Sanitary System Asset Management Plan

District of West Vancouver

February 4, 2010

AECOM

District of West Vancouver

Sanitary System Asset Management Plan

Final Report

Prepared by:

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Phil T. Bates
Manager, Engineering Services
District of West Vancouver
750 17th Street
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Dear Phil,

Re: West Vancouver's Sanitary System Asset Management Plan – Final Report

Thank you for your comments on our previous submission of the Sanitary System Asset Management Plan for West Vancouver. We have made revisions based on the comments received and are pleased to provide you with our final report (please see attached).

If you have any questions please don't hesitate to contact me. Thank you for the opportunity to work with you and your team on this most interesting project.

Sincerely,
AECOM Canada Ltd.

Nancy Hill

Nancy Hill, P.Eng.
Project Manager
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Encl:

NH

Version Log

Version #	Revised By	Date	Description
1	NH	June 25, 2009	1st draft
2	NH	July 23, 2009	2nd draft (with corrected GIS inventory)
3	NH	September 9, 2009	3rd submittal
4	NH	September 30, 2009	4th submittal
5	NH	October 13, 2009	5th Submittal
6	NH	January 15, 2010	Final Report
7	NH	February 4, 2010	Revised Final Report

Signature Page

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Report Reviewed By:

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Executive Summary

Within its sanitary sewer system West Vancouver owns and operates 57 lift stations, one wastewater treatment plant, 340 km of sanitary main, 208 grinder pumps, and one bioswale. The replacement value of this system is $300 million. The results of this study provides the District of West Vancouver with a long range forecast (100 years) of the financial resources required to support the renewal of West Vancouver's sanitary assets.

Figure ES.1 below shows the sanitary sewer system renewal requirements over the next 100 years in 2009 dollars. Although lift station renewals will be the main priority over the next 15 years, over the long term sewer mains represent the largest component of the sanitary renewal budget. By 2055 the sanitary main renewal requirements alone reach $7.7 million per year.

Figure ES.1 Sanitary System Annual Replacement Requirements 100 Year Forecast

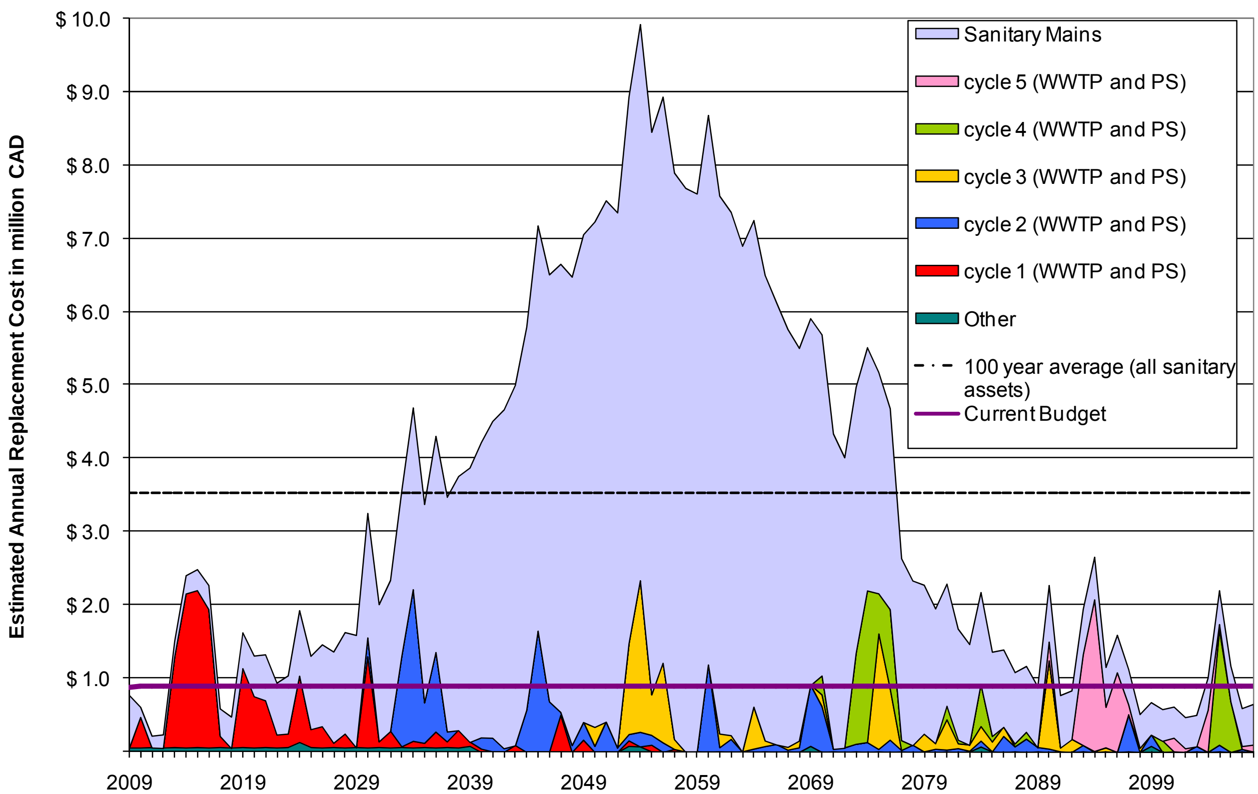
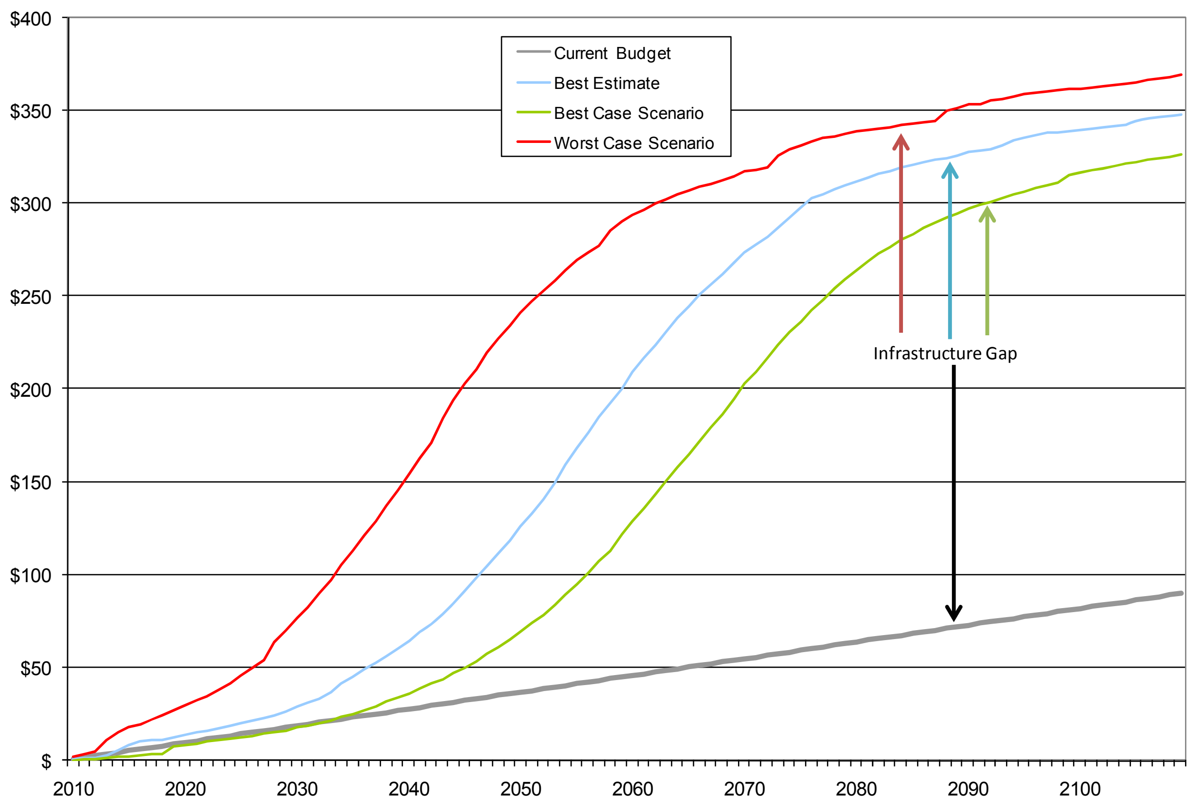


Figure ES.1 shows that on average the sanitary system will have replacement requirements of $3.5 million per year over the next 100 years. This compares with West Vancouver's current annual budget of $900,000 for the renewal of its sanitary assets. The financial projection in Figure ES.1 is based on typical lifespan estimates. Changing these estimates will impact the capital renewal forecast as demonstrated in Figure ES.2.

Figure ES.2 shows how the anticipated renewal requirements (cumulative) compare with the existing budget level under three scenarios. The first scenario represents a best estimate of the lifespan of West Vancouver's sanitary assets (as depicted in ES.1). The best case scenario shows the sanitary system renewal requirements if the assets last longer than expected and the worst case scenario shows the sanitary system renewal requirements if the assets don't last as long as expected. The difference between the renewal requirements and the existing budget is known as the "infrastructure gap".

Figure ES.2 Projected Infrastructure Gap – Three Scenarios

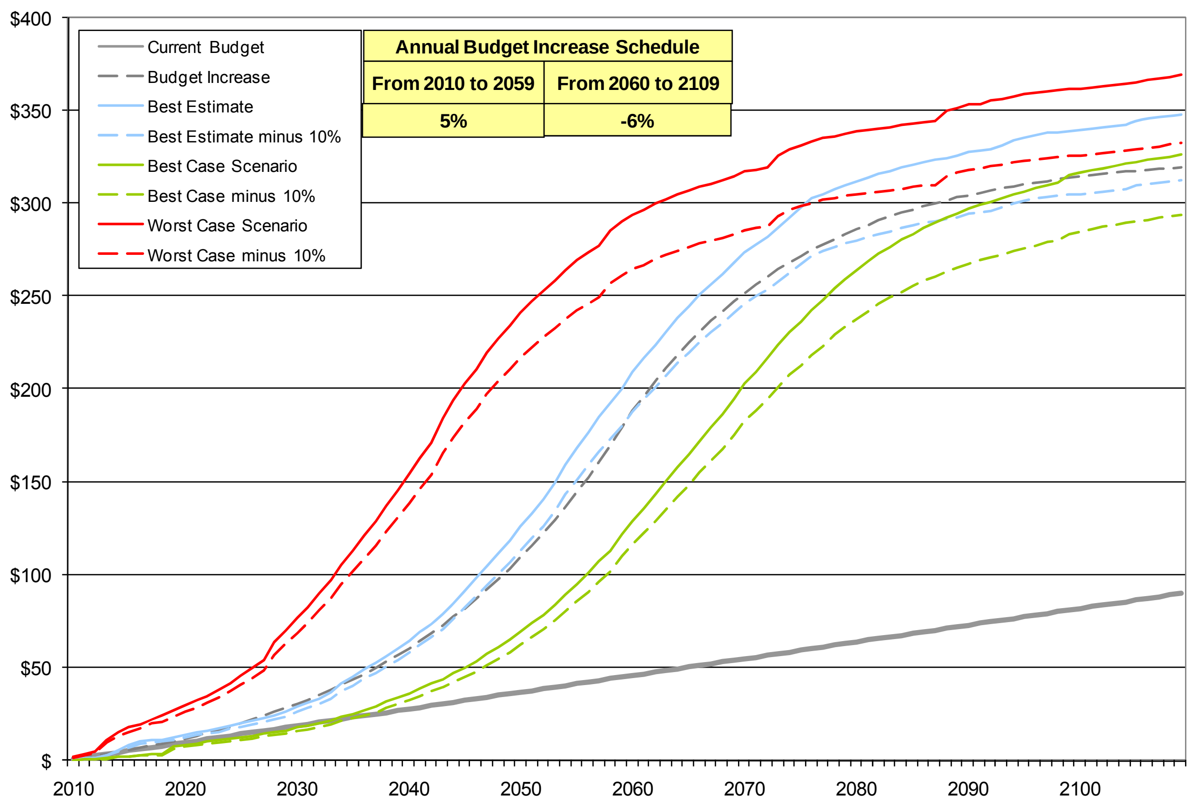


Under all three scenarios there is an anticipated infrastructure gap; $215-$255 million over the next 100 years. Under the best case scenario, West Vancouver has 25 years to prepare for a significant increase in renewal requirements but under the worst case scenario, West Vancouver has only 2 years before the infrastructure gap begins to grow dramatically.

In general, the anticipated infrastructure gap can be addressed by increasing the sanitary renewal budget and by optimizing the life cycle costs of its assets. West Vancouver can reduce the lifecycle costs of its assets through an effective preventative maintenance program, by identifying the most cost effective renewal strategy for each asset and by coordinating capital works wherever possible. In order to accomplish this West Vancouver needs more information about the state of its sanitary mains. Therefore, it is critical that the District continue with its sewer condition assessment program.

Figure ES.3 shows the impact on the infrastructure gap if West Vancouver were able to reduce the lifecycle cost of its assets and increase its renewal budget. West Vancouver would meet the anticipated renewal requirements under the best estimate scenario if it reduced the lifecycle cost of its assets by 10% and increased its sanitary renewal budget by 5% each year from 2010 to 2059. Within its sewer utility, West Vancouver currently has annual revenues of $7.55 million. A 5% increase in the sewer renewal budget represents an annual increase in sewer utility revenue requirements of 0.6%.

Figure ES.3 Addressing the Infrastructure Gap



The results of this study illustrate the need for West Vancouver to continue its condition assessment and preventative maintenance program, to prioritize assets for replacement and to increase the sanitary capital renewal budget. Effective communication is critical to educate and engage stakeholders to assist in meeting the upcoming challenges associated with the management of the District's infrastructure.

This study has adhered to present day best practices for performing strategic level asset management. A "needs-based" approach has been taken that gives consideration to our current knowledge of asset life spans, and current replacement costs. Consideration has not been given to factors that might either accelerate renewal efforts (e.g. elevation of risk or criticality, resource levelling), or decelerate renewal efforts (e.g. short term affordability). These additional factors will remain for continued public debate, and provide input into the annual rate setting process. Ultimately, a "budget-based" approach to asset management will govern the extent to which West Vancouver will manage assets in a sustainable fashion over the short and long term.

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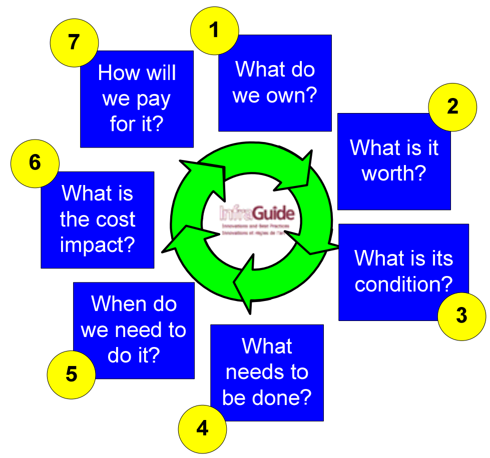
1. Introduction

Figure 1.1 Seven Whats of Asset Management



The District of West Vancouver commissioned this study to develop a long range forecast (100 years) of future sanitary infrastructure renewal requirements to ensure the financial sustainability of its infrastructure in perpetuity.

To help West Vancouver meet its objectives, AECOM developed this Asset Management Plan using the "Seven Whats of Asset Management" approach that is recommended by InfraGuide's "Best Practice for Managing Infrastructure Assets". The results of each of the seven steps shown in ***Figure 1.1*** are outlined in this report.

This project leveraged work recently completed to satisfy PSAB reporting requirements and is being complemented by similar plans for West Vancouver's water and stormwater systems. The results of this plan can be used to assist in developing infrastructure renewal budgets, identifying replacement priorities, determining sewer rates and communicating infrastructure needs to stakeholders such as City Council.

This plan covers all components within West Vancouver's sanitary system; namely the Citrus Wynd Wastewater Treatment Plant, 57 lift stations, 208 grinder pumps, a leachate bioswale and approximately 340 km of pipe.

The renewal forecast for this study was completed using an MS-Excel based Capital Asset Planning (CAP) model. An electronic version of this model, with instructions for updating it, will be provided to West Vancouver. A print out of the sanitary system inventory from the model is provided in Appendix A. It is important to note that this model and the findings in this report provide a current "snapshot" of West Vancouver's sanitary infrastructure. If the system changes, such as the upgrade of an existing pump station, then the model needs to be updated accordingly.

All costs estimates have been prepared using current (2009) dollars in order to facilitate year to year comparisons, and due to the uncertainty of projecting inflation and discount rates far into the future.

2. Asset Inventory: "What do we own?"

2.1 Data Sources

The pipe inventory was imported from GIS data provided by the District of West Vancouver in February 2009. Data was taken from the gravity sewer and the forcemain shape files as it was determined that all the sewers within the "trunk" file belong to Metro Vancouver. The mains within the forcemain shapefile that belong to Metro Vancouver were not included in this analysis. As it is not clear within the GIS data, which assets belong to Metro Vancouver and which assets belong to West Vancouver, we recommend that the District of West Vancouver identify Metro Vancouver assets as such within their GIS.

The GIS data regarding gravity sewer mains is fairly comprehensive. Where there were unknowns within the pipe inventory, assumptions were made as outlined in the table below. As can be seen in the table, in some cases where the material type was unknown, the material type was assumed based on the installation year. The remaining 1.7 km of pipes with unknown attributes, were assigned the average size and installation year of the pipe inventory with known attributes. The pipe inventory with known attributes has an average pipe diameter of 175 mm and an average installation year of 1973.

Where the pipe material was unknown and could not be estimated based on the year of installation, the material type remained "Unknown". As described in Section 6.2, pipes with unknown pipe material were assumed to have an estimated service life of 85 years, which is the same average service life used for cast iron, asbestos cement, HDPE and PVC.

Table 2.1 Assumptions Made for Unknown Gravity Sewer Data

If			Then Assumed		
Diameter	***Material***	***Installation***	***Diameter***	***Material***	***Installation***
Any	Unknown	Pre 1979		VC	
Any	Unknown	1979-1984		PVC	
Any	Unknown	1984-1986		Unknown (service life of 85 yr)	
Unknown	Unknown	Unknown	175 mm	Unknown (service life of 85 yr)	1973

There is very little data within GIS regarding the sanitary forcemains. Data on the forcemains associated with the District of West Vancouver's lift stations was obtained from the 2006 Sanitary Lift Station Condition Assessment Report completed by Dayton & Knight. The remaining forcemains (approximately 2.1 km) were assumed to be installed (on average) in 1980.

Within the GIS database there were a variety of abbreviations given for the same material type. Table 2.2 below outlines the various abbreviations within the GIS database and what material type was assumed for this study. We recommend that the District adopt standard nomenclature for data such as pipe material to facilitate the collection and analysis of asset information.

Table 2.2 Assumptions Made for Pipe Material Based on Abbreviations in GIS

Pipe Material	GIS Abbreviation
Unknown	9999, blanks
Asbestos Cement	AC
Cast Iron	CI
Vitrified Clay	CL, CLAY, VC, VCV, VIT
Corrugated metal pipe	CMP
Concrete	Conc, C
Ductile iron	DI
High density polyethylene	HDPE, SC
PVC	PVC, PCV, YMP
Steel	ST

The lift station inventory with service population, replacement costs and condition ratings was obtained from the 2006 Sanitary Lift Station Condition Assessment Report completed by Dayton & Knight. As the Westport lift station is decommissioned we have not included it within this study. District of West Vancouver staff noted that the 31st & Travers and foot of 31st lift stations were installed in 1971 and not 1992 as indicated in the 2006 Sanitary Lift Station Condition Assessment Report.

The exact installation years for the Caulfield Court, Gleneagles, Glenwynd and Pilot House Road lift stations are unknown. District of West Vancouver staff estimated that these lift stations were installed between 1976 and 1982. Based on the timing of residential development in the respective catchments the installation dates for the lift stations were estimated as follows.

- Caulfield Court - 1982
- Gleneagles – 1981
- Glenwynd - 1980
- Pilot House Road - 1976

Information regarding the Citrus Wynd Wastewater Treatment Plant was obtained from record drawings and the WWTP Operating Plan provided by the District of West Vancouver.

2.2 Asset Inventory Summary

West Vancouver owns and operates 57 lift stations, one wastewater treatment plant, 208 grinder pumps, one bioswale and approximately 340 km of sanitary main. Of the 340 km of sanitary main, approximately 10 km are forcemains and 330 km are gravity mains.

There are two separate sewage systems; one occupying a small area north of Horseshoe Bay which discharges to West Vancouver's Citrus Wynd Sewage Treatment Plant, and the remainder of the network which discharges to Metro Vancouver's Hollyburn Interceptor and is transported to the Lions Gate Treatment Plant.

As properties with West Vancouver owned grinder pumps are redeveloped or undergo significant renovations, the property owners are required to take ownership of the grinder pumps. Based on the assumption that all properties will be redeveloped or undergo significant renovations within the next 30 years, we have assumed that the District will no longer own grinder pumps by 2040. As grinder pumps, by value, are a small component of West Vancouver's sanitary system any assumptions regarding them will not have a significant impact on the District's total sanitary capital renewal requirements.

A summary of the existing gravity sanitary sewer main attributes are provided in Figures 2.1 – 2.4. Figure 2.1 shows that nearly 80% of the gravity mains are vitrified clay, with the remainder being mainly PVC.

Figure 2.1 Length of Sanitary Sewer Main by Material Type

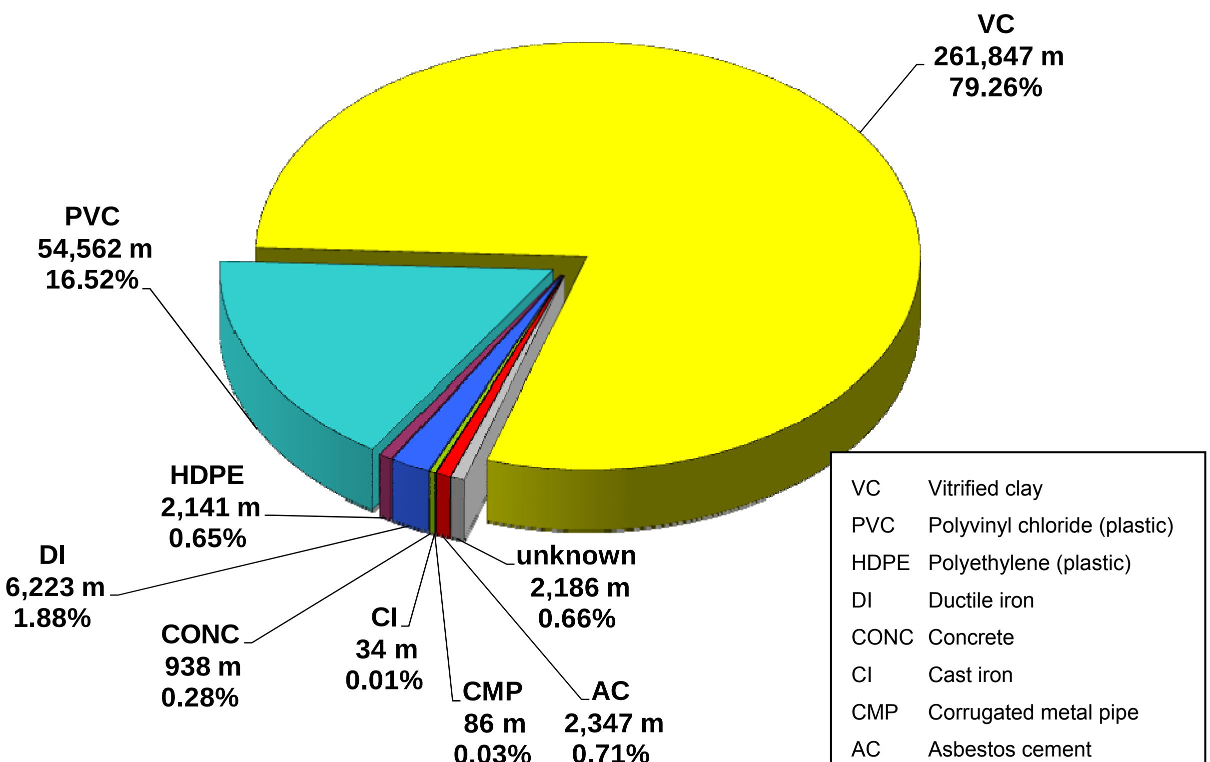


Figure 2.2 shows that vitrified clay was the predominant material used for sanitary main construction up to the late 1970's after which PVC became the preferred material. In addition, the majority of the system was constructed between 1960 and 1978.

Figure 2.2 Growth in Gravity Sewer System by Pipe Material

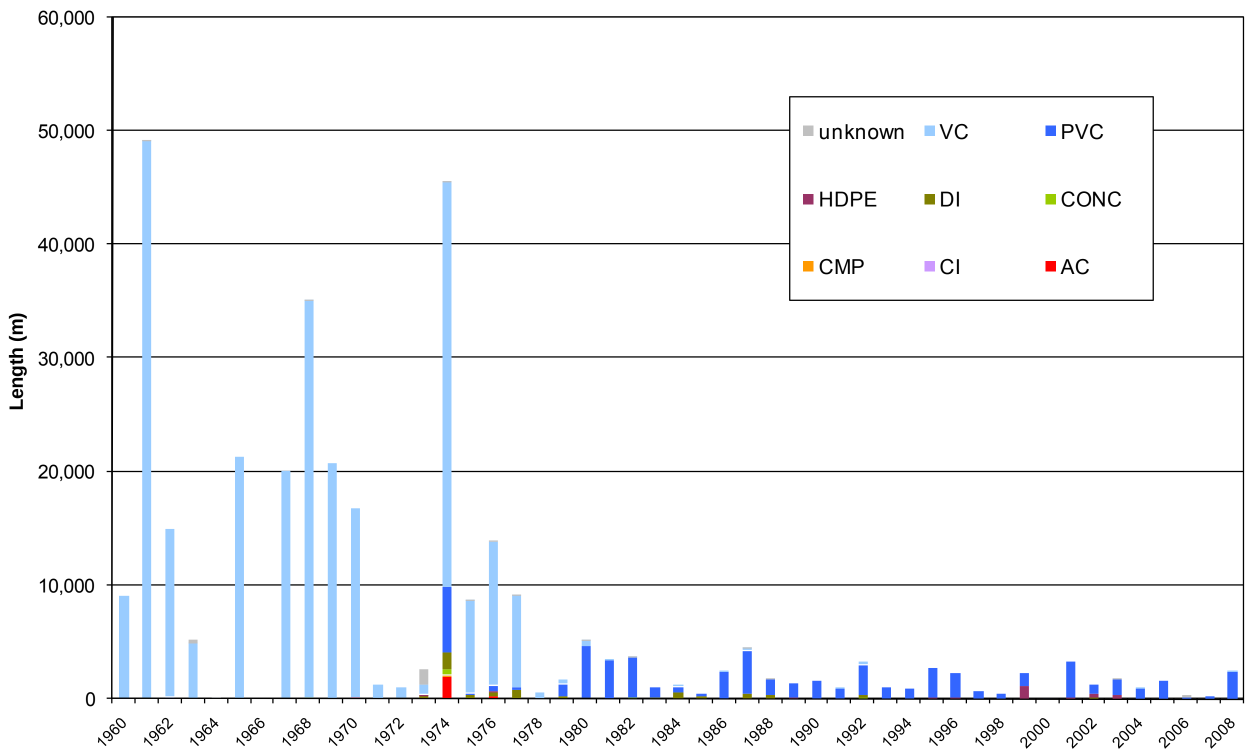


Figure 2.3 shows that approximately half of West Vancouver's gravity sanitary sewer mains have a diameter of 150 mm and the other half have a diameter of 200 mm. Figure 2.4 shows that most of the smaller sanitary mains were installed prior to 1983. Since 1983, mostly 200 mm pipe has been installed.

Figure 2.3 Length of Sanitary Mains by Diameter (in metres)

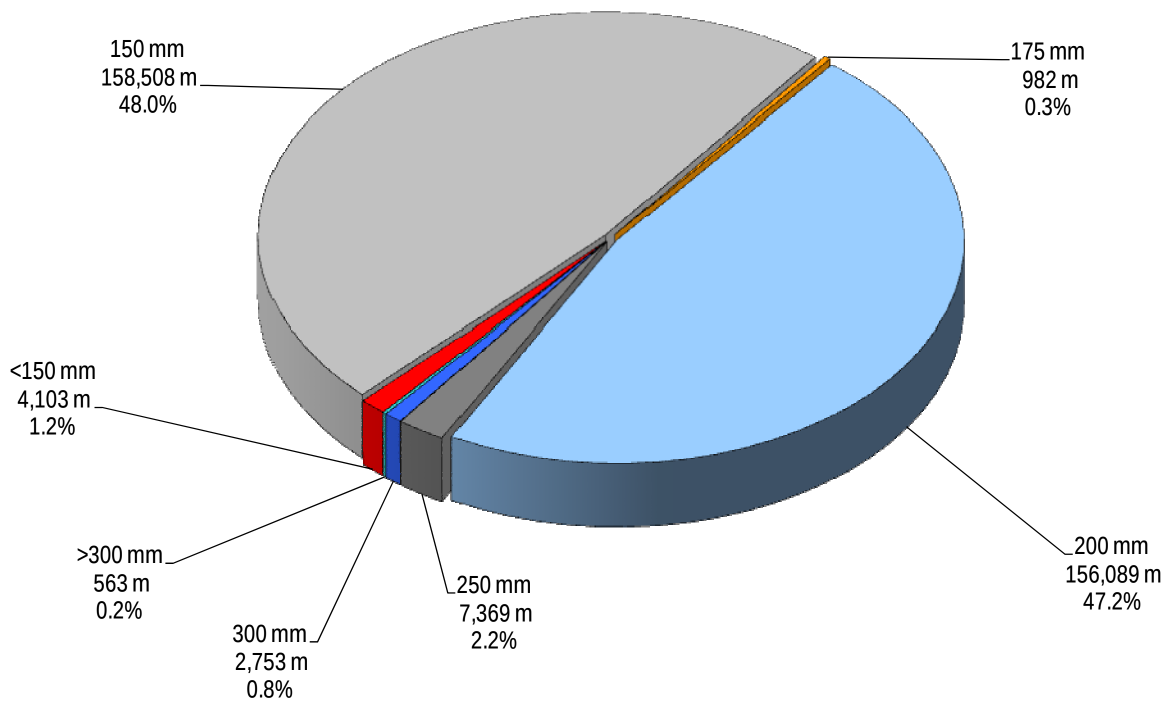
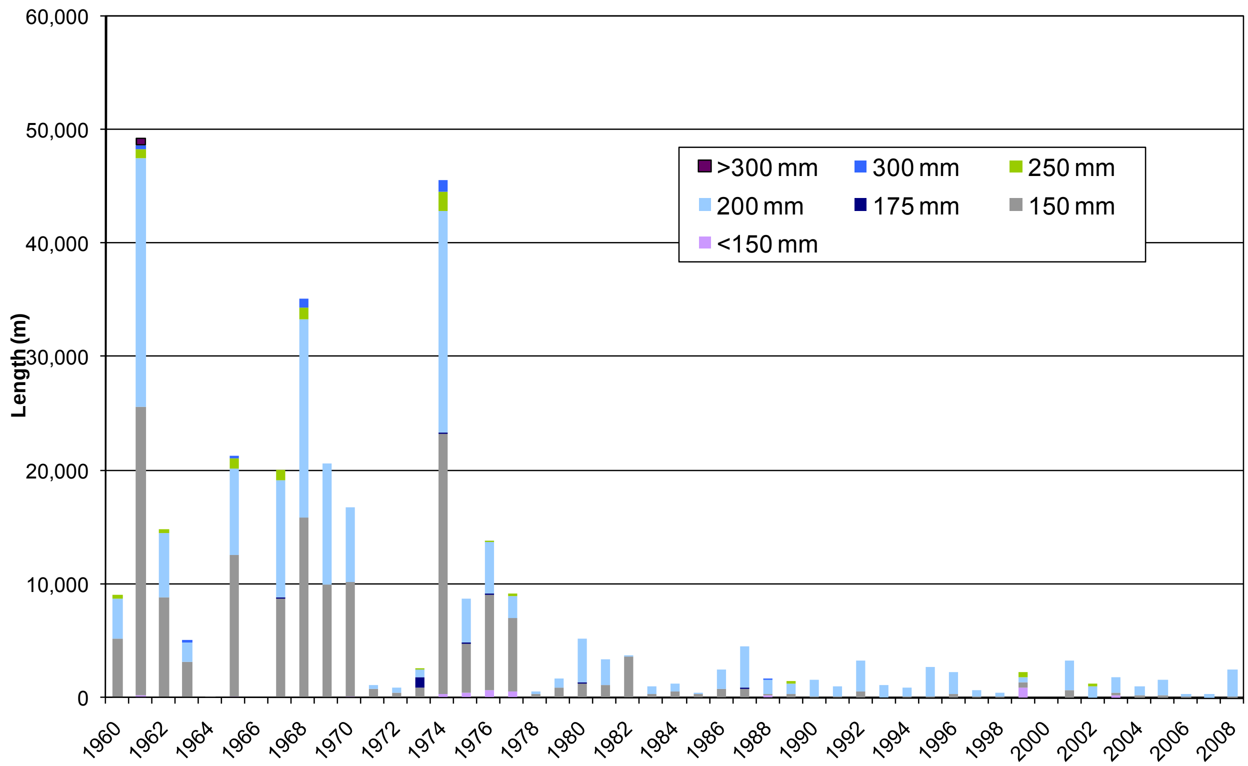
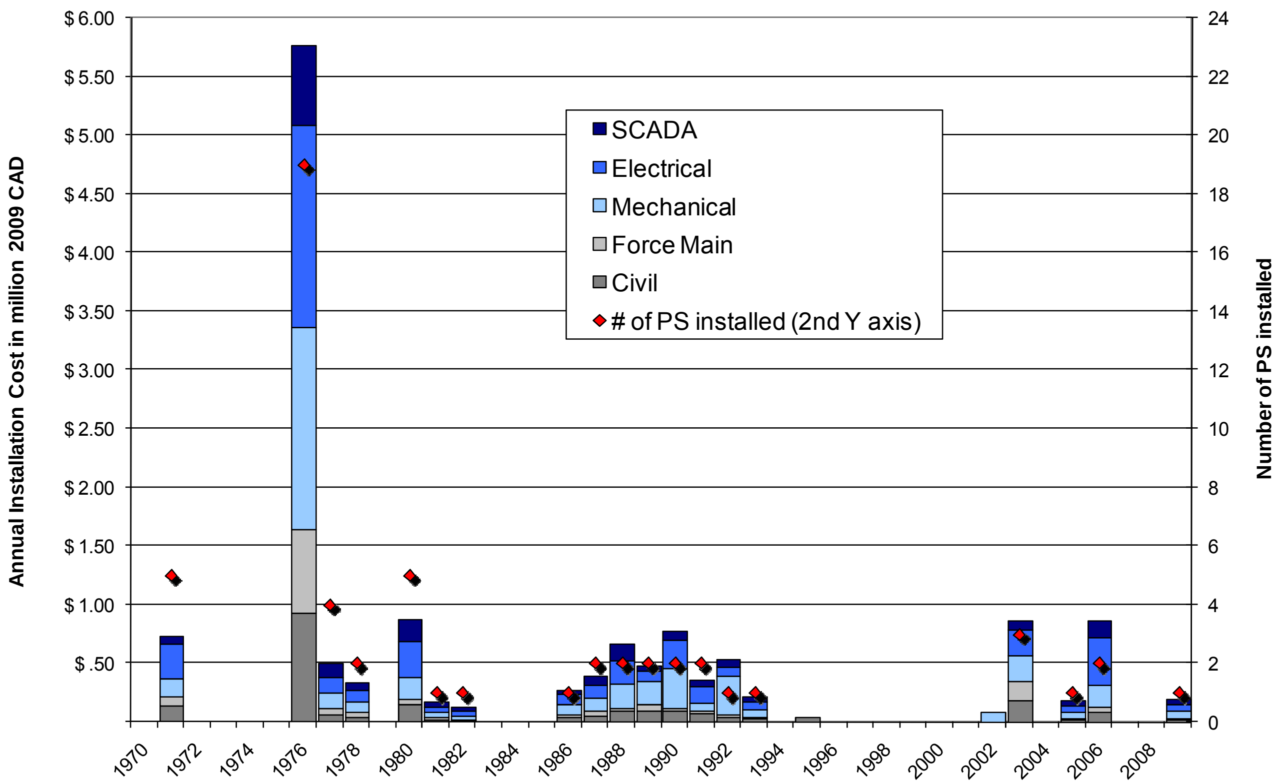


Figure 2.4 Growth of Sanitary Mains by Diameter



Seventeen (17) of West Vancouver's 57 lift stations have SCADA. The average dry weather flow (ADWF) to the lift stations range from 0.01 l/s to 3.75 l/s. The oldest lift station was installed in 1971 and the newest lift station was installed in 2006. A summary of the lift stations by installation year is shown in Figure 2.5. According to West Vancouver's records, approximately one third of the lift stations by number and replacement value were installed in 1976.

Figure 2.5 Lift Station Inventory by Year of Installation



3. Replacement Costs: "What is it worth?"

For the linear system the unit replacement cost includes manholes and service connections. The estimated unit replacement costs were developed based on recent construction costs within the District of West Vancouver. These costs are higher than figures typically used elsewhere in the Lower Mainland. The higher construction costs may be due to the need for frequent rock-blasting, the inability to use native soil as backfill, and the fact that West Vancouver doesn't always have utility right-of-ways. These unit costs will be reviewed after the District of West Vancouver completes the Keith Road utility construction works later this year.

The unit replacement costs (2009 dollars) for sanitary sewer mains used for this analysis are provided in Table 3.1 below. West Vancouver owns approximately 10 km of forcemain. Eight (8) kilometres of the forcemains are associated with a West Vancouver lift station and the replacement cost estimate for them has been taken from the 2006 Lift Station Condition Assessment. The replacement cost for the remaining two (2) kilometres of forcemain is estimated at $850/m.

Table 3.1 Unit Replacement Costs for Sanitary Sewer Mains

Size (mm)	$/m
<300	$850
300 -375	$900

The replacement values for the lift stations have been taken from the 2006 Sanitary Lift Station Condition Assessment Report and increased by 6.7% to account for inflation. Currently, West Vancouver is reviewing its SCADA strategy. However, for the purpose of this study it has been assumed that all new lift stations will have SCADA.

The replacement costs of the lift stations are broken down into civil, mechanical, forcemain, electrical and SCADA. These costs can be found in the asset inventory in Appendix A. The replacement cost for a grinder pump is estimated at $4,300, which includes the cost to remove and dispose of the old pump as well as the purchase and installation of the new pump.

Based on the assumptions documented in this report, West Vancouver's sanitary system has an estimated replacement value of $299.4 million (in 2009 dollars), a breakdown of which is shown in Table 3.2. In 2006, West Vancouver estimated that its sanitary system had a replacement cost of $285 million (reference DWV document #229508).

Table 3.2 Replacement Value – West Vancouver's Sanitary System

Component	Replacement Value
Mains	$282.8 million
Lift stations	$14.4 million
WWTP	$1.3 million
Grinder Pumps	$0.9 million
Total	**$299.4 million**

In 2005 UMA prepared a "Multi-Year Sanitary Sewer Condition Assessment Program" for the District of West Vancouver. Within the summary report, the replacement value of the sewer mains was estimated at $195 million. This estimate was likely based on a lower unit cost, which doesn't reflect current construction costs in West Vancouver.

4. What is its Condition?

In 2006 Dayton & Knight completed condition assessments of all of West Vancouver's sanitary lift stations. As part of this work they developed a 1 to 5 condition grade for the major components of each lift station. These grades were used to develop a condition rating for the civil, forcemain, mechanical, electrical and SCADA components for each lift station. These condition ratings, along with the standard expected service life for each asset type, were then used to help determine when each asset needs to be replaced (see Section 6 – When do we need to do it?).

A summary of the assessed condition of all lift stations from the 2006 District of West Vancouver Sanitary Lift Station Condition Assessment is shown in Table 4.1 and Figure 4.1 below. A condition grade of 1 represents excellent and 5 represents inoperable. A confidence factor of 1 represents "inspected and well documented" and 5 represents "not inspected and partly documented".

Table 4.1 Overall Summary of the Condition of West Vancouver's Lift Stations by Asset Type

Asset Type	Condition Grade	Confidence Index
Civil	2.6	3.1
Mechanical	2.6	2.3
Electrical	2.6	2.0
Total	*2.6*	*2.3*

Figure 4.1 shows that no lift stations have a condition grade of 5 (i.e. inoperable). Approximately 6% of the lift station assets, by value, are in poor condition (i.e. condition grade of 4). A summary of lift station assets with a condition grade of 3.5 or higher are listed in Table 4.2.

Figure 4.1 Condition Rating of the West Vancouver's Lift Stations by Replacement Value

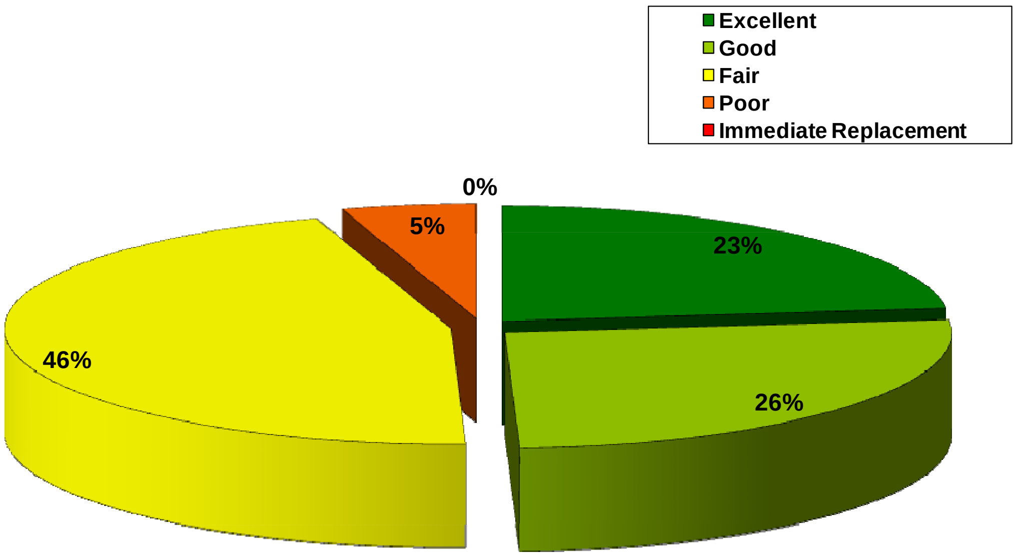


Table 4.2 Summary of Lift Stations Assets in Poor Condition

Lift Station	Asset Type in Poor Condition
3176 Travers	All
Garrow	Civil
Isleview	Civil
Marine & Beach	All
Parthenon	SCADA & forcemain
Radcliffe	All
Woodvalley	Civil
Blink Bonnie	SCADA & electrical
Cotton A	SCADA
Cove	SCADA
Dufferin A	SCADA
Eastmont	SCADA
Happy Valley	SCADA
Kew	SCADA and forcemain
Seaside	SCADA
Stone Crescent	Electrical
Taylor	SCADA
23rd	Forcemain
28th	Mechanical

The Citrus Wynd Wastewater Treatment Plant was constructed in 2003 so it is in "like-new" condition. As the plant ages and West Vancouver conducts future condition assessments, it may need to adjust the condition grades of the plant within the capital forecast tool used for this study.

As a member municipality of Metro Vancouver, the District of West Vancouver is committed to Metro Vancouver's Liquid Waste Management Plan (LWMP). Within the 2009 Draft of the LWMP municipalities are required to:

- Develop and implement inflow and infiltration management plans so that the wet weather inflow and infiltration are less than Metro Vancouver's inflow and infiltration allowance;
- Implement asset management plans for sewerage and wastewater treatment systems to help maintain infrastructure reliability and performance; and
- Inspect all sanitary sewers on a twenty year cycle.

Regular inspection of the sanitary sewers not only fulfills the District of West Vancouver's LWMP obligations but it will enable West Vancouver to prioritize sewers for rehabilitation and replacement as well as refine the financial projections completed as part of this project. In 2005 UMA/AECOM prepared a report titled "Developing a Multi-Year Sanitary Sewer Condition Assessment Program" (see Appendix C). Based on inspection costs of $5/m, the program recommended an annual inspection program at an estimated cost of $90,000 per year, over and above the sewer cleaning program. The report also prioritizes areas of West Vancouver's sewer system for inspection based on age, the cost of failure, infiltration levels and whether the pipe material is known or not.

In 2006 and 2007 the District of West Vancouver initiated a sewer condition assessment program of the gravity sanitary sewers within the Ambleside Basin IV area. Basin IV was identified in the 2005 study by UMA Engineering, as the area with the highest sanitary sewer inspection priority within West Vancouver. More specifically the 2006/2007 condition assessment program study area had the following approximate boundaries:

- Western boundary: 24th Street
- Eastern boundary: 13th Street
- Southern boundary: foreshore
- Northern boundary:
  - 13th Street to 18th Street: Duchess Avenue
  - 18th Street to 19th Street: Fulton Avenue
  - 19th Street to 22nd Street: Gordon Avenue
  - 22nd Street to 24th Street: Haywood Avenue

The 2006-2007 condition assessment program found that all defects (structural, service and infiltration) were localized and required only point repairs rather than full segment rehabilitation. A list of these defects can be found in the report located in Appendix C.

The 2008 sewer condition assessment program area is bounded to the north by Queens Avenue, to the south by Marine Drive, to the east by Taylor Way and to the west by 22nd Street. One kilometre of sewer along Keith Road and 3rd Street was also added to the 2008 condition assessment program. The sewers inspected were generally found in good structural condition, with only four lines (less than 10% of the inspected lines) having structural integrity concerns. Less than 5% of the lines had conditions that may reduce the capacity of the sewer or exacerbate potential for blockages or infiltration. The summary report for the 2008 Sewer Condition Assessment Program can be found in Appendix C.

Beyond the sewer condition assessment programs, the District of West Vancouver has recently found issues with the structural integrity of vitrified clay sanitary pipe within Brother's Creek and along the foreshore. In both cases the pipe is only 35 to 45 years old. The sanitary pipe within Brother's Creek has been exposed in several locations and is likely being damaged by rocks being carried along the stream bed. The integrity of the pipe along Brother's Creek is critical for three reasons:

- Cracks, gaps or holes can lead to significant I&I as creek water can easily enter the sanitary sewer;
- Cracks, gaps or holes can cause sewage to spill into Brother's Creek; and
- A loss of capacity within the sanitary pipe can lead to overflows or back-ups within the system.

In many areas along the foreshore, the sanitary sewers have minimal cover (i.e. less than 0.3 metres). This has been exacerbated where erosion by wave action has further reduced the cover of the sanitary sewer. Insufficient cover exposes the pipe to possible sources of damage, resulting in premature failure.

Over 90% of West Vancouver's sewer system has not been inspected, so assumptions on the condition of the overall system have to be extrapolated based on available data. By continuing with its sewer condition assessment program West Vancouver will be able to better determine the condition of its sewer system which will help fulfill its LWMP obligations, facilitate the prioritization of sewer maintenance and rehabilitation work, and allow West Vancouver to refine its financial projections for its long term capital renewal program.

It is important to note that this asset management plan addresses renewal based on asset condition. It does not address asset renewal in response to other factors such as capacity or maintenance requirements.

5. What Needs to be Done?

To sustain the functionality of West Vancouver's sanitary sewer system, numerous preventative and corrective maintenance activities must occur, and asset renewals must be made. In general, maintenance practices impact renewal requirements as effective preventative maintenance programs will help to extend the life of a given asset.

As this study provides a high level view of asset renewal requirements, the maintenance and rehabilitation of specific assets – such as the rebuilding of aging pumps – has not been identified. Instead, all assets are assumed to require replacement at the end of their predicted service life, which provides a more conservative approach to budgeting than if rehabilitation strategies were also considered. In Section 7, the potential for extending the life of assets through a targeted rehabilitation program is discussed.

In areas where inflow and infiltration (I&I) and the intrusion of tree roots are of concern, the District may want to consider a range of options to extend the life of a sewer and minimize maintenance costs. The sewer within Brothers Creek should be a priority for I&I investigation.

As mentioned in Section 4, under the LWMP, the District of West Vancouver is committed to develop and implement inflow and infiltration management plans so that wet weather inflow and infiltration are less than Metro Vancouver's inflow and infiltration allowance. West Vancouver also has a financial incentive to reduce I&I in order to decrease treatment costs at the Lion's Gate Treatment Plant. This will become increasingly important as the Lion's Gate Treatment Plant considers upgrading to secondary treatment.

The National Guide to Sustainable Municipal Infrastructure produced a Best Practice Report titled "Inflow/Infiltration Control/Reduction for Wastewater Collection Systems". The InfraGuide Best Practice Reports can be found at http://www.sustainablecommunities.fcm.ca/Infraguide/Best_Practice_Reports.asp.

Grouting, spot repairs, regular root cutting, video inspection and full replacement are some of the options that should be considered to determine the most cost effective strategy for operating and maintaining the sanitary system. The optimal strategy will have to be reviewed on a case by case basis depending upon a variety of factors such as the age, location and structural integrity of the sewer. A good reference for the review of rehabilitation strategies for sewers is the Best Practice by the National Guide to Sustainable Municipal Infrastructure titled "Selection of Technologies for Sewer Rehabilitation and Replacement". The InfraGuide Best Practice Reports can be found at the FCM web-site noted above.

From the 2006-2008 sewer condition assessment programs, a list of prioritized rehabilitation activities was recommended to restore structural integrity where required, to prevent further deterioration, and to ensure the intended level of service of the sewer. A list of rehabilitation recommendations can be found in the condition assessment program reports provided in Appendix C. Continuation of the sewer condition assessment program will support West Vancouver as it works to maintain and rehabilitate the linear sewer system in the most cost-effective manner; thereby extending the life of the sewer system and reducing the likelihood of damage or disruption from main failure.

6. When Do We Need To Do It?

The CAP (Capital Asset Planning) model predicts the replacement year of an asset based on its age, the expected service life for the type of asset, its condition, and the consequences associated with its failure. In some cases replacement needs may also be based on externalities such as development but as these externalities are largely unknown at this time they have not been considered in this analysis. The model also assumes that the whole asset category (i.e. the entire mechanical system for a given lift station) is replaced at the same time.

The model, which was developed for "top-down" asset renewal planning, can be used to estimate the remaining life of an asset but it is not an appropriate tool for determining short term capital programs. Identifying specific assets for replacement in the short term should be done in consultation with inspection results, maintenance records, capacity requirements, replacement programs of other utilities and roadways, and an understanding of the risk associated with a given asset failing. Short term capital planning should be done as part of a bottom-up asset renewal plan, as discussed in Section 6.5.

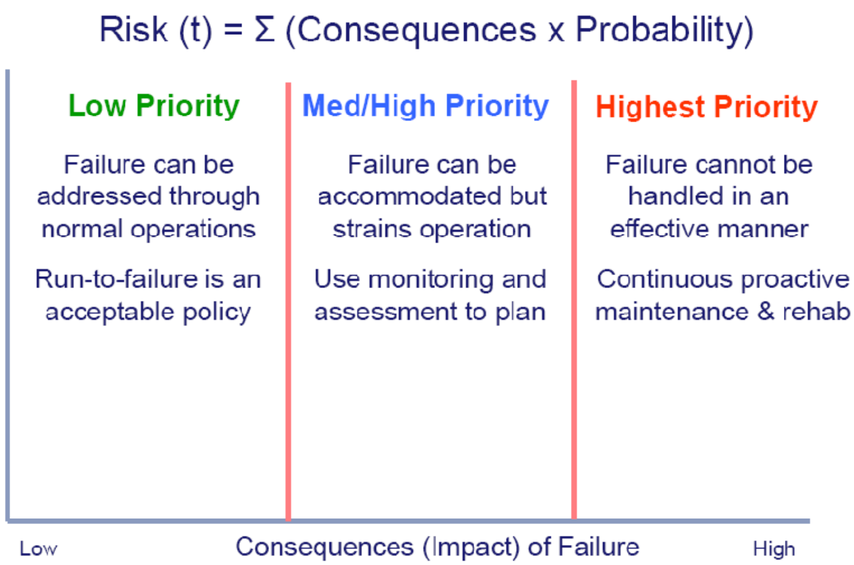
6.1 Risk

The risk associated with a given asset failing can be defined as the probability of an asset failing (based on age, material and condition) multiplied by the consequences of it failing (defined as its criticality).

Risk Exposure = Consequences of Failure X Probability of Failure

A risk based approach, as outlined in Figure 6.1, will allow West Vancouver to determine the most cost-effective strategy for maintaining an asset based on the consequences of failure.

Figure 6.1 Risk-based Approach to Asset Renewal Planning



This risk-based approach is similar to that which was developed for the Sanitary Sewer Condition Assessment Program prepared by UMA in 2005. The objective of the Sanitary Sewer Condition Assessment Program was to prioritize sanitary sewers for inspection and identify condition assessment requirements. As the objective of this study is to develop long term financial forecasts for renewing West Vancouver's sanitary system and not to prioritize the replacement of specific assets, the condition assessment risk model was not adopted for this study. However, we recommend that the risk model continue to be used for prioritizing sewers for inspection and to be used for a bottom-up renewal plan, as discussed in Section 6.5.

As part of Metro Vancouver's Draft Liquid Waste Management Plan (March 2009) municipalities are required as part of their asset management plans to consider risks such as climate change, sea level change and seismic activity. Although climate and sea level changes may have some impact on I&I within the sanitary sewer system, the impacts are minor in comparison with the drainage system.

Seismic activity does pose a risk to West Vancouver's sanitary system. However, many municipalities are willing to tolerate that risk, as the cost of constructing a sewer network to withstand seismic events is greater than the economic and social costs associated with the system failing during a seismic event. The criticality of a sanitary system during a seismic event is different than that for a potable water system which is necessary for fighting fires and providing clean drinking water.

6.2 Expected Service Life for Different Asset Types

A sewer main's service life depends on many factors – material, quality of installation, soil conditions, and disturbances by adjacent construction. Of these factors, West Vancouver, like most municipalities, only has reliable information on the material of its sewer mains. Fortunately, various industry sources exist that estimate a sewer main's typical service life based on its material type.

Table 6.1 summarises information on the estimated service life of sewer mains that were collected from industry organisations, a survey from the National Water and Wastewater Benchmarking program and West Vancouver's PSAB submission. The table also outlines the service lives that were used in this study.

Table 6.1 Estimated Service Lives for Sewer Mains by Material Type

Pipe Material	Estimated Service Life					
	Used for this Study	WRc	Canadian Wide Benchmarking Survey	National Clay Pipe Institute	West Van PSAB	NAASCO
Unknown	85		86		100	
AC	85	80-125	86		100	
CI	85	80-125	84		100	
VC	90	80-125	92	100	100	75
CMP	50	80-125			100	
Conc	95	80-125	95		100	
DI	100	80-125	87		100	
HDPE	85	40	86		100	50
PVC	85	40	86		100	50

Although it has been assumed that vitrified clay will last on average 90 years, not all pipes will fail at exactly 90 years of life. To simulate the reality that not all pipes with an expected service life of 90 years will fail at exactly 90 years, the Weibull probability distribution was used to model a replacement envelope and predict pipe failure as the network ages. This means that a portion of the pipes will fail before its expected service life and a portion will last beyond its expected service life.

For example there is approximately 4 km of vitrified clay along the foreshore and within Brother's Creek that has already failed or is at risk of failure. The Weibull probability function predicts that the District of West Vancouver will need to replace approximately 4 km of sanitary main in the next 10 years, even though the pipe will be on average 50 years old. More information about the Weibull Distribution can be found in Appendix D.

Any unknown pipe has been given an estimated service life of 85 years, which includes the 2 km of forcemain. As shown in Table 6.2 below the forcemains associated with the lift stations have been given an estimated service life of only 50 years. Forcemains connected to a lift station are often renewed when the lift station is renewed (approximately every 50 years) as changes in configuration or pumping capacities often necessitate a new forcemain.

As the majority of the pipes are vitrified clay and PVC, the estimated service lives for these two materials will have the largest impact on the study findings. A 90 year service life was chosen for vitrified clay to account for the risk of failure as explained in Section 6.3. PVC pipe manufacturers claim that PVC will last 100 years but since the material has only been used for the last 50 years a more conservative service life of 85 years was used. This is consistent with what other cities across Canada are estimating for their PVC pipes as shown in the recent National Water and Wastewater Benchmarking Survey results.

Based on discussions with pump suppliers and the experience of other municipalities, the average service life for grinder pumps has been estimated at 15 years. The lift stations and the wastewater treatment plant have been divided up into its civil (i.e. structural), forcemain, mechanical, electrical and SCADA components. Each group of components has been given an estimated service life as shown in the table below.

Table 6.2 Estimated Service Lives for Lift Station and Wastewater Treatment Plant Components

Asset	Estimated Service Life
Civil	50 years
Force Main	50 years
Mechanical	30 years
Electrical	20 years
SCADA	20 years

6.3 Criticality

The model uses a criticality rating to capture the consequences of failure. For instance, if the failure of an asset may cause irreparable environmental damage, human injury or extensive property damage, then the District would be less comfortable delaying replacement until the asset completely fails. Put in this context, criticality is seen as a “nerves factor” where the more nervous we are about the level of disruption or damage that may be associated with an asset’s failure, the sooner we want to replace it. Therefore the criticality rating is used to reduce or extend the expected service life of an asset.

The consequence of replacing critical mains before failure is a shorter asset lifespan. Many municipalities agree that the extra cost associated with a shorter asset lifespan outweighs the social and economic cost associated with allowing a critical pipe to run to failure.

Since the purpose of this study is not to prioritize the replacement of individual assets, criticality has only been considered where it would reduce the overall service life of a type of asset. For this asset management plan it was determined, in consultation with West Vancouver staff, that due to West Vancouver’s topography, that the failure of any sewer main could have significant consequences. Therefore the expected service life for vitrified clay pipe (80% of the sewer mains are vitrified clay) has been reduced from 100 years to 90 years. This addresses West Vancouver’s desire to address the risk of sewer main failure by replacing its pipes before ultimate failure.

The amount of environmental and property damage as well as general public discontent, due to a lift station failure is related to the tributary population of a given lift station. Therefore criticality factors have been assigned to lift stations according to Table 6.3 below. The criticality factor, along with the asset’s condition factor, is multiplied to the asset's expected service life to extend or shorten an asset's remaining service life. The tributary population for each lift station was obtained from the 2006 Sanitary Lift Station Condition Assessment Report.

Table 6.3 Lift Station Criticality Factor based on Tributary Population

Tributary Population	Criticality Factor
1	1.05
21	1.00
51	0.95
101	0.90
201	0.85

6.4 Sensitivity Analysis

The service life of the different asset types has been estimated based on industry standards, West Vancouver's limited CCTV data, and the experience of other municipalities in the Lower Mainland. In order to test the sensitivity of key assumptions worst and best case scenarios were developed. This generates a range within which the actual average service life for a given asset type is likely to occur.

A sensitivity analysis was conducted on the assets that represent the majority of the value of the system. Sewer mains represent 57% of the 25 year total costs and 83% of the 100 year total costs. The majority of the sewer mains (79%) are vitrified clay (VC) and 16% of the sewer mains are PVC. Two-thirds of the value of the lift stations consists of the electrical and mechanical components. The following table shows the range of estimated service lives used for the major assets of this study.

Table 6.4 Range of Estimated Average Service Lives Used

Asset Type	Estimated Average Service Life (years)		
	Worst Case	Best Estimate	Best Case
VC Mains	75	90	100
PVC Mains	75	85	100
Lift stations - electrical	15	20	40
Lift stations - mechanical	15	30	40

The impact of using a range of estimated average service lives can be seen in Section 7. If West Vancouver were to expand its CCTV program, then it could better estimate how long its assets will last and refine the financial forecasts provided in this report.

The costs and benefits of using rehabilitation strategies (i.e. spot repairs) to extend the life of an asset are presented in Section 7.

6.5 Bottom-up Asset Renewal Planning

This asset management plan represents a "top-down" approach to renewal planning, which is appropriate for strategic long-term planning and estimating future renewal budgets. A "bottom-up" asset renewal plan identifies specific assets for replacement based on priority and is critical for optimising available renewal budgets.

The bottom-up approach, which is used for short-term capital planning of projects, outlines asset renewal priorities based on asset condition and criticality. It is therefore important that West Vancouver determine the condition and criticality of its assets in order to develop a bottom-up sanitary asset renewal plan.

7. How Much Will It Cost?

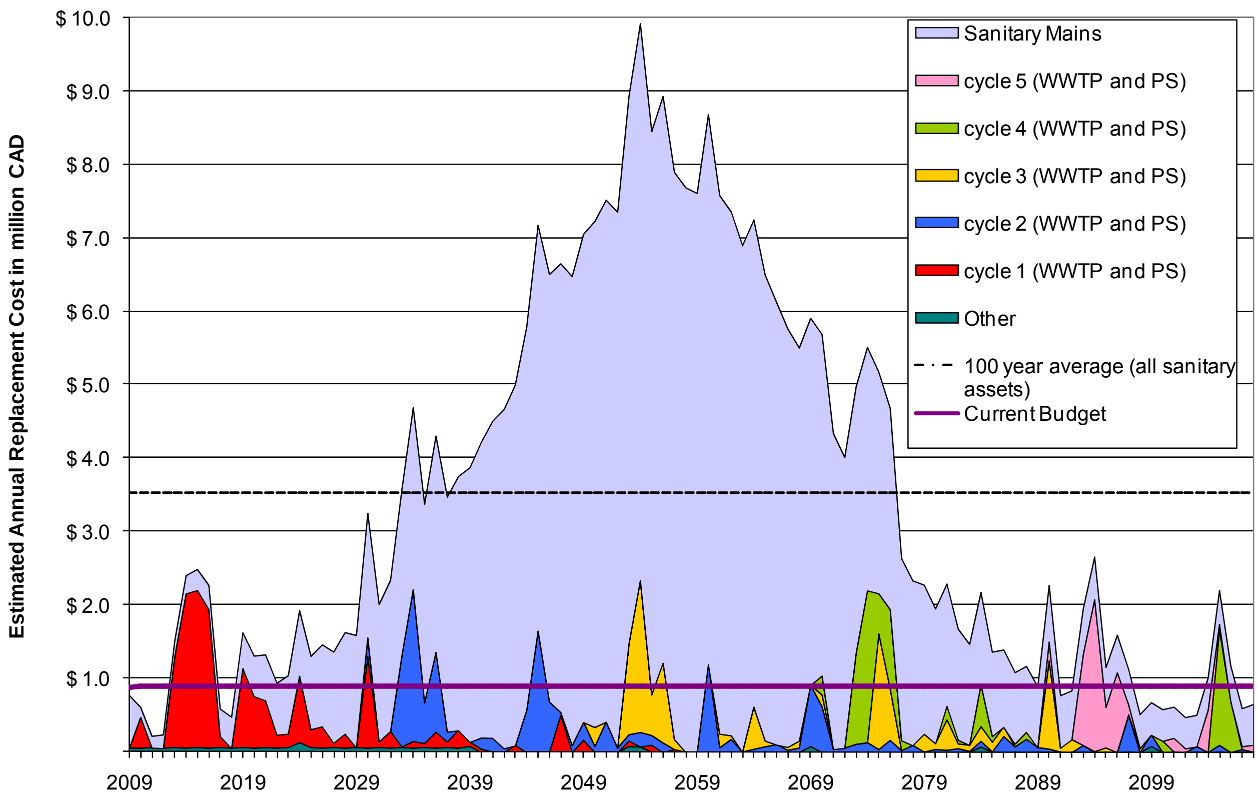
This study estimates required capital renewal budgets over the long term, which facilitates the setting of capital budgets and associated sewer rates. The District will still need to develop a prioritized capital renewal plan which identifies exactly which assets are to be replaced over the short term.

7.1 Long Range Forecast

The main objective of this study was to provide West Vancouver with a long range forecast of future sanitary infrastructure renewal requirements. All costs presented in this report are in 2009 dollars, in order to provide a consistent view for year to year comparisons. If inflation were included, then it would be difficult to see if future cost increases were due to aging infrastructure or simply due to the selected inflation rate.

Figure 7.1 shows the total annual capital replacement costs predicted by the CAP model for the next 100 years. Although lift station renewals will be the main priority over the next 15 years, over the long term, sewer mains represent the largest component of the sanitary renewal budget. The capital replacement needs will continue to grow to nearly $10 million per year by 2055. The average annual estimated capital renewal cost over the next 100 years is $3.5 million.

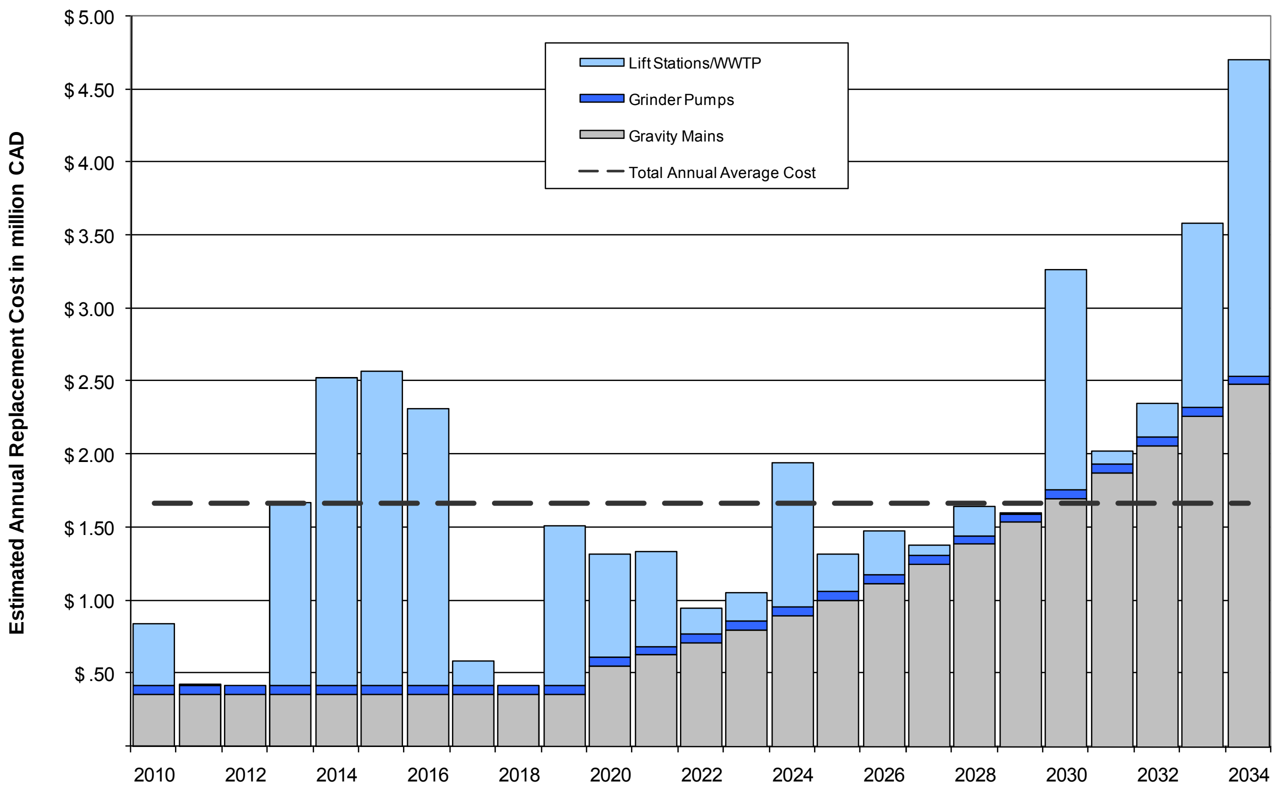
Figure 7.1 Sanitary System Annual Replacement Requirements 100 Year Forecast



Since the assets within the wastewater treatment plant (WWTP) and sanitary lift stations (PS) have service lives of 50 years or less, Figure 7.1 shows the multiple replacement cycles for these assets over the next 100 years. Included within the "Other" category in Figure 7.1 are grinder pumps, the WWTP grinders and cutters, and the leachate swale in Ambleside. The forcemains that are associated with a West Vancouver lift station have been included in the lift stations/WWTP category. The remainder of the forcemains (approximately 2 km) have been included in the sanitary main category.

Figure 7.2 shows that the average annual estimated capital replacement cost over the next 25 years is $1.7 million (in 2009 dollars). The danger in taking a 25 year view is that West Vancouver won't be prepared for the signficant increase in renewal requirements in years 2035-2060.

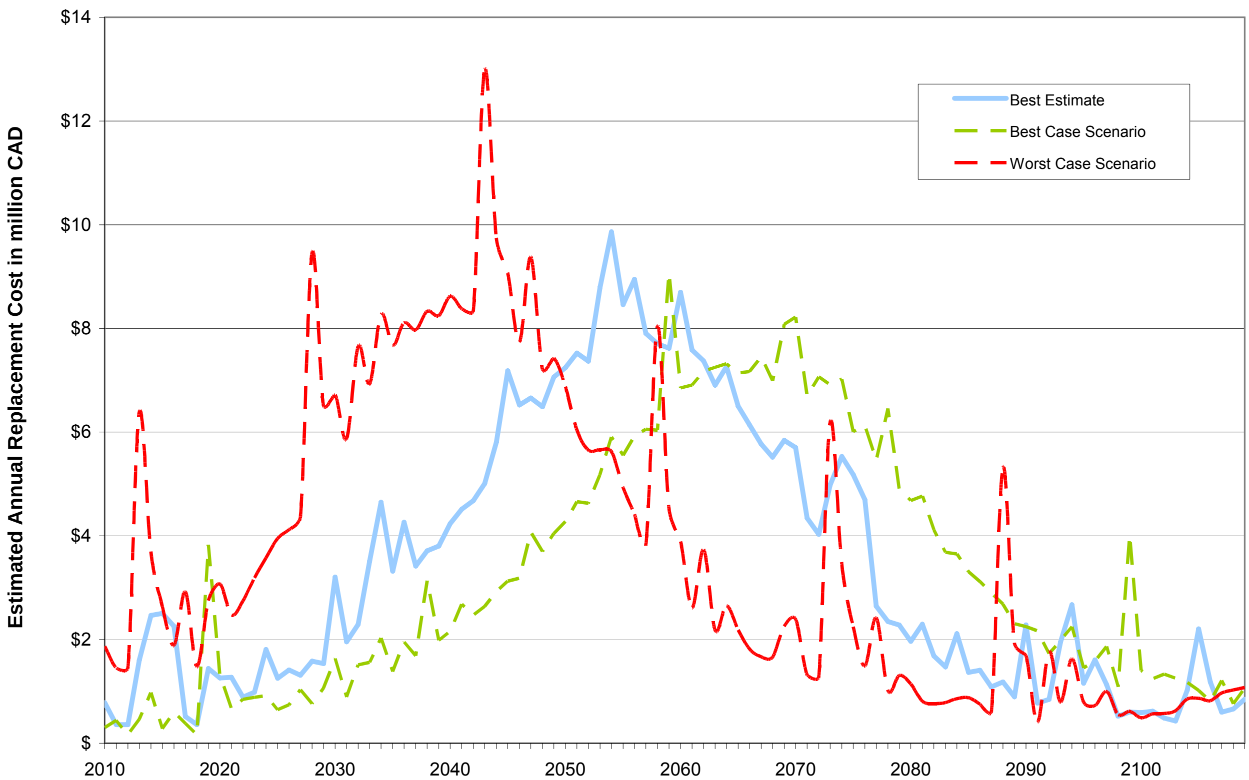
Figure 7.2 25 Year Annual Capital Renewal Costs



There is very little backlog of assets needing replacement. The lift station assets that currently require replacement have been included in the cost estimate for 2010. The portion of gravity mains that is "statistically" due for replacement has been spread out over 10 years (2010-2019).

As described in Section 6.4 a range of estimated service lives for different asset types was used to determine the sensitivity of key assumptions. The total capital renewal forecast using the original estimate of service lives as well as the worst and best case scenarios are presented in Figure 7.3.

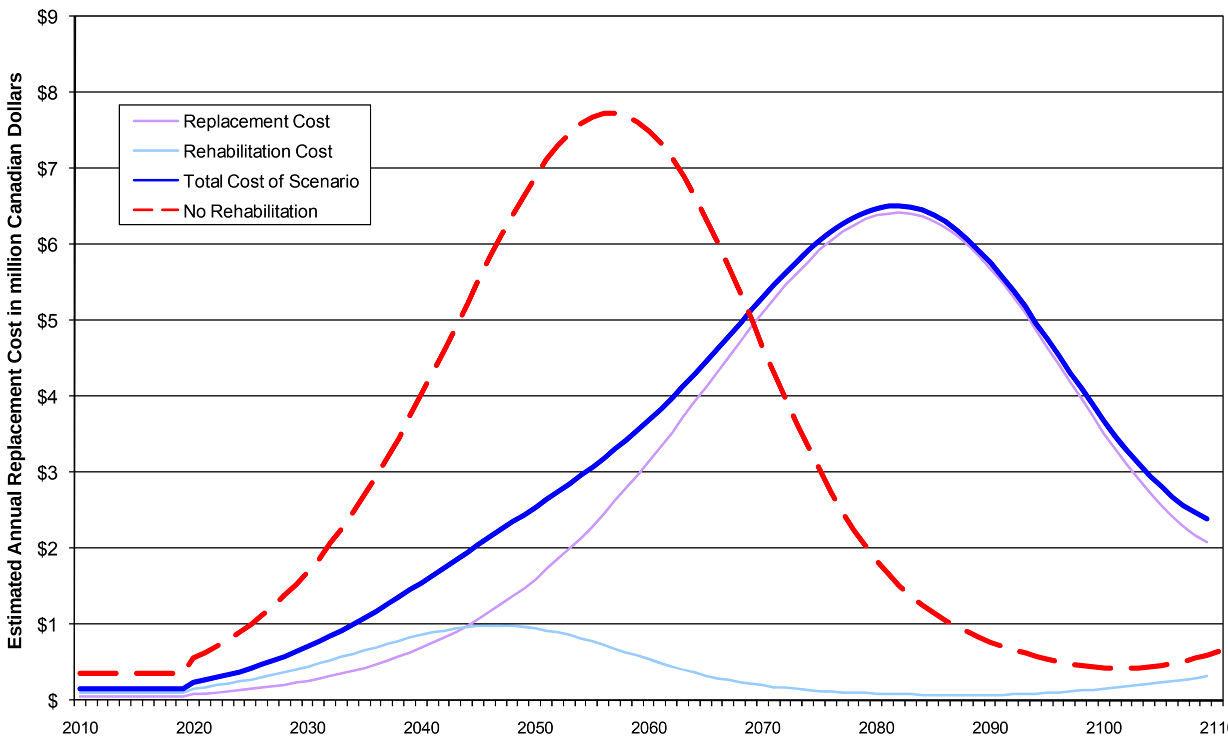
Figure 7.3 Total Annual Replacement Requirements Using a Range of Estimated Service Lives



If the assets last longer than predicted, then the "hump" of renewal requirements is pushed farther into the future and spread out over more years. If the assets don't last as long as predicted then West Vancouver will start to experience a significant increase in renewal requirements in the short-term.

Conducting rehabilitation work, such as spot repairs typically extends the life of an asset. Figure 7.4 looks at the costs and benefits of rehabilitating a sewer before the end of its life. It was assumed that at 10 years before the end of its life a sewer is rehabilitated at an average cost of $100 per metre, thereby extending its life by an additional 15 years. The total cost of this scenario (i.e rehabilitation cost plus eventual replacement cost) is compared with the baseline scenario where all sewers are simply replaced at the end of their service life. Although the total cost over 100 years under the two scenarios is almost the same, the rehabilitation scenario would allow West Vancouver to spread out the renewal work more evenly over the next 100 years.

Figure 7.4 Using Rehabilitation Strategies to Extend the Life of Sewers vs Baseline Scenario



Advancing West Vancouver's sewer condition assessment program is essential for identifying opportunities for extending the life of sewer mains through rehabilitation. Determining the criticality of each asset by identifying the consequences of its failure will help prioritize assets for inspection or renewal thereby optimizing West Vancouver's condition assessment, maintenance and renewal budgets.

7.2 Short Range Forecast – Lift Stations

A short term view of the lift station replacement needs was prepared. The replacements years and costs are broken down by component type – civil, mechanical, forcemain, electrical, and SCADA. In reality the upgrades for the different component types may be coordinated to occur at the same time.

This short term view is not meant to provide a detailed work plan but a guide as to which lift stations may need replacement in the near future and where to focus future maintenance and monitoring efforts. A summary of the 10 year view of the lift station replacement needs is provided in Appendix B. It provides an estimate of the cost and year of each upgrade. Stations where total replacement may need to be considered over the next 10 years due to condition and age of infrastructure are listed below.

- 3176 Travers
- Copper
- Cotton A
- Cotton B
- Eastmont
- Imperial
- Marine and Beach
- Piccadilly
- Radcliffe #3

When determining its lift station capital renewal plan for the next 10 years it is recommended that West Vancouver consider additional factors such as maintenance history, capacity, and accessibility.

West Vancouver could develop a short range forecast for its other sanitary assets by conducting a bottom-up sanitary renewal plan. Since the bottom-up approach requires knowing the condition and criticality of each asset the District must first conduct a condition and criticality assessment in order to develop a short-term renewal plan.

8. Funding Strategies: "How will we pay for it?"

This study has estimated the total reinvestment requirements for West Vancouver's sanitary system over the next 100 years. It shows when the District can expect waves of high capital expenditures, thereby helping West Vancouver to better determine utility revenue needs and to optimise O&M practices to extend the life of existing assets.

Now that West Vancouver has identified its sanitary capital reinvestment funding requirements, it can subtract any external contributions (i.e. from development or infrastructure grants) to determine required budget levels.

8.1 Current Funding Levels

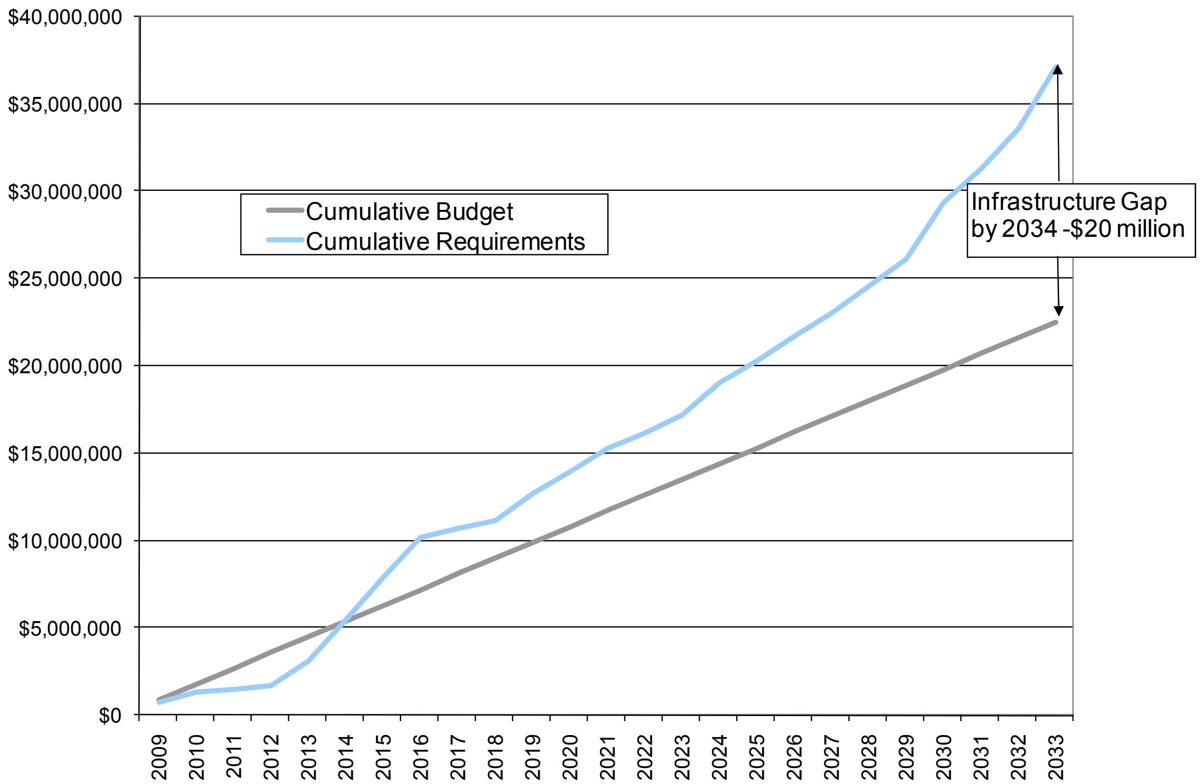
In 2009 West Vancouver had a budget of $830,000 for sanitary capital replacements. This budget does not include CCTV work. The current 5 year financial plan shows this figure increasing to $880,000 in 2010, to $900,000 in 2011 and then staying static until 2013. The current sanitary capital budget breakdown is shown in Table 8.1.

Table 8.1 West Vancouver's Current Sanitary Capital Budget

Category	2009 Budget
Lateral Replacements	$355,000
Lift Stations	$225,000
SCADA upgrades/repairs	$200,000
Other (studies)	$50,000
Total	**$830,000**

Figure 8.1 shows how the anticipated renewal requirements compare with the existing budget levels. In general the existing budget is only sufficient for the next 4 years. The infrastructure gap measures the difference between the required capital renewal budget and the available capital renewal budget. Assuming that the sanitary capital renewal budget is only raised to keep up with inflation, the estimated infrastructure gap for the sanitary sewer system is $20 million by 2034 (i.e. in 25 years).

Figure 8.1 Renewal Requirements vs. Existing Budget Levels – 25 Year View

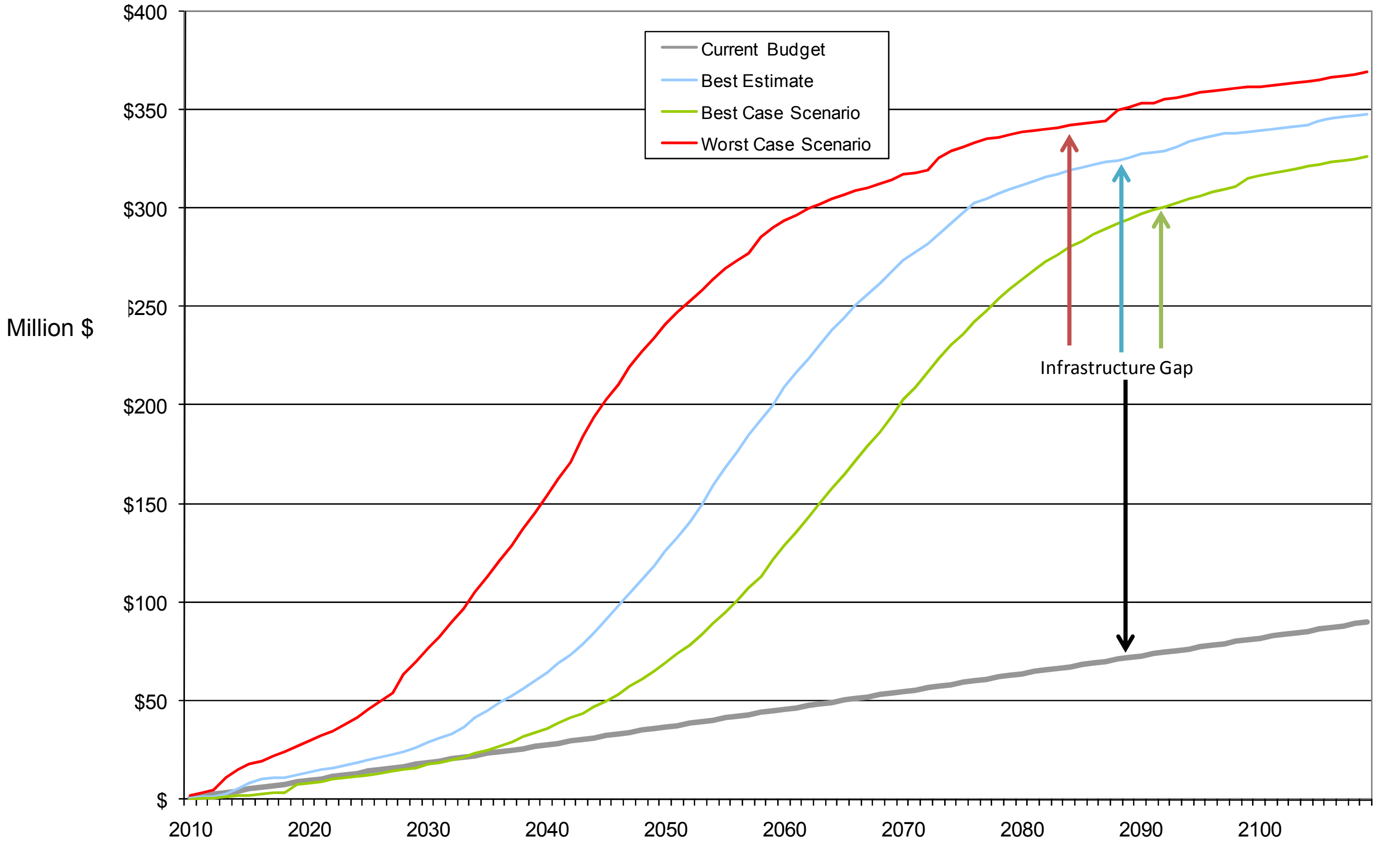


As described in Section 6.4 a range of estimated service lives for different asset types was used to determine the sensitivity of key assumptions. The infrastructure gap using the original estimate of service lives as well as the worst and best case scenarios are presented in Figure 8.2.

Figure 8.2 shows that the current renewal budget is sufficient for the best case scenario over the next 25 years. However, Figure 8.3 shows that even in the best case scenario, the current renewal budget is not sufficient after 25 years.

Therefore the question isn't whether there will be an infrastructure gap if existing renewal budgets are only increased to match inflation but how much will the infrastructure gap be and how soon will it come. Therefore it is recommended that West Vancouver take steps now, as discussed in Section 8.2, to address the pending infrastructure gap.

Figure 8.2 Best and Worst Case Estimate of 100 Year Infrastructure Gap



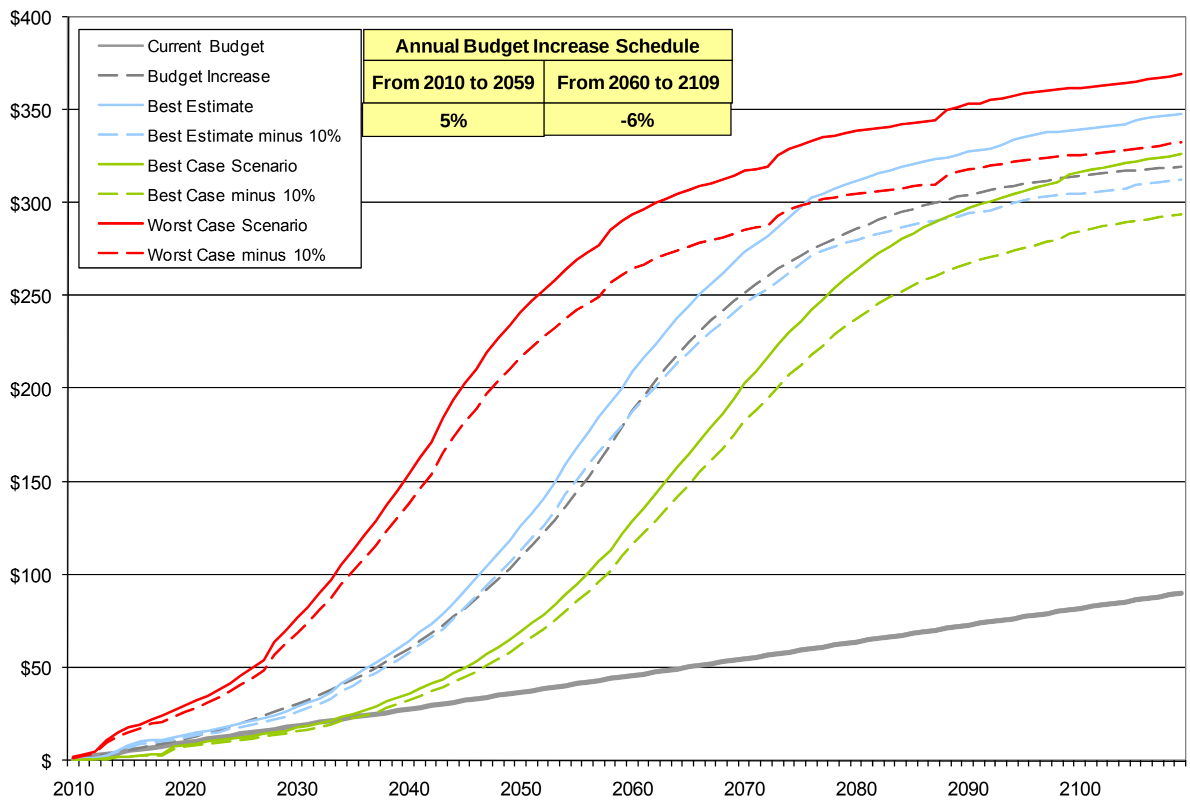
8.2 Future Strategies

The District needs to determine how it will address the forecasted infrastructure gap. The ultimate solution will likely come from a variety of sources:

- Extend the life of assets through a proactive inspection and rehabilitation program;
- Prioritize assets for replacement through a risk based bottom-up renewal plan (see Section 6);
- Reduce capital renewal costs through good asset management planning (see Section 9);
- Gradual but steady increase in capital renewal budgets; and
- Ensure that development driven improvements are partially or wholly funded by the development itself.

Figure 8.3 shows the impact on the infrastructure gap if West Vancouver were able to reduce the lifecycle cost of its assets and increase its renewal budget. West Vancouver would meet the anticipated renewal requirements under the best estimate scenario if it reduced the lifecycle cost of its assets by 10% and increased its sanitary renewal budget by 5% each year from 2010 to 2059.

Figure 8.3 Addressing the Infrastructure Gap



Within its sewer utility, West Vancouver currently has annual revenues of $7.55 million. A 5% increase in the sewer renewal budget represents an annual increase in sewer utility revenue requirements of 0.6%.

Effective communication is critical to educate and engage stakeholders to assist in meeting the upcoming challenges associated with the management of the District's infrastructure. Municipalities such as Edmonton and Hamilton have spent years quantifying their infrastructure renewal needs and communicating those needs to stakeholders. We recommend that West Vancouver use the information from this report and the National Water and Wastewater Benchmarking Initiative to inform senior management, City Council and the public on the following points:

- What assets does West Vancouver own?
- What are the assets worth?
- What is their condition?
- How much needs to be spent on infrastructure renewal?
- What is the relationship between renewal costs and maintenance costs?
- What is the level of service that West Vancouver residents receive?
- What is the relationship between infrastructure costs and levels of service?

8.3 Infrastructure Funding Mechanisms

Effective infrastructure renewal funding:

- Allocates costs to those benefiting from the service thus increasing equity in provision of services;
- Supports accountability by clear allocation of funds;
- Incorporates life cycle costs of infrastructure (i.e. depreciation, O&M and renewal);
- Provides reliable, predictable, dedicated funding to support multi-year infrastructure investment strategies; and
- Supports demand management efforts.

The District of West Vancouver currently uses sewer utility charges (which are tied to indoor water consumption), DCC's (development cost charges), and provincial and federal funding to support the renewal of its infrastructure. Sewer utility charges represent the largest, most stable source of funding for a long term infrastructure renewal program. West Vancouver will need to determine whether they want to create a reserve to pay for infrastructure renewal projects or to adopt a "pay as you go" approach.

It is recommended that West Vancouver take a long term approach to its rate planning in order to create relatively consistent rates to meet its renewal needs, rather than having rates fluctuate according to the capital works within a given year. Using a specifically designated reserve fund to collect renewal funding (similar to a capital reserve fund) facilitates a long term approach to rate planning. The results of this study are ideally suited for estimating the requirements of future reserves. It is important to note, that since the estimates in this study are based on 2009 replacement costs, they need to be revised on a periodic basis to reflect the actual renewal costs in future years.

Should West Vancouver want to investigate new funding mechanisms we recommend that they refer to the *National Guide to Sustainable Municipal Infrastructure's* best practice titled *"Alternative Funding Mechanisms"*. The *National Guide to Sustainable Municipal Infrastructure: Innovations and Best Practices* is a compendium of technical best practices for addressing infrastructure issues. The best practice on alternative funding mechanisms describes eight methods for developing innovation funding sources to meet infrastructure needs, or to align costs with benefits to users. The eight alternative funding mechanisms described are:

- Special Levies,
- Development Fees,
- Utility Models,
- Sponsorships,
- Innovative Transportation Revenues and Incentives,
- Government Service Partnerships,
- Funding Partnerships, and
- Strategic Funding Allocations.

8.4 Next Steps

This study provides a long term view of infrastructure renewal needs. In order to determine infrastructure renewal priorities over the next 10 years, West Vancouver needs to conduct a bottom-up assessment of the sanitary system that considers asset condition, maintenance history, criticality, and coordination with roads and other utilities. This will allow West Vancouver to better quantify short term infrastructure renewal requirements and determine the actual impact on sewer rates.

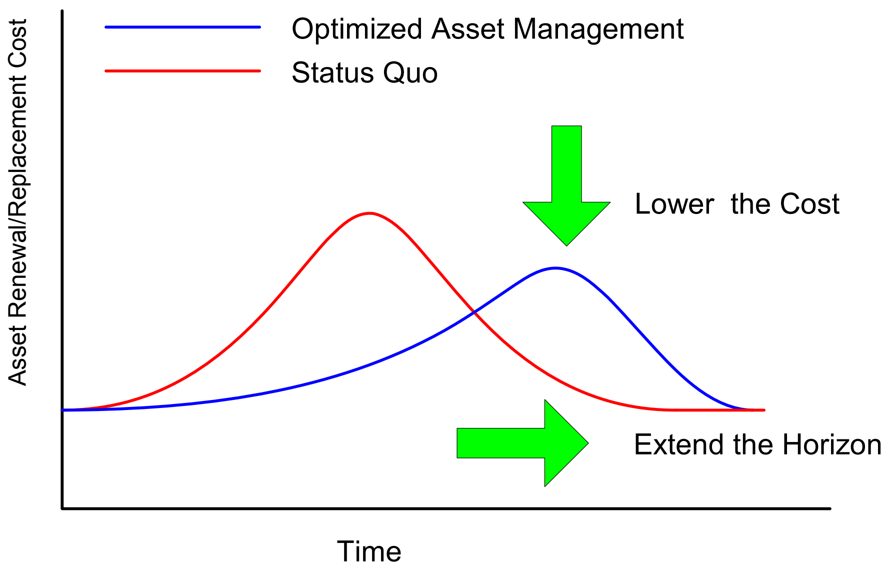
In order to conduct a bottom-up assessment, West Vancouver will need better information on the condition of its sanitary sewer mains. To accomplish this, it is recommended that the District continue the implementation of the program outlined in the 2005 report titled “Developing a Multi-Year Sanitary Sewer Condition Assessment Program” (see Appendix C). As part of this program West Vancouver should also perform a more thorough review of the criticality of its sanitary system. Determining the criticality of different assets will allow West Vancouver to identify which assets can run to failure and which assets should be renewed before failure.

This study has adhered to present day best practices for performing strategic level asset management. A “needs-based” approach has been taken that gives consideration to our current knowledge of asset life spans, and current replacement costs. Consideration has not been given to factors that might either accelerate renewal efforts (eg. elevation of risk or criticality, resource levelling), or decelerate renewal efforts (eg. short term affordability). These additional factors will remain for continued public debate, and provide input into the annual rate setting process. Ultimately, a “budget-based” approach to asset management will govern the extent to which West Vancouver will manage assets in a sustainable fashion over the short and long term.

9. Adopting Asset Management Practices

Good asset management planning seeks to capitalize on two means of cost savings: preventative maintenance and effective asset renewal planning. This will result in the optimization of lifecycle costs for individual assets as depicted in Figure 9.1.

Figure 9.1 Means of Achieving Savings through Asset Management



By continuing with its preventative maintenance program West Vancouver can attain, and hopefully extend, the expected service life of its infrastructure, and will benefit accordingly. West Vancouver can also periodically review its preventative maintenance program to ensure that it is gaining maximum benefit from lift station inspections, its CCTV program and its sewer cleaning program.

A risk based approach as discussed in Section 6 will allow West Vancouver to determine the most cost-effective strategy for maintaining an asset based on the consequences of failure. By identifying the most cost effective renewal and/or replacement strategy for each asset and by integrating capital works of different utilities (water, stormwater, road etc.) whenever possible, the District will optimise its capital renewal budgets. Together this will have the benefit of lowering the actual cost of the renewal program.

The efficient integration of capital works of different utilities requires coordinating the capital renewal programs for the water, sanitary, storm and road systems. Accomplishing this requires developing procedures and communication channels, which can be facilitated but not replaced by information management systems. Effectively managing and communicating asset information as outlined in the District of West Vancouver's Asset Management Information Management Strategy will help West Vancouver optimize sanitary asset maintenance and rehabilitation needs.

10. Recommendations

This section outlines the ten (10) key recommendations that are a result of this study. The recommendations address sustainable funding, improving asset information and optimizing renewal budgets.

10.1 Sustainable Funding

Without sustainable funding an asset manager cannot maintain a given level of service from its assets. The effective communication of this study's results to Council and the general public is key to obtaining sustainable infrastructure funding.

Recommendation #1
The District of West Vancouver should plan and implement an appropriate sewer rate structure to ensure that sufficient resources will be available to address both current and future infrastructure maintenance and replacement requirements.

Recommendation #2
The District of West Vancouver should develop a specific "Renewal Reserve Fund" for capital reinvestment in order to smooth out sewer utility rates, provide equitable and transparent infrastructure funding and to ensure that funds are available as infrastructure renewal requirements increase.

Recommendation #3
The District of West Vancouver should develop a communications plan to convey the current status and future requirements of the infrastructure management plan in advance of revising the current sewer rate structure.

Recommendation #4
West Vancouver should maintain and update the CAP model (or similar tool) to periodically check that its renewal funding is sufficient to meet its capital renewal needs.

10.2 Improving Asset Information and Optimizing Renewal Budgets

By identifying the most cost effective renewal and/or replacement strategy for each asset and by integrating capital works of different utilities (water, stormwater, road etc.) whenever possible, the District will optimise its capital renewal budgets. Together this will have the benefit of lowering the actual cost of the renewal program, but can only be accomplished with sufficient information about the assets. Recommendations 5 to 7 outline actions that are critical for identifying the most cost effective asset renewal strategy and reducing O&M costs. Recommendations 8 through 10 outline actions that would support West Vancouver's efforts to effectively manage its asset data.

Recommendation #5
The District of West Vancouver should advance its risk based sewer condition assessment program. This would allow West Vancouver to prioritize sewer maintenance and rehabilitation work, to extend the life of its sewer mains, to refine the financial projections presented in this report and to fulfill its sewer inspection obligations under Metro Vancouver's Liquid Waste Management Plan.

Recommendation #6
The District should coordinate its sanitary capital renewal program with other utilities (water, roads and drainage) to ensure that total costs are minimized.

Recommendation #7
In areas where inflow and infiltration (I&I) and the intrusion of tree roots are of concern, the District may want to consider a range of renewal options (grouting, spot repairs, regular root cutting, and full replacement) to extend the life of its sewers and to minimize maintenance costs.

Recommendation #8
Effectively managing and communicating asset information as outlined in the District of West Vancouver's Asset Management Information Management Strategy will help West Vancouver optimize sanitary asset maintenance and rehabilitation needs.

Recommendation #9
Assets that belong to Metro Vancouver should be clearly labelled as such within West Vancouver's GIS.

Recommendation #10
The District should adopt standard nomenclature for data such as pipe material to facilitate the collection and analysis of asset information. Currently, within West Vancouver's GIS there are five (5) different abbreviations for vitrified clay (CL, CLAY, VC, VCV, and VIT).

Appendix A – Asset Inventory

Asset #	Asset Group	Asset Type	Asset Name	Asset Component	Quantity or Length in m	2006 Replacement value (Unit Cost in CAD)	Date in Service	Expected Service Life (yrs)	Expected Replacement Year	% of Expected Service Life Used	Remaining service life (yrs)	Condition Rating (1=good, 5=poor)	Tributary Population	Condition adjustment factor	Condition Adjusted Remaining Service Life	Condition adjusted replacement year	Criticality adjustment factor	Criticality & Condition Adjusted Remaining Service Life	Condition and Criticality Adjusted Replacement Year	2009 Replacement Value
																			Total Sanitary Sewer System	$ 299,580,379
																			Total Sewer Pipes + Grinder Pumps	$ 283,691,553
	Sanitary Sewer	Pipes	Sewer Pipes		332,507	$ 850														$ 282,797,153
	Sanitary Sewer	Grinder Pumps (District maintained)			208	$ 4,300														$ 894,400
																			Total Lift Stations + WWTP	$ 15,888,826
	Wastewater Treatment	WWTP Grinder	Citrus Wynd WWTP	Raw Sewage Grinder Cutters	1	$ 7,500	2009	2	2011	50%	1		322	1	1	2011	0.85	1	2011	$ 7,500
	Wastewater Treatment	WWTP Grinder	Citrus Wynd WWTP	Raw Sewage Grinder	1	$ 75,000	2009	15	2024	7%	14		322	1	14	2024	0.85	12	2022	$ 75,000
	Wastewater Treatment	WWTP - Structures	Citrus Wynd WWTP	Civil	1	$ 300,000	2003	50	2053	14%	43		322	1	43	2053	0.85	37	2047	$ 320,220
	Wastewater Treatment	WWTP - MEI	Citrus Wynd WWTP	Mechanical	1	$ 900,000	2003	30	2033	23%	23		322	1	23	2033	0.85	20	2030	$ 960,660
	Wastewater Treatment	WWTP - Outfall	Citrus Wynd WWTP	Civil	1	$ 40,250	1995	50	2045	30%	35		322	1	35	2045	0.85	30	2040	$ 42,963
	Sanitary Sewer	Leachate Swale	Leachate Swale	Civil	1	$ 70,000	2003	50	2053	14%	43				43	2053	1.00	43	2053	$ 74,718
	Sanitary Sewer	Sanitary Lift Station	15th & Argyle	Civil	1	$ 26,000	2005	50	2055	10%	45	1	38	1	45	2055	1.00	45	2055	$ 27,752
	Sanitary Sewer	Sanitary Lift Station	15th & Argyle	Force Main	1	$ 7,000	2005	50	2055	10%	45	1.25	38	1	45	2055	1.00	45	2055	$ 7,472
	Sanitary Sewer	Sanitary Lift Station	15th & Argyle	Mechanical	1	$ 52,000	2005	30	2035	17%	25	1	38	1	25	2035	1.00	25	2035	$ 55,505
	Sanitary Sewer	Sanitary Lift Station	15th & Argyle	Electrical	1	$ 52,000	2005	20	2025	25%	15	1	38	1	15	2025	1.00	15	2025	$ 55,505
	Sanitary Sewer	Sanitary Lift Station	15th & Argyle	SCADA	1	$ 25,000	2005	20	2025	25%	15	1	38	1	15	2025	1.00	15	2025	$ 26,685
	Sanitary Sewer	Sanitary Lift Station	17th & Argyle	Civil	1	$ 3,500	2006	50	2056	8%	46	1	3	1	46	2056	1.05	48	2058	$ 3,736
	Sanitary Sewer	Sanitary Lift Station	17th & Argyle	Force Main	1	$ 2,500	2006	50	2056	8%	46	1	3	1	46	2056	1.05	48	2058	$ 2,669
	Sanitary Sewer	Sanitary Lift Station	17th & Argyle	Mechanical	1	$ 7,000	2006	30	2036	13%	26	1	3	1	26	2036	1.05	27	2037	$ 7,472
	Sanitary Sewer	Sanitary Lift Station	17th & Argyle	Electrical	1	$ 7,000	2006	20	2026	20%	16	1	3	1	16	2026	1.05	17	2027	$ 7,472
	Sanitary Sewer	Sanitary Lift Station	17th & Argyle	SCADA	1	$ -	2006	20	2026	20%	16	1	3	1	16	2026	1.05	17	2027	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	23rd	Civil	1	$ 53,100	1980	50	2030	60%	20	3	149	0.9	15	2025	0.90	14	2024	$ 56,679
	Sanitary Sewer	Sanitary Lift Station	23rd	Force Main	1	$ 2,500	1980	50	2030	60%	20	3.5	149	0.9	15	2025	0.90	14	2024	$ 2,669
	Sanitary Sewer	Sanitary Lift Station	23rd	Mechanical	1	$ 106,200	1992	30	2022	60%	12	2	149	1.1	15	2025	0.90	14	2024	$ 113,358
	Sanitary Sewer	Sanitary Lift Station	23rd	Electrical	1	$ 106,200	1980	20	2000	150%	-10	3	149	1.2	4	2014	0.90	4	2014	$ 113,358
	Sanitary Sewer	Sanitary Lift Station	23rd	SCADA	1	$ -	1980	20	2000	150%	-10	3	149	1.2	4	2014	0.90	4	2014	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	24th	Civil	1	$ 52,000	1990	50	2040	40%	30	2	485	1	30	2040	0.85	26	2036	$ 55,505
	Sanitary Sewer	Sanitary Lift Station	24th	Force Main	1	$ 16,000	1990	50	2040	40%	30	2	485	1	30	2040	0.85	26	2036	$ 17,078
	Sanitary Sewer	Sanitary Lift Station	24th	Mechanical	1	$ 104,000	1990	30	2020	67%	10	2	485	1.1	13	2023	0.85	11	2021	$ 111,010
	Sanitary Sewer	Sanitary Lift Station	24th	Electrical	1	$ 104,000	2006	20	2026	20%	16	1	485	1	16	2026	0.85	14	2024	$ 111,010
	Sanitary Sewer	Sanitary Lift Station	24th	SCADA	1	$ 35,000	2006	20	2026	20%	16	1	485	1	16	2026	0.85	14	2024	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	25th	Civil	1	$ 53,000	1980	50	2030	60%	20	3	67	0.9	15	2025	0.95	14	2024	$ 56,572
	Sanitary Sewer	Sanitary Lift Station	25th	Force Main	1	$ 17,000	1980	50	2030	60%	20	3	67	0.9	15	2025	0.95	14	2024	$ 18,146
	Sanitary Sewer	Sanitary Lift Station	25th	Mechanical	1	$ 106,000	1980	30	2010	100%	0	3	67	1.2	6	2016	0.95	6	2016	$ 113,144
	Sanitary Sewer	Sanitary Lift Station	25th	Electrical	1	$ 106,000	1980	20	2000	150%	-10	3	67	1.2	4	2014	0.95	4	2014	$ 113,144
	Sanitary Sewer	Sanitary Lift Station	25th	SCADA	1	$ -	1980	20	2000	150%	-10	3	67	1.2	4	2014	0.95	4	2014	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	28th	Civil	1	$ 52,000	1989	50	2039	42%	29	2	191	1	29	2039	0.90	26	2036	$ 55,505
	Sanitary Sewer	Sanitary Lift Station	28th	Force Main	1	$ 21,000	1989	50	2039	42%	29	2.25	191	1	29	2039	0.90	26	2036	$ 22,415
	Sanitary Sewer	Sanitary Lift Station	28th	Mechanical	1	$ 104,000	1989	30	2019	70%	9	3.5	191	0.9	6	2016	0.90	5	2015	$ 111,010
	Sanitary Sewer	Sanitary Lift Station	28th	Electrical	1	$ 104,000	2006	20	2026	20%	16	1	191	1	16	2026	0.90	14	2024	$ 111,010
	Sanitary Sewer	Sanitary Lift Station	28th	SCADA	1	$ 35,000	2006	20	2026	20%	16	1	191	1	16	2026	0.90	14	2024	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	28th & Palmerston	Civil	1	$ 31,000	1988	50	2038	44%	28	2	49	1	28	2038	1.00	28	2038	$ 33,089

DISTRICT OF WEST VANCOUVER ASSET EVALUATION STUDY - ASSET INVENTORY

Asset #	Asset Group	Asset Type	Asset Name	Asset Component	Quantity or Length in m	2006 Replacement value (Unit Cost in CAD)	Date in Service	Expected Service Life (yrs)	Expected Replacement Year	% of Expected Service Life Used	Remaining service life (yrs)	Condition Rating (1=good, 5=poor)	Tributary Population	Condition adjustment factor	Condition Adjusted Remaining Service Life	Condition adjusted replacement year	Criticality adjustment factor	Criticality & Condition Adjusted Remaining Service Life	Condition and Criticality Adjusted Replacement Year	2009 Replacement Value
	Sanitary Sewer	Sanitary Lift Station	28th & Palmerston	Force Main	1	$ 13,000	1988	50	2038	44%	28	2.25	49	1	28	2038	1.00	28	2038	$ 13,876
	Sanitary Sewer	Sanitary Lift Station	28th & Palmerston	Mechanical	1	$ 62,000	1988	30	2018	73%	8	2	49	1.1	11	2021	1.00	11	2021	$ 66,179
	Sanitary Sewer	Sanitary Lift Station	28th & Palmerston	Electrical	1	$ 62,000	1988	20	2008	110%	-2	2	49	1.3	6	2016	1.00	6	2016	$ 66,179
	Sanitary Sewer	Sanitary Lift Station	28th & Palmerston	SCADA	1	$ 25,000	1988	20	2008	110%	-2	2	49	1.3	6	2016	1.00	6	2016	$ 26,685
	Sanitary Sewer	Sanitary Lift Station	3026 Marine	Civil	1	$ 28,900	2009	50	2059	2%	49	1	58	1	49	2059	0.95	47	2057	$ 30,848
	Sanitary Sewer	Sanitary Lift Station	3026 Marine	Force Main	1	$ 2,500	2009	50	2059	2%	49	1	58	1	49	2059	0.95	47	2057	$ 2,669
	Sanitary Sewer	Sanitary Lift Station	3026 Marine	Mechanical	1	$ 57,800	2009	30	2039	3%	29	1	58	1	29	2039	0.95	28	2038	$ 61,696
	Sanitary Sewer	Sanitary Lift Station	3026 Marine	Electrical	1	$ 57,800	2009	20	2029	5%	19	1	58	1	19	2029	0.95	18	2028	$ 61,696
	Sanitary Sewer	Sanitary Lift Station	3026 Marine	SCADA	1	$ -	2009	20	2029	5%	19	1	58	1	19	2029	0.95	18	2028	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	3176 Travers	Civil	1	$ 17,200	1971	50	2021	78%	11	4	55	0.9	6	2016	0.95	6	2016	$ 18,359
	Sanitary Sewer	Sanitary Lift Station	3176 Travers	Force Main	1	$ 8,000	1971	50	2021	78%	11	4	55	0.9	6	2016	0.95	6	2016	$ 8,539
	Sanitary Sewer	Sanitary Lift Station	3176 Travers	Mechanical	1	$ 34,400	1971	30	2001	130%	-9	4	55	1	0	2010	0.95	0	2010	$ 36,719
	Sanitary Sewer	Sanitary Lift Station	3176 Travers	Electrical	1	$ 34,400	1971	20	1991	195%	-19	3.5	55	1.2	4	2014	0.95	4	2014	$ 36,719
	Sanitary Sewer	Sanitary Lift Station	3176 Travers	SCADA	1	$ 35,000	1988	20	2008	110%	-2	4	55	1	0	2010	0.95	0	2010	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	31st & Travers	Civil	1	$ 30,000	1971	50	2021	78%	11	2	12	1.2	21	2031	1.05	22	2032	$ 32,022
	Sanitary Sewer	Sanitary Lift Station	31st & Travers	Force Main	1	$ 18,000	1971	50	2021	78%	11	3	12	1.1	16	2026	1.05	17	2027	$ 19,213
	Sanitary Sewer	Sanitary Lift Station	31st & Travers	Mechanical	1	$ 60,000	1992	30	2022	60%	12	2	12	1.1	15	2025	1.05	16	2026	$ 64,044
	Sanitary Sewer	Sanitary Lift Station	31st & Travers	Electrical	1	$ 60,000	1971	20	1991	195%	-19	2	12	1.3	6	2016	1.05	6	2016	$ 64,044
	Sanitary Sewer	Sanitary Lift Station	31st & Travers	SCADA	1	$ -	1992	20	2012	90%	2	2	12	1.25	7	2017	1.05	7	2017	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	3200 Marine	Civil	1	$ 83,400	2006	50	2056	8%	46	2	225	1	46	2056	0.85	39	2049	$ 89,021
	Sanitary Sewer	Sanitary Lift Station	3200 Marine	Force Main	1	$ 30,000	2006	50	2056	8%	46	2	225	1	46	2056	0.85	39	2049	$ 32,022
	Sanitary Sewer	Sanitary Lift Station	3200 Marine	Mechanical	1	$ 166,800	2006	30	2036	13%	26	2.33	225	1	26	2036	0.85	22	2032	$ 178,042
	Sanitary Sewer	Sanitary Lift Station	3200 Marine	Electrical	1	$ 166,800	2006	20	2026	20%	16	2	225	1	16	2026	0.85	14	2024	$ 178,042
	Sanitary Sewer	Sanitary Lift Station	3200 Marine	SCADA	1	$ 35,000	2006	20	2026	20%	16	2	225	1	16	2026	0.85	14	2024	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Bedora	Civil	1	$ 22,600	1987	50	2037	46%	27	3	73	0.8	17	2027	0.95	16	2026	$ 24,123
	Sanitary Sewer	Sanitary Lift Station	Bedora	Force Main	1	$ 30,000	1987	50	2037	46%	27	3	73	0.8	17	2027	0.95	16	2026	$ 32,022
	Sanitary Sewer	Sanitary Lift Station	Bedora	Mechanical	1	$ 45,200	1987	30	2017	77%	7	3	73	1.1	10	2020	0.95	10	2020	$ 48,246
	Sanitary Sewer	Sanitary Lift Station	Bedora	Electrical	1	$ 45,200	1987	20	2007	115%	-3	3	73	1.2	4	2014	0.95	4	2014	$ 48,246
	Sanitary Sewer	Sanitary Lift Station	Bedora	SCADA	1	$ -	1987	20	2007	115%	-3	3	73	1.2	4	2014	0.95	4	2014	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Blink Bonnie	Civil	1	$ 40,000	1976	50	2026	68%	16	3	148	0.9	11	2021	0.90	10	2020	$ 42,696
	Sanitary Sewer	Sanitary Lift Station	Blink Bonnie	Force Main	1	$ 38,000	1976	50	2026	68%	16	3	148	0.9	11	2021	0.90	10	2020	$ 40,561
	Sanitary Sewer	Sanitary Lift Station	Blink Bonnie	Mechanical	1	$ 80,000	1976	30	2006	113%	-4	3	148	1.2	6	2016	0.90	5	2015	$ 85,392
	Sanitary Sewer	Sanitary Lift Station	Blink Bonnie	Electrical	1	$ 80,000	1976	20	1996	170%	-14	3.5	148	1.2	4	2014	0.90	4	2014	$ 85,392
	Sanitary Sewer	Sanitary Lift Station	Blink Bonnie	SCADA	1	$ -	1976	20	1996	170%	-14	3.66	148	1.2	4	2014	0.90	4	2014	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Bluebell	Civil	1	$ 4,100	1980	50	2030	60%	20	3	3	0.9	15	2025	1.05	16	2026	$ 4,376
	Sanitary Sewer	Sanitary Lift Station	Bluebell	Force Main	1	$ 2,500	1980	50	2030	60%	20	3	3	0.9	15	2025	1.05	16	2026	$ 2,669
	Sanitary Sewer	Sanitary Lift Station	Bluebell	Mechanical	1	$ 8,200	1980	30	2010	100%	0	3	3	1.2	6	2016	1.05	6	2016	$ 8,753
	Sanitary Sewer	Sanitary Lift Station	Bluebell	Electrical	1	$ 8,200	1980	20	2000	150%	-10	3	3	1.2	4	2014	1.05	4	2014	$ 8,753
	Sanitary Sewer	Sanitary Lift Station	Bluebell	SCADA	1	$ -	1980	20	2000	150%	-10	3	3	1.2	4	2014	1.05	4	2014	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Caulfield Court	Civil	1	$ 16,000	1982	50	2032	56%	22	2	23	1.1	27	2037	1.00	27	2037	$ 17,078
	Sanitary Sewer	Sanitary Lift Station	Caulfield Court	Force Main	1	$ 8,000	1982	50	2032	56%	22	2	23	1.1	27	2037	1.00	27	2037	$ 8,539
	Sanitary Sewer	Sanitary Lift Station	Caulfield Court	Mechanical	1	$ 32,000	1982	30	2012	93%	2	2	23	1.25	10	2020	1.00	10	2020	$ 34,157

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	Sanitary Sewer	Sanitary Lift Station	Caulfield Court	Electrical	1	$ 32,000	1982	20	2002	140%	-8	2.33	23	1.3	6	2016	1.00	6	2016	$ 34,157
	Sanitary Sewer	Sanitary Lift Station	Caulfield Court	SCADA	1	$ -	1982	20	2002	140%	-8	2.66	23	1.3	6	2016	1.00	6	2016	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Copper	Civil	1	$ 50,000	1976	50	2026	68%	16	3	214	0.9	11	2021	0.85	9	2019	$ 53,370
	Sanitary Sewer	Sanitary Lift Station	Copper	Force Main	1	$ 52,000	1976	50	2026	68%	16	3.25	214	0.9	11	2021	0.85	9	2019	$ 55,505
	Sanitary Sewer	Sanitary Lift Station	Copper	Mechanical	1	$ 100,000	1976	30	2006	113%	-4	3	214	1.2	6	2016	0.85	5	2015	$ 106,740
	Sanitary Sewer	Sanitary Lift Station	Copper	Electrical	1	$ 100,000	1976	20	1996	170%	-14	3	214	1.2	4	2014	0.85	3	2013	$ 106,740
	Sanitary Sewer	Sanitary Lift Station	Copper	SCADA	1	$ -	1976	20	1996	170%	-14	3	214	1.2	4	2014	0.85	3	2013	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Cotton A	Civil	1	$ 62,000	1976	50	2026	68%	16	3	212	0.9	11	2021	0.85	9	2019	$ 66,179
	Sanitary Sewer	Sanitary Lift Station	Cotton A	Force Main	1	$ 28,000	1976	50	2026	68%	16	3	212	0.9	11	2021	0.85	9	2019	$ 29,887
	Sanitary Sewer	Sanitary Lift Station	Cotton A	Mechanical	1	$ 124,000	1976	30	2006	113%	-4	3	212	1.2	6	2016	0.85	5	2015	$ 132,358
	Sanitary Sewer	Sanitary Lift Station	Cotton A	Electrical	1	$ 124,000	1976	20	1996	170%	-14	3	212	1.2	4	2014	0.85	3	2013	$ 132,358
	Sanitary Sewer	Sanitary Lift Station	Cotton A	SCADA	1	$ -	1976	20	1996	170%	-14	3.66	212	1.2	4	2014	0.85	3	2013	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Cotton B	Civil	1	$ 60,000	1976	50	2026	68%	16	3	247	0.9	11	2021	0.85	9	2019	$ 64,044
	Sanitary Sewer	Sanitary Lift Station	Cotton B	Force Main	1	$ 8,000	1976	50	2026	68%	16	3	247	0.9	11	2021	0.85	9	2019	$ 8,539
	Sanitary Sewer	Sanitary Lift Station	Cotton B	Mechanical	1	$ 120,000	1976	30	2006	113%	-4	3	247	1.2	6	2016	0.85	5	2015	$ 128,088
	Sanitary Sewer	Sanitary Lift Station	Cotton B	Electrical	1	$ 120,000	1976	20	1996	170%	-14	3	247	1.2	4	2014	0.85	3	2013	$ 128,088
	Sanitary Sewer	Sanitary Lift Station	Cotton B	SCADA	1	$ -	1976	20	1996	170%	-14	3	247	1.2	4	2014	0.85	3	2013	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Cove	Civil	1	$ 61,000	1976	50	2026	68%	16	3	331	0.9	11	2021	0.85	9	2019	$ 65,111
	Sanitary Sewer	Sanitary Lift Station	Cove	Force Main	1	$ 37,000	1976	50	2026	68%	16	3	331	0.9	11	2021	0.85	9	2019	$ 39,494
	Sanitary Sewer	Sanitary Lift Station	Cove	Mechanical	1	$ 122,000	1976	30	2006	113%	-4	3	331	1.2	6	2016	0.85	5	2015	$ 130,223
	Sanitary Sewer	Sanitary Lift Station	Cove	Electrical	1	$ 122,000	1976	20	1996	170%	-14	3	331	1.2	4	2014	0.85	3	2013	$ 130,223
	Sanitary Sewer	Sanitary Lift Station	Cove	SCADA	1	$ -	1976	20	1996	170%	-14	3.66	331	1.2	4	2014	0.85	3	2013	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Cypress Glen	Civil	1	$ 40,000	1990	50	2040	40%	30	3	26	0.8	20	2030	1.00	20	2030	$ 42,696
	Sanitary Sewer	Sanitary Lift Station	Cypress Glen	Force Main	1	$ 3,000	1990	50	2040	40%	30	2.25	26	1	30	2040	1.00	30	2040	$ 3,202
	Sanitary Sewer	Sanitary Lift Station	Cypress Glen	Mechanical	1	$ 80,000	1990	30	2020	67%	10	2	26	1.1	13	2023	1.00	13	2023	$ 85,392
	Sanitary Sewer	Sanitary Lift Station	Cypress Glen	Electrical	1	$ 80,000	1990	20	2010	100%	0	2	26	1.3	6	2016	1.00	6	2016	$ 85,392
	Sanitary Sewer	Sanitary Lift Station	Cypress Glen	SCADA	1	$ 35,000	1990	20	2010	100%	0	2	26	1.3	6	2016	1.00	6	2016	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Dufferin A	Civil	1	$ 50,000	1976	50	2026	68%	16	2	287	1.1	21	2031	0.85	18	2028	$ 53,370
	Sanitary Sewer	Sanitary Lift Station	Dufferin A	Force Main	1	$ 87,000	1976	50	2026	68%	16	3.25	287	0.9	11	2021	0.85	9	2019	$ 92,864
	Sanitary Sewer	Sanitary Lift Station	Dufferin A	Mechanical	1	$ 100,000	1976	30	2006	113%	-4	3	287	1.2	6	2016	0.85	5	2015	$ 106,740
	Sanitary Sewer	Sanitary Lift Station	Dufferin A	Electrical	1	$ 100,000	1976	20	1996	170%	-14	3	287	1.2	4	2014	0.85	3	2013	$ 106,740
	Sanitary Sewer	Sanitary Lift Station	Dufferin A	SCADA	1	$ -	1976	20	1996	170%	-14	3.66	287	1.2	4	2014	0.85	3	2013	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Dufferin B	Civil	1	$ 70,000	1976	50	2026	68%	16	3	777	0.9	11	2021	0.85	9	2019	$ 74,718
	Sanitary Sewer	Sanitary Lift Station	Dufferin B	Force Main	1	$ 42,000	1976	50	2026	68%	16	2.25	777	1.1	21	2031	0.85	18	2028	$ 44,831
	Sanitary Sewer	Sanitary Lift Station	Dufferin B	Mechanical	1	$ 140,000	1990	30	2020	67%	10	2	777	1.1	13	2023	0.85	11	2021	$ 149,436
	Sanitary Sewer	Sanitary Lift Station	Dufferin B	Electrical	1	$ 140,000	1990	20	2010	100%	0	2	777	1.3	6	2016	0.85	5	2015	$ 149,436
	Sanitary Sewer	Sanitary Lift Station	Dufferin B	SCADA	1	$ 35,000	1990	20	2010	100%	0	2	777	1.3	6	2016	0.85	5	2015	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Eagle Island	Civil	1	$ 39,600	1992	50	2042	36%	32	2	107	1	32	2042	0.90	29	2039	$ 42,269
	Sanitary Sewer	Sanitary Lift Station	Eagle Island	Force Main	1	$ 17,000	1992	50	2042	36%	32	2	107	1	32	2042	0.90	29	2039	$ 18,146
	Sanitary Sewer	Sanitary Lift Station	Eagle Island	Mechanical	1	$ 79,200	1992	30	2022	60%	12	2	107	1.1	15	2025	0.90	14	2024	$ 84,538
	Sanitary Sewer	Sanitary Lift Station	Eagle Island	Electrical	1	$ 79,200	1992	20	2012	90%	2	2	107	1.25	7	2017	0.90	6	2016	$ 84,538
	Sanitary Sewer	Sanitary Lift Station	Eagle Island	SCADA	1	$ 25,000	1992	20	2012	90%	2	2	107	1.25	7	2017	0.90	6	2016	$ 26,685

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	Sanitary Sewer	Sanitary Lift Station	Eastmont	Civil	1	$ 50,000	1976	50	2026	68%	16	3	218	0.9	11	2021	0.85	9	2019	$ 53,370
	Sanitary Sewer	Sanitary Lift Station	Eastmont	Force Main	1	$ 65,000	1976	50	2026	68%	16	3	218	0.9	11	2021	0.85	9	2019	$ 69,381
	Sanitary Sewer	Sanitary Lift Station	Eastmont	Mechanical	1	$ 100,000	1976	30	2006	113%	-4	3	218	1.2	6	2016	0.85	5	2015	$ 106,740
	Sanitary Sewer	Sanitary Lift Station	Eastmont	Electrical	1	$ 100,000	1976	20	1996	170%	-14	3	218	1.2	4	2014	0.85	3	2013	$ 106,740
	Sanitary Sewer	Sanitary Lift Station	Eastmont	SCADA	1	$ -	1976	20	1996	170%	-14	3.66	218	1.2	4	2014	0.85	3	2013	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Ferndale	Civil	1	$ 72,000	2003	50	2053	14%	43	1	951	1	43	2053	0.85	37	2047	$ 76,853
	Sanitary Sewer	Sanitary Lift Station	Ferndale	Force Main	1	$ 95,000	2003	50	2053	14%	43	1	951	1	43	2053	0.85	37	2047	$ 101,403
	Sanitary Sewer	Sanitary Lift Station	Ferndale	Mechanical	1	$ 144,000	2003	30	2033	23%	23	1	951	1	23	2033	0.85	20	2030	$ 153,706
	Sanitary Sewer	Sanitary Lift Station	Ferndale	Electrical	1	$ 144,000	2003	20	2023	35%	13	1.25	951	1	13	2023	0.85	11	2021	$ 153,706
	Sanitary Sewer	Sanitary Lift Station	Ferndale	SCADA	1	$ 36,000	2003	20	2023	35%	13	1	951	1	13	2023	0.85	11	2021	$ 38,426
	Sanitary Sewer	Sanitary Lift Station	Foot of 31st	Civil	1	$ 32,000	1971	50	2021	78%	11	3	46	1.1	16	2026	1.00	16	2026	$ 34,157
	Sanitary Sewer	Sanitary Lift Station	Foot of 31st	Force Main	1	$ 23,000	1971	50	2021	78%	11	2.5	46	1.2	21	2031	1.00	21	2031	$ 24,550
	Sanitary Sewer	Sanitary Lift Station	Foot of 31st	Mechanical	1	$ 64,000	1992	30	2022	60%	12	2	46	1.1	15	2025	1.00	15	2025	$ 68,314
	Sanitary Sewer	Sanitary Lift Station	Foot of 31st	Electrical	1	$ 64,000	1971	20	1991	195%	-19	2	46	1.3	6	2016	1.00	6	2016	$ 68,314
	Sanitary Sewer	Sanitary Lift Station	Foot of 31st	SCADA	1	$ 25,000	1971	20	1991	195%	-19	2	46	1.3	6	2016	1.00	6	2016	$ 26,685
	Sanitary Sewer	Sanitary Lift Station	Garrow	Civil	1	$ 15,000	1976	50	2026	68%	16	4	26	0.75	4	2014	1.00	4	2014	$ 16,011
	Sanitary Sewer	Sanitary Lift Station	Garrow	Force Main	1	$ 14,000	1976	50	2026	68%	16	3	26	0.9	11	2021	1.00	11	2021	$ 14,944
	Sanitary Sewer	Sanitary Lift Station	Garrow	Mechanical	1	$ 30,000	1976	30	2006	113%	-4	3	26	1.2	6	2016	1.00	6	2016	$ 32,022
	Sanitary Sewer	Sanitary Lift Station	Garrow	Electrical	1	$ 30,000	1976	20	1996	170%	-14	2	26	1.3	6	2016	1.00	6	2016	$ 32,022
	Sanitary Sewer	Sanitary Lift Station	Garrow	SCADA	1	$ -	1976	20	1996	170%	-14	2	26	1.3	6	2016	1.00	6	2016	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Gleneagles	Civil	1	$ 21,600	1981	50	2031	58%	21	2	20	1.1	26	2036	1.05	27	2037	$ 23,056
	Sanitary Sewer	Sanitary Lift Station	Gleneagles	Force Main	1	$ 19,000	1981	50	2031	58%	21	2	20	1.1	26	2036	1.05	27	2037	$ 20,281
	Sanitary Sewer	Sanitary Lift Station	Gleneagles	Mechanical	1	$ 43,200	1981	30	2011	97%	1	3	20	1.15	6	2016	1.05	6	2016	$ 46,112
	Sanitary Sewer	Sanitary Lift Station	Gleneagles	Electrical	1	$ 43,200	1981	20	2001	145%	-9	3	20	1.2	4	2014	1.05	4	2014	$ 46,112
	Sanitary Sewer	Sanitary Lift Station	Gleneagles	SCADA	1	$ -	1981	20	2001	145%	-9	3	20	1.2	4	2014	1.05	4	2014	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Gleneagles Pl.	Civil	1	$ 31,000	1993	50	2043	34%	33	2	23	1	33	2043	1.00	33	2043	$ 33,089
	Sanitary Sewer	Sanitary Lift Station	Gleneagles Pl.	Force Main	1	$ 13,000	1993	50	2043	34%	33	2	23	1	33	2043	1.00	33	2043	$ 13,876
	Sanitary Sewer	Sanitary Lift Station	Gleneagles Pl.	Mechanical	1	$ 62,000	1993	30	2023	57%	13	2	23	1.1	16	2026	1.00	16	2026	$ 66,179
	Sanitary Sewer	Sanitary Lift Station	Gleneagles Pl.	Electrical	1	$ 62,000	1993	20	2013	85%	3	2	23	1.2	7	2017	1.00	7	2017	$ 66,179
	Sanitary Sewer	Sanitary Lift Station	Gleneagles Pl.	SCADA	1	$ -	1993	20	2013	85%	3	2	23	1.2	7	2017	1.00	7	2017	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Glenwynd	Civil	1	$ 15,000	1980	50	2030	60%	20	2	15	1.1	25	2035	1.05	26	2036	$ 16,011
	Sanitary Sewer	Sanitary Lift Station	Glenwynd	Force Main	1	$ 10,000	1980	50	2030	60%	20	2	15	1.1	25	2035	1.05	26	2036	$ 10,674
	Sanitary Sewer	Sanitary Lift Station	Glenwynd	Mechanical	1	$ 30,000	1980	30	2010	100%	0	3	15	1.2	6	2016	1.05	6	2016	$ 32,022
	Sanitary Sewer	Sanitary Lift Station	Glenwynd	Electrical	1	$ 30,000	1980	20	2000	150%	-10	3.25	15	1.2	4	2014	1.05	4	2014	$ 32,022
	Sanitary Sewer	Sanitary Lift Station	Glenwynd	SCADA	1	$ -	1980	20	2000	150%	-10	3	15	1.2	4	2014	1.05	4	2014	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Gulf East	Civil	1	$ 21,600	1978	50	2028	64%	18	3	44	0.9	13	2023	1.00	13	2023	$ 23,056
	Sanitary Sewer	Sanitary Lift Station	Gulf East	Force Main	1	$ 14,000	1978	50	2028	64%	18	3	44	0.9	13	2023	1.00	13	2023	$ 14,944
	Sanitary Sewer	Sanitary Lift Station	Gulf East	Mechanical	1	$ 43,200	1978	30	2008	107%	-2	3	44	1.2	6	2016	1.00	6	2016	$ 46,112
	Sanitary Sewer	Sanitary Lift Station	Gulf East	Electrical	1	$ 43,200	1978	20	1998	160%	-12	3	44	1.2	4	2014	1.00	4	2014	$ 46,112
	Sanitary Sewer	Sanitary Lift Station	Gulf East	SCADA	1	$ -	1978	20	1998	160%	-12	3	44	1.2	4	2014	1.00	4	2014	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Gulf West	Civil	1	$ 21,600	1978	50	2028	64%	18	3	38	0.9	13	2023	1.00	13	2023	$ 23,056
	Sanitary Sewer	Sanitary Lift Station	Gulf West	Force Main	1	$ 23,000	1978	50	2028	64%	18	3	38	0.9	13	2023	1.00	13	2023	$ 24,550

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	Sanitary Sewer	Sanitary Lift Station	Gulf West	Mechanical	1	$ 43,200	1978	30	2008	107%	-2	3	38	1.2	6	2016	1.00	6	2016	$ 46,112
	Sanitary Sewer	Sanitary Lift Station	Gulf West	Electrical	1	$ 43,200	1978	20	1998	160%	-12	3	38	1.2	4	2014	1.00	4	2014	$ 46,112
	Sanitary Sewer	Sanitary Lift Station	Gulf West	SCADA	1	$ -	1978	20	1998	160%	-12	3	38	1.2	4	2014	1.00	4	2014	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Happy Valley	Civil	1	$ 61,000	1976	50	2026	68%	16	3	168	0.9	11	2021	0.90	10	2020	$ 65,111
	Sanitary Sewer	Sanitary Lift Station	Happy Valley	Force Main	1	$ 60,000	1976	50	2026	68%	16	3	168	0.9	11	2021	0.90	10	2020	$ 64,044
	Sanitary Sewer	Sanitary Lift Station	Happy Valley	Mechanical	1	$ 122,000	1976	30	2006	113%	-4	3	168	1.2	6	2016	0.90	5	2015	$ 130,223
	Sanitary Sewer	Sanitary Lift Station	Happy Valley	Electrical	1	$ 122,000	1976	20	1996	170%	-14	3	168	1.2	4	2014	0.90	4	2014	$ 130,223
	Sanitary Sewer	Sanitary Lift Station	Happy Valley	SCADA	1	$ -	1976	20	1996	170%	-14	3.66	168	1.2	4	2014	0.90	4	2014	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Imperial	Civil	1	$ 50,000	1976	50	2026	68%	16	3	203	0.9	11	2021	0.85	9	2019	$ 53,370
	Sanitary Sewer	Sanitary Lift Station	Imperial	Force Main	1	$ 18,000	1976	50	2026	68%	16	3	203	0.9	11	2021	0.85	9	2019	$ 19,213
	Sanitary Sewer	Sanitary Lift Station	Imperial	Mechanical	1	$ 100,000	1976	30	2006	113%	-4	3	203	1.2	6	2016	0.85	5	2015	$ 106,740
	Sanitary Sewer	Sanitary Lift Station	Imperial	Electrical	1	$ 100,000	1976	20	1996	170%	-14	3	203	1.2	4	2014	0.85	3	2013	$ 106,740
	Sanitary Sewer	Sanitary Lift Station	Imperial	SCADA	1	$ -	1976	20	1996	170%	-14	3	203	1.2	4	2014	0.85	3	2013	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Isleview	Civil	1	$ 15,000	1976	50	2026	68%	16	4	46	0.75	4	2014	1.00	4	2014	$ 16,011
	Sanitary Sewer	Sanitary Lift Station	Isleview	Force Main	1	$ 23,000	1976	50	2026	68%	16	3	46	0.9	11	2021	1.00	11	2021	$ 24,550
	Sanitary Sewer	Sanitary Lift Station	Isleview	Mechanical	1	$ 30,000	1976	30	2006	113%	-4	3	46	1.2	6	2016	1.00	6	2016	$ 32,022
	Sanitary Sewer	Sanitary Lift Station	Isleview	Electrical	1	$ 30,000	1976	20	1996	170%	-14	3	46	1.2	4	2014	1.00	4	2014	$ 32,022
	Sanitary Sewer	Sanitary Lift Station	Isleview	SCADA	1	$ -	1976	20	1996	170%	-14	3	46	1.2	4	2014	1.00	4	2014	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Kew	Civil	1	$ 40,000	1976	50	2026	68%	16	3	105	0.9	11	2021	0.90	10	2020	$ 42,696
	Sanitary Sewer	Sanitary Lift Station	Kew	Force Main	1	$ 40,000	1976	50	2026	68%	16	3.5	105	0.9	11	2021	0.90	10	2020	$ 42,696
	Sanitary Sewer	Sanitary Lift Station	Kew	Mechanical	1	$ 80,000	1976	30	2006	113%	-4	3	105	1.2	6	2016	0.90	5	2015	$ 85,392
	Sanitary Sewer	Sanitary Lift Station	Kew	Electrical	1	$ 80,000	1976	20	1996	170%	-14	2.66	105	1.3	6	2016	0.90	5	2015	$ 85,392
	Sanitary Sewer	Sanitary Lift Station	Kew	SCADA	1	$ -	1976	20	1996	170%	-14	3.66	105	1.2	4	2014	0.90	4	2014	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Klahanie	Civil	1	$ 5,800	2003	50	2053	14%	43	1	3	1	43	2053	1.05	45	2055	$ 6,191
	Sanitary Sewer	Sanitary Lift Station	Klahanie	Force Main	1	$ 46,000	2003	50	2053	14%	43	1.25	3	1	43	2053	1.05	45	2055	$ 49,100
	Sanitary Sewer	Sanitary Lift Station	Klahanie	Mechanical	1	$ 11,600	2003	30	2033	23%	23	1	3	1	23	2033	1.05	24	2034	$ 12,382
	Sanitary Sewer	Sanitary Lift Station	Klahanie	Electrical	1	$ 11,600	2003	20	2023	35%	13	1	3	1	13	2023	1.05	14	2024	$ 12,382
	Sanitary Sewer	Sanitary Lift Station	Klahanie	SCADA	1	$ -	2003	20	2023	35%	13	1	3	1	13	2023	1.05	14	2024	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Marine & Beach	Civil	1	$ 27,000	1971	50	2021	78%	11	4	81	0.9	6	2016	0.95	6	2016	$ 28,820
	Sanitary Sewer	Sanitary Lift Station	Marine & Beach	Force Main	1	$ 13,000	1971	50	2021	78%	11	4	81	0.9	6	2016	0.95	6	2016	$ 13,876
	Sanitary Sewer	Sanitary Lift Station	Marine & Beach	Mechanical	1	$ 54,000	1971	30	2001	130%	-9	4	81	1	0	2010	0.95	0	2010	$ 57,640
	Sanitary Sewer	Sanitary Lift Station	Marine & Beach	Electrical	1	$ 54,000	1971	20	1991	195%	-19	4	81	1	0	2010	0.95	0	2010	$ 57,640
	Sanitary Sewer	Sanitary Lift Station	Marine & Beach	SCADA	1	$ 30,000	1988	20	2008	110%	-2	4	81	1	0	2010	0.95	0	2010	$ 32,022
	Sanitary Sewer	Sanitary Lift Station	Park Lane	Civil	1	$ 31,000	1991	50	2041	38%	31	2	20	1	31	2041	1.05	33	2043	$ 33,089
	Sanitary Sewer	Sanitary Lift Station	Park Lane	Force Main	1	$ 7,000	1991	50	2041	38%	31	2	20	1	31	2041	1.05	33	2043	$ 7,472
	Sanitary Sewer	Sanitary Lift Station	Park Lane	Mechanical	1	$ 62,000	1991	30	2021	63%	11	2	20	1.1	14	2024	1.05	15	2025	$ 66,179
	Sanitary Sewer	Sanitary Lift Station	Park Lane	Electrical	1	$ 62,000	1991	20	2011	95%	1	2	20	1.25	6	2016	1.05	6	2016	$ 66,179
	Sanitary Sewer	Sanitary Lift Station	Park Lane	SCADA	1	$ 25,000	1991	20	2011	95%	1	2	20	1.25	6	2016	1.05	6	2016	$ 26,685
	Sanitary Sewer	Sanitary Lift Station	Parthenon	Civil	1	$ 41,000	1976	50	2026	68%	16	3	52	0.9	11	2021	0.95	10	2020	$ 43,763
	Sanitary Sewer	Sanitary Lift Station	Parthenon	Force Main	1	$ 33,000	1976	50	2026	68%	16	3.5	52	0.9	11	2021	0.95	10	2020	$ 35,224
	Sanitary Sewer	Sanitary Lift Station	Parthenon	Mechanical	1	$ 82,000	1976	30	2006	113%	-4	3	52	1.2	6	2016	0.95	6	2016	$ 87,527
	Sanitary Sewer	Sanitary Lift Station	Parthenon	Electrical	1	$ 82,000	1976	20	1996	170%	-14	3	52	1.2	4	2014	0.95	4	2014	$ 87,527

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	Sanitary Sewer	Sanitary Lift Station	Parthenon	SCADA	1	$ -	1976	20	1996	170%	-14	4	52	1	0	2010	0.95	0	2010	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Picadilly	Civil	1	$ 60,000	1976	50	2026	68%	16	3	340	0.9	11	2021	0.85	9	2019	$ 64,044
	Sanitary Sewer	Sanitary Lift Station	Picadilly	Force Main	1	$ 24,000	1976	50	2026	68%	16	3	340	0.9	11	2021	0.85	9	2019	$ 25,618
	Sanitary Sewer	Sanitary Lift Station	Picadilly	Mechanical	1	$ 120,000	1976	30	2006	113%	-4	3	340	1.2	6	2016	0.85	5	2015	$ 128,088
	Sanitary Sewer	Sanitary Lift Station	Picadilly	Electrical	1	$ 120,000	1976	20	1996	170%	-14	3	340	1.2	4	2014	0.85	3	2013	$ 128,088
	Sanitary Sewer	Sanitary Lift Station	Picadilly	SCADA	1	$ -	1976	20	1996	170%	-14	3	340	1.2	4	2014	0.85	3	2013	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Pilot House Road	Civil	1	$ 12,000	1976	50	2026	68%	16	2	6	1.1	21	2031	1.05	22	2032	$ 12,809
	Sanitary Sewer	Sanitary Lift Station	Pilot House Road	Force Main	1	$ 7,000	1976	50	2026	68%	16	2	6	1.1	21	2031	1.05	22	2032	$ 7,472
	Sanitary Sewer	Sanitary Lift Station	Pilot House Road	Mechanical	1	$ 24,000	1976	30	2006	113%	-4	2	6	1.3	9	2019	1.05	9	2019	$ 25,618
	Sanitary Sewer	Sanitary Lift Station	Pilot House Road	Electrical	1	$ 24,000	1976	20	1996	170%	-14	2	6	1.3	6	2016	1.05	6	2016	$ 25,618
	Sanitary Sewer	Sanitary Lift Station	Pilot House Road	SCADA	1	$ -	1976	20	1996	170%	-14	2	6	1.3	6	2016	1.05	6	2016	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Pitcairn	Civil	1	$ 21,600	1977	50	2027	66%	17	3	35	0.9	12	2022	1.00	12	2022	$ 23,056
	Sanitary Sewer	Sanitary Lift Station	Pitcairn	Force Main	1	$ 15,000	1977	50	2027		17	3	35	0.8	7	2017	1.00	7	2017	$ 16,011
	Sanitary Sewer	Sanitary Lift Station	Pitcairn	Mechanical	1	$ 43,200	1977	30	2007	110%	-3	3	35	1.2	6	2016	1.00	6	2016	$ 46,112
	Sanitary Sewer	Sanitary Lift Station	Pitcairn	Electrical	1	$ 43,200	1977	20	1997	165%	-13	3	35	1.2	4	2014	1.00	4	2014	$ 46,112
	Sanitary Sewer	Sanitary Lift Station	Pitcairn	SCADA	1	$ -	1977	20	1997	165%	-13	3	35	1.2	4	2014	1.00	4	2014	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Radcliffe #1	Civil	1	$ 30,000	1987	50	2037	46%	27	2	99	1	27	2037	0.95	26	2036	$ 32,022
	Sanitary Sewer	Sanitary Lift Station	Radcliffe #1	Force Main	1	$ 8,000	1987	50	2037	46%	27	2	99	1	27	2037	0.95	26	2036	$ 8,539
	Sanitary Sewer	Sanitary Lift Station	Radcliffe #1	Mechanical	1	$ 60,000	1987	30	2017	77%	7	2	99	1.2	13	2023	0.95	12	2022	$ 64,044
	Sanitary Sewer	Sanitary Lift Station	Radcliffe #1	Electrical	1	$ 60,000	1987	20	2007	115%	-3	2	99	1.3	6	2016	0.95	6	2016	$ 64,044
	Sanitary Sewer	Sanitary Lift Station	Radcliffe #1	SCADA	1	$ -	1987	20	2007	115%	-3	2	99	1.3	6	2016	0.95	6	2016	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Radcliffe #3	Civil	1	$ 30,000	1971	50	2021	78%	11	4	15	0.9	6	2016	1.05	6	2016	$ 32,022
	Sanitary Sewer	Sanitary Lift Station	Radcliffe #3	Force Main	1	$ 6,000	1971	50	2021	78%	11	4	15	0.9	6	2016	1.05	6	2016	$ 6,404
	Sanitary Sewer	Sanitary Lift Station	Radcliffe #3	Mechanical	1	$ 60,000	1971	30	2001	130%	-9	4	15	1	0	2010	1.05	0	2010	$ 64,044
	Sanitary Sewer	Sanitary Lift Station	Radcliffe #3	Electrical	1	$ 60,000	1971	20	1991	195%	-19	4	15	1	0	2010	1.05	0	2010	$ 64,044
	Sanitary Sewer	Sanitary Lift Station	Radcliffe #3	SCADA	1	$ -	1971	20	1991	195%	-19	4	15	1	0	2010	1.05	0	2010	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Radcliffe #4	Civil	1	$ 40,000	1991	50	2041	38%	31	2	181	1	31	2041	0.90	28	2038	$ 42,696
	Sanitary Sewer	Sanitary Lift Station	Radcliffe #4	Force Main	1	$ 10,000	1991	50	2041	38%	31	2.25	181	1	31	2041	0.90	28	2038	$ 10,674
	Sanitary Sewer	Sanitary Lift Station	Radcliffe #4	Mechanical	1	$ 80,000	2002	30	2032	27%	22	1	181	1	22	2032	0.90	20	2030	$ 85,392
	Sanitary Sewer	Sanitary Lift Station	Radcliffe #4	Electrical	1	$ 80,000	1991	20	2011	95%	1	2	181	1.25	6	2016	0.90	5	2015	$ 85,392
	Sanitary Sewer	Sanitary Lift Station	Radcliffe #4	SCADA	1	$ 25,000	1991	20	2011	95%	1	2	181	1.25	6	2016	0.90	5	2015	$ 26,685
	Sanitary Sewer	Sanitary Lift Station	Rockend	Civil	1	$ 16,000	1980	50	2030	60%	20	3	26	0.9	15	2025	1.00	15	2025	$ 17,078
	Sanitary Sewer	Sanitary Lift Station	Rockend	Force Main	1	$ 15,000	1980	50	2030	60%	20	3	26	0.9	15	2025	1.00	15	2025	$ 16,011
	Sanitary Sewer	Sanitary Lift Station	Rockend	Mechanical	1	$ 32,000	1980	30	2010	100%	0	3	26	1.2	6	2016	1.00	6	2016	$ 34,157
	Sanitary Sewer	Sanitary Lift Station	Rockend	Electrical	1	$ 32,000	1980	20	2000	150%	-10	3	26	1.2	4	2014	1.00	4	2014	$ 34,157
	Sanitary Sewer	Sanitary Lift Station	Rockend	SCADA	1	$ -	1980	20	2000	150%	-10	3	26	1.2	4	2014	1.00	4	2014	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Saint Georges	Civil	1	$ 50,000	1976	50	2026	68%	16	3	163	0.9	11	2021	0.90	10	2020	$ 53,370
	Sanitary Sewer	Sanitary Lift Station	Saint Georges	Force Main	1	$ 20,000	1976	50	2026	68%	16	3	163	0.9	11	2021	0.90	10	2020	$ 21,348
	Sanitary Sewer	Sanitary Lift Station	Saint Georges	Mechanical	1	$ 100,000	1976	30	2006	113%	-4	3	163	1.2	6	2016	0.90	5	2015	$ 106,740
	Sanitary Sewer	Sanitary Lift Station	Saint Georges	Electrical	1	$ 100,000	1976	20	1996	170%	-14	3	163	1.2	4	2014	0.90	4	2014	$ 106,740
	Sanitary Sewer	Sanitary Lift Station	Saint Georges	SCADA	1	$ -	1976	20	1996	170%	-14	3	163	1.2	4	2014	0.90	4	2014	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Seaside	Civil	1	$ 40,000	1986	50	2036	48%	26	3	44	0.8	16	2026	1.00	16	2026	$ 42,696

Asset #	Asset Group	Asset Type	Asset Name	Asset Component	Quantity or Length in m	2006 Replacement value (Unit Cost in CAD)	Date in Service	Expected Service Life (yrs)	Expected Replacement Year	% of Expected Service Life Used	Remaining service life (yrs)	Condition Rating (1=good, 5=poor)	Tributary Population	Condition adjustment factor	Condition Adjusted Remaining Service Life	Condition adjusted replacement year	Criticality adjustment factor	Criticality & Condition Adjusted Remaining Service Life	Condition and Criticality Adjusted Replacement Year	2009 Replacement Value
	Sanitary Sewer	Sanitary Lift Station	Seaside	Force Main	1	$ 25,000	1986	50	2036	48%	26	3	44	0.8	16	2026	1.00	16	2026	$ 26,685
	Sanitary Sewer	Sanitary Lift Station	Seaside	Mechanical	1	$ 80,000	1986	30	2016	80%	6	3	44	1.1	9	2019	1.00	9	2019	$ 85,392
	Sanitary Sewer	Sanitary Lift Station	Seaside	Electrical	1	$ 80,000	1986	20	2006	120%	-4	2.5	44	1.3	6	2016	1.00	6	2016	$ 85,392
	Sanitary Sewer	Sanitary Lift Station	Seaside	SCADA	1	$ -	1986	20	2006	120%	-4	3.66	44	1.2	4	2014	1.00	4	2014	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Seawalk	Civil	1	$ 26,800	2003	50	2053	14%	43	1	103	1	43	2053	0.90	39	2049	$ 28,606
	Sanitary Sewer	Sanitary Lift Station	Seawalk	Force Main	1	$ 9,000	2003	50	2053	14%	43	1	103	1	43	2053	0.90	39	2049	$ 9,607
	Sanitary Sewer	Sanitary Lift Station	Seawalk	Mechanical	1	$ 53,600	2003	30	2033	23%	23	1	103	1	23	2033	0.90	21	2031	$ 57,213
	Sanitary Sewer	Sanitary Lift Station	Seawalk	Electrical	1	$ 53,600	2003	20	2023	35%	13	1	103	1	13	2023	0.90	12	2022	$ 57,213
	Sanitary Sewer	Sanitary Lift Station	Seawalk	SCADA	1	$ 17,000	2005	20	2025	25%	15	1	103	1	15	2025	0.90	14	2024	$ 18,146
	Sanitary Sewer	Sanitary Lift Station	South Oxley	Civil	1	$ 8,400	1977	50	2027	66%	17	2	12	1.1	22	2032	1.05	23	2033	$ 8,966
	Sanitary Sewer	Sanitary Lift Station	South Oxley	Force Main	1	$ 17,000	1977	50	2027	66%	17	3	12	0.9	12	2022	1.05	13	2023	$ 18,146
	Sanitary Sewer	Sanitary Lift Station	South Oxley	Mechanical	1	$ 16,800	1977	30	2007	110%	-3	3	12	1.2	6	2016	1.05	6	2016	$ 17,932
	Sanitary Sewer	Sanitary Lift Station	South Oxley	Electrical	1	$ 16,800	1977	20	1997	165%	-13	3	12	1.2	4	2014	1.05	4	2014	$ 17,932
	Sanitary Sewer	Sanitary Lift Station	South Oxley	SCADA	1	$ -	1977	20	1997	165%	-13	3	12	1.2	4	2014	1.05	4	2014	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Stone Crescent	Civil	1	$ 16,000	1977	50	2027	66%	17	3	26	0.9	12	2022	1.00	12	2022	$ 17,078
	Sanitary Sewer	Sanitary Lift Station	Stone Crescent	Force Main	1	$ 7,000	1977	50	2027	66%	17	3	26	0.9	12	2022	1.00	12	2022	$ 7,472
	Sanitary Sewer	Sanitary Lift Station	Stone Crescent	Mechanical	1	$ 32,000	1977	30	2007	110%	-3	3	26	1.2	6	2016	1.00	6	2016	$ 34,157
	Sanitary Sewer	Sanitary Lift Station	Stone Crescent	Electrical	1	$ 32,000	1977	20	1997	165%	-13	3.66	26	1.2	4	2014	1.00	4	2014	$ 34,157
	Sanitary Sewer	Sanitary Lift Station	Stone Crescent	SCADA	1	$ -	1977	20	1997	165%	-13	3	26	1.2	4	2014	1.00	4	2014	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Suicide Bend	Civil	1	$ 64,000	1988	50	2038	44%	28	2	256	1	28	2038	0.85	24	2034	$ 68,314
	Sanitary Sewer	Sanitary Lift Station	Suicide Bend	Force Main	1	$ 10,000	1988	50	2038	44%	28	2.5	256	1	28	2038	0.85	24	2034	$ 10,674
	Sanitary Sewer	Sanitary Lift Station	Suicide Bend	Mechanical	1	$ 128,000	1988	30	2018	73%	8	2	256	1.1	11	2021	0.85	9	2019	$ 136,627
	Sanitary Sewer	Sanitary Lift Station	Suicide Bend	Electrical	1	$ 128,000	1988	20	2008	110%	-2	2	256	1.3	6	2016	0.85	5	2015	$ 136,627
	Sanitary Sewer	Sanitary Lift Station	Suicide Bend	SCADA	1	$ 35,000	1988	20	2008	110%	-2	2	256	1.3	6	2016	0.85	5	2015	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Taylor	Civil	1	$ 40,000	1976	50	2026	68%	16	3	67	0.9	11	2021	0.95	10	2020	$ 42,696
	Sanitary Sewer	Sanitary Lift Station	Taylor	Force Main	1	$ 37,000	1976	50	2026	68%	16	3	67	0.9	11	2021	0.95	10	2020	$ 39,494
	Sanitary Sewer	Sanitary Lift Station	Taylor	Mechanical	1	$ 80,000	1976	30	2006	113%	-4	3	67	1.2	6	2016	0.95	6	2016	$ 85,392
	Sanitary Sewer	Sanitary Lift Station	Taylor	Electrical	1	$ 80,000	1976	20	1996	170%	-14	3	67	1.2	4	2014	0.95	4	2014	$ 85,392
	Sanitary Sewer	Sanitary Lift Station	Taylor	SCADA	1	$ -	1976	20	1996	170%	-14	3.66	67	1.2	4	2014	0.95	4	2014	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	The Glen	Civil	1	$ 50,000	1976	50	2026	68%	16	3	178	0.9	11	2021	0.90	10	2020	$ 53,370
	Sanitary Sewer	Sanitary Lift Station	The Glen	Force Main	1	$ 35,000	1976	50	2026	68%	16	3	178	0.9	11	2021	0.90	10	2020	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	The Glen	Mechanical	1	$ 100,000	1976	30	2006	113%	-4	3	178	1.2	6	2016	0.90	5	2015	$ 106,740
	Sanitary Sewer	Sanitary Lift Station	The Glen	Electrical	1	$ 100,000	1976	20	1996	170%	-14	3	178	1.2	4	2014	0.90	4	2014	$ 106,740
	Sanitary Sewer	Sanitary Lift Station	The Glen	SCADA	1	$ -	1976	20	1996	170%	-14	3	178	1.2	4	2014	0.90	4	2014	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Westhaven	Civil	1	$ 40,000	1989	50	2039	42%	29	2	78	1	29	2039	0.95	28	2038	$ 42,696
	Sanitary Sewer	Sanitary Lift Station	Westhaven	Force Main	1	$ 36,000	1989	50	2039	42%	29	2	78	1	29	2039	0.95	28	2038	$ 38,426
	Sanitary Sewer	Sanitary Lift Station	Westhaven	Mechanical	1	$ 80,000	1989	30	2019	70%	9	2	78	1.1	12	2022	0.95	11	2021	$ 85,392
	Sanitary Sewer	Sanitary Lift Station	Westhaven	Electrical	1	$ 80,000	1989	20	2009	105%	-1	2	78	1.3	6	2016	0.95	6	2016	$ 85,392
	Sanitary Sewer	Sanitary Lift Station	Westhaven	SCADA	1	$ 35,000	1989	20	2009	105%	-1	2	78	1.3	6	2016	0.95	6	2016	$ 37,359
	Sanitary Sewer	Sanitary Lift Station	Woodvalley	Civil	1	$ 16,000	1977	50	2027	66%	17	4	23	0.75	5	2015	1.00	5	2015	$ 17,078
	Sanitary Sewer	Sanitary Lift Station	Woodvalley	Force Main	1	$ 14,000	1977	50	2027	66%	17	3	23	0.9	12	2022	1.00	12	2022	$ 14,944
	Sanitary Sewer	Sanitary Lift Station	Woodvalley	Mechanical	1	$ 32,000	1977	30	2007	110%	-3	3	23	1.2	6	2016	1.00	6	2016	$ 34,157

Asset #	Asset Group	Asset Type	Asset Name	Asset Component	Quantity or Length in m	2006 Replacement value (Unit Cost in CAD)	Date in Service	Expected Service Life (yrs)	Expected Replacement Year	% of Expected Service Life Used	Remaining service life (yrs)	Condition Rating (1=good, 5=poor)	Tributary Population	Condition adjustment factor	Condition Adjusted Remaining Service Life	Condition adjusted replacement year	Criticality adjustment factor	Criticality & Condition Adjusted Remaining Service Life	Condition and Criticality Adjusted Replacement Year	2009 Replacement Value
	Sanitary Sewer	Sanitary Lift Station	Woodvalley	Electrical	1	$ 32,000	1977	20	1997	165%	-13	3	23	1.2	4	2014	1.00	4	2014	$ 34,157
	Sanitary Sewer	Sanitary Lift Station	Woodvalley	SCADA	1	$ -	1977	20	1997	165%	-13	3	23	1.2	4	2014	1.00	4	2014	$ 37,359

Appendix B – Lift Station 10 Year Plan

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	TOTAL
Citrus Wynd WWTP	$ -	$ 7,500	$ -	$ 7,500	$ -	$ 7,500	$ -	$ 7,500	$ -	$ 7,500	$ 37,500
15th & Argyle	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
17th & Argyle	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
23rd	$ -	$ -	$ -	$ -	$ 150,717	$ -	$ -	$ -	$ -	$ -	$ 150,717
24th	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
25th	$ -	$ -	$ -	$ -	$ 150,503	$ -	$ 113,144	$ -	$ -	$ -	$ 263,648
28th	$ -	$ -	$ -	$ -	$ -	$ 111,010	$ -	$ -	$ -	$ -	$ 111,010
28th & Palmerston	$ -	$ -	$ -	$ -	$ -	$ -	$ 92,864	$ -	$ -	$ -	$ 92,864
3026 Marine	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
3176 Travers	$ 74,078	$ -	$ -	$ -	$ 36,719	$ -	$ 26,898	$ -	$ -	$ -	$ 137,695
31st & Travers	$ -	$ -	$ -	$ -	$ -	$ -	$ 64,044	$ 37,359	$ -	$ -	$ 101,403
3200 Marine	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Bedora	$ -	$ -	$ -	$ -	$ 85,605	$ -	$ -	$ -	$ -	$ -	$ 85,605
Blink Bonnie	$ -	$ -	$ -	$ -	$ 122,751	$ 85,392	$ -	$ -	$ -	$ -	$ 208,143
Bluebell	$ -	$ -	$ -	$ -	$ 46,112	$ -	$ 8,753	$ -	$ -	$ -	$ 54,864
Caulfield Court	$ -	$ -	$ -	$ -	$ -	$ -	$ 71,516	$ -	$ -	$ -	$ 71,516
Copper	$ -	$ -	$ -	$ 144,099	$ -	$ 106,740	$ -	$ -	$ -	$ 108,875	$ 359,714
Cotton A	$ -	$ -	$ -	$ 169,717	$ -	$ 132,358	$ -	$ -	$ -	$ 96,066	$ 398,140
Cotton B	$ -	$ -	$ -	$ 165,447	$ -	$ 128,088	$ -	$ -	$ -	$ 72,583	$ 366,118
Cove	$ -	$ -	$ -	$ 167,582	$ -	$ 130,223	$ -	$ -	$ -	$ 104,605	$ 402,410
Cypress Glen	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,751	$ -	$ -	$ -	$ 122,751
Dufferin A	$ -	$ -	$ -	$ 144,099	$ -	$ 106,740	$ -	$ -	$ -	$ 92,864	$ 343,703
Dufferin B	$ -	$ -	$ -	$ -	$ -	$ 186,795	$ -	$ -	$ -	$ 74,718	$ 261,513
Eagle Island	$ -	$ -	$ -	$ -	$ -	$ -	$ 111,223	$ -	$ -	$ -	$ 111,223
Eastmont	$ -	$ -	$ -	$ 144,099	$ -	$ 106,740	$ -	$ -	$ -	$ 122,751	$ 373,590
Ferndale	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Foot of 31st	$ -	$ -	$ -	$ -	$ -	$ -	$ 94,999	$ -	$ -	$ -	$ 94,999
Garrow	$ -	$ -	$ -	$ -	$ 16,011	$ -	$ 101,403	$ -	$ -	$ -	$ 117,414
Gleneagles	$ -	$ -	$ -	$ -	$ 83,471	$ -	$ 46,112	$ -	$ -	$ -	$ 129,582
Gleneagles Pl.	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 103,538	$ -	$ -	$ 103,538
Glenwynd	$ -	$ -	$ -	$ -	$ 69,381	$ -	$ 32,022	$ -	$ -	$ -	$ 101,403
Gulf East	$ -	$ -	$ -	$ -	$ 83,471	$ -	$ 46,112	$ -	$ -	$ -	$ 129,582
Gulf West	$ -	$ -	$ -	$ -	$ 83,471	$ -	$ 46,112	$ -	$ -	$ -	$ 129,582
Happy Valley	$ -	$ -	$ -	$ -	$ 167,582	$ 130,223	$ -	$ -	$ -	$ -	$ 297,805
Imperial	$ -	$ -	$ -	$ 144,099	$ -	$ 106,740	$ -	$ -	$ -	$ 72,583	$ 323,422
Isleview	$ -	$ -	$ -	$ -	$ 85,392	$ -	$ 32,022	$ -	$ -	$ -	$ 117,414
Kew	$ -	$ -	$ -	$ -	$ 37,359	$ 170,784	$ -	$ -	$ -	$ -	$ 208,143
Klahanie	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Marine & Beach	$ 147,301	$ -	$ -	$ -	$ -	$ -	$ 42,696	$ -	$ -	$ -	$ 189,997
Park Lane	$ -	$ -	$ -	$ -	$ -	$ -	$ 92,864	$ -	$ -	$ -	$ 92,864
Parthenon	$ 37,359	$ -	$ -	$ -	$ 87,527	$ -	$ 87,527	$ -	$ -	$ -	$ 212,413
Picadilly	$ -	$ -	$ -	$ 165,447	$ -	$ 128,088	$ -	$ -	$ -	$ 89,662	$ 383,197
Pilot House Road	$ -	$ -	$ -	$ -	$ -	$ -	$ 62,977	$ -	$ -	$ 25,618	$ 88,594
Pitcairn	$ -	$ -	$ -	$ -	$ 83,471	$ -	$ 46,112	$ 16,011	$ -	$ -	$ 145,593
Radcliffe #1	$ -	$ -	$ -	$ -	$ -	$ -	$ 101,403	$ -	$ -	$ -	$ 101,403
Radcliffe #3	$ 165,447	$ -	$ -	$ -	$ -	$ -	$ 38,426	$ -	$ -	$ -	$ 203,873
Radcliffe #4	$ -	$ -	$ -	$ -	$ -	$ 112,077	$ -	$ -	$ -	$ -	$ 112,077
Rockend	$ -	$ -	$ -	$ -	$ 71,516	$ -	$ 34,157	$ -	$ -	$ -	$ 105,673
Saint Georges	$ -	$ -	$ -	$ -	$ 144,099	$ 106,740	$ -	$ -	$ -	$ -	$ 250,839
Seaside	$ -	$ -	$ -	$ -	$ 37,359	$ -	$ 85,392	$ -	$ -	$ 85,392	$ 208,143
Seawalk	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
South Oxley	$ -	$ -	$ -	$ -	$ 55,291	$ -	$ 17,932	$ -	$ -	$ -	$ 73,224
Stone Crescent	$ -	$ -	$ -	$ -	$ 71,516	$ -	$ 34,157	$ -	$ -	$ -	$ 105,673
Suicide Bend	$ -	$ -	$ -	$ -	$ -	$ 173,986	$ -	$ -	$ -	$ 136,627	$ 310,613
Taylor	$ -	$ -	$ -	$ -	$ 122,751	$ -	$ 85,392	$ -	$ -	$ -	$ 208,143
The Glen	$ -	$ -	$ -	$ -	$ 144,099	$ 106,740	$ -	$ -	$ -	$ -	$ 250,839
Westhaven	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,751	$ -	$ -	$ -	$ 122,751
Woodvalley	$ -	$ -	$ -	$ -	$ 71,516	$ 17,078	$ 34,157	$ -	$ -	$ -	$ 122,751
TOTAL	**$ 424,185**	**$ 7,500**	**$ -**	**$ 1,252,088**	**$ 2,107,688**	**$ 2,154,041**	**$ 1,895,916**	**$ 164,408**	**$ -**	**$ 1,089,844**	**$ 9,095,670**

Civil		Mechanical	
Civil Electrical SCADA		Mechanical Electrical	
Civil Forcemain		Mechanical Electrical SCADA	
Electrical		Mechanical SCADA	
Electrical SCADA		SCADA	
Forcemain			

Appendix C – 2006-2008 Sewer Condition Assessment Program Reports

UMA | AECOM

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January 24, 2008 File Name: F438-008-00

Saleem Mahmood, P.Eng.
Project Engineer
District of West Vancouver
3755 Cypress Bowl Road
West Vancouver, BC
V7S 3E7

Dear Saleem:

Re: 2006 and 2007 Sewer Condition Assessment Program

1.0 Introduction

In 2006, the District of West Vancouver (the District) initiated a sewer condition assessment program of the gravity sanitary sewers within the Ambleside Basin IV area. Basin IV was identified in a 2005 study by UMA Engineering Ltd. (UMA) as the area with the highest sanitary sewer inspection priority within the municipality, based on factors including sewer age, socio-economic risks, reported basin-wide infiltration levels, and existing inventory gaps.

The District contracted Superior City Services Ltd. (Superior) to undertake the 2006 inspection program. From August to December 2006, Superior cleaned and inspected (via closed-circuit television (CCTV)) approximately 4.7km of sewers, to specifications provided to the District by UMA. Superior encountered problems with accessing lines and completing inspections within the assigned area, and due to scheduling issues were unable to complete the contract.

The District identified a new area within Basin IV for the 2007 condition assessment program, and contracted Mar-Tech Underground Service Ltd. (Mar-Tech) to undertake this work (identified as the Priority 2 area), as well as to complete the 2006 program (Priority 1 area). Mar-Tech completed approximately 4.1km of inspections from September to October 2007.

UMA was retained by the District to undertake the condition assessment of, and develop rehabilitation recommendations for, the sewers inspected under both the 2006 and 2007 programs. This letter report summarizes our findings of the structural and service condition of the inspected gravity sanitary sewers in both areas, as well as of observed infiltration. Our prioritized recommendations are also presented herein, complete with cost estimates and a hardcopy drawing.

2.0 Inspection Program

2.1 Study Area Sewers

As indicated by the District, the 2006/2007 study area has the following approximate boundaries:

- western boundary: 24th Street
- eastern boundary: 13th Street

- southern boundary: foreshore
- northern boundary:
    - 13th Street to 18th Street: Duchess Avenue
    - 18th Street to 19th Street: Fulton Avenue
    - 19th Street to 22nd Street: Gordon Avenue
    - 22nd Street to 24th Street: Haywood Avenue

The Metro Vancouver (formerly GVSDD/GVRD) trunk sewers within this area were excluded from the assessment. Also excluded were the Aquatic Centre sewers, due to ongoing construction in the area. Manhole assessments were also not undertaken, as the District had indicated that the manholes were previously inspected.

The inspected sewers range in size from 100mm to 250mm diameter, and consist of concrete, polyvinyl chloride (PVC), vitrified clay (VC), and asbestos cement (AC) pipe.

2.2 Manhole Numbering

The hardcopy sanitary sewer system drawings provided to Superior by the District for the 2006 program did not include any manhole numbers, as at that time the District did not have a numbering system that uniquely identifies each manhole within the municipality. Superior therefore assigned manhole numbers, adopting the following convention: 1S### or 1SC###, where:

- “1” denotes the first study area;
- “S” denotes sanitary manhole; and
- “SC” denotes sanitary cleanout.

The District has since assigned unique manhole numbers, which were provided to Mar-Tech for the 2007 program. All previous inspections completed by Superior are referenced in this report by the new manhole numbering system, with Superior’s numbering included to maintain a link between the District’s sewer system drawings and Superior’s inspection videos.

3.0 Sewer Condition Assessment

The CCTV inspection of mainline sewers was initiated in order to:

- Confirm the state of structural deterioration;
- Identify defects that could impair the ability of the sewer to perform at its intended level of service; and
- Identify potential infiltration sources.

3.1 Structural Condition Assessment

3.1.1 Methodology

The District administered the contracts with Superior and Mar-Tech, and forwarded subsequent hardcopy and digital inspection reports and data to UMA. The recorded inspection defect codes were uploaded directly into the UMA-developed Sewer Management System (SMS) software application. The SMS assigns structural defect scores to the individual defects recorded, in accordance with Water Research Centre (WRc) methodology. The SMS then converts the defect scores into a preliminary WRc Internal Condition Grade (ICG) value between 1 and 5, for each manhole-to-manhole segment. To convert the field inspections to preliminary ICGs, the application computes the following:

- The *peak score* of defects attained in any 1m length of sewer in the manhole-to-manhole reach;
- The *total score* for the manhole-to-manhole reach; and
- The *average or mean score* for the manhole-to-manhole reach.

This three-part screening of data identifies:

- Sewers with a reasonable risk of collapse in the short term due to a random event (identified by the peak score value);
- Lines with significant general deterioration (highlighted quickly by a review of the total reach score); and
- Lines with short reach lengths but significant deterioration (highlighted quickly by a review of the mean reach score).

Manhole-to-manhole reaches with ICGs of 1 and 2 generally require no further review, and their re-inspection frequency can be directly determined based on the consequences of a sewer collapse at that location. In our normal assessment process, detailed review of inspections is limited to sewer reaches with ICGs of 3 and higher. The purpose of this review is to convert the ICG to a final Structural Performance Grade (SPG) based on consideration of supplemental data, and to rationalize the most appropriate rehabilitation strategy for observed defects.

The conversion of ICGs to final SPGs includes consideration of the following factors:

- Review of collapse risk based on soil type and the potential for infiltration/exfiltration;
- Frequency of surcharging; and
- Significance of defects considering soil type and the potential for infiltration.

The final SPG that results from this procedure is a semi-quantitative indication of the potential for sewer collapse to occur in that particular reach of sewer. For illustrative purposes the implication of each SPG and the typical defects that may accompany it is summarized in the following table:

Table 3.1.1 - Implication of Structural Performance Grades

SPG	Implication	Typical Description (rigid pipe structures)
5	Collapsed or Collapse imminent	Already collapsed; or Deformation >10% and cracked, fractured or broken; or Extensive areas of missing pipe material.

SPG	Implication	Typical Description (rigid pipe structures)
4	Collapse likely in the near future	Deformation 5 – 10% and cracked, fractured or broken; or Broken or fractured; or Serious loss of level.
3	Collapse unlikely in the near future but further deterioration likely	Deformation 0 – 5% and cracked; or fractured; or Longitudinal/multiple cracking; or Occasional fractures; or Minor loss of level; or Badly made connections (sewer services).
2	Minimal collapse risk in the short term but potential for further deterioration	Circumferential cracking; or Moderate joint defects.
1	Acceptable structural condition	No structural defects.

3.1.2 Study Area Findings

The inspected sewers were found to be in fairly good structural condition, with approximately 19% of the total number of fully inspected runs from both areas having a SPG of 3 or higher. Table 3.1.2 summarizes the SPGs for both programs, for runs that were fully inspected (i.e. excluding incomplete inspections as discussed in Section 4.1.1). Although incomplete inspections are also included in the assessment, the SPGs are not reported as they may be artificially high given the shorter length, and therefore misrepresentative. Only 3% of the fully inspected runs scored a SPG of 4 or 5.

Table 3.1.2: Summary of Structural Performance Grades (SPGs)

			SPG				
Inspection Year	Diameter	MH to MH Segments	5	4	3	2	1
2006	150	47	1	4	13	9	20
	200	33	0	0	8	2	23
	Subtotal	**80**	**1**	**4**	**21**	**11**	**43**
2007	100	1	0	0	1	0	0
	150	41	0	0	2	1	38
	200	34	0	0	2	1	31
	250	7	0	0	0	0	7
	Subtotal	**83**	**0**	**0**	**5**	**2**	**76**
	Total	**163**	**1**	**4**	**26**	**13**	**119**

Structural defects are localized, and the more serious of these include holes, broken pipe, multiple fractures, and deformed pipe. In addition, there are recurring signs of general pipe material degradation (surface wear/spalling) throughout a number of the concrete pipe runs. Rehabilitation for these is not recommended at this time, but this should be reviewed when these sewers are next re-inspected (recommended in approximately 5 years).

Tables 5.1.1 and 5.1.2 provide recommendations for those runs scoring a SPG of 3 or higher, which currently warrant rehabilitation.

3.2 Service Condition Assessment

3.2.1 Methodology

In addition to the sewer structural assessment, it is important to review the service condition of the system, and specifically its inherent ability to provide its intended level of service. In a process similar to determining the Internal Condition Grade, UMA's SMS application assigns scores to service-related defects in accordance with WRc methodology. Service-related defects include conditions that may reduce the capacity of the sewer or exacerbate potential for blockages or infiltration, including: roots; encrustation; debris (silt or grease); and obstructions. The SMS calculates the Internal Service Grade (ISG) for each manhole-to-manhole run; again, a value from 1 to 5 that is based on the defect scoring.

3.2.2 Study Area Findings

Table 3.2.1 summarizes the ISGs for the fully inspected manhole-to-manhole runs in both inspection areas, again excluding incomplete inspections (see Section 4.1.1). Approximately 25% of these scored an ISG of 3 or higher, with 7% having an ISG of 4 or 5. Major service defects within the inspected sewers include blockages (obstructions or root masses), grease, and debris, which often resulted in incomplete inspections. Debris also tends to accumulate within a few metres of cleanouts, and in some cases is so significant that an external point repair may be required to remove the debris. Where there are no existing service connections upstream of the debris, we recommend that this be coordinated with other underground work. The District should implement a regular flushing program from the cleanouts to minimize debris accumulation. Recommendations are provided in Tables 5.1.1 and 5.1.2 for sewers with an ISG of 3 or higher.

Table 3.2.1: Summary of Internal Service Grades (ISGs)

Inspection Year	Diameter	MH to MH Segments	ISG 5	ISG 4	ISG 3	ISG 2	ISG 1
2006	150	47	3	4	16	10	14
	200	33	0	1	7	11	14
	Subtotal	**80**	**3**	**5**	**23**	**21**	**28**
2007	100	1	0	0	0	0	1
	150	41	0	2	6	8	25
	200	34	0	1	1	5	27
	250	7	0	0	0	1	6
	Subtotal	**83**	**0**	**3**	**7**	**14**	**59**
	Total	**163**	**3**	**8**	**30**	**35**	**87**

3.3 Mainline Infiltration

CCTV inspections are also useful in identifying the infiltration component of Inflow and Infiltration (I & I) in sewers. Infiltration is defined by the WRc as "the ingress of groundwater through a defect or faulty joint", and is quantified at four levels of increasing severity:

- Seeper – The slow ingress of water through a defect or faulty joint;
- Dripper – Water dripping in through a defect or faulty joint;
- Runner – Water running in through a defect or faulty joint; and
- Gusher – Water entering the pipe "under pressure" through a defect or faulty joint.

The following table summarizes the identified occurrences of infiltration in the 2006 and 2007 programs, as well as the number of runs in which they occur.

Table 3.3.1: Summary of Occurrences of Infiltration

Degree of Infiltration	2006		2007		Total	
	No. of Occurrences	No. of Runs	No. of Occurrences	No. of Runs	No. of Occurrences	No. of Runs
Gusher	1	1	1	1	2	2
Runner	10	5	1	1	11	6
Dripper	1	1	1	1	2	2
Seeper	27	15	12	9	39	24

Tables 5.1.1 and 5.1.2 provide recommendations for runs with identified infiltration gushers and runners, and for drippers or seepers where they occur through structural defects (e.g. fractures).

4.0 Additional Findings

4.1 Uninspected Sewers/Incomplete Inspections

The District provided UMA with a map and boundary descriptions for the 2006 and 2007 programs. Based on these, and excluding the Metro Vancouver and Aquatic Centre runs, there appears to still be a number of outstanding and incomplete inspections. There are 24 uninspected manhole-to-manhole runs, and the reasons for these missing inspections may include:

- A gap between the 2006 program and the Priority 1 area work of the 2007 program;
- Inaccessible or unlocated manholes/cleanouts;
- Sewer configurations differing from the plans, with some lines possibly not existing; and
- Difficult camera access due to manhole benching, runs ending in a cleanout or at a mainline without a manhole, or heavy debris.

The manholes and cleanouts for these runs should be located, benching and debris removed where required, and the sewers cleaned and inspected. These lines are listed in Table 5.1.3.

Incomplete inspections are denoted by the WRc defect code “SA” for “survey abandoned”. The majority of the survey abandoned runs do not have corresponding inspections for the reverse run, or have incomplete reverse inspections. Reasons for the SA code include the camera’s inability to pass:

- Obstructions;
- Roots;
- Debris;
- Grease;
- Bends in the sewer alignment; and
- Intruding service connections.

Again, several of the incomplete inspections are due to inaccessible/unlocated manholes and difficult camera access into the runs. Where possible, obstructions should be removed, debris flushed, and roots, grease and intruding connections cut to enable completion of these runs. Re-cleaning from the cleanouts may be required, and inspection with smaller “push cameras” might also be necessary. A few runs had reportedly high flows and should be re-inspected during low flow times, or with flow control. Many of the survey abandoned runs are addressed in Tables 5.1.1 or 5.1.2, and the remainder are listed in Table 5.1.3.

4.2 Sewer Service Connections

Although our assessment is restricted to the mainline sewers, several defects within service connections/ junctions were noted during our review (see Table 5.1.4). These are primarily service-related, including significant roots and debris, often completely blocking the service. The District should investigate these to determine whether the services are still live, and if so, clear the blockages (either from inspection chambers, the mainline, or with external point repairs).

5.0 Recommendations

5.1 General Recommendations

The importance of clean sewers and good quality data to enable proper sewer condition assessment cannot be stressed enough. We recommend that for future programs, the District adopts a Quality Assurance program which includes requirements for regular contractor submittals, and continual review of inspection data, reports, and videos, for image quality, camera speed, proper coding, etc. To facilitate assignment of ICGs and ISGs, it is equally important that the submitted database is compliant with the specifications. The contractor should also provide total sewer lengths, as opposed to just inspected lengths, so the quantity of uninspected sewers is known.

Both contractors had noted difficulties with camera access in this area, and we recommend co-ordination with District crews to locate manholes/remove benching as required during the field investigation phase to reduce the number of missing or incomplete inspections.

The contractors also identified a number of unplotted and unnumbered manholes, and sewer runs that do not appear to exist as shown on the provided plans. The District should confirm these and update its digital GIS information accordingly.

5.2 Prioritized Rehabilitation Recommendations

The following tables summarize our recommendations for the 2006 and 2007 study areas:

- Table 5.1.1 – Addresses and prioritizes significant structural, service, and infiltration defects. The defects are all localized, and point repair technologies (either external or trenchless) are recommended with no full-segment rehabilitation required.
- Table 5.1.2 – Addresses and prioritizes less serious structural defects, maintenance or service-related defects, and occurrences of infiltration.
- Table 5.1.3 – Lists uninspected and survey abandoned runs which were not captured in the first two tables.
- Table 5.1.4 – Lists defects within service connections/junctions that were noted during review of the mainline sewers.

Recommendations from the first three tables are presented graphically on the enclosed hardcopy drawing, with a reference to the corresponding item number in Tables 5.1.1 and 5.1.2. The drawing also indicates manholes and cleanouts that require locating, as well as unplotted manholes/cleanouts encountered during inspections.

This planning level study is intended to assess the current sewer condition, and hence the accuracy of cost estimates is commensurate with this level of detail. Where applicable, cost estimates are provided and are based on unit costs developed from rehabilitation projects recently tendered in the Lower Mainland. However, further engineering is required to develop a rehabilitation construction program with refined cost estimates.

In viewing these tables, it is important to note the following:

- Defect locations should be verified prior to rehabilitation;
- Hydraulic capacity of the subject system was not reviewed by the study, but should be considered prior to undertaking any significant repairs;
- Liner thicknesses (for trenchless point repairs) are to be designed by an engineer for each specific location prior to application (Note: effect of liners on hydraulic capacity is not reviewed as part of the scope of the current assessment program and is particularly important where lining is identified for sewers of 150mm diameter or less);
- Where external point repairs are undertaken, the replacement pipe is to be of the same material and of similar characteristics as the existing pipe, where possible;
- Cost estimates exclude engineering;
- Costs for flushing, inspection, and cutting of grease, roots, and intruding connections are based on a fair-sized program (as opposed to individual call-outs);
- For the purposes of estimating costs, lengths have been scaled off the District's drawings for missing/incomplete inspections; and
- Locating/accessing manholes and cleanouts, and further investigation of lines that do not appear as per the plans is assumed to be undertaken by District crews, and associated costs excluded.

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Table 5.1.1 - Major Structural, Service and Infiltration-Related Defects

Item No.	Contractor	Inspection ID	Priority	Start Manhole (Superior MH No.)	Finish Manhole (Superior MH No.)	Diameter (mm)	Material	Length (m)	SPG (ISG)	Defect Observation	Proposed Action	Estimated Cost
1	Mar-Tech	7254-039	1	1504	1503	150	CO	30	4 (5)	17.4m: Survey abandoned due to 100% debris in pipe (potential collapse). Could not locate MH1503 for reverse run.	External point repair (EPR) at approx. 17.0m (complete reverse run and determine full extent of EPR). District crew to locate MH 1503.	$5,300
2	Mar-Tech	7254-019	1	869	7587	150	CO	31.0	1 (5)	4.0m to 5.5m: 40% to 90% roots. Survey abandoned at 5.5m due to root mass with potential structural damage. Could not locate MH 7587 for reverse run.	Root cut and re-inspect to determine structural condition. District crew to locate MH 7587.	$300
3	Superior	20	1	958 (1S014)	7514 (1SC015)	150	CO	64	5 (1)	22.1m: Broken and deformed pipe. Survey abandoned at 22.1m.	EPR at approx. 22.1m and complete inspection.	$5,650
4	Superior	104	1	1160 (1S149)	7413 (1S150)	150	AC	88	1 (5)	Survey abandoned at 53.4m due to 100% root mass	Cut roots and complete inspection	$900
5	Mar-Tech	7254-1012a	1	870	871	200	CO	65.5	1 (5)	63.6m: Survey abandoned due to 95% root mass	Root cut and re-inspect to determine structural condition	$650
6	Superior	112	1	1164 (1S133)	1118 (1S132)	150	AC	13	1 (5)	Survey abandoned at 0.1m due to 80% grease	Grease cut and re-inspect	$150
7	Mar-Tech	7254-1003a	1	330	347	150	CO	49	1 (4)	29.6m: Survey abandoned due to obstruction (possibly roots). Repeated flushing attempts unsuccessful at removing obstruction. Reverse run from MH 347 not completed as high water levels prevent inspection with push camera and MH 347 would require benching removal for a crawler camera access.	Root cut and re-inspect from MH 330 during low flows.	$500
8	Mar-Tech	7254-023	1	1919 (c/o)	Downstream	100	ZZZ	87.0	1 (5)	Ramp to underground parking. c/o MH 1919 submerged in water. 6.4m: Survey abandoned due to unknown obstruction. Unable to locate downstream manhole for reverse run.	District crew to investigate downstream manhole. Flush sewer and re-inspect with flow control. EPR at 6.4m may be required to remove obstruction.	Flush & CCTV: $900 EPR: $5,000
9	Mar-Tech	7254-053	1	336	335	150	CO	26.0	1 (3)	3.0m: 75% root mass	Root cut and re-inspect to determine structural condition	$250
10	Superior	64	2	1161 (1S138)	1159 (1S137)	150	CO	80.5	3 (3)	56.3m: Roots coming in from gap at service connection. 77.2m: Hole (approx. 10 to 11 clock reference).	Root cut and grout with lateral packer at approx. 56.3m. Grout and cured-in-place pipe trenchless point repair (CIPP TPR) approx. 76.7 to 77.7m	$8,100
11	Superior	62	2	1125 (1S117)	1126 (1S118)	150	CO	108	4 (3)	108.1m: Hole (approx. 8 to 3 clock reference) with circumferential fracture	CIPP TPR approx. 106.9.m to 108.4m (MH) and grout behind liner	$5,000
12	Superior	66	2	1163 (1S151)	1163A (1SC152)	150	VC	79	4 (3)	5.3m: Small hole (image unclear). 8.1m: Hole with possible surface spalling (image unclear). 9.9m to 10.8m: Broken pipe and multiple fractures. Survey abandoned at 10.9m.	Re-inspect entire run and confirm defects and rehabilitation: Grout at approx. 5.3m Grout and 1m CIPP TPR at approx. 8.1m CIPP TPR approx. 9.7m to 11.2m.	$12,000 (to be confirmed)
13	Superior	59	3	1171 (1S121)	1170 (1S120)	150	CO	34.2	4 (1)	33.5m to 33.7m: Broken pipe with fractures	CIPP TPR approx. 33.2m to 34.2 (MH)	$3,000
14	Superior	50	3	1087 (1S098A)	7069 (1SC099)	150	CO	90	4 (3)	55.5m: Hole with multiple fractures.Survey abandoned at 65.5m.	Flush from cleanout and re-inspect.CIPP TPR approx. 55.0m to 56.0m.	$3,900

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Table 5.1.1 - Major Structural, Service and Infiltration-Related Defects

Item No.	Contractor	Inspection ID	Priority	Start Manhole (Superior MH No.)	Finish Manhole (Superior MH No.)	Diameter (mm)	Material	Length (m)	SPG (ISG)	Defect Observation	Proposed Action	Estimated Cost
15	Superior	115	4	1080 (1S104)	1090 (1S105)	150	AC	85.3	1 (2)	7.0m: Infiltration runner at joint. 18.9m: Infiltration gusher at joint (12 clock reference), infiltration runner at joint (4 and 9 clock reference). 24.2m to 24.4m: Infiltration runner through longitudinal fracture.	Grout joints at approx. 7.0m and 18.9m. Grout fracture from approx. 24.2m to 24.4m.	$6,500
16	Mar-Tech	7254-1011a	4	7582	870	150	CO	74.0	1 (3)	39.3m: Possible infiltration runner/gusher at joint at 5 and 7 clock references	Test grout possible infiltration runner/gusher	$2,500
17	Superior	68 / 114	5	1079 (1S103)	1080 (1S104)	150	CO	57	3 (4)	5.2m: Roots at connection, with possible hole and circumferential fracture. Reverse inspection (MH 1080 to MH 1079): 0.1m: Infiltration runner from circumferential fracture (7 to 5 clock reference). 21.0m: Infiltration runner at connection. Survey abandoned at 21.3m due to grease (20%).	Grease cut and re-inspect entire run. Root cut and trim intruding connection at approx. 5.2m from MH 1079. Confirm if connection requires grouting. Grout fracture at approx. 0.1m. Grout with lateral packer at approx. 21.0m.	$7,700 (to be confirmed)
18	Superior	116	5	1083 (1S156)	1082 (1S157)	150	CO	75.7	3 (2)	17.0m and 33.7m: Infiltration runner at 3 and 9 clock reference. 61.8m: Hole and fractures at connection, with roots inside connection.	Grout at approx. 17m and 33.7m. Root treatment at connection at approx. 61.8m, CIPP TPR 61.5m to 62.5m and reinstate service.	$9,000
19	Superior	109	6	1113 (1S093)	1115 (1S107)	200	AC	77.1	3 (2)	44.8m: Broken pipe (11 to 1 clock reference)	CIPP TPR from approx. 44.3m to 45.3m	$3,000
20	Superior	27	6	1486 (1S031)	7527 (1S030)	150	PVC	16.6	3 (1)	9.5m to 9.8m: Broken pipe. 10.5m: Possible broken pipe. 11.2m: Circumferential fracture.	Re-inspect to confirm broken pipe at approx. 10.5 m. Confirm CIPP TPR from 9.2m to 11.7m with service reinstatement, or CIPP TPR from 9.2m to 10.2m.	1m TPR: $3,200 2.5m TPR with service: $7,250 (to be confirmed)
21	Mar-Tech	7254-1048	7	1477	7519	150	CO	64.0	1 (4)	63.1m: 40% root mass from service and joint. 64.0m: 20% debris	Root cut and flush sewer. Grout with lateral packer at approx. 63.1m.	$3,350
22	Superior	19	7	958 (1S014)	1475 (1S026)	200	CO	60.8	1 (1)	0.6m: Infiltration runner at joint. 60.1m: Infiltration dripper at joint	Grout at approx. 0.6m and 60.1m	$4,500
23	Superior	79	7	1159 (1S137)	1158 (1S147)	200	CO	37.6	1 (1)	29.4m: Infiltration runner and seeper at circumferential fracture. 36.3m: Infiltration seeper at circumferential fracture.	Grout at approx. 29.4m and 36.3m	$4,500
24	Mar-Tech	7254-054	7	336	339	150	CO	43.8	3 (2)	36.2m: Circumferential fracture at joint from 2 to 5 clock reference with infiltration runner	Grout fracture at approx. 36.2m	$2,500
25	Superior	54	8	348A(1S 067)	7247(1SC0 66)	150	CO	59	2 (5)	Survey abandoned at 52.8m due to approx. 45% debris (rocks) from junction and blocking main ahead	Attempt flushing from cleanout and re-inspect. Confirm no other services upstream and repair if doing other underground work, otherwise EPR may be required.	$600EPR: $5,000(to be confirmed)
26	Superior	73 / 105	8	1117 (1S131)	1116 (1S111)	200	CO	81	1 (5)	Survey abandoned at 9.3m due to grease	Grease cut and re-inspect line	$800
27	Superior	80	8	1158 (1S147)	1157 (1S148)	200	AC	64	1 (4)	Survey abandoned at 8.7m due to approx. 40% debris grease	Grease cut and complete inspection	$650

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Table 5.1.1 - Major Structural, Service and Infiltration-Related Defects

Item No.	Contractor	Inspection ID	Priority	Start Manhole (Superior MH No.)	Finish Manhole (Superior MH No.)	Diameter (mm)	Material	Length (m)	SPG (ISG)	Defect Observation	Proposed Action	Estimated Cost
28	Superior	103	8	1160 (1S149)	1158 (1S147)	150	AC	64	2 (4)	Debris grease approx. 10 to 35%. Survey abandoned at 16.3m due to grease.	Grease cut and complete inspection	$650
29	Superior	21	8	694 (1S040)	7060 (1SC041)	150	CO	82	1 (3)	Survey abandoned at 80.5m due to debris (approx. 40%)	Flush sewer from cleanout and re-inspect.	$800
30	Mar-Tech	7254-1005a	8	346	1075	200	CO	39	1 (3)	36.9m: Survey abandoned due to heavy grease. Grease cutting was attempted but unable to proceed through blockage just upstream of MH 1075. Reverse run from MH 1075 unsuccessful due to heavy grease and water levels	Grease cut from MH 1075 and complete inspection	$400
31	Mar-Tech	7254-048	8	7416 (c/o)	1164	150	CO	68.0	2 (3)	Debris grease throughout run. 57.2m: Survey abandoned due to heavy grease. Unable to grease cut due to possible intruding connection.	Flush sewers with high powered nozzle and re-inspect during low flow. Trim connection as required.	$700
32	Mar-Tech	7254-049	8	7262 (c/o)	334 (c/o)	150	CO	50.0	1 (3)	Debris (large rocks, gravel, and silt) throughout run. 34.3m: Survey abandoned due to debris	Flush sewer from cleanout and re-inspect.	$500
33	Mar-Tech	7254-1054	8	865	864	150	CO	83	1 (3)	64.3m: Survey abandoned due to hard deposit at interface of service at 4 clock reference. Unable to remove with root-cutting equipment. High water levels and tight bend in channel in MH 864 prevents reverse inspection. Benching removal would be required for camera access from MH 864 for reverse run.	District crew to remove benching in MH 864. Flush and inspect reverse run. Determine debris type and whether it can be cut.	Flush & CCTV: $850 Cut: $450
34	Superior	15	8	946 (1S007)	7510 (1SC008)	150	CO	77	1 (3)	Survey abandoned at 62.3m due to approx. 10% debris	Flush sewer from cleanout and re-inspect	$800

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Table 5.1.2 - Minor Structural, Service and Infiltration-Related Defects

Item No.	Contractor	Inspection ID	Priority	Start Manhole (Superior MH No.)	Finish Manhole (Superior MH No.)	Diameter (mm)	Material	Length (m)	SPG (ISG)	Defect Observation	Proposed Action	Estimated Cost
35	Superior	72 / 77	9	1091 (1S140)	1092 (1S141)	200	CO	68.7	3 (3)	16.2m: H looks adequately externally repaired (no action required). 35.9m: Open joint with broken pipe and visible soil. 52.8m: Intruding connection with multiple fractures and grease.	Grease cut, cut intruding connection at approx. 52.8m, and re-inspect entire run. Grout at approx. 35.9m. CIPP TPR approx. 52.3m to 53.8m and reinstate service.	$8,150
36	Superior	52	9	348 (1S064)	348A (1S067)	150	VC	50.5	3 (1)	33.8-34.5m: Multiple fractures with possible broken pipe (6 clock reference) at 34.1m	CIPP TPR approx. 33.5m to 35.0m	$4,250
37	Mar-Tech	7254-018	9	348	8135	100	VC	31.5	3 (1)	0.1m: Multiple fractures from 10 to 6 clock reference	CIPP TPR from MH 348 interface to approx. 1.0m.	$3,000
38	Superior	9	9	713 (1S023)	714 (1S024)	200	CO	45.2	3 (1)	21m to 21.6m: Multiple fractures	CIPP TPR approx. 20.8m to 21.8m	$3,000
39	Superior	18	9	953 (1S010)	1479 (1S016)	200	CO	61.8	3 (2)	59.8m to 60.2m: Multiple fractures (7 to 4 clock reference)	CIPP TPR approx. 59.5m to 60.5m	$3,000
40	Superior	65	9	1163 (1S151)	1156 (1S153)	150	VC	32.3	3 (3)	0.9m: Broken pipe (6 clock reference)	CIPP TPR approx. 0.5m to 1.5m	$3,000
41	Superior	7	10	948 (1S012)	957 (1S013)	200	CO	103.7	3 (2)	2.5m, 25.5m and 50.7m: Defective connections with observed voiding	Grout connections at approx. 2.5m, 25.5m and 50.7m with lateral packer	$6,500
42	Superior	17	10	956 (1S011)	953 (1S010)	200	CO	87.3	3 (2)	12.2m: Hole at defective connection	Grout with lateral packer at approx. 12.2m	$2,700
43	Superior	30	10	1502 (1S034)	1485 (1S033)	150	PVC	34	3 (2)	4.4m: Large displaced joint. From reverse inspection (MH 1485 to MH 1502): 1.5m: Large displaced joint Inspection incomplete.	Re-inspect to confirm rehabilitation. EPRs may be required to repair displaced joints.	$400 EPR: $10,000 (to be confirmed)
44	Superior	58	10	1172 (1S122)	1171 (1S121)	150	CO	94.6	3 (2)	64.0m: Hole with fine roots	Grout hole at approx. 64.0m	$2,500
45	Mar-Tech	7254-1002a	10	331	330	150	CO	106.2	1 (3)	46.0m: Large displaced joint with potential soil migration. 61.0m, 71.0m: Large displaced joint 62.3m, 72.3m: Large open joint	Re-video to confirm soil migration and/or voiding in displaced and open joints. Grout joints where required.	CCTV: $550 Grout: $6,500 (to be confirmed)
46	Superior	70	10	1168(1S129)	1167 (1S128)	150	CO	81.7	3 (2)	22.6m: Open and displaced joint with visible soil	Grout at approx. 22.6m	$2,500
47	Superior	57	10	1124 (1S113)	7076 (1SC115)	150	CO	105.0	2 (3)	20.1m: Fine roots and infiltration seeper through circumferential fracture	Cut roots and grout fracture at approx. 20.1m	$3,000
48	Mar-Tech	7254-015a/b	11	1478	7520	150	CO	75.0	1 (3)	Debris (silt and rocks) in several locations throughout run	Flush sewer	$400
49	Mar-Tech	7254-1022	11	1119	1120	200	CO	62.6	1 (3)	1.0m: Approx. 20% debris, longitudinal crack and infiltration dripper at joint at clock reference 1. Minor debris in MH 1120.	Flush sewer. Monitor infiltration dripper and longitudinal crack by re-inspection in 5 years	$350

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Table 5.1.2 - Minor Structural, Service and Infiltration-Related Defects

Item No.	Contractor	Inspection ID	Priority	Start Manhole (Superior MH No.)	Finish Manhole (Superior MH No.)	Diameter (mm)	Material	Length (m)	SPG (ISG)	Defect Observation	Proposed Action	Estimated Cost
50	Superior	42	11	857 (1S056)	856 (1S055)	200	CO	81.6	1 (3)	80.1m: Root mass from junction	Cut roots at approx. 80.1m in JN	$450
51	Superior	41	11	854 (1S054)	855 (1S053)	200	CO	89.7	1 (3)	8.7m: Root mass from junction	Cut roots at approx. 8.7m in junction	$450
52	Superior	33	11	350 (1S073)	7259 (1SC074)	150	CO	68.4	1 (3)	68.1m: Approx. 10% debris	Flush sewer from cleanout	$350
53	Mar-Tech	7254-006	11	350	349	200	CO	69.3	3 (2)	3.8m: Large hole (9 to 12 clock reference) that appears to be externally repaired by a piece of PVC pipe (appears to be structurally sound, and no action is recommended at this time). 35.0m: Fine roots at service connection. Hole in lateral with visible soil.	Root cut and grout with lateral packer at approx. 35.0m	$3,050
54	Mar-Tech	7254-1009	12	1075	7065 (c/o)	150	CO	85.3	1 (4)	85.3m: 95% debris blockage. Line appears to bend up to a cleanout.	Attempt flushing from cleanout. Confirm no other services upstream and repair if doing other underground work.	$450
55	Mar-Tech	7254-020	12	1124	7077 (c/o)	150	CO	22.0	1 (4)	21.1m: Survey abandoned due to 90% debris blockage (possible hardened concrete). Line appears to bend up to a cleanout.	Attempt flushing from cleanout. Confirm no other services upstream; repair if doing other underground work.	$200
56	Mar-Tech	7254-043	12	1082	7068 (c/o)	150	CO	30.0	1 (4)	27.9m: Survey abandoned due to 25% debris silt, approx. 1m from cleanout	Flush sewer from cleanout	300
57	Mar-Tech	7254-1008b	12	353	7252 (c/o)	150	CO	91.5	1 (3)	0.3m: Metal rod at invert.90.3m: Survey abandoned due to 10% debris and slope up to cleanout (approx. 0.5m away)	Remove metal rod in pipe from MH 353. Flush sewer from cleanout	$950
58	Superior	61	12	1125 (1S117)	7079 (1SC116)	150	CO	26.4	1 (3)	26.4m: Obstruction (approx. 25%) near cleanout	Remove obstruction from cleanout	$200
59	Superior	31	13	1502 (1S034)	1502A (1S035A)	150	PVC	6.8	4 (4)	First pipe length deformed approx. 20% but likely stable. 6.4m: Approx. 40% debris from MH.	Monitor for increased deformation/cracks/fractures by re-inspection in 5 yrs. Monitor for reduced capacity and blockages. Remove debris in line from MH 1502A.	$200
60	Superior	6	13	954 (1S009)	953 (1S010)	150	PVC	48	3 (1)	Approx. 10% deformation at 0.1m, 2.0m and 13.0m, and 15% at 25.4m. Survey abandoned at 44.2m (see Table 5.1.3).	Monitor deformation by re-inspection in 5 yrs	$500
61	Superior	28	13	1486A (1S032)	1485 (1S033)	150	PVC	78.4	3 (2)	Approx. 5 to 10% deformation	Monitor deformation by re-inspection in 5 yrs	$800
62	Superior	10	14	711 (1S021)	7424 (1SC020)	150	CO	50.2	1 (4)	50.2m: Large rock located near cleanout	Remove rock if conducting other underground work.	District

Table 5.1.3 - Uninspected Runs/Incomplete Inspections

Contractor	Inspection ID	Start Manhole (Superior MH No.)	Finish Manhole (Superior MH No.)	Diameter (mm)	Material	Length (m)	Defect Observation	Proposed Action	Estimated Cost
Superior	76	89A (1S089A)	341 (1S090)	200	CO	45	No inspection data or report	Flush and inspect	$450
Mar-Tech	n/a	7263	333	100		20	Not inspected. MH 333 is beneath large woodpile. Unable to locate MH 7263 and appears to be a service not a main.	District crew to remove large woodpile, locate both manholes and confirm whether inspection required.	$200
Mar-Tech	n/a	946	947	150		75	Cleaning required. Notice left (letter) on two occasions. Dog not chained up.	District crew to notify resident. Flush and inspect.	$750
Mar-Tech	n/a	7078 (c/o)	1114	150		40	MH 7078 may be a cleanout and possibly buried. High flows in line and traffic control is required.	District crew to locate 7078 and provide traffic control. Flush and inspect.	$400
Mar-Tech	n/a	1093	1150	375		40	Line appears larger in diameter than size noted on plans. Flows are approx. 80-90% at time of inspection attempt making visuals impossible. MH 1150 appears to have been removed or paved over.	District crew to locate MH 1150. Flush and inspect during low flow.	$400
Mar-Tech	n/a	1150	1151			10	Line appears larger in diameter than size noted on plans. Flows are approx. 80-90% at time of inspection attempt making visuals impossible. 1150 appears to have been removed or paved over.	District crew to locate MH 1150. Flush and inspect during low flow.	$100
Mar-Tech	n/a	865	7230 (c/o)	150		40	High water levels after repeated flushing. Unable to locate cleanout 7230.	District crew to locate cleanout 7230. Flush and inspect during low flow.	$400
Mar-Tech	7254-005a/b	365	366	200	VC	30	Survey abandoned due to high flows and mitre bends inside and outside of manholes. No access with crawler/camera. Inspection with push camera not possible due to high flows-poor picture quality.	Flush and complete reverse inspection during low flow	$300
Mar-Tech	n/a	366	374			30	Mitre bends inside and outside of manholes. No access with crawler/camera. Access with push camera not possible due to high flows.	Flush and inspect with push camera during low flow	$300
	n/a	1479	992	200		45	Not inspected	Flush and inspect	$450
		700	992			100			$1,000
		958	703			105			$1,050
		869	868	150		20			$200
		868	867	150		25			$250
		867	866	150		15			$150
		866	376	200		10			$100
		1118	1093	375		65			$650
		1084	1085	150		15			$150
		7586	851			30			$300
Mar-Tech	n/a	7260	338	150		100	Manholes not located	District crew to locate both MHs. Flush and inspect.	$1,000
Mar-Tech	n/a	338	345			15			$150
Mar-Tech	n/a	7415	1162			30			$300
Mar-Tech	7254-1001a	331	7264 (c\o)	150	CO	39	22.9m: Survey abandoned due to bend in sewer. MH 7264 appears to be a cleanout and could not be located for reverse inspection	District crew to locate MH 7264. Flush and re-inspect.	$400
Mar-Tech	7254-1010a	1075	345	200	CO	38	15.5m: Survey abandoned due to bend in sewer. MH 345 could not be located for reverse run.	District crew to locate MH 345. Flush and complete reverse inspection.	$400
Mar-Tech	7254-040	1159	1162	150	CO	61	26.8m: Survey abandoned due to high flows. Unable to locate MH 1162 for reverse run.	District crew to locate MH 1162. Flush and complete reverse inspection during low flow.	$600

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Table 5.1.3 - Uninspected Runs/Incomplete Inspections

Contractor	Inspection ID	Start Manhole (Superior MH No.)	Finish Manhole (Superior MH No.)	Diameter (mm)	Material	Length (m)	Defect Observation	Proposed Action	Estimated Cost
Mar-Tech	7254-1007a	332	333	150	CO	50	26.2m: Survey abandoned due to dimension change to 100mm. Reverse not completed as MH 333 is under a large pile of wood	District crew to remove wood. Flush and complete reverse inspection.	$500
Mar-Tech	7254-1036a	1128	7081 (c/o)	150	CO	100	52.0m: Survey abandoned due to intruding connection. Cleanout 7081 could not be located for reverse run	District crew to locate cleanout 7081. Trim intruding connection at approx. 52.0m, flush and complete reverse inspection.	$1,000
Superior	12	1479 (1S016)	7059 (1SC017)	150	CO	48	Survey abandoned at 20.7m due to intruding connection	Trim intruding connection at approx. 20.7m, flush and re-inspect	$500
Superior	63	1161 (1S138)	7414 (1SC139)	150	CO	81	Survey abandoned at 10.3m due to intruding connection	Trim intruding connection at approx. 10.3m, flush and re-inspect	$800
Mar-Tech	7254-030a	855	859	250	PVC	50	0.9m: Survey abandoned due to diameter change to 200mm. Mar-Tech indicates an unplotted manhole (unplot-2) is located between 855 and 859. Reverse run not completed due to high flows	Flush and complete reverse inspection from unplotted manhole during low flow	$500
Mar-Tech	7254-038	7412	1093	100	PVC	122	57.0m: Survey abandoned due to end of cable. High flows. Debris and grease noted underwater. Appears to be relined pipe with reduced diameter preventing access with crawler/camera. MH 1093 not as shown on drawings and unable to complete reverse run due to line connects to main outside MH 1093.	Flush and re-inspect with push camera during low flow	$1,250
Mar-Tech	7254-1038	CO-2	7084(c/o)	150	PVC	50	23.0m: Survey abandoned due to bend in sewer. Cleanout 7084 is reportedly full of dirt.	Flush and complete reverse inspection from MH 7084 during low flow	$500
Mar-Tech	7254-021a	7080	1127	150	CO	79	59.7m: Survey abandoned due to high flow	Flush and re-inspect during low flow	$800
Superior	117	1083 (1S156)	1084 (1S155)	150	AC	62	Survey abandoned at 46.4m due to high water level (camera underwater)	Flush and complete reverse inspection at low flow	$650
Mar-Tech	7254-1021	1131	1132	200	CO	109	106.1m: Survey abandoned due to bend in sewer outside manhole. Unable to reverse due to high water levels in main.	Flush and complete reverse inspection during low flow	$1,100
Superior	6	954 (1S009)	953 (1S010)	150	PVC	48	Survey abandoned at 44.2m	Flush and complete reverse inspection	$500
Mar-Tech	7254-045	708	709	150	PVC	60	56.6m: Survey abandoned due to end of push cable	Flush and complete reverse inspection	$600
Superior	71	1167 (1S128)	1166 (1S127)	150	CO	69	Survey abandoned at 33.3m due to intruding connection	Flush and complete reverse inspection	$700
Mar-Tech	7254-034	859	863	200	CO	90	59.8M: Survey abandoned due to diameter change to 300mm or 375mm. Mar-Tech indicates an unplotted manhole (unplot-3 flow meter) between 859 and 863. Unable to complete reverse due to high flows. Heavy debris is noted upstream of Unplot 3 and District advised no flushing allowed through flow meter.	District to determine if inspection required. If so, District crew to remove flow meter to enable proper flushing and inspection.	$900
Mar-Tech	n/a	7061	708			40	Line does not appear to connect to MH 708. Line may not exist.	District to investigate and locate MH 7061	District
Superior	n/a	7232	348	150		65	Line does not appear to exist	District to investigate and locate MH 7232	District
Mar-Tech	n/a	7258	CO-1	150		40	Line does not appear to exist as indicated on plans. Unplotted clean-out (labeled CO-1) only flows out West towards MH#349.	District crew to locate MH 7258 and investigate.	District

Table 5.1.4 - Defective Service Connections/Junctions

Contractor	Inspection ID	Start Manhole (Superior MH No.)	Finish Manhole (Superior MH No.)	Location of Service Connection/Junction and Defect
Superior	2	1161 (1S138)	1159 (1S137)	12.4m: full of debris
Superior	3	1125 (1S117)	1126 (1S118)	41.6m: full of debris 79.4m: full of debris
Superior	28	1486A (1S032)	1485 (1S033)	61.0m: 40% debris grease
Superior	32	857 (1S056)	7223 (1SC057)	70.7m: full of roots
Superior	35	1474 (1S027)	1475 (1S026)	22.9m: full of debris/concrete
Superior	36	862 (1S061)	7231 (1SC062)	26.6m: full of roots
Superior	39	860 (1S059)	859 (1S058)	39.5m: 90% debris
Superior	42	857 (1S056)	856 (1S055)	80.3m: full of roots
Superior	54	348A (1S067)	7247 (1SC066)	52.8m: rocks from junction
Superior	55	1172 (1S122)	1172A (1SC123)	15.1m: full of debris
Superior	56	1124 (1S113)	1123 (1S112)	36.3m: obstruction
Superior	57	1124 (1S113)	7076 (1SC115)	30.1m: debris
Superior	62	1125 (1S117)	1126 (1S118)	79.4m: full of debris
Superior	63	1161 (1S138)	7414 (1SC139)	4.1m: full of gravel
Superior	77	1091 (1S140)	1092 (1S141)	11.4m: full of debris

Sincerely,

UMA Engineering Ltd.
Karen Leung, P.Eng.
Project Engineer
Karen.leung@uma.aecom.com

KL:cla

Encl.

January 15, 2009 File Name: F438-011-00

Saleem Mahmood, P.Eng.
Project Engineer
District of West Vancouver
3755 Cypress Bowl Road
West Vancouver, BC
V7S 3E7

Dear Saleem:

Re: Engineering Service for 2008 Sewer Condition Assessment Program & Keith Road / 3rd Street Sewer Condition Assessment.

1.0 Introduction

An annual sewer assessment program was initiated in 2006 by the District of West Vancouver (the District). This program was based on sewer prioritization and specifications provided to the District by AECOM. Approximately 13 km of sanitary sewer was identified for the 2008 program with an additional 1 km of sewer along Keith Road and 3rd Street which was subsequently added to the scope and assessed separately (see section 4).

McRae's Environmental Services (McRae's) was contracted by the District to undertake the cleaning and close-circuit television (CCTV) inspections. Field work commenced in May and carried into early November 2008.

AECOM was retained by the District to undertake a condition assessment and develop a rehabilitation program for the sanitary sewers inspected by McRae's. This letter report summarizes our findings of the structural and service condition of the inspected gravity sanitary sewers in both areas, as well as observed infiltration. Our recommendations are prioritized in order of significance and are complete with cost estimates and hard copy drawings highlighting our recommendations.

2.0 2008 Inspection Program Study Area

The 2008 Sewer Condition Assessment Program area is bounded to the North and South by Queens Avenue and Marine Drive, and to the East and West by Taylor Way and 22nd Street. Sewer mains that were included in the study are highlighted in grey in Drawing Sheets 1 to 5.

The sewer mains range in size from 100 mm to 300 mm diameter, and consist of polyvinyl chloride (PVC), vitrified clay (VC), asbestos cement (AC) pipe, and high density polyethylene (HDPE) pipe.

3.0 Sewer Condition Assessment

The CCTV inspection of sewer mains was initiated in order to:

- Confirm the state of structural deterioration (section 3.1);
- Identify defects that could impair the ability of the sewer to perform at its intended level of service (section 3.2); and
- Identify potential infiltration sources (section 3.3).

3.1 Structural Condition Assessment

3.1.1 Methodology

The District administered the contract with McRae's and forwarded hardcopy and digital inspection reports to AECOM. The inspection defect codes were uploaded directly into the AECOM-developed Sewer Assessment Web Service (SAWS) software application. SAWS assign structural defect scores to the individual defects recorded in accordance with Water Research Centre (WRc) methodology. Defects are then converted into a preliminary WRc Internal Condition Grade (ICG) value between 1 and 5, for each manhole-to-manhole segment by SAWS. To convert the field inspections to preliminary ICGs, the software application computes the following:

- The *peak score* of defects attained in any 1m length of sewer in the manhole-to-manhole reach;
- The *total score* for the manhole-to-manhole reach; and
- The *average or mean score* for the manhole-to-manhole reach.

This three-part screening of data identifies:

- Sewers with a reasonable risk of collapse in the short term due to a random event (identified by the peak score value);
- Lines with significant general deterioration (highlighted by a review of the total reach score); and
- Lines with short reach lengths but significant deterioration (highlighted by a review of the mean reach score).

Manhole-to-manhole reaches with ICGs of 1 and 2 generally require no further review, and their re-inspection frequency can be directly determined based on the consequences of a sewer collapse at that location. In our normal assessment process, detailed review of inspections is limited to sewer reaches with ICGs of 3 and higher. The purpose of this review is to convert the ICG to a final Structural Performance Grade (SPG) based on consideration of supplemental data, and to rationalize the most appropriate rehabilitation strategy for observed defects.

The conversion of ICGs to final SPGs includes consideration of the following factors:

- Review of collapse risk based on soil type and the potential for infiltration/exfiltration;
- Frequency of surcharging; and
- Significance of defects considering soil type and the potential for infiltration.

The final SPG that results from this procedure is a semi-quantitative indication of the potential for sewer collapse to occur in that particular reach of sewer. For illustrative purposes the implication of each SPG and the typical defects that may accompany it is summarized in Table 3.1.

Table 3.1: Implication of SPGs

SPG	Implication	Typical Description (rigid pipe structures)
5	Collapsed or Collapse imminent	Already collapsed; or Deformation >10% and cracked, fractured or broken; or Extensive areas of missing pipe material.
4	Collapse likely in the near future	Deformation 5 – 10% and cracked, fractured or broken; or Broken or fractured; or Serious loss of level.
3	Collapse unlikely in the near future but further deterioration likely	Deformation 0 – 5% and cracked; or fractured; or Longitudinal/multiple cracking; or Occasional fractures; or Minor loss of level; or Poor connections (sewer services).
2	Minimal collapse risk in the short term but potential for further deterioration	Circumferential cracking; or Moderate joint defects.
1	Acceptable structural condition	No structural defects.

3.1.2 Study Area Findings

The sewers inspected were generally found to be in good structural condition overall, with only two lines having a SPG of greater than three (one of which is in a cleanout pipe). Rehabilitation recommendations for the 2008 Sewer Condition Assessment Program are outlined in Table 5.1.

Table 3.2 summarizes the SPGs for inspected sewer runs, excluding survey abandoned runs, which is discussed in Section 3.4.1. Although survey abandoned runs are included in the assessment, the SPG's are not reported as they may be artificially high given the shorter length, and therefore misrepresentative. Less than 10% of the inspected lines have an SPG of 3 or higher.

Table 3.2: 2008 Inspection Area - Summary of SPGs

		SPG				
Diameter	MH to MH Segments	5	4	3	2	1
100	2	0	0	0	0	2
150	107	0	2	5	44	56
200	101	0	0	7	44	50
250	6	0	0	1	0	5
300	1	0	0	0	0	1
Totals	**217**	**0**	**2**	**13**	**88**	**144**

Structural defects requiring rehabilitation are localized for a majority of the runs. The more serious of these include joint displacements, holes, broken pipes, and multiple cracks and/or fractures.

Figure 3.1 shows a medium joint displacement with voiding of soil around the pipe. Voiding of soil around the pipe is a major concern as it reduces the structural ability of the pipe and over time the ingress of soil into the pipe may eventually lead to the development of a sink hole.

Figure 3.2 shows multiple cracks from clock reference 9 to 3 o'clock in MH 316 to MH 315. Trenchless Point Repair (TPR) at this stage of deterioration is ideal and will restore the structural integrity of the pipe. Additional loading can further advance the defects to fractures and eventually broken or collapsed pipe; at which point, rehabilitation would likely involve external point repairs (EPR) which are more costly and disruptive to the public.

Figure 3.1: Medium Joint Displacement with voiding MH 462 to MH 461

Figure 3.2: Cracks Multiple MH 316 to MH 315

3.2 Service Condition Assessment

3.2.1 Methodology

In addition to the sewer structural ability of the sewer, it is important to review the service condition and specifically its inherent ability to provide its intended level of service. In a process similar to determining the ICG, SAWS assigns scores to service-related defects in accordance with WRc methodology. Service-related defects include conditions that may reduce the capacity of the sewer or exacerbate potential for blockages or infiltration, including: roots, encrustation, debris (silt or grease), and obstructions. SAWS calculates the Internal Service Grade (ISG) for each manhole-to-manhole run; again, using a value from 1 to 5 that is based on the defect scoring.

3.2.2 Study Area Findings

The overall service condition of the inspected sewers was generally good with no service maintenance required in the immediate future. Table 3.3 summarizes the ISGs for the fully inspected manhole-to-manhole runs excluding incomplete inspections (see Section 4.1.1). Less than 5% of the lines inspected have an ISG of 3 or higher.

Table 3.3: 2008 Inspection Area - Summary of ISGs

		ISG				
Diameter	**MH to MH Segments**	**5**	**4**	**3**	**2**	**1**
100	2	0	0	0	0	2
150	107	0	1	4	20	82
200	101	0	0	0	17	84
250	6	0	0	0	0	6
300	1	0	0	0	0	1
Totals	**217**	**0**	**1**	**4**	**37**	**175**

General service defects include blockages (obstructions) and debris, which often result in incomplete or survey abandoned inspections. There were also three lines identified with accumulation of debris within a few meters of cleanouts.

Figure 3.3: Protruding Gasket MH 495 to MH 494

Figure 3.4: Obstruction MH 2057 to MH 2060

Figures 3.3 and 3.4 are examples of obstructions found in the inspected sewers that will restrict flow and overtime will build up debris. Removal of these obstructions is recommended to ensure acceptable serviceability of the sewer pipe.

3.3 Mainline Infiltration

CCTV inspections are also useful in identifying the infiltration component of Inflow and Infiltration (I & I) in sewers. Infiltration is defined by the WRc as “the ingress of groundwater through a defect or faulty joint”, and is quantified at four levels of increasing severity:

- Seeper – the slow ingress of water through a defect or faulty joint;
- Dripper – water dripping in through a defect or faulty joint;
- Runner – water running in through a defect or faulty joint; and
- Gusher – water entering the pipe “under pressure” through a defect or faulty joint.

There was one occurrence of an infiltration runner at a hole and another instance of a potential gusher which could not be verified (see Table 5.1).

3.4 Additional Findings

3.4.1 Uninspected Sewers/Incomplete Inspections

The District provided AECOM with sanitary sewer maps for the 2008 Inspection Area. Based on these maps there appear to be sewer runs that were incomplete or not inspected. We identified 17 manhole-to-manhole runs that were not inspected for a variety of reasons which were reportedly discussed between the District and McRae’s. Typical reasons for incomplete inspections generally include:

- Inaccessible or un-located manholes/cleanouts;
- Difficult camera access due to runs ending in a cleanout or at a mainline without a manhole, or heavy debris.

The manholes and cleanouts for these runs should be located, benching and debris removed where required, and the sewers cleaned and inspected. These lines are listed in Table 5.2.

Incomplete inspections are denoted by the WRc defect code "SA" for "survey abandoned". There was a total of seven survey abandoned runs that do not have corresponding inspections for the reverse run, or have incomplete reverse inspections. Five of these survey abandoned runs were in clean outs. Typical reasons for the SA code include:

- Camera slipping;
- Bends in the sewer alignment; and
- Camera's inability to pass obstruction and debris.

Where possible, obstructions should be removed, debris flushed, and grease cut to enable completion of these runs. Re-cleaning from the cleanouts may be required, and inspection with smaller "push cameras" might also be necessary. The survey abandoned runs are addressed in Table 5.2.

3.4.2 Sewer Service Connections

Although our assessment is restricted to the mainline sewers, some defects within service connections/ junctions were noted during our review and are included in Table 5.1. These are service-related, including significant roots and debris, often completely blocking the service. The District should investigate these to determine whether the services are still live, and if so, clear the blockages (either from inspection chambers, the mainline, or with external point repairs).

4.0 Keith Road and 3rd Street Additional Inspections

In mid-August approximately 1 km of sewer along Keith Road and 3rd Street was added to our scope of work for sewer condition assessment. As shown in Drawing Sheet 6, this area includes:

- Keith Road – from Capilano View Cemetery to Keith Place; and
- 3rd Street – from Keith Road to #902 3rd Street.

4.1 Sewer Condition Assessment

A total of 15 manhole-to-manhole runs were assessed for structural and service condition. Refer to Table 5.3 for the recommended rehabilitation for this area.

4.1.1 Structural Condition Assessment

Table 4.1 shows a summary of the SPGs for the Keith Road and 3rd Street sanitary sewers. Two runs were identified with a SPG of 4.

Table 4.1: Keith Road / 3rd Street - Summary of SPGs

		SPG				
Diameter	**MH to MH Segments**	**5**	**4**	**3**	**2**	**1**
200	1	0	1	0	0	0
250	5	0	1	0	0	4
300	9	0	0	0	5	4
Totals	**15**	**0**	**2**	**0**	**5**	**8**

MH 180 to MH 179 on Keith Road has numerous structural defects (cracks, fractures and broken pipe) for a majority of its length and is recommended for full segment lining. As shown in Figure 4.1, this section of sewer is experiencing the 4 point fracture and deformation of the pipe has begun. This is the ideal stage for undertaking trenchless technologies for rehabilitation. Once the deformation of rigid a pipe, such as AC pipe, exceeds ~10% the likelihood of collapse increases and the application of trenchless technologies for this type of work is eliminated. High flows were noted at the time of inspection and may be attributed to infiltration given the extent of cracks and fractures throughout the pipe.

Figure 4.1: Fracture Longitudinal MH 180 to MH 179

Figure 4.2: Hole in Sewer MH 183 to MH 185

Figure 4.2 shows a hole due to a defective connection (live) at 11 o'clock. Boulders are visible and an external point repair is recommended.

4.1.2 Service Condition Assessment

The overall service condition of the inspected sewers on Keith Road and 3rd Street was generally good. Table 4.2 summarizes the ISG for the fully inspected manhole-to-manhole runs.

Table 4.2: Keith Road / 3rd Street - Summary of ISGs

Diameter	MH to MH Segments	ISG				
		5	4	3	2	1
200	1	0	0	0	1	0
250	5	0	0	1	0	4
300	9	0	0	2	4	3
Totals	**15**	**0**	**0**	**3**	**5**	**7**

As shown in Figure 4.3, approximately 70% root mass at MH 186 to pipe interface was identified and requires root cutting to restore the serviceability of the pipe.

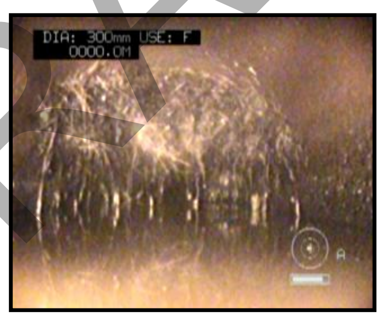

Figure 4.3: Root Mass at manhole to pipe interface MH 186

5.0 Prioritized Rehabilitation Recommendations

The overall condition of the sanitary sewers inspected in both the 2008 Sewer Condition Assessment Program and the Keith Road / 3rd Street Area are generally in good condition. However, rehabilitation as prioritized in Tables 5.1, 5.2, and 5.3 should be carried out in the near future to restore structural integrity, to prevent further deterioration, and to ensure the intended level of service of the sewer.

The following tables summarize our recommendations for both areas:

- Table 5.1: 2008 Sewer Condition Assessment Program – Recommended Rehabilitation for Structural, Service, and Infiltration Related Defects.
- Table 5.2: 2008 Sewer Condition Assessment Program – Uninspected Sewers and Incomplete Inspections
- Table 5.3: Keith Road / 3rd Street – Recommended Rehabilitation, Uninspected Sewers and Incomplete Inspections

This planning level study is intended to assess the current sewer condition, and hence the accuracy of cost estimates is commensurate with this level of detail. Where applicable, cost estimates are provided and are based on recent unit costs obtained by local contractors familiar in this type of rehabilitation works. However, further engineering is required to develop a rehabilitation construction program with refined cost estimates.

In viewing these tables, it is important to note the following:

- Defect locations should be verified prior to rehabilitation;
- Hydraulic capacity of the system was not reviewed by the study, but should be considered prior to undertaking any significant repairs;
- Liner thicknesses (for trenchless point repairs) are to be designed by an engineer for each specific location prior to application (Note: effect of liners on hydraulic capacity is not reviewed as part of the scope of the current assessment program and is particularly important where lining is identified for sewers of 150mm diameter or less);
- Where external point repairs are undertaken, the replacement pipe is to be of the same material and of similar characteristics as the existing pipe, where possible;
- Cost estimates exclude engineering;
- Costs for flushing, inspection, and cutting of grease, roots, and intruding connections are based on a fair-sized program (as opposed to individual call-outs);
- For the purposes of estimating costs, lengths have been scaled off the District's drawings for missing/incomplete inspections; and
- Locating/accessing manholes and cleanouts, and further investigation of lines that do not appear as per the plans is assumed to be undertaken by District crews, and associated costs are excluded.

Table 5.1: 2008 Sewer Condition Assessment Program - Recommended Rehabilitation for Structural, Service and Infiltration Related Defects

Priority	Set Up No.	SPG	DVD	MH-to-MH Run	Location	Drawing Sheet	Pipe Size (mm)	Pipe Material	Length (m)	Observation	Recommendation	Estimated Cost
1	82 [r] 83	4	WV010 [r] WV011	462 - 461	South of 1091 Clyde Ave	Sheet 1	150	AC	30.0	2.8m and 5.5m: Fracture circumferential 12 to 12 o'clock 6.9m: Exposed gasket from 7 to 11 o'clock 7.7m: Joint displaced medium (visible soil and some voiding) 8.0m: Survey abandoned due to joint displacement - reversal completed on Set Up No 83	Test grout displaced joint at 7.7m. Remove gasket at 6.9m. Monitor fractures by reinspection in 5 years.	$2,900
1	6	4	WV001	518 - CO3	East of 930 Braeside St	Sheet 2	150	VC	60.0	23.1m: Large joint displacement joint (no visible soil) 26.5m and 29.5m: Broken pipe from 10 to 4 o'clock 29.5m: Survey abandoned due to broken pipe. Reversal not completed.	External Point Repair (EPR) on cleanout pipe from 25.0m to 31.0m (located on property easement). Complete reversal from CO 3 - approximately 30m. Monitor large displaced joint by reinspection in 5 years.	$3,600
2	173	3	WV020	316 - 315	North of 1156 21st St	Sheet 4	200	VC	50.6	22.1m: Fracture circumferential at joint from 8 to 2 o'clock 35.1m: Crack circumferential from 12 to 12 o'clock 35.6m: Cracks multiple from 8 to 4 o'clock	Cured in Place Pipe Trenchless Point Repair (CIPP TPR) from 21.5m to 22.5m. CIPP TPR from 34.5m to 36.0m.	$4,600
2	117 [r] 122	3	WV014 [r] WV015	554-242	East of 1425 19th St	Sheet 5	200	VC	80.0	9.7m: Crack circumferential from 12 to12 o'clock 37.9m: Crack longitudinal at joint at 6 and 12 o'clock. Fracture longitudinal at joint at 7 and 4 o'clock 40.8m: Crack circumferential from 2 to 4 o'clock 58.9m: Hole at 12 o'clock Survey abandoned at 70.5m reversal completed on Set Up No 122	CIPP TPR from 37.5m to 39.0m CIPP TPR from 58.5m to 59.5m Monitor cracks by reinspection in 5 years	$4,600
2	47	3	WV007	454 - 459	South of 1075 Duchess Ave	Sheet 1	200	AC	48.4	45.7m: Fracture longitudinal at 11 and 1 o'clock. Fracture circumferential from 1 to 11 o'clock 47.0m: Fracture circumferential from 12 to 2 o'clock	CIPP TPR from 44.5m to 48.0m	$2,300
2	38	3	WV004	449 - 448	South of 1095 Esquimalt Ave	Sheet 1	150	AC	80.3	4.3m and 45.0m: Crack circumferential from 12 to 12 o'clock 45.7m: Hole at 6 o'clock 45.5m: Fracture circumferential from 6 to 11 o'clock 45.9m: Fracture circumferential from 12 to 5 o'clock 46.6m: Crack circumferential from 12 to 12 o'clock	Test grout hole at 45.7m followed by CIPP TPR from 44.0m to 48.0m. Monitor cracks by reinspection in 5 years.	$3,100
3	16	3	WV003	540 - 325	West of 824 11th St	Sheet 2	200	VC	109.6	33.5m: Crack longitudinal at 12 o'clock 34.0m: Hole at 12 o'clock	CIPP TPR from 32.5m to 35.0m	$2,300
3	11	3	WV002	536 - 537	South of 1031 Inglewood Ave	Sheet 2	200	VC	94.0	75.5m: Fracture longitudinal at joint at 12 o'clock. Fracture circumferential from 7 to 5 o'clock Light encrustation buildup at joints < 5% throughout run.	CIPP TPR from 74.5m to 76.5m.	$2,300
3	13	3	WV002	535 - 536	South of 975 Inglewood Ave	Sheet 2	200	VC	63.4	36.6m: Potential infiltration gusher at 6 o'clock 62.2m: Cracks multiple at joint from 10 to 2 o'clock	Test grout infiltration gusher at 36.6m. CIPP TPR from 61.0m to MH 536	$3,400
3	3	3	WV001	519 - 535	East of 1048 Braeside St	Sheet 2	150	VC	84.3	7.3m: Crack longitudinal at 3 o'clock 7.4m: Hole at 2 o'clock (old connection not properly decommissioned, back fill exposed) 7.6m: Crack longitudinal at 2 o'clock 7.7m: Crack circumferential from 3 to 4 o'clock Minor surface spalling throughout run.	Test grout hole at 7.4m (confirm location of hole when grouting. Tape slipping - meterage may be off) Monitor cracks and surface spalling by reinspection in 5 years.	$1,100
3	44	3	WV005	446 - 466	South of 1196 Fulton Ave	Sheet 1	200	AC	97.7	58.8m: Hole at connection with infiltration runner at 1 o'clock	Test grout hole at 58.8m.	$1,100
4	116	3	WV014	241 - 242	South of 1925 Mathers Ave	Sheet 5	200	VC	55.7	28.1m: Crack circumferential from 12 to 12 o'clock 34.4m: Hole in sewer at 6 o'clock 54.6m: Fracture circumferential from 12 to 12 o'clock	Test grout hole at 34.4m Monitor cracks and fractures by reinspection in 5 years	$1,100

Table 5.1: 2008 Sewer Condition Assessment Program - Recommended Rehabilitation for Structural, Service and Infiltration Related Defects

Priority	Set Up No.	SPG	DVD	MH-to-MH Run	Location	Drawing Sheet	Pipe Size (mm)	Pipe Material	Length (m)	Observation	Recommendation	Estimated Cost
4	4 [r] 5	3	WV001 [r] WV001	519 - 518	East of 1046 Braeside St	Sheet 2	150	VC	80.0	28.5m: Crack longitudinal at 12 o'clock 28.7m: Cracks multiple at 12 o'clock with surface spalling medium 28.9m: Crack circumferential from 1 to 4 o'clock 35.2m: Crack circumferential from 5 to 10 o'clock 35.4m: Fracture longitudinal at 4 and 10 o'clock 35.5m: Fracture circumferential with fine roots 47.2m: Survey abandoned - camera slipping Reversal completed on Set Up No 5: 1.4m: Crack longitudinal at 12 o'clock	CIPP TPR from 27.5m to 30.0m and 34.5m to 36.5m Monitor cracks by reinspection in 5 years	$3,900
4	77	3	WV010	495 - 494	South of 1090 Keith Rd	Sheet 1	150	AC	95.1	25.2m: Protruding gasket from 2 to 8 o'clock obstructing flow and causing debris buildup. 28.7m: 100% Debris in junction (potentially collapsed) 61.3m: Potential hole with infiltration seeper at 12 o'clock	Remove debris and gasket at 25.2m Test grout hole at 61.3m Investigate potentially collapsed junction at 28.7m.	$2,900
5	207	2	WV023	2057 - 2060	East of 1319 Sinclair St	Sheet 3	150	AC	55.0	50.6m: 40% Obstruction - appears to be concrete from 6 to 11 o'clock. 50.8m: Survey abandoned approximately 5m from MH 2060 due to obstruction. No reversal.	Remove obstruction at 50.6m and complete reversal.	$500
5	88	1	WV011	512 -513	South of 950 Esquimalt Ave	Sheet 1	150	VC	60.1	59.7m: 10% debris - possible concrete aprox 1m long. 60.1m: Survey abandoned aproximately 10m from MH due to debris.	Remove debris at 59.7m.	$500
5	101	2	WV013	2076 - 2075	East of 1013 Sinclair St	Sheet 3	200	PVC	3.2	2.2m: Obstruction under water. Water Level 35%.	Remove obstruction at 2.2m	$500
5	105	2	WV013	1072 - 1073	West of 860 Sinclair St	Sheet 3	200	AC	46.0	17.0m: Connection capped - voiding of soil around cap 43.8m: Gasket exposed at 10 o'clock	Investigate proper capping of connection. Monitor by reinspection in 5 years	O&M
6	55	2	WV007	453 - 454	South of 1075 Duchess Ave	Sheet 1	150	AC	82.7	14.3m, 14.8m, 42.4m, 46.3m, 60.8m, 81.5m: Crack circumferential from 12 to 12 o'clock 41.6m: Joint displacement slight 49.3m: 90% root mass in junction	Monitor cracks by reinspection in 5 years. Investigate removing roots in junction at 49.3m.	O&M
6	39	2	WV005	451 - CO11	South of 1150 Esquimalt Ave	Sheet 1	150	AC	76.2	1.4m: Crack circumferential from 12 to 12 o'clock 22.1m: Crack circumferential from 9 to 11 o'clock 33.0m, 46.3m, 70.5m: Crack circumferential from 7 to 11 o'clock 76.1m: 50% debris in clean out	Remove debris in clean out at 76.1m. Monitor cracks and fractures by reinspection in 5 years	O&M
6	234	2	WV026	523 - CO 5	East of 906 Leyland St	Sheet 2	150	VC	24.0	23.5m: Fracture longitudinal at 2 o'clock 24.0m: 90% Debris in clean out (possibly concrete)	Monitor fracture by reinspection in 5 years. Remove debris in clean out.	O&M
6	134	1	WV015	556 - CO 29	South of 1951 Kings Ave	Sheet 5	150	VC	62.4	62.4m: 15% Debris in clean out	Flush clean out	O&M
6	121	2	WV015	224 - 226	East of 1925 Jefferson Ave	Sheet 4	200	VC/PVC	47.1	0.8m: Large joint displacement (no visible backfill or voiding) 0.8m: Material change from VC to PVC 9.9m: Rock dimple at 5 o'clock, 5% 27.4m: Deformed sewer at joint < 5% 33.6m: Rock dimple at 2 o'clock, <5%	Monitor joint displacement, rock dimples & deformation by reinspection in 5 years	O&M
6	12	2	WV002	537 - 538	South of 1031 Inglewood Ave	Sheet 2	200	VC	109.1	105.6m: Fracture circumferential at joint from 2 to 5 o'clock	Monitor fracture by reinspection in 5 years	O&M
6	59	2	WV008	508 - 503	North of 970 Keith Rd	Sheet 1	200	VC	57.5	2.0m: Crack longitudinal at 2 o'clock 46.2m: Fracture circumferential from 3 to 8 o'clock. Fracture longitudinal at 3 o'clock.	Monitor cracks and fractures by reinspection in 5 years	O&M

Table 5.1: 2008 Sewer Condition Assessment Program - Recommended Rehabilitation for Structural, Service and Infiltration Related Defects

Priority	Set Up No.	SPG	DVD	MH-to-MH Run	Location	Drawing Sheet	Pipe Size (mm)	Pipe Material	Length (m)	Observation	Recommendation	Estimated Cost
6	41	3	WV005	445 - CO13	Easement North of 1095 Esquimalt Ave	Sheet 1	150	AC	80.8	3.4m and 4.8m: Fracture circumferential from 12 to 12 o'clock 4.6m: Fracture longitudinal at 1 o'clock	Monitor fractures by reinspection in 5 years	O&M
6	190	2	WV021	2047 - 2046	East of 947 22nd St	Sheet 4	250	HDPE	113.2	103.9m: Rock dimple 104.0m: Fracture longitudinal at 11 o'clock	Monitor by reinspection in 5 years	O&M
6	154	2	WV018	362 - 363	Gordon Ave North of Ice Rink	Sheet 4	200	AC	36.5	0.2m: Fracture circumferential from 9 to 3 o'clock	Monitor fracture by reinspection in 5 years	O&M
6	84	2	WV011	461 - 489	North of 1118 Keith Rd in easement	Sheet 1	200	AC	38.2	15.0m, 30.4m, 37.0m: Crack circumferential from 8 to 4 o'clock	Monitor cracks by reinspection in 5 years	O&M
											Total Estimated Cost (Excluding O&M)	**$40,700**

Table 5.2: 2008 Sewer Condition Assessment Program - Uninspected Sewers and Incomplete Inspections

Set Up No.	DVD	MH-to-MH Run	Location	Drawing Sheet	Pipe Size (mm)	Pipe Material	Length (m)	Observation	Recommendation	Estimated Cost
142	WV017	318 - CO 32	South of 2087 Kings Ave	Sheet 5	150	VC	100	22.0m: Obstruction at joint at 12 o'clock - unknown object - not obstructing flow 30.8m: Survey abandoned - camera slipping - no reversal	Complete reversal	$600
185 [r] 237	WV020 [r] WV026	Unmarked 3 - CO 46	West of 21st St on Marine Dr	Sheet 4	150	AC	40	No video of report on DVD. According to report at 5.3m large piece of concrete blocking pipe. Reversal on report 237 - incomplete: Survey abandoned due to debris at 28.5m	Remove debris and reinspect	$300
179	WV020	2066 - CO 27	North of Sinclair St at Inglewood Ave	Sheet 3	150	VC	50	Survey abandoned at 10.1m due to large joint displacement - deformed sewer PVC	Complete reversal	$200
183	WV020	849 - 853	North of 2196 Marine Dr	Sheet 4	200	PVC	60	Survey abandoned at 1.6m due to bend in pipe.	Complete reversal from MH 853	$200
19	WV003	523 - CO 6	East of 880 Leyland Ave	Sheet 2	150	VC	60	Survey abandoned at 9.1m due to bend in pipe.	Complete reversal from CO 6	$200
207	WV023	2057 - 2060	East of 1319 Sinclair St	Sheet 3	150	AC	55	Survey abandoned at 50.6m due to concrete obstruction.	Complete reversal from MH 2060	$100
21	WV003	540 - CO 8	East of 11th St as Gordon Ave	Sheet 2	150	VC	80	Survey abandoned at 40.6 due to camera slipping	Complete reversal from CO 8	$200
-	-	533 - 325	East of 11th St at Fulton Ave	Sheet 1	200	-	50	Not Inspected	Flush and CCTV	$300
-	-	529 - 533	South of 1075 Fulton Ave	Sheet 1	200	-	60	Not Inspected	Flush and CCTV	$400
-	-	459- CO	North of Dutchess Ave on 11th St	Sheet 1	150	-	90	Not Inspected	Flush and CCTV	$600
-	-	464 - CO	South of 1011 Esplanade Ave	Sheet 1	150	-	50	Not Inspected	Flush and CCTV	$300
-	-	539 - 540	West of 1080 11th St	Sheet 2	200	-	110	Not Inspected	Flush and CCTV	$700
-	-	224 - CO	North of 1925 Jefferson Ave	Sheet 4	150	-	70	Not Inspected	Flush and CCTV	$500
-	-	227 - CO	North of 1951 Inglewood Ave	Sheet 4	150	-	50	Not Inspected	Flush and CCTV	$300
-	-	354 - CO	West of 987 20th St	Sheet 4	150	-	30	Not Inspected	Flush and CCTV	$200
-	-	852 - 3755	South of Tennis Court between 21st and 22nd St	Sheet 4	200	-	110	Not Inspected	Flush and CCTV	$700
-	-	3755 - 2045	South of Ice Rink between 21st and 22nd St	Sheet 4	200	-	120	Not Inspected	Flush and CCTV	$800
-	-	1578 - CO	South of 2079 Queens Ave	Sheet 5	150	-	20	Not Inspected	Flush and CCTV	$200
-	-	1579 - 1580	West of 1815 19th St	Sheet 5	200	-	50	Not Inspected	Flush and CCTV	$300
-	-	1580 - 1581	West of 1795 19th St	Sheet 5	200	-	50	Not Inspected	Flush and CCTV	$300
-	-	1581 - 4229	Southwest of 2050 Westdean Cr	Sheet 5	200	-	60	Not Inspected	Flush and CCTV	$400
-	-	4232 - CO	Mathers Ct	Sheet 5	150	-	60	Not Inspected	Flush and CCTV	$400
-	-	4232 - 4231	Mathers Ct	Sheet 5	150	-	30	Not Inspected	Flush and CCTV	$200
-	-	4231 - 4230	Mathers Ct	Sheet 5	150	-	60	Not Inspected	Flush and CCTV	$400
									Total Estimated Cost (Excluding O&M)	**$8,800**

Table 5.3: Keith Road / 3rd Street - Recommended Rehabilitation, Uninspected Sewers and Incomplete Inspections

Priority	Set Up No.	SPG	DVD	MH-to-MH Run	Location	Drawing Sheet	Pipe Size (mm)	Pipe Material	Length (m)	Observation	Recommendation	Estimated Cost
1	202	4	WV023	183-185	North of 200 Keith Rd	Sheet 6	250	AC	104.9	50.0m: Crack circumferential from 9 to 3 o'clock 59.2m: Hole from 9 to 12 o'clock due to defective connection (boulders visible) 74.8m: Crack circumferential from 8 to 4 o'clock 97.6m: Hole in sewer at 2 o'clock. Fracture circumferential from 8 to 4 o'clock 103.8m: Crack circumferential from 8 to 4 o'clock	EPR at 59.2m. Test grout hole at 97.6m Monitor cracks by reinspection in 5 years.	$4,600
1	208	4	WV024	180 - 179	Top of Keith Rd	Sheet 6	200	AC	98.7	37.4m to 47.6m: Fracture longitudinal at 12 o'clock 38.6m: Broken pipe from 9 to 3 o'clock 41.8m, 50.8m, 52.4m, 53.8m, 55.4m, 57.0m, 63.0m, 70.5m: Fracture circumferential from 9 to 3 o'clock 47.6m, 50.6m:, 51.5m, 93.5m, 98.7m: Fracture longitudinal at 12 o'clock 49.1m: Fracture longitudinal at joint at 1 o'clock Light encrustation build up in fractures and high water levels noted.	Full segment liner. City to confirm if connections are live - one connection may be capped.	$15,200
2	222	2	WV025	214 - 217	East of 865 Third Ave	Sheet 6	300	AC	113.2	32.1m: Intruding connection at 10 o'clock possible voiding around connection	Reinspect sewer to verify voiding around connection at 32.1m.	$400
3	214	2	WV024	186 - 184	Northeast of 220 Keith Rd	Sheet 6	300	AC	71.9	0.0m: 70% root mass 55.6m: Crack circumferential from 12 to 12 o'clock	Root cut at MH 186 Monitor crack by reinspection in 5 years	$400
4	211 [r] 216	2	WV024 [r] WV024	186 - 187	East of Spuraway on Keith Rd	Sheet 6	300	AC	100.0	51.1m: Survey abandoned due to debris underwater. Reversal on Set Up No 216 - survey abandoned at 8.5m due to debris underwater	Remove debris and reinspect	$600
4	219	2	WV024	187 -217	East of Third St on Keith Rd	Sheet 6	300	AC	75.0	50.2m: Survey abandoned due to debris underwater, no reversal.	Remove debris and reinspect	$500
4	-	-	-	215 - 216	North of 364 Keith Rd	Sheet 6	-	-	40.0	Not inspected	Flush and CCTV	$300
4	-	-	-	216 - 217	South of 325 Keith Rd	Sheet 6	-	-	80.0	Not inspected	Flush and CCTV	$500
4	-	-	-	179 -181	North of Hwy 1 on Keith Rd	Sheet 6	-	-	80.0	Not inspected	Flush and CCTV	$500
4	-	-	-	181 - 182	North of Hwy 1 on Keith Rd	Sheet 6	-	-	80.0	Not inspected	Flush and CCTV	$500
											Total Estimated Cost (Excluding O&M)	**$23,500**

UMA | AECOM

District of West Vancouver

Developing a Multi-Year Sanitary Sewer Condition Assessment Program

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F438-002-00

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1.0 Background

1.1 This Report

The District of West Vancouver (District) owns and operates nearly 330 km of gravity sanitary sewers within its municipal boundaries. With no formal evaluation program in place, there is a large degree of uncertainty around the existing physical state of this infrastructure. Given its potential total replacement value of approximately $195 million, a strategic approach to managing this asset is invaluable. UMA Engineering Ltd. undertook to develop a risk model for the District's sewer system, as a tool for developing a multi-year condition assessment program. This report summarizes our methodology and provides a prioritization of the District's gravity sanitary sewer system.

1.2 Liquid Waste Management Program

As a member municipality of the Greater Vancouver Regional District (GVRD), the District of West Vancouver is committed to the GVRD's 2001 Liquid Waste Management Plan (LWMP). Specific to separate sanitary sewer systems, municipalities are responsible for:

- ongoing evaluation programs to assess condition (over a 20 year cycle);
- maintenance and repair to avoid deferring rehabilitation costs; and
- inflow and infiltration (I&I) reduction to the GVRD design allowance of 11,200 litres per hectare per day (lphpd).

This current risk assessment process aligns with the District's commitments to the GVRD's LWMP and is the first step in establishing a cyclical evaluation program that will assess condition and identify structural, service, and I&I-related repairs.

1.3 Sanitary Sewer System

The District's sanitary sewer network consists of approximately 326 km of mainline sewers, 12 km of forcemains, and 59 pump stations. The District-owned gravity sewer system (mainlines) is the focus of our evaluation program. There are 2 separate sewage systems; one located in Sunset Highlands which discharges to the District's Citrus Wynd wastewater treatment plant, and the remainder of the network which discharges to the GVRD's Hollyburn Interceptor and is transported to the Lions Gate Treatment Plant. This larger network is divided into 6 basins, with 2 of these basins (Basin III and Basin V) divided into sub-basins.

1.4 Previous Studies

In the early 1990s, identified capacity issues with the Hollyburn Interceptor due to high I&I rates led to a proposal for a relief sewer design. In response to the public's concerns with this, Dayton & Knight Ltd. undertook a study for the District and determined that reducing I&I flows to the GVRD design allowance level would eliminate the need for the relief sewer. The District deferred construction of the relief sewer and initiated a multi-year I&I study to identify and abate sources of I&I into the interceptor.

GVRD flow monitors had previously measured I&I flows in the area east of 25th Street at 2,550 gallons per acre per day (gpapd) or 28,700 lphpd, approximately 2.6 times the acceptable limit. I&I rates measured in the area west of 25th Street were 1,360 gpapd or 15,300 lphpd, approximately 1.4 times the GVRD allowance. The study therefore focused on the area east of 25th Street, which was divided into the Ambleside (currently Basin IV) and British Properties (currently Sub-Basins V_A, V_B, and V_C) study areas.

Investigations involved flow monitoring, smoke testing, closed-circuit television (CCTV) video inspection, and manhole inspections, and focussed primarily on the Ambleside area as initial flow monitoring determined the majority of I&I flows in West Vancouver originate here.

2.0 Methodology

2.1 Data Collection & Review

UMA collected the following background information from the District to assist in developing prioritization factors:

- previous Dayton and Knight Ltd. (D&K) reports:
  - "Preliminary Assessment of Inflow and Infiltration (I&I) into the Hollyburn Interceptor Sewer", July 1995
  - "1992 Infiltration & Inflow Study, Progress Report No. 5, 19th Street Trunk (Sub-Area C4), Video & MH Inspection", October 1994
  - "1992 Infiltration & Inflow Study, Progress Report No. 6, Esplanade Sub-Area", October 1994
  - "1995/96 I&I Study, Ambleside Area Flow Monitoring" + Appendices, November 1997
  - "1995/96 I&I Study, Ambleside Area Smoke Testing, Video and Manhole Inspections" + Appendices, October 1997
  - "Ambleside Area 1998/99 Sanitary Sewer Flow Monitoring Study, Pre-Priority Sewer Rehabilitation, 13th Street Sub-Area B4 & 22nd Street Sub-Area C6" + Appendices, May 2000
  - "Ambleside Area 1999/2000 Sanitary Sewer Flow Monitoring Study, Post-Priority Sewer Rehabilitation, 13th Street Sub-Area B4 & 22nd Street Sub-Area C6" + Appendices, November 2000
  - "Ambleside Area Sanitary Sewer Inflow & Infiltration Reduction Pilot Study Area Rehabilitation, 2001/2002 Progress Report", February 2003
  - "Rehabilitation of Sanitary Service Connections – Pilot Area, Summary Report", January 2004;
- Earth Tech Technical Memorandum No. 1, "Liquid Waste Management Plan (LWMP) Commitment Review", December 2004, complete with CD-ROM of GIS layers;
- District of West Vancouver sanitary and storm sewer manhole inspections (MS Excel file);
- digital GIS data in ESRI "Shape File" format representing the District's entire inventory of sanitary mains, trunk sewers, force mains, manholes, basins, zoning, land parcels and topographic contour lines;
- hardcopy road classification map; and
- anecdotal information acquired through conversations with District operations personnel.

2.2 Data Manipulation & Assumptions

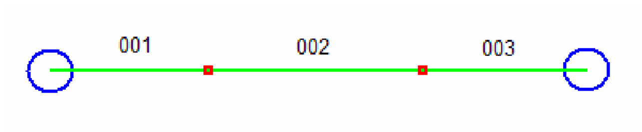
In order to compile a risk model for a sewer network, the appropriate data must be compiled and applied to each sewer main asset. It was determined that the main factors that should be used to assess risk in a sewer network consist of the following:

- depth;
- size;
- material;
- age;
- basin;

- soil conditions; and
- traffic volume.

2.2.1 Sewer Main Asset Delineation

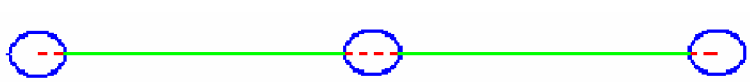
In order to apply risk factors to linear assets such as sewer mains, the asset delineation in the GIS should be defined in a logical manner that is conducive to the application of inspection, maintenance and rehabilitation techniques. In the case of sewer mains, this delineation is typically defined as a single linear segment whose end points are bounded between two access points (manholes). The current GIS segmentation model of the District's sewer network allows for multiple linear segments in between two manhole access points, as shown below.



In order to apply risk factors to sewer main segments in a manner that is consistent with asset management best practices, the District's sewer GIS data needed to be manipulated. The process used to manipulate this data involved the utilization of a series of spatial analysis functions that can be performed with most GIS software without the aid of a network analysis add-in. If such network analysis tools are deployed, a different approach could be used to generate the desired sewer main asset delineation.

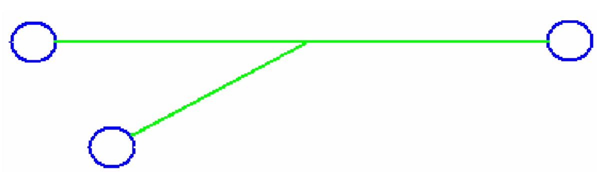
Procedure:

- Create small buffer areas (e.g. 50mm) around all manhole points within the manhole GIS feature.
- Create a spatial difference of sewer main segments minus the manhole buffer areas created in previous step. The result should consist of all the sewer segments contained within the original data set, with a small section removed near the manholes (as shown below).



- Create a spatial merge of all sewer main segments where they touch. Because a small linear section was removed near the manholes during the previous step, the segments will not merge at the manholes. The result will be a series of sewer segments that run from manhole to manhole. In order to enable identification of each sewer main asset, a unique, temporary ID ("TEMP_ID") was applied by using a random number generator.

NOTE: Sewers that intersect at a tee, rather than at a manhole will result in a segment consisting of all reaches merged into a single geometry, with a configuration similar to that shown below:



Anomalies such as this represent less than 5% of the total number of segments and should not affect the results by a significant amount. This anomaly could be avoided if a sewer tee GIS feature was incorporated into the District's GIS. Such a sewer tee feature would allow buffer areas to be created in the same manner as manholes and would therefore result in multiple segment reaches not being merged as shown previously. It should be noted that if a network analysis procedure was utilized instead, the result would still be undesirable because there is no sewer tee feature to "stop" the network trace at the intersection.

The segment merge operation could be streamlined if an asset numbering scheme was used, such that a single ID number is applied to all segments in between two manholes, as shown below.

The resulting "asset number" could be used as a parameter in conjunction with the "touching" parameter during the merge operation in order to avoid using the manhole buffer/spatial difference procedure to separate other sewer mains connected to the same manhole. This asset numbering scheme would also enable external database applications such as condition assessment tools and work management systems to reference permanent ID numbers that represent actual manhole-to-manhole sewer main assets rather than arbitrary segment ID numbers that change whenever segments are split to accommodate changes in pipe material.

2.2.2 Depth

The sewer main GIS feature have upstream and downstream invert elevation attributes, however sewer depths are not readily available due to the lack of rim elevation information in the manhole GIS feature. The District provided additional GIS files of topographic contour lines, from which approximate manhole rim elevations were derived by using AutoCAD Land Development Desktop.

The procedure to apply depth values to the derived manhole-to-manhole sewer segments is as follows:

- Create buffer areas that are slightly larger than the buffer areas used to derive the manhole-to-manhole sewer segments (e.g. 75mm) around the manhole GIS feature containing the derived rim elevation.
- Use spatial analysis functions to extract the start point geometry from the derived manhole-to-manhole sewer segments. Ensure that the "TEMP_ID" and the upstream invert elevation ("INVERT" field) of the segment are applied to the point geometry.
- Use spatial analysis functions to extract the end point geometry from the derived manhole-to-manhole sewer segments. Ensure that the "TEMP_ID" and the downstream invert elevation ("END_INVERT" field) of the segment are applied to the point geometry.
- Use a spatial intersection function to join the manhole buffer areas to the segment start point geometry. Calculate the start depth within this data set by subtracting the upstream invert elevation of the sewer segment from the manhole rim elevation.
- Use a spatial intersection function to join the manhole buffer areas to the segment end point geometry. Calculate the end depth within this data set by subtracting the downstream invert elevation of the sewer segment from the manhole rim elevation.
- Join the start and end depth data sets based on the common "TEMP_ID" field.
- Calculate maximum depth by determining the maximum value of the start and end depth fields.

NOTE: There were 121 occurrences of erroneous depth values (e.g. 0.008 m, 301 m) which were filtered out such that all depths < 0.5 m and > 15 m were assigned a value of zero (indicating unknown). Erroneous depths can be attributed to original “INVERT” and “END_INVERT” values of 99999, or because there was no upstream manhole located near the sewer main segment.

2.2.3 Size

Sewer main size data was extracted from the “SIZE” field within the District’s sewer main GIS feature. Because there can be multiple values of “SIZE” for a sewer main due to the derived manhole-to-manhole sewer segments containing multiple District segments, the maximum value was extracted in order to apply the worst case scenario.

2.2.4 Material

Sewer main material data was extracted from the “MATERIAL” field within the District’s sewer main GIS feature. Because there can be multiple values of “MATERIAL” for a sewer main due to the derived manhole-to-manhole sewer segments containing multiple District segments, the predominant value was extracted based on the longest District segment.

It was determined that similar material types within the “MATERIAL” field of the District GIS data are often given different values. For example, concrete is listed as “C”, “RC”, and “CONC”. Such values were reassigned a common descriptor (e.g. “CONC”). There are also a few erroneous material type entries, likely due to typing errors or incorrect field entries. Table 2.1 summarizes the assumptions made, along with the number of occurrences.

Table 2.1: Revised Material

Original GIS “MATERIAL”	Revised “MATERIAL”	Number of Occurrences
C	CONC	55
RC	CONC	24
PE	HDPE	2
SCLAIRPIPE	HDPE	1
VIT	VC	15
YMP	CMP	2
GAL	CMP	1
750	NA	1

It should be noted that a significant number of derived manhole-to-manhole sewer segments (approximately 3,700) are missing a value for this field (i.e. equal to “NA”).

2.2.5 Age

Sewer main age data was extracted from the “INSTALLATI” field within the District’s sewer main GIS feature. Because there can be multiple values of “INSTALLATI” for a sewer main due to the derived manhole-to-manhole sewer segments containing multiple District segments, the minimum (i.e. oldest) value was extracted in order to apply the worst case scenario.

It was determined that there are erroneous values present within this field that were reassigned a new value. The table below summarizes the assumptions that were made and the number of occurrences.

Table 2.2: Revised Installation Year

Original GIS “INSTALL”	Revised “INSTALL”	Number of Occurrences
192	1992	1
1003	2003	1

2.2.6 Basin

There are two sources of information that could be used to derive the basin in which the sewer mains are contained - the “Basin Boundary” GIS feature from Earth Tech’s technical memorandum and the District’s “Sub-Area_Boundary” GIS feature. These features differ slightly, which may be due to the District’s sewer system being divided into several small sub-areas for the earlier D&K I&I studies, and Earth Tech’s subsequent memorandum identifying only 5 basins with a few sub-basins. It was determined that the Earth Tech basin delineation (i.e. “Basin Boundary” GIS feature) should be used.

In order to assign basin values to the derived manhole-to-manhole sewer segments, a spatial intersection function was used to derive a new “BASIN” field. It was subsequently noticed that some of pipe segments did not have a value assigned. This was determined to be caused by the basin polygon areas not entirely containing all the sewer segments within the inventory. The District confirmed that a portion of these sewer mains are outside of the District’s system on Capilano Indian Reserve No. 5, and these are excluded from the current analysis. The remainder of these are in the Sunset Highlands area, and an additional basin (Basin VI) was created to include these sewers. The sub-basins were re-assigned an “A”, “B” or “C” subscript for clarity. Table 2.3 summarizes revisions to the basin names from Earth Tech’s GIS file.

Table 2.3: Revised Basin

GIS “Basin Boundary” (from Earth Tech memo)	Revised “Basin Boundary”
Sub Basin II	Basin II
Basin III	Sub-Basin III_A
Sub Nasin IIIA	Sub-Basin III_B
Sub Basin IIIB	Sub-Basin III_C
Ambleside Basin IV	Basin IV
British	Sub-Basin V_A
Basin VA	Sub-Basin V_B
Basin VB	Sub-Basin V_C
unclassified	Basin VI

2.2.7 Soil Conditions

Very minimal geotechnical information was extracted from a previous D&K report[1]. This report indicates that soils north of the Upper Levels Highway are generally glacial deposits over bedrock and that soils below the Upper Levels Highway are generally sand and gravel. The exception is Ambleside, in which soils are marine sand with a water table that varies with tides. Given the potential for problems during excavation (e.g. requiring dewatering and/or stabilization), the Ambleside area (i.e. BASIN = "Basin IV") was determined to be "Bad Ground" (see Section 2.3.1 below) and the remainder of the District to be "Good Ground".

2.2.8 Traffic Volume

Three major road classifications of "Freeway", "Arterial" and "Collector" were manually digitized from the District's hardcopy road classification map into a new GIS linear feature. Buffer areas were then created around this new GIS feature. The width of the buffer area was varied according to the value of the road classification in order to optimize the coverage within the given right-of-ways, and is summarized as follows:

- "COLLECTOR" = 20m;
- "ARTERIAL" = 30m; and
- "FREEWAY" = 100m.

In order to assign the road classification values to the derived manhole-to-manhole sewer segments, a spatial intersection function between the road classification buffer areas and the segments was used to derive a new "ROAD_TYPE" field. The following traffic volumes based on averages from the Transportation Association of Canada (TAC) Geometric Design Guide for Canadian Roads was subsequently applied:

Table 2.4: Assumed Traffic Volumes

Traffic Volume (veh/day) (typical)	Road Classification				
	Collectors		Arterials		Freeways
			Minor	Major	
TAC[2]	<8,000	1,000-12,000	5,000-20,000	10,000-30,000	>20,000
Assumed	7,000		16,250		>20,000

It was assumed that the sewers that do not spatially intersect any road classification buffer area are located on local and private roads and will thus carry less than 5,000 vehicles per day.

2.3 Risk Model Development

The Water Research Centre (WRc) risk model[3] classifies sewers into three broad categories of risk based on consequences of failure and repair costs: A, B, and C. Categories A and B form the "critical sewer network", and are defined as sewers:

[1] Dayton & Knight Ltd., "Preliminary Assessment of Inflow and Infiltration (I&I) into the Hollyburn Interceptor Sewer", July 1995
[2] From Table 1.3.4.2. Characteristics of Urban Roads, Transportation Association of Canada Geometric Design Guide for Canadian Roads, September 1999

- whose costs to repair in the event of failure are high;
- which in the event of failure result in high traffic delay costs; and
- that are strategically important.

For example, repairs of failed Category A sewers may be twice as costly as planned renewal, or 3 to 4 times as costly as planned renovation. Failure of Category B sewers does not carry as serious financial implications, but given the potential for disruptions unplanned failures are ideally avoided.

Classifying sewers in this manner facilitates focusing on strategically important sewers with higher repair costs, and allows a more coherent rationalization of the timing of repairs. The primary goals of rehabilitation programs based on structural deterioration considerations include:

1. Elimination of unplanned failures in Category A sewers
2. Minimized number of unplanned failures of Category B sewers
3. Proactive cleaning programs in Category C sewers to minimize the impacts of unplanned failures
4. Optimized scheduling of rehabilitation requirements

The development of the WRc Risk Model facilitates policy development in a manner that will meet all of these objectives.

2.3.1 Repair Cost Factor

The preliminary screening process in the WRc risk model assigns a Repair Cost Factor (RCF) to each manhole-to-manhole segment based on diameter (greater than or less than 900 mm), depth, and soil conditions (good or bad – see Section 2.3.1). The RCF is indicative of the direct cost ramifications of sewer failure. It is not intended to be utilized for benefit-cost analysis but facilitates a more discrete understanding of risk consequences within the sewer network on a segment by segment basis. Tables 2.5 and 2.6 below show RCF values at varying depths for sewers ≤900 mm diameter and >900 mm diameter, respectively. We determined the RCF for each pipe run and added this field to the sewer main GIS feature.

Table 2.5: Repair Cost Factors (RCFs) for Pipe Sewers ≤900 mm Diameter[4]

Depth (m)	1.0-1.99	2.0-2.99	3.0-3.99	4.0-4.99	5.0-5.99	6.0+
Good Ground	1.0	2.0	3.0	4.0	5.5	7.0
Bad Ground	1.5	2.5	3.5	5.0	6.5	8.5
Category	C		B		A	

Table 2.6: Repair Cost Factors (RCFs) for Pipe Sewers >900 mm Diameter[5]

Depth (m)	1.0-1.99	2.0-2.99	3.0-3.99	4.0-4.99	5.0-5.99	6.0+
Good Ground	4.0	7.0	13.0	19.0	26.0	33.0
Bad Ground	5.5	9.0	16.0	24.0	31.0	40.0
Category	B	A				

[3] Presented in the WRc Sewerage Rehabilitation Manual – Volume 1, 4th Edition, 2001
[4] From Table D.3, WRc Sewerage Rehabilitation Manual – Volume 1, 4th Edition, 2001
[5] From Table D.4, WRc Sewerage Rehabilitation Manual – Volume 1, 4th Edition, 2001

2.3.2 Overall Cost Factor

The Overall Cost Factor (OCF) considers the socio-economic impacts (e.g. disruptions) or indirect costs (e.g. pavement damage and traffic rerouting) of a sewer failure. Roads are termed “highly important” if they form part of a central integrated network (e.g. a one-way system) or if there are no clear detours or alternative routes that will not lead to further delays throughout the system. “Marginally important” routes are those carrying at least 5,000 vehicles per day (veh/day) where delays are significant but sufficient alternate routes are available. For this assessment we have assumed that freeways and arterials are highly important roads, collectors are marginally important roads, and local and private roads are not important routes.

In addition to the “highly important” vs. “marginally important” designation, the WRc risk model assumes that socio-economic impacts increase with increasing traffic volume. Previous study has indicated that they increase as a function of the RCF. The proportional increase along highly important routes is much greater than along highly important routes due to the expanded impact on the public.

Overlaying the traffic information, we derive OCFs from RCFs as follows:

Table 2.7: Overall Cost Factors (OCFs) Including Traffic Delays[6]

Traffic Flow (veh/day)	Highly Important Roads	Marginally Important Roads
5,000-7,499	4.8 x RCF	1.6 x RCF
7,500-9,999	6.3 x RCF	1.9 x RCF
10,000-12,499	7.8 x RCF	2.1 x RCF
12,500-14,999	9.3 x RCF	2.4 x RCF
15,000-17,499	10.8 x RCF	2.6 x RCF
17,500-19,999	12.3 x RCF	2.9 x RCF
20,000+	13.8 x RCF	3.1 x RCF

2.3.3 Sewer Category

The last step in the development of the WRc risk model is to group sewers into three broad categories to facilitate policy decisions. These categories are based on the OCF and the following criteria:

Table 2.8: Overall Cost Categories[7]

OCF	0-2.9	3.0-5.9	6.0+
Category	C	B	A

While the Categories are useful in developing general policy guidelines, the hard OCF values are not lost and can and should be used to provide more discrete prioritization within each Risk Category band.

[6] From Table D.5, WRc Sewerage Rehabilitation Manual – Volume 1, 4th Edition, 2001
[7] From Table D.5, WRc Sewerage Rehabilitation Manual – Volume 1, 4th Edition, 2001

3.0 Sewer Inventory Summary

3.1 Sewer Age, Size, and Depth

The sewer inventory was complied on a segment level basis and then grouped into the currently recommended basin designations to facilitate the review of basin-wide characteristics and ultimately the development of basin-level prioritization factors.

The following table summarizes the length-weighted average sewer age, size, and depth where known, of manhole-to-manhole segments within each basin and sub-basin. Also presented are the percentages, based on length, of missing (i.e. unknown/unpopulated) data.

Table 3.1: Summary of Sewer Depth, Size, and Age

Basin	Total Length (m)	Average Age	Unknown Age	Average Size (mm)	Unknown Size	Average Depth (m)	Unknown Depth
I	20,753.7	34	9.9%	165	0.4%	1.78	26.5%
II	63,117.6	31	3.8%	182	0.4%	1.97	12.5%
III_A	34,007.3	35	1.4%	169	0.1%	2.42	15.5%
III_B	5,020.0	35	0.0%	180	0.0%	1.95	2.8%
III_C	3,939.0	30	5.4%	183	0.0%	2.41	9.9%
IV	89,732.1	44	1.3%	175	0.8%	2.45	3.2%
V_A	67,668.2	37	0.4%	183	0.2%	2.65	5.3%
V_B	14,888.6	41	0.8%	174	0.3%	2.66	1.5%
V_C	26,202.8	45	0.5%	177	0.0%	2.25	2.6%
VI	973.0	28	26.1%	156	4.0%	3.69	83.5%
Total	326,302.4						

3.2 Sewer Material

Table 3.2 summarizes the distribution of material types found within each basin/sub-basin area, expressed as a percentage length.

Table 3.2: Summary of Sewer Material

Basin	Length (m)	Asbestos Cement (AC)	Cast Iron (CI)	Corrugated Metal Pipe (CMP)	Concrete (CONC)	Ductile Iron (DI)	High Density Polyeth-ylene (HDPE)	Polyvinyl Chloride (PVC)	Vitrified Clay (VC)	Unknown
I	20,753.7					2.5%		1.5%	3.9%	92.0%
II	63,117.6	0.5%	0.1%	0.2%	0.7%	5.2%	0.1%	20.7%	54.7%	17.7%
III_A	34,007.3	6.0%		0.1%	0.2%	3.5%	3.4%	16.7%	0.4%	69.7%
III_B	5,020.0							1.2%		98.8%
III_C	3,939.0					3.5%		19.1%		77.3%
IV	89,732.1				0.1%	0.1%	0.4%	2.4%	0.7%	96.3%
V_A	67,668.2				0.3%	0.9%		22.7%		76.1%
V_B	14,888.6							6.0%		94.0%
V_C	26,202.8									100.0%
VI	973.0						8.9%			91.1%
Total Network	326,302.4	0.7%	0.0%	0.0%	0.2%	1.8%	0.5%	11.7%	11.1%	73.8%

3.3 Sewer Category

Table 3.3 summarizes the percentage of sewers, based on length, falling within the three risk categories (A, B, and C) in each basin and sub-basin area. Unknown sewer category is a result of unknown depth.

Table 3.3: Summary of Sewer Categories

Basin	Length (m)	Category A	Category B	Category C	Unknown
I	20,753.7	4.4%	4.1%	65.0%	26.5%
II	63,117.6	10.2%	11.7%	65.6%	12.5%
III_A	34,007.3	14.5%	20.4%	49.6%	15.5%
III_B	5,020.0	9.4%	7.6%	80.3%	2.8%
III_C	3,939.0	5.9%	14.2%	70.0%	9.9%
IV	89,732.1	6.4%	33.7%	56.6%	3.2%
V_A	67,668.2	8.0%	28.8%	57.9%	5.3%
V_B	14,888.6	2.7%	45.8%	50.0%	1.5%
V_C	26,202.8	3.2%	23.6%	70.6%	2.6%
VI	973.0	0.0%	11.6%	4.9%	83.5%
Total Network	326,302.4	7.8%	24.2%	59.6%	8.4%

4.0 Sewer Ranking

4.1 Multi-Variate Selection Criteria

To prioritize sanitary sewer inspection and condition assessment requirements on a basin/sub-basin basis, we identified the following factors as driving current inspection priorities:

- average age;
- mean Overall Cost Factor (OCF);
- basin-wide infiltration levels; and
- inventory gaps in material type.

With the exception of infiltration, these categories were built from the segment level characteristics of the sewer network which were summed for each basin and sub-basin area to form overall basin/sub-basin characteristics, as discussed in the following sections. This will ultimately facilitate drilling down within the basin/sub-basin areas to examine priorities more discretely over time.

4.2 Scoring Factors

4.2.1 Average Age

Age was rationalized as being a key driving criterion as previous study has indicated that sewer deterioration is ultimately impacted by age.

As presented in Table 3.1 above, we calculated an average basin/sub-basin age from the sum of length-weighted ages for all known manhole-to-manhole segments within each area. We selected a baseline age of 100 years (typical design life) to compare relative ages.

4.2.2 Mean Overall Cost Factor

OCF was also rationalized as key driving criterion. As previously discussed, the OCF provides an indication of risk and is derived based on factors including sewer size and depth, geotechnical conditions and traffic volume.

For each segment of known depth we calculated an OCF and determined a summed, length-weighted average for each basin/sub-basin area. For scoring these were indexed against a value of 6, which marks the transition from Category B to Category A sewers, where Category A represents the highest socio-economic risk.

4.2.3 Basin-Wide Infiltration

In the absence of actual infiltration rates, basin-wide infiltration was categorized at three levels, each representing degree of compliance with the GVRD's 11,200 lphpd design allowance. We assigned each category a numeric value as summarized in the following table:

Table 4.1: Basin-wide Infiltration Levels

Level	Significance	Value
low	general regulatory compliance	1
medium	1 – 2x regulatory requirement	2
high	> 2x regulatory requirement	3

From past D&K reports, the Ambleside and British Properties study areas (i.e. Basin IV and Sub-Basin V_A) were reported to have high infiltration levels. For the remainder of the areas, specific rates are unknown. As unknown values are not definitive in terms of demonstrating regulatory compliance they were assigned a medium level weighting in terms of their significance.

As the District's flow monitoring program evolves and more quantitative data is compiled, these three qualitative descriptors should be replaced with actual basin/sub-basin level values, indexed to the regulatory baseline of 11,200 lphpd. In the interim we have used a baseline value of 2 (the transition between regulatory compliance and non-compliance).

4.2.4 Inventory Gaps – Unknown Material

From Table 3.2 it is evident that a large percentage (approximately 74% of the entire gravity network by length) of sewer material type is unknown, or unpopulated in the GIS. Unknown material type seriously compromises the District's ability to extrapolate observations made within their known inventory to the remaining inventory. This would include observations relative to physical and service condition deterioration and infiltration levels. As one of the indirect benefits of CCTV inspection is a positive delineation of the material type, it can be rationalized that the severe lack of inventory data should at least be considered in the assessment of inspection priorities.

The percentage of unknown material per basin/sub-basin area was indexed against the optimum value of 100%.

4.3 Basin/Sub-basin Prioritization

Having established the critical criteria that should drive inspection priorities it is necessary to rationalize the relative significance of each criterion. The baseline values proposed above were intended to take each driver category and reduce it to a reasonably common baseline. Proportional weighting factors can then applied to each driver category in reasonable proportion to the significance of the overall priorities of the District. This type of analysis can be referred to as a multi-variate proportional weight model and is very similar to the analytical techniques commonly applied to Water Distribution Systems to rationalize overall priorities based on a wide variety of driving categories.

The primary drivers for the District to inspect sewer inventory are both regulatory, based on the GVRD's LWMP and the District's desire to practice fundamental sound asset management. The driving criteria behind the LWMP are not inconsistent with the District's objectives with the possible exception that the District has questioned the technical feasibility of achieving full regulatory compliance with the GVRD's I&I value in all soil types. As indicated earlier the LWMP indicates that municipalities are responsible for:

- ongoing evaluation programs to assess condition (over a 20 year cycle);
- maintenance and repair to avoid deferring rehabilitation costs; and
- inflow and infiltration (I&I) reduction to the GVRD design allowance of 11,200 litres per hectare per day (lphpd).

Based on this it was rationalized that District's interests would best be served by assigning equal proportional weights to average age, mean OCF, and basin-wide infiltration characteristics, and a lower proportional weight to inventory gaps as there are other means to close inventory gaps and the commitment to the inspection program itself will systematically remove inventory gap information.

Table 4.2 presents the four selection criteria, their proportionate weight in the ranking score, the baseline values, and the final ranking for each basin and sub-basin. It also provides associated sewer inspection costs per basin/sub-basin, based on an estimate of $5/m for contracted sewer cleaning and CCTV inspection in accordance with WRc methodology.

Table 4.2: Overall Cost Factors (OCFs) Including Traffic Delays

Basin	Average Age	Mean OCF	Basin-Wide Infiltration	Inventory Gaps (unknown material)	Ranking Score	Basin Priority	Total Length (m)	Inspection Costs ($5/m)
Proportionate Weight	30%	30%	30%	10%				
Baseline Value	100	6	2	100%				
I	34.45	2.23	1	92.0%	45.7	8	20,753.7	$103,800
II	31.46	3.14	1	17.7%	41.9	10	63,117.6	$315,600
III_A	35.24	5.04	1	69.7%	57.7	5	34,007.3	$170,000
III_B	34.69	3.29	1	98.8%	51.7	6	5,020.0	$25,100
III_C	29.57	2.41	1	77.3%	43.6	9	3,939.0	$19,700
IV	43.61	4.40	2	96.3%	74.7	1	89,732.1	$448,700
V_A	37.36	4.40	2	76.1%	70.8	3	67,668.2	$338,300
V_B	41.17	4.37	2	94.0%	73.6	2	14,888.6	$74,400
V_C	44.94	2.73	2	100.0%	67.1	4	26,202.8	$131,000
VI	28.34	3.18	1	91.1%	48.5	7	973.0	$4,900
Total							326,302.4	$1,631,500

The highest level priority is Basin IV, followed by Sub-Basin V_B, Sub-Basin V_A, and Sub-Basin V_C. Infiltration levels and regulatory compliance are primary drivers in these areas, as well as the impact of the WRc risk model considerations (i.e. mean OCF values).

5.0 Multi-Year Condition Assessment Program Requirements

While priorities for undertaking inspections were reasonably rationalized in the previous section, the magnitude of the size of the annual program needs to be rationalized as well.

The LWMP mandate for sewer condition assessment of the District's inventory indicates a 20 year cycle to assess the physical condition of the sanitary sewer inventory. This suggests an annual program size on the order of $90,000 with no allowance for inflation (i.e. based on completing the entire inventory within a 20 year timeframe).

Sewer inspection requirements for the overall system, however, will consist of both short-term and long-term inspection requirements. In the short-term, the primary objective will be directed at determining baseline condition and identifying areas with unacceptable levels of infiltration. A 20 year timeframe to establish baseline condition may be undesirably long as the District may already have amassed a considerable backlog of required rehabilitation work in the absence of a systematic capital program to address physical condition and service related deficiencies.

As well, sewer inspection in the short-term may have to be integrated with sewer cleaning in order to obtain reliable physical condition data. In the longer term sewer cleaning and sewer inspection usually evolve into two distinctly unique programs with different frequencies and focussing on different aspects of the sewer infrastructure.

1. Sewer cleaning is a required maintenance function for all sewer infrastructure. The frequency of sewer cleaning will largely be determined by experience and in storm sewer infrastructure be driven by other maintenance programs such as street cleaning frequency and catch basin cleaning. The required frequency will be somewhat independent of sewer condition and typically is required over a much shorter cycle than sewer inspection, if sewers are in good structural condition. Best practices to establish sewer cleaning frequencies typically range from 5 to 8 year cleaning cycles.

2. Sewer inspection in the long-term is a program that will be most focussed on the critical sewer network, but at lower frequencies, also directed at the lower risk areas of the sewer network as there are considerable benefits that can be achieved by proactively addressing sewer deterioration in these areas as well.

Short-term requirements are often referred to as an initial screening program. The initial screening program will establish the baseline condition for all sewer infrastructure in the system. It will provide an adequate information base to:

- systematically identify required rehabilitation requirements to meet structural condition performance objectives;
- implement other infrastructure programs that are affected by sewer structural or service condition such as the meeting of regulatory infiltration requirements and future street maintenance and rehabilitation programs;
- integrate condition-related information with existing and future hydraulic models developed in the I&I programs; and

- determine the sustainable funding level that is required to meet structural and service condition performance objectives through the development of preliminary deterioration curves and a sustainable funding framework.

The long-term inspection requirements for the sewer system will be based on a balance of the concept of *collapse risk management* in the critical sewer network, optimizing reduced rehabilitation costs associated with early lifecycle repairs in the entire sewer network, and service level objectives associated with the level of infiltration control that is required to meet regulatory requirements. The required frequency for re-inspection of individual sewer reaches will be a function of observed sewer condition during initial screening (both structural and service related condition), the probability of collapse, and the ramifications of failure should a collapse occur.

5.1 Monitoring of Sewer Condition

In some jurisdictions future inspections are focussed entirely on the critical sewer network. The condition of Category C sewers in these jurisdictions is typically monitored solely through routine sewer cleaning, maintenance history, and the limited amount of inspection carried out to facilitate the sewer cleaning program and to calibrate and verify sewer deterioration models. Studies[8] on rehabilitation cost versus condition state in both Winnipeg, MB and Hamilton, ON, suggest there is considerable merit in carrying out systematic physical condition assessment of the entire inventory based on the reduced cost of rehabilitation at earlier stages in the deterioration cycle. This would be particularly true for communities where infiltration was a primary driver for rehabilitation both because inspection of the entire inventory is required to locate the infiltration and because of the rehabilitation technologies that are most effective at arresting excessive levels of infiltration.

Long-term monitoring of sewer condition in critical sewers is necessary to ensure that unanticipated failure does not occur in areas that would compromise public safety, that level of service objectives are maintained, and that future repairs can be scheduled at the most cost effective point in the sewer's deterioration cycle. Determining the required re-inspection frequency to ensure that this occurs will allow the determination of the necessary annual funding level for inspection of the sewer network. We call this funding level the *sustainable annual inspection cost.*

The *sustainable annual inspection cost* for the system can be defined as the level of annual inspection work that must be carried out to meet the stated performance objectives for structural condition. Based on deterioration and risk models in the U.K.[9], the structural performance objective for sewer infrastructure is to rehabilitate all critical sewers with SPG's of 3 or higher (i.e. maintain the critical sewer network condition at SPG 2). The following criteria are typical criteria that are commonly applied to determine when sewer infrastructure is considered for rehabilitation based purely on structural deterioration and risk considerations:

- Category A sewers at SPG 3
- Category B sewers in transition from 3 to 4
- Category C sewer at SPG 5

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[8] Macey, Bainbridge, et al "The Development of Advanced Asset Deterioration Models and Their Role in Making Better Rehabilitation Decisions", No-Dig 2005, Orlando, Florida, April 2005

[9] Water Research Centre (WRc), "Sewerage Rehabilitation Manual, Second Edition", January, 1990.

This ensures that no unanticipated failure occurs in critical areas of the District and that rehabilitation can be continuously scheduled at the optimum point in the deterioration cycle. As a starting point this will be used as a basis for determining the optimum mode of managing the sewer infrastructure asset.

This *sustainable annual inspection cost* will be of function of:

- the characteristics of the overall sewer network in terms of the split between Category A, B, and C sewers; and
- the average condition of the sewer infrastructure at any point in time.

The optimum value for the *sustainable annual inspection* funding level will only be able to be determined based on considerable experience. Initially, however, reasonable assumptions can be made for balancing re-inspection frequencies versus risk based on the experience of others.

The WRc recommends the following re-inspection frequencies based Final SPG and sewer category, irrespective of flow type:

Table 5.1: WRc Recommended Re-inspection Frequencies

Final Structural Performance Grade	Category A Sewers	Category B Sewers
5	N/A	N/A
4	-*	5 years
3	3 years	15 years
2	5 years	20 years
1	10 years	20 years

**where rehabilitation is not planned in the immediate future sewer condition should be monitored frequently to prevent unanticipated failure.*

To address the requirement to attach an inspection frequency to the entire inventory the following frequencies are recommended as a balance between the technical requirements of the LWMP and best practices aimed at minimizing both risk and rehabilitation cost.

Table 5.2: Recommended Re-inspection Frequencies for West Vancouver

Final Structural Performance Grade	Category A Sewers	Category B Sewers	Category C Sewers
5	N/A	N/A	1 year
4	-*	5 years	7 years
3	3 years	15 years	20 years
2	5 years	20 years	25 years
1	10 years	20 years	30 years

**where rehabilitation is not planned in the immediate future sewer condition should be monitored frequently to prevent unanticipated failure.*

5.2 Cost of Monitoring Required to Meet Performance Objectives

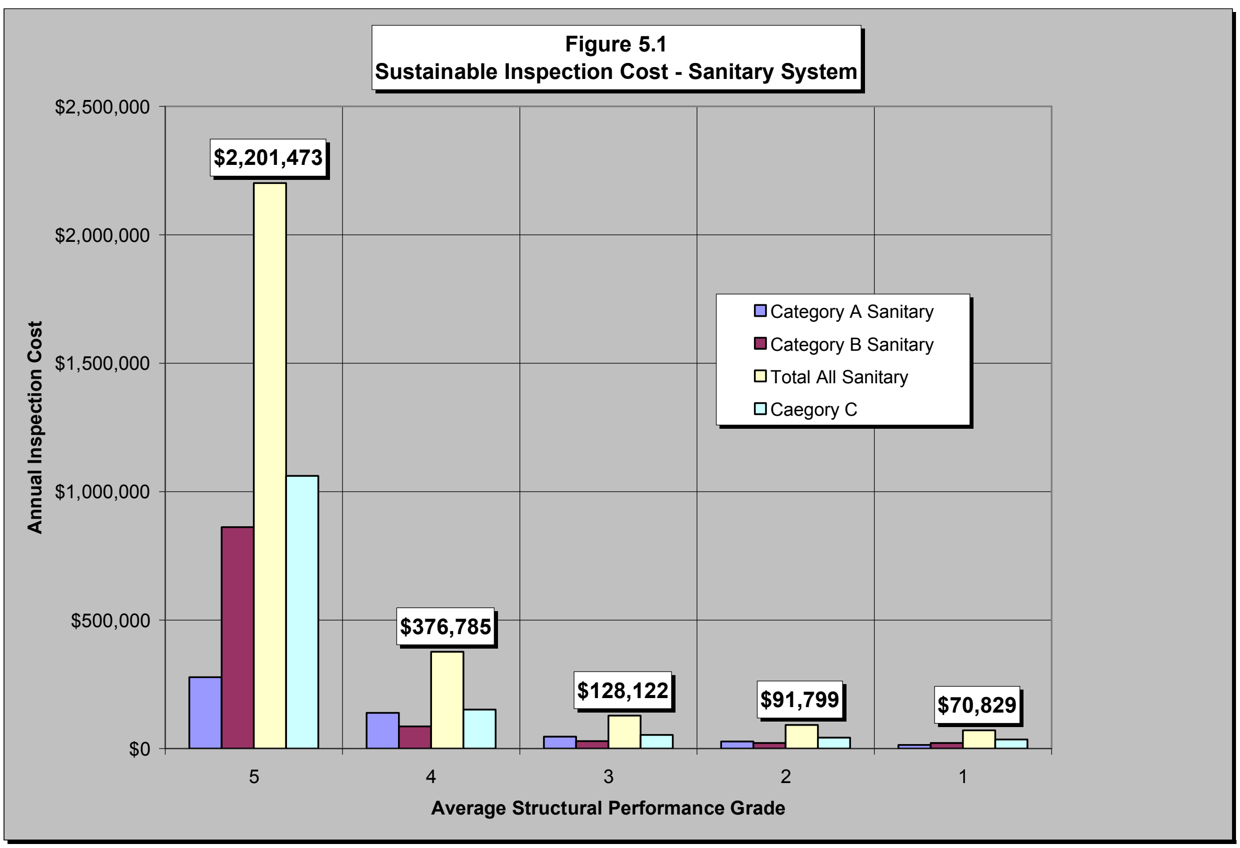
Having identified a set of recommended re-inspection frequencies, one can directly determine the relationship between average system structural condition and the required sustainable funding level for sewer inspection.

The existing inventory was presented in Table 3.3. The total inventory of sanitary sewers was comprised of 7.8% Category A sewers, 24.2% Category B sewers, 59.6% Category C sewers and 8.4% of sewers with an unknown classification. In order to present a representative estimate of the *sustainable annual inspection cost* the length of sewers with an unknown classification was proportionally distributed between Categories A, B, and C to arrive at the estimated inventory characterization presented in Table 5.2.

Table 5.2: Estimated Inventory of Sewer by Flow Type Based on Redistributed Length of Unknown Sewer Classification

	Length (m) and Category of Sewer		
Flow Type	**A**	**B**	**C**
WWS	27,786	86,207	212,310
% of o/all Total	8.52%	26.42%	65.07%

The sustainable annual cost can then be calculated by taking the length of sewer in each category times the average cost of inspection ($5.00) divided by the appropriate re-inspection frequency. For illustrative purposes, sewers with a SPG of 5 were assumed to have a required re-inspection frequency of 0.5 years. In this manner the sustainable cost for annual sewer inspection as a function of average SPG was calculated for all sanitary sewer inventory in Figure 5.1.



Using this model the rate of inspection priorities in the long-term would largely be driven by the observed physical condition of the inspected sewer network. While it does provide a reasonable framework for rationalizing the annual program size based on the inspected physical condition and observed deterioration patterns, it would be prudent to rationalize what level of deterioration may be present based upon the lack of an annual capital upgrading program to date and the rates of deterioration observed by others.

5.3 Estimate of Condition State of the Current Inventory

UMA has developed deterioration rates for both Winnipeg, MB and Hamilton, ON based upon the inspection of over 1500 km of sewer infrastructure. These observations have been analysed and developed into a series of simple Markov chain deterioration models that are reflective of the average rate of condition state change that the inventory is likely to experience on an annual basis.

In a Markov model, elements within the system change from one state to another at fixed probabilities. These probabilities are typically shown as a State Transition diagram (Figure 5.2) or as a Matrix (Figure 5.3).

The Markov model is used to simulate the change in a system over time, beginning with the current distribution and changing according to the Markov transition for each discrete simulation time step. In the case of sewer inventories, the installation date of each sewer is only known to the nearest year, or in some cases can only be estimated to the nearest 5 or 10 years. The model developed in Winnipeg has used 5 year groupings while the models developed for Hamilton were initially based on 10 year groupings and are currently being upgraded to 5 year groupings based on additional research into sewer age.

Figure 5.2 - Markov State Transition Diagram

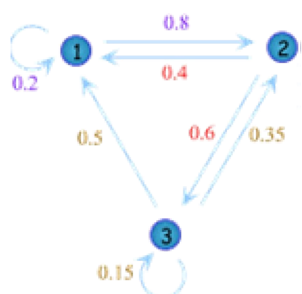
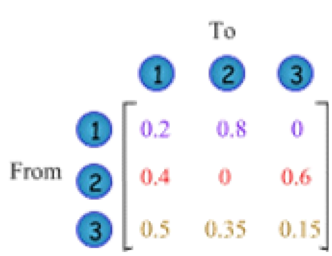


Figure 5.3 - Markov Matrix



Beginning with an initial distribution of sewers in various condition states (SPGs) and a Markov Matrix, the new distribution after any number of time steps can be calculated using matrix multiplication, as follows:

$$D_N = D_o M^N \qquad [1]$$

Where

D_N is the distribution of sewer conditions after N time steps
D_0 is the initial distribution of sewer conditions (at time 0)
M is the Markov matrix
N is the number of time steps

The beauty of a Markov system is that a very simple model can represent the complex behaviour of a system without the need to understand what's driving the system, only the need to see if the system is behaving in a statistically relevant manner. The Markov matrix used to represent sewer deterioration is straightforward; after any given time step, a sewer can either remain in its current state, or degrade to the next lower state.

By definition, a sewer cannot miss a step in the degradation process, so a sewer could never degrade from SPG 1 to SPG 3 without going through SPG 2. In reality, catastrophic failure such as an earthquake or soil collapse can occur that would change condition state instantaneously. These sudden, random failures cannot be simulated by the Markov model, which assumes that the system changes over time based according to fixed probabilities. Fortunately, in real life these failures represent a very small portion of a much larger dataset.

While UMA has developed discrete Markov models around a number of sewer parameters (e.g. pipe material, pipe size, etc.) it is not known how relevant these matrices are to the local data set. For simplicity, therefore, the best fit average condition state transition matrix was used based on the City of Winnipeg data set, which includes observations from over 1000 km of sewer infrastructure. This matrix is depicted in Table 5.3 below.

Table 5.3 - Best-Fit Markov Model for Sewer Deterioration (City of Winnipeg dataset)

		To				
		SPG 1	SPG2	SPG 3	SPG 4	SPG 5
From	SPG 1	96.3%	3.7%	0.0%	0.0%	0.0%
	SPG 2	0.0%	96.1%	3.9%	0.0%	0.0%
	SPG 3	0.0%	0.0%	97.5%	2.5%	0.0%
	SPG 4	0.0%	0.0%	0.0%	97.0%	3.0%
	SPG 5	0.0%	0.0%	0.0%	0.0%	100.0%

The two percentages in each condition state above represent the percentage of inventory that would be expected to remain in its current condition state and the percentage that would be expected to transition to the next condition state.

Utilizing the above deterioration rates, the average existing condition was estimated for each sub-basin based on its average age and the assumption that 80% of the new inventory was at SPG 1 when constructed and 20% was at SPG 2. For infrastructure that is brought into inventory with CCTV inspection at Final Acceptance (e.g. an inspection carried out 1-2 years after installation) this is not an unusual split.

The results of the analysis for each basin are summarized in Table 5.4 below.

The results of the assessment indicate that current average condition states range from a low of 2.20 in Basin VI to a high of 2.74 in Basin V_C with a length weighted average of 2.52. Based on Figure 5.1, therefore, the sustainable annual inspection cost for the overall system would be expected to be approximately $111,000 (the interpolated value between condition state 2 and 3).

While this amount represents a reasonable estimate of what level of annual investment in inspection should initially be made, it should be used with a great deal of caution, as ultimately these requirements should be refined based on the initial results of inspection.

It should also be noted that there is likely a substantial backlog of repairs that would benefit either infiltration objectives or the development of optimum rehabilitation scheduling. These repairs cannot currently be scheduled or prioritized due to a lack of current condition assessment data. It would be prudent, therefore, to ensure that condition assessment data is accumulated more aggressively as opposed to less aggressively over the short-term until a realistic assessment can be made of the current backlog, and the financial ramifications associated with leaving it unaddressed can be reasonably quantified.

Table 5.4 Estimate of Current Average Condition State for Each Basin

Basin	Assumed Initial condition	Estimated Average Condition	% Change
I	1.20	2.40	-99.69%
II	1.20	2.30	-91.60%
III_A	1.20	2.43	-102.35%
III_B	1.20	2.43	-102.35%
III_C	1.20	2.27	-88.87%
IV	1.20	2.71	-125.47%
V_A	1.20	2.49	-107.62%
V_B	1.20	2.62	-117.94%
V_C	1.20	2.74	-127.95%
VI	1.20	2.20	-83.35%
Length Weighted Average		**2.52**	

Appendix A
Sewer Inspection Specification Guidelines

ADD ENTIRE SECTION

1.0 GENERAL

.1 Section 02733 refers to those portions of the work that are unique to the requirements for cleaning new and existing sanitary, storm, and combined sewer pipe, and pipe culverts. Sewer cleaning shall remove all debris from sewers and manholes to alleviate blockages and prevent sewer backups, overflows and property damage, to restore hydraulic capacity, to reduce odours, to permit thorough condition inspection, and to allow rehabilitation works to be performed. Definitions for debris are generally consistent with the nomenclature contained in the Water Research Centre (WRc) publication, “Manual of Sewer Condition Classification” (MSCC), as presented in the North American Association of Pipeline Inspectors (NAAPI) Sewer Condition Classification Training Course. This section must be referenced to and interpreted simultaneously with all other sections pertinent to the works described herein.

1.1 Related Work

.1	Traffic Regulation	Section 01570
.2	Storm Sewers	Section 02721
.3	Pipe Culverts	Section 02723
.4	Manholes and Catchbasins	Section 02725
.5	Sanitary Sewers	Section 02731
.6	Sewage Forcemains	Section 02732
.7	CCTV Video Inspection	Section 02733

1.2 References

.1 The abbreviated standard specifications for testing, materials, fabrication and supply, referred to herein, are fully described in References – Section 02000.

1.3 Work Regulations

.1 Work to conform to all applicable regulations of the Workers’ Compensation Board (WCB). Confirm training compliance in the following:
- .1 Confined space rescue
- .2 Confined space entry
- .3 Ventilation
- .4 Atmospheric monitoring
- .5 Self-contained breathing apparatus
- .6 Personal protective equipment

.2 Provide written confirmation to the Contract Administrator that workers have knowledge of confined space entry practices and of the equipment required for confined space entry.

.3 Work to conform to all applicable bylaws and regulations.

1.4 Scheduling of Work

.1 Schedule work to minimize interruptions to existing services.

.2 Schedule work to comply with District Noise Bylaws.

1.5 Measurement for Payment

.1 All units of measurement for payment will be as specified herein unless shown otherwise in the Schedule of Quantities and Prices.

.2 Payment for all work performed under this Section will be made at the respective unit price bid in the Schedule of Quantities and Prices.

.3 Sewer Cleaning

Sewer cleaning will be measured on a length basis. The length paid will be the total number of lineal metres acceptably cleaned. Measurement will be made above ground from centre of manhole to centre of manhole as confirmed by steel tape measurement in conjunction with sewer inspection.

If cleaning is abandoned the length paid will be measured from the centre of the start manhole to the point of abandonment.

Separate payments will be made for sewer cleaning prior to repairs (i.e. on sections inspected prior to tender) and for sewer cleaning to facilitate CCTV inspections (i.e. on sections not inspected prior to tender).

Separate payment will be made for sewer sizes exceeding 350 mm diameter, as indicated in the Schedule of Quantities and Prices.

Manhole cleaning will not be measured for payment and will not be paid for separately. Payment is to be included in the prices bid for sewer cleaning.

.4 Reverse Set-Up

Separate payment will not be made for reverse set-up cleaning. Payment to be included in the prices bid for sewer cleaning

.5 Solid Debris Cutting

Solid debris cutting (e.g. grease, encrustation, roots) will be measured on a length basis. The length paid will be the total number of lineal metres acceptably cut, as computed by measurements taken from the sewer inspection.

Separate payments will be made for solid debris cutting prior to repairs (i.e. on sections inspected prior to tender) and for solid debris cutting to facilitate CCTV inspections (i.e. on sections not inspected prior to tender).

No separate payment will be made for each size or size range of sewers.

.6 Flow Control and Traffic Control

Separate payment will not be made for flow control or traffic control. Payment to be included in the prices bid for sewer cleaning.

2.0 PRODUCTS

2.1 High Velocity Cleaning Equipment

.1 High velocity sewer cleaning equipment to be constructed for ease and safety of operation. Equipment to have a selection of hydraulically or hydrodynamically propelled nozzles that are capable of producing a scouring action from 15 to 45 degrees, effectively scouring the sewer and transporting debris in all sizes of sewers to be cleaned. Equipment to be capable of providing a minimum flow of 4.1 l/s at 13,800 kPa. Equipment to include a water tank, auxiliary engines, pumps, a hydraulically driven hose reel, a wash down gun for cleaning manholes, and an approved back flow preventing device for water tank filling.

2.2 Debris Removal Equipment

.1 Debris removal equipment to consist of a vacuum unit complete with positive displacement pumps or fans producing a minimum of 700 l/s air movement, a storage tank, and hoses. Storage tank to be water tight and configured in such a manner as to allow the liquid portion of the debris to be returned to the sewer. Suction hose is to have a minimum diameter of 150 mm. Equipment to be capable of removing debris at a minimum of 4.5 m of vertical head.

2.3 Solid Debris Cutting Equipment

.1 Solid debris cutting equipment to be capable of removing heavy roots and solid debris such as encrustation and grease, and includes hydraulic cutters, saw or blade, and remotely operated robotic routers or grinders.

2.4 Sewer Plugs

.1 Sewer plugs to be designed to stop or reduce flow from upstream sewer(s) and are to permit tethering to and be removable from the ground surface.

3.0 EXECUTION

3.1 Sewer Cleaning

.1 Deliver District notification letters to residents at least one week prior to commencing any cleaning work. Contact information for the CCTV Contractor will be provided in this initial notification letter. The Contractor may be required to provide further information and/or written notices to residents.

.2 Provide a minimum of 24 hours notice to the Contract Administrator, of the locations where the cleaning will be performed on the following day(s).

.3 Clean all pipelines using high velocity equipment. Take precautions to ensure that no flooding of public or private property occurs during the cleaning, taking particular care with lots having short frontages.

.4 Scour and remove all debris from the sewers and manholes including but not limited to sludge, dirt, sand, gravel, rocks, bricks, grease, roots, and other solid and semi-solid materials. Some deposits such as heavy grease or root masses may require additional equipment and effort.

.5 Begin cleaning at the upstream sewer in the system and proceed downstream. Scour clean manhole walls and benching prior to cleaning the downstream sewer. Do not proceed downstream until all contributing upstream sewers have been cleaned. Clean sewers in the direction of flow unless a reverse set-up is required.

.6 If at any time during the cleaning operation pipe material or backfill is observed, immediately notify the Contract Administrator. Jointly, the Contractor and Contract Administrator will agree to:

- complete or attempt to complete cleaning;
- suspend cleaning operations and inspect the sewer; or
- simultaneously clean and inspect the sewer.

3.2 Reverse Set-up

.1 If cleaning of an entire sewer cannot be completed from the upstream manhole, move cleaning equipment to the downstream manhole and attempt cleaning again. Up to one hour is to be spent removing or attempting to remove a specific blockage in order to reduce upstream flow levels and permit complete sewer cleaning.

3.3 Debris Removal

.1 Vacuum type debris removal equipment is to be on site and in operation in the downstream manhole at all times during sewer cleaning. Remove all debris from the downstream manhole of the sewer being cleaned and do not pass debris from manhole to manhole. Decant excess water and return to the sewer downstream of the sewer being cleaned.

.2 Keep solid and semi-solid debris in totally enclosed containers at all times and remove from the site at the end of each day to be disposed of offsite.

3.4 Solid Debris Cutting

.1 Obtain the Contract Administrator's approval prior to undertaking any cutting and removal of excessive roots or solid debris from the sewer. The limits will be as identified by post-cleaning sewer inspection and as directed by the Contract Administrator. Perform the work using remote controlled equipment and monitor and record the entire operation by CCTV. Consider the existing pipe material and condition in selecting equipment and take care not to damage the existing pipe during the cutting and removal operation.

3.5 Flow Control

.1 If sewer flows are hampering effective sewer cleaning, undertake flow control measures. Flow control measures include but are not limited to, off peak work and plugging. Provide the Contract Administrator with 48 hours notice prior to undertaking any flow control measures. Select a method that ensures flooding of public or private property does not occur.

Monitor flow levels upstream of a plugged sewer at all times.

3.6 Supply of Water

.1 Water for sewer cleaning operations will be supplied from District fire hydrants. Provide the Contract Administrator with 3 days notification of intended hydrant location(s). The specific hydrant in the requested location will be selected and equipped with an appropriate back flow preventing device by District forces. The Contractor will be advised of the hydrant location. The back flow preventing device must be used at all times and the fire hydrant is not to be obstructed in the event of a fire in the area served by the hydrant.

3.7 Quality Control

.1 Acceptance of all work described in this section will be made upon successful inspection by the Contract Administrator. If the inspection reveals the work to be deficient, the sewer is to be re-cleaned and the work re-performed and re-inspected at the Contractor's expense until fully compliant with the specifications contained herein.

END OF SECTION

ADD ENTIRE SECTION

1.0 GENERAL

.1 Section 02734 refers to those portions of the work that are unique to the requirements for inspecting new and existing sanitary, storm, and combined sewer pipe, and pipe culverts by closed-circuit television. Sewer inspections shall be performed to: observe and record structural defects, service defects, infiltration, and construction features; to assess thoroughness of cleaning; and to verify the quality of new installation and rehabilitation work prior to acceptance. All observations shall be coded in accordance with the Water Research Centre (WRc) publication, "Manual of Sewer Condition Classification" (MSCC), as presented in the North American Association of Pipeline Inspectors (NAAPI) Sewer Condition Classification Training Course. This section must be referenced to and interpreted simultaneously with all other sections pertinent to the works described herein.

1.1 Related Work

.1	Traffic Regulation	Section 01570
.2	Storm Sewers	Section 02721
.3	Pipe Culverts	Section 02723
.4	Manholes and Catchbasins	Section 02725
.5	Sanitary Sewers	Section 02731
.6	Sewage Forcemains	Section 02732
.7	Sewer Cleaning	Section 02734

1.2 References

.1 The abbreviated standard specifications for testing, materials, fabrication and supply, referred to herein, are fully described in References – Section 02000.

1.3 Work Regulations

.1 Work to conform to all applicable regulations of the Workers' Compensation Board (WCB). Confirm training compliance in the following:

- .1 Confined space rescue
- .2 Confined space entry
- .3 Ventilation
- .4 Atmospheric monitoring
- .5 Self-contained breathing apparatus
- .6 Personal protective equipment

.2 Provide written confirmation to the Contract Administrator that workers have knowledge of confined space entry practices and of the equipment required for confined space entry.

.3 Work to conform to all applicable bylaws and regulations.

1.4 Scheduling of Work

.1 Schedule work to minimize interruptions to existing services.

.2 Schedule work to comply with District Noise Bylaws.

1.5 Measurement for Payment

.1 All units of measurement for payment will be as specified herein unless shown otherwise in the Schedule of Quantities and Prices.

.2 Payment for all work performed under this Section will be made at the respective unit price bid in the Schedule of Quantities and Prices. CCTV video inspection will be measured on a length basis. The length paid will be the total number of linear metres acceptably inspected. Measurement will be made above ground from the centre of the start manhole to the centre of the finish manhole, as confirmed by steel tape measurement.

Separate payments will be made for inspections of post-repair sections and for those sections not inspected prior to tender.

No payment will be made for any pre-repair inspection or for the one-year warranty inspection, as it is incidental to payment made in other sections. Note that the limits of work for the one-year maintenance period inspection need only be sufficient to inspect the repairs and sewer cleaning work carried out by the Contractor.

.3 Separate payment may be made for sewer sizes exceeding 350 mm diameter, as indicated in the Schedule of Quantities and Prices.

.4 For sections of pipe where inspection is abandoned (e.g. a blockage or obstruction occurs), measurement will be from the centre of the start manhole to the point of abandonment of survey.

.5 For sections of pipe with the Water Research Centre (WRc) condition code CU (camera underwater) for a continuous distance greater than five (5) metres, the measurement above will be reduced by the distance in excess of five metres.

.6 Separate payment will not be made for flow control, with the exception of bypass pumping. Payment for bypass pumping as required, and where approved by the Contract Administrator, will be made on a per occurrence basis (refer to Clause 3.4).

.7 Separate payment will not be made for inspection reports, video recordings, or photographs. Payment is to be included in the prices bid for CCTV video inspection.

.8 Separate payment will not be made for reverse set-up inspection or traffic control. Payment is to be included in the process bid for the CCTV video inspection.

1.6 Additional Work

.1 Additional work may be identified by the Contract Administrator after reviewing the inspection reports provided for those sections not inspected prior to tender. This work will be paid under tendered prices, where applicable, and will be covered by the contingency amount provided.

.2 Schedule CCTV inspection of those sections not previously inspected at the start of work and provide for a two week review period by the Contract Administrator once inspection reports have been submitted.

2.0 PRODUCTS

2.1 Inspection Unit

.1 Inspection unit to consist of a self-contained vehicle with separate areas for viewing and equipment storage. All equipment utilized within the pipeline to be stored outside of the viewing, recording and control area. External power sources from public or private sources are not permitted. Each inspection unit to be equipped with a cellular telephone and suitable communication system linking all crew members. Each unit to be equipped with fans and blowers to remove any fog that may be present in the sewer at the time of inspection.

.2 Viewing and control area to be insulated against noise and extremes in temperature. Proper seating accommodation to be provided to enable one person in addition to the operator to clearly view the monitor. External and internal sources of light to be controllable to ensure that light does not impede the view of the monitor.

2.2 Inspection Equipment

.1 Inspection equipment includes cameras, lighting, cables, power source, monitor, video recording device, and other related equipment.

.2 Camera to be capable of producing high quality colour imagery and providing complete inspection and view of all laterals and deficiencies. Live picture to be visible with no interference. Camera to be pan and tilt type with panning capability of 360° and tilting capability of 270°. The focus and iris are to be remotely adjustable to allow optimum picture quality. Focal range to be adjustable from 100 mm in front of the camera's lens to infinity.

.3 Light source to be remotely adjustable to allow an even distribution of light around the sewer perimeter without loss of contrast, flare out of picture, or shadowing.

.4 Video overlay equipment to be capable of superimposing alphanumeric information onto the video file with a minimum of 15 lines of information, 30 characters per line (refer to Clause 3.3.2).

.5 Camera to be transported through the sewer by means of a crawler or rubber tired tractor. Mounting of the camera on a float or skid for towing through the sewer will only be permitted where the condition of the sewer or flow level precludes the use of a tractor. If the camera is towed the supporting equipment is not to impede the view of the camera and is to be stable to ensure steady and smooth progress.

.6 Camera transport to permit complete inspection of the sewer from the centre of the start manhole to the centre of the finish manhole. The camera transport and cable to be capable of inspecting a minimum of 150 metres of sewer from a single access point. Each unit to carry sufficient numbers of guides and rollers such that when surveying, all cables are supported away from pipe and manhole edges. All CCTV cables and lines used to measure the camera's location within the pipeline to be maintained in a taut manner and set at right angles, where possible, to run through or over the measuring equipment. A remote reading counter to be used to measure distance travelled from the centre of the start manhole. Measurements to be recorded in metres to the nearest 0.1 m.

.7 Camera height to be adjustable so as to position the centre of the lens in the centre of circular sewers, and at 2/3 the height of the pipe measured from the invert for elliptical sewers.

2.3 Sewer Plugs

.1 Sewer plugs to be designed to stop or reduce flow from upstream sewer(s) and to permit tethering to and be removable from the ground surface. Plugs to permit all or any portion of flow to be released.

2.4 Bypass Pumping

.1 Bypass pumping equipment includes pumps, piping, tank trucks, and other related equipment. Equipment selection and configuration to be reviewed on a site-specific basis.

3.0 EXECUTION

3.1 Sewer Inspection

.1 Provide a minimum of 24 hours notice to the Contract Administrator, of the locations where the inspections will be performed on the following day(s).

.2 Prior to CCTV video inspection, clean sewers in accordance with Sewer Cleaning Supplementary Specifications - Section 02733.

.3 Prior to beginning the inspection measure the distance on the ground surface between the centres of the start and finish manholes using a steel tape measurer. Ensure a minimum of 80% of the height of the sewer is visible for the entire inspection. Notify the Contract Administrator of excessive flows before implementing flow control measures (refer to Clause 3.4). Keep the camera lens clean at all times and the sewer clear of fog during the entire inspection by introducing forced air flow by means of fans or blowers.

.4 Conduct all inspections in the direction of flow unless a reverse set-up is required. Inspections are generally to begin with the upstream sewer in the system and proceed downstream in a consecutive manner. Inspection is not to proceed downstream until all contributing upstream sewers have been cleaned.

.5 The face of the start manhole is to be clearly visible at the start of the inspection. Perform the inspection from the centre of the start manhole to the centre of the finish manhole. Note the condition of pipe joints at manhole walls at the beginning and end of each pipeline. At the start of the inspection record the length of sewer from the centre of the manhole to the cable calibration point and adjust the distance reading at the cable calibration point such that zero is at the centre of the start manhole.

.6 Indicate the automatic distance measurement on the screen during the entire inspection. This should begin to move immediately as the camera moves.

.7 Limit camera travel speed to the following:
.1 0.10 m/s for pipeline diameter < 200 mm
.2 0.15 m/s for pipeline diameter 200 mm – 310 mm
.3 0.20 m/s for pipeline diameter > 310 mm

.8 During the inspection keep the picture in focus from the point of observation to a minimum of two pipe diameters ahead.

.9 Stop the camera for a minimum of 2 seconds at rehabilitated sewer sections, any observed major defects, change of pipe condition, connections, junctions and major branches. Major defects include but are not limited to: deformed sewers, holes, broken pipe, large displaced joints, large open joints, and obstructions. Position the camera to provide a perpendicular view of major defects, connections, junctions, and major branches. Pan each service such that the camera looks down the centreline of the service and note the condition of the joint or pipe/service interface.

.10 Photograph all major defects as defined in the MSCC by condition codes B, CC, CL, CM, CX, CXI, D, FC, FL, FM, H, IR, IG, JDL, JX, OB, OJL, RT, RM, and X.

Overlay on each photograph the following data in alphanumeric form such that it will not interfere with the defect condition reported:
.1 Report/job number
.2 Chainage
.3 Manhole from/to numbers and/or pipe length reference number
.4 Photograph number
.5 Condition defect code
.6 Date of survey (yyyy.mm.dd)

Capture the photograph and alphanumeric data as a digital image in Joint Photographic Experts Group (JPEG) format (.jpg) or as specified in the Contract Documents.

.11 If inspection of an entire sewer cannot be completed due to collapse, excessive deformation or solid debris, intruding connections, obstructions, or large displaced joints, move the equipment to the upstream manhole and attempt inspection again. If complete inspection still cannot be performed immediately notify the Contract Administrator. Jointly, the Contractor and Contract Administrator will decide to:

- Abandon the inspection; or
- Complete the inspection subsequent to:
    - Performing solid debris cutting;
    - Removing intruding connections;
    - Modifying camera set-up (position and/or method of transport); and/or
    - Completing emergency repairs.

.12 If during the inspection clear water infiltration, flow disparity, a hole, collapse, void, or deformation greater than 10% is observed, capture an image (digital photograph and video) and immediately notify the Contract Administrator. If a void is visible or suspected outside the pipe immediately place barricades around the location and notify the Contract Administrator or Emergency Services. If required, the Contract Administrator will coordinate emergency repairs by District forces or another contractor. Between the time of notification and until said repairs are complete, the Contractor shall carry out inspection works in areas not affected by the repairs. The Contract Administrator will notify the Contractor when the repairs are complete so the inspection may be completed and the repair quality assessed.

3.2 Inspection Reports

.1 Inspection reports are to consist of hardcopy CCTV inspection reports, original DVDs, and CD-ROMs of digital data output files and digital photographs. Submissions are to be made biweekly for the previous weeks' work as the CCTV inspection proceeds.

Store digital data output files on CD-ROM in NAAPI standard (WRc) file format as a Microsoft Access database (.mdb). The digital database file is to contain survey report information identical to the printed report, exclusive of photographs.

Reproduce photographs, where required, in colour with minimum image size of 3.5 inches x 5 inches on premium glossy ink jet paper. Store digital photographs on CD-ROM in JPEG (.jpg) format. Coordinate photographs with the written report by reference number and insert into the report following the relevant section of pipeline inspected.

All dimensions and chainages in the reports to be in metric units.

.2 Present inspection reports in an 8.5 inch x 11 inch three ring binder organised by catchment area or as specified in the Contract Documents. Insert the accompanying inspection DVDs and CD-ROMs of digital database files and digital photographs in a three-hole punched plastic sheet holder at the front of the corresponding binder. Start each binder with an index of all survey inspection reports contained within. For each section of sewer surveyed, attach to the corresponding inspection report a District-supplied, scale drawing high-lighting the inspected pipeline.

Attach identical identification labels on the binder, DVDs and CD-ROMs with the following information:

.1 Contract/Project ID
e.g. District of West Vancouver Basin VA
.2 Inclusive inspection/report numbers
e.g. 001-020
.3 Inclusive DVD ID
e.g. DVD1 & DVD2
.4 Contractor name
e.g. XYZ Ltd.
.5 Dates of inspection
e.g. 2005/01/01 – 2005/02/28

.3 Provide additional copies of the printed report if required, as specified in Contract Documents.

3.3 DVD Recordings

.1 Capture inspections in colour MPEG2 format from the live video source, on new, unused DVD+RW or DVD-RW media. All digital videos to be first generation recordings. Submit one complete single digital file for each inspection. The final file may be produced in one of three ways:

.1 Using a computer system and capture card, the original recording may be captured continuously, regardless of the progress of the inspection. Where inspection progress is not continuous, edit the original raw digital file to remove pauses prior to submitting;
.2 Using a computer system and capture card, the original recording may be captured intermittently, where inspection progress is not continuous. Combine original raw digital files to form one continuous file for submission; or
.3 Employ specialized video recording equipment which is capable of pausing and resuming live recording to produce one single file for submission.

.2 At the start of each survey use video overlay equipment to clearly display the following alphanumeric information on the monitor and video recording for a minimum of 30 seconds:

.1 Contract ID
e.g. District of West Vancouver Basin VA
.2 Inspection/report number
e.g. 001
.3 Street name/location
e.g. 5th Avenue from 1st Street to 2nd Street
.4 Sewer size (diameter)
e.g. 200 mm
.5 Sewer pipe material
e.g. PVC
.6 Type or use of pipe

e.g. sanitary
.7 Start MH ID number
e.g. 1234
.8 Finish MH ID number
e.g. 5678
.9 Contractor name
e.g. XYZ Ltd.
.10 Date and time of inspection
e.g. 2005/01/01-15:15
.11 Direction of inspection
e.g. downstream
.12 Cable calibration distance
e.g. 1.5 m
.13 Verbal description of all the above on screen information

Enter this information prior to beginning the inspection.

.3 During the inspection clearly display the following information at the periphery of the monitor and video recording, arranged such that interference with the inspection image is minimized:
.1 Automatic update of the camera's distance from the centre of the start manhole
e.g. 15.3 m
.2 Start MH ID number
e.g. 1234
.3 Finish MH ID number
e.g. 5678
.4 Inspection/report number of the run
e.g. 001

.4 In addition to continuously displayed data, overlay WRc sewer condition codes on the monitor and video recording at defects, connections and junctions.

3.4 Flow Control

.1 Reduce flow in the pipeline to approximately 20% of the pipe diameter during CCTV inspection.

If sewer flows are hampering effective sewer inspection, undertake flow control measures. Flow control measures include but are not limited to: off-peak work; plugging or impeding flow; using sewer cleaning equipment to lower downstream flow levels; and bypass pumping. Provide the Contract Administrator with 48 hours notice prior to undertaking any flow control measures. Select a method that ensures no flooding of public or private property occurs.

.2 Prior to requesting the use of bypass pumping the Contractor must demonstrate that off-peak work, plugging, sewer cleaning equipment, or a combination thereof cannot effectively reduce flow levels to the specified maximum. Temporary bypass hoses and pumps to be of sufficient capacity to handle the peak flow, and all hoses and couplings to be leak free. Approved bypass pumping to be set up such that flow is pumped to a downstream manhole on the same system or run whilst the inspection takes place.

.3 Monitor flow levels upstream of a plugged or bypassed sewer at all times.

3.5 Quality Control

.1 Camera Position

Camera position tolerance is +/-10% of the vertical dimension of the sewer.

If the camera position does not satisfy the requirements the inspection is to be re-performed at the Contractor's expense.

.2 Distance Accuracy

Distance measurement within the sewer to be accurate to within 0.5% of the above ground measurement as confirmed by steel tape measurement between start and finish manhole centres.

Check the chainage tolerance at the start of the contract and a minimum of once every two weeks thereafter, or every 5000 metres of pipeline inspected, whichever is greater.

If the distance measurement does not satisfy the accuracy requirements the inspection is to be re-performed at the Contractor's expense.

.3 Recording Resolution

All digital video editing to be done with non-linear video editing software and in no case shall edited digital files be recompressed. Digital video files shall conform to the following requirements:
Picture Size: NTSC 704 x 480 @ 29.97 frames per second
Data/Bit Rate: MPEG2 @ 5 M-bits per second

Video capture equipment to be capable of capture with no frame loss.

Camera to be capable of registering a minimum number of 400 lines of resolution at the periphery.

Resolution to be confirmed at the beginning of each DVD and with each new camera introduced, using a Marconi or RETMA resolution chart as follows:

1. Recording to show camera being introduced and reaching its final position for the test
2. Resolution chart to fill monitor screen
3. Resolution chart to be illuminated evenly and uniformly without reflection, and illumination source to accurately simulate lighting used in sewer
4. Test to be recorded for minimum of 30 seconds

.4 Operator Qualifications - Inspection and Condition Coding

Each inspection unit to have a minimum of one operator on site at all times who has successfully completed the NAAPI Sewer Condition Classification Training Course. Condition coding to be performed by this duly qualified operator who is fully trained in all aspects of sewer inspection and is capable of making accurate observations and recordings of all conditions that may be encountered in the sewers.

Submit a copy of each operator's current NAAPI qualifications at least 2 business days prior to the commencement of work.

If no NAAPI certified operators are available on a given day, no inspection work is to be performed.

.5 Sample Inspection Report

At least 2 weeks prior to beginning the inspection work submit a sample inspection report, DVD and corresponding digital data files and digital photographs for review. One submission is to be made for each camera proposed for use on the work. Clearly identify the camera make, model and serial number on each video. Demonstrate the resolution of each camera by performing a recording resolution test using the procedure contained herein. Sample submission to satisfy all of the specifications contained herein and the accepted report submission will be used as a benchmark for subsequent inspection report submissions.

No inspection work to be performed until an acceptable sample inspection report has been submitted and approved for each camera to be used in the completion of the work.

.6 Coding Accuracy

Coding accuracy to be a function of the number of defects or construction features not recorded (omissions) and the correctness of the coding and classification recorded. Coding accuracy to satisfy the following requirements:

- header accuracy 95%
- detail accuracy 85%

Implement a formal coding accuracy verification system at the onset of the work. Verify coding accuracy on a random basis, on a minimum of 10% of the inspection reports. The Contract Administrator is entitled to review the accuracy verification system and results and to be present when the assessments are being conducted. A minimum of two accuracy verifications are to be performed for each operator for each working week.

Coding not satisfying the accuracy requirements is to be re-coded at the Contractor's expense, and the accuracy of the inspection report immediately preceding and following the non-compliant inspection to be verified. This process is to be repeated until the preceding and subsequent inspections meet the accuracy requirements.

Any operator failing to meet the accuracy requirements on two occasions will not be permitted to code on the remainder of the project until successfully re-attending the NAAPI Sewer Condition Classification Training Course.

.7 Sewer Cleaning

For sewers that are deemed by the Contract Administrator to be unacceptably cleaned, CCTV video inspection reports will be rejected and the sewer re-cleaned and re-videoed at the Contractor's expense.

.8 Report Submissions

Inspection reports, DVDs, digital data files, and digital photographs will be reviewed by the Contract Administrator on a random basis on a minimum of 10% of the inspection reports, to ensure compliance with the specifications. The frequency of review will be adjusted based on the results of the review. The Contract Administrator will return non-compliant submissions for correction at the Contractor's expense.

Resubmit corrected submissions within 5 working days.

END OF SECTION

Appendix D – Weibull Distribution

To simulate the reality that not all pipes with an expected service life of 90 years will fail at exactly 90 years, the Weibull Distribution was used to model a replacement envelope and predict pipe failure as the network ages. The Weibull Distribution, which has a broad range of applications, is used in this case to distribute the probability of assets to fail over time and associates this probability with a cost. This statistical tool does not predict when each individual asset will fail but it accurately describes how a large inventory of similar assets (e.g. pipes) actually behaves in real life.

Another advantage of Weibull Distribution is that it provides a simple and informative graphical plot. X axis is a measure of time in calendar years and Y axis is either the annual length to be replaced or the annual cost of replacement anticipated for each year.

It is important to note that Weibull Distribution's reliability depends entirely on the accuracy of parameters used in the calculation. In this analysis, these parameters are:

- installation year;
- expected service life; and
- shape parameter.

While the installation year is defined (or estimated), both the expected service life and the shape parameter are estimated. Pipe materials' expected service lives are described in Section 6. The shape parameter, or β, which is unitless and dimensionless, is also known as the slope. This is because the value of β is equal to the slope of the regressed line in a probability plot. In other words, it indicates whether the failure rate is increasing, constant or decreasing. A β <1.0 indicates that the asset has a decreasing failure rate. A β =1.0 indicates a constant failure rate and a β >1.0 indicates an increasing failure rate which is typical of assets that are wearing out like pipes. Based on research papers and actual field observations, it is generally agreed that for a pipe inventory, an accurate value for β is between 7.0 and 8.0.

Please note that all Weibull calculation sheets and charts produced with MS Excel for the purpose of this study are dynamic. This allows users to change most variables, including the shape parameter and expected service lives, and see in real-time the effects of these changes on the charts. With time, as more failure data becomes available, the shape parameter can be refined to fit the District's own failure rate. Eventually this will lead to more accurate results.

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