DILLON CONSULTING

MUNICIPAL DISTRICT OF ST. STEPHEN

Roads Condition Assessment and Needs Analysis

Final Report

July 2024 – 24-7695

DILLON
CONSULTING

274 Sydney Street
Suite 100
Saint John, New Brunswick
Canada
E2L 0A8
Telephone
902.633.5000

July 24, 2024

St. Stephen Municipal District Office
22 Budd Avenue
St. Stephen, NB
E3L 1E9

Attention: Mr. Jeff Renaud
Chief Administrative Officer

Mr. Sean Morton
Director of Infrastructure

Roads Condition Assessment and Needs Analysis

Dillon Consulting Limited (Dillon) is pleased to submit the Roads Condition Assessment and Needs Analysis report for road assets that are owned and maintained by the Municipal District of St. Stephen (the Municipality). This report presents the methodology used for assessing the road as well as the findings, including the results of the condition assessment, an evaluation of funding scenarios, and a recommended capital plan.

Dillon would like to acknowledge the time, effort, and information that was provided by Municipal staff throughout the project. Please do not hesitate to contact the undersigned if you have any questions.

Sincerely,

DILLON CONSULTING LIMITED

Taylor McNeill, P.Eng.	Austen Underhill, EIT
Project Manager, Associate	Asset Analyst

AMU:lmk

Our file: 24-7695

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1.0 Introduction

The Municipal District of St. Stephen (the Municipality) is a municipality located in Charlotte County, situated on the east bank of the St. Croix River in New Brunswick. The Municipality has a population of approximately 8,100 and spans a land area of approximately 13.7 km^2.

The following report presents a comprehensive roads condition assessment and needs analysis for the Municipality. The purpose of this study is to provide insight into the current condition of the municipal roads, with an objective to help make informed decisions on maintenance, rehabilitation, and reconstruction needs and associated capital reinvestment. The report intentionally omits all rural roads in the municipality and focuses exclusively on local and collector roads.

1.1 Overview of the Report

The report provides a 10-year outlook to support decision making regarding maintenance, rehabilitation, and replacement of the roads which is ultimately refined into a 5-year prioritized capital plan. It is based on the condition assessment results and discussions with representatives from the Municipality. The following sections have been included in the report:

- **Section 1** of this report presents an overview of the methodology employed for the condition assessment of Municipal roads and assumptions;
- **Section 2** presents the condition assessment results which details the inventory of municipality-owned and maintained road assets, including estimated replacement costs, remaining useful life, and condition;
- **Section 3** provides an overview of the reinvestment scenarios considered by Dillon, which have been evaluated using road lifecycle modeling of preventative maintenance, rehabilitation, and reconstruction activities and associated expenditures; and
- **Section 4** summarizes the prioritization strategy employed for capital project planning and a 5-Year Capital Plan based on the information discussed in the report.

1.2 Methodology and Approach

In order to provide the Municipality with condition and performance information, Dillon completed a field program to collect the data and desktop analysis. The methodology and approach are outlined in the following section.

1.2.1 Pavement Condition Index

The condition of asphalt (paved) roads is commonly measured by a condition rating system known as the Pavement Condition Index (PCI) which considers the frequency and severity of physical distresses observed (e.g., cracking, potholes) on a road segment during a visual inspection to assign a condition rating from 0 to 100. A new road is assigned a PCI of 100, and over time, as the road ages and through wear and tear, the PCI number drops to 0 which is the worst possible condition. **Figure 1-1** illustrates how the condition of the road deteriorates over time and the thresholds for lifecycle activities such as preventative maintenance, rehabilitation, and reconstruction. For this report, PCI values were considered as the main condition measure.

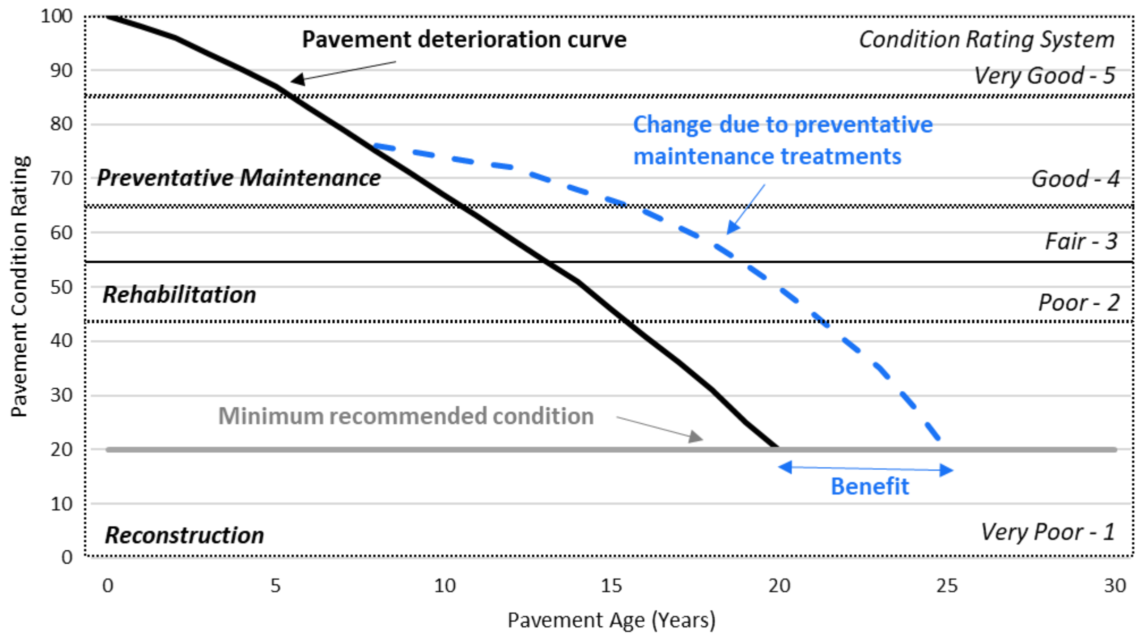

Figure 1-1: Pavement Condition Index and Lifecycle Activities

1.2.2 International Roughness Index

The International Roughness Index (IRI) is a globally recognized and utilized standard for measuring road roughness. The IRI provides a numerical value that represents the road's overall ride comfort, measuring surface irregularities in relation to distance and is often expressed in meters of vertical displacement per kilometer. The lower the IRI value, the smoother and more comfortable the ride, thereby indicating a superior road condition. Generally, a driver's perception of road roughness varies depending on travel speed and smoother roads (i.e., lower IRI values) are desired for roads with higher posted speed limits. **Table 1-1** summarizes the suggested IRI thresholds for various operational (i.e., posted) speeds. For this report, IRI values were considered as a road performance measure during the prioritization of road treatment needs.

Table 1-1: IRI Thresholds for Various Operational Speeds (m/Km) (Yu, Chou, and Yau, 2006)

Quality	70 Km/h	60 Km/h	50 Km/h	40 Km/h	30 Km/h
Very Good	< 1.63	< 1.90	< 2.28	< 2.86	< 3.80
Good	1.64 – 2.57	1.91 – 2.99	2.29 – 3.59	2.87 – 4.49	3.81 – 5.99
Fair	2.58 – 3.25	3.00 – 3.79	3.60 – 4.54	4.50 – 5.69	6.00 – 7.59
Poor	3.26 – 4.63	3.80 – 5.40	4.55 – 6.25	5.70 – 8.08	7.60 – 10.80
Very Poor	> 4.63	> 5.40	> 6.25	> 8.08	> 10.80

1.2.3 Site Investigation

Dillon completed a site investigation to collect the existing condition information on the roads. The field team consisted of two Dillon staff members that collected PCI and IRI data from May 7 to 14, 2024. The field team used the field mobile application called TotalPave to collect the road condition data.

1.2.4 TotalPave

Condition assessments conducted for municipal roads used the data gathering and management tool TotalPave. TotalPave is a mobile software application that collects road condition data based on Pavement Condition Index (PCI) and International Roughness Index (IRI) standards. Here is a summary of how TotalPave was used to collect PCI and IRI data for road segments:

- **PCI Collection:** TotalPave allows users to record observed road distresses for a predetermined road segment and based on the total road length of the segment, calculates an overall PCI value. The severity and frequency of individual types of pavement distresses on the road were captured in the application for each road segment as part of Dillon's field program. The TotalPave PCI application has predefined types of pavement distress and different severity levels which calculate the total road segment PCI based on the inputs from the assessors; and
- **IRI Collection:** For this data collection method a phone (leveled) is firmly mounted to the windshield using a stationary mount. With the TotalPave application open and GPS phone locator active, the entire road segment is driven at the posted speed limit, or reasonable speed if posted limit is unsafe. Provided the pre-determined road segment location on the application and the GPS phone data collected in real-time are closely matched, an IRI value is assigned to the roadway segment based on recording vertical displacement throughout the drive.

1.2.5 Condition Ratings

Table 1-2 outlines the condition rating system which ranges from 1 (very poor) to 5 (very good), including the alignment of the condition rating system with PCI values and some general descriptions.

Table 1-2: Condition Rating System

PCI	Condition Grade	Description
85 – 100	Very Good	Asset (or asset element) is physically sound, performing as intended and resembles "like-new" condition.
65 – 84	Good	Asset (or asset element) is physically sound and performing as intended. Needs to be re-inspected in the medium term.
55 – 64	Fair	Showing deterioration, with some elements physically deficient. Early stages of decay or dereliction are becoming evident.
45 – 54	Poor	Major portion of asset (or asset element) is physically deficient. It is not functioning properly due to significant deterioration and is a candidate for replacement in the short term.
0 – 44	Very Poor	Asset (or asset element) is physically unsound. There is a high probability it will fail, or it already has. Immediate replacement is required.

1.2.6 Estimated Replacement Cost

The estimated replacement costs for municipal roads were developed using engineer's estimates in conjunction with recent unit costs observed for the supply of road materials. **Table 1-3** summarizes the unit costs used to estimate road replacement costs in this report. These unit costs are estimated based on like-for-like replacement of the existing assets only.

Table 1-3: Summary of Unit Costs Used to Estimate Road Replacement Costs

Construction Material	Road Class	Unit	Unit Cost (2024 dollars)
Asphalt (Paved) Surface	Collector	Square Metre	$125
	Local	Square Metre	$90
Gravel (Unpaved) Surface	Local	Square Metre	$50

1.3 Assumptions

The following general assumptions were made while developing this report:

- Visual and non-invasive inspections conducted to assign condition ratings provide an accurate representation of the condition and remaining service life of a road segment;
- Regular maintenance, where appropriate, is expected to be conducted throughout the lifespan of the road. The road lifecycle expenditures provided in this report do not consider what is currently being spent, or current operation and maintenance costs;
- Assets with a PCI rating of 85 or above are in very good condition, have close to a full lifecycle ahead, and do not require intervention;
- Conversely, any road with a PCI rating below 45 is at the end of its lifecycle and can no longer provide a reliable level of service;

- Given the nature of the cost estimates and study period, cost estimates are intended to be for budgetary purposes and are expected to be within +/- 30% of final installed costs. Cost estimates consider a like-for-like replacement of an asset; and
- The replacement value represents the current value (2024 dollars) of constructing the road segment (i.e., new condition).

2.0 State of Roads

A summary of the road inventory, the expected useful life of roads, and the condition of the roads is presented in the following subsections, along with estimated replacement cost in 2024 dollars.

It is noted that the Municipality has an inventory of the utility infrastructure (water, wastewater, and stormwater) and the condition based on age. However, the systematic incorporation of this inventory was not part of this report. The next iteration of the Asset Management Plan (AMP) will further integrate these elements. For this report, the focus was to examine the inventory of roads indicated for utility renewals or other priority work within the upcoming five years. The findings from this assessment helped shape the prioritization process for street rehabilitation.

2.1 Inventory and Replacement Costs

The Municipality owns and maintains predominantly asphalt (paved) roads, aside from one road segment that is currently constructed of a gravel (unpaved). **Table 2-1** summarizes the road inventory by construction material and road class. There is a total of 7.9 km of collector roads and 39.6 km of local roads.

Table 2-1: Summary of Roads Inventory

Construction Material	Road Class	Total Length (km)[1]	Estimated Replacement Cost (2024)
Asphalt (Paved)	Collector	7.87	$8.7 M
	Local	39.39	$24.2 M
Gravel (Unpaved)	Local	0.21	$61.5 K
Total		**47.46**	**$32.9 M**

Note:

1. All road lengths have been measured using the shapefiles provided by the Municipality in a geographical information system.

2.2 Condition

The road conditions were assessed based on the methodology outlined in **Section 1.2**. **Table 2-2** and **Figure 2-1** summarize the condition results based on data collected as part of Dillon's field program.

Table 2-2: Road Network Condition Summary

Construction Material	Condition Grade	Total Length (Km)	% of Road Network Length	Estimated Replacement Cost (2024)
Asphalt (Paved) Surface	Very Good	7.40	15.6	$7.4 M
	Good	8.17	17.2	$5.2 M
	Fair	3.38	7.1	$2.1 M
	Poor	11.29	23.8	$7.7 M
	Very Poor	17.02	35.9	$10.5 M
Gravel (Unpaved) Surface	Fair	0.21	0.4	$61.5 K
	Total	**47.46**	**100%**	**$32.9 M**

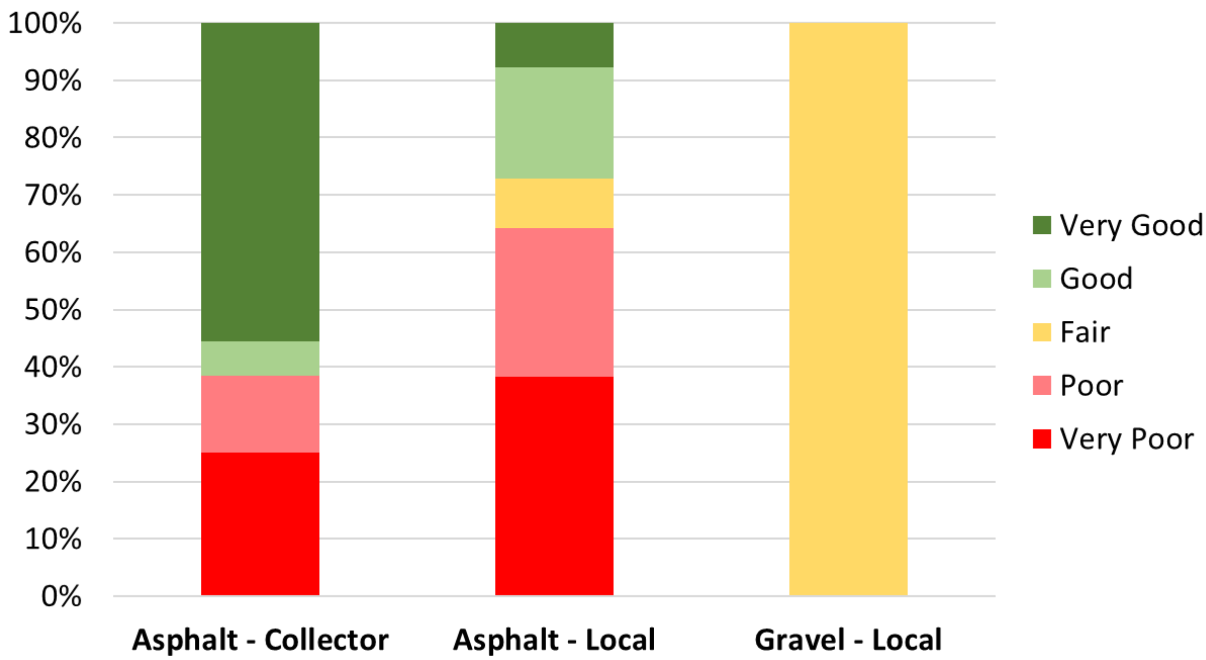

Figure 2-1: Road Network Condition Distribution by Length

Additional condition insights can be found in the roads condition summary card in **Appendix A**.

3.0 Needs Analysis

Adequate and timely road treatments can significantly contribute to extending the lifespan of roads, improving road safety, and upgrading overall driving conditions. The strategic evaluation and prioritization of road treatment needs is a crucial element in maintaining a sustainable, efficient, and safe road network that meets the expectations of the community. This section of the report discusses road lifecycle activities and presents the results of road lifecycle modeling for the Municipality's Road network over a 10-year horizon.

3.1 Lifecycle Activities

Construction

The initial lifecycle activity of a road is its construction. The road should be constructed to adhere to applicable requirements, codes, and design guidelines. Design of the road should consider the level of service expected to be provided by that road, such as the anticipated speed or volume of traffic.

Preventative Maintenance

Preventative maintenance activities are smaller in scale than rehabilitation or reconstruction. They can be used to address localized issues on the road surface (i.e., conduct spot maintenance) and are typically not applied to the full surface of the road segment. Preventative maintenance activities are most effective in the early stages of a road beginning to deteriorate and assist with prolonging further deterioration. Examples of preventative maintenance activities include crack sealing and pothole repair.

Rehabilitation

Rehabilitation lifecycle activities are significant in scale and include works that encompass the full surface of a road segment. Rehabilitation activities are warranted when roads have deteriorated significantly but have not lost their load-carrying capacity (i.e., road base is still operational). Examples of rehabilitation activities include mill and pave or large-scale patch repairs.

Reconstruction

Reconstruction lifecycle activities include works that encompass the full surface and/or subgrade of a road segment. Reconstruction activities are typically expensive and time-consuming activities but are necessary for roads that are beyond repair and rehabilitation. The reconstruction or roads may include full depth resurfacing or even the replacement of the entire surface and subgrade.

Decommissioning/Disposal

Disposal includes the removal of a road from service. Disposal is typically implemented when a road segment has been determined to be no longer required. A road may be removed from service by removing and disposing construction materials or establishing a barricade to prevent continued usage of the road. Disposal activities should be conducted such that health and safety protocols are being followed, and spent materials are disposed of at an approved facility.

3.2 Re-investment Rates

According to the 2016 Canadian Infrastructure Report Card, increasing reinvestment rates will help slow the deterioration of municipal infrastructure. On average, the rates of reinvestment in Canada were lower than targets recommended by asset management practitioners which is demonstrated in **Table 3-1**. These rates are used to confirm what financial reinvestment should be done annually within a municipality based on the replacement value of assets.

Table 3-1: Target Reinvestment Rates vs 2016 Reinvestment Rate

Infrastructure Category	Lower Target Investment Rate	Upper Target Investment Rate	Canadian Average Reinvestment Rate (2016)
Roads and Sidewalks	2.0%	3.0%	1.1%

In the following subsection, Dillon has considered the recommended lower target investment rate as a reinvestment scenario to determine how funding road lifecycle investments at the rate would impact the condition of the road network.

3.3 Scenario Analysis

Based on the current state of the Municipality's roads and in consideration of preventative maintenance, rehabilitation, and reconstruction lifecycle activities, a budget scenario analysis was completed based on roads lifecycle modeling for the next 10 years. The goal of the analysis is to conduct lifecycle activities in a manner that will achieve a cost-effective and sustainable approach to the management of the road network including the provision of an acceptable level of service for the community. For this analysis, it was assumed that roads will deteriorate on a non-linear basis (**see Figure 1-1**) and the lifecycle activities can be implemented at varying stages of a road's lifecycle. The outputs from the analysis and recommended scenario were used to inform the improvement plan (**see Section 4**).

For this report, the scenario analysis was completed using Dillon's Predictive Scenario Software (DPSS). DPSS is a Microsoft Access-based tool that can consider multiple types of interventions (i.e., road preventative maintenance, rehabilitation, and reconstruction) and generate forecasted expenditures based on a given study period. An allocated budget is required to run the model, however, based on the recommended interventions the entire budget within that year may not be used. A summary of the two financial variables considered within DPSS is provided below.

Allocated Budget: The allocated budget is the specific budget amount that is entered into DPSS and is a predetermined limit for expenditures each year. It essentially acts as a 'threshold' value and determines the maximum amount available for spending. For example, consider having two roads that require replacement. If the allocated budget is insufficient to cover the costs of both roads, only one of them can be addressed in that particular year. The second road will be designated for priority in the following

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year when budget constraints may be reassessed. The allocated budget per year inputted into DPSS for all scenarios can be found in **Appendix B.**

Forecast Expenditures: The forecast expenditures are the results generated by DPSS, indicating the potential interventions or expenses for the year based on the available budget. This value is a projection of the feasible expenditures within the given financial year, and they do not surpass the allocated budget. In summary, it serves as a guide for decision-makers, outlining what can be accomplished within the financial constraints set by the allocated budget.

For the analysis, the lifecycle activities do not consider growth initiatives (i.e., road network expansion) as part of the modelling.

3.3.1 Lifecycle Model Configuration

The lifecycle activities anticipated to be completed by the Municipality pertaining to preventative maintenance, rehabilitation, and reconstruction for asphalt roads were determined by Dillon and confirmed by the Municipality. These activities help to understand the needs and projected capital work on the road network for the next 10 years.

A summary of the lifecycle activities for asphalt roads, as used in Dillon's lifecycle modeling, can be found below in **Table 3-2**. Historically, the Municipality has taken a reactive approach to maintaining their road network by addressing road needs based on input from Municipal staff.

Table 3-2: Road Lifecycle Activities Based on Surface Type and Condition

Surface Type	Lifecycle Activity	Treatment Types	PCI Threshold	PCI Rebound
Asphalt	Reconstruction	Full Reconstruction, Full Depth Reclamation (FDR), Partial Depth Reconstruction	PCI < 44	100
	Rehabilitation	Mill & Overlay, Asphalt Overlay	45 < PCI < 64	80
	Preventative Maintenance	Crack Sealing, Pothole Repair, Skin Patching	65 < PCI < 84	84
	Defer Repair	None	PCI > 85	-

As shown in the above in **Table 3-2**, PCI thresholds were inputted into DPSS to inform the model on appropriate road interventions to schedule given the roads condition. It is important to note that roads continue to decay starting from the determined 2024 PCI values based on predetermine deterioration curves throughout the projection window. Additionally, PCI rebounds were established for each lifecycle activity representing the assumed change in PCI that accompanies the completion of the lifecycle activity for the road segment.

Table 3-3 summarizes the unit costs estimated for the lifecycle activities performed on asphalt roads, as employed in the lifecycle modeling. It is important to note that all budgeting scenarios take into consideration an assumed average annual inflation rate of 3%.

Table 3-3: Asphalt Roads - Lifecycle Activity Unit Costs Used in Modeling

Road Class	Lifecycle Activity	2024 Unit Cost ($/m^2)
Collector – 20-Year Expected Useful Life	Preventative Maintenance	$10.00
	Rehabilitation	$45.00
	Reconstruction	$125.00
Local – 30-Year Expected Useful Life	Preventative Maintenance	$10.00
	Rehabilitation	$45.00
	Reconstruction	$90.00

3.3.2 Budget Scenario Summaries

The following subsections summarize the findings of lifecycle modeling projections for asphalt roads considering a 10-year projection window and different allocated budget scenarios. The scenarios reviewed for this report include the following:

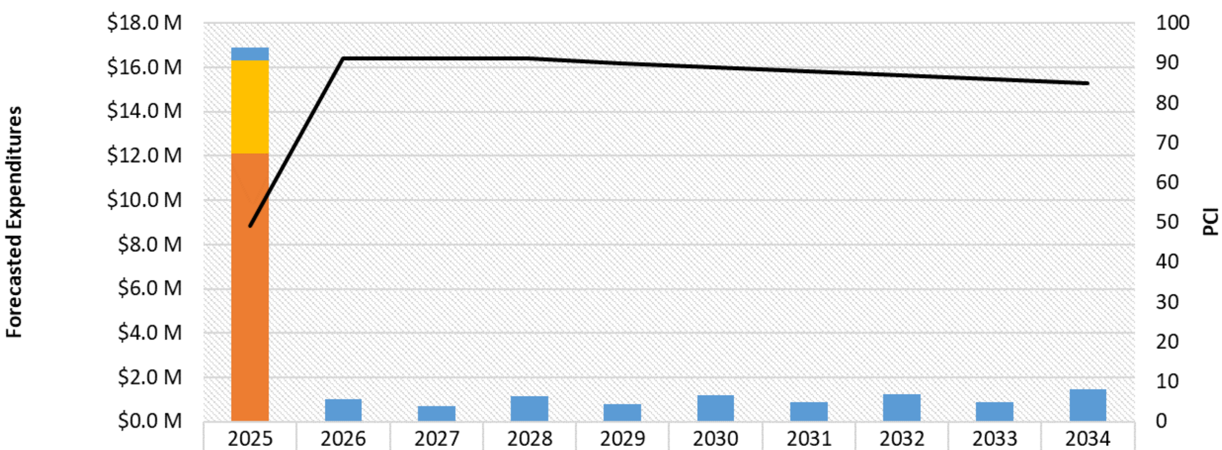
1. **Unconstrained Budget:** This scenario assumed availability of capital is unconstrained and represents a needs-based budget that assumes funding could be provided for each road segment in the first year that a lifecycle activity threshold is reached. Essentially, this scenario demonstrates the required expenditures to eliminate existing backlog for the road network based on current road conditions;
2. **Reinvest 2% of Total Replacement Cost:** This scenario includes targeting to reinvest 2% of the total replacement cost of the road network based on the lower target investment rate determined by the 2016 Canadian Infrastructure Report Card;
3. **Increase Average PCI to 70 in 5 Years and Maintain:** This scenario considers increasing the average PCI of the road network to 70 (i.e., average condition of good) in 5 years and maintaining the 70 PCI average throughout the remainder of the 10-year period. This scenario represents a decision to significantly increase the level of service being provided by the road network as the 2024 average PCI was determined to be 51 (i.e., average condition of poor); and
4. **Increase Average PCI to 70 in 10 Years:** This scenario considers increasing the average PCI of the road network to 70 in 10 years. This scenario represents a decision to significantly increase the level of service being provided by the road network as the 2024 average PCI was determined to be 51 (i.e., average condition of poor).

3.3.2.1 Scenario 1: Unconstrained Budget

Scenario 1 represents the road lifecycle needs and associated expenditures that could be addressed given an unconstrained budget. Although not representative of a realistic scenario for the Municipality, this scenario is useful to identify the existing lifecycle needs of the road network. A summary of the unconstrained budget scenario can be found in **Table 3-4** and **Figure 3-1**.

Table 3-4: Unconstrained Budget Scenario – Lifecycle Modeling Summary

Total 10-Year Cost	Average Annual Cost	Resulting Average PCI	% Change in PCI	Average Annual Reinvestment Rate
$26.2 M	$2.6 M	85	73.5%	6.79%



	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Preventative	$.5 M	$1.0 M	$.7 M	$1.2 M	$.8 M	$1.2 M	$.9 M	$1.2 M	$.9 M	$1.5 M
Rehabilitation	$4.2 M									
Reconstruction	$12.1 M									
Average PCI	49	91	91	91	90	89	88	87	86	85

Figure 3-1: Unconstrained Budget Scenario

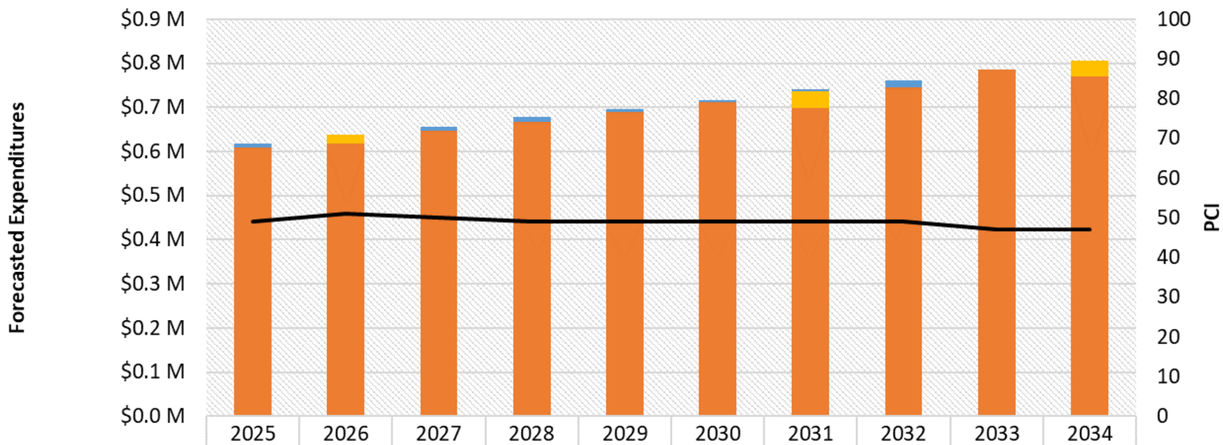
Based on the findings presented in **Table 3-4** and **Figure 3-1**, it is anticipated that the Municipality would require approximately **$16.9 M** in 2025 to address existing preventative maintenance, rehabilitation, and reconstruction needs of the road network. In summary, this scenario communicates that there is significant backlog to be addressed for the road network.

3.3.2.2 Scenario 2: Reinvest 2% of Total Replacement

Scenario 2 is to reinvest 2% of the total replacement cost ($32.9 M) of the road network based on the lower target investment rate determined by the 2016 Canadian Infrastructure Report Card. The budgeting approach used in this scenario was to reinvest 2% of the total replacement cost for the asphalt road network each year assuming 3% inflation. A summary of the scenario can be found in **Table 3-5** and **Figure 3-2**.

Table 3-5: Reinvest 2% of Total Replacement Cost Scenario - Lifecycle Modeling Summary

Total 10-Year Cost	Average Annual Cost	Resulting Average PCI	% Change in PCI	Average Annual Reinvestment Rate
$7.1 M	$709.2 K	47	-4.1%	1.84%



	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Preventative	$9 K		$8 K	$11 K	$6 K	$4 K	$5 K	$16 K		
Rehabilitation		$19 K					$37 K			$35 K
Reconstruction	$609 K	$618 K	$647 K	$667 K	$690 K	$712 K	$698 K	$746 K	$785 K	$771 K
Average PCI	49	51	50	49	49	49	49	49	47	47

Figure 3-2: Reinvest 2% of Total Replacement Scenario

Based on the findings presented in **Table 3-5** and **Figure 3-2**, it is anticipated that reinvesting 2% of the total replacement cost of the road network would result in an average PCI of 47 at the end of the 10-year window. The resulting average PCI of 47 represents an average condition grade of poor, and is a decrease from the 2024 average PCI of 51. The Municipality should consider a higher reinvestment rate to address backlog and increase the average condition of the road network.

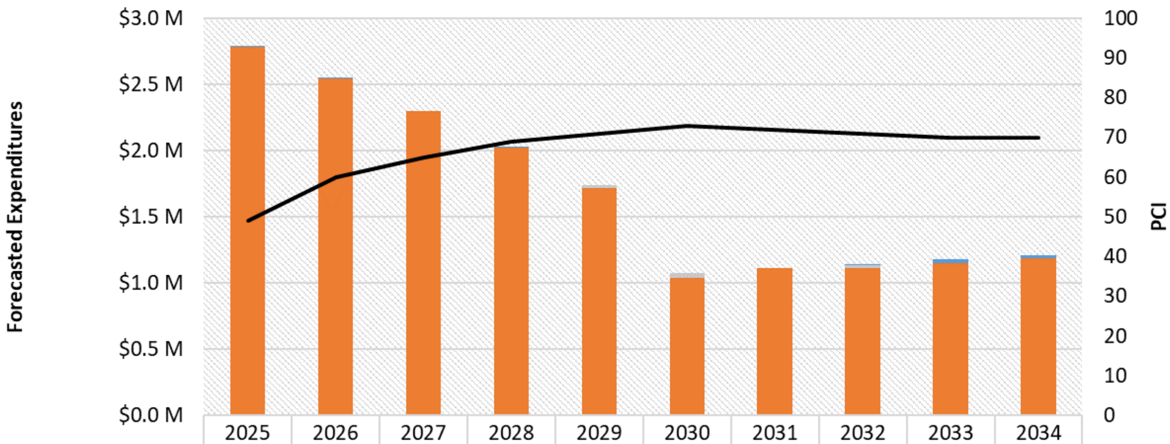
3.3.2.3 Scenario 3: Increase Average PCI to 70 in 5 Years and Maintain

Scenario 3 evaluates the possibility of increasing the average PCI of the road network to 70 in 5 years and maintaining the 70 PCI average throughout the remainder of the 10-year window. This scenario represents a decision to significantly increase the level of service being provided by the road network as the average PCI is predicted to drop to 49 in 2025.

The budgeting approach used in this scenario was to reinvest 9% of the total replacement cost for the road network in 2025, decrease the reinvestment rate 1% each year from 2026 to 2029, and decrease the budget to 3% of total replacement cost from 2030 to 2034. A summary of the scenario can be found in **Table 3-6** and **Figure 3-3**.

Table 3-6: Increase Average PCI to 70 in 5 Years Scenario - Lifecycle Modeling Summary

Total 10-Year Cost	Average Annual Cost	Resulting Average PCI	% Change in PCI	Average Annual Reinvestment Rate
$17.1 M	$1.7 M	70	42.9%	4.44%



	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Preventative	$4 K	$8 K		$12 K				$5 K	$24 K	$22 K
Rehabilitation					$25 K	$35 K		$27 K		
Reconstruction	$2.8 M	$2.5 M	$2.3 M	$2.0 M	$1.7 M	$1.0 M	$1.1 M	$1.1 M	$1.2 M	$1.2 M
Average PCI	49	60	65	69	71	73	72	71	70	70

Figure 3-3: Increase Average PCI to 70 in 5 Years Scenario

Based on the findings outlined in **Table 3-6** and **Figure 3-3**, it is anticipated that the budgeting approach would result in achieving an average PCI of 70 by 2029 and maintaining an average of 70 PCI or higher for the remainder of the 10-year window. The resulting average PCI of 70 represents an average condition grade of good for the road network and achieves a desirable level of service for the community.

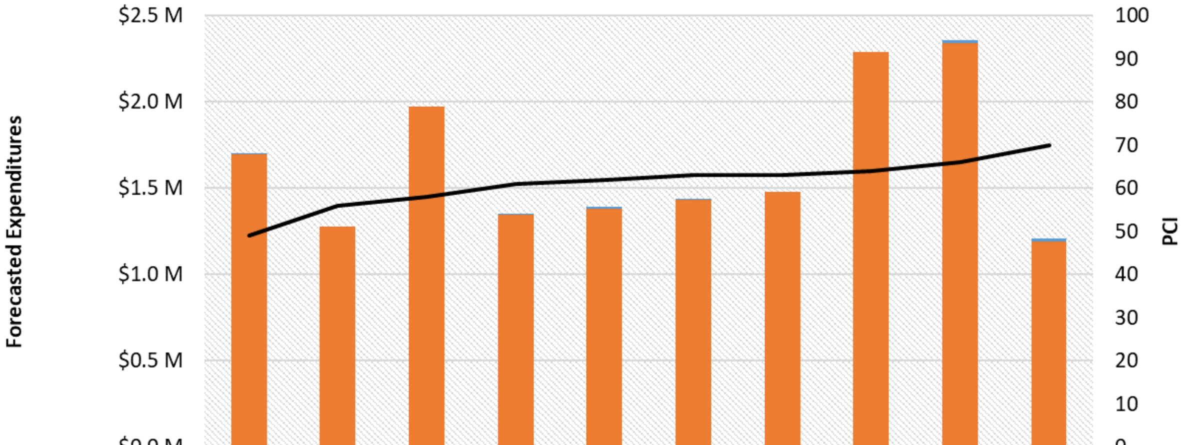
3.3.2.4 Scenario 4: Increase Average PCI to 70 in 10 Years

Scenario 4 represents increasing the average PCI of the road network to 70 in 10 years. This scenario represents a decision to significantly increase the level of service being provided by the road network as the average PCI is predicted to drop to 49 in 2025.

The budgeting approach used in this scenario was to change the amount reinvested in each year to increase the average PCI. A summary of the scenario can be found in **Table 3-7** and **Figure 3-4**.

Table 3-7: Increasing Average PCI to 70 in 10 Years Scenario – Lifecyle Modeling Summary

Total 10-Year Cost	Average Annual Cost	Resulting Average PCI	% Change in PCI	Average Annual Reinvestment Rate
$16.5 M	$1.6 M	70	42.9%	4.27%



	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Preventative	$8 K			$6 K	$14 K	$5 K			$16 K	$18 K
Reconstruction	$1.7 M	$1.3 M	$2.0 M	$1.3 M	$1.4 M	$1.4 M	$1.5 M	$2.3 M	$2.3 M	$1.2 M
Average PCI	49	56	58	61	62	63	63	64	66	70

Figure 3-4: Increase Average PCI to 70 in 10 Years Scenario

Based on the findings outlined in **Table 3-7 and Figure 3-4**, it is anticipated that the budgeting approach would result in an average PCI of 70 for the road network by 2034. The resulting average PCI of 70 represents an average condition grade of good for the road network and achieves a desirable level of service for the community.

3.4 Summary and Recommendations

The average PCI rating in 2024 for the Municipality's road network is 51 and it is anticipated to drop to 49 in 2025. A summary of the four (4) analysis options is presented in **Table 3-8**.

Table 3-8: Summary of Proposed Budget Results

Scenario	Total 10-Year Cost	Average Annual Cost	Resulting Average PCI	% Change in PCI	Average Annual Reinvestment Rate
1	$26.2 M	$2.6 M	85	73.5%	6.79%
2	$7.1 M	$709.2 K	47	-4.1%	1.84%
3	$17.1 M	$1.7 M	70	42.9%	4.44%
4	$16.5 M	$1.6 M	70	42.9%	4.27%

Based on the existing condition of the road network (average condition rating of poor) further supported by the lifecycle modeling results, it is evident that significant reinvestment is needed in road reconstruction activities to address existing backlog for the road network and return the road network to a better state of repair.

For Scenario 2, targeting a 2% reinvestment rate of the total replacement cost of the road network would not provide significant improvements to the overall condition of the road network. This is due to the current condition of the roads and an existing backlog.

Scenarios 3 and 4 both aim to achieve an average PCI rating of 70 over different periods (one within five years and the other within ten years). The average annual costs for both scenarios over the 10-year period, based on the DPSS lifecycle modeling outputs, appear similar. For Scenario 3, an aggressive reinvestment of approximately **$11.3 M** is required in the first five years. In contrast, Scenario 4 proposes a more feasible projected cost of approximately **$7.7 M** (around $3.6 M less than Scenario 3) over the same period.

The annual reinvestments for the 10-year window are more evenly distributed in Scenario 4 which allows for increased flexibility in project scheduling and a more practical capital plan for obtaining an average PCI of 70 across the road network. Therefore, it is recommended to approach the road needs with Scenario 4.

4.0 Improvement Plan

A core objective of this report is to proactively extend the useful life of roads, by ensuring existing deterioration is well understood and properly addressed through timely preventative maintenance, rehabilitation, and replacement activities. The provision of reliable road infrastructure is crucial to make that the Municipality can continue to deliver reliable services to its current residents. As the Municipality's roads age, significant reinvestment will be required for the replacement of deteriorated roads to increase service delivery.

Figure 4-1 depicts the full lifecycle of an infrastructure asset and demonstrates the cumulative cost of ownership which increases throughout the asset's service life and amounts to far more than the initial investment. An infrastructure asset's lifecycle begins in the planning and design phase, where the need for the new asset is identified and a strategic plan is created. This is followed by the first asset-related expenditure which is the initial investment to construct or create the asset. Once the asset has been created, the asset enters the operational phase, requiring regular maintenance to keep it functional. Over time, as deterioration increases, capital reinvestment is required to extend the useful life of the asset and prolong service delivery through rehabilitation. After rehabilitation, the asset re-enters the operational phase, accumulating additional costs associated with operation and maintenance before reaching the end of its useful life and requiring replacement.

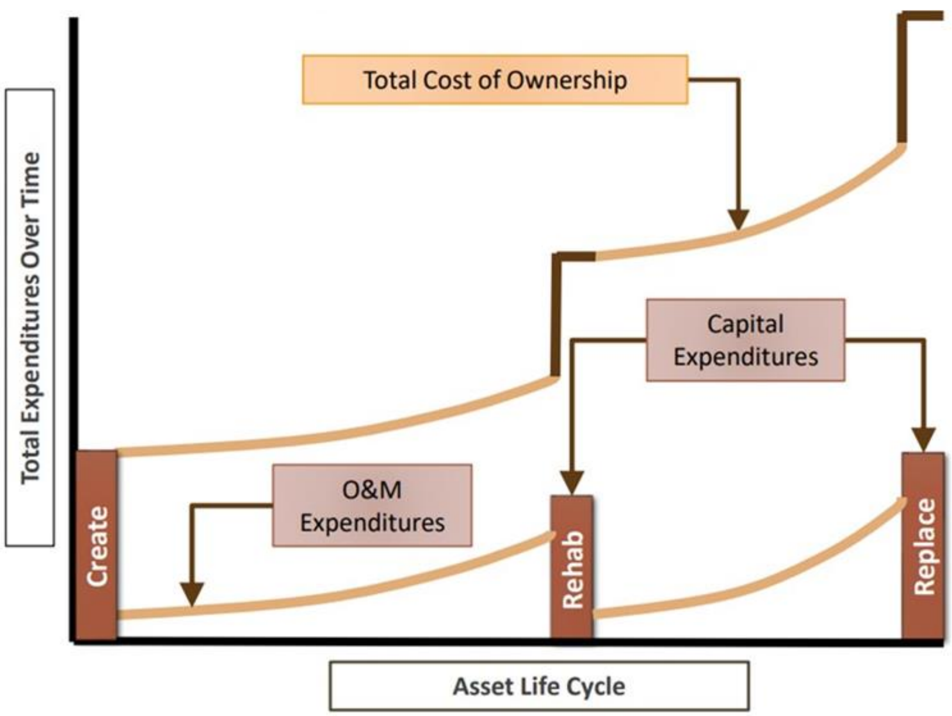


Figure 4-1: Cumulative Cost of Asset Ownership (AMOntario)

Lifecycle modeling allows for the Municipality to understand the future reinvestment needs of their existing assets by generating a theoretical replacement forecast for the existing road inventory. The expected useful life, replacement cost, and condition of each road can be leveraged within the lifecycle model to proactively plan for reinvestment over a period of interest.

4.1 Long-Term Planning Perspective

If the Municipality were to consider a reactive approach, only replacing roads at the end of their useful life, there would be significant spikes in the annual reinvestment required for roads. To put this into a long-term planning context, the following road replacement forecast shown in **Figure 4-2** estimates the potential replacement of the road network over a 25-year horizon. This estimate assumes roads would only be replaced at the end of their lifespan, with no interventions to extend it.

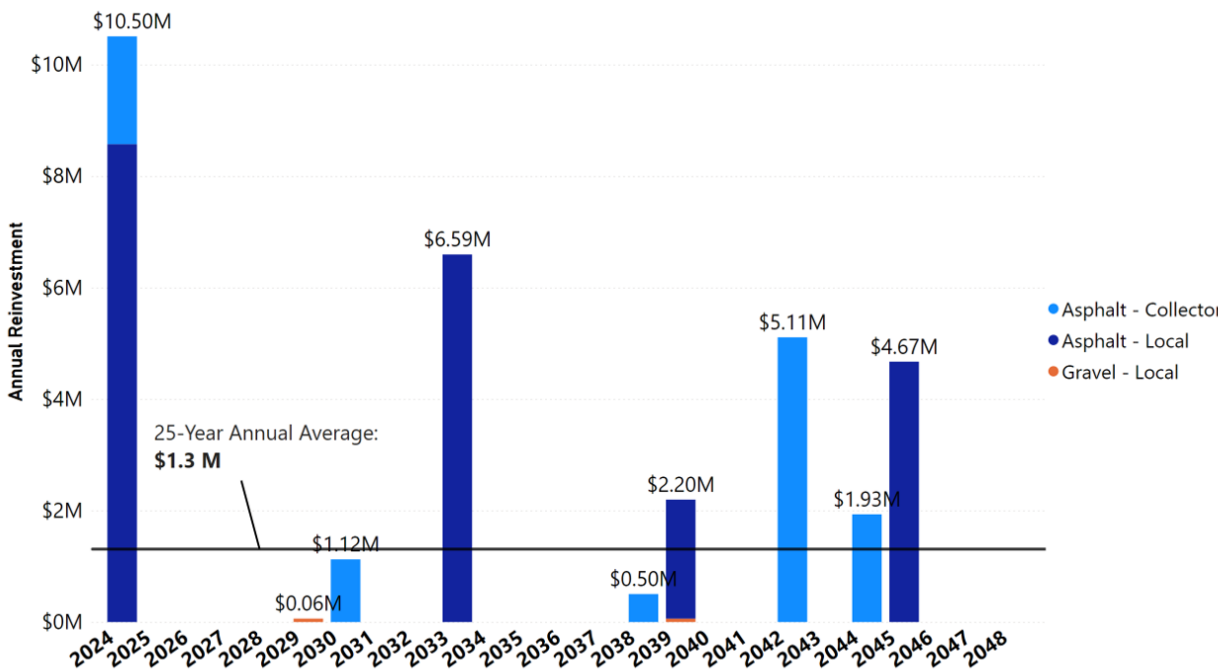


Figure 4-2: 25-Year Renewal Needs

Based on this outlook, it is anticipated that the Municipality should be spending at minimum **$1.3 M** annually for road reconstruction activities, separate from any investment in rehabilitation or preventative maintenance activities.

4.2 Prioritization

Capital infrastructure investment decisions can be challenging to navigate due to competing goals and priorities for the Municipality. A prioritization process can help consider various needs and create a path forward to maintain an acceptable level of service and forecast expenditures to support long-term budgeting considerations. This report focuses on the road network, but other factors and assets should be assessed before making final capital work decisions. For instance, if underground utilities (i.e., water, sanitary, or storm infrastructure) exists under a road segment, an evaluation of these systems should be made for repair or replacement before any surface roadwork begins.

The prioritization process for this report focused on a next 5-year horizon as priorities can change significantly in the future. The prioritization process focuses on existing condition, and realistic replacement schedules can be difficult to predict.

Step 1: Identify Needs based on Criticality

The initial step was to use DPSS to review the road needs based on lifecycle modeling, using condition data and the expected useful life of the road to recommend interventions over a 10-year planning period. This involves four modeling scenarios as summarized in **Section 3.3**. From the chosen scenario for the Municipality, a list of preventative maintenance, rehabilitation, and reconstruction needs was produced that could be accommodated within the allocated budget. The output from DPSS is a proposed schedule of interventions (i.e., implementation plan). DPSS prioritizes reconstruction needs as the top priority, followed by rehabilitation works, and then preventative maintenance work. The goal is to address roads in the most critical condition as promptly as possible.

Step 2: Strategic Coordination and Scheduling

The next step involved further developing of the implementation plan based on other external project considerations. These considerations could include budget limits, ability to get the project to tender, seasonal considerations, etc.). Activities include:

- Generating the lifecycle activity schedule of projects. (DPSS outputs). If budget is exceeded in a given year, review the projects and consider which investments can wait or be delivered over multiple years. Reassign the year for investment;
- Reviewing the overall investment plan to determine if any lifecycle activity projects can be moved to accommodate higher priority projects; and
- Reviewing the efficiency of projects to identify projects that can be combined based on region or type of work. Projects could be combined (or bundled) based on resource availability and where bundling projects makes sense for ease of implementation (tendering projects, working with one contractor vs many contractors, etc.).

4.3 Proposed Improvement Plan

4.3.1 Funding Sources

The Municipality uses a combination of funding sources to fund their capital road projects. This includes the municipal budget, PMHP (Provincial Municipal Highway Program), Infrastructure Canada Funding (various programs), and Canada Community-Building Fund (CCBF). It is important to note that the proposed reinvestment outlined in this improvement plan can be largely supplemented by applying for funding programs and will not need to be completely funded by the municipal budget.

4.3.2 5-Year Plan

Based on the recommended budgeting scenario discussed in **Section 3.3** and the prioritization process, a summary of the proposed 5-year capital plan can be found in **Table 4-1**. A detailed list of proposed roads based on the scenario analysis can be found in **Appendix C**.

As mentioned previously, the Municipality has a large backlog of reconstruction projects that are required to improve the overall condition of the road network. The proposed reconstruction projects outlined in the plan account for the replacement of like-for-like assets. For instance, if the current material for the road is asphalt, it is assumed that the replacement or repair will be the same material.

Table 4-1: Summary of Proposed Road Needs

Proposed Year	Road Class	Lifecycle Activity	Approx. Length (Km)	Anticipated Costs (2024 dollars)
2025	Collector	Reconstruction	1.1	$1.03 M
	Local	Reconstruction	2.3	$1.19 M
		Preventative Maintenance	0.1	$7.71 K
2026	Local	Reconstruction	2.9	$1.84 M
2027	Collector	Reconstruction	0.5	$545 K
	Local	Reconstruction	2.2	$1.31 M
2028	Local	Reconstruction	2.5	$1.35 M
		Preventative Maintenance	0.1	$6.02 K
2029	Local	Reconstruction	2.6	$1.78 M
		Preventative Maintenance	0.2	$14.4 K
		Total	**14.5**	**$9.07 M**

Due to the existing backlog of road needs, the majority of the proposed projects involve reconstruction work. It is recommended that the Municipality also considers increasing the preventative maintenance of roads that are currently in good condition (as of 2024) to prolong the lifecycle of roads. This may include developing annual crack sealing and pothole repair programs.

Figure 4-3 provides an overview of the anticipated preventative maintenance needs, for roads in good condition over the next five years. It is important to note that the projected maintenance needs could not be addressed within the allocated budget provided for the chosen reinvestment scenario and associated lifecycle modeling (i.e., **surplus funding to consider outside the capital plan**). Based on the existing condition and future road network deterioration, it is anticipated that the Municipality should consider spending an annual average of approximately **$242,500** on preventative maintenance for the road network.

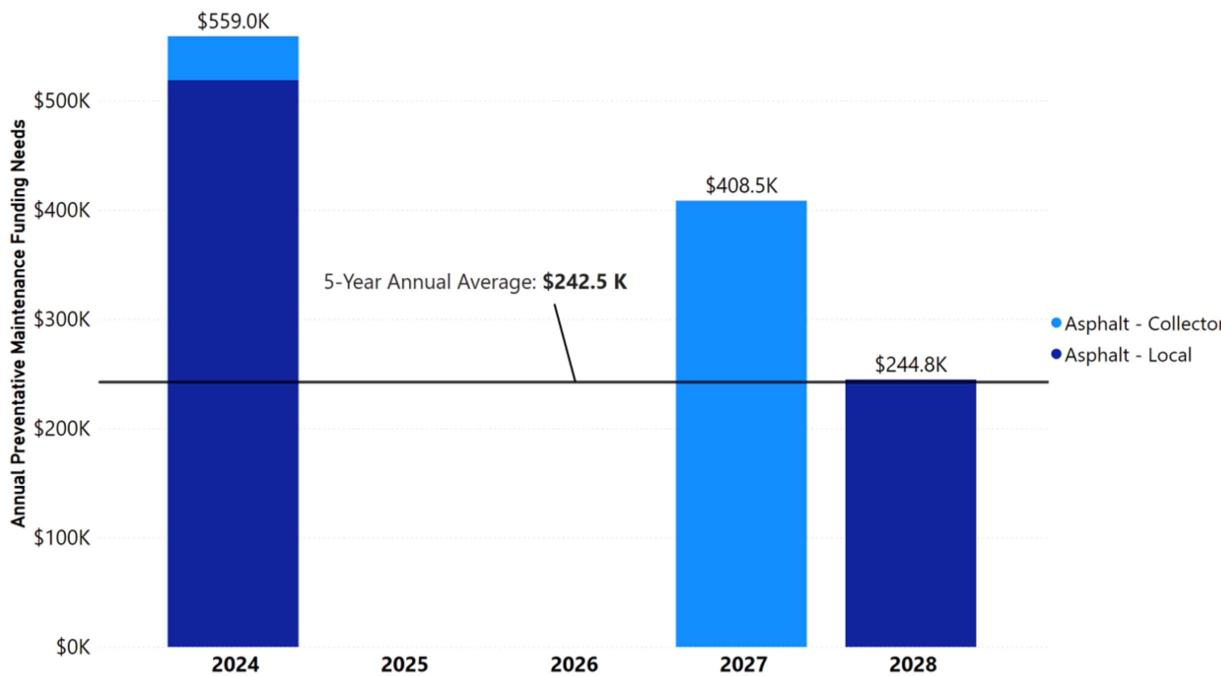


Figure 4-3: 5-Year Preventative Maintenance Funding Needs

5.0 Summary and Next Steps

This is the first iteration of the Municipality's Road Condition Assessment and Needs Analysis. The goal of the report was to determine the current condition of the roads based on visual assessment and provide information to help optimize the lifecycle of road assets, along with information to support decision making for the assets.

The report can be considered as the initial approach for implementation and is anticipated to be refined further over time. The key findings and next steps based on the analysis completed in this report are summarized below.

Key Findings

- The Municipality currently owns and maintains approximately $33 million in roads;
- The average condition of asphalt roads is poor;
- The Municipality is currently taking a reactive lifecycle approach to road maintenance rather than proactively planning for lifecycle activities; and
- There is a significant amount of backlog ($16.9 M) attributed to lifecycle activities to improve the road network.

Next Steps

The proposed next steps for the Municipality based on the findings and outcomes of the condition assessment and needs analysis is shown in **Table 5-1**.

Table 5-1: Recommended Next Steps

Item	Description	Timing
Develop a Comprehensive Plan for all infrastructure within the road right-of-way	To help with prioritization and planning of capital projects, a consolidated map or data showcasing the road network and associated infrastructure will help in decision-making and provide detailed courses of action.	2025
Refine the Prioritization Process	Once the data and information are available for all other infrastructure, a refined prioritization process should be developed for capital planning. This may involve assigning more importance to full road reconstructions than to milling and paving, or vice versa.	2026
Data Review and Updating	Implement a system for regular reviews and updates of road data to assist in decisions regarding capital work.	Annually
Regular Condition Assessment and Analysis	Keep regularly monitoring and collecting road condition data. Conduct a visual condition assessment or needs analysis to help with the next planning period.	Every 5 years

Appendix A

Condition Summary Card

DILLON CONSULTING

Municipal Roads - Condition Summary Card

What are they worth? What is their condition and expected remaining useful life?

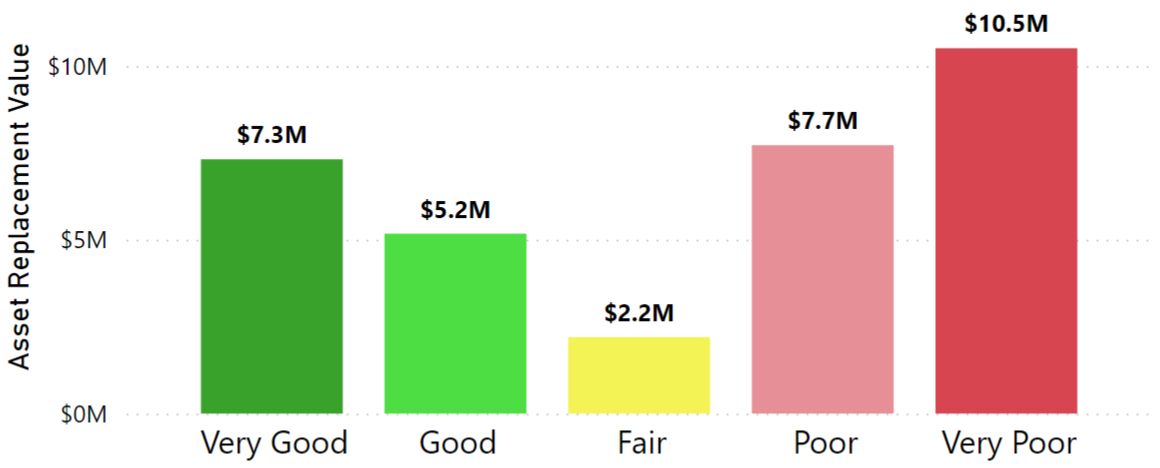
Total Replacement Value

$32.9M

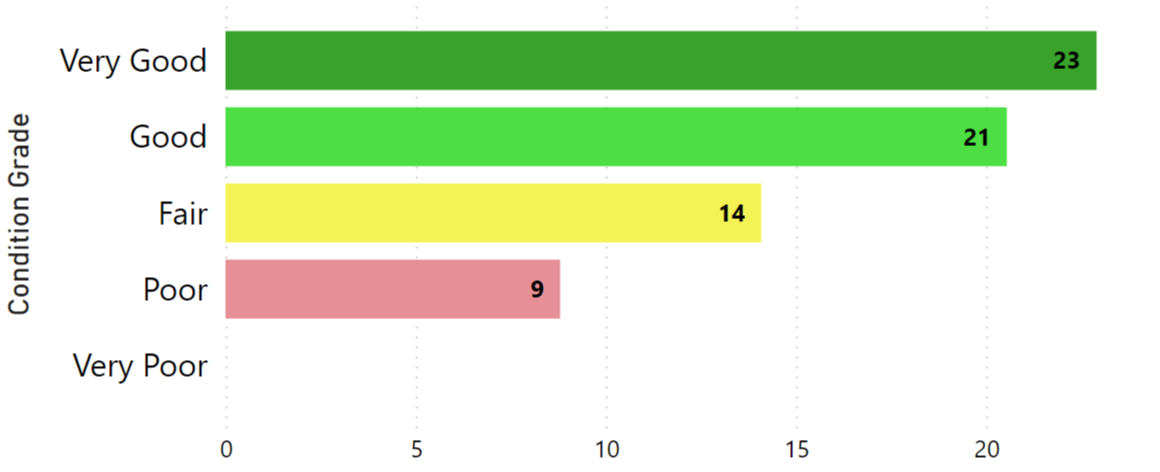
Average PCI Rating

51 (Poor)

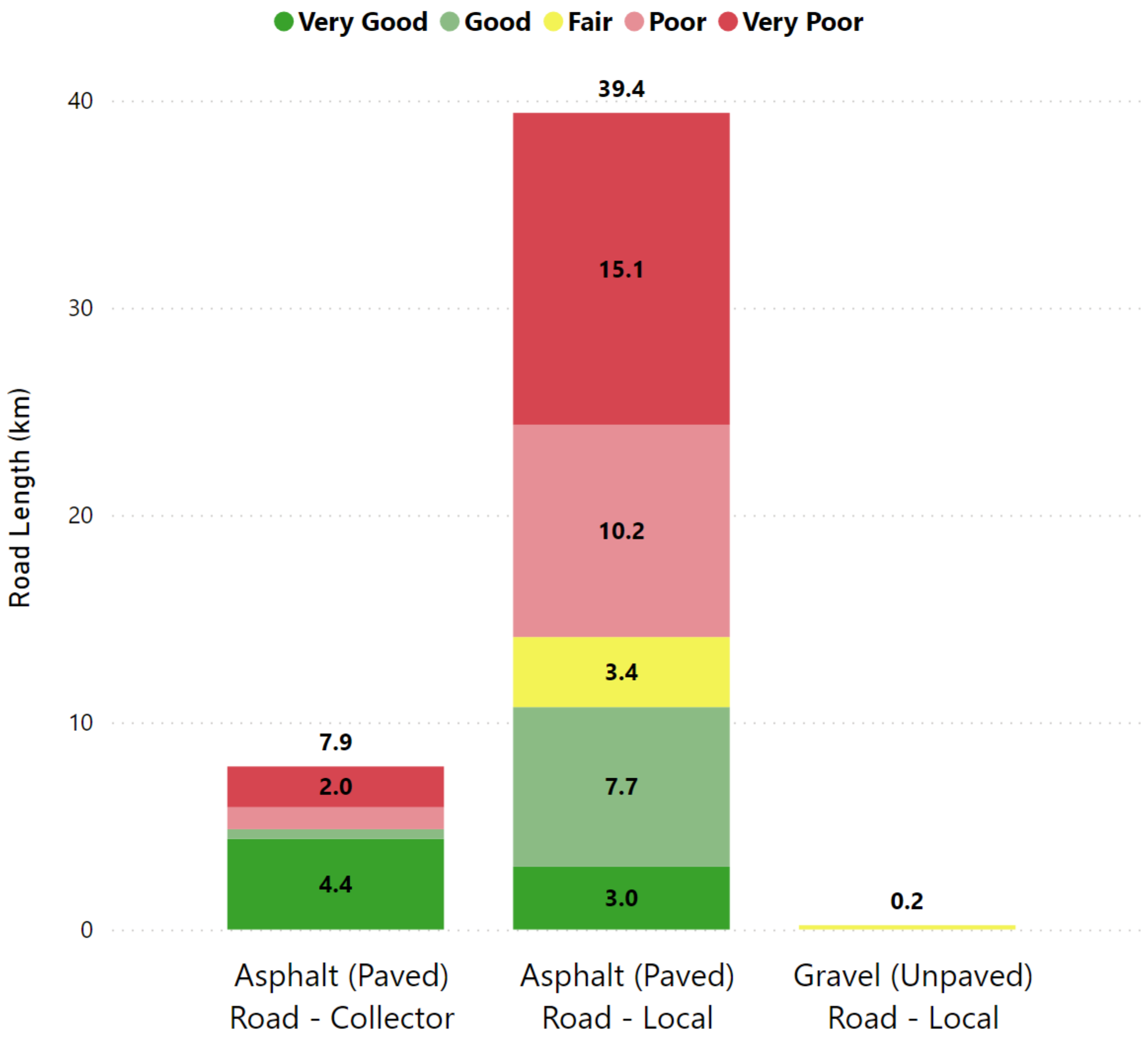
Asset Replacement Value by Condition



Average Remaining Useful Life (Years) by Condition



Road Length (km) by Construction Material, Road Class, and Condition



Appendix B

Allocated Budget Inputs for Scenarios

Table B-1: Allocated Budgets Used in DPSS

Planning Year	Scenario 1	Scenario 2	Scenario 3	Scenario 4
2025	$17,000,000	$620,100	$2,790,336	$1,705,206
2026	$17,000,000	$638,800	$2,554,708	$1,277,354
2027	$17,000,000	$658,000	$2,302,431	$1,973,512
2028	$17,000,000	$677,800	$2,032,717	$1,355,145
2029	$17,000,000	$698,200	$1,744,749	$1,395,799
2030	$17,000,000	$719,200	$1,078,255	$1,437,673
2031	$17,000,000	$740,800	$1,110,603	$1,480,803
2032	$17,000,000	$763,100	$1,143,921	$2,287,841
2033	$17,000,000	$786,000	$1,178,238	$2,356,476
2034	$17,000,000	$809,600	$1,213,585	$1,213,585

Appendix C

Detailed Capital Plan

Segment ID	Road Name	Road Class	Road Material	Road Segment Description	Length (Km)	Lifecycle Activity	Estimated Cost (2024)	PCI 2024	IRI 2024	Forecasted Year (DPSS)	Proposed Year (Capital Plan)	Work Notes	Justification for Scheduling Adjustment
RD-043-01	HAMILTON Lane	Local	Asphalt	HAMILTON Lane	0.05	Reconstruction	$14,688	0	12.64	2025	2025		
RD-011-02	BROOK Street	Local	Asphalt	BROOK Street (End to Main St)	0.05	Reconstruction	$14,104	6	8.93	2025	2025		
RD-030-01	EDGEWOOD Street	Local	Asphalt	EDGEWOOD Street	0.14	Reconstruction	$71,211	10	9.74	2025	2025		
RD-029-01	EATON Street	Local	Asphalt	EATON Street	0.09	Reconstruction	$34,904	10	6.54	2025	2025		
RD-006-01	BELLIVEAU Avenue	Local	Asphalt	BELLIVEAU Avenue	0.03	Reconstruction	$14,307	10	9.41	2025	2025		
RD-059-01	MCINTEE Lane	Local	Asphalt	MCINTEE Lane	0.03	Reconstruction	$13,417	10	3.74	2025	2025		
RD-040-01	GREENWOOD Street	Local	Asphalt	GREENWOOD Street	0.16	Reconstruction	$73,315	11	8.81	2025	2025		
RD-094-01	ST JAMES Street	Local	Asphalt	ST JAMES Street	0.10	Reconstruction	$50,345	12	7.77	2025	2025		
RD-044-01	HARTFORD Lane	Local	Asphalt	HARTFORD Lane	0.22	Reconstruction	$87,749	13	10.29	2025	2025		
RD-042-01	HALEY Street	Local	Asphalt	HALEY Street	0.15	Reconstruction	$84,021	14	7.18	2025	2025		
RD-032-01	EDWIN Street	Local	Asphalt	EDWIN Street	0.13	Reconstruction	$60,793	16	0.00	2025	2025		
RD-086-01	RUSHTON Street	Local	Asphalt	RUSHTON Street	0.38	Reconstruction	$216,228	17	7.08	2025	2025		
RD-104-01	WALL Street	Local	Asphalt	WALL Street	0.24	Reconstruction	$138,621	17	5.98	2025	2025		
RD-018-01	CHIPMAN Street	Local	Asphalt	CHIPMAN Street	0.12	Reconstruction	$74,699	17	4.70	2025	2025		
RD-036-01	GARDEN Street	Local	Asphalt	GARDEN Street	0.10	Reconstruction	$62,366	18	6.11	2025	2025	Bundle with Addition of Sidewalk (Near Hospital).	
RD-107-01	WILDWOOD Street	Local	Asphalt	WILDWOOD Street	0.10	Reconstruction	$52,006	18	9.58	2025	2025		
RD-010-01	BREWER Lane	Local	Asphalt	BREWER Lane (Maple St to end)	0.14	Reconstruction	$91,962	22	7.79	2025	2025		
RD-039-01	GREEN Street	Local	Asphalt	GREEN Street	0.11	Reconstruction	$40,037	22	6.34	2025	2025		
RD-099-04	UNION Street	Collector	Asphalt	UNION Street (Rose Street to Hawthorne Street)	0.43	Reconstruction	$381,507	33	6.08	2027	2025	Bundle with All Union Street Segments (RD-099-04, RD-099-05, RD-099-06) and Utilities Renewal & Sewer Separation.	Advanced as a high priority road (collector, fire station).
RD-099-06	UNION Street	Collector	Asphalt	UNION Street (King Street to Marks Street)	0.24	Reconstruction	$249,836	38	4.67	2030	2025	Bundle with All Union Street Segments (RD-099-04, RD-099-05, RD-099-06) and Utilities Renewal & Sewer Separation.	Advanced as a high priority road (collector, fire station).
RD-099-05	UNION Street	Collector	Asphalt	UNION Street (Marks Street to Rose Street)	0.40	Reconstruction	$395,969	39	4.54	2030	2025	Bundle with All Union Street Segments (RD-099-04, RD-099-05, RD-099-06) and Utilities Renewal & Sewer Separation.	Advanced as a high priority road (collector, fire station).
RD-096-02	THOMPSON Avenue	Local	Asphalt	THOMPSON Avenue (Garden street to Prince William Street)	0.11	Preventative	$7,710	69	6.37	2025	2025		
RD-083-01	ROSE Street	Local	Asphalt	ROSE Street	0.46	Reconstruction	$250,190	19	7.33	2026	2026		
RD-009-01	BREWER Lane	Local	Asphalt	BREWER Lane (Church St to end)	0.13	Reconstruction	$55,165	21	7.91	2026	2026		
RD-050-01	KINGS Court	Local	Asphalt	KINGS Court	0.13	Reconstruction	$70,109	23	5.19	2026	2026		
RD-065-01	OAKSWAY Street	Local	Asphalt	OAKSWAY Street	0.18	Reconstruction	$103,175	24	6.12	2026	2026		
RD-067-01	PARKWOOD Drive	Local	Asphalt	PARKWOOD Drive	0.45	Reconstruction	$242,454	24	7.32	2026	2026	Bundle with Utilities Renewal & Sewer Separation.	
RD-016-01	CEDAR Street	Local	Asphalt	CEDAR Street	0.15	Reconstruction	$77,258	26	8.11	2027	2026	Bundle with Utilities Renewal & Sewer Separation.	Advanced for balancing of expenditures.
RD-084-02	ROSS Avenue	Local	Asphalt	ROSS Avenue (from beginning of road to beginning of gravel p	0.06	Reconstruction	$18,580	27	11.80	2026	2026		
RD-053-01	MAIN Street	Local	Asphalt	MAIN Street (Queen Street West to Brook Street)	0.28	Reconstruction	$171,906	28	7.68	2026	2026		
RD-093-01	ST CROIX Street	Local	Asphalt	ST CROIX Street	0.23	Reconstruction	$132,510	28	8.04	2026	2026		
RD-049-04	KING Street	Local	Asphalt	KING Street (Queen Street Intersection to Young Street)	0.24	Reconstruction	$153,840	45	4.13	2032	2026		Adjusted to 2026 based on previously approved NBDTI funding (100%).
RD-049-03	KING Street	Local	Asphalt	KING Street (Young Street to King Roundabout)	0.62	Reconstruction	$564,186	51	3.19	2034	2026		Adjusted to 2026 based on previously approved NBDTI funding (100%).
RD-049-06	KING Street	Local	Asphalt	KING Street (Budd Avenue to Civic 90)	0.06	Reconstruction	$33,113	21	2.79	2026	2027		Adjusted to 2027 based on pending approval of NBDTI funding (pending at 100%).
RD-068-01	PINE Street	Local	Asphalt	PINE Street (Union Street to Queen Street West)	0.50	Reconstruction	$304,695	23	7.42	2025	2027	Bundle with Utilities Renewal & Sewer Separation.	Delayed to allow for previously identified utilities & CSS renewal.
RD-081-01	RIVER Street	Local	Asphalt	RIVER Street	0.14	Reconstruction	$81,004	24	6.74	2027	2027		
RD-002-01	ABERDEEN Street	Local	Asphalt	ABERDEEN Street	0.08	Reconstruction	$45,688	25	5.34	2027	2027		
RD-035-01	ELM Street	Local	Asphalt	ELM Street (Queen Street West to end)	0.24	Reconstruction	$101,052	26	7.34	2027	2027		
RD-073-01	POST COVE Road	Local	Asphalt	POST COVE Road	0.07	Reconstruction	$42,153	26	10.55	2027	2027		
RD-074-01	PRESCOTT Court	Local	Asphalt	PRESCOTT Court	0.10	Reconstruction	$66,681	28	8.17	2027	2027		
RD-061-01	MILLTOWN Boulevard	Collector	Asphalt	MILLTOWN Boulevard (Riverside Drive to Border)	0.09	Reconstruction	$95,674	30	8.88	2027	2027		
RD-035-02	ELM Street	Local	Asphalt	ELM Street (Union Street to Queen Street West)	0.47	Reconstruction	$267,763	32	7.43	2027	2027		
RD-053-02	MAIN Street	Local	Asphalt	MAIN Street (Union Street to Queen Street West)	0.45	Reconstruction	$333,599	32	6.72	2027	2027		
RD-079-01	QUEEN Street West	Collector	Asphalt	QUEEN Street West (Elm Street to Hawthorne Street)	0.42	Reconstruction	$449,413	32	4.74	2027	2027		
RD-101-01	VICTOR Street	Local	Asphalt	VICTOR Street	0.11	Reconstruction	$29,856	34	6.49	2027	2027		
RD-064-01	NESBITT Avenue	Local	Asphalt	NESBITT Avenue	0.09	Reconstruction	$48,482	29	8.25	2028	2028		
RD-025-01	DEACONS Lane	Local	Asphalt	DEACONS Lane	0.33	Reconstruction	$116,255	30	5.80	2028	2028		
RD-045-03	HAWTHORNE Street	Local	Asphalt	HAWTHORNE Street (Milltown Boulevard to Union Street)	0.31	Reconstruction	$182,443	30	5.68	2028	2028	Bundle with upsizing of watermain to 300 mm to complete redundent link to Milltown Boulevard.	
RD-012-01	BUCHANAN Street	Local	Asphalt	BUCHANAN Street	0.11	Reconstruction	$38,176	32	6.98	2028	2028		
RD-024-01	COVE Street	Local	Asphalt	COVE Street	0.21	Reconstruction	$107,180	32	8.40	2028	2028		
RD-108-01	YOUNG Street	Local	Asphalt	YOUNG Street	0.20	Reconstruction	$144,243	32	4.78	2028	2028		
RD-090-01	SPRING Street	Local	Asphalt	SPRING Street	0.54	Reconstruction	$361,314	33	5.41	2028	2028		
RD-102-01	VICTORIA Street	Local	Asphalt	VICTORIA Street	0.39	Reconstruction	$205,265	35	7.94	2028	2028		
RD-087-01	SCHOODIC Street	Local	Asphalt	SCHOODIC Street	0.27	Reconstruction	$144,357	36	6.06	2028	2028		
RD-048-01	KING Roundabout	Local	Asphalt	KING Roundabout	0.05	Preventative	$6,015	80	3.21	2028	2028		
RD-047-01	HILL Street	Local	Asphalt	HILL Street (Queensway to Civic 42)	0.36	Reconstruction	$197,518	18	7.82	2025	2029	Bundle with Utilities Renewal & Sewer Separation.	Delayed to allow for previously identified utilities & CSS renewal.
RD-047-02	HILL Street	Local	Asphalt	HILL Street (Civic 42 to end)	0.39	Reconstruction	$199,145	23	4.77	2026	2029	Bundle with Utilities Renewal & Sewer Separation.	Delayed to allow for previously identified utilities & CSS renewal.
RD-011-01	BROOK Street	Local	Asphalt	BROOK Street (Main St to Queen St W)	0.22	Reconstruction	$67,093	33	5.93	2029	2029		
RD-019-01	CHOCOLATE Drive	Local	Asphalt	CHOCOLATE Drive	0.16	Reconstruction	$108,268	33	4.93	2029	2029		
RD-020-02	CHURCH Street	Local	Asphalt	CHURCH Street (Civic 140 - 188)	0.86	Reconstruction	$870,531	33	2.26	2029	2029		
RD-066-01	PAGAN Street	Local	Asphalt	PAGAN Street	0.14	Reconstruction	$75,126	33	6.38	2029	2029		
RD-007-01	BIRCHWOOD Court	Local	Asphalt	BIRCHWOOD Court	0.08	Reconstruction	$55,862	36	7.85	2029	2029		

Segment ID	Road Name	Road Class	Road Material	Road Segment Description	Length (Km)	Lifecycle Activity	Estimated Cost (2024)	PCI 2024	IRI 2024	Forecasted Year (DPSS)	Proposed Year (Capital Plan)	Work Notes	Justification for Scheduling Adjustment
RD-022-01	CITIZENS Court	Local	Asphalt	CITIZENS Court	0.10	Reconstruction	$52,414	37	9.73	2029	2029		
RD-026-01	DENULLY Court	Local	Asphalt	DENULLY Court	0.10	Reconstruction	$58,353	37	7.39	2029	2029		
RD-089-01	SINCLAIR Street	Local	Asphalt	SINCLAIR Street	0.16	Reconstruction	$93,668	39	6.37	2029	2029		
RD-033-01	ELIZABETH Street	Local	Asphalt	ELIZABETH Street	0.16	Preventative	$8,199	81	4.12	2029	2029		
RD-051-01	LINDSAY Lane	Local	Asphalt	LINDSAY Lane	0.08	Preventative	$6,189	83	3.15	2029	2029		

References

Yu, J., Chou, E., and Yau, J.-T. (2006). Development of Speed-Related Ride Quality Thresholds Using International Roughness Index. Transportation Research Record, No. 1974, 47-53.