Prepared By:

Town Of Georgina

Criticality Analysis

GMBP File: 714077-2

September 1st, 2016

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APPENDICES

1. Introduction

The Town of Georgina has retained GM BluePlan Engineering Limited to develop a prioritized capital program budget estimate through the criticality analysis and risk assessment of the Town's water distribution and sanitary sewer system assets. The primary objective of the assignment was to develop an Excel based analytical tool that can be used in risk-based decision making for a prioritized capital program. A series of asset replacement program scenarios were developed with differing risk thresholds to understand the impacts of increasing, maintaining, or decreasing capital expenditure.

1.1 Project Scope

In consultation with the Town of Georgina, the tool and capital program were developed to achieve the following objectives:

- Development of a dynamic Excel-based tool with transparent analysis
- Development of a risk score for each asset based on likelihood of failure and consequence of failure. As part of the development of a risk score, the tool will:
    - Identify water and wastewater system priority components
    - Identify costs and timings associated with the replacement of individual or system wide assets
- Development of asset replacement program scenarios with varying degrees of associated risk and expenditure

1.2 Report Scope

The scope of this report is to outline the process in which the risk assessment tool and prioritized capital program were developed including:

- Overview of data used to populate the tool's database
- Methodology for developing the tool and capital program scenarios
- Outline of both the risk based and age based replacement programs
- Recommendations for utilizing the tool in future asset management applications

1.3 Existing Data

The following is a list of data received and utilized in risk assessment of both the Town's watermains and sanitary sewers:

- GIS data
    - Town's water distribution system
        - Geometry, age, material, location, and ownership
    - Town's sanitary sewer system
        - Geometry, age, material, ownership, and location of sewage pumping stations
    - Environmental features
    - Road classes
- All-pipe hydraulic water model
- Historic break information
- Billing and population data
- Historic watermain maintenance issues (e.g. frozen watermains)
- Estimated Service Life (ESL) by material type

2. System Overview

2.1 Water System

The Town of Georgina's water distribution system consists of approximately 206 km of watermains averaging an age of 21 years. Table 1 summarizes the Town's water distribution asset characteristics in terms of remaining life, material, and diameter.

Table 1: Water Distribution System Overview

Remaining Life (Years)			Material[(1)]			Diameter (mm)		
0	1%	2,854 m	**AC**	3%	6,587 m	**≤100**	1%	2,525 m
5	3%	5,596 m	**CI**	4%	7,235 m	**150**	56%	115,727 m
10	3%	5,855 m	**CPP**	2%	3,872 m	**200**	15%	30,193 m
20	8%	16,816 m	**DI**	7%	15,050 m	**250**	5%	9,333 m
40	16%	33,153 m	**PVC**	82%	169,728 m	**300**	11%	23,142 m
60	55%	113,213 m	**Other**	2%	3,260 m	**≥350**	12%	24,811 m
Total Length		205,732 m	**Total Length**		205,732 m	**Total Length**		205,732 m

(1) For unabbreviated material types refer to Table 3

2.2 Wastewater System

The Town of Georgina's water distribution system consists of approximately 175 km of gravity sewers averaging an age of 22 years. Table 2 summarizes the Town's sanitary gravity sewer characteristics in terms of remaining life, material, and diameter.

Table 2: Sanitary Sewer System Overview (Gravity Sewers Only)

Remaining Life (Years)			Material[(1)]			Diameter (mm)		
0	<1%	459 m	**AC**	7%	11,846 m	**≤150**	<1%	111 m
20	<1%	549 m	**CP**	4%	6,162 m	**200**	76%	132,463 m
40	7%	11,527 m	**PVC**	89%	155,958 m	**250**	11%	19,647 m
60	19%	33,719 m	**Other**	<1%	603 m	**300**	3%	5,582 m
80	90%	156,695				**≥350**	10%	16,766 m
Total Length		174,570 m	**Total Length**		174,570 m	**Total Length**		174,570 m

(1) For unabbreviated material types refer to Table 3

3. Asset Replacement Program Scenarios – Overview and Methodology

A number of asset replacement programs were developed to further understand the impacts of aging assets and their associated risks while emphasizing sustainable capital expenditure. The foundation for the capital replacement program relies on the total replacement cost for each asset which was based on an assumed unit cost per metre of pipe plus 25% to account for associated engineering and contingency allowances.

The timing schedule for asset replacement was influenced by the estimated useful life for each material type. Table 3 summarizes the unit costs by diameter and estimated useful life by material for both watermains and sewers.

This section outlines the three methodologies for the different asset replacement approaches:

1. Average Asset Replacement Value – All Assets
2. Age Based Replacement Program – 20 Year Average
3. Risk Based Replacement Program – 20 Year Program

The results and summary of the three methodologies are shown in Sections 4 through 6.

A summary of the Excel based tool's dynamic features is located in Appendix A.

Table 3: Unit Cost by Diameter and Estimated Useful Life by Material

Diameter (mm)	Unit Costs ($/m)			Material		Estimated Service Life (Years)	
	Watermains	Sewers				Watermains	Sewers
≤150	500	500		**Asbestos Cement**	AC	75	75
200	600	500		**Cast Iron**	CI	50	60
250	600	500		**Clay Pipe**	CP	-	90
300	750	618		**Concrete Pressure Pipe**	CPP	75	-
350	800	-		**Copper**	COP	50	-
375	-	659		**Corrugated Steel**	CSP	-	25
400	900	-		**Ductile Iron**	DI	50	60
450	970	715		**High Density Polyethylene**	HDPE	75	75
500	1,100	-		**Poly Vinyl**	PV	75	-
525	-	769		**Polyethylene**	PE	75	-
600	1,300	990		**Polyvinyl Chloride**	PVC	75	90
675	-	1,200		**Steel**	STL	60	-
750	1,550	1,331		**Unknown**	UNK	50	60
825	-	1,428					
900	-	1,680					

3.1 Average Asset Replacement Value – All Assets

The Average Asset Replacement Value represents the long term average annual costs to replace every asset in the system. This program was based on the cumulative asset replacement costs and the maximum period of time to replace every asset in the system. This methodology provides a general, long term average replacement need of the entire system based on the estimated service life of each asset.

Average Annual Cost for Replacement = Total Replacement Cost ÷ Year for Full Replacement

3.2 Age Based Replacement Program – 20 Years

The Age Based Replacement Program was based on the current age and estimated service life of each asset.

Replace Asset When → Asset Age = Estimated Service Life

The replacement timing schedule was based on estimated useful life by material types listed in Table 3. The Age (ESL) Based Replacement Program estimates the asset replacement needs for the following timeframes:

- 1-5 Years
- 6-10 Years
- 11-20 Years
- 20+ Years

The critical value derived from this calculation is the average replacement needs over the next 20 years. This methodology provides an indication of the average annual asset replacement needs over the next 20 years based on the current age of the network.

3.3 Risk Based Replacement Program

The development of a Risk Based Replacement Program is the focus of the study. This program incorporated specific asset variables and parameters in order assign a criticality score to each pipe. This criticality score drives the immediate and long term replacement program.

A risk score was assigned to each asset based on a number of weighted criteria which govern its Likelihood of Failure (LOF) and Consequence of Failure (CoF) scoring. The higher weightings were assigned to each criteria with greater importance or consequences. A pairwise analysis was used to develop a weighted relationship between two or more relevant factors and was applied to failure indicators, consequence criteria, and consequence categories.

The resulting scores are governed by the importance of each potential impact relative to other impacts. With the determination of the likelihood of failure and consequence of failure scoring, risk was calculated by the following formula:

Risk: Likelihood of Failure & Consequence of Failure

The subsequent risk score was used in determining an action and timing schedule for each asset assessed.

3.3.1 Likelihood of Failure

The Likelihood (or Probability) of Failure is the probability in which an asset will fail when considering physical condition, age and reliability. The most accurate means of determining the LoF is using up to date condition information; however, condition information was not available during this study. As such, the LoF was based off a comparison of known asset characteristics which are known indicators for failure. These indicators include the following:

- Watermains:
  - Age, estimated service life, and remaining life
  - Historic breaks
  - Material
- Sewers:
  - Age, estimated service life, and remaining life

Each of the above criteria were given a 1-5 rating based on the impacts of each factor on the LoF (e.g. a pipe with very little to no estimated remaining life receives an "Age Score" of 5, a new pipe receives an "Age Score" of 1). These ratings were weighted against one another based on relative influence on pipe failure, then added together to obtain a total LoF score between 1 and 5.

3.3.2 Consequence of Failure

The Consequence of Failure is a measure of the impacts of failure of an asset on that particular asset's service area. The CoF for the purposes of this study were divided into two categories:

- Hydraulic level of service (LOS) Impacts – System wide impacts to customers
- Property and Environmental Impacts – Immediate area impacts to the asset's surrounding environment

The following is a list of customer level of service and property and environmental indicators:

- Watermains:
  - Hydraulic LOS impacts
    - Number of customers that experience a loss of service as determined by the hydraulic model (Total Loss, < 20 psi, <40 psi)
    - Land use; Residential or ICI
  - Property and environmental impacts
    - Flow rate; Discharge into the environment
    - Max day pressures
    - Road class; traffic interruptions
    - Proximity to an environmental feature with emphasis on direct water feature crossings
- Sewers:
  - LOS impacts
    - Diameter and peak wet weather flow rates are a direct result of the upstream catchment area the sewer is servicing
  - Property and environmental impacts
    - Location of sewer to a sewage pumping station
    - Road class
    - Proximity to an environmental feature with emphasis on direct water feature crossings

Each of the above criteria were given a rating based on the impacts of each factor on the CoF and then weighted using a pairwise analysis. Table 4 outlines the CoF impacts and their corresponding ratings. A second pairwise analysis was performed between LOS impacts and Property and Environmental impacts. The total consequence of failure was determined as the sum of the two weighted categories.

Table 4: Consequence of Failure Categories

Rating		Total Customer Impact (Water)	Total Customer Impact (Wastewater)	Property and Environmental Impact
5	**Extreme**	Impact Score >500	Diameter >525 (Trunk Sewer) Largest Catchment Area, failure impacts highest number of customers	Significant disruption/impact
4	**Major**	Impact Score 201-500	>450 Diameter ≤525 (Sub-trunk sewer) Large Catchment Area, failure impacts high number of customers	Major disruption/impact
3	**Moderate**	Impact Score 51-200	>375 Diameter ≤450 (Sub-trunk sewer) Medium catchment area, failure impacts moderate number of customers	Moderate disruption/impact
2	**Minor**	Impact Score 2-50	>250 Diameter ≤375 (Local collector sewer) Small catchment area, failure impacts low number of customers	Minor disruption/impact
1	**Minimal**	Impact Score <1	Diameter ≤250 (Local sewer) Smallest catchment area, failure impacts least number of customers	Trivial disruption/impact

4. Average Asset Replacement Program – All Assets

The Average Asset Replacement Program was based on the average annual costs required to replace all assets over the period of their estimated life. The average annual costs for replacement is outlined in Table 5.

Table 5: Average Asset Replacement Costs

	Watermains	Sewers
Total System Replacement Cost	$155M	$136M
Years for Full Replacement	74	89
Average Annual Cost for Replacement	**$2.1M/year**	**$1.5M/year**

5. Age Based Replacement Program – 20 Year

The Age Based Replacement Program was based on the estimated service life of each asset. The estimated remaining life and subsequent estimated replacement year were calculated for all of the Town of Georgina's water and wastewater assets. The total estimated replacement costs for each time period were calculated and are shown in Table 6. In addition, the table highlights the average annual costs over the first 20 year period. Due to the overall age of the Town's water system, the results show that this program is highly weighted to asset replacement beyond the 20 year period.

Table 6: Aged Based Replacement Program

Risk Based	Timing	Water(1)	Wastewater(1)
Age Based	**20 Year Annual**	**$ 646,000**	**$ 21,000**
	1-5	$ 3,744,000	$ 371,000
	6-10	$ 50,000	$ 57,000
	10-20	$ 9,129,000	$ -
	20+	$ 142,368,000	$ 135,500,000
	Total	**$ 155,291,000**	**$ 135,500,000**

(1) Values have been rounded to the nearest thousand

The results of the age based and average asset replacement analysis are summarized in Figure 1 and Figure 2, (*average* replacement needs over the long term are shown as the orange dotted lines) as follows:

- Between 2016 and 2050 there is a generally lower than the average asset replacement value
- Post 2050, the annual replacement needs are estimated to be significantly higher than the average asset replacement value

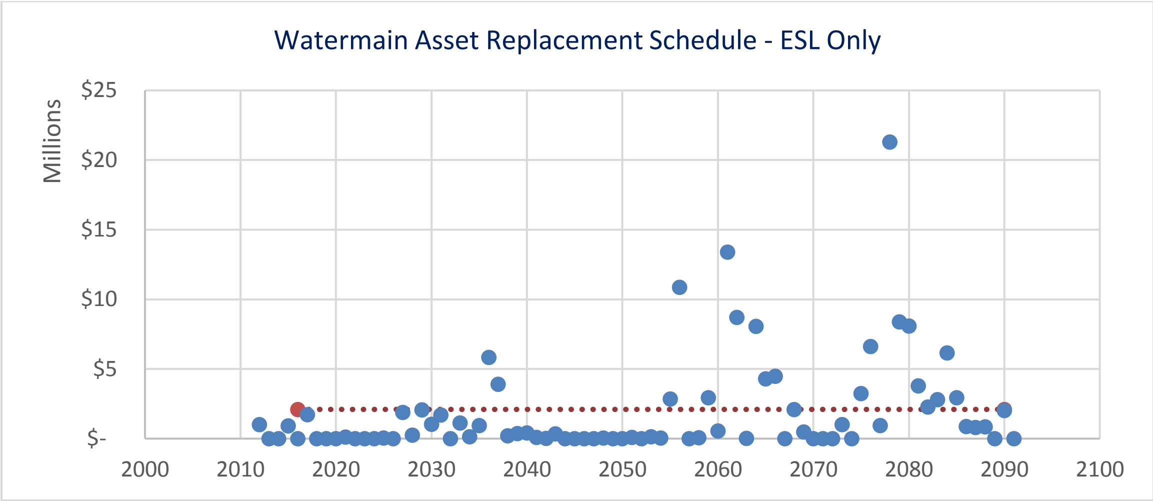

Figure 1: Age Based Watermain Asset Replacement Schedule and Costs

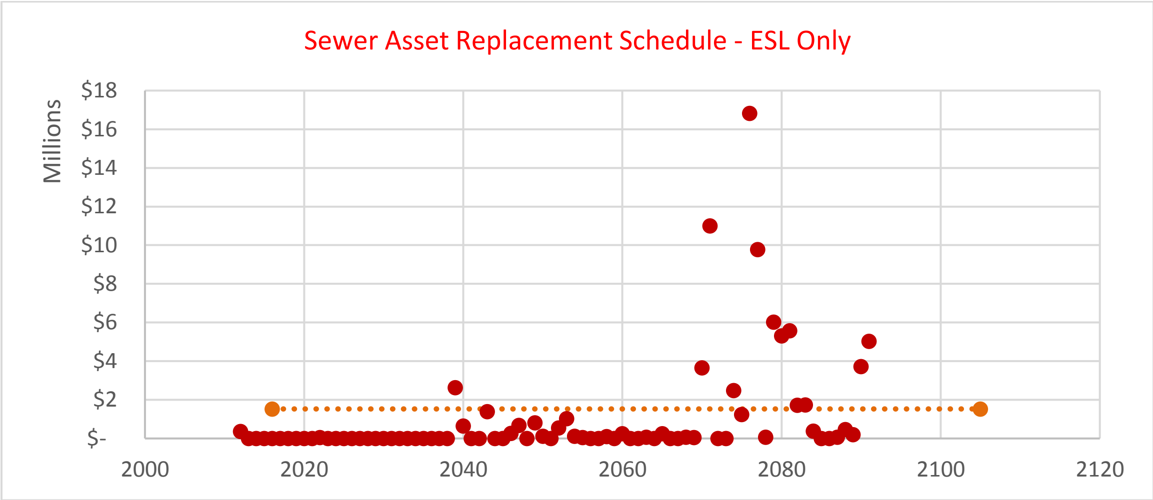

Figure 2: Age Based Sewer Asset Replacement Schedule and Costs

6. Risk Based Replacement Program

The Risk Based Replacement Programs are dependent on the risk scores derived from the LoF and CoF. The severity of the risk scores is highly dependent on the CoF over the LoF.

6.1 Scenarios

Three risk-based scenarios were developed under this analysis targeting high, medium, and low levels of service. Table 7 indicates the actions associated with each risk score for each level of service scenario.

6.1.1 High Level of Service Scenario

A high level of service is the result of a low risk tolerance thus enabling assets to be triggered for replacement at a lower risk score. By having a low risk tolerance, this scenario is more proactive due to a higher rate of replacement.

6.1.2 Low Level of Service Scenario

A low level of service is the result of a high risk tolerance which enables assets to be triggered for replacement at a higher risk score. By having a high risk tolerance, this scenario is the more reactive. The replacement of an asset is only triggered when absolutely necessary resulting in high costs at the back end of the replacement period.

6.1.3 Medium Level of Service Scenario

A medium level of service is the result of a medium risk tolerance and it is the result of a risk score between low and high.

Table 7: Risk and Action Summary

					Low LoS	Medium LoS	High LoS
CoF	**LoF**	**Risk Score**	**Risk Score**	**Action**	**Timing**	**Timing**	**Timing**
1	1	1, 1	**1**	Do nothing-replace	At Asset Failure (20+)	At Asset Failure (20+)	At Asset Failure (20+)
1	2	1, 2	**2**	Do nothing-replace	At Asset Failure (20+)	At Asset Failure (20+)	At Asset Failure (20+)
1	3	1, 3	**3**	Do nothing-replace	At Asset Failure (20+)	At Asset Failure (20+)	6-10 Years
1	4	1, 4	**4**	Do nothing-replace	At Asset Failure (20+)	10-20 Years	6-10 Years
1	5	1, 5	**5**	Rehab/replace	10-20 Years	6-10 Years	1-5 Years
2	1	2, 1	**2**	Do nothing-replace	At Asset Failure (20+)	At Asset Failure (20+)	At Asset Failure (20+)
2	2	2, 2	**4**	Do nothing-replace	At Asset Failure (20+)	At Asset Failure (20+)	At Asset Failure (20+)
2	3	2, 3	**6**	Do nothing-replace	At Asset Failure (20+)	10-20 Years	10-20 Years
2	4	2, 4	**8**	Rehab/replace	10-20 Years	10-20 Years	10-20 Years
2	5	2, 5	**10**	Rehab/replace	6-10 Years	6-10 Years	1-5 Years
3	1	3, 1	**3**	Do nothing-replace	At Asset Failure (20+)	At Asset Failure (20+)	At Asset Failure (20+)
3	2	3, 2	**6**	Do nothing-replace	At Asset Failure (20+)	At Asset Failure (20+)	At Asset Failure (20+)
3	3	3, 3	**9**	Do nothing-replace	At Asset Failure (20+)	10-20 Years	10-20 Years
3	4	3, 4	**12**	Rehab/replace	6-10 Years	6-10 Years	6-10 Years
3	5	3, 5	**15**	Rehab/replace	6-10 Years	6-10 Years	1-5 Years
4	1	4, 1	**4**	Do nothing-replace	At Asset Failure (20+)	At Asset Failure (20+)	At Asset Failure (20+)
4	2	4, 2	**8**	Do nothing-replace	At Asset Failure (20+)	At Asset Failure (20+)	10-20 Years
4	3	4, 3	**12**	Rehab/replace or reduce criticality score by adding redundancy	10-20 Years	6-10 Years	6-10 Years
4	4	4, 4	**16**	Rehab/replace or reduce criticality score by adding redundancy	6-10 Years	1-5 Years	1-5 Years
4	5	4, 5	**20**	Rehab/replace or reduce criticality score by adding redundancy	1-5 Years	1-5 Years	1-5 Years
5	1	5, 1	**5**	Do nothing-replace	At Asset Failure (20+)	At Asset Failure (20+)	At Asset Failure (20+)
5	2	5, 2	**10**	Rehab/replace or reduce criticality score by adding redundancy	At Asset Failure (20+)	10-20 Years	10-20 Years
5	3	5, 3	**15**	Rehab/replace or reduce criticality score by adding redundancy	10-20 Years	6-10 Years	1-5 Years
5	4	5, 4	**20**	Rehab/replace or reduce criticality score by adding redundancy	6-10 Years	1-5 Years	1-5 Years
5	5	5, 5	**25**	Rehab/replace and/or reduce criticality score by adding redundancy	1-5 Years	1-5 Years	1-5 Years

6.2 Watermain Risk Based Program

Table 8 summarizes the Town's current water distribution system. Overall, the Town's watermains are relatively new and are expected to have large costs associated with replacement near the end of the system's life cycle.

Table 8: Water Distribution Program Overview

Total System Length	205,732 m
Average Asset Age	21 years
Total System Replacement Cost	$155M
Period for the Replacement of Every Asset	74 Years
Average Cost per Year	$2.1M/year
System Currently Exceeding Useful Life	1%

6.2.1 Likelihood of Failure Criteria and Weighting

LoF was based on the combined scoring and weighting of break history, remaining life, and material of each watermain. Table 9 outlines the high scoring criteria (i.e. results within these categories that produce ratings of 4 or 5), the results of the pairwise analysis, and each criteria's respective weighting.

Table 9: Likelihood of Failure Pairwise Analysis

	High Scoring	Comment	Pairwise Weighting
Breaks	Historically broken watermains	Based on historic data	35%
Remaining Life	Older watermains	Low estimated useful life remaining	41%
Material	Cast iron and copper pipes	Higher failure rated materials	24%

6.2.2 Consequence of Failure Criteria and Weighting

CoF was based on Hydraulic LOS and Property and Environmental impacts. Hydraulic LOS is dependent on the number and type of customers effected by a failing watermain. LOS was divided into total loss of service, service less than 20 PSI, and service less than 40 PSI which the highest scoring for total loss of service and ICI customers over Residential customers.

Property and Environmental impacts were based on flow rate, max day pressure, road class, and proximity to environmental feature. Table 10 outlines the high scoring criteria, the results of the pairwise analysis, and each criteria's respective weighting. The flow rate and road class have a very strong influence on the final Property and Environmental impact score.

Table 10: Watermain Property and Environment Impact Criteria and Weighting

	High Scoring	Impact	Pairwise Weighting
Flow	High flow rates	Property/environment damage	35%
Max Day Pressure	High pressures	Property/environment damage	11%
Road Class	High traffic roads	Traffic disruption	35%
Proximity to an Environmental Feature	Assets crossing environmental features	Environment damage	19%

An additional pairwise analysis weights Hydraulic LOS against Property and Environmental impacts. Table 11 outlines the pairwise analysis between the two criteria.

Table 11: Watermain Consequence of Failure Pairwise Weighting

	Pairwise Weighting
Hydraulic Loss of Service	67%
Property and Environmental	33%

6.2.3 Replacement Program

The costs associated with each Risk Replacement Program for watermains is outlined in the below Table 12. The water distribution system is relatively new, with minimal historic breaks and minimal break impacts to customers due to looping. Overall, the water system produces low risk scores and has higher costs associated with the back end of the 20 year program and 20+ year program

Table 12: Watermain Replacement Program Costs

Risk Based	Timing	Water(1)
Low LOS - High Risk Tolerance	20 Year Annual	$ 78,000/yr
	1-5 Total	$ -
	6-10 Total	$ 394,000
	10-20 Total	$ 1,168,000
	20+ Total	$ 153,729,000
	Total	**$ 155,291,000**
Medium LOS - Med Risk Tolerance	20 Year Annual	$ 595,000/yr
	1-5 Total	$ 48,000
	6-10 Total	$ 1,034,000
	10-20 Total	$ 10,813,000
	20+ Total	$ 143,396,000
	Total	**$ 155,291,000**
High LOS - Low Risk Tolerance	20 Year Annual	$ 1,038,000/yr
	1-5 Total	$ 275,000
	6-10 Total	$ 10,517,000
	10-20 Total	$ 9,971,000
	20+ Total	$ 134,529,000
	Total	**$ 155,291,000**

(1) Values have been rounded to the nearest thousand

6.3 Wastewater Risk Based Program

Table 13 summarizes the Town's current wastewater system. Overall the Town's sewers are relatively new and are expected to have large costs associated with replacement near the end of the system's life cycle.

Table 13: Sanitary Sewer Program Overview

Total System Length	174,570 m
Average Asset Age	22 years
Total System Replacement Cost	$136M
Period for the Replacement of Every Asset	89 years
Average Cost per Year	$1.5M/year
System Currently Exceeding Useful Life	<1%

6.3.1 Likelihood of Failure Criteria and Weighting

LOF was based on the combined scoring and weighting of remaining life of a sewer. The estimated remaining useful life results in a higher likelihood of failure.

6.3.2 Consequence of Failure Criteria and Weighting

CoF was based on Hydraulic LOS and Property and Environmental impacts. Hydraulic LOS is dependent on gravity sewer diameter.

Property and Environmental impacts were based on peak wet weather flow, whether a sewer is downstream a sewage pumping station, road class, and proximity to environmental features. Table 10 outlines the high scoring criteria and the results of the pairwise analysis and each criteria's respective weighting.

Table 14: Watermain Property and Environment Impact Criteria and Weighting

	High Scoring	Impact	Pairwise Weighting
Flow Rate	Large flow rate due to large catchment area	Environmental and property damage	34%
Downstream SPS	Downstream a SPS	Environmental and property damage	37%
Road Class	High traffic roads	Traffic disruption	17%
Proximity to an Environmental Feature	Assets crossing environmental features	Environment damage	11%

An additional pairwise analysis weights Hydraulic LOS against Property and Environmental impacts. Table 11 evaluates the pairwise analysis between the two criteria.

Table 15: Sewer Consequence of Failure Pairwise Weighting

	Pairwise Weighting
Hydraulic Loss of Service	60%
Property and Environmental	40%

6.3.3 Replacement Program

The costs associated with each Risk Replacement Program for sewers is outlined in the below Table 16. The wastewater system is relatively young, with minimal impacts to customers due to lower peak wet weather flow rates. Overall, the wastewater system produces low risk scores and has higher costs associated with the back end of the 20 year program.

Table 16: Wastewater Replacement Program Costs

Risk Based	Timing	Wastewater[1]	
Low LOS - High Risk Tolerance	20 Year Annual	$	240,000/yr
	1-5 Total	$	146,000
	6-10 Total	$	456,000
	10-20 Total	$	4,193,000
	20+ Total	$	131,131,000
	Total	**$**	**135,928,000**
Medium LOS - Med Risk Tolerance	20 Year Annual	$	443,000/yr
	1-5 Total	$	146,000
	6-10 Total	$	456,000
	10-20 Total	$	8,250,000
	20+ Total	$	127,075,000
	Total	**$**	**135,928,000**
High LOS - Low Risk Tolerance	20 Year Annual	$	831,000/yr
	1-5 Total	$	428,000
	6-10 Total	$	1,667,000
	10-20 Total	$	14,530,000
	20+ Total	$	119,303,000
	Total	**$**	**135,928,000**

(1) Values have been rounded to the nearest thousand

7. Scenario Summaries

Table 17, Figure 3, and Figure 4 summarize the replacement program timings and costs for scenarios based on level of service and aging infrastructure.

Table 17: Asset Replacement Program – Water and Wastewater

Risk Based	Timing	Water[1]	Wastewater[1]
Low LOS - High Risk Tolerance	20 Year Annual	$ 78,000	$ 240,000
	1-5	$ -	$ 146,000
	6-10	$ 394,000	$ 456,000
	10-20	$ 1,168,000	$ 4,193,000
	20+	$ 153,729,000	$ 131,131,000
	Total	**$ 155,291,000**	**$ 135,928,000**
Medium LOS - Med Risk Tolerance	20 Year Annual	$ 595,000	$ 443,000
	1-5	$ 48,000	$ 146,000
	6-10	$ 1,034,000	$ 456,000
	10-20	$ 10,813,000	$ 8,250,000
	20+	$ 143,396,000	$ 127,075,000
	Total	**$ 155,291,000**	**$ 135,928,000**
High LOS - Low Risk Tolerance	20 Year Annual	$ 1,038,000	$ 831,000
	1-5	$ 275,000	$ 428,000
	6-10	$ 10,517,000	$ 1,667,000
	10-20	$ 9,971,000	$ 14,530,000
	20+	$ 134,529,000	$ 119,303,000
	Total	**$ 155,291,000**	**$ 135,928,000**
Age Based	20 Year Annual	$ 646,000	$ 21,000
	1-5	$ 3,744,000	$ 371,000
	6-10	$ 50,000	$ 57,000
	10-20	$ 9,129,000	$ -
	20+	$ 142,368,000	$ 135,500,000
	Total	**$ 155,291,000**	**$ 135,500,000**
Years for Full Replacement		74	89
Average Annual Cost for Replacement		$ 2,099,000	$ 1,527,278

(1) Values have been rounded to the nearest thousand

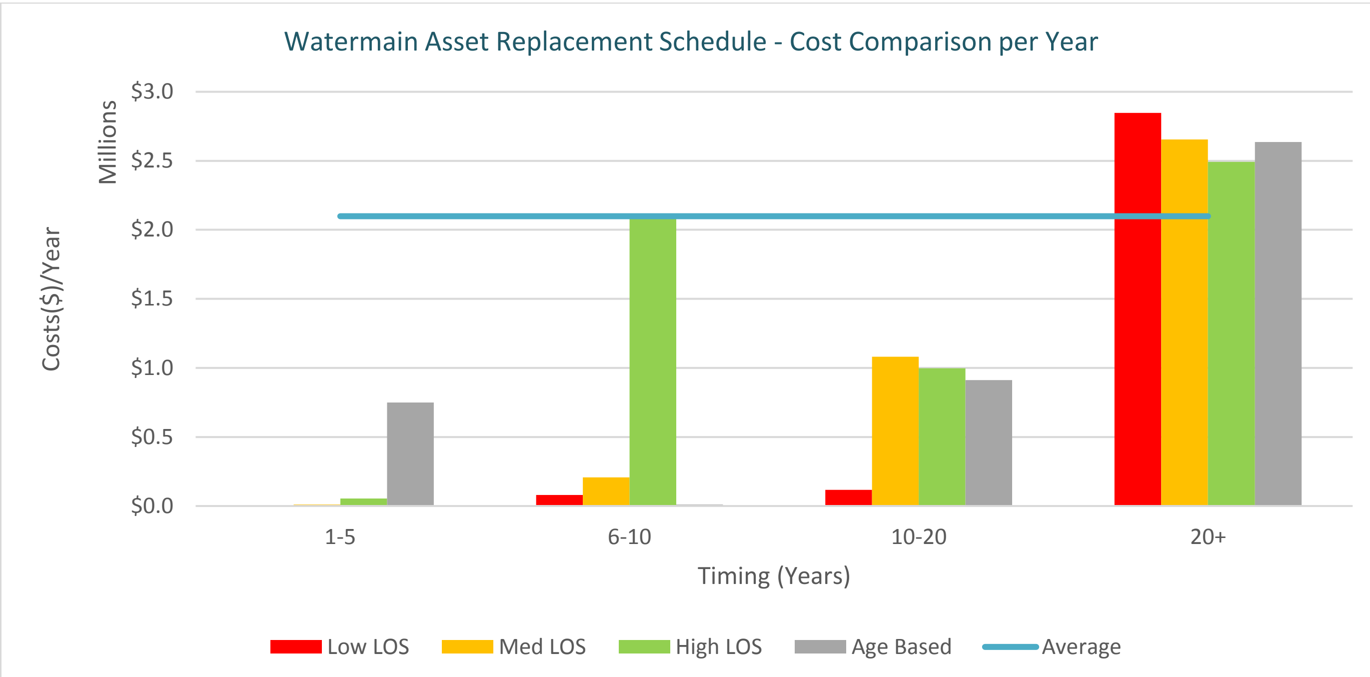

Figure 3: Watermain Asset Replacement Schedule – Cost Comparison

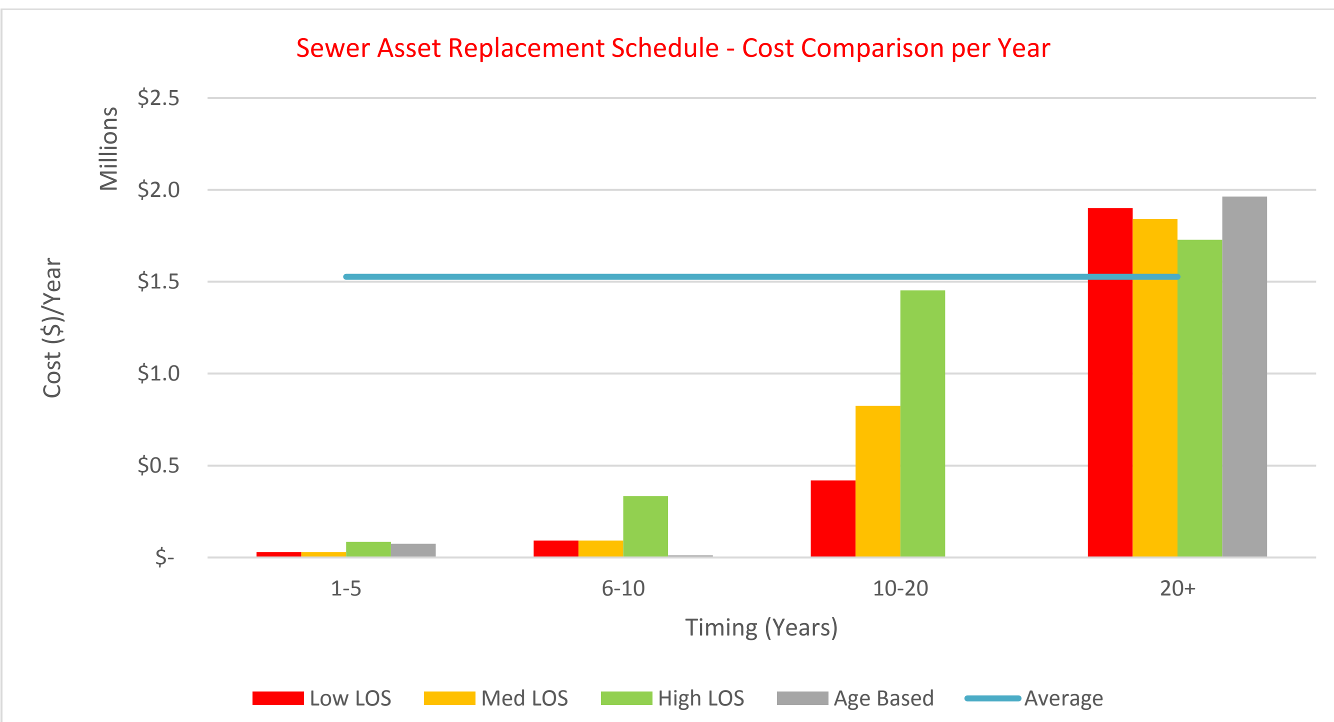

Figure 4: Sewer Asset Replacement Schedules - Cost Comparison

8. Summary

1. The Town of Georgina Water and Wastewater Criticality Analysis can be summarized as follows:
   - The dynamic Excel-based tool was developed to assist in:
     - Assessment of relative individual pipe (water and wastewater) criticality
     - Development of a risk-based prioritized capital replacement plan
   - Prioritized replacement of watermains, sewers, and roads to minimize disruptions and optimize costs
   - Higher costs are a result of lower risk tolerances
   - The Town's system is very new and total replacement is heavily weighted for the 20+ year schedule
2. In order to develop CoF and LoF, the criticality assessment tool applied the following inputs:
   - Watermains:
     - Age, historic breaks, material
     - Loss of service, flow rate, max day pressure, road class, proximity to an environmental feature
   - Sewers:
     - Age
     - Diameter, peak wet weather flow rate, location of sewage pumping station, road class, proximity to an environmental feature

Several replacement program scenarios with varying levels of service, risk tolerance and annual costs for the subsequent 20 years were developed. The total replacement costs of each were calculated using unit costs by pipe diameter. The scenarios are summarized as follows:

- Low level of service with high risk tolerance produced low annual costs
- Medium level of service with medium risk tolerance produced medium annual costs
- High level of service with low risk tolerance produced high annual costs
- Aging infrastructure based scenario produced medium annual costs

Table 18 summarizes the annual costs associated with the above scenarios.

Table 18: Annual Asset Replacement Program Costs

Risk Based	Timing	Water[1]	Wastewater[1]
Low LOS - High Risk Tolerance	20 Year Annual	$ 78,000	$ 240,000
Medium LOS - Med Risk Tolerance	20 Year Annual	$ 595,000	$ 443,000
High LOS - Low Risk Tolerance	20 Year Annual	$ 1,038,000	$ 831,000
Age Based	20 Year Annual	$ 646,000	$ 21,000
Years for Full Replacement		74	89
Average Annual Cost for Replacement		$ 2,099,000	$ 1,527,278

(1) Values have been rounded to the nearest thousand

8.1 Recommendations

- Town of Georgina use the criticality tool to develop a refined capital replacement plan that prioritizes the higher risk assets within the water and wastewater network
- Feed the results of the replacement scenarios into the ongoing water and wastewater rate study
- Town of Georgina continually update the watermain and sewer data within the tool as necessary and further refine the risk scoring and weighting to reflect any newly available information and/or Town priorities (e.g. Sewer PACP scores, watermain break information, sewer model results, water & sewer replacement information, etc)

APPENDIX A:
Criticality Analysis Tool Instructions

Instructions

Table of Contents

1. Introduction

Tab Name	System	Overview	Action Taken	Comments
Instructions	NA	Instructions for using the tool	Static	
Definitions	NA	Definition for likelihood of failure and consequence of failure categories for Water and Wastewater System	Static	
Summary	Water and Wastewater	Summary table of the replacement program costs and timing	Static	
Weighting W	Water	Weighting and scoring factors that control total risk, likelihood of failure, and consequence of failure scores	Dynamic	
Watermain ASSESSMENT	Water	List of all watermains within Georgina and their respective characteristics, weightings, scores, and low to high replacement programs	Static	
Assessment Distribution	Water	Distribution tables and graphs for major criteria, likelihood of failure, and consequence of failure assessed	Static	
Water Risk & Action Summary	Water	Description of timings and actions associated with respective risk scores derived from likelihood of failure and consequence of failure	Static	No sheet modifications needed when adjusting weighting factors Sheet modifications required to accommodate inclusion of additional analysis components and/or adjustment of timing envelopes.
Weighting WW	Wastewater	Weighting and scoring factors that control total risk, likelihood of failure, and consequence of failure scores	Dynamic	
WW ASSESSMENT	Wastewater	List of all gravity sewers within Georgina and their respective characteristics, weightings, scores, and low to high replacement programs	Static	
WW Risk & Action Summary	Wastewater	Description of timings and actions associated with respective risk scores derived from likelihood of failure and consequence of failure	Static	No sheet modifications needed when adjusting weighting factors Sheet modifications required to accommodate inclusion of additional analysis components and/or adjustment of timing envelopes.
Data Tabs	Water and Wastewater	Raw data used to populate the tool's database (multiple tabs)	Static	Replace existing data within tabs as new/revised information becomes available

2. Dynamics of Weighting Tabs

2.1 Watermain Weighting

Dynamic features are in red text

2.1.1 Analysis Year

ANALYSIS YEAR
2016

Current year or year analysis is being performed

2.1.2 Likelihood of Failure

LIKELIHOOD OF FAILURE

Scoring for watermain materials

Breaks		
0		1
1	1	4
>	1	5

Numerical range and scoring for historic watermain breaks

Material		
PVC	Polvinyl Chloride	2
CI	Cast Iron	5
COP	Copper	5
CPP	Concrete Pressure Pipe	2
DI	Ductile Iron	3
PE	Polyethylene	2
UNK	Unkown	5
STL	Steel	5
AC	Asbestos Cement	2
HDPE	High Density Polyethylene	2
PV		5

Remaining Life		
>	60	1
59	41	2
40	21	3
20	10	4
<	10	5

Numerical range and scoring for remaining life of each watermain based on watermain material

Likelihood of Failure	Breaks	Remaining Life	Material	Total	Weighting
Breaks		2	4	6	**35%**
Remaining Life	3		4	7	**41%**
Material	2	2		4	**24%**

Likelihood of failure pairwise analysis for watermain breaks, remaining life, and material

Estimated Useful Life		
PVC	Polyvinyl Chloride	75
CI	Cast Iron	50
COP	Copper	50
CPP	Concrete Pressure Pipe	75
DI	Ductile Iron	50
PE	Polyethylene	75
UNK	Unknown	50
STL	Steel	60
AC	Asbestos Cement	75
HDPE	High Density Polyethylene	75
PV	Poly Vinyl	75

Town Of Georgina - 2015 State of Infrastructure - Oct 2015

Estimated useful life of each watermain based on material

2.1.3 Consequence of Failure

2.1.3.1 Hydraulic Level of Service Impacts

Hydraulic Level of Service Impacts

Loss of Service	
Total Loss	2
< 20 psi	1
< 40 psi	0.5

Land Use Factor	
Res	1
ICI	5
Special	5

Hydraulic Loss of Service Impacts				
5	Extreme	Impact Score > 500	≥	500
4	Major	Impact Score 301-500	201	500
3	Moderate	Impact Score 101-300	51	200
2	Minor	Impact Score 26-100	2	50
1	Minimal	Impact Score < 1	≤	1

Scoring for loss of service to customers based on hydraulic model analysis

Scoring for land use associated with proximity to each watermain

Numerical range for the number of customers that are impacted by a hydraulic loss of service determined by billing data and the hydraulic model

2.1.3.2 Property and Environmental Impacts

Property and Environmental Impacts

Flow (L/s)		
0	25	1
26	75	2
76	125	3
126	200	4
201	1000	5

Numerical range and scoring for max flow rate through associated watermain

Max Day Pressure (psi)		
<	50	1
51	80	2
>	80	4
		4
		5

Numerical range and scoring for max day pressures experienced through associated watermain

Road Class	
	1
Laneway	1
Private Road	1
Proposed Road	1
Rural Road	2
Urban Road	3
Arterial Road	4
Regional Road	5

Scoring for road class associated with the road adjacent to each watermain

Proximity to Environmental Feature (m)		
>	100	1
11	100	3
<	10	5

Numerical range and scoring for a watermain within proximity to an environmental feature (e.g. Lake Simcoe, lakes, rivers, streams, ponds, etc.)

Property and Environment	Flow	Max Day Pressure	Road Class	Prox to Env Feature	Total	Weighting
Flow		4	4	5	13	**35%**
Max Day Pressure	1		1	2	4	**11%**
Road Class	4	5		4	13	**35%**
Proximity to Env Feature	3	1	3		7	**19%**

Property and environment pairwise analysis for flow, max day pressure, road class, and proximity to an environmental feature

2.1.3.3 Consequence of Failure Weighting

Consequence of Failure Weighting

Hydraulic LOS (Customer) Impact vs Property and Environmental (Rd/Env) Impact	Hyd LOS	P & E			Total	Weighting
Hydraulic LOS		4			4	**67%**
Property and Environmental	2				2	**33%**

Consequence of failure pairwise analysis hydraulic loss of service and property and environmental

2.1.4 Cost Estimating

COST ESTIMATING

Watermain	
Diameter (mm)	Unit Cost ($/m)
19	$ 500
32	$ 500
38	$ 500
50	$ 500
100	$ 500
150	$ 500
200	$ 600
250	$ 600
300	$ 750
350	$ 800
400	$ 900
450	$ 970
500	$ 1,100
600	$ 1,300
750	$ 1,550

Eng + Contingency	25%

Engineering and contingency percentage added onto total replacement costs for each watermain

Watermain unit costs per meter by watermain diameter

2.2 Wastewater Weighting

2.2.1 Analysis Year

ANALYSIS YEAR

2016

Current year or year analysis is being performed

2.2.2 Likelihood of Failure

LIKELIHOOD OF FAILURE

Remaining Life		
>	70	1
69	50	2
49	30	3
29	10	4
<	9	5

Numerical range and scoring for the remaining life of a sewer

PACP Score		
1	Acceptable	1
2	Minimal Risk	2
3	Collapse Unlikely in Near Future	3
4	Collapse Likely in Near Future	4
5	Collapse Imminent	5

Scoring for PACP
NOTE There is currently no PACP data available but this can be included in the analysis when data becomes available

2.2.3 Consequence of Failure

2.2.3.1 Hydraulic Level of Service Impacts

Hydraulic Level of Service Impacts

Gravity Diameter (mm)		
0	250	1
250	375	2
375	450	3
450	525	4
>	525	5

Numerical range and scoring for sewer diameter

DS SPS	
No	1
Yes	5

Scoring for sewers downstream of pumping stations

2.2.3.2 Property and Environmental Impacts

Property and Environmental Impacts

PWWF (L/s)		
0	1	1
1	2	2
2	5	3
5	20	4
		5

Numerical range and scoring for peak wet weather flow rate associated with upstream catchment

Road Class	
	1
Laneway	1
Private Road	1
Proposed Road	1
Rural Road	2
Urban Road	3
Arterial Road	4
Regional Road	5

Scoring for road class associated with each adjacent sewers

Proximity to Environmental Feature (m)		
>	100	1
11	100	4
<	10	5

Numerical range and scoring for a sewer within proximity to an environmental feature (e.g. Lake Simcoe, lakes, rivers, streams, ponds, etc.)

Property and Environment						
	PWWF	DS SPS	Road Class	Proximity to Env Feature	Total	Weighting
PWWF		3	4	5	12	**34%**
DS SPS	3		5	5	13	**37%**
Road Class	1	2		3	6	**17%**
Proximity to Env Feature	1	1	2		4	**11%**

Property and environment pairwise analysis for PWWF, DS SPS, road class, and proximity to an environmental feature

2.2.3.3 Consequence of Failure Weighting

Consequence of Failure Weighting

Hydraulic LOS (Customer) Impact vs Property and Environmental (Rd/Env) Impact						
	Hyd LOS	P & E			Total	Weighting
Hydraulic LOS		3			3	**60%**
Property and Environmental	2				2	**40%**

Consequence of failure pairwise analysis hydraulic loss of service and property and environmental

2.2.4 Cost Estimating

COST ESTIMATING

Sewer	
Diameter (mm)	Unit Cost ($/m)
100	$ 500
150	$ 500
200	$ 600
250	$ 600
300	$ 618
375	$ 659
450	$ 715
525	$ 769
600	$ 990
675	$ 1,200
750	$ 1,331
825	$ 1,428
900	$ 1,680

Eng + Contingency	25%

Engineering and contingency percentage added onto total replacement costs for each sewer

Sewer unit costs per meter by sewer diameter

3. Assessment Tables

3.1 Likelihood of Failure

Likelihood of Failure

Age	Expected Life	Remaining Life	Age Score	Weighted AGE SCOR	Number of Breaks	BREAK SCORE	Weighted Break Score	Material	MATERIAL SCORE	Weighted Material Score	TOTAL LOF
29	75	46	2	0.8	0	1	0.4	PVC	2	0.5	2
29	75	46	2	0.8	0	1	0.4	PVC	2	0.5	2
29	75	46	2	0.8	0	1	0.4	PVC	2	0.5	2
29	75	46	2	0.8	0	1	0.4	PVC	2	0.5	2

Scoring for likelihood of failure is the weighted sum of age, break history, and material

3.2 Consequence of Failure

3.2.1 Hydraulic Loss of Service

Hydraulic LOS

RES			ICI				
Total Loss of Service	< 20 psi	20-40 psi	Total Loss of Service	< 20 psi	20-40 psi	Hydraulic LOS Impac	Total Hydraulic LOS Score
451	0	0	0	0	0	902	5
451	0	0	0	0	0	902	5
451	0	0	0	0	0	902	5
332	0	0	0	0	0	665	5

Scoring for hydraulic loss of service is determined by loss of service impacts, land use and pressure received by a customer

3.2.2 Property and Environment Impact

Consequence of Failure												
Property and Environmental Impact												
MDD Flow (L/s)	Flow Score	**Weighted Flow Score**	Max Day Pressure (psi)	MDP Score	**Weighted MDP Score**	Road Class	Road Class Score	**Weighted RC Score**	Proximity to Env Feature	Env Feature Score	**Weighted Env Feature Score**	**Total Property & Env Impact Score**
2.3	1.0	**0.4**	75.5	2.0	**0.2**	Arterial Road	4	**1.4**	13	3	**0.6**	**2.5**
2.2	1.0	**0.4**	75.4	2.0	**0.2**	Arterial Road	4	**1.4**	39	3	**0.6**	**2.5**
2.3	1.0	**0.4**	75.2	2.0	**0.2**	Arterial Road	4	**1.4**	13	3	**0.6**	**2.5**
1.7	1.0	**0.4**	74.6	2.0	**0.2**	Arterial Road	4	**1.4**	40	3	**0.6**	**2.5**
1.7	1.0	**0.4**	74.7	2.0	**0.2**	Arterial Road	4	**1.4**	39	3	**0.6**	**2.5**

Scoring for total property and environmental impact is the weighted sum of flow rate, pressure, road class, and proximity to an environmental feature

3.2.3 Consequence of Failure Score

Consequence of Failure																					
Hydraulic LOS								Property and Environmental Impact													
RES			ICI																		
Total Loss of Service	< 20 psi	20-40 psi	Total Loss of Service	< 20 psi	20-40 psi	**Hydraulic LOS Impact**	**Total Hydraulic LOS Score**	MDD Flow (L/s)	Flow Score	**Weighted Flow Score**	Max Day Pressure (psi)	MDP Score	**Weighted MDP Score**	Road Class	Road Class Score	**Weighted RC Score**	Proximity to Env Feature	Env Feature Score	**Weighted Env Feature Score**	**Total Property & Env Impact Score**	**TOTAL COF**
451	0	0	0	0	0	902	5	2.3	1.0	**0.4**	75.5	2.0	**0.2**	Arterial Road	4	**1.4**	13	3	**0.6**	**2.5**	**4**
451	0	0	0	0	0	902	5	2.2	1.0	**0.4**	75.4	2.0	**0.2**	Arterial Road	4	**1.4**	39	3	**0.6**	**2.5**	**4**
451	0	0	0	0	0	902	5	2.3	1.0	**0.4**	75.2	2.0	**0.2**	Arterial Road	4	**1.4**	13	3	**0.6**	**2.5**	**4**
332	0	0	0	0	0	665	5	1.7	1.0	**0.4**	74.6	2.0	**0.2**	Arterial Road	4	**1.4**	40	3	**0.6**	**2.5**	**4**

Scoring for consequence of failure is the weighted sum of total hydraulic loss of service score and total property and environmental impacts score

3.3 Replacement Program

3.3.1 Basis for Timing and Costs

Unit Cost ($/m)	Total Replacement Cost ($)	ESL Replacement Date
$ 600	$ 46,168	2062
$ 600	$ 27,341	2062
$ 600	$ 13,715	2062
$ 600	$ 37,103	2062

A unit cost, total replacement cost, and replacement date are calculated for each watermain

3.3.2 Age Based Replacement Program

			1-20	1-5	6-10	10-20	20+
Total Cost	$ 197,330,560	$ 178,534,179	$ 18,796,381	$ 3,744,042	$ 50,345	$ 9,159,689	$184,376,484
Years for full Replacement	74	$4,699,095.32	$ 939,819	$ 647,704			
Avg Annual Cost for Replacement	$ 2,666,629						

Summed total costs of an age based replacement program by timing schedule

					AGE BASED				
& nt	TOTAL COF	Unit Cost ($/m)	Total Replacement Cost ($)	ESL Replacement Date	1-20 Years (Age/ ESL Only)	1-5 Years	6-10 Years	10-20 Years	20+
	4	$ 600	$ 46,168	2062	$ -	$ -	$ -	$ -	$ 46,168
	4	$ 600	$ 27,341	2062	$ -	$ -	$ -	$ -	$ 27,341
	4	$ 600	$ 13,715	2062	$ -	$ -	$ -	$ -	$ 13,715

Cost and timing schedule for each watermain for an age based replacement program

3.3.3 Total Risk Scores

Risk Score (COF, LOF)
4, 2
4, 2
4, 2
4, 2

Total risk score determined by from consequence of failure and likelihood of failure; corresponds with adjacent table

		Probability of Failure				
		1	2	3	4	5
Consequence of Failure	1	1	2	3	4	5
	2	2	4	6	8	10
	3	3	6	9	12	15
	4	4	8	12	16	20
	5	5	10	15	20	25

3.3.4 Risk Based Replacement Programs

		1-5	6-10	10-20	20+	TOTAL
		$ -	$ 394,065	$ 1,168,437	$ 195,768,058	$ 197,330,560
	20 Year Annual	$ 78,125				

Three risk based replacement programs (low, medium, and high) with summed total costs for each timing schedule; defined programs are outlined in the water risk and action summary tab

Replacement Program						
LOW LOS - HIGH RISK TOLERANCE						
		RISK BASED				
Action	Timing	1-5 Years	6-10 Years	10-20 Years	20+	Action
Do nothing-replace	At Asset Failure (20+)	$ -	$ -	$ -	$ 46,168	Do nothing-replace
Do nothing-replace	At Asset Failure (20+)	$ -	$ -	$ -	$ 27,341	Do nothing-replace

Cost and timing schedule for each watermain for a risk based replacement program

4. Risk and Action Summary

Risk Score	Watermain Action	LOW Level of Service Timing	MEDIUM Level of Service Timing	HIGH Level of Service Timing
1	Do nothing-replace	At Asset Failure (20+)	At Asset Failure (20+)	At Asset Failure (20+)
2	Do nothing-replace	At Asset Failure (20+)	At Asset Failure (20+)	At Asset Failure (20+)
3	Do nothing-replace	At Asset Failure (20+)	At Asset Failure (20+)	6-10 Years
4	Do nothing-replace	At Asset Failure (20+)	10-20 Years	6-10 Years
5	Rehab/replace	10-20 Years	6-10 Years	1-5 Years
2	Do nothing-replace	At Asset Failure (20+)	At Asset Failure (20+)	At Asset Failure (20+)
4	Do nothing-replace	At Asset Failure (20+)	At Asset Failure (20+)	At Asset Failure (20+)
6	Do nothing-replace	At Asset Failure (20+)	10-20 Years	10-20 Years
8	Rehab/replace	10-20 Years	10-20 Years	10-20 Years
10	Rehab/replace	6-10 Years	6-10 Years	1-5 Years
3	Do nothing-replace	At Asset Failure (20+)	At Asset Failure (20+)	At Asset Failure (20+)
6	Do nothing-replace	At Asset Failure (20+)	At Asset Failure (20+)	At Asset Failure (20+)
9	Do nothing-replace	At Asset Failure (20+)	10-20 Years	10-20 Years
12	Rehab/replace	6-10 Years	6-10 Years	6-10 Years
15	Rehab/replace	6-10 Years	6-10 Years	1-5 Years
4	Do nothing-replace	At Asset Failure (20+)	At Asset Failure (20+)	At Asset Failure (20+)
8	Do nothing-replace	At Asset Failure (20+)	At Asset Failure (20+)	10-20 Years
12	Rehab/replace or reduce criticality score by adding redundancy	10-20 Years	6-10 Years	6-10 Years
16	Rehab/replace or reduce criticality score by adding redundancy	6-10 Years	1-5 Years	1-5 Years
20	Rehab/replace or reduce criticality score by adding redundancy	1-5 Years	1-5 Years	1-5 Years
5	Do nothing-replace	At Asset Failure (20+)	At Asset Failure (20+)	At Asset Failure (20+)
10	Rehab/replace or reduce criticality score by adding redundancy	At Asset Failure (20+)	10-20 Years	10-20 Years
15	Rehab/replace or reduce criticality score by adding redundancy	10-20 Years	6-10 Years	1-5 Years
20	Rehab/replace or reduce criticality score by adding redundancy	6-10 Years	1-5 Years	1-5 Years
25	Rehab/replace and/or reduce criticality score by adding redundancy	1-5 Years	1-5 Years	1-5 Years

Defined timing schedules for each risk score based on the timing options below

Defined watermain action for each risk score

Timing Options
At Asset Failure (20+)
10-20 Years
6-10 Years
1-5 Years

Timing options to be used in above table

		Probability of Failure				
		1	2	3	4	5
Consequence of Failure	1	1	2	3	4	5
	2	2	4	6	8	10
	3	3	6	9	12	15
	4	4	8	12	16	20
	5	5	10	15	20	25

Defined risk score based on consequence of failure and likelihood of failure results