

# INTEGRATED INFRASTRUCTURE CAPITAL PLAN (IICP)

## Prioritized Roadway Capital Plan

Prepared for:

**The City of Castlegar**

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Submitted by:

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**Report for**

Integrated Infrastructure Capital Plan (IICP)  
Prioritized Roadway Capital Plan


**Prepared for**

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## 1.0 INTRODUCTION

Climate change is an important issue for British Columbia. One of the most serious impacts of climate change is the increase of extreme events – warm days and precipitation. Forecasts suggest that the province will experience temperature increases by mid-century, relative to historical average, of between 2 to 4°C. It is anticipated that the number of heavy precipitation events will increase in frequency and magnitude and there will be a shift in the seasonal pattern of occurrence. These changes will result in a longer growing season, and increased likelihood of floods and droughts. This change in climate will likely result in decreased infrastructure service-life. For example, an increased frequency of freeze/thaw events will degrade roads and increased frequency and magnitude of extreme precipitation events will result in floods and potential infrastructure damage due to undersized drainage capacity.

Incorporation of climate change into asset management and master plans has so far been limited, with the vast majority of new infrastructure continuing to be designed using established codes or history-based, asset-specific environmental criteria. The impacts of climate change will increase infrastructure costs as we move forward. The climate-related challenges that communities face are compounded by the maintenance, monitoring and replacement costs of aging infrastructure.

The objective of this report is to provide a risk-based approach and an intuitive process to integrate climate change with asset management into the capital planning process for the City's roadway infrastructure.

### 1.1 Background

In 2010, a PIEVC Engineering Protocol for Climate Change Infrastructure Vulnerability Assessment was completed for the City of Castlegar's stormwater infrastructure. The intent of this PIEVC Protocol was to improve the community's understanding of the context for developing local climate change adaptation strategies. To date, the results of this assessment have not been incorporated in any City plan. The City of Castlegar recently received funding under the Strategic Priorities Fund for the development of an Asset Management and Climate Change Prioritization Framework that incorporates the PIEVC results for the City's linear infrastructure assets.

The desired outcome of the project is to develop a framework that outlines:

1. How to conduct a climate change vulnerability assessment,
2. How to integrate these results with an asset management plan, and
3. Subsequently into a capital plan as a way to prioritize infrastructure replacement with the appropriate capacity and timing.

## 1.2 Roadway Context

The City of Castlegar's roadway network contains approximately 88km of roads valued at approximately \$54 million (not including curb, gutter and sidewalks). The arterial and collector roads make up 26km valued at approximately \$20 million. The City currently invests approximately \$1.0 million annually into the operations, maintenance and renewal of its existing roads.

A road condition assessment was completed by the City in 2012, where a pavement condition rating (PCR) was assigned to each road segment in the City (with 1 being the poorest condition and 10 the best condition). The two graphs below from the assessment summarize the PCR score by metres of road and the required annual investment to renew all the road segments over a 25 year period.

*Figure 1.1 - Meters of Road by Condition*

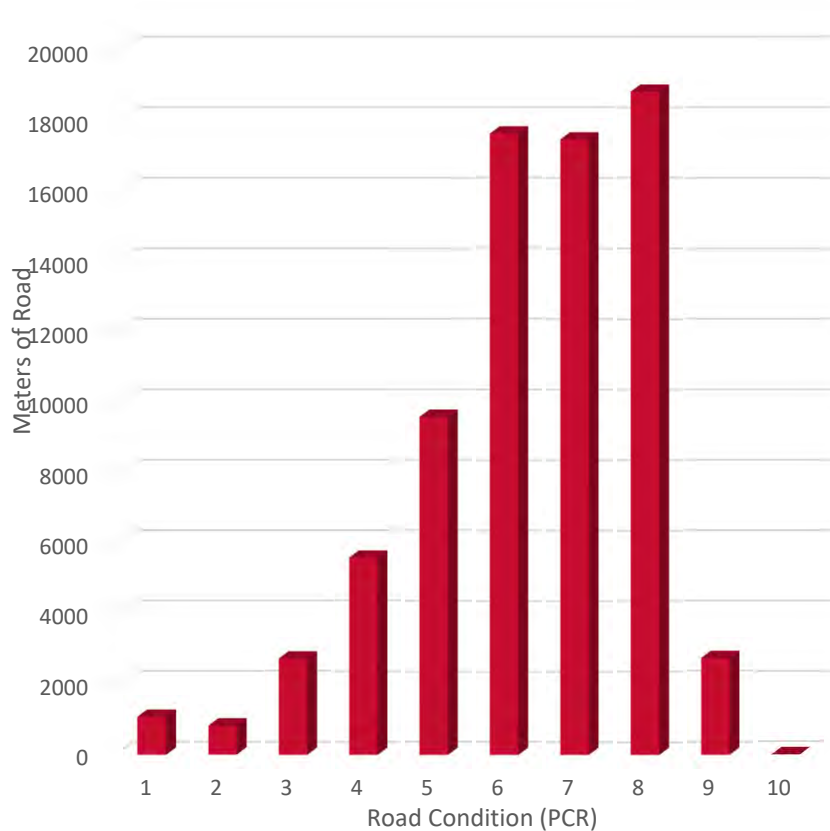
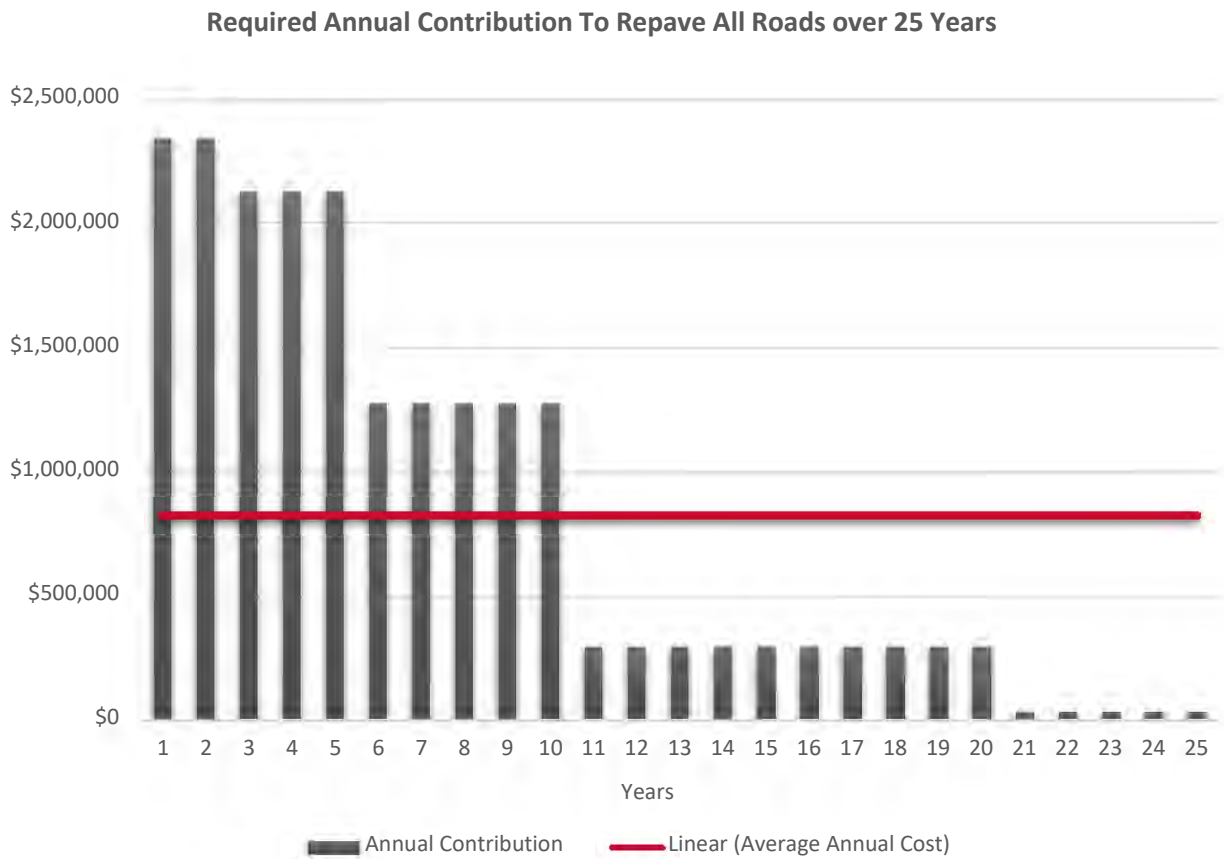


Figure 1.2 - Required Annual Contribution



Based upon the 2012 field evaluations 6% (5.1km) have no substantial defect and require no repairs, 50.7% have moderate defects and should be monitored for future repair; and 4% (3.5km) have severe defects and should be repaired immediately.

The estimated average annual investment from the condition assessment is approximately \$0.82 million; which is lower than the theoretical average annual life cycle investment<sup>1</sup> (AALCI) estimate of a \$1.6 million (replacement cost / service life) for the entire road network. Unfortunately, these reinvestment amounts in the roadway system far exceed the City’s affordability limits so prioritizing investments is needed.

<sup>1</sup>The average annual Life Cycle Investment (AALCI) is defined as the summation of each asset’s annual depreciation which is based on replacement cost and service life. The AALCI is typically used as the ideal target for investment levels when actual condition information does not exist.

In order to prioritize investments and set sustainable levels of service for the roadway network, the City engaged Urban Systems to prioritize roadway projects based on a risk assessment that also considers climate change. The risk assessment is based on likelihood and consequence of failure for the roadway infrastructure. The list of prioritized road asset replacements will be utilized to inform the City's Long-Term infrastructure planning and assist in the development of a multi-year capital plan.

## 2.0 RISK ASSESSMENT AND CLIMATE CHANGE

A risk assessment is being undertaken to prioritize when to renewal/replacement of roadways. Two scenarios for the risk assessment were completed for comparison and consideration:

1. Asset Management
2. Asset Management + Climate Change

Two primary factors are considered within the context of asset management – condition, which is an indication of service life; and capacity, which can trigger replacement or upgrades before service life has been reached. For this study, it has been assumed that the capacity of the roadway network is adequate to serve the community for the next twenty years (i.e the four laning of roadways will not be required). Section 2.1 outlines how condition assessments from the Road Condition Assessment (RCA) will be applied in assigning a risk score to each road segment in the City of Castlegar for the asset management scenario (#1).

For the purposes of asset management and capital planning, only climate changes that impact condition (service life) of an asset have been considered in scenario #2.

While it's true that an asset can be affected by catastrophic events such as floods, landslides, stream bank erosion, and/or forest fires – all potentially impacted by climate change – the potential for such events is typically not a factor in determining when to replace or upgrade a capital roadway asset. The exception is for drainage assets, which are designed protect most other infrastructure from surface runoff, which can be impacted by climate change events.

### 2.1 Asset Management Scenario

This section outlines the methodology on how condition assessments from the Road Condition Assessment (RCA) will be applied in assigning a risk score to each road segment in the City of Castlegar. The methodology is broken down into three parts: an assessment of the likelihood of failure; an assessment of the consequence of failure; and, a risk score. These condition risk scores will be used in conjunction with the risk scores for the water, drainage and sewer infrastructure to inform the multi-utility prioritization process.

## PART 1 – LIKELIHOOD OF FAILURE

The likelihood (probability) of asset failure for roads is based on the actual road condition as identified in the Road Data Collection Report completed by LVM. The roads were assigned a Pavement Condition Rating (PCR) score between 0 and 10. Using ranges from the PCR, we assigned a likelihood of failure score based on **Table 2.2**.

*Table 2.1 – Condition Likelihood of Failure Score*

Likelihood of Failure	Criteria
5	Failed – PCR score is < 1.9
4	Poor – PCR score is >2.0 to <3.9
3	Fair – PCR score is >4.0 to < 5.9
2	Good – PCR score is > 6.0 to < 7.9
1	Excellent – PCR score is > 8.0

A score of 5 indicates that the likelihood of failure is very high and a score of 1 indicates that the likelihood of failure is very low.

The likelihood (probability) of asset failure will be based on the age of asset, where no actual physical condition data exists. A simple 1 to 5 scale will be applied whereby a condition rank of 5 would indicate that the likelihood of failure is very high and a score of 1 would indicate that the probability of failure is very low. Asset age based on approximate year of installation is used as a proxy to indicate the likelihood of failure, as defined in **Table 2.3**.

*Table 2.2 - Condition Ranking*

Likelihood of Failure	Criteria
5	Asset age exceeds its SL* by 50%
4	Asset age exceeds its SL* by 25% - 50%
3	Asset age exceeds its SL* by 0% - 25%
2	75% of its SL* < Asset Age < 100% of its SL*
1	Asset age < 75% of its SL*

\* **SL** = Service Life: Service life is the number of years that an asset is estimated to be able to fulfill its intended function to the community before it needs to be replaced.

## PART 2 – CONSEQUENCE OF FAILURE

For this assignment, the consequence of failure is based on the importance (service level/zoning serviced) of the road segment to the overall function of the roadway network. It is assumed that the higher the road level of service (LOS) classification, the higher the importance to the function of the roadway network. The criteria for identifying the consequence of failure are based on LOS, function and adjacent land-use. A simple 1 to 5 scale is used to classify the consequence of failure. **Table 2.4** summarizes the consequence of failure ranking by road classification.

*Table 2.3 - Consequence of Failure by Road Classification*

Road LOS	Consequence of Failure
Bus Route/ Commercial/ Institutional	5
Industrial	4
Multi-Family Res.	3
Single Family Res.	3
Alleyway/Lane	2
Driveway/Open Space	1

## PART 3 – RISK SCORE

The risk score combines the likelihood of asset failure and the consequence of failure into a single 1 to 25 rating. A risk score of 25 represents the highest risk and a score of 1 the least risk. **Table 2.5** correlates the consequence and the likelihood of failure to the risk score.

*Table 2.4 - Risk Score*

	5	10	15	20	25
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5
	1	2	3	4	5

Likelihood of Failure

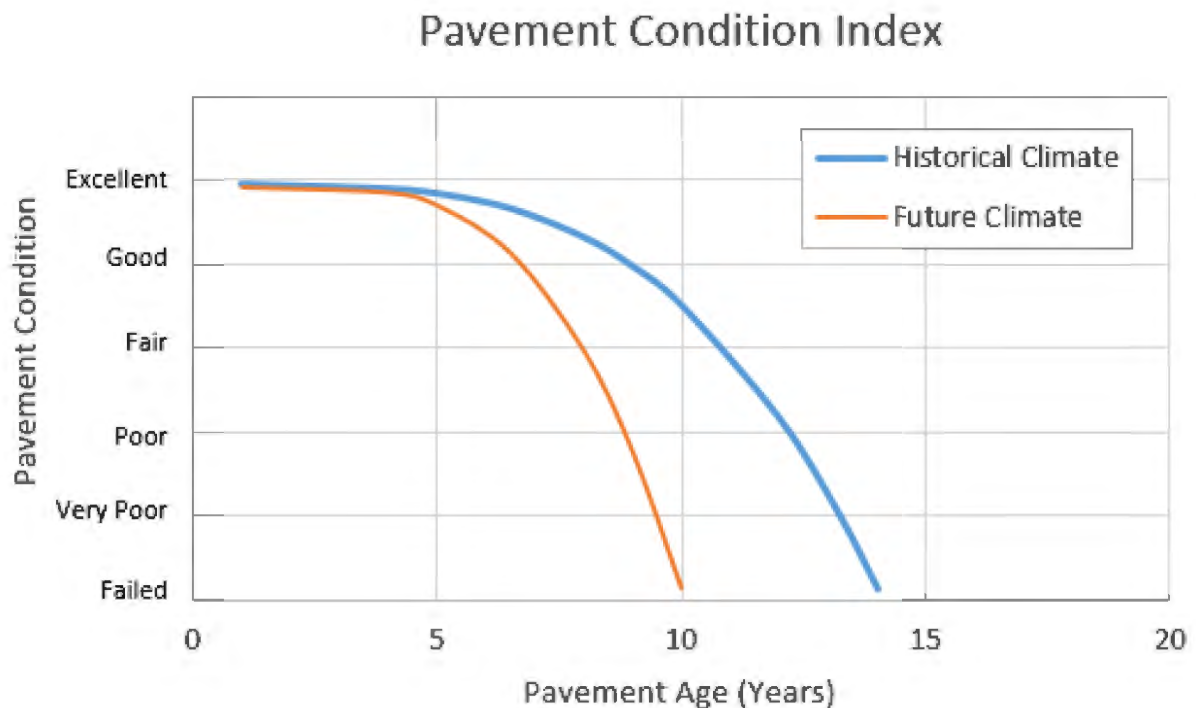
It is important to recognize that a road asset that has a moderate or low risk attached to it may transition to having a higher risk over time due to changes in land use or the deterioration of the pavement surface from weather, drainage concerns or traffic loading. With this in mind, there must be emphasis on keeping the condition assessment and risk assessment a dynamic and living process.

## 2.2 Climate Change Scenario

For this project, the primary focus for roads is service life (condition). Road service life is typically estimated by assessing the asphalt pavement condition, which is a function of road base and pavement performance. The following responses to climate variables have been identified as the most critical with respect to road longevity (service life).

- Asphalt rutting and cracking due to reduced road base strength caused by increased soil moisture content. Too much moisture can reduce road base strength and, during winter, often results in frost heaves. These conditions result in a variety of pavement damage.
- Asphalt cracks due to freeze/thaw cycles and large temperature fluctuations.
- Asphalt rutting due to reduced asphalt strength caused by extended periods of high temperatures, which increase vulnerability to traffic loads.

The following figure shows pavement condition as a function of age. It reflects the above factors based on both historical and potential future climate. Note that in this example, future climate is likely to accelerate pavement deterioration, shortening its service life. Also note that this figure is illustrative only – actual service life will vary from road segment to road segment.



Since we are most interested in the climate variables that impact pavement service life, and since service life is primarily affected by soil moisture and temperature, the following climate variables have been identified as appropriate for the climate change risk assessment.

<b><i>Climate Variable</i></b>	<b><i>Rational</i></b>
<b><i>Precipitation – Average Annual</i></b>	Precipitation contributes to the overall volume of water in the soil matrix. This can reduce road base strength and increase potential for frost heaves
<b><i>Freeze/Thaw Cycles (Inferred from seasonal temperatures)</i></b>	More or less freeze/thaw cycles per year will decrease or increase average service life respectively.
<b><i>Annual Temperature Range (Function of Annual max and min temperatures)</i></b>	Most pavements are designed to function within a specified temperature range. Exceeding the range limits is not recommended and can reduce service life through excessive contraction / expansion.
<b><i>Extreme High Temperature</i></b>	Prolonged extreme high temperatures ( $T > xx\text{ }^{\circ}\text{C}$ ) can soften asphalt, reducing strength and making it more vulnerable to damage from traffic loads

For this project, the impacts of potential climate change on pavement service life have been assessed and incorporated into the risk assessment (scenario #1) to create scenario #2. The methodology is based on the following assumptions:

- The soils within Castlegar have essentially the same drainage characteristics, so any change to climate variables that contributes to soil moisture will impact all roads in the same way.
- Asphalt thickness and composition are the same for all roads within a classification or LOS.
- All climate variables selected for the climate change risk assessment will impact each road in the same way. For example, the impacts of extremely high temperatures will be the same for each paved road.

A typical climate focused risk assessment matrix considers the impacts of individual climate variables on a set of selected infrastructure elements. In this case, we have only one type of infrastructure to assess – asphalt pavement, and as stated in the assumptions listed above, any response to climate change is anticipated to be the same for each classification of road within Castlegar. Therefore, a risk assessment matrix will not be required.

Since the impacts of any changes to the climate variables selected above are cumulative, the focus of the climate change risk assessment will be to estimate the combined impacts on pavement service life. Therefore, the assessment methodology for roads is as follows:

1. Obtain projected climate change for each selected climate variable. Given the typical service life of 10 to 15 years, the time horizon would be the 2020's (2010-2039).

2. Determine whether the change for each climate variable is likely to increase or decrease pavement service life.
3. Consider the combined impacts of the climate changes, and assign a service life reduction factor for each road class. Consider the mechanisms that cause the conditions used to assess each road condition (cracking, spalling, rutting, etc.) and use engineering judgement to assess the overall impact of the projected climate changes on service life.

**Appendix B** contains a technical memo which describes this methodology in more detail.

### 3.0 RESULTS AND CAPITAL PRIORITIZATION

The risk analysis described above was applied to each roadway asset in the City's network (not including curb, gutter and sidewalks). The result was a database of over 500 road segment assets with their own classification, characteristics, function, service level, replacement cost, operation and maintenance cost including over 135 assets with a combined risk score of greater than 14.

In order to prioritize the inventory of risks into a strategic list of assets, in sequence of importance, road assets have been organized into three priority categories based on the physical and functional characteristics of the road corridor. This categorization was completed to yield a hierarchy of upgrades. This hierarchy relates directly to levels of service.

The prioritization categories are defined as:

**Priority 1 (High)** – Roads that are either a bus route or serve commercial and institutional areas.

**Priority 2 (Medium)** - Roads that serve Industrial areas.

**Priority 3 (Low)** – Roads that primarily serve residential areas and open spaces or act as laneways.

The risk assessment was first completed for scenario #1 (asset management). Following completion of the analysis, climate changes that impact condition (service life) of an asset have been considered in scenario #2.

#### 3.1 Scenario #1 – Asset Management

The timing of the renewal or replacement for the roadway within each category was estimated based on age and condition and should be confirmed in the field. The roads as part of the capital prioritization process are organized by the combined risk score, modelled timing, and estimated remaining life which is then sorted within each priority category.

The following table summarizes the pavement surface replacement value by road priority and timing based on remaining life (condition) for the asset management scenario. It also includes a financial indicator which estimates the theoretical average annual investment

2 that should be ideally invested into the assets to maintain current service levels. The AALCI (\$1,652,350) is the ideal (maximum) funding level for sustaining existing infrastructure over the life cycle of the assets and should be a long-term target for communities. When planned for appropriately, the AALCI can be used in ensuring long term revenue stability, preventing unnecessary risk, and enabling a community to apply one-time funding to support new asset/capital needs as opposed to addressing emergency situations.

*Table 3.1 - Cost Summary*

Priority and Timing	Pavement Surface Replacement Value	Average Annual Life Cycle Investment (AALCI)
<b>0-5 Years</b>		
Priority 1	\$1,369,000*	\$38,260
Priority 2	\$289,000	\$9,425
Priority 3	\$5,409,000	\$155,070
Sub-Total	\$7,067,000	\$202,755
<b>5-10 Years</b>		
Priority 1	\$8,014,000	\$304,690
Priority 2	\$6,834,000	\$259,075
Priority 3	\$9,627,000	\$269,590
Sub-Total	\$24,475,000	\$833,355
<b>10-20 Years</b>		
Priority 1	\$4,257,000	\$130,350
Priority 2	\$3,657,000	\$161,030
Priority 3	\$10,886,000	\$324,860
Sub-Total	\$18,800,000	\$616,240
<b>Grand Total</b>	<b>\$50,342,000</b>	<b>\$1,652,350</b>

\*Does not include costs for planned upgrades to Columbia Ave

<sup>22</sup> The average annual Life Cycle Investment (AALCI) is defined as the summation of each asset's annual depreciation which is based on replacement cost and service life.

Selecting the preferred level of service and funding level to provide often comes down to community preferences and affordability. Based on the existing funding level amount of \$500,000 annually, the following asset replacement investment scenarios are suggested for scenario #1:

**Priority 1** – to be funded and implemented as quickly as possible

**Priority 2** – aim to gradually increase revenues over the 20-year time frame so that this level of service is achieved by 2036

**Priority 3** – replacement of assets not to be funded unless synergies with other projects and cost savings can be realized e.g. neighboring utilities are planned or upgrades to drainage infrastructure is needed to improve system capacity.

**Note:** The total investment level into replacement of high priority roads over the 20-year horizon is \$13,640,000 (avg. \$682,000/yr) for scenario #1.

### RECOMMENDED WORKS

A list of potential upgrades, based on the condition assessment, under each category is submitted along with a webmap (live online for one year) and geodatabase which includes all the results of the modelling. The geodatabase is in electronic form to allow GIS personnel to manipulate and present the information in a variety of ways, depending on the needs of City staff. **Appendix A** contains a map to illustrate the high priority projects.

## 3.2 Integrating Climate Change – Scenario #2

In scenario #1, the timing of the replacement for the pavement surface within each category was estimated primarily based on condition. Asphalt pavement condition is a function of road base and pavement performance. These two functions are directly impacted by moisture and temperature. In scenario #2, key moisture and temperature climate parameters that affect service life were analyzed.

The key climate change parameters that cumulatively impact service life over time are:

- Increased average annual precipitation
- Slightly decreased number of freeze/thaw cycles
- Slightly larger annual temperature range
- Increased extreme high temperatures

Based on engineering judgement (and previous work completed with the Maintenance Branch at the MOTI) a service life reduction factor of 15% was assigned for each road segment and the analysis for scenario #1 was re-run.

The results summarized in Table 5 for scenario #1 did not change the replacement values or the timing in a significant way. However, the AALCI did increase by \$500,000 to \$2.1M/year since it is primarily a function of asset service life (shorter the service life, the higher the AALCI). This result indicates that climate change may result in long term changes to the performance of the

roadway and in order to maintain current service levels, it is recommended that increased investment will be required into the maintenance roadways.

### ROADWAY MAINTENANCE

The City is responsible for maintaining its roadway network. This consists of work that is performed to care for and maintain the roads and associated facilities so that the roads reach their designed service lives, improve safety and retain their original intended use and function. Examples of road summer and winter maintenance include:

- Pavement patching, crack sealing and pot hole repair;
- Ditch and shoulder grading;
- culvert and catchbasin cleaning;
- Controlling vegetation so it does not block signs or obstruct intersections/roadways;
- Sidewalk repair;
- Line painting; and
- Snow removal/plowing.

The City currently has an annual maintenance budget of approximately \$0.45 million for its roadways.

Using the Maintenance Accountability Process (MAP) developed by the Washington State Department of Transportation, each roadway category was assigned a service level and corresponding maintenance cost based on the service level for both winter and summer conditions.

**Table 6** below outlines the recommended maintenance budget allocations.

*Table 3.2 - Maintenance Budget Allocations*

Level of Service	Winter	Summer	Unit
A	\$7,710	\$14,320	km
B	\$6,480	\$12,030	km
C	\$3,080	\$5,730	km
D	\$2,460	\$4,590	km
F	\$620	\$1,140	km

The recommended budget scenario results in an annual maintenance budget of approximately \$1.1 million for all roads in Castlegar.

Ideally the maintenance budget set should be adequate to optimize asset service lives and be increased to \$1.1 million/year. Reduced or inadequate maintenance budget levels reduce service life of roadways and increase the costs and frequency of more expensive renewal. Potentially, inadequate maintenance budgets can permit the cumulative effects of climate change further reduce service life of roadways. Given the gap between current and recommended maintenance

budgets, it is recommended that the City annually increase its maintenance budget over the next few years to reach the preferred level.

### MITIGATING THE CUMULATIVE IMPACT OF CLIMATE CHANGE

Based on the research and analysis, there are also several steps that Castlegar can take to mitigate the cumulative effect of climate change on reducing roadway service life.

#### 3.2.1 *Revise Design and Construction Standards*

One of the important factors for maximizing pavement service life and minimizing pavement maintenance cost is the selection of a gravel base with sufficient material resistance to damage under traffic loads and to environmental conditions.

### ENVIRONMENTAL CONDITIONS

Frost action caused by moisture susceptibility is a major catalyst for pavement damage, which plays a key role in the performance of the pavement. The two basic forms of frost action (frost heave and thawing) both require water. Water is sourced in two categories:

1. **Surface water:** enters the pavement primarily by infiltration through surface cracks and joints, and through adjacent unpaved surfaces, during periods of rain and melting snow and ice.
2. **Subsurface water:** can enter the road structure from three primary sources:
  - High groundwater table
  - Moisture held in soil voids or drawn upward by capillary forces
  - Moisture that moves laterally under the pavement from an external source

Mitigating the effects of frost action involves ensuring the roadway pavement design considers both surface water and groundwater impacts on the base and subgrade.

- Ensure the surface has a 2-3% crown
- Removing and replacing existing subgrade and granular base with non-frost-susceptible soils
- Design the pavement structure based on reduced subgrade support
- Providing a capillary break

### TRAFFIC LOADING

Damage from traffic loading is also a major catalyst for reducing the service life and deteriorating the pavement condition. Subgrade and base gravels that are frost susceptible can result in significant pavement weakening with traffic loading. The City should consider using load restrictions on existing arterial, bus routes, collector and industrial roadways as well as increasing the pavement structure in these corridors with the inclusion of geotextiles or thicker gravels.

### 3.2.2 Increase and Focus Maintenance Activities

As mentioned above, surface water can lead to significant damage to the pavement structure if not addressed properly. Surface water can enter the pavement through infiltration through surface cracks and joints and through adjacent unpaved surfaces. Surface water which is permitted to pond on the pavement surface, shoulder or adjacent ditch line can significantly increase the amount of water infiltration. In order to mitigate the infiltration of surface water, it is recommended that the City increase the following maintenance activities to extend the service life of its roadway assets which will minimize/defer expensive replacement:

- Pavement patching, crack sealing and pot hole repair
- Ditch and shoulder grading to ensure positive flow
- Culvert and catch-basin cleaning

## 4.0 IMPLEMENTATION

The roadways identified, through the risk assessment process, for renewal/replacement in this plan were prioritized based on their condition and function with a consideration of climate change. The intent of the Prioritized Roadway Capital Plan is to organize the costs and expenditures over 20 years.

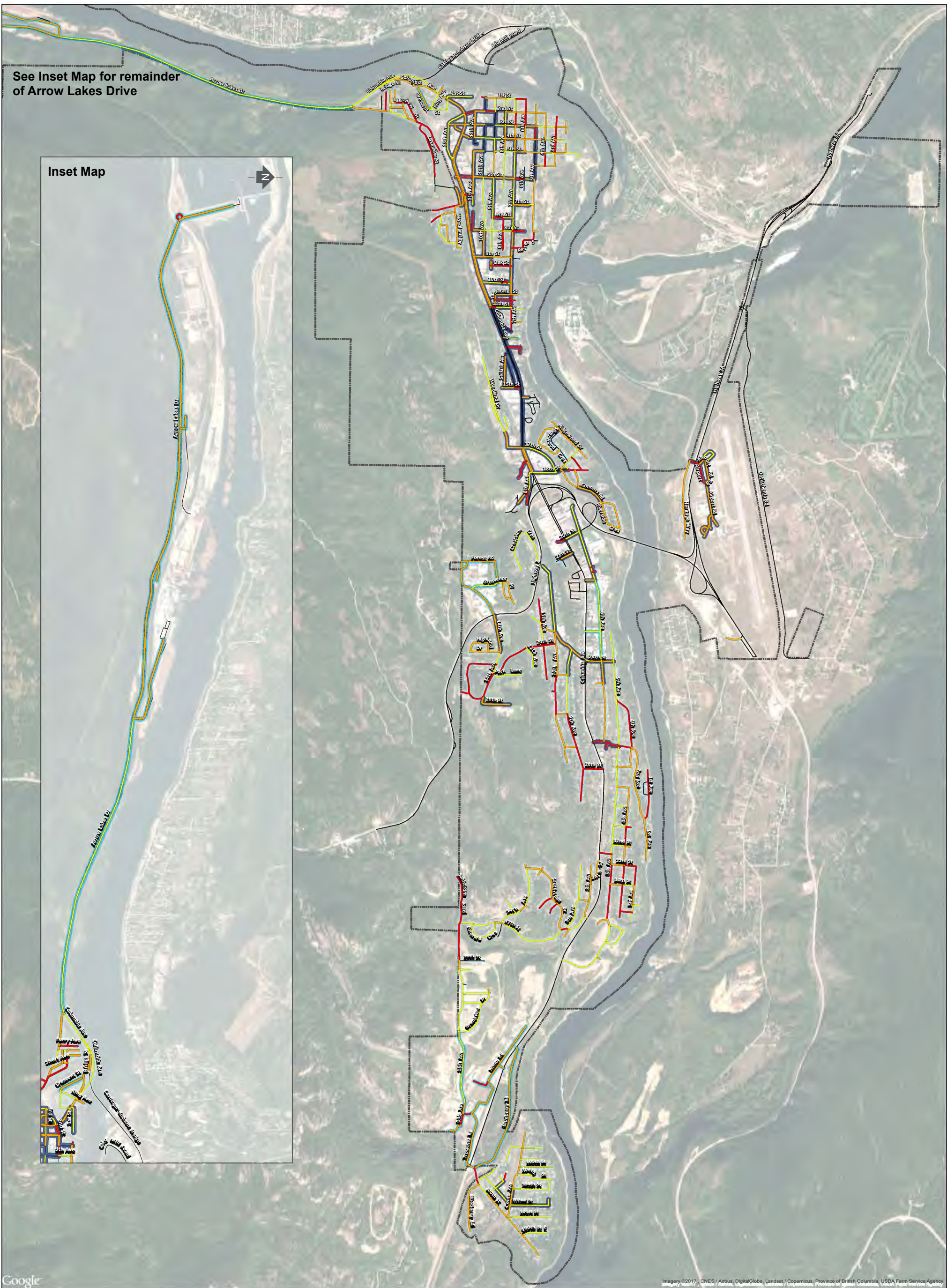
The refinement of timing, phasing and affordability of projects will be completed as part of the financial planning and integrated capital planning process for the IICP.

The City should also consider the following recommendations:

1. Increase funding to its maintenance program for its roads. Preventative maintenance investments are the most cost-effective method of optimizing roadway road surface life cycles, and minimizing and deferring expensive resurfacing and reconstruction.
2. The data used in this analysis is from 2012. In order to improve the data and information utilized for capital planning, the City should consider regularly updating its road condition assessment data. This can be done by developing a pavement management plan that uses up to date condition data and models the best treatment options for each segment of road.
3. It is recommended that the City undertake geotechnical investigations to confirm the preliminary findings of the RCA before undertaking the design of its capital rehabilitation program.
4. Update its roadway design criteria in the Subdivision Servicing Bylaw with a gravel base with sufficient material resistance to damage under traffic loads and to environmental conditions (changing climate).

Appendix A

# *Prioritized Road Upgrades*




**CASTLEGAR**

City of Castlegar  
Integrated Infrastructure  
Capital Plan (IICP)

**Roads Risk Assessment Results**

**Legend**

**Roads Renewal Timing**

- 0-5 Years
- 5-10 Years
- 10-20 Years

**Priority Level**

- 1
- 2
- 3

City Boundary

Note: This figure is prepared to be printed at 22x34 inches (D Size).

0 125 250 500 750 1,000  
Metres

**Coordinate System:**  
NAD 1983 UTM Zone 11N

**Scale:**  
1:15,000

**Data Sources:**  
Data provided by -  
City of Castlegar  
Urban Systems Ltd

Project #: 0841.0099.01  
Author: BP  
Checked: SS  
Status: **- DRAFT -**  
Revision: A  
Date: 2017 / 10 / 6

**URBAN systems**

**FIGURE A**

The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.