DEVELOPMENT OF A TRUE-COST CONCEPT FOR RENEWAL OF MUNICIPAL UNDERGROUND PIPELINE SYSTEMS

by

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ABSTRACT

DEVELOPMENT OF A TRUE-COST CONCEPT FOR RENEWAL OF MUNICIPAL UNDERGROUND PIPELINE SYSTEMS

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Asset management principles for underground pipeline infrastructure (UPI) are used by municipalities for efficient delivery of water, wastewater, and storm sewers. Due to budget constraints and limited resources, municipalities need to improve their operations, utilizing an optimum cost to provide their asset management services. Life cycle costs (LCC) include the total cost of facility ownership taking into account all capital costs, operation and maintenance costs, and renewing or disposing costs. Asset management costs include the maintenance and renewal portion of LCC.

The main objective of this research is to develop asset management strategies with consideration of all the cost factors that include the concept of True Cost (TC). True Cost includes design, construction, operation, and maintenance as well as municipal administrative costs, which are not usually considered as part of the life cycle costs.

For any city or municipality, infrastructure is the biggest expense and income driving potential. However, visible infrastructure which includes roads, alleys, sidewalks and storm inlets are inspected and responded to more quickly than the hidden infrastructure that includes

water lines, sanitary sewer lines and storm sewers. The reason for this discrepancy is that cities address issues which are reported by their visibly-oriented citizens, plus, political entities gain public recognition by addressing visible issues. Unfortunately, most of the time, the hidden infrastructure gets ignored or does not get addressed in time to get the best value from the final investment. The result is that cities have to spend more dollars to fix the neglected problem, thereby elevating their TCs.

The TC concept for this dissertation includes the sanitary sewer portion of the UPI and utilizes asset management data from construction, maintenance, and administrative costs. This information was collected from three municipalities in the North Texas area. Since TC is typically not accounted for in municipal environment, an overall understanding of True Cost will help municipalities and stakeholders determine the actual cost of the underground infrastructure. This will enable them to make better budgeting decisions when addressing deteriorating and failing infrastructure. This research has developed a framework to calculate municipal administrative cost, and thereby the TC, which can be used by cities as a tool. This dissertation also explores some of the factors affecting TC in a municipal environment. These factors include theoretical asset management, use of hot spots in geographical information systems, failed management of sanitary sewer systems including benchmarking, and social costs.

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ACRONYMS

ASCE – American Society of Civil Engineers

ALOS – Asset Level of Service

AWWA – American Water Works Association

BMP – Best Management Practices

CCTV – Closed Circuit Television

CIP – Capital Improvement Project

EPA – Environmental Protection Agency

F&F – Furniture & Fixtures

FV – Future Value

GA – Genetic Algorithm

GIS – Geographical Information System

GPS – Global Positioning System

IF– Impact Fee

I&I – Inflow and Infiltration

IIMM – International Infrastructure Management Manual

LCC – Life Cycle Costs

LOS – Level of Service

MAC – Municipal Administrative Costs

MIAMSSS – Municipal Infrastructure Asset Management for Sanitary Sewer Systems

MIAS – Municipal Infrastructure Asset Management

M&RPPI – Maintenance and Rehabilitation Planning for Public Infrastructure

NPDES – National Pollution Discharge Elimination System

NCTCOG – North Central Texas Council of Governments

NER – National Equipment Registry

O&M – Operations and Management

PV – Present Value

PVC – Polyvinyl Chloride

RDII – Rainfall Dependent Infiltration & Inflow

ROW – Right of Way

RR&M – Renewal, Repair, and Maintenance

SCADA – Supervisory Control and Data Acquisition

SDR – Standard Dimension Ratio

SSES – Sanitary Sewer Evaluation Study

SSO – Sanitary Sewer Overflow

SSMP – Sanitary Sewer Master Plan

SWPPP – Storm Water Pollution Prevention Plan

TAMS – Theoretical Asset Management System

TCEQ – Texas Commission on Environmental Quality

TC – True Cost

TT – Trenchless Technology

UACM – Uniform Annualized Cost Method

UPI – Underground Pipeline Infrastructure

UF – Utility Fee

WIN – Water Infrastructure Network

WSM – Wastewater System Model

DEFINITIONS

For the purpose of this dissertation, the following definitions are determined:

Benchmarking - The term benchmarking of municipal sanitary sewer assets in this dissertation is used to understand the phased expenses that come with the installation of municipal infrastructure, specifically determined by the age of the infrastructure in the area of the city where it is being installed.

Best Management Practices (BMP) – According to EPA, "A BMP is a technique, process, activity, or structure used to reduce the pollutant content of a storm water discharge. BMPs include simple nonstructural methods, such as good housekeeping and preventive maintenance. BMPs may also include structural modifications, such as the installation of bioretention measures. BMPs are most effective when used in combination with each other, and customized to meet the specific needs (drainage, materials, activities, etc.) of a given operation. The focus of EPA's general permits is on preventive BMPs, which limit the release of pollutants into storm water discharges. BMPs can also function as treatment controls." (EPA, 1972)

Failure and Deterioration - Failure in sanitary sewer pipeline infrastructure has several causes. Deterioration is one of the causes of failure. Deterioration is the degradation of the municipal sanitary sewer pipeline infrastructure that leads to ultimate failure.

Hot Spot Maps - The hot spot maps are a component of GIS, for looking at patterns rather than the locations of individual features. It measures a number of features using a uniform unit, such as hectares or square miles, and used as input for correlation analysis or time series analysis.

Maintenance of Pipes – Performing routine activities that keep the sanitary sewer pipes in working order.

Municipal Enterprise Solution – A methodology of collecting infrastructure-related information in a municipality and is determined by establishing a relationship between document information, field information, and GIS information.

Municipal Social Cost – Municipal social cost generically includes inconvenience to the citizens and customers, and disturbance and damage caused to the neighborhood and environment by renewal, repair, or maintenance activities of municipal sanitary sewer infrastructure. Time spent by municipal personnel addressing the inconvenience to the citizens and customers is the only municipal social cost considered in this research.

Rainfall Dependent Infiltration/Inflow (RDII) normally occurs when rainfall enters the sanitary sewer system through missing cleanout caps, roof drains, manhole covers and frame seals, storm sewer cross connections etc.

Renewal of Pipes – Renewal is "All aspects of upgrading with a new design life for the performance of existing pipeline systems. Includes rehabilitation, renovation, and replacement Najafi and Gokhale (2005).

Repair of Pipes – Repair is "Reconstruction of short pipe lengths, but not the reconstruction of a whole pipeline. Therefore, a new design life is not provided" Najafi and Gokhale (2005).

Repair, Renewal and Maintenance (RR&M) of Pipes – Activities performed by city crews that include fixing broken pipes of short lengths, replacing sections of existing pipes with new pipes, and performing routine activities to keep the sanitary sewer flowing.

Theoretical Asset Management System (TAMS) - A collection of documents and information management portion of a municipal asset management system. TAMS include as-built drawings, reports and studies and repair and maintenance inventories related to sanitary sewer systems.

Trenchless Technology – Methods of pipeline and utility installations with minimum amount of surface excavation (Najafi and Gokhale, 2005).

True Cost - The true cost of a sanitary sewer municipal asset is defined as the life cycle costs with the addition of municipal administrative costs and the time value of money factored into its calculation.

Underground Pipeline Infrastructure (UPI) – Is the municipal pipeline infrastructure that includes water lines, sanitary sewer (wastewater) lines and storm sewer infrastructure.

DISCLAIMER

The data and case studies presented in this dissertation are openly available public information, and assumed to be reasonably accurate. The sources for the data are listed in the references. The contents of this dissertation reflect the views of the author, who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views of the University of Texas at Arlington.

CHAPTER 1

INTRODUCTION & BACKGROUND

1.1 Introduction

The underground municipal assets include water, sewer, and storm sewer lines, colloquially referred to as “wet utilities” by contractors and municipalities. Due to their low visibility, asset management of underground utilities is usually neglected and allowed to deteriorate until a failure (sometimes a catastrophic failure) occurs. Municipalities commonly have the out-of-sight out-of-mind approach to wet utilities, and cannot address their maintenance issues similar to visible infrastructure such as pavement and bridges. With tight budgets, it is rare to have enough money to deal with all of the pressing issues of a sanitary sewer system. Most municipalities have to find the best way to spend the limited funds available and be a responsible steward of their sanitary sewer system assets.

This dissertation focuses on the importance and calculation of municipal administration expenses related to sanitary sewer system renewal and repair. The municipal administrative cost is part of a True Cost (TC) which is defined and explained in detail in this research.

As there are limited funds available, municipalities need to make sure they are renewing and replacing the deteriorated and failed sanitary sewer projects at the right time. Facts are needed to ensure that service levels can be met while seeing to it that operations and maintenance efforts and capital spending truly reduce the risk of failure. The goal is to determine and collect adequate information concerning infrastructure conditions. Based on the right asset management technology, a costly and difficult asset repair and renewal option can become more feasible.

1.2 Condition of Municipal Infrastructure

The 2009 Report Card for America's Infrastructure by American Society of Civil Engineers (ASCE) has assigned drinking water and wastewater grades of D-. Aging systems discharge billions of gallons of untreated wastewater into U.S. surface waters each year. The Environmental Protection Agency (EPA) estimates that the nation must invest $390 billion over the next 20 years to update or replace existing systems and build new ones to meet increasing demand (ASCE 2009). An analysis of available data indicates Canadian Municipalities could save in excess of $1 billion per year or $33 per capita/per year by adopting best practices and proven technologies for infrastructure construction, maintenance, and rehabilitation (Félio and Maerschal, 1998). A detailed design life of water system components is illustrated in Table 1.1.

Table 1.1 Clean Water and Drinking Water Infrastructure

Design Life of Water System Components	Years of Design Life
Collections	80 – 100
Treatment Plants - Concrete Structures	50
Treatment Plants – Mechanical and Electrical	15 – 25
Force Mains	25
Pumping Stations - Concrete Structures	50
Pumping Stations - Mechanical and Electrical	15
Interceptors	90 – 100

Source: EPA 2002

Municipal Pipe Infrastructure laid in North America in 2004 was approximately 1.4 billion feet or 460,000 km (Rahman, 2007). Municipalities today are faced with increasing challenges that go beyond the basic water, sewer and road services. Difficult decisions must be made daily to establish investment priorities. Municipalities must watch every dollar spent and aim for the highest return on their investment (Félio and Potkins, 2000).

There are key issues with the selection of appropriate rehabilitation technologies due to the lack of adequate information concerning the condition of infrastructure (Abraham et-al, 1998). The results in a costly and difficult decision making process to select appropriate rehabilitation options.

Utility services are key factors in the quality of city life. The proper treatment of wastewater and an adequate storm water system contribute to the health, safety and welfare of residents. Municipalities charge a fee for providing potable water, sanitary sewer and storm water services to residents and businesses. The revenue generated from these fees is used to cover most of the costs of providing utility services. Quality infrastructure and utility services at affordable rates makes a city an attractive place for businesses and improves the quality of life for its residents (City of Plano Comprehensive Plan, 1998).

1.2.1 Sanitary Sewer System Deterioration and Failures

As said earlier, the lack of proper maintenance can result in accelerated deteriorated sewers with subsequent basement backups, overflows, cave-ins, hydraulic overloads at treatment plants, and other safety, health, and environmental problems. Of the most serious and environmentally threatening problems, sanitary sewer overflows (SSOs) are frequent cause of water quality violations and are a threat to public health and the environment (New England Interstate Water Pollution Control Commission, 2003). Lakes, streams, creeks and river pollution result in inadequate collection systems with improper management, operation, and maintenance. The poor performance of many sanitary sewer systems and resulting potential health and environmental risks highlight the need to optimize operation and maintenance of these systems.

1.2.2 Municipal Infrastructure Deficit

The municipalities in North America are already in or headed towards municipal infrastructure deficit. Municipal infrastructure deficit is defined as the difference between the funding needs for maintenance, repair, rehabilitation, retrofitting, and replacement of existing deteriorated infrastructure and the funding available from all resources, including taxes, government subsidies and grants, private sector contributions, etc. (Mirza, 2007). The US Water Infrastructure Network (WIN)[1] has generated a “gap analysis” to estimate the total increased spending required by water and wastewater utilities to avoid getting behind in funding infrastructure replacement over the next 20 years. The “gap” between the baseline expenditure forecast and the future “needs” forecast is the amount of additional expenditure that must be forthcoming in order for water and wastewater utilities to maintain their critical infrastructure in healthy condition. WIN has estimated that water and wastewater utilities together need to increase their investments in infrastructure by almost $1 trillion in the next 20 years (AWWA, 2001). Additional studies from Canada have shown the water and wastewater systems infrastructure deficit was approximately $23 billion in 1996, and has increased to approximately $32 billion in 2007. Figure 1.1 illustrates the municipal infrastructure deficit in Canada increasing over the next 60 years for different percentages of maintenance performed in terms of dollars invested.

1.2.3 Municipal Infrastructure Budget

Solutions addressing the aging sanitary sewer system infrastructure and the municipal infrastructure deficit are obtained by municipalities through revenue generated by bonds, grants, and user fees. The allocation of the municipal revenue to specific infrastructure rehabilitation and renewal projects is performed through adoption of a budget. The budget of a typical municipality for the specific maintenance and renewal of a sanitary sewer system consists of two expenses:

1. Internal expense represents the municipal employee and overhead expenses to run the utility.

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[1] Water Infrastructure Network is a broad-based coalition of local elected officials, drinking water and wastewater service providers, state environmental and health administrators, engineers and environmentalists dedicated to preserving and protecting the health, environmental and economic gains that America's drinking water and wastewater infrastructure provides.

2. External expenses that are paid to the contractors to build, and design consultants to design projects.

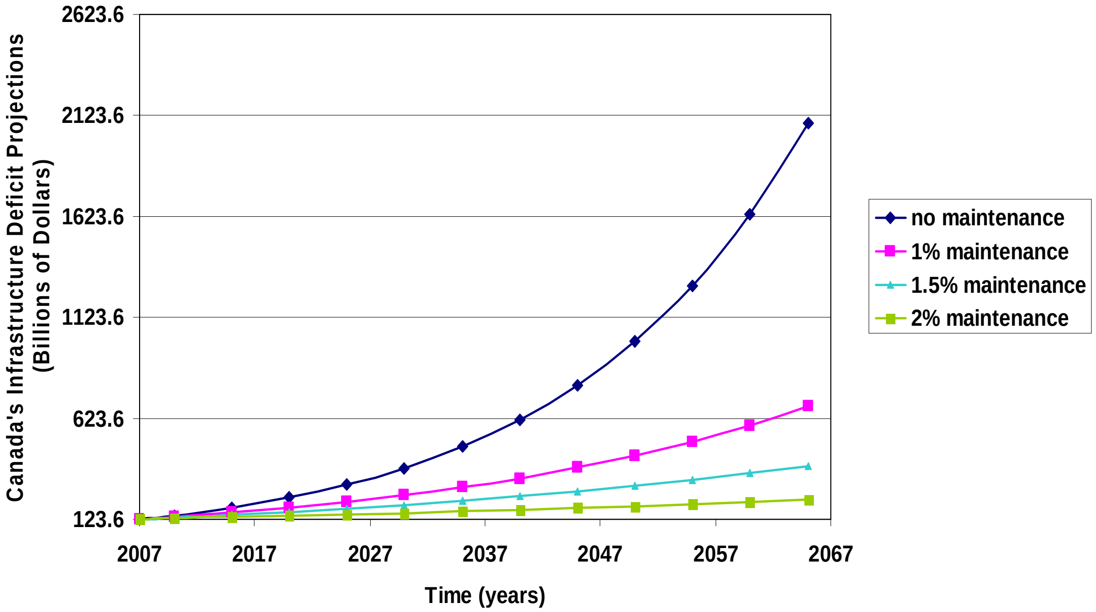


Figure 1.1 Canada's Municipal Infrastructure Deficit
Source: Mirza, 2007

1.2.4 Concept of Life Cycle Cost (LCC)

The life cycle cost (LCC) of an asset is defined as the total costs in present or annual value that includes the initial costs, and maintenance repair and renewal costs over the service life or a specified life cycle (Rahman and Vanier, 2004).

1.2.4.1 Phases of Life Cycle Cost (LCC)

Life Cycle Cost for a UPI project is accounted for in three phases as established by (Najafi and Gokhale, 2005). The three phases and their tasks are as follows:

Preconstruction

- Conceptual planning, risk and impact analysis
- Land acquisition
- Surveying and documentation of existing site conditions
- Easements and permits

- Design fees and preparation of contract drawings
- Legal fees

Construction

- Direct construction costs (labor, material, and equipment)
- Indirect construction costs (overhead)
- Inspection and testing costs
- Social costs

Post Construction

- Operation and Maintenance
- Depreciation (decrease in value)
- Loss of revenue due to emergency repairs

1.2.4.2 Determination of LCC

Determination of LCC is very difficult as there are several variables that affect the cost of municipal infrastructure. The bottom line for a municipality is to maximize infrastructure use at minimum cost. The variables affecting the infrastructure can be classified as predictable, unpredictable and trends that can be affected by design or costs.

Predictable variables affecting infrastructure include:

- Manufacturing of the sanitary sewer pipes and lift station pumps in controlled environments.
- Transportation and installation of the sanitary sewer infrastructure.
- Design of the sanitary sewer system.

Unpredictable variables affecting infrastructure include:

- Dynamic loads including movements of the soil and the live loads due to traffic.

- Static loads that might be built on top of the pipe after it is installed. An example may include construction of a parking lot several years after the initial installation of a sanitary sewer infrastructure.
- Weather related expansion and contraction of soils and pipe material and joints.
- Uncertainty of future costs will affect future cost of renewal and repair. For example interest rates, inflation and prices cannot be predicted.

Trends affecting infrastructure include factors, which can cause sewer system blockages, such as:

- Proximity of trees to sanitary sewers increases possibility of root blockage.
- Flatter slopes in pipes trends towards more blockages due to settling and accumulation of debris.
- Accumulation of grease in commercial areas also causes excess pipe blockage.

1.2.5 Concept of True Cost (TC)

The internal expenses add to the cost of any municipal project whether it is a Capital Improvement Program (CIP, from municipal bond money) or Development Project (from private developers). This internal cost is incorporated as the True Cost in the overall cost of the project as compared to life cycle costs (LCC) that do not commonly include municipal administrative cost.

The true cost of a sanitary sewer municipal asset, therefore, is defined as the life cycle costs with the addition of municipal administrative costs and the time value of money factored into calculation. In municipal construction, when a project is said to cost $1 million, the municipal administrative cost and the private utility relocation costs are not included. This dissertation will not address the additional costs of utility relocation costs which typically consist of gas, electric, fiber optics, telephone and cable etc. To understand TCs, the internal functions related to financing and economics must be defined especially as they relate to asset management practices and management decisions. A sanitary sewer system's maintenance strategy must also be factored when estimating TC expenses as the higher the maintenance costs, the higher the True Costs.

1.2.6 Time Value of Money in True Cost Calculations

Overhead expenses or administration costs are calculated by using the Present Value (PV) Method and Uniform Annualized Cost Method (UACM). Both of these methodologies use the Time Value of Money concept (Peterson, 2005).

1.2.6.1 Present Value Method

The Present Value (PV) for a sanitary sewer asset is determined for future expenses by taking into account the anticipated inflation of present dollars and discounting that amount by a predicted rate over the period between anticipated time of future expenses or future value (FV) and present time (Eq.1.1).

$$\mathrm{PV} = \mathrm{FV}\left\{\frac{1}{(1+i)^n}\right\}$$

1.2.6.2 Uniform Annualized Cost Method (UACM)

This method is used to convert present costs or future costs into uniform annual costs. The expression for UACM is (Eq 1.2):

$$\mathrm{A} = \mathrm{PV}\left\{\frac{[i(1+i)^n]}{[(1+i)^n - 1]}\right\}$$

where A = Annualized Cost, PV = Present Value, i = interest rate in present and n = number of years corresponding to interest rate

1.2.7 Financial Implications of Asset Management Practices

Cities in general have a certain amount of budgets attributed to new construction, renewal, repair, and maintenance based on availability of bonds or other sources (City of Allen

Annual Budget, 2009). The difference between the funding needed for repair, renewal and maintenance collectively called (RR&M) of existing deteriorated infrastructure compared to the funding available from all sources including taxes, government subsidies, grants, and private sector contributions is called municipal infrastructure deficit (Mirza, 2007). An out of sight, out of mind management decision in many municipalities is usually reactionary in addressing sanitary sewer system issues instead of pro-active. The critical evaluation, typically performed by municipalities for underground pipeline infrastructure, use an asset management ranking system based on pipe age, pipe material, number of complaints, camera inspections, etc. There are several research papers that have refined asset management systems (Sharma, 2010). These asset management systems use empirical and statistical methods, but do not address the actual functioning of a municipality and its management system, specifically as it relates to budgets, leading to ineffective use of the latest technologies. For example, there is a hesitation by municipal managers to use the latest trenchless technologies, as all the benefits including social costs are not recognized (Jung and Sinha 2007). To achieve the objective of determining True Cost, this dissertation uses an infrastructure cost process to understand the actual costs incurred by municipalities (Figure 1.2). Figure1.3 (a) and Figure 1.3 (b) illustrate the cost breakdown of pipeline infrastructure renewal and pipeline infrastructure repair and/or maintenance respectively.

1.3 Research Need

As said previously, municipalities charge a fee for providing potable water, sanitary sewer and storm water services to residents and businesses. However, depending on the conditions of the underground pipeline infrastructure (UPI), this fee may not be adequate to cover all the costs to provide utility services. The stakeholders including city management, politicians and customers are demanding more effective use of the financial resources to address municipal infrastructure issues. To effectively make decisions, all the expenses related to municipal infrastructure need to be known and understood.

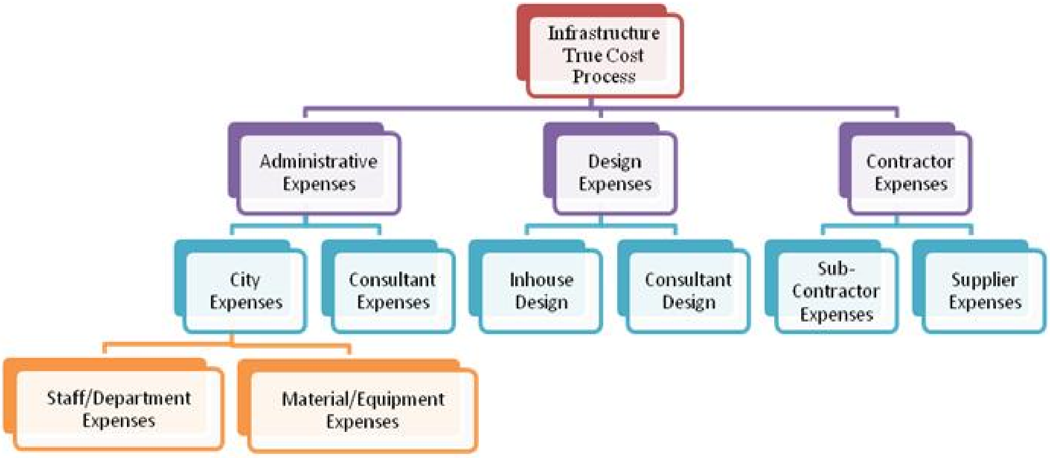


Figure 1.2 Components of True Costs

The True Cost concept presented in this research will address the expenses incurred by municipalities in the RR&M of a sanitary sewer project. Currently, TC is not well defined, and detailed studies have not been performed from a municipal standpoint.

The municipality expects longer life of a sanitary sewer system asset with minimal maintenance. The benefit to the municipality is lower TC expenses. Cities that have extensive historical data on construction projects with the TC expenses related to RR&M over the life of an asset can use these data for making effective management decisions in terms of:

- Municipal budgets,
- Cost to the customers,

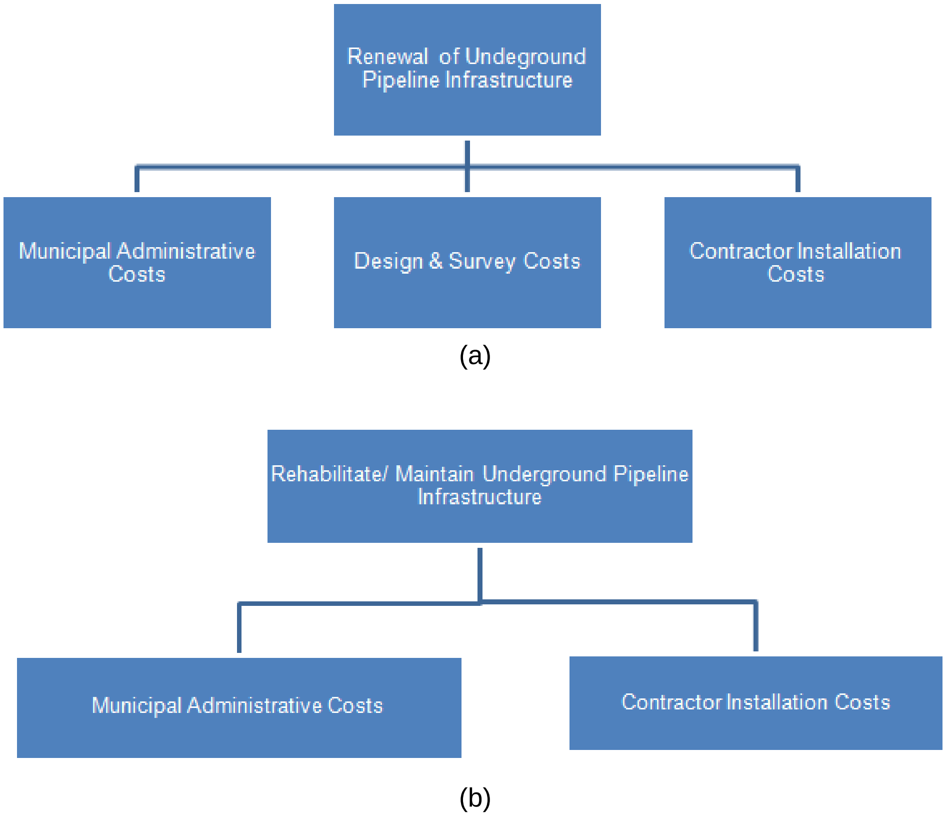


Figure 1.3 (a) & (b) Components of True Costs for New & Old UPI

- Prioritization of projects when compared in terms of cost, and
- Accurate analytical decision based on cost.

In this dissertation, some of the factors affecting True Cost, such as municipal enterprise solution, asset management strategies, failure rate and deterioration, and municipal-related components of social costs are discussed and extended to get a better understanding of TC. The provision of TC information will provide the stakeholders optimum service of the utility at the least cost, and thereby achieve the goal of improving the quality of life for their customers.

1.4 Research Objectives

The objectives of this research study are to:

- Develop a framework to determine UPI True Cost for municipal environment.
- Discuss factors affecting True Cost including asset management strategies, municipal enterprise solutions, deterioration and failure of sanitary sewers rates, trenchless technology, and social costs.

1.5 Hypothesis

This research will focus on evaluating the “True Cost” in municipal environment, which has not been considered previously. The emphasis will be on municipal sanitary sewer system. True Cost can be significant in terms of dollars when aggregated over many renewal and repair projects. This research will also demonstrate that by using True Cost factors, the overall cost estimate of renewal and repair projects will be more accurate, and will enable the stakeholders to make better asset management decisions.

1.6 Scope

The scope of this research is limited to:

- Sanitary sewer system as an example for underground pipeline infrastructure
- Case studies of three North Texas Cities: Allen, Garland and Rowlett

1.7 Organization of the Dissertation

This dissertation consists of nine chapters and six appendices, which achieve the goals and objectives of this research.

Chapter 1 presented and introduced, background, history and issues with infrastructure conditions in North America. It explained the concept of LCC and TC. The need statement objectives and organization of the research were provided.

Chapter 2 presents a literature review related to life cycle costs and asset management of infrastructure, mathematical and statistical deterioration models, as well as engineering economic concepts relating to time value of money and maintenance, renewal and repair of municipal infrastructure.

Chapter 3 presents the methodology and research approach.

Chapter 4 provides the detailed information for municipal expenses and overhead costs and provides the formulas for calculating True Costs for Cities of Allen and Rowlett that are used as case studies.

Chapter 5 provides sanitary sewer system data collected from cities in North Texas. The data is analyzed and presented in the form of tables and charts. A discussion on the implementation of the formulas and information from Chapter 4, and incorporation in actual projects of Kenwood Heights in Rowlett and Walden Park in Allen is presented. The goal is to calculate true cost for the referenced projects.

Chapter 6 provides a breakdown of the municipal administrative and overhead costs calculated based on different phases of planning that a municipality incorporates into infrastructure renewal and repair projects. Theoretical asset management, municipal enterprise solutions with hot spots and benchmarking relationships to True Costs are discussed.

Chapter 7 presents the concept of deterioration and failure. A mathematical formula to determine failure rate has been incorporated into the concept of True Cost.

Chapter 8 introduces the topic of social costs as related to projects in the municipal environment and the challenges faced by the affected stakeholders. It also presents options to minimize social costs by the use of trenchless technology.

Chapter 9 provides research conclusions, limitations, and recommendations for future, research.

1.8 Chapter Summary

This chapter introduced the state of municipal infrastructure in North America and the issues facing the sanitary sewer systems. Problems and costs associated with addressing the renewal and repair of sanitary sewer systems. The concept of Life Cycle Costs (LCCs) and

True Costs (TCs) were summarized, and the need statement, hypothesis, scope, research objectives and organization of this dissertation were discussed.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

A literature review was undertaken to evaluate and summarize past research. The following illustrates the topics reviewed in this chapter:

1. Asset management and costs of municipal infrastructure, specifically urban infrastructure development.
2. Infrastructure RR&M of municipal infrastructure with information on associated costs.
3. Engineering economic concepts for life cycle analysis (LCC) as it pertains to True Cost of Infrastructure in the municipal environment.
4. Use of existing mathematical or statistical deterioration models.
5. Using trenchless technology for extension of infrastructure life and social and economic impacts.
6. State of the art or current practices and understanding in the field of infrastructure asset management

2.2 Infrastructure Asset Management

Asset management has been used by municipalities for several decades. The level and depth of data collection to conduct an effective asset management can range from significant to minimal.

2.2.1 Decision Support System Level of Service

Municipalities are associating the infrastructure costs with Level of Service (LOS), which is an index that measures the quality of service provided to the user. LOS assists in decision making and investment planning related to the development, operation, and RR&M of municipal infrastructure. Sharma (2010) developed a framework for Asset Levels of Service (ALOS) based on a decision support system for municipal infrastructure network. This framework is based on the fact that ALOS should be the main criteria for municipal infrastructure RR&M. ALOS is based on qualitative and quantitative parameters, and therefore, its use will result in improved funding allocation. Secondary parameters used for municipal infrastructure investment decisions include physical deterioration of assets, future growth and the impact on dependent infrastructure network.

2.2.2 Historic Perspective of Phoenix Water and Sewer Development

The development of Phoenix water and sewer utilities during World War II passed through four stages. The delivery of water and collection of sewage began as a private enterprise in the 19th century (Stage 1). At the turn of the century, reformers from within and without city government campaigned for municipal ownership of utilities. Municipalities' successful battle for ownership of water and sewer utilities (Stage 2) led to a third stage, one of transitional improvements, as municipal government improved and perfected its utility service (Stage 3). Stage 4 for development came before the end of World War II and represented an era of new initiatives as municipal leaders took on large improvement projects forcing out many private interests which lacked the financial capability to compete (Kupel, 1995).

2.2.3 Infrastructure Asset Management Software Solution from South Africa

South Africa faces a large backlog in the delivery of basic services to communities; their existing infrastructure is showing signs of aging. Furthermore, municipalities are inadequately staffed and have limited funding which makes it difficult to provide effective services. An engineering consulting company, Africon Engineering International, identified the opportunity to support South African municipalities with the delivery of sustainable infrastructure services through the implementation of infrastructure asset management best practices. The end result was development of infrastructure asset management software that satisfied the need of municipalities (Von Holdt, 2006).

According to Von Holdt:

> “The International Infrastructure Management Manual (IIMM) defines infrastructure asset management as the goal to meet a required level of service, in the most cost effective manner, through the management of assets for present and future customers (IIMM Manual, 2006). The key elements include:
>
> - taking a life cycle approach,
> - developing cost effective management strategies for the long term,
> - providing a determined level of service and monitoring performance,
> - understanding and meeting the impact of growth through demand management and infrastructure investment,
> - managing risks associated with asset failures,
> - sustainable use of physical resources, and
> - continuous improvement in infrastructure asset management practices.”

2.2.4 Life Cycle Cost Analysis as a Decision Support Tool

Every municipal infrastructure asset has a series of life cycle phases from the time it is conceived, through the planning phases, during construction and service life phases, until the asset is declared surplus and is decommissioned. Typical infrastructure life cycle phases are listed below, each contributing different types of costs:

- Ideas/Concept
- Design/Planning
- Installation/Construction
- Operation and Maintenance
- Repair
- Decommissioning/Renewal

Municipal infrastructure managers must have immediate access to reliable cost data to make responsible engineering decisions. For example, the decision makers must take into account the different methods of LCC analysis, the typical acquisition expenses, the anticipated ownership costs, the probability of future LCCs, and the uncertainties in the LCC calculations (Rahman and Vanier, 2004).

2.3 Strategies of Cost Investment when Building Municipal Sanitary Sewer Infrastructure

The City of Edmonton, Canada uses a long-range servicing plan to facilitate development growth for the next 75 years. Some of the key aspects of the service plan include:

- to avoid building extensive trunk systems (major transmission sanitary sewer lines) all at once and incurring huge debts;
- to hold back flows in trunk segments that will act as storage tanks during rainfall events when existing downstream systems are overloaded;
- to make use of the significant capacity available in the existing downstream system when it is not raining to provide service to new developments and to empty the trunk segment storage tanks to the wastewater treatment system;
- to add trunk segments as development needs and revenues accumulate and are able to pay for them; and
- to delay connecting the trunk segments and completing sewer systems' connection to treatment plants until the money is available (City of Edmonton,1999).

2.4 Renewal and Repair of Infrastructure

2.4.1 Montreal Metro System – A Case Study of Maintenance and Rehabilitation

Maintenance and Rehabilitation Planning for Public Infrastructure (M&RPPI) was developed as a generic approach to any type of public infrastructure. The method aims at determining the optimal rehabilitation intervention and its optimal timing. The M&RPPI method is based on life cycle costing with a probabilistic and continuous rating approach for conditions requiring a new approach using the dynamic Markov chain to represent the impact of rehabilitation interventions on such infrastructure. Markov chain is a random process such that conditional probability of a future state depends on the immediately preceding state, and is unaffected by any additional knowledge of the past history of the system.

As an optimization technique, genetic algorithm (GA) is used in conjunction with Markov chain in order to find the optimal or quasi-optimal relationship profile (Farran, 2010).

2.4.2 Using Artificial Intelligence – A Case study of Sewer Rehabilitation Planning

Due to low visibility, sewer systems need attention to monitor, maintain, and rehabilitate to prevent failures, environmental pollution, and wastewater treatment overflow. However, sewer renovation usually costs an immense amount of money and is hampered by a limited budget. Thus, efficient planning of maintenance and renovation for sewer upkeep is demanded. An optimization model has been built to find an appropriate rehabilitation strategy consisting of a renovation method and a substitute material for each pipe failure under a limited budget. The optimization model was designed to search for a Pareto curve[2] (or trade-off front) consisting of a set of optimal solutions with desirable rehabilitation effectiveness for the least cost. The study employs genetic algorithms (GA) to obtain a Pareto curve at a low computation cost for large and complex sewer systems. The optimization model was applied to a sewerage system in the 9th district of Taichung City, Taiwan. Compared with the experts' manual estimation, the optimization model saved about 7.5% of the rehabilitation cost for Taichung City (Yang et-al, 2009).

2.5 Politics of Municipal Infrastructure Programs

2.5.1 Building Political Capital

Spending on public infrastructure that is based on distributive policies (distributing capital on different projects and therefore, keeping projects in maintenance phase for longer periods rather than renewing the infrastructure) masks the real costs of capital investments and undermines the application of efficient pricing policies. The political expediency associated with

---

[2] Pareto Curve is the shape created when the bars of a Pareto Chart are progressively summed and the points joined together.

this kind of spending weakens the accountability of decision making for management of local public assets. Rather than promoting the principles of sustainable development and integrated asset management, this spending supports short-term political interests (Hilton, 2007).

2.6 Maintenance and Deterioration Research

Extensive research has been developed in determining the suitable quantitative approaches towards decision making regarding scheduling of construction as well as rehabilitating and maintenance of various infrastructure assets based on optimum cost. The following presents a summary of this research:

2.6.1 Maintenance of Municipal Infrastructure

The maintenance of municipal infrastructure has been researched in terms of empirical models (Lofsten, 1998). According to Lofsten:

> "It is crucial to emphasize that planning should be carried out in two stages: (1) The fundamental planning problem; and (2) the complementary control problem. First the fundamental planning problem results in a plan where each separate object has a number of combinations of maintenance measures together with a point in time for each measure. In the next stage the resources needed and the budget requirements for each of these combinations are discussed."

2.6.2 Decision Analysis and Concept of Deterioration

A performance curve depicting deterioration across the life cycle of an asset is shown in Figure 2.1, and a graph of deterioration versus time for infrastructure is depicted in Figure 2.2. From Figure 2.1 and Figure 2.2, it can be inferred that the deterioration of sanitary sewer pipes is based on the phase of life of the pipe, and with preventative maintenance and rehabilitation the life of the pipe is extended.

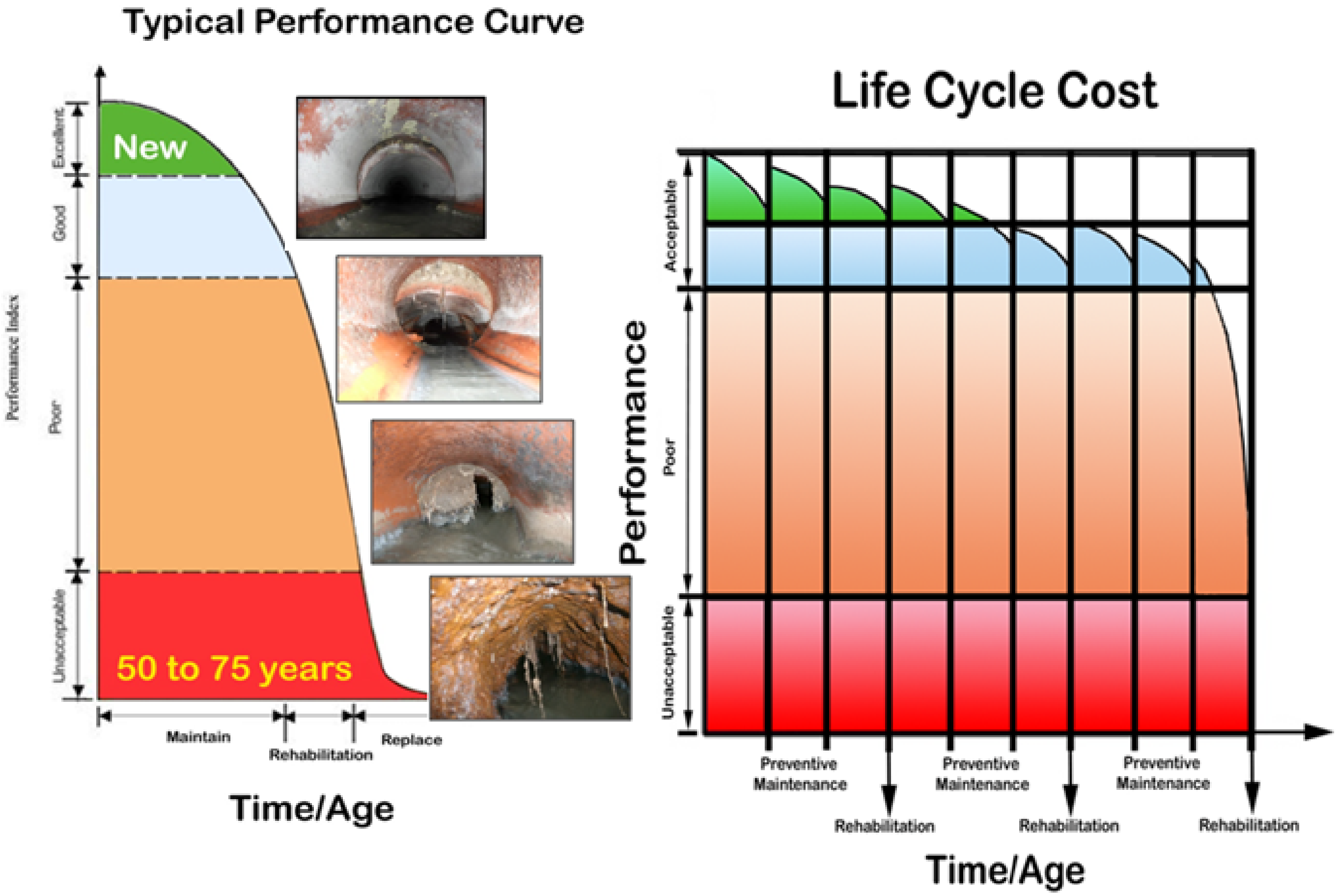
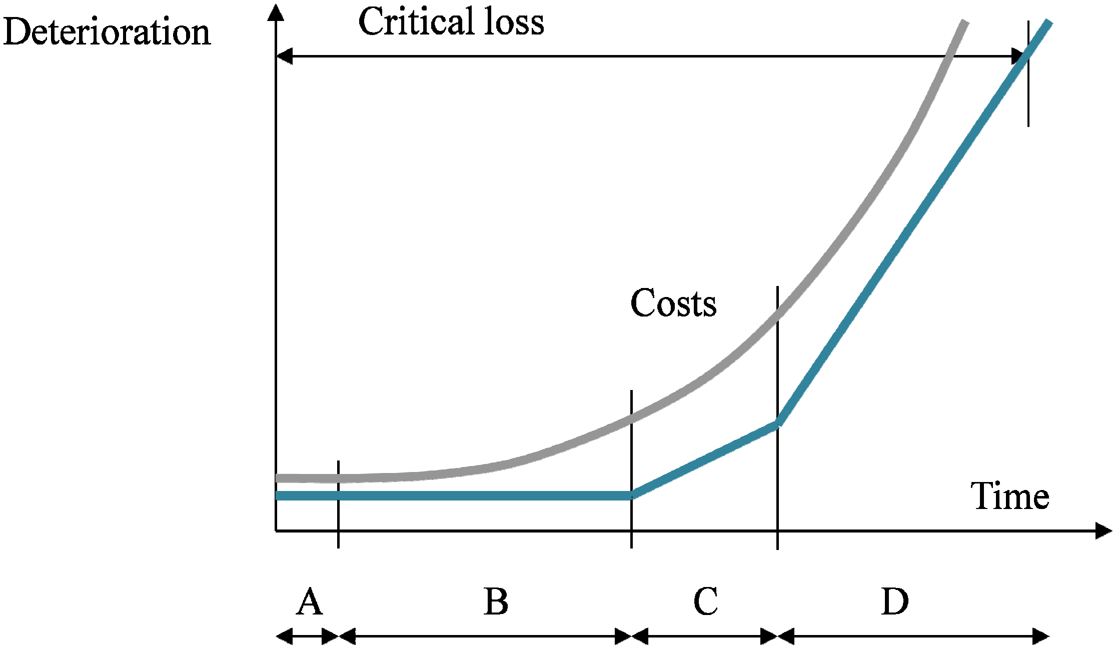


Figure 2.1 Sanitary Sewer Asset Performance Curve
Source: Forbes, 2010



Phase A – Design and construction

Phase B – Initiation of deterioration

Phase C – Increasing deterioration

Phase D – Accelerated deterioration requiring replacement

Figure 2.2 Deterioration versus Time, for Infrastructure
Source: Mirza, 2007

2.6.3 Cleaning and Maintenance Problems

Several cities have standard procedures for cleaning and maintenance of sanitary sewer system. Appendix H is incorporated from the Modified Preventative Maintenance Plan of New Orleans (Sewage and Water Board of New Orleans, 2010). It gives in detail the types of methodology to be used in the field by sewer maintenance personnel. The documentation includes specific problems, sources, and cause of the problem, the solution to be used to rectify the issue, and the appropriate equipment to be utilized.

2.6.4 Effectiveness of Solution

The effectiveness of cleaning a sewer line with several different applications is shown in Table 2.1. The appropriate use of mechanical, biological, and chemical options are ranked for the effectiveness in addressing sanitary sewer problems.

Table 2.1 Solutions to Problems in Sewer Pipes

Cleaning Solutions	**Type of Problems**				
	Emergency Stoppage	Grease	Roots	Sand, Grits, Debris	Odors
Balling[a]	NA	4	NA	4	4
High Velocity Cleaning	1	5	NA	4	3
Flushing	NA	NA	NA	NA	2
Sewer Scooters	NA	3	NA	3	NA
Bucket Machines, Scrapers	NA	NA	NA	2	NA
Power Rodders	4	1	3	NA	NA
Hand Rods	5[c]	1	2	NA	NA
Chemicals[b]	NA	2	5	NA	1
Bacteria[d]	NA	4	NA	NA	NA

Source: Sewage and Water Board of New Orleans

Effectiveness scale: 1 = Low; 5 = High

a. Kites, tires, bags, parachutes, scooters, and cones are commonly used instead of balls in large sewers (greater than 24 inches in diameter) with similar results
b. Effectiveness depends on type of chemical and its intended use.
c. Power rodders and high-velocity cleaners may be faster (if available) under certain conditions.
d. Effectiveness depends on formulation of cultures.

2.7 Statistical and Mathematical Models

2.7.1 Deterioration through Semi-Markov Process

Kleiner (2001) used a stochastic Semi-Markov process to model deterioration of large infrastructure assets which can be applied to underground pipeline infrastructure. Then, he computed total cost associated with an asset as a function of time. This involved the use of Monte-Carlo simulation (a simulation with repeated random sampling). These steps led to the appropriate mathematical tools for making decisions regarding optimum time to rehabilitate which serves to minimize costs.

The Semi-Markov quantitative and mathematical process is comprised of the following steps:

1. Defining Condition States

   The life of every infrastructure can be divided into the desired number of condition states such as good, fair, needs replacement, failure. These states can be denoted as 1 = Good, 2 = Fair, 3 = Needs Replacement, 4 = Failure. In general one can define as many condition states as needed, say 1, 2, 3,……, n. These condition states can be represented as independent random variables function of a given time t, denoted by X(t).

   The time t takes discrete values, such as 5 years, 10 years, etc. This defines the n-state space of a discrete semi-Markov deterioration process. The state of the process at any time t is typically stochastic and is defined by a probability mass function that is denoted by an n-dimensional vector

   $$A(t) = \{a_1^t , a_2^t, \ldots\ldots, a_n^t\};\ \textstyle\sum_{i=1}^{n} a_i^t = 1$$

   where a_i^t denotes the probability that the deterioration process is in state i at time t.

   The probability mass function of the process at time t+k is thus obtained by:

$A(t+k) = A(t)P^{t,t+1}\, P^{t+1,t+2} \ldots P^{t+k-1,t+k}$,

where P^{ij} denotes the transition probabilities of going from state i to state j, j is equal to i+1, and k is an increment in time; that is to say if the process is in state i at time t, the conditional probability that it will transit to the next state and j = i+1 in the next time step t+1 is called the transition probability.

2. Computing the Waiting Time in Each State

   Based on the available data and expert judgment, the choice of probability distribution of waiting time in each state must be made. Kleiner (2001) used Weibull probability distribution for a 4-state space of the deterioration process of an infrastructure asset. Waiting time in each of the condition state is shown in Figure 2.3.

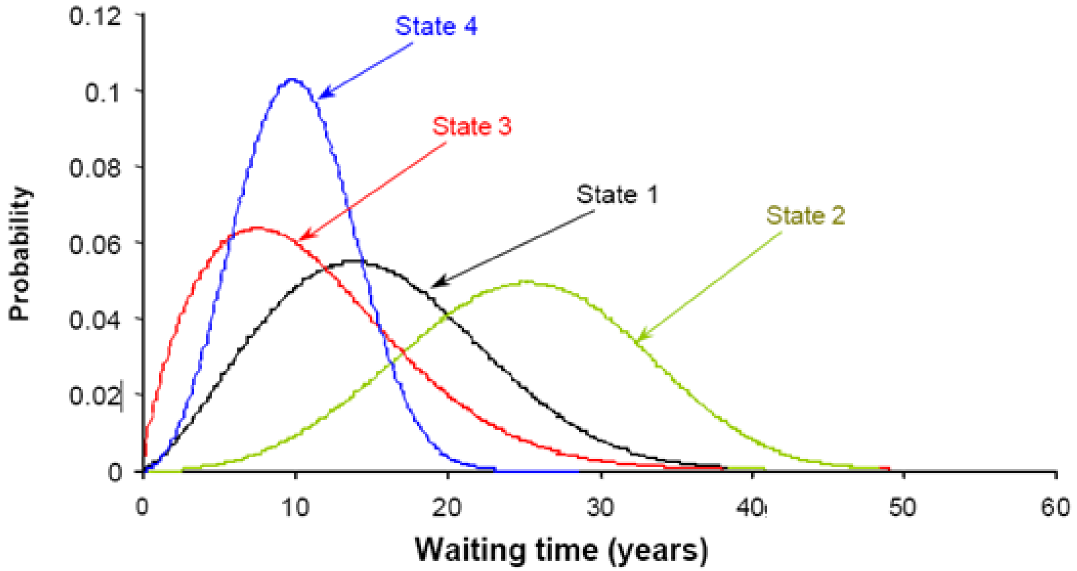
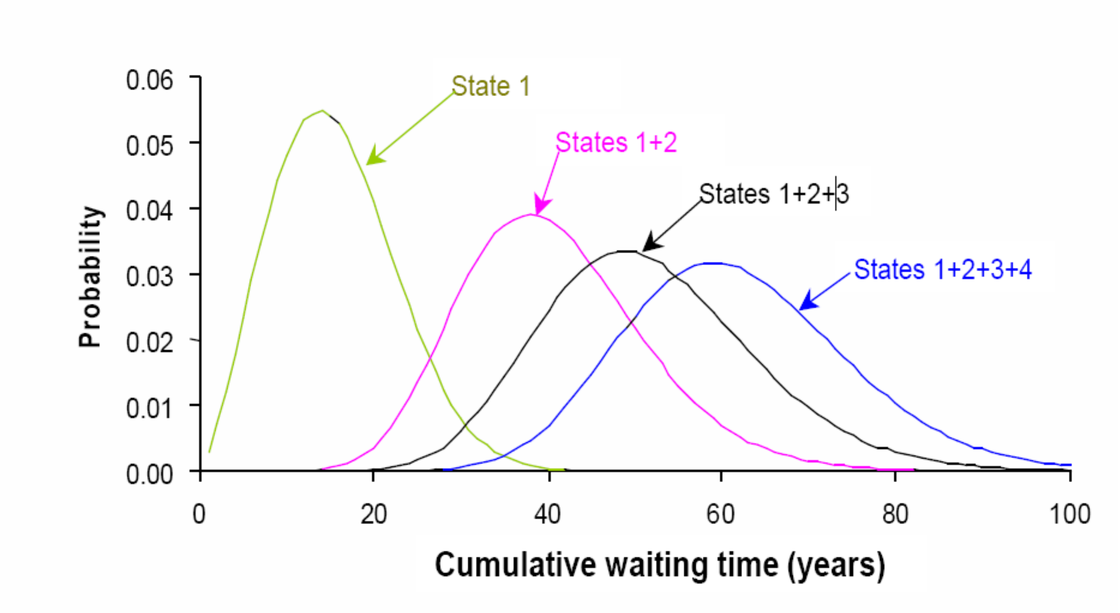


Figure 2.3 Probability versus Waiting Time
Source: Kleiner, 2001

3. Computing the Cumulative Waiting Time:

   In this step, the sum of waiting times up to each state is calculated, and probability distribution of these cumulative waiting times is obtained. This computation helps understand the lifespan of the infrastructure asset, and the time span during which there is a likelihood of failure. The cumulative waiting time in each condition state is shown in Figure 2.4

Figure 2.4 Probability versus Cumulative Waiting Time



Source: Kleiner 2001

2.8 Social Costs and Trenchless Technology

The cost-effective construction of pipeline projects require consideration of all possible cost items associated with the project. Trenchless Technology (TT) is an alternative means of installing and renewing UPI to facilitate utility construction and renewal with minimal surface disruption and social costs. According to Indian Society of Trenchless Technology it "is a branch of construction engineering dealing with techniques and related equipment used to develop, maintain and renew subsurface utility networks without excavating continuous trenches. It is a branch of applied engineering, which is State-of-Art, used to develop, manage, and renew continuous cabled and piped networks for transferring signals and fluids respectively. Major applications of these techniques are for Water Supply, Rainwater Disposal, Sewer Disposal, Gas, and Petrochemical products, electrical and telecom signals and other underground networks" (IndSTT Website). Trenchless methods have benefits that provide higher construction productivity and involve less risk, and therefore, lower social costs (Najafi and Gokhale, 2005).

2.9 Chapter Summary

This chapter provided a literature review of past research from municipalities that incorporate asset management components such as asset cost studies, strategies of RR&M and deterioration records, and mathematical and statistical models to study deterioration and obtain technological solutions.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter includes information from three cities in the North Texas area, which pertains to sanitary sewer systems' management and accompanying records on RR&M. The data collection, sorting, classification, and analysis were complicated as there was no uniformity in the way information was handled by the three cities for their sewer collection systems. The research methodology as detailed in Figure 3.1 was conducted according to the following tasks:

- Collect municipal background and information
    - Conducted literature review for existing research on life cycle costs, municipal asset management, deterioration, and failure rates.
    - Conducted inquiries with engineers, sanitary sewer department employees and GIS managers.
- Develop spreadsheets to input data from engineers and sanitary sewer data personnel
- Sort and classify information into categories that include:
    - Personnel wages and benefit costs
    - Overhead costs
    - Repair and renewal costs
    - Maintenance costs

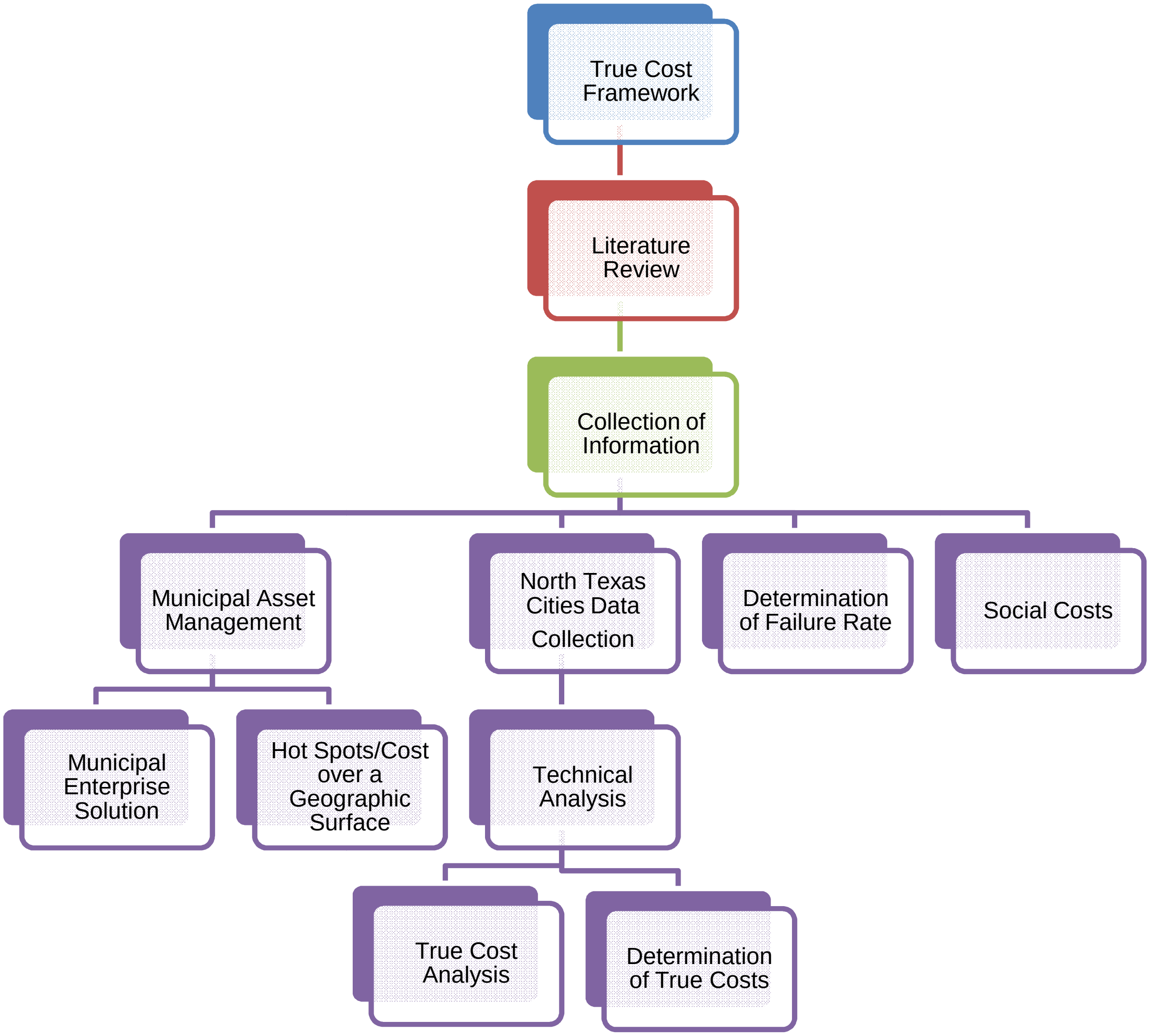


Figure 3.1 Research Methodology

- Analyze data and formulate equations providing detailed calculations for:
    - Present value and uniform annual cost
    - Failure rates
    - Annual cost per failure

3.2 Data Collection

Raw data was collected in the form of non electronic reports and documents, and electronically in the form of databases from the cities of Allen, Garland, and Rowlett. The data included Excel spreadsheets, emails, and study report documents. Individual calls and questions were forwarded to administrators, planners, and accountants in the cities finance and sanitary sewer departments, and any personnel who could enhance the quality and quantity of data was surveyed. Several meetings were held to gather information. The amount and variety of data collected by cities, which were never utilized was surprising. Finally, as a city employee, the author visited and worked at several sites within the area of study to get an in-depth view of data.

3.3 Data Analysis

The data was collected from three different cities in the North Texas area - Rowlett, Allen and Garland. Data from cities of Rowlett and Allen were analyzed to determine True Costs based on administrative expense during the approval and design phases of sanitary sewer infrastructure development. In addition, data from these cities were analyzed on a major CIP project to determine True Cost.

Data from cities of Rowlett and Garland were analyzed to determine minor RR&M activities, time activity duration, and activity costs. The dollar amount estimates calculated and used in data are for 2010-2011 fiscal year unless specified.

3.4 True Cost and Associated Factors

There are several factors associated with True Cost that need to be analyzed. Synopses of the factors affecting True Cost are explored in this research and are depicted in

Figure 3.2. These factors include, Theoretical Asset Management Systems (TAMS), benchmarking, failure rate, social costs and municipal enterprise solution are concepts studied in this research.

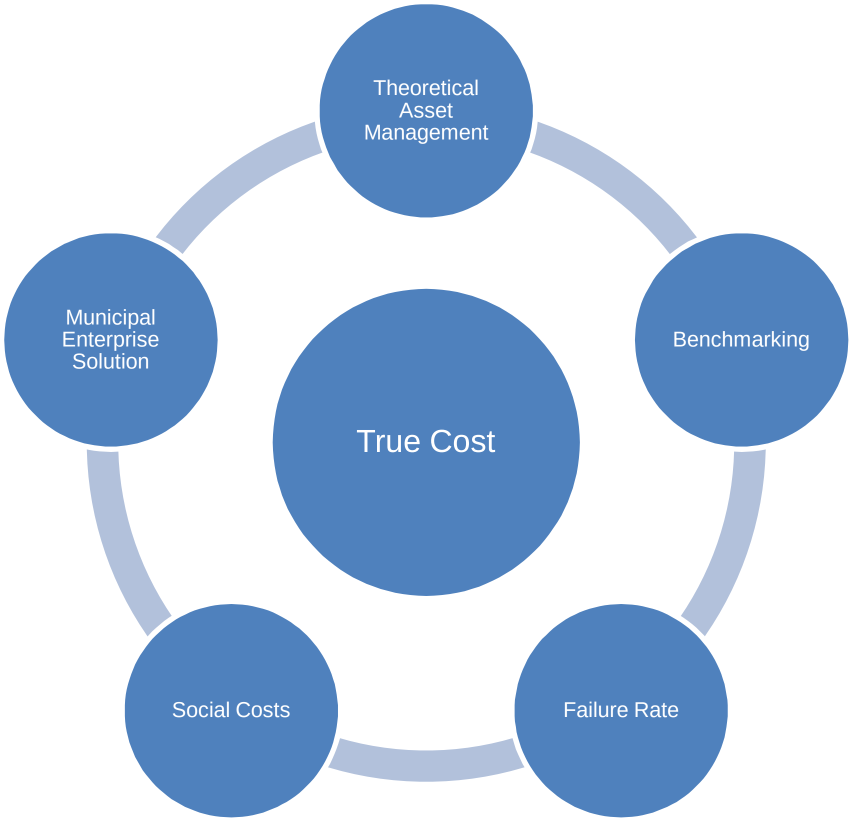


Figure 3.2 Factors Affecting True Costs

3.5 Chapter Summary

This chapter included conducting literature review addressing existing municipal research, collecting information and background from the three cities, sorting and analyzing of collected data, and researching the factors affecting TC.

CHAPTER 4

TRUE COST CALCULATION FOR MUNICIPALITIES

4.1 Introduction

In Chapter 1, the concepts of True Cost and Life Cycle Costs were introduced. This chapter describes more details on True Cost. In addition, this chapter discusses the factors of Municipal Infrastructure Asset Management as related to True Cost. In addition, this chapter will provide detailed calculations to determine municipal administrative costs. The dollar amount estimates calculated and used in data are for 2010-2011 fiscal year unless specified.

4.1.1 Generation of True Costs in the Municipal Environment

Municipalities have budgets for Capital Improvement Projects (CIPs) that are generated from bond money and other cash projects which are paid for from Utility Fees (UF) and Impact Fees (IF). The CIP typically pays for major renewals, while the UF typically pays for smaller renewal, repair, and maintenance projects. The major department participants within the municipality interested in TC, include personnel from the Public Works and Engineering Departments, with accountants and planners from the Finance Department and City Manager's office as minor participants. The other departments in the city have minimal administrative costs as compared to the referenced departments.

The life cycle municipal administrative costs from the inception of project, maintenance, and asset's end of life are not accounted for in the cost of the project. In addition, the time value of money for overhead costs, and the expenses related to bond expenses are also not included in the cost of UPI for municipal projects. Construction estimates account for the contractor bids that take into account the bid items for the installation of UPI, and LCC capture most expenses related to the project. However, LCC in a municipal environment have not included the above referenced municipal administrative costs.

4.1.2 Paid Costs and Unpaid Costs

Municipalities typically have several stakeholders consisting of the public, business, and semi-private utility companies, other governmental agencies, and city employees. There are paid and unpaid entities among the stakeholders. This dissertation focuses on the administrative expenses attributed to municipal employees and their related overhead.

- Municipal paid costs include employee expenses and overhead expenses that include resources like facilities and equipment.
- Unpaid costs include political entity expenses (City Council, Planning & Zoning and volunteer citizens who spend time on city projects).

A municipal project has four major components that constitute True Costs:

1. Administrative Expense
    - Finance
    - Engineering
    - Public Works
    - City Manager's Department
    - Miscellaneous (other municipal contributors)
2. Design Expense (External or Internal)
3. Contractor Expense or Construction Expense
4. Operations and Maintenance Expense
    - Public Works
    - Engineering
    - Finance

4.2 Municipal Infrastructure Asset Management (MIAS) and True Costs

The participants in MIAS involve the stakeholders mentioned in section 4.1.2. In addition, other stakeholders including politicians, other governmental entities, and vendors, could participate in the contribution to TC in terms of voluntary time or paid time. The goal of the different stakeholders is to appropriate funding for the infrastructure, obtain a level of service while minimizing risks, and maximize the quality of use for the ultimate stakeholder who is the citizen. The key steps in MIAS are shown in Figure 4.1 and include:

- Planning Phase
- Implementation Phase
- Maintenance Phase
- Renovation and Replacement Phase
- Continuous Improvement Phase (improvement phase based on feedback and experience, as the municipality learns through the process of implementing projects)

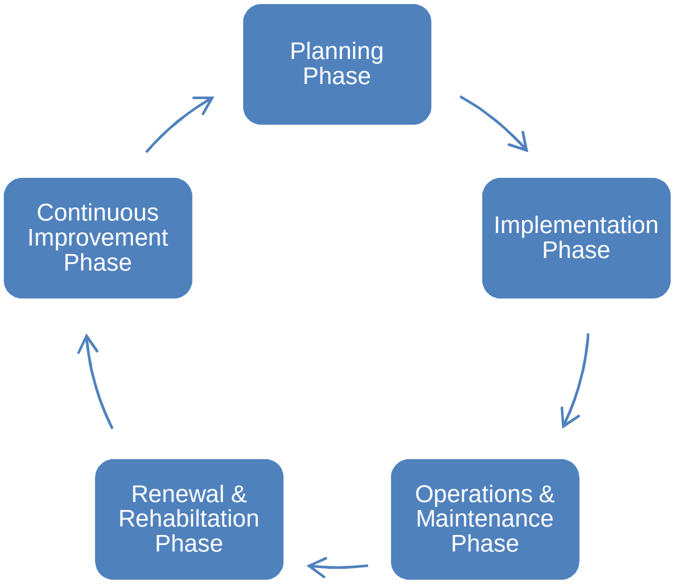


Figure 4.1 Steps in Municipal Infrastructure Asset Management

4.2.1 Planning Phase

The planning phase is divided into two sub-phases that include:

- Strategic planning, and
- Consensus planning.

4.2.1.1 Strategic Planning

The stakeholders in the strategic planning phase are typically the regional leaders, municipal leaders, political leaders, and the city organization leaders. The components of strategic planning phase can be regional and include transmission lines of wet utilities that cross several municipal boundaries and can also include several governmental jurisdictions and departments or could be specific to a singular municipality. From a TC perspective, both the regional and multi-municipality planning can be evaluated; however, this dissertation is more specific to singular municipalities.

The strategic planning phase for a typical municipality for sanitary sewer assets is done through a Sanitary Sewer Master Plan (SSMP) that is generated typically when the city is changing from a rural setting to an urban setting due to growth. The SSMP is a part of the comprehensive plan and includes input of existing and proposed zoning of a city in its development. The design of the SSMP study includes the existing sanitary sewer infrastructure and the potential growth. The city uses SSMP as a guide to generate a Capital Improvement Program (CIP). The CIP is usually done in 5 year increments, with an update every year to evaluate the achievements and move projects in terms of prioritizing or removing projects. The decisions of including or removing a project from the CIP list are typically based on criticality of the asset or the budget and occasionally politics. This dissertation has utilized renewal and repair data from two cities and has performed a detailed analysis to understand the costs associated with the concept of TCs.

4.2.1.2 Consensus Planning

The objective of consensus planning phase is to provide the strategic planners information on several viable projects to be implemented with information on approximate costs, time schedules and needs of the citizens (customers) to provide or maintain optimum services through wet utilities. The steps of consensus planning phase consist of collecting and analyzing:

- Raw data from an asset management system.
- Priority projects based on costs, needs of customers obtained from existing maintenance records, and studies conducted by the city or consultants of specific needs.
- Time schedule feasibility and implementation.

The city team involved in the collection of consensus planning information includes municipal entities consisting of employees from the city manager's office, engineering, public works, finance and occasionally citizen focus groups. The TC associated with the collection of data is not accommodated in the life cycle costs of municipal assets, such as construction of a new pipeline or a pipeline renewal project. In addition some of the consensus planning phase effort is voluntary performed by citizen focus groups. The TC of the time spent by volunteers during consensus planning phase has not been included in this study. The paid hours of municipal employees spend working on consensus planning tasks (labor costs) and other material costs need to be itemized at this stage to determine project TC.

4.2.2 Implementation Phase

The implementation phase includes municipal entities relying on the engineering, public works, purchasing, public relations, and finance departments as well as involvement from non-municipal entities that include design consultants and contractors depending on the size of a project. The implementation phase includes construction planning and scheduling, design, and construction of the project. It is the most expensive phase of all the referenced phases and includes the conversion of the construction plans into actual constructed of the project.

The stages in implementation phase includes research and collection of data related to the sewer pipelines from as-built plans, physical walkthroughs of the site, asset management systems, GIS databases, maintenance personnel and interviewing the experienced and veteran technical personnel within the city. In situations where municipalities have to deal with projects that have been completed several years earlier, acquiring accurate as-built plans and verification of the design on the plans become difficult. Asset management using GIS is making the documentation process more accurate and reliable.

This dissertation's implementation phase has two distinct cost structures which places a major project cost at $100,000 and above and a minor project below $100,000. The major project cost usually includes outside consultants unless the city has an internal design team and construction crew and provides for survey and additional design and construction services in its engineering or public works department.

4.2.3 Explanation of Overhead Expense Calculation

Theoretically, overhead expense ($) can be calculated by the following equation:

$$OE = H \times O \quad \ldots\ldots\ldots\ldots\ldots \text{(4.1)}$$

where; O = Overhead strategic planning phase expense per hour

H = Number of hours spent in strategic planning phase

In order to apply this equation to a real project, documentation of the number of hours (H) for that project has to be available. Assuming that there are five renewal and repair projects in that particular year, OE is estimated as 20% of building expense for the cities of Rowlett and Allen example calculations.

4.2.4 Calculating Planning and Implementation Phase Expenses

An Individual Employee's Expense incurred during Planning or Implementation Phase can be determined by the following equation:

$E_i = N_i \times (H_i + B_i) + O_i \times OM \times H_i$; $i = 1,2,3,\ldots\ldots n$ employees ..... (4.2)

where E_i= Hourly expense of the i^{th} employee

H_i= Hourly rate of the employee

N_i= number of hours spent on a phase by i^{th} employee

B_i= Benefits multiplier of the i^{th} employee

O_i= Number of overtime hours i^{th} employee

OM = Overtime multiplier

PE = Phase Expense, and is given by:

$$PE = \sum_{i=1}^{n} Ei + OE \qquad .. (4.3)$$

4.2.5 Calculating Municipal Administrative Cost (MAC) and True Cost (TC)

Municipal administrative cost is the sum of planning phase expense (strategic planning and consensus planning) and implementation phase expense. This can be determined by the following equation:

$$MAC = PE_S + PE_C + PE_I \qquad ... (4.4)$$

where; PE_S = Phase expense for the strategic planning

PE_C = Phase expense for the consensus planning

PE_I = Phase expense for implementation

True Cost (TC) is the sum of municipal administrative costs, contract costs, design costs, construction costs, and maintenance costs (Eq. 4.5).

TC = MAC + Contract Costs + Design Costs + Maintenance Costs .... (4.5)

4.2.6 Operations and Maintenance (O&M) Phase

True Cost is related to O&M as municipal resources are expended for the life of the sanitary sewer asset after its construction and into its renewal and repair. The municipal industry follows the typical asset management philosophy of having planned maintenance. The level of planned maintenance will vary in depth and level of implementation across the sanitary sewer assets based on the budgets cities have for maintenance. The planned maintenance is typically divided into three parts of periodic, predictive and preventative maintenance. The International Infrastructure Manual (Roberts et-al, 2006) defines these maintenance types as:

1. Periodic Maintenance – Necessary to ensure the reliability or to sustain the design life of asset.
2. Predictive Maintenance – Condition monitoring activities used to predict failure.
3. Preventative Maintenance – Can be initiated without routine or continuous checking e.g., using information contained in maintenance manuals or manufacturers recommendations) and is not condition based.

The data for the maintenance of sanitary sewer assets have to be strategically incorporated to ensure that there is a short-term (1-4 years), mid-term (5-29 years), and long-term (30-100 years) component phase with the emphasis on cumulative planning. The municipalities can include TC expenses in each of the referenced phases.

Most cities typically have a maintenance manual that includes schedules, procedures of maintenance, equipment used to provide effective maintenance, safety aspects, and other miscellaneous details. The maintenance phase in this dissertation is divided into routine maintenance and emergency maintenance.

4.2.6.1 Routine Maintenance

The typical routine maintenance for a sewer system includes inspection, scheduled cleaning or jetting of obstacles from lines or basin areas shown to have repeated clogging issues, investigating with Closed Circuit Television (CCTV), sanitary sewer overflow, manhole repairs, maintenance of mechanical equipment, and responding to customer complaints of sewer smell or sewer gases in the house. Routine maintenance is included in city budgets, and the city usually has a strategy of response for different scenarios. Trained city crews with specific skills respond to the situation in the field. The advantage of these crews is that they are productive and complete the task in a certain amount of time and at minimal cost. Example of the productivity of a crew that has specialized in CCTV can be measured by calculating the amount of pipeline footage videotaped in a typical work shift of 8 or 10 hours. The experience, knowledge, specialized skills, and team coordination results in a higher productivity with less cost to the city per unit length of the pipeline, which ultimately leads to lower TC. Cities cross train personnel within crews, and select assistants from other crews to handle scenarios where crew members are not available. Productivity of a crew can be determined based on the data collected for this dissertation.

Based on TC, the routine maintenance is fairly easy to determine, and can be included on a unit basis for the life of the sewer pipe system. Routine maintenance costs usually grow steadily based on the life stage of the sewer system. There is a point in the life of a pipe where the routine maintenance costs to address repeated failure on the same pipe will equal the cost of replacement of the pipe. As significant portions of the sewer system get renewed or replaced, the TC goes down, and the capital cost of renewal increases.

4.2.6.2 Emergency Maintenance

There are two types of emergencies that can be evaluated in sanitary sewer systems:

1) Small-scale Emergency—An example is when clogging of main sewer line occurs along with back up of the sewer through the service into the house. From the municipal standpoint this is a routine emergency maintenance, but from the customer stand point this is critical because the house becomes uninhabitable and affects the quality of life of the customer.

2) Large-scale Emergency Maintenance—Typically this happens on a larger scale when a main sewer line breaks, when there are problems with lift stations, and when the health or environment of a community can be seriously jeopardized by a break or leak. One example of a related health and environmental problem occurred in Rowlett, when the lake that provides water to the city of Dallas was in proximity to some of the major sewer transmission lines and lift stations maintained by Rowlett, Texas. Any break in the sewer system would let the sewer flow into the lake and jeopardize the health of the community. Such a spill would become a huge

negative factor in TC analysis due to both the social inconvenience and economic consequences. .Large scale emergency maintenance can be expensive and obviously cannot be planned for all scenarios.

Cities have some budgets assigned to respond to emergency scenarios. The assigned budgets might not be used for several years or could be used and easily exceeded with a single major emergency. The goal of every city is to minimize emergency maintenance. Cities address cost of emergencies in many ways. Some cities might buy insurance for emergency maintenance, or a city might assign some emergency maintenance costs based on the time and resources expended in to past emergencies. Emergency maintenance usually ends up with the involvement of contractors and city crews that have to work overtime to resolve the situation. The costs for emergency response grow in a mathematical exponential form until the emergency is contained or the situation is brought under control. Figure 4.2 shows a typical hierarchy of crews that are used by cities in operations and maintenance.

4.2.7 Renewal and Repair Phase

The same city crews that deal with operations and maintenance become part of the renewal and repair phase for small projects (typically less than $100,000). Usually, major (greater than $100,000) renewal and repair projects are bid out to contractors and performed with city input. Examples of Kenwood Heights in Rowlett and Walden Park in Allen are studied in Chapter 5.

4.2.8 Continuous Improvement

The continuous improvement phase incorporates lessons learnt and a detailed forensic analysis of the project and needs to be included in TAMS. Cities in this research incorporated documented some lessons gained from personnel, however, if the personnel leaves the city, the institutional knowledge also leaves.

4.3 Calculation of True Costs for City of Rowlett

4.3.1 Strategic Plan Expenses

The following is the calculation of the Rowlett's TCs. The strategic plan expenses are shown in Table 4.1 and Figure 4.3 for a typical renewal project. The municipal administrative cost is divided into city employee expenses of approximately $905 per hour and overhead expenses of approximately $33 per hour. Therefore, the total strategic planning costs per hour for Rowlett with a population of 54,500 (United States Census, 2010) for staffing expense, and benefits and overhead costs will be approximately $938 per hour. Appendix A provides a detailed calculation of the overhead expenses.

4.3.2 Consensus Plan Expenses

The following is the calculation for Rowlett's TCs. The consensus plan expenses are shown in Table 4.2 and Figure 4.4 for a typical renewal project. The municipal administrative cost is divided into city employee expenses of approximately $885, and overhead expenses of approximately $33. Therefore, the total consensus planning costs per hour for Rowlett for staffing expenses, benefits and overhead costs will be approximately $918. Appendix A presents a detailed calculation of the overhead expenses.

4.3.3 Implementation Plan Expenses

The following is the calculation of Rowlett's TCs. The implementation plan expenses are shown in Table 4.3 and Figure 4.5 for a typical renewal project. The municipal administrative cost is divided into city employee expenses of approximately $809 per hour and overhead expenses of approximately $66 per hour. Therefore, the total implementation phase costs per hour for Rowlett for staffing expense, benefits and overhead costs will be approximately $875 per hour. Appendix A presents a detailed calculation of the overhead expenses.

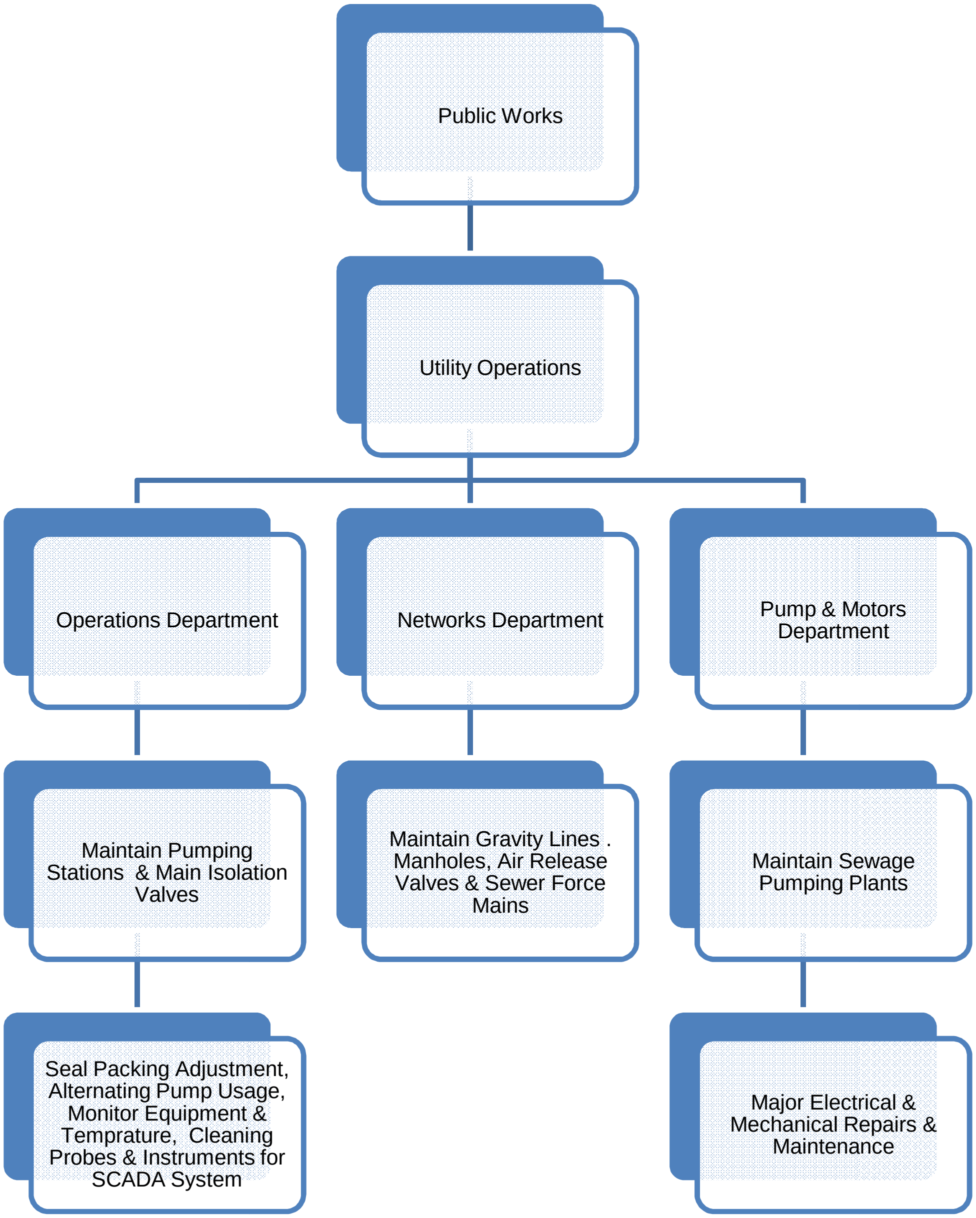


Figure 4.2 Typical RR&M Group Hierarchy
Source: City of Rowlett

Table 4.1 Municipal Administrative and Overhead Expenses for Rowlett's Strategic Planning (2010-2011 dollars)

City of Rowlett Strategic Planning Phase Staff Expenses Per Hour				
City Employees	Yearly	Hourly	Hourly Benefits (35%)	Cumulative Expense
City Manager	$162,000.00	$77.88	$27.26	$105.14
Assistant City Manager	$141,000.00	$67.79	$23.73	$91.51
Public Works Director	$128,000.00	$61.54	$21.54	$83.08
Finance Director	$110,000.00	$52.88	$18.51	$71.39
City Engineer	$102,000.00	$49.04	$17.16	$66.20
City Council	$9,000.00	$4.33	$0.00	$4.33
Administrator	$50,400.00	$24.23	$8.48	$32.71
City Attorney		$150.00		$150.00
Consulting for Facilitation		$150.00		$150.00
Total				$754.37
Total Including Miscellaneous Staff Time of 20%				**$905.24**
City of Rowlett Strategic Planning Phase Overhead Expenses Per Hour				
Overhead Components		Hourly		Cumulative Expense
Electricity*		$6.39		$6.39
Water & Sewer*		$7.47		$7.47
Building Expense *		$11.81		$11.81
Building Contents Expense		$2.69		$2.69
Total				$28.36
Total with Miscellaneous Expenses (15%)				**$32.62**
TOTAL STRATEGIC PLANNING PHASE EXPENSES				**$937.86**
* For 9,300 sq. ft. of the renovated building which cost $1.3 M used for meetings & office space				
of the strategic planning team using council chambers and council office				

Source: City of Rowlett

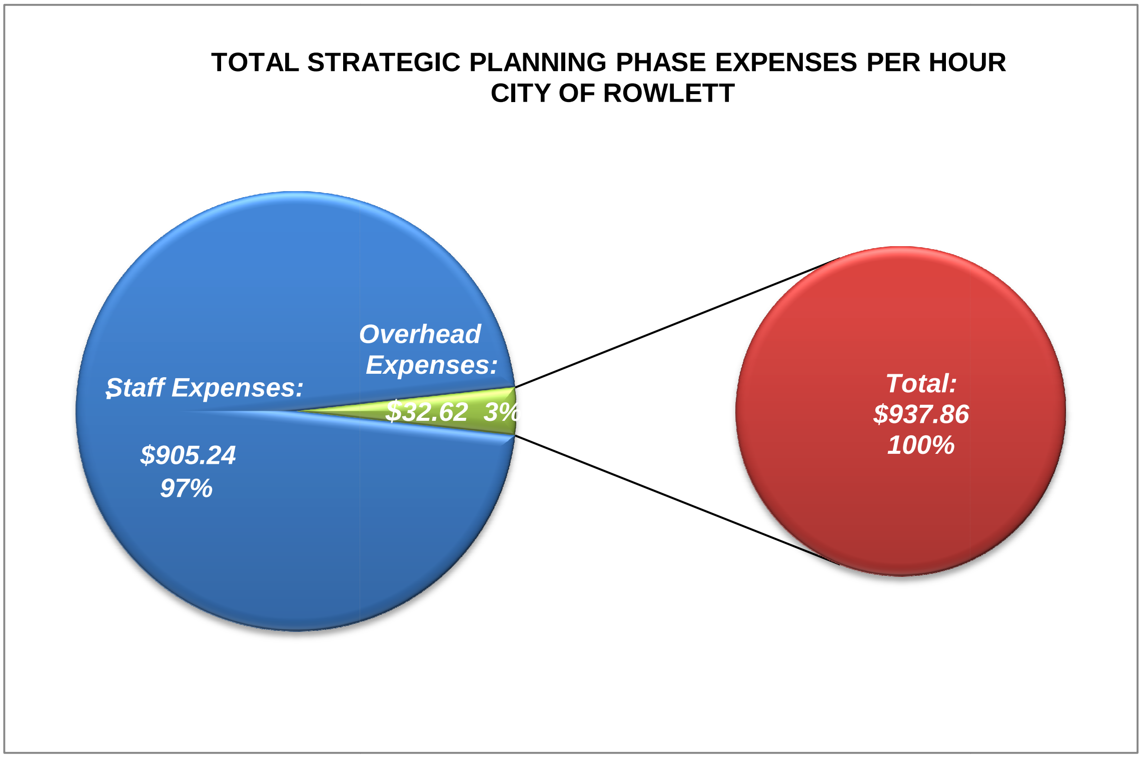


Figure 4.3 Strategic Plan Expenses City of Rowlett
Source: City of Rowlett

4.4 Calculation of True Costs for City of Allen

4.4.1 Strategic Plan Expenses

The following is the calculation of the Allen's TCs. The strategic plan expenses are shown in Table 4.4 and Figure 4.6 for a typical renewal project. The municipal administrative cost is divided into city employee expenses of approximately $1,002 per hour and overhead expenses of approximately $33 per hour. Therefore, the total strategic planning costs per hour for Allen with a population of 88,000 (United States Census 2010), for staffing expense and benefits and overhead costs will be approximately $1,035 per hour. Appendix B presents a detailed calculation of the overhead expenses.

Table 4.2 Municipal Administrative and Overhead Expenses for Consensus Planning for Rowlett (2010-2011 dollars)

City of Rowlett Consensus Phase Planning Staff Expenses Per Hour				
City Employees	Yearly	Hourly	Benefits Multiplier (35%)	Cumulative Expense
City Manager	$162,000	$77.88	$27.26	$105.14
Assistant City Manager	$141,000	$67.79	$23.73	$91.51
Public Works Director	$128,000	$61.54	$21.54	$83.08
Finance Director	$110,000	$52.88	$18.51	$71.39
City Engineer	$102,000	$49.04	$17.16	$66.20
Assistant City Engineer	$84,000	$40.38	$14.13	$54.52
Waste Water Manager	$72,828	$35.01	$12.25	$47.27
Administrator	$35,000	$16.83	$5.89	$22.72
City Attorney		$150.00		$150.00
Purchasing Agent	$61,000	$29.33	$10.26	$39.59
Consulting for SSMP		$0.46		$0.46
Consulting for SSES		$5.71		$5.71
Total				$737.59
Total Including Miscellaneous Staff Time of 20%				**$885.11**
City of Rowlett Consensus Phase Planning Overhead Expenses Per Hour				
Overhead Components		Hourly		Cumulative Expense
Electricity*		$6.39		$6.39
Water & Sewer*		$7.47		$7.47
Building Expense		$11.81		$11.81
Building Contents Expense		$2.69		$2.69
Total				$28.36
Total with Miscellaneous Expenses (15%)				**$4.25**
Total Overhead Expenses				**$32.62**
TOTAL CONSENSUS PHASE PLANNING EXPENSES				**$889.36**

* For 9,300 sq. ft. of the renovated building which cost $1.3 M used for meetings & office space of the consensus team using council chambers and council office

Source: City of Rowlett

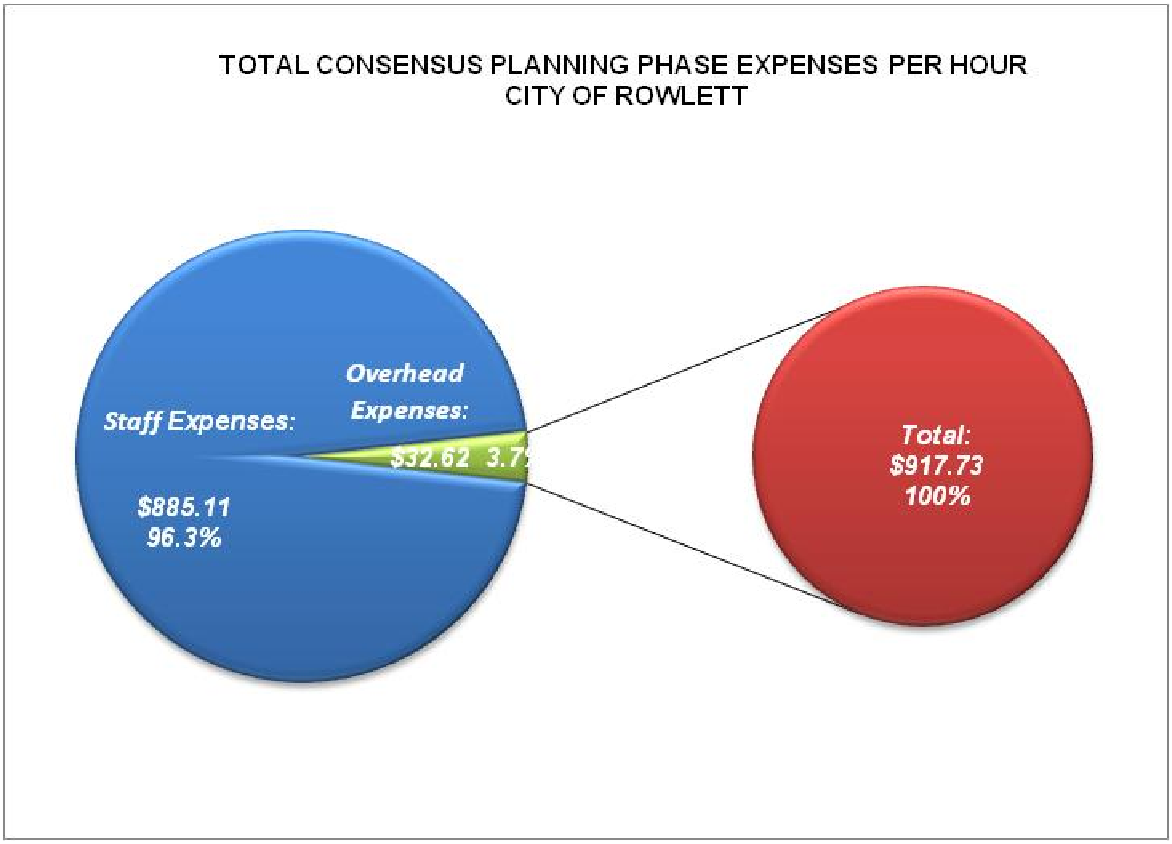


Figure 4.4 Consensus Plan Expenses City of Rowlett
Source: City of Rowlett

4.4.2 Consensus Plan Expenses

The following is the calculation of the City of Allen TC's. The consensus plan expenses are shown in Table 4.5 and Figure 4.7 for a typical renewal project. The municipal administrative cost is divided into city employee expenses of approximately $948 per hour, and overhead expenses of approximately $33 per hour. Therefore, the consensus planning costs per hour for Allen for staffing expense and benefits and overhead costs will be approximately $981 per hour. Appendix B presents a detailed calculation of the overhead expenses.

Table 4.3 Municipal Administrative and Overhead Expenses for Rowlett's Implementation Phase (2010-2011 dollars)

City of Rowlett Implementation Phase Staff Expenses Per Hour

City Employees	Yearly	Hourly	Benefits Multiplier (35%)	Cumulative Expense
Public Works Director	$125,000	$60.10	$21.03	$81.13
City Engineer	$102,000	$49.04	$17.16	$66.20
Assistant City Engineer	$84,000	$40.38	$14.13	$54.52
Waste Water Manager	$72,828	$35.01	$12.25	$47.27
Administrator	$35,000	$16.83	$5.89	$22.72
Purchasing Agent	$61,000	$29.33	$10.26	$39.59
Public Information Officer	$43,791	$21.05	$7.37	$28.42
Accounting Agent	$63,869	$30.71	$10.75	$41.45
City Inspector	$50,000	$24.04	$8.41	$32.45
GIS Manager	$54,000	$25.96	$9.09	$35.05
Right of Way Inspector	$47,186	$22.69	$7.94	$30.63
Equipment Operator Crew (4 people)	$210,000	$100.96	$35.34	$136.30
Camera Crew (2 people)	$90,000	$43.27	$15.14	$58.41
Total				$674.14
Total Including Miscellaneous Staff Time of 20%				**$808.97**

City of Rowlett Implementation Phase Overhead Expenses Per Hour

Overhead Components	Hourly		Cumulative Expense
Electricity*	$6.39		$6.39
Water & Sewer*	$7.47		$7.47
Building Expense *	$17.99		$17.99
Building Contents Expense **	$3.13		$3.13
Field Expense	$22.83		$22.83
Total			$57.81
Total with Miscellaneous Expenses (15%)			**$66.49**
TOTAL IMPLEMENTATION PHASE EXPENSES			**$875.45**

* For 15,148 sq. ft. of the public works building which cost $2.0439 M used for meetings & office space of the consensus team using council chambers and council office

** Valued at $350,000 based on Insurance Coverage assuming F & F life at 10 years

Source: City of Rowlett

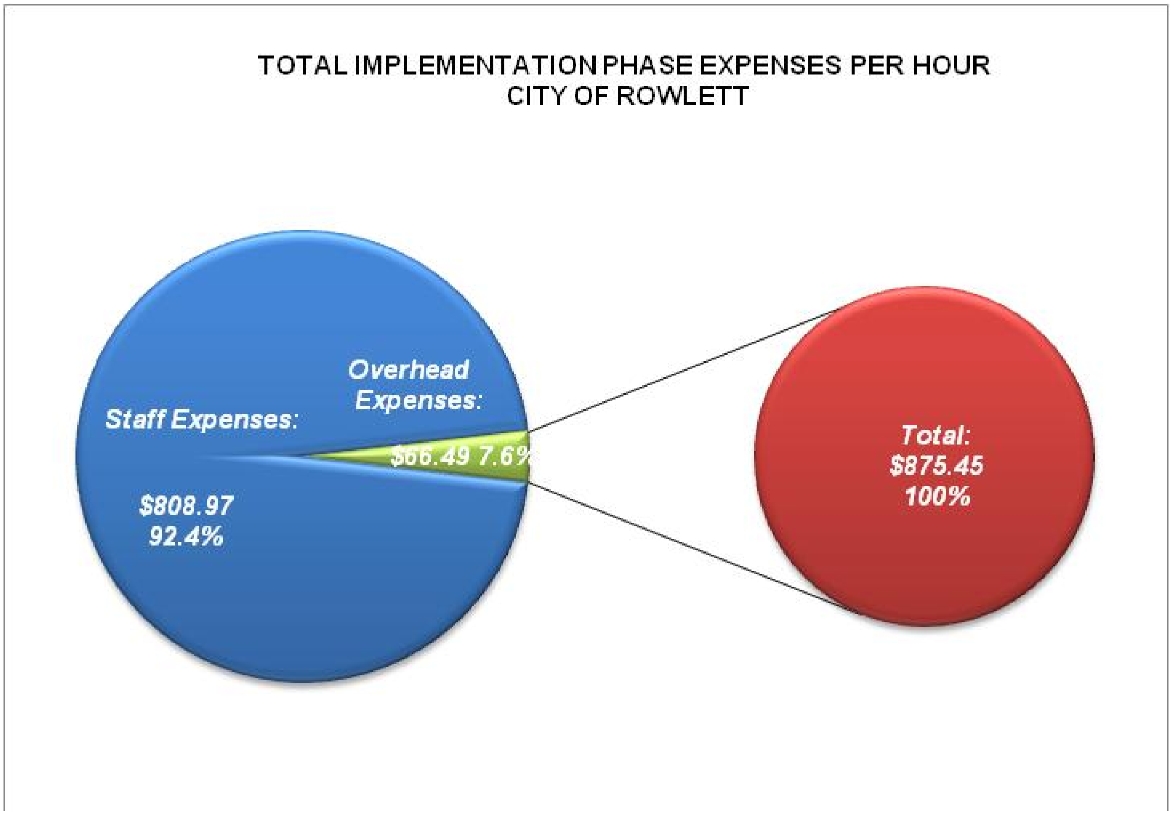


Figure 4.5 Implementation Phase Expenses City of Rowlett
Source: City of Rowlett

4.4.3 Implementation Phase Expenses

The following is the calculation of the city of Allen’s TCs. The implementation phase expenses are shown in Table 4.6 and Figure 4.8 for a typical renewal project. The municipal administrative cost is divided into city employee expenses of approximately $843 per hour and overhead expenses of approximately $59 per hour. Therefore, the total implementation phase costs per hour for a city like Allen for staffing expense, benefits and overhead costs will be approximately $902. Appendix B presents a detailed calculation of the overhead expenses. Note: Allen has a new service center building inaugurated in May of 2011 that would provide more accurate cost for building expense.

Table 4.4 Municipal Administrative and Overhead Expenses for Strategic Planning for Allen (2010-2011 dollars)

City of Allen Strategic Planning Phase Staff Expenses Per Hour			
City Employees	Hourly	Benefits Multiplier of (35%)	Cumulative Expense
City Manager	$108.00	$37.80	$145.80
Assistant City Manager	$54.32	$19.01	$73.33
Director of Engineering	$67.30	$23.56	$90.86
Finance Director	$67.30	$23.56	$90.86
Community Services Director	$67.30	$23.56	$90.86
Assist. Community Services Director	$37.25	$13.04	$50.29
Assist. Director Engg.	$37.25	$13.04	$50.29
Project Technician	$19.80	$6.93	$26.73
Administrator	$3.00	$1.05	$4.05
City Attorney	$160.00		$160.00
Purchasing Manager	$32.70	$11.45	$44.15
Accounting Manager	$32.70	$11.45	$44.15
Consulting for Facilitation	$170.00		$170.00
Total			$871.34
Total with Miscellaneous Staff Time (15%)			**$1,002.04**
City of Allen Strategic Planning Phase Overhead Expenses Per Hour			
Overhead Components	Hourly		Cumulative Expense
Electricity*	$6.82		$6.82
Water*	$7.47		$7.47
Building Expense *	$12.41		$12.41
Building Contents Expense	$1.77		$1.77
Total			$28.47
Total with Miscellaneous Expenses (15%)			**$4.27**
Total Overhead Expenses			**$32.75**
TOTAL STRATEGIC PLANNING PHASE EXPENSES			**$1,034.79**

* For 10,000 sq. ft. of 60,457 sq. ft. the building that cost $8.9 M, used for meetings & office space or 16.50% of the overall building to house the strategic team

Source: City of Allen

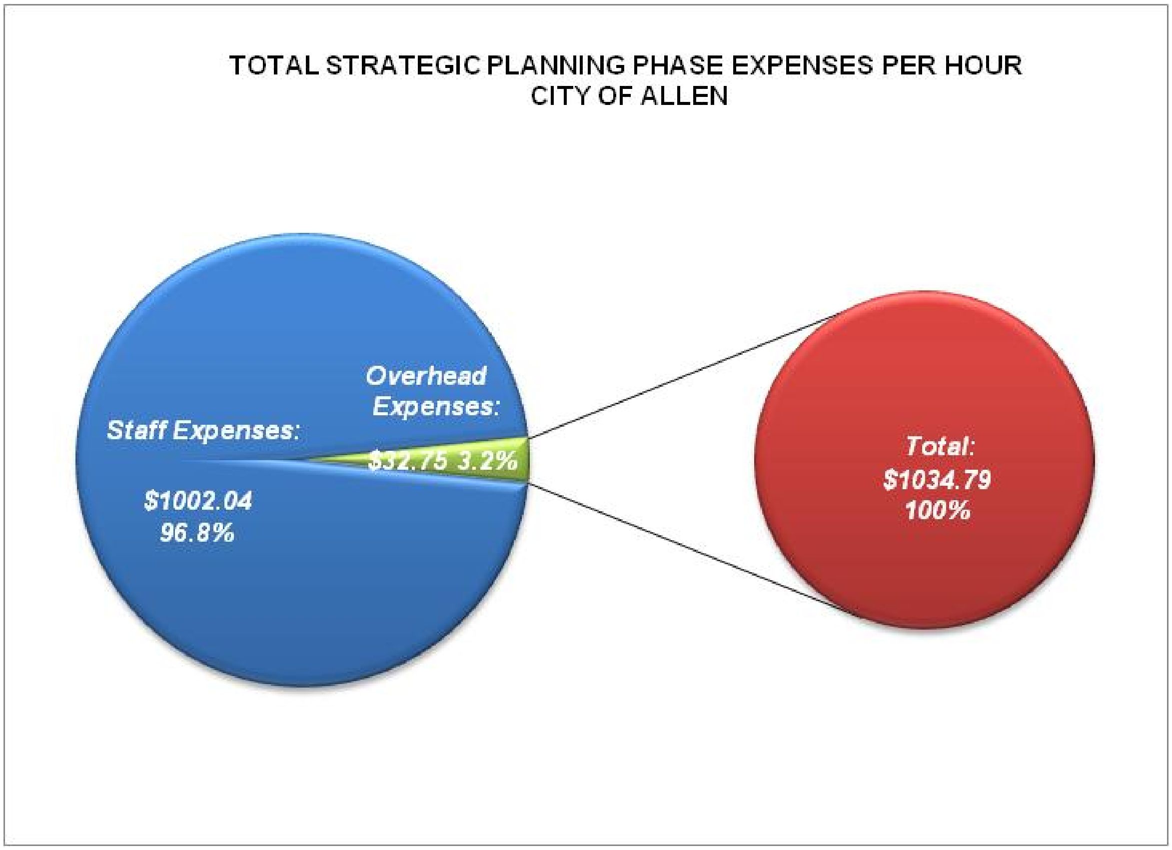


Figure 4.6 Strategic Plan Expenses City of Allen
Source: City of Allen

4.5 Administrative Cost and Overhead Expense Summary

The calculations for cities of Rowlett and Allen, Texas, for strategic, consensus, and implementation phase were included. Table 4.7 and Table 4.8 summarize the different costs.

4.6 True Cost Framework

A TC framework was developed in Microsoft Excel as part of this dissertation. Strategic planning, consensus planning, implementation phase, and overhead costs can be calculated by inputting data from municipalities, and the tool provides the output. Appendix E provides a sample output of this framework.

Table 4.5 Allen’s Municipal Administrative and Overhead Expenses for Consensus Planning (2010-2011 dollars)

City of Allen Consensus Planning Phase Staff Expenses Per Hour

City Employees	Hourly	Benefits Multiplier (35%)	Cumulative Expense
City Manager	$108.00	$37.80	$145.80
Assistant City Manager	$54.30	$19.01	$73.31
Director of Engineering	$67.30	$23.56	$90.86
Finance Director	$67.30	$23.56	$90.86
Assist. Community Services Director	$37.25	$13.04	$50.29
Assist. Director Engg.	$37.25	$13.04	$50.29
Project Technician	$19.80	$6.93	$26.73
Civil Engineer	$32.70	$11.45	$44.15
Administrator	$3.00	$1.05	$4.05
City Attorney	$160.00	$0.00	$160.00
Purchasing Manager	$32.70	$11.45	$44.15
Accounting Manager	$32.70	$11.45	$44.15
Consulting for SSMP	$0.48		$0.48
Total			$824.61
Total with Miscellaneous Staff Time (15%)			**$948.30**

City of Allen Consensus Planning Phase Overhead Expenses Per Hour

Overhead Components	Hourly		Cumulative Expense
Electricity*	$6.82		$6.82
Water*	$7.47		$7.47
Building Expense *	$12.41		$12.41
Building Contents Expense	$1.77		$1.77
Total			$28.47
Total with Miscellaneous Expenses (15%)			**$4.27**
Total Overhead Expenses			**$32.75**

TOTAL CONSENSUS PHASE PLANNING EXPENSES			**$981.04**

* For 10,000 sq. ft. of 60,457 sq. ft. the building that cost $8.9 M for meetings & office space or 16.50% of the overall building to house the consensus team

Source: City of Allen

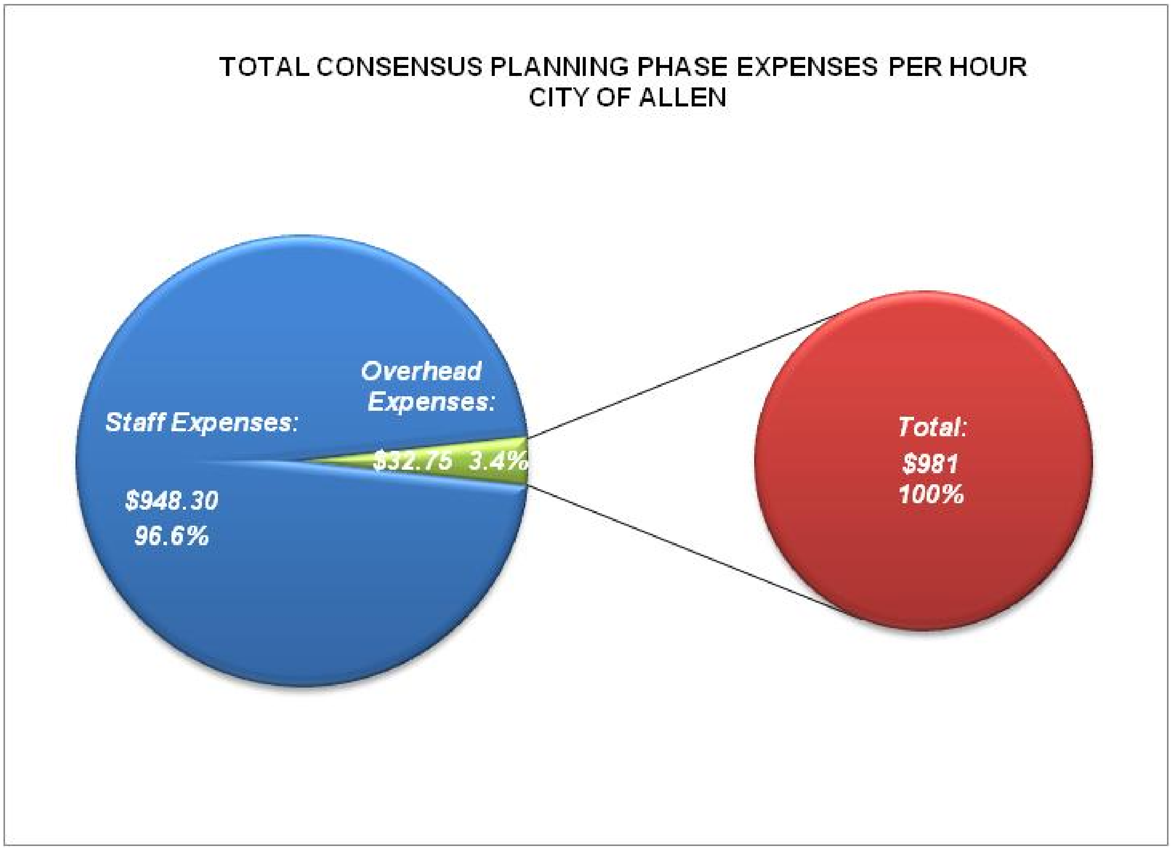


Figure 4.7 Consensus Plan Expenses City of Allen
Source: City of Allen

Table 4.6 Municipal Administration & Overhead Expenses for Implementation Phase for Allen (2010-2011 dollars)

City of Allen Implementation Phase Staff Expenses Per Hour

City Employees	Hourly	Benefits Multiplier (35%)	Cumulative Expense
Director of Engineering	$67.30	$23.56	$90.86
Assist. Community Services Director	$37.25	$13.04	$50.29
Assist. Director Engg.	$37.25	$13.04	$50.29
Project Technician	$19.80	$6.93	$26.73
Civil Engineer	$32.70	$11.45	$44.15
Sanitary Sewer Supervisor	$25.48	$8.92	$34.40
Administrator	$17.49	$6.12	$23.61
GIS Technician	$17.49	$6.12	$23.61
Right of Way Coordinator	$19.07	$6.67	$25.74
City Inspector	$24.60	$8.61	$33.21
Line Locator	$19.07	$6.67	$25.74
Purchasing Manager	$32.70	$11.45	$44.15
Accounting Manager	$32.70	$11.45	$44.15
Equipment Operator Crew (4 people)	$112.00	$39.20	$151.20
Camera Crew (2 people)	$48.00	$16.80	$64.80
Total			$732.92
Total with Miscellaneous Staff Time (15%)			**$842.85**

City of Allen Implementation Phase Overhead Expenses Per Hour

Overhead Contents	Hourly		Cumulative Expense
Electricity*	$6.82		$6.82
Water*	$7.47		$7.47
Building Expense *	$12.41		$12.41
Building Content & Insurance**	$1.77		$1.77
Equipment	$22.83		$22.83
Total			$51.31
Total with Miscellaneous Expenses (15%)			**$59.00**
TOTAL IMPLEMENTATION PHASE EXPENSES			**$901.85**

* For 10,000 sq. ft. of 60,457 sq. ft. the building that cost $8.9 M, used for meetings & office space or 16.50% of the overall building to house the implementation team

** City of Allen has recently moved to a new Sevice Center that has not been used in this research

Source: City of Allen

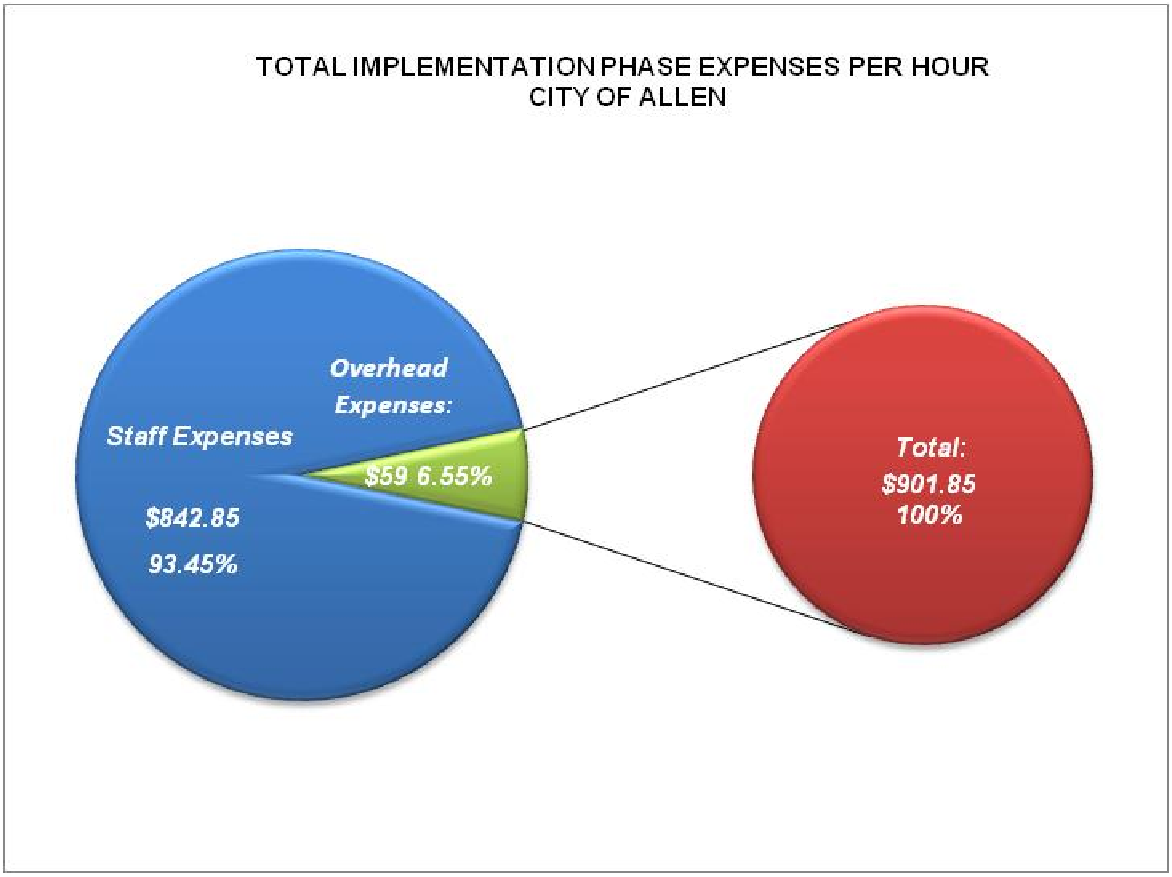


Figure 4.8 Implementation Plan Expenses City of Allen
Source: City of Allen

Table 4.7 Summary of City of Rowlett Administrative & Overhead Expenses per Hour (2010-2011 dollars)

City of Rowlett	Administrative Expenses ($/hour)	Overhead Expenses ($/hour)	Total Expenses ($/hour)
Strategic Planning	$905	$33	$938
Consensus Planning	$885	$33	$918
Implementation Phase	$809	$66	$875

Source: City of Rowlett

Table 4.8 Summary of City of Allen Administrative & Overhead Expenses per Hour (2010-2011 dollars)

City of Allen	Administrative Expenses ($/hour)	Over Head Expenses ($/hour)	Total Expenses ($/hour)
Strategic Planning	$1,002	$33	$1,035
Consensus Planning	$948	$33	$938
Implementation Phase	$843	$59	$902

Source: City of Allen

4.7 Chapter Summary

This chapter provided a review of municipal infrastructure asset system and its relationship to True Cost.

CHAPTER 5

DATA COLLECTION

5.1 Review of Data Collected from Cities

The cities in this study collect data as part of their renewal, repair, and maintenance (RR&M) projects. The core RR&M activities in these cities with regards to their sanitary sewer system are similar as documented in this research. The difference between these cities is in the use and documentation of the collected data. Basically there is vast difference between the TAMS component of the different cities. City of Garland has extensive data on their day-to-day RR&M activities, but do not have a completed and updated GIS mapping with attributes of size, age, material etc. of the sanitary sewer system. In addition, Garland has a monitoring room with several cameras that are incorporated in their critical asset areas. Meanwhile, the city of Rowlett has paper documentation and has started a detailed electronic documentation of RR&M activities since two years ago, and has an updated GIS map; however, the accuracy and amount of attribute information is limited and sketchy, as as-built drawings are not always accurate.

Allen, by the same token, has paper documentation and has not adopted the computer technology available for the RR&M process. However, there is detailed information available in GIS and AutoCAD. The cities referenced above have Supervisory Control and Data Acquisition (SCADA) for all their critical assets. In addition, there is redundant data as two separate departments (action center and public works) maintain the same information which increases TC. For example, Rowlett has an action center where customers can call in with any issues related to city services. If a plumber calls saying that the clogging of sewer is on the city side, the action center will call the public works department and a work order is set up in the action center. The sanitary crew responds to the call and after addressing the issue creates a detailed work order that has more details than the work order from the action center.

5.2 City of Rowlett Sanitary Sewer Data

As of 2010, the Rowlett collection system was comprised of approximately 221 miles of sanitary sewer, 2,559 manholes, and 667 mainline cleanouts. Stretched end to end, the system would reach from Rowlett to Houston. Thirty-three percent (33%) of the collection system is comprised of six-inch and smaller pipes. The majority of this pipeline is vitrified clay, which will continue to be problematic for the utility due to poor soil conditions, marginal capacity and deterioration due to age. The wastewater collection system has a replacement value of approximately $175 million in 2010 dollars. In addition, the city contains 26 lift stations.

Following is a summary of the comparison using the current estimated population of 56,103 (United States Census, 2010):

Average Winter Water Use (2005 - 2008) = 5.13 mgd (91 gpcd)
Recorded Dry Weather Wastewater Flow = 4.93 mgd (88 gpcd)
Theoretical Water Use = 56,103 x 100 gpcd = 5.61 mgd
Percent Return Flow = 88% (Forbes, 2010)

Table 5.1 and Figure 5.1 show the age of Rowlett's sewer system and the amount of sanitary sewer pipeline contained in the system. The sanitary sewer system in Rowlett is approximately 7% older than 30 years, 12% between 25 and 30 years, 33% between 20-24 years, 6% between 15 and 19 years, 15% between 11 and 14 years, and 27% between 0 and 10 years. Based on this information, the city can calculate the TC expenses for and repair, and plan its budget effectively. The city can use the factors that affect TC and repair and maintenance data, to effectively prioritize the projects that need to be renewed and repaired. The dollar amount estimates calculated and used in data for RR&M activities are for 2010-2011 fiscal year unless specified.

Table 5.1 Age of Sanitary Sewer Lines in Rowlett

Age of Sanitary Sewer Lines City of Rowlett			
Sewer Lines	Feet	Miles	Percentage of Overall
0-10 Years	345,043	65.35	27%
11-14 Years	194,549	36.85	15%
15-19 Years	78,638	14.89	6%
20-24 Years	411,990	78.03	33%
25-30 Years	148,061	28.04	12%
Over 30 Years	85,954	16.28	7%
Total	**1,264,235**	**239.44**	**100%**

Source: City of Rowlett

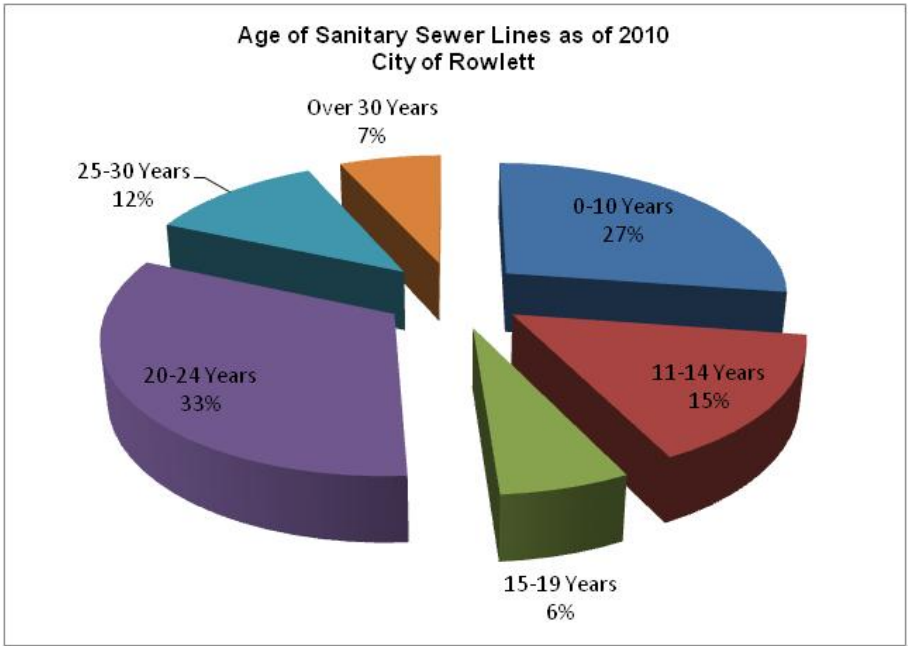


Figure 5.1 Age of Rowlett's Sanitary Sewer Lines
Source: City of Rowlett

5.2.1 Activity Codes in Rowlett

The TAMS for repair and maintenance data can be effectively used and organized. Rowlett uses activity codes to classify the jobs they are performing on the sanitary sewer system. For the RR&M, Rowlett uses a major alphabetical code from A through F and several numerical sub-codes. Table 5.2 identifies the major codes and minor codes. This dissertation has provided a cost component for each code, based on the crews that respond to the different jobs. Appendices D and F show calculations and sample data related to activity codes.

Table 5.2 Activity Codes used by Rowlett

Activity Codes City of Rowlett					
A - Stoppages	B - Preventative Maintenance	C - Digups	D - Lift Stations	E - Miscellaneous	F - Manhole/Ring & Lid/Mainline c/o
1 - Mains	1 - Jet Main	1 - Install c/o	1 - Rounds	1 - Dress ups	1 - Re-grouted
2 - Services	2 - Dispense Redhot/Degreaser	2 - Repair Sewer Main	2 - Repairs	2 - Paperwork/Prep for job	2 - Replaced
----	3 - Camera Service	3 - Repair Tap	3 - Maint.	3 - Sewer Odor Complaints	3 - Located
----	4 - Camera Main	4 - Repair c/o stack	----	4 - Install Rainguard	4 - Repaired
----	5 - Mini Jet Service	----	----	5 - Check for Breaks in Main	5 - Raise
----	----	----	----	6 - Check Main for Flow	6 - Lower
----	----	----	----	----	7 - Manhole Offset
----	----	----	----	----	8 - Stuck Manhole Lid

c/o - Cleanout

Source: City of Rowlett

5.2.2 Renewal, Repair, & Maintenance (RR&M) Activities in Rowlett

Based on the detailed data collected for RR&M in the years 2009 through 2011 by the City of Rowlett, an analysis was conducted in this research to identify the time breakdown of the activities performed to address issues with the sanitary sewer system (Table 5.3 and Table 5.4). It can be seen that the number of hours and dollars spent on maintenance was 3,036 and $534,896 in 2009-2010, and 1,749 and $318,335 respectively for years 2009-2010 and 2010-2011. Note that the data for 2010-2011 was not complete for August and September. Appendix D presents sample calculations for RR&M expenses in city of Rowlett.

A generic breakdown of the activities in Table 5.3 is depicted in Figure 5.2 and Figure 5.3. The lift and metering stations, which are critical assets, uses 41% of the time that could include routine maintenance or actual repairs conducted on the sanitary sewer system. The next major category was dig-ups (21%), followed by preventative maintenance (17%), miscellaneous (12%), stoppages (7%), and manhole activity (3%) respectively.

Table 5.3 Sanitary Sewer RR&M Hours and Dollars (2009 – 2010)

Sanitary Sewer Hours 2009-2010		
Activities	Hours	Dollars
Stoppages	202	$41,509
Preventative Maintenance	512	$105,524
Digups	634	$131,704
Lift Stations	1237	$190,074
Miscellenaeous	352	$46,474
Manhole Activity	100	$19,611
Total	3036	$534,896

Source: City of Rowlett

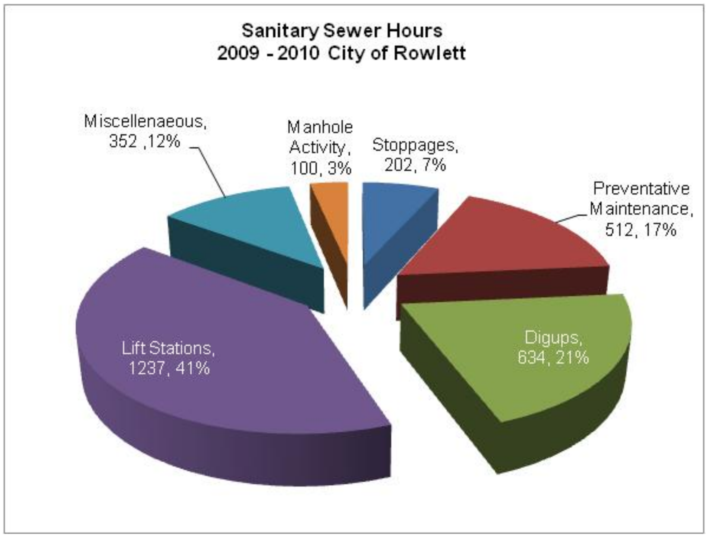


Figure 5.2 Generic Breakdowns of RR&M Hours for the Sanitary Sewer System (2009 -2010)
Source: City of Rowlett

The TC dollars spent on the renewal and repair are shown in Figure 5.3. The lift and metering stations use 35% of the costs. The next major category in expenditures is dig-ups (23%), followed by preventative maintenance (18%), miscellaneous (9%), stoppages (8%), and manhole activity (4%), respectively. Based on the hours and expense data in Figure 5.2 and

Figure 5.3, it can be observed that the number of hours spent on a particular activity is not proportional to the expense of the activity.

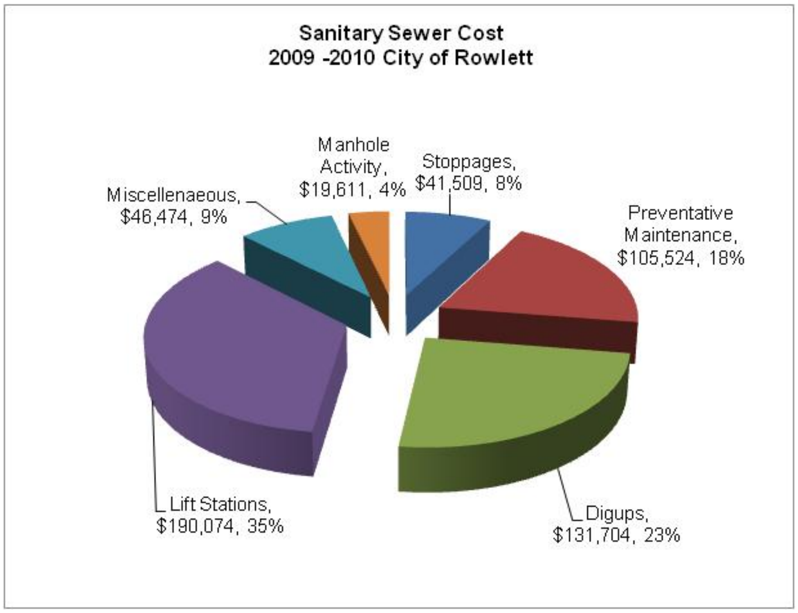


Figure 5.3 RR&M Costs for the Sanitary Sewer System (2009-2010 dollars)
Source: City of Rowlett

A generic breakdown of the activities in Table 5.4 is depicted in Figure 5.4 and Figure 5.5. The lift and metering stations, which are critical assets, uses 36% of the time that could include routine maintenance or actual repairs conducted on the sanitary sewer system. The next major category was dig-ups (23%) followed by preventative maintenance (15%), stoppages (14%), miscellaneous (7%), and manhole activity (5%) respectively.

Table 5.4 Sanitary Sewer RR&M Hours in City of Rowlett (2010 – 2011 dollars)

Sanitary Sewer Hours 2010-2011*

Activities	Hours	Dollars
Stoppages	245	$ 50,470
Preventative Maintenance	260	$ 53,632
Digups	397	$ 80,818
Lift Stations	637	$ 99,643
Miscellenaeous	118	$ 15,845
Manhole Activity	91	$ 17,927
Total	1749	$ 318,335

* August - September Incomplete

Source: City of Rowlett

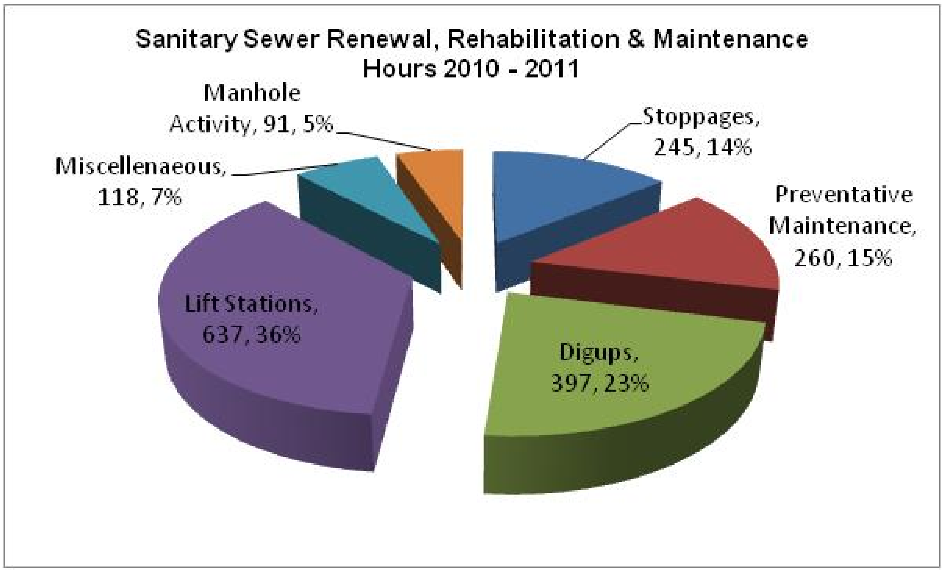


Figure 5.4 RR&M Hours for Rowlett's Sanitary Sewer System (2010 - 2011)
Source: City of Rowlett

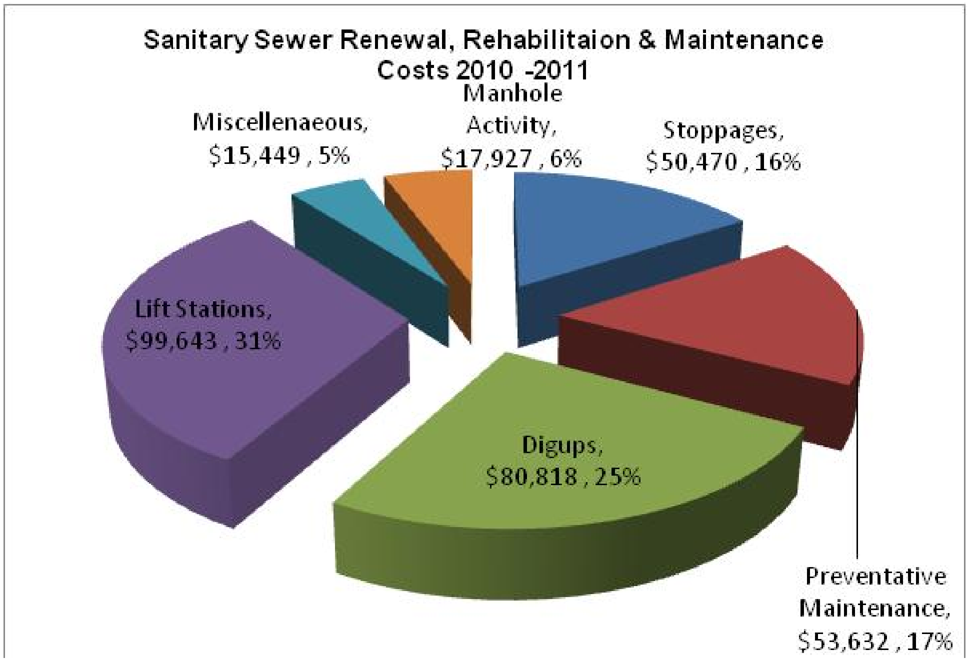


Figure 5.5 RR&M Costs for Rowlett's Sanitary Sewer System (2010-2011 dollars)
Source: City of Rowlett

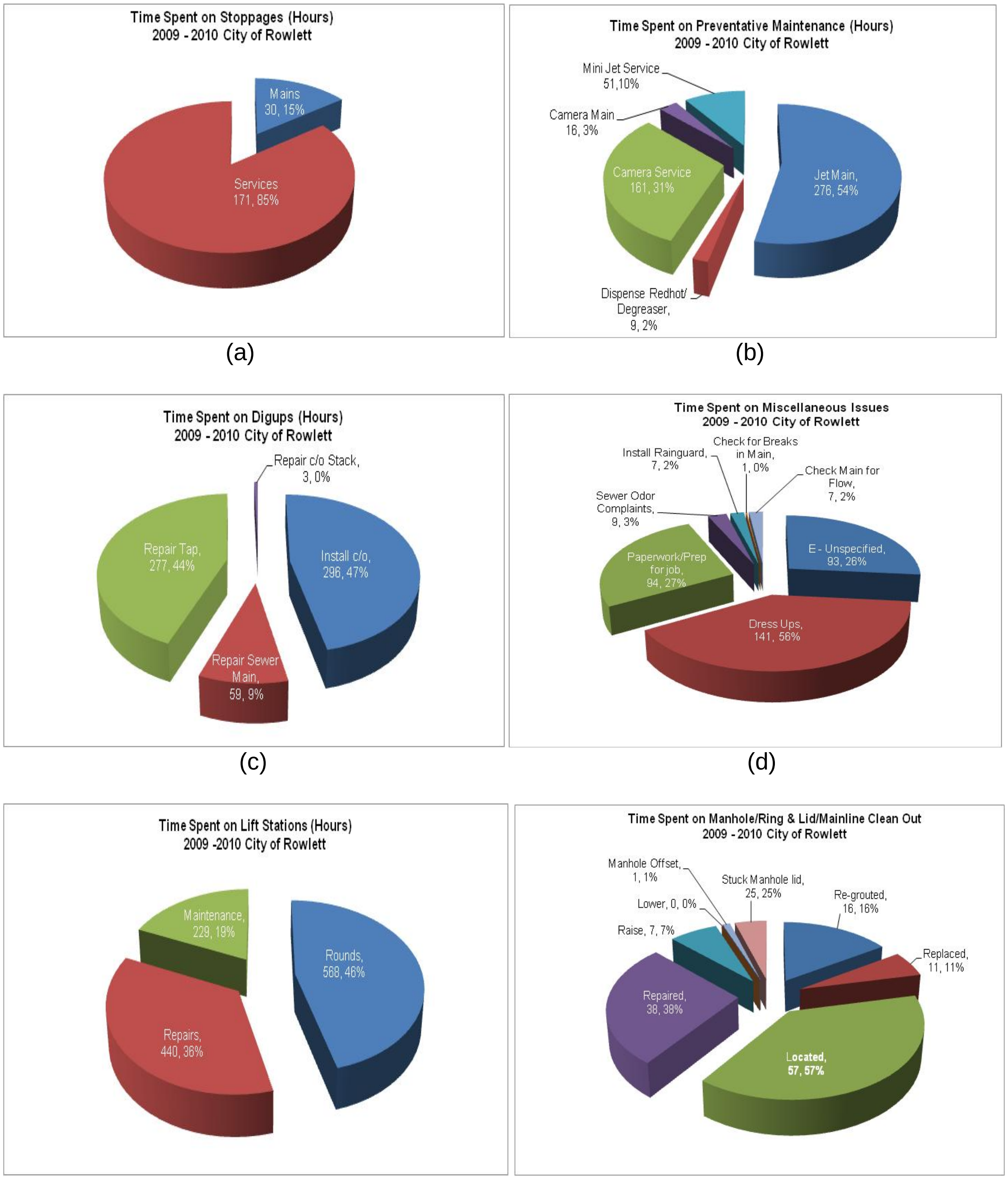
The TC dollars spent on the renewal and repair are shown in Figure 5.5 and show that the lift and metering stations use 31% of the dollars. The next major category in expenditures was dig-ups (25%) followed by preventative maintenance (17%), stoppages (16%), manhole activity (6%), and miscellaneous (5%), respectively. Based on the hours and expense data in Figure 5.4 and Figure 5.5, it can be observed that the number of hours spent on a particular activity is not proportional to the expense of the activity.

Table 5.5 and Figure 5.6 (a through f) provide a detailed breakdown of the 2009 – 2010 RR&M activities, while Table 5.6 and Figure 5.7 (a through f) present a detailed breakdown of RR&M activities for 2010 – 2011.

Table 5.5 Detailed Breakdown of RR&M City of Rowlett (2009-2010 dollars)

City of Rowlett Repair,Rehabilitation, Renewal & Maintenance Hours & Expenses 2009-2010			
Sanitary Sewer	Hours	Hourly Cost	Total Cost
A - Stoppages			
1 - Mains	30	$206	$6,232
2 - Services	171	$206	$35,278
Total	202		$41,509
B - Preventative Maintenance			
1 -Jet Main	276	$206	$56,774
2 - Dispense Redhot/Degreaser	9	$206	$1,916
3 - Camera Service	161	$206	$33,094
4 - Camera Main	16	$206	$3,214
5 - Mini Jet Service	51	$206	$10,527
Total	512		$105,524
C - Digups			
1 - Install C/O	296	$197	$58,263
2 - Repair Sewer Main	59	$312	$18,252
3 - Repair Tap	277	$197	$54,549
4 - Repair C/O Stack	3	$197	$640
Total	634		$131,704
D - WasteWater Stations			
1 - Rounds	568	$127	$72,095
2 - Repairs	440	$202	$88,870
3 - Maint.	229	$127	$29,108
Total	1,237		$190,074
E -Miscellaneous			
E - unspecified	93	$75	$7,009
1 -Dress ups	141	$197	$27,826
2 - Paperwork/Prep for Job	94	$75	$7,039
3 - Sewer Odor Complaints	9	$197	$1,812
4 - Install Rainguard	7	$197	$1,320
5 - Check for Breaks in Main	1	$197	$118
6 - Check Main for Flow	7	$197	$1,349
Total	352		$46,474
F - Manhole/Ring & Lid/Main Line c/o			
1 - Re-grouted	16	$197	$3,093
2 - Replaced	6	$197	$1,133
3 - Located	38	$197	$7,535
4 - Repaired	27	$197	$5,349
5 - Raise	7	$197	$1,379
6 - Lower	-	$197	$0
7 - Manhole Offset	1	$197	$217
8 - Stuck Manhole Lid	5	$197	$906
Total	100		$19,611
Grand Total	3,036		$534,896
Feet Jetted	23,050		

Source: City of Rowlett



(a) (b)

(c) (d)

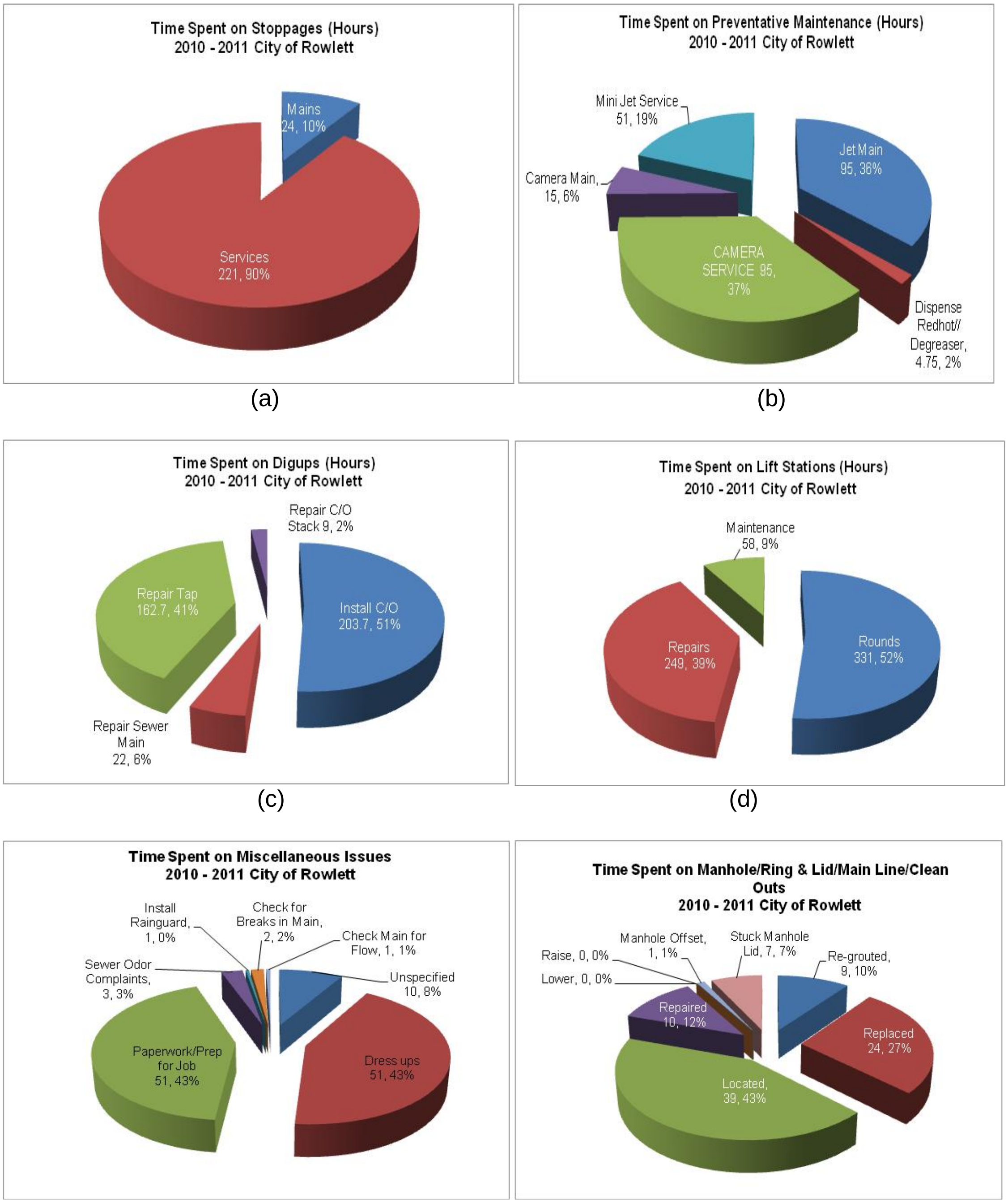
(e) (f)

Figure 5.6 (a) through (f) Breakdown of RR&M hours for Sanitary Sewer System (2009 – 2010)
Source: City of Rowlett

Table 5.6 Detailed Breakdowns of RR&M City of Rowlett (2010-2011 dollars)

City of Rowlett Repair,Rehabilitation, Renewal & Maintenance Hours & Expenses 2010-2011			
Sanitary Sewer	Hours	Hourly Cost	Total Cost
A - Stoppages			
1 - Mains	24	$206	$5,026
2 - Services	221	$206	$45,444
Total	245		$50,470
B - Preventative Maintenance			
1 -Jet Main	95	$206	$19,488
2 - Dispense Redhot/Degreaser	5	$206	$979
3 - Camera Service	95	$206	$19,663
4 - Camera Main	15	$206	$3,059
5 - Mini Jet Service	51	$206	$10,444
Total	260		$53,632
C - Digups			
1 - Install C/O	204	$197	$40,129
2 - Repair Sewer Main	22	$312	$6,864
3 - Repair Tap	163	$197	$32,052
4 - Repair C/O Stack	9	$197	$1,773
Total	397		$80,818
D - WasteWater Stations			
1 - Rounds	331	$127	$42,040
2 - Repairs	249	$202	$50,359
3 - Maint.	57	$127	$7,245
Total	637		$99,643
E -Miscellaneous			
E - unspecified	10	$75	$746
1 -Dress ups	51	$197	$10,015
2 - Paperwork/Prep for Job	51	$75	$3,803
3 - Sewer Odor Complaints	3	$197	$650
4 - Install Rainguard	1	$197	$99
5 - Check for Breaks in Main	2	$197	$394
6 - Check Main for Flow	1	$197	$138
Total	118		$15,845
F - Manhole/Ring & Lid/Main Line c/o			
1 - Re-grouted	9	$197	$1,852
2 - Replaced	24	$197	$4,797
3 - Located	39	$197	$7,713
4 - Repaired	10	$197	$2,049
5 - Raise	0	$197	$0
6 - Lower	0	$197	$0
7 - Manhole Offset	1	$197	$197
8 - Stuck Manhole Lid	7	$197	$1,320
Total	91		$17,927
Grand Total	1,749		$ 318,335
Feet Jetted	Not Available		

Source: City of Rowlett



(a) (b)

(c) (d)

(e) (f)

Figure 5.7 (a) through (f) Breakdown of RR&M hours for Sanitary Sewer System (2010 – 2011)
Source: City of Rowlett

5.3 City of Allen Sanitary Sewer Data

As of 2009, the Allen collection system has been comprised of approximately 320 miles of sanitary sewer, 3,929 manholes and 626 mainline cleanouts. Sixteen percent (16%) of the collection system is comprised of six-inch and smaller pipe. The pipe material for the system is contained on as-builts and not included in the GIS system (Table 5.7 and Figure 5.8). In addition, the city contains 13 Lift Stations. Efforts were made to get detailed information of Allen's costs and repair inventory; however, it was indicated that the City does not have any electronic data for repairs and are using paper forms to fill in any field reports.

Following is a summary of the comparison using the projected population of 98,823:

Design Standard = 100 gallon per capita day (gpcd)

Theoretical Water Use = 98,823 x 100 gpd = 9.88 mgd (City of Allen SSMP, 2002)

5.4 City of Garland Sanitary Sewer Data

As of 2006, the Garland collection system had approximately 985 miles of sanitary sewer, 3,929 manholes and 626 mainline cleanouts. Sixteen percent (16%) of the collection system was comprised of six-inch and smaller pipe. The pipe material for the system is still contained on as-builts and not included in the GIS system. Furthermore, the city contains 13 Lift Stations. There are 908 miles of sewer mains 12" or smaller that would require a four-year 48-month cycle for "cleaning and stripping". The average time would be 18.92 miles every month based on existing crews. Following is a summary of the comparison using the projected population of 226,876:

Design Standard = 100 gallon per capita day (gpcd)

Theoretical Water Use = 226,876 x 100 gpd = 22.68 mgd

Table 5.7 Sanitary Sewer System Size and Length City of Allen up to 2009

Size of Sanitary Sewer System	Miles	Feet
4"	2	9,663
6"	49	259,188
8"	196	1,034,060
10"	0	1,462
12"	12	64,385
14"	0	234
16"	12	60,827
18"	6	34,085
20"	0	2,208
21"	5	24,690
24"	4	21,607
27"	4	22,711
30"	2	11,111
33"	2	11,488
36"	3	15,932
42"	2	9,424
48"	2	10,143
60"	8	40,712
Total	309.46	1,633,930

Source: City of Allen

5.4.1 Activity Codes in Garland

Garland has its own activity codes for its RR&M. The city uses a combination of alphanumeric and numeric digits to name its codes. Table 5.8 identifies the major codes and minor codes. For Garland, this dissertation has provided a cost component for some of the codes based on the crews that respond to the different work orders. Appendices C and E show the calculations and sample data related to the activity codes.

5.4.2 Size and Length of Garland's Sanitary Sewer System

The city of Garland has an extensive sanitary sewer system as shown in Table 5.9 and depicted in Figure 5.9

Table 5.8 Activity Codes used by the City of Garland

Maintainance	Desc. of Sewer Jobs	Repair	Desc. of Sewer Jobs	I/I	Desc of Sewer Jobs
CASS	Call About Sewer Stoppage	CHC	Check Comments	AOC	Assist Outside Contractor
CHC	Check Comments	CO1	Repair cleanout	CHC	Check Comments
CO4	Gen CO maint	CO2	Adjust CO to grade	CO1	Repair cleanout
CO5	Clean CO overflow	CO3	Install main CO	CO2	Adjust CO to grade
COFW	Cleanout Overflowing	CO4	Gen CO maint	CO3	Install main CO
JCCO	Jet City Cleanout	ICCO	Install City CO	CO4	Gen CO maint
MH6	MH inspection	JKH	Jack Hammer	COFW	Cleanout Overflowing
MH7	MH cleaned	MH1	Repaired MH	ICCO	Install City CO
MH8	Clean MH overflow	MH2	Adjust MH to grade	II2	MH I/L confined
MH11	MH OF during rain event	MH3	Locate MH	II3	Smoke testing
MHOF	MH overflow	MH4	Install MH	II4	TV inspect I/I
NS	No Service	MH5	Gen MH maint	II5	Dye testing
SBP	SBP Assessments	MH6	MH inspection	II6	Check outfall lines
SCU	Gen cleanup	NS	No Service	II7	MH repair I/I
SJ1	Cust contact	SBP	SBP Assessments	II9	Swr main repair
SM1	Maint line stoppage	SM9	Assist others - In Div.	II15	Flow Meter Monitoring
SM2	Sewer maint serv conn	SCU	Gen cleanup	MH2	Adjust MH to grade
SM3	Sewer maint serv line	SJ1	Cust contact -	MH3	Locate MH
SM4	No stoppage found	SJ8	Barricades	MH4	Install MH
SM5	Main stoppage rain/infil	SJ9	Gen Sewer sys maint	MH5	Gen MH maint
SM6	Sewer overflow cleanup	SJ10	Pre/post job inspect	MH6	MH inspection
SM7	Clean valve stack	SR1	Swr later repair	MH11	MH off during rain event
SM8	Clean up street	SR2	Repair swr main section	NS	No Service
SM9	Assist others - In Div.	SR3	New sewer tap	SBP	SBP Assessments
SM11	Problem main maint	SR4	Replace exist swr tap	SCU	Gen cleanup
SM12	Scheduled main maint	STR	Site Restoration	SJ1	Cust contact -
SM13	Root maint	VEND	Outside Vendor	SJ5	Assist others - City
SM14	Jet main - cust stoppage	WHSE	Whse parts pickup	SJ8	Barricades

Source: City of Garland

Table 5.8 Continued

Maintainance	Desc. of Sewer Jobs	Repair	Desc. of Sewer Jobs	I/I	Desc of Sewer Jobs
SM15	Main flowing-cust stoppage	IWC	Install WAC	SJ9	Gen Sewer sys maint
SM16	City CO Dry,Cust CO Wet	OMH	Open MH Lid	SJ10	Pre/post job inspect
SWO	Sewer Odor	RRL	Re-Set Ring & Lid	SM9	Assist others - In Div.
TV1	TV inspect, new main			SM11	Problem main maint
TV2	Problem detection TV			SR1	Swr later repair
TV4	TV Cust Service Lateral			STR	Site Restoration
XCO	Co Cust Cleanout			VEND	Outside Vendor
				WHSE	Whse parts pickup

Source: City of Garland

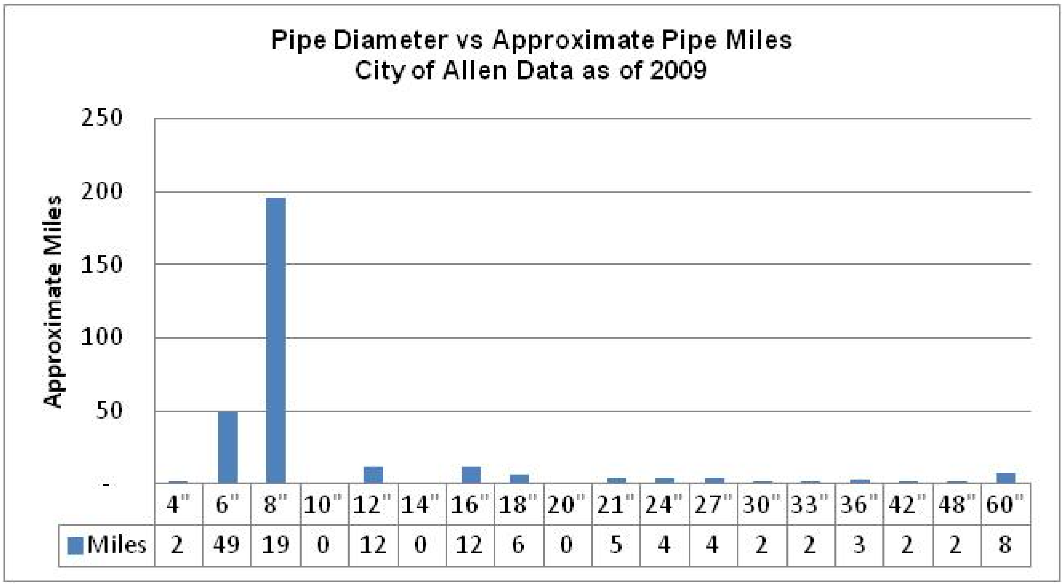


Figure 5.8 Sanitary Sewer System, City of Allen (as of 2009)
Source: City of Allen

5.5 Actual Samples of Major Projects

- Major renewal and repair projects from Allen and Rowlett are discussed here to determine the validity of the True Cost Concept. Specialized projects such as lift stations, wastewater treatment plants, etc. (that could be part of the sanitary sewer system) were not included in the calculation of TC.

5.5.1 Kenwood Heights Subdivision Renewal and Repair in Rowlett

The Kenwood Heights Subdivision was chosen for this research project as it was a huge project, and the whole subdivision was part of a renewal and repair project of the Rowlett CIP. The project included renewal and replacement of paving, replacing and upsizing water and sanitary sewer lines, and providing a street drainage system.

Table 5.9 Pipe Size and Length of the Sanitary Sewer System for the City of Garland

Pipe Size and Miles Up to March 2006 City of Garland			
Pipe Size	Feet	Miles	Percentage of Overall
4"	8,721	1.7	0.17%
6"	2,677,669	507.1	51.45%
8"	1,581,746	299.6	30.39%
10"	375,051	71.0	7.21%
12"	156,752	29.7	3.01%
15"	96,742	18.3	1.86%
16"	10,813	2.0	0.21%
18"	84,425	16.0	1.62%
21"	38,280	7.3	0.74%
24"	41,606	7.9	0.80%
27"	5,966	1.1	0.11%
30"	11,352	2.2	0.22%
36"	10,876	2.1	0.21%
42"	37,118	7.0	0.71%
48"	67,425	12.8	1.30%

Source: City of Garland

5.5.1.1 Cost Details

Kenwood Heights winning bid for the complete renewal of the subdivision as described in the section above was $5,788,747, and the Sanitary Sewer Portion of the Contract was $798,086 (Table 5.11). Mobilization and other services for the project was approximately 10% of Bid Cost or $578,874. Detailed calculations are shown below:

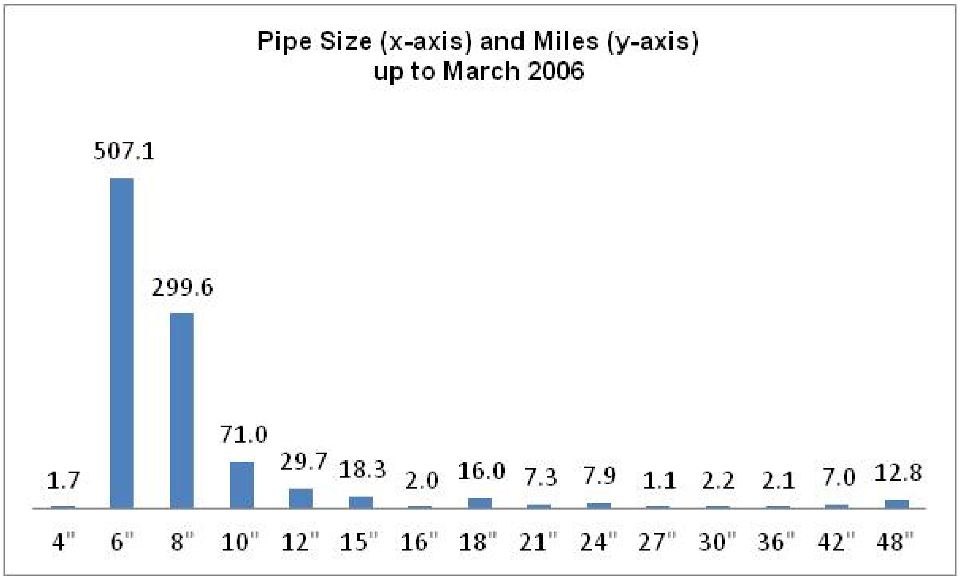


Figure 5.9 Garland's Sanitary Sewer System (up to 2006)
Source: City of Garland

Table 5.10 Generic Breakdown of RR&M from Nov. 2007- Aug. 2011 in Garland

Renewal, Repair, & Maintenance City of Garland, Nov 2007 - Oct 2011	
Repair Activities	Number of Jobs
CO	204
Flow Monitoring	53
TV Inspect I/I Smoke Test/Dye Test	937
Check Outfall Line	82
MH Repair I/I	1414
Sewer Main Repair	375
Line Locate/Emergency/Regular	1112
Install MH	30
Gen MH Maintenance	12
MH Inspection	148
Open MH Lid	7
Replace Reset Lid Ring	22
Customer Contact	18
Pre Post Job Inspect	111
Assist Other Crews	41
Sewer Maintenance	19
Site Restoration	53

Source: City of Garland

$$\text{Proportion of Sanitary Sewer to Overall Costs} = \frac{\$798{,}086}{\$5{,}788{,}747}$$

$$\text{Proportion of Sanitary Sewer to Overall Costs} \cong 13.8\% \text{ or } 14\%$$

$$\text{Sanitary Sewer to include Mobilization from Overall Costs} = \$798{,}086 + (\$578{,}874 \text{ x } 0.138)$$

$$\text{Sanitary Sewer to include Mobilization from Overall Costs} = \$877{,}971$$

$$\text{Sanitary Sewer Percentage of Overall Construction Costs} = \frac{\$877{,}971}{\$5{,}788{,}747} = 15.2\%$$

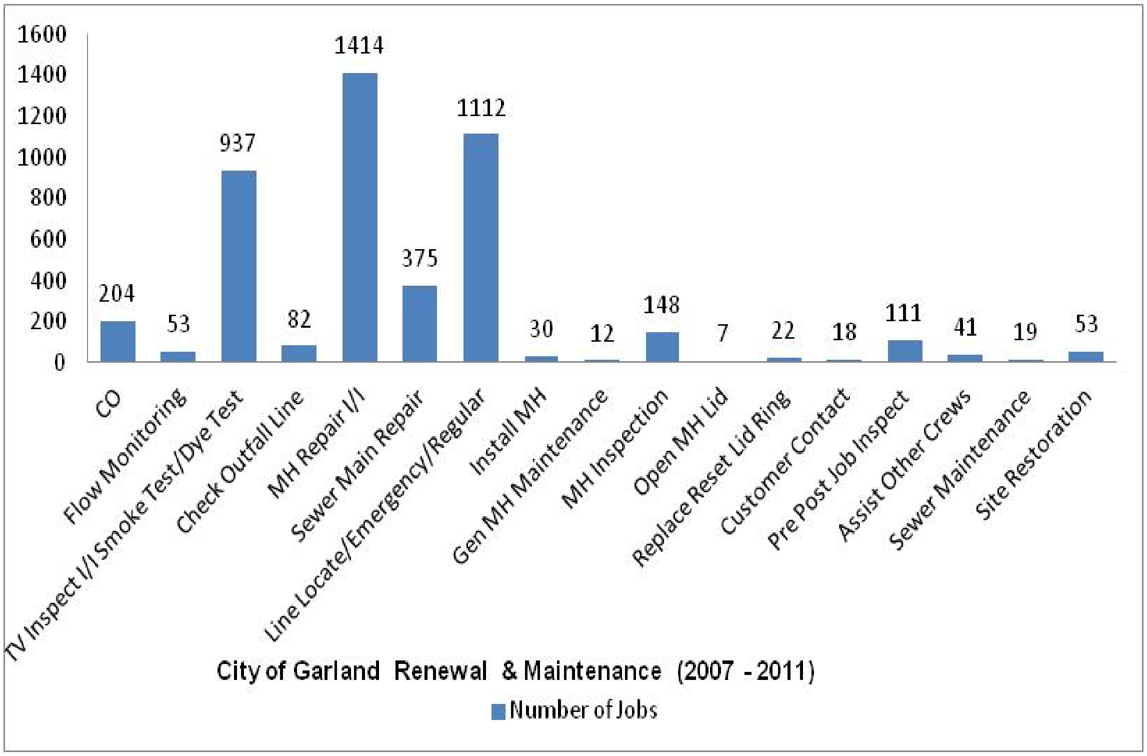


Figure 5.10 Sanitary Sewer RR&M from City of Garland (Nov 2007 - Aug 2011)
Source: City of Garland

5.5.1.2 The Administrative Expense of Planning Phase and Implementation Phase

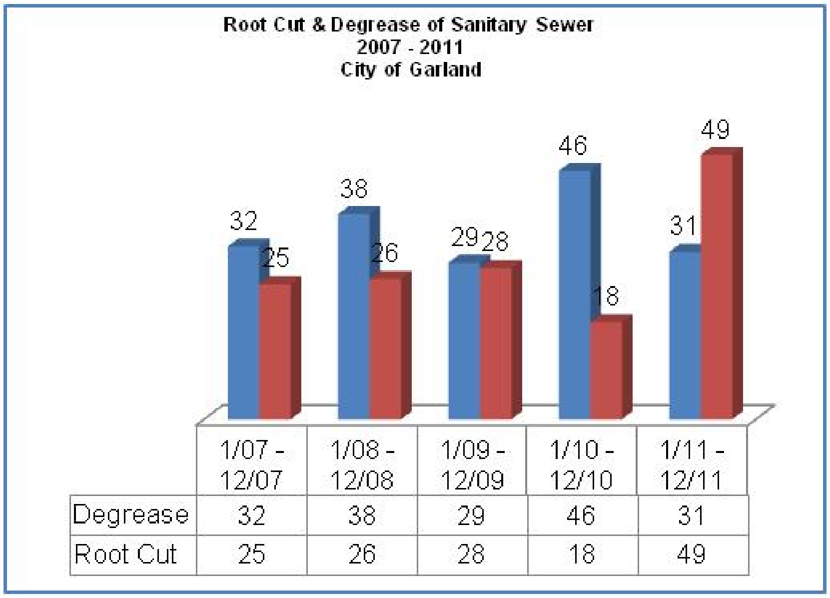
For Rowlett’s Kenwood Heights CIP Project, costs were calculated as follows:

The time required for strategic planning was 51 hours, consensus planning was approximately 215 hours, and implementation phase was 3,426 hours. The total planning and implementation phase municipal administrative cost without overhead was approximately $22,795 as depicted in Table 5.12 and Figure 5.12. The overhead costs were approximately calculated to be $15,754 from Table 5.13.

Kenwood Heights total project expenses = Municipal Administrative Costs + Overhead Costs

= $22,795 +$15,754 = $38,549.

Kenwood Heights administrative & overhead costs for sanitary sewer as percentage of total sanitary sewer contract including mobilization = ($38,549/877,971) = 4.4%



	1/07 - 12/07	1/08 - 12/08	1/09 - 12/09	1/10 - 12/10	1/11 - 12/11
Degrease	32	38	29	46	31
Root Cut	25	26	28	18	49

Figure 5.11 Sanitary Sewer Root & Degrease Jobs from Garland (Nov 2007 – Aug 2011)
Source: City of Garland

5.5.2 Uniform Annualized Cost Method Used with Kenwood Heights Project

Rowlett's municipal administrative costs for the sanitary sewer portion involving renewal and repair of Kenwood Heights Subdivision expenses was $38,549 or 4.4% of the total project expenses (*Section 5.5.1.2*), The annual distribution of the municipal administrative costs over the life of the sanitary sewer system in Kenwood Heights is shown in Table 5.14 based on UACM. The annualized costs are further depicted in Figure 5.13. If the entire sewer system in Kenwood Heights failed in year 50, the UACM cost that City of Rowlett will incur to replace the sewer system at 3% interest is $1,498 annually, with the assumption that there are no maintenance costs over the next 50 years. However, if there are maintenance costs, then those costs need to be added to UACM costs and annualized based on the year the maintenance was performed.

5.6 Walden Park Subdivision Renewal and Repair in Allen

The Walden Park Subdivision was chosen for this research project because it was a renewal and repair Capital Improvement Project for the city of Allen. The project included pavement renewal and replacement, water and sanitary sewer lines replacement, and removal of old system structures which included demolition.

5.6.1 Cost Details

Walden Park Bid Cost for the complete renewal of the subdivision as described in the section above was $883,304. The Sanitary Sewer Portion of the contract was $285,586 as shown in Table 5.15. Mobilization and other services for project implementation were approximately 10% of the Bid Cost which was $88,330.Further calculations and cost analysis is shown below:

$$\text{Proportion of Sanitary Sewer to Overall Costs} = \frac{\$285{,}586}{\$883{,}304}$$

$$\text{Proportion of Sanitary Sewer to Overall Costs} \cong 32.3\% \text{ or } 32\%$$

$$\text{Sanitary Sewer to include Mobilization from Overall Costs} = \$285{,}586 + (\$88{,}330 \text{ x } 0.32)$$

$$\text{Sanitary Sewer to include Mobilization from Overall Costs} = \$313{,}852$$

$$\text{Sanitary Sewer Percentage of Overall Construction Costs} = \frac{\$313{,}852}{\$883{,}304} = 35.5\%$$

Table 5.11 Rowlett’s Bid Document Expenses for Sanitary Sewer Portion of Kenwood Heights Reconstruction Project (2010 dollars)

Kenwood Heights Sanitary Sewer Reconstruction

Item. No.	Description of Item	Quantity Orignal Estimate	Unit of Measure	Unit Price	Total Contract Amount	Previous Quantity	Total Value of Work Completed
166	Furnish and install 12" sanitary sewer SDR 35 PVC	271	LF	$40.00	$10,840.00	271.00	$10,840.00
167	Furnish and install 10" sanitary sewer SDR 35 PVC	40	LF	$36.00	$1,440.00	40.00	$1,440.00
168	Furnish and install 8" sanitary sewer SDR 35 PVC	6,119	LF	$32.00	$195,808.00	3,025.00	$96,800.00
169	Furnish and install 12" sanitary sewer SDR 26 PVC	199	LF	$42.00	$8,358.00	199.00	$8,358.00
170	Furnish and install 10" sanitary sewer SDR 26 PVC	20	LF	$38.00	$760.00	20.00	$760.00
171	Furnish and install 8" sanitary sewer SDR 26 PVC	579	LF	$34.00	$19,686.00	3,614.00	$122,876.00
172	Furnish and install 10" sanitary sewer ASTM 2241 PVC	55	LF	$40.00	$2,200.00	55.00	$2,200.00
173	Furnish and install 8" sanitary sewer ASTM 2241 PVC	2,391	LF	$36.00	$86,076.00	2,689.00	$96,804.00
174	Furnish and install 10" sanitary sewer SDR 26 PVC by other than open cut (OTOC)	226	LF	$130.00	$29,380.00	108.00	$14,040.00
175	Furnish and install 10" sanitary sewer ASTM 2241 PVC by OTOC	111	LF	$135.00	$14,985.00	111.00	$14,985.00
176	Furnish and install concrete encasement for 8" pipe	70	LF	$20.00	$1,400.00	70.00	$1,400.00
177	Furnish and install sanitary sewer manhole	48	EA	$2,600.00	$124,800.00	54.00	$140,400.00
177-A	For extra depth of manhole	39	VF	$180.00	$7,020.00	39.00	$7,020.00
178	Furnish and install 12" x 12" concrete pad for san. service cleanout	260	EA	$50.00	$13,000.00	260.00	$13,000.00
179	Furnish and install typical cleanout	260	EA	$200.00	$52,000.00	260.00	$52,000.00
180	Furnish and install 4" sanitary sewer SDR 35 PVC laterals	6,826	LF	$27.00	$184,302.00	6,298.00	$170,046.00
181	For visual inspection (TV) of san. sewer by photographic means	9,674	LF	$2.00	$19,348.00	9,674.00	$19,348.00
182	For vacuum test proposed sanitary sewer manholes	48	EA	$100.00	$4,800.00	48.00	$4,800.00
183	For excavation safety system design	1	LS	$1,000.00	$1,000.00	1.00	$1,000.00
184	Furnish and install excavation safety system	15,888	LF	$1.00	$15,888.00	15,888.00	$15,888.00
	CHANGE ORDER #1						
174	10" SDR-26 PVC SS by OTOC	-111.00	LF	$130.00	($14,430.00)	-111.00	-$14,430.00
195	12" DR-21 HDPE SS by Pipe Bursting	111.00	LF	$175.00	$19,425.00	111.00	$19,425.00
	Total				**$798,086.00**		**$799,000.00**

Source: City of Rowlett

Table 5.12 Rowlett's Payroll Expenses for Sanitary Sewer Portion of Kenwood Heights' Sanitary Sewer Reconstruction Project (2010 dollars)

Kenwood Heights Project Staff Expenses						
City Staff	All	Sanitary	Hourly	Overtime	Total All	Total Sanitary
City Manager	41.5	5.81	$105.14	1	$4,363.31	$610.86
Assistant City Manager	27.5	3.85	$91.51	1	$2,516.53	$352.31
Public Works Director	138.5	19.39	$81.13	1	$11,236.48	$1,573.11
Finance Director	39	5.46	$71.39	1	$2,784.21	$389.79
City Engineer	259	36.26	$66.20	1	$17,146.30	$2,400.48
Assistant City Engineer	411	57.54	$54.52	1	$22,407.40	$3,137.04
Waste Water Manager	213	29.82	$47.27	1	$10,068.12	$1,409.54
Engineering Inspector	1881	263.34	$32.45	1	$61,042.07	$8,545.89
EI Overtime	156	21.84	$32.45	1.5	$7,593.30	$1,063.06
Right of Way Inspector	92	12.88	$30.63	1	$2,817.55	$394.46
Engineering Administrator	156	21.84	$22.72	1	$3,543.75	$496.13
Purchasing Agent	64	8.96	$39.59	1	$2,533.85	$354.74
Accountant	66	9.24	$41.45	1	$2,735.70	$383.00
GIS Manager	18	2.52	$35.05	1	$630.87	$88.32
Public Information Officer	64	8.96	$28.42	1	$1,819.01	$254.66
Sanitary Sewer Crew (4 people)	56	7.84	$136.30	1	$7,632.80	$1,068.59
City Attorney	9	1.26	$150.00	1	$1,350.00	$189.00
Consultant Review of Construction Plans					$600.00	$84.00
Total	**3691.5**	**516.81**			**$162,821.23**	**$22,794.97**

Source: City of Rowlett

Table 5.13 Rowlett's City Overhead Expense for Kenwood Heights' Sanitary Sewer Reconstruction Project (2010 dollars)

City Overhead Expense	
Overall Building Cost*	$2,049,300
Electricity expense yearly for Building	$55,977
Water & Sewer for Building	65,437
Building Contents Expense **	350,000
Miscellaneous Multiplier (%)	15%
Intrest Rate (i)	4.5%
Number of years of bond	20
Annual Expense for Building Cost	$157,542
City Overhead Expense per Project* **	**$15,754**
* For 15,148 sq ft of Public Works Building used for meetings and office space	
**Based on Insurance Coverage and Furniture & Fixtures life for 10 years	
***Assumed 10% for Rowlett	

Source: City of Rowlett

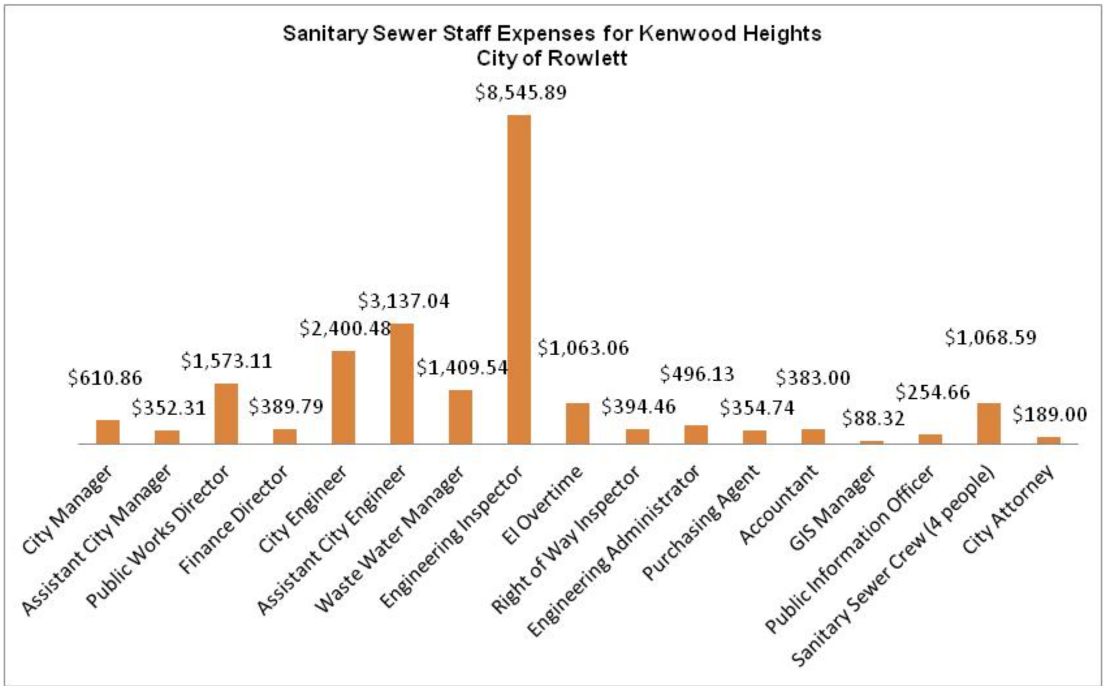


Figure 5.12 Rowlett's Staff Expenses for Sanitary Sewer Portion in Kenwood Heights (2010 dollars)
Source: City of Rowlett

5.6.1.1 The Administrative Expense of Planning Phase and Implementation Phase

For Allen's Walden Park CIP Project, costs were calculated as follows:

The time required for strategic planning was 20 hours, consensus planning was approximately 48 hours, and implementation phase was 1,075 hours. The total planning and implementation phase municipal administrative cost without overhead was approximately $20,074 as depicted in Table 5.16. The overhead costs were approximately calculated to be $10,805 (Table 5.17).

Walden Park total project expenses = Municipal Administrative Costs + Overhead Costs

= $20,074 +$10,805 = $30,879.

Walden Park administrative & overhead costs for sanitary sewer as percentage of total sanitary sewer contract including mobilization = ($30,879/$313,852) = 9.8%

A distribution of the City of Allen's employee expenses as related to Walden Park Project is shown in Figure 5.14.

Table 5.14 Annualized Expenses from 10 years to 100 years with Varying Interest Rates for Kenwood Heights Project (2010 dollars)

Kenwwood Heights Subdivision - City of Rowlett							
i = 3%							
n	PV	i	(1+i)^n	(1+i)^n - 1	i x (1+i)^n	(i x (1+i)^n)/((1+i)^n)-1)	A
10	$ 38,549	0.03	1.34	0.34	0.04	0.12	$ 4,519
15	$ 38,549	0.03	1.56	0.56	0.05	0.08	$ 3,229
20	$ 38,549	0.03	1.81	0.81	0.05	0.07	$ 2,591
25	$ 38,549	0.03	2.09	1.09	0.06	0.06	$ 2,214
30	$ 38,549	0.03	2.43	1.43	0.07	0.05	$ 1,967
50	$ 38,549	0.03	4.38	3.38	0.13	0.04	$ 1,498
75	$ 38,549	0.03	9.18	8.18	0.28	0.03	$ 1,298
100	$ 38,549	0.03	19.22	18.22	0.58	0.03	$ 1,220
i = 4%							
n	PV	i	(1+i)^n	(1+i)^n - 1	i x (1+i)^n	(i x (1+i)^n)/((1+i)^n)-1)	A
10	$ 38,549	0.04	1.48	0.48	0.06	0.12	$ 4,753
15	$ 38,549	0.04	1.80	0.80	0.07	0.09	$ 3,467
20	$ 38,549	0.04	2.19	1.19	0.09	0.07	$ 2,837
25	$ 38,549	0.04	2.67	1.67	0.11	0.06	$ 2,468
30	$ 38,549	0.04	3.24	2.24	0.13	0.06	$ 2,229
50	$ 38,549	0.04	7.11	6.11	0.28	0.05	$ 1,794
75	$ 38,549	0.04	18.95	17.95	0.76	0.04	$ 1,628
100	$ 38,549	0.04	50.50	49.50	2.02	0.04	$ 1,573
i = 5%							
n	PV	i	(1+i)^n	(1+i)^n - 1	i x (1+i)^n	(i x (1+i)^n)/((1+i)^n)-1)	A
10	$ 38,549	0.05	1.63	0.63	0.08	0.13	$ 4,992
15	$ 38,549	0.05	2.08	1.08	0.10	0.10	$ 3,714
20	$ 38,549	0.05	2.65	1.65	0.13	0.08	$ 3,093
25	$ 38,549	0.05	3.39	2.39	0.17	0.07	$ 2,735
30	$ 38,549	0.05	4.32	3.32	0.22	0.07	$ 2,508
50	$ 38,549	0.05	11.47	10.47	0.57	0.05	$ 2,112
75	$ 38,549	0.05	38.83	37.83	1.94	0.05	$ 1,978
100	$ 38,549	0.05	131.50	130.50	6.58	0.05	$ 1,942
i = 6%							
n	PV	i	(1+i)^n	(1+i)^n - 1	i x (1+i)^n	(i x (1+i)^n)/((1+i)^n)-1)	A
10	$ 38,549	0.06	1.79	0.79	0.11	0.14	$ 5,238
15	$ 38,549	0.06	2.40	1.40	0.14	0.10	$ 3,969
20	$ 38,549	0.06	3.21	2.21	0.19	0.09	$ 3,361
25	$ 38,549	0.06	4.29	3.29	0.26	0.08	$ 3,016
30	$ 38,549	0.06	5.74	4.74	0.34	0.07	$ 2,801
50	$ 38,549	0.06	18.42	17.42	1.11	0.06	$ 2,446
75	$ 38,549	0.06	79.06	78.06	4.74	0.06	$ 2,343
100	$ 38,549	0.06	339.30	338.30	20.36	0.06	$ 2,320

Source: City of Rowlett

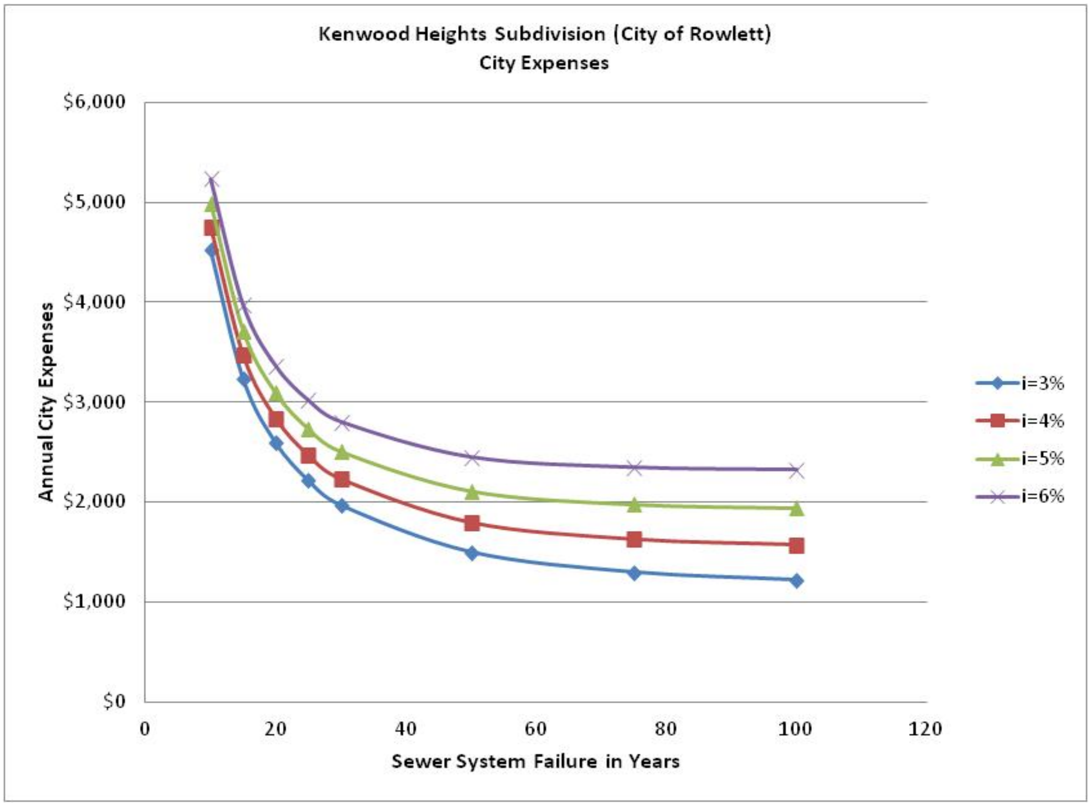


Figure 5.13 Annualized Value of Rowlett Expense in Kenwood Heights Project
(2010 dollars)
Source: City of Rowlett

5.6.2 Uniform Annualized Cost Method Used with Walden Park Project

Allen's municipal administrative costs for sanitary sewer portion of the renewal and repair of Walden Park Subdivision expenses were $30,879 or 9.8% of the total project expenses (*Section 5.6.1*). Based on UACM, the annual distribution of the municipal administrative costs over the life of the sanitary sewer system in Walden Park is shown in Table 5.18. The annualized costs are further depicted in Figure 5.15. If the entire sewer system failed in year 50, Allen's UACM cost at 3% interest is $1,200 which means that the municipal administrative costs would be $1,200 annually for the next 50 years. The assumption has been made that there are no maintenance costs in the first 50 years. However, maintenance costs need to be added to UACM costs and annualized, based on the year the maintenance was performed.

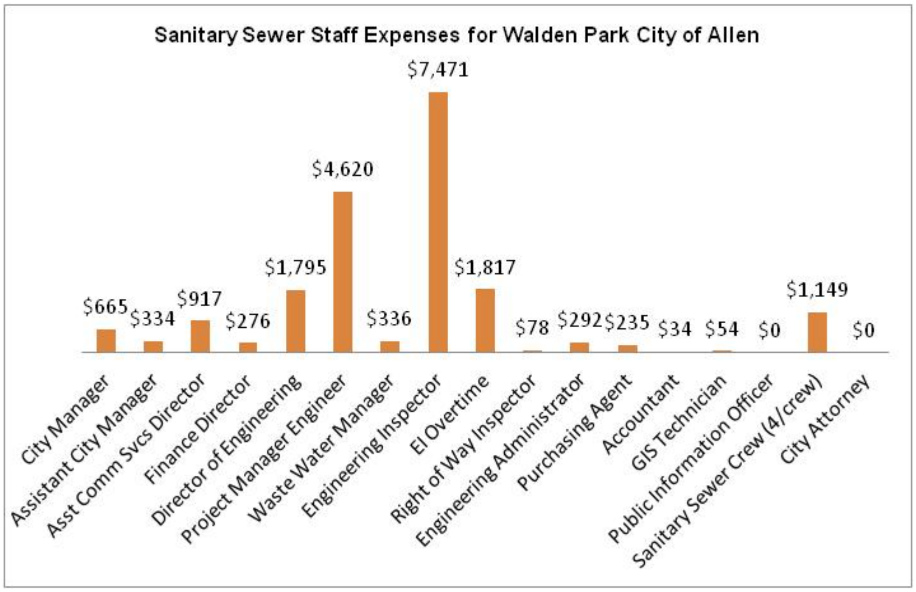


Figure 5.14 Allen's Staff Expenses for Sanitary Sewer Portion in Walden Park (2010 dollars)
Source: City of Allen

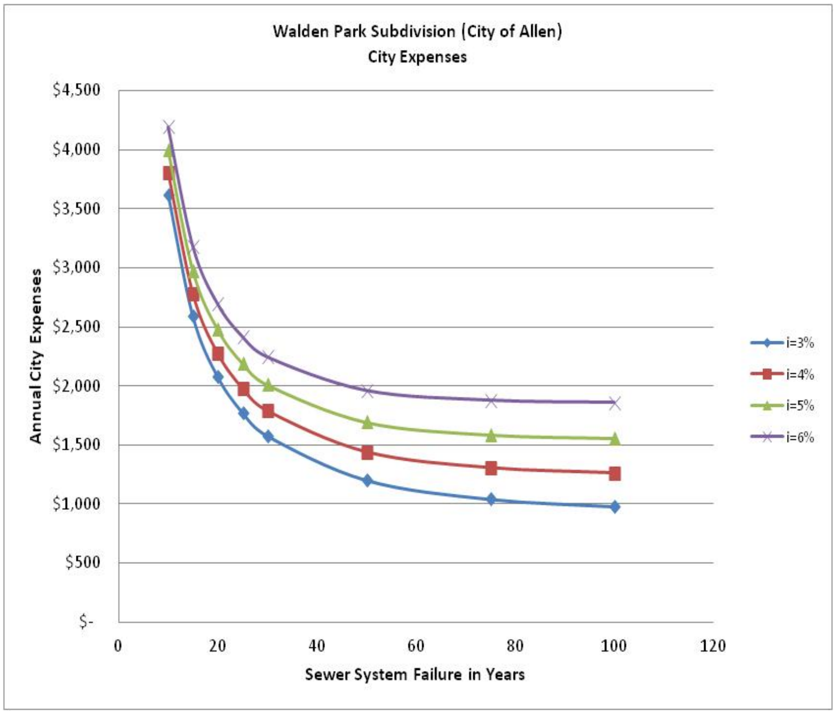


Figure 5.15 Annualized Value of Allen Expense in Walden Park Project (2010 dollars)
Source: City of Rowlett

Table 5.15 Allen Bid Document Items for Sanitary Sewer Portion in Walden Park Project (2010 dollars)

Walden Park Sanitary Sewer (City of Allen)					
Item	Description	Unit	Quantity	Price/Unit	Bid Total
34	Furnish and install 8" PVC, SDR 35, sanitary sewer pipe, 0'-6' depth	L.F.	876	$ 30.00	$ 26,280.00
35	Furnish and install 8" PVC, SDR 35, sanitary sewer pipe, 6'-8' depth	L.F.	1,623	$ 30.00	$ 48,690.00
36	Furnish and install 8" PVC, SDR 35, sanitary sewer pipe, 8'-10' depth	L.F.	787	$ 30.00	$ 23,610.00
37	Furnish and install 8" PVC, SDR 26, sanitary sewer pressure pipe, 6'-8' depth	L.F.	40	$ 31.00	$ 1,240.00
38	Furnish and install 8" PVC, SDR 26, sanitary sewer pressure pipe, 8'-10' depth, including embedment	L.F.	95	$ 31.00	$ 2,945.00
39	Furnish and install 6" PVC, SDR 35, sanitary sewer pipe, 6'-8' depth	L.F.	1,967	$ 29.00	$ 57,043.00
40	Furnish and install 6" PVC, SDR 26, sanitary sewer pressure pipe, 6'-8' depth, including embedment	L.F.	80	$ 29.00	$ 2,320.00
41	Furnish and install 4" PVC, SDR 35, sanitary sewer pipe for services, including embedment	L.F.	1,480	$ 22.00	$ 32,560.00
42	Furnish and install two-way cleanouts	EA.	79	$ 250.00	$ 19,750.00
43	Furnish and install two-way cleanouts with cast iron caps	EA.	8	$ 300.00	$ 2,400.00
44	Furnish and install Std. 4' dia. Manhole, 0-6' depth	EA.	24	$ 2,000.00	$ 48,000.00
45	Furnish and install Std. 4' dia. Drop Manhole, 0-6' depth, over existing line	EA.	3	$ 2,700.00	$ 8,100.00
46	Furnish and install additional manhole vertical depth	V.F.	36	$ 75.00	$ 2,700.00
47	Connect sanitary sewer to existing manhole	EA.	1	$ 2,500.00	$ 2,500.00
48	By-pass pumping, through duration of construction	L.S.	1	$ 500.00	$ 500.00
49	Initial TV Testing and subsequent TV Testing at 21 months after completion of the project	L.F.	6,948	$ 1.00	$ 6,948.00
50				**Total:**	**$ 285,586.00**

Source: City of Allen

Table 5.16 Allen’s Payroll for Sanitary Sewer in Walden Park Project (2010 dollars)

Walden Park Project Staff Expenses						
City Staff	Total Project Hours	Sanitary Sewer Proportion	Hourly Wages	Overtime Wages	Total All Wages	Total Sanitary Sewer Costs
City Manager	12	5	$145.8	1	$1,750	$665
Assistant City Manager	12	5	$73.3	1	$880	$334
Asst Comm Svcs Director	48	18	$50.3	1	$2,414	$917
Finance Director	8	3	$90.9	1	$727	$276
Director of Engineering	52	20	$90.9	1	$4,725	$1,795
Project Manager Engineer	223	85	$54.5	1	$12,158	$4,620
Waste Water Manager	20	8	$44.2	1	$883	$336
Engineering Inspector	592	225	$33.2	1	$19,660	$7,471
EI Overtime	96	36	$33.2	1.5	$4,782	$1,817
Right of Way Inspector	8	3	$25.7	1	$206	$78
Engineering Administrator	30	11	$25.7	1	$770	$292
Purchasing Agent	14	5	$44.2	1	$618	$235
Accountant	2	1	$44.2	1	$88	$34
GIS Technician	6	2	$23.6	1	$142	$54
Public Information Officer	0	0	$28.4	1	$0	$0
Sanitary Sewer Crew (4/crew)	20	8	$151.2	1	$3,024	$1,149
City Attorney	0	0	$150.0	1	$0	$0
Total	**1143**	**434.34**			**$52,826**	**$20,074**

Source: City of Allen

Table 5.17 Allen’s Building Overhead Expense for Walden Park Project (2010 dollars)

City Overhead Expense	
Overall Building Cost*	$1,468,500
Electricity expense yearly for Building	$59,743
Water & Sewer for Building	$65,437
Building Contents Expense **	$198,000
Miscellaneous Multiplier (%)	20%
Overhead Multiplier (%)	10%
Intrest Rate (i)	4.00%
Number of years of bond	20
Annual Building Overhead Expense	$108,055
City Overhead Expense per Project***	$10,805
* For 10,000 sq ft of Public Works Building used for meetings and office space	
**Based on Insurance Coverage and Furniture & Fixtures life for 10 years	
***Assumed 10% of annual expense for building	

Source: City of Allen

Table 5.18 Annualized Expenses from 10 to 100 Years with Varying Interest Rates
Walden Park Project (2010 dollars)

Walden Park Subdivision - City of Allen

i = 3%

n	PV	i	(1+i)^n	(1+i)^n - 1	i x (1+i)^n	(i x (1+i)^n)/((1+i)^n)-1)	A
10	$ 30,879	0.03	1.34	0.34	0.04	0.12	$ 3,620
15	$ 30,879	0.03	1.56	0.56	0.05	0.08	$ 2,587
20	$ 30,879	0.03	1.81	0.81	0.05	0.07	$ 2,076
25	$ 30,879	0.03	2.09	1.09	0.06	0.06	$ 1,773
30	$ 30,879	0.03	2.43	1.43	0.07	0.05	$ 1,575
50	$ 30,879	0.03	4.38	3.38	0.13	0.04	$ 1,200
75	$ 30,879	0.03	9.18	8.18	0.28	0.03	$ 1,040
100	$ 30,879	0.03	19.22	18.22	0.58	0.03	$ 977

i = 4%

n	PV	i	(1+i)^n	(1+i)^n - 1	i x (1+i)^n	(i x (1+i)^n)/((1+i)^n)-1)	A
10	$ 30,879	0.04	1.48	0.48	0.06	0.12	$ 3,807
15	$ 30,879	0.04	1.80	0.80	0.07	0.09	$ 2,777
20	$ 30,879	0.04	2.19	1.19	0.09	0.07	$ 2,272
25	$ 30,879	0.04	2.67	1.67	0.11	0.06	$ 1,977
30	$ 30,879	0.04	3.24	2.24	0.13	0.06	$ 1,786
50	$ 30,879	0.04	7.11	6.11	0.28	0.05	$ 1,437
75	$ 30,879	0.04	18.95	17.95	0.76	0.04	$ 1,304
100	$ 30,879	0.04	50.50	49.50	2.02	0.04	$ 1,260

i = 5%

n	PV	i	(1+i)^n	(1+i)^n - 1	i x (1+i)^n	(i x (1+i)^n)/((1+i)^n)-1)	A
10	$ 30,879	0.05	1.63	0.63	0.08	0.13	$ 3,999
15	$ 30,879	0.05	2.08	1.08	0.10	0.10	$ 2,975
20	$ 30,879	0.05	2.65	1.65	0.13	0.08	$ 2,478
25	$ 30,879	0.05	3.39	2.39	0.17	0.07	$ 2,191
30	$ 30,879	0.05	4.32	3.32	0.22	0.07	$ 2,009
50	$ 30,879	0.05	11.47	10.47	0.57	0.05	$ 1,691
75	$ 30,879	0.05	38.83	37.83	1.94	0.05	$ 1,585
100	$ 30,879	0.05	131.50	130.50	6.58	0.05	$ 1,556

i = 6%

n	PV	i	(1+i)^n	(1+i)^n - 1	i x (1+i)^n	(i x (1+i)^n)/((1+i)^n)-1)	A
10	$ 30,879	0.06	1.79	0.79	0.11	0.14	$ 4,195
15	$ 30,879	0.06	2.40	1.40	0.14	0.10	$ 3,179
20	$ 30,879	0.06	3.21	2.21	0.19	0.09	$ 2,692
25	$ 30,879	0.06	4.29	3.29	0.26	0.08	$ 2,416
30	$ 30,879	0.06	5.74	4.74	0.34	0.07	$ 2,243
50	$ 30,879	0.06	18.42	17.42	1.11	0.06	$ 1,959
75	$ 30,879	0.06	79.06	78.06	4.74	0.06	$ 1,876
100	$ 30,879	0.06	339.30	338.30	20.36	0.06	$ 1,858

Source: City of Allen

5.7 Chapter Summary

This chapter provided the details of sanitary sewer system data collected from several cities in North Texas. The data is analyzed and presented in the form of tables and charts. A discussion on the implementation formulas and information collected from Chapter 4 was incorporated in actual sanitary sewer system renewal and repair projects of Kenwood Heights in Rowlett, and Walden Park in Allen. Specialized projects such as lift stations, wastewater treatment plants, etc. (that could be part of the sanitary sewer system) were not included in the calculation of TC in this research.

CHAPTER 6

FACTORS AFFECTING TRUE COST

6.1 Introduction

There are numerous factors affecting TC. This dissertation explores use of some of these factors specific to sanitary sewer RR&M:

Municipal Infrastructure Asset Management (Chapter 6)

Municipal Enterprise Solution (Chapter 6)

Municipal Sanitary Sewer Deterioration and Failure (Chapter 7)

Municipal Social Costs (Chapter 8)

6.2 Municipal Infrastructure Asset Management

Municipal infrastructure asset management should provide a required level of service in the most cost effective manner through the management of infrastructure assets for present and future customers. It should also include Management Information Systems that contain scanned documents of AutoCAD as-builts and GIS Databases. In addition, this dissertation asserts that any municipal infrastructure asset management plan specific to sanitary sewer infrastructure should include the concept of a Theoretical Asset Management System (TAMS).

6.2.1 Key Elements of Municipal Infrastructure Asset Management

The following set of management elements are essential to the success of any project. The same list can be found in International Infrastructure Management Manual, 2006, and additions have been made as part of this dissertation.

- Taking a lifecycle approach
- Developing cost-effective management strategies for the long-term

- Providing a defined level of service and meeting the impact of growth through demand management and infrastructure investment
- Managing risks associated with infrastructure failure
- Sustainable use of physical resources
- Improving continuously in asset management practices

6.2.2 Enabling Asset Management

Asset management programs are judged by their success in determining the lowest life cycle cost to meet service level goals for the critical and non critical components of the municipal infrastructure system. The goal of an asset management system is to ensure with ease low cost solutions which utilize the latest and most relevant information about municipal infrastructure assets.

6.3 Municipal Infrastructure Asset Management for Sanitary Sewer Systems (MIAMSSS)

Not all of the sanitary sewer system infrastructure assets in a municipality are equally important to the sanitary sewer system infrastructure operation. While all assets present risks for failure, understanding the consequence of a structural failure or an operation and maintenance (O&M) failure or a capacity failure is essential.

Operation and maintenance resources and municipal budgets should be allocated to those critical assets that have the highest risk of failing and the greatest consequence of failure. With limited budget dollars, it is essential to do the right project at the right time—one that most mitigates risk of failure and supports ability to maintain required levels of service.

The MIAMSSS consists of many components and different methodologies for collection information related to achieving city objectives. It must have tools enabling managers and planners to understand the sanitary sewer assets in and above ground level. MIAMSSS must also have a theoretical asset management system (TAMS) consisting of document and information management tools that include as-built drawings, reports and studies as well as repair and maintenance inventories.

6.3.1 Critical and Non Critical Assets of a Sanitary Sewer System

One of the key elements of a municipal asset management system is to have an inventory of the system’s individual components. The component can be defined as the specific part of a sanitary sewer asset having independent physical or functional identity and having specific attributes that could include life expectancy, maintenance requirements, and criticality within the system. This dissertation includes TAMS as part of the functional identity of asset management.

The components of a typical sanitary sewer system include critical assets and non-critical assets. The critical assets are components wherein the financial, business or service level consequences of failure are sufficiently severe to justify proactive inspection and rehabilitation. Critical assets have a lower threshold for action than non-critical assets (Roberts et-al, 2006). The critical assets are expensive from a procurement and maintenance standpoint and are capital intensive when they are being built and implemented into operations. In addition, these critical assets can be extremely expensive with emergency repairs, as a failure of the system or any component of the system can lead to environmental disasters, The critical assets in a municipal system that are typically visible aboveground) get more attention from a maintenance standpoint than the not-visible underground components, and are more cost intensive. Table 6.1 shows a breakdown of municipal sanitary sewer assets into critical and non critical assets.

6.3.2 Advantages of Having an MIAMSSS in terms of True Costs

- Meeting the goal of service delivery at minimum cost and therefore minimum TC
- Optimizing life cycle costs and minimizing municipal administrative costs as shown in Figure 6.1
- Maximizing revenue at minimum cost

Table 6.1 Critical and Non Critical Assets of Sanitary Sewer System

Critical Assets of Sanitary Sewer System	Non-critical Assets of Sanitary Sewer System
Force main sanitary sewer pipelines	Gravity sanitary sewer pipelines
Lift Stations	Manholes
Waste Water Treatment Plant	Metering Stations
TAMS	Service Facility (not included in this dissertation)

- Diverting municipal personnel resources to address other issues
- Budgeting for municipalities becomes more efficient for CIP as the knowledge database of asset management leads to precise decisions
- Saving customers of the municipality taxes in the long run
- Leads to continuous improvement of sanitary sewer systems with less disruptions due to emergencies
- Long-term planning of sanitary sewer infrastructure becomes more efficient

6.4 Theoretical Asset Management System (TAMS)

The TAMS is a critical asset, as it is the precursor to the generation of the physical and functional identity. TAMS is the document and information management portion of an asset management system that includes as-built drawings, reports and studies related to sanitary sewer systems and repair and maintenance inventories. In the municipal sanitary sewer system there are three critical studies and reports that include:

- Sanitary Sewer Master Plan (SSMP)
- Sanitary Sewer Evaluation Survey (SSES) that deals with Inflow and Infiltration (I&I)
- Wastewater System Modeling (WSM) that establishes capacity analysis of the system

Section 6.5. provides details of above terminologies. Municipalities may combine these reports and studies together or keep them separate and one municipality might require more detailed analysis and deliverables as compared to another.

Figure 6.1 Optimizing Life Cycle Cost of an Asset
Source: Earth Tech

6.4.1 TAMS and its Use by Municipalities

Municipalities usually use the TAMS reports for future development and for technical purposes that include upsizing, renewing and replacing the sanitary sewer system for capacity related issues. The level of information contained in TAMS, and the frequency at which it is collected or updated, varies with different municipalities. If the information contained in TAMS is detailed, comprehensive, and simplified, the application and decision making becomes easier by the stakeholders in the municipality. Installation data, as-builts, repair, and service call information collected from TAMS is being used in this dissertation to determine deterioration and failure rate that occur in the sanitary sewer system of the cities selected for this research.

TAMS can be used to predict and prevent some of the future issues based on the data gathered. Detailed forensic analysis of any deterioration or failure needs to be performed on existing systems and should become part of TAMS. The forensic information can be used for future use, and the lessons learned will prepare stakeholders to propose the right solution that can prevent future failures. For example, if a certain area of a city has a lot of issues from a renewal and repair standpoint, the stakeholders in the city need to evaluate the information that needs to be incorporated in TAMS on a case by case basis. This collection of information will help the city deal with specific failures and predict the time, cost, equipment and specific skilled personnel required to solve these failures.

It is recommended that stakeholders, who implement solutions for failures, revisit the existing issues with public works or community services, and that the daily operators of the system study the effectiveness of the information contained in TAMS and incorporate “lessons learned” for future use. The expansion of knowledge by both engineers and operators using TAMS can be projected to reduce the True Costs in the long run.

6.4.2 Collection and Documentation of Information in TAMS

A key success of TAMS is its ability to organize the repair and maintenance information with the right asset management system. Forensic work in the field is reduced if trends that have occurred previously in the sanitary sewer system were documented in TAMS.

For example, if field observations indicate that the sanitary sewer system failed due to the buildup of gases, the logical question is: How can sanitary sewer gases be reduced in the system? Possible solutions on a case-by-case basis could be:

- design the system so that the pipe is in full flow as compared to partial flow
- prevent excessive drops in manholes
- adjust the slopes

Based on a management standpoint, sometimes there is a minimal communication between the engineers and the operators. The level of sanitary sewer failure documentation varies between cities. The key is documentation in the field and accurate information by the operators that can be verified by managers or engineers.

6.4.3 Design Considerations in TAMS

The SSMP needs to identify the initial implementation, potential elevations and topographical features to ensure the size of the sanitary sewer line in consideration. A scenario from the design standpoint could include the upstream end with a recommendation that incorporates a “depth of the sanitary sewer line”. The current SSMP typically indicate the capacity of the referenced sanitary sewer line as a 10-inch sewer line. Example of the recommendation should include a 10-inch pipe with a minimum specified slope percent and, if the slope is not possible, use a 12-inch pipe with shallower slope.

Other design considerations could include questions such as: Can the receiving system of the creeks be placed even a foot deeper to minimize flatness in the upstream section? Can trenchless technology be used far more easily in the vicinity of creeks rather than in the presence of trees and root systems? Can more inspectors be dedicated to areas where there are issues? For instance, if the design shows flat elevations on a sanitary sewer line, the city might want to provide more inspection resources during installation to prevent issues like bellies (depressions) in the pipe. The advantage for the city is in terms of long-term maintenance in the future. Can certified surveying documents be obtained in instances of minimum pipe slope for verification of the design slope problems and solutions from the contractor?

Strategy for municipalities is to invest in TAMS for more detailed information and save on the O&M phase of the sanitary sewer system asset. The consulting and municipal engineers associated with creating documents related to TAMS, should provide the precise analysis to mitigate the expenditures in the maintenance phase.

6.4.4 Advantages of TAMS

The advantages of TAMS are shown in Figure 6.2 and the details are included below:

- Easy access to information in the field leads to:
    - Shortening response time by relating TAMS to issues in the field.
    - GIS maps, as-built drawings and repair history can be accessed to determine the attributes of the system.
- Accurate information of sanitary sewer attributes leads to:
    - Deciding the parts that might be required including size, material, particular model, etc.

- Effective decisions based on availability of information leads to:
    - Reduction of chaos at the failure site as random decisions based on hypothetical's and memory of personnel are reduced, and decisions are made based on facts.

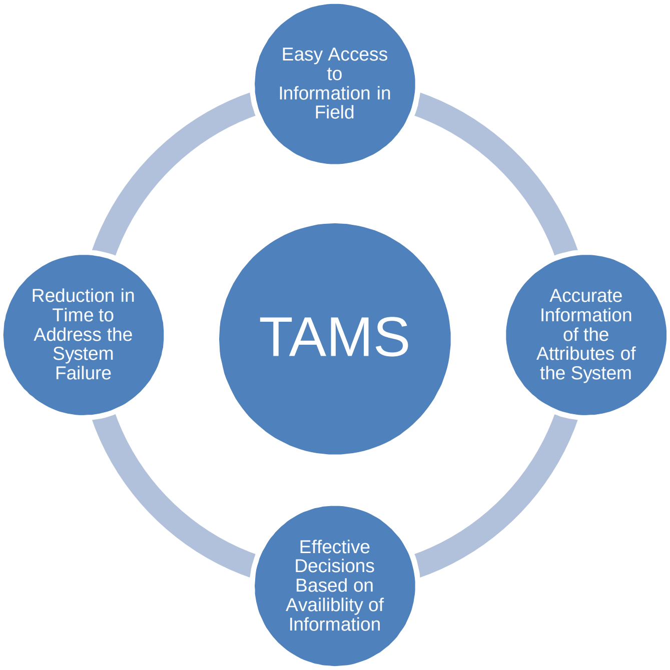


Figure 6.2 Advantages of TAMS

- Reduction in time to address system failure leads to:
    - Less property damage
    - Customer satisfaction
    - Prevention of environmental issues
    - Less expense
    - Improved safety
    - Lower social costs
- Updating of accurate information in the field leads to:
    - Accurate information as repairs are conducted.
    - Updating of accurate time, maps, and repair work order is possible.

6.5 Sanitary Sewer System Plans

The Sanitary Sewer Master Plan (SSMP) for most cities is developed as an element of the Comprehensive Plan which is typically generated for planning purposes. The plan describes the historical development of the sanitary sewer system and the characteristics of the existing system. System goals and policies are established which guide decisions about the design, expansion, and maintenance of the system. Projections of sewer flows through a particular timeframe typically 20-30 years are made based upon forecasted growth, and the system goals and policies are presented followed by an implementation strategy.

The SSMP's are prepared in accordance with the requirements of the Regional Metropolitan or State Requirements which are derived from National Pollutant Discharge Elimination System (NPDES). Permits are issued by the Texas Commission on Environmental Quality (TCEQ) to various industrial and governmental users in Texas to regulate the performance of wastewater discharges to surface waters. Permits issued for these projects extend for the life of the project, and stipulate that Best Management Practices (BMP) techniques are followed. For example the cities of Rowlett, Garland, and Allen use both TCEQ and North Central Texas Council of Governments (NCTCOG) permit guidelines to prepare their SSMP. Cities can have different levels of emphasis to examine the municipal sewer system needs. A common practice is to conduct a Tier Analysis. For example, the City of Bloomington, Minnesota conducted a Tier I study that includes a more general nature report for a portion of the city in its southern part and a more extensive Tier II analysis for the northern part of the city that aligns the I-494 corridor (Short, 1998).

6.5.1 Relationship of Sanitary Sewer System to Comprehensive Plan Elements

The sanitary sewer system of a community is closely tied to its Comprehensive Plan. The land use identified for specific properties in the Comprehensive Plan allows uses that generate typical sewer flows. The intensity of the use as regulated by the zoning ordinance defines the daily sewer flow rate. The rate of sewer flows is utilized to determine the appropriate capacity and facilities needed for the sanitary sewer system. The key to including sewer analysis in the Comprehensive Plan is to ensure that adequate information is available for future decisions to generate guidelines in allowing future expansion of commercial and industrial properties. The studies might include the effects of potential redevelopment alternatives within areas of the city on the existing sanitary sewer systems. The cost of the initial SSMP and its updates need to be included in the True Cost of the sanitary sewer asset management plan.

6.5.2 Sanitary Sewer Evaluation Survey (SSES)

The key terms in SSES are Infiltration and Inflow, and include the following:

- Infiltration occurs when groundwater enters sewer lines and manholes. There are two infiltration concepts in use:
    1. Groundwater Infiltration and
    2. Storm water Infiltration.
- Inflow occurs when public and private sector sources contribute to the sewer lines through cross-connection with storm sewers, vented manhole covers, mainline defects, defective frame seals, defective cleanouts, direct connection to sanitary sewers from downspouts and other areas (i.e., grease traps).

The SSES is provided by a municipality to assess the extraneous water from Inflow & Infiltration (I&I) sources and reduces the capacity of the sanitary sewer collection system to transport wastewater which can result in Sanitary Sewer Overflows (SSO's). Infiltration occurs when existing sewer lines undergo deterioration. Groundwater may enter the collection system through defects such as open pipe joints, cracks, broken pipes, dropped joints etc. Inflow (Rainfall Dependent Infiltration/Inflow or RDII) normally occurs when rainfall enters the sanitary sewer system through missing cleanout caps, roof drains, manhole covers and frame seals, storm sewer cross connections etc. When these types of defects are located in low ponding areas, such as drainage ditches or creeks, the extraneous storm water that enters the pipeline in volume and rate as it enters the system can be significant (Forbes, 2010).

In the City of Rowlett, the necessity of conducting a SSES evolved due to regulations from TCEQ and the fact that Rowlett pays Garland $2.21 for every 1,000 gallons to treat Rowlett's wastewater. The True Cost savings to Rowlett by repairing or renewing portions of the sanitary sewer system will be significant and will reduce environmental risks as well as provide benefits to their customers by providing a better quality of service and by reducing maintenance costs. Such improvements will lessen social costs by reducing service interruptions due to sanitary sewer pipeline surcharges and/or blockage of the sanitary sewer piped thereby backing up sewage into houses through the service laterals. Rowlett's SSES divides the city into several basins and verifies the size, length, condition, and material of sanitary sewer pipes; they also check the diameter, type, material and condition of manholes, and impose a conditional rating for the lift station and its associated equipment.

6.5.3 Wastewater System Model (WSM)

The WSM key objectives are divided into short term and long term objectives, as follow:

- Short-term Objectives:
    - Identify existing constraints in the sanitary sewer system through the model.
    - Identify locations that have sanitary sewer overflows (SSO's) during peak flow event.
    - Assist in establishing the five year CIP and address the city funds to the right project improvements.
- Long-term Objectives:
    - Provide city with a planning tool to assist in managing and improving the system as future development occurs (Grantham, 2010).

6.5.4 Factors Involved with Sanitary Sewer Inflow and Infiltration (I&I)

Factors involved with sanitary sewer, I&I can be summarized as follow:

- Advantage of I&I is that the concentration of gases go down.
- TC due to I&I goes up, because of treatment costs. As said earlier, City of Rowlett pays $2.21 to treat 1000 gallons of sewer water, and if I&I is minimized, the potential savings are maximized.
- Based on billing information, True Cost in sanitary sewer systems related to weather indicate that TC's increase with rain as I&I increases. Conversely, dry weather I&I costs are less.
- Within 48 hours the flows return to pre-storm levels indicating that system defects contribute extraneous inflow primarily during the storm runoff period. Once the runoff from the storm subsides, the flows return to normal (Forbes, 2010).

6.6 Municipal Asset Management Information System

The present and future of sanitary sewer asset management lies with a municipal enterprise solution where administrators, supervisors and working crews in the field can use technology that includes GIS that works with Global Positioning System (GPS), Orthographic and Satellite Images, and sanitary sewer modeling information. The use of the above referenced technologies helps in overlaying of a line map and identifying street names addresses and GPS coordinates that allow the municipality and other stakeholders to locate the utility precisely. The Hot Spot map is an example of GIS technology used in Rowlett in conjunction with this research to understand the areas of possible renewal within sanitary systems.

6.6.1 Data Collection in Municipal Enterprise System

The municipal enterprise solution is used to collect data including:

- Material used
- Cost of repair

- Components that failed
- Duration time of repair
- Associated impacts to neighborhood loss of service
- Social costs (hammering at night, machinery moving)
- Date of repair
- Assessment of repair (notes to assess the neighboring visible areas)
- Documentation by pictures and videos
- Data collection to assess expected service life
- Access to information concerning people associated with your enterprise (this is important when balancing between too much security that hampers productivity and at the same time maintaining liability protection due to security breaches.)
- Mapping of the sanitary sewer system within the City
- Incorporating components of the TAMS

The benefits of an accurate municipal enterprise solution are:

- Accurate Sanitary Sewer System Maps – The maps can be updated on an ongoing basis and are the priority dataset for displaying new and updated sanitary sewer information.
- Efficient – Users can download immediately through file transfer protocol or print on regular plotters and printers within minutes and not days.
- Cost effective – Stakeholders can obtain accurate data and save the cost of developing sewer information and reduce field time.

The municipal enterprise solution is shown in Figure 6.3 and shows the relationship between document information, field information, and GIS information.

6.6.2 Hot Spot Maps

As part of the asset management information system, the Hot Spot maps are particularly useful for looking at patterns rather than the locations of individual features (eg. pipe failure, reasons of failure, etc.). A hot spot map lets you measure the number of features using a uniform real unit, such as hectares or square miles, so you can clearly see the attributes of pipes. Hot spot maps can be used as input for correlation analysis or time series analysis. It can be performed by comparing two consecutive time periods. The other aspect of hot spot maps is that you can determine the state of your infrastructure based on problems, and address those areas prior to complete deterioration. Appendix F provides an example of sewer clogging in Rowlett. Based on the figures in Appendix F, the light orange shading in year 2011 is compared to 2008, and it can be estimated that the sanitary sewer system in Kenwood Heights that went through renewal and repair has fixed clogging problems. Conversely, from 2008 through 2011, the map's color coding for Lakeview Meadows shows growing clogging problems.

6.6.3 Cost Over a Geographic Surface

Cost can include time and money such as cost per hour to repair a clogged sewer based on the number of people working to clear the sewer and the equipment used. Using the cost layer, the Geographical Information System (GIS) totals the cost as it crosses each cell from the source, assigning a cumulative cost to each cell in a new layer it creates. Each cell is given a cost, using its size unit. In GIS, the cost can be restricted to certain areas by using barriers. This feature can be used to calculate TC for any area of the city. In addition, it makes it easy to compare the costs from one area to another, or you can compare the number of failures (clogging) from one area to another (Mitchell, 1999).

A sample of this analysis was tested with this dissertation. The test data was based on costs for renewal, repair, and maintenance, which were collected from Rowlett. The test data includes detailed sanitary sewer inspection information collected during field visits by the repair crew. The results are shown in Appendix G and indicate that the critical assets that include metering stations and lift stations have the maximum TC expenses as they are routinely visited to collect data; moreover, any repair or renewal of a critical asset is expensive and time consuming.

The concept of benchmarking addresses the implications of changing TC associated with various phases of infrastructure due to the changes in the phase of growth or recession of a particular city.

6.7 Benchmarking of Sanitary Sewer Assets

The term benchmarking of sanitary sewer assets in this dissertation is used to determine the phased expenses that come with the installation of municipal infrastructure. Most cities do not develop at a consistent pace or regress at a consistent pace. The growth of a city and, therefore, its infrastructure assets are associated with its population and development. Under ordinary circumstances, typical deterioration of sanitary sewer assets, where maintenance might be required begins after five years of the asset being in the ground. The expenses on maintenance typically start increasing after a 10-year period and the sanitary sewer asset progressively moves into the renewal and repair era based on conversations with municipal personnel in the researched cities.

6.7.1 Growth Mode

A city in growth mode, which typically relates to a good economy, employs staff in the Engineering Department or Public Works Department to inspect and make sure that the installation of sanitary sewer assets is performed according to specifications and design standards established by the city. The majority of installations in sanitary sewer asset systems are performed under the supervision of construction inspectors, and the design standards and construction plans are reviewed by engineers. The city gets inspection fees for these projects; therefore, the installation phase is paid for by developers; some of the TCs are reimbursed for by those fees.

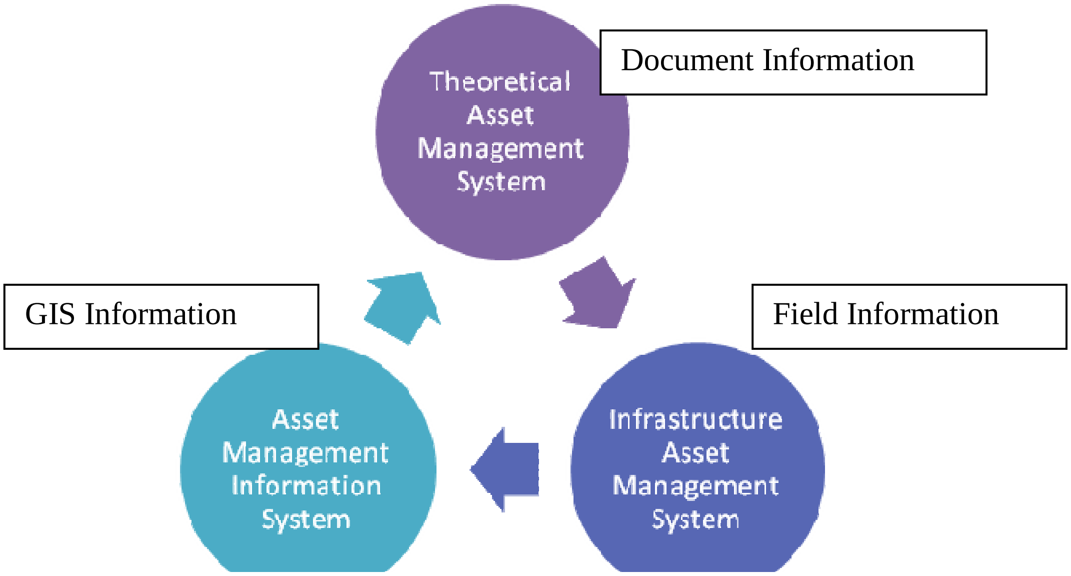


Figure 6.3 Municipal Enterprise Solutions

The problem of deterioration and failure rates is exacerbated once the city phases into a maintenance mode that typically is 10 to 15 years after the installation. The ideal scenario would be that the revenues generated from water and sewer fees would pay for the maintenance cost, renewal and repair of the sanitary sewer infrastructure. However, these water and sewer user fees cannot always cover the optimum maintenances cost since they can be diverted from utility funds to other funds leading to a lack of either human or equipment resources. This leads to the cycle of accelerated deterioration of the sanitary sewer infrastructure. The reason for not generating adequate fees could be due to decisions made by political entities which can originate in departments, from city management (stakeholders) or from the grassroots level (citizen requests).

The problem with not generating adequate fees results in the sanitary sewer asset system going into the deficit mode due to reduction in maintenance and inspection of the sanitary sewer asset. Once the sanitary sewer assets enter the deficit mode, a chain reaction in terms of shortened deterioration transition times occurs between the conditional rating classifications of the asset. For example, with a rating system of new, good, fair, bad and failed for a sanitary sewer asset, the transition times accelerate from a good rating to fair, and subsequently to bad, accelerating transition until the failure rating is reached.

It costs a city exponentially more dollars to renew or repair a sanitary sewer asset system that has moved to failed rating. The municipalities need to educate stakeholders on the benchmarking issues and try to generate the necessary fees to prevent accelerated deteriorations and failures.

6.7.2 Regressing Growth

Cities with regressive growth experience problems for raising revenues. In addition, the cities face limited city staff support, insufficient local and state resources, and federal assistance that do not keep up with the needs. Most seriously of all, citizens and their representatives tend to ignore the widespread evidence of urban infrastructure decay, and often do not support efforts to repair damages. Most mid-western cities appear to be virtually unorganized in their attack on the capital infrastructure deterioration problem (Checkoway and Patton, 1985)

In the case of a city which is regressing in population, the revenues generated from water and sewer fees for RR&M of the sanitary sewer infrastructure actually decreases. With fewer customers in the pool paying the water and sewer fund fees, regressing growth cities such as Detroit and Cleveland are finding the impact to be substantial as the people leaving the city are middle and upper income residents due to the depressed economy. The result is that the burden of water and sewer fees falls on the lower income strata of society who are already monetarily disadvantaged.

This can result in cities addressing only critical failures, which lead to frequent emergency repairs. The discrepancy between sanitary sewer system’s maintenance needs and dollars available for maintenance widens rapidly as the transition between the conditional ratings of the sanitary sewer system moves from very good to poor to end of life at an alarmingly accelerated rate. In a rating system of very good, good, fair, bad, to end of the life, the transition times between the individual ratings become extremely short.

6.7.3 True Cost and Benchmarking

The TC of the installation in a city with growth mode usually goes up because of the overtime paid to the inspectors and other staff to keep up with the excessive amount of infrastructure placement. The unfortunate aspect of this rapid growth is that the city staff tries to rush from job to job endangering quality of the installation of the infrastructure.

The TC of the installation in a city with regressive growth will suffer from staff resources that are kept the same or reduced. This reduction in staff leads to fewer staff to deal with the infrastructure problems. The result is that infrastructure rating moves quickly towards deterioration and failure resulting in fewer staff to deal with increasing emergency calls, with patchwork repairs and minimal renewal or repair. In the long run, the city in regressive growth will end up paying more in TC with lower quality of service during the shortened life of the infrastructure.

6.8 Chapter Summary

This chapter presented new concepts that have been used by this research. A summary of the new topics are included below:

- Theoretical Asset Management System (TAMS)
    - TAMS is a methodology for effectively looking at documentation and reports as part of an asset management system instead of a detailed inventory of physical assets. This author’s thesis revolves around municipalities using TAMS in their planning phases to save True Cost in the RR&M phases.
- Hot spots for Sanitary Sewer Renewal
    - Hot spots show the trend of problems in the sanitary sewer system. If monitored and documented effectively, decisions on which systems need to be addressed can be generated. Based on the pictorial hot spot maps, it helps

    non-technical decision makers, typically politicians and city managers, get an idea of which area of the sanitary sewer system needs the most attention.

- Benchmarking
    - The concept of benchmarking has been in existence among planners. The literature search involved Midwest cities; however, generically all cities go through the growth and regressive phases. Cities must be aware of the potential consequences of growth and regressive phases.

CHAPTER 7

MUNICIPAL SANITARY SEWER DETERIORATION AND FAILURE RATES

7.1 Deterioration and Failure Introduction

Failure in sanitary sewer pipeline infrastructure has several causes. Deterioration is one of the causes of failure. Deterioration is the degradation of the sanitary sewer pipeline infrastructure that leads to ultimate failure. Deterioration can be accelerated due to extraneous factors as discussed in Section 7.2.1.2. This chapter analyzes the sanitary sewer system for the failure rate per year (λ) as it gives a cost component to deterioration and, therefore, can be allocated in the TC component.

7.2 Deterioration

7.2.1 Classical Deterioration

If pipe life of deteriorated pipelines can be extended with the use of trenchless technology and other recent innovations, then there are benefits in terms of True Costs and social costs. In order to figure out the advantages to extending life of deteriorated pipelines, the concept of how pipeline deterioration occurs needs to be understood. The other aspect is to determine the process used by municipalities to assess which sanitary sewer component needs to be renewed or repair. The generic process is to collect and analyze data, evaluate several criteria including attributes of pipe, repairs and failure data, as well as costs, and to determine the appropriate technology for addressing the deterioration.

7.2.1.1 Study of Deterioration of Sanitary Sewer Systems in Municipalities

The cities of Rowlett, Garland and Allen approach deterioration of the infrastructure in different ways. The most comprehensive approach is to perform a Sanitary Sewer Evaluation Study (SSES) to determine the condition of their sanitary sewer system. This methodology is also the most expensive in terms of TCs, as the consultant usually requires information on the existing system from city staff. A solution to address this information collection overload is to have an ongoing asset management system with features of TAMS incorporated as discussed earlier. The Sanitary Sewer Evaluation Study (SSES) provides relevant information on the present condition of the pipe based on a rating system and a component rating for manholes, lift stations, air release valves etc. The typical SSES identifies problem areas in terms of point locations or group locations or basin wide locations. The different components that affect the TC is the time it takes to administer the replacement of the pipe and associated appurtenances, and the complications that are associated with the renewal and repair of a project. The possible complications include location, the cost of inflow and infiltration in terms of treatment, and the social costs during replacement.

7.2.1.2 Rates of Deterioration and True Cost

The following terms are described in this section:

Accelerated Deterioration: This occurs when certain characteristics around the sanitary sewer system lead to reduced transition times between the conditional rating classifications of the asset ultimately leading to asset failure. Increased TCs can be due to requirements for more maintenance which can be caused by a number of factors:

1. Unnatural failure due to mechanical impacts on pipe
2. Improper installation
3. Sanitary sewer system is chemically attacked externally and/or internally
4. Seismic or earth movements due to settling, excessive compaction
5. Material flaws

Normal Deterioration: This occurs when characteristics around the sanitary sewer system follow the design standards leading to normal transition times between the conditional rating classifications of the asset. Normal deterioration results in stable TCs, and the timeframe of deterioration simulates the laboratory tests conducted on the pipe.

Slow Deterioration: This occurs when characteristics around the sanitary sewer system degrade slower than the design standards leading to extended transition times. Results in TCs not being expended beyond the life of the pipe and the timeframe of deterioration exceeds that of the predicted life. This scenario arises under ideal conditions where the pipe is not used to its ultimate capacity, is installed properly and is not internally or externally chemically attacked.

7.2.1.4 Other Deterioration Factors and True Cost

Other deterioration factors include mechanical deterioration and chain reaction deterioration leading to failure and improper design deterioration. The other deterioration factors usually affect the critical sanitary sewer assets, and are expensive in terms of TCs, and include:

Mechanical Deterioration: In sanitary sewer systems, the mechanical operations of pumping address time factored changes that include peak and ebb flows. The change in usage creates concentrated sewer gases due to the constant churning of sewer. In addition, the change in usage, frequency, capacity, flows and velocity create additional loads on the pump systems and the sewer pipes that include force mains, transition manholes, gravity systems, and other equipment like air release valves and control valves. Typical field observations conducted in this research include:

- Deterioration, approximately 100 to 200 feet from a force main to a gravity system usually start at the transition manhole.
- Deterioration usually occurs approximately 100 to 200 feet from a force main to the wet well of the lift station.

Chain Reaction Deterioration: This typically occurs in the higher transition time period of the sanitary sewer system. It occurs when an existing failure is being addressed and due to the already deteriorated stage of the pipe, additional deterioration and failure issues are created caused by the construction technique, renewal and replacement design, changing of the existing elements in the vicinity of the sanitary sewer system, and construction errors.

Typical issues arising from chain reaction deterioration observed in this research include:

- Damaging of the existing pipe during construction
- Placing additional loads due to movement of soil
- Improper backfilling and other standard construction practices to bring the line back into operation
- Collapse of material from wet well leading to damage of pumps

Figure 7.1 illustrates a relation due to chain reaction deterioration where costs in older subdivisions increase compared to the same renewal and repair activity conducted in a comparatively new subdivision. The issues with older subdivisions include mature trees, narrower easements, older infrastructure, lack of as-builts, and abandoned utilities. The referenced issues make the cost of performing renewal and repair projects in older subdivisions more expensive.

Improper Design Deterioration

Improper design practices can lead to deterioration of the sanitary sewer system. The major design failures reduce the life of the sanitary sewer system and result in excessive repeated RR&M issues. Typical issues observed during the research include:

- Improper placement of air release valves in the system
- Pump motors specified with less head leading to reduced capacity and excessive usage of the pumps
- Drop manholes in transition from force mains to gravity system
- Air pockets leading to mushroom cloud failure (failure that occurs in sewer lines due to trapped air)

Figure 7.1 Chain Reaction Deterioration
Source: City of Rowlett

7.3 Failure Rates and True Costs

7.3.1 Failure rate per year (λ)

The failure rate varies over the life cycle of a pipe for various reasons. For example, a pipe's failure rate in its 50th year of service may be many times greater than its failure rate during its first year of service. One does not expect to replace a pipe or have major repair problems in a new pipe under normal circumstances. For the purposes of this dissertation, failure can be classified into three categories, as follows.

1. Static Failure
    - Clogging/system backup or blockage failure usually builds up over long periods of time and can be cleared in many instances without any renewal or repair of the sanitary sewer system (Figure 7.2).
    - Occasionally a failure can be caused by a dynamic or instantaneous failure, and the blockage over time might make it appear to be a static failure until it is investigated.

Figure 7.2 Static Failure (Root Intrusion)
Source: Forbes, 2010

2. Dynamic Failure

Failure due to pressure, cracking, collapse, soil movement, excessive loads etc. builds up over time and can require patchwork, renewal or repair of the sewer system (Figure 7.3).

3. Instantaneous Failure
    - Failure due to foreign objects affecting the sanitary sewer system by drilling machines, backhoe accidents, natural disasters etc., can lead to complete failure of the sanitary sewer system. The exception is when the utility was punched through a pipe or force main and leads to a static failure over time (Figure 7.4).

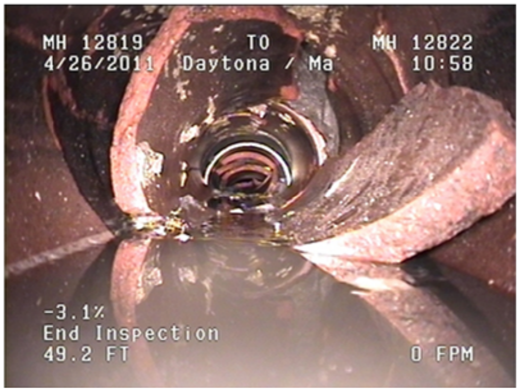


Figure 7.3 Dynamic Failure (Collapse of Pipe)
Source: Forbes, 2010

Figure 7.4 Instantaneous Failure (Backhoe Damage)
Source: City of Rowlett

The variation in the failure rate is defined by the following formula (Eq. 7.1):

$$\text{Failure Rate per year } \lambda = \frac{\text{Total number of failures within a chosen network of pipe syste}}{\text{Sum of the age of each pipe in the chosen network of pipe system}} \quad \ldots\ldots\ (7.1)$$

In case of a network of sanitary sewer pipes, the sum of failure rates of individual pipes gives the failure rate of the system (in the case of this dissertation it is the failure rate throughout a municipality), provided the time unit used is the same for all the components. In the example in Table 7.1, the time unit used was years.

7.3.2 Example of Failure Rate and Annual Cost of Pipe Failure

Suppose that age of pipe and number of failures for 10 pipes are recorded, as presented in Table 7.1. Then, the failure rate can be calculated as

$$\lambda \text{ overall } = \frac{33}{3132} = 0.25 \text{ failures per year}$$
$$\lambda \text{ overall} = \text{ number of overall failures per year}$$

Since the cost associated with each type of failure cannot be assumed to be same, it is meaningful to break down the number of failures by type of failure, as shown in Table 7.2. Cost associated with each type of failure can then be calculated individually and summed to yield the annual cost of failure, as shown in Table 7.3.

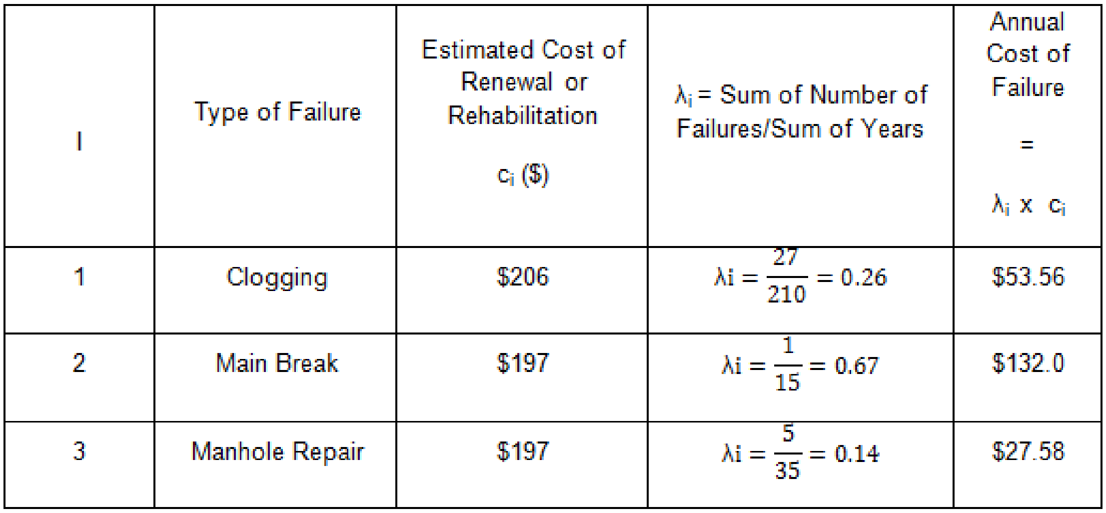
Table 7.1 Hypothetical Data to Calculate Failure Rates

Pipeline #	Age (yrs)	# of Failures
1	30	3
2	15	2
3	50	22
4	2	0
5	3	0
6	10	1
7	12	4
8	1	0
9	1	0
10	8	1
Total	132	33

Table 7.2 Failure Rate Based on Different Types of Failures (Hypothetical Data)

Pipeline #	Age (yrs)	# of Failures	Type of Failure
1	30	3	Clogging
2	15	2	Clogging
3	50	22	Clogging
4	2	0	Main Break
5	3	0	Main Break
6	10	1	Main Break
7	25	4	Manhole Repair
8	1	0	Manhole Repair
9	1	0	Manhole Repair
10	8	1	Manhole Repair

Table 7.3 Calculation of Annual Cost of Failures (Based on Hypothetical Data)



I	Type of Failure	Estimated Cost of Renewal or Rehabilitation c_i ($)	λ_i = Sum of Number of Failures/Sum of Years	Annual Cost of Failure = λ_i x c_i
1	Clogging	$206	$\lambda i = \frac{27}{210} = 0.26$	$53.56
2	Main Break	$197	$\lambda i = \frac{1}{15} = 0.67$	$132.0
3	Manhole Repair	$197	$\lambda i = \frac{5}{35} = 0.14$	$27.58

$$\mathit{Annual\ Cost\ of\ Failure} = \sum_{i=1}^{n} \lambda i\ ci = \$53.56 + \$132 + \$27.58 \cong \$213.2$$

where c_i = the cost associated with each type of failure

i = 1, 2,.........,n (n = number of failure types)

Based on the determination of failure rates, and thereby the cost of failure and the incorporation of historical information in determining the failure rate, a municipality can plan better by selecting specific hot spots. Specific costs determined from the failure rates can be assigned to hot spots to have better control over budgets by using a better methodology, and thereby lowering True Costs by spending resources where the needs are the greatest.

7.4 Chapter Summary

This chapter introduced types of deterioration and failure rates. The concepts of deterioration and failure rate of municipal sanitary sewer systems has been explored.

CHAPTER 8

MUNICIPAL SOCIAL COSTS AND EFFECTS ON TRUE COST

8.1 Social Cost Introduction

Anytime a municipal employee responds to complaints, concerns, and issues related to construction activity, a monetary municipal administrative cost is expended. Municipal social cost in this dissertation is divided into tangible and intangible costs which occur due to the renewal and repair of the sanitary sewer system.

The tangible costs are monetary cost savings and thereby represent TC savings. The intangible costs are not monetary and typically focus on social aspects affecting the quality of life for the customer, owner and contractor of the project. The maximization of tangible and intangible costs can be achieved by reducing the project's carbon footprints through use of detailed planning during the design phase. This ecologically beneficial design emphasis can be implemented by using TAMS, matching the right technology for the renewal and repair, and ultimately keeping in mind the social impacts on the stakeholders.

8.2 Social Costs in Municipal Environment

8.2.1 Social Costs and Sanitary Sewer Renewal

Sanitary sewer renewal and repair is a critical service that cities provide for their customers to maintain a certain quality of life. The precise planning and execution of any sanitary sewer renewal or repair is critical in minimizing the inconvenience to the customers of a municipality, thereby keeping the tangible and intangible social costs to a minimum.

8.2.1.1 Tangible Cost of Sanitary Sewer Renewal and Repair

The key to reducing tangible costs is to reduce the area disturbed by construction. So, the desired objective is to reduce the movement of soil caused due to construction activities. The TC savings include the following benefits:

- The generation of a detailed and comprehensive Storm Water Pollution Prevention Plan (SWPPP) might not be required thereby minimizing the reporting efforts.
- Less disturbance leads to lesser activities to maintain on the construction site.
- Erosion control and watering expense to keep dust down is minimized.
- Equipment costs for fuel and wear and tear is reduced.
- Less steps and less complications in construction have the probability of minimizing change orders that might arise due to complaints from customers.
- Rehabilitation by seeding and planting is minimized.
- There is less expense on traffic control. Costs for the customers go up as they have to drive through diversions in the neighborhood.
- City staff time is reduced in addressing complaints if the area of construction is large.

8.2.1.2 Intangible Cost of Sanitary Sewer Renewal and Repair

The intangible costs cannot be measured in terms of monetary expenses even though they affect homeowners and commercial establishments. By reducing the amount of disturbance due to construction, the intangible savings could include:

- Disruption Factors
    - Noise due to machinery is minimized.
    - Traffic diversions and crowding due to lane closures cause mental stress and time losses for the customers
- Effects on Property Values

    - If a house or business is for sale or rent in the affected area, the access and aesthetic value is reduced or avoided by some potential buyers or leasers.
- Damage to vehicles can occur due to distraction of construction activity and increase in accidents due to implementation of differing traffic patterns.
- Psychological Factors
    - Citizens become stressed when construction periods are extended beyond a comfortable timeframe. Construction takes a toll on senior citizens and the handicapped as they are forced to deal with situations that they are not used to and may not venture out of their homes because of construction disruptions. Handicapped people lose access to the sidewalks and have to go into areas that are often not according to American with Disabilities compatible.
    - Complaints are issued on foundation cracking due to construction.
    - Water and sewer facilities might be interrupted for few hours.
    - Citizens resent losing convenience of access to their house or business especially when forced to park far away and walk to their destination.
    - Contractors and city personnel are stressed because of citizen & commercial business owners’ complaints.
- Technological Factors
    - Due to the easy access to cell phones, internet, and email, the customers have become used to instant answers to problems and expect cities to address concerns immediately.
    - Conversely, the referenced technological advances help the city by customers reporting dangerous or potentially unsafe situations.
- Environmental Factors
    - There is usually minimum loss of trees or green space by using trenchless technologies.

  - Dust and fumes from construction machinery aggravate asthmatic and allergy-sensitive neighbors. Dust can also coat nearby cars and flower gardens. Some contractors are forced to put up a dust shield to keep this from happening.
- Nuisance Factors
  - Standing water due to construction can lead to mosquito growth. This typically happens due to alteration of the drainage area.
  - Dry or wet mud leads to fears of getting stuck or having to wash cars.
- The threat of vandalism can be a concern to both the community and the construction workers. The National Equipment Register (NER, Equipment Theft Report, 2007) estimates the total value of equipment stolen annually from construction sites range between $300 million and $1 billion. To neighbors, the fear of crime rings coming in to construction areas makes them concerned about their own safety and security (Hartford Financial Services Group, 2009).
- Municipal Factors
  - Political factors such as the need to push a certain replacement ahead of others can disrupt whole communities and frustrate construction companies. Curiosity factors can be very dangerous. Neighborhood kids are attracted to a construction area seeing it as a playground. This can lead to serious injuries if area is not secure.
  - Fire calls due to smoke testing can be stressful and costly.
  - Medical Factors are also important. Emergency response times for fire and police can change due to minimization of the construction area and a delay of just a few minutes can be disastrous.
  - Convenience of access to a sick person’s home can be disrupted by construction activities. For example, a gurney is very hard to take in an out of a business or home that has its front yard or the whole street dug up.

8.2.2 Solution to Social Costs during Sanitary Sewer Renewal

A solution to minimize municipal social costs is trenchless technology. It is used by municipalities for extending life of the deteriorated pipelines or renewing the pipeline. In terms of TC, trenchless technology (TT) at first glance, is more expensive, based only on bid prices as compared to open cut as shown in Table 5.11. The costs associated with TT, however, are reducing as the technology improves and techniques are getting more sophisticated and accurate, having minimal impact on the customers. From a social cost standpoint, TT is the optimum solution. TT has been researched extensively; therefore, this dissertation is looking at it from a municipal standpoint (Najafi, 2010). The provision of municipal bids based on the bidder who provides the minimum cost, leads to TT not being used generically making it the exception rather than the rule.

8.3 Chapter Summary

This chapter provided the concept of social costs and trenchless technology. Trenchless methods can potentially have reduced social costs.

CHAPTER 9

CONCLUSIONS, LIMITATIONS, AND RECOMMENDATIONS

9.1 Conclusions

9.1.1 True Cost

True Cost (TC) is the sum of municipal administrative costs that include city employee expenses and overhead costs, design cost, and construction cost to complete a sanitary sewer system renewal and repair project. The research through case studies on TC analysis revealed the following conclusions:

- Based on the renewal and repair of sanitary sewer system data collected from the City of Rowlett, the municipal administrative cost was estimated as 4.4% of the sanitary sewer construction costs of the Kenwood Heights Project.
- Based on the renewal and repair of sanitary sewer system data collected from City of Allen, the municipal administrative cost was estimated as 9.8% of the sanitary sewer construction costs of the Walden Heights Project.
- True Costs as evaluated by the samples of Rowlett and Allen can be significant when aggregated over several projects.
- True Costs for renewal and repair of municipal sanitary projects can be calculated based on the framework provided. Other municipalities can model similar TC framework.
- True Costs for repair and maintenance were calculated as an example calculation for the cities of Rowlett and Garland.
- Calculation and analysis of the annual costs of failures for sample cities can be utilized in assigning costs to areas that need renewal and repair of the sanitary sewer system.

- This research introduced ideas related to factors affecting TC in the municipal environment such as MIAS, MES, municipal sanitary sewer deterioration and failure, municipal social costs, and benchmarking.
    - MIAS, if implemented in municipalities, will lead to organized data collection and management of information related to sanitary sewer assets that can reduce TC.
    - Hot spots and TAMS are some of the factors of MES that affect TC. It can be hypothesized that due to the availability of hot spot technology, TC can be estimated in advance, enabling stakeholders to optimize project selection and strategize the budgets accordingly. Similarly, TAMS can reduce TC by providing easy access to accurate information, leading to effective decision-making capabilities in design at the office and at the construction site.
    - Annual cost of failure due to deterioration is TC that can be used by municipalities to estimate renewal and repair expenses for budgeting purposes.
    - Minimizing area disturbed by construction will reduce the tangible social costs incurred by municipalities in terms of municipal administrative costs. One such solution is to minimize disturbance by the use of TT which not only helps extend the life of deteriorated pipeline, but also reduces the disturbance and disruption in the vicinity of the construction site.
    - Benchmarking in municipalities in growth or regressive mode can have a direct effect on TC of the sanitary sewer infrastructure. TC in growth mode are higher because of the overtime paid to the city staff. In regressive mode, there is minimal staff available to address routine maintenance needs, leading to frequent failures and higher TC.

9.1.2 Data Collection and Technological Issues

The criteria, methodology, and collection of data related to sanitary sewer system management within the sample cities were not uniform. The result was a huge amount of data that was not sorted or organized and therefore underutilized. For example, City of Allen does not have any electronic information on the repair inventory and one has to sort through thousands of papers to get any meaningful outcome. It can also be concluded from this research that although the municipalities have existing technologies that include GIS, Auto-CAD, and asset management software, all the technology features to represent data in analytical, visual, and spatial forms are not being utilized

9.2 Limitations

- The limitation of this research is that only three cities were considered in the North Texas. Including a large sample of data from many cities will help demonstrate the veracity of the TC framework.
- Municipal social cost is limited to actual time spent by city personnel in addressing issues when reported by customers.
- The research included two renewal and repair projects from the cities of Allen and Rowlett as examples for calculation of TC. Specialized projects such as lift stations, wastewater treatment plants, etc. (that could be part of the sanitary sewer system) were not included in the calculation of TC.

9.3 Recommendations

How to reduce True Costs in sanitary sewer renewal and repair projects?

The True Costs can be reduced by performing the following:

1. Research information on the sanitary sewer layout, and consider utilities and facilities in the vicinity of the projects. The advantages are:
    a. Hazards, costs, and labor to produce the final design in the renewal of the sanitary sewer are minimized.

    b. Safety is enhanced.
    c. Unexpected conflicts are minimized or eliminated.
    d. Relocations and on-the-field decisions are minimized.
2. Have a standard policy guideline for the municipal enterprise solution.
3. Include field notes, revised plans with corrected errors, photos with measured benchmarks, inspector notes, global positioning system coordinates, and incorporation of specifications in GIS mapping and databases.
4. Plan and train municipal inspectors, field crews, engineers, and GIS personnel to achieve standard requirements for the municipal enterprise solutions.
5. Document accurately during all the steps of the sanitary sewer renewal process by municipal inspectors and crew for major and minor renewal and repair projects. The contractor must be educated to comply with the documentation required by the municipality
6. Plan for the consequences of failures to reduce True Costs, as the different departments in the municipality can react faster to the issues.
7. Rely on experienced personnel. Municipal engineers and crew, who have institutional knowledge and experience of pipe failures and the methodology of renewal and repair, can save significantly on True Costs. These experienced personnel have institutional knowledge of the sanitary sewer system, and, therefore, reduce the renewal and repair time and usually end up with the best fix the first time. The indirect benefit of a quick response is that failure-related issues like environmental disasters can be mitigated.
8. Invest in initial design of the system and save on the TC for the life of the system.
9. Use TAMS methodology to determine pipe size and life cycle. The ultimate design provides life cycle strategy where the sanitary sewer system goes

through several stages of use. An example is a municipal sanitary sewer system that was oversized in terms of the pipe for ultimate build out rather than balancing with the growth of the drainage area of the system. The result leads to the sanitary sewer system being in the ground for several decades with underutilized capacity and low flows. The low flows cause sewer gases to build up and eventually corrode the pipe causing a premature need for replacement. The solution is to plan the system based on TAMS and phase the system.

10. Schedule regular maintenance. TCs of main line repairs and lift stations is more impactful in a shorter period of time than point repairs on regular lines; however, the cumulative costs of manholes and main lines can be significant because their number or quantity is significant
11. Use Trenchless Technology (TT) for minimizing disturbance in and around the construction area. Due to accidents in the installation of other utilities in easements and ROW, a significant increase in terms of damage to wet utilities has been observed by municipalities. This phenomenon has resulted in a significant increase in TC for municipalities.
12. Communicate with all players for the sake of efficiency and lower TC. Minimizing TC by communication, where the right person does the right job, in terms of plan coordination, ROW management, utility placement (to avoid conflict), and guidance of contractors and subs.

9.4 Future Research

Possible future research can be performed as following:

- Increase the number of sample projects from different states and regions.
- Increase the number and types of specialized projects (lift stations, wastewater treatment plants) to have more comprehensive understanding of TC.

- Include water, pavement and drainage and other information to determine their effects on TCs.
- Study growing and regressing cities to predict TC.
- Classify of TC based on area and population. For example, mega cities such as New York and Los Angeles can be included.

APPENDIX A

CITY OF ROWLETT CALCULATIONS FOR OVERHEAD EXPENSES

City of Rowlett City Hall Building Contents Hourly Expense Calculation

City Hall Contents Estimated at \$300,000 based on Insurance i = 4.5%, n = 20 year bond therefore

$$A = \$300{,}000\left\{\frac{[0.045(1+0.045)^{20}]}{[(1+0.045)^{20}-1]}\right\}$$

A = \$300,000 x 0.0769

A = \$23,070

A* = Adding 2% insurance premium charges per year that equals \$461

$$\text{City Hall Building Contents Hourly Expense} = \frac{A^{*}}{365 \text{ days per year} * 24 \text{ hours a day}}$$

$$\text{City Hall Contents Building Hourly Expense} = \frac{\$23{,}531}{365 \text{ days per year} * 24 \text{ hours a day}}$$

$$\boxed{\mathit{City\ of\ Rowlett\ Contents\ of\ City\ Hall\ Building\ Hourly\ Expense} = \$2.69}$$

City of Rowlett Public Works Building Hourly Expense Calculation

PV of Building remodeled in 1998 = \$2,004,039, i = 4.5%, n = 20 year bond therefore

$$A = \$2{,}049{,}300\left\{\frac{[0.045(1+0.045)^{20}]}{[(1+0.045)^{20}-1]}\right\}$$

A = \$2,049,300 x 0.0769

A = \$157,591

$$\text{Building Hourly Expense} = \frac{A}{365 \text{ days per year} * 24 \text{ hours a day}}$$

$$\text{Building Hourly Expense} = \frac{\$157{,}591}{365 \text{ days per year} * 24 \text{ hours a day}}$$

$$\textbf{City of Rowlett Public Works Building Hourly Expense} = \mathbf{\$17.99}$$

City of Rowlett City Hall Building Contents Hourly Expense Calculation

City Hall Contents Estimated at $350,000 based on Insurance i = 4.5%, n = 20 year bond therefore

$$A = \$350{,}000$$

$$A = \$350{,}000\left\{\frac{[0.045(1+0.045)^{20}]}{[(1+0.045)^{20}-1]}\right\}$$

$$A = \$350{,}000 \times 0.0769$$

$$A = \$26{,}915$$

A* = Adding 2% insurance premium charges per year that equals $538

$$\text{City Hall Building Contents Hourly Expense} = \frac{A*}{365 \text{ days per year} * 24 \text{ hours a day}}$$

$$\text{City Hall Contents Building Hourly Expense} = \frac{\$27{,}453}{365 \text{ days per year} * 24 \text{ hours a day}}$$

$$\textbf{City of Rowlett Contents of City Hall Building Hourly Expense} = \$\mathbf{3.13}$$

APPENDIX B

CITY OF ALLEN CALCULATIONS FOR OVERHEAD EXPENSES

City of Allen Building Hourly Expense Calculation

PV of City Hall Building built in 2000 including Bond Expenses = \$8,900,000, i = 4.0%, n = 20 year bond

The building area used for Strategic and Consensus Planning purposes is approximately 10,000 sq. ft. or 16.5% of the total building size of 60,457 square feet therefore

Building Cost used for Strategic and Consensus Planning = \$8,900,000 x 16.5%

Building Cost used for Strategic and Consensus Planning = \$1,468,500

$$A = \$1{,}468{,}500 \left\{ \frac{[0.040(1+0.040)^{20}]}{[(1+0.040)^{20} - 1]} \right\}$$

$$A = \$1{,}468{,}500 \text{ x } 0.074$$

$$A = \$108{,}669$$

$$\text{Building Hourly Expense} = \frac{A}{365 \text{ days per year} * 24 \text{ hours a day}}$$

$$\text{Building Hourly Expense} = \frac{\$108{,}669}{365 \text{ days per year} * 24 \text{ hours a day}}$$

$$\boxed{\textit{City of Allen Building Hourly Expense} = \$12.41}$$

City of Allen City Hall Building Contents Hourly Expense Calculation

City Hall Contents Estimated at \$1,200,000 based on Insurance i = 4.0%, n = 20 year bond

Building Contents Cost used for Strategic and Consensus Planning = \$1,200,000 x 16.5%

Building Contents Cost used for Strategic and Consensus Planning = \$198,000

$$A = \$198{,}000\ \left\{\frac{[0.040(1+0.040)^{20}]}{[(1+0.040)^{20}-1]}\right\}$$

$$A = \$198{,}000 \times 0.0769$$

$$A = \$15{,}226$$

$$A = \$198{,}000\ \left\{\frac{[0.040(1+0.040)^{20}]}{[(1+0.040)^{20}-1]}\right\}$$

$$A = \$198{,}000 \times 0.0769$$

$$A = \$15{,}226$$

A* = Adding 2% insurance premium charges per year that equals $305

$$\text{City Hall Building Contents Hourly Expense} = \frac{A^{*}}{365 \text{ days per year} * 24 \text{ hours a day}}$$

$$\text{City Hall Contents of City Hall Building Hourly Expense} = \frac{\$15{,}531}{365 \text{ days per year} * 24 \text{ hours a day}}$$

$$City\ of\ Allen\ Contents\ of\ \ City\ Hall\ Building\ Hourly\ Expense = \$1.77$$

Note : The same numbers for building expenses have been used for Implementation Phase as the Service Center was under construction during this research

APPENDIX C

CITY OF GARLAND RENEWAL, REPAIR, AND MAINTENANCE EXPENSES

City of Garland RR&M Expenses

Calculation of Crew Expenses on Average age at 2011 Rates

Sewer Maintenance (jetting main & customer stoppages, CCTV, root cut, etc)

2 people/vehicle average wage is: $18.73 per person plus benefits of 35% & 20% for miscellaneous

Average labor hourly expense = 2 x $18.73 = $37.5 + ($37.5 x 0.55) = $58.13

Average vehicle hourly expense for jet truck = $150

Inflow/Infiltration (CCTV, manhole repairs, sewer main repairs, smoke testing, etc.)

2 people/vehicle average wage is: $18.87 per person & benefits of 35% & 20% for miscellaneous

Average labor hourly expense = 2 x $18.87 = $37.5 + ($37.5 x 0.55) = $58.44

Average vehicle hourly expense =$150 for camera truck

Average equipment hourly expense =$65 - $75 for backhoe

Sewer Repair (sewer main repair, repair renewal of city clean out, lateral repair, saw & jack hammer, etc.)

3 people/vehicle average wage is: $20.68 per person & benefits of 35% & 20% for miscellaneous

Average labor hourly expense = 3 x $20.68 = $62 + ($62 x 0.55) = 96.10

Average equipment hourly expense = $65 - $75 for backhoe

Average equipment hourly expense = $1 for jack hammer and $6 for saw

Total average equipment hourly expense = $77

APPENDIX D

CITY OF ROWLETT RENEWAL, REPAIR, AND MAINTENANCE EXPENSES

City of Rowlett RR&M Expenses

Calculation of Crew Expenses on Average age at 2011 Rates

Sewer Maintenance (jetting main & customer stoppages, CCTV, root cut, etc)

2 people/vehicle average wage is: $46.3 per crew & 20% miscellaneous

Average labor hourly expense =$46.3 + 20% = 55.56

Average equipment hourly expense =$150

Total Equipment and Labor ~ $206

Inflow/Infiltration (CCTV, manhole repairs, sewer main repairs, smoke testing, etc.)

3 people/vehicle average wage is: $76.93 per crew

Average labor hourly expense =$76.93 + 20% = 92.32

Average vehicle hourly expense =$150 for camera truck

Average equipment hourly expense =$65 - $75 for backhoe

Total average equipment hourly expense = $220

Sewer Repair (sewer main repair, city clean out, lateral repair, saw & jack hammer, etc.)

4 people/vehicle average wage is: $100.08 per crew

Average labor hourly expense =$100.08 x 20% = 120.10

Average equipment hourly expense = $65 - $75 for backhoe

Average equipment hourly expense = $1 for jack hammer and $6 for saw

Total average equipment hourly expense = $77

Lift Station Repair (rounds, maintenance, repair etc.)

3 people/vehicle average wage is: $76.92 per crew

Average labor hourly expense =$76.92 x 20% = 92.30

Average equipment hourly expense = $35 for truck

Average equipment hourly expense = $75 for crane

Total average equipment hourly expense = $202.30 for repairs

Total average equipment hourly expense = $127.30 for maintenance and rounds

Assuming 75% maintenance and 25% repairs = $142 for lift station repair

Sewer Inquiries & Paperwork

2 people Wastewater Supervisor/Crew Leader: $62.59 per field responded inquiry

Average labor hourly expense = $62.59 x 20% = $75.11

APPENDIX E

TRUE COST CALCULATION FRAMEWORK

Strategic Planning Framework

Legend	
🟩	Input Values
🟪	Output Values

Regular Hours	209.3
Overtime Hours	26
Total Strategic Planning Hours (H)	**235.3**

$$PE_S = \sum_{i=1}^{n} Ei + OE$$

Table I: City Staff Expense Per Strategic Planning Project Phase

Management Employees	**Yearly**	**Hourly Rate**	**Regular Hours (N_i)**	**Overtime Hours (O_i)**	**Overtime Rate**	**Benefits (B_i)**	**Staff Expense Per Phase (E_i)**
City Manager	$162,000	$78	5.8			$27	$610
Assistant City Manager	$141,000	$68	3.9			$24	$357
Public Works Director	$125,000	$60	19.4			$21	$1,574
Finance Director	$110,000	$53	5.5			$19	$393
City Engineer	$102,000	$49	36.3			$17	$2,403
Assistant City Engineer	$84,000	$40	57.5			$14	$3,135
Waste Water Manager	$72,828	$35	23.9			$12	$1,130
Additional Personnel							
City Attorney		$150	1.3			$53	$195
Purchasing Agent	$61,000	$29	9			$10	$356
Accountant	$63,870	$31	9.2			$11	$381
GIS Manager	$54,000	$26	2.5			$9	$88
Public Information Officer	$43,800	$21	9			$7	$256
Additional Personnel							
Consulting for SSMP		$0				$0	$0
Consulting for SSES		$0				$0	$0
Hourly Employees							
Administrator	$35,000	$17	26	1	$25	$6	$616
Miscellaneous Expense							$2,299
Total Staff Expense (SE)							**$13,792**

Source: City of Rowlett

Consensus Planning Framework

Legend	
🟩	Input Values
🟪	Output Values

Regular Hours	472.6
Overtime Hours	289.3
Total Consensus Planning Hours (H)	**761.9**

$$PE_C = \sum_{i=1}^{n} Ei + OE$$

Table I: City Staff Expense Per Consensus Planning Project Phase

Management Employees	**Yearly**	**Hourly Rate**	**Regular Hours (N_i)**	**Overtime Hours (O_i)**	**Overtime Rate**	**Benefits (B_i)**	**Staff Expense Per Phase (E_i)**
City Manager	$162,000	$78	5.8			$27	$610
Assistant City Manager	$141,000	$68	3.9			$24	$357
Public Works Director	$125,000	$60	19.4			$21	$1,574
Finance Director	$110,000	$53	5.5			$19	$393
City Engineer	$102,000	$49	36.3			$17	$2,403
Assistant City Engineer	$84,000	$40	57.5			$14	$3,135
Waste Water Manager	$72,828	$35	23.9			$12	$1,130
Additional Personnel							
City Attorney		$150	1.3			$53	$195
Purchasing Agent	$61,000	$29	9			$10	$356
Accountant	$63,870	$31	9.2			$11	$381
GIS Manager	$54,000	$26	2.5			$9	$88
Public Information Officer	$43,800	$21	9			$7	$256
Hourly Employees							
Administrator	$35,000	$17	26	1	$25	$6	$616
Engineering Inspector	$50,000	$24	263.3	22	$36	$8	$9,331
Miscellaneous Expense							$4,165
Total Staff Expense (SE)							**$24,988**

Source: City of Rowlett

Implementation Phase Framework

Legend	
🟩	Input Values
🟪	Output Values

Regular Hours	493
Overtime Hours	289.3
Total Implementation Phase Hours	**782.3**

$$PE_I = \sum_{i=1}^{n} Ei + OE$$

Table I: City Staff Expense Per Implementation Phase of Project

Management Employees	Yearly	Hourly Rate	Regular Hours (N_i)	Overtime Hours (O_i)	Overtime Rate	Benefits (B_i)	Staff Expense Per Phase (E_i)
City Manager	$162,000	$78	5.8			$27	$610
Assistant City Manager	$141,000	$68	3.9			$24	$357
Public Works Director	$125,000	$60	19.4			$21	$1,574
Finance Director	$110,000	$53	5.5			$19	$393
City Engineer	$102,000	$49	36.3			$17	$2,403
Assistant City Engineer	$84,000	$40	57.5			$14	$3,135
Waste Water Manager	$72,828	$35	23.9			$12	$1,130
Right of Way Inspector	$47,200	$23	12.6			$8	$386
City Attorney		$150	1.3			$53	$195
Purchasing Agent	$61,000	$29	9			$10	$356
Accountant	$63,870	$31	9.2			$11	$381
GIS Manager	$54,000	$26	2.5			$9	$88
Public Information Officer	$43,800	$21	9			$7	$256
Sanitory Sewer Crew	$210,000	$101	7.8			$35	$1,063
Consulting for SSMP		$0				$0	$0
Consulting for SSES		$0				$0	$0
Hourly Employees							
Administrator	$35,000	$17	26	1	$25	$6	$616
Engineering Inspector	$50,000	$24	263.3	22	$36	$8	$9,331
Miscellaneous Expense							$4,455
Total Staff Expense (SE)							**$26,727**

Source: City of Rowlett

True Cost and Overhead Expense Calculation Framework

Legend	
🟩	Input Values
🟪	Output Values

Table II: Building Overhead Expense	
Overall Building Cost*	$1,468,500
Electricity expense yearly for Building	$59,743
Water & Sewer for Building	$65,437
Building Contents Expense **	$198,000
Miscellaneous Multiplier (%)	15%
Overhead Multiplier (%)	10%
Intrest Rate (i)	4.00%
Number of years of bond	20
Annual Building Overhead Expense	$108,055
City Overhead Expense per Project***	$10,805
* For 10,000 sq ft of Public Works Building used for meetings and office space	
**Based on Insurance Coverage and Furniture & Fixtures life for 10 years	
***Assumed 10% of annual expense for building	

Equation For Municipal Administrative cost for Renewal of Project	
Municipal Administrative Cost (MAC)= $PE_S + PE_C + PE_I + OE$	**$76,313**
True Cost (TC) = MAC + Contract Build Cost + Design Cost + Maintenance Cost (if needed)*	
*Some Social Costs are incuded in City Costs used to address issues in the field during Implementation Phase	

Source: City of Rowlett

APPENDIX F

CITY OF ROWLETT HOT SPOT MAPS

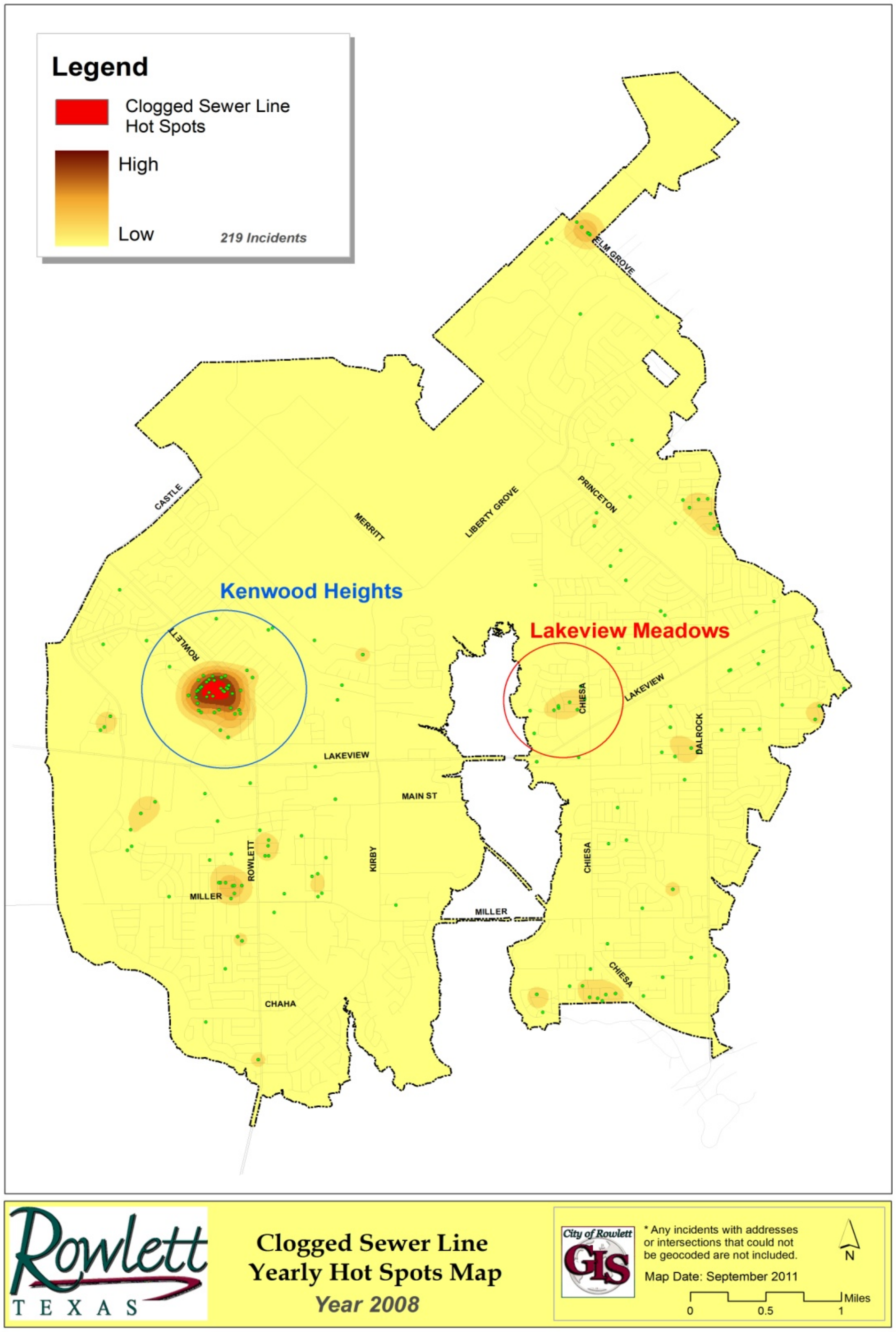


Figure F-1 Hot Spot Map 2008
Source: City of Rowlett

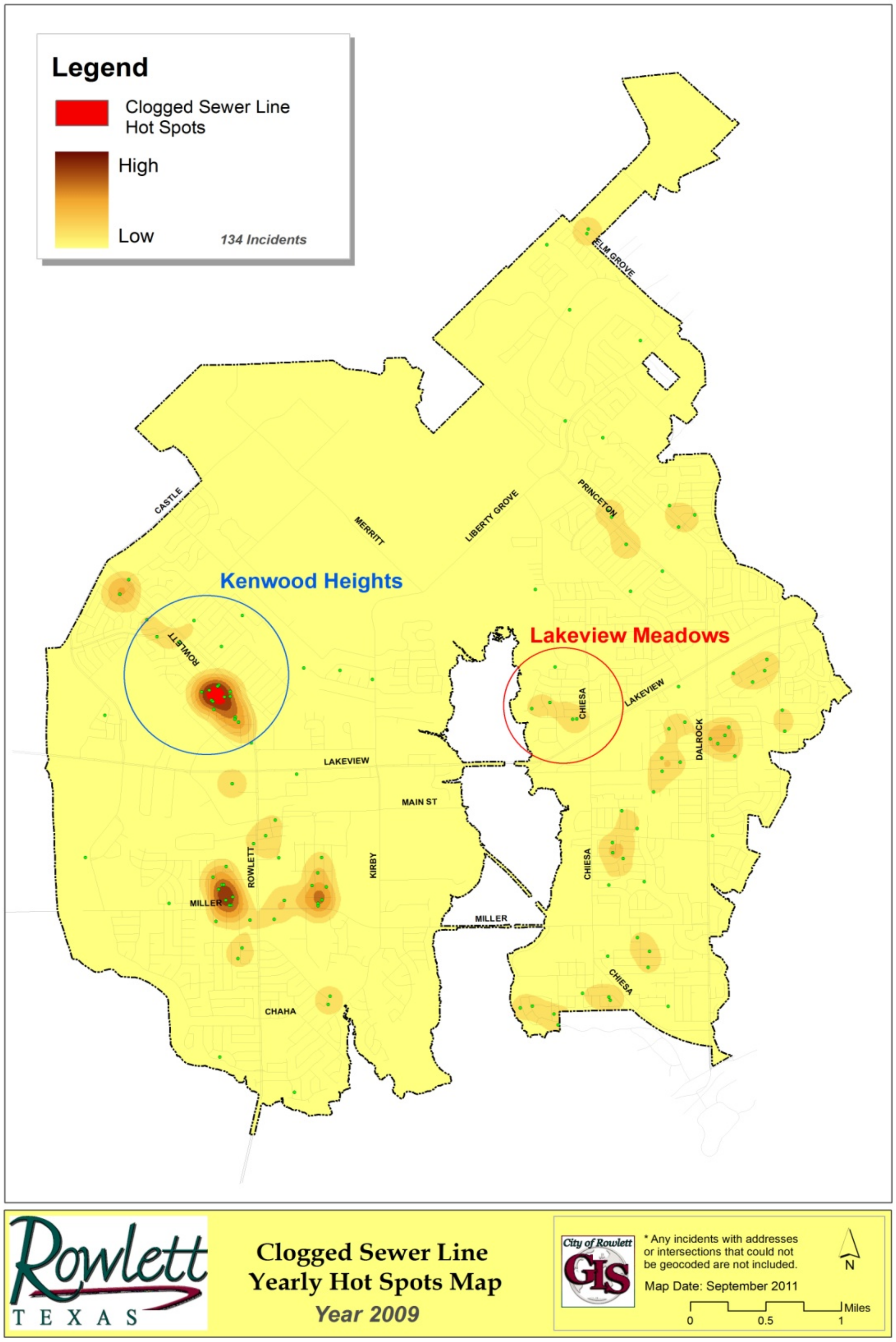


Figure F-2 Hot Spot Map 2008
Source: City of Rowlett

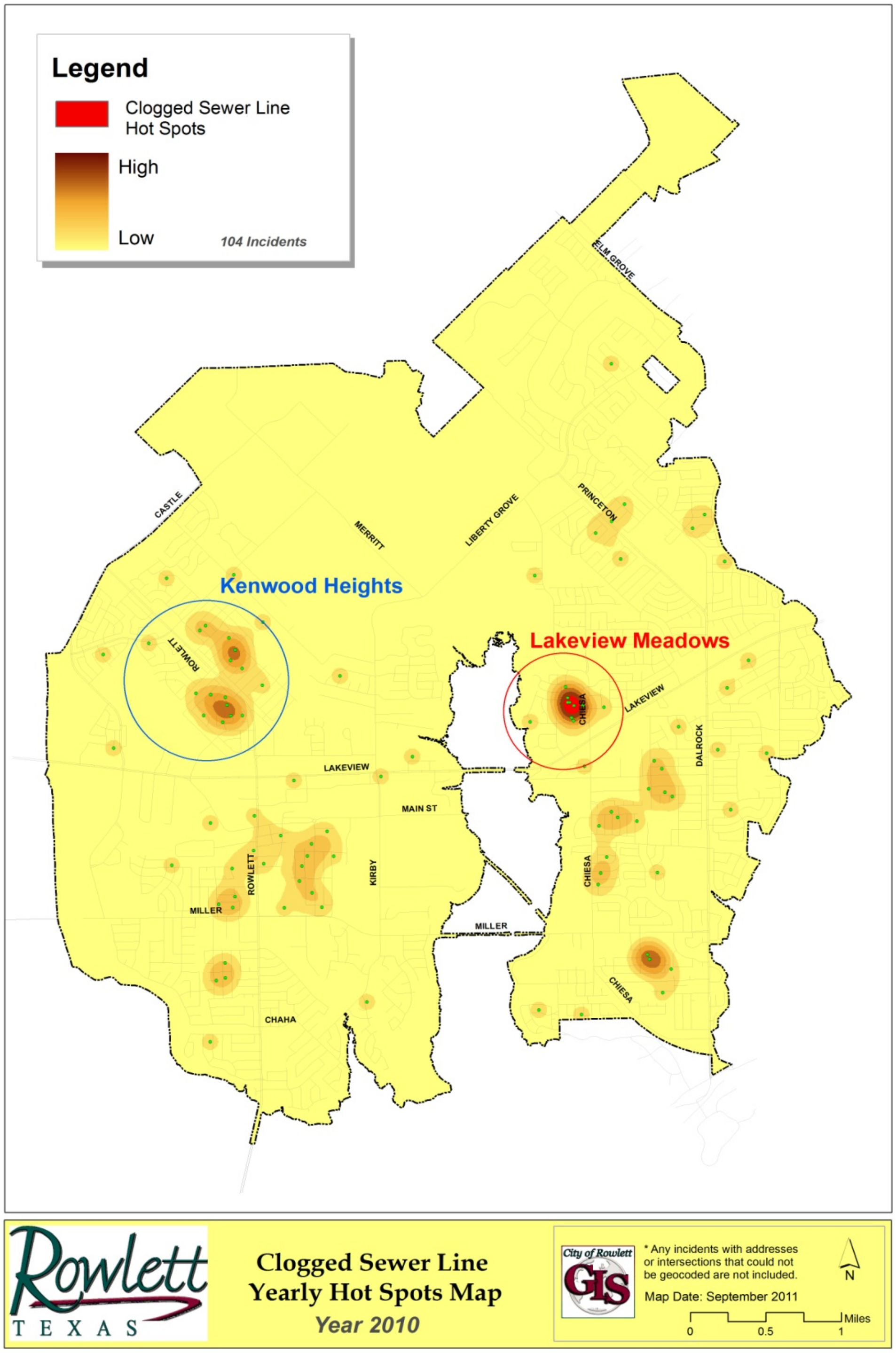


Figure F-3 Hot Spot Map 2010
Source: City of Rowlett

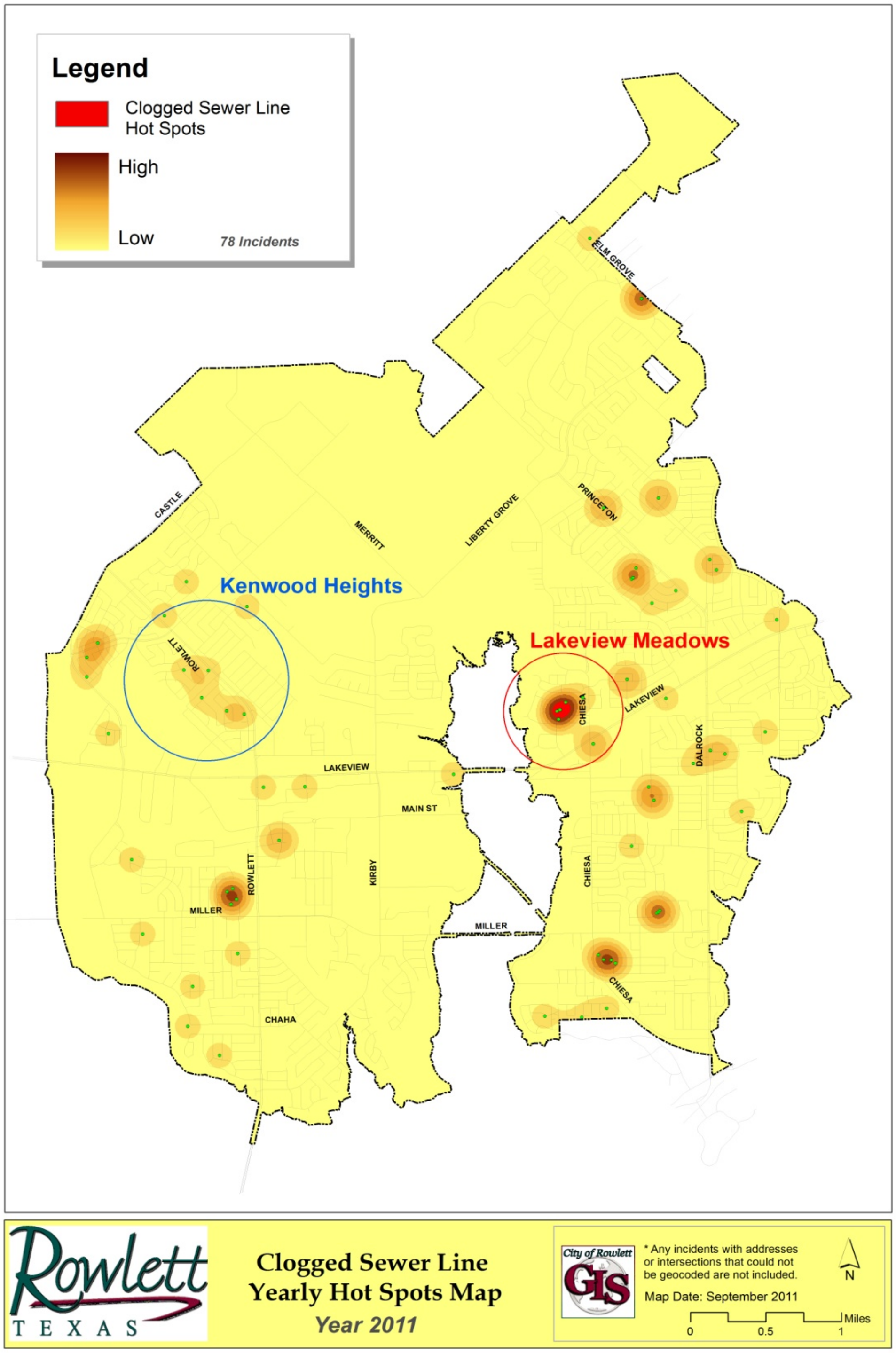


Figure F-4 Hot Spot Map 2011
Source: City of Rowlett

APPENDIX G

CITY OF ROWLETT GEOGRAPHIC COST MAPS

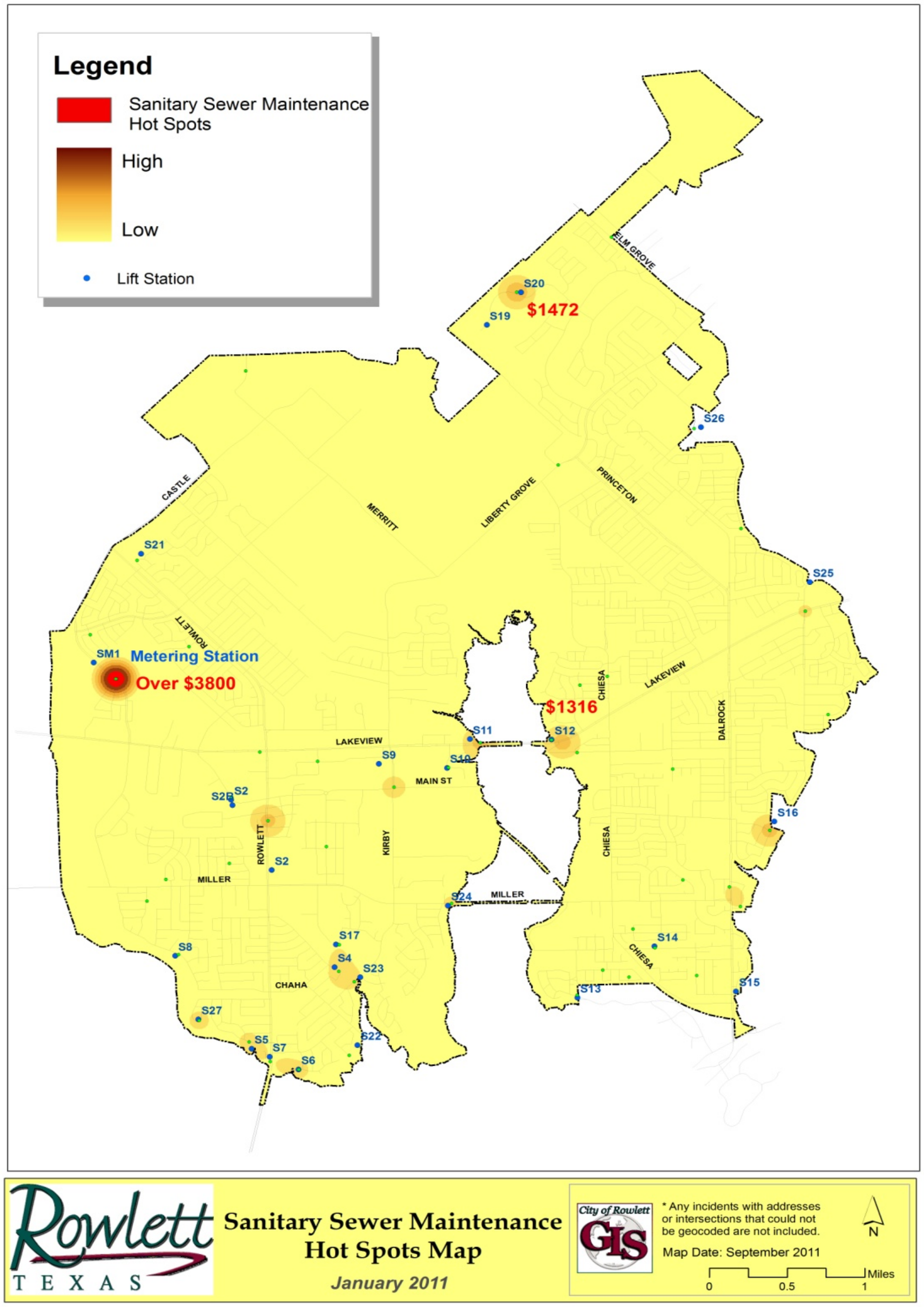


Figure G-1 Hot Spot Geographic Cost Map January 2011
Source: City of Rowlett

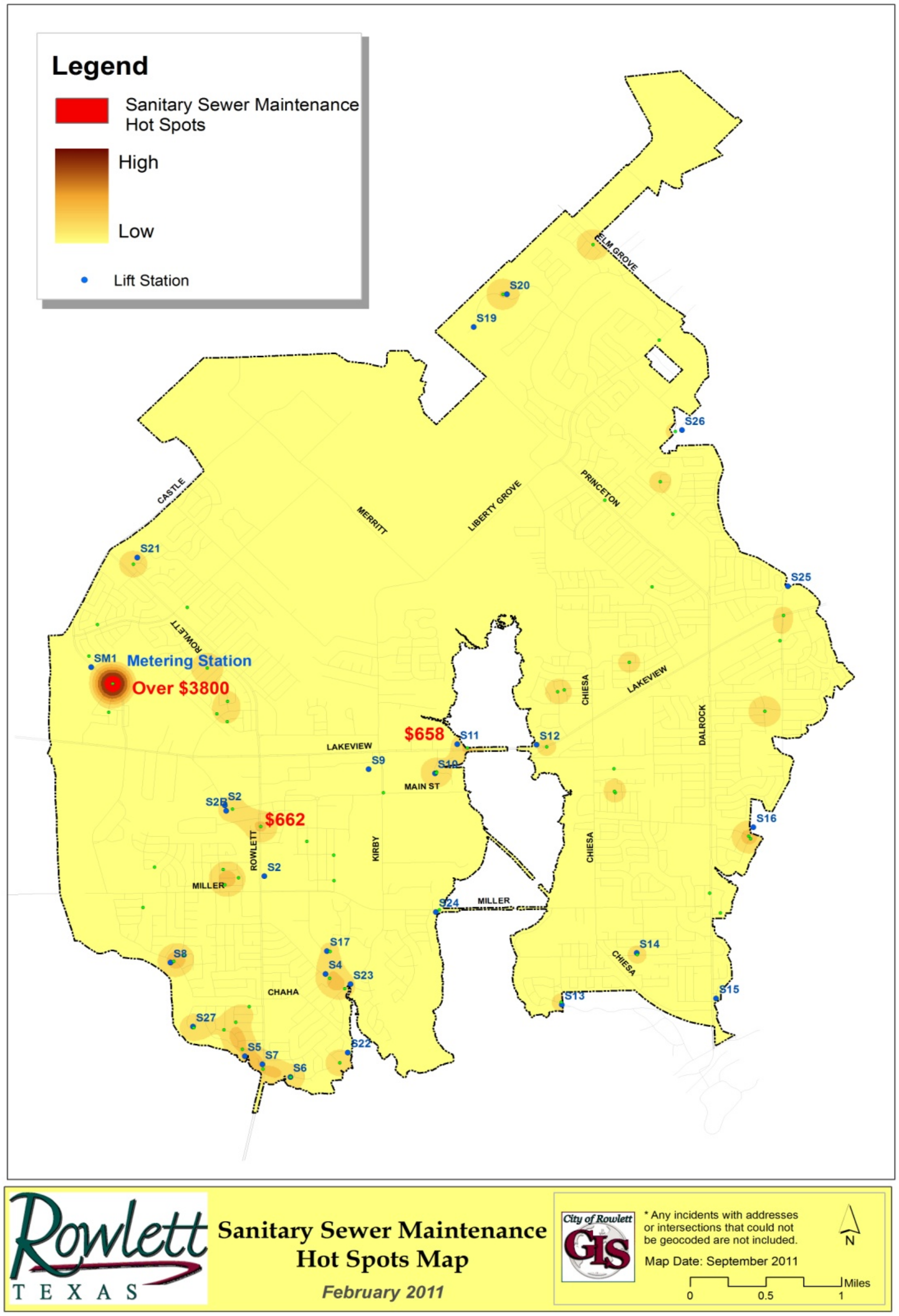


Figure G-2 Hot Spot Geographic Cost Map February 2011
Source: City of Rowlett

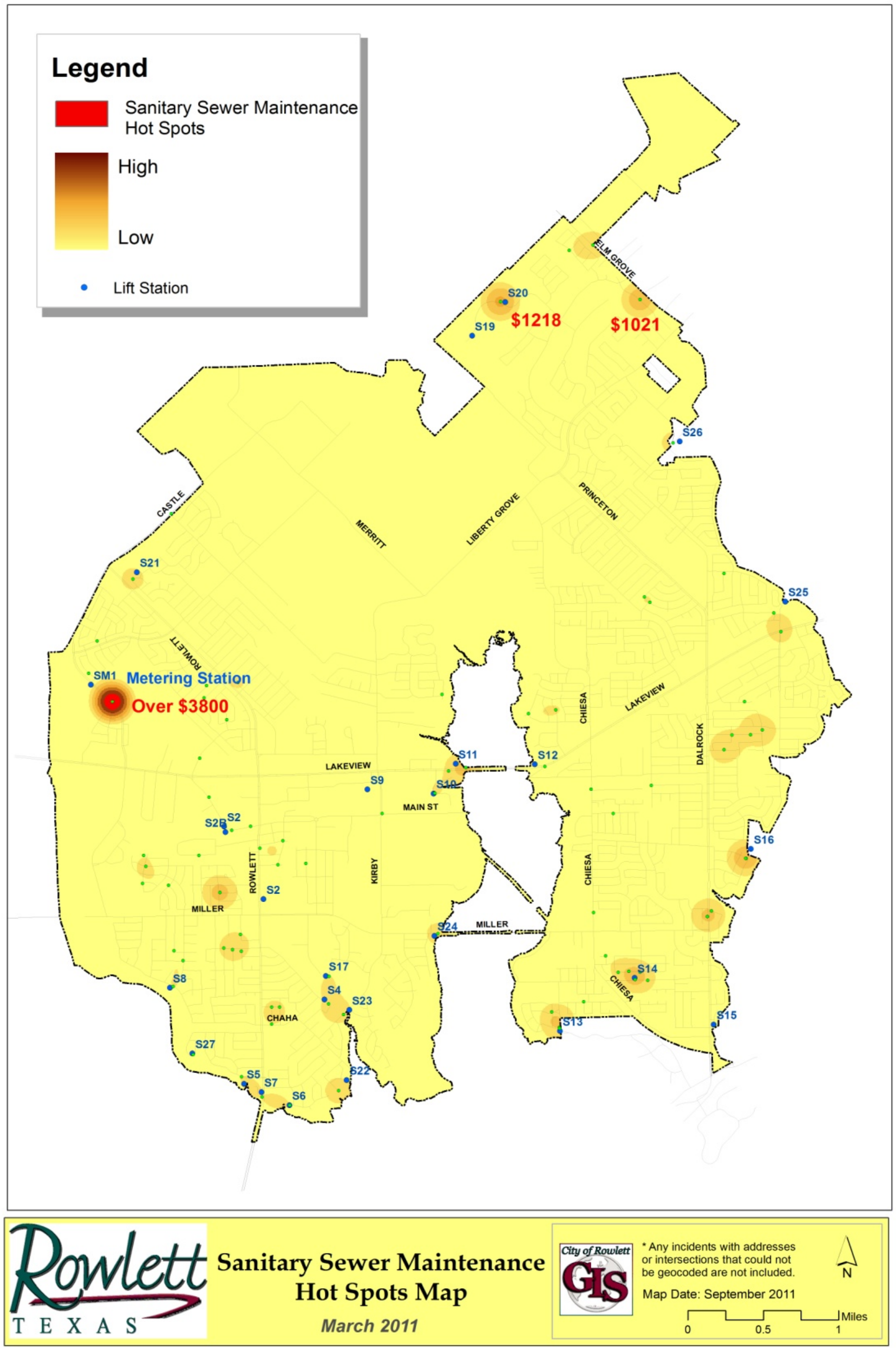
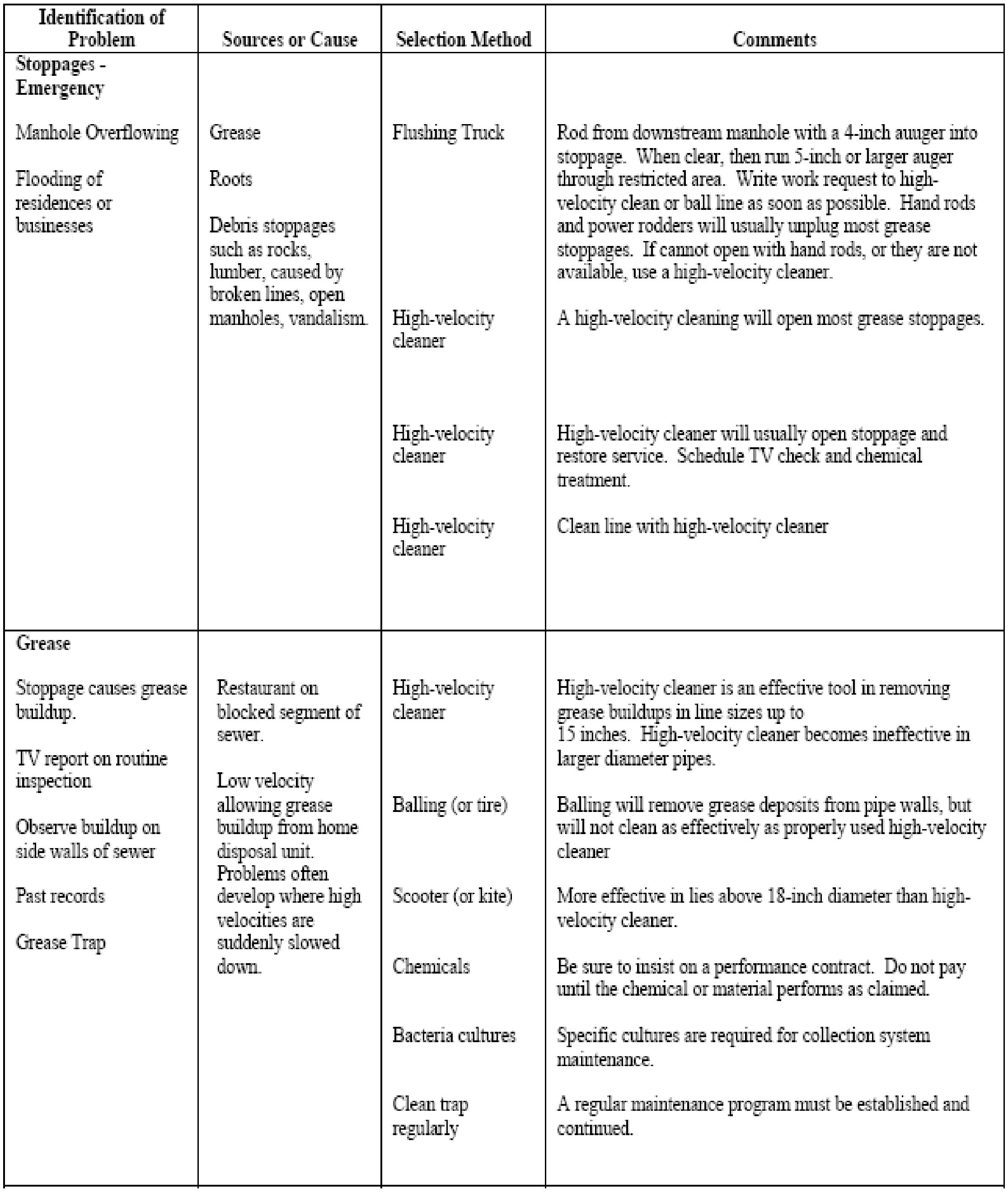


Figure G-3 Hot Spot Geographic Cost Map March 2011
Source: City of Rowlett

APPENDIX H

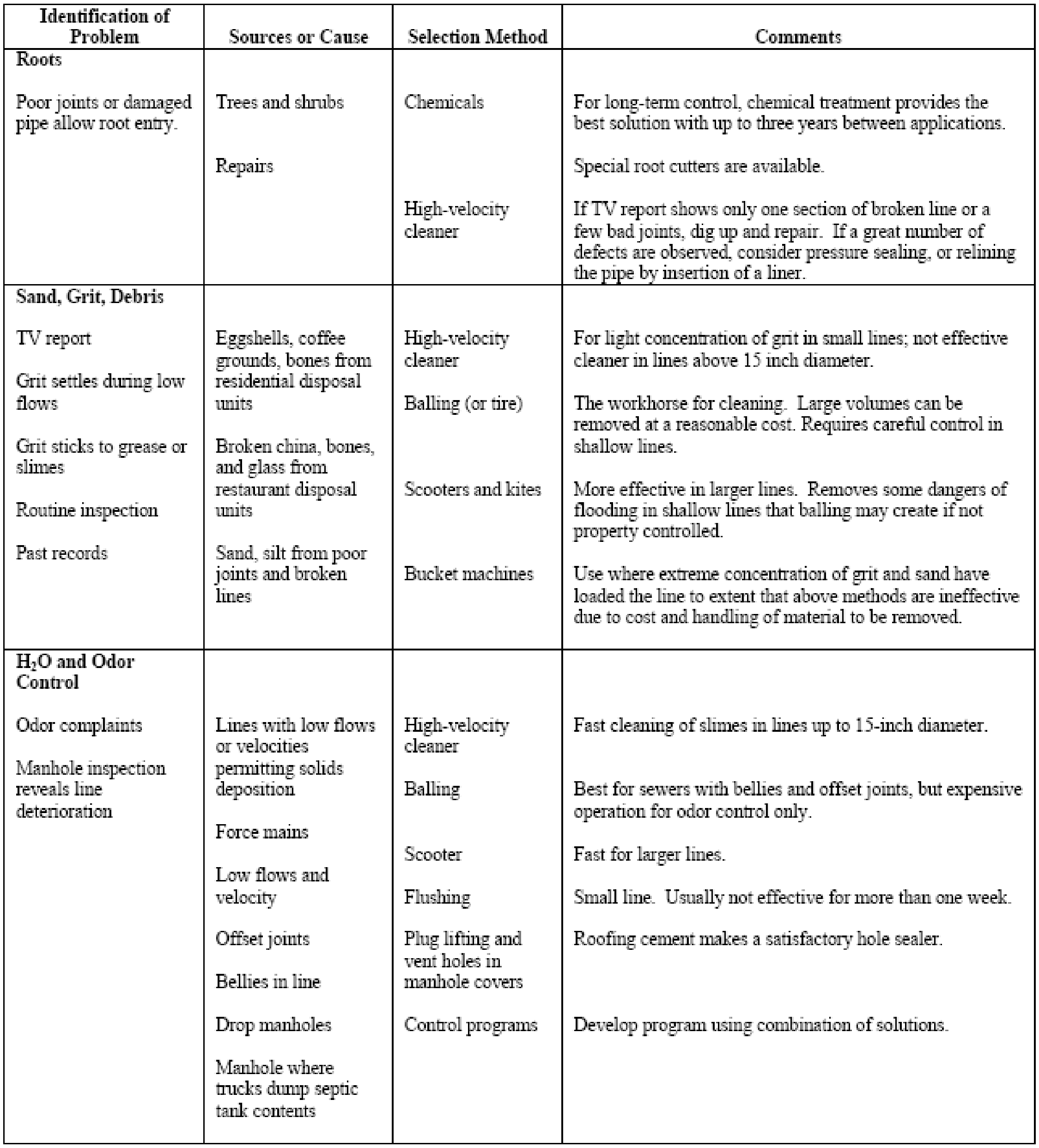
CITY OF NEW ORLEANS SEWER PIPE CLEANING DOCUMENTATION

Cleaning of Sewer Pipes & Documentation Methodology (City of New Orleans, 2010)



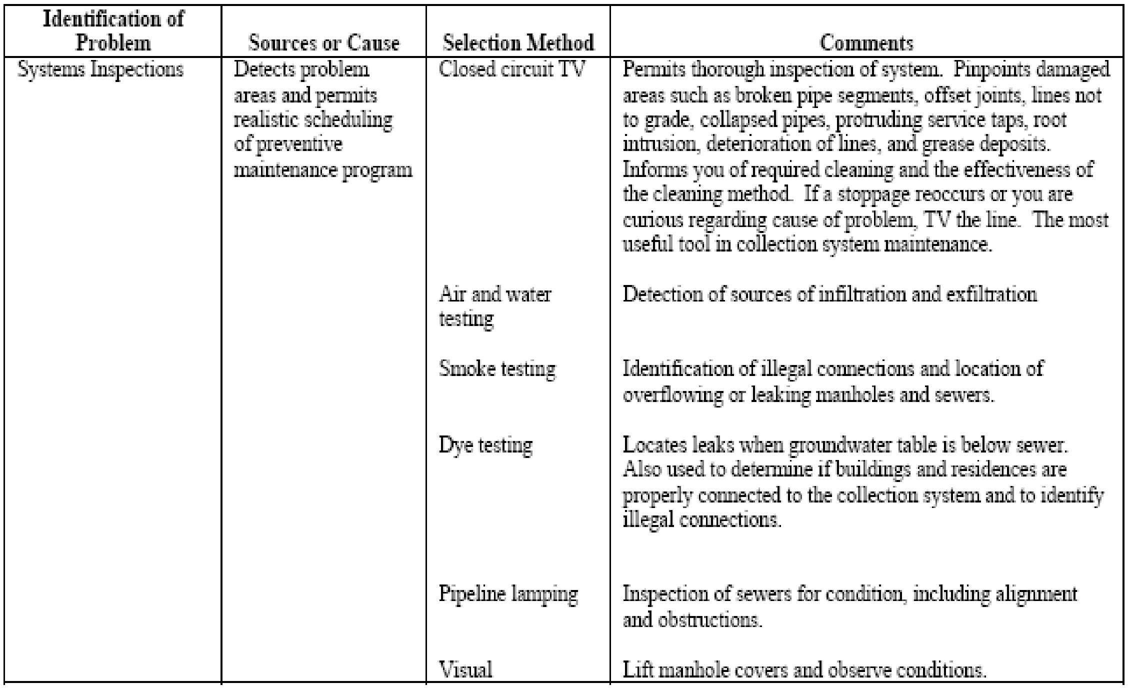
Identification of Problem	Sources or Cause	Selection Method	Comments
Stoppages - Emergency Manhole Overflowing Flooding of residences or businesses	Grease Roots Debris stoppages such as rocks, lumber, caused by broken lines, open manholes, vandalism.	Flushing Truck	Rod from downstream manhole with a 4-inch auuger into stoppage. When clear, then run 5-inch or larger auger through restricted area. Write work request to high-velocity clean or ball line as soon as possible. Hand rods and power rodders will usually unplug most grease stoppages. If cannot open with hand rods, or they are not available, use a high-velocity cleaner.
		High-velocity cleaner	A high-velocity cleaning will open most grease stoppages.
		High-velocity cleaner	High-velocity cleaner will usually open stoppage and restore service. Schedule TV check and chemical treatment.
		High-velocity cleaner	Clean line with high-velocity cleaner
Grease Stoppage causes grease buildup. TV report on routine inspection Observe buildup on side walls of sewer Past records Grease Trap	Restaurant on blocked segment of sewer. Low velocity allowing grease buildup from home disposal unit. Problems often develop where high velocities are suddenly slowed down.	High-velocity cleaner	High-velocity cleaner is an effective tool in removing grease buildups in line sizes up to 15 inches. High-velocity cleaner becomes ineffective in larger diameter pipes.
		Balling (or tire)	Balling will remove grease deposits from pipe walls, but will not clean as effectively as properly used high-velocity cleaner
		Scooter (or kite)	More effective in lies above 18-inch diameter than high-velocity cleaner.
		Chemicals	Be sure to insist on a performance contract. Do not pay until the chemical or material performs as claimed.
		Bacteria cultures	Specific cultures are required for collection system maintenance.
		Clean trap regularly	A regular maintenance program must be established and continued.

Source: City of New Orleans Sewer District



Identification of Problem	Sources or Cause	Selection Method	Comments
Roots			
Poor joints or damaged pipe allow root entry.	Trees and shrubs	Chemicals	For long-term control, chemical treatment provides the best solution with up to three years between applications.
	Repairs		Special root cutters are available.
		High-velocity cleaner	If TV report shows only one section of broken line or a few bad joints, dig up and repair. If a great number of defects are observed, consider pressure sealing, or relining the pipe by insertion of a liner.
Sand, Grit, Debris			
TV report	Eggshells, coffee grounds, bones from residential disposal units	High-velocity cleaner	For light concentration of grit in small lines; not effective cleaner in lines above 15 inch diameter.
Grit settles during low flows		Balling (or tire)	The workhorse for cleaning. Large volumes can be removed at a reasonable cost. Requires careful control in shallow lines.
Grit sticks to grease or slimes	Broken china, bones, and glass from restaurant disposal units		
Routine inspection		Scooters and kites	More effective in larger lines. Removes some dangers of flooding in shallow lines that balling may create if not property controlled.
Past records	Sand, silt from poor joints and broken lines	Bucket machines	Use where extreme concentration of grit and sand have loaded the line to extent that above methods are ineffective due to cost and handling of material to be removed.
H_2O and Odor Control			
Odor complaints	Lines with low flows or velocities permitting solids deposition	High-velocity cleaner	Fast cleaning of slimes in lines up to 15-inch diameter.
Manhole inspection reveals line deterioration		Balling	Best for sewers with bellies and offset joints, but expensive operation for odor control only.
	Force mains		
		Scooter	Fast for larger lines.
	Low flows and velocity	Flushing	Small line. Usually not effective for more than one week.
	Offset joints	Plug lifting and vent holes in manhole covers	Roofing cement makes a satisfactory hole sealer.
	Bellies in line		
	Drop manholes	Control programs	Develop program using combination of solutions.
	Manhole where trucks dump septic tank contents		

Source: City of New Orleans Sewer District



Identification of Problem	Sources or Cause	Selection Method	Comments
Systems Inspections	Detects problem areas and permits realistic scheduling of preventive maintenance program	Closed circuit TV	Permits thorough inspection of system. Pinpoints damaged areas such as broken pipe segments, offset joints, lines not to grade, collapsed pipes, protruding service taps, root intrusion, deterioration of lines, and grease deposits. Informs you of required cleaning and the effectiveness of the cleaning method. If a stoppage reoccurs or you are curious regarding cause of problem, TV the line. The most useful tool in collection system maintenance.
		Air and water testing	Detection of sources of infiltration and exfiltration
		Smoke testing	Identification of illegal connections and location of overflowing or leaking manholes and sewers.
		Dye testing	Locates leaks when groundwater table is below sewer. Also used to determine if buildings and residences are properly connected to the collection system and to identify illegal connections.
		Pipeline lamping	Inspection of sewers for condition, including alignment and obstructions.
		Visual	Lift manhole covers and observe conditions.

Source: City of New Orleans Sewer District

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BIOGRAPHICAL INFORMATION

Dennis Abraham received his Masters Degree in Civil Engineering from Old Dominion University, Norfolk, Virginia in May 1991, and Masters of Business Administration from University of Texas at Dallas in June 1997. Dennis is a registered professional engineer in the state of Texas and a certified floodplain administrator. Dennis has worked in the field of civil engineering in various capacities for the past 21 years, and is currently serving as the City Engineer for a North Texas city. He has also publicly served as a Planning and Zoning Commissioner on the Transportation Advisory Board and on the Animal Services Advisory Board for the City of Plano. Dennis decided to pursue a Ph.D. in Civil Engineering to enhance his knowledge in Infrastructure Engineering. In August 2008, he entered Department of Civil Engineering at the University of Texas at Arlington as a doctoral student. His research uses academic solutions to real-life municipal problems to enhance the field of Municipal Engineering.