DATA ASSESSMENT AND UTILIZATION FOR IMPROVING ASSET MANAGEMENT OF SMALL AND MEDIUM SIZE WATER UTILITIES

by

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ABSTRACT

Data regarding water main breaks are essential for undertaking informed and effective infrastructure asset management. This thesis reports on the findings of a survey regarding water main break data collection practices across North America and develops an approach for constructing databases and integrating the data with break prediction models to improve the asset management practices of a utility.

The survey determines the amount and type of data collected by water utilities, the level of comfort with the amount of data collected and the availability of alternate sources of data. The responses provide insight into the strategies and data collection practices of small to mid-size utilities and show that the amount of data collected by utilities can be classified by the degree of data richness and defined as either an expanded, intermediate, limited or minimal data set. Utilities can implement recommended practices to increase the amount of data they collect, increase effectiveness of data collection and processing and consider additional sources of data for water main breaks to improve their data sets.

The thesis also introduces an approach for constructing a water main break and general network database that relates data from multiple sources to augment the amount of data available for asset management analysis while maintaining existing data warehousing practices. When used, managers may gain insight into current and future performance of the distribution network and develop future asset management strategies. The approach is flexible, uses commonly available software tools and anticipates the evolution of data collection, verification and storage capabilities within the utility.

Finally, a framework is presented that guides small to medium water utilities in identifying key data to be used in asset management and pipe break prediction modeling

and in selecting appropriate water main break prediction models. The framework may be used to identify the magnitude of a utility's pipe burst problems today and in the future, enhance the development of pipe replacement priorities based on forecasted breaks and identify key data to collect in future data acquisition programs. Water utilities with varying amounts of data can easily implement it with their existing data management and analysis tools.

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CO-AUTHORSHIP STATEMENT

Andrew Wood was the lead and principal researcher of the work contained in the thesis titled "Data Assessment and Utilization for Improving Asset Management of Small and Medium Size Water Utilities". Dr. Barbara Lence, the Research Supervisor of the thesis, provided inspiration and supported the writing of the papers and Wilson Liu assisted with the preparation of figures used in the paper submitted as Chapter 3.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Reliable, efficient and effective water distribution systems are crucial to public health and safety. These systems are also essential to the economic well-being of many municipalities since manufacturing, industry and commerce rely to a large degree on obtaining reliable and economically-priced water delivered through a network of water pipe lines, more commonly referred to as water mains.

Many of these water mains installed over the decades in North America are now beginning to break and fail. The traditional public works emphasis on managing water main breaks has been directed toward minimizing the loss of water to key businesses and critical facilities and the damage to built and natural infrastructure. However, breaks are also potential gateways to contamination of the water distribution system (AWWA and EES, 2002) and are identified as a high priority in the assessment of water supply health risks by the National Research Council of Academy Sciences (2005). By replacing the pipes just before they fail, utilities reduce their risks and costs of water main breaks.

This thesis is focused on helping small and medium size utilities by providing information on water main break data collection, construction, compilation, and management in support of asset management. The research presented includes an approach for these utilities to use water main break prediction models on a pipe by pipe basis for prioritizing the replacing of water mains. The work is presented as a series of three manuscripts that are published in peer-reviewed journals or are in the process of being peer-reviewed.

When I embarked on this research program my goal was to assist small and medium size utilities with managing their pipe networks to address the risks and costs associated with replacing water mains. Specifically, I wanted to assist them with identifying, collecting and constructing relevant pipe break data to analyze their pipe network, prioritizing their water main replacements by using break predictions and guiding their data acquisition and analysis programs. During my almost twenty years of experience as a professional engineer in public utilities I observed that my colleagues in other utilities were not using break prediction models in their practice. Within the organizations with which I was familiar, collection of water main break data was undertaken on an *ad-hoc* basis and storage of such information was not typically comprehensive. Among those utilities, there were no common practices or standards for data collection and very few utilities, if any, were aware of the data collected by other utilities. Best practices for Canadian water utilities regarding which data to collect were introduced in 2002 (NSGMI, 2002). As a manager, I also wanted to compare the information I was collecting with that of other utilities, to understand how data were informing us and to share this knowledge with my colleagues.

During this time, I also became aware of the general belief held by many utility managers that asset management is a panacea for solving our aging water system problems. We needed to know when, where and how many pipes to replace; but we were focusing on the entire network, not on specific pipes, to obtain funding for programs. I found that among my colleagues, once funding was obtained, decisions on prioritizing pipe replacements were based on historical data, experiences and management policies rather than on the expected performance of specific pipes though there are models for predicting water main breaks. In fact, many of my colleagues were not aware of these models and none, if any, were using them. Thus, I was convinced that we needed an approach that applied pipe break models to inform our decisions regarding the prioritization and scheduling of specific pipe replacements.

As a result of my observations, my thesis identifies data that are collected and available for analysis across utilities in North America, develops a methodology for creating and linking data across various data sources and develops a framework for assisting in the prioritization of water main replacements and data acquisition based on predictions of future water main breaks within a given water distribution system. The framework may be applied across the range of data available in typical water utilities, acknowledges existing industry needs and practices and will help managers identify and use key available break data.

Our water mains are aging and failing. The water mains of many municipalities are predominantly of the 1960s to 1990s vintage because of extensive urban development during those years, with some smaller amounts prior to that period. However, the replacement needs of aging public works infrastructure has become the focus of governmental and academic attention in recent years. Because few water utilities have actively pursued aggressive water main rehabilitation or replacement programs, they are now facing the problem of replacing or rehabilitating their aging systems (Deb *et al.*, 2002). The United States Environmental Protection Agency (USEPA) identifies that while United States (US) communities spent one trillion US dollars in 2001 on drinking water treatment, supply and waste water treatment and disposal, this expenditure level may not be sufficient to keep pace with future infrastructure needs (USEPA, 2002). They also identify in a 2003 survey that the 53,000 community water systems and 21,400 not-for-profit non-community water systems in the US will need an estimated $276.8 billion to continue to provide their services (USEPA, 2005). Similarly, the Ontario Ministry of Public Infrastructure Renewal (PIR) identifies that over the next 15 years, $25 billion will be needed for capital renewal of Ontario's $72 billion water and waste water assets (Ontario PIR, 2005). The Federation of

Canadian Municipalities (FCM) state that key investments must be made in core public infrastructure to manage waste and water systems, to meet pressing environmental and air quality needs and to maintain the economic health of Canada's communities (FCM, 2001). Given the current level of expenditures and the increasing age of systems, utilities need to predict breaks and use this information to prioritize and plan when pipes should be replaced.

The ability to respond to the challenge of knowing when to replace a pipe varies among water utilities. Small to medium size utilities may find it particularly challenging due to their limited resources and technical capacity and there are many of these utilities across North America. In the US, small water systems make up 90 percent of those 53,000 community water systems (American Society of Civil Engineers, ASCE, 1999). No analogous data exist for Canada, although the Canadian National Research Council (CNRC) identifies that there are 3500 municipalities serving fewer than 5000 people and that there are only 63 municipalities serving populations greater than 100,000 (Vanier and Rahman, 2004).

Most small to medium size water utilities and municipalities share similar characteristics. They purchase bulk water from a regional or larger supplier and require some treatment. The treatment processes are simple processes such as ozonation, ultra-violet (UV) or chlorine disinfection. Small utility systems are typically comprised of small diameter pipes and as noted by Kettler and Goulter (1985), smaller pipes break have been observed to break more frequently than larger ones. This may be because their beam strength and wall thickness are generally less than those of larger pipes.

Smaller utilities have scarce resources and technical expertise is typically not available because staff are generally expected to undertake a number of different functions and do not have the luxury of developing in-house expertise. Compounding this is the fact that within these systems, there is little or no reliable documentation of the location, capacity, condition and adequacy of pipe network elements for meeting present or future needs (Myers, 2001). These utilities may also lack the resources, financially and organizationally, to implement a complex information management system program, nor the historical data or tools to fully analyze their system. They require capital to rehabilitate, upgrade and install infrastructure, but face an economic challenge in paying for these costs given a small revenue base. For example, although the costs of a small water system may be modest compared with those of large systems, the per household costs are significantly higher than those of larger systems (USEPA, 2001). The data shown in Figure 1.1 are the per household costs for different sized water systems for meeting anticipated needs. These data show that households in small systems face costs that are over three and one half times those of households serviced by large systems.

Utilities are viewing asset management as an approach for addressing this dilemma of planning pipe replacements by understanding how much rehabilitation will cost, what to do first and when to rehabilitate their systems. Asset management is a business administration approach to decision-making that covers an extended time horizon, draws from economics as well as engineering science and considers a broad range of assets. The approach incorporates the economic assessment of alternative investment options and uses this information to help make cost-effective investment decisions (United States Federal Highway Administration, USFHWA, 1999). The benefits of applying an asset management approach include the ability to link user expectations and needs and to identify the means of assessing value, system condition, performance, service life and management and investment strategies. However, for smaller utilities to adopt asset management, they need portable, readily useable approaches that require little modification, are likely to be met with little organizational resistance and serve to incrementally improve water main replacement analysis and planning. The need for planning is urgent and the need to improve the planning approaches will only increase with time.

1.2 THESIS OBJECTIVES AND ORGANIZATION

This thesis:

- assesses the state of data available to small and medium size water utilities,
- develops an approach for constructing and compiling water main break data for analysis and
- develops a framework that guides the identification of key data for asset management and the selection of the most appropriate data and models for predicting water main breaks.

Organization of thesis. The thesis is presented as a series of three manuscripts that are published in peer-reviewed journals or are in the process of being published or peer-reviewed. Each of the three manuscript chapters (Chapters 2 to 4) contains a preface, introduction, overview of the literature, body, conclusion and references. Tables and figures referenced in each chapter are included at the end of that chapter and all appendices are provided at the end of the thesis. Finally, Chapter 5 summarizes the major conclusions of this work.

There are many benefits of a manuscript-based thesis over the traditional thesis and the primary benefit is that research findings are published and shared with the research community much earlier than in the production of a traditional thesis. However, there are also significant disadvantages. Literature reviews are often repeated, some continuity is lost and much of the data, results, and observations that would be in a traditional thesis are condensed or eliminated. This results in an abbreviated thesis and a perception by the reader of a lesser effort than was the case in the research. This thesis attempts to address these limitations by including a section in this chapter on the approach, methodology and context of the research. Each chapter preface provides the context for the work presented in that chapter (paper) with respect to the overall research and thesis and the preceding chapter. Data not provided in the papers are also included in the appendices.

Chapter 2 provides the results of a survey that investigates the state of data collection practices, the commonly available water main break data and the data sources within North American water utilities. The paper was published in the July 2006 issue of the Journal of the AWWA. A comparison of the survey questions and those of Deb *et al.* (2002) is presented in Appendix A.

Chapter 3 presents an approach for building and relating data from various sources for analysis, based on observations drawn from the survey responses reported in Chapter 2. This work demonstrates how to construct water main data and databases which are based on linking, relating, extracting and compiling data from sources internal and external to a utility for the purpose of analysis, or in other words *relating relational databases*. Issues related to creating, linking, transforming, cleansing, scrubbing and integrating data are identified and approaches for addressing them are presented. A number of databases were created in this portion of the research. These are summarized in Appendix G. This paper was submitted to the Journal of the AWWA in February 2006, revised in October 2006 and is scheduled for publication in January 2007.

Chapter 4 develops a framework that guides utilities in identifying key data to be used in asset management in general and specifically in pipe break prediction modeling and in selecting the most appropriate model for predicting water main breaks. It provides the utility with a method for considering future pipe breaks in the analysis of pipe prioritization strategies. It incorporates existing tools for data management and analysis that are widely available and easy to implement by small to medium size utilities with varying amounts of data. This paper was submitted to the ASCE Journal of Infrastructure Systems in July, 2006. The fifth and final chapter summarizes the conclusions of and discussions arising from the research. A discussion of future research is also presented.

1.3 ASSET MANAGEMENT

Six components of an asset management program have been suggested (Vanier, 2001). These are inventory, asset value, deferred maintenance, condition, service life prediction, and prioritization of rehabilitation, replacement and renewal.

Inventory. The first building block of asset management is to determine the type, composition, quantity and extent of the assets. The primary capital assets that typical water utilities own include water supply reservoirs, dams and supporting hydraulic structures, water treatment plants, water distribution systems including pipes, valves, fire hydrants, distribution reservoirs, pump stations, pressure reducing valves and meters to measure distributed and purchased water. Utilities are typically maintaining inventories using tools such as Geographic Information Systems (GISs), Computer Aided Drafting (CAD) systems and relational databases. These systems require significant effort and resources to implement and maintain but for small systems, a simple spreadsheet may be all that is required. Wood and Lence (2006) found that archival records are still the predominant sources of data for utilities that serve populations fewer than 50,000. In recent years, the use of Computerized Maintenance Management Systems (CMMSs) has also grown in popularity and these systems usually interface with or use GIS data. These systems are expensive to implement and require significant resources to maintain. Many utilities still do not have CMMSs.

Asset value. To plan for replacement, water utility managers must know the total value of their assets. Managers must have a basic understanding of system worth and how much is required to replace it. According to Vanier (2001), the six commonly used terms to describe asset value are historical, appreciated historical, capital replacement, performance-in-use, deprival cost and market value. Historical value is defined as the original or book value, appreciated historical value is the historical value calculated in current dollars and capital replacement value is the cost of the asset in current dollars. The performance-in-use value is the prescribed value of the actual asset to the user. Deprival cost is the cost that would be incurred if deprived of the asset but still required to deliver the service. Finally, market value is the value if the asset is sold on the open market. Utilities may not use all of these values.

Few municipalities have specific asset values. In most cases, utilities inherit their new infrastructure from developers who install it as part of a housing subdivision and then transfer the ownership and maintenance of the assets to the municipality. Only the book value of the assets constructed directly by the municipality is typically recorded. For many utilities, the value of their assets are simply calculated by multiplying an average cost of construction per metre of pipe by the total length of the network.

Condition. Asset management requires knowledge of the condition of the assets. In the past, a significant amount of data were captured for evaluating operational values and objectives and a simple spreadsheet was used to record these data. In recent years, CMMS have been used to warehouse and process information and the management of maintenance activity planning. However, asset managers face the problem of determining how and what to evaluate, of defining what constitutes condition and indices, of providing for data storage and of determining how to use condition data. Not only are there are no standard condition indices for water mains (Grigg, 2004), but the challenge for many water utilities is that condition assessments have to be on-going. They can be costly and only provide information for that asset at a specific time. There is also a need for a significant improvement in the level of accuracy in pipeline condition assessment and accurate prediction of pipeline failures (DeSilva *et al.,* 2002).

Deferred maintenance. Deferred maintenance is maintenance that has not been performed or has been deferred. For utilities, managing deferred utility maintenance requires identifying and managing the maintenance that is to be deferred and the compounding effect of maintenance that has not been performed such as not cleaning or repairing water mains. The challenge for water utility asset management lies in managing and integrating the amount of deferred maintenance between the various components that make up a system with the subjective nature of how a maintenance backlog is calculated. For example, most pipe networks are segmented and of differing age, condition, value and consequence of failure. Determining quantitatively the maintenance backlog of that network is very difficult without accounting for reservoirs, pump stations and other assets. Thus there is very little information regarding deferred maintenance of water distribution systems and few if any municipalities can determine their deferred maintenance.

Remaining service life. Managing water utility assets and planning replacement requires estimates of technical and economic service life. Asset managers face funding constraints and competing needs, thus optimizing the expenditures from technical and economic perspectives is important. While technical life may be difficult to predict, determining economic service life is much simpler since it compares the immediate costs of repairs with the costs of renewal. So the question that is often raised as part of the understanding and analysis of pipe deterioration is when does a pipe reach the end of its useful life? One definition of when a pipe reaches the end of its useful life is when the pipe is replaced by a utility. This can be misleading since a utility's decision to replace a pipe may be based on other factors such as political choice, perception of the reliability of the pipe or the need to increase the hydraulic capacity of the pipe. Rajani and Makar (2000) define the time of death of a pipe as the time at which its mechanical factor of safety falls below an acceptable value set by the utility. Kleiner and Rajani (1999) propose that the useful life of a pipe is a function of the economic costs of deterioration rate and replacement and suggest that pipe death coincides with the optimal time of replacement. Statistics Canada defines the service life of an asset as its useful life at the time of its acquisition which generally ends at demolition (Statistics Canada, 2006). According to Deb *et al.* (1998), there are no standardized methods for predicting the life of distribution systems.

Prioritizing. Finally, effective management of water utility assets requires the prioritization of replacement needs. That is, managers must be able to determine what to replace and when to replace it. This issue is closely tied to resolving financial and technical challenges as to whether to maintain, repair or renew an asset or to choose an alternative such as twinning a water main. Because utility managers are usually required to plan annual capital projects, this component of asset management is usually performed. In doing so, they have to overcome obstacles to effective prioritization such as how to address uncertainty when longer-term planning horizons are considered or how to balance the various needs among an organization. Traditionally, utilities have prioritized pipe replacements based on a combination of current management practices and historical pipe breakage data. Management practices include directives based on general guidelines, consequence assessments, legislative requirements and other utility priorities. Rudimentary analyses that interpret historical pipe break data, including location, time and date of break and pipe diameter and material have provided information regarding where and how many breaks are occurring and what pipes are experiencing breaks (Kleiner and Rajani, 1999).

1.4 PREDICTING WATER MAIN BREAKS

A primary goal of prioritizing pipe replacements is to identify investment strategies that, on one hand, avoid premature replacement of pipes (i.e., unnecessary pre-investment of funds), and on the other hand, avoid water main breaks, interruptions in service, potential contamination of water and the costs of damage. If utilities can predict when and where water mains may break, this information is also useful for assisting with optimizing crew efforts and minimizing the results of loss of water to key businesses and critical facilities. Thus asset management decisions can be improved by an ability to determine the future performance of water mains by predicting water main breaks and possibly identifying how such breaks may occur.

Causes of breaks. A number of authors have analyzed the causes of breaks, including O'Day (1982), Male *et al.* (1990), Savic and Walters (1999), Rajani and Makar (2000), Rajani and Kleiner (2001) and Dingus *et al.* (2002). According to Rajani and Tesfamariam (2005), a combination of circumstances leads to pipe failure in most cases and different factors cause failure in different pipe networks. The causes of breaks include deterioration as a result of use (e.g., internal corrosion), physical loads applied to the pipe (e.g., traffic, frost), limited structural resistance of the pipe because of construction practices during installation and declining resistance over time (e.g., corrosion, aging factors). Dingus *et al.* (2002) surveyed the 46 largest American Water Works Association Research Foundation (AWWARF) member utilities in 1997 and noted multiple common failure modes for cast iron piping systems. Corrosion, improper installation and ground movement were the three most common causes of pipe failure.

Break prediction models. Break prediction models have been developed to help the water industry understand how pipes deteriorate and when pipes will break in the future. These models are typically grouped into two classes – statistical and physical-mechanical models (Kleiner and Rajani, 2001). Statistical models use historical pipe break data to identify break patterns and extrapolation of these patterns to predict future pipe breaks, or degrees of deterioration. Physical-mechanical models predict failure by simulating the physical effects and loads on pipes and the capacity of the pipe to resist failure over time.

Statistical models have been used to analyze large distribution systems (e.g., Kleiner and Rajani, 1999) and are typically characterized as either statistical deterministic or statistical probabilistic equations (Kleiner and Rajani, 2001). Under the statistical deterministic models, the pipe breakage is estimated based on a fit of pipe breakage data to various time-dependent equations, which may represent the cumulative pipe breaks as a function of time from date of installation or from the earliest date of available break data, and most commonly are time-linear (Kettler and Goulter, 1985) or time-exponential functions (Shamir and Howard, 1979; Walski, 1982 and Kleiner and Rajani, 1999). Deterministic models were developed as early as 1979.

Statistical probabilistic models predict not only the failure potential, but the distribution of failure. These models are more complex than deterministic models and require more data. Examples of these include cohort survival, such as KANEW (Deb *et al.*, 2002), Bayesian diagnostic, break clustering, semi-Markov Chain and data filtering methods. Survival analysis has been demonstrated by Mailhot *et al.* (2000) as useful if there are adequate histories of pipe failures. Statistical models can use available historical data on past failures to identify breakage patterns and are useful if the data are limited. Statistical methods require some technical expertise in developing the models and interpreting results, but not to the degree of expertise required of staff if physical-mechanical models are used. Kleiner and Rajani (2001) suggest that statistical models based on fewer data may be used to gain insights for future performance.

Physical-mechanical models typically fall into one of two classes: deterministic models which estimate pipe failure based on simulation of the physical conditions affecting the pipe (Doleac *et al.,* 1980 and Rajani and Makar, 2000), and probabilistic models that use a distribution of input conditions, such as rate of corrosion, to predict the likelihood and distribution of pipe failure (Ahammed and Melchers, 1994). Physical models have been developed primarily for cast iron and cement pipes and have significant data needs. Kleiner and Rajani (2001) suggest that only larger diameter mains with costly consequences of failure may justify the required data collection efforts for these models.

Other developments in recent years include the use of Artificial Neural Networks (ANNs) by Sacluti (1999) and fuzzy-based techniques by Kleiner *et al.* (2004). The ANN model predicts the number of water main breaks based on a seven day weather forecast and is applied only to homogeneous groups of water mains for short-term maintenance work. The fuzzy-based techniques are applied to large transmission water mains. In addition, an agent-based system for predicting water main breaks is proposed by Davis (2000).

While much work has been undertaken toward developing deterioration models, the use of these models is not common among utilities. Utilities face obstacles such as a lack of key data, limited institutional capacity within their organization to understand and use models and the complexity in managing work that involves a number of groups. There is no common model that may be applied to every water system. Because the literature suggests that breaks and causes of breaks for any particular water distribution system are system-specific (Rajani and Tesfamariam, 2005), a utility must create its system-specific model based on factors of deterioration that are relevant for the utility.

Small and medium size utilities typically have the capacity to use statistical deterministic models, but the implementation of more sophisticated models is not practical due to the data collection efforts and model maintenance required. As this research demonstrates, statistical deterministic models show promise for use by these utilities because they can be applied using commonly used software, they do not require specialized tools or expertise to operate, and may by their degree of accuracy provide managers with insights into their system on future pipe breaks.

Ultimately, prediction models need data and in particular, data that are relevant for the models and are explanatory for accurate predictions. Data collection regarding water main breaks is not a simple exercise nor is the practice consistent across utilities. For all utilities data collection can have significant costs if performed at a comprehensive level. These costs include not only out of pocket costs but also organizational effort and human resources.

While a collection of best practices have been recommended by the National Guide to Sustainable Municipal Infrastructure (NGSMI, 2002) and AWWARF (*Deb at al.*, 2002), the current state of knowledge of data collected by small and medium size utilities is limited. Recent water utility surveys include those initiated by the National Water and Wastewater Benchmarking Initiative (Earth Tech, 2004), the American Water Works Association, (AWWA, 2004) and AWWARF (Deb *at al.,* 2002). The National Water and Wastewater Benchmarking Initiative, a partnership of a number of Canadian utilities, examines water main breaks as a performance measure but does not examine water main break data in detail. The AWWA database (AWWA, 2004), compiled as a joint effort between AWWA and AWWARF, focuses on generalized data for distribution systems, utility revenue, treatment practices and finances and does not include data on water main breaks except the number of breaks. The survey by Deb *et al.* (2002) reports on responses from five utilities serving populations fewer than 100,000 and 32 with populations greater than 100,000. Thus knowledge of what small and medium size utilities have is needed.

Small and medium size utilities need help with making predictions of the remaining service life of water mains and guidance for integrating data acquisition and analysis programs to improve the prioritization of their water main replacements. They lack knowledge regarding how to develop databases that support their efforts in predicting future breaks and what to do with break predictions. In particular, research is needed to determine the extent of data collected, how the data should be compiled and what can be done to support the use of models within these utilities.

1.5 RESEARCH METHODS

Institutional factors affecting asset management. The research goals were initially focused on designing and conducting experiments to determine key data available in small and medium size utilities and to assist these data with using break prediction models that are applied on a pipe by pipe basis. As the research progressed, it became apparent that an understanding of utility organizational structures, behaviors and practices, as well as a willingness on the part of organization was needed if this research is to influence practice. This is because water utilities are complex organizations with many staff that have various roles, responsibilities and accountabilities. In addition, these organizations face a significant amount of staff retirements and "institutional memory loss" in the coming years. Practices that are easily taught and documented will be important for business continuity.

Furthermore, utilities also cannot rely solely on oral corporate knowledge and need data that are shared among the organization as well as systems that facilitate data sharing. Most utilities are typically comprised of operations, financial, information technology and engineering departments. Operations departments are responsible for operation and maintenance activities, financial departments manage the financial aspects of the utility business, information technology departments maintain and manage data systems, while engineering departments are responsible for the expansion or construction of new network assets. In many utilities, operating departments are responsible for determining which pipes should be replaced. Commonly activities, roles and responsibilities evolve to fit a particular person, their strengths and interests, though these may be inconsistent with the general organizational structure. Data are usually collected and managed on an ad-hoc basis throughout the organization by those who are involved in a specific activity or who have specific interest in the data. No one single person typically coordinates or manages all the data (typically asset management initiatives stall in many organizations due to the inability to dedicate or create a position for this role). Furthermore, within any utility, data may be oral or documented and the format and storage of such data may differ throughout that utility.

In addition, budgets constrain activities in these organizations. Decisions and changes in these organizations are usually based on dialogue among and acceptance by those affected. While practices require approval by senior managers, public policy decisions are referred to municipal councils. The prioritization and scheduling of asset replacement projects are usually performed by groups of individuals or in some cases by one individual and submitted to their municipal council for approval. These factors required developing research methods that could be applied to a variety of organizational structure, technical discipline, knowledge, skill, ability and size.

The District of Maple Ridge. The District of Maple Ridge, the case study for the research is a typical water utility. Maple Ridge was incorporated as a municipality in 1874 and experienced significant urban development over the past three decades. It was used to test the practicalities of applying the framework and approaches developed herein. Maple Ridge was interested in learning and improving its practices. But it was a challenge as a researcher to know, not only for Maple Ridge but for utilities in general, what data were available, to identify potential sources of data, to determine how to access the data, to develop approaches to create useful data from various sources, and to develop a framework for associating, accessing, and managing the data across all functional lines respecting responsibility, management and territorial issues.

For example, in Maple Ridge, data are "owned" and managed by various departments. Water main break data are collected, stored and managed by those operating crews that respond to breaks. Other pipe related data such as pipe material, diameter and age are stored in the Engineering department. The operations department manager who oversees the superintendents and operating crews prepares and submits a list of replacement projects to the individual tasked as the corporate capital program coordinator who then schedules those projects along with all other capital projects (that are submitted by all other departments). The scheduling respects the available annual funding and is based on the submitted information and the coordinator's view of the future needs of the organization. The scheduled projects are then reviewed by the senior managers and the Chief Administrative Officer (more commonly known as "City Manager" in many municipalities) prior to submission to municipal council for approval. Thus the use of Maple Ridge as a case study required the research methods that could identify data in multiple sources, validate historic projected and estimated data, determine the basis of collaborated decisions and distinguish policy and practice.

Research time frame and tools. The research in Maple Ridge began in early 2002 and was completed by mid-year 2006. It is based on three components: firstly, on conducting a survey of North American water utilities, secondly, on creating, linking and mining data and finally, on developing the framework for using prediction models. The data used in the experiments are actual water system data from the District of Maple Ridge. Analytical software used in the research include Microsoft Access® and Excel®, (Microsoft Office 2000 versions), Adobe Acrobat Reader v6, KANEW by Weston Solutions (based on Microsoft Access® Office 97 version), S-Plus v6 and v7 (Insightful Corporation) and Arcview GIS 3.2A and Arcmap v9 by ESRI.

Survey of North American utilities. There were a number of challenges involved in determining the data collection practices of North American water utilities. The best practices indicated by Deb *et al.* (2002) and NSGMI (2002) are fairly recent observations and there are no published reports regarding industry awareness or use of the recommended best practices. Because the best practices recommended in these documents are not exactly the same, it was necessary to reconcile the differences and develop the questions in the survey questionnaire to reflect both sets of best practices.

Another challenge in developing the survey was the need to balance the degree of detail in which I was interested with the effort required of the respondent to voluntarily provide such information. I soon recognized that in order for the survey to fulfill my research goal of identifying the data available to mid-size utilities, the questionnaire would have to be detailed and that the information would not be readily available in one place or with any one person within any organization except within very small organizations. The survey would have to be easy to read, and not discourage utilities from responding to it. It would have to create interest and encourage persistence within those organizations attempting to complete it. The survey would need a layout and format that was easy to read and complete (regardless of the ability of the person completing it), and yet easy for me to compile the responses. While a few electronic formats were examined, it became apparent that the survey would be most easily completed if the forms were sent out as a spreadsheet workbook in order that they could be printed, completed by hand and faxed back or that they could be completed and sent back electronically to me by users (because spreadsheet software is commonly used by utilities). A draft version of the survey was sent to four colleagues, two in Maple Ridge, one in the City of West Vancouver and one in the City of Burnaby for their comments and this allowed me to test methods of electronically compiling the results. Minor editorial and clarification changes were made and incorporated in the final version. The final version included text control (for compiling and analyzing the data) using drop down boxes which also made the survey easier for users to complete.

Another challenge was how to distribute the survey and how to encourage people to complete the survey. I considered giving honoraria but decided against that due to costs. To encourage responses, I noted in the distribution that the results would be shared. I selected email distribution to minimize the distribution costs and delivery time. Not all professional associations I approached to help me distribute the survey were helpful, though most were. Over 400 surveys were directly sent out and about thirty personal requests and specific follow up telephone calls were made. In all, three mailings of the same survey were sent out. The first mailing was sent to members of the Canadian Water and Waste Association

(CWWA). The second to the members of the American Public Works Association (APWA) and third to the City Engineers in the Greater Vancouver Regional District.

The responses were received gradually and the initial deadline for receiving surveys was extended because of a low number of timely responses. The first set of responses was from the CWWA members. The APWA distribution was made through the APWA to its members who were water resources professionals and this mailing generated a large response from a number of U.S. utilities. The CWWA distribution included the spreadsheet file while the APWA email distribution contained a link to the file. The link affected the submission of some utilities as it added another step to the response process and it created confusion on the part of the respondents. In many APWA cases, only a portion of the survey was returned initially and the utilities had to re-send the survey. While a majority of surveys were completed and sent back electronically, a number of responses were returned by fax. The faxed responses were then inputted manually into spreadsheets for processing.

When the responses were received, they were reviewed for errors and text control. The raw data were exported into a Microsoft Access® database. The database was queried and then inputted to a Microsoft Excel® file for data manipulation, analysis and graphing.

Most respondents spent about 45 minutes completing the survey. Of the 70 responses received, 11 responses were rejected as incomplete. These usually had only one or more of the seven spread sheets completed due to the confusion caused by the linking requirement or did not realize that the file contained several spreadsheets. Those surveys were sent back and follow up telephone calls were made where appropriate. The design and development of the survey began in 2003 and the surveys were finally distributed, compiled and analyzed in 2004. A manuscript reporting on the survey, Chapter 2, was submitted to Journal AWWA in 2005 and was published in July 2006.

Data creation. The creation of data described in Chapter 3 was inspired by the survey results that showed a gap between data presently collected and those available (see Figure 2.2 of Chapter 2), as well as by the fact that utilities noted the locations of different data within their various departments. It was also driven by the discovery that the data set purchased from the City of Seattle which was thought to have breadth and history was actually quite incomplete. After repeated correspondences and a site visit to Seattle, it was determined that the data from Seattle could not be used for the experiments. I then contacted four municipalities in the Greater Vancouver Regional District (Burnaby, Richmond, West Vancouver and Coquitlam and reviewed the breadth and history of their data. Yet again I determined that the data provided by these municipalities was insufficient. Thus I decided to use Maple Ridge data, though limited, for input for the experiments because of my ability to access these data, and to collect data from other internal and external sources for this work and for other municipal projects beyond the focus of my research.

Because of its limited data, Maple Ridge is representative of many utilities and is ideal for demonstrating the concepts of finding and gathering data within and external to an organization and of constructing and linking data for asset management. The Laity View area of Maple Ridge was selected to be a case study area because it represents an urban area and experienced construction practices typical for the municipality. It comprises 13 percent of the utility's pipe network. Determining if data were available required meeting with and exploring activities of various work units throughout the organization. The research effort of creating data was significant and the approach and techniques used in doing so are presented in this thesis. These tools are general and may be used by all utilities. New data constructed for Maple Ridge in this research include soil, surface material, water pressure and flow in pipes, bedding and backfill material and traffic loading. Additional activities were carried out to verify data including field surveys of soil and preliminary pipe sampling and analysis.

With different departments collecting and storing data, the process of scrubbing data was not a straightforward exercise. During the process of linking the data, inconsistencies and missing data in the various databases were discovered (e.g., missing material or diameter data or discrepancies between the hydraulic model and GIS data). Typically, I had to delve into the details of those databases to see which data were more current or in some cases, to verify those data using another source. For example, if a pipe had different ages in the different databases (e.g., the hydraulic model and the GIS), I checked the age in each database to ensure that an input error had not been made, and checked the capital works program to see if the pipe had been replaced but that the age of the new pipe had not been updated in one of the databases. I also reviewed the data for consistency with the knowledge I have about Maple Ridge's practices (e.g., policies such as that there should not be asbestos cement pipes installed after 1985). Where discrepancies existed, as-built drawings were reviewed to determine if data were correct. It was unfortunate that data were sometimes lost or deleted (e.g., at Maple Ridge when a pipe is replaced, all records pertaining to that pipe are typically eliminated). In some cases, I was able to verify some data for these pipes, but I was not successful in most cases.

As well, the research required the development of a technique to facilitate creating on-demand databases for analysis and updating. This was required to address the need to obtain data for experiments and to be able to update the original database but also to respect the ownership of the data and the organizational structure.

An example of how creating data. How pipe break records were created for this research and how they are planned to be managed in the future by Maple Ridge is an example of the activities and efforts described above. The break records for Maple Ridge are not stored in any one location but in various files and physical locations and with different staff of the operations department in the operations building (which is separate from City Hall and the engineering department). Because of my experiences with other utilities, I was certain that Maple Ridge had some records on water main breaks. In the course of conversations with various staff over a number of months, I made many inquiries and requests of various operations and engineering staff (with suggestions of who may have the data or where they may be stored, e.g., the archive files, in someone's previous files or in work request logs), I was able to obtain all water main break data for the period 1983-2004. Information regarding water main breaks for certain years was only available from field staff break forms, in paper form, and for other years, it was available on printed computer reports stored in separate files. Once all the records were obtained, the data were reviewed and scrubbed to separate out records of service connection failures (e.g. saddle failures, leaking copper service lines) from those of pipe breaks. Subsequently, an electronic database of the breaks was then created by inputting the data by hand into spreadsheets, identifying the specific identification number (see Chapter 3) of the pipes that broke by locating those pipes on maps using the location data recorded, and adding the GIS pipe identification number as a pipe attribute. The spreadsheets were then exported to a Microsoft Access® database where a new input form was created to allow the addition of future break data from revised field record forms (as discussed in Chapter 3). The storage location of the new water main break database was identified and mapped by those responsible in the engineering department for data warehousing. The database is available to the operations department staff for searching, finding and sharing the raw data. The break data for the Laity View case study was then extracted from the new water main break database for the experiments described in Chapter 4.

While the creation of the database became more mechanical once the paper records were obtained, creating the database required discussion and resolution regarding i) future data collection resources, efforts, quality control and training, and ii) database building, ownership, management and maintenance. A number of discussions and negotiations transpired between the engineering, operations and information technology departments regarding the goals and potential results resulting from pipe break data collection and analysis, the roles and responsibilities for data collection, storage, management and access, and the contribution by each department of staff time and finances. These discussions and my desire to improve data warehousing practices, yet respecting data ownership issues within Maple Ridge, inspired the development of the distributed but related databases for on-demand analysis described in Chapter 3. This portion of the research took from early 2004 until summer 2005.

Framework for using prediction models. This portion of the research experiments was initially based on analyzing the created data to determine if there were key data that are currently available to most small and medium size utilities that could be used in prediction models for improving asset management. The Laity View data set with break history from 1983 to 2004 was used for the experiments and is described in Chapter 4.

The experiments were designed to use statistical deterministic time-exponential and time-linear regression models, survival analysis models and KANEW (Deb *et al.,* 1998). Time-linear and time-exponential models can be used by small to medium size utilities because these utilities typically have the institutional capacity to use spreadsheets or simple statistical software packages. The survival analysis and KANEW (Deb *et al.,* 1998) techniques were applied to determine the suitability of those applications for more adept utilities, even though most utilities may not have the ability to use these more sophisticated techniques or operate the more complex software required.

While not reported in Chapter 4, the application of survival analysis was not successful due to the low number of breaks in the Laity View case which is a young system, the limited breaks in older pipes and the loss of data regarding pipes that were replaced. Survival functions were derived for all the pipe groups described in Chapter 4 but were incomplete for the most part because survival analysis is dependent in knowing the failure history across a large range of pipe ages. There were not enough failures in the older pipes to determine a complete survival function for any type of pipe. As such, it was concluded that survival functions cannot be expected to be commonly used by small and medium size utilities with limited data.

Similarly, the use of KANEW is constrained by the limited break history to derive cohort specific survivals. KANEW, a Microsoft Access® 97-based program was developed based on interviews with utility staff regarding their experience and can be very conservative. I had a number of discussions with the developers of KANEW regarding the program, its development, use, limitations and application. Again, because of the incomplete failure history of pipes in Maple Ridge, KANEW could not be applied with success and was not reported on in Chapter 4. The strength of KANEW is in allowing a utility to develop replacement budgets. Using expected pipe lives from the experiences of other utilities has some value for developing network replacement budgets but is not useful for pipe by pipe replacements.

The experiments reported on in Chapter 4 were conducted during summer and fall 2005, and the analysis was completed in 2006.

Contribution of research. This thesis offers a number contributions for small and medium size utilities and future researchers. It assesses the data collected by utilities, it develops and demonstrates how to create and link data for asset management in general and it explores the underlying causes of water main breaks. Finally, the research develops a framework for utilities to use break prediction models on a pipe by pipe basis to improve their method of prioritizing the replacing of water mains for asset management and to inform their future data acquisition and storage programs. Managers may gain insights from the lessons learned from conducting this research on organizational considerations such as institutional memory, staff training, engineering and operations responsibilities and strategic thinking for asset management. In particular, researchers will benefit from this thesis because it identifies which data are available for developing future asset management tools and how to access and construct water main break data.

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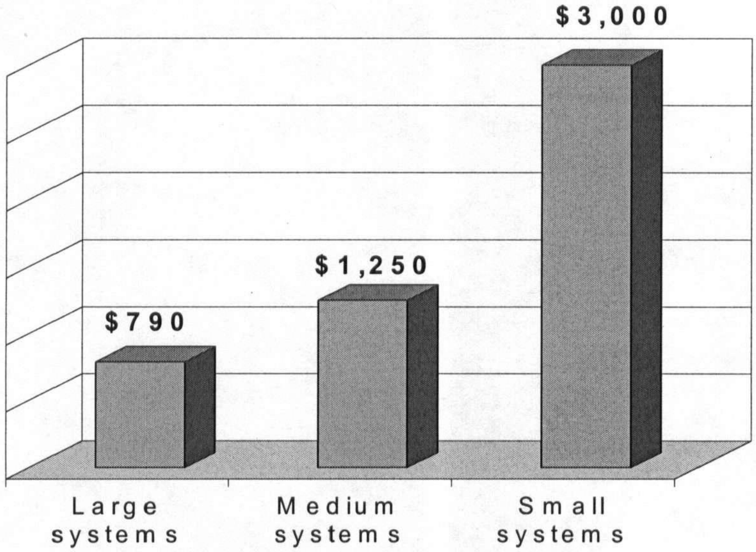
Figure 1.1 Twenty-year total per household infrastructure cost estimates for different sized water systems



Source: USEPA 1999 Drinking Water Infrastructure Needs Survey

CHAPTER 2

ASSESSMENT OF WATER MAIN BREAK DATA FOR ASSET MANAGEMENT

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PREFACE

Much research has been conducted over the years regarding the development of water main break models. But as a manager, I found that none of the medium size utilities with whom I was familiar, used break prediction models to prioritize their pipe replacements. Instead of developing more models, I wanted to find a way to use break prediction models and existing data in asset management and in prioritizing specific pipes and to help other utilities to do likewise. As a manager, I knew that the utility that I worked for did not have a large amount of data which would limit their ability to use models and I wanted to know if the amount of data available was also a hindrance for other similar size utilities.

In addition, as a manager, I was interested in comparing our data collection performance with other utilities and in improving our collection practices. Though best practices for water main break data collection were recommended in 2002 (see National Guide To Sustainable Municipal Infrastructure (NGSMI, 2002) and AWWARF (Deb *et al.*, 2002), I could not find reports regarding the use of the best practices, although Deb *et al.* (2002) had surveyed some large utilities (see Appendix A for a summary of the size of utilities surveyed and the questions posed). Therefore, I developed a survey, the results of which would serve as a foundation for my research and distributed it to small and medium size utilities in order that I might use it to guide my research in developing tools and techniques for improving utility asset management.

I have received feedback on the results such as it is timely and provides managers with a benchmark of what is currently being done by utilities against best practices. Some of the results were presented at the 2006 British Columbia Public Works Association Conference, Qualicum Beach, BC and questions by attendees include: which data are most important to collect, what methods should utilities employ to collect data and how should data be stored and analyzed for asset management?

The raw data regarding survey responses are appended to this thesis.

2.1 INTRODUCTION

Water main breaks can result in loss of water to key businesses and critical facilities, and lead to damage of infrastructure. Such events highlight the deterioration of aging infrastructure, which is at the forefront of policy and program discussions between national and provincial or state governments. The need for aging water main rehabilitation is increasing, the costs of repairs and replacement can be high, and the impact to customers potentially significant (USEPA 2001). For utility managers, collecting, recording and monitoring water main breaks is important, not only because such events may result in significant public impact and destruction of private property, but also because the data obtained from breaks may provide insights for management of the system as a whole. This information is important in developing the tradeoffs between expenditures and the level of service provided, and in managing rehabilitation programs to achieve a desired level of service.

This paper reports on the results of a 2004 survey of water utilities in the U.S. and Canada that determines the degree and types of field information that are currently collected and other data available within different departments of the utility regarding water main breaks. Queries were posed with reference to the best practices recommended by the National Guide to Sustainable Municipal Infrastructure (NGSMI, 2002) and AWWARF (Deb *et al.*, 2002). The survey results identify the data that are deemed important and the approach undertaken for recording and storing these data by different sizes of utilities. The level of confidence that respondents have in some of the data being collected and their level of comfort with the amount and types of data collected, is also identified.

The survey provided the utility managers with a list of data recommended as best practices against which they could assess their own data collection practices. The survey findings are important for the broader infrastructure management community, because knowledge of the data available underpins the development of relevant data acquisition and storage strategies and the advancement of asset management approaches. They also provide utility managers with a basis for gauging their practices relative to those of other utilities.

The survey was developed considering other recent water utility surveys, including those initiated by the National Water and Wastewater Benchmarking Initiative (Earth Tech, 2004), the American Water Works Association, (AWWA, 2004), and AWWARF (Deb *et al.,* 2002). The National Water and Wastewater Benchmarking Initiative (Earth Tech, 2004), a partnership of Canadian utilities, considers water main breaks as a benchmarking measure but does not examine water main break data in detail. The AWWA (AWWA, 2004) database, compiled as a joint effort between AWWA and AWWARF, is based on a 2002 and 2003 survey of 337 small, medium, and large U.S. and Canadian utilities and focuses on a broad range of potable water distribution characteristics including general information regarding service population, pipe material, valves, fire hydrants and flushing, finished water storage facilities, corrosion control, customer metering, water supply auditing, and leakage management. It includes the reported number of water main breaks of the utilities surveyed but does not include data recorded on water main breaks.

The survey reported on in this paper builds on previous AWWA work (Deb *et al.,* 2002), but queried in greater detail the data that are collected by utilities, such as failure causes and the general physical characteristics of the pipe and soil, and had more responses from small to medium size utilities. In this survey, 37 utilities serving populations below 100,000 and 22 utilities serving populations greater than 100,000 responded, compared with five utilities serving populations below 100,000 and 32 utilities serving populations greater than 100,000 that responded to the 2002 survey.

2.2 DESIGN OF THE SURVEY

The survey was designed for ease of completion and compilation into a data base for analysis. Users were able to print the survey and complete it by hand, or complete it electronically using personal digital assistants and laptops. Microsoft Excel® work sheets were chosen due to their common use.

Design of the questionnaire. Based on a review of the literature (NGSMI, 2002; and Deb *et al.*, 2002), the questions posed in the survey were grouped into the following six categories:

- General information such as time of break, customers affected, response personnel and equipment, and cost of repairs;
- Location data such as nearest property address and geographical coordinates;
- Physical data such as pipe material and depth of cover;
- Environmental data such as depth of frost and soil and air temperature;
- Failure information such as type and cause of failure; and
- Repair information such as components replaced, repaired or installed.

The survey respondents were queried regarding how they currently store data related to water main breaks, their estimated level of confidence in selected data, their comfort with the amount of data and the percentage of events for which data are recorded. They were also given the opportunity to list the additional data elements that they collect.

Survey distribution. The survey was distributed by direct email to members of the Canadian Water and Waste Association (CWWA), and members of the American Public Works Association (APWA) who identified in their member profile that they were either directly responsible for, or interested in, water distribution and treatment.

2.3 SURVEY RESULTS

Seventy responses were received and after a review of each response for completeness, 59 surveys were deemed complete and analyzed herein as respondents. The general feedback from the respondents was that, while water main break data collection has been identified as important and a strategic initiative (Grigg, 2004), utilities are just beginning to collect data comprehensively, collection practices vary widely, and most utilities view their efforts as evolving.

The sizes of the respondents range from one utility serving 2,600 people to two utilities serving a population of over one million. Most of the respondents serve populations of between 50,000 and 500,000. The service populations of the respondents are shown in Table 2.1.

General water main break information. General water main break information includes the date and time that a break is reported, the response time and resources used to address the break, and the impact on customers. The percentages of all respondents that collect different general information are also shown in Figure 2.1. All the respondents indicated that they record the date and time when a break was reported. The data related to resources expended on the repair are generally reported in terms of the amount of crew hours spent responding to a reported break. However, only about 70 percent of respondents record labor, materials, and equipment costs and less than 30 percent record the cost of property damage or the effect of the break on customers.

From a management perspective, water main breaks are a liability and thus clear documentation of a report of the break or the request for assistance, and the utility response to the information, are required should claims be filed against the utility. Lengthy break response times may result in significant private or public property damage and can be costly and embarrassing for utility managers.

Only 70 percent of respondents record costs. While this is surprising, it may be due to the difficulty associated with recording some costs (e.g., some costs may only be determined at a later time, such as costs from a claim or for re-paving a road). Some costs may be determined using other sources of data such as through payroll or work order systems. In addition, while managers need to track expenditures for cost control, accountability of resources and planning for future management decisions, they may use different reporting systems and may be required to report the costs for responding to water main breaks only on an aggregate basis.

The survey responses show that few respondents record the effect of the breaks on customers in terms of damages incurred and the number or type of customers that experience a water stoppage as a result of the break or repair. However, the data may be available or calculated if necessary by determining if and where valves were operated to shut off water to sections of a water main and if services were turned off, how long it took to restore the water service. This would allow a utility to calculate the number of customers affected and the length of the interruption as a surrogate for the direct impact on customers. In addition, claims data were also referenced as a potential source of information.

Location data. Location data include the nearest property address, cross street, and geospatial coordinates. The percentage of respondents that record various location data is shown in Table 2.2. Location data along with maps can aid response crews in determining the time and effort of response, the size of main to be repaired, the supplies needed to repair the break and the location of valves that need to be closed in order to facilitate repairs. In addition, recording the location of the break allows future managers to determine if there are repeated breaks in a particular section of water main and may help to assess if rehabilitation or replacement of the main is required.

Most respondents record the nearest property address and cross street name, but few record additional information that can identify the exact location of the break. The survey responses suggest that address and cross street data come from the initial report of the break (i.e., the customer) but are not revised when the actual break location is determined. The fact that data are collected suggests that dispatching a response is the primary motivation for the collection, but that collecting location details that would assist future break analyses is not as high a priority.

The lack of actual break location data may suggest that either respondents find it difficult to record and store spatial data or do not consider the specific location of a break important. The fact that few respondents record whether isolation valves are operated can make it difficult for utility managers to determine the number of customers affected by a break and a repair. The use of Geographic Information Systems (GISs) for storing information and visualizing break data, and the low cost of Global Positioning System (GPS) survey equipment, may change this practice in the future. GIS-stored location information may ultimately enhance decision-making regarding rehabilitation and replacement.

Physical data. The data typically classified as physical include: the age, material and characteristics of the pipe, and surrounding soil. The results reported in Figure 2.2 show that most respondents collect a narrow variety of physical data. Most respondents record data that include pipe diameter, pipe material, water service type, cover depth, and whether the surface is a roadway or other surface.

The lack of physical data collected by respondents may be attributed to the fact that water main breaks are typically treated as emergency situations in which the goals are to contain damage, repair the break, and restore lost water service to customers or that some information on the physical characteristics of water mains may be available elsewhere in the data warehouse of the utility, such as in as-built records, or in GIS form. When other data sources are accounted for, the percentage of respondents that possess the various data elements increases. Analysis of the survey results suggests respondents and utilities can be classified, according to the richness of the data recorded, into four groups. These groups include utilities possessing:

i. basic data consisting of pipe size and material;

ii. basic material and diameter data plus limited information such as age of the pipe, use of the surface at ground level, operating pressure, and type of pipe joint. If pipes in a network are failing at joints, details about joints can be used to develop a strategy to anticipate, prevent, and repair breaks;

iii. in addition to the data described in (i) and (ii), data on construction of the water main; and

iv. in addition to data described in (i), (ii), and (iii), detailed pipe information such as pipe wall thickness and pipe fracture toughness (typically as a result of pipe testing).

Failure causes and modes. An important aspect of water main break data is the nature of the failure. Though the mode of failure cannot be definitively correlated with specific causes of the failure, they may indicate a failure mechanism and suggest a cause of failure for analysis by asset managers. The survey queried the respondents regarding eleven common failure modes and the responses to the survey show that 85 percent of respondents record leaking joints, valves, hydrants and service connections and between 70 and 83 percent record the remaining seven failure modes. These failures modes are: leaking joint, leaking service connection, leaking valve, leaking hydrant, longitudinal break, blow-out, split bell, corrosion pit hole, curb stop failure, tap failure and failed blow-off (i.e., air release valve). Respondents could also select an "other failure modes" category in the event that the failure is different from the list of failure modes provided. No other modes were reported.

While utilities are able to determine and record the failure mode, only 25 percent of respondents record the cause in 100 percent of their records, 37 percent of the respondents record the cause in 75 percent of their records, and only 40 percent of respondents record a cause in at least 50 percent of their records. This suggests that few respondents have a consistently high level of information on the causes of breaks to their water mains. The different causes of failure and the percentage of respondents that record a specific cause of failure are shown on Figure 2.3.

The analysis of data shown in Figure 2.3 suggests that it is difficult for respondents to determine the cause of failure. Managers may find that in their organization, breaks are treated as emergency situations and the utility staff at the scene of the break focus on controlling the extent of collateral damage from the break. Also, some specialized engineering background is required to confidently determine the cause of breaks under response situations.

Repair activities. While it may be difficult to determine and record the cause of breaks, the response regarding the recording of repair activities is high. The data in Figure 2.4 show the percentage of respondents that record a specific repair activity. Repair activities typically include repairing clamps and joints or replacing sections of pipes, valves, hydrants, and connections. This could be explained by the fact that utilities can more readily record response actions in the field than determine the cause of a water main break.

Environmental data. Environmental data related to water main breaks include information such as air temperature, soil acidity, and moisture, and other antecedent conditions. The environment is important for water mains as the National Research Council of the National Academies (2005) identifies that water main breaks and their repairs are also potential gateways to contamination of the water distribution system. The survey responses show that very little environmental information is collected by respondents. Only 12 percent of the respondents record environmental data for all of their water main breaks and only 27 percent record any environmental data at all. In fact, environmental data is the least recorded group of information for all of the respondents.

If a respondent collects environmental information, most likely it is information on the depth of frost (27 percent of respondents). Less than 10 percent of the respondents take soil samples. This is surprising as it is well publicized that there is a significant relationship between external corrosion of water mains and soil conditions. Figure 2.5 shows the percentage of the respondents that record a given type of environmental data, or can obtain the data elsewhere either within the utility or from sources external to the utility such as other agencies. In some cases, a significantly greater percentage of respondents indicated that more data are available from other sources than are recorded.

Hydraulic models. When asked whether the utility has a water model and whether it is used, 78 percent of the respondents report having a hydraulic model. Only 71 percent of the respondents use these models for some purpose. The most popular uses of models in descending order of popularity (i.e., based on the percentage of respondents) are for capital planning (69 percent), development planning (61 percent), operations (56 percent), and maintenance purposes (42 percent).

Confidence in data. A key survey question regards the level of confidence that a utility places on the physical data that it collects. Utilities were asked if their confidence in the data collected is high. The intent was to determine not only the level of confidence but also if this level varies by data type. The confidence of the respondents in selected parameters is summarized in Figure 2.6. As shown in Figure 2.6, at least 72 percent of utilities have high confidence in pipe diameter and material, but only 48 percent are highly confident about the year of installation.

Level of comfort with the amount of data collected. Utilities were asked to indicate their level of comfort with the amount of data collected. Sixty-four percent of the respondents were comfortable with the amount of data collected. However, 22 percent were not comfortable and 14 percent had no opinion regarding their level of confidence in the data collected. The level of comfort with the amount of data collected varies with utility size. Between 50 and 60 percent of respondents with service populations between 10,000 and 100,000 and approximately 70 percent of those serving between 100,000 and 500,000 are comfortable with the amount of data collected. Both respondents with service populations greater than one million were also comfortable with their data.

Sources of data available to utilities. The additional sources of physical data for the respondents are summarized in Table 2.3. The number of respondents that indicated that data were available from the other sources is also listed. For example, 46 percent of respondents identified other sources for obtaining normal operating pressures. Managers may use this table to consider similar data sources within their organization. They may also be encouraged to determine if this information is available from other sources that are not as yet identified.

Storage of data. Different sizes of utilities have different means of data storage. The use of a GIS as a data management system is greatest for respondents that serve a population of between 50,000 and 100,000 (four of these ten communities use GISs), and archival records are the predominant source of data for utilities that serve a population of between 10,000 and 50,000 (eight of these fourteen communities use archival records). Of the fifteen respondents that serve a population of between 100,000 and 500,000, seven use archival records (such as as-builts and other paper-based historical records) as a source of water main break data, and four use GISs.

Statistical confidence of the survey results. Although the number of respondents is low, the survey results can be used to draw some inferences regarding the practices of water utilities in general. A statistical analysis of the significance of the survey sample for providing observations for the general Canadian-U.S. utility population was undertaken. The accepted measure range of confidence limits is calculated using Wild and Seber (2000), to be between 11 percent and 13 percent for this survey. This is to say that if 63 percent of the respondents indicate that they record when water service is restored, we may expect that more than 50 percent (i.e., the lower confidence limit) but less than 75 percent (i.e., the higher confidence limit) of all water utilities in the general population would record the same. Appendix B summarizes the statistical confidence of these results.

2.4 DISCUSSION AND RECOMMENDATIONS

While all respondents are collecting data, they clearly do not collect all data suggested by best practices recommended by the National Guide to Sustainable Municipal Infrastructure (NGSMI, 2002) and AWWARF (Deb *at al.*, 2002). However, based on the responses it is apparent that data acquisition is evolving and that there is a strong interest in comparing their practices with others and with best practices.

Feedback from the respondents indicates that the average respondent spent about 30 to 45 minutes completing the survey. This is in addition to the time that respondents spent determining the appropriate people within the organization to complete the survey. Such decisions are common among larger organizations where responsibilities for data collection, management and analysis are shared.

The amount of data that respondents and utilities in general have can be categorized into general classes of data richness. Based on the survey results, it is suggested that four classes exist. These are: expanded, intermediate, limited and minimal data set classes. As shown in Figure 2.7, the proposed data set classes are based on the breadth and record length of data irrespective of the traditional data categories such as break, pipe inventory, and operational data because the survey results indicate that many respondents collect data in varying amounts in each of the traditional data categories. ***Expanded data sets*** are comprised of information, and records over a long period of time. These may include: an inventory of pipes that is correlated to pipe information such as diameter, material, year of installation, type of joint, surface cover, type of failures, probable cause of failure, type of repair, pipe testing information such as pipe wall thickness at time of break, type of pipe lining, soil testing information such as corrosivity, and pH. ***Intermediate data sets*** are comprised of information on inventory and pressure zones, a break history of some length of time, and some amount of information regarding pipe diameter, material, age, exterior surface condition, and installation, surface cover, and pipe protection. A utility possessing information with this degree of data richness has generalized descriptions regarding the type of failures encountered and probable cause of those failures. This case is similar to the expanded data case but does not include pipe and soil testing data although installation details may be available. ***Limited data sets*** have only limited information on the pipe network, surface uses and loads. This would be an inventory, information regarding pressure zones and generalized problem areas, a break history of a minimal length of time, and a nominal amount of information regarding pipe diameter, pipe material, year of installation, and surface cover. Under this case, the information comprising the intermediate data set is significantly reduced. ***Minimal data sets*** are comprised of pipe lengths, identification of pressure zones, generalized problem areas, and nominal information regarding pipe diameters.

Given that asset management is becoming important for utility managers, more attention and effort should be given to improving data collection in the following areas:

Collect for the future. Managers need to consider the long view when assessing their data collection strategy. Water main break data will be useful for future asset managers who will have to make difficult investment decisions regarding which pipes to replace. Estimates for the U.S. (USEPA, 2002) suggest that the capital needs for drinking water in the U.S. for the period between 2000 and 2019 range from 154 to 446 billion U.S. dollars. There are no similar estimates for Canada. Future managers will need to make wise decisions to take into account not only the ability of the public to afford replacing these pipes but also the scarcity of human resources and capital to actually perform the work. Because the practice of infrastructure asset management will evolve, data requirements for making critical decisions are important but can also be expected to grow. Thus, the data collection strategy for utilities should be to gather the data recommended as best practices keeping in mind that much of the data will be useful for future management decisions rather than for today's decisions. It will likely take some time to establish a data record of sufficient length to support such decisions. Many managers may resist this approach because they may prefer to know what is needed and why before embarking on data collection programs. In some cases, such a strategy may be undertaken with little additional effort. For example, a utility may be able to accumulate more information by collecting additional information as part of existing tasks, such as a description of the failure mode, bedding, backfill and depth of cover. To facilitate asset management, data collection efforts should also include, where possible, the types and causes of breaks, and the physical data of all mains so as to provide a deeper understanding of the failure modes and mechanisms.

Record data effectively. For collection practices to be effective, utilities need to record data continuously, consistently, and accurately. Data should be collected on all breaks to ensure that the records portray the state of the whole system. Missing records may create a level of uncertainty regarding the records that are collected and undermine the confidence in conclusions drawn from technical analyses and lead to organizational frustration.

In order to record data in a consistent manner, the use of standard operating practices, procedures, and forms as well as training for those who collect data are important. If a utility is already collecting data, a review of all data collection forms is useful to ensure consistency in methods as well as to expand the data collected if appropriate. An audit of the records for quality and accuracy should be undertaken periodically. A suggested model for an audit exercise is the formation of a quality control group within the utility to audit the data and ensure quality across the organization. This group could also develop guidelines of practice for educating staff.

The most efficient approach for recording data will vary among utilities and should reflect business and work flow processes and organizational structure of the utility. Many utilities may have different departments, such as laboratory, maintenance, technical, and financial departments, and response teams that collect or generate information. In such cases, it may be beneficial to bundle or group data based on organizational departments and develop a process for ensuring that the data are collected, assessed for relational links related to other data, recorded and stored in an effective manner. For example, data forms could be circulated among selected departments within the organization to collect input data comprehensively and to improve the sharing of information among departments, or depending on the data and organization, the data collection process between departments could be independent but linked or related via an asset index.

The storage of data can be undertaken in various ways (see Table 2.3), or in a comprehensive data warehouse. Some utilities prefer a comprehensive data warehouse to facilitate the synthesis and visual representation of data and view GIS technology as the ideal tool for this purpose.

Alternate sources of data and relating data. The survey results clearly show that alternate sources of data related to water main breaks exist in many organizations. Table 2.4 summarizes the potential range of information sources identified in this work for different data elements. For example, current and future capital project designs, as-builts, or asset pro-formas can be used to capture information such as specifications, test pit logs, and inspection records.

Utilities may wish to consider the concept of a data web, which may be thought of as a relational structure of the utility's data sources, including break records, maintenance reports, pipe and soil samples, customer information, archival systems, hydraulic model output, capital rehabilitation planning data, GISs, and maintenance management systems. The links between these data sources, support the web, and are keyed to some index of the asset, for example, a pipe identification number. The use of the links reduces the need to convert data when a new information management system is developed and implemented and facilitates the synthesis of existing corporate data for specific analyses. A data web is not a data storage application nor software, but a concept of relating or linking data and separate data sources in an organization to each other. While the development of a data web for a utility reduces the need to convert and store data, the addition of data elements in each data system, such as the asset index (e.g., corresponding to a pipe identification number) may be required. A well-designed data web would enhance utility management, particularly for small communities who cannot afford wholesale data management system implementation, conversions and upgrades. Design considerations may include identification of the architecture of the web, the characteristics and number of required links, and the appropriate connections between the elements to be "webbed". Tacit information or knowledge that is currently not recorded can also be linked within the web.

Decision support tools. In developing decision tools for supporting asset management, utilities should consider a range of systems that are flexible and easily accessible for both present and future uses. The systems should be reliable and maintained over time. Data that have been collected are useless if the decision makers within the organization cannot access them or are unaware of their existence.

Analysis of the survey results suggests that decision support tools for prioritizing the replacement or rehabilitation of water mains should be tailored to the degree of richness of the data available to a utility. Utilities that have a minimal amount of data cannot use sophisticated tools such as physical (Rajani and Makar, 2000) or statistical pipe deterioration models (Shamir and Howard, 1979; Jacobs and Karney, 1994; Andreou *et al.*, 1987; Kleiner and Rajani, 1999), or life cycle costing. These tools, and most recent research in water distribution asset management have focused on utilities that possess large amounts of data and more research is required to develop robust approaches for utilities with limited or minimal data records. These tools should also be flexible enough to adapt as utilities increase the amount and types of data collected.

2.5 CONCLUSIONS

Studies, even as recent as in 2004, have identified the need for standardized main break databases and terminology and continued research regarding database development as strategic for informed infrastructure management (e.g., Grigg, 2004; O'Day *et al.*, 1986). The results of the survey reported herein indicate that water main break data collection is evolving, that industry practices do not match best practices recommended by the National Guide to Sustainable Municipal Infrastructure (NGSMI, 2002) and AWWARF (Deb *et al.*, 2002) at this time, and that most respondents recognize the need for a strategy for data quality improvement. The data-related challenges that all utilities face include difficulty in mobilizing financial and human resources, absence of historical data, lack of knowledge of current organizational practices, low reliability of previously collected data, difficulty in prioritizing data collection, and the need to develop effective data storage programs.

While it is generally accepted that the use of reliable data regarding asset inventory and condition will enhance the management of municipal infrastructure (Vanier, 2001), the feedback from the respondents is that data collection practices regarding both inventory and condition vary widely. General data regarding customer location, time of break, and emergency response actions are typically available, but information regarding specific pipe location and physical attributes is inconsistent. Most respondents do not have a consistently high level of information regarding causes of failure and soil and pipe sampling are generally not undertaken. Confidence in and comfort with the amount of data collected varies; mid-size respondents expressed the least level of comfort with the amount of data collected. Many respondents identified additional sources of information including archival, operation and maintenance and GIS information, and hydraulic models. Moreover, having a hydraulic model does not guarantee that it is used. This may depend on the staffs' ability to operate and maintain the model and on the reliability and currency of the input data.

While both physical and statistical models have been developed for predicting pipe deterioration and for developing water main rehabilitation plans, it is evident that the choice and application of these models are limited by the data that utilities have regarding water main breaks (Rajani and Kleiner, 2001; Kleiner and Rajani, 2001). In general, utilities can be classified as those possessing expanded, intermediate, limited or minimal data. Characterization of these classes may be used to inform the development of new asset management techniques such as condition models or heuristics and new ways of effectively collecting, storing, combining, and representing water main break data. This is a subject of a forthcoming paper by the authors.

2.6 ACKNOWLEDGEMENTS

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Table 2.1 Service population of respondents

Service Population	**>1,000 but ≤5,000**	**≤10,000**	**≤50,000**	**≤100,000**	**≤500,000**	**≤ 1 million**	**>1 million**	**Total**
Canadian utilities [a]	1[b]	2	8	9	6	3	1	**30**
U.S. Utilities [c]		1	13	3	11		1	**29**
Total responses	1	3	21	12	17	3	2	59

a) Canadian respondents were from Alberta (5), British Columbia (9), Manitoba (2), New Brunswick (2), Newfoundland (1), Nova Scotia (1), Ontario (6) and Saskatchewan (4). An incomplete survey was received from one Quebec municipality so its response was not included in the analysis. Admittedly, the survey was in English and may be a reason for the low number of responses from Quebec.

b) Population served is approximately 2600.

c) U.S. respondents were from Alaska (1), Arizona (1), California (3), Colorado (1), Florida (1), Illinois (1), Kansas (2), Massachusetts (1), Maryland (1), Michigan (1), Minnesota (1), Mississippi (1), North Carolina (1), Nevada (1), Pennsylvania (1), South Dakota (1), Tennessee (1), Texas (3), Utah (1), Washington (4) and Wisconsin (1).

Table 2.2 Percentage of respondents that record location data

Location Data	**Percentage of respondents that record location data**
Nearest property address	93%
Cross street name	78%
Distance from cross street	44%
Isolation valve operated	36%
Distance from nearest property line	34%
Coordinates (northing and easting)	10%

Table 2.3 Additional sources of break-related physical data for respondents

	Number of respondents having additional sources	Archival	O&M[1]	GISs[2]	Other
Normal operating pressure	27	X	X	X	Models, fire flow tests
Traffic classification or type of road usage	23	X	X	X	External sources and traffic management systems
Year of installation	22	X	X	X	
Typical flow in area of break	21	X	X	X	Models
Pipe wall thickness / classification	19	X	X	X	External sources
Type of pipe lining	16	X	X	X	External sources
Length of pipe segment containing the repair	14	X	X	X[3]	
Pipe protection (wrapped / anodes)	13	X	X	X	
Under boulevard or roadway	12	X		X	External sources
Surface material	11	X		X	Pavement management systems
Depth of cover	9	X	X		
Type of joint	8	X	X	X	
Bedding material	8	X	X		
Type of water service	7	X		X	
Category of native soil	7	X	X	X	
Pipe fracture toughness	4	X	X		External sources
Backfill material	4	X	X		
Pipe modulus or rupture	3			X	External sources
Pipe sample collected	2	X			Main tappings

Condition of cement lined pipe interior	2		X [4]		Models
Pipe material	1	X			
Pipe diameter	1	X			
Condition of unlined pipe interior	1	X			
Condition of bedding	1	X			
Condition of pipe exterior	1	X			

1 *Operation and Maintenance records (O&M)*

2 *Geographic Information Systems (GISs)*

3 *GISs are the most popular source of length of pipe segment containing repair data.*

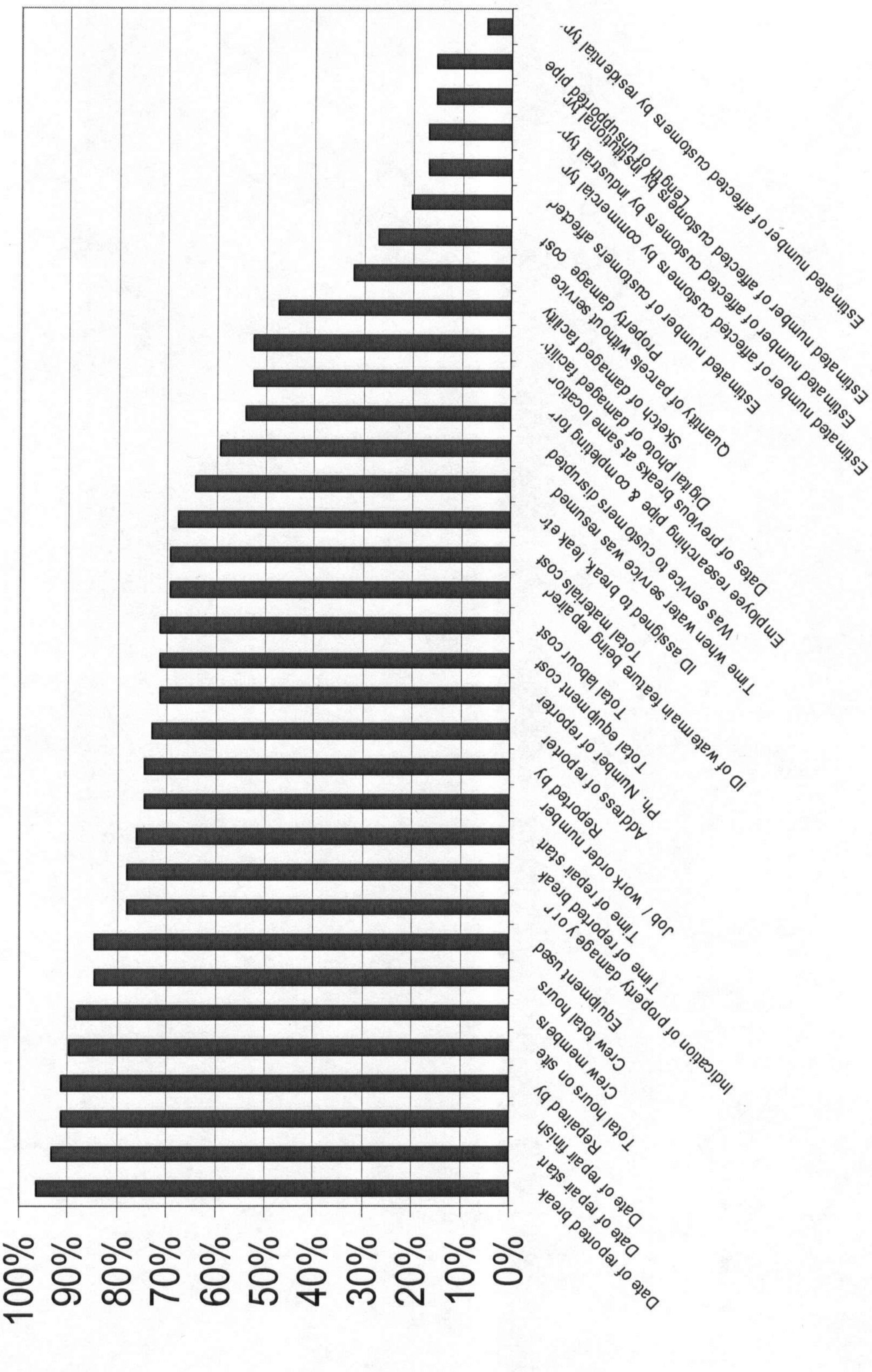
4 *Evaluated with swabbing.*

Table 2.4 Suggested sources and approaches for collecting physical data on water main breaks

Physical data	**Suggested sources of information**
Pipe diameter	Best captured in the field during break repairs and available from as-builts
Depth of cover	Best captured in the field during break repairs and available from as-builts
Pipe material	Could be captured in the field during break repairs, available from as-builts and analyzed off-site, e.g., in a laboratory for determining the different types of cast iron pipes
Condition of bedding	Could be captured in the field during break repairs and also obtained with extra field work
Category of native soil	Could be captured in the field during break repairs, determined from other records and also could be analyzed in a laboratory
Condition of unlined pipe interior	Could be captured in the field during break repairs, and also could be analyzed in a laboratory
Condition of pipe exterior	Could be captured in the field during break repairs and slo could be analyzed in a laboratory
Type of water service	Could be captured in the field during break repairs or from other sources of information (e.g. land use plans)
Surface material	Could be captured in the field during break repairs or from other sources of information (e.g. models)
Surface use (under boulevard or roadway)	Could be captured in the field during break repairs or from other sources of information (e.g. model)
Traffic classification or type of road usage	Could be captured in the field during break repairs or from other sources of information (e.g. transportation plan, traffic models)
Length of pipe segment containing the repair	Could be captured in the field during break repairs or obtained with additional field work, or from as-builts or GIS
Bedding material	Could be captured in the field during break repairs, may be available from as-builts and other sources and/or bundled with information gained through additional field work
Pipe protection (wrapped/anodes)	Could be captured in the field during break repairs, may be available from as-builts and other sources and/or bundled with information gained through additional field work

Physical data	Suggested sources of information
Type of joint	Could be captured in the field (bundled with information gained through additional field work or from other sources of information (e.g., archives or construction inspection records)
Year of installation	May be available from as-builts or other archival records such as construction inspection reports
Backfill material	May be available from as-builts or other archival records such as construction inspection reports
Typical flow in area of break	Technical tools (e.g., models)
Normal operating pressure	Technical tools (e.g., models)
Condition of cement lined pipe interior	May be available from as-builts and better analyzed in a laboratory for current condition
Pipe modulus of rupture	May be available from as-builts and better analyzed in a laboratory for current condition
Type of pipe lining	May be available from as-builts and better analyzed in a laboratory for current condition
Pipe wall thickness/classification	May be available from as-builts and better analyzed in a laboratory for current condition
Pipe fracture toughness	May be available from as-builts and better analyzed in a laboratory for current condition

Figure 2.1 Percentage of respondents that collect general information



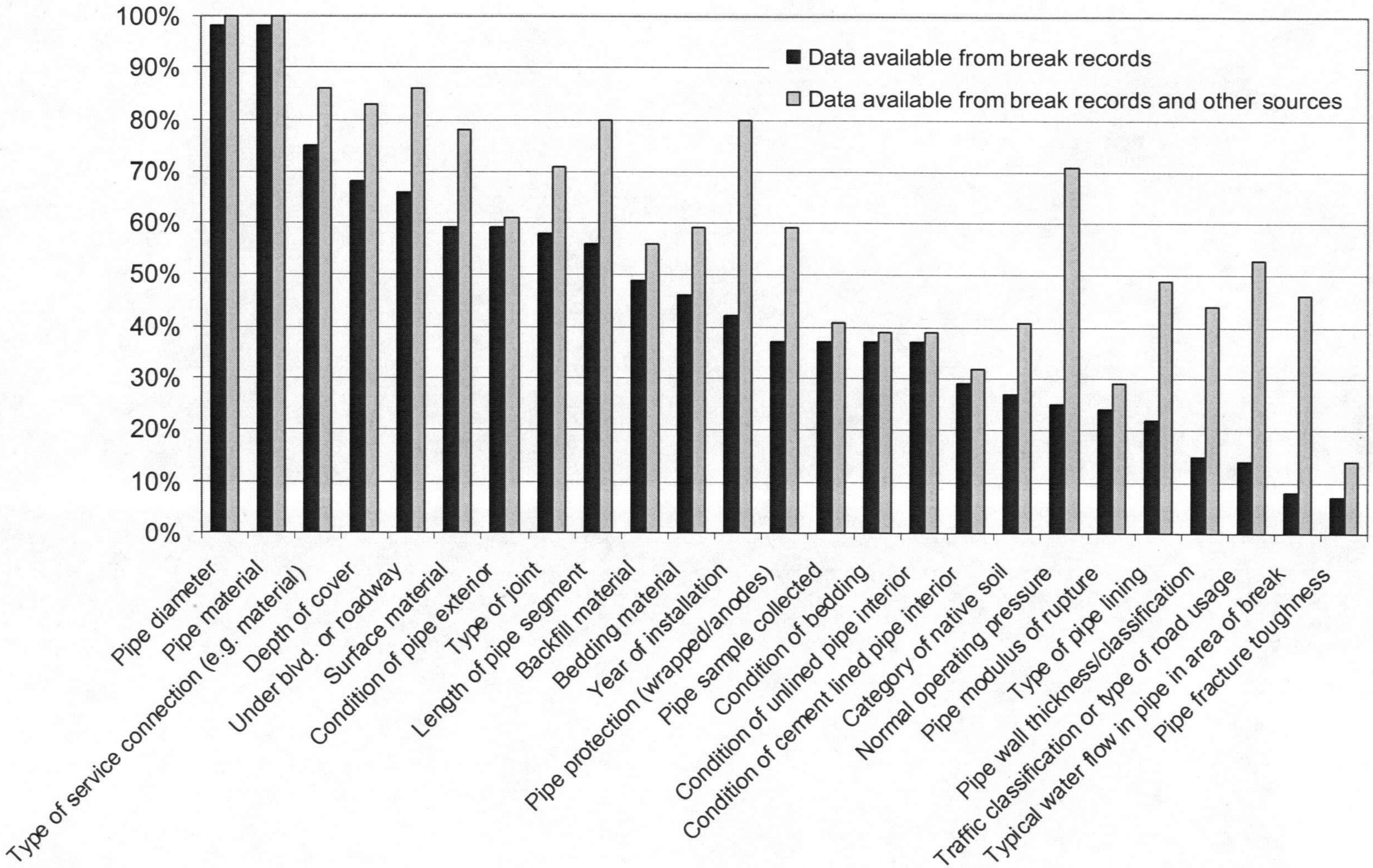


Figure 2.2 Percentage of respondents that record physical data

Figure 2.3 Percentage of respondents that record failure causes

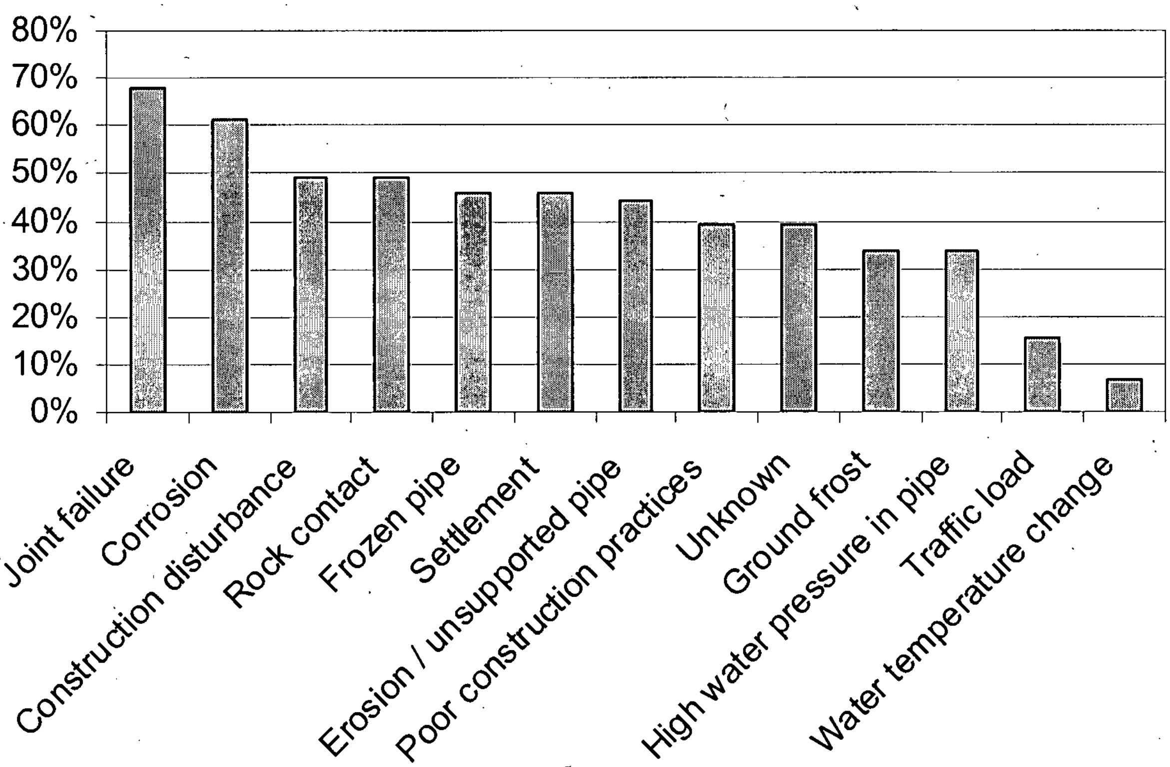


Figure 2.4 Percentage of respondents that record repair activities

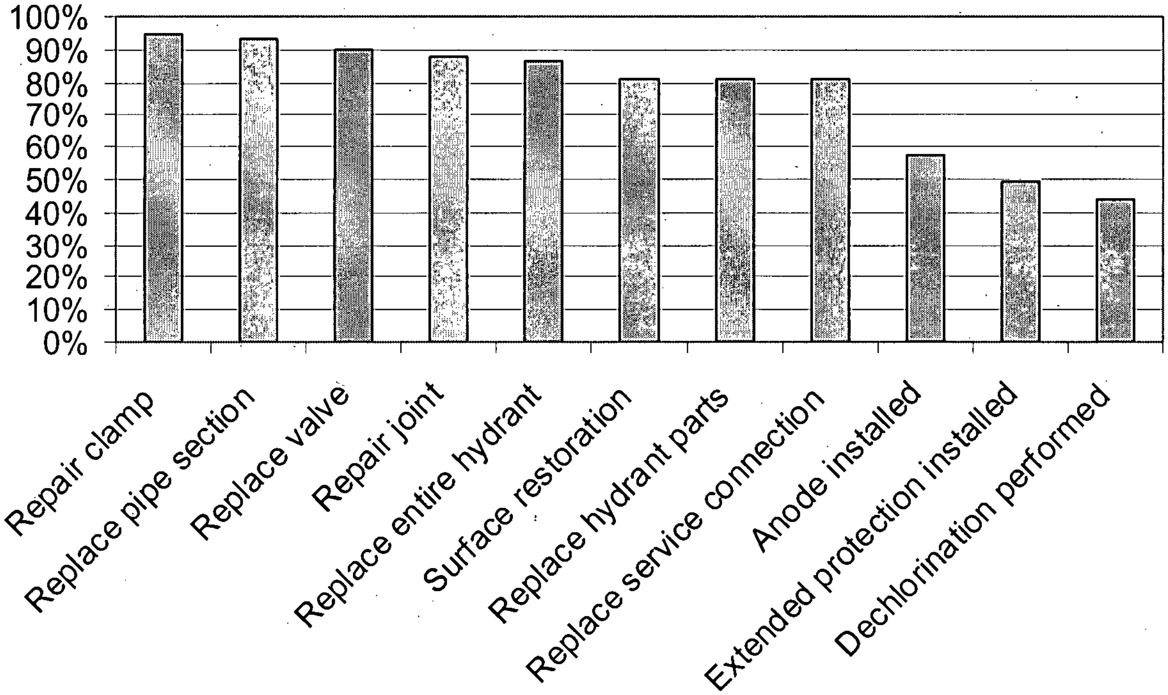


Figure 2.5 Percentage of respondents that collect different types of environmental data

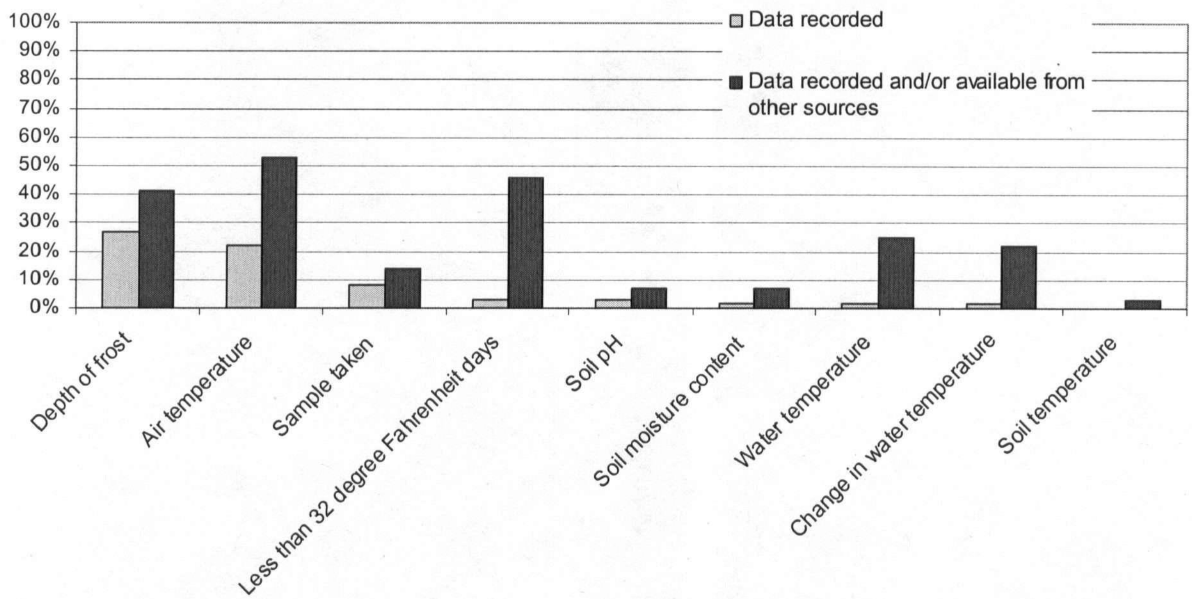


Figure 2.6 Percentage of respondents that expressed confidence in data collected

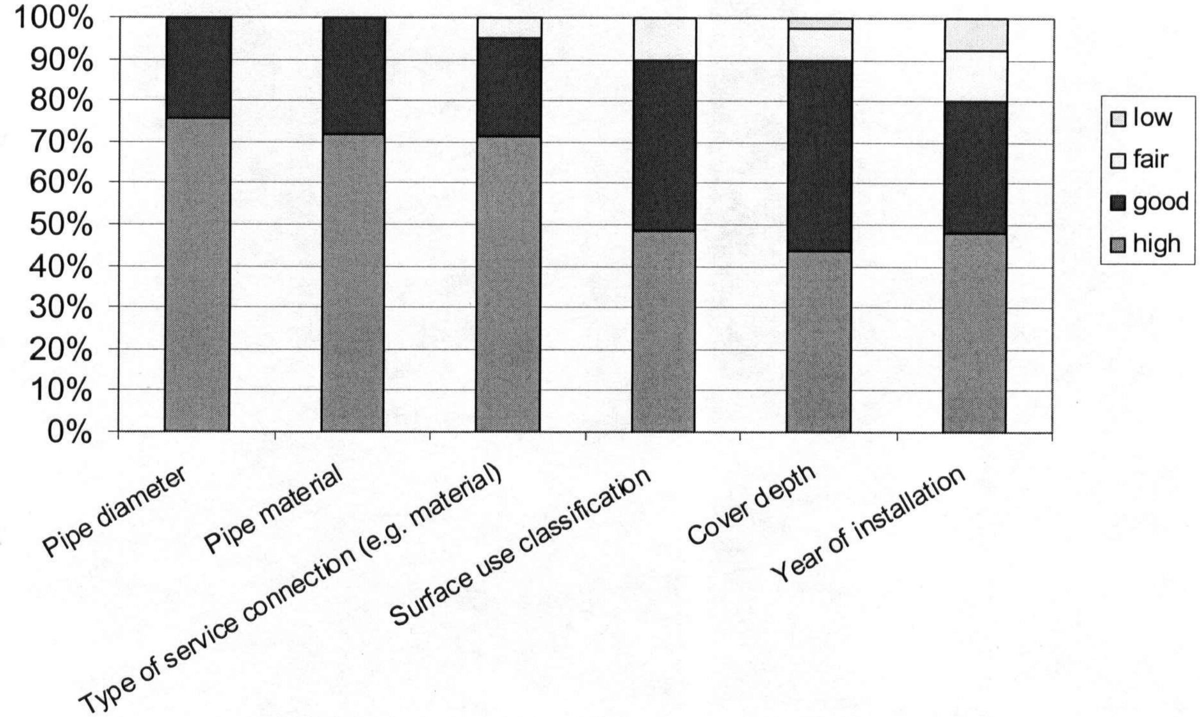
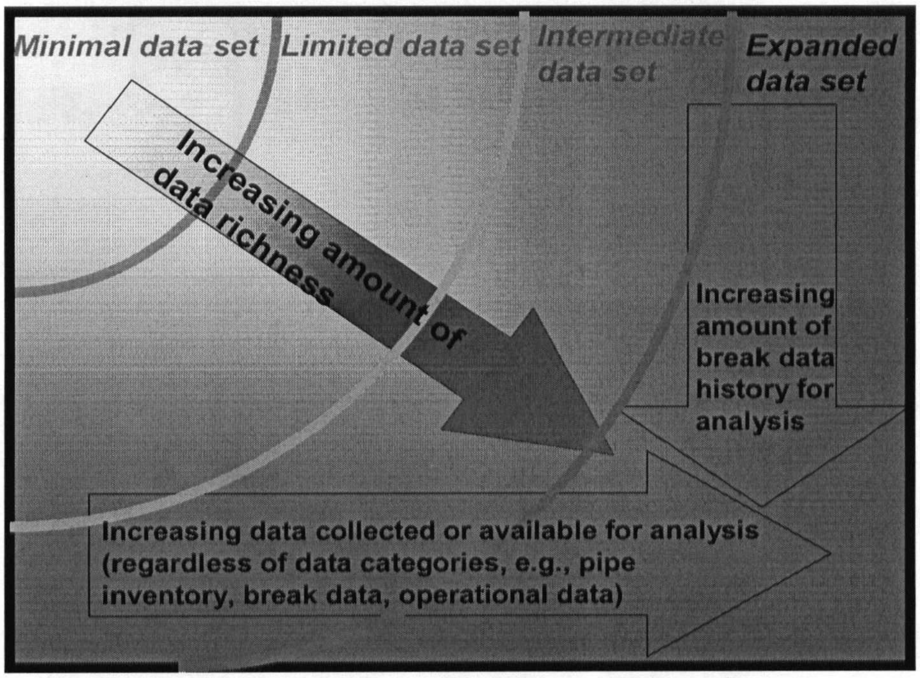


Figure 2.7 Classes of data richness among water utilities



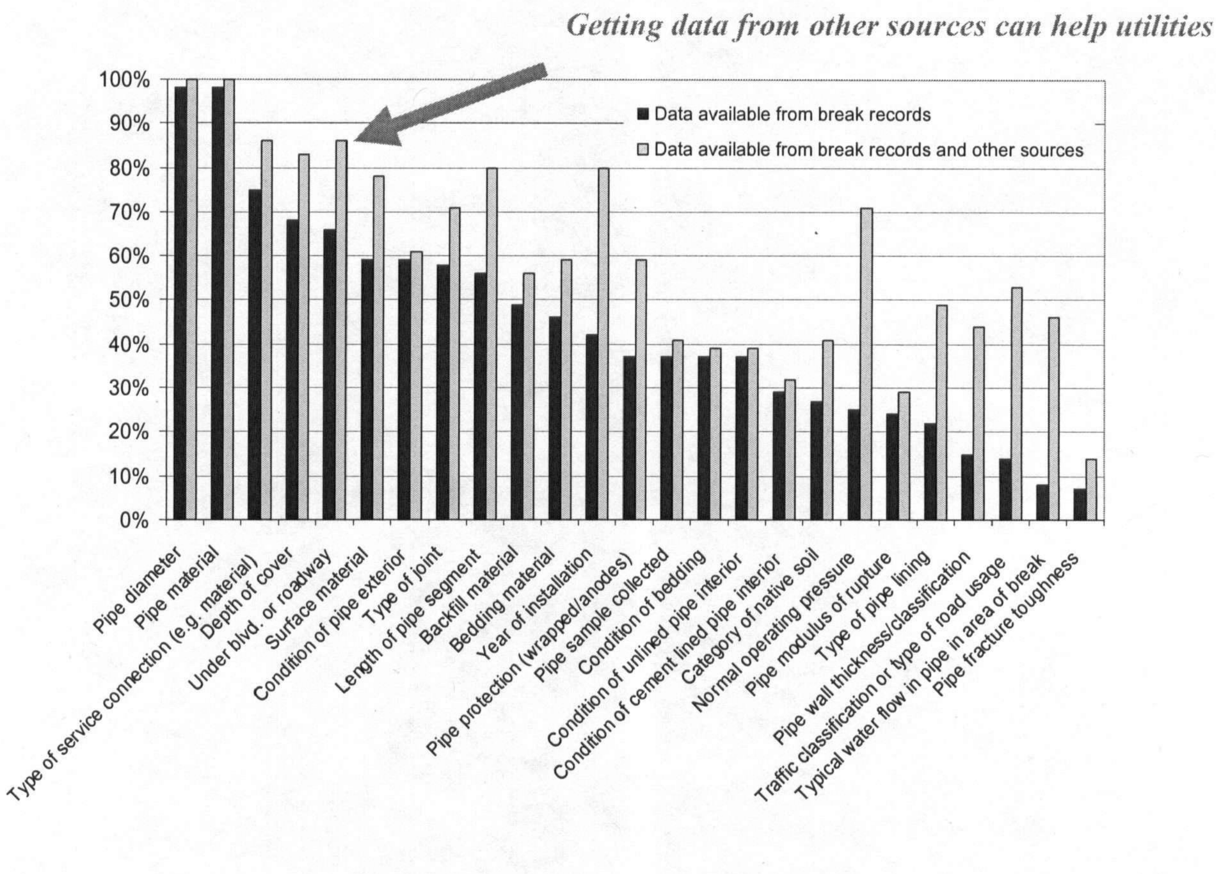
CHAPTER 3

CONSTRUCTING WATER MAIN BREAK DATABASES FOR ASSET MANAGEMENT

A version of this paper has been accepted and scheduled for publication in the January 2007 issue of Journal AWWA. The paper is titled as Constructing Water Main Break Databases for Asset Management by A. Wood, B. J. Lence and W. Liu.

PREFACE

The survey results as reported in Chapter 2 confirm that a number of sources of data exist for use in analyzing water main breaks. In fact, the figure shown below (reference Figure 2.2) inspired my interest in developing an approach for obtaining and maximizing data from different sources internal and external to the utility. If utilities can obtain and integrate data from a wide variety of sources for analysis, they should be able to improve the breadth and richness of their water main break data for asset management.



A key consideration for utilities is storage and management once the data are created. The focus of how to manage data in the Asset Management Systems currently being marketed is on consolidating all data into one large database (e.g., MAXIMO and

Hansen). Converting and consolidating data into one database is expensive, resource intensive, and creates data ownership conflicts. It is unrealistic to expect small and medium water utilities to make the financial and organizational investment to achieve such as database and thus this is a significant barrier to improving asset management. The research presented in this chapter describes an approach for accomplishing the acquisition and integration of data from other sources for analysis and may be used to foster discussion between various departments on how asset management data can be managed and coordinated within an organization. The research provides techniques and approaches for creating data, constructing databases and relating those databases to each other. Most importantly, this work can be applied to practice, and has been the case of the Laity View area of Maple Ridge.

For Maple Ridge, the research resulted in the construction of a water main break database, the compilation of soil type data with which to analyze the relationship between soil and water main breaks, a review of the current water main replacement policy (of solely replacing asbestos cement pipes), a survey of soil and corrosion potential and a renewed staff interest in improving the process and framework of deciding why, which and when pipes should be replaced. In addition, the approach of constructing databases from different sources and relating databases has been adopted by staff for dealing with all water system data and is being explored for use with Maple Ridge's sewer system.

3.1 INTRODUCTION

The traditional public works emphasis on managing water main breaks has been directed toward minimizing the loss of water to key businesses and critical facilities (such as hospitals and industrial plants) and minimizing the damage to built and natural infrastructure. However, breaks are also potential gateways to contamination of the water distribution system and have been identified as a high priority in the assessment of water supply health risks by the National Research Council of Academy Sciences (2005).

Predicting water main breaks to reduce such risks and optimize the investment in aging infrastructure requires reliable pipe data. These data include age, diameter and material for the subject distribution system and the number and nature of breaks that occur in the water mains. A recent study identifies a need for standardized main break databases and continued research regarding database development (Grigg, 2004). Based on a 2004 survey of North American utilities, Wood and Lence (2006) observe that water main break data collection is evolving and industry practices do not match best practices recommended by the National Guide to Sustainable Municipal Infrastructure (NGSMI, 2002) and AWWARF (Deb *et al.*, 2002).

For utility managers, collecting, recording and monitoring water main breaks is also important because such events may be used to gain insights for the management of the entire network. This information is important in developing the tradeoffs between expenditures and level of service provided, and in managing rehabilitation programs to achieve a desired level of service. For example, many utilities focus their water main replacement program on tolerating a certain level of breaks in the water distribution system, or perhaps through targeting replacement of water mains of a particular vintage, or of a material that is prone to breaks.

Wood and Lence (2006) suggest a number of sources of data that may be used for improving a utility's data breadth and richness for analyzing water main breaks. This paper introduces an approach for constructing a water main database which is based on linking or "relating" data from sources internal and external to a utility for the purpose of knowledge discovery, or in other words *relating relational databases*. Issues related to creating, linking, transforming, cleansing, scrubbing and integrating data are identified and approaches for addressing them are presented. This approach may assist utilities in developing data acquisition and management strategies and guiding knowledge discovery. Recognizing that data collection and storage is organizationally driven, the approach is designed to be easily adapted.

The approach links information among multiple databases and respects decentralized data input in order to maintain ease of data storage and management. This reduces the need for wholesale conversion of data to a central database and is likely to be cost effective for small to mid-size utilities. The decentralized approach to database construction requires coordination of data acquisition, personnel and a clear strategy for encouraging departmental cooperation.

To demonstrate the efficacy of this approach for use in analyzing and predicting breaks in a water distribution system, a data schematic is created for analyzing water mains and predicting future breaks for the Laity View area of the District of Maple Ridge, BC. The development of a data schematic is not merely a data storage exercise. Rather it is the creation of linkages that can be used to aggregate information for analysis and that allow data to be updated over time. The linkages are created among primary and secondary data sources. For example, a municipality may not have a transportation plan that specifies traffic volumes, but if knowledge of the volume of vehicle traffic over a water main is desired, it may be able to use volume data from a traffic management system database. The use of data from different sources provides flexibility for utilities to focus on collecting data for future analyses without having to commit to specific application software.

3.2 STATE OF DATA IN UTILITIES

Water main break data collection practices vary across utilities and for many utilities, data collection can have significant costs if performed at a comprehensive level. These costs include direct financial costs as well as organizational effort and human resources. The challenges of collecting data include difficulty in mobilizing financial and human resources, absence of historical data, lack of knowledge of current organizational practices, poor reliability of previously collected data, complications due to the emergency-oriented collection conditions when breaks occur, difficulty in prioritizing collection efforts, and the need to develop effective data storage programs (Wood and Lence, 2006). In recent years, many utilities have been developing improved data acquisition and management strategies for water main breaks and in some cases using third parties for analytical tasks for obtaining specialized data such as soil conductivity.

Most municipalities do have some information regarding their water pipes and conditions, but few have been maintaining records of pipe breaks for longer than a decade, and very little information is available regarding individual pipes in a given network (Pelletier *et al.,* 2003). In a case study of three municipalities in Quebec, they found that only six parameters (diameter, length, type of material, year of installation, type of soil and land use above the pipe) were available for analysis. In recent years, best practices have been identified for water main break data collection (Deb *et al.*, 2002; NSGMI, 2002). Wood and Lence (2006) surveyed North American utilities and conducted detailed interviews to determine the richness of data available to utilities for analyzing water main breaks. They found that utilities in general can be categorized into general classes of data richness. These are the: expanded, intermediate, limited and minimal data set class. The data set classes are based on the breadth and record length of data irrespective of the traditional data categories such as break, pipe inventory, and operational data because the survey results indicate that many respondents collect data in varying amounts in each of the traditional data categories. The results of the survey also showed that while many utilities do not typically have a common break and water main database or the appropriate data, they may find relevant information available elsewhere in their organization and use this information to expand their database.

3.3 WATER MAIN BREAK DATA FOR ASSET MANAGEMENT

Two challenging asset management issues are the determination of remaining service life and the prioritization of rehabilitation efforts. Both of these issues rely on knowledge discovery. To determine remaining service life, one must be able to assess the condition of a pipe and the expected remaining life or some measure of how long a given pipe can be expected to last from the date of installation. It is difficult to determine the exact condition of buried pipes because they are difficult to comprehensively inspect. As a minimum, utilities should have a database of water main breaks because the occurrence of breaks may reflect the condition of a pipe and typically the number of annual water main breaks is used as a surrogate for the condition of the network. However, breaks do not necessarily reflect pipe condition as there are many causes of breaks such as damage from adjacent construction and frost heave.

Once pipe condition is determined, the calculation of remaining service life can be made using deterioration models that predict when failure or future breaks will occur. These models may be either statistically or physically based. The concept of remaining service life is that, given use and time, all pipes will reach a point when they are replaced for reasons such as poor condition, perception of poor reliability or the need to increase hydraulic capacity. Rajani and Makar (2000) define the time of death of a pipe as the time at which its mechanical factor of safety falls below an acceptable value. Kleiner and Rajani (1999) propose that the useful life of a pipe is a function of the economic costs of deterioration and replacement and suggest that pipe death coincides with the optimal time of replacement.

Prioritization of rehabilitation efforts involve the timing and scheduling of repairs or replacement of pipes. This is closely tied to resolving financial and technical challenges as to whether to maintain, repair or renew an asset or to choose an alternative such as twinning a water main or constructing an alternative water main. Prioritization is compounded by uncertainty regarding available funds and organizational trends when longer-term planning horizons are considered. Many engineers have faced circumstances where short-term solutions may not be the most economical in the long term but are the most expedient, for instance when a main is repeatedly repaired instead of replaced because capital replacement funds are difficult to obtain, but emergency operating funds are available.

Deb *et al.* (2002) describe four general approaches for prioritizing pipes for replacement: the Deterioration Point Assignment method (DPA), break-even analysis, failure probability and regression methods, and mechanistic methods. Kleiner and Rajani (2001) suggest that only larger diameter mains with costly consequences of failure may justify the data collection efforts and costs required to calibrate mechanistic models. Deb *et* *al.* (2002) suggests that break-even analyses be augmented with predictive techniques for pipe breaks, such as failure probability, regression and mechanistic methods. Other considerations for prioritizing water main replacements also include reliability (Xu and Goulter, 1998), consequence of failure (Cooper *et al.,* 2000), consideration of other assets (Grigg, 2004; Vanier, 2001), and on-going engineering and management processes.

Davis (2000) suggests that for analyzing the impact of changes in a water main rehabilitation strategy, an agent-based approach is promising. Agents are defined as information-processing systems and are based on artificial intelligence approaches. Davis proposes a loosely coupled generic agent-based decision support framework for water utilities. In this framework, agents are used to extract data from infrastructure, Geographic Information Systems (GIS) and strategic databases. Agents are also used to cleanse data, interface with other databases, predict pipe deterioration and assist in developing rehabilitation strategies. Small to medium size utilities often do not have staff with the skills to implement agent-based approaches. For these utilities, an approach that employs engineering expertise and common data processing systems is likely to be more feasible.

Knowledge discovery is the process of identifying valid, useful and ultimately understandable patterns in data (Torra *et al.,* 2004). The analysis of water main breaks is limited by the challenges faced in constructing databases such as limited personnel and resources, missing and conflicting data, and non-computerized information (Pelletier *et al.*, 2003; Habibian, 1992; and O'Day, 1982). Furthermore, baby-boomer staff of many utilities will retire over the coming years and data mining will be overshadowed by the issue of data creation and storage because much water distribution data are orally recorded or are stored in discrete departmentally managed databases rather than in a central database.

3.4 CONSTRUCTING WATER MAIN DATABASES

The approach for sourcing, constructing and linking water main break data proposed herein is to create a connected data schematic and undertake knowledge discovery based on these data as shown as Figure 3.1. Identifiers that are shared among databases are used to loosely associate and relate data across databases, as represented by the wavy lines in the figure. Data from different databases such as pipe break data files, soil characteristics maps, ortho-photographs, as-builts and orally recorded information are linked by creating identifiers in each data source that are common to one or more sources. For example, specific pipe segments, surface material and break data can each be assigned a common pipe identification number (pipe ID).

Information that are only orally recorded and transmitted between staff or no longer documented within an organization may be used to "create" data that can be verified and integrated for analysis. Construction standards and practices and manufacturer data can be identified through interviews. Data from external sources such as the US Department of Agriculture (USDA) and Canadian Soil Survey (CSC) can also be related.

The database is created using processed and blended data. The processing and blending of data is performed by technical specialists using tools such as GIS, spreadsheets and databases. Analysis of the data can then be performed to identify network performance including the occurrence of water main breaks, complaints and pressure deficiencies. These can be accomplished with various approaches such as statistical, physical and neural network modeling and risk analysis. From the analysis and knowledge discovery, utilities can develop strategies to predict the remaining service life and prioritize rehabilitation efforts.

Identifying the Purpose of Analysis. The first step is to identify the purpose for which the data are to be analyzed. In addition to asset management, objectives such as performance measurement and improvement, research and development, cost recovery of services, transparency and public accountability may be identified. After the purpose is established, the data required may be determined, i.e., if the purpose of the analysis is to determine factors associated with breaks that lead to service life estimates, the data should include pipe material, age and diameter. Asset management analyses of pump stations require horsepower rating, pump run times, vibration levels and maintenance details. Pavement asset management requires data on pavement thickness, sub-base material, Annual Average Daily Traffic (AADT) and type of axle loading. The purpose of the analysis affects the design of the schematic, the reliability of the relationships between the elements and the degree of information transferred across a link.

Developing a data schematic. A data schematic identifies the data required, their potential sources and if and how they are related. The schematic should be constructed considering the characteristics of the data elements including the availability of data, whether sources are primary or secondary or require interpretation, whether data can be obtained from parallel or through a series of sources, the confidence in and explicitness of the data, and how data may be linked. In addition, data can be obtained from multiple sources and some sources may be more readily available than others. Parallel sources contain the same or related data and data can be drawn in parallel, while sources that are in series contain data that in some way can be related to each other and are drawn in series. Once sourced, data can be linked across various databases using identifiers that are unique for specific databases or are common across a number of databases (e.g., a common pipe ID number). Linking data from various sources also allows for the updating of the various sources of data as a result of analysis, knowledge discovery or further research. For instance, if the purpose of the analysis is to determine if water mains under heavily traveled roads experience higher rates of water main breaks, data of interest include the surface material, road function and traffic volumes. If current network pipe data do not include these attributes, surface ortho-photographs may be used to determine the surface material. The road function on the surface over a water main may be determined using a transportation plan. Alternatively, if the transportation plan does not contain road use data, but traffic counts or a traffic network plan exist, this information may be used to determine traffic loading.

Identifying Sources of data. Wood and Lence (2006) provide a list of alternate secondary sources for break-related data based on survey respondents' written observations and personal interviews. On their own, these data are not very useful for analyzing breaks, but when combined, they can provide useful information for developing rehabilitation and operation and maintenance strategies. The following is a detailed discussion of the alternative sources that utilities should consider in building a water main break database.

Network data. Network data may be available from GISs, Asset Management (AM) / Facilities Management (FM) systems, databases, spreadsheet systems and other analytical models, e.g., hydraulic models. Other sources of data include Supervisory Control and Data Acquisition (SCADA) systems and monitoring systems. AM/FM and SCADA systems typically are enterprise systems, used by many departments throughout an organization, store large amounts of data on large server databases and operate on a client-server environment. AM/FM systems collect and store maintenance, repair and financial information while SCADA systems collect and store operating data such as pump-run times, pressure and hydraulic data.

If GISs are being used for network mapping, each pipe in the system is given an individual pipe ID and may have corresponding information such as year of installation, length of pipe segments, diameter and material. The length of pipe segment is typically obtained from the geometry of the spatial file and are usually collected from as-builts as part of the construction of the GIS. Many utilities use hydraulic models for their water, sewer and drainage infrastructure. Hydraulic models contain information such as flow, pressure and pipe layout that can be useful for analysis of water main breaks and asset management. For example, roughness, mass balance discrepancies and hydraulic losses calculated in a model can be indications of pipe condition. As-built drawings, previous construction standards, staff experience, purchasing records, manufacturer specifications, inspector and surveyor field notes, main tappings, flushing records, swabbing, laboratory, hydrant fire flow testing, inspections, water quality testing results, and customer complaints may be used to indicate information such as the bedding and backfill material, depth of cover, type of joints, pipe protection, original pipe wall thickness, current wall thickness, condition of pipe interior and level of internal corrosion.

Surface data. Sources for surface material, land use and traffic loading data include high resolution (e.g., 0.15 metre / 6 inches) ortho-photographs and as-built drawings. Land use and transportation plans, GIS maps of roads and orally recorded knowledge of types and ratios of road users, and traffic patterns provide information about surface use, traffic loading, and potential sources of damage from surface activities. Ortho-photographs may be loaded into GIS as a "background theme" and overlain with the pipe network to generate drawings to determine surface material data for each pipe. This may reduce the need for field surveys.

Soil data. Soil data are available from both provincial and federal government databases in Canada and analogous sources in the US. The CSC National Soil Database contains the soil types for all of Canada and is the national repository for survey information from the broad (1:1 million scale) to the detailed level (1:10,000 to 1:250,000 scale). The USDA Natural Resources Conservation Service is responsible for the National Cooperative Soil Survey which includes the efforts of federal, state, and academic institutions (Rossiter, 2005). The Washington Suburban Sanitary Commission has developed soil corrosivity maps based on USDA soil survey results (Habibian,1992). While agricultural surveys may be limited in terms of their usefulness in corrosion analysis, when combined with a soil sampling or survey program, they may be used to provide a general understanding of the soil conditions. Utilities should also review boreholes and logs from previous studies, well drilling data and information gathered on construction projects. Soil permeability data and water table information can be useful for drainage and sanitary sewer inflow and infiltration analysis.

Other sources of data. Utilities should explore the data collected by others or used within the organization such as mapping of environmentally sensitive areas, pavement management systems and infrastructure plans. Environmental information such as water and ambient temperature and the frequency of frost, may be available from water quality testing, weather and environment agencies. Gas pipeline, electrical, telecommunication or other utilities operating in the area may have information on soil data, stray currents and the corrosivity of soils.

Information that are not recorded but available orally from staff can be obtained by using interviews of staff to determine, for example, the type of bedding and backfill material, pipe lining and pipe protection. Whenever possible, verification of observations is recommended. Broad surveys and spot testing are other techniques to consider when obtaining data. For example, a program that samples soil for corrosivity and relates the agricultural classifications to soils can yield insights into potential corrosion hot spots and focus monitoring efforts.

Linking data. The objective of connecting or linking data is by relating relational databases to support on-demand data analysis. Data from multiple sources may be linked in series, or parallel or remain unlinked. This approach can facilitate the updating of the analysis data set as data sources are updated and thereby support future knowledge discovery. Information processing tools, such as GISs, spreadsheets and databases can be used to create electronic records, manipulate and analyze data. Output from these tools is also easily exported to other, comprehensive databases. GIS shape files can contain a myriad of information that may be viewed and exported for analysis using other analytical software such as spreadsheets and databases. Depending on the expertise and skills of those analyzing the data for knowledge discovery, utilities may choose to use a spreadsheet file as the main data analysis file. An example of which is described in the case study presented in this paper.

If break records are stored only on paper, an electronic break database should be created. Spreadsheets are easy to use and the data can be easily transferred to GIS format for viewing while being retained as the key database. Pipe ID numbers that are assigned for GIS network maps can be used as the connection between the break records and pipe characteristic data. If records do not specify the exact location of the break along a pipe segment, some extrapolation may be required to identify the damaged pipe. For example, a house number may need to be used to define the location along a pipe where the break occurred.

A process for converting geographical archival information into electronic data for relating data is shown in Figure 3.2. In the first step, information in the form of paper maps is scanned to create Tag Image File Format (TIFF) images. Then the images are digitized to create polyline drawings and GIS are used to build polygon coverage. Attributes are attached for each polygon and then related to a common identifier, such as a pipe ID. Using the intersect function of the GIS, the attributes of the network pipes and the attributes of the polygons are combined and exported as a spreadsheet file. All the files form a portion of the data warehouse that is used to create the main analysis file. For example, soil image maps may be digitized to create a closed polyline drawing of soil types, fitted to the cadastral drawings of the water network in AutoDesk Map® using the 2D transformation process, and then used to build polygon coverage of the soil conditions with ArcMap®. If each polygon is assigned a soil type identification number that corresponds to a soil type, then using the intersect function of ArcMap®, the pipe and corresponding soil attributes can be generated and exported to a shape file, and ultimately exported as a spreadsheet file of pipe IDs and corresponding soil type.

Hydraulic models may be used to calculate the flow through model links, and the pressure and heads at nodes within the water distribution system. A process for estimating pressure data along each link within the network is shown in Figure 3.3. Hydraulic model outputs (e.g., flow and friction coefficient estimates in links and pressure estimates at nodes) are determined for the corresponding pipe ID. The pipe link and node shape files are combined using GIS tools, exported to a spreadsheet file, and thereafter combined with the other pipe network data, such as pipe material, diameter, date of installation, and length.

Often, the hydraulic model and the pipe network do not have a one to one relationship, and commonly the hydraulic model is a skeleton of the network where a link in the model may actually represent a number of pipes in the real system. For example, the City of Toronto recently skeletonized their 307,956 pipe network to a 76,989 link hydraulic model (Schick, 2005). In this case, the pressure and flow may be related by buffering the hydraulic model output to the pipe network data. Buffering creates a relationship between the links in the model and the well documented pipes in the pipe network; a process shown in Figure 3.4. Here, the pipe network data (a .DWG file) is converted to a shape file with identification numbers (usually the pipe ID) and the hydraulic model data are prepared as a shape file. The two shape files are buffered using GIS analysis tools. Buffering the two shape files creates a relationship between each pipe and the model pressure and flow in the links. Using this process, all pipes can be associated with corresponding flows and pressures. This approach may also be used for combining sewer or drainage hydraulic models or other spatial data.

Processing Data. Prior to the analysis stage, data should be processed to reduce errors and inconsistencies and to produce a coherent data set. Data processing activities include simple transformations (e.g., detecting and removing outliers), cleaning and scrubbing, blending data from the various sources and summarizing the data to reduce the number of records (Torra *et al.,* 2004).

In the process of relating the data, analysts may discover inconsistencies in the databases and may have to determine the reliability of the data and how to treat incomplete data, e.g., pipes that do not have an installation date. Analysts may also find pipes that are missing material or diameter data or that hydraulic model output and GIS data differ. It falls on the analyst and data schematic builder to carefully consider the impacts of data use approaches and how these approaches affect the ability to achieve the purpose of the analysis.

Knowledge discovery. Once data processing is complete, utility managers may analyze and extract knowledge and gain insights regarding their system. Typical knowledge discovery techniques include spatial and statistical analyses using GIS, spreadsheets, databases, physical and statistical pipe deterioration models and artificial intelligence techniques. Here, patterns in the data may be determined such as break patterns, and rates for differing pipe materials, diameters, and ages and the spatial distribution of the breaks over time. As an example of the use of such observations, knowing the proportion of pipe materials of a distribution system and the failure rates within each material class can help determine the vulnerabilities and failures that may be expected of the system. Determining the past, present and future failure rates for pipes of different vintages, diameters, soil conditions, and surface loadings is important for guiding a utility's rehabilitation program.

3.5 WATER MAIN BREAK DATABASES FOR MAPLE RIDGE, BC

The construction of a data schematic for analyzing water main breaks is demonstrated here for the area of Laity View in the District of Maple Ridge. This area comprises 13 percent of the 335 kilometer distribution system for the District and represents an urban area. The Laity View area experienced construction practices and has soil types typical for Maple Ridge. The District has information residing in various formats (e.g., electronic, archival, and oral) that are distributed and managed across the organization. For example, the Operations Department has paper copies with limited information on the break history of water mains from 1983 to 2004, and no database, while the Engineering Department has a skeletonized hydraulic model of the system constructed in 2001 in a .DWG format and a spatial representation of the pipe network in GIS.

The purpose of this analysis was to determine relationships among water main breaks and factors such as pipe age, material, soil and depth of cover so as to aid in asset management (NSGMI, 2003). The information processing tools used were Microsoft Excel®, Microsoft Access®, ArcView® GIS and Autodesk® Map. These software tools were selected because they are available in-house, and District staff are trained to use them.

The data set for the Laity View area of Maple Ridge represents an *intermediate* water main break data set with a 20 year break history (1983 to 2004). The data included pipe material, pipe diameter, whether the pipe is under a boulevard or roadway, the year of installation, depth of cover, length of pipe segment, surface material, normal operating pressure, bedding material, whether the pipe is wrapped or anode protected (wrapped/anodes), backfill material, type of road function, traffic classification, type of pipe lining and typical flow in the pipe.

Constructing and linking data. The availability and location of the data, level of confidence in them, and information regarding how they were created are identified and listed in Table 3.1. Data associated with a low level of confidence are candidates for a data verification program. Based on the various sources of the data and the goal of aiding asset management, the schematic of how data can be related as shown in Figure 3.5 was created. The schematic identifies potential links and inputs for analysis and major data of interest. Primary sources of data typically aggregate data and are readily available but do not contain all the data deemed of interest for asset management. Secondary sources that contain additional information were identified. Many of these use various data formats (e.g., databases and paper records) and are distributed across the organization. Some data are available from parallel sources and one or all of the sources may be used for analysis. For example, traffic volumes may be obtained from a transportation plan or from a traffic network plan, traffic volume database and pavement management system. The transportation plan, traffic network plan and pavement management system use AADT for defining the volume of traffic while the traffic network plan contains 24-hour vehicle volumes which may be transformed to equivalent AADT.

Where possible, data were linked using the pipe ID as the common link across the databases in order to facilitate updating of all data sources using the results of the knowledge discovery process and additional field investigation. Like many utilities, the electronic water distribution network information for Maple Ridge includes year of installation, diameter and material and these are available from the GIS and drawing files. The length of the pipe segment was obtained from the geometry of the pipes in these files. Autodesk Map® tools were used to define and create the shape file for the region. The study area was defined for extraction from the water network map, and exported to a shape file with the object data for each pipe. The shape file was viewed and plotted in ArcView® GIS 3.2A and exported as a spreadsheet file as the main data file for analyses. The District's hydraulic model data are stored in a .DWG format but the model uses links and nodes which do not completely relate to specific pipes. In many cases, links represent a number of pipes in series and required buffering.

The break history for Maple Ridge is limited in detail, but is relatively long. Breaks are recorded by operation and maintenance staff and stored in paper form. The recording of break locations as well as the amount of environmental and break information varies among the records within a given year and during the period of record. Field crews typically record locations with respect to the nearest cross street but do not record the exact location of the break. As a result, if a pipe experienced multiple breaks but the exact locations of these breaks are not identified, it cannot be determined if the pipe failed at the same location or at multiple sites along the pipe. However, identification of the exact location was not necessary because the purpose of this analysis was to determine if and when a pipe broke and not the exact location of the break along each pipe.

To create the electronic break database, the data from the field crew reports were entered into an electronic spreadsheet. Pipe ID from the water network map were added to the break record. The data worksheet was then converted to a database that was then exported as a .DBF file to GIS where it was plotted for visualization..

The District does not have detailed soil information. To construct these data, a number of secondary sources including federal, provincial and local government reports (Golder, 2002; Luttmerding, 1981; Luttmerding, 1980) were reviewed. While the provincial reports use agricultural soil classifications, soil groups based on the parent material (i.e., the upper stratigraphic unit) better represent the soil types at installation depth. The three main classes of parent material are: marine clay, marine sand or eolian silt. The provincial soil maps were converted into an electronic form and intersected with the water network maps as described previously in the linking data section.

To obtain information regarding surface material, the ortho-photographs of surface features were plotted as background to the water distribution network. The possible surface material types are asphalt, gravel (typically representing a road shoulder) and landscaping. Whether the water main is under a boulevard or roadway was similarly determined and recorded.

A GIS-based map of the roads, overlaid on the water pipe network and knowledge based on the District of Maple Ridge Transportation Plan was used to classify the traffic on the ground surface above the water main. Categories of traffic loads that were used include those attributed to local, collector, arterial, and commercial roads, and lanes and those experiencing no traffic, such as boulevards. In the case where a pipe is under two or more road classifications, the classification corresponding to the heavier traffic road function was selected. As is the case for many utilities, the quality and amount of construction details provided in as-builts varies depending on the designer, contractor and time period during which the main was constructed. Thus, the confidence in these details also varies. However, in spite of the variability of records, utilities may find that construction standards, in place for years, may provide reliable information. For example, the standard cover used for construction in Maple Ridge is generally 900 millimetres (three feet) and has been verified by interviews with staff (Thain, 2005).

Data regarding bedding and backfill material, and pipe lining and protection practices were determined through interviews with staff. Relationships between the bedding and pipe material were established and a data set of bedding material was created. Similarly, whether pipe protection exists for pipes in the study area was determined using the soil type for each pipe. Where the soil type indicates clay and the pipe material is ductile iron, the pipe was considered on the basis of practice to be wrapped. All other pipes are considered to be unprotected. This assumption is identified as one which may require further verification.

While some data were obtained using secondary sources, it was not possible to obtain or construct all data. Also, while minimal scrubbing of the data was required, there were some gaps in data. For example, when the District replaces a pipe or segment of a pipe, it does not retain any history of the pipe. Consequently, there is no information regarding the former history of the age, material or diameter of pipes that have been replaced unless the data are recoded on the break record form (typically this would only be diameter and material data).

Preliminary analysis and knowledge discovery. Knowledge discovery results for this case are reported in Figures 3.6 to 3.8 and Tables 3.2 and 3.3. In the study area, 69 percent of the pipes are ductile iron, 26 percent are asbestos cement, five percent are cast iron and less than one percent is steel pipe. The number of breaks over time, plotted in Figure 3.6, may help managers develop strategies and budgets. While data indicate a stable number of annual breaks over the past years, a prediction model would be useful to estimate if and when the number of breaks will increase. Of the 47 breaks that occurred, there were 32 first-time breaks. During 1983-1999, ten breaks occurred in nine pipes and these pipes were replaced. Because Maple Ridge does not retain data on pipes that are replaced except what is on the break records (which may record the pipe diameter and material), only 37 breaks had associated pipe diameter, material and age data. The usefulness of knowledge discovery is in determining patterns of pipe breakage and insights based on these patterns. One example pattern is illustrated in Figure 3.7 and Table 3.2 which show that the majority of first breaks occur when pipes are between 15 to 19 years old, and that pipes of the 1960-1974 vintage have a significantly higher rate of failure than others, and thus attention should be given to these pipes. In addition, other relationships such as that between breaks and pipe size (as shown in Table 3.3) and breaks and soil conditions (as shown in Figure 3.8) can provide insights, such as the amount of failures in ductile iron pipes that are installed in clay soils.

Currently, the water main replacement program of Maple Ridge is targeted at replacing asbestos cement pipes. As a result of this project, Maple Ridge initiated a soil corrosivity survey and plans to correlate those results with the soil data created in this study. They are also examining ways to improve prioritization of the rehabilitation of water mains using the newly gained knowledge. Practices have also been revised including: data on replaced pipes are now retained, field data are now being collected when new pipes are installed, and new water main break forms have been implemented. Communication on data collection is improving as departments work together to collect and share data and have a better understanding of each other's role in achieving the common goal of effective asset management.

3.6 DISCUSSION

The process of creating a data schematic among multiple databases for data compilation, analysis and knowledge discovery may yield valuable insights for improving asset management practices. It expands the data available for analysis for both present and future applications and respects decentralized data input and management. The use of decentralized data storage reduces problems related to data ownership among units within organizations regarding data collection, management and dissemination of water, sewer, drainage or other infrastructure information.

As in any business process, it is important to document the purpose for constructing, structuring, sourcing and linking the data schematic. A clearly documented outline of the relationships between the key data sets is important for future managers and those utilizing the data. NSGMI (2003) suggests some key relating information such as asset number, asset location and work order numbers. The work undertaken herein suggests that those collecting data within an organization should share information regarding the purpose for collecting and selecting the amount and type of information to avoid duplication and focus efforts. Data managers must also be aware of disclosure control in which important or confidential data may be inadvertently connected and unintentionally released to third parties (Torra *et al.*, 2004). For public utilities, the issue of private and proprietary information is important and should be considered (e.g., considering the Freedom of Information Act in British Columbia.).

Processing of data is a significant step in data schematic construction and relating data. For example, in the Maple Ridge case study, use of agricultural soil classifications resulted in too many soil zones for analysis but reducing the number of classifications and using the parent material categories improved the understanding of the relationship between soil type and the number of water main breaks. Summarizing and aggregating data requires expertise and knowledge of the intended analyses.

In seeking data sources, utilities should consider data that other agencies are collecting even if they are doing so for different purposes and determine whether the data are useful as a secondary source. Application of new technologies, such as infrared, electro-magnetic surveys and Light Detection and Ranging (LIDAR) may be employed to capture relevant data.

Utilities face the challenge of capturing undocumented institutional information and knowledge over the next decades as their baby-boomer staff retire. As demonstrated herein, interviews are useful in capturing these data, but the processes of interviewing staff can be awkward. The authors found that staff shared more information when interviewers began the session by making observations and asking about the validity of these observations, and then asking specific questions. Maps and other visual cues usually triggered the interviewee's memory. It is important for interviewers to pose questions and present the exercise as soliciting information to aid in knowledge discovery rather than criticism of past practices. It is equally important to, where appropriate, validate the observations and experiences of staff. It is noted that retired staff seem uncomfortable with general observations unless they could also provide exceptions. Though there may be confidence in orally recorded data, verification should be undertaken where possible.

A limitation of constructed databases is the possibility that created data are more correlated than data that are collected independently. For example, in the case study, all ductile iron pipes are defined as cement mortar lined and the pipe material determined the backfill and bedding data. This may affect the amount of explanatory variables in an analysis. Other limitations include the fact that data may not always be accurate or quantifiable. The limitations may be overcome by a program to verify the data over time, which is a long-term exercise. For predicting future water main breaks, it may be difficult to determine if variables are significant if there is a limited history of breaks. It is important that the data are stored and that future break data be added to increase the history and data set for further analysis.

3.7 CONCLUSIONS

Grigg (2005) has identified the need for standardized main break databases and continued research regarding database development as strategic for informed infrastructure management though the topic of databases has been the subject of other authors such as Deb *et al.*, (2002); Habibian (1992), and O'Day, 1982). However, surveys and literature indicate that data are typically scarce. Compounding this, water main break data in centralized databases are not common and approaches and techniques to relate and manage data for analysis are needed.

The approach presented herein expands the sources (including, in particular, oral transmission) and the amount of data for asset management. Researchers and managers may gain insight into a system by systematically sourcing, relating, processing, blending and analyzing data. The framework is flexible, anticipates the evolution of data collection, building, verification and storage and allows for a variety of users. It does not abruptly disrupt data collection and warehousing practices.

A key benefit of this approach of relating data is that it allows managers to continue to expand data collection because databases are decentralized. It also fosters a dialogue of data development, knowledge discovery and information processing across an organization. It is flexible and can be adapted to all utilities, whether they are small, medium or large, and regardless of the uniqueness of the data collected and organizational framework.

The recording of future breaks and verification tasks are important for building confidence in the data and for augmenting it. A long-term strategy should be developed that verifies and improves the breadth of data and confidence in the database. The tasks can be opportunistic, undertaken when other repairs of the system are occurring, or systematic. When pipes are replaced or new service connections are installed, opportunities arise for obtaining physical samples and verifying the nature and condition of pipe protection, bedding, backfill and the pipe exterior. An example systematic program is a utility-wide survey of soil corrosivity in various soil classifications and an exercise that improves the understanding of the relationships among soil classifications, corrosivity and breaks.

This approach can also be used for sewerage, drainage and other systems for improving asset management, operation and maintenance analysis, performance and public accountability. For example, by relating and analyzing grease build-up areas, complaints, slope, flow and model flushing velocities, a sewer system manager can analyze performance and resource efforts and develop plans to address previously "un-connected" problem areas. As well, for a road network, constructing relationships between complaints, traffic volume, speed and crash data, lighting level, signage, road condition and geometry, managers may be able to improve road safety and predict high crash locations.

As observed in the Laity View area case study, the process and results improve communication and the basis for decision making. New insights can assist managers in focusing effort and resources and discovering unanticipated issues and challenges. While the focus of utilities has been on collecting and storing data, the next step will be in the application of data mining and knowledge discovery. As more tools become available to analyze data, managers need to consider the business intelligence that it should employ to wisely invest resources to meet future demands.

3.8 ACKNOWLEDGEMENTS

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Table 3.1 Water main break data availability for Maple Ridge

Data element	Availability for "off the shelf" analysis	Secondary source	Notes	Confidence/reliability
Pipe material	Available in AutoCad in .DWG format			High
Pipe diameter	Available in AutoCad in .DWG format and GIS			High
Type of water service		Available in Ortho-photographs (0.5metre/1.6 feet and 0.15metre/0.5 feet intervals)	Requires interpretation of data available	Medium
Under boulevard or roadway		Available in Ortho-photographs (0.5metre/1.6 feet and 0.15metre/0.5 feet intervals)	Requires interpretation of data available	High
Year of installation /age	Available in AutoCad in .DWG format and GIS			Medium – high
Depth of cover		Orally recorded information	Based on standards of the day	Medium – but could be verified over time
Length of pipe segment	Available in AutoCad in .DWG format and GIS			Medium
Normal operating pressure		Available in model and in .DWG format	Need buffering to assign pipe with node data	Medium – High
Type of joint		Not available	Field investigation commenced for future pipe breaks	Low
Condition of pipe exterior	Not available		Field investigation commenced for future pipe breaks	
Bedding material		Orally recorded information	Data inferred from known pipe material, future field verification required	Medium – but could be verified over time

Data element	Availability for "off the shelf" analysis	Secondary source	Notes	Confidence/reliability
Pipe protection (wrapped/anodes)		Orally recorded information	Use of soil maps to infer information, future field verification required	Medium – but could be verified over time
Backfill material		Orally recorded information	Data inferred from known pipe material, Future field verification required	Medium – but could be verified over time
Traffic classification or type of road usage		Transportation plan designation and maps	Need better understanding of traffic loading	
Type of pipe lining		Orally recorded information	Data inferred from known pipe material, future field verification required	Medium – but could be verified over time
Typical flow in area of break		Available in hydraulic model and in .DWG format	Some more modeling information (typical flow)	Medium-high (from model confidence)

Table 3.2 Water main breaks for a given year of installation (1983-1999)

Year of Installation	Number of Pipes	Length in metres (feet)	Number of breaks as an age group	Percentage of pipes in age group with breaks
1955-1959	14	1,687 (5,535)	4	29%
1960-1964	32	2,968 (9,738)	8	25%
1965-1969	12	1,511 (4,958)	7	58%
1970-1974	52	4,791 (15,719)	11	21%
1975-1979	56	4,030 (13,222)	3	5%
1980-1984	56	4,122 (13,524)	1	2%
1985-1989	56	4,584 (15,040)	3	5%
1990-1994	96	7,452 (24,450)	0	0%
1995-1999	51	3,003 (9,853)	0	0%
Unknown	4	29 (95)	0	0%
Total	**429**	**34,177 (112,135)**	**37**	**9%**

Table 3.3 Pipe breaks for pipes of a given diameter (1983-1999)

Pipe diameter in millimeters	Number of Pipes	Number of breaks	Percentage of pipes for each diameter group with breaks
100	2	0	0.0%
150	246	26	10.6%
200	117	7	6.0%
250	62	4	6.5%
300	2	0	0.0%
350	0	0	0.0%
	429	**37**	**9.0%**

Figure 3.1 A schematic for constructing and using water main break data for knowledge discovery

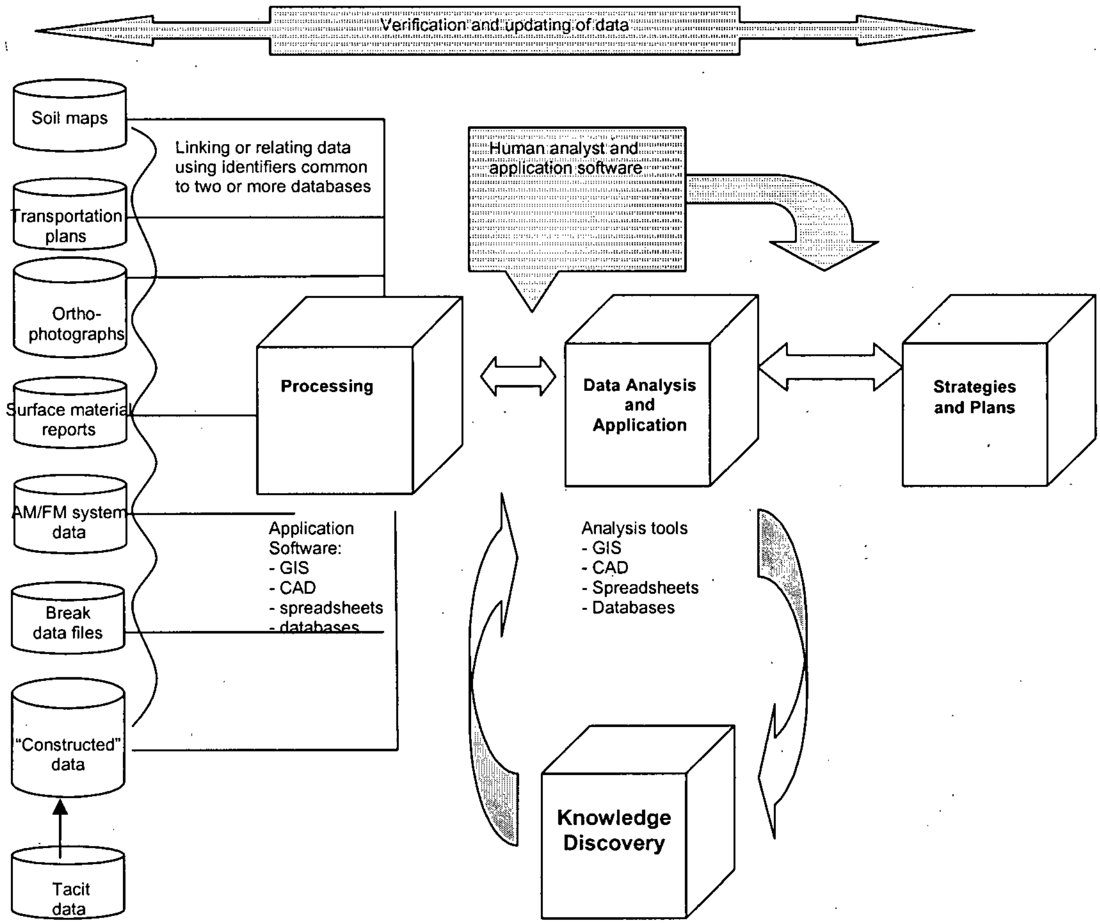
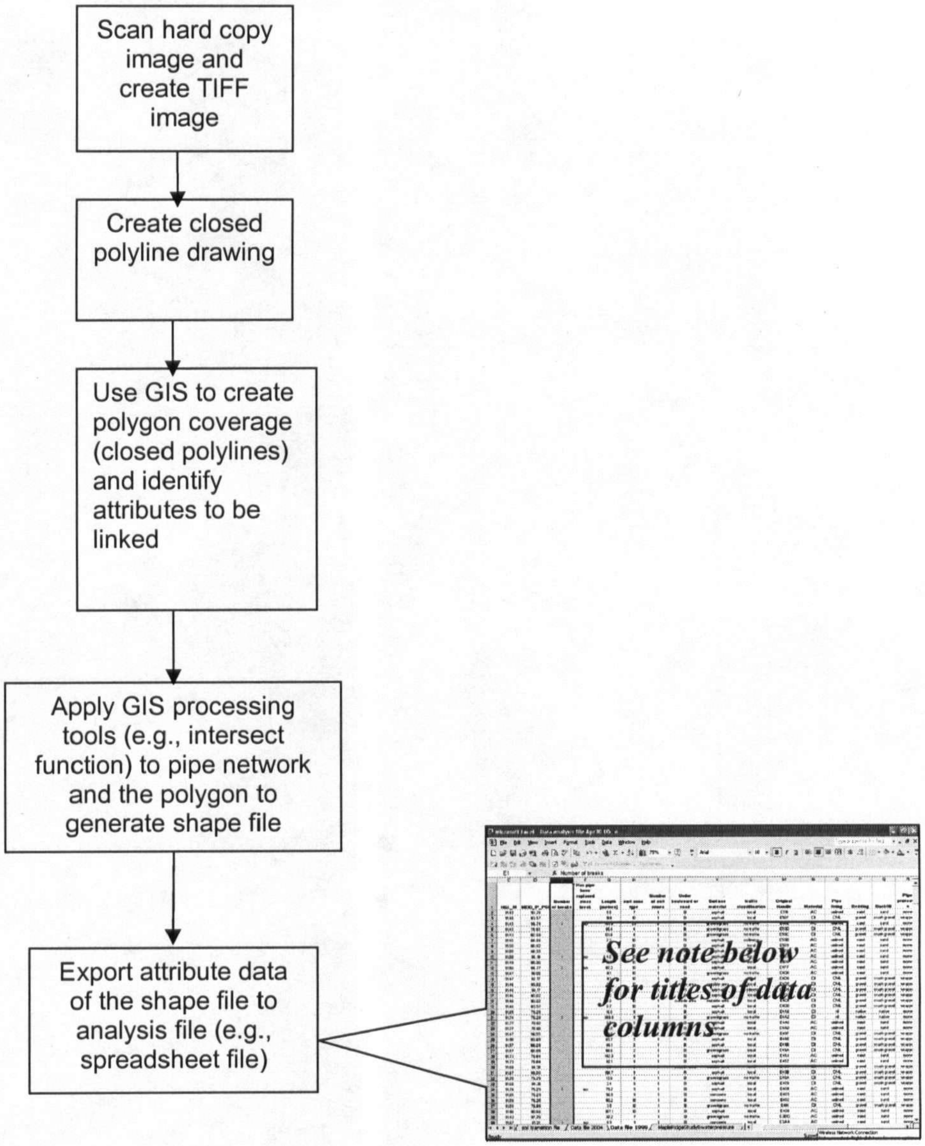


Figure 3.2 Process for digitizing and creating data from archival geographical data



Note: Title of data columns

Pipe ID	Size	Material	Material Code	Year of installation	Year Of Failure	Month Of Failure	Years of Service	Years In Ground	Pipe length (metres)	Number of breaks to 1999

Has pipe been replaced since break?	Soil zone type	Number of soil zones	Under boulevard or road	Surface material	Traffic classification	Pipe lining	Bedding	Backfill

Pipe protection	C factor	Roughness	Q (l/s)	V (m/s)	C_number (Hazen)	HGL (metres)	Max demand day pressure _(PSI)

Figure 3.3 Linking hydraulic model data with network data

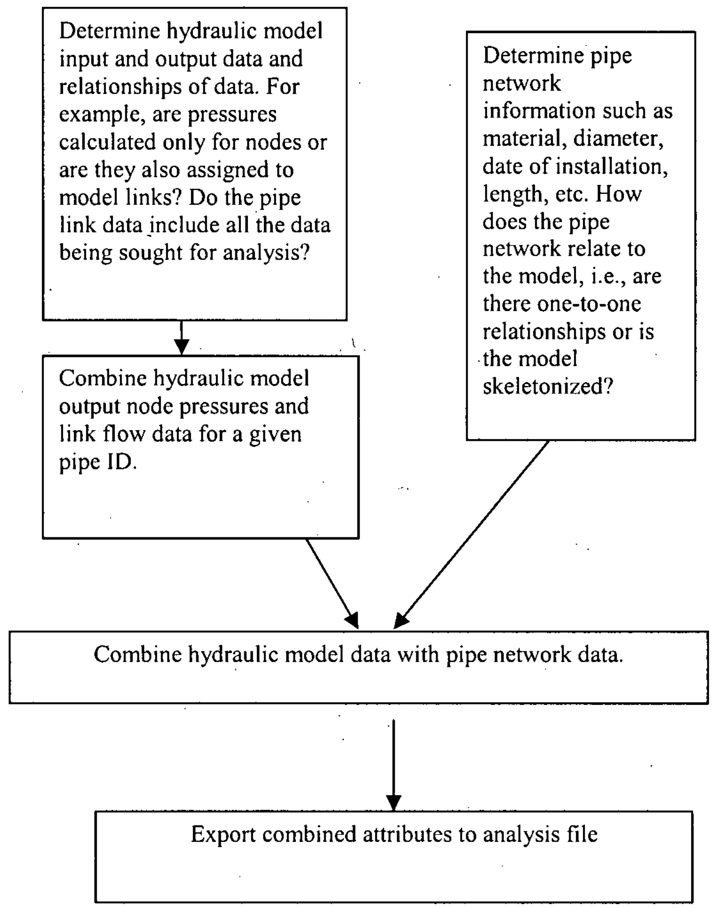


Figure 3.4 Buffering data to create data relationships using GIS

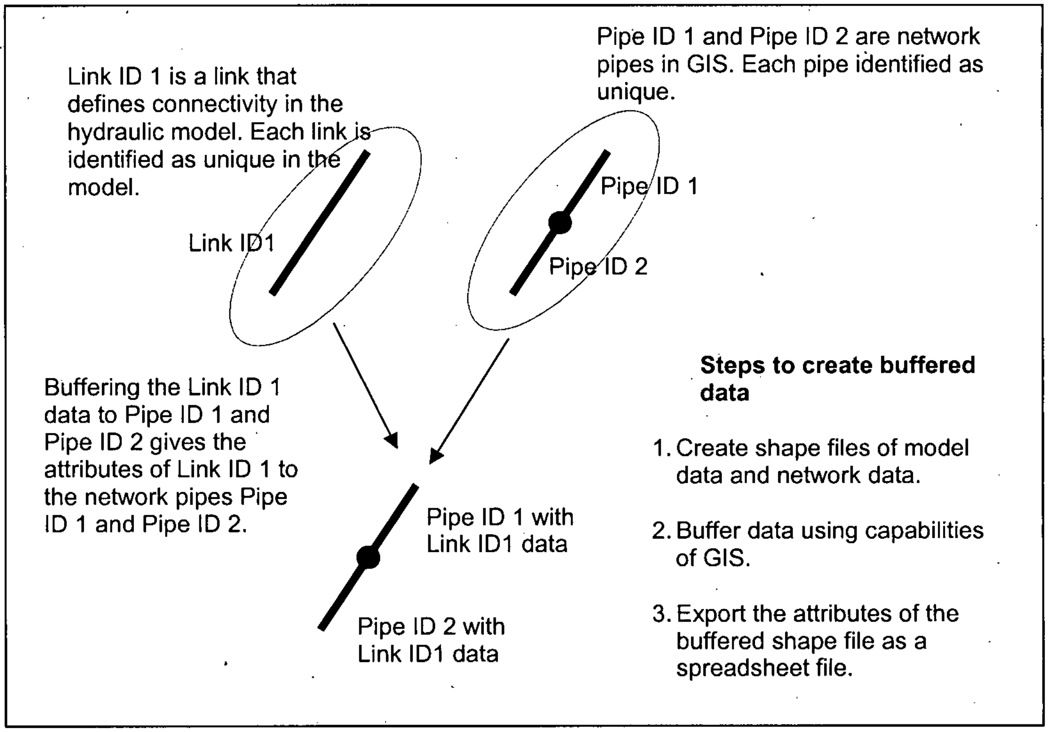


Figure 3.5 Maple Ridge water main break analysis data schematic

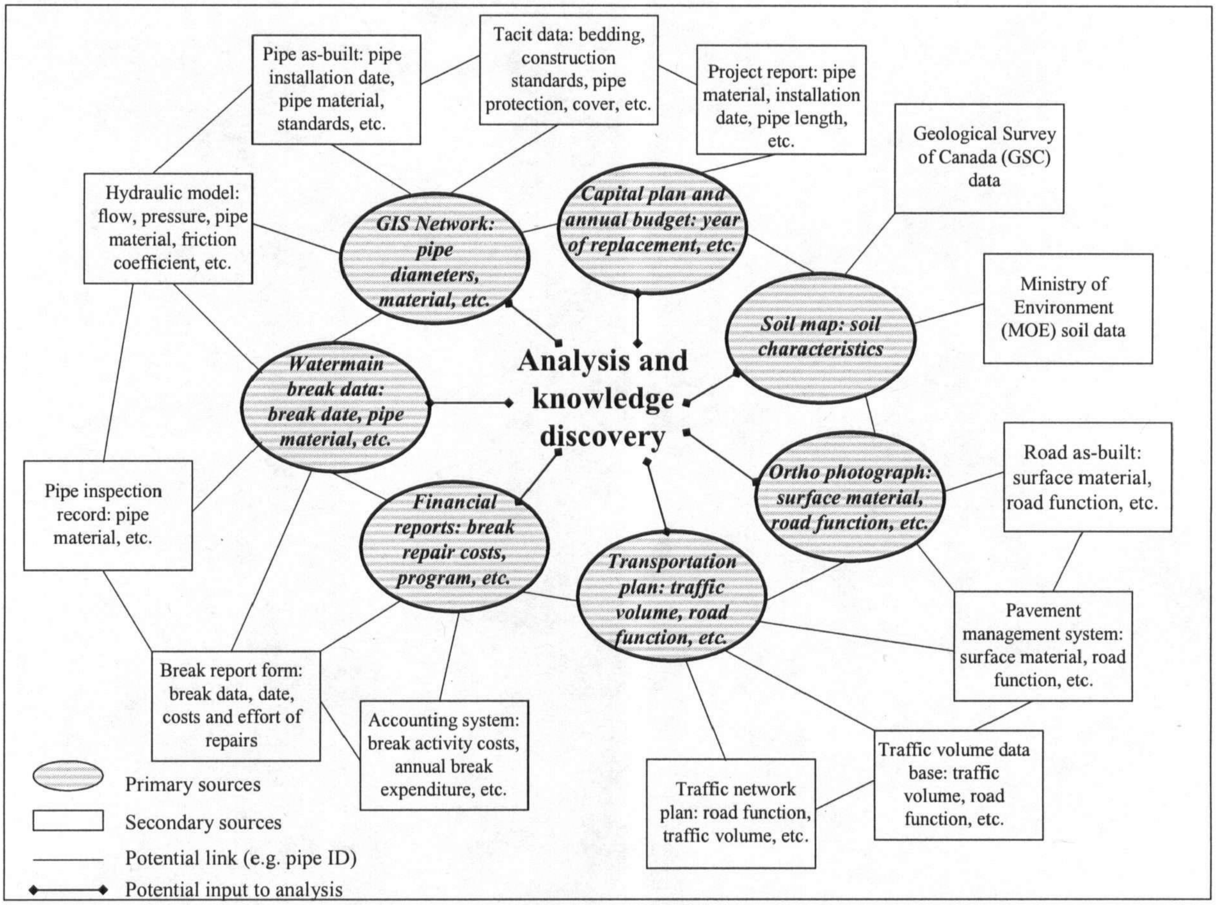


Figure 3.6 Cumulative breaks in Laity View area (1983-1999)

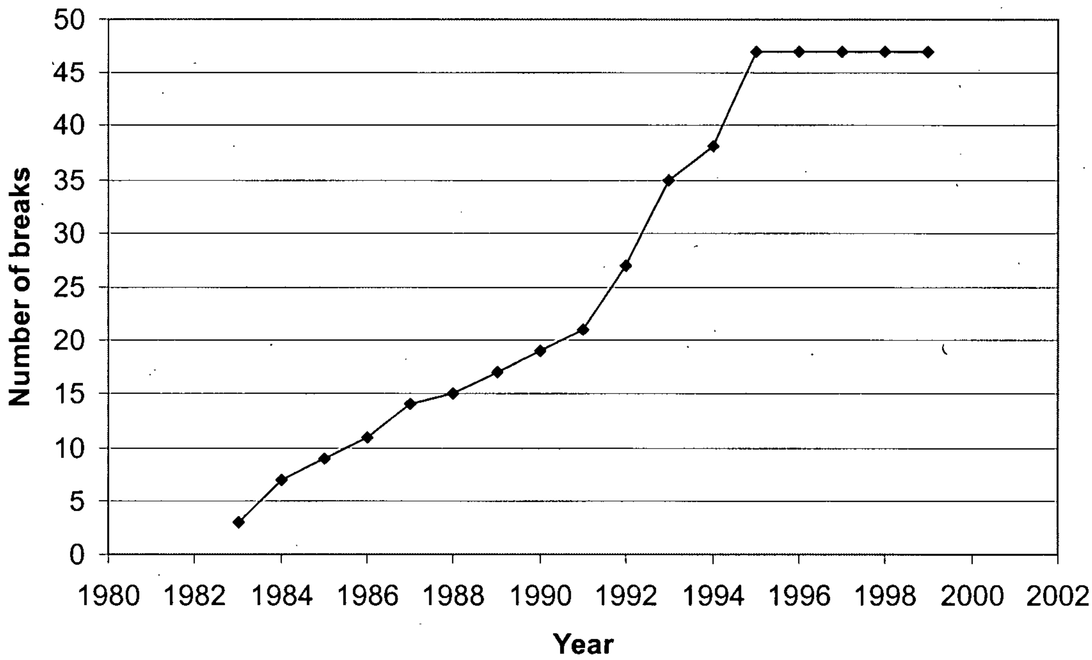
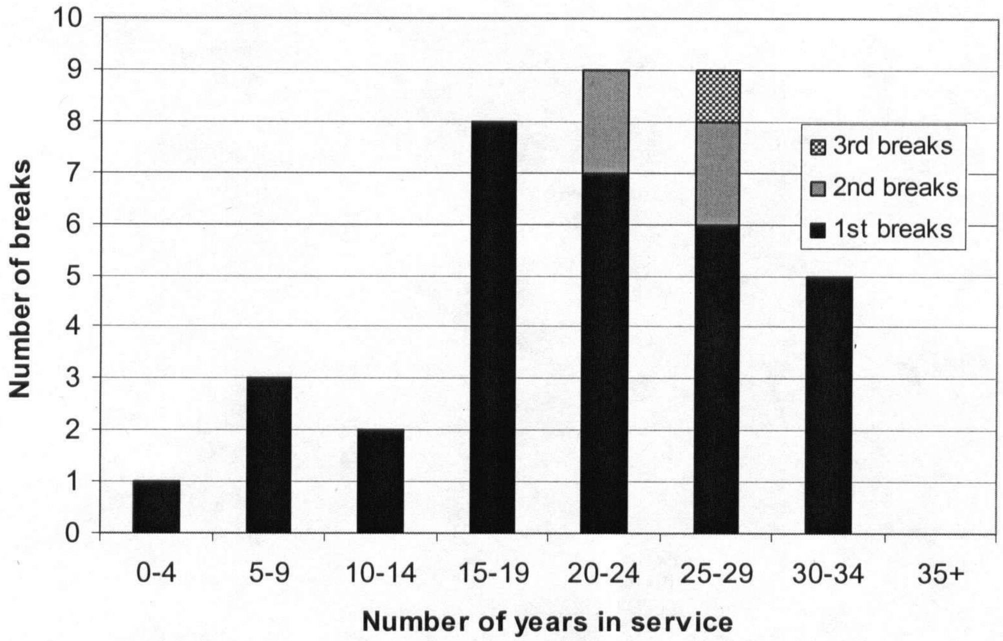
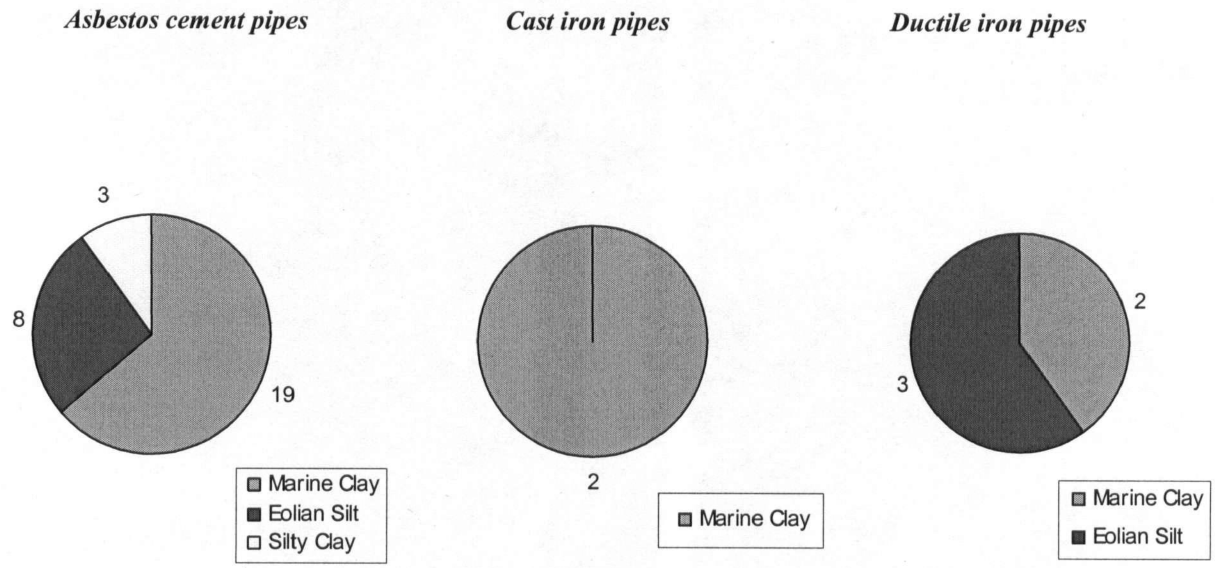


Figure 3.7 Number of years in service when break occurred in pipes (1983-1999)



Note: *Of the 47 breaks in the area, no pipe age data were available for 10 of the 47 breaks.*

Figure 3.8 Number of breaks for pipes in a given soil type installation (1983-1999)



CHAPTER 4

USING WATER MAIN BREAK DATA

TO

IMPROVE ASSET MANAGEMENT

FOR SMALL AND MEDIUM UTILITIES

A version of this paper has been submitted for publication to ASCE Journal of Infrastructure Systems as Using Water Main Break Data to Improve Asset Management for Small and Medium Utilities by A. Wood and B. J. Lence.

PREFACE

In the previous chapter, I created data and a number of databases to demonstrate some techniques that utilities can employ to enrich their asset management data sets. In Chapter 4, I demonstrate that once data are created and linked for analysis, utilities can use these data within a framework that I developed for improving their asset management practices. The intent of this research is not to create a new model, but to develop a framework that uses break prediction models that small and medium size utilities can apply. The soil and surface material data that were created in Chapter 3 were used in the experimental application of this framework and give significant insights into the factors that influence pipe breaks.

While the data created provided a demonstration case, there was not sufficient information to apply all the models that I initially proposed to investigate. The use of statistical deterministic time-linear and time-exponential models could be sufficiently demonstrated with the data created in Chapter 3, but there were insufficient data to obtain meaningful results from an application of the survival analysis and KANEW (Deb *at al.,* 1998) models. Thus, all four types of models were applied in an effort to obtain proof of concept, but only two types of models are reported in the manuscript that comprises Chapter 4.

It is important for utilities to continue to create and mine data. This research reinforces the notion that not all data may be useful for applying sophisticated models but that unsophisticated pipe break models can provide insights into the performance of a water main system, be used in identifying system specific factors that may cause breaks, guide the development of a water main break data collection strategy, be used to identify groups of pipes, their historical and predicted break frequency to further investigate and prioritize for replacing and thus be a benefit to communities.

4.1 INTRODUCTION

Water utilities have aging and deteriorating infrastructure and must prioritize the replacement of their water mains to minimize pipe breaks. Breaks result in loss of water to key businesses and critical facilities, may lead to damage of other infrastructure, and have been identified as a pathway for microbial contamination of distribution systems (AWWA and EES, 2002). The need for rehabilitating aging water mains is increasing, the costs of repairs and replacement can be high, and the impact on customers potentially significant (USEPA, 2001). Asset management practices are generally used to prioritize pipe replacements and thereby identify investment strategies that, on one hand, avoid premature replacement of pipes (i.e., unnecessary pre-investment of funds), and on the other hand, avoid water main breaks, commensurate interruptions in service and the costs of damage. An effective asset management decision is dependent on the ability to determine the future performance of water mains by predicting water main breaks, and identifying how such breaks may occur.

Much research has focused on the development of models for predicting water main breaks and pipe deterioration, but the use of such models is not common among utilities. In addition, the amount and quality of water main break data available for developing or implementing these models varies among utilities (Wood and Lence, 2006). Many utilities lack data and are not confident in the data they have and this is generally an impediment to their investing in pipe prediction models. However, they can create and relate data that can be useful for asset management (Wood *et al.,* 2007).

This paper develops a framework that guides utilities in identifying key data to be used in asset management in general and specifically for pipe break prediction modeling and selecting the most appropriate model for predicting water main breaks. This information may then be used to enhance the development of replacement priorities based on forecasted breaks, the maintenance of the database, and the identification of future data acquisition programs. It provides the utility with a method for considering future pipe breaks in the analysis of pipe prioritization strategies, and it incorporates existing tools for data management and analysis that are widely available and easy to implement by small and medium size utilities. The framework is applicable to utilities with varying amounts of data, and it is demonstrated here with a case study based on the Laity View area of Maple Ridge, B.C and constructed data. The following sections review the available techniques for predicting pipe breaks, the factors that influence break predictions, the framework developed for assisting in asset management of pipe networks and the results of the Maple Ridge example implementation of this framework. The framework can be applied without creating and constructing data, but the usefulness without such efforts is limited.

4.2 WATER MAIN BREAKS

A number of authors analyze and report on the causes of breaks, including O'Day (1982), Marks *et al.* (1987), Male *et al.* (1990), Savic and Walters (1999), Rajani and Makar (2000), Rajani and Kleiner (2001) and Dingus *et al.* (2002). According to Rajani and Tesfamariam (2005), a combination of circumstances leads to pipe failure in most cases and different factors cause failure in different pipe networks. The causes of breaks include deterioration as a result of use (e.g., internal corrosion), physical loads applied to the pipe (e.g., traffic, frost), limited structural resistance of the pipe because of construction practices during installation and declining resistance over time (e.g., corrosion, aging factors). Dingus *et al.* (2002) surveyed the 46 largest American Water Works Association Research Foundation (AwwaRF) member utilities in 1997 and note multiple common failure modes for cast iron pipe systems. Corrosion, improper installation and ground movement are the three most common causes of pipe failure. According to Levelton (2005), corrosion is dependent on a number of factors including material, soil type, chemical characteristics of soil, soil bacteria and stray electrical currents.

Prediction modeling of water main breaks. Break prediction models have been developed to help the water industry understand how pipes deteriorate and when pipes will break in the future. These models are typically grouped into two classes – statistical and physical-mechanical models (Kleiner and Rajani, 2001). Statistical models use historical pipe break data to identify break patterns and extrapolation of these patterns to predict future pipe breaks, or degrees of deterioration. Physical-mechanical models predict failure by simulating the physical effects and loads on pipes and the capacity of the pipe to resist failure over time.

Statistical models are typically characterized as either deterministic or probabilistic equations (Kleiner and Rajani, 2001). Under the deterministic models, the pipe breakage is estimated based on a fit of pipe breakage data to various time-dependent equations, which may represent the cumulative pipe breaks as a function of time from date of installation or from the earliest date of available break data, most commonly are time-linear (Kettler and Goulter, 1985) or time-exponential functions (Shamir and Howard, 1979; Walski, 1982 and Kleiner and Rajani, 1999). Prior to fitting these functions, pipes are partitioned into groups that have similar characteristics, and the functions are evaluated for these groups. The characteristics used to sort the pipes are based on the factors that are assumed to influence breaks such as pipe age, pipe material, diameter, or soil type. Probabilistic models predict not only the failure potential, but the distribution of failure. These models are more complex than deterministic models and require more data. Examples of these include cohort survival, such as KANEW (Deb *et al.* 1998), Bayesian diagnostic, break clustering, semi-Markov Chain and data filtering methods. Physical-mechanical models typically fall into one of two classes: deterministic models which estimate pipe failure based on simulation of the physical conditions affecting the pipe (Doleac *et al.,* 1980, and Rajani and Makar, 2000), or probabilistic models that use a distribution of input conditions, such as rate of corrosion, to predict the likelihood and distribution of pipe failure (Ahammed and Melchers, 1994). These models have been developed primarily for cast iron and cement pipes.

Physical models have significant data needs. Kleiner and Rajani (2001) suggest that only larger diameter mains with costly consequences of failure may justify the required data collection efforts for these models, and that statistical models based on fewer data may be used to gain insights for future performance. Rajani and Tesfamariam (2005), in using a probabilistic approach, suggests that breaks and causes of breaks for any particular water distribution network are system-specific and that a utility must create its system-specific model based on the deterioration factors that are relevant for that utility. While small and medium utilities typically have the capacity to use statistical deterministic models, the implementation of physical models is not practical due to the data collection efforts and model maintenance required. For small and medium utilities, it is often most important to gain insights about the rate of pipe breakage, that is, whether the quantity of expected breaks is increasing linearly or exponentially. Knowing the rate of change for utility managers is important because budgets and performance are based in part on future needs such as the number and rate of breaks in the system.

Factors for predicting water main breaks. A number of studies identify factors for predicting water main breaks, though what is considered relevant data appears to be specific to the system investigated. O'Day (1982) reviews break studies in Manhattan and Binghamton, New York, and cites a number of studies that use age as an indicator for predicting break rates for cast iron pipes. He notes, however, that age alone is a poor predictor of main break patterns and identifies the major determinants of water main break rates, as localized factors such as corrosion conditions, construction practices and external loads. He also finds that soil type affects external forces on water mains, such as shrink-swell, frost penetration and external corrosion. According to Jacobs and Karney (1994), pipe age range is an effective basis for models because pipes of a given age range are typically uniform with respect to manufacture, installation and to a large extent, operating conditions. Moreover, pipe installed in geographically contiguous sections often share similar soil conditions, installation conditions and pressure regimes. In their study, Jacobs and Karney group pipes based on material, diameter and fairly broad age ranges and develop regression relationships for pipe breakage versus age and versus pipe length. Savic and Walters (1999) suggest that the causes of water main failures may be split into pipe quality and age, type of environment, quality of construction workmanship and service condition and find that age, length, and diameter are the most important variables in influencing pipe bursts. Kettler and Goulter (1985) find that break rate, age and material are related for asbestos cement and cast iron pipes. In their study, no single type of failure of asbestos cement pipes exhibited a marked change in the rate of failure with time, while there were distinct changes in the failure rate with time for some types of failure in cast iron pipes. According to Male (1990), different manufacturing processes of cast iron pipes can account for differences in durability. Cooper *et al.* (2000) apply a probabilistic approach to estimate trunk main failure probability, based on four key variables: number of buses per hour, pipe diameter, soil corrosivity and density of pipes in a given area. They find that pipe age and material are important factors contributing to the break probability. Rajani and Tesfamariam (2005) show that long-term performance of buried cast iron is dictated by pit growth rate, unsupported length, fracture toughness and temperature differential.

Data typically used in models are surrogates for factors that can explain breaks. For example, as shown in Table 4.1, the age of a pipe may represent the method of pipe manufacture or particular construction standards, as well as deterioration over time. Bedding material may be an indicator of a particular construction practice that induces physical stress, of the structural resistance of the pipe, or of the soil type. For example, in some utilities where native soil is used as backfill, the soil may not screened for rocks and other objects or properly leveled. As a result, this construction practice results in circumstances where a stress is induced on pipes and ultimately causes failures. In some cases, fines migration of corrosive native soil through particular bedding types can occur and create the potential for external corrosion. Soil type can represent corrosivity and potential for external pipe corrosion, this is also dependent on the pipe material.

Availability of water main data within utilities for models. The amount of water main break data needed for extensive model development is not commonly available in utilities (Wood and Lence, 2006), in spite of best practices recommended by the National Guide to Sustainable Municipal Infrastructure (NGSMI, 2002) and AWWARF (Deb *et al.*, 2002). Most municipalities only have limited recorded pipe breakage histories and do not have much data for analysis (Pelletier *et al.*, 2003). However, in many instances utilities may have more available data than they realize. They can apply approaches such as constructing and relating available data from archives, models and other such sources (Wood and Lence, 2006) to construct and link databases for analysis.

A key to any data management strategy is identifying the purpose for which one is collecting and analyzing the data, whether it is for asset management, compiling an inventory of assets or discovering the magnitude and nature of pipe breaks. There is growing interest in using Knowledge Discovery techniques such as data mining for water main break data (Savic and Walters, 1999). Knowledge Discovery is the process of identifying valid, novel, potentially useful and ultimately understandable patterns in data (Torra *et al.,* 2004). Such patterns may help to identify factors that are related to breaks.

4.3 A FRAMEWORK FOR USING DATA AND PREDICTION MODELS TO IMPROVE ASSET MANAGEMENT

The framework developed herein may be used to guide a utility in identifying the magnitude of its water main break problems today and in the future, and thereby enhance the development of strategies for prioritizing pipe replacements and data collection. Its salient feature is that it integrates break prediction or deterioration models that provide an indication of future pipe conditions with existing data, and thereby uses enhanced estimates of vulnerability for each pipe. It is designed to accommodate systems with limited data but is sufficiently flexible to adapt for additional information that may be acquired over time. Other design considerations include ease and transparency of use and facilitation of a decision-making process that is repeatable and defensible.

Traditionally, utilities prioritize pipe replacements based on a combination of current management practices and historical pipe breakage data. Management practices include directives based on general guidelines, consequence assessments, legislative requirements, and other utility priorities. Rudimentary analyses employed interpret historical pipe break data, including location, time and date of break, and pipe diameter and material, and typically has provided information regarding where and how many breaks are occurring, and what pipes are experiencing breaks (Kleiner and Rajani, 1999). Considering this information, the priority of the utility may be to replace water mains of a certain material or size, those in a certain area due to previous failures, those under roads that are to be re-paved, those that are currently undersized, or those that have significant consequences if failures were to occur, such as mains that serve hospitals. Some utilities may use a multiple objective approach, weighting each of a number of prioritization criteria, and assigning points to each pipe that describe the degree to which it meets a given criteria (Deb *et al.,* 2002; Sargeant, 2003). For each pipe, the sum of the product of the weight and assigned points for each prioritization criteria is obtained and used to prioritize candidate pipes.

The framework developed in this research is shown in Figure 4.1. In order to forecast pipe breaks, the historical data set may need to be expanded with data available from other sources within the utility and from external agencies. In addition to historical pipe breakage data, data for factors that may be important for predicting water main breaks as previously described may need to be obtained, including soil type, surface, bedding, and backfill material, type of road usage, or typical flow in area of break. This information may be consolidated by creating a schematic of data, which does not establish a new database per se, but draws from available data for analysis when required, as described by Wood and Lence (2006) and Wood *et al.*, 2007.

These data may be used directly in the prioritization process and as input to break prediction and deterioration models. The input to the models is developed by grouping pipes in which breaks have occurred based on factors that contribute to breaks. Material and diameter data are available to most utilities and should be considered as the minimum factors on which to base pipe groups. The decision of whether to use a physical-mechanical or statistical break prediction model may be made at this point, because the pipe material determines whether a physical model exists for a given pipe and the diameter influences the practicality of applying such a model. For small and medium size utilities, the practical starting point is deterministic statistical models, which may be developed with readily available commercial software, including spreadsheets. More capable utilities may consider more complex statistical or even physical-mechanical models, however, the long term use and maintenance of these models is a serious consideration for those who choose these models.

To evaluate the accuracy of a given statistical model, a portion of the break data should be used to develop the equations and the most recent portion of the break data should be retained as a holdout sample for comparison. For example, if a utility has twenty years of break history, it may choose to develop models based on the first fifteen years of data, and compare the model predictions with the remaining five years of actual breaks to assess the accuracy of the predictive model. While five years is a reasonable length of holdout sample, this is a function of the length of record, and data required to generate the statistical models.

In developing and using statistical models, one must determine the amount of data that are required, the level of detail to be modeled, and the knowledge that will be gained. In order to determine the length of record required to develop a credible statistical model, the pipe break record used to model the system may be varied to evaluate the sensitivity of the model accuracy to the length of record used.

In order to evaluate the important factors for predicting pipe breaks, the pipe break data may be subdivided into different sub-groups and models for each of these sub-groups may be developed and compared in terms of their relative accuracy. This process naturally reduces the number of breaks within each sub-group used in performing statistical analyses, but may yield more credible models. Considering data that are typically available to utilities (Wood and Lence, 2006), potential sub-groups of pipes for these models, include those of a specified i) pipe material and diameter, which indicate pipe strength; ii) pipe material, diameter, and age which indicate pipe strength and age effects such as deterioration and construction practices; and iii) pipe material, diameter, soil type, and age which indicate pipe strength, interaction of the pipe material and the soil, and age effects. Should the utility have access to information regarding surface conditions, this may also be considered in forming the pipe sub-groups.

With the knowledge gained from the model results, managers can then target pipes that have the highest predicted breaks or rates of breaks for prioritization. This information is also useful for identifying future investigative programs such as soil and pipe condition assessments and data acquisition strategies such as changes in field collection practices. The utility may also choose to verify the data or conduct investigative assessments to understand the deterioration of pipes that have significant breaks but cannot be accurately modeled. From these activities, new data can be created to improve the understanding of pipe deterioration factors.

Pipe network management practices may also be altered based on the model results. Examples of such changes include identification of new design specifications such as the type of joints required for certain pipes in a particular soil, and introduction of corrective measures such as cathodic protection programs. In order to maintain relevance, it is recommended that models be routinely reviewed and updated as part of the detailed capital plan of the utility and to account for changes in the rate at which breaks are occurring as a result of the changes in pipe management practices. Finally, break data should be kept current.

4.4 BREAK PREDICTION MODELS FOR LAITY VIEW, MAPLE RIDGE, BC

The application of the framework is demonstrated using the Laity View area of Maple Ridge, BC, Canada. This area comprises 13 percent of the 335 kilometer distribution system for Maple Ridge, is representative of the urban area, experienced the same construction practices and has soil types found in the rest of the municipality, and is home to a population of approximately 6,000. The pipe materials found in the area are asbestos cement, cast iron, ductile iron and steel, and in diameters of 150, 200 and 250 mm. Pipe installation records began in 1959 and few pipes in Maple Ridge were installed before this date. The soil types found in the Laity View area are clay, silty-clay, silt and sand.

Break data are available from 1983 to 2004. A total of 54 breaks occurred in this period, and seven of these occurred after the year 2000. Preliminary analysis of these data indicates that breaks are occurring in asbestos cement, cast iron and ductile iron pipes, in pipes that are greater than 15 years old, and in clay and silty-clay type soils (Wood *et al.*, 2007).

Given the 20-year history of record, the final five years from 2000 to 2004 was selected as the holdout sample. To investigate the important factors for predicting pipe breaks, pipes in the area were grouped based on the four types of sub-groups previously described. Information for surface material which included asphalt, concrete, and gravel or grass, is available for this region and thus another sub-grouping was examined that included pipes of a specified pipe material, diameter, age and surface material. The combination of knowing which factors are important for predicting breaks and the common failure types for a network can provide insight on pipe deterioration behavior.

Pipe age sub-groups were created by examining the data and identifying time periods in which a meaningful number of breaks occurred. For asbestos cement and cast iron pipes, these sub-groups were comprised of pipes with installation dates before 1959, between 1960 and 1974, and between 1975 and 1984. Asbestos cement and cast iron pipes were not installed in Maple Ridge after 1984. Ductile iron pipes were sub-grouped into pipes with installation dates between 1970 and 1979, 1980 and 1989, 1990 and 1999, and subsequent to 1999. The only steel pipes were installed in 1978 and are approximately 24 metres in length. These have not broken. Statistical deterministic equations for each group of Laity View pipes were developed for time-linear and time-exponential functions. Statistical deterministic equations were selected as most appropriate for Maple Ridge because they do not have a sufficient amount of pipes (e.g. grey cast iron) and data (such as remaining pipe wall thickness) to use physical-mechanical models or the resources to maintain complicated models (Maple Ridge has only three engineers on staff and relies on technical support staff for much of the engineering department duties and responsibilities). Statistical deterministic models can be easily taught to and applied by technical staff and require fewer data. The results should provide insights for future performance and improve Maple Ridge's current practices of prioritizing water main replacements which are based on experience.

The time-linear equations for the cumulative number of breaks at year t are based on Equation 1.

$$N(t) = A\,(t-t_o) + C \qquad (1)$$

Where N(t) is the cumulative number of breaks for the year t, t_o is the reference year, in the case of Laity View, 1983, A is a coefficient and C is a constant.

Time-exponential equations for the cumulative number of breaks at year t are based on Equation 2.

$$N(t) = A\, e^{k(t-to)} \qquad (2)$$

Where A and k are coefficients and all other variables are as described above.

As noted earlier in this chapter, these equations and their coefficients are specific to the Laity View area pipes and their respective sub-groups. Utilities should develop their own equations using their system-specific data, selected sub-groups and estimated coefficients (though they may choose to also use time-linear and time-linear regression). For each sub-group which had sufficient data, equations were derived using S-Plus® and spreadsheet software to solve for the coefficients. A minimum of two breaks is required in order to estimate these equations, and thus equations could not be derived for all sub-groups analyzed. For each sub-grouping analysis, the percent of all pipes for which an equation could be derived was estimated, as this is an indication of the extent of the network that may be modeled. The accuracy of the derived equations, henceforth referred to as models, was calculated as the percent error of model predictions relative to the cumulative breaks in 2004. Finally for time-linear models, R- squared estimates are reported.

Results of break prediction models. The accuracy of the prediction results for both time-linear and time-exponential models for the various sub-groups are shown in Figures 4.2 through 4.6. The different amount of breaks and the rate of breaks among the various groups suggest that there are differences in behavior for deterioration and breakage. For the material sub-groups, three sub-groups could be modeled; those for asbestos cement, cast iron and ductile iron pipes and these represent approximately one hundred percent of the pipe length in the network. As shown in Figure 4.2, the time-linear models are more accurate than the time-exponential models for asbestos cement and ductile iron pipes; the percent error for the time-linear models was 29 and 34, and the percent error for the time-exponential models was 210 and 136, for the asbestos cement and ductile iron pipes, respectively. The range of R-squared statistic for all of the time-linear models was 0.81 to 0.92 and the average R-squared value was 0.84. The results for the cast iron pipes indicate that while few breaks have occurred in these pipes they are occurring at an increasing rate.

The accuracy of predictions for material and diameter sub-groups is shown in Figure 4.3. Here, seven sub-groups had sufficient number of breaks to be modeled and these represent 99 percent of the pipe length in the network. Again, with the exception of the cast-iron pipes, the time-linear models are more accurate than the time-exponential models. While the most accurate model is the time-linear model for the ductile iron pipe with a diameter of 150 mm, in general the performance of time-linear models for the asbestos cement and ductile iron pipes is similar. The average R-squared statistic for all of the time-linear models was 0.84 and the R-squared statistic was between 0.75 and 0.95.

When age was considered, seven sub-groups contained sufficient number of breaks to be modeled, and these represent 56 percent of the pipe length in the network. As shown in Figure 4.4, the accuracy of the time-linear models for ductile iron pipes improved dramatically, indicating that age effects are important in predicting break rates for these pipes, and should be investigated. With respect to the asbestos cement pipes, the age delineated sub-groups suggest that different age groups of 150 mm asbestos cement pipes are behaving differently with respect to breaks, the ability to accurately predict breaks differ and that the number of breaks for pipes installed between 1975 and 1984 are increasing. The R-squared statistic for all of the time-linear models was between 0.75 and 0.94 and the average R-squared statistic was 0.84.

When pipe-soil interactions were considered, eight sub-groups could be modeled, but this represented only 38% of the pipe length in the network. The accuracy of predictions for the material, diameter, soil and age sub-groups is shown in Figure 4.5. These results suggest that the accuracy of predictions for pipes of the same material differs in different soils, even when they are installed at the same time. When clay is considered as a factor in the analysis, the accuracy of the time-linear models stayed the same or improved relative to analyses that considered only material, diameter and age. The average R-squared statistic for all of the time-linear models for these sub-groupings was 0.78 and ranged between 0.63 and 0.94.

The accuracy of the models for material, diameter, age, and surface material sub-groups is shown in Figure 4.6. Here, eight sub-groups could be modeled but these represent only 40 percent of the pipe length in the network. While the average R-squared statistic for all time-linear models for this case was 0.84 and ranged from 0.72 to 0.95, the accuracy of these models is no better than the accuracy of the time-linear models for the material, diameter, and age sub-groups alone. This indicates that, in contrast to soil type, surface material may not be an important factor to consider in predicting pipe breaks for Maple Ridge.

Observations. It is important to note that some of the data that were created as part of an earlier water main break database constructed (see Chapter 3) contributed to increasing the accuracy of the applications of the break prediction models. In particular, the soil data provided insights for engineering staff by indicating that soil characteristics may be an influence on the rate of corrosion in certain pipes or bedding and backfill used in installing the pipes and thus confirmed the value of creating, relating and processing data. As a result, though the effort was significant, the data creation and mining provided insights and is useful for management decisions and asset management. Without created data, the analysis and use of prediction models would be limited.

For Maple Ridge, the pipe groups associated with models that accurately predict high break rates are: 250 millimeter diameter asbestos cement pipes installed in clay soil between 1960 and 1969 and 150 millimeter diameter asbestos cement pipes installed in clay soil between 1960 and 1969. As a result of these analyses, consideration of the break rates of various pipe groups and discussions with operations and maintenance staff, asbestos cement pipes will be prioritized for replacement (along with cast iron pipes when opportunities arise) and further attention will be given to collecting data on ductile iron pipes. More importantly, because soil type was identified as an important factor in modeling breaks, a soil sampling program was undertaken to improve the utility's information regarding soil resistivity, pH, chlorides and soil type. A preliminary pipe sampling program was implemented at the same time to collect information on asbestos cement pipes and ductile iron pipes in the area. As a result of the sampling programs, the importance of bedding and backfilling practices and construction inspections was identified and changes in construction specifications and inspection practices are being developed. Plans are underway to apply this framework to the rest of the Maple Ridge network. Ultimately, scheduling of the pipe replacements and budget estimates will be undertaken in conjunction with other management considerations such as road rehabilitation.

An ongoing problem for utility managers is the allocation of scarce resources for both data collection and analysis. One approach for determining the value of the framework and a supporting data collection program is to evaluate the value of the additional information obtained. The value of additional information may be estimated by comparing the decision that would be undertaken without the additional information with the decision that would be undertaken with the additional information (Schuyler, 2001). For example, for Laity View, the value of developing statistical models that incorporate soil data may be determined by comparing the cost of replacing the group of pipes that has the highest break rates based on data for material, diameter and age (i.e., 250 mm diameter asbestos cement pipes) with that of a replacement strategy that considers replacing only those 250 mm diameter asbestos cement pipes in clay soils. If all 250 mm diameter asbestos cement pipes, with a total length of 646 meters were to be replaced, the total cost of replacement would be $193,800 (assuming a replacement cost of $300 per meter). By applying the framework it was determined that all the breaks in these pipes occurred in clay soil. If it is assumed that all future breaks of this pipe type will occur in clay soils, replacement of these pipes, with a total length of only 258 meters would cost $77,400. Thus the value of the analysis and the soil information is approximately $193,800 - $77,400 = $116,400.

While this additional information may not always lead to savings in terms of reducing the cost of pipe replacement, for example in cases where the all pipes of a certain material, diameter and age were installed in the same soil type, the information regarding soil type may still be of benefit. This information could be used to improve the installation practices or justify corrective measures.

4.5 CONCLUSIONS

Predictive modeling is useful for identifying replacement needs over time. However, utilities do not commonly use predictive modeling as part of their asset management practices. There are no common databases for break analysis or common condition indices, and few utilities undertake condition assessment (Grigg, 2004), all of which hinders industry-wide use of predictive modeling. The framework presented in this paper improves upon the traditional pipe prioritization approaches that only look at the past history in aggregate and do not necessarily take into account trends and timing of future breaks. An advantage of the framework is that it can be applied by small to medium size utilities with limited information and commonly used analytical tools. For example, for Maple Ridge, while useful information was gained by investigating soil type, reasonable insights may have been drawn from analyses that considered only material, diameter and age, information that is typically available to most utilities. Because factors that cause breaks vary among utilities, utilities may find individually that creating more data (such as by collecting traffic loading, backfill and pressure data) and relating data for mining and analysis is worthy of the effort and expands the use of this framework. With this in mind, the framework is flexible and allows for consideration of any available data. In addition to guiding water main replacements, the framework may also be used to identify the key data for predicting water main breaks.

Because there is variability in the causes of pipe breaks among different utilities, in order to understand the performance of their system, utilities should collect data as identified in recommended Best Practices; see National Guide to Sustainable Municipal Infrastructure (NGSMI, 2002) and AWWARF (Deb *et al.*, 2002). Additional information may often be obtained efficiently at the time of the break repair by revising forms to collect more information, such as bedding or backfill material (Wood and Lence, 2006). Training will often be required, and it is prudent to verify data. Convincing staff to collect data may be an obstacle, but involving them in decision making can be a way to gain support. By using models to predict future breaks, reviewing the accuracy of the predictions and updating the models, a utility can improve its asset management practices.

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Table 4.1 Typical data used in models and factors for which they are a surrogate

Surrogate	Factor
Age	Method of pipe manufacture, construction standards, deterioration over time
Pipe material	Construction practice, method of manufacture, failure mechanisms and causes, joint failures
Pipe diameter	Wall thickness and resistance to beam loading, pipe use, method of pipe manufacture, construction standards
Type of pipe lining	Method of pipe manufacture, resistance to corrosion
Bedding and backfill material	Physical stress on pipes caused by construction practices, structural resistance, soil type, fines migration
Pipe protection (wrapped/anodes)	Structural resistance, life expectancy, construction practice, method of pipe manufacture
Pipe condition	Remaining life
Soil type	Soil corrosivity, physical loading on the pipe such as swelling and frost, level of pipe protection, ground water effects such as draining ability or corrosion, construction practice, bedding and/or backfill material
Under a boulevard or roadway	Physical loading from surface loads such as traffic, road salt effects
Depth of cover	Physical loading on the pipe from the weight of soil
Surface material/type	Physical loading from surface use
Normal operating pressure	Internal pressure on pipe structure
Typical flow in area of break	Physical impact from factors such as accelerated internal corrosion from low flow mains
Traffic classification	Physical loading from surface loads such as traffic volumes and wheel loads
Road/surface usage	Physical loading from surface loads

Figure 4.1 Improving asset management using pipe break prediction models

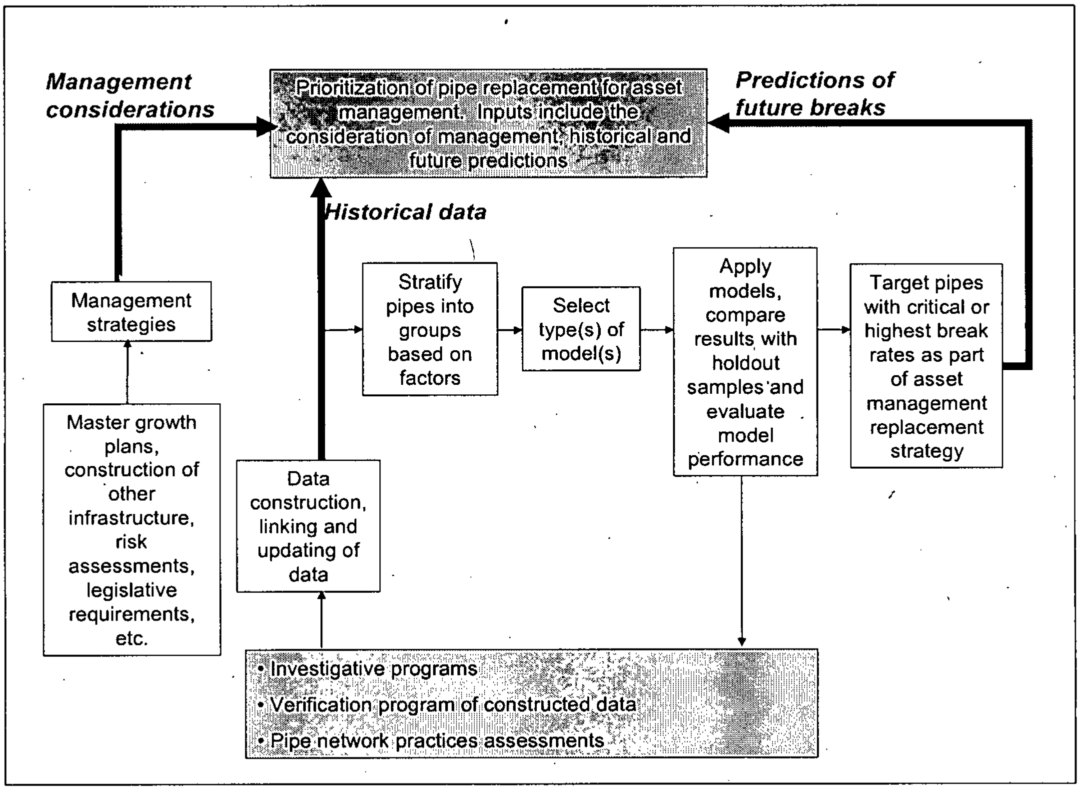
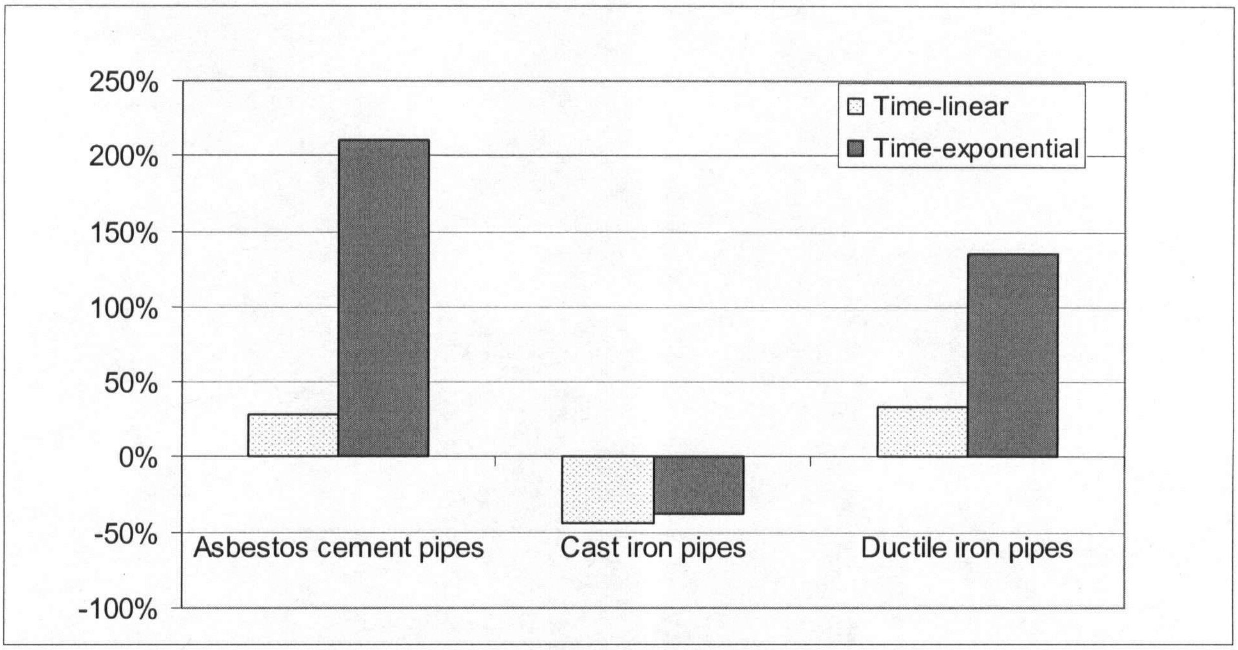


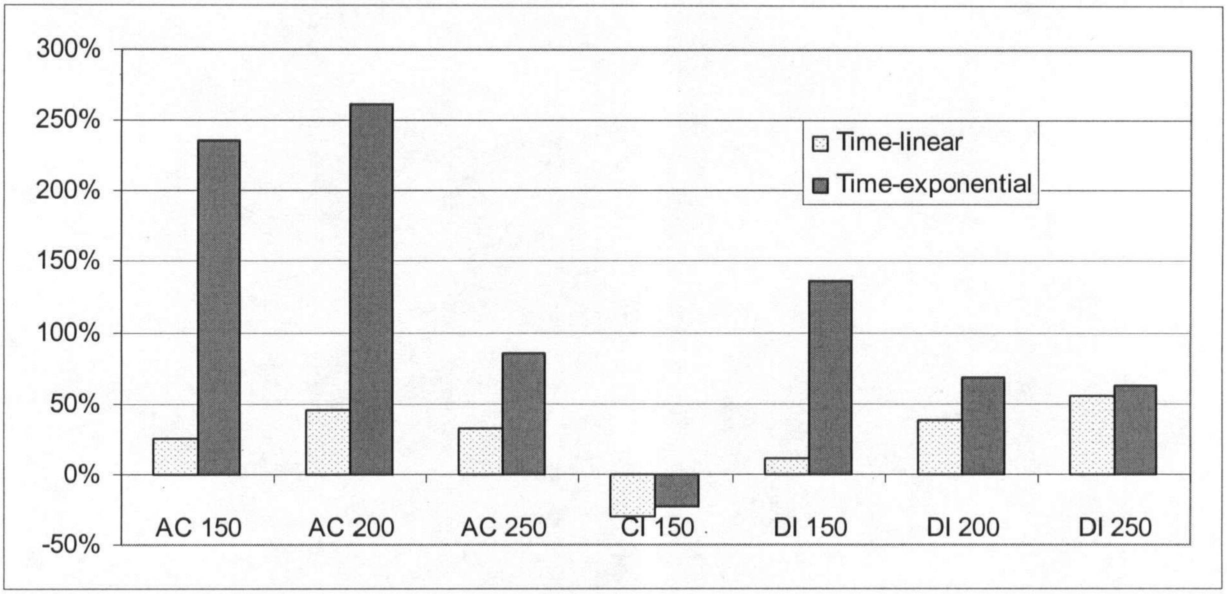
Figure 4.2 Degree of accuracy of time-linear and time-exponential predictions for material groups



Note

In 2004, there were a total of 32 breaks in asbestos cement pipes, 5 in cast iron pipes and 17 in ductile iron pipes.

Figure 4.3 Degree of accuracy of time-linear and time-exponential predictions for material and diameter groups



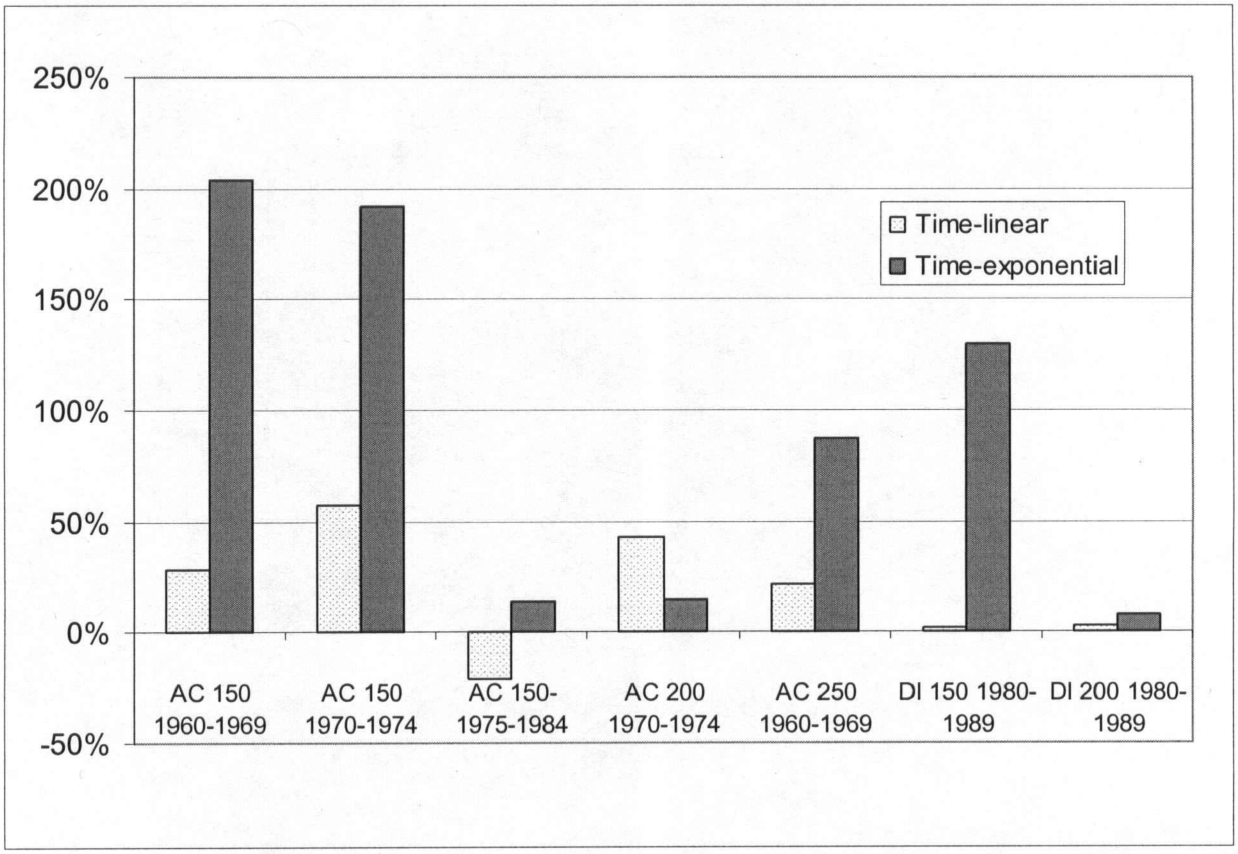
Notes

AC denotes asbestos cement pipes, CI denotes cast iron pipes and DI denotes ductile iron pipes.

Pipes are grouped by material and diameter (in millimeters). For example, AC 150 pipes are asbestos cement pipes of 150 millimeters diameter.

In 2004, there were 24 breaks in AC 150 pipes, 5 in AC 200, 3 in AC 250, 4 in CI 150, 9 in DI 150 and 2 in DI 250 pipes.

Figure 4.4 Degree of accuracy of time-linear and time-exponential predictions for material, diameter and age groups



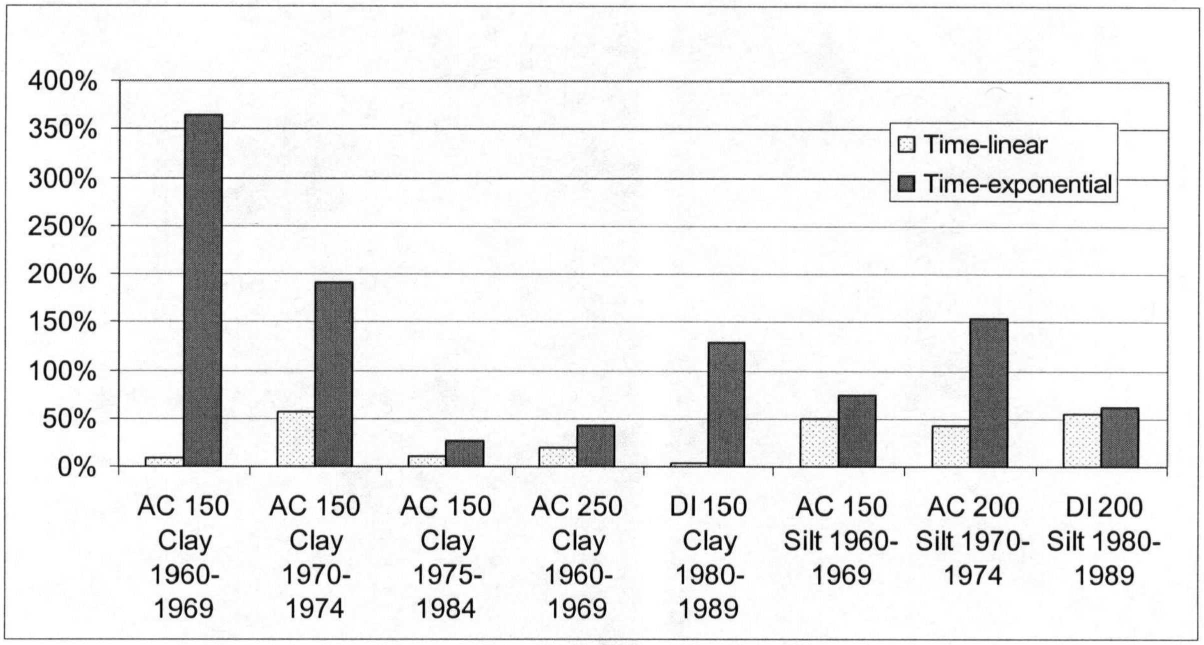
Notes

AC denotes asbestos cement pipes, CI denotes cast iron pipes and DI denotes ductile iron pipes.

Pipes are grouped by material, diameter (in millimeters) and age. For example, AC 150 1960-1969 pipes are asbestos cement pipes of 150 millimeters diameter installed between 1960 and 1969.

In 2004, there were 12 breaks in AC 150 1960-1969 pipes, 7 in AC 150 1970-1974, 5 in AC 150 1975-1984, 3 in AC 200 1970-1974, 3 in AC 250 1960-1969, 4 in DI 150 1980-1989 and 3 in DI 200 1980-1989 pipes.

Figure 4.5 Degree of accuracy of time-linear and time-exponential predictions for material, diameter, soil and age groups



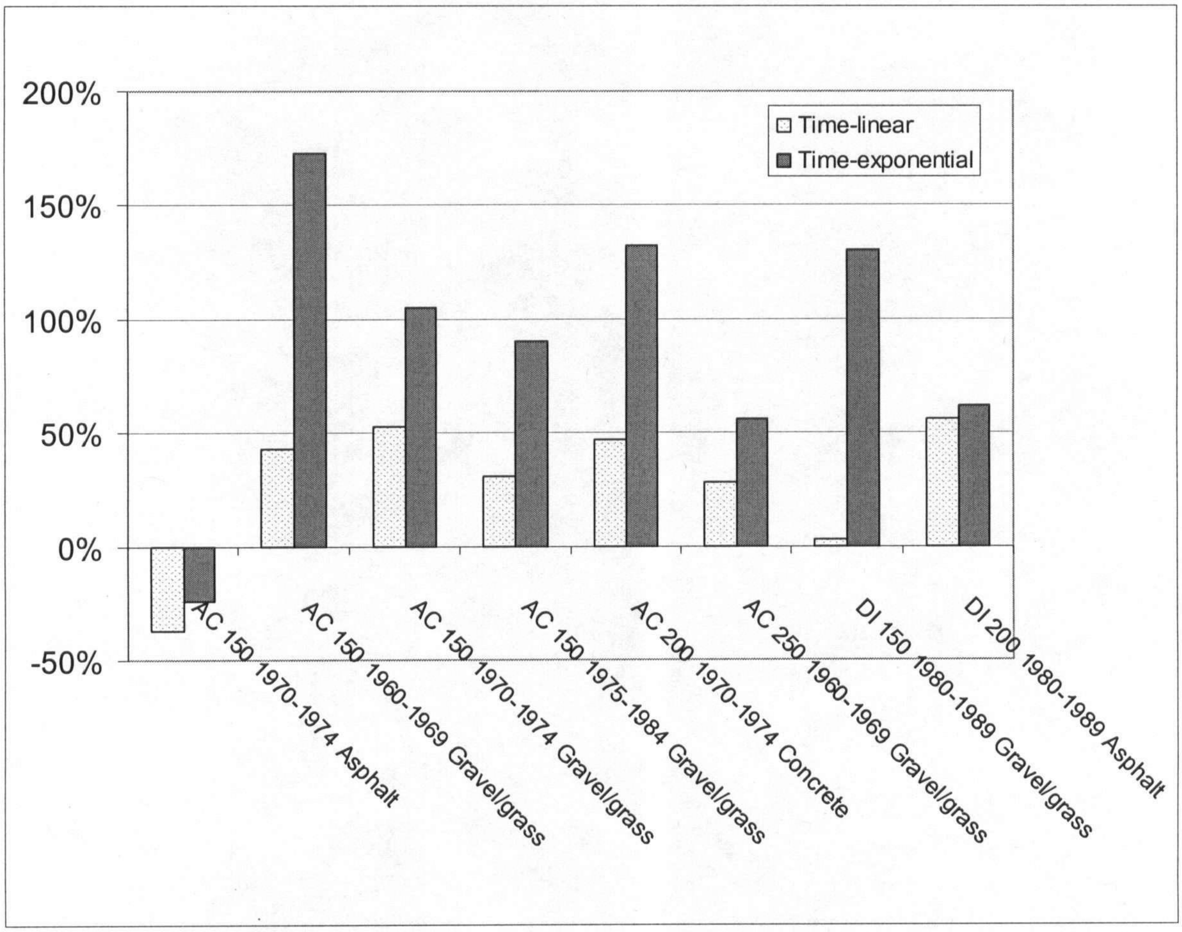
Notes

AC denotes asbestos cement pipes, CI denotes cast iron pipes and DI denotes ductile iron pipes.

Pipes are grouped by material, diameter (in millimeters), soil type and age. For example, AC 150 Clay 1960-1969 pipes are asbestos cement pipes of 150 millimeters diameter installed in clay soil between 1960 and 1969.

In 2004, there were 7 breaks in AC 150 Clay 1960-1969 pipes, 7 in AC 150 Clay 1970-1974, 2 in AC 150 Clay 1975-1984, 2 in AC 250 Clay 1960-1969, 4 in DI 150 Clay 1980-1989, 3 in AC 150 Silt 1960-1969, 3 in AC 200 Silt 1970-1974 and 2 in DI 200 Silt 1980-1989 pipes.

Figure 4.6 Degree of accuracy of time-linear and time-exponential predictions for material, diameter, age and surface material groups



Notes

AC denotes asbestos cement pipes, CI denotes cast iron pipes and DI denotes ductile iron pipes.

Pipes are grouped by material, diameter (in millimeters), age and surface material. For example, AC 150 1970 - 1974 Asphalt pipes are asbestos cement pipes of 150 millimeters diameter installed between 1970 and 1974 under an asphalt surface.

In 2004, there were 5 breaks in AC 150 1970-1974 Asphalt pipes, 7 in AC 150 1960-1969 Gravel/grass, 5 in AC 150 1970-1974 Gravel/grass, 3 in AC 150 1975-1984 Gravel/grass, 2 in AC 200 1970-1974 Concrete, 2 in AC 250 1960-1969 Gravel/grass, 4 in DI 150 1980-1989 Gravel/grass and 2 in DI 200 1980-1989 Asphalt pipes.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 SUMMARY OF RESEARCH GOALS

Asset management of water systems involves assessing when to replace aging and deteriorating pipes. The goal of this research is to assist small to medium size utilities with identifying, collecting and constructing relevant pipe break data to analyze their pipe network, and using break predictions to inform their water main replacement strategy and guide their data acquisition programs. First, the data that are collected and available for analysis across utilities in North America are identified. Next, a methodology to create and link data obtained from various data sources that can be used in utilities of all sizes to construct databases is developed. Finally, a framework to assist the prioritization of water main replacements and data acquisition based on predicting future water main breaks within a given water distribution system is presented. The framework is applicable for the range of data available in typical water utilities, acknowledges existing industry needs and practices and may help managers to acquire and use available data.

Much of the focus of water main break research has been on the data rich and technically sophisticated larger utilities. However, small and medium size utilities need the techniques developed in this research because they have scarce resources for asset management within their organizations. Compared with larger utilities, they do not have the staffing expertise or the capacity for training, monitoring or developing back-up systems (Ontario PIR, 2005). Within these utilities, there is little or no reliable documentation regarding the location, capacity, condition and adequacy of pipe network elements for meeting present or future needs (Myers, 2001). These utilities may also lack the financial and organizational resources to implement a complex asset management program or lack the historical data or tools to fully analyze their system. They need relatively inexpensive techniques. This research provides adaptable approaches for efficiently acquiring data regarding water main breaks, compiling, analyzing and using the data to predict future water main breaks and improving prioritization of pipe replacements.

Selecting the case study. The research in this thesis uses real data from the District of Maple Ridge, BC. Maple Ridge was selected because it is a medium size water utility, is similar to municipalities that have undergone urbanization over the past decades and possesses data that were made available to me. Moreover, Maple Ridge was interested in using break prediction models to improve its asset management practices and while it lacked a comprehensive water main break database, it was receptive to developing databases for analysis. It also needed a strategy to manage and maintain the data after they were used to predict water main breaks. Appendix C is a summary description of the Maple Ridge water system.

5.2 CONCLUSIONS

Water main break data collection is evolving and industry practices do not match best practices recommended by NGSMI (2002) and Deb *et al.* (2002) at this time. Utilities need a strategy for data quality improvement that will help them deal with challenges such as difficulty in mobilizing financial and human resources, absence of historical data, lack of knowledge of current organizational practices, low reliability of previously collected data, difficulty in prioritizing data collection, and the need to develop effective data storage programs. In general, utilities can be classified as those possessing expanded, intermediate, limited or minimal data. While both physical and statistical models have been developed for predicting pipe deterioration and for developing water main rehabilitation plans, it is evident that the choice and application of these models are limited by the data that utilities have regarding water main breaks (Rajani and Kleiner, 2001; Kleiner and Rajani, 2001).

For practitioners and researchers alike, characterization of these data classes may be used to inform the development of new asset management techniques that are tailored to the data limitations that utilities face. Utilities may also improve their data collection by modifying their current practices and more significantly, they can seek out alternative data sources from which to analyze breaks and ultimately predict future breaks. The alternate sources that are identified in this research can yield information for researchers and managers alike.

The process of creating the data schematic as developed in this research is useful for linking multiple databases in order to compile and analyze data. It expands the data available for analysis for both present and future applications and allows decentralized data input and management. More importantly, it is a flexible approach that all utilities can employ without significant resource commitments. It reduces problems related to data ownership among units within organizations regarding data collection, management and dissemination of infrastructure information.

The framework developed in this research for linking data is flexible, anticipates the evolution of data collection, building, verification and storage and allows for a variety of users. It does not abruptly disrupt data collection and warehousing practices and it allows managers to continue to expand data collection because databases are decentralized. It is flexible and can be easily adapted to all utilities, whether they are small, medium or large, and regardless of the uniqueness of the data collected and organizational framework. This technique can also incorporate tacit data. The importance of capturing tacit data will increase over the next decades as baby boomer staff retire.

This thesis develops an approach for using break prediction models for identifying replacement needs over time and uses improvement in model accuracy as means of identifying the key data for predicting future water main breaks and informing future data acquisition strategies. Traditional approaches for prioritizing pipe replacements do not incorporate break predictions. The framework developed in this research allows for the construction, assessment and use of any available data by any size utility.

5.3 OBSERVATIONS

General observations. A number of observations arise from this research. While this research primarily focuses on engineering science, a number of the observations relate to management science and the relationships organizations and people have with data utilization. While these topics arise from the research, they are not addressed in this thesis and future research in these areas will be valuable.

1. As noted in the thesis, data are collected throughout an organization by various departments and staff for various purposes. For data to be used corporately, executives must acknowledge and address data ownership among departments and managers.

2. Because asset management is a corporate responsibility, proprietary issues and organizational compartmentalization can pose major challenges to implementing an asset management program. Corporate objectives of knowledge management (e.g., database development and maintenance) should be established and most importantly, be accepted by those responsible for collecting, managing and analysing the data. These objectives should be established and promoted by utility executives throughout the utility because in some organizations knowledge may be viewed as power and data may be interpreted as a surrogate for knowledge.

3. An important task for managers is to establish and encourage a culture of knowledge sharing (Connelly, 2000). Motivating and coaching staff to share knowledge can be a major challenge. As well, managers themselves are not immune to the habit of hoarding information and knowledge, though this tendency may be reflective of the corporate culture and the individual's relationship with their subordinates, peers and supervisor.

4. A significant need exists in utilities for capturing institutional memory and data that currently exist and which will be lost as employees retire. Commonly, large amounts of institutional memory are not recorded. For most utilities, there is a need to capture the memory of operating departments since they are more often characterized as "action oriented" and "hands on" rather than "paper loving". Managers must find solutions to address this important issue.

5. Water utilities also face recruiting, training and capacity building challenges. The view that staff will join an organization early in their career and spend thirty years in that organization is becoming extinct. For example, District of Maple Ridge recruiters consider obtaining five to ten years of service from a non-union manager (before he or she leaves the organization) as a valuable experience. Compounding this, currently, there is significant competition among BC employers to recruit and retain engineers. Utilities also require training and capacity building programs for new staff as well as existing staff. One challenge for many utilities is that training budgets are often the first to be cut in times of financial restraint (because budgets are primarily viewed as supporting expenditures and training as a discretionary expense). This was the case in Maple Ridge's history. The success of training programs is dependent on the marketing and implementation of the training as well as the quality of the training. This aspect of organizational development is

also important because according to Jacobson and Prusak (2006), organizations will receive greater value from information by developing strategies and training staff to help them use what they have rather than by searching for more data.

6. Utility managers also need to inspire and motivate positive change. During the course of the research, the author observed that managers find that support for change (from their supervisor or employees) is not automatic, and factors that influence the support or change include the career goals of their supervisor, their level of influence within the organization's politics, staff motivators and how the utility is governed. For example, changes in data collection practices because of legislation tend to be more rapidly implemented than other reasons for changes (NSGMI, 2003).

7. A final observation is that organizational leadership, structure and behaviour have a major influence on a utility's focus and practices. Based on what I have observed of various utilities, the manner in which engineering and maintenance departments function and in which responsibilities are distributed within a utility can lead to duplication of work (because of ambiguity or the desire to possess the information or responsibility) or the incompletion of work (because each department may deny responsibility and assume that the other is addressing the issue). Furthermore, utility executives need to provide strategic thinking and leadership of the organization, while balancing corporate and individual goals and strengths. Without this, staff efforts may be misplaced or frustrated or may flounder.

Professional applications. This thesis has many practical applications for small and medium size utilities. It provides information on data collection and presents an approach that a water utility may adopt should they decide to use break prediction models.

Given the work reported in Chapter 2, utilities can assess their practices against those of their peers and those recommended as best practices. They can identify and improve their data collection practices and use the survey results to facilitate discussions within their organization regarding the availability and storage of data. They may find additional data available from other sources such as those identified in this thesis. If there are insufficient data for analysis, they may compile and link data and construct additional databases to extend the breadth of data as demonstrated in Chapter 3. Following that example, they can construct a data schematic for their organization to analyze their system for asset management in general and to explore the underlying causes of water main breaks. Once they have constructed and analyzed the data which is useful despite the effort required, they can then use the framework developed and demonstrated in Chapter 4 to incorporate the use of break prediction models to improve asset management and to inform their future data acquisition and storage programs. The approaches developed in Chapters 3 and 4 address the problems faced by utilities, and are designed to be adaptable to their needs and the examples used are based on real data.

Researchers will also benefit from the work reported in Chapters 2 and 3 which identifies the data that are available for developing future asset management tools and how utilities can access and construct data for research purposes.

Lessons learned. While the research has a number of applications, a number of lessons were learned. When applying the research as described in Chapter 3, a utility requires staff and external help in two areas. Firstly, they require technical assistance in the following tasks:

- Deciding on the objective of the exercise. A suggested objective is presented in the thesis and other purposes are also identified. These should be developed by managers and engineers.

- Creating data by reviewing different sources of data (internal and external to the utility). The thesis presents a number of techniques such as buffering a collection of data, interviewing people to capture tacit information, examining previous practice standards and conducting surveys. Some of this work can be undertaken by consultants and by training existing staff.
- Deciding upon the databases to be related and the nature of the relationships. Some databases and relationships are suggested in this thesis, but these decisions should be determined jointly by utility and data managers.

Secondly, the utility will require more technical resources to:

- Review the extent of data availability throughout the organization. The thesis suggests sources to explore.
- Create data from paper records.
- Establish links among various databases.
- Map the links and various databases. This can be undertaken by line staff and this thesis provides guidance for this task.
- Perform some exploratory analyses.

It should be noted, that the technical work requires some understanding of the data and some ability to read design drawings. In addition, the project manager applying the research should have strong communication and interpersonal skills to determine where data may be available and to obtain consensus on data sharing among various departments. They should be tactful, diplomatic, persuasive, patient and persistent and should not be easily discouraged because applying the work will take time within any utility. Sponsorship and support from the utility executive should be obtained which will help when working through departmental and corporate issues. Finally, it is not unrealistic to expect that a project such as described in Chapter 3 would take a 1.2 person years to two person years of effort and a project such as described in Chapter 4 may take as much as one person year.

Validation of the work. While the proof of this work lies in the arguments and demonstration of the approaches developed, the validation of the contribution will be the acceptance of the methods proposed in practice and whether they are employed by utilities to improve asset management and data productivity. In using their own system-specific data and the thesis as guidance, this research may be applied and adapted to utilities of various sizes possessing a range of abilities for improving their asset management practices. Ultimate validation may be undertaken by evaluating the success of such applications.

Further research. To make the application of this research more useful, further research is needed in the following areas.

1. The survey was developed in English and forwarded to those communities listed in Appendix E. Only one response was received from the Anglo-Quebec municipalities. Investigation of French-Canadian water main break data collection practices could inform these communities and the larger water utility industry, although the data available to Pelletier *et al.* (2003) suggest that French-Canadian practices are no different than those identified in this research. Regardless, translating and distributing the survey throughout Quebec is a potential future project.

2. Testing the framework of using water main break prediction models in a utility that has more water main breaks, a longer history of breaks or different climate would add

further confirmation of the applicability of the research to other utilities. The framework has been designed and demonstrated to be robust, though further confirmation would be useful. Furthermore, with a larger number of breaks to analyze, it is possible that other key data may be identified as important for determining the accuracy of break prediction models.

3. Application of a combination of statistical and physical-mechanical models should be explored within the framework provided herein. The accuracy of predictions for the different types of models could also be assessed to give further guidance for choosing models. In addition, combining the models in a case study could provide insights that can be used to potentially demonstrate or improve the robustness and flexibility of the framework developed herein.

4. Finally, the topics identified in the general observations section should be further explored to assist utilities in applying the research in practice. These issues include how utilities can increase knowledge sharing (of data and practices) within their organization and identifying key organizational structures, leadership attributes and motivators that are needed to improve water utility management. While small and medium size utilities are able to make operating policy and practice changes quickly because decision making typically rests with fewer staff than is the case in larger organizations, they are like most organizations. They are limited by resources including leadership and motivation skills and training to execute large changes. Research in determining and assessing the required skills, personality aptitudes, abilities, training and human resource needs for institutionalizing the approaches presented in Chapters 3 and 4 would be useful in extending the impact of this work.

Future research interests of the author. Three areas that I am considering for further research arising from the work in this thesis include applying additional approaches to analyzing break data, applying the data construction approach and framework developed herein to other infrastructure assets, and enhancing utility knowledge management practices.

1. Applying Knowledge Discovery tools such as artificial intelligence to analyse large water main break databases. This has potential to assist those water utilities fortunate enough to have a breadth of data and a long history of breaks and to reduce the necessity for having many experienced staff to manage infrastructure assets.

2. Applying the concept of linking and relating data (as shown in the water main break schematic shown in Chapter 3) and using statistical deterministic and other prediction models to sewerage and drainage systems. Extending the approach presented in this thesis to these infrastructure systems has several advantages. These systems are usually owned and managed within the same managerial unit and typically have similar replacement values as water systems. Nonetheless, there are differences among the systems. For example, sewer systems are easier to inspect using video cameras and a common condition rating system for them exists. Though drainage systems could use the same condition rating system, they are rarely evaluated and wear out at a faster rate.

3. Examining how to manage knowledge of a system within an organization. The data schematic and concept of relating relational databases as discussed in this thesis has potential to play a significant role in connecting data for various services among the members of an organization, but research is needed to assist utilities in capturing, managing, maintaining and using this knowledge. Example research questions include: what are the best techniques for interviewing and recording tacit data from retiring

employees, what is the optimal organizational structure for sharing knowledge among engineers and maintenance staff, and what are the most efficient and effective approaches that utilities can employ to make data accessible across an organization?

5.4 CLOSING REMARKS

The approaches developed herein are easily applied. There are significantly more small and medium size utilities than larger utilities (Vanier and Rahman, 2004) and these utilities can benefit from applying the work. The approaches have been demonstrated with real data and may provide utilities with insights and guidance for allocating their scarce resources, considering their current limitations and future needs. The application is practical and can be implemented incrementally. The thesis chapters are at various stages of publication or review. Chapter 2 was published in the July 2006 issue of the Journal of the AWWA. Chapter 3 is published in the January 2007 issue of the Journal of the AWWA. Chapter 4 was submitted to the ASCE Journal of Infrastructure Systems in July, 2006. An invited presentation on the results of the first paper was made at the September 2006 Annual Public Works Association of BC (a chapter of the American Public Works Association) Conference in Qualicum Beach, BC. In addition, the work will be presented as part of a water system asset management workshop to engineers in the Greater Vancouver area.

In closing, as a result of the work conducted in this thesis, Maple Ridge has implemented a number of the findings to improve its water main break data collection practices. It has undertaken soil surveys, tested a number of pipe samples and verified some of the linked and related data. It is also developing a utility wide data schematic that will form the basis of a data warehouse strategy that will be applied to the entire water system and sanitary sewer system. Finally, the framework for determining the data that contribute to pipe failures will be implemented beyond the case study area to improve Maple Ridge's asset management practices.

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APPENDICES

APPENDIX A

Appendix A summarizes the utilities surveyed and the data queried by *Deb et al.* (2002) and by the author as part of the survey reported on in Chapter 2. A comparison of the survey responses by service population is shown in Table A.1. A comparison of the questions asked by the two surveys is shown in Table A.2.

Table A.1 Comparison of North American utility responses by service populations

Survey	**<100,000**	**>100,000**
Survey by Deb *et al* (2002)	5	32
Survey by Wood and Lence (2006)	37	22

Table A.2 Comparison of questions posed by Deb et al. (2002) and Wood and Lence (2006)

Survey question by Deb et al (2002)	**Question addressed by Wood and Lence**	**Notes**
Utility size	yes	
Water production	no	
Total length of pipe	yes	
Main failures		
Formal program for control of failure	n/a	
Main inventory	n/a	
Computerized main inventory of total	n/a	
Failure records	yes	Wood and Lence survey focused on failure records
Computerized failure records of total	n/a	
General Information	yes	
Date, address	yes	
Temperature	yes	Wood and Lence also queried air, water, change in water temperature and soil temperature
Time of detection and arrival	yes	includes repair date
Impact on surroundings		
Services affected	yes	Wood and Lence survey includes type of services and length of outage

Blocks affected	no	Wood and Lence survey includes quantity of parcels and number of customers affected and property damage
Hydrants affected	no	
Proximity to buried objects	no	
Water main information		
Material	yes	
Location in street	yes	Wood and Lence survey includes surface use
Diameter	yes	
Depth	yes	Cover depth
Installation date	yes	
Cathodic protection	yes	Wood and Lence survey queried pipe protection and /or anode installation
Joint type	yes	
Type of repair	yes	
Pressure		
Range	yes	Operating pressure
Pump station status	no	Wood and Lence survey queried flow in area
Failures		
Type of failure	yes	Wood and Lence survey queried on suite of types (11), Deb et al. just queried if type of failure was recorded
Probable cause	yes	Wood and Lence survey queried on suite of causes (13)
Type of repair	yes	Wood and Lence survey queried on suite of repairs (7) and additional treatments
Exterior/interior of pipe	yes	Wood and Lence survey queried on both exterior and interior, lining condition and other details
Bell condition	no	Wood and Lence survey queried on Joint type
Condition of valves		
Required for isolation	yes	
Condition	no	

Reporting bedding conditions	yes	Wood and Lence survey queried on material and condition separately
Reporting of seismic/geotechnical conditions		
Soil description	yes	Wood and Lence survey queried on native soil, soil pH, soil Moisture content while Deb at al. identified if soil description was recorded
Geologic unit description	no	
Groundwater depth	no	
Seismic hazard unit	no	
Collecting field samples		
Pipe samples	yes	
Soil samples	yes	
Use of automated systems		Wood and Lence survey explored other sources of data
Field portable computers	see note	
GPS	see note	
GIS	see note	
DBMS	see note	
Formal renewal program		
Main replacement	n/a	
Main rehabilitation	n/a	
Costs records		
Direct labour	yes	Wood and Lence survey queried on crew hours
Indirect labour	see note	Wood and Lence survey queried on all labour costs
Materials	yes	
Equipment	yes	
Surface repairs	see note	Wood and Lence survey queried on Property damage costs
Damage	yes	Wood and Lence survey queried on Property damage costs

APPENDIX B

Appendix B provides the statistical analysis for guiding the interpretation of the survey results and their applicability to the general population of water utilities. Given a specified percentage of respondents that collect a particular type of data, one may wish to determine the percentage of all water utilities that are likely to collect the given data. Such questions are addressed using the confidence range of observations regarding the particular type of data for utilities in the general population, and these are based on the standard error of the sample population.

Wild and Seber (2000) suggest that an accepted measure of the confidence in the behaviour of the general population (e.g., all water utilities) is equivalent to two standard errors of the sample proportion (e.g., the respondents). The standard error of the sample proportion is calculated using the equation:

$$Se\,(p) = (p*(1-p)/n)^{0.5} \qquad \text{(B1)}$$

Where $Se\,(p)$ = the standard error of a sample proportion,

p = the proportion of the sample that collects a given data type or element,

n = the sample size, in this case 59 utilities.

For example, using Equation B1, if 63 percent of the respondents (i.e., 37 responses of the 59 survey respondents), indicate that they record when water service was restored, we may expect that more than 50 percent (i.e., the lower confidence limit) but less than 75 percent (i.e., the upper confidence limit) of all water utilities in the general population would record the same. The lower confidence limit of 50 percent is calculated by the response proportion minus two times the standard error of the sample population, i.e., $0.50 = 0.63 - 0.13$, where $0.13 = 2*Se(p) = 2\,(0.63*0.37/59)^{0.5}$.

Because the standard error is calculated using the sample proportions, the standard error varies with the number of responses. For example, the higher the number of responses for recording a given type of data, the more certain we are of the general population recording that type of data. The range of standard error is between 5.5 percent and 6.5 percent for response proportions of between 33 percent (20 responses) and 76 percent (45 responses) A summary of values for the standard error for various levels of responses and the general population confidence limits corresponding to those responses is shown in Table B.1.

Table B.1 Confidence limits for the general population[a] based on proportion of responses

Number of responses	Percentage of respondents	Standard error of response - %	Upper limit of the confidence level for the general population (within 2 standard errors)	Lower limit of the confidence level for the general population (within 2 standard errors)
20	34%	6.2%	46%	22%
30	51%	6.5%	64%	38%
37	63%	6.3%	75%	50%
39	66%	6.2%	78%	54%
44	75%	5.7%	86%	63%
45	76%	5.5%	87%	65%

***a*) Based on 59 responses (i.e., the sample size).**

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APPENDIX C

Appendix C describes the municipality of Maple Ridge, its water utility and the Laity View area.

MAPLE RIDGE, B.C.

General description. The District of Maple Ridge (BC) is a municipality located within the Greater Vancouver region. Of the 75,000 people that resided in the municipality in 2005, approximately 65,000 residents were served by the water utility and 12,000 were served by on-site private wells. The municipality is in transition from being predominantly rural to being a suburban community. It has a town centre and surrounding urban area. Outside of the urban boundary are lands that are zoned rural and agricultural.

Distribution system. The distribution system of Maple Ridge has over 15,000 connections and is comprised of 5 pump stations, 7 reservoirs and approximately 350,000 metres of water mains. A summary of the utility's pipe inventory by material types for 2001 is shown in Table C.1 A summary of the volume of water purchased in 2001 from the Greater Vancouver Water District (GVWD) and distributed daily is presented in Table C.2.

A comparison of the age of Maple Ridge water mains with a number of municipalities across Canada that are part of the Earth Tech benchmarking initiative (Earth Tech 2004) is shown in Table C.3. The table shows the distribution of pipes by age cohorts of Maple Ridge compared with the entire set of communities in the study. The participants include Richmond Hill (ON), City of Delta (BC), City of Waterloo (ON), City of Calgary (AB), City of Ottawa (ON), Regional Municipality of Halton (ON), City of Saskatoon (SK), City of London (ON), City of Toronto (ON), City of Hamilton (ON), City of Thunder Bay (ON), City of St. Catherines (ON) and City of Victoria (BC).

Financial measures. Financially, the utility operates as a self-liquidating utility – i.e., annual revenues and expenditures must balance. A five year business plan is submitted to Maple Ridge Council each year and rates are established by Council bylaw. In 2003, residential water customers were charged $230 per household and metered customers were charged $0.395 per cubic metre. A financial summary of the 2001 major expenditure categories is shown in Table C.4.

Laity View. The Laity View area of Maple Ridge represents approximately ten percent of the water distribution system of Maple Ridge and serves a population of approximately 6,000.

The total length of water mains in this area is 36,300 metres. A regional water main forms the boundary on one side of the study area while larger pipes may be used to form the internal boundaries for six selected pipe zones. These zones are comprised of mainly 150 mm pipes. One zone has a few metres of 100 mm pipe serving a very short cul-de-sac. The zones are shown in Figure C.1. Because Maple Ridge has a minimal number of pressure zones (most of the urban part of the District is served by one water pressure zone), the study area has only one water pressure zone.

Laity View is known to have multiple and routine breaks. Typical break repairs are approximately three metres in length. The number of connections and number of people affected by breaks are not recorded. A comparison of Laity View break rates against those of North American and European water utilities as identified in an AWWARF study (Deb *et al.,* 2002) is shown in Table C.5 below. The break rates for Laity View are comparable with those of other North American utilities, and are less than those of European systems.

Table C.1 . Maple Ridge water system inventory

	Asbestos cement (m)	Cast iron (m)	Copper (m)	Ductile iron (m)	Galvanized Iron (m)	Poly Vinyl Chloride (m)	Steel (m)	Total length of mains (m)
Total	67,422	13,183	59	252,501	180	2,968	11,856	348,169

Table C.2 Maple Ridge system water volumes

	Annual Average Daily Water Consumption (ML/d*)	Peak Day (ML/d)	Annual Total Volume Purchased (ML)
2001	29ML/d (6.4 MGD)	52 ML/day (11.5MGD)	10,400 (22,900 MG)

** ML/d is Mega-litres per day, ML is Mega-litres and MGD is Million Imperial gallons per day and MG is Million Imperial gallons.*

Table C.3 Comparison of age cohorts of Maple Ridge pipes against

Earth Tech National benchmarking utilities

	Maple Ridge	Participating utilities
0 – 24	55	46
25 – 49	45	42
50 – 74	0	6
75 – 99	0	5
> 100	0	1
Total	100	100

Table C.4 Summary of major annual expenditure categories for 2001

	Total Utility Revenues	Total Utility Expenditures	Water Purchase Expenditures	Debt Servicing
2001	$6.5M	$6.5M	$2.4M	$2.6M

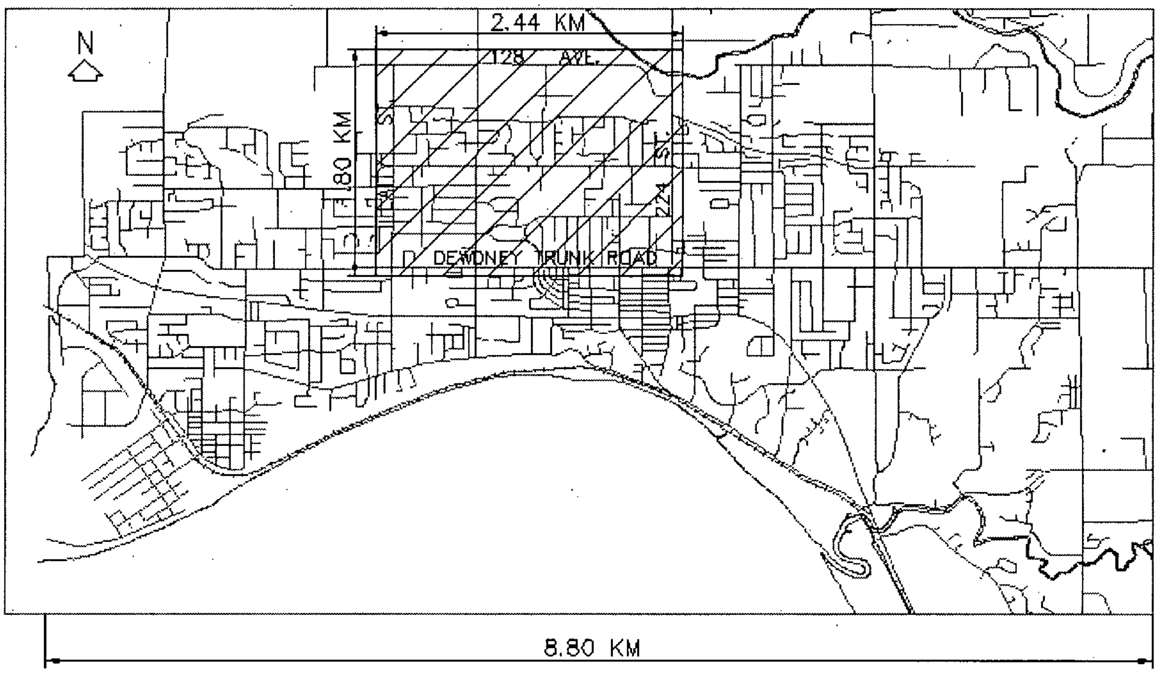
Table C.5 Comparison of Laity View pipe break rates against those of other North American and European systems

	Laity View average break rates	**North America break rates***	**European break rates ***
Break rate (breaks/m/year)	0.0001126	0.0001375	0.000313

* *source: Deb et al. (2002)*

Figure C.1 Laity View area

The following figure is of the approximate extent of Maple Ridge's water system and the boundaries of the Laity View system. There are some developing sections northeast of the figure.



APPENDIX D

Appendix D is the survey that was distributed to North American water utilities in 2004. The survey was comprised of seven spreadsheets.

Survey of Water System (mains and fittings) failure

Please complete this page and the 6 subsequent pages of questions about the information that your organization maintains on water main and fitting failures. If you are not the best source of this information please forward the survey to the appropriate person(s) in your organization.

Organization [ ]

Department [ ] Position title [ ]

Contact (name of person who completed this survey) [ ]

E-mail address: [ ]

Telephone number: [Area code] - [ ] - [Extension]

Address [ ]

What is the total population of your jurisdiction [ ]

What is the population served by your water system? [ ]

What is the total length of your water mains? [ ]

General water system breakage data are collected by: [ ]

Our data are managed using: [ ]

INCIDENT GENERAL INFORMATION	DATA RECORDED IN BREAK RECORD	CONFIDENCE LEVEL IN DATA COLLECTED
Date of reported break		
Time of reported break		
Reported by		
Address of reporter		
Ph. Number of reporter		
Date of repair start		
Time of repair start		
Date of repair finish		
Time when water service was resumed		
Total hours on site		
Quantity of parcels without service		
Was service to customers disrupted		
Estimated number of customers affected		
affected customers by residential type		
affected customers by commercial type		
affected customers by industrial type		
affected customers by institutional type		
Repaired by		
Indication of property damage y or n		
Property damage cost		
Employee researching pipe & completing form		
ID of water main feature being repaired		
ID assigned to break, leak etc		
Sketch of damaged facility		
Digital photo of damaged facility		
Length of unsupported pipe		
Job / work order number		
Dates of previous breaks at same location		
Equipment used		
Crew members		
Crew total hours		
Total labour cost		
Total materials cost		
Total equipment cost		

Please list any locational incident details that your organization records and also any comments that you would like to include:

INCIDENT LOCATION INFORMATION	DATA RECORDED IN BREAK RECORD	CONFIDENCE LEVEL IN DATA COLLECTED
Nearest property address		
Distance from nearest property line		
Cross street name		
Distance from nearest cross street		
Northing and Easting coordinates		
Isolation Valve operated *(Gate valve ID)*		
Isolation Valve operated *(Gate valve ID)*		

Please list any locational incident details that your organization records and also any comments you would like to include:

INCIDENT PHYSICAL DATA	DATA RECORDED IN BREAK RECORD	CONFIDENCE LEVEL IN DATA COLLECTED	IS DATA AVAILABLE FROM OTHER SOURCES? YES or NO	OTHER SOURCE OF INFORMA -TION	COMMENTS
Pipe diameter					
Pipe material					
Length of pipe segment containing the repair					
Year of installation					
Pipe wall thickness / classification					
Type of pipe lining					
Pipe protection (wrapped / anodes)					
Type of joint					
Type of water service					
Normal operating pressure					
Under boulevard or roadway					
Surface material					
Depth of cover					
Bedding material					
Condition of bedding					
Backfill material					
Category of native soil					
Pipe sample collected					
Condition of pipe exterior					
Condition of unlined pipe interior					
Condition of cement lined pipe interior					
Traffic classification or type of road useage					
Pipe modulus or rupture					
Pipe fracture toughness					
Typical flow in area of break					
Please list any locational incident details that your organization records and also any comments that you would like to include:					

INCIDENT FAILURE DESCRIPTION	DATA RECORDED IN BREAK RECORD	CONFIDENCE LEVEL IN DATA COLLECTED	COMMENTS
Types of failure are recorded in this precentage of our incidents			
The following failure modes are fields that are recorded: YES or NO		NONE - HIGH	
Longitudinal break			
Blow out			
Split bell			
Corrosion pit hole			
Leaking joint			
Leaking hydrant			
Leaking valve			
Tap failure			
Curbstop failure			
Leaking service connection			
Failed blow-off			

Please list below any additional types of failure that your organization records and any comments you would like to include:

SUSPECTED CAUSE OF FAILURE	DATA RECORDED IN BREAK RECORD	CONFIDENCE LEVEL IN DATA COLLECTED	ARE DATA EASILY AVAILABLE FROM OTHER SOURCES?	IF DATA ARE AVAILABLE, SOURCE OF INFORMATION IS	COMMENTS
Is your water corrosive to your watermains (yes or no)					
Causes of failure are recorded in this percentage of our records					
The following causes are fields that are recorded:	YES or NO	NONE - HIGH	YES or NO	PICK BOX	
Corrosion					
Traffic load					
Poor construction practices					
Ground frost					
Settlement					
Joint failure					
rock contact					
Construction disturbance					
High pressure					
Water temperature change					
Frozen pipe					
Errosion / unsupported pipe					
Unknown					

Please list any locational incident details that your organization records and also any comments you would like to include:

INCIDENT REPAIR DETAILS	DATA RECORDED IN BREAK RECORD	CONFIDENCE LEVEL IN DATA COLLECTED
Repair activities are recorded in this precentage of our incidents		
The following activities are fields that are recorded:	YES or NO	NONE - HIGH
Repair clamp		
Replace pipe section		
Replace valve		
Replace service connection		
Replace hydrant part(s)		
Replace entire hydrant		
Anode installed		
External protection installed		
Repair joint		
Surface restoration		
Dechlorination performed		
Please list any locational incident details that your organization records and also any comments you would like to include:		

INCIDENT ENVIRONMENT CONDITIONS	DATA RECORDED IN BREAK RECORD	CONFIDENCE LEVEL IN DATA COLLECTED	ARE DATA EASILY AVAILABLE FROM OTHER SOURCES?	IF DATA ARE AVAILABLE, SOURCE OF INFORMATION	COMMENTS
Environment information is recorded in this percentage of our incidents					
The following information are fields that are recorded	YES or NO	NONE - HIGH	YES or NO	PICK BOX	
Water temperature					
Air temperature					
No. of consecutive days below 32 f or 0 c					
Depth of frost					
Water temperature change					
Soil temperature at pipe depth					
Soil sample taken					
Soil PH					
Soil moisture content					

Please list any locational incident details that your organization records and also any comments you would like to include:

Does your organization possess a water model?

Is your model used?

For what reasons does your organization use your model?

- *Development planning*
- *Capital Works planning*
- *Operation of water system*
- *Maintenance of water system*
- *Specify other:*

What is the name of your water system model?

Do you feel comfortable that the amount of data you collect and manage, adequately serves your utility?

How many minutes did you take to complete the survey?

Comments on the survey :

Would you like a copy of the survey results? *Yes or No*

If so, by mail, fax or e-mail?

Please return the completed .xls file to Andrew Wood by E-mail :

awood@mapleridge.org ***or by fax :*** **604-467-7425**

This survey is being conducted by the Corporation of the District of Maple Ridge - Engineering Department

District of Maple Ridge

11995 Haney Place

Maple Ridge, British Columbia

Canada, V2X 6A9
attention: Andrew Wood, Municipal Engineer

Thank you very much for your participation.

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APPENDIX E

Appendix E lists the organizations to which the Wood and Lence 2004 survey was directly mailed, not including those sent by the Canadian Water and Waste Association (CWWA). A list of those communities contacted by the CWWA is not available. The total number of organizations to whom surveys were mailed was 411.

Name of organization	**State/Province**	**Country**
Abbotsford, City of	British Columbia	CAN
Aberdeen, City of	South Dakota	USA
Abilene, City of	Texas	USA
Ada, City of	Oklahoma	USA
Addison, Village of	Illinois	USA
Aiken, City of	South Carolina	USA
Alachua County	Florida	USA
Albuquerque, City of	New Mexico	USA
Alexander City, City of	Alabama	USA
Allentown, City of	Pennsylvania	USA
Anchorage, City of	Alaska	USA
Antioch, City of	California	USA
Arlington County	Virginia	USA
Arroyo Grande, City of	California	USA
Atlanta, City of	Georgia	USA
Auburn, City of	Georgia	USA
Auburn, City of	Alabama	USA
Augusta County	Georgia	USA
Bakersfield, City of	California	USA
Ballwin, City of	Missouri	USA
Bangor, City of	Maine	USA
Barrie, City of	Ontario	CAN
Barrington, Village of	Illinois	USA
Bathurst	New Brunswick	CAN
Bay City, City of	Michigan	USA
Bedford, City of	Virginia	USA
Bellingham, City of	Washington	USA
Beloit, City of	Wisconsin	USA
Beloit, City of	Wisconsin	USA
Bexley, City of	Ohio	USA
Birmingham, City of	Alabama	USA
Bismarck, City of	North Dakota	USA
Blair, City of	Nebraska	USA
Bloomington, City of	Indiana	USA
Bloomington, City of	Minnesota	USA
Bolingbrook, Village of	Illinois	USA

Boone County	Kentucky	USA
Bowling Green, City of	Ohio	USA
Boyle County	Kentucky	USA
Brampton	Ontario	CAN
Brandon, City of	Mississippi	USA
Bridgewater, Town of	Nova Scotia	CAN
Brookline, Town of	Massachusetts	USA
Broward County	Florida	USA
Brownwood, City of	Texas	USA
Bryant, City of	Arkansas	USA
Burlington, City of	North Carolina	USA
Burlington, City of	Iowa	USA
Butler, Township of	Ohio	USA
Cabot, City of	Arkansas	USA
Caledónia, Town of	Wisconsin	USA
Cambridge	Ohio	USA
Camden, City of	South Carolina	USA
Campbell, City of	California	USA
Camrose, City of	Alberta	CAN
Capital, Regional District	British Columbia	CAN
Carmel-by-the-Sea, City of	California	USA
Carpinteria, City of	California	USA
Cartersville, City of	Georgia	USA
Cary, Town of	North Carolina	USA
Cedar Rapids, City of	Iowa	USA
Chamberlain, City of	South Dakota	USA
Champaign, City of	Illinois	USA
Chandler, City of	Arizona	USA
Charlotte, City of	North Carolina	USA
Chatham County	Georgia	USA
Chatham-Kent, Municipality of	Ontario	CAN
Chattahoochee, City of	Florida	USA
Chattanooga, City of	Tennessee	USA
Chersterfield, City of	Missouri	USA
Chester Metropolitan District	South Carolina	USA
Chetwynd, District of	British Columbia	CAN
Chicopee, City of	Massachusetts	USA
Chilliwack, City of	British Columbia	CAN
City of University	Texas	USA
Claremont, City of	California	USA
Clarksville, City of	Tennessee	USA
Clearwater, City of	Florida	USA
Cleveland, City of	Mississippi	USA
Cleveland, City of	Ohio	USA
Clinton, City of	Mississippi	USA

Clovis, City of	California	USA
Coconut Creek, City of	Florida	USA
Collierville, Town of	Tennessee	USA
Columbia Heights, City of	Minnesota	USA
Columbia, City of	Missouri	USA
Columbia, City of	South Carolina	USA
Columbia, Govt of District of	District of Columbia	USA
Columbus, City of	Ohio	USA
Columbus, City of	Nebraska	USA
Concord, City of	California	USA
Cooper City, City of	Florida	USA
Coral Gables, City of	Florida	USA
Corner Brook, City of	Newfoundland	CAN
Coronado, City of	California	USA
Council Bluffs, City of	Iowa	USA
Crystal Lake, City of	Illinois	USA
Cullman, City of	Alabama	USA
Cumberland, Town of	Maine	USA
Dalton,	Georgia	USA
Danvers, Town of	Massachusetts	USA
Dauphin	Manitoba	CAN
Daytona Beach, City of	Florida	USA
Dekalb County	Georgia	USA
Delta, District Municpaliy of	British Columbia	CAN
DesMoines, City of	Iowa	USA
Dodge City, City of	Kansas	USA
Dorion, Ville de	Quebec	CAN
Dorval, Ville de	Quebec	CAN
Dover, City of	New Hampshire	USA
Downey, City of	California	USA
Dublin, City of	Ohio	USA
Dubuque, City of	Iowa	USA
Durham, Regional Municipality of	Ontario	CAN
Eagan, City of	Minnesota	USA
Eau Claire, City of	Wisconsin	USA
Edmundston, City of	New Brunswick	CAN
Effingham, City of	Illinois	USA
Elgin, City of	Illinois	USA
Enterprise, City of	Alabama	USA
EPCOR Water Services Inc.	Alberta	CAN
Escondido, City of	California	USA
Esquimalt, Township of	British Columbia	CAN
Eugene, City of	Oregon	USA
Everett, City of	Washington	USA
Fairhope, City of	Alabama	USA

Fairview Heights, City of	Illinois	USA
Fenton, City of	Michigan	USA
Flower Mound, Town of	Texas	USA
Forsyth, Village of	Illinois	USA
Fort Wayne, City	Indiana	USA
Fox Point, Village of	Wisconsin	USA
Franklin, City of	Virginia	USA
Fredericton, City of	New Brunswick	CAN
Fresno, City of	California	USA
Ft. Myers, City of	Florida	USA
Gainesville, City of	Florida	USA
Galesburg, City of	Illinois	USA
Gander, Town of	Newfoundland	CAN
Garland, City of	Texas	USA
Gastonia, City of	North Carolina	USA
Georgetown County	South Carolina	USA
Germantown, City of	Tennessee	USA
Glendale, City of	Arizona	USA
Goffstown, City of	New Hampshire	USA
Golden Valley, City of	Minnesota	USA
Goodyear, City of	Arizona	USA
Grafton, Town of	Massachusetts	USA
Grand Falls-Windsor, Town of	Newfoundland	CAN
Grand Prairie, City of	Texas	USA
Greater Chicago, District of	Illinois	USA
Greensboro	North Carolina	USA
Greenville County	South Carolina	USA
Guelph, City of	Ontario	CAN
Halifax, Regional Municipality of	Nova Scotia	CAN
Hallandale Beach	Florida	USA
Halton, Regional Municipality of	Ontario	CAN
Hamilton, City of	Ohio	USA
Hampton, City of	Virginia	USA
Harford, County of	Maryland	USA
Harlan, City of	Iowa	USA
Hartsville, City of	South Carolina	USA
Hastings, City of	Minnesota	USA
Hattiesburg, City of	Mississippi	USA
Helix Water District	California	USA
Henderson, City of	Nevada	USA
Henrico County	Virginia	USA
High Point, City of	North Carolina	USA
Highland Village, City of	Texas	USA
Highline Water District	Washington	USA
Hillsboro	Oregon	USA

Houston, City of	Texas	USA
Huntsville, City of	Alabama	USA
Huron, City of	South Dakota	USA
Huron-Kinloss, Township of	Ontario	CAN
Hutchinson, City of	Minnesota	USA
Iles-de-la-Madeleine	Quebec	CAN
Incline, Village of	Nevada	USA
Independence, City of	Missouri	USA
Iowa City, City of	Iowa	USA
Irving, City of	Texas	USA
Jackson, City of	Mississippi	USA
Jacksonville, City of	Florida	USA
Kansas City, City of	Missouri	USA
Kelowna, City of	British Columbia	CAN
Kennewick, City of	Washington	USA
Kerrville, City of	Texas	USA
Killeen, City of	Texas	USA
Kingsport, City of	Tennessee	USA
Kingston, City of	Ontario	CAN
Kirksville, City of	Missouri	USA
Knoxville, City of	Iowa	USA
Knoxville, City of	Tennessee	USA
La Palma, City of	California	USA
La Vista, City of	Nebraska	USA
Lake Zurich, Village of	Illinois	USA
Lakeland, City of	Florida	USA
Lakewood, City of	California	USA
Laporte, City of	Texas	USA
Las Vegas, City of	Nevada	USA
Lawrence, City of	Kansas	USA
Leawood, City of	Kansas	USA
Leduc, City of	Alberta	CAN
Lenexa, City of	Kansas	USA
Lewiston, City of	Maine	USA
Lexington	North Carolina	USA
Lexington-Fayette Urban County	Kentucky	USA
Lincoln City, City of	Oregon	USA
Lindsay, City of	California	USA
Little Rock, City of	Arkansas	USA
Lombard, Village of	Illinois	USA
Lompoc, City of	California	USA
London, City of	Ontario	CAN
Longview, City of	Washington	USA
Los Angeles, City of	California	USA
Louisville Metro Government	Kentucky	USA

Lowndes County	Georgia	USA
Lubbock County	Texas	USA
Macon, City of	Georgia	USA
Madera, City of	California	USA
Madison, City of	Mississippi	USA
Madison, City of	Wisconsin	USA
Maitland, City of	Florida	USA
Mandeville, City of	Louisiana	USA
Mankato, City of	Minnesota	USA
Mansfield, Town of	Connecticut	USA
Maple Ridge, District of	British Columbia	CAN
Marana, Town of	Arizona	USA
Markham	Ontario	CAN
Marquette	Michigan	USA
Maryville, City of	Tennessee	USA
Mc Comb, City of	Mississippi	USA
McAllen, City of	Texas	USA
Medley, Town of	Florida	USA
Medicine Hat, City of	British Columbia	CAN
Memphis, City of	Tennessee	USA
Middletown, City of	Ohio	USA
Milwaukee, City of	Wisconsin	USA
Miramichi, City of	New Brunswick	CAN
Mission Viejo, City of	California	USA
Mission, District of	British Columbia	CAN
Missouri City, City of	Texas	USA
Mobile, City of	Alabama	USA
Moncton, City of	New Brunswick	CAN
Monterey, City of	California	USA
Montreal-Nord, Ville de	Quebec	CAN
Morton, Village of	Illinois	USA
Mount Vernon, City of	Ohio	USA
Mountain View, City of	California	USA
Mt. Zion, Village of	Illinois	USA
Murray City, City of	Utah	USA
Murrieta, City of	California	USA
Muskegon, City of	Michigan	USA
Muskoka,District of	Ontario	CAN
Nelson, City of	British Columbia	CAN
New Albany	Ohio	USA
New Lenox, Village of	Illinois	USA
New Orleans, City of	Louisiana	USA
Newington, Town of	Connecticut	USA
Newport News, City of	Virginia	USA
Newton, City of	Kansas	USA

Niagra, Regional Municipality of	Ontario	CAN
Norfolk, City of	Virginia	USA
North Battleford	Saskatchewan	CAN
North Las Vegas, City of	Nevada	USA
North Miami Beach, City of	Florida	USA
North Miami, City of	Florida	USA
North Redding, Town of	Massachusetts	USA
North Vancouver, District of	British Columbia	CAN
Northbrook, City of	Illinois	USA
Oak Park, Village of	Illinois	USA
Oklahoma City, City of	Oklahoma	USA
Oakland, County of	Mississippi	USA
Olathe, City of	Kansas	USA
Olympia, City of	Washington	USA
Omaha, City of	Nebraska	USA
Orlando, City of	Florida	USA
Oromocto, Town of	New Brunswick	CAN
Ottawa, City of	Ontario	CAN
Overland Park, City of	Kansas	USA
Owensboro, City of	Kentucky	USA
Oxford, County of	Ontario	CAN
Ozark, City of	Alabama	USA
Palatine, Village of	Illinois	USA
Palmdale, City of	California	USA
Pasadena, City of	California	USA
Pasadena, Town of	Newfoundland	CAN
Pebble Beach	California	USA
Penticton, City of	British Columbia	CAN
Peterborough, Utilities Corp.	Ontario	CAN
Phoenix, City of	Arizona	USA
Pierre, City of	South Dakota	USA
Pigeon Forge, City of	Tennessee	USA
Pitt Meadows, District of	British Columbia	CAN
Plainview, City of	Texas	USA
Plano, City of	Texas	USA
Plantation, City of	Florida	USA
Plymouth, Town of	Massachusetts	USA
Pointe Claire	Quebec	CAN
Pomona, City of	California	USA
Port Angeles, City of	Washington	USA
Port Coquitlam, City of	British Columbia	CAN
Port Moody, City of	British Columbia	CAN
Port St Lucie, City of	Florida	USA
Portland, City of	Oregon	USA
Portsmouth, City of	New Hampshire	USA

Presque Isle, City of	Maine	USA
Prince Albert	Saskatchewan	CAN
Punta Gorda, City of	Florida	USA
Qualicum Beach	British Columbia	CAN
Quispamsis, Town of	New Brunswick	CAN
Ralston, City of	Nebraska	USA
Rapid City, City of	South Dakota	USA
Red Deer	Alberta	CAN
Redmond, City of	Washington	USA
Redwood City, City of	California	USA
Regina, City of	Saskatchewan	CAN
Reno, City of	Nevada	USA
Revelstoke, City of	British Columbia	CAN
Richardson, City of	Texas	USA
Richmond, City of	Virginia	USA
Rio Rancho, City of	New Mexico	USA
Rockford, City of	Illinois	USA
Rocky Hill,	Connecticut	USA
Round Rock, City of	Texas	USA
Royal Palm Beach Utilities, Village of	Florida	USA
Sacramento County CA	California	USA
Salmon Arm, District of	British Columbia	CAN
San Antonio-DPW, City of	Texas	USA
San Buenaventura, City of	California	USA
San Diego, City of	California	USA
San Francisco, City & County of	California	USA
San Jose, City of	California	USA
San Luis Obispo, City of	California	USA
Sandford, City of	North Carolina	USA
Sanford, City of	Florida	USA
Santa Ana, City of	California	USA
Santa Clara, City of	California	USA
Sarasota, City of	Florida	USA
Saskatoon, City of	Saskatchewan	CAN
Savoy, Village of	Illinois	USA
Scottsdale, City of	Arizona	USA
Seattle, City of	Washington	USA
Selkirk, City of	Manitoba	CAN
Shaker Heights, City of	Ohio	USA
Shawnee, City of	Kansas	USA
Shelton, City of	Connecticut	USA
Shorewood, Village of	Wisconsin	USA
Sioux Falls, City of	South Dakota	USA
Skowhegan, Town of	Maine	USA
Slidell, City of	Louisiana	USA

South Bend, City of	Indiana	USA
South Daytona, City of	Florida	USA
South Portland, City of	Maine	USA
Southbridge, Town of	Massachusetts	USA
Spartanburg County	South Carolina	USA
Spokane, City of	Washington	USA
Springfield, City of	Illinois	USA
Springfield, City of	Missouri	USA
Springfield, Town of	Vermont	USA
St. Peters, City of	Missouri	USA
St. Tammany Parish LA	Louisiana	USA
Starkville, City of	Mississippi	USA
Strathcona	Alberta	CAN
Sturgis, City of	South Dakota	USA
Sunset Hills, City of	Missouri	USA
Surrey, City of	British Columbia	CAN
Tacoma, City of	Washington	USA
Tallahassee, City of	Florida	USA
Thousand Oaks, City of	California	USA
Thornton, City of	Colorado	USA
Tifton, City of	Georgia	USA
Topeka, City of	Kansas	USA
Topsham, Town of	Maine	USA
Toronto City of	Ontario	CAN
Traverse City, City of	Michigan	USA
Tucson, City of	Arizona	USA
Tulsa, City of	Oklahoma	USA
Tupelo, City of	Mississippi	USA
Upper Arlington, City of	Ohio	USA
University of Wisconson	Wisconsin	USA
Urbana, City of	Illinois	USA
Uxbridge, Town of	Massachusetts	USA
Valdosta, City of	Georgia	USA
Venice, City of	Florida	USA
Vernon Hills, Village of	Illinois	USA
Virginia Beach, City of	Virginia	USA
Visalia, City of	California	USA
Wakefield, Town of	Maine	USA
Washington County MD	Maryland	USA
Watertown, City of	South Dakota	USA
Wauwatosa, City of	Wisconsin	USA
Wellington, Village of	Florida	USA
Weslaco, City of	Texas	USA
West Allis, City of	Wisconsin	USA
West Vancouver, City of	British Columbia	CAN

Westbrook, City of	Maine	USA
Whitby	Ontario	CAN
Wichita, City of	Kansas	USA
Wickliffe, City of	Ohio	USA
Williston, City of	North Dakota	USA
Wilmette, Village of	Illinois	USA
Windham, Town of	Maine	USA
Winfield, City of	Kansas	USA
Winnipeg, City of	Manitoba	CAN
Winston Salem	North Carolina	USA
Wood River, City of	Illinois	USA
Woodridge, Village of	Illinois	USA
Wyoming, City of	Michigan	USA
Yarmouth, Town of	Massachusetts	USA
York, Region of	Ontario	CAN

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APPENDIX F

Appendix F provides the number of respondents for the queries in the Wood and Lence 2004 survey and the data collected. The number of respondents are reported by country of respondent.

Number of respondents that collect general information

	Canadian utilities	U.S. utilities
Address of reporter	21	22
Crew members	27	25
Crew total hours	26	24
Date of repair finish	28	26
Date of repair start	29	26
Date of reported break	30	27
Dates of previous breaks at same location	15	16
Digital photo of damaged facility	15	16
Employee researching pipe & completing form	15	17
Equipment used	26	24
Estimated number of affected customers by commercial type	5	5
Estimated number of affected customers by industrial type	5	5
Estimated number of affected customers by institutional type	5	4
Estimated number of affected customers by residential type	1	2
Estimated number of customers affected	6	6
ID assigned to break, leak etc	23	17
ID of watermain feature being repaired	22	19
Indication of property damage y or n	23	23
Job / work order number	24	20
Length of unsupported pipe	4	5
Ph. Number of reporter	19	23
Property damage cost	7	9
Quantity of parcels without service	10	9
Repaired by	28	26
Reported by	22	22
Sketch of damaged facility	19	9
Time of repair start	23	22
Time of reported break	23	23
Time when water service was resumed	18	20
Total equipment cost	23	19
Total hours on site	28	25
Total labour cost	22	20
Total materials cost	23	18
Was service to customers disrupted	18	17

Number of respondents that record physical data

Physical data recorded by utilities	Canadian utilities	U.S. utilities
Backfill	18	11
Bedding material	17	10
Native soil	9	7
Bedding condition	12	10
Cement lining condition	7	10
Pipe exterior condition	20	15
Pipe interior condition (unlined)	11	11
Cover depth	24	16
Pipe segment length	18	15
Operating pressure	6	9
Pipe diameter	29	29
Fracture toughness	1	3
Pipe material	30	28
Pipe modulus	7	7
Pipe protection	13	9
Pipe sampled	14	8
Pipe wall thickness	2	7
Surface material	20	15
Traffic classification	3	5
Joint type	21	13
Pipe lining type	6	7
Water service type	21	23
Flow in area	1	4
Surface use class	21	18
Year of installation	14	11

Physical data recorded and/or available elsewhere for utilities	Canadian utilities	U.S. utilities
Backfill	20	13
Bedding material	20	15
Native soil	11	13
Bedding condition	12	11
Cement lining condition	9	10
Pipe exterior condition	21	15
Pipe interior condition (unlined)	12	11
Cover depth	28	21
Pipe segment length	24	23
Operating pressure	19	23
Pipe diameter	30	29
Fracture toughness	2	6
Pipe material	30	29
Pipe modulus	8	9
Pipe protection	20	15
Pipe sampled	15	9
Pipe wall thickness	10	16
Surface material	24	22

Physical data recorded and available elsewhere for utilities	Canadian utilities	U.S. utilities
Traffic classification	14	17
Joint type	24	18
Pipe lining type	13	16
Water service type	24	27
Flow in area	14	13
Surface use class	26	25
Year of installation	24	23

Number of respondents that record failure causes

Failure cause data recorded by utilities	Canadian utilities	U.S. utilities
Construction disturbance	13	16
Corrosion	20	16
Erosion / unsupported pipe	13	13
Frozen pipe	14	13
Ground frost	13	7
High pressure	8	12
Joint failure	22	18
Poor construction practices	10	13
rock contact	14	15
Settlement	14	13
Traffic load	3	6
Unknown	11	12
Water temperature change	2	2

Causes are recorded in this percentage of records	Canadian utilities	U.S. utilities
0 percent	2	2
25 percent	6	4
50 percent	1	1
75 percent	4	3
100 percent	7	8
n/a	10	11

Number of respondents that record repair activities

Repair activity data recorded by utilities	Canadian utilities	U.S. utilities
Anode installed	24	10
Dechlorination performed	14	12
Extended protection installed	15	14
Repair clamp	29	27
Repair joint	27	25
Replace entire hydrant	24	27
Replace hydrant parts	23	25
Replace pipe section	29	26
Replace service connection	23	25
Replace valve	26	27
Surface restoration	22	26

Number of respondents that collect different types of environmental data

Environmental data recorded	Canadian utilities	U.S. utilities
Air temperature	8	5
Depth of Frost	9	7
< 32oC days	0	2
Soil Moisture Content	0	1
Soil pH	1	1
Sample taken	2	3
Soil temperature	0	0
Water temperature	1	0
Change in water temperature	1	0

Environmental data recorded and/or available elsewhere for utilities	Canadian utilities	U.S. utilities
Air temperature	16	15
Depth of Frost	12	12
< 32 degree days	13	14
Soil Moisture Content	1	3
Soil pH	1	3
Sample taken	3	5
Soil temperature	0	2
Water temperature	7	8
Change in water temperature	7	6

Number of respondents that expressed confidence in data collected

Confidence in data collected	High	Good	Fair	Low
Pipe diameter	44	14		
Pipe material	41	16		
Water service type	30	10	2	
Surface use classification	19	16	4	
Cover depth	17	18	3	1
Year of installation	12	8	3	2

Number of respondents that record types of failures

Types of Failure recorded by utilities	Canadian utilities	U.S. utilities
Blow out	26	23
Corrosion pit hole	25	22
Curbstop failure	24	23
Failed blow-off	21	20
Leaking hydrant	23	27
Leaking joint	26	24
Leaking service connection	24	26
Leaking valve	24	26
Longitudinal break	27	22
Split bell	26	21
Tap failure	23	24

Number of respondents that record location data

Location data recorded by utilities	Canadian utilities	U.S. utilities
Cross street name	24	22
Distance from cross street	16	10
Distance from nearest property line	15	5
Isolation valve operated	12	9
Nearest property address	28	27
Coordinates (northing and easting)	2	4

Number of respondents that express comfort with recording location data and use water models

Comfort with level of data collected by utilities	Canadian utilities	U.S. utilities
Yes	21	17
No	5	8
N/A	4	4

Number of respondents that have water models and what they use the models for

	Canadian utilities	U.S. utilities
Number of utilities that have a water model	24	22
Number of utilities that use their water model	21	21
Number of utilities that uses a water model for:		
Capital planning	20	21
Development planning	19	20
Operations	16	17
Maintenance planning	11	14

Population and Country data of survey responses

City ID	Country	Description	Total
21	Can	What is the total population of your jurisdiction	115000
42	Can	What is the total population of your jurisdiction	7700
55	Can	What is the total population of your jurisdiction	15669
56	Can	What is the total population of your jurisdiction	380000
72	Can	What is the total population of your jurisdiction	2600
428	Can	What is the total population of your jurisdiction	70000
413	Can	What is the total population of your jurisdiction	20000
100	Can	What is the total population of your jurisdiction	8085
103	Can	What is the total population of your jurisdiction	102000
112	Can	What is the total population of your jurisdiction	600000
120	Can	What is the total population of your jurisdiction	884700
134	Can	What is the total population of your jurisdiction	48000
418	Can	What is the total population of your jurisdiction	73000
227	Can	What is the total population of your jurisdiction	222000
231	Can	What is the total population of your jurisdiction	52000
240	Can	What is the total population of your jurisdiction	60000
249	Can	What is the total population of your jurisdiction	14000
260	Can	What is the total population of your jurisdiction	14500
401	Can	What is the total population of your jurisdiction	86000
283	Can	What is the total population of your jurisdiction	32000
284	Can	What is the total population of your jurisdiction	72000
295	Can	What is the total population of your jurisdiction	53000
301	Can	What is the total population of your jurisdiction	40000
424	Can	What is the total population of your jurisdiction	73000
433	Can	What is the total population of your jurisdiction	190093
332	Can	What is the total population of your jurisdiction	212000
435	Can	What is the total population of your jurisdiction	65000
400	Can	What is the total population of your jurisdiction	2385421
383	Can	What is the total population of your jurisdiction	42000
392	Can	What is the total population of your jurisdiction	631200
403	USA	What is the total population of your jurisdiction	106000
409	USA	What is the total population of your jurisdiction	260000
10	USA	What is the total population of your jurisdiction	98000
48	USA	What is the total population of your jurisdiction	45000
404	USA	What is the total population of your jurisdiction	200000
411	USA	What is the total population of your jurisdiction	22950
76	USA	What is the total population of your jurisdiction	13842
414	USA	What is the total population of your jurisdiction	25500
141	USA	What is the total population of your jurisdiction	220657
405	USA	What is the total population of your jurisdiction	100001
402	USA	What is the total population of your jurisdiction	14500
430	USA	What is the total population of your jurisdiction	65000
431	USA	What is the total population of your jurisdiction	9400
415	USA	What is the total population of your jurisdiction	48000
416	USA	What is the total population of your jurisdiction	85000
407	USA	What is the total population of your jurisdiction	35000
417	USA	What is the total population of your jurisdiction	32000
432	USA	What is the total population of your jurisdiction	20600
419	USA	What is the total population of your jurisdiction	20000
426	USA	What is the total population of your jurisdiction	35000
420	USA	What is the total population of your jurisdiction	100001

427	USA	What is the total population of your jurisdiction	105000
422	USA	What is the total population of your jurisdiction	343700
434	USA	What is the total population of your jurisdiction	1300000
342	USA	What is the total population of your jurisdiction	140000
408	USA	What is the total population of your jurisdiction	107000
423	USA	What is the total population of your jurisdiction	123000
379	USA	What is the total population of your jurisdiction	47000
389	USA	What is the total population of your jurisdiction	27000

General data of survey responses

City ID	Description	% Recorded
420	Date of reported break	100
427	Date of reported break	100
76	Date of reported break	100
430	Date of reported break	100
10	Date of reported break	100
301	Date of reported break	100
100	Date of reported break	100
416	Date of reported break	100
134	Date of reported break	100
414	Date of reported break	100
409	Date of reported break	100
415	Date of reported break	100
55	Date of reported break	100
284	Date of reported break	100
249	Date of reported break	100
141	Date of reported break	100
260	Date of reported break	100
432	Date of reported break	100
42	Date of reported break	100
295	Date of reported break	100
428	Date of reported break	100
411	Date of reported break	100
405	Date of reported break	
433	Date of reported break	100
342	Date of reported break	100
332	Date of reported break	100
21	Date of reported break	100
48	Date of reported break	
103	Date of reported break	100
434	Date of reported break	100
392	Date of reported break	100
407	Date of reported break	100
408	Date of reported break	100
404	Date of reported break	100
413	Date of reported break	75
402	Date of reported break	100
240	Date of reported break	100
401	Date of reported break	100
72	Date of reported break	100
435	Date of reported break	100
422	Date of reported break	100
423	Date of reported break	100
419	Date of reported break	100
431	Date of reported break	100
389	Date of reported break	100

227	Date of reported break	100
112	Date of reported break	100
403	Date of reported break	100
418	Date of reported break	100
231	Date of reported break	100
383	Date of reported break	100
283	Date of reported break	100
424	Date of reported break	100
426	Date of reported break	100
400	Date of reported break	100
379	Date of reported break	100
120	Date of reported break	100
417	Date of reported break	100
56	Date of reported break	100
283	Time of reported break	100
332	Time of reported break	100
389	Time of reported break	100
379	Time of reported break	75
418	Time of reported break	100
433	Time of reported break	75
428	Time of reported break	100
112	Time of reported break	0
295	Time of reported break	100
404	Time of reported break	100
284	Time of reported break	100
76	Time of reported break	50
423	Time of reported break	100
424	Time of reported break	100
260	Time of reported break	100
342	Time of reported break	0
411	Time of reported break	0
420	Time of reported break	100
21	Time of reported break	100
240	Time of reported break	75
120	Time of reported break	100
407	Time of reported break	100
383	Time of reported break	100
392	Time of reported break	0
432	Time of reported break	0
416	Time of reported break	100
417	Time of reported break	100
430	Time of reported break	100
10	Time of reported break	75
100	Time of reported break	100
427	Time of reported break	100
415	Time of reported break	50
249	Time of reported break	0
141	Time of reported break	100
431	Time of reported break	100

134	Time of reported break	100
56	Time of reported break	75
409	Time of reported break	75
426	Time of reported break	100
422	Time of reported break	0
401	Time of reported break	100
435	Time of reported break	50
419	Time of reported break	100
402	Time of reported break	100
227	Time of reported break	0
403	Time of reported break	100
72	Time of reported break	100
400	Time of reported break	100
48	Time of reported break	
434	Time of reported break	100
405	Time of reported break	
55	Time of reported break	0
231	Time of reported break	0
301	Time of reported break	0
103	Time of reported break	100
413	Time of reported break	75
408	Time of reported break	100
414	Time of reported break	100
42	Time of reported break	25
419	Reported by	100
426	Reported by	100
48	Reported by	
424	Reported by	
423	Reported by	100
422	Reported by	0
417	Reported by	
383	Reported by	
379	Reported by	75
418	Reported by	100
402	Reported by	100
55	Reported by	0
227	Reported by	0
433	Reported by	75
112	Reported by	100
403	Reported by	100
240	Reported by	100
103	Reported by	100
134	Reported by	100
342	Reported by	0
21	Reported by	75
76	Reported by	100
301	Reported by	100
408	Reported by	100
407	Reported by	100

427	Reported by	100
420	Reported by	
332	Reported by	50
411	Reported by	50
413	Reported by	
405	Reported by	
249	Reported by	25
432	Reported by	25
141	Reported by	100
404	Reported by	75
283	Reported by	100
414	Reported by	100
56	Reported by	0
415	Reported by	75
409	Reported by	
416	Reported by	100
10	Reported by	75
120	Reported by	100
435	Reported by	25
260	Reported by	75
434	Reported by	100
100	Reported by	75
284	Reported by	100
430	Reported by	100
392	Reported by	100
401	Reported by	0
389	Reported by	100
72	Reported by	75
231	Reported by	100
400	Reported by	
431	Reported by	100
42	Reported by	75
295	Reported by	100
428	Reported by	100
420	Address of reporter	100
120	Address of reporter	0
76	Address of reporter	0
379	Address of reporter	75
10	Address of reporter	75
427	Address of reporter	100
260	Address of reporter	25
431	Address of reporter	100
249	Address of reporter	0
404	Address of reporter	75
141	Address of reporter	100
56	Address of reporter	0
284	Address of reporter	100
283	Address of reporter	100
409	Address of reporter	75

432	Address of reporter	0
433	Address of reporter	75
295	Address of reporter	100
301	Address of reporter	75
411	Address of reporter	100
428	Address of reporter	100
55	Address of reporter	0
405	Address of reporter	
48	Address of reporter	
413	Address of reporter	0
434	Address of reporter	25
392	Address of reporter	50
430	Address of reporter	100
100	Address of reporter	75
103	Address of reporter	
407	Address of reporter	100
42	Address of reporter	100
21	Address of reporter	50
415	Address of reporter	100
408	Address of reporter	100
134	Address of reporter	75
414	Address of reporter	50
342	Address of reporter	0
332	Address of reporter	50
418	Address of reporter	100
422	Address of reporter	0
400	Address of reporter	50
419	Address of reporter	100
401	Address of reporter	0
383	Address of reporter	50
435	Address of reporter	25
402	Address of reporter	25
423	Address of reporter	100
416	Address of reporter	50
240	Address of reporter	100
426	Address of reporter	100
227	Address of reporter	0
417	Address of reporter	75
231	Address of reporter	0
112	Address of reporter	100
403	Address of reporter	75
389	Address of reporter	0
72	Address of reporter	75
424	Address of reporter	25
434	Ph. Number of reporter	100
112	Ph. Number of reporter	100
42	Ph. Number of reporter	100
408	Ph. Number of reporter	100
383	Ph. Number of reporter	50

435	Ph. Number of reporter	50
432	Ph. Number of reporter	25
21	Ph. Number of reporter	75
134	Ph. Number of reporter	25
249	Ph. Number of reporter	0
240	Ph. Number of reporter	100
403	Ph. Number of reporter	75
411	Ph. Number of reporter	25
389	Ph. Number of reporter	
405	Ph. Number of reporter	
72	Ph. Number of reporter	100
48	Ph. Number of reporter	
227	Ph. Number of reporter	0
332	Ph. Number of reporter	75
428	Ph. Number of reporter	100
407	Ph. Number of reporter	100
392	Ph. Number of reporter	50
418	Ph. Number of reporter	
342	Ph. Number of reporter	0
100	Ph. Number of reporter	75
231	Ph. Number of reporter	0
402	Ph. Number of reporter	25
55	Ph. Number of reporter	0
103	Ph. Number of reporter	
413	Ph. Number of reporter	0
431	Ph. Number of reporter	100
420	Ph. Number of reporter	100
423	Ph. Number of reporter	100
416	Ph. Number of reporter	75
414	Ph. Number of reporter	50
295	Ph. Number of reporter	100
415	Ph. Number of reporter	100
426	Ph. Number of reporter	100
284	Ph. Number of reporter	100
404	Ph. Number of reporter	75
433	Ph. Number of reporter	75
260	Ph. Number of reporter	0
141	Ph. Number of reporter	100
283	Ph. Number of reporter	100
56	Ph. Number of reporter	0
424	Ph. Number of reporter	25
379	Ph. Number of reporter	75
400	Ph. Number of reporter	25
120	Ph. Number of reporter	0
417	Ph. Number of reporter	75
419	Ph. Number of reporter	100
427	Ph. Number of reporter	25
76	Ph. Number of reporter	0
10	Ph. Number of reporter	50

401	Ph. Number of reporter	0
301	Ph. Number of reporter	75
422	Ph. Number of reporter	0
409	Ph. Number of reporter	50
430	Ph. Number of reporter	100
426	Date of repair start	100
295	Date of repair start	100
419	Date of repair start	100
56	Date of repair start	100
414	Date of repair start	100
141	Date of repair start	100
134	Date of repair start	100
434	Date of repair start	100
403	Date of repair start	100
400	Date of repair start	50
405	Date of repair start	
422	Date of repair start	0
100	Date of repair start	100
10	Date of repair start	100
435	Date of repair start	100
249	Date of repair start	100
401	Date of repair start	100
402	Date of repair start	100
408	Date of repair start	100
48	Date of repair start	
430	Date of repair start	100
431	Date of repair start	100
413	Date of repair start	100
415	Date of repair start	100
427	Date of repair start	100
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432	Date of repair start	100
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392	Date of repair start	100
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283	Date of repair start	100
420	Date of repair start	100
42	Date of repair start	100
433	Date of repair start	100
407	Date of repair start	100

404	Date of repair start	100
379	Date of repair start	100
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411	Date of repair start	100
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231	Date of repair start	100
301	Date of repair start	100
416	Date of repair start	100
55	Date of repair start	100
342	Date of repair start	100
240	Date of repair start	100
423	Date of repair start	100
383	Date of repair start	100
389	Date of repair start	100
418	Date of repair start	100
418	Time of repair start	75
76	Time of repair start	100
402	Time of repair start	100
420	Time of repair start	100
427	Time of repair start	100
409	Time of repair start	100
10	Time of repair start	50
72	Time of repair start	0
249	Time of repair start	50
400	Time of repair start	50
416	Time of repair start	100
422	Time of repair start	0
419	Time of repair start	50
231	Time of repair start	0
240	Time of repair start	100
227	Time of repair start	100
423	Time of repair start	100
401	Time of repair start	100
383	Time of repair start	75
417	Time of repair start	75
120	Time of repair start	100
260	Time of repair start	100
415	Time of repair start	0
426	Time of repair start	100
435	Time of repair start	100
424	Time of repair start	100
379	Time of repair start	50
56	Time of repair start	0
301	Time of repair start	0
141	Time of repair start	100
284	Time of repair start	100
404	Time of repair start	100
431	Time of repair start	0
283	Time of repair start	100

48	Time of repair start	
405	Time of repair start	
55	Time of repair start	100
42	Time of repair start	50
407	Time of repair start	100
332	Time of repair start	100
432	Time of repair start	0
21	Time of repair start	100
408	Time of repair start	100
134	Time of repair start	100
392	Time of repair start	0
112	Time of repair start	0
430	Time of repair start	75
100	Time of repair start	0
413	Time of repair start	100
403	Time of repair start	100
414	Time of repair start	100
433	Time of repair start	100
295	Time of repair start	100
342	Time of repair start	100
103	Time of repair start	100
428	Time of repair start	100
434	Time of repair start	100
389	Time of repair start	0
411	Time of repair start	100
400	Date of repair finish	50
240	Date of repair finish	100
392	Date of repair finish	0
411	Date of repair finish	100
426	Date of repair finish	100
417	Date of repair finish	75
433	Date of repair finish	100
100	Date of repair finish	100
424	Date of repair finish	100
416	Date of repair finish	100
430	Date of repair finish	100
55	Date of repair finish	100
383	Date of repair finish	75
422	Date of repair finish	0
260	Date of repair finish	100
403	Date of repair finish	100
295	Date of repair finish	100
231	Date of repair finish	100
283	Date of repair finish	100
112	Date of repair finish	0
227	Date of repair finish	100
423	Date of repair finish	100
405	Date of repair finish	
419	Date of repair finish	50

48	Date of repair finish	
434	Date of repair finish	100
408	Date of repair finish	100
42	Date of repair finish	100
249	Date of repair finish	100
72	Date of repair finish	100
10	Date of repair finish	100
402	Date of repair finish	100
141	Date of repair finish	100
432	Date of repair finish	100
76	Date of repair finish	100
428	Date of repair finish	100
427	Date of repair finish	100
301	Date of repair finish	100
420	Date of repair finish	100
414	Date of repair finish	100
284	Date of repair finish	100
389	Date of repair finish	100
103	Date of repair finish	100
134	Date of repair finish	100
413	Date of repair finish	100
56	Date of repair finish	100
409	Date of repair finish	100
332	Date of repair finish	100
342	Date of repair finish	100
120	Date of repair finish	100
401	Date of repair finish	100
404	Date of repair finish	75
407	Date of repair finish	100
21	Date of repair finish	100
431	Date of repair finish	100
418	Date of repair finish	75
415	Date of repair finish	100
379	Date of repair finish	100
435	Date of repair finish	100
240	Time when water service was resumed	100
435	Time when water service was resumed	100
418	Time when water service was resumed	25
403	Time when water service was resumed	100
295	Time when water service was resumed	100
430	Time when water service was resumed	25
48	Time when water service was resumed	
55	Time when water service was resumed	100
21	Time when water service was resumed	100
134	Time when water service was resumed	100
103	Time when water service was resumed	
432	Time when water service was resumed	0
428	Time when water service was resumed	0
284	Time when water service was resumed	100

401	Time when water service was resumed	100
427	Time when water service was resumed	0
416	Time when water service was resumed	100
249	Time when water service was resumed	0
10	Time when water service was resumed	25
433	Time when water service was resumed	50
231	Time when water service was resumed	0
76	Time when water service was resumed	100
141	Time when water service was resumed	100
424	Time when water service was resumed	100
426	Time when water service was resumed	0
227	Time when water service was resumed	0
419	Time when water service was resumed	50
283	Time when water service was resumed	100
420	Time when water service was resumed	100
423	Time when water service was resumed	100
407	Time when water service was resumed	50
260	Time when water service was resumed	100
415	Time when water service was resumed	0
417	Time when water service was resumed	75
404	Time when water service was resumed	75
332	Time when water service was resumed	75
100	Time when water service was resumed	0
434	Time when water service was resumed	100
409	Time when water service was resumed	100
392	Time when water service was resumed	0
301	Time when water service was resumed	0
42	Time when water service was resumed	25
414	Time when water service was resumed	100
120	Time when water service was resumed	100
400	Time when water service was resumed	0
389	Time when water service was resumed	100
72	Time when water service was resumed	0
112	Time when water service was resumed	0
408	Time when water service was resumed	100
411	Time when water service was resumed	25
56	Time when water service was resumed	0
383	Time when water service was resumed	75
431	Time when water service was resumed	0
379	Time when water service was resumed	25
405	Time when water service was resumed	
342	Time when water service was resumed	100
402	Time when water service was resumed	0
422	Time when water service was resumed	0
413	Time when water service was resumed	100
379	Total hours on site	100
76	Total hours on site	75
415	Total hours on site	100
249	Total hours on site	100

424	Total hours on site	100
383	Total hours on site	100
423	Total hours on site	100
56	Total hours on site	100
141	Total hours on site	100
404	Total hours on site	100
55	Total hours on site	100
134	Total hours on site	100
413	Total hours on site	0
408	Total hours on site	100
48	Total hours on site	
103	Total hours on site	100
405	Total hours on site	
433	Total hours on site	100
411	Total hours on site	100
432	Total hours on site	100
407	Total hours on site	100
402	Total hours on site	100
332	Total hours on site	100
21	Total hours on site	100
409	Total hours on site	100
427	Total hours on site	100
283	Total hours on site	100
301	Total hours on site	100
420	Total hours on site	100
342	Total hours on site	100
403	Total hours on site	100
414	Total hours on site	100
418	Total hours on site	100
417	Total hours on site	100
284	Total hours on site	100
231	Total hours on site	25
10	Total hours on site	100
227	Total hours on site	100
428	Total hours on site	100
260	Total hours on site	50
392	Total hours on site	0
120	Total hours on site	100
434	Total hours on site	100
422	Total hours on site	0
295	Total hours on site	100
100	Total hours on site	100
430	Total hours on site	25
419	Total hours on site	100
42	Total hours on site	100
400	Total hours on site	25
401	Total hours on site	100
426	Total hours on site	100
112	Total hours on site	100

240	Total hours on site	100
72	Total hours on site	100
389	Total hours on site	0
435	Total hours on site	100
416	Total hours on site	100
431	Total hours on site	100
407	Quantity of parcels without service	0
134	Quantity of parcels without service	100
435	Quantity of parcels without service	50
72	Quantity of parcels without service	0
434	Quantity of parcels without service	100
55	Quantity of parcels without service	100
405	Quantity of parcels without service	
295	Quantity of parcels without service	25
431	Quantity of parcels without service	0
411	Quantity of parcels without service	0
10	Quantity of parcels without service	0
433	Quantity of parcels without service	0
100	Quantity of parcels without service	0
401	Quantity of parcels without service	0
48	Quantity of parcels without service	
400	Quantity of parcels without service	0
231	Quantity of parcels without service	0
418	Quantity of parcels without service	0
423	Quantity of parcels without service	0
389	Quantity of parcels without service	0
413	Quantity of parcels without service	100
112	Quantity of parcels without service	0
240	Quantity of parcels without service	0
416	Quantity of parcels without service	0
383	Quantity of parcels without service	0
424	Quantity of parcels without service	100
404	Quantity of parcels without service	75
260	Quantity of parcels without service	0
284	Quantity of parcels without service	100
120	Quantity of parcels without service	100
332	Quantity of parcels without service	100
428	Quantity of parcels without service	0
379	Quantity of parcels without service	0
420	Quantity of parcels without service	100
342	Quantity of parcels without service	0
42	Quantity of parcels without service	0
432	Quantity of parcels without service	0
392	Quantity of parcels without service	0
283	Quantity of parcels without service	0
301	Quantity of parcels without service	0
430	Quantity of parcels without service	0
21	Quantity of parcels without service	0
76	Quantity of parcels without service	0

103	Quantity of parcels without service	
227	Quantity of parcels without service	50
414	Quantity of parcels without service	100
419	Quantity of parcels without service	100
56	Quantity of parcels without service	0
422	Quantity of parcels without service	0
141	Quantity of parcels without service	100
417	Quantity of parcels without service	0
402	Quantity of parcels without service	0
415	Quantity of parcels without service	0
409	Quantity of parcels without service	75
403	Quantity of parcels without service	50
408	Quantity of parcels without service	100
427	Quantity of parcels without service	0
426	Quantity of parcels without service	0
249	Quantity of parcels without service	0
432	Was service to customers disrupted	0
389	Was service to customers disrupted	100
418	Was service to customers disrupted	0
301	Was service to customers disrupted	100
55	Was service to customers disrupted	100
379	Was service to customers disrupted	0
414	Was service to customers disrupted	100
427	Was service to customers disrupted	25
407	Was service to customers disrupted	100
42	Was service to customers disrupted	100
227	Was service to customers disrupted	100
56	Was service to customers disrupted	0
428	Was service to customers disrupted	0
383	Was service to customers disrupted	100
423	Was service to customers disrupted	0
112	Was service to customers disrupted	0
240	Was service to customers disrupted	50
409	Was service to customers disrupted	75
21	Was service to customers disrupted	75
231	Was service to customers disrupted	0
283	Was service to customers disrupted	100
260	Was service to customers disrupted	0
426	Was service to customers disrupted	0
392	Was service to customers disrupted	0
332	Was service to customers disrupted	75
417	Was service to customers disrupted	0
141	Was service to customers disrupted	0
120	Was service to customers disrupted	100
416	Was service to customers disrupted	0
10	Was service to customers disrupted	100
342	Was service to customers disrupted	0
404	Was service to customers disrupted	75
401	Was service to customers disrupted	0

415	Was service to customers disrupted	100
411	Was service to customers disrupted	100
402	Was service to customers disrupted	0
249	Was service to customers disrupted	100
413	Was service to customers disrupted	0
431	Was service to customers disrupted	100
76	Was service to customers disrupted	50
72	Was service to customers disrupted	100
134	Was service to customers disrupted	100
408	Was service to customers disrupted	100
403	Was service to customers disrupted	100
435	Was service to customers disrupted	50
400	Was service to customers disrupted	0
424	Was service to customers disrupted	100
405	Was service to customers disrupted	
48	Was service to customers disrupted	
100	Was service to customers disrupted	0
284	Was service to customers disrupted	100
433	Was service to customers disrupted	100
430	Was service to customers disrupted	50
422	Was service to customers disrupted	0
434	Was service to customers disrupted	100
420	Was service to customers disrupted	100
103	Was service to customers disrupted	
295	Was service to customers disrupted	100
419	Was service to customers disrupted	100
383	Estimated number of customers affected	0
428	Estimated number of customers affected	0
423	Estimated number of customers affected	0
414	Estimated number of customers affected	100
415	Estimated number of customers affected	0
141	Estimated number of customers affected	0
404	Estimated number of customers affected	
283	Estimated number of customers affected	0
56	Estimated number of customers affected	0
424	Estimated number of customers affected	100
76	Estimated number of customers affected	0
100	Estimated number of customers affected	
403	Estimated number of customers affected	100
72	Estimated number of customers affected	0
10	Estimated number of customers affected	0
400	Estimated number of customers affected	0
402	Estimated number of customers affected	0
435	Estimated number of customers affected	50
401	Estimated number of customers affected	0
431	Estimated number of customers affected	0
295	Estimated number of customers affected	0
434	Estimated number of customers affected	100
422	Estimated number of customers affected	0

120	Estimated number of customers affected	100
419	Estimated number of customers affected	100
418	Estimated number of customers affected	0
284	Estimated number of customers affected	100
392	Estimated number of customers affected	
227	Estimated number of customers affected	50
42	Estimated number of customers affected	0
231	Estimated number of customers affected	0
417	Estimated number of customers affected	0
260	Estimated number of customers affected	0
416	Estimated number of customers affected	0
112	Estimated number of customers affected	0
240	Estimated number of customers affected	
426	Estimated number of customers affected	0
389	Estimated number of customers affected	0
430	Estimated number of customers affected	0
301	Estimated number of customers affected	0
103	Estimated number of customers affected	
48	Estimated number of customers affected	
342	Estimated number of customers affected	0
413	Estimated number of customers affected	
411	Estimated number of customers affected	0
433	Estimated number of customers affected	
409	Estimated number of customers affected	50
55	Estimated number of customers affected	100
405	Estimated number of customers affected	
432	Estimated number of customers affected	0
420	Estimated number of customers affected	100
21	Estimated number of customers affected	0
249	Estimated number of customers affected	0
408	Estimated number of customers affected	
427	Estimated number of customers affected	0
407	Estimated number of customers affected	0
134	Estimated number of customers affected	0
379	Estimated number of customers affected	0
332	Estimated number of customers affected	
301	Estimated number of affected customers by residential type	
295	Estimated number of affected customers by residential type	0
423	Estimated number of affected customers by residential type	
434	Estimated number of affected customers by residential type	
407	Estimated number of affected customers by residential type	
103	Estimated number of affected customers by residential type	
120	Estimated number of affected customers by residential type	-1
260	Estimated number of affected customers by residential type	0
231	Estimated number of affected customers by residential type	
112	Estimated number of affected customers by residential type	
332	Estimated number of affected customers by residential type	-1
422	Estimated number of affected customers by residential type	
141	Estimated number of affected customers by residential type	

419	Estimated number of affected customers by residential type	-1
405	Estimated number of affected customers by residential type	
100	Estimated number of affected customers by residential type	
426	Estimated number of affected customers by residential type	0
284	Estimated number of affected customers by residential type	100
240	Estimated number of affected customers by residential type	
389	Estimated number of affected customers by residential type	
416	Estimated number of affected customers by residential type	
392	Estimated number of affected customers by residential type	
431	Estimated number of affected customers by residential type	
430	Estimated number of affected customers by residential type	
415	Estimated number of affected customers by residential type	0
427	Estimated number of affected customers by residential type	
134	Estimated number of affected customers by residential type	0
432	Estimated number of affected customers by residential type	
424	Estimated number of affected customers by residential type	0
10	Estimated number of affected customers by residential type	100
418	Estimated number of affected customers by residential type	
404	Estimated number of affected customers by residential type	
342	Estimated number of affected customers by residential type	
420	Estimated number of affected customers by residential type	100
72	Estimated number of affected customers by residential type	0
249	Estimated number of affected customers by residential type	
76	Estimated number of affected customers by residential type	
403	Estimated number of affected customers by residential type	-1
408	Estimated number of affected customers by residential type	
414	Estimated number of affected customers by residential type	0
435	Estimated number of affected customers by residential type	
379	Estimated number of affected customers by residential type	
417	Estimated number of affected customers by residential type	0
48	Estimated number of affected customers by residential type	
21	Estimated number of affected customers by residential type	0
428	Estimated number of affected customers by residential type	0
227	Estimated number of affected customers by residential type	0
283	Estimated number of affected customers by residential type	
433	Estimated number of affected customers by residential type	
55	Estimated number of affected customers by residential type	
400	Estimated number of affected customers by residential type	
42	Estimated number of affected customers by residential type	0
401	Estimated number of affected customers by residential type	
56	Estimated number of affected customers by residential type	
413	Estimated number of affected customers by residential type	
383	Estimated number of affected customers by residential type	
411	Estimated number of affected customers by residential type	
402	Estimated number of affected customers by residential type	0
409	Estimated number of affected customers by residential type	
42	Estimated number of affected customers by commercial type	0
422	Estimated number of affected customers by commercial type	
231	Estimated number of affected customers by commercial type	0

428	Estimated number of affected customers by commercial type	0
407	Estimated number of affected customers by commercial type	0
55	Estimated number of affected customers by commercial type	
434	Estimated number of affected customers by commercial type	0
435	Estimated number of affected customers by commercial type	50
403	Estimated number of affected customers by commercial type	100
134	Estimated number of affected customers by commercial type	0
72	Estimated number of affected customers by commercial type	0
10	Estimated number of affected customers by commercial type	100
400	Estimated number of affected customers by commercial type	0
402	Estimated number of affected customers by commercial type	0
411	Estimated number of affected customers by commercial type	
401	Estimated number of affected customers by commercial type	
433	Estimated number of affected customers by commercial type	0
431	Estimated number of affected customers by commercial type	0
227	Estimated number of affected customers by commercial type	0
295	Estimated number of affected customers by commercial type	0
417	Estimated number of affected customers by commercial type	0
103	Estimated number of affected customers by commercial type	
430	Estimated number of affected customers by commercial type	0
405	Estimated number of affected customers by commercial type	
100	Estimated number of affected customers by commercial type	0
392	Estimated number of affected customers by commercial type	0
284	Estimated number of affected customers by commercial type	100
413	Estimated number of affected customers by commercial type	0
419	Estimated number of affected customers by commercial type	-1
48	Estimated number of affected customers by commercial type	
426	Estimated number of affected customers by commercial type	0
424	Estimated number of affected customers by commercial type	0
383	Estimated number of affected customers by commercial type	
332	Estimated number of affected customers by commercial type	100
56	Estimated number of affected customers by commercial type	
240	Estimated number of affected customers by commercial type	50
249	Estimated number of affected customers by commercial type	0
432	Estimated number of affected customers by commercial type	
260	Estimated number of affected customers by commercial type	0
301	Estimated number of affected customers by commercial type	
112	Estimated number of affected customers by commercial type	0
389	Estimated number of affected customers by commercial type	0
423	Estimated number of affected customers by commercial type	
141	Estimated number of affected customers by commercial type	0
427	Estimated number of affected customers by commercial type	0
408	Estimated number of affected customers by commercial type	
418	Estimated number of affected customers by commercial type	0
120	Estimated number of affected customers by commercial type	100
283	Estimated number of affected customers by commercial type	0
415	Estimated number of affected customers by commercial type	100
379	Estimated number of affected customers by commercial type	0
416	Estimated number of affected customers by commercial type	0

414	Estimated number of affected customers by commercial type	0
420	Estimated number of affected customers by commercial type	100
409	Estimated number of affected customers by commercial type	0
404	Estimated number of affected customers by commercial type	25
76	Estimated number of affected customers by commercial type	0
342	Estimated number of affected customers by commercial type	0
21	Estimated number of affected customers by commercial type	0
431	Estimated number of affected customers by industrial type	0
76	Estimated number of affected customers by industrial type	0
434	Estimated number of affected customers by industrial type	0
283	Estimated number of affected customers by industrial type	0
295	Estimated number of affected customers by industrial type	0
379	Estimated number of affected customers by industrial type	0
10	Estimated number of affected customers by industrial type	100
48	Estimated number of affected customers by industrial type	
414	Estimated number of affected customers by industrial type	0
408	Estimated number of affected customers by industrial type	
435	Estimated number of affected customers by industrial type	75
427	Estimated number of affected customers by industrial type	0
420	Estimated number of affected customers by industrial type	100
424	Estimated number of affected customers by industrial type	0
56	Estimated number of affected customers by industrial type	
411	Estimated number of affected customers by industrial type	
403	Estimated number of affected customers by industrial type	100
404	Estimated number of affected customers by industrial type	25
383	Estimated number of affected customers by industrial type	
432	Estimated number of affected customers by industrial type	
423	Estimated number of affected customers by industrial type	
342	Estimated number of affected customers by industrial type	0
400	Estimated number of affected customers by industrial type	0
72	Estimated number of affected customers by industrial type	0
249	Estimated number of affected customers by industrial type	0
401	Estimated number of affected customers by industrial type	
134	Estimated number of affected customers by industrial type	0
402	Estimated number of affected customers by industrial type	0
417	Estimated number of affected customers by industrial type	0
428	Estimated number of affected customers by industrial type	0
392	Estimated number of affected customers by industrial type	0
416	Estimated number of affected customers by industrial type	0
332	Estimated number of affected customers by industrial type	100
21	Estimated number of affected customers by industrial type	0
284	Estimated number of affected customers by industrial type	100
240	Estimated number of affected customers by industrial type	50
407	Estimated number of affected customers by industrial type	0
55	Estimated number of affected customers by industrial type	
42	Estimated number of affected customers by industrial type	0
419	Estimated number of affected customers by industrial type	-1
227	Estimated number of affected customers by industrial type	0
112	Estimated number of affected customers by industrial type	0

415	Estimated number of affected customers by industrial type	100
260	Estimated number of affected customers by industrial type	0
409	Estimated number of affected customers by industrial type	0
413	Estimated number of affected customers by industrial type	0
422	Estimated number of affected customers by industrial type	
418	Estimated number of affected customers by industrial type	0
433	Estimated number of affected customers by industrial type	0
100	Estimated number of affected customers by industrial type	0
301	Estimated number of affected customers by industrial type	
389	Estimated number of affected customers by industrial type	0
426	Estimated number of affected customers by industrial type	0
430	Estimated number of affected customers by industrial type	0
120	Estimated number of affected customers by industrial type	100
405	Estimated number of affected customers by industrial type	
231	Estimated number of affected customers by industrial type	0
141	Estimated number of affected customers by industrial type	0
103	Estimated number of affected customers by industrial type	
10	Estimated number of affected customers by institutional type	100
231	Estimated number of affected customers by institutional type	0
72	Estimated number of affected customers by institutional type	0
419	Estimated number of affected customers by institutional type	-1
415	Estimated number of affected customers by institutional type	100
76	Estimated number of affected customers by institutional type	0
414	Estimated number of affected customers by institutional type	0
42	Estimated number of affected customers by institutional type	0
379	Estimated number of affected customers by institutional type	0
55	Estimated number of affected customers by institutional type	
301	Estimated number of affected customers by institutional type	
417	Estimated number of affected customers by institutional type	0
48	Estimated number of affected customers by institutional type	
283	Estimated number of affected customers by institutional type	0
426	Estimated number of affected customers by institutional type	0
295	Estimated number of affected customers by institutional type	0
431	Estimated number of affected customers by institutional type	0
100	Estimated number of affected customers by institutional type	0
383	Estimated number of affected customers by institutional type	
402	Estimated number of affected customers by institutional type	0
413	Estimated number of affected customers by institutional type	0
249	Estimated number of affected customers by institutional type	0
284	Estimated number of affected customers by institutional type	100
240	Estimated number of affected customers by institutional type	50
407	Estimated number of affected customers by institutional type	0
389	Estimated number of affected customers by institutional type	0
411	Estimated number of affected customers by institutional type	
260	Estimated number of affected customers by institutional type	0
134	Estimated number of affected customers by institutional type	0
432	Estimated number of affected customers by institutional type	
332	Estimated number of affected customers by institutional type	100
424	Estimated number of affected customers by institutional type	0

21	Estimated number of affected customers by institutional type	0
427	Estimated number of affected customers by institutional type	0
428	Estimated number of affected customers by institutional type	0
227	Estimated number of affected customers by institutional type	0
423	Estimated number of affected customers by institutional type	
420	Estimated number of affected customers by institutional type	100
409	Estimated number of affected customers by institutional type	0
433	Estimated number of affected customers by institutional type	0
434	Estimated number of affected customers by institutional type	0
141	Estimated number of affected customers by institutional type	0
400	Estimated number of affected customers by institutional type	0
401	Estimated number of affected customers by institutional type	
408	Estimated number of affected customers by institutional type	
404	Estimated number of affected customers by institutional type	0
342	Estimated number of affected customers by institutional type	0
435	Estimated number of affected customers by institutional type	75
405	Estimated number of affected customers by institutional type	
422	Estimated number of affected customers by institutional type	
120	Estimated number of affected customers by institutional type	100
416	Estimated number of affected customers by institutional type	0
112	Estimated number of affected customers by institutional type	0
418	Estimated number of affected customers by institutional type	0
403	Estimated number of affected customers by institutional type	100
430	Estimated number of affected customers by institutional type	0
392	Estimated number of affected customers by institutional type	0
103	Estimated number of affected customers by institutional type	
56	Estimated number of affected customers by institutional type	
55	Repaired by	100
301	Repaired by	100
433	Repaired by	100
332	Repaired by	100
342	Repaired by	100
430	Repaired by	75
21	Repaired by	100
432	Repaired by	100
407	Repaired by	100
434	Repaired by	100
283	Repaired by	100
231	Repaired by	100
416	Repaired by	100
120	Repaired by	100
260	Repaired by	50
42	Repaired by	100
240	Repaired by	100
418	Repaired by	100
392	Repaired by	100
284	Repaired by	100
389	Repaired by	100
100	Repaired by	100

428	Repaired by	100
424	Repaired by	100
423	Repaired by	100
383	Repaired by	100
76	Repaired by	100
295	Repaired by	100
420	Repaired by	100
404	Repaired by	
379	Repaired by	100
112	Repaired by	0
72	Repaired by	100
427	Repaired by	100
409	Repaired by	100
402	Repaired by	100
419	Repaired by	50
413	Repaired by	100
415	Repaired by	100
249	Repaired by	100
401	Repaired by	100
403	Repaired by	100
426	Repaired by	100
141	Repaired by	100
48	Repaired by	
56	Repaired by	100
414	Repaired by	100
227	Repaired by	100
400	Repaired by	0
422	Repaired by	100
435	Repaired by	100
405	Repaired by	
134	Repaired by	100
411	Repaired by	100
431	Repaired by	100
10	Repaired by	100
408	Repaired by	100
103	Repaired by	100
417	Repaired by	100
227	Indication of property damage y or n	0
417	Indication of property damage y or n	100
56	Indication of property damage y or n	100
389	Indication of property damage y or n	100
416	Indication of property damage y or n	100
403	Indication of property damage y or n	100
283	Indication of property damage y or n	100
418	Indication of property damage y or n	50
240	Indication of property damage y or n	100
260	Indication of property damage y or n	0
422	Indication of property damage y or n	0
415	Indication of property damage y or n	100

402	Indication of property damage y or n	100
112	Indication of property damage y or n	0
120	Indication of property damage y or n	100
379	Indication of property damage y or n	50
407	Indication of property damage y or n	100
48	Indication of property damage y or n	
405	Indication of property damage y or n	
134	Indication of property damage y or n	100
433	Indication of property damage y or n	75
411	Indication of property damage y or n	100
103	Indication of property damage y or n	100
301	Indication of property damage y or n	0
408	Indication of property damage y or n	100
55	Indication of property damage y or n	100
249	Indication of property damage y or n	100
342	Indication of property damage y or n	100
141	Indication of property damage y or n	0
427	Indication of property damage y or n	100
424	Indication of property damage y or n	100
413	Indication of property damage y or n	100
432	Indication of property damage y or n	100
409	Indication of property damage y or n	100
426	Indication of property damage y or n	0
404	Indication of property damage y or n	50
420	Indication of property damage y or n	100
383	Indication of property damage y or n	75
332	Indication of property damage y or n	-1
76	Indication of property damage y or n	0
414	Indication of property damage y or n	100
419	Indication of property damage y or n	100
423	Indication of property damage y or n	75
21	Indication of property damage y or n	100
400	Indication of property damage y or n	75
401	Indication of property damage y or n	100
10	Indication of property damage y or n	100
284	Indication of property damage y or n	100
434	Indication of property damage y or n	100
431	Indication of property damage y or n	100
72	Indication of property damage y or n	50
100	Indication of property damage y or n	100
430	Indication of property damage y or n	100
428	Indication of property damage y or n	100
42	Indication of property damage y or n	25
231	Indication of property damage y or n	0
435	Indication of property damage y or n	100
392	Indication of property damage y or n	0
295	Indication of property damage y or n	100
112	Property damage cost	0
427	Property damage cost	0

55	Property damage cost	
411	Property damage cost	0
432	Property damage cost	0
434	Property damage cost	0
408	Property damage cost	100
301	Property damage cost	0
48	Property damage cost	
413	Property damage cost	
420	Property damage cost	0
76	Property damage cost	0
249	Property damage cost	100
134	Property damage cost	0
295	Property damage cost	100
407	Property damage cost	100
42	Property damage cost	0
332	Property damage cost	0
405	Property damage cost	
433	Property damage cost	0
428	Property damage cost	100
431	Property damage cost	0
342	Property damage cost	0
392	Property damage cost	0
418	Property damage cost	25
424	Property damage cost	0
283	Property damage cost	0
430	Property damage cost	0
389	Property damage cost	0
403	Property damage cost	100
423	Property damage cost	100
72	Property damage cost	0
409	Property damage cost	100
400	Property damage cost	0
415	Property damage cost	0
100	Property damage cost	50
56	Property damage cost	0
404	Property damage cost	25
227	Property damage cost	0
416	Property damage cost	100
231	Property damage cost	0
120	Property damage cost	0
422	Property damage cost	0
284	Property damage cost	100
435	Property damage cost	100
417	Property damage cost	0
402	Property damage cost	0
260	Property damage cost	0
401	Property damage cost	0
103	Property damage cost	
426	Property damage cost	0

141	Property damage cost	0
21	Property damage cost	0
379	Property damage cost	0
10	Property damage cost	100
414	Property damage cost	0
419	Property damage cost	50
383	Property damage cost	0
240	Property damage cost	0
48	Employee researching pipe & completing form	
420	Employee researching pipe & completing form	100
55	Employee researching pipe & completing form	
404	Employee researching pipe & completing form	100
342	Employee researching pipe & completing form	100
432	Employee researching pipe & completing form	0
21	Employee researching pipe & completing form	100
392	Employee researching pipe & completing form	0
379	Employee researching pipe & completing form	0
430	Employee researching pipe & completing form	100
332	Employee researching pipe & completing form	
301	Employee researching pipe & completing form	100
426	Employee researching pipe & completing form	0
417	Employee researching pipe & completing form	75
435	Employee researching pipe & completing form	100
403	Employee researching pipe & completing form	75
422	Employee researching pipe & completing form	100
402	Employee researching pipe & completing form	0
415	Employee researching pipe & completing form	0
400	Employee researching pipe & completing form	0
227	Employee researching pipe & completing form	0
10	Employee researching pipe & completing form	100
419	Employee researching pipe & completing form	50
56	Employee researching pipe & completing form	0
414	Employee researching pipe & completing form	100
434	Employee researching pipe & completing form	75
141	Employee researching pipe & completing form	0
431	Employee researching pipe & completing form	0
409	Employee researching pipe & completing form	100
413	Employee researching pipe & completing form	
401	Employee researching pipe & completing form	100
427	Employee researching pipe & completing form	100
249	Employee researching pipe & completing form	100
408	Employee researching pipe & completing form	100
103	Employee researching pipe & completing form	100
411	Employee researching pipe & completing form	0
134	Employee researching pipe & completing form	100
295	Employee researching pipe & completing form	100
405	Employee researching pipe & completing form	
407	Employee researching pipe & completing form	100
433	Employee researching pipe & completing form	

72	Employee researching pipe & completing form	0
120	Employee researching pipe & completing form	0
389	Employee researching pipe & completing form	0
428	Employee researching pipe & completing form	0
283	Employee researching pipe & completing form	100
424	Employee researching pipe & completing form	100
423	Employee researching pipe & completing form	100
418	Employee researching pipe & completing form	50
112	Employee researching pipe & completing form	0
260	Employee researching pipe & completing form	0
76	Employee researching pipe & completing form	100
240	Employee researching pipe & completing form	50
100	Employee researching pipe & completing form	75
383	Employee researching pipe & completing form	50
231	Employee researching pipe & completing form	100
416	Employee researching pipe & completing form	0
284	Employee researching pipe & completing form	0
42	Employee researching pipe & completing form	0
434	ID of watermain feature being repaired	100
120	ID of watermain feature being repaired	0
432	ID of watermain feature being repaired	0
301	ID of watermain feature being repaired	100
72	ID of watermain feature being repaired	0
260	ID of watermain feature being repaired	0
100	ID of watermain feature being repaired	100
435	ID of watermain feature being repaired	50
409	ID of watermain feature being repaired	100
408	ID of watermain feature being repaired	100
21	ID of watermain feature being repaired	100
76	ID of watermain feature being repaired	100
430	ID of watermain feature being repaired	100
414	ID of watermain feature being repaired	0
295	ID of watermain feature being repaired	100
418	ID of watermain feature being repaired	50
249	ID of watermain feature being repaired	100
427	ID of watermain feature being repaired	100
424	ID of watermain feature being repaired	100
417	ID of watermain feature being repaired	100
431	ID of watermain feature being repaired	100
426	ID of watermain feature being repaired	0
423	ID of watermain feature being repaired	0
284	ID of watermain feature being repaired	100
42	ID of watermain feature being repaired	0
413	ID of watermain feature being repaired	
332	ID of watermain feature being repaired	75
433	ID of watermain feature being repaired	100
48	ID of watermain feature being repaired	
55	ID of watermain feature being repaired	
401	ID of watermain feature being repaired	100

383	ID of watermain feature being repaired	100
392	ID of watermain feature being repaired	100
407	ID of watermain feature being repaired	100
134	ID of watermain feature being repaired	100
231	ID of watermain feature being repaired	75
415	ID of watermain feature being repaired	100
141	ID of watermain feature being repaired	100
405	ID of watermain feature being repaired	
112	ID of watermain feature being repaired	100
402	ID of watermain feature being repaired	100
416	ID of watermain feature being repaired	0
420	ID of watermain feature being repaired	100
400	ID of watermain feature being repaired	0
389	ID of watermain feature being repaired	100
422	ID of watermain feature being repaired	75
379	ID of watermain feature being repaired	75
403	ID of watermain feature being repaired	100
56	ID of watermain feature being repaired	100
411	ID of watermain feature being repaired	0
419	ID of watermain feature being repaired	25
283	ID of watermain feature being repaired	100
404	ID of watermain feature being repaired	100
240	ID of watermain feature being repaired	100
428	ID of watermain feature being repaired	0
10	ID of watermain feature being repaired	0
342	ID of watermain feature being repaired	0
103	ID of watermain feature being repaired	100
227	ID of watermain feature being repaired	100
134	ID assigned to break, leak etc	100
428	ID assigned to break, leak etc	0
295	ID assigned to break, leak etc	100
408	ID assigned to break, leak etc	0
423	ID assigned to break, leak etc	0
411	ID assigned to break, leak etc	0
283	ID assigned to break, leak etc	0
417	ID assigned to break, leak etc	100
414	ID assigned to break, leak etc	0
416	ID assigned to break, leak etc	100
400	ID assigned to break, leak etc	100
402	ID assigned to break, leak etc	100
422	ID assigned to break, leak etc	75
415	ID assigned to break, leak etc	100
231	ID assigned to break, leak etc	100
112	ID assigned to break, leak etc	100
227	ID assigned to break, leak etc	100
10	ID assigned to break, leak etc	100
240	ID assigned to break, leak etc	100
403	ID assigned to break, leak etc	100
72	ID assigned to break, leak etc	0

56	ID assigned to break, leak etc	100
434	ID assigned to break, leak etc	100
435	ID assigned to break, leak etc	100
141	ID assigned to break, leak etc	0
260	ID assigned to break, leak etc	0
42	ID assigned to break, leak etc	0
426	ID assigned to break, leak etc	0
120	ID assigned to break, leak etc	100
409	ID assigned to break, leak etc	100
413	ID assigned to break, leak etc	
418	ID assigned to break, leak etc	50
401	ID assigned to break, leak etc	100
427	ID assigned to break, leak etc	100
249	ID assigned to break, leak etc	100
419	ID assigned to break, leak etc	25
301	ID assigned to break, leak etc	100
424	ID assigned to break, leak etc	100
342	ID assigned to break, leak etc	0
55	ID assigned to break, leak etc	100
430	ID assigned to break, leak etc	0
21	ID assigned to break, leak etc	100
392	ID assigned to break, leak etc	100
76	ID assigned to break, leak etc	0
48	ID assigned to break, leak etc	
379	ID assigned to break, leak etc	100
407	ID assigned to break, leak etc	100
389	ID assigned to break, leak etc	100
433	ID assigned to break, leak etc	
420	ID assigned to break, leak etc	100
431	ID assigned to break, leak etc	100
332	ID assigned to break, leak etc	100
103	ID assigned to break, leak etc	100
404	ID assigned to break, leak etc	100
432	ID assigned to break, leak etc	0
100	ID assigned to break, leak etc	100
405	ID assigned to break, leak etc	
383	ID assigned to break, leak etc	100
284	ID assigned to break, leak etc	100
332	Sketch of damaged facility	25
55	Sketch of damaged facility	75
56	Sketch of damaged facility	25
414	Sketch of damaged facility	50
120	Sketch of damaged facility	100
301	Sketch of damaged facility	0
404	Sketch of damaged facility	25
408	Sketch of damaged facility	0
426	Sketch of damaged facility	0
76	Sketch of damaged facility	0
419	Sketch of damaged facility	25

72	Sketch of damaged facility	0
260	Sketch of damaged facility	100
21	Sketch of damaged facility	0
415	Sketch of damaged facility	0
417	Sketch of damaged facility	25
284	Sketch of damaged facility	100
42	Sketch of damaged facility	75
435	Sketch of damaged facility	50
403	Sketch of damaged facility	100
432	Sketch of damaged facility	100
400	Sketch of damaged facility	100
383	Sketch of damaged facility	50
416	Sketch of damaged facility	0
420	Sketch of damaged facility	100
10	Sketch of damaged facility	0
422	Sketch of damaged facility	0
430	Sketch of damaged facility	0
379	Sketch of damaged facility	0
112	Sketch of damaged facility	0
342	Sketch of damaged facility	0
227	Sketch of damaged facility	100
392	Sketch of damaged facility	0
424	Sketch of damaged facility	0
141	Sketch of damaged facility	0
231	Sketch of damaged facility	75
409	Sketch of damaged facility	100
240	Sketch of damaged facility	25
402	Sketch of damaged facility	0
283	Sketch of damaged facility	75
48	Sketch of damaged facility	
401	Sketch of damaged facility	75
428	Sketch of damaged facility	0
100	Sketch of damaged facility	50
249	Sketch of damaged facility	100
434	Sketch of damaged facility	0
427	Sketch of damaged facility	0
389	Sketch of damaged facility	0
423	Sketch of damaged facility	0
411	Sketch of damaged facility	0
407	Sketch of damaged facility	50
103	Sketch of damaged facility	
295	Sketch of damaged facility	50
418	Sketch of damaged facility	25
405	Sketch of damaged facility	
134	Sketch of damaged facility	0
433	Sketch of damaged facility	
413	Sketch of damaged facility	
431	Sketch of damaged facility	0
408	Digital photo of damaged facility	0

295	Digital photo of damaged facility	100
379	Digital photo of damaged facility	0
240	Digital photo of damaged facility	50
435	Digital photo of damaged facility	100
389	Digital photo of damaged facility	0
112	Digital photo of damaged facility	0
227	Digital photo of damaged facility	0
415	Digital photo of damaged facility	50
433	Digital photo of damaged facility	25
141	Digital photo of damaged facility	0
332	Digital photo of damaged facility	50
405	Digital photo of damaged facility	
10	Digital photo of damaged facility	100
120	Digital photo of damaged facility	0
402	Digital photo of damaged facility	100
400	Digital photo of damaged facility	0
403	Digital photo of damaged facility	75
103	Digital photo of damaged facility	100
407	Digital photo of damaged facility	100
426	Digital photo of damaged facility	0
283	Digital photo of damaged facility	0
411	Digital photo of damaged facility	25
404	Digital photo of damaged facility	75
424	Digital photo of damaged facility	0
413	Digital photo of damaged facility	
422	Digital photo of damaged facility	0
432	Digital photo of damaged facility	0
383	Digital photo of damaged facility	100
423	Digital photo of damaged facility	25
420	Digital photo of damaged facility	0
260	Digital photo of damaged facility	0
417	Digital photo of damaged facility	25
428	Digital photo of damaged facility	0
21	Digital photo of damaged facility	0
72	Digital photo of damaged facility	50
416	Digital photo of damaged facility	0
401	Digital photo of damaged facility	75
134	Digital photo of damaged facility	0
434	Digital photo of damaged facility	25
301	Digital photo of damaged facility	0
409	Digital photo of damaged facility	100
76	Digital photo of damaged facility	0
342	Digital photo of damaged facility	50
431	Digital photo of damaged facility	25
418	Digital photo of damaged facility	25
414	Digital photo of damaged facility	50
55	Digital photo of damaged facility	25
231	Digital photo of damaged facility	50
419	Digital photo of damaged facility	25

100	Digital photo of damaged facility	0
284	Digital photo of damaged facility	0
427	Digital photo of damaged facility	0
430	Digital photo of damaged facility	25
42	Digital photo of damaged facility	100
392	Digital photo of damaged facility	0
249	Digital photo of damaged facility	50
48	Digital photo of damaged facility	
56	Digital photo of damaged facility	25
400	Length of unsupported pipe	0
409	Length of unsupported pipe	0
413	Length of unsupported pipe	
42	Length of unsupported pipe	0
431	Length of unsupported pipe	0
342	Length of unsupported pipe	0
383	Length of unsupported pipe	50
100	Length of unsupported pipe	0
120	Length of unsupported pipe	0
434	Length of unsupported pipe	0
72	Length of unsupported pipe	0
414	Length of unsupported pipe	50
56	Length of unsupported pipe	0
423	Length of unsupported pipe	0
260	Length of unsupported pipe	0
332	Length of unsupported pipe	25
379	Length of unsupported pipe	0
301	Length of unsupported pipe	0
405	Length of unsupported pipe	
408	Length of unsupported pipe	0
389	Length of unsupported pipe	0
112	Length of unsupported pipe	0
404	Length of unsupported pipe	25
415	Length of unsupported pipe	0
422	Length of unsupported pipe	0
411	Length of unsupported pipe	0
417	Length of unsupported pipe	0
407	Length of unsupported pipe	0
392	Length of unsupported pipe	0
284	Length of unsupported pipe	0
103	Length of unsupported pipe	
401	Length of unsupported pipe	0
295	Length of unsupported pipe	100
76	Length of unsupported pipe	0
231	Length of unsupported pipe	0
430	Length of unsupported pipe	0
249	Length of unsupported pipe	0
432	Length of unsupported pipe	0
418	Length of unsupported pipe	0
424	Length of unsupported pipe	0

283	Length of unsupported pipe	0
227	Length of unsupported pipe	0
419	Length of unsupported pipe	0
416	Length of unsupported pipe	0
240	Length of unsupported pipe	0
426	Length of unsupported pipe	0
141	Length of unsupported pipe	0
428	Length of unsupported pipe	0
427	Length of unsupported pipe	0
435	Length of unsupported pipe	25
420	Length of unsupported pipe	50
10	Length of unsupported pipe	100
21	Length of unsupported pipe	0
403	Length of unsupported pipe	100
55	Length of unsupported pipe	
433	Length of unsupported pipe	
48	Length of unsupported pipe	
134	Length of unsupported pipe	0
402	Length of unsupported pipe	0
48	Job / work order number	
407	Job / work order number	100
283	Job / work order number	0
405	Job / work order number	
21	Job / work order number	0
428	Job / work order number	100
423	Job / work order number	100
301	Job / work order number	100
433	Job / work order number	100
260	Job / work order number	100
141	Job / work order number	100
409	Job / work order number	100
42	Job / work order number	100
112	Job / work order number	0
240	Job / work order number	100
426	Job / work order number	0
413	Job / work order number	
416	Job / work order number	100
420	Job / work order number	100
432	Job / work order number	100
342	Job / work order number	100
103	Job / work order number	100
417	Job / work order number	100
403	Job / work order number	100
411	Job / work order number	100
383	Job / work order number	100
427	Job / work order number	100
424	Job / work order number	100
408	Job / work order number	0
379	Job / work order number	0

76	Job / work order number	0
404	Job / work order number	0
249	Job / work order number	100
332	Job / work order number	100
55	Job / work order number	
389	Job / work order number	100
418	Job / work order number	100
134	Job / work order number	100
401	Job / work order number	0
56	Job / work order number	100
100	Job / work order number	100
431	Job / work order number	100
422	Job / work order number	0
419	Job / work order number	0
72	Job / work order number	100
430	Job / work order number	100
402	Job / work order number	100
227	Job / work order number	100
284	Job / work order number	100
295	Job / work order number	100
392	Job / work order number	100
415	Job / work order number	100
231	Job / work order number	100
434	Job / work order number	100
120	Job / work order number	100
10	Job / work order number	100
414	Job / work order number	100
400	Job / work order number	100
435	Job / work order number	100
433	Dates of previous breaks at same location	50
383	Dates of previous breaks at same location	100
400	Dates of previous breaks at same location	0
295	Dates of previous breaks at same location	100
411	Dates of previous breaks at same location	100
402	Dates of previous breaks at same location	100
424	Dates of previous breaks at same location	100
415	Dates of previous breaks at same location	0
405	Dates of previous breaks at same location	
48	Dates of previous breaks at same location	
401	Dates of previous breaks at same location	0
409	Dates of previous breaks at same location	100
76	Dates of previous breaks at same location	0
431	Dates of previous breaks at same location	100
417	Dates of previous breaks at same location	100
72	Dates of previous breaks at same location	0
332	Dates of previous breaks at same location	100
55	Dates of previous breaks at same location	
379	Dates of previous breaks at same location	0
403	Dates of previous breaks at same location	25

10	Dates of previous breaks at same location	100
407	Dates of previous breaks at same location	100
103	Dates of previous breaks at same location	100
134	Dates of previous breaks at same location	0
301	Dates of previous breaks at same location	75
435	Dates of previous breaks at same location	25
404	Dates of previous breaks at same location	0
432	Dates of previous breaks at same location	0
422	Dates of previous breaks at same location	0
408	Dates of previous breaks at same location	0
434	Dates of previous breaks at same location	0
21	Dates of previous breaks at same location	50
420	Dates of previous breaks at same location	0
419	Dates of previous breaks at same location	0
141	Dates of previous breaks at same location	100
430	Dates of previous breaks at same location	50
423	Dates of previous breaks at same location	100
426	Dates of previous breaks at same location	100
413	Dates of previous breaks at same location	
42	Dates of previous breaks at same location	25
260	Dates of previous breaks at same location	0
283	Dates of previous breaks at same location	25
416	Dates of previous breaks at same location	100
120	Dates of previous breaks at same location	0
342	Dates of previous breaks at same location	100
56	Dates of previous breaks at same location	0
240	Dates of previous breaks at same location	0
100	Dates of previous breaks at same location	75
112	Dates of previous breaks at same location	0
231	Dates of previous breaks at same location	75
227	Dates of previous breaks at same location	0
427	Dates of previous breaks at same location	100
284	Dates of previous breaks at same location	100
249	Dates of previous breaks at same location	0
414	Dates of previous breaks at same location	25
418	Dates of previous breaks at same location	100
428	Dates of previous breaks at same location	0
389	Dates of previous breaks at same location	0
392	Dates of previous breaks at same location	0
332	Equipment used	100
48	Equipment used	
100	Equipment used	100
301	Equipment used	100
435	Equipment used	50
120	Equipment used	100
21	Equipment used	100
10	Equipment used	100
231	Equipment used	25
112	Equipment used	0

400	Equipment used	50
428	Equipment used	100
42	Equipment used	100
240	Equipment used	100
283	Equipment used	25
76	Equipment used	0
431	Equipment used	100
392	Equipment used	0
389	Equipment used	0
418	Equipment used	100
424	Equipment used	100
284	Equipment used	100
383	Equipment used	100
432	Equipment used	100
430	Equipment used	25
342	Equipment used	100
55	Equipment used	100
423	Equipment used	100
260	Equipment used	100
434	Equipment used	100
416	Equipment used	100
404	Equipment used	75
72	Equipment used	100
401	Equipment used	100
420	Equipment used	100
379	Equipment used	25
295	Equipment used	100
414	Equipment used	100
422	Equipment used	75
407	Equipment used	100
415	Equipment used	100
227	Equipment used	100
419	Equipment used	25
56	Equipment used	100
402	Equipment used	100
103	Equipment used	
134	Equipment used	100
141	Equipment used	100
411	Equipment used	100
426	Equipment used	0
249	Equipment used	100
413	Equipment used	
427	Equipment used	100
409	Equipment used	100
408	Equipment used	100
405	Equipment used	
417	Equipment used	100
433	Equipment used	100
403	Equipment used	100

249	Crew members	100
408	Crew members	100
405	Crew members	
404	Crew members	75
389	Crew members	100
403	Crew members	100
10	Crew members	100
134	Crew members	100
420	Crew members	100
424	Crew members	100
426	Crew members	100
120	Crew members	100
416	Crew members	100
260	Crew members	100
42	Crew members	100
56	Crew members	100
141	Crew members	0
383	Crew members	100
428	Crew members	100
103	Crew members	
432	Crew members	100
419	Crew members	25
414	Crew members	100
231	Crew members	75
100	Crew members	100
112	Crew members	100
379	Crew members	100
433	Crew members	100
413	Crew members	100
411	Crew members	100
72	Crew members	100
48	Crew members	
418	Crew members	100
21	Crew members	100
434	Crew members	100
301	Crew members	100
407	Crew members	100
422	Crew members	0
240	Crew members	100
295	Crew members	100
409	Crew members	100
332	Crew members	100
435	Crew members	25
402	Crew members	100
392	Crew members	0
423	Crew members	100
430	Crew members	100
284	Crew members	100
76	Crew members	100

415	Crew members	100
283	Crew members	0
342	Crew members	100
417	Crew members	100
427	Crew members	100
431	Crew members	100
55	Crew members	100
400	Crew members	50
401	Crew members	100
227	Crew members	100
426	Crew total hours	100
416	Crew total hours	100
413	Crew total hours	100
260	Crew total hours	100
423	Crew total hours	100
427	Crew total hours	100
400	Crew total hours	50
409	Crew total hours	100
418	Crew total hours	100
283	Crew total hours	0
419	Crew total hours	25
72	Crew total hours	100
434	Crew total hours	100
295	Crew total hours	100
415	Crew total hours	100
402	Crew total hours	100
401	Crew total hours	100
431	Crew total hours	100
392	Crew total hours	0
227	Crew total hours	100
435	Crew total hours	25
284	Crew total hours	100
231	Crew total hours	75
430	Crew total hours	100
240	Crew total hours	100
100	Crew total hours	100
120	Crew total hours	100
403	Crew total hours	100
414	Crew total hours	100
10	Crew total hours	100
141	Crew total hours	100
428	Crew total hours	100
417	Crew total hours	100
42	Crew total hours	100
112	Crew total hours	100
56	Crew total hours	100
422	Crew total hours	0
407	Crew total hours	100
404	Crew total hours	100

301	Crew total hours	0
249	Crew total hours	100
379	Crew total hours	100
433	Crew total hours	100
342	Crew total hours	100
134	Crew total hours	100
424	Crew total hours	100
21	Crew total hours	100
383	Crew total hours	100
332	Crew total hours	100
408	Crew total hours	100
103	Crew total hours	
55	Crew total hours	100
432	Crew total hours	100
411	Crew total hours	100
405	Crew total hours	
48	Crew total hours	
76	Crew total hours	0
389	Crew total hours	0
420	Crew total hours	100
407	Total labour cost	100
383	Total labour cost	100
42	Total labour cost	100
120	Total labour cost	100
332	Total labour cost	100
401	Total labour cost	0
240	Total labour cost	100
400	Total labour cost	0
295	Total labour cost	100
112	Total labour cost	0
389	Total labour cost	0
430	Total labour cost	100
415	Total labour cost	100
141	Total labour cost	100
231	Total labour cost	75
342	Total labour cost	100
392	Total labour cost	0
414	Total labour cost	50
103	Total labour cost	
419	Total labour cost	25
418	Total labour cost	100
431	Total labour cost	100
426	Total labour cost	0
432	Total labour cost	
55	Total labour cost	100
428	Total labour cost	100
409	Total labour cost	100
405	Total labour cost	
402	Total labour cost	0

227	Total labour cost	100
21	Total labour cost	0
403	Total labour cost	100
404	Total labour cost	25
423	Total labour cost	100
408	Total labour cost	100
134	Total labour cost	100
283	Total labour cost	0
301	Total labour cost	0
435	Total labour cost	100
420	Total labour cost	75
422	Total labour cost	0
260	Total labour cost	100
427	Total labour cost	100
249	Total labour cost	100
100	Total labour cost	100
417	Total labour cost	100
72	Total labour cost	100
416	Total labour cost	100
76	Total labour cost	0
379	Total labour cost	0
434	Total labour cost	100
56	Total labour cost	100
10	Total labour cost	25
413	Total labour cost	100
284	Total labour cost	100
424	Total labour cost	100
48	Total labour cost	
411	Total labour cost	100
433	Total labour cost	100
420	Total materials cost	0
134	Total materials cost	75
379	Total materials cost	0
422	Total materials cost	0
284	Total materials cost	100
55	Total materials cost	100
72	Total materials cost	100
400	Total materials cost	25
417	Total materials cost	100
10	Total materials cost	25
48	Total materials cost	
403	Total materials cost	100
301	Total materials cost	0
435	Total materials cost	100
295	Total materials cost	100
21	Total materials cost	0
392	Total materials cost	0
434	Total materials cost	100
433	Total materials cost	100

415	Total materials cost	100
407	Total materials cost	100
332	Total materials cost	100
401	Total materials cost	0
402	Total materials cost	0
431	Total materials cost	100
227	Total materials cost	100
112	Total materials cost	0
141	Total materials cost	100
103	Total materials cost	
428	Total materials cost	100
423	Total materials cost	100
383	Total materials cost	100
283	Total materials cost	0
42	Total materials cost	100
419	Total materials cost	25
260	Total materials cost	100
432	Total materials cost	
249	Total materials cost	100
416	Total materials cost	100
405	Total materials cost	
56	Total materials cost	100
424	Total materials cost	100
426	Total materials cost	0
411	Total materials cost	100
240	Total materials cost	100
427	Total materials cost	0
404	Total materials cost	25
342	Total materials cost	100
430	Total materials cost	100
76	Total materials cost	0
389	Total materials cost	0
100	Total materials cost	100
231	Total materials cost	75
418	Total materials cost	100
413	Total materials cost	100
408	Total materials cost	100
414	Total materials cost	50
409	Total materials cost	100
120	Total materials cost	100
405	Total equipment cost	
227	Total equipment cost	100
249	Total equipment cost	100
72	Total equipment cost	100
389	Total equipment cost	0
435	Total equipment cost	100
418	Total equipment cost	100
434	Total equipment cost	100
427	Total equipment cost	0

426	Total equipment cost	0
404	Total equipment cost	25
48	Total equipment cost	
21	Total equipment cost	0
283	Total equipment cost	0
417	Total equipment cost	100
260	Total equipment cost	100
403	Total equipment cost	100
400	Total equipment cost	25
301	Total equipment cost	0
423	Total equipment cost	100
76	Total equipment cost	0
416	Total equipment cost	100
10	Total equipment cost	25
284	Total equipment cost	100
103	Total equipment cost	
431	Total equipment cost	100
401	Total equipment cost	0
392	Total equipment cost	0
342	Total equipment cost	100
55	Total equipment cost	100
402	Total equipment cost	0
379	Total equipment cost	0
432	Total equipment cost	
120	Total equipment cost	100
231	Total equipment cost	75
430	Total equipment cost	100
409	Total equipment cost	100
422	Total equipment cost	0
141	Total equipment cost	100
414	Total equipment cost	25
420	Total equipment cost	100
407	Total equipment cost	100
413	Total equipment cost	100
56	Total equipment cost	100
415	Total equipment cost	100
100	Total equipment cost	100
295	Total equipment cost	100
408	Total equipment cost	100
419	Total equipment cost	25
240	Total equipment cost	100
411	Total equipment cost	100
428	Total equipment cost	100
42	Total equipment cost	100
332	Total equipment cost	100
433	Total equipment cost	100
134	Total equipment cost	100
383	Total equipment cost	100
424	Total equipment cost	100

112	Total equipment cost	0

Physical data recorded by survey respondents

City ID	Description	Recorded(%)	Confidence	Available from other	Sources	Comments
21	Backfill material	100	HIGH	NO	Archival records	NIL
42	Backfill material	50	MEDIUM	NA	NA	NIL
55	Backfill material	100	HIGH	Yes	Other	NIL
56	Backfill material	100	GOOD	NO	NA	NIL
72	Backfill material	50	GOOD	NA	NA	NIL
428	Backfill material	0	NA	NA	NA	NIL
413	Backfill material	100	HIGH	NO	NA	NIL
100	Backfill material	100	HIGH	NO	NA	NIL
103	Backfill material	100	HIGH	NA	NA	NIL
112	Backfill material	0	NA	NA	NA	NIL
120	Backfill material	0	NONE	NO	NA	NIL
134	Backfill material	100	HIGH	NO	NA	NIL
418	Backfill material	0	NONE	NO	NA	NIL
227	Backfill material	100	GOOD	YES	O&M records	Hansen WO data
231	Backfill material	0	NONE	NO	NA	NIL
240	Backfill material	50	GOOD	NO	NA	NIL
249	Backfill material	100	MEDIUM	NO	NA	as built drawings
260	Backfill material	0	NA	NA	NA	NIL
401	Backfill material	0	NA	YES	Archival records	NIL
283	Backfill material	0	GOOD	NO	NA	NIL
284	Backfill material	25	LOW	NA	NA	NIL
295	Backfill material	0	HIGH	NO	NA	NIL
301	Backfill material	100	GOOD	NO	NA	NIL
424	Backfill material	0	HIGH	NO	NA	NIL
433	Backfill material	75	GOOD	NA	NA	NIL
332	Backfill material	50	MEDIUM	NO	NA	NIL
435	Backfill material	100	GOOD	NO	NA	NIL
400	Backfill material	0	NONE	NO	NA	NIL
383	Backfill material	100	HIGH	NA	NA	NIL
392	Backfill material	0	NONE	YES	Archival records	NIL
403	Backfill material	100	HIGH	YES	External	NIL
409	Backfill material	100	HIGH	NA	NA	NIL
10	Backfill material	0	NA	NA	NA	NIL
48	Backfill material	0	high	no	NA	NIL
404	Backfill material	0	NONE	NA	NA	NIL
411	Backfill material		NA	NA	NA	NIL
76	Backfill material	0	NA	Yes	Archival records	NIL
414	Backfill material	0	NA	NO	NA	NIL
141	Backfill material	0	NA	NO	NA	NIL
405	Backfill material	100	HIGH	NA	NA	NIL
402	Backfill material	100	HIGH	YES	Archival records	NIL

430	Backfill material	0	GOOD	NO	NA	NIL
431	Backfill material	100	HIGH	NO	NA	NIL
415	Backfill material	0	NONE	NO	NA	NIL
416	Backfill material	0	NONE	NO	NA	NIL
407	Backfill material	100	HIGH	NO	NA	NIL
417	Backfill material	0	NONE	NO	NA	NIL
432	Backfill material	0	NA	NO	NA	NIL
419	Backfill material	100	HIGH	NO	NA	NIL
426	Backfill material	0	NONE	NA	NA	NIL
420	Backfill material	100	HIGH	NO	NA	NIL
427	Backfill material	0	NONE	NO	NA	NIL
422	Backfill material	0	NO	NO	NA	NIL
434	Backfill material	25	MEDIUM	NO	NA	NIL
342	Backfill material	0	NA	NO	NA	NIL
408	Backfill material		NA	NA	NA	NIL
423	Backfill material	100	GOOD	YES	Archival records	NIL
379	Backfill material	0	NONE	YES	O&M records	NIL
389	Backfill material	100	HIGH	NA	Other	NIL
21	Bedding material	100	HIGH	NO	Archival records	NIL
42	Bedding material	75	GOOD	NA	NA	NIL
55	Bedding material	0	NA	NA	NA	NIL
56	Bedding material	0	NA	NA	NA	NIL
72	Bedding material	50	GOOD	NA	NA	NIL
428	Bedding material	0	NA	NA	NA	NIL
413	Bedding material		NA	NA	NA	NIL
100	Bedding material	100	HIGH	YES	Archival records	NIL
103	Bedding material	100	HIGH	NA	NA	NIL
112	Bedding material	0	NONE	YES	Archival records	NIL
120	Bedding material	0	NONE	NO	NA	NIL
134	Bedding material	100	HIGH	NO	NA	NIL
418	Bedding material	0	NONE	NO	NA	NIL
227	Bedding material	100	GOOD	YES	O&M records	Hansen WO data
231	Bedding material	0	NONE	YES	Archival records	Soil beddign may be available from contract documents.
240	Bedding material	50	MEDIUM	NO	NA	NIL
249	Bedding material	100	LOW	YES	NA	as built drawings
260	Bedding material	0	NA	NA	NA	NIL
401	Bedding material	25	GOOD	YES	Archival records	recorded if significant
283	Bedding material	0	GOOD	NO	NA	NIL
284	Bedding material	25	LOW	NA	NA	NIL
295	Bedding material	0	HIGH	NO	NA	NIL
301	Bedding material	100	GOOD	NO	NA	NIL

424	Bedding material	0	HIGH	NO	NA	NIL
433	Bedding material	25	GOOD	NA	NA	NIL
332	Bedding material	25	MEDIUM	NO	NA	NIL
435	Bedding material	75	GOOD	NO	NA	NIL
400	Bedding material	50	MEDIUM	YES	Archival records	NIL
383	Bedding material	100	HIGH	NA	NA	NIL
392	Bedding material	0	NONE	YES	Archival records	NIL
403	Bedding material	50	GOOD	NO	NA	NIL
409	Bedding material	100	HIGH	NA	NA	NIL
10	Bedding material	0	NA	NA	NA	NIL
48	Bedding material	0	high	no	NA	NIL
404	Bedding material	0	NONE	NA	NA	NIL
411	Bedding material		NA	NA	NA	NIL
76	Bedding material	0	NA	No	External	NIL
414	Bedding material	0	NA	NO	NA	NIL
141	Bedding material	0	NA	NO	NA	NIL
405	Bedding material	100	HIGH	NA	NA	NIL
402	Bedding material	0	HIGH	YES	Archival records	NIL
430	Bedding material	25	GOOD	NO	NA	NIL
431	Bedding material	100	HIGH	NO	NA	NIL
415	Bedding material	50	LOW	NO	NA	NIL
416	Bedding material	0	NONE	NO	NA	NIL
407	Bedding material	100	HIGH	NO	NA	NIL
417	Bedding material	0	NONE	NO	NA	NIL
432	Bedding material	100	GOOD	NO	NA	NIL
419	Bedding material	100	HIGH	NO	Archival records	NIL
426	Bedding material	0	NONE	NA	NA	NIL
420	Bedding material	0	NONE	YES	O&M records	NIL
427	Bedding material	0	NONE	YES	O&M records	Technical Specs
422	Bedding material	0	GOOD	NO	NA	NIL
434	Bedding material	0	NA	NO	NA	NIL
342	Bedding material	0	NA	NO	NA	NIL
408	Bedding material	0	NONE	NO	NA	NIL
423	Bedding material	0	NA	YES	Archival records	NIL
379	Bedding material	0	NONE	YES	Archival records	NIL
389	Bedding material	100	HIGH	NA	Other	NIL
21	Category of native soil	0	NA	NO	NA	NIL
42	Category of native soil	50	MEDIUM	NA	NA	NIL
55	Category of native soil	0	NA	NA	NA	NIL
56	Category of native soil	0	NA	NA	NA	NIL

72	Category of native soil	0	GOOD	NA	NA	NIL
428	Category of native soil	0	NA	NA	NA	NIL
413	Category of native soil		NA	NA	NA	NIL
100	Category of native soil	0	GOOD	NO	NA	NIL
103	Category of native soil	0	NA	NA	NA	NIL
112	Category of native soil	0	NA	NA	NA	NIL
120	Category of native soil	0	NONE	NO	NA	NIL
134	Category of native soil	100	HIGH	NO	NA	NIL
418	Category of native soil	0	NONE	NO	NA	NIL
227	Category of native soil	100	GOOD	YES	O&M records	Hansen WO data
231	Category of native soil	100	GOOD	YES	Archival records	Soil Condition may be available from geotechnical reports.
240	Category of native soil	75	MEDIUM	NO	NA	NIL
249	Category of native soil	0	NONE	NO	NA	as built drawings
260	Category of native soil	0	NA	NA	NA	NIL
401	Category of native soil	0	NA	NO	NA	NIL
283	Category of native soil	100	GOOD	NO	NA	NIL
284	Category of native soil	25	LOW	NA	NA	NIL
295	Category of native soil	0	HIGH	NO	NA	NIL
301	Category of native soil	0	NA	NO	NA	NIL
424	Category of native soil	0	HIGH	NO	NA	NIL
433	Category of native soil	25	LOW	NA	NA	NIL
332	Category of native soil	0	NONE	YES	Other	NIL
435	Category of native soil	50	GOOD	NO	NA	NIL
400	Category of native soil	0	NONE	NO	NA	NIL

383	Category of native soil	0	NA	NA	NA	NIL
392	Category of native soil	0	NONE	YES	Archival records	NIL
403	Category of native soil	0	NA	NA	NA	NIL
409	Category of native soil	100	HIGH	NA	NA	NIL
10	Category of native soil	0	NA	NA	NA	NIL
48	Category of native soil	0	high	no	NA	NIL
404	Category of native soil	0	NONE	NA	NA	NIL
411	Category of native soil		NA	NA	NA	NIL
76	Category of native soil	0	NA	Yes	Archival records	NIL
414	Category of native soil	0	NA	NO	NA	NIL
141	Category of native soil	0	NA	YES	GIS system	NIL
405	Category of native soil	0	NONE	NA	NA	NIL
402	Category of native soil	0	HIGH	NO	Archival records	NIL
430	Category of native soil	0	GOOD	NO	NA	NIL
431	Category of native soil	25	MEDIUM	YES	External	NIL
415	Category of native soil	50	MEDIUM	NO	NA	NIL
416	Category of native soil	0	NONE	NO	NA	NIL
407	Category of native soil	100	HIGH	NO	NA	NIL
417	Category of native soil	0	NONE	NO	NA	NIL
432	Category of native soil	100	GOOD	NO	NA	NIL
419	Category of native soil	0	LOW	NO	NA	NIL
426	Category of native soil	0	NONE	NA	NA	NIL
420	Category of native soil	0	NONE	NO	NA	NIL
427	Category of native soil	0	NONE	YES	O&M records	Technical Specs
422	Category of native soil	0	GOOD	NO	NA	NIL
434	Category of native soil	25	MEDIUM	NO	NA	NIL

342	Category of native soil	0	NA	YES	GIS system	NIL
408	Category of native soil		NA	NA	NA	NIL
423	Category of native soil	0	NA	NO	NA	NIL
379	Category of native soil	0	NONE	YES	Archival records	NIL
389	Category of native soil	100	GOOD	NA	Other	NIL
21	Condition of bedding	0	NA	NO	NA	NIL
42	Condition of bedding	75	GOOD	NA	NA	NIL
55	Condition of bedding	0	NA	NA	NA	NIL
56	Condition of bedding	0	NA	NA	NA	NIL
72	Condition of bedding	50	GOOD	NA	NA	NIL
428	Condition of bedding	0	NA	NA	NA	NIL
413	Condition of bedding		NA	NA	NA	NIL
100	Condition of bedding	50	GOOD	NO	NA	NIL
103	Condition of bedding	0	NA	NA	NA	NIL
112	Condition of bedding	0	NA	NA	NA	NIL
120	Condition of bedding	0	NONE	NO	NA	NIL
134	Condition of bedding	0	NONE	NO	NA	NIL
418	Condition of bedding	0	NONE	NO	NA	NIL
227	Condition of bedding	100	GOOD	YES	O&M records	Hansen WO data
231	Condition of bedding	0	NONE	NO	NA	NIL
240	Condition of bedding	25	LOW	NO	NA	NIL
249	Condition of bedding	0	NONE	NO	NA	NIL
260	Condition of bedding	0	NA	NA	NA	NIL
401	Condition of bedding	25	GOOD	YES	Archival records	recorded if significant
283	Condition of bedding	0	GOOD	NO	NA	NIL
284	Condition of bedding	25	LOW	NA	NA	NIL

295	Condition of bedding	25	HIGH	NO	NA	NIL
301	Condition of bedding	0	NA	NA	NA	NIL
424	Condition of bedding	0	HIGH	NO	NA	NIL
433	Condition of bedding	25	GOOD	NA	NA	NIL
332	Condition of bedding	25	LOW	NO	NA	NIL
435	Condition of bedding	75	GOOD	NO	NA	NIL
400	Condition of bedding	0	NONE	NO	NA	NIL
383	Condition of bedding	100	HIGH	NA	NA	NIL
392	Condition of bedding	0	NONE	NO	NA	NIL
403	Condition of bedding	75	GOOD	NO	NA	NIL
409	Condition of bedding	100	HIGH	NA	NA	NIL
10	Condition of bedding	0	NA	NA	NA	NIL
48	Condition of bedding	0	high	no	NA	NIL
404	Condition of bedding	0	NONE	NA	NA	NIL
411	Condition of bedding		NA	NA	NA	NIL
76	Condition of bedding	0	NA	No	External	NIL
414	Condition of bedding	0	NA	NO	NA	NIL
141	Condition of bedding	0	NA	NO	NA	NIL
405	Condition of bedding	100	HIGH	NA	NA	NIL
402	Condition of bedding	0	HIGH	NO	Archival records	NIL
430	Condition of bedding	25	GOOD	NO	NA	NIL
431	Condition of bedding	100	HIGH	NO	NA	NIL
415	Condition of bedding	100	GOOD	NO	NA	NIL
416	Condition of bedding	0	NONE	NO	NA	NIL
407	Condition of bedding	100	HIGH	NO	NA	NIL
417	Condition of bedding	0	NONE	NO	NA	NIL

432	Condition of bedding	100	GOOD	NO	NA	NIL
419	Condition of bedding	100	HIGH	NO	Archival records	NIL
426	Condition of bedding	0	NONE	NA	NA	NIL
420	Condition of bedding	0	NONE	NO	NA	NIL
427	Condition of bedding	0	NONE	NO	NA	NIL
422	Condition of bedding	0	GOOD	NO	NA	NIL
434	Condition of bedding	50	MEDIUM	NO	NA	NIL
342	Condition of bedding	0	NA	NO	NA	NIL
408	Condition of bedding		NA	NA	NA	NIL
423	Condition of bedding	0	NA	YES	Archival records	NIL
379	Condition of bedding	0	NONE	NO	O&M records	NIL
389	Condition of bedding	0	NA	NA	NA	NIL
21	Condition of cement lined pipe interior	0	NA	YES	Other	swabbing existing mains
42	Condition of cement lined pipe interior		NA	NA	NA	NIL
55	Condition of cement lined pipe interior		NA	NA	NA	Not Applicable
56	Condition of cement lined pipe interior	25	GOOD	NO	NA	NIL
72	Condition of cement lined pipe interior	0	GOOD	NA	NA	NIL
428	Condition of cement lined pipe interior	0	NA	NA	NA	NIL
413	Condition of cement lined pipe interior		NA	NA	NA	NIL
100	Condition of cement lined pipe interior	0	GOOD	NO	NA	NIL
103	Condition of cement lined pipe interior	0	NA	NA	NA	NIL

112	Condition of cement lined pipe interior	25	HIGH	NA	NA	NIL
120	Condition of cement lined pipe interior	0	NONE	NO	NA	NIL
134	Condition of cement lined pipe interior	0	NONE	YES	Other	Distribution System Model
418	Condition of cement lined pipe interior	0	NONE	NO	NA	NIL
227	Condition of cement lined pipe interior	0	NA	NA	NA	NIL
231	Condition of cement lined pipe interior	0	NONE	NO	NA	NIL
240	Condition of cement lined pipe interior	25	MEDIUM	NO	NA	NIL
249	Condition of cement lined pipe interior	0	NONE	NO	NA	NIL
260	Condition of cement lined pipe interior	0	NA	NA	NA	NIL
401	Condition of cement lined pipe interior	0	NA	NO	NA	NIL
283	Condition of cement lined pipe interior	0	GOOD	NO.	NA	NIL
284	Condition of cement lined pipe interior	25	LOW	NA	NA	NIL
295	Condition of cement lined pipe interior	100	HIGH	NO	NA	NIL
301	Condition of cement lined pipe interior	0	NA	NA	NA	NIL
424	Condition of cement lined pipe interior	0	HIGH	NO	NA	NIL
433	Condition of cement lined pipe interior	0	MEDIUM	NA	NA	NIL
332	Condition of cement lined pipe interior		NA	NA	NA	NIL

435	Condition of cement lined pipe interior	50	GOOD	NO	NA	NIL
400	Condition of cement lined pipe interior	0	NONE	NO	NA	NIL
383	Condition of cement lined pipe interior	75	GOOD	NA	NA	NIL
392	Condition of cement lined pipe interior	0	NONE	NO	NA	NIL
403	Condition of cement lined pipe interior	100	HIGH	NO	NA	NIL
409	Condition of cement lined pipe interior	25	MEDIUM	NA	NA	NIL
10	Condition of cement lined pipe interior	0	NA	NA	NA	NIL
48	Condition of cement lined pipe interior	0	high	no	NA	NIL
404	Condition of cement lined pipe interior	50	GOOD	YES	Archival records	NIL
411	Condition of cement lined pipe interior		NA	NA	NA	NIL
76	Condition of cement lined pipe interior	0	NA	No	Other	NIL
414	Condition of cement lined pipe interior	50	MEDIUM	YES	O&M records	NIL
141	Condition of cement lined pipe interior	0	NA	NO	NA	NIL
405	Condition of cement lined pipe interior	100	GOOD	NA	NA	NIL
402	Condition of cement lined pipe interior	0	HIGH	NO	Other	NIL
430	Condition of cement lined pipe interior	0	GOOD	NO	NA	NIL
431	Condition of cement lined pipe interior	25	LOW	YES	External	NIL

415	Condition of cement lined pipe interior	50	LOW	NO	NA	NIL
416	Condition of cement lined pipe interior	0	NONE	NO	NA	NIL
407	Condition of cement lined pipe interior	100	HIGH	NO	NA	NIL
417	Condition of cement lined pipe interior	0	NONE	NO	NA	NIL
432	Condition of cement lined pipe interior	0	NA	NO	NA	NIL
419	Condition of cement lined pipe interior	50	MEDIUM	YES	NA	NIL
426	Condition of cement lined pipe interior	0	NONE	NA	NA	NIL
420	Condition of cement lined pipe interior	0	NONE	NO	NA	NIL
427	Condition of cement lined pipe interior	0	NONE	NO	NA	NIL
422	Condition of cement lined pipe interior	0	GOOD	NO	NA	NIL
434	Condition of cement lined pipe interior	25	MEDIUM	NO	NA	NIL
342	Condition of cement lined pipe interior	0	NA	NO	NA	NIL
408	Condition of cement lined pipe interior		NA	NA	NA	NIL
423	Condition of cement lined pipe interior	0	NA	NA	NA	NIL
379	Condition of cement lined pipe interior	0	NONE	NO	NA	NIL
389	Condition of cement lined pipe interior	0	NA	NA	NA	NIL
21	Condition of pipe exterior	50	GOOD	NO	NA	NIL
42	Condition of pipe exterior	100	GOOD	NA	NA	NIL

55	Condition of pipe exterior		NA	NA	NA	When applicable
56	Condition of pipe exterior	25	MEDIUM	NO	NA	NIL
72	Condition of pipe exterior	0	GOOD	NA	NA	NIL
428	Condition of pipe exterior	0	NA	NA	NA	NIL
413	Condition of pipe exterior	100	HIGH	NO	NA	NIL
100	Condition of pipe exterior	0	GOOD	NO	NA	NIL
103	Condition of pipe exterior	100	HIGH	NA	NA	NIL
112	Condition of pipe exterior	100	HIGH	NA	NA	NIL
120	Condition of pipe exterior	100	HIGH	NO	NA	NIL
134	Condition of pipe exterior	25	LOW	YES	Other	Distribution System Model
418	Condition of pipe exterior	0	NONE	NO	NA	NIL
227	Condition of pipe exterior	0	NA	NA	NA	NIL
231	Condition of pipe exterior	100	GOOD	YES	Other	Occasional Picture taken
240	Condition of pipe exterior	25	LOW	NO	NA	NIL
249	Condition of pipe exterior	0	NONE	NO	NA	If problem was evident it would be recorded
260	Condition of pipe exterior	0	NA	NA	NA	NIL
401	Condition of pipe exterior	25	GOOD	NO	NA	recorded if significant
283	Condition of pipe exterior	100	GOOD	NO	NA	NIL
284	Condition of pipe exterior	25	LOW	NA	NA	NIL
295	Condition of pipe exterior	100	HIGH	NO	NA	NIL
301	Condition of pipe exterior	100	HIGH	NO	NA	NIL
424	Condition of pipe exterior	25	HIGH	NO	NA	NIL
433	Condition of pipe exterior	25	MEDIUM	NA	NA	NIL

332	Condition of pipe exterior	25	MEDIUM	NO	NA	If exterior is in very bad shape, this will be noted in foreman's report
435	Condition of pipe exterior	50	GOOD	NO	NA	NIL
400	Condition of pipe exterior	0	NONE	NO	NA	NIL
383	Condition of pipe exterior	100	HIGH	NA	NA	NIL
392	Condition of pipe exterior	0	NONE	YES	Archival records	NIL
403	Condition of pipe exterior	100	HIGH	NO	NA	NIL
409	Condition of pipe exterior	100	HIGH	NA	NA	NIL
10	Condition of pipe exterior	25	GOOD	YES	GIS system	NIL
48	Condition of pipe exterior	0	high	no	NA	NIL
404	Condition of pipe exterior	50	GOOD	YES	Archival records	NIL
411	Condition of pipe exterior		NA	NA	NA	NIL
76	Condition of pipe exterior	0	NA	No	Other	NIL
414	Condition of pipe exterior	50	MEDIUM	NO	O&M records	NIL
141	Condition of pipe exterior	0	NA	NO	NA	NIL
405	Condition of pipe exterior	100	HIGH	NA	NA	NIL
402	Condition of pipe exterior	0	HIGH	NO	Other	NIL
430	Condition of pipe exterior	0	GOOD	NO	NA	NIL
431	Condition of pipe exterior	100	HIGH	NO	NA	NIL
415	Condition of pipe exterior	100	GOOD	NO	NA	NIL
416	Condition of pipe exterior	0	NONE	NO	NA	NIL
407	Condition of pipe exterior	50	HIGH	NO	NA	NIL
417	Condition of pipe exterior	0	NONE	NO	NA	NIL
432	Condition of pipe exterior	100	GOOD	NO	NA	NIL
419	Condition of pipe exterior	50	MEDIUM	YES	NA	NIL

426	Condition of pipe exterior	0	NONE	NA	NA	NIL
420	Condition of pipe exterior	0	NONE	NO	NA	NIL
427	Condition of pipe exterior	75	MEDIUM	NO	NA	NIL
422	Condition of pipe exterior	0	GOOD	NO	NA	NIL
434	Condition of pipe exterior	25	MEDIUM	NO	NA	NIL
342	Condition of pipe exterior	0	NA	NO	NA	NIL
408	Condition of pipe exterior		NA	NA	NA	NIL
423	Condition of pipe exterior	100	NA	NO	NA	NIL
379	Condition of pipe exterior	75	MEDIUM	NO	O&M records	NIL
389	Condition of pipe exterior	0	NA	NA	NA	NIL
21	Condition of unlined pipe interior	0	NA	YES	Other	swabbing existing mains
42	Condition of unlined pipe interior	100	GOOD	NA	NA	NIL
55	Condition of unlined pipe interior		NA	NA	NA	Not Applicable
56	Condition of unlined pipe interior	25	MEDIUM	NO	NA	NIL
72	Condition of unlined pipe interior	0	GOOD	NA	NA	NIL
428	Condition of unlined pipe interior	0	NA	NA	NA	NIL
413	Condition of unlined pipe interior		NA	NA	NA	NIL
100	Condition of unlined pipe interior	0	GOOD	NO	NA	NIL
103	Condition of unlined pipe interior	0	NA	NA	NA	NIL
112	Condition of unlined pipe interior	25	HIGH	NA	NA	NIL
120	Condition of unlined pipe interior	0	NONE	NO	NA	NIL

134	Condition of unlined pipe interior	25	LOW	YES	Other	Distribution System Model
418	Condition of unlined pipe interior	0	NONE	NO	NA	NIL
227	Condition of unlined pipe interior	0	NA	NA	NA	NIL
231	Condition of unlined pipe interior	0	NONE	NO	NA	NIL
240	Condition of unlined pipe interior	25	LOW	NO	NA	NIL
249	Condition of unlined pipe interior	0	NONE	NO	NA	NIL
260	Condition of unlined pipe interior	0	NA	NA	NA	NIL
401	Condition of unlined pipe interior	25	GOOD	NO	NA	recorded if significant
283	Condition of unlined pipe interior	0	GOOD	NO	NA	NIL
284	Condition of unlined pipe interior	25	LOW	NA	NA	NIL
295	Condition of unlined pipe interior	100	HIGH	NO	NA	NIL
301	Condition of unlined pipe interior	0	NA	NA	NA	NIL
424	Condition of unlined pipe interior	0	HIGH	NO	NA	NIL
433	Condition of unlined pipe interior	25	MEDIUM	NA	NA	NIL
332	Condition of unlined pipe interior		NA	NA	NA	NIL
435	Condition of unlined pipe interior	50	GOOD	NO	NA	NIL
400	Condition of unlined pipe interior	0	NONE	NO	NA	NIL

383	Condition of unlined pipe interior	75	GOOD	NA	NA	NIL
392	Condition of unlined pipe interior	0	NONE	NO	NA	NIL
403	Condition of unlined pipe interior	100	HIGH	NO	NA	NIL
409	Condition of unlined pipe interior	25	MEDIUM	YES	O&M records	NIL
10	Condition of unlined pipe interior	25	GOOD	YES	GIS system	NIL
48	Condition of unlined pipe interior	0	high	no	NA	NIL
404	Condition of unlined pipe interior	50	GOOD	YES	Archival records	NIL
411	Condition of unlined pipe interior		NA	NA	NA	NIL
76	Condition of unlined pipe interior	0	NA	No	Other	NIL
414	Condition of unlined pipe interior	50	MEDIUM	NO	O&M records	NIL
141	Condition of unlined pipe interior	0	NA	NO	NA	NIL
405	Condition of unlined pipe interior	0	NONE	NA	NA	NIL
402	Condition of unlined pipe interior	0	HIGH	NO	Other	NIL
430	Condition of unlined pipe interior	0	GOOD	NO	NA	NIL
431	Condition of unlined pipe interior	0	NONE	NO	NA	NIL
415	Condition of unlined pipe interior	50	LOW	NO	NA	NIL
416	Condition of unlined pipe interior	0	NONE	NO	NA	NIL

407	Condition of unlined pipe interior	100	HIGH	NO	NA	NIL
417	Condition of unlined pipe interior	0	NONE	NO	NA	NIL
432	Condition of unlined pipe interior	25	MEDIUM	NO	NA	NIL
419	Condition of unlined pipe interior	50	MEDIUM	YES	NA	NIL
426	Condition of unlined pipe interior	0	NONE	NA	NA	NIL
420	Condition of unlined pipe interior	0	NONE	NO	NA	NIL
427	Condition of unlined pipe interior	0	NONE	NO	NA	NIL
422	Condition of unlined pipe interior	0	GOOD	NO	NA	NIL
434	Condition of unlined pipe interior	25	MEDIUM	NO	NA	NIL
342	Condition of unlined pipe interior	0	NA	NO	NA	NIL
408	Condition of unlined pipe interior		NA	NA	NA	NIL
423	Condition of unlined pipe interior	100	NA	NO	NA	NIL
379	Condition of unlined pipe interior	0	NONE	NO	NA	NIL
389	Condition of unlined pipe interior	0	NA	NA	NA	NIL
21	Depth of cover	100	HIGH	YES	Archival records	NIL
42	Depth of cover	75	HIGH	NA	NA	NIL
55	Depth of cover	100	HIGH	YES	Other	NIL
56	Depth of cover	75	GOOD	NO	NA	NIL
72	Depth of cover	50	GOOD	NA	NA	NIL
428	Depth of cover	0	NA	NA	NA	NIL
413	Depth of cover	100	HIGH	NO	NA	NIL
100	Depth of cover	100	HIGH	YES	Archival records	NIL
103	Depth of cover	100	HIGH	NA	NA	NIL

112	Depth of cover	100	HIGH	YES	Archival records	NIL
120	Depth of cover	100	GOOD	NO	NA	NIL
134	Depth of cover	100	MEDIUM	YES	Archival records	NIL
418	Depth of cover	0	NONE	YES	Archival records	NIL
227	Depth of cover	100	GOOD	YES	O&M records	Hansen WO data
231	Depth of cover	100	HIGH	NO	Other	Depth of Main recorded on break sheet.
240	Depth of cover	100	GOOD	NO	NA	NIL
249	Depth of cover	100	GOOD	YES	NA	as built drawings
260	Depth of cover	0	NA	YES	Archival records	NIL
401	Depth of cover	0	NA	YES	Archival records	NIL
283	Depth of cover	100	GOOD	YES	Archival records	NIL
284	Depth of cover	50	MEDIUM	NA	NA	NIL
295	Depth of cover	0	HIGH	NO	NA	NIL
301	Depth of cover	0	NA	YES	NA	NIL
424	Depth of cover	100	HIGH	YES	Archival records	NIL
433	Depth of cover	25	GOOD	NA	GIS system	NIL
332	Depth of cover	75	GOOD	YES	Archival records	NIL
435	Depth of cover	100	GOOD	NO	NA	NIL
400	Depth of cover	75	GOOD	NO	NA	NIL
383	Depth of cover	25	NA	NA	NA	NIL
392	Depth of cover	100	MEDIUM	YES	Archival records	NIL
403	Depth of cover	100	HIGH	NO	NA	NIL
409	Depth of cover	100	HIGH	NA	NA	NIL
10	Depth of cover	0	NA	NA	NA	NIL
48	Depth of cover	100	high	no	NA	NIL
404	Depth of cover	50	GOOD	YES	Archival records	NIL
411	Depth of cover		NA	NA	NA	NIL
76	Depth of cover	0	NA	Yes	Archival records	NIL
414	Depth of cover	75	GOOD	NO	O&M records	NIL
141	Depth of cover	0	NA	NO	NA	NIL
405	Depth of cover	100	GOOD	NA	NA	NIL
402	Depth of cover	0	HIGH	YES	Archival records	NIL

430	Depth of cover	25	GOOD	YES	O&M records	NIL
431	Depth of cover	100	HIGH	YES	GIS system	NIL
415	Depth of cover	100	GOOD	YES	Archival records	NIL
416	Depth of cover	0	NONE	NO	NA	NIL
407	Depth of cover	100	HIGH	NO	NA	NIL
417	Depth of cover	25	LOW	NO	NA	NIL
432	Depth of cover	100	HIGH	NO	NA	NIL
419	Depth of cover	100	HIGH	NO	Archival records	NIL
426	Depth of cover	0	NONE	NA	NA	NIL
420	Depth of cover	0	NONE	YES	O&M records	NIL
427	Depth of cover	0	NONE	NO	NA	NIL
422	Depth of cover	0	GOOD	NO	NA	NIL
434	Depth of cover	100	HIGH	NO	NA	NIL
342	Depth of cover	0	NA	YES	Archival records	NIL
408	Depth of cover	75	GOOD	YES	Other	As-built dwg
423	Depth of cover	0	NA	YES	Archival records	NIL
379	Depth of cover	0	LOW	NO	Archival records	NIL
389	Depth of cover	100	GOOD	NA	Other	NIL
21	Length of pipe segment containing the repair	0	NA	YES	GIS system	NIL
42	Length of pipe segment containing the repair	100	HIGH	NA	NA	NIL
55	Length of pipe segment containing the repair		NA	NA	NA	Available, not included in break report
56	Length of pipe segment containing the repair	100	MEDIUM	NO		NIL
72	Length of pipe segment containing the repair	0	GOOD	NA	NA	NIL
428	Length of pipe segment containing the repair	0	NA	NA	NA	NIL
413	Length of pipe segment containing the repair		NA	NA	NA	NIL
100	Length of pipe segment containing the repair	100	HIGH	NO	NA	NIL
103	Length of pipe segment containing the repair	100	HIGH	NA	NA	NIL
112	Length of pipe segment containing the repair	100	HIGH	YES	Archival records	NIL

120	Length of pipe segment containing the repair	0	NONE	NO	NA	NIL
134	Length of pipe segment containing the repair	0	NONE	YES	GIS system	NIL
418	Length of pipe segment containing the repair	75	GOOD	YES	O&M records	NIL
227	Length of pipe segment containing the repair	0	NA	YES	O&M records	Hansen IMS data
231	Length of pipe segment containing the repair	25	MEDIUM	NO	Other	Sheet not set-up for tracking, but occasionally is recorded.
240	Length of pipe segment containing the repair	50	GOOD	NO	NA	NIL
249	Length of pipe segment containing the repair	0	NONE	YES	GIS system	NIL
260	Length of pipe segment containing the repair	50	GOOD	NO		NIL
401	Length of pipe segment containing the repair	100	GOOD	YES	GIS system	entered automatically from database
283	Length of pipe segment containing the repair	25	GOOD	NO	NA	NIL
284	Length of pipe segment containing the repair	100	GOOD	NA	NA	NIL
295	Length of pipe segment containing the repair	25	HIGH	NO	NA	NIL
301	Length of pipe segment containing the repair	0	NA	YES	NA	NIL
424	Length of pipe segment containing the repair	100	HIGH	NO	NA	NIL
433	Length of pipe segment containing the repair	25	GOOD	NA	GIS system	NIL
332	Length of pipe segment containing the repair	0	NONE	YES	GIS system	NIL
435	Length of pipe segment containing the repair	75	GOOD	NO	NA	NIL
400	Length of pipe segment containing the repair	100	HIGH	NO	NA	NIL
383	Length of pipe segment containing the repair	100	HIGH	NA	NA	NIL

392	Length of pipe segment containing the repair	0	NONE	NO	NA	NIL
403	Length of pipe segment containing the repair	100	HIGH	NO	NA	NIL
409	Length of pipe segment containing the repair	100	HIGH	NA	NA	NIL
10	Length of pipe segment containing the repair	50	GOOD	YES	GIS system .	NIL
48	Length of pipe segment containing the repair	100	high	no	NA	NIL
404	Length of pipe segment containing the repair	100	GOOD	NA	NA	NIL
411	Length of pipe segment containing the repair		NA	NA	NA	NIL
76	Length of pipe segment containing the repair	0	NA	Yes	Archival records	NIL
414	Length of pipe segment containing the repair	100	HIGH	YES	O&M records	NIL
141	Length of pipe segment containing the repair	0	NA	YES	GIS system	NIL
405	Length of pipe segment containing the repair	100	HIGH	NA	NA	NIL
402	Length of pipe segment containing the repair	0	HIGH	YES	O&M records	NIL
430	Length of pipe segment containing the repair	100	HIGH	YES	O&M records	NIL
431	Length of pipe segment containing the repair	0	NONE	YES	GIS system	NIL
415	Length of pipe segment containing the repair	0	NONE	NO	NA	NIL
416	Length of pipe segment containing the repair	100	HIGH	NO	NA	NIL
407	Length of pipe segment containing the repair	100	HIGH	NO	NA	NIL
417	Length of pipe segment containing the repair	50	LOW	NO	NA	NIL
432	Length of pipe segment containing the repair	0	NA	NO		NIL
419	Length of pipe segment containing the repair	100	HIGH	YES	GIS system	NIL

426	Length of pipe segment containing the repair	0	NONE	NO	NA	NIL
420	Length of pipe segment containing the repair	100	HIGH	NO	NA	NIL
427	Length of pipe segment containing the repair	0	NONE	YES	GIS system	NIL
422	Length of pipe segment containing the repair	50	MEDIUM	NO	NA	NIL
434	Length of pipe segment containing the repair	0	NA	YES	GIS system	NIL
342	Length of pipe segment containing the repair	0	NA	YES	GIS system	NIL
408	Length of pipe segment containing the repair	25	HIGH	NO	Archival records	NIL
423	Length of pipe segment containing the repair	0	NA	NO	NA	NIL
379	Length of pipe segment containing the repair	0	NONE	YES	Archival records	NIL
389	Length of pipe segment containing the repair	0	NA	NA	NA	NIL
21	Normal operating pressure	0	NA	YES	Other	J.D.Edwards
42	Normal operating pressure		NA	NA	NA	NIL
55	Normal operating pressure		NA	NA	NA	Not Applicable
56	Normal operating pressure	0	NA	YES	O&M records	NIL
72	Normal operating pressure	0	GOOD	NA	NA	NIL
428	Normal operating pressure	0	NA	NA	NA	NIL
413	Normal operating pressure	100	HIGH	YES	Archival records	NIL
100	Normal operating pressure	0	HIGH	NO	NA	NIL
103	Normal operating pressure	0	NA	NA	NA	NIL
112	Normal operating pressure	0	NA	YES	Archival records	NIL
120	Normal operating pressure	0	NONE	YES	Other	NIL
134	Normal operating pressure	25	MEDIUM	YES	O&M records	NIL

418	Normal operating pressure	0	NONE	YES	Other	NIL
227	Normal operating pressure	0	NA	NA	NA	NIL
231	Normal operating pressure	100	GOOD	YES	Other	Hydrant records
240	Normal operating pressure	25	LOW	YES	Other	hydraulic model
249	Normal operating pressure	0	NONE	YES	O&M records	NIL
260	Normal operating pressure	0	NA	YES	Other	Fire Dept. flow tests
401	Normal operating pressure	0	NA	YES	GIS system	NIL
283	Normal operating pressure	0	GOOD	YES	O&M records	NIL
284	Normal operating pressure	50	MEDIUM	NA	NA	NIL
295	Normal operating pressure	0	HIGH	YES	Archival records	NIL
301	Normal operating pressure	0	NA	YES	NA	NIL
424	Normal operating pressure	0	HIGH	NO	NA	NIL
433	Normal operating pressure	0	GOOD	NA	External	NIL
332	Normal operating pressure	0	NONE	YES	Other	Entire distribution system has been electronically modelled
435	Normal operating pressure	75	GOOD	YES	NA	NIL
400	Normal operating pressure	0	NONE	NO	NA	NIL
383	Normal operating pressure	0	NA	NA	NA	NIL
392	Normal operating pressure	0	NONE	YES	Other	NIL
403	Normal operating pressure	25	MEDIUM	YES	GIS system	NIL
409	Normal operating pressure	0	HIGH	YES	O&M records	NIL
10	Normal operating pressure	25	GOOD	YES	GIS system	NIL
48	Normal operating pressure	0	high	no	NA	NIL
404	Normal operating pressure	0	NONE	NA	NA	NIL
411	Normal operating pressure		NA	NA	NA	NIL
76	Normal operating pressure	0	NA	Yes	Archival records	NIL

414	Normal operating pressure	0	NA	YES	O&M records	NIL
141	Normal operating pressure	100	HIGH	YES	O&M records	NIL
405	Normal operating pressure	100	GOOD	NA	NA	NIL
402	Normal operating pressure	0	HIGH	YES	O&M records	NIL
430	Normal operating pressure	0	GOOD	YES	Other	Hydraulic model
431	Normal operating pressure	100	HIGH	YES	GIS system	NIL
415	Normal operating pressure	50	MEDIUM	YES	O&M records	NIL
416	Normal operating pressure	0	NONE	YES	Other	Model
407	Normal operating pressure	0	HIGH	NO	NA	NIL
417	Normal operating pressure	50	MEDIUM	NO	NA	NIL
432	Normal operating pressure	0	NA	YES	Archival records	NIL
419	Normal operating pressure	100	HIGH	YES	External	NIL
426	Normal operating pressure	0	NONE	YES	O&M records	NIL
420	Normal operating pressure	0	NONE	YES	O&M records	NIL
427	Normal operating pressure	0	NONE	NO	NA	NIL
422	Normal operating pressure	0	GOOD	YES	Other	NIL
434	Normal operating pressure	0	NA	YES	GIS system	NIL
342	Normal operating pressure	0	NA	YES	GIS system	NIL
408	Normal operating pressure	100	HIGH	YES	GIS system	NIL
423	Normal operating pressure	0	NA	YES	O&M records	NIL
379	Normal operating pressure	0	NONE	YES	Archival records	NIL
389	Normal operating pressure	0	NA	NA	NA	NIL
21	Pipe diameter	100	HIGH	YES	GIS system	NIL
42	Pipe diameter	100	HIGH	NA	NA	NIL
55	Pipe diameter	100	HIGH	YES	GIS system	NIL
56	Pipe diameter	100	HIGH	YES	Other	Cadastrals
72	Pipe diameter	50	GOOD	NA	NA	NIL
428	Pipe diameter	100	HIGH	NA	NA	NIL

413	Pipe diameter	100	HIGH	YES	Archival records	NIL
100	Pipe diameter	100	HIGH	YES	Archival records	NIL
103	Pipe diameter	100	HIGH	NA	NA	NIL
112	Pipe diameter	100	HIGH	YES	Archival records	NIL
120	Pipe diameter	100	HIGH	YES	GIS system	NIL
134	Pipe diameter	100	HIGH	YES	GIS system	NIL
418	Pipe diameter	100	HIGH	YES	GIS system	NIL
227	Pipe diameter	75	HIGH	YES	O&M records	Hansen IMS data, distribution sheets
231	Pipe diameter	100	HIGH	YES	GIS system	Also available on record dwgs.
240	Pipe diameter	100	GOOD	YES	GIS system	NIL
249	Pipe diameter	100	GOOD	YES	GIS system	NIL
260	Pipe diameter	0	NA	YES	Archival records	NIL
401	Pipe diameter	100	GOOD	YES	GIS system	entered manually as a check against database
283	Pipe diameter	100	GOOD	YES	Archival records	NIL
284	Pipe diameter	100	GOOD	NA	NA	NIL
295	Pipe diameter	100	HIGH	YES	Archival records	NIL
301	Pipe diameter	100	HIGH	YES	O&M records	NIL
424	Pipe diameter	100	HIGH	YES	Archival records	NIL
433	Pipe diameter	100	HIGH	YES	GIS system	NIL
332	Pipe diameter	100	HIGH	YES	GIS system	NIL
435	Pipe diameter	100	GOOD	YES	Archival records	NIL
400	Pipe diameter	100	GOOD	YES	GIS system	NIL
383	Pipe diameter	100	HIGH	NA	NA	NIL
392	Pipe diameter	100	HIGH	YES	GIS system	NIL
403	Pipe diameter	100	HIGH	YES	GIS system	NIL

409	Pipe diameter	100	HIGH	NA	NA	NIL
10	Pipe diameter	75	GOOD	YES	GIS system	NIL
48	Pipe diameter	100	high	no	NA	NIL
404	Pipe diameter	100	GOOD	YES	GIS system	NIL
411	Pipe diameter	100	NA	NA	NA	NIL
76	Pipe diameter	100	High	YES	Archival records	NIL
414	Pipe diameter	100	HIGH	YES	O&M records	NIL
141	Pipe diameter	100	HIGH	YES	GIS system	NIL
405	Pipe diameter	100	HIGH	NA	NA	NIL
402	Pipe diameter	100	HIGH	YES	Archival records	NIL
430	Pipe diameter	100	HIGH	YES	O&M records	NIL
431	Pipe diameter	100	HIGH	YES	GIS system	NIL
415	Pipe diameter	100	GOOD	YES	Archival records	NIL
416	Pipe diameter	100	HIGH	YES	O&M records	NIL
407	Pipe diameter	100	HIGH	NO	NA	NIL
417	Pipe diameter	75	GOOD	NO	NA	NIL
432	Pipe diameter	100	HIGH	YES	Archival records	NIL
419	Pipe diameter	100	HIGH	YES	GIS system	NIL
426	Pipe diameter	100	HIGH	YES	GIS system	NIL
420	Pipe diameter	100	HIGH	YES	O&M records	NIL
427	Pipe diameter	100	GOOD	YES	GIS system	NIL
422	Pipe diameter	100	GOOD	YES	Archival records	NIL
434	Pipe diameter	100	HIGH	YES	GIS system	NIL
342	Pipe diameter	100	HIGH	YES	GIS system	NIL
408	Pipe diameter	100	HIGH	YES	GIS system	NIL
423	Pipe diameter	100	HIGH	YES	GIS system	NIL
379	Pipe diameter	100	HIGH	YES	Archival records	NIL
389	Pipe diameter	100	HIGH	NA	Archival records	NIL
21	Pipe fracture toughness	0	NA	NO	NA	NIL

42	Pipe fracture toughness		NA	NA	NA	NIL
55	Pipe fracture toughness	0	NA	NA	NA	NIL
56	Pipe fracture toughness	0	NA	NA	NA	NIL
72	Pipe fracture toughness	0	GOOD	NA	NA	NIL
428	Pipe fracture toughness	0	NA	NA	NA	NIL
413	Pipe fracture toughness		NA	NA	NA	NIL
100	Pipe fracture toughness	0	GOOD	NO	NA	NIL
103	Pipe fracture toughness	0	NA	NA	NA	NIL
112	Pipe fracture toughness	0	NA	NA	NA	NIL
120	Pipe fracture toughness	0	NONE	NO	NA	NIL
134	Pipe fracture toughness	0	NONE	NO	NA	NIL
418	Pipe fracture toughness	0	NONE	YES	External	NIL
227	Pipe fracture toughness	0	NA	NA	NA	NIL
231	Pipe fracture toughness	0	NONE	NO	NA	NIL
240	Pipe fracture toughness	0	NONE	NO	NA	NIL
249	Pipe fracture toughness	0	NONE	NO	NA	NIL
260	Pipe fracture toughness	0	NA	NA	NA	NIL
401	Pipe fracture toughness	0	NA	NO	NA	NIL
283	Pipe fracture toughness	0	GOOD	NO	NA	NIL
284	Pipe fracture toughness	0	NONE	NA	NA	NIL
295	Pipe fracture toughness	0	HIGH	NO	NA	NIL
301	Pipe fracture toughness	0	NA	NA	NA	NIL
424	Pipe fracture toughness	0	HIGH	NO	NA	NIL
433	Pipe fracture toughness	0	MEDIUM	NA	NA	NIL
332	Pipe fracture toughness		NA	NA	NA	NIL
435	Pipe fracture toughness	50	GOOD	NO	NA	NIL

400	Pipe fracture toughness	0	NONE	NO'	NA	NIL
383	Pipe fracture toughness	0	NA	NA	NA	NIL
392	Pipe fracture toughness	0	NONE	NO	NA	NIL
403	Pipe fracture toughness	0	NA	NA	NA	NIL
409	Pipe fracture toughness	0	NA	NA	NA	NIL
10	Pipe fracture toughness	50	GOOD	YES	GIS system	NIL
48	Pipe fracture toughness	0	high	no	NA	NIL
404	Pipe fracture toughness	0	NONE	NA	NA	NIL
411	Pipe fracture toughness		NA	NA	NA	NIL
76	Pipe fracture toughness	0	NA	No	Other	NIL
414	Pipe fracture toughness	0	NA	YES	Archival records	NIL
141	Pipe fracture toughness	0	NA	NO	NA	NIL
405	Pipe fracture toughness	100	HIGH	NA	NA	NIL
402	Pipe fracture toughness	0	HIGH	YES	Other	NIL
430	Pipe fracture toughness	0	GOOD	NO	NA	NIL
431	Pipe fracture toughness	0	LOW	NO	NA	NIL
415	Pipe fracture toughness	0	NONE	NO	NA	NIL
416	Pipe fracture toughness	0	NONE	YES	External	NIL
407	Pipe fracture toughness	0	HIGH	NO	NA	NIL
417	Pipe fracture toughness	0	NONE	NO	NA	NIL
432	Pipe fracture toughness	0	NA	NO	NA	NIL
419	Pipe fracture toughness	50	MEDIUM	NO	NA	NIL
426	Pipe fracture toughness	0	NONE	NA	NA	NIL
420	Pipe fracture toughness	0	NONE	NO	NA	NIL
427	Pipe fracture toughness	0	NONE	NO	NA	NIL
422	Pipe fracture toughness	0	GOOD	NO	NA	NIL

434	Pipe fracture toughness	0	NA	NO	NA	NIL
342	Pipe fracture toughness	0	NA	NO	NA	NIL
408	Pipe fracture toughness		NA	NA	NA	NIL
423	Pipe fracture toughness	0	NA	NA	NA	NIL
379	Pipe fracture toughness	0	NONE	NO	NA	NIL
389	Pipe fracture toughness	0	NA	NA	NA	NIL
21	Pipe material	100	HIGH	YES	GIS system	NIL
42	Pipe material	100	GOOD	NA	NA	NIL
55	Pipe material	100	HIGH	YES	GIS system	NIL
56	Pipe material	100	HIGH	YES	Other	NIL
72	Pipe material	50	GOOD	NA	NA	NIL
428	Pipe material	100	HIGH	NA	NA	NIL
413	Pipe material	100	HIGH	YES	Archival records	NIL
100	Pipe material	100	HIGH	YES	Archival records	NIL
103	Pipe material	100	HIGH	NA	NA	NIL
112	Pipe material	100	HIGH	YES	Archival records	NIL
120	Pipe material	100	HIGH	YES	GIS system	NIL
134	Pipe material	100	HIGH	YES	O&M records	NIL
418	Pipe material	100	HIGH	YES	GIS system	NIL
227	Pipe material	100	HIGH	YES	O&M records	Hansen IMS data, distribution sheets
231	Pipe material	100	HIGH	YES	GIS system	Record book of main materials
240	Pipe material	100	GOOD	YES	GIS system	NIL
249	Pipe material	100	GOOD	YES	GIS system	NIL
260	Pipe material	50	GOOD	YES	Archival records	NIL
401	Pipe material	100	GOOD	YES	GIS system	entered manually as a check against database
283	Pipe material	100	GOOD	YES	Archival records	NIL

284	Pipe material	100	GOOD	NA	NA	NIL
295	Pipe material	100	HIGH	YES	Archival records	NIL
301	Pipe material	100	HIGH	YES	Archival records	NIL
424	Pipe material	100	HIGH	YES	Archival records	NIL
433	Pipe material	100	HIGH	NA	GIS system	NIL
332	Pipe material	100	GOOD	YES	GIS system	NIL
435	Pipe material	100	GOOD	YES	Archival records	NIL
400	Pipe material	100	HIGH	YES	GIS system	NIL
383	Pipe material	100	HIGH	NA	NA	NIL
392	Pipe material	100	HIGH	YES	GIS system	NIL
403	Pipe material	100	HIGH	YES	GIS system	NIL
409	Pipe material	100	HIGH	NA	NA	NIL
10	Pipe material	100	GOOD	YES	GIS system	NIL
48	Pipe material	50	high	no	NA	NIL
404	Pipe material	100	GOOD	YES	GIS system	NIL
411	Pipe material	100	NA	NA	NA	NIL
76	Pipe material	100	High	Yes	Archival records	NIL
414	Pipe material	100	HIGH	YES	O&M records	NIL
141	Pipe material	100	HIGH	NO	NA	NIL
405	Pipe material	100	HIGH	NA	NA	NIL
402	Pipe material	100	HIGH	YES	Archival records	NIL
430	Pipe material	100	HIGH	YES	O&M records	NIL
431	Pipe material	100	HIGH	YES	GIS system	NIL
415	Pipe material	100	GOOD	YES	Archival records	NIL
416	Pipe material	100	HIGH	YES	O&M records	NIL
407	Pipe material	100	HIGH	NO	NA	NIL
417	Pipe material	75	GOOD	NO	NA	NIL
432	Pipe material	100	HIGH	YES	O&M records	NIL
419	Pipe material	100	HIGH	YES	GIS system	NIL
426	Pipe material	100	HIGH	YES	GIS system	NIL

420	Pipe material	100	HIGH	YES	O&M records	NIL
427	Pipe material	100	GOOD	YES	GIS system	NIL
422	Pipe material	100	GOOD	YES	Archival records	NIL
434	Pipe material	100	HIGH	YES	GIS system	NIL
342	Pipe material	100	HIGH	YES	Archival records	NIL
408	Pipe material	100	HIGH	YES	Archival records	NIL
423	Pipe material	100	HIGH	YES	GIS system	NIL
379	Pipe material	0	NONE	YES	Archival records	NIL
389	Pipe material	100	HIGH	NA	Other	NIL
21	Pipe modulus or rupture	0	NA	NO	NA	NIL
42	Pipe modulus or rupture		NA	NA	NA	NIL
55	Pipe modulus or rupture	100	HIGH	Yes	Other	NIL
56	Pipe modulus or rupture	100	HIGH	NA	NA	NIL
72	Pipe modulus or rupture	0	GOOD	NA	NA	NIL
428	Pipe modulus or rupture	0	NA	NA	NA	NIL
413	Pipe modulus or rupture		NA	NA	NA	NIL
100	Pipe modulus or rupture	0	GOOD	NO	NA	NIL
103	Pipe modulus or rupture	100	HIGH	NA	NA	NIL
112	Pipe modulus or rupture	100	HIGH	NA	NA	NIL
120	Pipe modulus or rupture	0	NONE	NO	NA	NIL
134	Pipe modulus or rupture	0	NONE	NO	NA	NIL
418	Pipe modulus or rupture	0	NONE	YES	External	NIL
227	Pipe modulus or rupture	0	NA	NA	NA	NIL
231	Pipe modulus or rupture	0	NONE	NO	NA	NIL
240	Pipe modulus or rupture	0	NONE	NO	NA	NIL
249	Pipe modulus or rupture	0	NONE	NO	NA	NIL
260	Pipe modulus or rupture	0	NA	NA	NA	NIL

401	Pipe modulus or rupture	0	NA	NO	NA	NIL
283	Pipe modulus or rupture	0	GOOD	NO	NA	NIL
284	Pipe modulus or rupture	0	NONE	NA	NA	NIL
295	Pipe modulus or rupture	0	HIGH	NO	NA	NIL
301	Pipe modulus or rupture	100	GOOD	NO	NA	NIL
424	Pipe modulus or rupture	0	HIGH	NO	NA	NIL
433	Pipe modulus or rupture	0	MEDIUM	NA	NA	NIL
332	Pipe modulus or rupture	0	NONE	NA	NA	Has been recorded in past, but is no longer tracked
435	Pipe modulus or rupture	50	MEDIUM	NO	NA	NIL
400	Pipe modulus or rupture	0	NONE	NO	NA	NIL
383	Pipe modulus or rupture	100	HIGH	NA	NA	NIL
392	Pipe modulus or rupture	0	NONE	NO	NA	NIL
403	Pipe modulus or rupture	0	NA	NA	NA	NIL
409	Pipe modulus or rupture	0	NA	NA	NA	NIL
10	Pipe modulus or rupture	50	GOOD	YES	GIS system	NIL
48	Pipe modulus or rupture	0	high	no	NA	NIL
404	Pipe modulus or rupture	0	NONE	NA	NA	NIL
411	Pipe modulus or rupture		NA	NA	NA	NIL
76	Pipe modulus or rupture	0	NA	No	Other	NIL
414	Pipe modulus or rupture	0	NA	NO	O&M records	NIL
141	Pipe modulus or rupture	0	NA	YES	GIS system	NIL
405	Pipe modulus or rupture	100	HIGH	NA	NA	NIL
402	Pipe modulus or rupture	0	HIGH	NO	Other	NIL
430	Pipe modulus or rupture	0	GOOD	NO	NA	NIL
431	Pipe modulus or rupture	100	HIGH	NO	NA	NIL

415	Pipe modulus or rupture	100	GOOD	NO	NA	NIL
416	Pipe modulus or rupture	0	NONE	YES	External	NIL
407	Pipe modulus or rupture	100	HIGH	NO	NA	NIL
417	Pipe modulus or rupture	0	NONE	NO	NA	NIL
432	Pipe modulus or rupture	0	NA	NO	NA	NIL
419	Pipe modulus or rupture	50	MEDIUM	NO	NA	NIL
426	Pipe modulus or rupture	0	NONE	NA	NA	NIL
420	Pipe modulus or rupture	0	NONE	NO	NA	NIL
427	Pipe modulus or rupture	0	NONE	NO	NA	NIL
422	Pipe modulus or rupture	0	GOOD	NO	NA	NIL
434	Pipe modulus or rupture	0	NA	NO	NA	NIL
342	Pipe modulus or rupture	0	NA	NO	NA	NIL
408	Pipe modulus or rupture		NA	NA	NA	NIL
423	Pipe modulus or rupture	0	NA	NA	NA	NIL
379	Pipe modulus or rupture	100	HIGH	NO	NA	NIL
389	Pipe modulus or rupture	0	NA	NA	NA	NIL
21	Pipe protection (wrapped / anodes)	100	HIGH	YES	Archival records	NIL
42	Pipe protection (wrapped / anodes)		NA	NA	NA	NIL
55	Pipe protection (wrapped / anodes)	100	HIGH	YES	Other	Another Database
56	Pipe protection (wrapped / anodes)	25	GOOD	YES	Archival records	NIL
72	Pipe protection (wrapped / anodes)	0	GOOD	NA	NA	NIL
428	Pipe protection (wrapped / anodes)	0	NA	NA	NA	NIL
413	Pipe protection (wrapped / anodes)		NA	NA	NA	NIL

100	Pipe protection (wrapped / anodes)	100	HIGH	YES	Archival records	NIL
103	Pipe protection (wrapped / anodes)	0	NA	NA	NA	NIL
112	Pipe protection (wrapped / anodes)	0	NA	NA	NA	NIL
120	Pipe protection (wrapped / anodes)	0	NONE	YES	GIS system	NIL
134	Pipe protection (wrapped / anodes)	100	HIGH	NO	NA	NIL
418	Pipe protection (wrapped / anodes)		NONE	NO	NA	NIL
227	Pipe protection (wrapped / anodes)	100	HIGH	YES	O&M records	Hansen IMS data
231	Pipe protection (wrapped / anodes)	0	NONE	NA	Other	sometimes recorded.
240	Pipe protection (wrapped / anodes)	25	LOW	NO	NA	NIL
249	Pipe protection (wrapped / anodes)	0	NONE	YES	NA	as built drawings
260	Pipe protection (wrapped / anodes)	0	NA	YES	Archival records	NIL
401	Pipe protection (wrapped / anodes)	0	NA	YES	Archival records	NIL
283	Pipe protection (wrapped / anodes)	0	GOOD	YES	Archival records	Sometimes
284	Pipe protection (wrapped / anodes)	50	MEDIUM	NA	NA	NIL
295	Pipe protection (wrapped / anodes)	25	HIGH	NO	NA	NIL
301	Pipe protection (wrapped / anodes)	100	HIGH	YES	NA	NIL
424	Pipe protection (wrapped / anodes)	100	HIGH	YES	Archival records	NIL

433	Pipe protection (wrapped / anodes)	0	GOOD	NA	GIS system	NIL
332	Pipe protection (wrapped / anodes)	75	MEDIUM	NO	NA	NIL
435	Pipe protection (wrapped / anodes)	75	GOOD	YES	NA	NIL
400	Pipe protection (wrapped / anodes)	0	NONE	YES	O&M records	NIL
383	Pipe protection (wrapped / anodes)	0	NA	NA	NA	NIL
392	Pipe protection (wrapped / anodes)	0	NONE	YES	GIS system	NIL
403	Pipe protection (wrapped / anodes)	0	NONE	YES	GIS system	NIL
409	Pipe protection (wrapped / anodes)	100	HIGH	NA	NA	NIL
10	Pipe protection (wrapped / anodes)	0	NA	NA	NA	NIL
48	Pipe protection (wrapped / anodes)	0	high	no	NA	NIL
404	Pipe protection (wrapped / anodes)	0	NONE	NA	NA	NIL
411	Pipe protection (wrapped / anodes)		NA	NA	NA	NIL
76	Pipe protection (wrapped / anodes)	0	NA	Yes	Archival records	NIL
414	Pipe protection (wrapped / anodes)	100	HIGH	YES	O&M records	NIL
141	Pipe protection (wrapped / anodes)	0	NA	NO	NA	NIL
405	Pipe protection (wrapped / anodes)	0	NONE	NA	NA	NIL
402	Pipe protection (wrapped / anodes)	100	HIGH	YES	Archival records	NIL

430	Pipe protection (wrapped / anodes)	50	GOOD	NO	NA	NIL
431	Pipe protection (wrapped / anodes)	100	HIGH	YES	GIS system	NIL
415	Pipe protection (wrapped / anodes)	100	MEDIUM	NO	NA	NIL
416	Pipe protection (wrapped / anodes)	0	NONE	NO	NA	NIL
407	Pipe protection (wrapped / anodes)	0	HIGH	NO	NA	NIL
417	Pipe protection (wrapped / anodes)	0	NONE	NO	NA	NIL
432	Pipe protection (wrapped / anodes)	0	NA	NO	NA	NIL
419	Pipe protection (wrapped / anodes)	100	HIGH	YES	GIS system	NIL
426	Pipe protection (wrapped / anodes)	0	NONE	NA	NA	NIL
420	Pipe protection (wrapped / anodes)	100	HIGH	YES	O&M records	NIL
427	Pipe protection (wrapped / anodes)	0	NONE	YES	O&M records	Technical Specs
422	Pipe protection (wrapped / anodes)	0	GOOD	NO	NA	NIL
434	Pipe protection (wrapped / anodes)	50	HIGH	YES	GIS system	NIL
342	Pipe protection (wrapped / anodes)	0	NA	YES	Archival records	NIL
408	Pipe protection (wrapped / anodes)	0	NONE	NO	NA	NIL
423	Pipe protection (wrapped / anodes)	0	NA	YES	Archival records	NIL
379	Pipe protection (wrapped / anodes)	0	LOW	YES	Archival records	NIL

389	Pipe protection (wrapped / anodes)		NA	NA	NA	NIL
21	Pipe sample collected	0	NA	YES	Other	coupons from main tappings
42	Pipe sample collected	50	HIGH	NA	NA	NIL
55	Pipe sample collected	0	NA	NA	NA	NIL
56	Pipe sample collected	25	LOW	NO	NA	NIL
72	Pipe sample collected	0	GOOD	NA	NA	NIL
428	Pipe sample collected	100	HIGH	NA	NA	NIL
413	Pipe sample collected		NA	NA	NA	NIL
100	Pipe sample collected	25	GOOD	NO	NA	NIL
103	Pipe sample collected	100	HIGH	NA	NA	NIL
112	Pipe sample collected	25	HIGH	NA	NA	NIL
120	Pipe sample collected	0	NONE	NO	NA	NIL
134	Pipe sample collected	25	MEDIUM	NO	NA	NIL
418	Pipe sample collected	0	NONE	NO	NA	NIL
227	Pipe sample collected	0	NA	NA	NA	NIL
231	Pipe sample collected	0	NONE	NO	NA	NIL
240	Pipe sample collected	25	LOW	NO	NA	NIL
249	Pipe sample collected	0	NONE	NO	Archival records	NIL
260	Pipe sample collected	0	NA	NA	NA	NIL
401	Pipe sample collected	0	NA	NO	NA	NIL
283	Pipe sample collected	25	GOOD	NO	NA	NIL
284	Pipe sample collected	25	LOW	NA	NA	NIL
295	Pipe sample collected	25	HIGH	NO	NA	NIL
301	Pipe sample collected	25	MEDIUM	NO	NA	NIL
424	Pipe sample collected	0	HIGH	NO	NA	NIL

433	Pipe sample collected	0	GOOD	NA	NA	NIL
332	Pipe sample collected	0	NONE	NA	NA	NIL
435	Pipe sample collected	25	GOOD	NO	NA	NIL
400	Pipe sample collected	0	NONE	NO	NA	NIL
383	Pipe sample collected	75	GOOD	NA	NA	NIL
392	Pipe sample collected	0	NONE	NO	NA	NIL
403	Pipe sample collected	100	HIGH	NA	NA	NIL
409	Pipe sample collected	25	MEDIUM	NA	NA	NIL
10	Pipe sample collected	0	NA	NA	NA	NIL
48	Pipe sample collected	0	high	no	NA	NIL
404	Pipe sample collected	50	GOOD	YES	Archival records	NIL
411	Pipe sample collected		NA	NA	NA	NIL
76	Pipe sample collected	0	NA	No	Other	NIL
414	Pipe sample collected	0	NA	NO	O&M records	NIL
141	Pipe sample collected	0	NA	NO	NA	NIL
405	Pipe sample collected	100	HIGH	NA	NA	NIL
402	Pipe sample collected	0	HIGH	NO	Other	NIL
430	Pipe sample collected	0	GOOD	NO	NA	NIL
431	Pipe sample collected	25	GOOD	YES	O&M records	NIL
415	Pipe sample collected	0	NONE	YES	Archival records	NIL
416	Pipe sample collected	0	NONE	NO	NA	NIL
407	Pipe sample collected	100	HIGH	NO	NA	NIL
417	Pipe sample collected	0	NONE	NO	NA	NIL
432	Pipe sample collected	0	NA	NO	NA	NIL
419	Pipe sample collected	0	LOW	NO	NA	NIL
426	Pipe sample collected	0	NONE	NA	NA	NIL

420	Pipe sample collected	0	NONE	NO	NA	NIL
427	Pipe sample collected	0	NONE	NO	NA	NIL
422	Pipe sample collected	0	GOOD	NO	NA	NIL
434	Pipe sample collected	0	NA	NA	NA	NIL
342	Pipe sample collected	25	GOOD	NO	NA	NIL
408	Pipe sample collected		NA	NA	NA	NIL
423	Pipe sample collected	25	NA	NO	NA	NIL
379	Pipe sample collected	0	LOW	NO	Other	NIL
389	Pipe sample collected	0	NA	NA	NA	NIL
21	Pipe wall thickness / classification	0	NA	NO	NA	NIL
42	Pipe wall thickness / classification		NA	NA	NA	NIL
55	Pipe wall thickness / classification	0	NA	NA	NA	NIL
56	Pipe wall thickness / classification	0	NA	YES	Archival records	NIL
72	Pipe wall thickness / classification	0	GOOD	NA	NA	NIL
428	Pipe wall thickness / classification	0	NA	NA	NA	NIL
413	Pipe wall thickness / classification		HIGH	NO	NA	NIL
100	Pipe wall thickness / classification	100	HIGH	NO	NA	NIL
103	Pipe wall thickness / classification	0	NA	NA	NA	NIL
112	Pipe wall thickness / classification	0	NA	NA	NA	NIL
120	Pipe wall thickness / classification	0	NONE	YES	Archival records	NIL

134	Pipe wall thickness / classification	0	NONE	NO	NA	NIL
418	Pipe wall thickness / classification	0	NONE	YES	External	NIL
227	Pipe wall thickness / classification	0	NA	NA	NA	NIL
231	Pipe wall thickness / classification	0	NONE	NO	NA	We do nt record pipe wall thickness during repair.
240	Pipe wall thickness / classification	0	LOW	YES	External	NIL
249	Pipe wall thickness / classification	0	NONE	NO	NA	NIL
260	Pipe wall thickness / classification	0	NA	YES	Archival records	NIL
401	Pipe wall thickness / classification	0	NA	YES	Archival records	NIL
283	Pipe wall thickness / classification	0	GOOD	NO	NA	NIL
284	Pipe wall thickness / classification	0	NONE	NA	NA	NIL
295	Pipe wall thickness / classification	0	HIGH	NO	NA	NIL
301	Pipe wall thickness / classification	0	NA	NO	NA	NIL
424	Pipe wall thickness / classification		HIGH	YES	Archival records	NIL
433	Pipe wall thickness / classification	0	GOOD	NA	NA	NIL
332	Pipe wall thickness / classification	0	NONE	YES	Archival records	NIL
435	Pipe wall thickness / classification	50	GOOD	NO	NA	NIL
400	Pipe wall thickness / classification		NONE	NO	NA	NIL

383	Pipe wall thickness / classification		NA	NA	NA	NIL
392	Pipe wall thickness / classification	0	NONE	NO	NA	NIL
403	Pipe wall thickness / classification	25	HIGH	YES	External	NIL
409	Pipe wall thickness / classification		MEDIUM	YES	O&M records	NIL
10	Pipe wall thickness / classification	0	NA	NA	NA	NIL
48	Pipe wall thickness / classification		high	no	NA	NIL
404	Pipe wall thickness / classification	25	MEDIUM	YES	Archival records	NIL
411	Pipe wall thickness / classification		NA	NA	NA	NIL
76	Pipe wall thickness / classification	0	NA	Yes	Archival records	NIL
414	Pipe wall thickness / classification	50	MEDIUM	YES	Archival records	NIL
141	Pipe wall thickness / classification	0	NA	NO	NA	NIL
405	Pipe wall thickness / classification	25	MEDIUM	NA	NA	NIL
402	Pipe wall thickness / classification	0	HIGH	NO	Archival records	NIL
430	Pipe wall thickness / classification	0	GOOD	NO	NA	NIL
431	Pipe wall thickness / classification	100	HIGH	YES	GIS system	NIL
415	Pipe wall thickness / classification	0	NONE	NO	NA	NIL
416	Pipe wall thickness / classification	0	NONE	YES	O&M records	NIL

407	Pipe wall thickness / classification	100	HIGH	NO	NA	NIL
417	Pipe wall thickness / classification		NONE	NO	NA	NIL
432	Pipe wall thickness / classification	0	NA	NO	NA	NIL
419	Pipe wall thickness / classification	100	HIGH	YES	GIS system	NIL
426	Pipe wall thickness / classification	0	NONE	NO	NA	NIL
420	Pipe wall thickness / classification		NONE	YES	O&M records	NIL
427	Pipe wall thickness / classification	0	NONE	YES	O&M records	Technical Specs
422	Pipe wall thickness / classification	0	GOOD	YES	Archival records	NIL
434	Pipe wall thickness / classification	0	NA	YES	GIS system	NIL
342	Pipe wall thickness / classification	0	NA	YES	Archival records	NIL
408	Pipe wall thickness / classification	0	NONE	NO	NA	NA
423	Pipe wall thickness / classification	0	NA	NO	NA	NIL
379	Pipe wall thickness / classification	0	NONE	YES	Archival records	NIL
389	Pipe wall thickness / classification	0	NA	NA	NA	NIL
21	Surface material	100	HIGH	YES	NA	NIL
42	Surface material		NA	NA	NA	NIL
55	Surface material	100	HIGH	YES	Other	NIL
56	Surface material	100	HIGH	NO	NA	NIL
72	Surface material	50	GOOD	NA	NA	NIL
428	Surface material	0	NA	NA	NA	NIL
413	Surface material		NA	NA	NA	NIL
100	Surface material	100	HIGH	NA	NA	NIL
103	Surface material	100	HIGH	NA	NA	NIL
112	Surface material	100	HIGH	YES	Archival records	NIL

120	Surface material	0	NONE	YES	Other	NIL
134	Surface material	100	HIGH	YES	Archival records	NIL
418	Surface material	0	NONE	YES	GIS system	NIL
227	Surface material	100	GOOD	YES	O&M records	Hansen WO data
231	Surface material	100	GOOD	NO	Other	surface recorded on break sheet.
240	Surface material	100	GOOD	YES	Other	pavement management system
249	Surface material	100	GOOD	YES	NA	as built drawings
260	Surface material	50	GOOD	NA	NA	NIL
401	Surface material	0	NA	NO	NA	NIL
283	Surface material	0	GOOD	YES	GIS system	NIL
284	Surface material	50	MEDIUM	NA	NA	NIL
295	Surface material	0	HIGH	NO	NA	NIL
301	Surface material	100	HIGH	YES	NA	NIL
424	Surface material	100	HIGH	YES	Archival records	NIL
433	Surface material	100	GOOD	NA	GIS system	NIL
332	Surface material	75	GOOD	YES	GIS system	NIL
435	Surface material	75	GOOD	YES	NA	NIL
400	Surface material	75	GOOD	YES	GIS system	NIL
383	Surface material	0	NA	NA	NA	NIL
392	Surface material	0	NONE	YES	GIS system	NIL
403	Surface material	100	HIGH	NO	NA	NIL
409	Surface material	100	HIGH	NA	NA	NIL
10	Surface material	100	GOOD	YES	GIS system	NIL
48	Surface material	0	high	no	NA	NIL
404	Surface material	50	GOOD	YES	GIS system	NIL
411	Surface material		NA	NA	NA	NIL
76	Surface material	50	Low	Yes	Archival records	NIL
414	Surface material	0	NA	YES	NA	NIL
141	Surface material	100	HIGH	NO	NA	NIL
405	Surface material	100	HIGH	NA	NA	NIL
402	Surface material	0	HIGH	YES	Archival records	NIL
430	Surface material	0	MEDIUM	NO	NA	NIL
431	Surface material	100	HIGH	YES	GIS system	NIL

415	Surface material	0	NONE	YES	Archival records	NIL
416	Surface material	0	NONE	NO	NA	NIL
407	Surface material	100	HIGH	NO	NA	NIL
417	Surface material	0	NONE	NO	NA	NIL
432	Surface material	100	HIGH	NO	NA	NIL
419	Surface material	100	HIGH	NO	GIS system	NIL
426	Surface material	0	NONE	NA	NA	NIL
420	Surface material	75	GOOD	YES	O&M records	NIL
427	Surface material	0	NONE	YES	Other	NIL
422	Surface material	0	GOOD	NO	NA	NIL
434	Surface material	0	NA	YES	GIS system	NIL
342	Surface material	0	NA	YES	GIS system	NIL
408	Surface material	0	NONE	YES	Other	As-built dwg
423	Surface material	100	GOOD	YES	GIS system	NIL
379	Surface material	50	MEDIUM	NO	Other	NIL
389	Surface material	100	HIGH	NA	Other	NIL
21	Traffic classification or type of road useage	0	NA	YES	NA	NIL
42	Traffic classification or type of road useage		NA	NA	NA	NIL
55	Traffic classification or type of road useage		NA	NA	NA	Not Applicable
56	Traffic classification or type of road useage	0	NA	NA	NA	NIL
72	Traffic classification or type of road useage	0	GOOD	NA	NA	NIL
428	Traffic classification or type of road useage	0	NA	NA	NA	NIL
413	Traffic classification or type of road useage		NA	NA	NA	NIL
100	Traffic classification or type of road useage	0	GOOD	NO	NA	NIL
103	Traffic classification or type of road useage	0	NA	NA	NA	NIL
112	Traffic classification or type of road useage	0	NONE	YES	Archival records	NIL
120	Traffic classification or type of road useage	0	NONE	YES	External	NIL

134	Traffic classification or type of road useage	0	NONE	YES	GIS system	NIL
418	Traffic classification or type of road useage	0	NONE	YES	Other	NIL
227	Traffic classification or type of road useage	0	NA	NA	NA	NIL
231	Traffic classification or type of road useage	0	NONE	NO	NA	NIL
240	Traffic classification or type of road useage	0	LOW	NO	NA	NIL
249	Traffic classification or type of road useage	0	NONE	nO	NA	NIL
260	Traffic classification or type of road useage	0	NA	YES	Archival records	NIL
401	Traffic classification or type of road useage	0	NA	YES	GIS system	NIL
283	Traffic classification or type of road useage	0	GOOD	YES	GIS system	NIL
284	Traffic classification or type of road useage	0	NONE	NA	NA	NIL
295	Traffic classification or type of road useage	0	HIGH	NO	NA	NIL
301	Traffic classification or type of road useage	100	GOOD	YES	NA	NIL
424	Traffic classification or type of road useage	0	HIGH	YES	Archival records	NIL
433	Traffic classification or type of road useage	25	MEDIUM	NA	GIS system	NIL
332	Traffic classification or type of road useage	0	NONE	YES	GIS system	NIL
435	Traffic classification or type of road useage	25	GOOD	YES	NA	NIL
400	Traffic classification or type of road useage	0	NONE	NO	NA	NIL
383	Traffic classification or type of road useage	0	NA	NA	NA	NIL
392	Traffic classification or type of road useage	0	NONE	YES	GIS system	NIL

403	Traffic classification or type of road useage	50	GOOD	NO	NA	NIL
409	Traffic classification or type of road useage	100	HIGH	NA	NA	NIL
10	Traffic classification or type of road useage	0	NA	NA	NA	NIL
48	Traffic classification or type of road useage	0	high	no	NA	NIL
404	Traffic classification or type of road useage	25	MEDIUM	YES	O&M records	NIL
411	Traffic classification or type of road useage		NA	NA	NA	NIL
76	Traffic classification or type of road useage	0	NA	Yes	Archival records	NIL
414	Traffic classification or type of road useage	0	NA	YES	NA	NIL
141	Traffic classification or type of road useage	0	NA	YES	External	NIL
405	Traffic classification or type of road useage	0	NONE	NA	NA	NIL
402	Traffic classification or type of road useage	0	HIGH	YES	Other	NIL
430	Traffic classification or type of road useage	0	GOOD	NO	NA	NIL
431	Traffic classification or type of road useage	0	LOW	YES	GIS system	NIL
415	Traffic classification or type of road useage	0	NONE	YES	Archival records	NIL
416	Traffic classification or type of road useage	0	NONE	YES	GIS system	NIL
407	Traffic classification or type of road useage	0	HIGH	NO	NA	NIL
417	Traffic classification or type of road useage	0	NONE	NO	NA	NIL

432	Traffic classification or type of road useage	0	NA	YES	GIS system	NIL
419	Traffic classification or type of road useage	50	MEDIUM	NO	NA	NIL
426	Traffic classification or type of road useage	0	NONE	NA	NA	NIL
420	Traffic classification or type of road useage	0	NONE	YES	O&M records	NIL
427	Traffic classification or type of road useage	0	NONE	YES	GIS system	NIL
422	Traffic classification or type of road useage	0	GOOD	NO	NA	NIL
434	Traffic classification or type of road useage	0	NA	YES	GIS system	NIL
342	Traffic classification or type of road useage	0	NA	YES	GIS system	NIL
408	Traffic classification or type of road useage	75	GOOD	YES	Other	Traffic
423	Traffic classification or type of road useage	0	NA	NA	NA	NIL
379	Traffic classification or type of road useage	0	NONE	NO	Other	NIL
389	Traffic classification or type of road useage	0	NA	NA	NA	NIL
21	Type of joint	50	GOOD	NO	NA	NIL
42	Type of joint		NA	NA	NA	NIL
55	Type of joint	0	NA			NIL
56	Type of joint	75	HIGH	NO	NA	NIL
72	Type of joint	50	GOOD	NA	NA	NIL
428	Type of joint	0	NA	NA	NA	NIL
413	Type of joint	100	HIGH	NO	NA	NIL
100	Type of joint	100	HIGH	YES	Archival records	NIL
103	Type of joint	100	HIGH	NA	NA	NIL
112	Type of joint	0	NA	NA	NA	NIL
120	Type of joint	0	NONE	YES	Archival records	NIL
134	Type of joint	100	HIGH	NO	NA	NIL
418	Type of joint	0	NONE	YES	Archival records	NIL

227	Type of joint	50	GOOD	YES	O&M records	NIL
231	Type of joint	50	MEDIUM	NA	NA	NIL
240	Type of joint	25	MEDIUM	NO	NA	NIL
249	Type of joint	100	GOOD	YES	O&M records	as built drawings
260	Type of joint	0	NA	NA	NA	NIL
401	Type of joint	0	NA	YES	Archival records	NIL
283	Type of joint	0	GOOD	NO	NA	NIL
284	Type of joint	50	MEDIUM	NA	NA	NIL
295	Type of joint	25	HIGH	NO	NA	NIL
301	Type of joint	100	HIGH	NO	NA	NIL
424	Type of joint	50	HIGH	YES	Archival records	NIL
433	Type of joint	75	GOOD	NA	GIS system	NIL
332	Type of joint	50	MEDIUM	YES	GIS system	NIL
435	Type of joint	50	GOOD	NO	NA	NIL
400	Type of joint	50	GOOD	YES	Archival records	NIL
383	Type of joint	100	HIGH	NA	NA	300
392	Type of joint	50	MEDIUM	NO	NA	NIL
403	Type of joint	100	HIGH	YES	GIS system	NIL
409	Type of joint	100	HIGH	NA	NA	NIL
10	Type of joint	0	NA	NA	NA	NIL
48	Type of joint	0	high	no	NA	NIL
404	Type of joint	0	NONE	NA	NA	NIL
411	Type of joint		NA	NA	NA	NIL
76	Type of joint	50	Good	Yes	Archival records	NIL
414	Type of joint	100	HIGH	YES	O&M records	NIL
141	Type of joint	0	NA	NO	NA	NIL
405	Type of joint	0	NONE	NA	NA	NIL
402	Type of joint	100	HIGH	YES	Archival records	NIL
430	Type of joint	0	MEDIUM	NO	NA	NIL
431	Type of joint	100	HIGH	YES	GIS system	NIL
415	Type of joint	100	GOOD	YES	Archival records	NIL
416	Type of joint	0	NONE	YES	O&M records	NIL
407	Type of joint	100	HIGH	NO	NA	NIL
417	Type of joint	0	NONE	NO	NA	NIL
432	Type of joint	0	NA	NO	NA	NIL
419	Type of joint	100	HIGH	YES	GIS system	NIL
426	Type of joint	0	NONE	NA	NA	NIL

420	Type of joint	50	MEDIUM	YES	O&M records	
427	Type of joint	0	NONE	YES	GIS system	NIL
422	Type of joint	0	GOOD	NO	NA	NIL
434	Type of joint	25	HIGH	YES	GIS system	NIL
342	Type of joint	0	NA	YES	Archival records	NIL
408	Type of joint	75	GOOD	NO	Archival records	NIL
423	Type of joint	0	NA	YES	Archival records	NIL
379	Type of joint	0	LOW	YES	314	NIL
389	Type of joint	100	HIGH	NA	Other	NIL
21	Type of pipe lining	0	NA	NO	NA	NIL
42	Type of pipe lining		NA	NA	NA	NIL
55	Type of pipe lining		NA	NA	NA	Not Applicable
56	Type of pipe lining	25	GOOD	YES	Archival records	NIL
72	Type of pipe lining	0	GOOD	NA	NA	NIL
428	Type of pipe lining	0	NA	NA	NA	NIL
413	Type of pipe lining		NA	NA	NA	NIL
100	Type of pipe lining	0	HIGH	NO	NA	NIL
103	Type of pipe lining	0	NA	NA	NA	NIL
112	Type of pipe lining	0	NA	NA	NA	NIL
120	Type of pipe lining	0	NONE	YES	Archival records	NIL
134	Type of pipe lining	0	NONE	NO	NA	NIL
418	Type of pipe lining	0	NONE	YES	External	NIL
227	Type of pipe lining	0	NA	NA	NA	NIL
231	Type of pipe lining	25	MEDIUM	NA	Other	Sometimes recorded, sometimes not.
240	Type of pipe lining	25	MEDIUM	YES	External	NIL
249	Type of pipe lining	0	NONE	YES	NA	as built drawings
260	Type of pipe lining	0	NA	YES	Archival records	NIL
401	Type of pipe lining	0	NA	YES	Archival records	NIL
283	Type of pipe lining	0	GOOD	NO	NA	NIL
284	Type of pipe lining	100	GOOD	NA	NA	NIL
295	Type of pipe lining	0	HIGH	NO	NA	NIL
301	Type of pipe lining	0	NA	YES	NA	NIL
424	Type of pipe lining	0	HIGH	YES	Archival records	NIL
433	Type of pipe lining	0	GOOD	NA	NA	NIL

332	Type of pipe lining		NA	NA	NA	To date, we have not lined any water mains
435	Type of pipe lining	25	GOOD	YES	NA	NIL
400	Type of pipe lining	25	HIGH	YES	O&M records	NIL
383	Type of pipe lining	0	NA	NA	NA	NIL
392	Type of pipe lining	0	NONE	NO	NA	NIL
403	Type of pipe lining	100	HIGH	YES	GIS system	NIL
409	Type of pipe lining	50	MEDIUM	YES	O&M records	NIL
10	Type of pipe lining	0	NA	NA	NA	NIL
48	Type of pipe lining	0	high	no	NA	NIL
404	Type of pipe lining	0	NONE	NA	NA	NIL
411	Type of pipe lining		NA	NA	NA	NIL
76	Type of pipe lining	0	NA	Yes	Archival records	NIL
414	Type of pipe lining	100	HIGH	YES	O&M records	NIL
141	Type of pipe lining	0	NA	NO	NA	NIL
405	Type of pipe lining	0	NONE	NA	NA	NIL
402	Type of pipe lining	0	HIGH	NO	Archival records	NIL
430	Type of pipe lining	25	MEDIUM	NO	NA	NIL
431	Type of pipe lining	0	HIGH	YES	GIS system	NIL
415	Type of pipe lining	0	NONE	NO	NA	NIL
416	Type of pipe lining	0	NONE	YES	O&M records	NIL
407	Type of pipe lining	100	HIGH	NO	NA	NIL
417	Type of pipe lining	75	GOOD	NO	NA	NIL
432	Type of pipe lining	0	NA	NO	NA	NIL
419	Type of pipe lining	100	HIGH	YES	GIS system	NIL
426	Type of pipe lining	0	NONE	NA	NA	NIL
420	Type of pipe lining	0	NONE	YES	O&M records	
427	Type of pipe lining	0	NONE	YES	GIS system	NIL
422	Type of pipe lining	0	GOOD	NO	NA	NIL
434	Type of pipe lining	0	NA	YES	GIS system	NIL
342	Type of pipe lining	0	NA	YES	Archival records	NIL
408	Type of pipe lining	0	NONE	NO	NA	NIL
423	Type of pipe lining	0	NA	YES	GIS system	NIL
379	Type of pipe lining	0	NONE	YES	Archival records	NIL
389	Type of pipe lining	0	NA	NA	NA	NIL

21	Type of water service	100	HIGH	YES	Archival records	NIL
42	Type of water service	100	HIGH	NA	NA	NIL
55	Type of water service	100	HIGH	YES	Other	NIL
56	Type of water service	100	HIGH	YES	Other	Cadastrals
72	Type of water service	`0	GOOD	NA	NA	NIL
428	Type of water service	100	HIGH	NA	NA	NIL
413	Type of water service	100	HIGH	YES	Archival records	NIL
100	Type of water service	100	HIGH	YES	Archival records	NIL
103	Type of water service	100	HIGH	NA	NA	NIL
112	Type of water service	0	NA	NA	NA	NIL
120	Type of water service	0	NONE	NO	NA	NIL
134	Type of water service	100	HIGH	YES	O&M records	NIL
418	Type of water service	25	LOW	YES	GIS system	NIL
227	Type of water service	0	NA	NA	NA	NIL
231	Type of water service	100	HIGH	YES	GIS system	90% of service material in GIS
240	Type of water service	100	GOOD	YES	Archival records	NIL
249	Type of water service	100	GOOD	YES	O&M records	as built drawings
260	Type of water service	0	NA	NA	NA	NIL
401	Type of water service	0	NA	YES	GIS system	NIL
283	Type of water service	0	GOOD	YES	GIS system	Sometimes
284	Type of water service	50	MEDIUM	NA	NA	NIL
295	Type of water service	0	HIGH	NO	NA	NIL
301	Type of water service	100	GOOD	YES	NA	NIL
424	Type of water service	100	HIGH	YES	Archival records	NIL
433	Type of water service	100	GOOD	NA	GIS system	NIL
332	Type of water service	100	GOOD	YES	GIS system	NIL

435	Type of water service	75	GOOD	YES	NA	NIL
400	Type of water service	75	HIGH	NO	Archival records	NIL
383	Type of water service	100	HIGH	NA	NA	NIL
392	Type of water service	0	NONE	YES	Other	NIL
403	Type of water service	100	HIGH	NO	NA	NIL
409	Type of water service	100	HIGH	NA	NA	NIL
10	Type of water service	100	GOOD	YES	GIS system	NIL
48	Type of water service	100	high	no	NA	NIL
404	Type of water service	100	GOOD	YES	GIS system	NIL
411	Type of water service	100	NA	NA	NA	NIL
76	Type of water service	0	NA	Yes	Archival records	NIL
414	Type of water service	100	HIGH	YES	O&M records	NIL
141	Type of water service	0	NA	NO	NA	NIL
405	Type of water service	100	HIGH	NA	NA	NIL
402	Type of water service	100	HIGH	YES	Archival records	NIL
430	Type of water service	100	HIGH	YES	O&M records	NIL
431	Type of water service	100	HIGH	YES	GIS system	NIL
415	Type of water service	100	GOOD	YES	Archival records	NIL
416	Type of water service	100	HIGH	NO	NA	NIL
407	Type of water service	100	HIGH	NO	NA	NIL
417	Type of water service	0	NONE	NO	NA	NIL
432	Type of water service	100	HIGH	YES	O&M records	NIL
419	Type of water service	100	HIGH	YES	Archival records	NIL
426	Type of water service	100	GOOD	NO	NA	NIL
420	Type of water service	100	HIGH	YES	O&M records	NIL
427	Type of water service	0	NONE	YES	Other	NIL

422	Type of water service	0	GOOD	YES	Archival records	NIL
434	Type of water service	100	HIGH	YES	GIS system	NIL
342	Type of water service	100	HIGH	YES	Archival records	NIL
408	Type of water service	100	HIGH	YES	GIS system	NIL
423	Type of water service	0	NA	YES	GIS system	NIL
379	Type of water service	50	MEDIUM	YES	Archival records	NIL
389	Type of water service	100	HIGH	NA	Other	NIL
21	Typical flow in area of break	0	NA	YES	Archival records	NIL
42	Typical flow in area of break		NA	NA	NA	NIL
55	Typical flow in area of break	0	NA	NA	NA	NIL
56	Typical flow in area of break	0	NA	YES	O&M records	NIL
72	Typical flow in area of break	0	GOOD	NA	NA	NIL
428	Typical flow in area of break	0	NA	NA	NA	NIL
413	Typical flow in area of break		NA	NA	NA	NIL
100	Typical flow in area of break	0	GOOD	NO	NA	NIL
103	Typical flow in area of break	0	NA	NA	NA	NIL
112	Typical flow in area of break	0	NA	NA	NA	NIL
120	Typical flow in area of break		NONE	YES	Other	NIL
134	Typical flow in area of break	0	NONE	YES	Other	Distribution System Model
418	Typical flow in area of break	0	NONE	YES	Other	NIL
227	Typical flow in area of break	0	NA	NA	NA	NIL
231	Typical flow in area of break	0	NONE	YES	Other	Modelling or manual calculation
240	Typical flow in area of break	0	NONE	YES	Other	hydraulic model
249	Typical flow in area of break	0	NONE	YES	O&M records	treatment plant data
260	Typical flow in area of break	0	NA	YES	Other	NIL
401	Typical flow in area of break	0	NA	YES	Other	NIL

283	Typical flow in area of break	0	GOOD	YES	Other	NIL
284	Typical flow in area of break	0	NONE	NA	NA	NIL
295	Typical flow in area of break	0	HIGH	NO	NA	NIL
301	Typical flow in area of break	0	NA	NA	NA	NIL
424	Typical flow in area of break	0	HIGH	NO	NA	NIL
433	Typical flow in area of break	0	MEDIUM	NA	External	NIL
332	Typical flow in area of break	0	NONE	YES	GIS system	NIL
435	Typical flow in area of break	.75	MEDIUM	YES	NA	NIL
400	Typical flow in area of break	0	NONE	NO	NA	NIL
383	Typical flow in area of break	0	NA	NA	NA	NIL
392	Typical flow in area of break	0	NONE	YES	Other	NIL
403	Typical flow in area of break	0	NA	NA	NA	NIL
409	Typical flow in area of break	0	NA	YES	O&M records	NIL
10	Typical flow in area of break	0	NA	NA	NA	NIL
48	Typical flow in area of break	0	high	no	NA	NIL
404	Typical flow in area of break	0	NONE	NA	NA	NIL
411	Typical flow in area of break		NA	NA	NA	NIL
76	Typical flow in area of break	0	NA	Yes	Archival records	NIL
414	Typical flow in area of break	0	NA	YES	O&M records	NIL
141	Typical flow in area of break	100	HIGH	YES	O&M records	NIL
405	Typical flow in area of break	0	NONE	NA	NA	NIL
402	Typical flow in area of break	50	HIGH	NO	Other	NIL
430	Typical flow in area of break	0	GOOD	YES	Other	Hydrualic model
431	Typical flow in area of break	0	GOOD	YES	External	NIL
415	Typical flow in area of break	0	NONE	NO	NA	NIL
416	Typical flow in area of break	0	NONE	YES	Other	Model

407	Typical flow in area of break	100	HIGH	NO	NA	NIL
417	Typical flow in area of break	0	NONE	NO	NA	NIL
432	Typical flow in area of break	0	NA	NO	NA	NIL
419	Typical flow in area of break	75	MEDIUM	NO	NA	NIL
426	Typical flow in area of break	0	NONE	NA	NA	NIL
427	Typical flow in area of break	0	NONE	NO	NA	NIL
422	Typical flow in area of break	0	GOOD	NO	NA	NIL
434	Typical flow in area of break	0	NA	YES	GIS system	NIL
342	Typical flow in area of break	0	NA	YES	Other	Water Model
408	Typical flow in area of break		NA	NA	NA	NIL
423	Typical flow in area of break	0	NA	NA	NA	NIL
379	Typical flow in area of break	0	NONE	YES	Other	NIL
389	Typical flow in area of break	0	NA	NA	NA	NIL
21	Under boulevard or roadway	100	HIGH	YES	NA	NIL
42	Under boulevard or roadway	100	GOOD	NA	NA	NIL
55	Under boulevard or roadway	100	HIGH	YES	Other	Water Break Report
56	Under boulevard or roadway	0	NA	NA	NA	NIL
72	Under boulevard or roadway	0	GOOD	NA	NA	NIL
428	Under boulevard or roadway	100	HIGH	NA	NA	NIL
413	Under boulevard or roadway	100	HIGH	YES	Archival records	NIL
100	Under boulevard or roadway	100	HIGH	YES	Archival records	NIL
103	Under boulevard or roadway	0	NA	NA	NA	NIL
112	Under boulevard or roadway	100	HIGH	YES	Archival records	NIL
120	Under boulevard or roadway	0	NONE	YES	GIS system	NIL
134	Under boulevard or roadway	100	HIGH	YES	Archival records	NIL
418	Under boulevard or roadway	25	MEDIUM	YES	GIS system	NIL

227	Under boulevard or roadway	100	GOOD	YES	O&M records	Hansen WO data
231	Under boulevard or roadway	100	GOOD	YES	GIS system	break location identifies this.
240	Under boulevard or roadway	100	GOOD	NO	NA	NIL
249	Under boulevard or roadway	100	GOOD	YES	NA	as built drawings
260	Under boulevard or roadway	50	GOOD	NA	NA	NIL
401	Under boulevard or roadway	0	NA	YES	Archival records	NIL
283	Under boulevard or roadway	0	GOOD	YES	GIS system	NIL
284	Under boulevard or roadway	50	MEDIUM	NA	NA	NIL
295	Under boulevard or roadway	0	HIGH	NO	NA	NIL
301	Under boulevard or roadway	100	HIGH	YES	NA	NIL
424	Under boulevard or roadway	0	HIGH	YES	Archival records	NIL
433	Under boulevard or roadway	100	GOOD	NA	GIS system	NIL
332	Under boulevard or roadway	75	GOOD	YES	GIS system	NIL
435	Under boulevard or roadway	100	GOOD	YES	NA	NIL
400	Under boulevard or roadway	25	GOOD	YES	GIS system	NIL
383	Under boulevard or roadway	25	MEDIUM	NA	NA	NIL
392	Under boulevard or roadway	0	NONE	YES	GIS system	NIL
403	Under boulevard or roadway	100	GOOD	NO	NA	NIL
409	Under boulevard or roadway	100	HIGH	NA	NA	NIL
10	Under boulevard or roadway	25	GOOD	YES	GIS system	NIL
48	Under boulevard or roadway	100	high	no	NA	NIL
404	Under boulevard or roadway	100	GOOD	YES	GIS system	NIL
411	Under boulevard or roadway		NA	NA	NA	NIL
76	Under boulevard or roadway	50	Good	Yes	Archival records	NIL
414	Under boulevard or roadway	0	NA	YES	Archival records	NIL
141	Under boulevard or roadway	0	NA	YES	External	NIL

405	Under boulevard or roadway	100	HIGH	NA	NA	NIL
402	Under boulevard or roadway	0	HIGH	YES	Archival records	NIL
430	Under boulevard or roadway	25	MEDIUM	NO	NA	NIL
431	Under boulevard or roadway	100	HIGH	YES	GIS system	NIL
415	Under boulevard or roadway	0	NONE	NO	NA	NIL
416	Under boulevard or roadway	100	HIGH	YES	GIS system	NIL
407	Under boulevard or roadway	100	HIGH	NO	NA	NIL
417	Under boulevard or roadway	0	NONE	NO	NA	NIL
432	Under boulevard or roadway	100	HIGH	YES	O&M records	NIL
419	Under boulevard or roadway	100	HIGH	YES	GIS system	NIL
426	Under boulevard or roadway	0	NONE	NA	NA	NIL
420	Under boulevard or roadway	100	HIGH	YES	O&M records	NIL
427	Under boulevard or roadway	0	NONE	YES	GIS system	NIL
422	Under boulevard or roadway	0	GOOD	YES	Archival records	NIL
434	Under boulevard or roadway	0	NA	YES	GIS system	NIL
342	Under boulevard or roadway	100	HIGH	YES	Archival records	NIL
408	Under boulevard or roadway	100	GOOD	YES	GIS system	NIL
423	Under boulevard or roadway	0	NA	YES	GIS system	NIL
379	Under boulevard or roadway	100	GOOD	NO	Other	NIL
389	Under boulevard or roadway	100	HIGH	NA	Other	NIL
21	Year of installation	75	GOOD	YES	Archival records	NIL
42	Year of installation	100	HIGH	NA	NA	NIL
55	Year of installation		NA	NA	NA	Available, not recorded
56	Year of installation	0	NA	YES	Archival records	NIL
72	Year of installation	0	GOOD	NA	NA	NIL
428	Year of installation	0	NA	NA	NA	NIL
413	Year of installation	0	NA		NA	NIL
100	Year of installation	75	HIGH	YES	Archival records	NIL
103	Year of installation	0	NA	NA	NA	NIL

112	Year of installation	100	GOOD	YES	Archival records	NIL
120	Year of installation	0	NONE	YES	GIS system	NIL
134	Year of installation	0	NONE	YES	Archival records	NIL
418	Year of installation	0	NONE	YES	GIS system	NIL
227	Year of installation	0	MEDIUM	YES	O&M records	Hansen IMS data
231	Year of installation	100	GOOD	YES	GIS system	Record book of Mains installed
240	Year of installation	75	MEDIUM	YES	GIS system	NIL
249	Year of installation	0	NONE	YES	GIS system	as built drawings
260	Year of installation	0	NA	YES	Archival records	NIL
401	Year of installation	100	GOOD	YES	GIS system	entered automatically from database
283	Year of installation	0	GOOD	YES	Archival records	Sometimes
284	Year of installation	100	GOOD	NA	NA	NIL
295	Year of installation	25	HIGH	YES	Archival records	NIL
301	Year of installation	75	GOOD	YES	NA	NIL
424	Year of installation	100	HIGH	YES	Archival records	NIL
433	Year of installation	0	GOOD	NA	GIS system	NIL
332	Year of installation	25	LOW	YES	GIS system	NIL
435	Year of installation	25	GOOD	YES	NA	NIL
400	Year of installation	0	NONE	YES	GIS system	NIL
383	Year of installation	100	HIGH	NA	NA	NIL
392	Year of installation	0	NONE	YES	GIS system	NIL
403	Year of installation	100	HIGH	YES	GIS system	NIL
409	Year of installation	100	HIGH	NA	NA	NIL
10	Year of installation	0	NA	NA	NA	NIL
48	Year of installation	0	high	NA	NA	NIL
404	Year of installation	25	MEDIUM	YES	Archival records	NIL
411	Year of installation		NA	NA	NA	NIL
76	Year of installation	0	NA	Yes	Archival records	NIL
414	Year of installation	100	HIGH	YES	O&M records	NIL
141	Year of installation	0	NA	NO	NA	NIL
405	Year of installation	100	HIGH	NA	NA	NIL

402	Year of installation	0	HIGH	YES	Archival records	NIL
430	Year of installation	100	HIGH	YES	O&M records	NIL
431	Year of installation	100	HIGH	YES	GIS system	NIL
415	Year of installation	100	LOW	YES	Archival records	NIL
416	Year of installation	0	NONE	YES	O&M records	NIL
407	Year of installation	0	HIGH	NO	NA	NIL
417	Year of installation	75	GOOD	NO	NA	NIL
432	Year of installation	0	NA	YES	Archival records	NIL
419	Year of installation	100	HIGH	YES	GIS system	NIL
426	Year of installation	0	NONE	YES	Other	NIL
420	Year of installation	0	NONE	YES	O&M records	NIL
427	Year of installation	75	MEDIUM	YES	GIS system	NIL
422	Year of installation	0	GOOD	YES	Archival records	NIL
434	Year of installation	0	NA	YES	GIS system	NIL
342	Year of installation	0	NA	YES	Archival records	NIL
408	Year of installation	0	NONE	YES	Other	As-built dwg
423	Year of installation	0	NA	YES	Archival records	NIL
379	Year of installation	0	NONE	YES	Archival records	NIL
389	Year of installation	0	NA	NA	NA	NIL

Failure Cause data recorded by survey respondents

City ID	Description	Data Recorded	Comments
417	Is your water corrosive to your watermains (yes or no)	NA	
379	Is your water corrosive to your watermains (yes or no)	NO	
112	Is your water corrosive to your watermains (yes or no)	YES	
295	Is your water corrosive to your watermains (yes or no)	NO	
100	Is your water corrosive to your watermains (yes or no)	NO	
424	Is your water corrosive to your watermains (yes or no)	NO	
120	Is your water corrosive to your watermains (yes or no)	NO	
10	Is your water corrosive to your watermains (yes or no)	NO	NA
408	Is your water corrosive to your watermains (yes or no)	NA	
418	Is your water corrosive to your watermains (yes or no)	YES	
420	Is your water corrosive to your watermains (yes or no)	NO	
426	Is your water corrosive to your watermains (yes or no)	NO	
415	Is your water corrosive to your watermains (yes or no)	NA	NIL
284	Is your water corrosive to your watermains (yes or no)	YES	
48	Is your water corrosive to your watermains (yes or no)	NO	
392	Is your water corrosive to your watermains (yes or no)	NO	
409	Is your water corrosive to your watermains (yes or no)	NO	
383	Is your water corrosive to your watermains (yes or no)	YES	
42	Is your water corrosive to your watermains (yes or no)	YES	
404	Is your water corrosive to your watermains (yes or no)	NO	
428	Is your water corrosive to your watermains (yes or no)	NO	
430	Is your water corrosive to your watermains (yes or no)	NO	
260	Is your water corrosive to your watermains (yes or no)	NO	
342	Is your water corrosive to your watermains (yes or no)	NO	
423	Is your water corrosive to your watermains (yes or no)	NO	
405	Is your water corrosive to your watermains (yes or no)	NO	
435	Is your water corrosive to your watermains (yes or no)	NA	
21	Is your water corrosive to your watermains (yes or no)	NO	NA
416	Is your water corrosive to your watermains (yes or no)	NA	
249	Is your water corrosive to your watermains (yes or no)	NA	
419	Is your water corrosive to your watermains (yes or no)	NA	NIL
402	Is your water corrosive to your watermains (yes or no)	NA	
389	Is your water corrosive to your watermains (yes or no)	NO	
332	Is your water corrosive to your watermains (yes or no)	NO	
134	Is your water corrosive to your watermains (yes or no)	NO	
401	Is your water corrosive to your watermains (yes or no)	YES	
141	Is your water corrosive to your watermains (yes or no)	NA	
301	Is your water corrosive to your watermains (yes or no)	NA	
240	Is your water corrosive to your watermains (yes or no)	YES	
422	Is your water corrosive to your watermains (yes or no)	NO	
231	Is your water corrosive to your watermains (yes or no)	NO	
427	Is your water corrosive to your watermains (yes or no)	NO	
407	Is your water corrosive to your watermains (yes or no)	NO	
56	Is your water corrosive to your watermains (yes or no)	NO	

72	Is your water corrosive to your watermains (yes or no)	NA	
283	Is your water corrosive to your watermains (yes or no)	NO	
432	Is your water corrosive to your watermains (yes or no)	NO	
76	Is your water corrosive to your watermains (yes or no)	No	
411	Is your water corrosive to your watermains (yes or no)	NA	NIL
227	Is your water corrosive to your watermains (yes or no)	NO	
403	Is your water corrosive to your watermains (yes or no)	NO	
400	Is your water corrosive to your watermains (yes or no)	NA	
413	Is your water corrosive to your watermains (yes or no)	NO	
433	Is your water corrosive to your watermains (yes or no)	NA	
103	Is your water corrosive to your watermains (yes or no)	NO	
434	Is your water corrosive to your watermains (yes or no)	NA	
55	Is your water corrosive to your watermains (yes or no)	NO	
414	Is your water corrosive to your watermains (yes or no)	YES	
431	Is your water corrosive to your watermains (yes or no)	YES	
332	Corrosion	NO	NIL
21	Corrosion	YES	NIL
342	Corrosion	YES	NIL
411	Corrosion	NA	NIL
227	Corrosion	NO	NIL
416	Corrosion	NO	NIL
427	Corrosion	YES	NIL
419	Corrosion	YES	NIL
389	Corrosion	NA	NIL
414	Corrosion	YES	Work Order System
260	Corrosion	NO	NIL
403	Corrosion	NO	NIL
379	Corrosion	YES	NIL
415	Corrosion	YES	NIL
426	Corrosion	NO	NIL
420	Corrosion	YES	NIL
383	Corrosion	YES	NIL
301	Corrosion	YES	NIL
408	Corrosion	NO	NIL
424	Corrosion	YES	NIL
405	Corrosion	YES	NIL
422	Corrosion	NA	NIL
141	Corrosion	NA	NIL
428	Corrosion	NO	NIL
409	Corrosion	NA	NIL
418	Corrosion	YES	NIL
402	Corrosion	NO	NIL
407	Corrosion	YES	
433	Corrosion	YES	NIL
417	Corrosion	YES	NIL
56	Corrosion	YES	NIL
413	Corrosion	NA	NIL
103	Corrosion	YES	NIL

392	Corrosion	YES	NIL
134	Corrosion	NO	NIL
435	Corrosion	NA	NIL
10	Corrosion	YES	Other is our work order
112	Corrosion	YES	NIL
100	Corrosion	YES	NIL
120	Corrosion	NA	NIL
295	Corrosion	YES	NIL
284	Corrosion	YES	NIL
42	Corrosion	YES	NIL
231	Corrosion	YES	NIL
48	Corrosion	yes	
434	Corrosion	YES	NIL
240	Corrosion	NO	NIL
431	Corrosion	YES	NIL
283	Corrosion	YES	NIL
72	Corrosion	YES	NIL
432	Corrosion	YES	NIL
76	Corrosion	No	NIL
400	Corrosion	YES	NIL
55	Corrosion	YES	Access Database
430	Corrosion	NO	NIL
404	Corrosion	YES	Recorded taps
249	Corrosion	NA	NIL
401	Corrosion	YES	NIL
423	Corrosion	NO	NIL
431	Traffic load	NO	NIL
414	Traffic load	NO	NIL
103	Traffic load	NA	NIL
55	Traffic load	NO	Titan and Tops Traffic Data
434	Traffic load	YES	NIL
401	Traffic load	NA	NIL
284	Traffic load	NO	NIL
56	Traffic load	NO	NIL
231	Traffic load	NO	NIL
426	Traffic load	NO	NIL
392	Traffic load	NO	NIL
435	Traffic load	NA	NIL
21	Traffic load	NO	NIL
415	Traffic load	NO	NIL
409	Traffic load	NA	NIL
433	Traffic load	NO	NIL
260	Traffic load	NO	NIL
430	Traffic load	NO	NIL
400	Traffic load	NO	NIL
403	Traffic load	YES	NIL
411	Traffic load	NA	NIL

227	Traffic load	NO	NIL
76	Traffic load	No	NIL
428	Traffic load	NO	NIL
301	Traffic load	NO	NIL
283	Traffic load	NO	NIL
240	Traffic load	NO	pavement management
141	Traffic load	NA	NIL
422	Traffic load	NA	NIL
427	Traffic load	NO	NIL
72	Traffic load	YES	NIL
413	Traffic load	NA	NIL
432	Traffic load	NO	NIL
379	Traffic load	NO	NIL
407	Traffic load	YES	
418	Traffic load	YES	NIL
419	Traffic load	YES	NIL
383	Traffic load	NO	NIL
295	Traffic load	NO	NIL
405	Traffic load	NO	NIL
249	Traffic load	NA	NIL
112	Traffic load	YES	NIL
100	Traffic load	NO	NIL
402	Traffic load	NO	NIL
424	Traffic load	NO	NIL
134	Traffic load	NO	NIL
10	Traffic load	NO	system
42	Traffic load	NO	NIL
389	Traffic load	NA	NIL
416	Traffic load	NO	NIL
332	Traffic load	NO	NIL
342	Traffic load	NO	NIL
120	Traffic load	NA	NIL
408	Traffic load	NO	NIL
420	Traffic load	YES	NIL
423	Traffic load	NO	NIL
404	Traffic load	YES	NIL
417	Traffic load	NO	NIL
48	Traffic load	no	
76	Poor construction practices	No	NIL
10	Poor construction practices	YES	NIL
430	Poor construction practices	NO	NIL
417	Poor construction practices	NO	NIL
411	Poor construction practices	NA	NIL
283	Poor construction practices	NO	NIL
141	Poor construction practices	NA	NIL
284	Poor construction practices	NO	NIL
426	Poor construction practices	NO	NIL
415	Poor construction practices	YES	NIL

227	Poor construction practices	NO	NIL
249	Poor construction practices	NA	NIL
435	Poor construction practices	NA	NIL
419	Poor construction practices	YES	NIL
416	Poor construction practices	NO	NIL
48	Poor construction practices	no	
401	Poor construction practices	YES	NIL
295	Poor construction practices	YES	NIL
428	Poor construction practices	NO	NIL
103	Poor construction practices	YES	NIL
414	Poor construction practices	YES	Work Order System
231	Poor construction practices	NO	NIL
402	Poor construction practices	NO	NIL
55	Poor construction practices	NO	NIL
240	Poor construction practices	YES	NIL
433	Poor construction practices	NO	If crew believes they may comment, only theoretical.
432	Poor construction practices	YES	NIL
21	Poor construction practices	NO	NIL
424	Poor construction practices	NO	NIL
427	Poor construction practices	NO	NIL
134	Poor construction practices	YES	NIL
418	Poor construction practices	YES	NIL
420	Poor construction practices	YES	NIL
405	Poor construction practices	YES	NIL
120	Poor construction practices	NA	NIL
423	Poor construction practices	YES	NIL
422	Poor construction practices	NA	NIL
301	Poor construction practices	YES	NIL
332	Poor construction practices	NO	NIL
400	Poor construction practices	NO	NIL
392	Poor construction practices	NO	NIL
72	Poor construction practices	YES	NIL
407	Poor construction practices	YES	
404	Poor construction practices	NO	NIL
383	Poor construction practices	NA	NIL
56	Poor construction practices	NO	NIL
434	Poor construction practices	NA	NIL
260	Poor construction practices	NO	NIL
342	Poor construction practices	YES	NIL
409	Poor construction practices	NA	NIL
379	Poor construction practices	YES	NIL
408	Poor construction practices	NO	NIL
413	Poor construction practices	NA	NIL
431	Poor construction practices	YES	NIL
100	Poor construction practices	NO	NIL
112	Poor construction practices	YES	NIL

42	Poor construction practices	YES	NIL
389	Poor construction practices	NA	NIL
403	Poor construction practices	YES	NIL
112	Ground frost	YES	NIL
433	Ground frost	YES	Only if crew comments on frost depth.
392	Ground frost	NO	NIL
227	Ground frost	NO	NIL
72	Ground frost	YES	NIL
402	Ground frost	NO	NIL
426	Ground frost	NO	NIL
432	Ground frost	YES	NIL
55	Ground frost	YES	Access Database
430	Ground frost	NO	NIL
416	Ground frost	NO	NIL
260	Ground frost	NO	NIL
405	Ground frost	NO	NIL
231	Ground frost	YES	Env. Canada Temp. Data
240	Ground frost	YES	NIL
419	Ground frost	NO	NIL
417	Ground frost	NO	NIL
48	Ground frost	no	
342	Ground frost	YES	NIL
403	Ground frost	YES	NIL
408	Ground frost	NO	NIL
21	Ground frost	YES	NIL
411	Ground frost	NA	NIL
409	Ground frost	NA	NIL
415	Ground frost	YES	NIL
420	Ground frost	YES	NIL
428	Ground frost	NO	NIL
400	Ground frost	YES	NIL
295	Ground frost	YES	NIL
120	Ground frost	NA	NIL
422	Ground frost	NA	NIL
389	Ground frost	NA	NIL
427	Ground frost	NO	NIL
423	Ground frost	NO	NIL
413	Ground frost	NA	NIL
134	Ground frost	YES	NIL
424	Ground frost	NO	NIL
284	Ground frost	YES	NIL
435	Ground frost	NA	NIL
332	Ground frost	NO	NIL
383	Ground frost	NO	NIL
100	Ground frost	NO	NIL
76	Ground frost	No	NIL
418	Ground frost	NO	NIL

401	Ground frost	NA	NIL
379	Ground frost	YES	NIL
434	Ground frost	NA	NIL
407	Ground frost	NO	
103	Ground frost	YES	NIL
249	Ground frost	NA	NIL
404	Ground frost	NO	NIL
141	Ground frost	NA	NIL
431	Ground frost	NO	NIL
42	Ground frost	YES	NIL
56	Ground frost	NO	NIL
414	Ground frost	YES	Work Order System
301	Ground frost	NO	NIL
10	Ground frost	NO	NIL
283	Ground frost	NO	NIL
418	Settlement	YES	NIL
416	Settlement	NO	NIL
332	Settlement	NO	NIL
342	Settlement	YES	NIL
231	Settlement	YES	NIL
389	Settlement	NA	NIL
404	Settlement	YES	NIL
100	Settlement	YES	NIL
48	Settlement	no	
112	Settlement	YES	NIL
400	Settlement	NO	NIL
10	Settlement	NO	NIL
42	Settlement	YES	NIL
134	Settlement	YES	NIL
120	Settlement	NA	NIL
435	Settlement	NA	NIL
249	Settlement	NA	NIL
401	Settlement	YES	NIL
419	Settlement	YES	NIL
430	Settlement	NO	NIL
431	Settlement	YES	NIL
426	Settlement	NO	NIL
392	Settlement	NO	NIL
260	Settlement	NO	NIL
428	Settlement	NO	NIL
55	Settlement	No	NIL
284	Settlement	YES	NIL
403	Settlement	YES	NIL
423	Settlement	NO	NIL
422	Settlement	NA	NIL
141	Settlement	NA	NIL
407	Settlement	YES	
433	Settlement	NO	NIL

420	Settlement	YES	NIL
240	Settlement	NO	NIL
415	Settlement	YES	NIL
72	Settlement	YES	NIL
434	Settlement	YES	NIL
21	Settlement	YES	NIL
408	Settlement	NO	NIL
432	Settlement	YES	NIL
413	Settlement	NA	NIL
427	Settlement	NO	NIL
301	Settlement	NO	NIL
283	Settlement	NO	NIL
414	Settlement	YES	Work Order System
56	Settlement	YES	NIL
103	Settlement	YES	NIL
409	Settlement	NA	NIL
227	Settlement	NO	NIL
402	Settlement	NO	NIL
76	Settlement	No	NIL
379	Settlement	YES	NIL
295	Settlement	YES	NIL
383	Settlement	YES	NIL
405	Settlement	YES	NIL
417	Settlement	NO	NIL
424	Settlement	NO	NIL
411	Settlement	NA	NIL
423	Joint failure	NO	NIL
401	Joint failure	YES	NIL
411	Joint failure	YES	NIL
100	Joint failure	YES	NIL
295	Joint failure	YES	NIL
404	Joint failure	YES	NIL
414	Joint failure	YES	Work Order System
103	Joint failure	YES	NIL
76	Joint failure	No	NIL
283	Joint failure	YES	NIL
413	Joint failure	NA	NIL
10	Joint failure	YES	NIL
141	Joint failure	NA	NIL
112	Joint failure	YES	NIL
407	Joint failure	YES	
134	Joint failure	YES	NIL
427	Joint failure	YES	NIL
284	Joint failure	YES	NIL
403	Joint failure	YES	NIL
120	Joint failure	NA	NIL
42	Joint failure	YES	NIL

435	Joint failure	NA	NIL
400	Joint failure	YES	NIL
422	Joint failure	NA	NIL
72	Joint failure	YES	NIL
227	Joint failure	NO	NIL
420	Joint failure	YES	NIL
55	Joint failure	YES	Access Database
392	Joint failure	YES	NIL
301	Joint failure	YES	NIL
417	Joint failure	YES	NIL
56	Joint failure	YES	NIL
408	Joint failure	NO	NIL
434	Joint failure	YES	NIL
389	Joint failure	NA	NIL
416	Joint failure	NO	NIL
419	Joint failure	YES	NIL
383	Joint failure	YES	NIL
405	Joint failure	YES	NIL
424	Joint failure	YES	NIL
332	Joint failure	YES	NIL
428	Joint failure	NO	NIL
418	Joint failure	YES	NIL
231	Joint failure	YES	NIL
342	Joint failure	YES	NIL
426	Joint failure	NO	NIL
249	Joint failure	NA	NIL
402	Joint failure	NO	NIL
48	Joint failure	yes	
431	Joint failure	YES	NIL
433	Joint failure	YES	NIL
260	Joint failure	NO	NIL
240	Joint failure	YES	NIL
379	Joint failure	YES	NIL
409	Joint failure	NA	NIL
21	Joint failure	NO	NIL
432	Joint failure	YES	NIL
415	Joint failure	YES	NIL
430	Joint failure	NO	NIL
100	rock contact	NO	NIL
392	rock contact	NO	NIL
283	rock contact	YES	NIL
400	rock contact	NO	NIL
434	rock contact	YES	NIL
72	rock contact	YES	NIL
240	rock contact	YES	NIL
295	rock contact	YES	NIL
284	rock contact	NO	NIL
431	rock contact	YES	NIL
432	rock contact	YES	NIL

231	rock contact	YES	NIL
55	rock contact	YES	Access Database
76	rock contact	No	NIL
120	rock contact	NA	NIL
414	rock contact	YES	Work Order System
332	rock contact	NO	NIL
405	rock contact	YES	NIL
424	rock contact	YES	NIL
420	rock contact	YES	NIL
417	rock contact	YES	NIL
408	rock contact	NO	NIL
21	rock contact	YES	NIL
409	rock contact	NA	NIL
379	rock contact	NO	NIL
415	rock contact	YES	NIL
402	rock contact	NO	NIL
56	rock contact	NO	NIL
383	rock contact	YES	NIL
103	rock contact	YES	NIL
301	rock contact	NO	NIL
10	rock contact	YES	NIL
427	rock contact	YES	NIL
422	rock contact	NA	NIL
413	rock contact	NA	NIL
407	rock contact	NO	
141	rock contact	NA	NIL
403	rock contact	YES	NIL
227	rock contact	NO	NIL
411	rock contact	NA	NIL
433	rock contact	NO	Unless crew comment.
423	rock contact	NO	NIL
42	rock contact	YES	NIL
426	rock contact	NO	NIL
430	rock contact	NO	NIL
418	rock contact	YES	NIL
435	rock contact	NA	NIL
404	rock contact	YES	NIL
112	rock contact	YES	NIL
260	rock contact	NO	NIL
342	rock contact	YES	NIL
389	rock contact	NA	NIL
428	rock contact	NO	NIL
401	rock contact	NA	NIL
419	rock contact	YES	NIL
48	rock contact	yes	
249	rock contact	NA	NIL
416	rock contact	NO	NIL

134	rock contact	YES	NIL
76	Construction disturbance	No	NIL
260	Construction disturbance	NO	NIL
413	Construction disturbance	NA	NIL
407	Construction disturbance	YES	
134	Construction disturbance	YES	NIL
48	Construction disturbance	yes	
411	Construction disturbance	NA	NIL
42	Construction disturbance	NA	NIL
249	Construction disturbance	NA	NIL
301	Construction disturbance	NO	NIL
432	Construction disturbance	YES	NIL
431	Construction disturbance	YES	NIL
415	Construction disturbance	YES	NIL
389	Construction disturbance	NA	NIL
417	Construction disturbance	NO	NIL
379	Construction disturbance	YES	NIL
426	Construction disturbance	NO	NIL
419	Construction disturbance	YES	NIL
100	Construction disturbance	NO	NIL
55	Construction disturbance	YES	Access Database
402	Construction disturbance	NO	NIL
383	Construction disturbance	YES	NIL
414	Construction disturbance	YES	Work Order System
72	Construction disturbance	YES	NIL
103	Construction disturbance	NA	NIL
433	Construction disturbance	NO	NIL
231	Construction disturbance	YES	NIL
418	Construction disturbance	YES	NIL
21	Construction disturbance	YES	NIL
284	Construction disturbance	YES	NIL
295	Construction disturbance	YES	NIL
423	Construction disturbance	YES	NIL
434	Construction disturbance	YES	NIL
408	Construction disturbance	NO	NIL
427	Construction disturbance	NO	NIL
424	Construction disturbance	NO	NIL
404	Construction disturbance	YES	NIL
10	Construction disturbance	YES	NIL
392	Construction disturbance	NO	NIL
120	Construction disturbance	NA	NIL
416	Construction disturbance	NO	NIL
112	Construction disturbance	YES	NIL
435	Construction disturbance	NA	NIL
401	Construction disturbance	YES	NIL
428	Construction disturbance	NO	NIL
409	Construction disturbance	NA	NIL
430	Construction disturbance	NO	NIL

420	Construction disturbance	YES	NIL
400	Construction disturbance	NO	NIL
283	Construction disturbance	NO	NIL
332	Construction disturbance	NO	NIL
405	Construction disturbance	YES	NIL
56	Construction disturbance	YES	NIL
227	Construction disturbance	NO	NIL
422	Construction disturbance	NA	NIL
342	Construction disturbance	YES	NIL
240	Construction disturbance	YES	NIL
141	Construction disturbance	NA	NIL
403	Construction disturbance	YES	NIL
416	High pressure	NO	NIL
301	High pressure	NO	NIL
402	High pressure	NO	NIL
332	High pressure	NO	communicated from Water Treatment Plant when output pressures change
418	High pressure	NO	NIL
403	High pressure	YES	NIL
42	High pressure	NO	NIL
112	High pressure	YES	NIL
419	High pressure	YES	NIL
383	High pressure	YES	NIL
422	High pressure	NA	NIL
428	High pressure	NO	NIL
56	High pressure	NO	NIL
430	High pressure	NO	NIL
426	High pressure	NO	NIL
407	High pressure	YES	
100	High pressure	NO	NIL
427	High pressure	YES	NIL
103	High pressure	YES	NIL
405	High pressure	YES	NIL
389	High pressure	NA	NIL
141	High pressure	NA	NIL
413	High pressure	NA	NIL
414	High pressure	NO	NIL
408	High pressure	NO	NIL
409	High pressure	NA	NIL
424	High pressure	NO	NIL
342	High pressure	YES	NIL
404	High pressure	YES	NIL
260	High pressure	NO	NIL
415	High pressure	YES	NIL
417	High pressure	NO	NIL
21	High pressure	NO	NIL
227	High pressure	NO	NIL

423	High pressure	NO	NIL
420	High pressure	YES	NIL
10	High pressure	NO	NIL
411	High pressure	NA	NIL
433	High pressure	NO	Crew would not be able to determine in field.
231	High pressure	YES	Review with Field Ops.
400	High pressure	NO	NIL
76	High pressure	No	NIL
431	High pressure	YES	NIL
392	High pressure	NO	NIL
48	High pressure	yes	
434	High pressure	NA	NIL
432	High pressure	NO	NIL
134	High pressure	YES	NIL
435	High pressure	NA	NIL
401	High pressure	YES	NIL
284	High pressure	NO	NIL
295	High pressure	YES	NIL
72	High pressure	NO	NIL
379	High pressure	YES	NIL
120	High pressure	NA	NIL
240	High pressure	NO	hydraulic model
283	High pressure	NO	NIL
55	High pressure	YES	Access Database
249	High pressure	NA	NIL
431	Water temperature change	NO	NIL
283	Water temperature change	NO	NIL
417	Water temperature change	NO	NIL
260	Water temperature change	NO	NIL
404	Water temperature change	NO	NIL
433	Water temperature change	NO	NIL
420	Water temperature change	YES	NIL
10	Water temperature change	NO	NIL
48	Water temperature change	no	
21	Water temperature change	NO	NIL
295	Water temperature change	YES	NIL
141	Water temperature change	NA	NIL
389	Water temperature change	NA	NIL
432	Water temperature change	NO	NIL
231	Water temperature change	NO	NIL
76	Water temperature change	No	NIL
413	Water temperature change	NA	NIL
342	Water temperature change	NO	NIL
227	Water temperature change	NO	NIL
103	Water temperature change	NA	NIL
411	Water temperature change	NA	NIL
434	Water temperature change	NA	NIL

414	Water temperature change	NO	NIL
240	Water temperature change	NO	NIL
284	Water temperature change	NO	NIL
408	Water temperature change	NO	NIL
400	Water temperature change	NO	NIL
55	Water temperature change	No	From Pump Station
422	Water temperature change	NA	NIL
379	Water temperature change	NO	NIL
428	Water temperature change	NO	NIL
401	Water temperature change	NA	NIL
301	Water temperature change	NO	NIL
419	Water temperature change	NO	NIL
435	Water temperature change	NA	NIL
383	Water temperature change	NO	NIL
403	Water temperature change	NO	NIL
426	Water temperature change	NO	NIL
416	Water temperature change	NO	NIL
430	Water temperature change	NO	NIL
249	Water temperature change	NA	NIL
407	Water temperature change	NO	
134	Water temperature change	NO	NIL
72	Water temperature change	NO	NIL
415	Water temperature change	NO	NIL
392	Water temperature change	NO	NIL
424	Water temperature change	NO	NIL
332	Water temperature change	NO	communicated from Water Treatment Plant when output temp changes
405	Water temperature change	YES	NIL
56	Water temperature change	NO	NIL
423	Water temperature change	NO	NIL
100	Water temperature change	NO	NIL
409	Water temperature change	NA	NIL
427	Water temperature change	NO	NIL
402	Water temperature change	NO	NIL
112	Water temperature change	YES	NIL
42	Water temperature change	NO	NIL
120	Water temperature change	NA	NIL
418	Water temperature change	NO	NIL
413	Frozen pipe	NA	NIL
432	Frozen pipe	YES	NIL
76	Frozen pipe	No	NIL
405	Frozen pipe	YES	NIL
56	Frozen pipe	NO	NIL
332	Frozen pipe	YES	NIL
400	Frozen pipe	YES	NIL
403	Frozen pipe	YES	NIL

72	Frozen pipe	YES	NIL
227	Frozen pipe	NO	NIL
301	Frozen pipe	YES	NIL
407	Frozen pipe	YES	
411	Frozen pipe	NA	NIL
422	Frozen pipe	NA	NIL
283	Frozen pipe	NO	NIL
240	Frozen pipe	YES	NIL
409	Frozen pipe	NA	NIL
415	Frozen pipe	YES	NIL
10	Frozen pipe	NO	NIL
424	Frozen pipe	NO	NIL
379	Frozen pipe	NO	NIL
402	Frozen pipe	NO	NIL
423	Frozen pipe	NO	NIL
418	Frozen pipe	NO	NIL
416	Frozen pipe	NO	NIL
392	Frozen pipe	NO	NIL
435	Frozen pipe	NA	NIL
420	Frozen pipe	YES	NIL
134	Frozen pipe	YES	NIL
100	Frozen pipe	YES	NIL
112	Frozen pipe	YES	NIL
428	Frozen pipe	NO	NIL
401	Frozen pipe	NA	NIL
120	Frozen pipe	NA	NIL
426	Frozen pipe	NO	NIL
408	Frozen pipe	NO	NIL
249	Frozen pipe	NA	NIL
42	Frozen pipe	YES	NIL
48	Frozen pipe	yes	
231	Frozen pipe	YES	Review with Field Ops.
389	Frozen pipe	NA	NIL
427	Frozen pipe	YES	NIL
434	Frozen pipe	NA	NIL
103	Frozen pipe	NA	NIL
55	Frozen pipe	YES	Access Database
342	Frozen pipe	YES	NIL
414	Frozen pipe	YES	Work Order System
284	Frozen pipe	YES	NIL
141	Frozen pipe	NA	NIL
419	Frozen pipe	YES	NIL
433	Frozen pipe	YES	NIL
430	Frozen pipe	YES	NIL
383	Frozen pipe	YES	NIL
404	Frozen pipe	NO	NIL
21	Frozen pipe	NO	NIL

417	Frozen pipe	NO	NIL
295	Frozen pipe	NO	NIL
260	Frozen pipe	NO	NIL
431	Frozen pipe	YES	NIL
408	Errosion / unsupported pipe	NO	NIL
112	Errosion / unsupported pipe	YES	NIL
72	Errosion / unsupported pipe	YES	NIL
400	Errosion / unsupported pipe	NO	NIL
434	Errosion / unsupported pipe	YES	NIL
431	Errosion / unsupported pipe	YES	NIL
392	Errosion / unsupported pipe	NO	NIL
100	Errosion / unsupported pipe	NO	NIL
423	Errosion / unsupported pipe	NO	NIL
42	Errosion / unsupported pipe	NO	NIL
405	Errosion / unsupported pipe	YES	NIL
404	Errosion / unsupported pipe	YES	NIL
342	Errosion / unsupported pipe	YES	NIL
260	Errosion / unsupported pipe	NO	NIL
389	Errosion / unsupported pipe	NA	NIL
332	Errosion / unsupported pipe	YES	NIL
383	Errosion / unsupported pipe	YES	NIL
120	Errosion / unsupported pipe	NA	NIL
401	Errosion / unsupported pipe	YES	NIL
415	Errosion / unsupported pipe	YES	NIL
433	Errosion / unsupported pipe	YES	Would comment if thought.
21	Errosion / unsupported pipe	NO	NIL
417	Errosion / unsupported pipe	NO	NIL
420	Errosion / unsupported pipe	YES	NIL
424	Errosion / unsupported pipe	NO	NIL
379	Errosion / unsupported pipe	NO	NIL
402	Errosion / unsupported pipe	NO	NIL
416	Errosion / unsupported pipe	NO	NIL
428	Errosion / unsupported pipe	NO	NIL
419	Errosion / unsupported pipe	YES	NIL
426	Errosion / unsupported pipe	NO	NIL
414	Errosion / unsupported pipe	YES	Work Order System
249	Errosion / unsupported pipe	NA	NIL
418	Errosion / unsupported pipe	YES	NIL
435	Errosion / unsupported pipe	NA	NIL
10	Errosion / unsupported pipe	YES	NIL
134	Errosion / unsupported pipe	YES	NIL
48	Errosion / unsupported pipe	no	
295	Errosion / unsupported pipe	YES	NIL
284	Errosion / unsupported pipe	NO	NIL
231	Errosion / unsupported pipe	YES	NIL
55	Errosion / unsupported pipe	YES	Access Database
240	Errosion / unsupported pipe	NO	NIL

432	Errosion / unsupported pipe	NO	NIL
283	Errosion / unsupported pipe	YES	NIL
76	Errosion / unsupported pipe	No	NIL
430	Errosion / unsupported pipe	NO	NIL
409	Errosion / unsupported pipe	NA	NIL
227	Errosion / unsupported pipe	NO	NIL
103	Errosion / unsupported pipe	YES	NIL
407	Errosion / unsupported pipe	YES	
411	Errosion / unsupported pipe	NA	NIL
403	Errosion / unsupported pipe	YES	NIL
427	Errosion / unsupported pipe	YES	NIL
422	Errosion / unsupported pipe	NA	NIL
141	Errosion / unsupported pipe	NA	NIL
301	Errosion / unsupported pipe	NO	NIL
56	Errosion / unsupported pipe	NO	NIL
413	Errosion / unsupported pipe	NA	NIL
431	Unknown	YES	NIL
434	Unknown	YES	NIL
10	Unknown	YES	NIL
405	Unknown	YES	NIL
422	Unknown	NA	NIL
435	Unknown	NA	NIL
407	Unknown	YES	
100	Unknown	NO	NIL
392	Unknown	NO	NIL
134	Unknown	YES	NIL
48	Unknown	no	
295	Unknown	YES	NIL
284	Unknown	YES	NIL
55	Unknown	No	NIL
301	Unknown	NO	NIL
400	Unknown	YES	NIL
432	Unknown	NA	NIL
231	Unknown	YES	NIL
240	Unknown	YES	NIL
408	Unknown	NA	NIL
72	Unknown	NO	NIL
283	Unknown	NA	NIL
409	Unknown	NA	NIL
76	Unknown	No	NIL
379	Unknown	NA	NIL
56	Unknown	NO	NIL
433	Unknown	YES	They would mark if leak type was unknown.
424	Unknown	NO	NIL
227	Unknown	NO	NIL
417	Unknown	NO	NIL
420	Unknown	YES	NIL

21	Unknown	YES	NIL
383	Unknown	YES	NIL
141	Unknown	NA	NIL
413	Unknown	NA	NIL
427	Unknown	YES	NIL
404	Unknown	YES	NIL
415	Unknown	NA	NIL
414	Unknown	YES	Work Order System
260	Unknown	NO	NIL
103	Unknown	NA	NIL
423	Unknown	NO	NIL
411	Unknown	NA	NIL
249	Unknown	NA	NIL
402	Unknown	NO	NIL
403	Unknown	YES	NIL
342	Unknown	YES	NIL
430	Unknown	NO	NIL
120	Unknown	NA	NIL
418	Unknown	NO	NIL
419	Unknown	YES	NIL
332	Unknown	NA	NIL
428	Unknown	NO	NIL
112	Unknown	YES	NIL
389	Unknown	NA	NIL
42	Unknown	NA	NIL
416	Unknown	NO	NIL
401	Unknown	YES	NIL
426	Unknown	NO	NIL

Repair data recorded by survey respondents

CityID	Description	Data Recorded
426	Repair clamp	YES
428	Repair clamp	YES
427	Repair clamp	YES
389	Repair clamp	YES
112	Repair clamp	YES
405	Repair clamp	YES
418	Repair clamp	YES
76	Repair clamp	YES
411	Repair clamp	YES
424	Repair clamp	YES
260	Repair clamp	YES
141	Repair clamp	NA
404	Repair clamp	YES
240	Repair clamp	YES
408	Repair clamp	YES
413	Repair clamp	YES
283	Repair clamp	YES
432	Repair clamp	YES
21	Repair clamp	YES
55	Repair clamp	YES
342	Repair clamp	YES
48	Repair clamp	yes
379	Repair clamp	YES
433	Repair clamp	YES
249	Repair clamp	YES
420	Repair clamp	YES
416	Repair clamp	YES
134	Repair clamp	YES
332	Repair clamp	YES
383	Repair clamp	YES
423	Repair clamp	YES
407	Repair clamp	YES
103	Repair clamp	YES
301	Repair clamp	YES
430	Repair clamp	YES
72	Repair clamp	YES
295	Repair clamp	YES
401	Repair clamp	YES
403	Repair clamp	YES
120	Repair clamp	YES
400	Repair clamp	YES
56	Repair clamp	YES
415	Repair clamp	YES

414	Repair clamp	YES
434	Repair clamp	YES
100	Repair clamp	YES
431	Repair clamp	YES
284	Repair clamp	YES
402	Repair clamp	YES
227	Repair clamp	YES
42	Repair clamp	YES
392	Repair clamp	YES
422	Repair clamp	NA
409	Repair clamp	YES
419	Repair clamp	YES
417	Repair clamp	YES
10	Repair clamp	YES
435	Repair clamp	NA
231	Repair clamp	YES
134	Replace pipe section	YES
415	Replace pipe section	YES
301	Replace pipe section	YES
422	Replace pipe section	NA
342	Replace pipe section	YES
332	Replace pipe section	YES
417	Replace pipe section	YES
433	Replace pipe section	YES
411	Replace pipe section	YES
419	Replace pipe section	YES
408	Replace pipe section	YES
141	Replace pipe section	NA
48	Replace pipe section	yes
227	Replace pipe section	YES
409	Replace pipe section	YES
103	Replace pipe section	YES
427	Replace pipe section	YES
56	Replace pipe section	YES
405	Replace pipe section	YES
414	Replace pipe section	YES
402	Replace pipe section	YES
413	Replace pipe section	YES
249	Replace pipe section	YES
407	Replace pipe section	YES
426	Replace pipe section	YES
100	Replace pipe section	YES
112	Replace pipe section	YES
418	Replace pipe section	YES
283	Replace pipe section	YES
416	Replace pipe section	YES
120	Replace pipe section	YES
428	Replace pipe section	YES

42	Replace pipe section	YES
392	Replace pipe section	YES
389	Replace pipe section	YES
430	Replace pipe section	YES
260	Replace pipe section	YES
434	Replace pipe section	YES
284	Replace pipe section	YES
401	Replace pipe section	YES
295	Replace pipe section	YES
431	Replace pipe section	YES
400	Replace pipe section	YES
435	Replace pipe section	NA
10	Replace pipe section	YES
72	Replace pipe section	YES
231	Replace pipe section	YES
432	Replace pipe section	YES
423	Replace pipe section	YES
403	Replace pipe section	YES
420	Replace pipe section	YES
383	Replace pipe section	YES
379	Replace pipe section	NO
404	Replace pipe section	YES
55	Replace pipe section	YES
76	Replace pipe section	YES
21	Replace pipe section	YES
240	Replace pipe section	YES
424	Replace pipe section	YES
420	Replace valve	YES
402	Replace valve	YES
284	Replace valve	YES
401	Replace valve	YES
433	Replace valve	YES
417	Replace valve	YES
231	Replace valve	YES
422	Replace valve	NA
295	Replace valve	YES
435	Replace valve	NA
10	Replace valve	YES
21	Replace valve	NO
403	Replace valve	YES
55	Replace valve	YES
76	Replace valve	YES
249	Replace valve	YES
103	Replace valve	YES
283	Replace valve	NO
416	Replace valve	YES
427	Replace valve	YES
426	Replace valve	YES

227	Replace valve	YES
424	Replace valve	YES
134	Replace valve	YES
240	Replace valve	YES
428	Replace valve	YES
141	Replace valve	NA
419	Replace valve	YES
432	Replace valve	YES
418	Replace valve	YES
430	Replace valve	YES
48	Replace valve	yes
414	Replace valve	YES
413	Replace valve	YES
434	Replace valve	YES
120	Replace valve	YES
260	Replace valve	YES
392	Replace valve	YES
100	Replace valve	YES
342	Replace valve	YES
404	Replace valve	YES
409	Replace valve	YES
301	Replace valve	YES
431	Replace valve	YES
408	Replace valve	YES
400	Replace valve	YES
379	Replace valve	YES
423	Replace valve	YES
72	Replace valve	YES
407	Replace valve	YES
389	Replace valve	YES
415	Replace valve	YES
56	Replace valve	NO
332	Replace valve	YES
411	Replace valve	YES
112	Replace valve	YES
42	Replace valve	YES
383	Replace valve	YES
405	Replace valve	YES
332	Replace service connection	YES
433	Replace service connection	YES
428	Replace service connection	YES
134	Replace service connection	YES
42	Replace service connection	YES
342	Replace service connection	YES
48	Replace service connection	yes
407	Replace service connection	YES
301	Replace service connection	YES
403	Replace service connection	YES

389	Replace service connection	YES
418	Replace service connection	YES
423	Replace service connection	YES
424	Replace service connection	YES
112	Replace service connection	YES
432	Replace service connection	YES
383	Replace service connection	NA
260	Replace service connection	YES
404	Replace service connection	YES
240	Replace service connection	YES
422	Replace service connection	NA
416	Replace service connection	YES
55	Replace service connection	YES
231	Replace service connection	YES
379	Replace service connection	YES
21	Replace service connection	NO
120	Replace service connection	YES
283	Replace service connection	NO
295	Replace service connection	YES
284	Replace service connection	YES
419	Replace service connection	YES
103	Replace service connection	YES
401	Replace service connection	NO
409	Replace service connection	NA
227	Replace service connection	YES
431	Replace service connection	YES
141	Replace service connection	NA
414	Replace service connection	YES
413	Replace service connection	NA
56	Replace service connection	YES
435	Replace service connection	NA
400	Replace service connection	NA
417	Replace service connection	YES
415	Replace service connection	YES
72	Replace service connection	YES
10	Replace service connection	YES
402	Replace service connection	YES
249	Replace service connection	YES
76	Replace service connection	YES
434	Replace service connection	YES
405	Replace service connection	YES
392	Replace service connection	YES
426	Replace service connection	YES
100	Replace service connection	YES
420	Replace service connection	NA
411	Replace service connection	YES
408	Replace service connection	YES
427	Replace service connection	YES

430	Replace service connection	YES
112	Replace hydrant part(s)	YES
430	Replace hydrant part(s)	YES
231	Replace hydrant part(s)	YES
435	Replace hydrant part(s)	NA
72	Replace hydrant part(s)	YES
418	Replace hydrant part(s)	YES
400	Replace hydrant part(s)	YES
295	Replace hydrant part(s)	YES
260	Replace hydrant part(s)	YES
434	Replace hydrant part(s)	YES
42	Replace hydrant part(s)	YES
416	Replace hydrant part(s)	YES
100	Replace hydrant part(s)	YES
428	Replace hydrant part(s)	YES
431	Replace hydrant part(s)	YES
392	Replace hydrant part(s)	YES
240	Replace hydrant part(s)	YES
401	Replace hydrant part(s)	NO
284	Replace hydrant part(s)	YES
120	Replace hydrant part(s)	YES
283	Replace hydrant part(s)	NO
103	Replace hydrant part(s)	NA
426	Replace hydrant part(s)	YES
48	Replace hydrant part(s)	yes
249	Replace hydrant part(s)	YES
419	Replace hydrant part(s)	YES
433	Replace hydrant part(s)	YES
414	Replace hydrant part(s)	YES
134	Replace hydrant part(s)	YES
10	Replace hydrant part(s)	YES
407	Replace hydrant part(s)	YES
21	Replace hydrant part(s)	NO
402	Replace hydrant part(s)	YES
76	Replace hydrant part(s)	YES
411	Replace hydrant part(s)	YES
227	Replace hydrant part(s)	YES
405	Replace hydrant part(s)	YES
427	Replace hydrant part(s)	YES
409	Replace hydrant part(s)	YES
332	Replace hydrant part(s)	YES
141	Replace hydrant part(s)	NA
422	Replace hydrant part(s)	NA
389	Replace hydrant part(s)	YES
413	Replace hydrant part(s)	NA
423	Replace hydrant part(s)	YES
424	Replace hydrant part(s)	YES
415	Replace hydrant part(s)	YES

432	Replace hydrant part(s)	NO
56	Replace hydrant part(s)	NO
383	Replace hydrant part(s)	YES
301	Replace hydrant part(s)	YES
404	Replace hydrant part(s)	YES
408	Replace hydrant part(s)	YES
420	Replace hydrant part(s)	YES
55	Replace hydrant part(s)	YES
379	Replace hydrant part(s)	NO
403	Replace hydrant part(s)	YES
342	Replace hydrant part(s)	YES
417	Replace hydrant part(s)	YES
413	Replace entire hydrant	NA
431	Replace entire hydrant	YES
402	Replace entire hydrant	YES
295	Replace entire hydrant	YES
417	Replace entire hydrant	YES
72	Replace entire hydrant	YES
415	Replace entire hydrant	YES
414	Replace entire hydrant	YES
301	Replace entire hydrant	YES
76	Replace entire hydrant	YES
389	Replace entire hydrant	YES
432	Replace entire hydrant	YES
260	Replace entire hydrant	YES
383	Replace entire hydrant	YES
283	Replace entire hydrant	NO
379	Replace entire hydrant	YES
48	Replace entire hydrant	yes
231	Replace entire hydrant	YES
240	Replace entire hydrant	YES
284	Replace entire hydrant	YES
134	Replace entire hydrant	YES
249	Replace entire hydrant	YES
407	Replace entire hydrant	YES
55	Replace entire hydrant	YES
100	Replace entire hydrant	YES
426	Replace entire hydrant	YES
411	Replace entire hydrant	YES
419	Replace entire hydrant	YES
42	Replace entire hydrant	YES
420	Replace entire hydrant	YES
416	Replace entire hydrant	YES
430	Replace entire hydrant	YES
141	Replace entire hydrant	NA
433	Replace entire hydrant	YES
408	Replace entire hydrant	YES
342	Replace entire hydrant	YES

409	Replace entire hydrant	YES
392	Replace entire hydrant	YES
401	Replace entire hydrant	NO
21	Replace entire hydrant	NO
418	Replace entire hydrant	YES
103	Replace entire hydrant	YES
405	Replace entire hydrant	YES
332	Replace entire hydrant	YES
120	Replace entire hydrant	YES
428	Replace entire hydrant	YES
427	Replace entire hydrant	YES
56	Replace entire hydrant	NO
400	Replace entire hydrant	YES
10	Replace entire hydrant	YES
423	Replace entire hydrant	YES
403	Replace entire hydrant	YES
435	Replace entire hydrant	NA
424	Replace entire hydrant	YES
422	Replace entire hydrant	NA
112	Replace entire hydrant	YES
227	Replace entire hydrant	YES
404	Replace entire hydrant	YES
434	Replace entire hydrant	YES
423	Anode installed	NO
301	Anode installed	YES
389	Anode installed	NO
21	Anode installed	YES
134	Anode installed	YES
432	Anode installed	NO
55	Anode installed	YES
379	Anode installed	NO
383	Anode installed	NO
424	Anode installed	YES
342	Anode installed	NO
420	Anode installed	YES
404	Anode installed	NO
48	Anode installed	no
141	Anode installed	NA
415	Anode installed	NO
422	Anode installed	NA
403	Anode installed	NO
417	Anode installed	YES
10	Anode installed	YES
414	Anode installed	YES
56	Anode installed	NO
227	Anode installed	YES
402	Anode installed	NO
103	Anode installed	YES

409	Anode installed	YES
433	Anode installed	YES
419	Anode installed	YES
411	Anode installed	NO
427	Anode installed	NO
426	Anode installed	NO
408	Anode installed	NO
407	Anode installed	YES
249	Anode installed	YES
405	Anode installed	YES
332	Anode installed	YES
413	Anode installed	YES
428	Anode installed	YES
401	Anode installed	YES
284	Anode installed	YES
430	Anode installed	NO
392	Anode installed	YES
431	Anode installed	YES
100	Anode installed	YES
283	Anode installed	YES
434	Anode installed	NO
42	Anode installed	YES
416	Anode installed	YES
112	Anode installed	YES
260	Anode installed	YES
400	Anode installed	YES
435	Anode installed	NA
295	Anode installed	YES
231	Anode installed	NO
418	Anode installed	NO
120	Anode installed	YES
72	Anode installed	NO
240	Anode installed	YES
76	Anode installed	NO
411	External protection installed	NO
427	External protection installed	NO
392	External protection installed	NO
100	External protection installed	YES
55	External protection installed	YES
408	External protection installed	NO
426	External protection installed	NO
231	External protection installed	NO
407	External protection installed	YES
103	External protection installed	NA
227	External protection installed	YES
10	External protection installed	YES
400	External protection installed	NO
422	External protection installed	NA

403	External protection installed	NO
72	External protection installed	NO
414	External protection installed	YES
295	External protection installed	YES
141	External protection installed	NA
56	External protection installed	NO
409	External protection installed	YES
434	External protection installed	NO
402	External protection installed	YES
413	External protection installed	NA
431	External protection installed	YES
284	External protection installed	YES
249	External protection installed	YES
401	External protection installed	NO
419	External protection installed	YES
435	External protection installed	NA
416	External protection installed	YES
48	External protection installed	yes
379	External protection installed	NO
112	External protection installed	YES
420	External protection installed	YES
430	External protection installed	YES
283	External protection installed	NO
415	External protection installed	NO
42	External protection installed	YES
383	External protection installed	YES
342	External protection installed	YES
404	External protection installed	NO
424	External protection installed	NO
260	External protection installed	YES
432	External protection installed	NO
389	External protection installed	YES
423	External protection installed	NO
76	External protection installed	YES
418	External protection installed	NO
417	External protection installed	NO
332	External protection installed	NO
405	External protection installed	NO
120	External protection installed	NO
433	External protection installed	YES
240	External protection installed	YES
134	External protection installed	YES
301	External protection installed	NO
428	External protection installed	YES
21	External protection installed	YES
431	Repair joint	YES
400	Repair joint	YES
120	Repair joint	YES

411	Repair joint	YES
405	Repair joint	YES
422	Repair joint	NA
414	Repair joint	YES
42	Repair joint	YES
389	Repair joint	YES
404	Repair joint	YES
72	Repair joint	YES
408	Repair joint	YES
260	Repair joint	YES
379	Repair joint	NO
407	Repair joint	YES
342	Repair joint	YES
112	Repair joint	YES
409	Repair joint	YES
434	Repair joint	YES
383	Repair joint	YES
301	Repair joint	YES
392	Repair joint	YES
56	Repair joint	YES
413	Repair joint	YES
100	Repair joint	YES
332	Repair joint	YES
423	Repair joint	YES
21	Repair joint	NA
231	Repair joint	YES
76	Repair joint	YES
433	Repair joint	YES
141	Repair joint	NA
419	Repair joint	YES
432	Repair joint	YES
240	Repair joint	YES
424	Repair joint	YES
55	Repair joint	YES
134	Repair joint	YES
427	Repair joint	YES
426	Repair joint	NO
283	Repair joint	YES
416	Repair joint	YES
418	Repair joint	YES
249	Repair joint	YES
103	Repair joint	YES
428	Repair joint	YES
417	Repair joint	YES
48	Repair joint	yes
10	Repair joint	YES
295	Repair joint	YES
420	Repair joint	YES

435	Repair joint	NA
430	Repair joint	YES
403	Repair joint	YES
415	Repair joint	YES
284	Repair joint	YES
227	Repair joint	NA
402	Repair joint	YES
401	Repair joint	YES
389	Surface restoration	YES
404	Surface restoration	YES
424	Surface restoration	YES
383	Surface restoration	YES
342	Surface restoration	YES
418	Surface restoration	YES
420	Surface restoration	YES
48	Surface restoration	yes
417	Surface restoration	NO
428	Surface restoration	YES
432	Surface restoration	YES
231	Surface restoration	YES
400	Surface restoration	YES
10	Surface restoration	YES
295	Surface restoration	YES
72	Surface restoration	YES
434	Surface restoration	YES
435	Surface restoration	NA
284	Surface restoration	YES
431	Surface restoration	YES
112	Surface restoration	YES
401	Surface restoration	NO
76	Surface restoration	YES
430	Surface restoration	YES
100	Surface restoration	YES
120	Surface restoration	NO
240	Surface restoration	YES
42	Surface restoration	NA
283	Surface restoration	NO
416	Surface restoration	YES
260	Surface restoration	YES
423	Surface restoration	YES
392	Surface restoration	NO
402	Surface restoration	YES
405	Surface restoration	YES
249	Surface restoration	YES
409	Surface restoration	YES
56	Surface restoration	NO
407	Surface restoration	YES
413	Surface restoration	NA

414	Surface restoration	YES
426	Surface restoration	YES
227	Surface restoration	YES
427	Surface restoration	YES
379	Surface restoration	YES
55	Surface restoration	YES
141	Surface restoration	NA
411	Surface restoration	YES
419	Surface restoration	YES
408	Surface restoration	YES
301	Surface restoration	YES
103	Surface restoration	YES
21	Surface restoration	YES
134	Surface restoration	YES
403	Surface restoration	YES
332	Surface restoration	YES
422	Surface restoration	NA
415	Surface restoration	YES
433	Surface restoration	YES
403	Dechlorination performed	NO
415	Dechlorination performed	NO
400	Dechlorination performed	YES
100	Dechlorination performed	NO
402	Dechlorination performed	YES
120	Dechlorination performed	NO
10	Dechlorination performed	YES
295	Dechlorination performed	YES
231	Dechlorination performed	NO
141	Dechlorination performed	NA
413	Dechlorination performed	NA
414	Dechlorination performed	YES
392	Dechlorination performed	NO
431	Dechlorination performed	NO
56	Dechlorination performed	YES
422	Dechlorination performed	NA
72	Dechlorination performed	NO
42	Dechlorination performed	NA
227	Dechlorination performed	YES
284	Dechlorination performed	YES
435	Dechlorination performed	NA
434	Dechlorination performed	YES
417	Dechlorination performed	NO
401	Dechlorination performed	NO
21	Dechlorination performed	NO
433	Dechlorination performed	YES
389	Dechlorination performed	YES
404	Dechlorination performed	NO
405	Dechlorination performed	YES

301	Dechlorination performed	YES
424	Dechlorination performed	NO
428	Dechlorination performed	YES
134	Dechlorination performed	NO
249	Dechlorination performed	YES
383	Dechlorination performed	YES
342	Dechlorination performed	NO
332	Dechlorination performed	NO
420	Dechlorination performed	YES
48	Dechlorination performed	no
379	Dechlorination performed	NO
55	Dechlorination performed	YES
408	Dechlorination performed	NO
240	Dechlorination performed	NO
409	Dechlorination performed	YES
411	Dechlorination performed	NO
419	Dechlorination performed	YES
427	Dechlorination performed	NO
112	Dechlorination performed	YES
432	Dechlorination performed	NO
426	Dechlorination performed	NO
418	Dechlorination performed	NO
416	Dechlorination performed	YES
76	Dechlorination performed	NO
407	Dechlorination performed	YES
260	Dechlorination performed	YES
423	Dechlorination performed	NO
103	Dechlorination performed	NA
430	Dechlorination performed	YES
283	Dechlorination performed	YES

Environmental data recorded by survey respondents

City ID	Description	Data Recorded	Available from other	Sources
379	Water temperature	NO	NO	NA
411	Water temperature	NO	NA	NA
405	Water temperature	NO	NA	NA
420	Water temperature	NO	NO	NA
407	Water temperature	NO	NA	NA
332	Water temperature	NO	YES	Other
432	Water temperature	NO	NO	NA
419	Water temperature	NO	YES	External
301	Water temperature	NO	NA	NA
112	Water temperature	NO	NA	NA
76	Water temperature	NO	YES	Other
408	Water temperature	NO	NA	NA
404	Water temperature	NO	YES	External
418	Water temperature	NO	NO	NA
283	Water temperature	NO	NO	NA
383	Water temperature	NO	NA	NA
423	Water temperature	NO	YES	O&M records
416	Water temperature	NO	YES	O&M records
240	Water temperature	NO	YES	External
389	Water temperature	NO	NA	NA
424	Water temperature	NO	NO	NA
415	Water temperature	NO	NO	Other
227	Water temperature	NO	NO	NA
141	Water temperature	NA	YES	External
402	Water temperature	NO	NO	NA
403	Water temperature	NO	NO	NA
72	Water temperature	NO	NA	NA
426	Water temperature	NO	NO	NA
417	Water temperature	NO	NO	NA
422	Water temperature	NA	NA	NA
55	Water temperature	No	YES	Other
249	Water temperature	NO	NO	NA
21	Water temperature	NO	NO	NA
56	Water temperature	NO	NA	NA
103	Water temperature	NO	NA	NA
134	Water temperature	NO	NO	NA
414	Water temperature	NO	NA	NIL
409	Water temperature	NO	YES	O&M records
433	Water temperature	NA	NA	NA
48	Water temperature	no	no	NA
413	Water temperature	NO	NA	NA
342	Water temperature	NO	NA	NA
427	Water temperature	NO	NO	NA
295	Water temperature	YES	NO	Archival

				records
100	Water temperature	NO	NO	NA
434	Water temperature	NO	NO	NA
435	Water temperature	NO	YES	Archival records
430	Water temperature	NO	NO	NA
401	Water temperature	NO	YES	Other
120	Water temperature	NA	NA	NA
260	Water temperature	NO	NA	NA
10	Water temperature	NO	NA	NA
231	Water temperature	NO	NO	NA
428	Water temperature	NO	NA	NA
431	Water temperature	NO	YES	External
284	Water temperature	NO	YES	O&M records
400	Water temperature	NO	NO	NA
392	Water temperature	NO	NO	NA
42	Water temperature	no	NA	NA
100	Air temperature	NO	YES	External
112	Air temperature	NO	NA	NA
284	Air temperature	YES	YES	External
426	Air temperature	NO	YES	External
409	Air temperature	NO	YES	External
408	Air temperature	YES	YES	Archival records
405	Air temperature	YES	NA	NA
411	Air temperature	NO	NA	NA
55	Air temperature	No	YES	Other
401	Air temperature	NO	YES	External
301	Air temperature	NO	NA	NA
134	Air temperature	YES	YES	Other
249	Air temperature	NO	NO	NA
422	Air temperature	NA	NA	NA
415	Air temperature	NO	NO	Other
400	Air temperature	YES	NO	NA.
56	Air temperature	NO	NA	NA
433	Air temperature	NA	NA	NA
295	Air temperature	YES	NO	Archival records
413	Air temperature	YES	NA	NA
417	Air temperature	NO	NO	NA
414	Air temperature	YES	YES	Other
434	Air temperature	NO	NO	NA
407	Air temperature	NO	NA	NA
427	Air temperature	NO	NO	NA
48	Air temperature	no	no	NA
103	Air temperature	NO	NA	NA
419	Air temperature	NO	YES	External
420	Air temperature	NO	NO	NA
231	Air temperature	YES	YES	External

120	Air temperature	NA	NA	NA
404	Air temperature	NO	YES	External
283	Air temperature	NO	NO	NA
383	Air temperature	NO	NA	NA
418	Air temperature	NO	YES	External
423	Air temperature	NO	YES	O&M records
141	Air temperature	NA	NO	NA
416	Air temperature	NO	YES	O&M records
428	Air temperature	NO	NA	NA
240	Air temperature	YES	YES	External
389	Air temperature	YES	NA	External
227	Air temperature	NO	NO	NA
72	Air temperature	NO	NA	NA
260	Air temperature	NO	YES	Archival records
424	Air temperature	NO	YES	External
76	Air temperature	NO	YES	Other
431	Air temperature	NO	YES	External
402	Air temperature	NO	NO	NA
342	Air temperature	YES	NA	External
403	Air temperature	NO	YES	NA
392	Air temperature	NO	NO	NA
430	Air temperature	NO	NO	NA
21	Air temperature	YES	YES	External
435	Air temperature	NO	YES	Archival records
332	Air temperature	NO	YES	External
379	Air temperature	NO	NO	NA
10	Air temperature	NO	NA	NA
432	Air temperature	NO	YES	External
42	Air temperature	no	NA	NA
427	No. of consecutive days below 32 f or 0 c	NO	NO	NA
419	No. of consecutive days below 32 f or 0 c	NO	YES	External
141	No. of consecutive days below 32 f or 0 c	NA	YES	External
10	No. of consecutive days below 32 f or 0 c	NO	NA	NA
426	No. of consecutive days below 32 f or 0 c	NO	YES	External
420	No. of consecutive days below 32 f or 0 c	NA	NO	NA
240	No. of consecutive days below 32 f or 0 c	NO	YES	External
428	No. of consecutive days below 32 f or 0 c	NO	NA	NA
416	No. of consecutive days below 32 f or 0 c	NO	YES	O&M records
283	No. of consecutive days below 32 f or 0 c	NO	NO	NA
76	No. of consecutive days below 32 f or 0 c	NO	YES	Other
418	No. of consecutive days below 32 f or 0 c	NO	YES	External
231	No. of consecutive days below 32 f or 0 c	NO	YES	External
430	No. of consecutive days below 32 f or 0 c	NO	NO	NA
21	No. of consecutive days below 32 f or 0 c	NO	YES	External
432	No. of consecutive days below 32 f or 0 c	NO	YES	Archival records
249	No. of consecutive days below 32 f or 0 c	NO	YES	External

55	No. of consecutive days below 32 f or 0 c	No	YES	Other
284	No. of consecutive days below 32 f or 0 c	NO	YES	External
401	No. of consecutive days below 32 f or 0 c	NO	YES	External
48	No. of consecutive days below 32 f or 0 c	no	no	NA
433	No. of consecutive days below 32 f or 0 c	NA	NA	NA
134	No. of consecutive days below 32 f or 0 c	NO	YES	External
295	No. of consecutive days below 32 f or 0 c	NO	NA	NA
435	No. of consecutive days below 32 f or 0 c	NO	YES	Archival records
103	No. of consecutive days below 32 f or 0 c	NO	NA	NA
424	No. of consecutive days below 32 f or 0 c	NA	NO	NA
423	No. of consecutive days below 32 f or 0 c	NO	YES	External
409	No. of consecutive days below 32 f or 0 c	NA	YES	External
413	No. of consecutive days below 32 f or 0 c	NA	NA	NA
408	No. of consecutive days below 32 f or 0 c	NO	NA	NA
411	No. of consecutive days below 32 f or 0 c	NO	NA	NA
405	No. of consecutive days below 32 f or 0 c	NO	NA	NA
407	No. of consecutive days below 32 f or 0 c	NO	NA	NA
332	No. of consecutive days below 32 f or 0 c	NO	YES	External
227	No. of consecutive days below 32 f or 0 c	NO	NO	NA
342	No. of consecutive days below 32 f or 0 c	NO	YES	External
379	No. of consecutive days below 32 f or 0 c	NO	NO	NA
414	No. of consecutive days below 32 f or 0 c	NO	NA	NIL
383	No. of consecutive days below 32 f or 0 c	NA	NA	NA
301	No. of consecutive days below 32 f or 0 c	NO	NA	NA
389	No. of consecutive days below 32 f or 0 c	NO	NA	NA
112	No. of consecutive days below 32 f or 0 c	NO	NA	NA
260	No. of consecutive days below 32 f or 0 c	NO	YES	Archival records
120	No. of consecutive days below 32 f or 0 c	NA	NA	NA
42	No. of consecutive days below 32 f or 0 c	no	NA	NA
392	No. of consecutive days below 32 f or 0 c	NO	NO	NA
100	No. of consecutive days below 32 f or 0 c	NO	YES	External
434	No. of consecutive days below 32 f or 0 c	NO	YES	External
431	No. of consecutive days below 32 f or 0 c	NO	YES	External
400	No. of consecutive days below 32 f or 0 c	NA	NO	NA
72	No. of consecutive days below 32 f or 0 c	NO	NA	NA
404	No. of consecutive days below 32 f or 0 c	NO	YES	External
415	No. of consecutive days below 32 f or 0 c	YES	NO	Other
403	No. of consecutive days below 32 f or 0 c	NO	NO	NA
402	No. of consecutive days below 32 f or 0 c	YES	YES	O&M records
422	No. of consecutive days below 32 f or 0 c	NA	NA	NA
56	No. of consecutive days below 32 f or 0 c	NO	NA	NA
417	No. of consecutive days below 32 f or 0 c	NA	NO	NA
10	Depth of frost	NO	NA	NA
260	Depth of frost	NO	NA	NA
112	Depth of frost	NO	NA	NA
428	Depth of frost	NO	NA	NA
240	Depth of frost	YES	NO	NA

426	Depth of frost	NO	NO	NA
423	Depth of frost	NO	YES	External
42	Depth of frost	YES	NA	NA
416	Depth of frost	NO	NO	NA
301	Depth of frost	NO	NA	NA
427	Depth of frost	NO	NO	NA
76	Depth of frost	NO	YES	Other
404	Depth of frost	NO	YES	External
417	Depth of frost	NO	NO	NA
389	Depth of frost	YES	NA	Other
141	Depth of frost	NA	YES	External
227	Depth of frost	NO	NO	NA
72	Depth of frost	NO	NA	NA
400	Depth of frost	YES	NO	NA
419	Depth of frost	NO	NO	NA
435	Depth of frost	NO	NO	NA
295	Depth of frost	NO	NA	NA
231	Depth of frost	YES	NO	NA
434	Depth of frost	NO	NO	NA
120	Depth of frost	NA	NA	NA
100	Depth of frost	NO	NO	NA
401	Depth of frost	NO	NO	NA
284	Depth of frost	YES	NO	NA
392	Depth of frost	NO	NO	NA
402	Depth of frost	NO	NO	NA
383	Depth of frost	NO	NA	NA
430	Depth of frost	NO	NO	NA
431	Depth of frost	NO	YES	External
48	Depth of frost	no	no	NA
407	Depth of frost	NO	NA	NA
420	Depth of frost	NO	NO	NA
379	Depth of frost	NO	NO	NA
405	Depth of frost	YES	NA	NA
283	Depth of frost	YES	NO	NA
249	Depth of frost	NO	NO	NA
411	Depth of frost	NO	NA	NA
415	Depth of frost	YES	NO	Other
21	Depth of frost	NO	NO	NA
55	Depth of frost	No	YES	Other
103	Depth of frost	NO	NA	NA
413	Depth of frost	YES	NA	NA
409	Depth of frost	YES	NA	NA
433	Depth of frost	NA	NA	NA
134	Depth of frost	YES	NO	NA
56	Depth of frost	NO	NA	NA
414	Depth of frost	YES	YES	Other
408	Depth of frost	NO	NA	NA
403	Depth of frost	YES	YES	Archival records

422	Depth of frost	NA	NA	NA
432	Depth of frost	YES	NO	NA
424	Depth of frost	YES	NO	NA
332	Depth of frost	NO	YES	External
342	Depth of frost	NO	NA	NA
418	Depth of frost	NO	YES	External
134	Water temperature change	NO	NO	NA
419	Water temperature change	NO	NO	NA
72	Water temperature change	NO	NA	NA
379	Water temperature change	NO	NO	NA
231	Water temperature change	NO	NO	NA
76	Water temperature change	NO	YES	Other
413	Water temperature change	NO	NA	NA
431	Water temperature change	NO	YES	External
383	Water temperature change	NO	NA	NA
414	Water temperature change	NO	NA	NIL
402	Water temperature change	NO	NO	NA
295	Water temperature change	YES	NO	Archival records
42	Water temperature change	no	NA	NA
415	Water temperature change	NO	NO	Other
417	Water temperature change	NO	NO	NA
260	Water temperature change	NO	NA	NA
407	Water temperature change	NO	NA	NA
55	Water temperature change	NO	YES	Other
301	Water temperature change	NO	NA	NA
48	Water temperature change	no	no	NA
426	Water temperature change	NO	NO	NA
284	Water temperature change	NO	NO	NA
249	Water temperature change	NO	YES	O&M records
432	Water temperature change	NO	NO	NA
411	Water temperature change	NO	NA	NA
283	Water temperature change	NO	NO	NA
100	Water temperature change	NO	NO	NA
240	Water temperature change	NO	NO	NA
389	Water temperature change	NA	NA	NA
403	Water temperature change	NO	NO	NA
416	Water temperature change	NO	YES	O&M records
332	Water temperature change	NO	YES	Other
56	Water temperature change	NO	NA	NA
430	Water temperature change	NO	NO	NA
408	Water temperature change	NO	NA	NA
420	Water temperature change	NO	NO	NA
120	Water temperature change	NA	NA	NA
404	Water temperature change	NO	YES	External
103	Water temperature change	NO	NA	NA
21	Water temperature change	NO	NO	NA
433	Water temperature change	NA	NA	NA
401	Water temperature change	NO	YES	Other

112	Water temperature change	NO	NA	NA
392	Water temperature change	NO	NO	NA
435	Water temperature change	NO	YES	Archival records
423	Water temperature change	NO	YES	External
418	Water temperature change	NA	YES	O&M records
400	Water temperature change	NO	NO	NA
141	Water temperature change	NA	YES	External
424	Water temperature change	NO	NO	NA
227	Water temperature change	NO	NO	NA
405	Water temperature change	NO	NA	NA
10	Water temperature change	NO	NA	NA
422	Water temperature change	NA	NA	NA
342	Water temperature change	NO	NA	NA
434	Water temperature change	NO	NO	NA
428	Water temperature change	NO	NA	NA
427	Water temperature change	NO	NO	NA
409	Water temperature change	NO	NA	NA
411	Soil temperature at pipe depth	NO	NA	NA
48	Soil temperature at pipe depth	no	no	NA
408	Soil temperature at pipe depth	NO	NA	NA
420	Soil temperature at pipe depth	NO	NO	NA
407	Soil temperature at pipe depth	NO	NA	NA
405	Soil temperature at pipe depth	NO	NA	NA
301	Soil temperature at pipe depth	NO	NA	NA
424	Soil temperature at pipe depth	NO	NO	NA
432	Soil temperature at pipe depth	NO	NO	NA
55	Soil temperature at pipe depth	NO	NA	NA
103	Soil temperature at pipe depth	NO	NA	NA
402	Soil temperature at pipe depth	NO	NO	NA
141	Soil temperature at pipe depth	NA	NO	NA
419	Soil temperature at pipe depth	NO	NO	NA
227	Soil temperature at pipe depth	NO	NO	NA
10	Soil temperature at pipe depth	NO	NA	NA
427	Soil temperature at pipe depth	NO	NO	NA
426	Soil temperature at pipe depth	NO	NO	NA
433	Soil temperature at pipe depth	NA	NA	NA
415	Soil temperature at pipe depth	NO	NO	Other
21	Soil temperature at pipe depth	NO	NO	NA
249	Soil temperature at pipe depth	NO	NO	NA
422	Soil temperature at pipe depth	NA	NA	NA
414	Soil temperature at pipe depth	NO	NA	NIL
56	Soil temperature at pipe depth	NO	NA	NA
332	Soil temperature at pipe depth	NO	NO	NA
134	Soil temperature at pipe depth	NO	NO	NA
413	Soil temperature at pipe depth	NO	NA	NA
409	Soil temperature at pipe depth	NO	NA	NA
403	Soil temperature at pipe depth	NO	NO	NA
401	Soil temperature at pipe depth	NO	NO	NA

428	Soil temperature at pipe depth	NO	NA	NA
240	Soil temperature at pipe depth	NO	NO	NA
417	Soil temperature at pipe depth	NO	NO	NA
112	Soil temperature at pipe depth	NO	NA	NA
430	Soil temperature at pipe depth	NO	NO	NA
231	Soil temperature at pipe depth	NO	NO	NA
42	Soil temperature at pipe depth	no	NA	NA
423	Soil temperature at pipe depth	NO	NO	NA
100	Soil temperature at pipe depth	NO	NO	NA
260	Soil temperature at pipe depth	NO	NA	NA
284	Soil temperature at pipe depth	NO	NO	NA
392	Soil temperature at pipe depth	NO	NO	NA
431	Soil temperature at pipe depth	NO	NO	NA
435	Soil temperature at pipe depth	NO	NO	NA
295	Soil temperature at pipe depth	NO	NA	NA
434	Soil temperature at pipe depth	NO	NO	NA
72	Soil temperature at pipe depth	NO	NA	NA
400	Soil temperature at pipe depth	NO	NO	NA
120	Soil temperature at pipe depth	NA	NA	NA
76	Soil temperature at pipe depth	NO	YES	Other
342	Soil temperature at pipe depth	NO	NA	NA
418	Soil temperature at pipe depth	NO	NO	NA
389	Soil temperature at pipe depth	NO	NA	NA
383	Soil temperature at pipe depth	NO	NA	NA
404	Soil temperature at pipe depth	NO	YES	External
379	Soil temperature at pipe depth	NO	NO	NA
283	Soil temperature at pipe depth	NO	NO	NA
416	Soil temperature at pipe depth	NO	NO	NA
403	Soil sample taken	NO	NO	NA
405	Soil sample taken	NO	NA	NA
392	Soil sample taken	NO	NO	NA
431	Soil sample taken	YES	NO	NA
415	Soil sample taken	NO	NO	Other
417	Soil sample taken	NO	NO	NA
120	Soil sample taken	NA	NA	NA
227	Soil sample taken	NO	NO	NA
379	Soil sample taken	NO	NO	NA
434	Soil sample taken	YES	NO	NA
72	Soil sample taken	NO	NA	NA
402	Soil sample taken	NO	NO	NA
400	Soil sample taken	NO	NO	NA
301	Soil sample taken	NO	NA	NA
408	Soil sample taken	NO	NA	NA
411	Soil sample taken	NO	NA	NA
423	Soil sample taken	NO	NO	NA
409	Soil sample taken	YES	NA	NA
389	Soil sample taken	NO	NA	NA
404	Soil sample taken	NO	YES	External

260	Soil sample taken	NO	NA	NA
383	Soil sample taken	NO	NA	NA
56	Soil sample taken	NO	NA	NA
342	Soil sample taken	NA	NA	NA
332	Soil sample taken	NO	YES	External
42	Soil sample taken	no	NA	NA
407	Soil sample taken	NO	NA	NA
414	Soil sample taken	NO	NA	NIL
422	Soil sample taken	NA	NA	NA
100	Soil sample taken	NO	NO	NA
112	Soil sample taken	NO	NA	NA
413	Soil sample taken	NO	NA	NA
432	Soil sample taken	NO	NO	NA
231	Soil sample taken	NO	NO	NA
103	Soil sample taken	NO	NA	NA
249	Soil sample taken	NO	NO	NA
418	Soil sample taken	NO	NO	NA
284	Soil sample taken	NO	NO	NA
295	Soil sample taken	NO	NA	NA
435	Soil sample taken	NO	NO	NA
430	Soil sample taken	NO	NO	NA
134	Soil sample taken	NO	NO	NA
76	Soil sample taken	NO	YES	Other
424	Soil sample taken	NO	NO	NA
21	Soil sample taken	YES	NO	NA
48	Soil sample taken	no	no	NA
55	Soil sample taken	NO	NA	NA
420	Soil sample taken	NO	NO	NA
240	Soil sample taken	YES	NO	NA
401	Soil sample taken	NO	NO	NA
433	Soil sample taken	NA	NA	NA
427	Soil sample taken	NO	NO	NA
428	Soil sample taken	NO	NA	NA
10	Soil sample taken	NO	NA	NA
419	Soil sample taken	NO	NO	NA
426	Soil sample taken	NO	NO	NA
141	Soil sample taken	NA	NO	NA
283	Soil sample taken	NO	NO	NA
416	Soil sample taken	NO	NO	NA
423	Soil PH	NO	NO	NA
407	Soil PH	NO	NA	NA
417	Soil PH	NO	NO	NA
428	Soil PH	NO	NA	NA
401	Soil PH	NO	NO	NA
100	Soil PH	NO	NO	NA
405	Soil PH	NO	NA	NA
240	Soil PH	YES	NO	NA
260	Soil PH	NO	NA	NA

301	Soil PH	NO	NA	NA
424	Soil PH	NO	NO	NA
55	Soil PH	NO	NA	NA
389	Soil PH	NO	NA	NA
383	Soil PH	NO	NA	NA
416	Soil PH	NO	NO	NA
404	Soil PH	NO	YES	External
342	Soil PH	NA	NA	NA
284	Soil PH	NO	NO	NA
432	Soil PH	NO	NO	NA
112	Soil PH	NO	NA	NA
430	Soil PH	NO	NO	NA
231	Soil PH	NO	NO	NA
283	Soil PH	NO	NO	NA
379	Soil PH	NO	NO	NA
42	Soil PH	no	NA	NA
120	Soil PH	NA	NA	NA
76	Soil PH	NO	YES	Other
418	Soil PH	NO	NO	NA
426	Soil PH	NO	NO	NA
433	Soil PH	NA	NA	NA
414	Soil PH	NO	NA	NIL
295	Soil PH	NO	NA	NA
408	Soil PH	NO	NA	NA
422	Soil PH	NA	NA	NA
103	Soil PH	NO	NA	NA
415	Soil PH	NO	NO	Other
56	Soil PH	NO	NA	NA
403	Soil PH	NO	NO	NA
434	Soil PH	YES	NO	NA
427	Soil PH	NO	NO	NA
10	Soil PH	NO	NA	NA
227	Soil PH	NO	NO	NA
419	Soil PH	NO	NO	NA
141	Soil PH	NA	NO	NA
402	Soil PH	NO	NO	NA
400	Soil PH	NO	NO	NA
72	Soil PH	NO	NA	NA
411	Soil PH	NO	NA	NA
420	Soil PH	NO	NO	NA
332	Soil PH	NO	NO	NA
413	Soil PH	NO	NA	NA
134	Soil PH	NO	NO	NA
48	Soil PH	no	no	NA
431	Soil PH	NO	NO	NA
249	Soil PH	NO	NO	NA
409	Soil PH	NO	NA	NA
392	Soil PH	NO	NO	NA

21	Soil PH	NO	NO	NA
435	Soil PH	NO	NO	NA
10	Soil moisture content	NO	NA	NA
392	Soil moisture content	NO	NO	NA
400	Soil moisture content	NO	NO	NA
120	Soil moisture content	NA	NA	NA
240	Soil moisture content	NO	NO	NA
430	Soil moisture content	NO	NO	NA
112	Soil moisture content	NO	NA	NA
295	Soil moisture content	NO	NA	NA
42	Soil moisture content	no	NA	NA
72	Soil moisture content	NO	NA	NA
431	Soil moisture content	NO	NO	NA
434	Soil moisture content	NO	NO	NA
284	Soil moisture content	NO	NO	NA
435	Soil moisture content	NA	NA	NA
401	Soil moisture content	NO	NO	NA
231	Soil moisture content	NO	NO	NA
100	Soil moisture content	NO	NO	NA
103	Soil moisture content	NO	NA	NA
379	Soil moisture content	NO	NO	NA
409	Soil moisture content	NO	NA	NA
21	Soil moisture content	NO	NO	NA
134	Soil moisture content	NO	NO	NA
413	Soil moisture content	NO	NA	NA
56	Soil moisture content	NO	NA	NA
433	Soil moisture content	NA	NA	NA
249	Soil moisture content	NO	NO	NA
48	Soil moisture content	no	no	NA
422	Soil moisture content	NA	NA	NA
420	Soil moisture content	NO	NO	NA
415	Soil moisture content	NO	NO	Other
403	Soil moisture content	NO	NO	NA
426	Soil moisture content	NO	NO	NA
427	Soil moisture content	NO	NO	NA
417	Soil moisture content	NO	NO	NA
227	Soil moisture content	NO	NO	NA
419	Soil moisture content	NA	NA	NA
402	Soil moisture content	NO	NO	NA
414	Soil moisture content	NO	NA	NIL
332	Soil moisture content	NO	YES	External
423	Soil moisture content	NO	NO	NA
428	Soil moisture content	NO	NA	NA
283	Soil moisture content	NO	NO	NA
389	Soil moisture content	NO	NA	NA
404	Soil moisture content	NO	YES	External
416	Soil moisture content	NO	NO	NA
76	Soil moisture content	NO	YES	Other

383	Soil moisture content	NA	NA	NA
411	Soil moisture content	NO	NA	NA
418	Soil moisture content	NO	NO	NA
260	Soil moisture content	NO	NA	NA
141	Soil moisture content	NA	NO	NA
432	Soil moisture content	NO	NO	NA
301	Soil moisture content	NO	NA	NA
405	Soil moisture content	YES	NA	NA
424	Soil moisture content	NO	NO	NA
55	Soil moisture content	NO	NA	NA
407	Soil moisture content	NO	NA	NA
408	Soil moisture content	NO	NA	NA
342	Soil moisture content	NO	NA	NA

Types of failure recorded by survey respondents

City ID	Description	DataRecorded	Comments
21	Blow out	YES	NIL
42	Blow out	YES	NIL
55	Blow out	YES	NIL
56	Blow out	NO	NIL
72	Blow out	YES	NIL
100	Blow out	NO	NIL
103	Blow out	YES	NIL
112	Blow out	YES	NIL
120	Blow out	YES	NIL
134	Blow out	YES	NIL
227	Blow out	YES	NIL
231	Blow out	YES	NIL
240	Blow out	YES	NIL
249	Blow out	YES	NIL
260	Blow out	YES	NIL
283	Blow out	YES	NIL
284	Blow out	YES	NIL
295	Blow out	YES	NIL
301	Blow out	YES	NIL
332	Blow out	YES	NIL
383	Blow out	YES	NIL
392	Blow out	YES	NIL
400	Blow out	YES	NIL
401	Blow out	YES	NIL
413	Blow out	NA	NIL
418	Blow out	YES	NIL
424	Blow out	YES	NIL
428	Blow out	NO	NIL
433	Blow out	YES	NIL
435	Blow out	YES	NIL
10	Blow out	YES	NIL
48	Blow out	NA	NIL
76	Blow out	YES	NIL
141	Blow out	YES	NIL
342	Blow out	YES	NIL
379	Blow out	YES	NIL
389	Blow out	YES	NIL
402	Blow out	NO	NIL
403	Blow out	YES	NIL
404	Blow out	YES	NIL
405	Blow out	YES	NIL
407	Blow out	YES	NIL
408	Blow out	NO	NIL
409	Blow out	YES	NIL
411	Blow out	NA	NIL

414	Blow out	YES	Work Order System
415	Blow out	YES	NIL
416	Blow out	YES	Field Experience
417	Blow out	YES	NIL
419	Blow out	YES	NIL
420	Blow out	YES	NIL
422	Blow out	NA	NIL
423	Blow out	YES	NIL
426	Blow out	NO	NIL
427	Blow out	YES	NIL
430	Blow out	YES	NIL
431	Blow out	YES	NIL
432	Blow out	YES	NIL
434	Blow out	YES	NIL
21	Corrosion pit hole	YES	NIL
42	Corrosion pit hole	YES	NIL
55	Corrosion pit hole	YES	NIL
56	Corrosion pit hole	YES	NIL
72	Corrosion pit hole	YES	NIL
100	Corrosion pit hole	NO	NIL
103	Corrosion pit hole	YES	NIL
112	Corrosion pit hole	YES	NIL
120	Corrosion pit hole	YES	NIL
134	Corrosion pit hole	YES	NIL
227	Corrosion pit hole	YES	NIL
231	Corrosion pit hole	YES	NIL
240	Corrosion pit hole	YES	NIL
249	Corrosion pit hole	YES	NIL
260	Corrosion pit hole	YES	NIL
283	Corrosion pit hole	YES	NIL
284	Corrosion pit hole	YES	NIL
295	Corrosion pit hole	YES	NIL
301	Corrosion pit hole	YES	NIL
332	Corrosion pit hole	YES	NIL
383	Corrosion pit hole	NA	NIL
392	Corrosion pit hole	YES	NIL
400	Corrosion pit hole	NA	NIL
401	Corrosion pit hole	YES	NIL
413	Corrosion pit hole	NA	NIL
418	Corrosion pit hole	YES	NIL
424	Corrosion pit hole	YES	NIL
428	Corrosion pit hole	NO	NIL
433	Corrosion pit hole	YES	NIL
435	Corrosion pit hole	YES	NIL
10	Corrosion pit hole	YES	NIL
48	Corrosion pit hole	NA	NIL
76	Corrosion pit hole	YES	NIL
141	Corrosion pit hole	YES	NIL
342	Corrosion pit hole	YES	NIL

379	Corrosion pit hole	YES	NIL
389	Corrosion pit hole	YES	NIL
402	Corrosion pit hole	NO	NIL
403	Corrosion pit hole	YES	NIL
404	Corrosion pit hole	YES	NIL
405	Corrosion pit hole	YES	NIL
407	Corrosion pit hole	YES	NIL
408	Corrosion pit hole	NO	NIL
409	Corrosion pit hole	NA	NIL
411	Corrosion pit hole	NA	NIL
414	Corrosion pit hole	YES	Work Order System
415	Corrosion pit hole	YES	NIL
416	Corrosion pit hole	YES	Field Experience
417	Corrosion pit hole	YES	NIL
419	Corrosion pit hole	YES	NIL
420	Corrosion pit hole	YES	NIL
422	Corrosion pit hole	NA	NIL
423	Corrosion pit hole	YES	NIL
426	Corrosion pit hole	NO	NIL
427	Corrosion pit hole	YES	NIL
430	Corrosion pit hole	YES	NIL
431	Corrosion pit hole	YES	NIL
432	Corrosion pit hole	YES	NIL
434	Corrosion pit hole	YES	NIL
21	Curbstop failure	NO	NIL
42	Curbstop failure	YES	NIL
55	Curbstop failure	YES	NIL
56	Curbstop failure	YES	NIL
72	Curbstop failure	YES	NIL
100	Curbstop failure	YES	NIL
103	Curbstop failure	NA	NIL
112	Curbstop failure	YES	NIL
120	Curbstop failure	YES	NIL
134	Curbstop failure	YES	NIL
227	Curbstop failure	YES	NIL
231	Curbstop failure	YES	NIL
240	Curbstop failure	YES	NIL
249	Curbstop failure	YES	NIL
260	Curbstop failure	YES	NIL
283	Curbstop failure	NO	NIL
284	Curbstop failure	YES	NIL
295	Curbstop failure	YES	NIL
301	Curbstop failure	YES	NIL
332	Curbstop failure	YES	NIL
383	Curbstop failure	YES	NIL
392	Curbstop failure	YES	NIL
400	Curbstop failure	NO	NIL
401	Curbstop failure	NO	recorded in other databases
413	Curbstop failure	YES	NIL

418	Curbstop failure	YES	NIL
424	Curbstop failure	YES	NIL
428	Curbstop failure	NO	NIL
433	Curbstop failure	YES	NIL
435	Curbstop failure	YES	NIL
10	Curbstop failure	YES	NIL
48	Curbstop failure	NA	NIL
76	Curbstop failure	YES	NIL
141	Curbstop failure	YES	NIL
342	Curbstop failure	YES	NIL
379	Curbstop failure	YES	NIL
389	Curbstop failure	YES	NIL
402	Curbstop failure	YES	NIL
403	Curbstop failure	YES	NIL
404	Curbstop failure	YES	NIL
405	Curbstop failure	YES	NIL
407	Curbstop failure	YES	NIL
408	Curbstop failure	NO	NIL
409	Curbstop failure	YES	NIL
411	Curbstop failure	YES	NIL
414	Curbstop failure	YES	Work Order System
415	Curbstop failure	YES	NIL
416	Curbstop failure	YES	Field Experience
417	Curbstop failure	YES	NIL
419	Curbstop failure	YES	NIL
420	Curbstop failure	YES	NIL
422	Curbstop failure	NA	NIL
423	Curbstop failure	YES	NIL
426	Curbstop failure	NO	NIL
427	Curbstop failure	YES	NIL
430	Curbstop failure	YES	NIL
431	Curbstop failure	YES	NIL
432	Curbstop failure	NO	NIL
434	Curbstop failure	NO	(service failure)
21	Failed blow-off	NO	NIL
42	Failed blow-off	YES	NIL
55	Failed blow-off	YES	NIL
56	Failed blow-off	NO	NIL
72	Failed blow-off	YES	NIL
100	Failed blow-off	NO	NIL
103	Failed blow-off	NA	NIL
112	Failed blow-off	YES	NIL
120	Failed blow-off	YES	NIL
134	Failed blow-off	YES	NIL
227	Failed blow-off	YES	NIL
231	Failed blow-off	YES	NIL
240	Failed blow-off	YES	NIL
249	Failed blow-off	YES	NIL
260	Failed blow-off	YES	NIL

283	Failed blow-off	NO	NIL
284	Failed blow-off	YES	NIL
295	Failed blow-off	YES	NIL
301	Failed blow-off	YES	NIL
332	Failed blow-off	YES	NIL
383	Failed blow-off	YES	NIL
392	Failed blow-off	NO	NIL
400	Failed blow-off	YES	NIL
401	Failed blow-off	YES	NIL
413	Failed blow-off	NA	NIL
418	Failed blow-off	YES	NIL
424	Failed blow-off	NO	NIL
428	Failed blow-off	NO	NIL
433	Failed blow-off	YES	NIL
435	Failed blow-off	YES	NIL
10	Failed blow-off	YES	NIL
48	Failed blow-off	NA	NIL
76	Failed blow-off	YES	NIL
141	Failed blow-off	YES	NIL
342	Failed blow-off	YES	NIL
379	Failed blow-off	NO	NIL
389	Failed blow-off	YES	NIL
402	Failed blow-off	NO	NIL
403	Failed blow-off	YES	NIL
404	Failed blow-off	YES	NIL
405	Failed blow-off	YES	NIL
407	Failed blow-off	YES	NIL
408	Failed blow-off	NO	NIL
409	Failed blow-off	YES	NIL
411	Failed blow-off	NA	NIL
414	Failed blow-off	YES	Work Order System
415	Failed blow-off	YES	NIL
416	Failed blow-off	YES	Field Experience
417	Failed blow-off	NO	NIL
419	Failed blow-off	YES	NIL
420	Failed blow-off	YES	NIL
422	Failed blow-off	NA	NIL
423	Failed blow-off	YES	NIL
426	Failed blow-off	NO	NIL
427	Failed blow-off	YES	NIL
430	Failed blow-off	YES	NIL
431	Failed blow-off	YES	NIL
432	Failed blow-off	NO	NIL
434	Failed blow-off	YES	NIL
21	Leaking hydrant	NO	NIL
42	Leaking hydrant	YES	NIL
55	Leaking hydrant	YES	NIL
56	Leaking hydrant	NO	NIL
72	Leaking hydrant	YES	NIL

100	Leaking hydrant	YES	NIL
103	Leaking hydrant	YES	NIL
112	Leaking hydrant	YES	NIL
120	Leaking hydrant	YES	NIL
134	Leaking hydrant	YES	NIL
227	Leaking hydrant	YES	NIL
231	Leaking hydrant	YES	NIL
240	Leaking hydrant	YES	NIL
249	Leaking hydrant	YES	NIL
260	Leaking hydrant	YES	NIL
283	Leaking hydrant	NO	NIL
284	Leaking hydrant	YES	NIL
295	Leaking hydrant	YES	NIL
301	Leaking hydrant	YES	NIL
332	Leaking hydrant	YES	NIL
383	Leaking hydrant	YES	NIL
392	Leaking hydrant	YES	NIL
400	Leaking hydrant	NO	NIL
401	Leaking hydrant	NO	recorded in other databases
413	Leaking hydrant	NA	NIL
418	Leaking hydrant	YES	NIL
424	Leaking hydrant	YES	NIL
428	Leaking hydrant	NO	NIL
433	Leaking hydrant	YES	NIL
435	Leaking hydrant	YES	NIL
10	Leaking hydrant	YES	NIL
48	Leaking hydrant	NA	NIL
76	Leaking hydrant	YES	NIL
141	Leaking hydrant	YES	NIL
342	Leaking hydrant	YES	NIL
379	Leaking hydrant	YES	NIL
389	Leaking hydrant	YES	NIL
402	Leaking hydrant	YES	NIL
403	Leaking hydrant	YES	NIL
404	Leaking hydrant	YES	NIL
405	Leaking hydrant	YES	NIL
407	Leaking hydrant	YES	NIL
408	Leaking hydrant	YES	NIL
409	Leaking hydrant	YES	NIL
411	Leaking hydrant	YES	NIL
414	Leaking hydrant	YES	Work Order System
415	Leaking hydrant	YES	NIL
416	Leaking hydrant	YES	Field Experience
417	Leaking hydrant	YES	NIL
419	Leaking hydrant	YES	NIL
420	Leaking hydrant	YES	NIL
422	Leaking hydrant	NA	NIL
423	Leaking hydrant	YES	NIL
426	Leaking hydrant	YES	NIL

427	Leaking hydrant	YES	NIL
430	Leaking hydrant	YES	NIL
431	Leaking hydrant	YES	NIL
432	Leaking hydrant	YES	NIL
434	Leaking hydrant	YES	NIL
21	Leaking joint	YES	NIL
42	Leaking joint	YES	NIL
55	Leaking joint	YES	NIL
56	Leaking joint	NO	NIL
72	Leaking joint	YES	NIL
100	Leaking joint	NO	NIL
103	Leaking joint	YES	NIL
112	Leaking joint	YES	NIL
120	Leaking joint	YES	NIL
134	Leaking joint	YES	NIL
227	Leaking joint	YES	NIL
231	Leaking joint	YES	NIL
240	Leaking joint	YES	NIL
249	Leaking joint	YES	NIL
260	Leaking joint	YES	NIL
283	Leaking joint	YES	NIL
284	Leaking joint	YES	NIL
295	Leaking joint	YES	NIL
301	Leaking joint	YES	NIL
332	Leaking joint	YES	NIL
383	Leaking joint	YES	NIL
392	Leaking joint	YES	NIL
400	Leaking joint	NO	NIL
401	Leaking joint	YES	NIL
413	Leaking joint	YES	NIL
418	Leaking joint	YES	NIL
424	Leaking joint	YES	NIL
428	Leaking joint	NO	NIL
433	Leaking joint	YES	NIL
435	Leaking joint	YES	NIL
10	Leaking joint	YES	NIL
48	Leaking joint	NA	NIL
76	Leaking joint	YES	NIL
141	Leaking joint	YES	NIL
342	Leaking joint	YES	NIL
379	Leaking joint	YES	NIL
389	Leaking joint	YES	NIL
402	Leaking joint	NO	NIL
403	Leaking joint	YES	NIL
404	Leaking joint	YES	NIL
405	Leaking joint	YES	NIL
407	Leaking joint	YES	NIL
408	Leaking joint	NO	NIL
409	Leaking joint	YES	NIL

411	Leaking joint	YES	NIL
414	Leaking joint	YES	Work Order System
415	Leaking joint	YES	NIL
416	Leaking joint	YES	Field Experience
417	Leaking joint	YES	NIL
419	Leaking joint	YES	NIL
420	Leaking joint	YES	NIL
422	Leaking joint	NA	NIL
423	Leaking joint	YES	NIL
426	Leaking joint	NO	NIL
427	Leaking joint	YES	NIL
430	Leaking joint	YES	NIL
431	Leaking joint	YES	NIL
432	Leaking joint	YES	NIL
434	Leaking joint	YES	NIL
21	Leaking service connection	NO	NIL
42	Leaking service connection	YES	NIL
55	Leaking service connection	YES	NIL
56	Leaking service connection	YES	NIL
72	Leaking service connection	YES	NIL
100	Leaking service connection	NO	NIL
103	Leaking service connection	NA	NIL
112	Leaking service connection	YES	NIL
120	Leaking service connection	YES	NIL
134	Leaking service connection	YES	NIL
227	Leaking service connection	YES	NIL
231	Leaking service connection	YES	NIL
240	Leaking service connection	YES	NIL
249	Leaking service connection	YES	NIL
260	Leaking service connection	YES	NIL
283	Leaking service connection	NO	NIL
284	Leaking service connection	YES	NIL
295	Leaking service connection	YES	NIL
301	Leaking service connection	YES	NIL
332	Leaking service connection	YES	NIL
383	Leaking service connection	YES	NIL
392	Leaking service connection	YES	NIL
400	Leaking service connection	YES	NIL
401	Leaking service connection	NO	recorded in other databases
413	Leaking service connection	YES	NIL
418	Leaking service connection	YES	NIL
424	Leaking service connection	YES	NIL
428	Leaking service connection	NO	NIL
433	Leaking service connection	YES	NIL
435	Leaking service connection	YES	NIL
10	Leaking service connection	YES	NIL
48	Leaking service connection	NA	NIL
76	Leaking service connection	YES	NIL
141	Leaking service connection	YES	NIL

342	Leaking service connection	YES	NIL
379	Leaking service connection	YES	NIL
389	Leaking service connection	YES	NIL
402	Leaking service connection	YES	NIL
403	Leaking service connection	YES	NIL
404	Leaking service connection	YES	NIL
405	Leaking service connection	YES	NIL
407	Leaking service connection	YES	NIL
408	Leaking service connection	NO	NIL
409	Leaking service connection	YES	NIL
411	Leaking service connection	YES	NIL
414	Leaking service connection	YES	Work Order System
415	Leaking service connection	YES	NIL
416	Leaking service connection	YES	Field Experience
417	Leaking service connection	YES	NIL
419	Leaking service connection	YES	NIL
420	Leaking service connection	YES	NIL
422	Leaking service connection	NA	NIL
423	Leaking service connection	YES	NIL
426	Leaking service connection	YES	NIL
427	Leaking service connection	YES	NIL
430	Leaking service connection	YES	NIL
431	Leaking service connection	YES	NIL
432	Leaking service connection	YES	NIL
434	Leaking service connection	YES	NIL
21	Leaking valve	NO	NIL
42	Leaking valve	YES	NIL
55	Leaking valve	YES	NIL
56	Leaking valve	NO	NIL
72	Leaking valve	YES	NIL
100	Leaking valve	NO	NIL
103	Leaking valve	YES	NIL
112	Leaking valve	YES	NIL
120	Leaking valve	YES	NIL
134	Leaking valve	YES	NIL
227	Leaking valve	YES	NIL
231	Leaking valve	YES	NIL
240	Leaking valve	YES	NIL
249	Leaking valve	YES	NIL
260	Leaking valve	YES	NIL
283	Leaking valve	NO	NIL
284	Leaking valve	YES	NIL
295	Leaking valve	YES	NIL
301	Leaking valve	YES	NIL
332	Leaking valve	YES	NIL
383	Leaking valve	YES	NIL
392	Leaking valve	YES	NIL
400	Leaking valve	YES	NIL
401	Leaking valve	NO	recorded in other databases

413	Leaking valve	YES	NIL
418	Leaking valve	YES	NIL
424	Leaking valve	YES	NIL
428	Leaking valve	NO	NIL
433	Leaking valve	YES	NIL
435	Leaking valve	YES	NIL
10	Leaking valve	YES	NIL
48	Leaking valve	NA	NIL
76	Leaking valve	YES	NIL
141	Leaking valve	YES	NIL
342	Leaking valve	YES	NIL
379	Leaking valve	YES	NIL
389	Leaking valve	YES	NIL
402	Leaking valve	YES	NIL
403	Leaking valve	YES	NIL
404	Leaking valve	YES	NIL
405	Leaking valve	YES	NIL
407	Leaking valve	YES	NIL
408	Leaking valve	YES	NIL
409	Leaking valve	YES	NIL
411	Leaking valve	YES	NIL
414	Leaking valve	YES	Work Order System
415	Leaking valve	YES	NIL
416	Leaking valve	YES	Field Experience
417	Leaking valve	YES	NIL
419	Leaking valve	YES	NIL
420	Leaking valve	YES	NIL
422	Leaking valve	NA	NIL
423	Leaking valve	YES	NIL
426	Leaking valve	NO	NIL
427	Leaking valve	YES	NIL
430	Leaking valve	YES	NIL
431	Leaking valve	YES	NIL
432	Leaking valve	YES	NIL
434	Leaking valve	YES	NIL
21	Longitudinal break	YES	NIL
42	Longitudinal break	YES	NIL
55	Longitudinal break	YES	NIL
56	Longitudinal break	YES	NIL
72	Longitudinal break	NO	NIL
100	Longitudinal break	NO	NIL
103	Longitudinal break	YES	NIL
112	Longitudinal break	YES	NIL
120	Longitudinal break	YES	NIL
134	Longitudinal break	YES	NIL
227	Longitudinal break	YES	NIL
231	Longitudinal break	YES	NIL
240	Longitudinal break	YES	NIL
249	Longitudinal break	YES	NIL

260	Longitudinal break	YES	NIL
283	Longitudinal break	YES	NIL
284	Longitudinal break	YES	NIL
295	Longitudinal break	YES	NIL
301	Longitudinal break	YES	NIL
332	Longitudinal break	YES	NIL
383	Longitudinal break	YES	NIL
392	Longitudinal break	YES	NIL
400	Longitudinal break	YES	NIL
401	Longitudinal break	YES	NIL
413	Longitudinal break	YES	NIL
418	Longitudinal break	YES	NIL
424	Longitudinal break	YES	NIL
428	Longitudinal break	NO	NIL
433	Longitudinal break	YES	NIL
435	Longitudinal break	YES	NIL
10	Longitudinal break	NO	NIL
48	Longitudinal break	NA	NIL
76	Longitudinal break	YES	NIL
141	Longitudinal break	YES	NIL
342	Longitudinal break	YES	NIL
379	Longitudinal break	YES	NIL
389	Longitudinal break	YES	NIL
402	Longitudinal break	NO	NIL
403	Longitudinal break	YES	NIL
404	Longitudinal break	YES	NIL
405	Longitudinal break	YES	NIL
407	Longitudinal break	YES	NIL
408	Longitudinal break	NO	NIL
409	Longitudinal break	YES	NIL
411	Longitudinal break	NA	NIL
414	Longitudinal break	YES	Work Order System
415	Longitudinal break	YES	NIL
416	Longitudinal break	YES	Field Experience
417	Longitudinal break	YES	NIL
419	Longitudinal break	YES	NIL
420	Longitudinal break	YES	NIL
422	Longitudinal break	NA	NIL
423	Longitudinal break	YES	NIL
426	Longitudinal break	NO	NIL
427	Longitudinal break	YES	NIL
430	Longitudinal break	YES	NIL
431	Longitudinal break	YES	NIL
432	Longitudinal break	YES	NIL
434	Longitudinal break	YES	NIL
21	Split bell	NO	NIL
42	Split bell	YES	NIL
55	Split bell	YES	NIL
56	Split bell	YES	NIL

72	Split bell	YES	NIL
100	Split bell	NO	NIL
103	Split bell	YES	NIL
112	Split bell	YES	NIL
120	Split bell	YES	NIL
134	Split bell	YES	NIL
227	Split bell	NO	NIL
231	Split bell	YES	NIL
240	Split bell	YES	NIL
249	Split bell	YES	NIL
260	Split bell	YES	NIL
283	Split bell	YES	NIL
284	Split bell	YES	NIL
295	Split bell	YES	NIL
301	Split bell	YES	NIL
332	Split bell	YES	NIL
383	Split bell	YES	NIL
392	Split bell	YES	NIL
400	Split bell	YES	NIL
401	Split bell	YES	NIL
413	Split bell	YES	NIL
418	Split bell	YES	NIL
424	Split bell	YES	NIL
428	Split bell	NO	NIL
433	Split bell	YES	NIL
435	Split bell	YES	NIL
10	Split bell	YES	NIL
48	Split bell	NA	NIL
76	Split bell	YES	NIL
141	Split bell	YES	NIL
342	Split bell	YES	NIL
379	Split bell	YES	NIL
389	Split bell	YES	NIL
402	Split bell	NO	NIL
403	Split bell	YES	NIL
404	Split.bell	YES	NIL
405	Split bell	YES	NIL
407	Split bell	YES	NIL
408	Split bell	NO	NIL
409	Split bell	YES	NIL
411	Split bell	NA	NIL
414	Split bell	YES	Work Order System
415	Split bell	YES	NIL
416	Split bell	YES	Field Experience
417	Split bell	YES	NIL
419	Split bell	YES	NIL
420	Split bell	YES	NIL
422	Split bell	NA	NIL
423	Split bell	YES	NIL

426	Split bell	NO	NIL
427	Split bell	YES	NIL
430	Split bell	YES	NIL
431	Split bell	YES	NIL
432	Split bell	NO	NIL
434	Split bell	NO	NIL
21	Tap failure	NO	NIL
42	Tap failure	YES	NIL
55	Tap failure	YES	NIL
56	Tap failure	YES	NIL
72	Tap failure	YES	NIL
100	Tap failure	NO	NIL
103	Tap failure	NA	NIL
112	Tap failure	YES	NIL
120	Tap failure	YES	NIL
134	Tap failure	YES	NIL
227	Tap failure	YES	NIL
231	Tap failure	YES	NIL
240	Tap failure	YES	NIL
249	Tap failure	YES	NIL
260	Tap failure	YES	NIL
283	Tap failure	NO	NIL
284	Tap failure	YES	NIL
295	Tap failure	YES	NIL
301	Tap failure	YES	NIL
332	Tap failure	YES	NIL
383	Tap failure	NA	NIL
392	Tap failure	YES	NIL
400	Tap failure	NO	NIL
401	Tap failure	YES	NIL
413	Tap failure	YES	NIL
418	Tap failure	YES	NIL
424	Tap failure	YES	NIL
428	Tap failure	NO	NIL
433	Tap failure	YES	NIL
435	Tap failure	YES	NIL
10	Tap failure	YES	NIL
48	Tap failure	NA	NIL
76	Tap failure	YES	NIL
141	Tap failure	YES	NIL
342	Tap failure	YES	NIL
379	Tap failure	YES	NIL
389	Tap failure	YES	NIL
402	Tap failure	YES	NIL
403	Tap failure	YES	NIL
404	Tap failure	YES	NIL
405	Tap failure	YES	NIL
407	Tap failure	YES	NIL
408	Tap failure	NO	NIL

409	Tap failure	YES	NIL
411	Tap failure	YES	NIL
414	Tap failure	YES	Work Order System
415	Tap failure	YES	NIL
416	Tap failure	YES	Field Experience
417	Tap failure	YES	NIL
419	Tap failure	YES	NIL
420	Tap failure	YES	NIL
422	Tap failure	NA	NIL
423	Tap failure	YES	NIL
426	Tap failure	NO	NIL
427	Tap failure	YES	NIL
430	Tap failure	YES	NIL
431	Tap failure	YES	NIL
432	Tap failure	NO	NIL
434	Tap failure	YES	NIL

Location data recorded by survey respondents

City ID	Description	%Recorded
404	Nearest property address	100
424	Nearest property address	100
103	Nearest property address	100
134	Nearest property address	100
301	Nearest property address	100
342	Nearest property address	100
433	Nearest property address	75
407	Nearest property address	100
379	Nearest property address	100
249	Nearest property address	100
415	Nearest property address	100
21	Nearest property address	100
403	Nearest property address	100
420	Nearest property address	75
383	Nearest property address	100
423	Nearest property address	100
432	Nearest property address	75
48	Nearest property address	100
408	Nearest property address	100
56	Nearest property address	100
422	Nearest property address	50
417	Nearest property address	50
414	Nearest property address	100
409	Nearest property address	100
72	Nearest property address	75
332	Nearest property address	100
413	Nearest property address	100
55	Nearest property address	100
227	Nearest property address	100
419	Nearest property address	100
141	Nearest property address	100
411	Nearest property address	100
405	Nearest property address	50
426	Nearest property address	100
427	Nearest property address	100
402	Nearest property address	0
240	Nearest property address	100
434	Nearest property address	0
100	Nearest property address	100
430	Nearest property address	100
76	Nearest property address	100
428	Nearest property address	100
401	Nearest property address	100
295	Nearest property address	100

392	Nearest property address	100
42	Nearest property address	100
284	Nearest property address	100
400	Nearest property address	100
231	Nearest property address	100
416	Nearest property address	100
418	Nearest property address	100
389	Nearest property address	100
112	Nearest property address	0
431	Nearest property address	100
10	Nearest property address	100
435	Nearest property address	75
283	Nearest property address	100
260	Nearest property address	50
120	Nearest property address	0
227	Distance from nearest property line	0
402	Distance from nearest property line	0
417	Distance from nearest property line	0
295	Distance from nearest property line	25
435	Distance from nearest property line	25
401	Distance from nearest property line	0
284	Distance from nearest property line	0
419	Distance from nearest property line	0
141	Distance from nearest property line	0
415	Distance from nearest property line	0
10	Distance from nearest property line	0
403	Distance from nearest property line	100
422	Distance from nearest property line	0
433	Distance from nearest property line	75
424	Distance from nearest property line	0
432	Distance from nearest property line	0
76	Distance from nearest property line	0
418	Distance from nearest property line	0
420	Distance from nearest property line	0
283	Distance from nearest property line	50
416	Distance from nearest property line	0
430	Distance from nearest property line	0
48	Distance from nearest property line	0
426	Distance from nearest property line	0
240	Distance from nearest property line	0
428	Distance from nearest property line	100
134	Distance from nearest property line	0
103	Distance from nearest property line	0
249	Distance from nearest property line	50
231	Distance from nearest property line	
55	Distance from nearest property line	100
427	Distance from nearest property line	0
21	Distance from nearest property line	0
407	Distance from nearest property line	0

112	Distance from nearest property line	0
342	Distance from nearest property line	0
411	Distance from nearest property line	0
405	Distance from nearest property line	75
100	Distance from nearest property line	75
400	Distance from nearest property line	25
408	Distance from nearest property line	0
431	Distance from nearest property line	25
389	Distance from nearest property line	0
332	Distance from nearest property line	75
423	Distance from nearest property line	0
383	Distance from nearest property line	0
301	Distance from nearest property line	0
56	Distance from nearest property line	0
404	Distance from nearest property line	25
379	Distance from nearest property line	0
434	Distance from nearest property line	0
392	Distance from nearest property line	75
72	Distance from nearest property line	75
413	Distance from nearest property line	100
42	Distance from nearest property line	0
260	Distance from nearest property line	50
414	Distance from nearest property line	0
120	Distance from nearest property line	100
409	Distance from nearest property line	100
428	Cross street name	100
42	Cross street name	100
240	Cross street name	75
383	Cross street name	100
423	Cross street name	0
403	Cross street name	100
434	Cross street name	100
404	Cross street name	50
21	Cross street name	100
420	Cross street name	100
389	Cross street name	0
432	Cross street name	75
120	Cross street name	100
424	Cross street name	25
416	Cross street name	100
283	Cross street name	50
284	Cross street name	100
260	Cross street name	100
430	Cross street name	100
76	Cross street name	25
100	Cross street name	100
418	Cross street name	50
112	Cross street name	100
231	Cross street name	100

409	Cross street name	100
295	Cross street name	25
433	Cross street name	75
408	Cross street name	0
227	Cross street name	25
435	Cross street name	75
402	Cross street name	0
48	Cross street name	100
400	Cross street name	100
141	Cross street name	0
10	Cross street name	100
417	Cross street name	0
414	Cross street name	100
72	Cross street name	0
56	Cross street name	0
422	Cross street name	0
415	Cross street name	25
413	Cross street name	
103	Cross street name	0
401	Cross street name	0
55	Cross street name	
342	Cross street name	100
134	Cross street name	100
419	Cross street name	100
392	Cross street name	75
332	Cross street name	75
301	Cross street name	75
431	Cross street name	50
249	Cross street name	50
407	Cross street name	100
379	Cross street name	25
427	Cross street name	100
426	Cross street name	100
405	Cross street name	100
411	Cross street name	25
284	Distance from nearest cross street	100
100	Distance from nearest cross street	0
72	Distance from nearest cross street	0
431	Distance from nearest cross street	0
295	Distance from nearest cross street	25
231	Distance from nearest cross street	
134	Distance from nearest cross street	50
415	Distance from nearest cross street	0
414	Distance from nearest cross street	0
417	Distance from nearest cross street	0
413	Distance from nearest cross street	100
402	Distance from nearest cross street	0
411	Distance from nearest cross street	0
419	Distance from nearest cross street	0

426	Distance from nearest cross street	0
407	Distance from nearest cross street	0
55	Distance from nearest cross street	
301	Distance from nearest cross street	0
240	Distance from nearest cross street	25
379	Distance from nearest cross street	25
48	Distance from nearest cross street	25
383	Distance from nearest cross street	0
432	Distance from nearest cross street	0
389	Distance from nearest cross street	0
76	Distance from nearest cross street	0
260	Distance from nearest cross street	100
283	Distance from nearest cross street	50
42	Distance from nearest cross street	25
249	Distance from nearest cross street	25
418	Distance from nearest cross street	0
141	Distance from nearest cross street	0
408	Distance from nearest cross street	0
420	Distance from nearest cross street	25
120	Distance from nearest cross street	50
427	Distance from nearest cross street	100
416	Distance from nearest cross street	0
405	Distance from nearest cross street	50
430	Distance from nearest cross street	0
103	Distance from nearest cross street	0
428	Distance from nearest cross street	0
332	Distance from nearest cross street	25
423	Distance from nearest cross street	0
433	Distance from nearest cross street	50
424	Distance from nearest cross street	0
342	Distance from nearest cross street	0
404	Distance from nearest cross street	25
21	Distance from nearest cross street	0
112	Distance from nearest cross street	100
401	Distance from nearest cross street	0
227	Distance from nearest cross street	0
435	Distance from nearest cross street	75
422	Distance from nearest cross street	0
392	Distance from nearest cross street	75
400	Distance from nearest cross street	50
434	Distance from nearest cross street	100
409	Distance from nearest cross street	100
403	Distance from nearest cross street	100
10	Distance from nearest cross street	100
56	Distance from nearest cross street	0
301	Northing and Easting coordinates	0
332	Northing and Easting coordinates	0
433	Northing and Easting coordinates	0
414	Northing and Easting coordinates	0

56	Northing and Easting coordinates	0
134	Northing and Easting coordinates	0
379	Northing and Easting coordinates	0
21	Northing and Easting coordinates	0
422	Northing and Easting coordinates	0
48	Northing and Easting coordinates	0
415	Northing and Easting coordinates	100
413	Northing and Easting coordinates	
402	Northing and Easting coordinates	0
409	Northing and Easting coordinates	
411	Northing and Easting coordinates	0
141	Northing and Easting coordinates	0
227	Northing and Easting coordinates	0
419	Northing and Easting coordinates	0
103	Northing and Easting coordinates	0
427	Northing and Easting coordinates	0
249	Northing and Easting coordinates	0
426	Northing and Easting coordinates	100
407	Northing and Easting coordinates	0
10	Northing and Easting coordinates	0
405	Northing and Easting coordinates	100
408	Northing and Easting coordinates	0
403	Northing and Easting coordinates	25
342	Northing and Easting coordinates	0
383	Northing and Easting coordinates	
260	Northing and Easting coordinates	0
430	Northing and Easting coordinates	0
112	Northing and Easting coordinates	0
416	Northing and Easting coordinates	0
283	Northing and Easting coordinates	0
434	Northing and Easting coordinates	0
42	Northing and Easting coordinates	0
401	Northing and Easting coordinates	0
76	Northing and Easting coordinates	0
428	Northing and Easting coordinates	0
240	Northing and Easting coordinates	0
120	Northing and Easting coordinates	0
392	Northing and Easting coordinates	0
100	Northing and Easting coordinates	0
231	Northing and Easting coordinates	100
284	Northing and Easting coordinates	0
435	Northing and Easting coordinates	50
400	Northing and Easting coordinates	
420	Northing and Easting coordinates	
417	Northing and Easting coordinates	
55	Northing and Easting coordinates	0
404	Northing and Easting coordinates	0
72	Northing and Easting coordinates	0
295	Northing and Easting coordinates	0

431	Northing and Easting coordinates	0
424	Northing and Easting coordinates	
432	Northing and Easting coordinates	0
389	Northing and Easting coordinates	0
423	Northing and Easting coordinates	0
418	Northing and Easting coordinates	0
413	Isolation Valve operated (Gate valve ID)	100
431	Isolation Valve operated (Gate valve ID)	100
434	Isolation Valve operated (Gate valve ID)	50
392	Isolation Valve operated (Gate valve ID)	0
56	Isolation Valve operated (Gate valve ID)	0
400	Isolation Valve operated (Gate valve ID)	100
72	Isolation Valve operated (Gate valve ID)	100
405	Isolation Valve operated (Gate valve ID)	100
383	Isolation Valve operated (Gate valve ID)	0
342	Isolation Valve operated (Gate valve ID)	0
404	Isolation Valve operated (Gate valve ID)	100
389	Isolation Valve operated (Gate valve ID)	0
379	Isolation Valve operated (Gate valve ID)	0
332	Isolation Valve operated (Gate valve ID)	100
423	Isolation Valve operated (Gate valve ID)	0
408	Isolation Valve operated (Gate valve ID)	0
260	Isolation Valve operated (Gate valve ID)	0
409	Isolation Valve operated (Gate valve ID)	100
112	Isolation Valve operated (Gate valve ID)	100
42	Isolation Valve operated (Gate valve ID)	0
414	Isolation Valve operated (Gate valve ID)	0
407	Isolation Valve operated (Gate valve ID)	0
120	Isolation Valve operated (Gate valve ID)	100
100	Isolation Valve operated (Gate valve ID)	0
411	Isolation Valve operated (Gate valve ID)	0
301	Isolation Valve operated (Gate valve ID)	0
416	Isolation Valve operated (Gate valve ID)	0
103	Isolation Valve operated (Gate valve ID)	0
249	Isolation Valve operated (Gate valve ID)	0
433	Isolation Valve operated (Gate valve ID)	25
134	Isolation Valve operated (Gate valve ID)	25
21	Isolation Valve operated (Gate valve ID)	0
48	Isolation Valve operated (Gate valve ID)	0
55	Isolation Valve operated (Gate valve ID)	100
424	Isolation Valve operated (Gate valve ID)	0
432	Isolation Valve operated (Gate valve ID)	0
426	Isolation Valve operated (Gate valve ID)	0
76	Isolation Valve operated (Gate valve ID)	50
420	Isolation Valve operated (Gate valve ID)	0
283	Isolation Valve operated (Gate valve ID)	0
428	Isolation Valve operated (Gate valve ID)	0
240	Isolation Valve operated (Gate valve ID)	50
430	Isolation Valve operated (Gate valve ID)	0

231	Isolation Valve operated (Gate valve ID)	
401	Isolation Valve operated (Gate valve ID)	0
284	Isolation Valve operated (Gate valve ID)	0
435	Isolation Valve operated (Gate valve ID)	100
295	Isolation Valve operated (Gate valve ID)	0
10	Isolation Valve operated (Gate valve ID)	100
418	Isolation Valve operated (Gate valve ID)	0
417	Isolation Valve operated (Gate valve ID)	75
427	Isolation Valve operated (Gate valve ID)	0
227	Isolation Valve operated (Gate valve ID)	100
422	Isolation Valve operated (Gate valve ID)	0
402	Isolation Valve operated (Gate valve ID)	0
415	Isolation Valve operated (Gate valve ID)	0
419	Isolation Valve operated (Gate valve ID)	0
141	Isolation Valve operated (Gate valve ID)	0
403	Isolation Valve operated (Gate valve ID)	100
56	Isolation Valve operated - (Gate valve ID)	0
430	Isolation Valve operated - (Gate valve ID)	0
100	Isolation Valve operated - (Gate valve ID)	
120	Isolation Valve operated - (Gate valve ID)	100
240	Isolation Valve operated - (Gate valve ID)	50
428	Isolation Valve operated - (Gate valve ID)	0
283	Isolation Valve operated - (Gate valve ID)	0
42	Isolation Valve operated - (Gate valve ID)	0
112	Isolation Valve operated - (Gate valve ID)	100
227	Isolation Valve operated - (Gate valve ID)	100
413	Isolation Valve operated - (Gate valve ID)	100
416	Isolation Valve operated - (Gate valve ID)	0
401	Isolation Valve operated - (Gate valve ID)	0
392	Isolation Valve operated - (Gate valve ID)	0
403	Isolation Valve operated - (Gate valve ID)	100
415	Isolation Valve operated - (Gate valve ID)	0
284	Isolation Valve operated - (Gate valve ID)	0
434	Isolation Valve operated - (Gate valve ID)	50
431	Isolation Valve operated - (Gate valve ID)	100
435	Isolation Valve operated - (Gate valve ID)	100
72	Isolation Valve operated - (Gate valve ID)	100
295	Isolation Valve operated - (Gate valve ID)	0
10	Isolation Valve operated - (Gate valve ID)	0
414	Isolation Valve operated - (Gate valve ID)	0
400	Isolation Valve operated - (Gate valve ID)	100
231	Isolation Valve operated - (Gate valve ID)	
249	Isolation Valve operated - (Gate valve ID)	0
21	Isolation Valve operated - (Gate valve ID)	0
134	Isolation Valve operated - (Gate valve ID)	
379	Isolation Valve operated - (Gate valve ID)	0
332	Isolation Valve operated - (Gate valve ID)	100
419	Isolation Valve operated - (Gate valve ID)	0
76	Isolation Valve operated - (Gate valve ID)	50

433	Isolation Valve operated - (Gate valve ID)	25
383	Isolation Valve operated - (Gate valve ID)	0
408	Isolation Valve operated - (Gate valve ID)	
301	Isolation Valve operated - (Gate valve ID)	0
405	Isolation Valve operated - (Gate valve ID)	100
407	Isolation Valve operated - (Gate valve ID)	0
103	Isolation Valve operated - (Gate valve ID)	0
426	Isolation Valve operated - (Gate valve ID)	0
427	Isolation Valve operated - (Gate valve ID)	0
404	Isolation Valve operated - (Gate valve ID)	100
260	Isolation Valve operated - (Gate valve ID)	0
423	Isolation Valve operated - (Gate valve ID)	0
402	Isolation Valve operated - (Gate valve ID)	0
418	Isolation Valve operated - (Gate valve ID)	
432	Isolation Valve operated - (Gate valve ID)	0
409	Isolation Valve operated - (Gate valve ID)	75
48	Isolation Valve operated - (Gate valve ID)	0
389	Isolation Valve operated - (Gate valve ID)	
342	Isolation Valve operated - (Gate valve ID)	0
424	Isolation Valve operated - (Gate valve ID)	0
417	Isolation Valve operated - (Gate valve ID)	75
141	Isolation Valve operated - (Gate valve ID)	0
422	Isolation Valve operated - (Gate valve ID)	0
420	Isolation Valve operated - (Gate valve ID)	0
55	Isolation Valve operated - (Gate valve ID)	
411	Isolation Valve operated - (Gate valve ID)	0

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APPENDIX G

Appendix G contains the break data compiled and created as part of the research and used in Chapters 3 and 4.

Laity View pipe break records with pipe identification numbers (1983-2004)

PIPE ID	CEP Check (break to current pipe or pipe replaced)	MATERIAL	SIZE	YEAR INSTALLED	REPLACED (FROM GIS)	DATE OF BREAK	COMMENTS
10012	current	AC	150	1975	N	14/04/1983	Water hammer caused by something plugging hydrant during line flushing of mains. Valved down pressure to control leakage, repaired damage section of pipe
13347	replaced	DI	75	1985	Y	08/03/1983	Failure of needle valve on pressure reducing valve caused 15# increase in line pressure. Cut out bad section and installed new 6' piece
13827	current	AC	250	1964	N	20/09/1983	
12535	replaced	DI	100	1986	Y	09/07/1984	100mm C/I w/m broken straight across - probable cause due to settlement of material under pipe.
13889	replaced	DI	150	1994	Y	08/05/1984	Repaired broken 150mm A/C w/m caused by overtightening of service corp. stop.
13895	replaced	DI	150	1994	Y	09/07/1984	Break occurred where sewer connection had been installed some time ago. Repaired 150mm A/C w/m by installing 150mm x 300mm repair clamp
13974	current	AC	150	1964	N	13/12/1984	Watermain broken due to settlement of old sanitary sewer trench. No property damage from break. Cut out damaged section of A/C w/m and repaired with D/I pipe.
12320	current	CI	150	1968	N	22/08/1985	
13980	replaced	DI	150	1994	Y	27/12/1985	150mm 2/m broke due to settlement of storm sewer trench.
12307	current	AC	150	1972	N	24/09/1986	150mm A/C w/m had been marked by back-hoe tooth when sewer connection was installed by Contractor a few years ago. Installed s/s repair clamp over horizontal crack.
12461	replaced	DI	200	1992	Y	26/12/1986	Old light C/I w/m split approx. 5' along side of pipe possibly from shoulder settlement. Repaired broken 20mm C/I w/m.

11386	current	AC	150	1971	N	14/04/1987	Repaired broken 150mm A/C w/m with s/s/ repair clamp which was damaged by shoulder settlement. (Note: pipe is deep to go under culvert).
12461	replaced	DI	100	1992	Y	21/01/1987	100mm C/I w/m broke straight across due to settlement of road shoulder where new sewerline was installed (Note: 3rd break). Repaired broken 100mm C/I w/m.
13974	current	AC	150	1964	N	09/09/1987	150mm A/C w/m broke due to settlement of shoulder. Installed s/s repair clamp where A/C pipe had cracked by connection tap.
14584	replaced	DI	100	1991	Y	20/02/1988	Shoulder of road settling where sewer had crossed line caused break of 100mm C/I w/m. (Exist 100 CI pipe segments abandoned).
12286	current	AC	150	1972	N	19/04/1989	Resident pounded rebar through collar in 150mm A/C w/m while fixing up end of his driveway culvert. Crew put on a rebard repair clamp & resident will clean up shoulder & seed area.
13974	current	AC	150	1964	N	16/02/1989	150mm A/C w/m broke where contractor had installed storm under a few years ago.
11405	current	AC	150	1975	N	14/06/1990	Repaired 6" A/C w/m with stainless steel repair clamp. (Leaking at collar).
13872	current	DI	100	1986	N	14/03/1990	Roads Foreman called out due to hole in road, undermined due to leak in waterline. Hole temporarily filled with 3/4" crushed rock and flasher put up. Repaired by Water Dept. on Apr. 20th.
12308	current	AC	18	1972	N	03/11/1991	Turned water off on the street and dug it out. Put on a stainless steel saddle with a 3/4 hole as the service saddle rusted away. Backfill.
12448	replaced	DI	100	1991	Y	31/01/1991	Pipe broke due to settlement of road shoulder.
11014	replaced	DI	150	1999	Y	08/06/1992	Repair watermain break.
11494	current	AC	200	1973	N	21/12/1992	Repair watermain break.
12017	current	DI	200	1982	N	20/02/1992	Repair watermain break.
12259	current	AC	150	1969	N	21/07/1992	Repair watermain break.
12437	current	AC	150	1964	N	08/06/1992	Repair watermain break.
14302	current	AC	150	1959	N	06/03/1992	Repair watermain break.

10118	current	CI	150	1959	N	24/09/1993	Repair watermain break.
11151	current	AC	250	1964	N	23/02/1993	Repair watermain break.
12308	current	AC	150	1972	N	02/04/1993	Repair watermain break.
12541	current	DI	200	1986	N	02/05/1993	Repair watermain break.
14548	current	DI	250	1974	N	08/10/1993	Repair watermain break.
10363	current	AC	250	1964	N	19/05/1994	Repaired AC waterline on 224 St where crossing for building was.
12284	current	AC	150	1969	N	12/02/1994	**COMPLETION TO REPAIRS & A LATER DATE
13896	current	AC	150	1973	N	20/06/1994	Possibly caused by construction near this location. (Note: large trucks hauling)
10019	current	AC	200	1964		10/02/1995	
11391	current	AC	150	1975	N	12/11/1995	
12254	current	AC	150	1969	N	13/12/1995	W/M broke where gas service had been installed (possibly hit by mole). Approx. 2' section blown out of pipe bottom - some houses in area flooded.
12254	current	AC	150	1969		14/12/1995	
12255	current	AC	150	1969		12/12/1995	
12284	current	AC	150	1969		05/12/1995	
12471	current	DI	150	1986		19/11/1995	
12471	current	DI	150	1986	N	18/11/1995	150mm DI W/M broke possibly due to electrolysis corrosion of W/M.
13986	current	AC	150	1969	N	12/01/1995	
10027	current	AC	200	1973	N	14/02/1993	Repair watermain break.
10269	current	AC	200	1959	N	02/12/1993	Repair watermain break.
12313	current	AC	150	1972	N	14/02/1993	Repair watermain break.
14523	current	AC	200	1973	N	17/12/1995	
12471	current	DI	150	1986	N	23/04/2002	Clay soil causing DI pipe to corrode which is causing holes in the pipe (put dechlorination bags in 2 spots; valved down W/M & crews arrived to repair W/M.
10118	current	CI	150	1959	N	15/02/2003	Broken copper waterline 3" from cork @ main (split copper). Large sinkhole at site. Old line, wear & tear, vibration caused? Found leak, placed dechl. pucks at c/b. Shut down main for approx. 1.5 hrs to repair service. Rep'd w 150 robar

11364	current	AC	150	1975	N	11/03/2001	old 150mm A/C main in poor shape (very soft in the area of this break). Cut out 4' section of A/C main & replaced with D/I pipe. Put cork in main for 12475-214 St. at the same time.
11408	current	AC	150	1977	N	21/04/2002	Leak appears to be on our side @ edge of s/w. Need hoe & crew to repair 100mm PVC pipe. Installed meter setter & box @ 21285 Douglas Ave.
12293	current	AC	150	1969	N	05/08/2002	Broken AC W/M @ intersection of 126 Ave. & Grace St. Crew & hoe arrived and repairs made.
12317	current	CI	200	1959	N	25/07/2002	Broken 200mm CI W/M. Repaired sidewalk as well.
11361	current	CI	150	1977	N	03/07/2003	Repaired with 150 AC robar repair clamp. AC broken at intersection of 124 Ave. & Laity St. going east on 124 Ave.

PIPE ID	Size	Pipe mat.	Year	Year Of Failure - all first breaks	Soil zone	Month Of Failure	Number of breaks (to 1999)	# of first breaks	# of 2nd breaks	Age cohort
12448	200	DI	1991	1991	30	1	1	0		1990-1994
13872	150	DI	1986	1990	30	3	1	1		1985-1989
12541	200	DI	1986	1993	40	5	1	1		1985-1989
10012	150	AC	1975	1983	30	4	1	1		1975-1979
12471	150	DI	1986	1995	30	11	1	1		1985-1989
12017	200	DI	1982	1992	40	2	1	1		1980-1984
12307	150	AC	1972	1986	30	9	1	1		1970-1974
11405	150	AC	1975	1990	60	6	1	1		1975-1979
11386	150	AC	1971	1987	30	4	1	1		1970-1974
12286	150	AC	1972	1989	30	4	1	1		1970-1974
12320	150	CI	1968	1985	30	8	1	1		1965-1969
12308	150	AC	1972	1991	30	11	2	1	1	1970-1974
13827	250	AC	1964	1983	30	9	1	1		1960-1964
11494	200	AC	1973	1992	40	12	1	1		1970-1974
14548	250	DI	1974	1993	40	10	1	1		1970-1974
11391	150	AC	1975	1995	30	11	1	1		1975-1979
10027	200	AC	1973	1993	40	2	1	1		1970-1974
13974	150	AC	1964	1984	40	12	3	1	2	1960-1964
12313	150	AC	1972	1993	30	2	1	1		1970-1974
13896	150	AC	1973	1994	30	6	1	1		1970-1974
14523	200	AC	1973	1995	40	12	1	1		1970-1974
12284	150	AC	1969	1994	30	2	2	1	1	1965-1969
12254	150	AC	1969	1995	30	12	2	1	1	1965-1969
12255	150	AC	1969	1995	30	12	1	1		1965-1969
13986	150	AC	1969	1995	30	1	1	1		1965-1969
12437	150	AC	1964	1992	60	6	1	1		1960-1964
11151	250	AC	1964	1993	60	2	1	1		1960-1964
10363	250	AC	1964	1994	30	5	1	1		1960-1964
10019	200	AC	1964	1995	40	2	1	1		1960-1964
14302	150	AC	1959	1992	40	3	1	1		1955-1959
10269	200	AC	1959	1993	30	12	1	1		1955-1959
10118	150	CI	1959	1993	30	9	1	1		1955-1959
12259	150	AC	1969	1992	30		1	1		1965-1969
12535	200	DI	1986	1984	30	7	1	0		1985-1989
13895	200	DI	1994	1984	30	7	1	0		1990-1994
13980	200	DI	1994	1985	30	12	1	0		1990-1994
12461	150	DI	1992	1986	30	12	2	0		1990-1994
14584	150	DI	1991	1988	40	2	1	0		1990-1994
13347	150	DI	1985	1983	60	3	1	0		1985-1989
13889	200	DI	1994	1984	60	5	1	0		1990-1994
11014	250	DI	1999	1992	60	6	1	0		1995-1999
							47	**32**	**5**	

Note: 47 breaks, 9 pipes unknown, 10 breaks unknown

Soil data codes

Type of soil	**Code**
Marine Clay (Clayey Marine)	30
Eolian Silt (Silty Eolian)	40
Clayey/Silty	60
Silty/Sandy	70
Sandy/Clayey	80
Marine Sand (Sandy Marine)	50

Note: The type of soil is defined by Luttmerding, 1980 and Luttmerding, 1981.

The following section is the break data file used for the experiments in Chapter 4. It also contains the data created as part of Chapter 3.

	A	H	I	J	K	L	M	N
1	WATERID	Size	Material	Material Code	Year	Year Of Failure	Month Of Failure	Years of Service
2	10010	150	AC	1	1975			
3	10011	250	DI	3	1994			
4	10012	150	AC	1	1975	1983	4	8
5	10013	150	DI	3	1983			
6	10014	150	DI	3	1983			
7	10015	250	AC	1	1974			
8	10017	200	AC	1	1964			
9	10018	200	AC	1	1964			
10	10019	200	AC	1	1964	1995	2	31
11	10020	200	AC	1	1982			
12	10027	200	AC	1	1973	1993	2	20
13	10068	250	DI	3	1997			
14	10118	150	CI	2	1959	1993	9	34
15	10119	250	AC	1	1959			
16	10120	250	AC	1	1959			
17	10121	150	DI	3	1985			
18	10122	200	DI	3	1984			
19	10194	250	AC	1	1959			
20	10195	250	AC	1	1959			
21	10266	150	DI	3	1982			
22	10267	250	DI	3	1978			
23	10268	250	DI	3	1982			
24	10269	200	AC	1	1959	1993	12	34
25	10274	200	AC	1	1973			
26	10275	200	AC	1	1973			
27	10276	150	DI	3	1986			
28	10277	200	AC	1	1973			
29	10344	150	AC	1	1975			
30	10363	250	AC	1	1964	1994	5	30
31	10377	250	DI	3	1999			
32	10397	200	DI	3	1995			
33	10411	150	DI	3	1981			
34	10497	250	DI	3	1999			
35	10552	200	DI	3	1995			
36	10640	150	DI	3	1983			
37	10673	250	AC	1	1974			
38	10736	150	DI	3	1981			
39	10809	150	DI	3	1995			
40	10810	200	DI	3	1975			
41	10811	200	DI	3	1995			
42	10812	200	DI	3	1995			
43	10954	150	DI	3	1984			
44	10970	250	DI	3	1999			
45	10989	150	DI	3	1999			
46	11014	250	DI	3	1999	1992	6	
47	11015	250	DI	3	1999			

	A	H	I	J	K	L	M	N
48	11016	250	DI	3	1999			
49	11017	250	DI	3	1999			
50	11078	200	DI	3	1984			
51	11114	200	DI	3	1976			
52	11150	250	AC	1	1964			
53	11151	250	AC	1	1964	1993	2	29
54	11152	150	DI	3	1991			
55	11153	150	AC	1	1972			
56	11351	150	AC	1	1959			
57	11352	150	DI	3	1992			
58	11353	150	DI	3	1991			
59	11354	150	DI	3	1991			
60	11357	150	DI	3	1980			
61	11358	150	DI	3	1994			
62	11360	150	DI	3	1982			
63	11361	150	CI	2	1977			
64	11362	150	CI	2	1977			
65	11363	150	CI	2	1977			
66	11364	150	AC	1	1975			
67	11365	150	DI	3	1990			
68	11366	150	DI	3	1991			
69	11367	150	DI	3	1991			
70	11368	150	DI	3	1990			
71	11369	150	DI	3	1991			
72	11370	150	DI	3	1991			
73	11373	200	DI	3	1982			
74	11375	200	DI	3	1982			
75	11376	200	DI	3	1982			
76	11377	150	AC	1	1964			
77	11379	200	DI	3	1997			
78	11380	200	DI	3	1982			
79	11381	200	DI	3	1982			
80	11382	200	DI	3	1980			
81	11383	200	DI	3	1980			
82	11385	200	DI	3	1991			
83	11386	150	AC	1	1971	1987	4	16
84	11387	150	DI	3	1987			
85	11388	150	DI	3	1982			
86	11389	150	DI	3	1982			
87	11390	150	AC	1	1975			
88	11391	150	AC	1	1975	1995	11	20
89	11392	150	AC	1	1975			
90	11393	150	AC	1	1975			
91	11394	150	AC	1	1975			
92	11397	150	DI	3	1986			
93	11398	150	DI	3	1986			
94	11399	150	AC	1	1975			
95	11400	150	DI	3	1986			
96	11401	150	AC	1	1975			
97	11402	150	AC	1	1975			
98	11403	150	AC	1	1975			

	A	H	I	J	K	L	M	N
99	11404	150	DI	3	1983			
100	11405	150	AC	1	1975	1990	6	15
101	11406	150	AC	1	1975			
102	11407	150	AC	1	1975			
103	11408	150	AC	1	1977			
104	11409	150	AC	1	1977			
105	11410	150	AC	1	1977			
106	11411	150	AC	1	1975			
107	11412	150	DI	3	1983			
108	11413	150	DI	3	1983			
109	11414	150	DI	3	1983			
110	11416	150	AC	1	1975			
111	11430	200	DI	3	1976			
112	11431	200	DI	3	1976			
113	11432	200	DI	3	1976			
114	11433	200	DI	3	1976			
115	11445	200	AC	1	1973			
116	11491	200	AC	1	1971			
117	11492	200	AC	1	1973			
118	11494	200	AC	1	1973	1992	12	19
119	11500	200	AC	1	1973			
120	11961	200	DI	3	1991			
121	11966	200	AC	1	1959			
122	11991	200	DI	3	1995			
123	11992	200	DI	3	1995			
124	12015	150	DI	3	1997			
125	12016	200	DI	3	1997			
126	12017	200	DI	3	1982	1992	2	10
127	12035	200	DI	3	1995			
128	12037	150	DI	3	1998			
129	12038	150	CI	2	1964			
130	12043	150	DI	3	1997			
131	12046	250	DI	3	1998			
132	12047	250	DI	3	1998			
133	12253	200	DI	3	1994			
134	12254	150	AC	1	1969	1995	12	26
135	12255	150	AC	1	1969	1995	12	26
136	12258	150	DI	3	1982			
137	12259	150	AC	1	1969	1992		23
138	12274	200	DI	3	1991			
139	12282	150	DI	3	1995			
140	12283	150	DI	3	1995			
141	12284	150	AC	1	1969	1994	2	25
142	12286	150	AC	1	1972	1989	4	17
143	12287	150	AC	1	1972			
144	12288	150	AC	1	1972			
145	12289	150	AC	1	1969			
146	12291	150	AC	1	1969			
147	12292	150	AC	1	1972			
148	12293	150	AC	1	1969			
149	12294	150	DI	3	1986			

	A	H	I	J	K	L	M	N
150	12297	150	AC	1	1972			
151	12298	150	DI	3	1994			
152	12299	200	DI	3	1994			
153	12301	150	DI	3	1994			
154	12302	150	DI	3	1994			
155	12303	100	CI	2	1965			
156	12305	200	DI	3	1994			
157	12307	150	AC	1	1972	1986	9	14
158	12308	150	AC	1	1972	1991	11	19
159	12309	150	AC	1	1972			
160	12310	150	AC	1	1972			
161	12311	150	AC	1	0			
162	12312	150	AC	1	1975			
163	12313	150	AC	1	1972	1993	2	21
164	12314	150	AC	1	1972			
165	12315	150	CI	2	0			
166	12316	200	CI	2	1956			
167	12317	200	CI	2	1959			
168	12319	150	AC	1	1964			
169	12320	150	CI	2	1968	1985	8	17
170	12321	150	DI	3	0			
171	12324	150	DI	3	1990			
172	12326	150	DI	3	1990			
173	12327	150	DI	3	1990			
174	12328	100	CI	2	0			
175	12329	150	DI	3	1990			
176	12330	150	DI	3	1990			
177	12331	150	DI	3	1997			
178	12332	150	AC	1	1975			
179	12333	150	AC	1	1972			
180	12334	150	AC	1	1972			
181	12335	150	AC	1	1980			
182	12337	150	DI	3	1978			
183	12338	150	DI	3	1994			
184	12339	150	AC	1	1964			
185	12340	200	AC	1	1973			
186	12341	200	AC	1	1973			
187	12342	200	AC	1	1973			
188	12343	150	DI	3	1986			
189	12344	150	DI	3	0			
190	12346	200	AC	1	1973			
191	12347	200	AC	1	1973			
192	12349	200	AC	1	1973			
193	12350	200	AC	1	1973			
194	12429	200	AC	1	1959			
195	12430	200	AC	1	1973			
196	12431	200	AC	1	1973			
197	12432	200	AC	1	1959			
198	12433	200	CI	2	1956			
199	12435	150	DI	3	1990			
200	12436	150	DI	3	1990			

	A	H	I	J	K	L	M	N
201	12437	150	AC	1	1964	1992	6	28
202	12439	250	DI	3	1982			
203	12441	150	CI	2	1975			
204	12442	250	DI	3	1978			
205	12443	250	DI	3	1978			
206	12445	250	DI	3	1978			
207	12446	150	AC	1	1969			
208	12447	200	DI	3	1991			
209	12448	200	DI	3	1991	1991	1	0
210	12450	200	DI	3	1991			
211	12451	200	DI	3	1991			
212	12452	150	AC	1	1964			
213	12453	250	DI	3	1978			
214	12456	150	DI	3	1982			
215	12457	150	DI	3	1982			
216	12458	150	DI	3	1992			
217	12459	150	DI	3	1992			
218	12460	150	DI	3	1992			
219	12461	150	DI	3	1992	1986	12	
220	12462	200	DI	3	1994			
221	12464	150	DI	3	1984			
222	12465	150	DI	3	1986			
223	12466	150	DI	3	1985			
224	12467	150	DI	3	1985			
225	12468	150	DI	3	1989			
226	12469	150	DI	3	1989			
227	12470	150	DI	3	1989			
228	12471	150	DI	3	1986	1995	11	9
229	12472	150	DI	3	1985			
230	12475	150	DI	3	1990			
231	12476	150	DI	3	1990			
232	12477	200	DI	3	1994			
233	12478	150	DI	3	1986			
234	12479	150	DI	3	1990			
235	12480	150	DI	3	1986			
236	12481	150	DI	3	1986			
237	12483	200	DI	3	1993			
238	12484	200	CI	2	1979			
239	12521	200	DI	3	1986			
240	12533	200	DI	3	1986			
241	12535	200	DI	3	1986	1984	7	
242	12537	200	DI	3	1986			
243	12539	200	DI	3	1986			
244	12540	200	DI	3	1986			
245	12541	200	DI	3	1986	1993	5	7
246	12542	200	DI	3	1986			
247	12543	150	AC	1	1964			
248	13053	300	STL	4	1978			
249	13054	300	STL	4	1978			
250	13061	250	DI	3	1982			
251	13091	200	DI	3	1993			

	A	H	I	J	K	L	M	N
252	13092	200	DI	3	1993			
253	13095	250	DI	3	1978			
254	13296	250	DI	3	1993			
255	13298	250	DI	3	1993			
256	13322	200	DI	3	1997			
257	13323	150	AC	1	1964			
258	13324	150	AC	1	1975			
259	13326	150	AC	1	1972			
260	13329	150	DI	3	1986			
261	13330	150	DI	3	1986			
262	13337	250	DI	3	1993			
263	13338	250	DI	3	1993			
264	13339	250	DI	3	1993			
265	13340	250	DI	3	1993			
266	13342	250	AC	1	1964			
267	13343	250	DI	3	1993			
268	13344	200	DI	3	1993			
269	13345	200	DI	3	1993			
270	13346	150	DI	3	1985			
271	13347	150	DI	3	1985	1983	3	
272	13348	250	DI	3	1993			
273	13349	200	DI	3	1993			
274	13350	150	AC	1	1964			
275	13354	150	DI	3	1996			
276	13355	150	DI	3	1996			
277	13375	200	DI	3	1978			
278	13388	150	DI	3	1995			
279	13390	200	DI	3	1995			
280	13391	150	DI	3	1982			
281	13827	250	AC	1	1964	1983	9	19
282	13828	250	AC	1	1964			
283	13829	250	AC	1	1964			
284	13830	200	DI	3	1993			
285	13833	200	DI	3	1986			
286	13868	200	DI	3	1993			
287	13869	150	DI	3	1990			
288	13870	150	DI	3	1990			
289	13871	150	DI	3	1994			
290	13872	150	DI	3	1986	1990	3	4
291	13873	200	DI	3	1984			
292	13874	200	DI	3	1984			
293	13875	150	DI	3	1986			
294	13876	150	DI	3	1986			
295	13877	150	DI	3	1984			
296	13878	150	DI	3	1984			
297	13879	200	DI	3	1984			
298	13880	200	DI	3	1984			
299	13881	200	DI	3	1988			
300	13882	200	DI	3	1986			
301	13883	150	DI	3	1989			
302	13884	150	DI	3	1989			

	A	H	I	J	K	L	M	N
303	13885	150	DI	3	1988			
304	13886	150	DI	3	1985			
305	13887	150	DI	3	1985			
306	13888	150	DI	3	1985			
307	13889	200	DI	3	1994	1984	5	
308	13890	200	DI	3	1994			
309	13891	200	DI	3	1994			
310	13892	150	DI	3	1994			
311	13893	200	DI	3	1994			
312	13894	200	DI	3	1994			
313	13895	200	DI	3	1994	1984	7	
314	13896	150	AC	1	1973	1994	6	21
315	13897	150	AC	1	1973			
316	13898	150	DI	3	1983			
317	13899	150	DI	3	1983			
318	13900	150	DI	3	1982			
319	13903	150	DI	3	1988			
320	13905	150	DI	3	1978			
321	13906	150	DI	3	1982			
322	13907	150	DI	3	1983			
323	13908	150	DI	3	1990			
324	13909	150	CI	2	1999			
325	13952	150	AC	1	1971			
326	13953	150	DI	3	1987			
327	13954	150	AC	1	1964			
328	13955	150	AC	1	1964			
329	13956	150	AC	1	1964			
330	13957	150	AC	1	1964			
331	13958	150	AC	1	1964			
332	13959	150	AC	1	1964			
333	13962	150	AC	1	1964			
334	13963	150	DI	3	1990			
335	13964	150	DI	3	1990			
336	13965	150	DI	3	1990			
337	13967	150	DI	3	1990			
338	13968	150	DI	3	1990			
339	13969	150	DI	3	1990			
340	13970	150	AC	1	1964			
341	13971	150	AC	1	1964			
342	13974	150	AC	1	1964	1984	12	20
343	13975	150	DI	3	1979			
344	13976	150	DI	3	1979			
345	13977	150	AC	1	1964			
346	13978	150	AC	1	1964			
347	13979	150	DI	3	1994			
348	13980	200	DI	3	1994	1985	12	
349	13981	200	DI	3	1994			
350	13982	150	DI	3	1991			
351	13983	150	DI	3	1991			
352	13984	150	DI	3	1991			
353	13985	150	AC	1	1972			

	A	H	I	J	K	L	M	N
354	13986	150	AC	1	1969	1995	1	26
355	13987	150	AC	1	1969			
356	13990	200	DI	3	1986			
357	13991	200	DI	3	1986			
358	13996	150	AC	1	1972			
359	13997	150	AC	1	1972			
360	13998	150	DI	3	1995			
361	14260	250	DI	3	1974			
362	14264	250	DI	3	1994			
363	14265	250	DI	3	1997			
364	14266	250	DI	3	1997			
365	14267	250	DI	3	1997			
366	14268	250	DI	3	1997			
367	14270	250	DI	3	1997			
368	14271	250	DI	3	1997			
369	14272	250	DI	3	1997			
370	14281	200	DI	3	1996			
371	14282	200	DI	3	1996			
372	14283	200	DI	3	1996			
373	14284	150	DI	3	1982			
374	14285	150	DI	3	1996			
375	14301	250	DI	3	1997			
376	14302	150	AC	1	1959	1992	3	33
377	14303	250	DI	3	1997			
378	14304	200	DI	3	1997			
379	14305	150	DI	3	1997			
380	14346	250	DI	3	1974			
381	14347	150	DI	3	1995			
382	14374	200	DI	3	1991			
383	14375	150	DI	3	1981			
384	14523	200	AC	1	1973	1995	12	22
385	14524	200	AC	1	1973			
386	14548	250	DI	3	1974	1993	10	19
387	14554	250	AC	1	1974			
388	14555	250	DI	3	1998			
389	14557	150	DI	3	1986			
390	14558	150	DI	3	1986			
391	14559	150	DI	3	1983			
392	14560	150	AC	1	1975			
393	14561	150	AC	1	1975			
394	14562	150	AC	1	1975			
395	14563	150	AC	1	1975			
396	14564	150	AC	1	1975			
397	14565	150	AC	1	1975			
398	14566	150	DI	3	1986			
399	14567	150	DI	3	1986			
400	14569	150	DI	3	1986			
401	14570	150	DI	3	1986			
402	14571	150	DI	3	1986			
403	14572	150	DI	3	1982			
404	14573	150	DI	3	1982			

	A	H	I	J	K	L	M	N
405	14574	250	DI	3	1994			
406	14575	150	AC	1	1975			
407	14576	150	DI	3	1982			
408	14577	200	DI	3	1991			
409	14578	200	DI	3	1980			
410	14579	150	DI	3	1994			
411	14580	200	DI	3	1982			
412	14581	200	DI	3	1982			
413	14582	150	DI	3	1991			
414	14583	150	DI	3	1991			
415	14584	150	DI	3	1991	1988	2	
416	14585	150	DI	3	1991			
417	14586	250	DI	3	1974			
418	14587	250	DI	3	1974			
419	14588	250	DI	3	1974			
420	14589	150	DI	3	1981			
421	14590	250	DI	3	1974			
422	14591	150	DI	3	1991			
423	14592	150	DI	3	1991			
424	14593	150	DI	3	1991			
425	14594	150	DI	3	1991			
426	14595	150	DI	3	1992			
427	14721	200	DI	3	1991			
428	14754	200	DI	3	1986			
429	14756	200	DI	3	1988			
430	14768	250	DI	3	1978			
431								
432								
433								
434								
435								
436								
437								

	O	P	Q	R	S	T	U
1	Years In Ground	Length (metres)	Number of breaks to 1999	Has pipe been replaced since break	soil zone type	Number of soil zones	Under boulevard or road
2	24	9.6			30	1	B
3	5	11.0			40	1	B
4	24	143.9	1	no	30	2	B
5	16	95.4			30	1	B
6	16	131.9			30	1	B
7	25	7.3			40	1	R
8	35	2.1			40	1	B
9	35	10.6			40	1	B
10	35	4.0	1	no	40	1	B
11	17	11.7			40	1	B
12	26	87.3	1	no	40	1	B
13	2	60.3			40	1	R
14	40	388.8	1	no	30	1	B
15	40	9.5			30	1	B
16	40	89.0			30	1	B
17	14	101.6			30	2	B
18	15	83.7			30	1	R
19	40	142.3			30	1	B
20	40	82.1			30	1	B
21	17	150.7			30	1	R
22	21	13.0			30	1	B
23	17	3.4			30	1	B
24	40	79.7	1	no	30	1	B
25	26	36.9			30	1	B
26	26	50.2			40	1	B
27	13	3.5			40	1	B
28	26	187.1			40	1	B
29	24	37.2			30	1	B
30	35	6.9	1	no	30	1	B
31	0	96.3			60	2	B
32	4	81.5			30	1	R
33	18	73.1			40	1	R
34	0	12.0			30	1	R
35	4	100.0			30	1	R
36	16	3.2			30	1	B
37	25	88.0			30	1	B
38	18	59.0			40	1	B
39	4	12.9			30	1	R
40	24	3.5			30	1	R
41	4	29.4			30	1	R
42	4	32.6			30	1	R
43	15	59.8			30	1	B
44	0	50.6			30	1	B
45	0	151.9			40	1	B
46	0	80.2	1	replaced	60	2	B
47	0	49.7			60	2	B

	O	P	Q	R	S	T	U
48	0	48.8			30	2	B
49	0	92.9			30	1	B
50	15	141.8			30	1	B
51	23	76.7			40	1	R
52	35	7.6			30	1	B
53	35	387.8	1	no	60	3	B
54	8	21.8			30	1	B
55	27	309.0			30	2	B
56	40	81.2			40	1	B
57	7	171.0			40	1	B
58	8	91.5			40	1	R
59	8	95.1			40	1	R
60	19	156.3			70	2	B
61	5	150.3			40	1	R
62	17	5.7			40	1	B
63	22	10.7			40	1	B
64	22	77.7			40	1	B
65	22	149.3			40	1	B
66	24	143.7			40	1	B
67	9	14.7			40	1	B
68	8	118.6			40	1	B
69	8	86.5			40	1	B
70	9	7.0			40	1	R
71	8	113.1			40	1	B
72	8	98.4			40	1	R
73	17	93.5			40	1	B
74	17	44.2			40	1	B
75	17	90.0			40	1	B
76	35	358.9			40	1	B
77	2	3.5			40	1	B
78	17	156.2			40	1	B
79	17	15.5			40	1	B
80	19	17.1			30	1	R
81	19	133.8			30	1	B
82	8	3.4			30	1	B
83	28	339.9	1	no	30	1	B
84	12	110.9			30	1	R
85	17	3.5			30	1	B
86	17	85.8			30	1	R
87	24	73.2			30	1	B
88	24	79.0	1	no	30	1	B
89	24	15.5			30	1	B
90	24	66.1			60	2	B
91	24	5.6			30	1	B
92	13	5.5			30	2	R
93	13	50.3				1	B
94	24	17.4				1	**B**
95	13	43.1			30	2	B
96	24	41.0			30	2	B
97	24	24.3			30	1	B
98	24	66.5			30	2	B

	O	P	Q	R	S	T	U
99	16	32.4			30	1	B
100	24	142.3	1	no	60	2	B
101	24	53.3			30	1	B
102	24	1.4			30	1	B
103	22	184.3			40	1	B
104	22	19.8			40	1	B
105	22	15.6			40	1	B
106	24	64.8			60	2	B
107	16	125.4			30	1	B
108	16	46.0			30	1	R
109	16	121.5			30	1	B
110	24	61.1			30	1	B
111	23	286.8			60	3	R
112	23	4.8			40	1	R
113	23	93.4			30	1	R
114	23	336.4			30	2	R
115	26	9.6			40	1	B
116	28	10.4			40	1	R
117	26	6.1			40	1	R
118	26	238.5	1	no	40	1	B
119	26	95.1			40	1	R
120	8	8.7			30	1	B
121	40	15.0			40	1	R
122	4	235.4			40	1	B
123	4	2.0			40	1	R
124	2	7.0			40	1	B
125	2	22.5			40	1	B
126	17	28.8	1	no	40	1	R
127	4	3.1			40	1	R
128	1	77.4			40	1	R
129	35	50.2			40	1	B
130	2	11.8			40	1	R
131	1	14.3			40	1	R
132	1	7.2			40	1	R
133	5	142.4			40	1	R
134	30	165.0	2	no	30	2	R
135	30	259.8	1	no	30	2	R
136	17	20.6			30	1	R
137	30	231.1	1	no	30	1	B
138	8	5.6			30	1	B
139	4	139.5			30	2	B
140	4	7.6			30	1	B
141	30	162.0	2	no	30	1	B
142	27	206.7	1	no	30	1	B
143	27	6.8			30	1	B
144	27	10.9			30	1	R
145	30	95.5			30	1	B
146	30	94.7			30	1	B
147	27	7.4			30	1	B
148	30	175.6			30	1	B
149	13	52.6			30	1	R

	O	P	Q	R	S	T	U
150	27	53.2			40	1	B
151	5	19.4			30	1	B
152	5	66.2			30	1	R
153	5	20.4			30	1	B
154	5	25.9			40	1	R
155	34	32.3			30	1	B
156	5	42.4			30	1	R
157	27	150.3	1	no	30	1	B
158	27	137.1	2	no	30	1	R
159	27	11.3			30	1	B
160	27	68.7			30	1	B
161		4.8			30	1	B
162	24	5.4			30	1	B
163	27	76.9	1	no	30	1	B
164	27	149.2			30	1	B
165		2.1			30	1	B
166	43	3.5			30	1	R
167	40	385.2			30	1	B
168	35	6.6			30	1	B
169	31	69.4	1	no	30	1	R
170		3.5			30	1	R
171	9	11.1			40	1	R
172	9	96.9			40	1	R
173	9	12.4			40	1	R
174		4.7			40	1	B
175	9	114.2			40	1	R
176	9	22.4			40	1	R
177	2	20.7			40	1	R
178	24	135.7			40	1	B
179	27	54.9			40	1	B
180	27	61.3			40	1	B
181	19	34.8			40	1	B
182	21	195.2			30	1	B
183	5	100.6			30	1	R
184	35	85.4			40	1	B
185	26	4.2			40	1	B
186	26	17.4			40	1	R
187	26	113.6			40	1	R
188	13	96.3			40	1	B
189		14.3			40	1	R
190	26	141.8			40	1	B
191	26	7.7			40	1	B
192	26	63.0			30	1	B
193	26	76.3			60	2	B
194	40	7.4			30	1	R
195	26	15.9			30	1	R
196	26	15.7			30	1	R
197	40	3.4			30	1	R
198	43	2.5			30	1	R
199	9	161.3			30	1	B
200	9	69.1			60	2	R

	O	P	Q	R	S	T	U
201	35	388.9	1	no	60	2	B
202	17	2.0			30	1	R
203	24	19.0			30	1	R
204	21	199.8			30	1	B
205	21	13.1			30	1	R
206	21	87.7			30	1	B
207	30	3.5			30	1	R
208	8	87.8			30	1	R
209	8	82.6	1	replaced	30	1	B
210	8	160.1			30	1	B
211	8	40.9			30	1	R
212	35	3.6			30	1	B
213	21	41.0			30	1	B
214	17	41.5			60	2	B
215	17	51.6			30	1	B
216	7	73.0			30	1	B
217	7	19.0			30	2	B
218	7	75.3			30	1	B
219	7	139.4	2	replaced	30	1	B
220	5	98.1			30	1	R
221	15	81.9			30	1	R
222	13	72.2			30	1	R
223	14	68.7			30	1	R
224	14	93.4			30	1	B
225	10	62.7			30	1	R
226	10	81.9			30	1	R
227	10	63.4			30	1	R
228	13	89.5	**1**	no	30	1	B
229	14	91.5			30	1	B
230	9	5.0			30	1	B
231	9	97.9			30	1	R
232	5	75.6			30	1	R
233	13	71.1			30	1	R
234	9	7.1			30	1	R
235	13	16.6			30	1	R
236	13	20.3			30	1	R
237	6	25.8			30	1	B
238	20	121.4			30	1	B
239	13	8.5			30	1	R
240	13	4.1			40	1	R
241	13	112.4	1	replaced	30	1	R
242	13	75.1			30	2	R
243	13	65.5			30	1	R
244	13	104.1			60	2	R
245	13	8.1	1	no	40	1	R
246	13	6.3			40	1	R
247	35	17.0			30	1	R
248	21	17.0			30	1	R
249	21	7.1			30	1	R
250	17	3.5			30	1	R
251	6	6.3			30	1	R

	O	P	Q	R	S	T	U
252	6	13.4			30	1	R
253	21	35.6			30	1	B
254	6	66.3			30	1	R
255	6	169.6			30	1	R
256	2	18.9			40	1	R
257	35	58.1			40	1	3 (closed roac
258	24	113.8			40	1	B
259	27	208.8			30	1	B
260	13	30.8			30	1	B
261	13	134.1			30	2	B
262	6	2.9			30	1	R
263	6	119.2			60	2	R
264	6	33.1			30	1	R
265	6	28.7			30	1	R
266	35	53.1			30	1	B
267	6	1.7			30	1	R
268	6	23.4			30	1	R
269	6	31.8			30	1	R
270	14	102.2			30	1	B
271	14	90.3	1	replaced	60	2	R
272	6	59.5			30	1	R
273	6	42.6			30	1	B
274	35	88.7			30	1	R
275	3	112.2			40	1	B
276	3	139.2			40	1	B
277	21	10.8			30	1	R
278	4	129.4			40	1	B
279	4	166.6			30	1	R
280	17	54.4			30	1	R
281	35	13.2	1	no	30	1	B
282	35	139.8			30	1	B
283	35	37.4			30	1	B
284	6	107.9			60	2	R
285	13	187.6			30	2	B
286	6	431.4			30	1	B
287	9	50.9			30	1	B
288	9	131.0			30	2	B
289	5	68.7			30	1	B
290	13	173.8	1	no	30	1	B
291	15	4.5			30	1	R
292	15	129.4			30	1	R
293	13	133.7			30	2	R
294	13	232.3			30	1	R
295	15	169.5			60	2	B
296	15	202.3			60	2	B
297	15	91.5			30	1	R
298	15	70.2			30	1	R
299	11	105.9			30	1	R
300	13	53.6			30	1	R
301	10	109.9			30	1	B
302	10	20.3			30	1	B

	O	P	Q	R	S	T	U
303	11	127.2			30	1	B
304	14	77.3			30	1	B
305	14	101.5			30	1	B
306	14	84.5			30	1	B
307	5	164.2	1	replaced	60	3	R
308	5	6.8			30	1	R
309	5	92.2			30	2	R
310	5	26.2			30	2	R
311	5	145.0			30	1	R
312	5	45.1			30	1	R
313	5	97.3	1	replaced	30	1	R
314	26	113.4	1	no	30	2	B
315	26	34.6			30	1	B
316	16	58.1			30	1	B
317	16	104.7			30	1	B
318	17	46.5			30	1	R
319	11	169.8			60	2	B
320	21	15.2			30	1	R
321	17	76.6			30	1	B
322	16	85.7			60	2	B
323	9	163.9			30	1	B
324	0	4.2			30	1	B
325	28	206.7			30	1	B
326	12	133.0			30	1	B
327	35	265.2			60	2	B
328	35	140.6			40	1	B
329	35	362.5			40	1	B
330	35	4.6			40	1	3 (closed road
331	35	6.6			40	1	R
332	35	23.7			40	1	R
333	35	9.7			40	1	B
334	9	27.1			40	1	B
335	9	58.9			40	1	B
336	9	19.6			40	1	R
337	9	80.8			40	1	B
338	9	50.2			40	1	B
339	9	137.2			40	1	B
340	35	75.1			40	1	B
341	35	73.5			60	2	R
342	35	266.3	3	no	40	1	B
343	20	58.4			30	1	R
344	20	138.9			30	2	R
345	35	18.2			30	1	R
346	35	1.5			30	1	B
347	5	30.6			30	1	R
348	5	113.3	1	replaced	30	1	R
349	5	164.0			60	2	R
350	8	23.6			30	1	B
351	8	163.5			30	2	B
352	8	18.1			30	1	B
353	27	18.0			30	1	B

	O	P	Q	R	S	T	U
354	30	120.1	1	no	30	2	B
355	30	102.2			30	1	B
356	13	63.3			30	1	R
357	13	74.0			30	1	R
358	27	79.8			30	1	B
359	27	230.5			30	2	B
360	4	9.2			30	1	B
361	25	72.2			40	1	R
362	5	12.1			40	1	R
363	2	143.0			40	1	R
364	2	1.3			40	1	R
365	2	32.3			40	1	R
366	2	99.5			40	1	R
367	2	98.5			40	1	R
368	2	19.8			40	1	R
369	2	115.6			40	1	R
370	3	85.3			40	1	B
371	3	8.6			40	1	R
372	3	8.8			40	1	R
373	17	37.9			40	1	B
374	3	6.0			40	1	R
375	2	73.7			40	1	R
376	40	397.3	1	no	40	1	B
377	2	118.4			40	1	R
378	2	9.2			40	1	R
379	2	28.6			40	1	B
380	25	82.8			40	1	R
381	4	118.4			40	1	R
382	8	14.3			30	1	R
383	18	124.9			40	1	R
384	26	147.0	1	no	40	1	B
385	26	78.4			40	1	R
386	25	252.3	1	no	40	1	R
387	25	155.2			40	1	R
388	1	5.5			40	1	R
389	13	161.0			30	2	B
390	13	23.0			30	1	B
391	16	48.4			30	1	B
392	24	178.0			30	1	B
393	24	16.5			30	1	R
394	24	73.1			30	1	B
395	24	16.2			30	1	R
396	24	38.0			30	1	B
397	24	21.3			30	1	R
398	13	12.3			30	1	B
399	13	151.4			30	2	R
400	13	173.1			30	2	B
401	13	91.9			30	1	B
402	13	30.0			30	1	B
403	17	51.4			30	2	R
404	17	8.9			30	1	R

	O	P	Q	R	S	T	U
405	5	22.5			40	1	R
406	24	152.3			60	2	B
407	17	9.4			30	1	R
408	8	259.8			30	1	B
409	19	189.8			30	1	B
410	5	20.3			40	1	B
411	17	158.0			40	1	B
412	17	81.7			40	1	B
413	8	177.6			40	1	R
414	8	217.5			40	1	R
415	8	16.8	1	replaced	40	1	R
416	8	193.4			40	1	R
417	25	52.5			40	1	R
418	25	44.4			40	1	R
419	25	51.1			40	1	R
420	18	113.4			40	1	B
421	25	47.8			40	1	R
422	8	141.1			40	1	B
423	8	46.4			40	1	B
424	8	74.3			40	1	B
425	8	123.9			40	1	B
426	7	156.8			40	1	B
427	8	70.0			30	2	B
428	13	30.0			40	1	R
429	11	126.9			30	1	R
430	21	2.1			30	1	R
431		total breaks	47				
432							
433							
434							
435							
436							
437							

	V	W	X	Y	Z	AA	AB
1	**Surface material**	**traffic classification**	**Pipe lining**	**Bedding**	**Backfill**	**Pipe protection**	**C factor**
2	asphalt	local	unlined	sand	sand	none	105
3	asphalt	local	CML	gravel	crush gravel	wrapped	136
4	gravel/grass	no traffic	unlined	sand	sand	none	105
5	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	113
6	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	111
7	asphalt	collector	unlined	sand	sand	none	118
8	asphalt	local	unlined	sand	sand	none	115
9	asphalt	local	unlined	sand	sand	none	115
10	asphalt	local	unlined	sand	sand	none	115
11	asphalt	local	unlined	sand	sand	none	122
12	asphalt	local	unlined	sand	sand	none	115
13	asphalt	collector	CML	gravel	crush gravel	wrapped	136
14	gravel/grass	no traffic	nil	native	native	none	95
15	asphalt	local	unlined	sand	sand	none	122
16	asphalt	local	unlined	sand	sand	none	122
17	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	116
18	asphalt	local	CML	gravel	crush gravel	wrapped	121
19	asphalt	local	unlined	sand	sand	none	115
20	asphalt	local	unlined	sand	sand	none	115
21	asphalt	local	CML	gravel	crush gravel	wrapped	111
22	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	118
23	asphalt	local	CML	gravel	crush gravel	wrapped	132
24	asphalt	local	unlined	sand	sand	none	115
25	concrete	local	unlined	sand	sand	none	115
26	concrete	local	unlined	sand	sand	none	115
27	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	
28	asphalt	local	unlined	sand	sand	none	115
29	gravel/grass	no traffic	unlined	sand	sand	none	105
30	concrete	local	unlined	sand	sand	none	115
31	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	124
32	asphalt	collector	CML	gravel	crush gravel	wrapped	105
33	asphalt	local	CML	gravel	crush gravel	wrapped	114
34	asphalt	local	CML	gravel	crush gravel	wrapped	111
35	asphalt	collector	CML	gravel	crush gravel	wrapped	105
36	asphalt	local	CML	gravel	crush gravel	wrapped	113
37	gravel/grass	no traffic	unlined	sand	sand	none	115
38	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	
39	asphalt	local	CML	gravel	crush gravel	wrapped	118
40	asphalt	collector	CML	gravel	crush gravel	wrapped	105
41	asphalt	collector	CML	gravel	crush gravel	wrapped	132
42	asphalt	collector	CML	gravel	crush gravel	wrapped	121
43	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	114
44	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	111
45	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	138
46	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	105
47	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	105

	V	W	X	Y	Z	AA	AB
48	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	105
49	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	105
50	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	132
51	asphalt	collector	CML	gravel	crush gravel	wrapped	118
52	gravel/grass	no traffic	unlined	sand	sand	none	126
53	gravel/grass	no traffic	unlined	sand	sand	none	115
54	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	100
55	gravel/grass	no traffic	unlined	sand	sand	none	105
56	gravel/grass	no traffic	unlined	sand	sand	none	
57	gravel/grass	parking	CML	gravel	crush gravel	wrapped	127
58	asphalt	local	CML	gravel	crush gravel	wrapped	126
59	asphalt	local	CML	gravel	crush gravel	wrapped	126
60	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	
61	asphalt	local	CML	gravel	crush gravel	wrapped	110
62	asphalt	local	CML	gravel	crush gravel	wrapped	110
63	gravel/grass	no traffic	nil	native	native	none	106
64	gravel/grass	no traffic	nil	native	native	none	99
65	gravel/grass	no traffic	nil	native	native	none	106
66	gravel/grass	no traffic	unlined	sand	sand	none	105
67	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	124
68	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	124
69	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	124
70	asphalt	local	CML	gravel	crush gravel	wrapped	124
71	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	124
72	asphalt	local	CML	gravel	crush gravel	wrapped	126
73	gravel/grass	parking	CML	gravel	crush gravel	wrapped	118
74	gravel/grass	parking	CML	gravel	crush gravel	wrapped	136
75	gravel/grass	parking	CML	gravel	crush gravel	wrapped	136
76	gravel/grass	no traffic	unlined	sand	sand	none	105
77	gravel/grass	parking	CML	gravel	crush gravel	wrapped	136
78	gravel/grass	parking	CML	gravel	crush gravel	wrapped	136
79	gravel/grass	parking	CML	gravel	crush gravel	wrapped	136
80	asphalt	arterial	CML	gravel	crush gravel	wrapped	128
81	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	128
82	asphalt	local	CML	gravel	crush gravel	wrapped	110
83	gravel/grass	no traffic	unlined	sand	sand	none	105
84	asphalt	local	CML	gravel	crush gravel	wrapped	
85	asphalt	local	CML	gravel	crush gravel	wrapped	111
86	asphalt	collector	CML	gravel	crush gravel	wrapped	111
87	gravel/grass	no traffic	unlined	sand	sand	none	105
88	gravel/grass	no traffic	unlined	sand	sand	none	105
89	gravel/grass	no traffic	unlined	sand	sand	none	105
90	gravel/grass	no traffic	unlined	sand	sand	none	
91	concrete	local	unlined	sand	sand	none	105
92	asphalt	local	CML	gravel	crush gravel	wrapped	118
93	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	118
94	gravel/grass	**no traffic**	unlined	sand	sand	none	
95	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	118
96	gravel/grass	no traffic	unlined	sand	sand	none	105
97	gravel/grass	no traffic	unlined	sand	sand	none	105
98	gravel/grass	no traffic	unlined	sand	sand	none	108

	V	W	X	Y	Z	AA	AB
99	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	118
100	gravel/grass	no traffic	unlined	sand	sand	none	108
101	gravel/grass	no traffic	unlined	sand	sand	none	
102	gravel/grass	no traffic	unlined	sand	sand	none	105
103	gravel/grass	no traffic	unlined	sand	sand	none	108
104	gravel/grass	no traffic	unlined	sand	sand	none	108
105	gravel/grass	no traffic	unlined	sand	sand	none	108
106	gravel/grass	no traffic	unlined	sand	sand	none	105
107	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	118
108	asphalt	local	CML	gravel	crush gravel	wrapped	
109	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	118
110	gravel/grass	no traffic	unlined	sand	sand	none	105
111	asphalt	collector	CML	gravel	crush gravel	wrapped	114
112	asphalt	collector	CML	gravel	crush gravel	wrapped	118
113	asphalt	collector	CML	gravel	crush gravel	wrapped	114
114	asphalt	collector	CML	gravel	crush gravel	wrapped	116
115	asphalt	local	unlined	sand	sand	none	115
116	asphalt	collector	unlined	sand	sand	none	115
117	asphalt	local	unlined	sand	sand	none	115
118	concrete	local	unlined	sand	sand	none	115
119	asphalt	local	unlined	sand	sand	none	115
120	asphalt	local	CML	gravel	crush gravel	wrapped	129
121	asphalt	local	unlined	sand	sand	none	115
122	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	110
123	asphalt	local	CML	gravel	crush gravel	wrapped	
124	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	100
125	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	136
126	asphalt	local	CML	gravel	crush gravel	wrapped	136
127	asphalt	local	CML	gravel	crush gravel	wrapped	
128	asphalt	local	CML	gravel	crush gravel	wrapped	
129	gravel/grass	no traffic	nil	native	native	none	99
130	asphalt	local	CML	gravel	crush gravel	wrapped	127
131	asphalt	collector	CML	gravel	crush gravel	wrapped	
132	asphalt	collector	CML	gravel	crush gravel	wrapped	
133	asphalt	collector	CML	gravel	crush gravel	wrapped	133
134	asphalt	local	unlined	sand	sand	none	105
135	asphalt	local	unlined	sand	sand	none	105
136	asphalt	collector	CML	gravel	crush gravel	wrapped	129
137	oncrete sidewa	no traffic	unlined	sand	sand	none	115
138	gravel/grass	local	CML	gravel	crush gravel	wrapped	129
139	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	100
140	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	100
141	gravel/grass	no traffic	unlined	sand	sand	none	105
142	gravel/grass	no traffic	unlined	sand	sand	none	
143	gravel/grass	no traffic	unlined	sand	sand	none	105
144	asphalt	local	unlined	sand	sand	none	105
145	concrete	no traffic	unlined	sand	sand	none	105
146	gravel/grass	no traffic	unlined	sand	sand	none	105
147	concrete	no traffic	unlined	sand	sand	none	105
148	concrete	no traffic	unlined	sand	sand	none	105
149	asphalt	local	CML	gravel	crush gravel	wrapped	

	V	W	X	Y	Z	AA	AB
150	gravel/grass	no traffic	unlined	sand	sand	none	130
151	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	130
152	asphalt	collector	CML	gravel	crush gravel	wrapped	133
153	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	100
154	asphalt	collector	CML	gravel	crush gravel	wrapped	132
155	gravel/grass	no traffic	nil	native	native	none	
156	asphalt	collector	CML	gravel	crush gravel	wrapped	133
157	gravel/grass	no traffic	unlined	sand	sand	none	105
158	asphalt	local	unlined	sand	sand	none	105
159	gravel/grass	no traffic	unlined	sand	sand	none	105
160	gravel/grass	no traffic	unlined	sand	sand	none	105
161	gravel/grass	no traffic	unlined	sand	sand	none	
162	gravel/grass	no traffic	unlined	sand	sand	none	105
163	gravel/grass	no traffic	unlined	sand	sand	none	
164	gravel/grass	no traffic	unlined	sand	sand	none	105
165	gravel/grass	local	nil	native	native	none	
166	asphalt	local	nil	native	native	none	105
167	gravel/grass	local	nil	native	native	none	105
168	asphalt	no traffic	unlined	sand	sand	none	105
169	asphalt	parking lot	nil	native	native	none	129
170	asphalt	parking lot	CML	gravel	crush gravel	wrapped	
171	asphalt	local	CML	gravel	crush gravel	wrapped	124
172	asphalt	local	CML	gravel	crush gravel	wrapped	124
173	asphalt	local	CML	gravel	crush gravel	wrapped	130
174	gravel/grass	no traffic	nil	native	native	none	
175	asphalt	local	CML	gravel	crush gravel	wrapped	124
176	asphalt	local	CML	gravel	crush gravel	wrapped	130
177	asphalt	local	CML	gravel	crush gravel	wrapped	126
178	gravel/grass	no traffic	unlined	sand	sand	none	115
179	gravel/grass	no traffic	unlined	sand	sand	none	
180	gravel/grass	no traffic	unlined	sand	sand	none	105
181	gravel/grass	no traffic	unlined	sand	sand	none	
182	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	100
183	asphalt	local	CML	gravel	crush gravel	wrapped	
184	gravel/grass	no traffic	unlined	sand	sand	none	105
185	asphalt	local	unlined	sand	sand	none	115
186	asphalt	local	unlined	sand	sand	none	115
187	asphalt	local	unlined	sand	sand	none	115
188	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	
189	asphalt	local	CML	gravel	crush gravel	wrapped	
190	concrete	local	unlined	sand	sand	none	115
191	asphalt	local	unlined	sand	sand	none	115
192	concrete	local	unlined	sand	sand	none	115
193	concrete	local	unlined	sand	sand	none	115
194	asphalt	local	unlined	sand	sand	none	115
195	asphalt	local	unlined	sand	sand	none	115
196	asphalt	local	unlined	sand	sand	none	115
197	asphalt	local	unlined	sand	sand	none	115
198	asphalt	local	nil	native	native	none	105
199	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	100
200	asphalt	local	CML	gravel	crush gravel	wrapped	100

	V	W	X	Y	Z	AA	AB
201	gravel/grass	no traffic	unlined	sand	sand	none	105
202	asphalt	local	CML	gravel	crush gravel	wrapped	132
203	asphalt	local	nil	native	native	none	
204	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	114
205	asphalt	local	CML	gravel	crush gravel	wrapped	114
206	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	114
207	asphalt	local	unlined	sand	sand	none	105
208	asphalt	commercial	CML	gravel	crush gravel	wrapped	134
209	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	129
210	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	129
211	asphalt	commercial	CML	gravel	crush gravel	wrapped	134
212	gravel/grass	parking	unlined	sand	sand	none	105
213	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	114
214	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	
215	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	111
216	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	95
217	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	95
218	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	95
219	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	95
220	asphalt	collector	CML	gravel	crush gravel	wrapped	133
221	asphalt	local	CML	gravel	crush gravel	wrapped	130
222	asphalt	local	CML	gravel	crush gravel	wrapped	
223	asphalt	local	CML	gravel	crush gravel	wrapped	
224	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	
225	asphalt	local	CML	gravel	crush gravel	wrapped	
226	asphalt	local	CML	gravel	crush gravel	wrapped	121
227	asphalt	local	CML	gravel	crush gravel	wrapped	
228	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	130
229	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	130
230	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	118
231	asphalt	local	CML	gravel	crush gravel	wrapped	114
232	asphalt	local	CML	gravel	crush gravel	wrapped	
233	asphalt	local	CML	gravel	crush gravel	wrapped	124
234	asphalt	local	CML	gravel	crush gravel	wrapped	124
235	asphalt	local	CML	gravel	crush gravel	wrapped	
236	asphalt	local	CML	gravel	crush gravel	wrapped	
237	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	132
238	gravel/grass	no traffic	nil	native	native	none	105
239	asphalt	224th	CML	gravel	crush gravel	wrapped	123
240	asphalt	224th	CML	gravel	crush gravel	wrapped	132
241	asphalt	224th	CML	gravel	crush gravel	wrapped	123
242	asphalt	224th	CML	gravel	crush gravel	wrapped	123
243	asphalt	224th	CML	gravel	crush gravel	wrapped	123
244	asphalt	224th	CML	gravel	crush gravel	wrapped	123
245	asphalt	224th	CML	gravel	crush gravel	wrapped	128
246	asphalt	local	CML	gravel	crush gravel	wrapped	128
247	asphalt	224th	unlined	sand	sand	none	105
248	asphalt	local	nil	nil	nil	nil	
249	asphalt	local	nil	nil	nil	nil	122
250	asphalt	local	CML	gravel	crush gravel	wrapped	114
251	asphalt	local	CML	gravel	crush gravel	wrapped	129

	V	W	X	Y	Z	AA	AB
252	asphalt	lane	CML	gravel	crush gravel	wrapped	134
253	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	114
254	asphalt	Brown Ave.	CML	gravel	crush gravel	wrapped	132
255	asphalt	Brown Ave.	CML	gravel	crush gravel	wrapped	132
256	asphalt	collector	CML	gravel	crush gravel	wrapped	136
257	asphalt	no traffic	unlined	sand	sand	none	119
258	gravel/grass	no traffic	unlined	sand	sand	none	115
259	gravel/grass	no traffic	unlined	sand	sand	none	118
260	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	118
261	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	118
262	asphalt	local	CML	gravel	crush gravel	wrapped	132
263	asphalt	Brown Ave.	CML	gravel	crush gravel	wrapped	132
264	asphalt	224th	CML	gravel	crush gravel	wrapped	132
265	asphalt	224th	CML	gravel	crush gravel	wrapped	132
266	gravel/grass	no traffic	unlined	sand	sand	none	115
267	asphalt	Brown Ave.	CML	gravel	crush gravel	wrapped	132
268	asphalt	commercial	CML	gravel	crush gravel	wrapped	118
269	asphalt	local	CML	gravel	crush gravel	wrapped	120
270	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	113
271	asphalt	local	CML	gravel	crush gravel	wrapped	
272	asphalt	Brown Ave.	CML	gravel	crush gravel	wrapped	114
273	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	120
274	asphalt	lane	unlined	sand	sand	none	105
275	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	130
276	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	130
277	asphalt	local	CML	gravel	crush gravel	wrapped	114
278	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	124
279	asphalt	local	CML	gravel	crush gravel	wrapped	123
280	asphalt	local	CML	gravel	crush gravel	wrapped	126
281	gravel/grass	local	unlined	sand	sand	none	115
282	gravel/grass	no traffic	unlined	sand	sand	none	115
283	gravel/grass	no traffic	unlined	sand	sand	none	115
284	asphalt	collector	CML	gravel	crush gravel	wrapped	128
285	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	118
286	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	126
287	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	118
288	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	118
289	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	132
290	lawns	no traffic	CML	gravel	crush gravel	wrapped	118
291	asphalt	local	CML	gravel	crush gravel	wrapped	121
292	asphalt	local	CML	gravel	crush gravel	wrapped	121
293	asphalt	local	CML	gravel	crush gravel	wrapped	100
294	asphalt	local	CML	gravel	crush gravel	wrapped	100
295	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	114
296	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	114
297	asphalt	local	CML	gravel	crush gravel	wrapped	123
298	asphalt	local	CML	gravel	crush gravel	wrapped	123
299	asphalt	local	CML	gravel	crush gravel	wrapped	123
300	asphalt	local	CML	gravel	crush gravel	wrapped	123
301	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	121
302	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	121

	V	W	X	Y	Z	AA	AB
303	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	100
304	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	116
305	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	118
306	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	126
307	asphalt	collector	CML	gravel	crush gravel	wrapped	121
308	asphalt	collector	CML	gravel	crush gravel	wrapped	133
309	asphalt	collector	CML	gravel	crush gravel	wrapped	133
310	asphalt	local	CML	gravel	crush gravel	wrapped	121
311	asphalt	collector	CML	gravel	crush gravel	wrapped	133
312	asphalt	collector	CML	gravel	crush gravel	wrapped	133
313	asphalt	collector	CML	gravel	crush gravel	wrapped	133
314	gravel/grass	no traffic	unlined	sand	sand	none	
315	gravel/grass	no traffic	unlined	sand	sand	none	133
316	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	111
317	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	111
318	asphalt	local	CML	gravel	crush gravel	wrapped	111
319	gravel/grass	parking	CML	gravel	crush gravel	wrapped	116
320	asphalt	local	CML	gravel	crush gravel	wrapped	
321	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	
322	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	
323	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	100
324	gravel/grass	local	nil	native	native	none	95
325	gravel/grass	no traffic	unlined	sand	sand	none	105
326	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	122
327	gravel/grass	no traffic	unlined	sand	sand	none	105
328	gravel/grass	no traffic	unlined	sand	sand	none	105
329	gravel/grass	parking	unlined	sand	sand	none	105
330	asphalt	no traffic	unlined	sand	sand	none	
331	asphalt	local	unlined	sand	sand	none	105
332	asphalt	local	unlined	sand	sand	none	105
333	gravel/grass	local	unlined	sand	sand	none	105
334	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	105
335	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	118
336	asphalt	collector	CML	gravel	crush gravel	wrapped	127
337	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	124
338	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	124
339	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	124
340	asphalt	parking	unlined	sand	sand	none	105
341	asphalt	local	unlined	sand	sand	none	105
342	gravel/grass	no traffic	unlined	sand	sand	none	105
343	asphalt	local	CML	gravel	crush gravel	wrapped	122
344	asphalt	parking lot	CML	gravel	crush gravel	wrapped	100
345	asphalt	local	unlined	sand	sand	none	105
346	gravel/grass	no traffic	unlined	sand	sand	none	105
347	asphalt	local	CML	gravel	crush gravel	wrapped	100
348	asphalt	collector	CML	gravel	crush gravel	wrapped	133
349	asphalt	collector	CML	gravel	crush gravel	wrapped	133
350	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	100
351	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	100
352	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	100
353	gravel/grass	no traffic	unlined	sand	sand	none	105

	V	W	X	Y	Z	AA	AB
354	gravel/grass	no traffic	unlined	sand	sand	none	105
355	gravel/grass	no traffic	unlined	sand	sand	none	105
356	asphalt	local	CML	gravel	crush gravel	wrapped	122
357	asphalt	local	CML	gravel	crush gravel	wrapped	122
358	gravel/grass	no traffic	unlined	sand	sand	none	
359	gravel/grass	no traffic	unlined	sand	sand	none	100
360	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	100
361	asphalt	collector	CML	gravel	crush gravel	wrapped	114
362	asphalt	collector	CML	gravel	crush gravel	wrapped	136
363	asphalt	collector	CML	gravel	crush gravel	wrapped	136
364	asphalt	local	CML	gravel	crush gravel	wrapped	
365	asphalt	collector	CML	gravel	crush gravel	wrapped	136
366	asphalt	collector	CML	gravel	crush gravel	wrapped	136
367	asphalt	collector	CML	gravel	crush gravel	wrapped	136
368	asphalt	collector	CML	gravel	crush gravel	wrapped	136
369	asphalt	collector	CML	gravel	crush gravel	wrapped	136
370	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	134
371	asphalt	local	CML	gravel	crush gravel	wrapped	134
372	asphalt	local	CML	gravel	crush gravel	wrapped	135
373	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	
374	asphalt	local	CML	gravel	crush gravel	wrapped	110
375	asphalt	collector	CML	gravel	crush gravel	wrapped	136
376	gravel/grass	no traffic	unlined	sand	sand	none	105
377	asphalt	collector	CML	gravel	crush gravel	wrapped	114
378	asphalt	collector	CML	gravel	crush gravel	wrapped	133
379	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	135
380	asphalt	collector	CML	gravel	crush gravel	wrapped	114
381	asphalt	local	CML	gravel	crush gravel	wrapped	
382	asphalt	arterial	CML	gravel	crush gravel	wrapped	129
383	asphalt	local	CML	gravel	crush gravel	wrapped	114
384	concrete	local	unlined	sand	sand	none	115
385	asphalt	local	unlined	sand	sand	none	115
386	asphalt	collector	CML	gravel	crush gravel	wrapped	110
387	asphalt	collector	unlined	sand	sand	none	118
388	asphalt	collector	CML	gravel	crush gravel	wrapped	114
389	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	113
390	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	113
391	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	113
392	gravel/grass	no traffic	unlined	sand	sand	none	132
393	asphalt	local	unlined	sand	sand	none	132
394	gravel/grass	local	unlined	sand	sand	none	105
395	asphalt	local	unlined	sand	sand	none	105
396	gravel/grass	no traffic	unlined	sand	sand	none	105
397	asphalt	local	unlined	sand	sand	none	
398	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	113
399	asphalt	local	CML	gravel	crush gravel	wrapped	
400	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	111
401	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	118
402	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	111
403	asphalt	collector	CML	gravel	crush gravel	wrapped	111
404	asphalt	collector	CML	gravel	crush gravel	wrapped	111

	V	W	X	Y	Z	AA	AB
405	asphalt	collector	CML	gravel	crush gravel	wrapped	130
406	gravel/grass	no traffic	unlined	sand	sand	none	105
407	asphalt	local	CML	gravel	crush gravel	wrapped	118
408	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	115
409	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	128
410	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	100
411	gravel/grass	parking	CML	gravel	crush gravel	wrapped	118
412	gravel/grass	parking	CML	gravel	crush gravel	wrapped	118
413	asphalt	local	CML	gravel	crush gravel	wrapped	126
414	asphalt	local	CML	gravel	crush gravel	wrapped	126
415	asphalt	local	CML	gravel	crush gravel	wrapped	126
416	asphalt	local	CML	gravel	crush gravel	wrapped	134
417	asphalt	collector	CML	gravel	crush gravel	wrapped	114
418	asphalt	collector	CML	gravel	crush gravel	wrapped	114
419	asphalt	collector	CML	gravel	crush gravel	wrapped	114
420	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	110
421	asphalt	collector	CML	gravel	crush gravel	wrapped	114
422	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	126
423	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	
424	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	126
425	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	126
426	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	127
427	gravel/grass	no traffic	CML	gravel	crush gravel	wrapped	
428	asphalt	collector	CML	gravel	crush gravel	wrapped	
429	asphalt	local	CML	gravel	crush gravel	wrapped	
430	asphalt	local	CML	gravel	crush gravel	wrapped	
431							
432							
433							
434							
435							
436							
437							

	AC	AD	AE	AF	AG	AH
1	**Roughness**	**Q_lps**	**V_mps**	**C_hazen**	**HGL_M**	**MDD_P_PSI**
2	120	1.1071	0.06	110	91.43	93.78
3	110	1.1846	0.02	120	91.46	83.57
4	120	0.1501	0.01	110	91.43	99.74
5	110	0.2895	0.01	120	91.43	111.83
6	110	0.489	0.02	120	91.43	112.69
7	120	3.4243	0.07	110	91.45	84.84
8	120	4.7193	0.15	110	91.50	86.62
9	120	6.8822	0.21	110	91.50	86.33
10	120	6.8822	0.19	120	91.50	86.19
11	120	6.8822	0.21	110	91.49	85.90
12	120	2.1733	0.07	110	91.50	84.77
13	110	3.8701	0.07	120	91.46	80.17
14	90	1.5892	0.09	90	91.74	79.29
15	120	14.9009	0.29	110	91.77	78.61
16	120	9.1198	0.18	110	91.77	78.61
17	110	0.8437	0.04	120	91.47	94.55
18	110	2.4353	0.07	120	91.51	113.65
19	120	8.8245	0.17	110	91.73	78.84
20	120	11.435	0.23	110	91.73	78.84
21	110	1.6043	0.08	120	91.67	88.00
22	110	6.1248	0.11	120	91.70	79.79
23	110	3.8281	0.07	120	91.68	84.31
24	120	6.7853	0.21	110	91.74	79.29
25	120	4.8998	0.15	110	91.65	79.29
26	120	1.061	0.03	110	91.59	78.35
27					91.54	78.86
28	120	2.9552	0.14	120	91.51	80.66
29	120	0.4502	0.02	110	91.43	97.76
30	120	4.9614	0.1	110	91.67	81.31
31	110	1.1072	0.05	120	91.68	86.88
32	120	2.1949	0.06	120	91.55	103.19
33	110	1.7867	0.09	120	91.48	84.32
34	110	3.386	0.06	120	91.68	84.31
35	120	3.5227	0.17	120	91.58	101.95
36	110	1.1173	0.05	120	91.69	77.64
37	120	2.9637	0.06	110	93.49	79.21
38					91.48	84.32
39	110	1.2098	0.06	120	91.55	102.48
40	120	2.1949	0.06	120	91.55	102.48
41	120	5.2512	0.25	120	91.55	103.19
42	110	3.7218	0.1	120	91.53	102.88
43	110	0.9815	0.05	120	91.51	104.13
44	110	0.8153	0.04	120	91.68	85.31
45	90	0	0	120	91.43	86.24
46	120	0.5066	0.01	120	91.68	86.88
47	120	3.2157	0.06	120	91.68	84.17

	AC	AD	AE	AF	AG	AH
48	120	0.3303	0.02	90	91.68	84.17
49	120	1.2259	0.02	120	91.68	81.47
50	110	3.0612	0.08	120	91.52	121.78
51	110	3.2905	0.09	120	91.45	85.69
52	120	5.7334	0.11	110	91.66	81.31
53	120	6.3895	0.13	110	91.62	102.00
54	110	0.8051	0.04	120	91.46	100.50
55	120	0.3031	0.02	110	91.47	92.26
56					91.50	80.64
57	110	0.7394	0.04	120	91.46	80.17
58	110	0.3845	0.02	120	91.46	80.73
59	110	0.4648	0.02	120	91.46	80.58
60					91.47	82.30
61	110	1.2489	0.06	120	91.45	83.42
62	110	1.2489	0.06	120	91.46	80.44
63	90	0.0189	0	90	91.45	84.84
64	90	1.0823	0.06	90	91.45	83.42
65	90	0.0189	0	90	91.45	83.42
66	120	1.0356	0.06	110	91.44	82.41
67	110	0.5388	0.03	120	91.46	80.58
68	110	0.5388	0.03	120	91.46	80.45
69	110	0.5388	0.03	120	91.46	80.45
70	110	0.5388	0.03	120	91.46	80.58
71	110	0.5388	0.03	120	91.46	80.58
72	110	0.4155	0.02	120	91.46	80.73
73	110	0.5985	0.02	120	91.46	80.73
74	110	0.4756	0.01	120	91.46	80.73
75	110	0.4756	0.01	120	91.46	80.73
76	120	0.9964	0.05	110	91.44	82.41
77	110	0.4756	0.01	120	91.46	80.73
78	110	0.4756	0.01	120	91.46	81.58
79	110	0.4756	0.01	120	91.46	81.58
80	110	1.0068	0.03	120	91.42	121.07
81	110	1.0068	0.03	120	91.42	121.07
82	110	0.2288	0.01	120	91.43	118.23
83	120	0.2288	0.01	110	91.43	118.23
84					91.43	108.56
85	110	0.4779	0.02	120	91.43	108.56
86	110	0.4779	0.02	120	91.43	105.01
87	120	0.4408	0.02	110	91.43	97.76
88	120	0.5804	0.03	110	91.43	93.91
89	120	0.1945	0.01	110	91.43	93.91
90					91.43	93.35
91	120	0.4408	0.02	110	91.43	94.20
92	110	0.0776	0	120	91.43	106.86
93	110	0.2576	0.01	120	91.43	106.86
94					91.43	93.91
95	110	0.2576	0.01	120	91.43	99.74
96	120	0.5236	0.03	110	91.43	101.17
97	120	0.5236	0.03	110	91.43	101.17
98	120	0.7474	0.04	110	91.43	101.45

	AC	AD	AE	AF	AG	AH
99	110	0.1077	0.01	120	91.43	104.15
100	120	0.8306	0.05	110	91.43	101.45
101					91.43	101.45
102	120	0.0851	0	110	91.43	101.17
103	120	0.8306	0.05	110	91.44	92.65
104	120	0.8306	0.05	110	91.45	83.42
105	120	0.8306	0.05	110	91.45	83.42
106	120	0.5236	0.03	110	91.43	88.08
107	110	0.1077	0.01	120	91.43	110.98
108					91.43	108.56
109	110	0.1077	0.01	120	91.43	104.15
110	120	0.5992	0.03	110	91.43	104.15
111	110	2.4234	0.07	120	91.44	92.65
112	110	3.2905	0.09	120	91.44	92.65
113	110	2.4234	0.07	120	91.43	111.69
114	110	1.7236	0.05	120	91.43	112.69
115	120	2.1733	0.07	110	91.50	86.62
116	120	6.1161	0.17	120	91.51	81.22
117	120	1.9733	0.06	110	91.51	81.08
118	120	1.1851	0.04	110	91.50	83.92
119	120	1.9733	0.06	110	91.50	83.92
120	110	0.9353	0.03	120	91.43	118.23
121	120	3.5309	0.11	110	91.51	81.22
122	110	0.6787	0.02	120	91.47	81.32
123					91.47	81.32
124	110	0.4584	0.02	120	91.48	80.04
125	110	0.4584	0.01	120	91.48	80.04
126	110	0.4756	0.01	120	91.46	81.58
127					91.47	81.32
128					91.44	82.41
129	90	1.0823	0.06	90	91.44	82.41
130	110	0.7394	0.04	120	91.46	80.17
131					91.46	81.44
132					91.46	81.58
133	110	0.8097	0.02	120	91.46	87.84
134	120	0.0634	0	110	91.43	97.76
135	120	0.3316	0.02	110	91.43	98.32
136	110	0.8527	0.04	120	91.43	104.44
137	120	1.2445	0.07	110	91.45	104.89
138	110	2.4291	0.07	120	91.43	118.23
139	110	0	0	120	91.45	91.81
140	110	0.602	0.03	120	91.45	94.66
141	120	0.602	0.03	110	91.45	93.95
142					91.47	109.76
143	120	0.3031	0.02	110	91.47	105.77
144	120	1.5164	0.08	110	91.47	105.77
145	120	1.2132	0.07	110	91.46	104.77
146	120	0.2848	0.02	110	91.46	104.77
147	120	1.353	0.07	110	91.45	104.89
148	120	1.353	0.07	110	91.46	104.77
149					91.47	107.06

	AC	AD	AE	AF	AG	AH
150	110	0.1904	0.01	110	91.46	86.56
151	110	1.1084	0.05	120	91.46	91.25
152	110	3.0086	0.08	120	91.46	91.83
153	110	1.068	0.05	120	91.47	91.41
154	120	0.298	0.01	120	91.46	87.84
155					91.46	90.98
156	110	4.1294	0.11	120	91.47	89.71
157	120	2.5283	0.14	110	91.52	96.32
158	120	2.5283	0.14	110	91.62	84.51
159	120	2.5283	0.14	110	91.62	84.51
160	120	2.5283	0.14	110	91.62	84.51
161					91.62	84.51
162	120	2.5283	0.14	110	91.62	84.51
163					91.62	84.51
164	120	3.2735	0.18	110	91.62	84.51
165					91.68	81.47
166	90	2.1304	0.07	90	91.68	81.61
167	90	2.1304	0.07	90	91.71	79.66
168	120	1.4798	0.08	110	91.50	85.48
169	90	2.2795	0.06	120	91.50	84.62
170					91.50	84.62
171	110	2.0341	0.1	120	91.48	81.04
172	110	2.0341	0.1	120	91.46	83.30
173	110	0.8769	0.04	120	91.46	83.30
174					91.46	83.01
175	110	0.3858	0.02	120	91.46	83.30
176	110	0.9671	0.05	110	91.49	84.90
177	110	0.4534	0.02	120	91.46	81.72
178	120	0	0	120	91.46	84.71
179					91.46	86.56
180	120	0.335	0.02	120	91.46	86.56
181					91.46	86.98
182	90	1.6621	0.08	120	91.47	89.71
183					91.51	94.02
184	120	4.2194	0.23	110	91.53	79.97
185	120	0.4455	0.01	110	91.59	78.49
186	120	2.6099	0.08	110	91.51	81.22
187	120	3.0467	0.15	120	91.57	79.18
188					91.54	78.86
189					91.54	78.86
190	120	3.2654	0.1	110	91.57	79.18
191	120	0.4455	0.01	110	91.59	78.63
192	120	5.2187	0.25	120	91.70	79.93
193	120	4.7481	0.26	110	91.59	78.49
194	120	8.7533	0.27	110	91.71	79.52
195	120	6.038	0.19	110	91.71	79.66
196	120	6.038	0.19	110	91.70	79.93
197	120	8.87	0.27	110	91.74	79.29
198	90	2.1304	0.07	90	91.71	79.66
199	110	2.8532	0.14	120	91.76	78.46
200	110	2.8532	0.14	120	91.68	86.45

	AC	AD	AE	AF	AG	AH
201	120	1.7252	0.09	110	91.68	86.88
202	110	3.8281	0.07	120	91.68	84.31
203					91.69	81.76
204	110	4.0012	0.07	120	91.69	81.76
205	110	6.0425	0.11	120	91.69	80.77
206	110	6.0425	0.11	120	91.69	80.77
207	120	1.7252	0.09	110	91.73	78.84
208	110	1.9234	0.05	120	91.69	77.64
209	110	2.0784	0.06	120	91.69	78.49
210	110	2.0784	0.06	120	91.68	82.61
211	110	1.9234	0.05	120	91.69	78.49
212	120	1.6847	0.09	110	91.67	81.59
213	110	4.4151	0.08	120	91.69	81.76
214					91.67	88.00
215	110	1.4272	0.07	120	91.67	88.00
216	90	3.0563	0.15	120	91.62	84.66
217	90	3.0563	0.15	120	91.62	84.66
218	90	3.0563	0.15	120	91.62	84.66
219	90	3.0563	0.15	120	91.55	103.19
220	110	2.6037	0.07	120	91.47	89.71
221	110	1.4629	0.07	120	91.52	98.30
222					91.47	104.22
223					91.47	101.23
224					91.47	94.55
225					91.48	104.93
226	110	0	0	120	91.48	104.93
227					91.48	104.93
228	110	0	0	120	91.49	108.37
229	110	0	0	120	91.49	110.93
230	110	1.2098	0.06	120	91.55	107.45
231	110	1.9252	0.09	120	91.55	108.17
232					91.51	113.94
233	110	0	0	120	91.55	111.02
234	110	0	0	120	91.55	108.17
235					91.55	111.02
236					91.55	111.02
237	110	3.2251	0.09	120	91.55	118.97
238	90	3.2498	0.1	90	91.57	119.28
239	110	3.2498	0.09	120	91.57	119.28
240	110	6.3895	0.17	120	91.61	102.00
241	110	3.425	0.09	120	91.59	110.07
242	110	4.531	0.12	120	91.60	107.66
243	110	4.681	0.13	120	91.60	107.66
244	110	3.45	0.09	120	91.61	102.00
245	110	9.6998	0.26	120	91.61	102.00
246	110	6.1446	0.17	120	91.61	102.00
247	120	1.6847	0.09	110	91.66	81.31
248					93.50	83.46
249	100	0	0	100	91.70	79.79
250	110	3.386	0.06	120	91.68	84.31
251	110	2.0784	0.06	120	91.69	78.49

	AC	AD	AE	AF	AG	AH
252	110	1.9234	0.05	120	91.69	78.49
253	110	4.4151	0.08	120	91.69	80.77
254	110	1.7401	0.05	120	91.69	77.92
255	110	2.4767	0.04	120	91.69	80.20
256	110	0.8741	0.02	120	91.47	79.75
257	120	0.9362	0.05	110	91.48	80.04
258	120	0	0	120	91.46	81.72
259	110	0.5766	0.03	120	91.47	107.62
260	110	1.2098	0.06	120	91.55	107.45
261	110	1.2098	0.06	120	91.55	102.62
262	110	2.0553	0.04	120	91.68	77.92
263	110	2.5847	0.05	120	91.69	78.35
264	110	2.9637	0.05	120	91.68	77.92
265	110	4.6401	0.08	120	91.68	77.06
266	120	4.6401	0.09	110	91.68	77.20
267	110	1.5757	0.03	120	91.69	78.35
268	110	1.1173	0.03	120	91.69	77.50
269	110	0	0	120	91.69	77.92
270	110	1.1173	0.05	120	91.69	77.50
271					91.69	77.92
272	110	1.4861	0.03	120	91.69	80.20
273	110	1.0633	0.03	120	91.69	79.21
274	120	1.0633	0.06	110	91.69	79.21
275	110	0.4198	0.02	120	91.46	80.59
276	110	0.4198	0.02	120	91.46	83.01
277	110	0	0	120	93.49	79.21
278	110	1.1189	0.05	120	91.50	81.64
279	110	0.0927	0	120	91.68	82.89
280	110	0.2009	0.01	120	91.68	82.61
281	120	6.3895	0.13	110	91.66	81.31
282	120	4.9614	0.1	110	91.67	81.31
283	120	4.9614	0.1	110	91.68	77.20
284	110	6.1446	0.17	120	91.58	101.95
285	110	3.3337	0.09	120	91.57	116.73
286	110	3.1851	0.09	120	91.52	121.78
287	110	2.3992	0.12	120	91.58	101.95
288	110	2.3992	0.12	120	91.55	108.17
289	110	0	0	120	91.51	112.81
290	110	2.7733	0.13	120	91.55	107.45
291	110	0.1132	0	120	91.51	112.81
292	110	3.1278	0.08	120	91.50	111.94
293	110	1.5294	0.07	120	91.53	102.88
294	110	1.5294	0.07	120	91.51	113.65
295	110	0.9815	0.05	120	91.51	104.13
296	110	0.9815	0.05	120	91.50	111.94
297	110	3.9726	0.11	120	91.50	111.94
298	110	3.5263	0.1	120	91.49	110.93
299	110	3.5263	0.1	120	91.48	108.64
300	110	2.4397	0.07	120	91.47	107.06
301	110	0.2161	0.01	120	91.48	103.65
302	110	0.6187	0.03	120	91.48	105.79

	AC	AD	AE	AF	AG	AH
303	110	0.6187	0.03	120	91.48	106.07
304	110	0.3952	0.02	120	91.47	101.23
305	110	0.3952	0.02	120	91.47	106.21
306	110	0.8437	0.04	120	91.47	94.55
307	110	3.7218	0.1	120	91.52	98.30
308	110	1.8562	0.05	120	91.52	98.30
309	110	4.3845	0.12	120	91.51	94.02
310	110	2.5283	0.12	120	91.52	96.32
311	110	4.23	0.11	120	91.51	94.02
312	110	4.23	0.11	120	91.48	89.29
313	110	4.23	0.11	120	91.48	89.29
314					91.62	84.66
315	120	3.89	0.21	110	91.64	85.11
316	110	3.9278	0.19	120	91.64	85.11
317	110	2.5708	0.12	120	91.66	86.00
318	110	1.4272	0.07	120	91.66	86.00
319	110	1.6847	0.08	120	91.67	81.59
320					91.69	80.77
321					91.69	80.77
322					91.69	81.76
323	110	2.8532	0.14	120	91.68	86.45
324	90	1.5892	0.09	90	91.68	81.47
325	120	0	0	110	91.50	82.50
326	110	0	0	120	91.66	81.58
327	120	1.4798	0.08	110	91.53	79.97
328	120	2.2682	0.12	110	91.50	81.64
329	120	1.1493	0.06	110	91.50	81.64
330					91.48	80.04
331	120	1.1493	0.06	110	91.48	80.04
332	120	1.4798	0.08	110	91.53	79.97
333	120	4.2194	0.23	110	91.53	79.97
334	110	0.3768	0.02	120	91.46	80.02
335	110	0.7627	0.04	120	91.46	80.31
336	110	0.7197	0.03	120	91.46	80.02
337	110	0.3858	0.02	120	91.46	80.02
338	110	0.3858	0.02	120	91.46	84.71
339	110	0.3858	0.02	120	91.46	80.59
340	120	2.8197	0.14	120	91.49	84.90
341	120	1.9387	0.09	120	91.50	85.48
342	120	0.2982	0.02	110	91.48	81.04
343	90	0.5254	0.03	120	91.50	85.48
344	90	1.6621	0.08	120	91.50	84.62
345	120	1.4798	0.08	110	91.50	85.48
346	120	1.4798	0.08	110	91.50	85.48
347	110	0	0	120	91.46	90.98
348	110	2.8325	0.08	120	91.46	91.83
349	110	1.5309	0.04	120	91.46	87.84
350	110	0.8051	0.04	120	91.47	92.26
351	110	0.8051	0.04	120	91.47	92.26
352	110	0.8051	0.04	120	91.46	100.50
353	120	1.068	0.06	110	91.47	92.26

	AC	AD	AE	AF	AG	AH
354	120	1.1084	0.06	110	91.45	94.09
355	120	0.602	0.03	110	91.45	104.89
356	110	2.0517	0.06	120	91.47	106.21
357	110	2.1664	0.06	120	91.47	105.63
358					91.47	109.76
359	110	0.066	0	120	91.47	109.76
360	110	0.9089	0.04	120	91.45	94.66
361	110	4.1153	0.07	120	91.46	81.58
362	110	2.181	0.04	120	91.46	83.57
363	110	2.181	0.04	120	91.46	81.58
364					91.46	81.58
365	110	4.5277	0.08	120	91.46	80.45
366	110	3.8411	0.07	120	91.46	80.45
367	110	4.7134	0.08	120	91.47	80.03
368	110	5.0581	0.14	120	91.47	79.75
369	110	5.5165	0.15	120	91.50	80.07
370	110	1.5417	0.04	120	91.47	82.17
371	110	1.5417	0.04	120	91.47	81.03
372	110	1.0539	0.03	120	91.47	81.03
373					91.47	82.17
374	110	1.5417	0.07	120	91.47	82.17
375	110	5.8588	0.1	120	91.47	80.03
376	120	0.4052	0.02	110	91.48	80.04
377	110	5.9162	0.1	120	91.50	80.07
378	110	6.1161	0.17	120	91.50	81.08
379	110	0	0	120	91.50	80.64
380	110	4.2474	0.07	120	91.46	81.58
381					91.46	81.58
382	110	0.9353	0.03	120	91.43	118.23
383	110	1.7867	0.09	120	91.50	84.77
384	120	1.1851	0.04	110	91.50	84.34
385	120	0.0337	0	110	91.50	84.34
386	110	6.3969	0.11	120	91.49	85.90
387	120	3.6812	0.07	110	91.45	84.84
388	110	3.937	0.07	120	91.46	81.58
389	110	0.2901	0.01	120	91.43	109.70
390	110	0.2901	0.01	120	91.43	108.56
391	110	0.2901	0.01	120	91.43	108.56
392	120	0.3314	0.02	110	91.43	93.91
393	120	0.3314	0.02	110	91.43	99.74
394	120	0.1501	0.01	110	91.43	101.17
395	120	0	0	110	91.43	93.35
396	120	0	0	110	91.43	93.91
397					91.43	93.91
398	110	0.2901	0.01	120	91.43	109.70
399					91.43	106.86
400	110	0.366	0.02	120	91.43	107.28
401	110	0.2901	0.01	120	91.43	109.70
402	110	0.366	0.02	120	91.43	105.01
403	110	0.3735	0.02	120	91.43	104.44
404	110	1.2262	0.06	120	91.43	104.44

	AC	AD	AE	AF	AG	AH
405	110	1.9001	0.03	120	91.46	83.85
406	120	1.9001	0.1	110	91.46	84.42
407	110	0.4779	0.02	120	91.43	108.85
408	110	1.1314	0.03	120	91.43	118.23
409	110	1.0068	0.03	120	91.42	120.08
410	110	0.9964	0.05	120	91.45	83.57
411	110	0.2405	0.01	120	91.46	80.44
412	110	1.4644	0.04	120	91.46	80.44
413	110	1.0055	0.05	120	91.46	80.45
414	110	0.0821	0	120	91.46	80.45
415	110	0.0821	0	120	91.46	81.59
416	110	1.3869	0.07	120	91.46	80.45
417	110	4.7829	0.08	120	91.46	81.59
418	110	5.8808	0.1	120	91.47	82.30
419	110	5.7859	0.1	120	91.47	82.30
420	110	1.5874	0.08	120	91.48	84.32
421	110	5.2991	0.09	120	91.47	82.74
422	110	0.9823	0.05	120	91.46	80.73
423					91.46	80.73
424	110	0.9823	0.05	120	91.47	80.03
425	110	0.9823	0.05	120	91.47	80.03
426	110	0.7394	0.04	120	91.46	80.73
427					91.42	120.08
428					91.61	102.00
429					91.48	108.64
430					91.70	79.79
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APPENDIX H

Degree of accuracy of time-linear and time-exponential predictions for material groups

Material	Breaks to 1999	Breaks (1999-2004)	Breaks to 2004	1999 Break rate (breaks/km)	2004 Break rate (breaks/km)
AC	29	3	32	2.524	2.785
CI	2	3	5	1.514	3.785
DI	16	1	17	0.750	0.797

		Linear				Exponential		
	Actual 2004 Breaks (cumulative)	**Predicted 2004 Breaks (cumulative)**	**Predicted - Actual**	**Percentage difference**	**R-Squared**	**Predicted 2004 Breaks (cumulative)**	**Predicted-Actual**	**Percentage difference**
AC	32	41.3058	9.3058	29.08%	0.9218	99.11865	67.11865	210%
CI	5	2.789	-2.211	-44.22%	0.8138	3.08255	-1.91745	-38%
DI	17	22.8023	5.8023	34.13%	0.9155	40.1167	23.1167	136%
				Average R^2=	0.8837			

Statistics

Linear				Exponential			
Mean	6.33%	SD	43.85%	Mean	102.46%	SD	127.40%
Median	29.08%			Median	135.98%		

Degree of accuracy of time-linear and time-exponential predictions for material and diameter groups

Material	Diameter	Breaks to 1999	Breaks (1999-2004)	Breaks to 2004	1999 Break rate (breaks/km)	2004 Break rate (breaks/km)
AC	150	21	3	24	2.406	2.759
AC	200	5	0	5	3.253	3.253
AC	250	3	0	3	2.459	2.459
CI	150	2	2	4	2.506	5.013
DI	150	7	2	9	0.597	0.767
DI	200	7	0	7	1.023	1.023
DI	250	2	0	2	0.727	0.727

			Linear				Exponential		
		Actual 2004 Breaks (cumulative)	Predicted 2004 Breaks (cumulative)	Predicted-Actual	Percentage difference	R^2	Predicted 2004 Breaks (cumulative)	Predicted - Actual	Percentage difference
AC	150	24	30.24	6.24	26.00%	0.9505	80.737	56.737	236%
AC	200	5	7.2476	2.2476	44.95%	0.8063	18.07	13.07	261%
AC	250	3	3.9982	0.9982	33.27%	0.7526	5.56	2.56	85%
CI	150	4	2.789	-1.211	-30.28%	0.8138	3.08	-0.92	-23%
DI	150	9	10.01	1.01	11.22%	0.9268	21.27	12.27	136%
DI	200	7	9.6832	2.6832	38.33%	0.8193	11.725	4.725	68%
DI	250	2	3.1053	1.1053	55.27%	0.7837	3.232	1.232	62%
					Avg R^2=	0.8361			

Statistics

Linear				Exponential			
Mean	25.54%	SD	28.30%	Mean	117.94%	SD	101.32%
Median	33.27%			Median	85.33%		
Mode				Mode			

Degree of accuracy of time-linear and time-exponential predictions for material, diameter and age groups

Material	Diameter	Age cohort	Breaks to 1999	Breaks (1999-2004)	Breaks to 2004	1999 Break rate (breaks/km)	2004 Break rate (breaks/km)
AC	150	1960-1969	11	1	12	3.002	3.275
AC	150	1970-1974	7	0	7	2.975	2.975
AC	150	1975-1984	3	2	5	1.463	2.438
AC	200	1970-1974	3	0	3	2.14	2.14
AC	250	1960-1969	3	0	3	4.644	4.644
DI	150	1980-1989	3	1	4	0.492	0.656
DI	200	1980-1989	2	1	3	0.782	1.174

				Linear			Exponential	
			Actual 2004 Breaks (cumulative)	Predicted 2004 Breaks (cumulative)	Percentage difference *	R^2	Predicted 2004 Breaks (cumulative)	Percentage difference*
AC	150	1960-1969	12	15.346	28%	0.8956	36.5	204%
AC	150	1970-1974	7	10.99	57%	0.94	20.41	192%
AC	150	1975-1984	5	3.93	-21%	0.8802	5.69	14%
AC	200	1970-1974	3	4.3	43%	0.82	7.6	153%
AC	250	1960-1969	3	4	33%	0.753	5.6	87%
DI	150	1980-1989	4	4.1	2%	0.84	9.19	130%
DI	200	1980-1989	3	3.1	3%	0.78	3.232	8%
					Avg R^2=	0.8441		

* Based on predicted minus actual

Statistics

Linear				Exponential			
Mean	20.71%	SD	27.15%	Mean	92.90%	SD	84.69%
Median	28.00%			Median	87.00%		

Degree of accuracy of time-linear and time-exponential predictions for material, diameter, soil and age groups

Material	Diameter	Soil type	Age cohort	Breaks to 1999	Breaks (1999-2004)	Breaks to 2004	1999 Break rate (breaks/km)	2004 Break rate (breaks/km)
AC	150	Clayey soil	1960-1969	6	1	7	3.883	4.531
AC	150	Clayey soil	1970-1974	7	0	7	2.959	2.959
AC	150	Clayey soil	1975-1984	2	0	2	2.083	2.083
AC	250	Clayey soil	1960-1969	2	0	2	7.752	7.752
DI	150	Clayey soil	1980-1989	3	1	4	0.650	0.867
AC	150	Silty soil	1960-1969	3	0	3	2.155	2.155
AC	200	Silty soil	1970-1974	3	0	3	2.513	2.513
DI	200	Silty soil	1980-1989	2	0	2	2.793	2.793

				Linear				Exponential	
				Actual 2004 Breaks (cumulative)	**Predicted 2004 Breaks (cumulative)**	**Percentage difference***	**R^2**	**Predicted 2004 Breaks (cumulative)**	**Percentage difference***
AC	150	Clayey soil	1960-1969	7	7.6	9%	0.6594	32.5	**364%**
AC	150	Clayey soil	1970-1974	7	10.95	**56%**	0.9409	20.4	191%
AC	150	Clayey soil	1975-1984	2	2.2	10%	0.625	2.54	**27%**
AC	250	Clayey soil	1960-1969	2	2.4	20%	0.6875	2.85	43%
DI	150	Clayey soil	1980-1989	4	4.11	**3%**	0.8356	9.19	130%
AC	150	Silty soil	1960-1969	3	4.5	50%	0.6927	5.21	74%
AC	200	Silty soil	1970-1974	3	4.3	43%	0.82	7.63	154%
DI	200	Silty soil	1980-1989	2	3.1	55%	0.7837	3.23	62%
						Avg R^2=	0.75566		

* Based on predicted minus actual

Linear				**Exponential**			
Mean	30.76%	SD	22.67%	Mean	130.56%	SD	110.44%
Median	31.67%			Median	101.71%		

Degree of accuracy of time-linear and time-exponential predictions for material, diameter, age and surface material groups

Material	Diameter	Age cohort	Surface Material	Breaks to 1999	Breaks (1999-2004)	Breaks to 2004	1999 Break rate (breaks/km)	2004 Break rate (breaks/km)
AC	150	1970-1974	Asphalt	2	0	2	13.514	13.514
AC	150	1960-1969	Gravel/grass	7	0	7	2.964	2.964
AC	150	1970-1974	Gravel/grass	5	0	5	2.101	2.101
AC	150	1975-1984	Gravel/grass	3	5	8	1.514	4.038
AC	200	1970-1974	Concrete	2	0	2	2.653	2.653
AC	250	1960-1969	Gravel/grass	2	0	2	3.13	3.13
DI	150	1980-1989	Gravel/grass	3	1	4	0.732	0.732
DI	200	1980-1989	Asphalt	2	0	2	1.584	1.584

					Linear			Exponential	
				Actual 2004 Breaks (cumulative)	Predicted 2004 Breaks (cumulative)	Percentage difference*	R^2	Predicted 2004 Breaks (cumulative)	Percentage difference*
AC	150	1970-1974	Asphalt	5	3.164	-37%	0.827	3.79	-24%
AC	150	1960-1969	Gravel/grass	7	10.03	43%	0.950	19.08	173%
AC	150	1970-1974	Gravel/grass	5	7.625	53%	0.926	10.26	105%
AC	150	1975-1984	Gravel/grass	3	3.926	31%	0.880	5.69	90%
AC	200	1970-1974	Concrete	2	2.94	47%	0.820	4.63	132%
AC	250	1960-1969	Gravel/grass	2	2.56	28%	0.729	3.12	56%
DI	150	1980-1989	Gravel/grass	4	4.11	3%	0.836	9.19	130%
DI	200	1980-1989	Asphalt	2	3.11	56%	0.780	3.23	62%
						Avg R^2=	0.843		

* Based on predicted minus actual

Statistics

Linear				Exponential			
Mean	27.90%	SD	31.13%	Mean	90.25%	SD	60.19%
Median	37.08%			Median	97.43%		