Real Loss Component Analysis: A Tool for Economic Water Loss Control [Project #4372]

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OBJECTIVES

The primary objectives of the Water Research Foundation (WRF) project, Real Loss Component Analysis: A Tool for Economic Water Loss Control, were:

- Review North American and international literature and best practices on component analysis of leakage and economic leakage analysis and guidelines.
- Develop a utility-tested software tool to undertake a leakage component analysis and economic leakage evaluation, enabling utilities to plan cost effective leakage control interventions.
- Develop a tool that complements the American Water Works Association (AWWA) Free Water Audit Software and the 3rd edition of AWWA’s Manual 36 (Water Audits and Loss Control Programs).
- Establish utility data collection guidelines for proper documentation of all leakage occurrences.
- Provide thorough instructions for use of the tools developed.
- Promote the adoption of the tools and the benefits of proactive leakage management.

The software tool and guidelines developed from this project will benefit and advance industry wide leakage management on several levels. This project is relevant to the following fields:

- Regulatory Agencies: Federal, State, Regional, Municipal
- Water Industry Wide: Private and Public Utilities, Consultants, and Contractors
- General Utility Management
- Distribution System Operation
- Water Conservation

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Planning and Engineering

BACKGROUND

Water utilities, regulatory agencies, and a variety of stakeholders continue to increase focus on infrastructure management and water efficiency due to continuing droughts, the increasing cost of providing potable water to customers, potential health risks posed by leaking pipes, and heightened awareness of the increasing cost of leakage. In fact, the WRF project #4109, *Criteria for Optimized Distribution Systems*, considers leakage as one of three key indicators of distribution system management performance (Friedman et al. 2010) and is being considered for adoption by AWWA’s Partnership for Safe Water Program.

Nevertheless, the vast majority of North American water utilities only employ a reactive leakage management strategy, repairing failures that have been reported to them in a more or less timely manner. As a result, water utilities continue to see an increase in leakage losses (water lost by leaks in the distribution system) due to a rising backlog of unreported failures in their distribution system. This is in spite of the fact that industry research and case studies have sufficiently demonstrated the benefits of proactive leakage management. The drinking water industry stands to benefit greatly in transitioning from purely reactive leakage management to proactive leakage management allowing them to achieve and sustain substantial reductions in leakage losses in an efficient and economic manner. (The terms real losses and leakage losses as well as the terms water audit and water balance have been used interchangeably in this report).

Generally, North American water utilities are still under little or no regulatory pressure to efficiently control leakage losses; however, a few agencies recently created water loss control related regulations or are closely evaluating the International Water Association (IWA)/American Water Works Association (AWWA) Water Audit Methodology. In this context of growing acknowledgement around the importance of proactive leakage management, the software tool and research provided by this project are especially timely.

The available AWWA and WRF literature provides all the necessary theoretical background on how to accurately assess leakage losses and plan efficient and economic leakage control interventions. There are three major steps in developing a real loss reduction strategy:

- “Top-down” water audit
- Component analysis of real losses
- Evaluation of least cost real loss reduction strategies

The AWWA Manual 36 (3rd edition) provides comprehensive guidance for all steps involved in undertaking a “top-down” water audit, component analysis of real losses, and planning and implementing a real loss control program. The AWWA Free Water Audit Software serves as a basic tool to compile a “top-down” water audit, which is the first step in developing a water loss control program. A “top-down” water audit calculates the overall system wide volume of real losses by deducting the authorized consumption volume and the apparent losses volume (customer meter inaccuracies, data
handling errors, and unauthorized consumption) from the system input volume. Once the overall system wide volume of real losses has been determined, this volume needs to be broken down into individual components of real losses/leakage by use of component analysis modeling.

A leakage component analysis disaggregates the total volume of real losses as calculated in the “top-down” water audit into its three components: Background Leakage, Unreported Leakage, and Reported Leakage. By combining the component analysis with an evaluation of least cost real loss reduction strategies it is possible to calculate how much of each leakage component can be economically reduced through the right combination of intervention tools. Very few water utilities have the necessary expertise in leakage loss management to efficiently undertake a leakage component analysis and design the correct leakage control program. This means that utilities often invest money in leakage control activities (such as simple leak detection programs) that are not based on sound Economic Level of Leakage (ELL) analysis. It is very likely that those programs do not yield the best results. There is industry-wide room for improvement in creating cost-effective and well informed and leakage intervention strategies. Figure ES.1 provides an overview of the literature that includes guidance for each step of developing a real loss reduction strategy and the available software tools for completing each step.

![Figure ES.1 Steps to Develop a Real Loss Reduction Strategy and Available Literature and Software Tools for Each Step](image)

This project provides North American water utilities with an analysis tool to better understand the sources of their real losses (reported, un-reported, or background) and a means of analyzing their economic intervention strategies. The tool created, called the Component Analysis Model (the Model) is utility-tested, user-friendly, and accessible while still maintaining a reasonable level of complexity.
**APPROACH**

The research team worked with 10 participating utilities, representing small, medium, and large water utilities from a variety of geographic regions. The participating utilities were instrumental in assuring that the Model was developed as an accessible tool that fits the needs of utilities nationwide.

The first step in this research project involved surveying the group of participating utilities to gauge general expectations for the Model in its content and complexity. Next, the research team collected and validated the data necessary to run the Model. This data collection included receipt of the following:

- AWWA Water Audit results
- Data on reported and unreported failures repaired during the audit period
- Information on current leakage management practices
- Utility cost data (total cost of operating the system, customer retail cost, variable production cost, cost of most expensive water source)

In parallel, the research team conducted a limited international review of water loss reporting guidelines. This research focused on select countries (Australia, Austria, and New Zealand) where the IWA/AWWA water balance and water loss performance indicators are recommended as best practice by the countries’ water industry association/s and where water balance software tools are used to aid the water industry in achieving efficient management of water resources.

The research team also reviewed the guidelines and regulations from nine North American state agencies and organizations that have the most progressive approaches to water loss control. The agencies examined within this research report include the Alberta Urban Municipalities Association, California Urban Water Conservation Council, Delaware River Basin Commission, Georgia Board of Natural Resources, New Mexico Office Of The State Engineer, Tennessee Comptroller of the Treasury, Texas Water Development Board, Washington State Department of Health, and the Wisconsin Public Services Commission. This component of the research effort aimed to position the research project in the context of water loss management throughout the nation. In developing the Model and expanding the array of resources available for utility water loss control programs, it is important to fully appreciate how currently available software tools, such as the AWWA Free Water Audit Software, have been received and adopted.

In the next phase of the project the research team conducted a literature review with the goal of providing an industry average failure frequency and an industry failure frequency benchmark. It is important to note that the term “failure” encompasses all types of utility leaks and breaks. In this effort, literature that addresses the condition of distribution systems was reviewed with reports that included average failure frequencies (defined as the number of failure incidents per length of distribution main per year).

The research team began the Model development in June 2012 and completed the Model in July 2013. Throughout this process the participating utilities were active participants in providing feedback and improving the Model. Upon validating the data from each utility, the research team tested the Model’s functionality and use. Working with the participating utilities in this way enabled the research team to develop the Model.
so that it accommodates most data system approaches. Each participating utility was given a thorough introduction of the Model wherein the research team reviewed the purpose and use of each worksheet. After a couple weeks of using the Model independently, the participating utilities reconnected with the research team to share feedback. This was a critical process in identifying areas of the Model that needed clarification and more instruction.

RESULTS/CONCLUSIONS

The main findings and conclusions of this research project are:

**Exemplary countries that pursue proactive leakage management feature freely available software tools.** This statement was based on a limited international review focusing on countries (Australia, Austria, and New Zealand) where the IWA/AWWA water balance and water loss performance indicators were a recommended best practice. The review also provided an interesting perspective of water loss performance achieved or targeted in these three countries. Especially in Austria and Australia, water utilities have achieved, on average, very low levels of real losses. For example the Australian Government National Water Commission in its 2011 Annual National Performance Reports reported an average real loss volume for water utilities with more than 100,000 service connections of 18.5 gallons/connection/day.

**The adoption and understanding of existing AWWA Free Water Audit Software shows room for improvement.** The results from the examination of state agency efforts to require and collect water audits from their member water providers was a very important exercise in understanding the extent to which water loss control software tools have been successfully adopted and properly used. The research team reviewed state agencies that exemplify proactive approaches by applying the industry’s best practices in creating regulations and policies around water loss control. In general, the research team found that the data quality of water audits produced by water utilities for their reporting requirements leaves ample room for improvement. For example the water audit results received by the California Urban Water Conservation Council (CUWCC) showed that about 35% of water audits produced by the CUWCC’s member agencies contained implausible results. Similar data quality issues were found when reviewing the water audit results from other state agencies. This highlights the industry wide need for further outreach, education, and training in how to conduct a water audit, validate the audit data, and develop water loss control strategies.

**Real Loss Component Analysis is relatively new.** The first step in this research project involved surveying the group of participating utilities to gauge general expectations for the Model in its content and complexity. Here, the research team found that a majority of the participating utilities selected the “Beginner” (focused on data validation and establishing benchmark performance indicators) or “Intermediate” (focused on implementing initial intervention strategies and improving an existing water loss control program) in describing their water loss control activities. This level of experience appears to be representative of the North American water industry.
The Component Analysis Model was successfully developed and employed by two utilities. The research team successfully developed the Model with significant input from the participating water utilities and the project advisory committee. The Model was designed using a standard Microsoft Office Excel™ software program. The Model was developed with the needs of the utility users in mind to provide a water loss analysis software tool that is accessible, user-friendly, and has a reasonable level of complexity. Each of the participating utilities utilized and tested the model with the results of Eastern Municipal Water District and Water and Wastewater Authority of Wilson County being discussed in this report. For both water utilities the Model helped in breaking down their real loss volume, as determined through the AWWA Free Water Audit, into its components, assessed the volume of hidden leakage (detectable leaks currently running undetected), and evaluated least cost real loss reduction strategies.

There is ample room for improvement in the data quality of failure records collected by North American water utilities. The research team’s failure frequency literature review revealed that the failure repair records collected by North American water utilities are often incomplete (a finding that was supported by the participating utilities’ dataset). In light of this, the average failure frequencies as assessed by various industry studies are only best estimates reflecting the quality of available failure data. A majority of the documented failure frequencies in the reviewed literature do not have well characterized source data. In other words, the failure frequencies are reported in aggregate without much detail on the original data or the quality assurance measures taken to calculate the aggregate failure frequency. In this context, it is difficult to distinguish between the failure frequencies on the basis of data source, confidence, and reliability. Several areas in the collection of leak repair data need to be improved in order to achieve a better and more accurate understanding of failure frequencies.

Terminology for documenting pipe failures needs to be consistent. The terminology used by water utilities for documenting pipe failures is highly inconsistent. The terms leak, break, and burst are all used throughout the industry and they may all have different interpretations/definitions depending on the water utility. Some utilities for example categorize a break as a failure event of significant nature that requires immediate action and the term leak is used for smaller pipe failures, which do not require immediate response. Therefore, it was important to feature clear definitions for the failure data inputs needed for the Model developed for this research project. Every failure event in the transmission system, distribution system, and on service connections needs to be documented and used in the Model’s leakage component analysis. The term ‘failure’ is used throughout this report and the model to encompass all leak/break terminology.

A Leak Repair Data Collection Guide was developed. The need to provide clear guidance on failure data collection and documenting was addressed by the research team through the development of a Leak Repair Data Collection Guide in form of an open source MS Office Excel spread sheet.

Failure frequency benchmarks were identified during the literature review. The goal of the failure frequency literature review (see Figure ES.2) was to isolate two
failure frequency benchmarks that can be used in the Model for comparison to a typical North American distribution system or to a suggested target for an optimized distribution system. The following failure frequency benchmarks were assessed:

- Aggregate North American failure frequencies based on the data in six studies in the literature review: approximately 25 failures / 100 miles / year.
- Failure frequency goal for an optimized distribution system: 15 failures / 100 miles / year (taken from Friedman et al. 2010).

**Source:** Compiled. See Table 2.14

**Figure ES.2:** Diagram of reports that feature North American failure frequencies, organized by year and failure frequency value

**APPLICATIONS/RECOMMENDATIONS**

The Component Analysis Model (the Model) was developed to provide the water industry with a computer-based model for leakage component analysis, failure frequency analysis, economic leakage control intervention strategy evaluation, and display of key water loss performance indicators. The Model is a complementary analysis tool to the

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1NOTE: the break frequency as provided in Friedman 2010 represents a goal for an optimized distribution system and is therefore not directly comparable to the other average break frequencies as cited by the other studies.
AWWA Free Water Audit Software and was designed using a standard Microsoft Office Excel software program. The Model was developed with the needs of the utility users in mind to provide a water loss analysis software tool that is accessible, user-friendly, and has a reasonable level of complexity.

The research team is careful to acknowledge that the Model is only as useful and instructive as the quality of the user’s inputs. Throughout the instructions provided in the Model (and throughout this report), there is particular emphasis on the importance of data quality and validation. In making the Model freely available and encouraging its adoption, the research team will continue to highlight the importance of data quality.

Furthermore it is important to highlight that the Model requires a significant amount of validated data and its "outputs" are meant to provide opportunities to test scenarios but do not represent concrete goals or hard and fast targets. The Model is a dynamic tool meant for guidance and not a mechanism for direct reporting like the AWWA software or regulatory target setting.

In addition to the model the research team developed a Leak Repair Data Collection Guide in the form of an open source MS Office Excel spreadsheet to aid the industry in collecting consistent failure data. This tool offers guidance to water utilities as a standardized format to document failure events; thereby generating the appropriate data to execute a reliable leakage component analysis. Utilities that carefully document all failure events have a means to define failure trends occurring in their system.

MULTIMEDIA

The Component Analysis Model and the Leak Repair Data Collection Guide, both MS Office Excel spreadsheets, can be downloaded from the WRF Website by clicking on their respective links.

RESEARCH PARTNER

U.S. Environmental Protection Agency