;
7. compare pilot results against standard workflow outcomes;
8. document lessons learned, integration needs, and scale-up considerations.

5.5 Stakeholders

The pilot must engage diverse utility functions, including:

- operations,
- engineering,
- asset management,
- distribution maintenance,
- compliance and regulatory staff,
- executive leadership,
- finance or capital planning teams where relevant.

Cross-functional participation ensures the system is evaluated not just on detection accuracy, but on its ability to enhance coordination, planning quality, and overall confidence in infrastructure decisions.

6. Expected Metrics and Evaluation Criteria

To ensure credibility, the project must be assessed using measurable operational criteria. The critical evaluation is whether the system's outputs actively improve the quality and speed of utility decisions.

Core evaluation metrics may include:

- **time to detect** likely leak conditions,
- **time to investigate** flagged anomalies,
- **time to repair** validated issues,
- number of actionable detections generated,
- field validation rate,
- false positive and false negative rate,
- estimated reduction in avoidable water loss,
- improvement in prioritization of high-risk assets,
- usefulness in guiding maintenance deployment,
- usefulness in supporting capital planning and lead service line sequencing,
- staff confidence in output quality and operational relevance.

For utilities managing lead service line replacement programs, evaluation may also include:

- improvement in identification of priority segments,
- alignment between field findings and replacement targeting,
- usefulness for documenting replacement rationale,

- support for grant, compliance, or reporting requirements.

Financial savings estimates should be approached rigorously. Any claims regarding cost avoidance, water savings, or efficiency gains must be grounded in transparent assumptions and documented methodologies. Unsupported national-scale or system-wide claims should be avoided unless they can be validated with utility-specific logic.

A credible evaluation framework ensures that the project is judged by real operational value rather than promotional language.

7. Implementation Risks and Assumptions

A professional infrastructure strategy must transparently outline associated risks and operating assumptions. This clarity helps utilities assess the realistic viability of the proposed approach within their specific environments.

7.1 Key Risks

Potential implementation risks include:

- incomplete or inconsistent asset records,
- limited sensor coverage,
- data integration complexity across multiple platforms,
- uneven quality in historical maintenance or field data,
- false positives or inconclusive anomaly signals,
- staff bandwidth limitations,
- difficulty aligning outputs with existing work-order processes,
- overreliance on model outputs without sufficient field validation,
- short pilot periods that do not capture enough variability.

These risks do not invalidate the approach; rather, they inform implementation design and expectations. Risk should be mitigated through scoped deployments, rigorous utility review, field verification, and realistic performance benchmarking.

7.2 Core Assumptions

The proposed operational model assumes:

- utility access to at least some usable data inputs,
- willingness to define and support a pilot area,
- availability of staff for validation and review,
- a clear operational use case,
- agreement on success criteria,
- the ability to compare results against existing workflows.

Crucially, the approach assumes that analytics serve to augment human decision-making. Engineering judgment, operational experience, and physical field verification remain paramount to any credible deployment.

7.3 Governance and Validation

Effective implementation requires structured governance dictating how anomaly flags are reviewed, how thresholds are calibrated, how field findings are reintegrated into the model, and how insights are disseminated across teams. Governance is essential because the ultimate value of a monitoring system rests on the quality of the operational decisions it precipitates.

8. Next Steps

The transition from conceptual framing to a structured pilot planning process is the recommended next step. A limited, measurable deployment provides the most credible mechanism to validate operational value prior to broad scale-up.

Recommended actions include:

1. **Identify a pilot utility or target service area.** Select a system, district, or asset cluster where NRW reduction, leak visibility, or lead service line prioritization is an immediate priority.
2. **Define the specific operational problem to be tested.** Clarify if the primary focus is leak detection, response prioritization, replacement planning, or a hybrid use case.
3. **Establish baseline conditions and success metrics.** Document current workflows, available data constraints, and exact metrics for assessing pilot value.
4. **Assess data and monitoring readiness.** Inventory available acoustic, pressure, flow, GIS, and program data, identifying gaps requiring supplementary instrumentation.
5. **Design the pilot implementation plan.** Outline the scope, duration, team responsibilities, reporting cadence, and validation protocols.

6. **Launch a phased pilot.** Initiate with a constrained footprint, utilizing iterative utility reviews to refine outputs before any expansion.
7. **Evaluate outcomes and determine scale-up potential.** Benchmark performance against baseline conditions to ascertain if the approach warrants broader deployment or refinement.

A structured pilot empowers utilities and partners to rigorously test practical value while strictly controlling risk. Successful pilots can subsequently be expanded into comprehensive asset intelligence and infrastructure planning models.