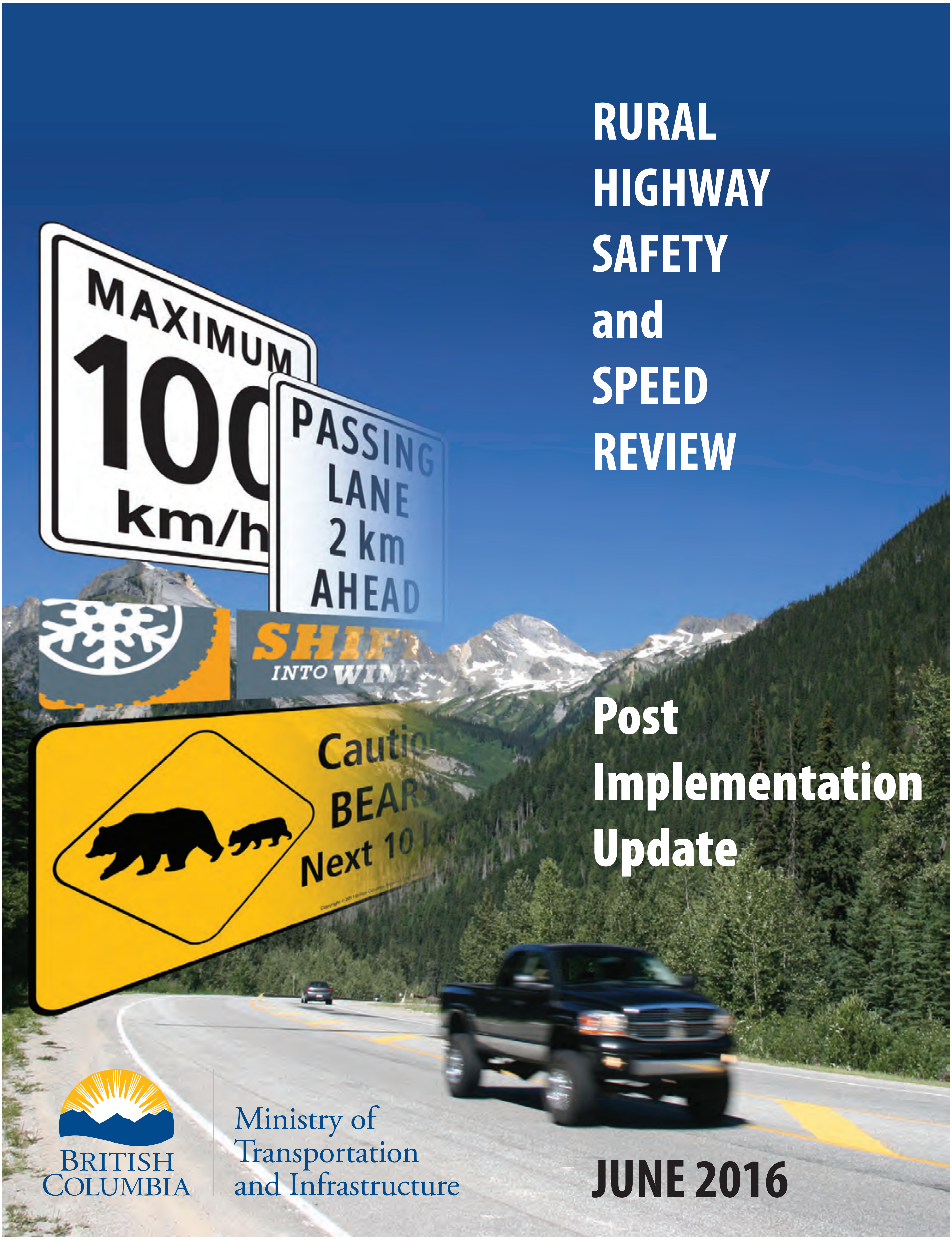

RURAL HIGHWAY SAFETY and SPEED REVIEW

Post Implementation Update

BRITISH COLUMBIA
Ministry of Transportation and Infrastructure

JUNE 2016

FOREWORD

In October 2013 the Ministry of Transportation and Infrastructure initiated a broad review of safety and speed on the province's rural highways. This review included both a technical component and the collection and consideration of public input. The Ministry's Professional Engineers specializing in traffic operations and highway safety led the technical portion of the review. The technical review consisting of four areas:

1. Setting of appropriate speed limits
2. Requirements for winter tires
3. Slower moving vehicles
4. Wildlife hazards

In July 2014, the Ministry of Transportation and Infrastructure announced actions to improve safety on B.C.'s rural highways as a result of the province wide Rural Highway Safety and Speed Review.

This report provides progress to-date on the actions undertaken since July 2014 as well as early indications of post implementation performance.

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TABLE OF CONTENTS

Executive Summary

In July 2014, the Ministry of Transportation and Infrastructure released the outcome of the Rural Highway Speed and Safety Review. Public input was collected alongside a detailed technical analysis to develop recommendations of the project. The four key areas of the review were:

1. Rural highway speed limits
2. Winter tire requirements and use
3. Slower moving vehicles
4. Wildlife hazards

This report provides progress to-date on the recommendations of the July 2014 report as well as early indications of post implementation performance.

Rural Highway Speed Limits

Based on a review by professional engineers, government increased the speed limit on about 1,300 km of rural provincial highway after an engineering review and public consultation on over 9,100 km of rural provincial highway. The majority of these increases are limited to an additional 10 km/h, which matched the speed limit with the existing travelled speed and improve speed limit consistency along corridors. This engineering assessment was based on speed zoning practices recommended by the Institute of Transportation Engineers and adopted by road authorities throughout North America.

Throughout the fall of 2013, over 300 speed surveys were conducted on rural numbered highways across the province. From these surveys, the 85th percentile speeds were calculated. The 85th percentile speeds, safety statistics, the geometric design of the highway along with public input, were the components of decisions to change speed limits. The speed limit increases were implemented in the summer/fall of 2014. Supporting the speed limit changes, over 1000 curve advisory signs were updated, passing zones on 2 lane highways were updated and additionally crash attenuators and advance warning flashers were upgraded as necessary.

Post-implementation speed surveys were conducted. Comparison of before and after speed surveys gathered indicated that, as expected, overall changes to the 85th percentile speed were 2 km/h. Some highways saw a decrease or no change in speed, while some saw an increase. For example, Highway 99 Horseshoe Bay to Squamish saw an increase of 2 km/h, Highway 5 Hope to Kamloops saw no change and Highway 3 Sunday Summit to Whipsaw Creek had a decrease of 3 km/h.

Severe collision rates over the last ten years were analyzed on each changed segment. Collision rates are an analysis technique which normalizes the number of collisions with the traffic volume. The collision rate accounts for the number of kilometres travelled on a segment over a time period. This permits an effective side-by-side comparison between highway segments. Collision rates have the unit collisions per million vehicle kilometres travelled (C/MVK).

Reviewing the changes in collision rates over multiple years, it is clear that there can be large fluctuations per highway segment. When the changes in collision rates were shown beside changes in 85th percentile speed it was found that over half the changed segments (19 out of 33) saw a decrease or no change in collision rate after the change in the posted speed limit. Notably, Highway 5, the Coquihalla, where the speed limit was raised to 120 km/h had the lowest rate in 10 years of 0.16 collisions per million vehicle kilometres travelled. 7 segments saw an increase in collision rate, despite also having a decrease in 85th percentile speed. Only 7 of the 33 segments had an increase in 85th percentile speed and an increase in collision rate.

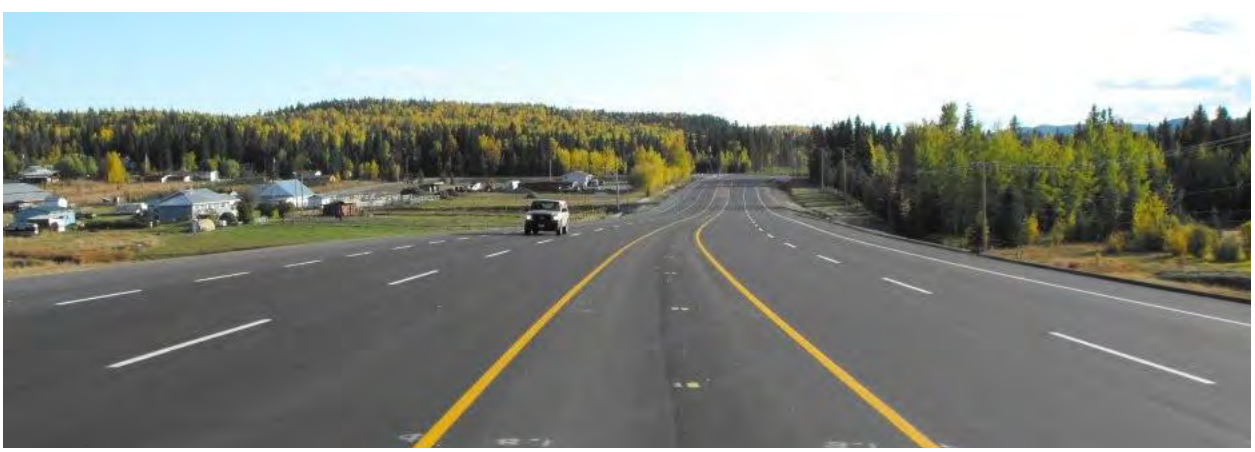


Table 1 – Comparison of changed segments 85th Percentile and Collision Rate

Highway Description	85th Percentile Speed Change	Serious Collision Rate Change
Hwy 1, Victoria to Nanaimo	↓	↑
Hwy 1, Abbotsford to Hope	↑	↑
Hwy 1, Hope to Cache Creek		
Hope to Boston Bar	↑	↑
Hope to Jackass Mountain	↓	↑
Hwy 1, Cache Creek to Kamloops	↑	↓
Hwy 1, Kamloops to Salmon Arm	↑	↑
Hwy 1, Salmon Arm to Alberta Border		
Salmon Arm to Revelstoke	↓	↓
Revelstoke to Golden	↑	↓
Hwy 3, Hope to Princeton		
Hope to Coquihalla	↑	↑
Sunshine Valley to Manning Park East Boundary	↑	↓
Sunday Summit to Princeton	↓	↓
Hwy 5, Coquihalla	↓	↓
Hwy 5, Kamloops to Tête Jaune Cache	↑	↓
Hwy 5A, Princeton to Merritt	↑	↑
Hwy 6, Nelson to Nakusp		
New Denver to Hills	↓	↓
Summit Lake to Nakusp	↓	↓
Hwy 7, Mission to Hope	↓	↑
Hwy 19, Nanaimo to Campbell River	↑	↓
Hwy 19, Campbell River to Port Hardy		
Campbell River to Bloedel	↑	↓
Bloedel to Sayward	↑	↑
Port McNeill to Port Hardy	↑	↓
Hwy 33, Rock Creek to Kelowna		
Black Mountain to McCulloch Road	↑	↑
Rock Creek to Westbridge	↓	↓
Hwy 97, Cache Creek to Williams Lake	↑	↓
Hwy 97, Vernon to Kamloops	↑	↓
Hwy 97A, Vernon to Sicamous		
Armstrong to Enderby	↓	↑
Grindrod to Sicamous	↓	↓
Hwy 97C, Okanagan Connector		
Merritt to Aspen Grove	↓	↑
Aspen Grove to Peachland	↓	↑
Hwy 99, Sea-to-Sky Highway		
Horseshoe Bay to Squamish	↑	↓
Squamish to Whistler	↑	↓
Hwy 99, Whistler to Cache Creek		
Whistler to Pemberton	↓	↑
Lillooet to Cache Creek	↑	↓

When police attend a collision site they gather data on the collision type as well as the factors that contributed to the crash. The top 3 contributing factors for serious collisions for all highways with speed limit changes and all numbered highways in British Columbia continue to be driver inattentiveness, road conditions and driving too fast for conditions. These three factors make up 54% of serious collisions on highways where speed limits have been changed.

Driver inattentiveness increased 6% on highways with changed speed limits. Government has announced stiffer penalties for distracted driving, effective June 1, 2016. Significantly higher fines, more penalty points and earlier interventions for repeat offenders will reinvigorate the Province's push to eliminate distracted driving.

Road conditions and driving too fast for conditions remain top contributing factors. It is expected that the 3 Variable Speed Limit Systems should reduce the instances of driving too fast for conditions.

An independent analysis of preliminary safety data conducted by UBC estimated the change of collision occurrence where speed limits were increased in relation to comparison sites. A full-Bayes prediction modelling technique looking at 28 months pre-implementation data and 12 month post implementation was used. UBC noted that safety results of the individual highway segments were not statistically significant due to the relatively short data period. When all the segments were combined the model showed an 11% increase on changed segments when compared to similar sites. Furthermore, the model predicts that any initial increase in severe collisions may be reduced over time and therefore, the UBC study recommends repeating the analysis when more data is available for a longer post-treatment period with more accurate results. Typically, 3 years before and 3 years after data is used for analysis.

Variable Speed Limits

Variable speed limit systems have been installed on Highway 5 the Coquihalla, through Snowshed Hill, along Highway 99, between Squamish and Whistler, and on Highway 1, from Sicamous to Revelstoke. These pilot systems will improve safety in adverse weather by lowering the speed limit based on conditions. The systems were activated in June 2016.

Winter Tire Requirements and Use

Winter tire and chain legislation as well as signage in the field have been updated. Signs clearly show the time of year when winter tires are required. The definition of winter tires have been clarified as those with either the mud and snow or mountain/snowflake symbol as well as a minimum tread depth of 3.5 mm. The definition of chains has been broadened to include other types of alternative traction devices which will allow drivers more flexibility to choose the appropriate device for their vehicle type.

Slow Moving Vehicles

Keep right legislation was updated to clarify when drivers can use the left lane. Signs are also being piloted on Highway 4 requiring slower drivers who are impeding 5 others to use pullouts. These initiatives will help reduce driver frustration and promote safe passing behaviour.

Wildlife Hazards

The province is piloting two wildlife detection systems for Highway 3 near Sparwood and Elko. These systems will detect wildlife near the highway and alert drivers. Wildlife detection systems were activated in April 2016. To further reduce wildlife collisions on B.C. highways, new wildlife gateway signs are being installed on longer highway segments where there is an increased risk of encountering large wildlife.

1.0 Introduction

In the fall of 2013, the Ministry of Transportation and Infrastructure (MoTI) initiated a Rural Highway Safety and Speed Review. The overarching purpose of this review is highway safety and ensuring that speed limits on rural highways are set appropriately.

The Ministry of Transportation and Infrastructure's last broad formal speed review was completed in 2003.

The 2003 report identified areas where speed limits could be raised, along with some areas where speed limits should be lowered. Since 2003, the Ministry has used the principles outlined in that report to adjust speed limits around the province, including some increases on major highways such as Highway 1. The latest review built on the work done during the 2003 review.

In the 10 years prior to the review, $14 billion has been invested in upgrades to most of the major highway corridors in B.C., including Highway 1, Highway 97 along the Cariboo Connector, and through the Okanagan Corridor Valley.

The following are just some of the completed safety improvements:

- 180 kilometres of new four- and six-lane sections,
- 30 new passing lanes,
- 14 new interchanges,
- 16 pullouts for slower-moving vehicles, and
- over 6,500 kilometres of rumble strips.

During this period of substantial highway investment there have also been improvements in other areas of highway safety, for example:

- driver licensing/training/education,
- vehicle technology,
- enforcement of high risk activities,
  - distracted driving,
  - impaired driving,
  - aggressive driving.

In consideration of these significant changes, it was decided to review aspects of safety along longer stretches of provincial rural highways between communities in the following areas:

- **Speed Limits:** Reviewing speed limits will help ensure that everyone travelling B.C.'s highways can do so as safely and efficiently as possible.
- **Winter Tires:** Winter tires have undergone significant technological advancements in recent years, and it is time to look at the winter tire definition and the regulations around their use.
- **Slower-Moving Vehicles:** Slower-moving vehicles, such as recreational vehicles, vehicles towing others or slow vehicles in the left-hand (passing) lane, reduce the efficiency of the highway system and can cause driver frustration.
- **Wildlife Hazards:** Wildlife on the highway can pose a serious hazard to motorists in many areas of B.C., either when drivers try to avoid animals or if they strike animals.

For each of these components, the Ministry conducted a technical analysis conducted by the Ministry's engineers in parallel with public consultation to gather feedback and ideas from across the province.

In July 2014, the Ministry released the Rural Highway Safety and Speed Review report. The report outlined a series of actions to improve safety and mobility on rural highways.

This Post-Implementation report provides details on progress to-date of the actions taken well as early indications of safety and mobility performance.

2.0 Rural Highway Speed Limits

For the Speed Limit portion of the review, the ministry assessed approximately 9,100 kilometres of rural provincial highway.

In reviewing speed limits, Ministry professional engineers carried out an evaluation using the Institute of Transportation Engineers (ITE) document, entitled "Speed Zone Guidelines– A Proposed Recommended Practice".

This evaluation practice recommends that speed limits be set on the basis of an engineering study that includes an analysis of the speed distribution of free flowing vehicles to determine the 85th percentile speed. In order to determine speed limit recommendations this data was used in combination with the following:

- safety history
- geometry characteristics of the highway
- consistency of speed limits
- land use

As a result of that review the ministry took the following actions:

- Adjusted the speed limit on 33 sections of highway covering 1,300 kilometres (approximately 15% of the length of highway reviewed).
- Introduced a new maximum speed limit of 120 km/h on certain sections of divided multi-lane highways

The speed limit changes on rural highway occurred between July and November of 2014. The cumulative totals of the changed highways are:

- 187 km of 90 km/h speed limits
- 596 km of 100 km/h speed limits
- 140 km of 110 km/h speed limits
- 392 km of 120 km/h speed limits

Implementing speed limit changes included additional work beyond installing new regulatory signs.

- 1000 curve speed advisory signs were reviewed and updated
- Crash attenuators were upgraded
- Passing zones on two lane highways were adjusted to correspond to the new speed limits
- Advanced warning flashers at signalized intersections were relocated where required

2.1 Speed Surveys

250 speed surveys have been collected since the speed limit changes. The speed surveys provide a clear picture of 85th percentile speeds on rural highways.

Figure 1 – 120 km/h sign on Highway 5

2.1.1 85th Percentile Speed

The speed surveys measured free flow speeds on rural numbered routes. From the speed survey results 85th percentile speeds were calculated. The 85th percentile speed represents the speed at or below which 85% of vehicles travel. It is a key factor used in engineering studies for setting speed limits in North America.

The 85th percentile speed is a statistical representation of the speed at which the majority of reasonable prudent drivers chooses to travel along a highway. Appropriate speed limits align the posted speed limits with the safe speed that the majority of drivers choose under ideal conditions.

Differences in the 85th percentile speeds before and after implementation were compared on each highway segment to determine whether there were changes in operating speed and the speed differential. Operating speed results on key changed highway segments are shown in Table 2.

Table 2 – Speed Survey Results on Key Changed Highway Segments

Highway Segment	Current Speed Limit	85th% Speed (km/h)	
		Before	After (Summer 2015)
Hwy 1: Abbotsford to Hope	110	116	119
Hwy 1: Kamloops to Salmon Arm	100	105	111
Hwy 1: Revelstoke to Golden	100	103	109
Hwy 3: Sunday Summit to Whipsaw Creek	90	103	100
Hwy 5: Hope to Kamloops	120	127	127
Hwy 19: Parksville to Campbell River	120	121	125
Hwy 97C: Aspen Grove to Peachland	120	126	126
Hwy 99: Horseshoe Bay to Squamish	90	102	104
Hwy 99: Squamish to Whistler	100	105	106

Summer 2015 speed surveys were compared with results from 2013. The speed surveys were taken in the same locations and under ideal conditions (bare, dry and good visibility). It was found that the 85th percentile changes varied by highway. The changes ranged from -3 km/h to +9 km/h with an average 2 km/h increase in the 85th percentile speed. Changes in driver speeds within 3 km/h are typical to speed limit changes and are considered part of normal variation. A summary of the speed survey results is included in Appendix D.

The Ministry sought to confirm if the speed limit changes on the changed highway segments would have an impact on the operating speed of other highways in the province. Speed survey data was collected for highways adjacent to changed highway segments as well as several highways in the northern part of the province where the speed limit did not change. A 2 km/h increase in the 85th percentile speed was seen on these unchanged corridors.

Table 3 – Speed Survey Results on Adjacent Unchanged Highway Segments

Highway Segment	Current Speed Limit	85th% Speed (km/h)	
		2013	2015
Highway 1			
Cache Creek to Kamloops (Holloway Drive)	100	111	111
Kamloops to Salmon Arm (Hilltop to Tappen)	100	108	115
Highway 3			
Hope to Princeton (West of Princeton)	100	114	118
Highway 5			
Kamloops to Tete Jaune Cache (Kamloops to Heffley)	100	113	117
Highway 7			
Mission to Hope (Agassiz to Hope)	100	107	108
Highway 97			
Cache Creek to Williams Lake (70 Mile)	100	113	112
Highway 97A			
Vernon to Sicamous (Swan Lake to Smith)	100	114	114
Highway 99			
Whistler to Cache Creek (Pavilion Lake)	80	95	97

Table 4 – Speed Survey Results on Northern Highways with Unchanged Speed Limits

Highway Segment	Current Speed Limit	85th% Speed (km/h)	
		2013	2015
Highway 16			
Prince George to Vanderhoof	100	104	110
Vanderhoof to Burns Lake	100	108	109
Terrace to Prince Rupert	90	96	98
McBride to Alberta Border	100	112	110
Highway 5			
Valemount to Blue River	100	111	111
Highway 37			
Kitimat to Terrace	100	109	110

This illustrates that adjusting speed limits has had a minimal effect on most rural highway operating speeds in other parts of the province, although some sections did see changes up to 6 km/h.

2.1.2 Differential Speed

Speed choice by drivers is based on a variety of factors including: highway characteristics, weather and environment, traffic characteristics, vehicle characteristics, and the purpose of travel. This results in a range of operating speeds on a highway. The difference in the 15th percentile and 85th percentile speed is called the differential speed. As differential speed decreases, a more consistent traffic flow is developed which improves driver certainty and roadway safety. Speed limits which are set relative to the expectations of drivers are expected to decrease the speed differential.

Corridors where the speed limits were changed saw a minimal change in differential speed.

Table 5 summarizes the change in differential speed, grouped by posted speed limit.

Table 5 – Change in Differential Speed

Speed Limit (km/h)	Change in Differential Speed (km/h)
90	0
100	1
110	1
120	0

2.2 Safety Analysis

The Ministry committed to review safety performance one year after implementation. For safety analysis, one year of collision data is considered a short timeframe. Safety analysis typically uses 3 years of before and after data. Using only one year of data on individual highway segments does not return statistically significant findings however the data can still provide engineers a degree of insight into changes in safety performance.

A post-implementation safety analysis was carried out on the changed highway segments. This was supplemented with a review of provincial safety trends on all highways. Safety trends from other countries were reviewed to understand how road safety is changing internationally. An independent safety analysis was also carried out by the University of British Columbia (UBC) on the changed highway segments, which compared them to corridors of similar location and characteristics.

The collision data used for the analysis was gathered through ICBC for collisions where police attend and complete a MV6020 collision form. Only serious collisions (fatal + injury) attended by the police were considered due to data reliability and accuracy. At the time of this analysis, complete collision data was available up to October 31, 2015. The majority of new speed limits were implemented by October 2014 and hence, the one year post-implementation time period considered for safety analysis was November 1, 2014 to October 31, 2015.

In order to compare changes over time, 10 years of collision data was used from 2005 to 2014. To align with the post-implementation data, the adjusted annual data considered was from November 1 to October 31 of the following year. In addition, a 10 year average collision rate was determined and used for comparison.

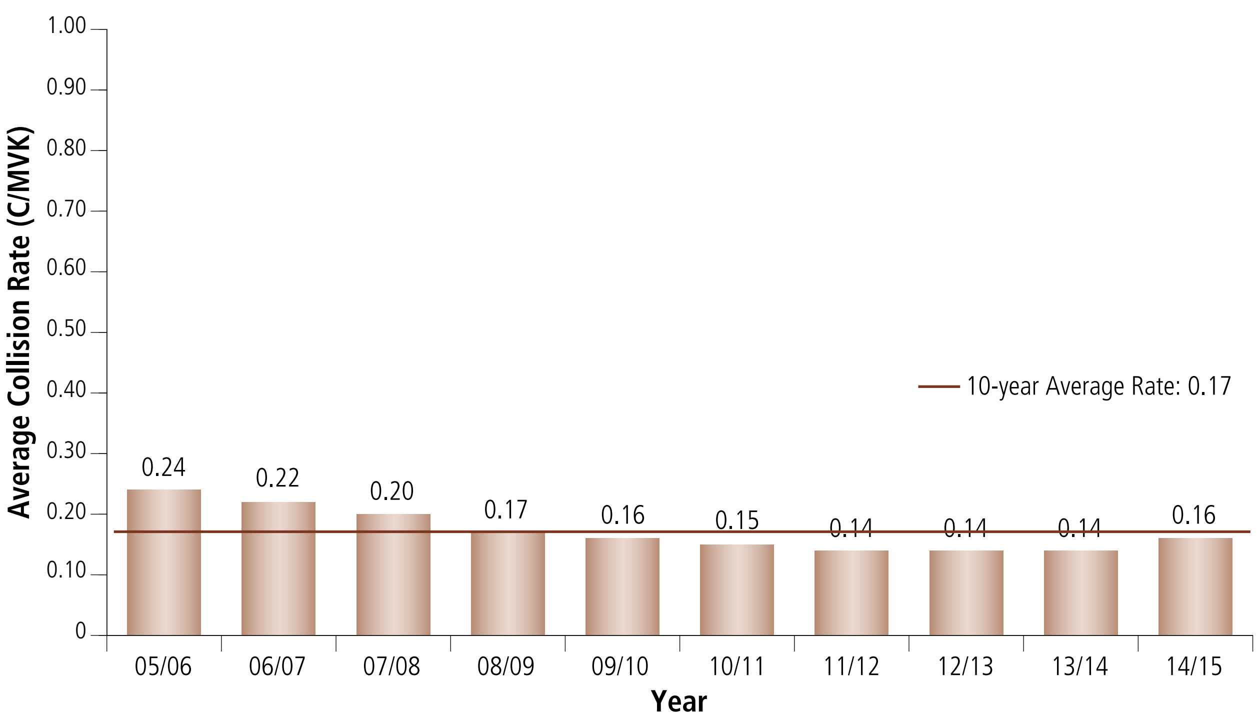
Serious collisions are reported out as a collision rate, which normalizes the number of collisions with the traffic volume. The collision rate accounts for the number of kilometres travelled on a segment over a given time period. This allows an effective side-by-side comparison between highway segments. Collision rates have the unit collisions per million vehicle kilometres travelled (C/MVK).

2.2.1 Changed Highway Segment Collision Review

2.2.1.1 Yearly Trend

Annual serious collision rates for all changed highway segments are illustrated in Figure 2. Overall, the 10 year data shows a 32% reduction in serious collisions when 05/06 data is compared to 14/15 post-implementation data.

Figure 2 – Annual Serious Collision Rate, All Changed Segments



2.2.1.2 Contributing Factors

When police attend the scene of a collision they document their findings. Part of those findings are a determination of factors that directly contributed to the collision. The top contributing factors were found to be:

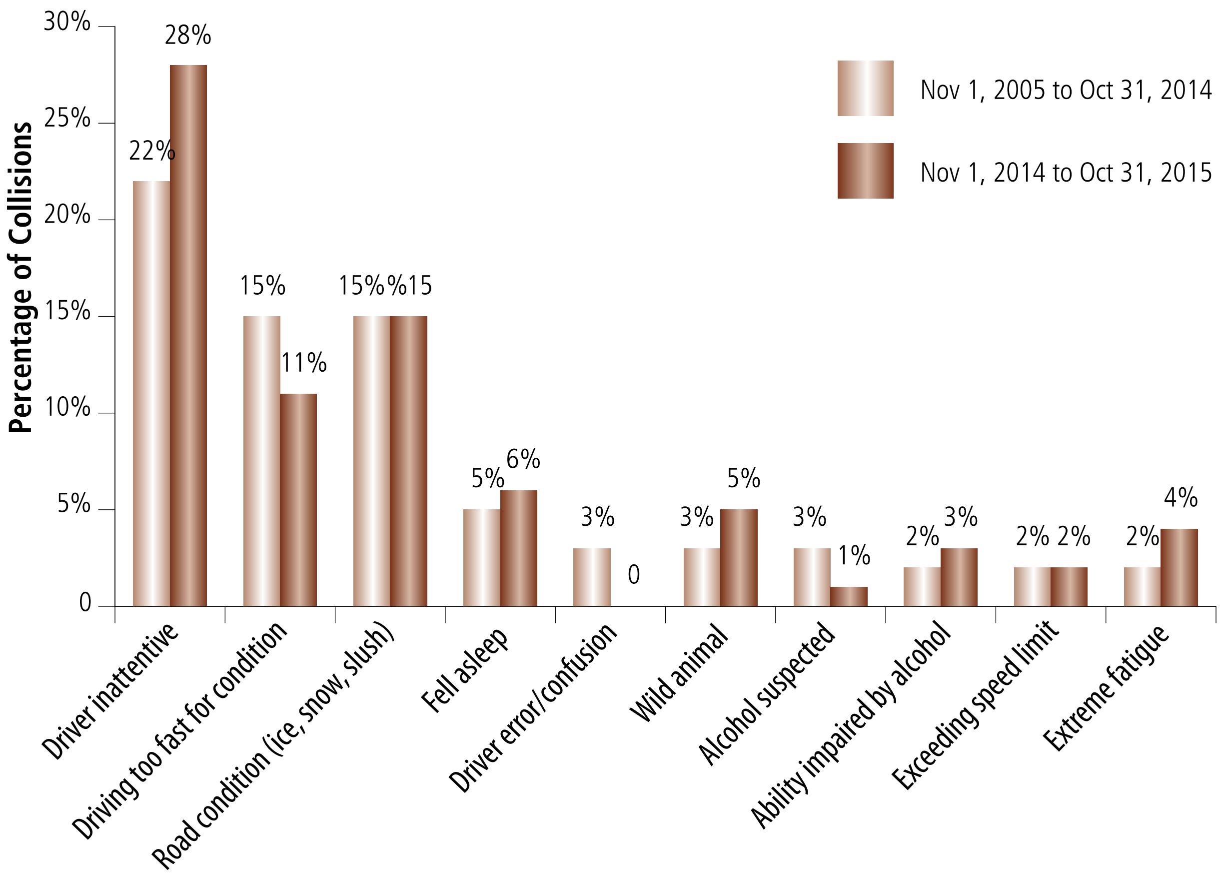
- Driver inattentiveness
- Road conditions
- Driving too fast for conditions

Pre-implementation data shows that 52% of serious collisions were attributed to these three factors. Since the speed limit changes were implemented:

- An additional 6% of collisions were attributed to driver inattentiveness
- Driving too fast for conditions decreased by 4%
- Serious collisions as a result of road condition was constant at 15%

In the post-implementation period, 54% of serious collisions were contributed to driver inattentiveness, road condition, and driving too fast for conditions. Figure 3 demonstrates the top contributing factors on the highway segments after the speed limit changes were implemented.

Figure 3 – First Contributing Factors, Serious Collisions – Changed Highway Segments



2.2.2 Review of Individual Changed Highway Segments

The 33 changed highway segments were reviewed independently to observe the collision rate and contributing factors over time. These individual reviews are summarized in Appendix A.

2.2.2.1 Segment Changes in Collisions and Speed

The relationship between 85th percentile speed and safety is complex. There are many confounding factors affecting safety such as the attentiveness of the driver, the weather conditions, etc. When the 85th percentile speed and safety were compared on a segment by segment basis it was found that on over half of the segments (19 of 33) the collision rate stayed the same or decreased when the last three years were examined. 7 segments saw an increase in collision rate, despite also having a decrease in 85th percentile speed. Only 7 of the 33 segments had an increase in 85th percentile speed and an increase in collision rate.

Table 6 summarizes the observed relationship between operating speed and serious collisions. Each number in the matrix is a count of the number of changed highway segments which fall into each category. Changes in serious collisions are compared against changes in the 85th percentile speed. From this matrix, it is clear that the majority of changed highway segments have seen a decrease in serious collisions when compared to previous years.

Table 6 – Number of Segments with 85th% Speed Change and Collision Rate Changes

	Collision Rate decreased / unchanged	Collision Rate Increased
85th% speed increased	12	7
85th% speed decreased/unchanged	7	7

When the highway segment comparisons are shown together the variation in changes is highlighted:

Table 7 – Changed Highway Segment Comparison

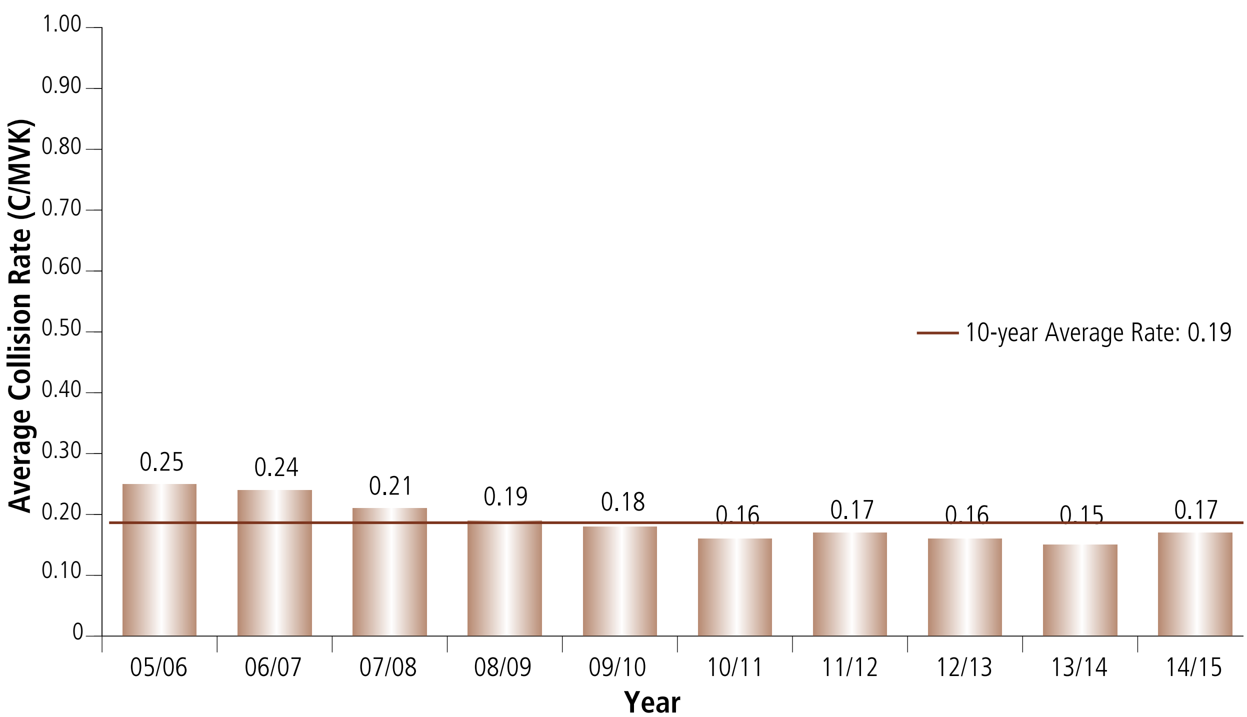
Highway Description	85th Percentile Speed Change	Serious Collision Rate Change
Hwy 1, Victoria to Nanaimo	↓	↑
Hwy 1, Abbotsford to Hope	↑	↑
Hwy 1, Hope to Cache Creek		
Hope to Boston Bar	↑	↑
Hope to Jackass Mountain	↓	↑
Hwy 1, Cache Creek to Kamloops	↑	↓
Hwy 1, Kamloops to Salmon Arm	↑	↑
Hwy 1, Salmon Arm to Alberta Border		
Salmon Arm to Revelstoke	↓	↓
Revelstoke to Golden	↑	↓
Hwy 3, Hope to Princeton		
Hope to Coquihalla	↑	↑
Sunshine Valley to Manning Park East Boundary	↑	↓
Sunday Summit to Princeton	↓	↓
Hwy 5, Coquihalla	↓	↓
Hwy 5, Kamloops to Tête Jaune Cache	↑	↓
Hwy 5A, Princeton to Merritt	↑	↑
Hwy 6, Nelson to Nakusp		
New Denver to Hills	↓	↓
Summit Lake to Nakusp	↓	↓
Hwy 7, Mission to Hope	↓	↑
Hwy 19, Nanaimo to Campbell River	↑	↓
Hwy 19, Campbell River to Port Hardy		
Campbell River to Bloedel	↑	↓
Bloedel to Sayward	↑	↑
Port McNeill to Port Hardy	↑	↓
Hwy 33, Rock Creek to Kelowna		
Black Mountain to McCulloch Road	↑	↑
Rock Creek to Westbridge	↓	↓
Hwy 97, Cache Creek to Williams Lake	↑	↓
Hwy 97, Vernon to Kamloops	↑	↓
Hwy 97A, Vernon to Sicamous		
Armstrong to Enderby	↓	↑
Grindrod to Sicamous	↓	↓
Hwy 97C, Okanagan Connector		
Merritt to Aspen Grove	↓	↑
Aspen Grove to Peachland	↓	↑
Hwy 99, Sea-to-Sky Highway		
Horseshoe Bay to Squamish	↑	↓
Squamish to Whistler	↑	↓
Hwy 99, Whistler to Cache Creek		
Whistler to Pemberton	↓	↑
Lillooet to Cache Creek	↑	↓

2.2.3 All Provincial Highways

2.2.3.1 Yearly Trend

A summary of serious collision rates from November 1, 2005 to October 31, 2015 is displayed in Figure 4 for the entire provincial highway network. This time period was chosen to align the data for general comparative purposes with the changed highway segments. Overall, serious collisions have been showing a declining trend. These findings are similar to the trends seen on highway segments where the speed limits were changed. Overall, crashes increase 9% from 2013/14 to 2014/15.

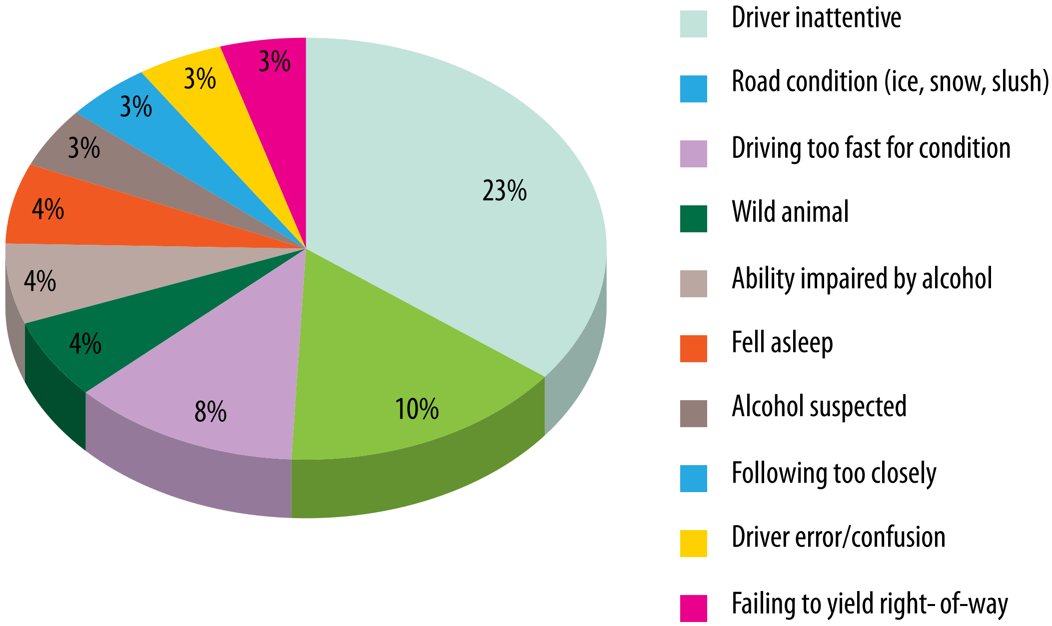
Figure 4 – Annual Serious Collision Trend – All provincial highways



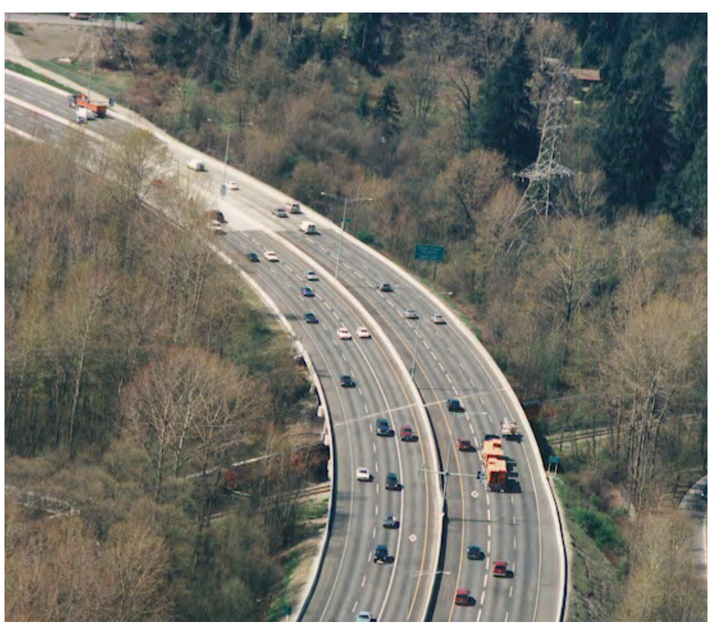
2.2.3.2 Contributing Factors

The top ten first contributing factors for all provincial highways are displayed in Figure 5. The top three contributing factors are driver inattentiveness, road conditions due to ice, snow or slush, and driving too fast for conditions. These top three contributing factors are attributed to 41% of serious collisions. Although the approximate proportion of collisions attributed to driver inattentiveness has increased on changed highway segments, road conditions and driving too fast for conditions are less prominent on the provincial scale. This may be related to the highway characteristics of the changed highway segments. These segments were rural, and included only a few areas in the lower mainland where winter road conditions are less common.

Figure 5 – First Contributing Factors – Serious Collisions for All Provincial Highways



**Note: Chart only shows top contributing factors that were identified by police and therefore percentages do not total 100*



2.2.4 Safety Trends in Other Countries

2.2.4.1 United States

Historic collision data was looked at for states with similar geography to British Columbia. An increase in collisions in 2015 was seen in all of these states. This may be attributed to the increase in vehicle kilometres travelled due to the decrease in fuel prices.

Table 8 – Fatality Data for Select U.S. States

State	January – June			% Increase (2014–2015)
	2013	2014	2015	
Washington	191	225	235	4%
Oregon	136	128	204	59%
Colorado	202	200	236	18%

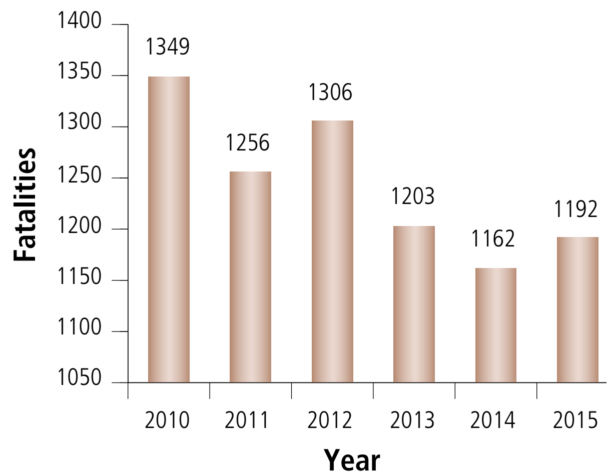
Table 9 – U.S. States with a significant increase in fatalities in the first six months of 2015

State	% Increase 2015
Oregon	59%
Florida	29%
Georgia	26%
Minnesota	26%
Indiana	23%
North Dakota	22%
South Carolina	21%
California	20%
Louisiana	20%
Maryland	19%
North Carolina	19%
Utah	19%
Wisconsin	19%
Arizona	18%
Colorado	18%
Ohio	17%
Arkansas	14%
Vermont	12%
Virginia	12%

2.2.4.2 Australia

Fatalities in Australia have been on the general decline over the past five years, but did see a 2.5% increase in 2015 (compared to 2014).

Figure 6 – Preliminary Australian Fatality Data for 2015



2.2.5 Independent Third Party Safety Analysis

An independent safety analysis of the highway segments where the speed limits were changed was carried out by Dr. Tarek Sayed, Ph.D., P.Eng. and Emanuele Sacchi, Ph.D., from the University of British Columbia (UBC). The analysis estimates collision occurrence during the post-implementation period using full Bayesian technique —a well-established statistical methodology for safety evaluations.

The Ministry provided start and end points of highway segments safety data and traffic volumes. The analysis looked at 2.5 years before and 1 year after data. The low number of collisions that occurred did not allow the development of statistically significant findings on specific segments of highway. When the data is aggregated over all segments, the analysis found an 11% increase in serious collisions.

The above finding is based on a relatively short period of post implementation data. The UBC model predicts that any initial increase in severe collisions may be reduced over time and therefore the UBC study recommends repeating the analysis when more data is available for a longer post-treatment period with more accurate results. Typically 3 years of before and 3 years of after date is used for analysis. Considering the limited post implementation data used for the UBC analysis, it is advised that the findings of the report be considered preliminary. A complete copy of the UBC report is included in Appendix C.

2.3 Rural Highway Speed Limits Conclusion

Serious collisions on the provincial highway network have been on the general decline over the last ten years. However, similar to trends occurring in other jurisdictions, serious collisions have increased in 2014/2015. Fatalities have been reported to increase in the United States and Australia in 2015.

The safety trends for highways with increased speed limits are also changing similar to all provincial highways. Limited one year post-implementation data (2014/2015) is showing an increase in serious collisions. Driver inattentiveness continues to be a top contributing factor.

The UBC report stated that serious collisions have increased when compared to aggregated data for similar highways. This evaluation was based on a relatively short post-implementation period and the authors suggest additional analysis for a longer after period be undertaken. The review was unable to complete a statistically significant assessment on individual corridors due to the low number of crashes in a one year sample.

There are a number of safety focussed highway improvement projects committed in highway corridors where speed limits were changed and in other parts of the province in 2016 and beyond. These projects include but are not limited to roadside delineations, safety barrier installation, and intersection improvements that will aim to enhance road safety.

Driver inattentiveness is a primary contributing factor involving serious collisions. Working with other safety partners and organizations will assist in collectively raising drivers' awareness through an educational campaign on the consequence of speeding and inattentiveness.

2.4 Variable Speed Limits

Figure 7 – Variable Speed Limit Sign

Variable speed limit systems (VSL) are an innovative safety tool that is being rolled out on three corridors in the province. These are corridors where changing road conditions can cause challenges to drivers during weather events. The VSL system the Ministry has developed uses roadside collected data on weather, surface condition, and vehicle speed to recommend a speed limit based on current conditions. This speed limit provides a safer and more reliable journey through these mountainous corridors.

Table 10 – Variable Speed Limit Locations

Highway	Segment	Length
Hwy 99	Squamish Valley Rd to Function Junction	40 km
Hwy 5	Portia Interchange to former Toll Plaza	25 km
Hwy 1	Perry River Bridge to Revelstoke	40 km

Design of the variable speed limit systems took place through 2015 and the system was activated in June 2016. Overall, a total of 47 overhead LED variable speed limit signs have been installed. They are equipped with yellow amber flashers that activate when a reduced speed limit is in place. Overhead digital message signs at the beginning of each corridor alert drivers to upcoming weather or road events which have triggered a speed limit reduction.

Variable speed limits are calculated using real time vehicle speed and road condition information to accurately determine the current conditions of the road. The data is compiled and reviewed in the Regional Transportation Management Centre where a speed limit is recommended and sent to the variable speed limit sign. Variable speed limits are meant to be reflective of current road conditions, therefore data is collected every five minutes and speed limits can adjust as often as every fifteen minutes. Variable speed limits are regulatory and can be enforced under the Motor Vehicle Act. It is important that drivers remember that regardless of any regular or variable speed limit, they drive with due care and attention to the conditions of the road.

3.0 Additional Accomplishments

The ministry has implemented many of the recommendations from the Speed and Safety Review in the past year.
In addition to the speed limit review, the Ministry has implemented improvements on variable speed limits, winter tires, slower moving vehicles, as well as wildlife detection.

3.1 Winter Tires

Winter weather in British Columbia can vary greatly. British Columbia's mountain passes and interior regions can experience significant winter conditions that challenge both drivers and vehicles. The Ministry posts Winter Tire signs on routes requiring winter tires or chains through the winter season. However, the definition of a winter tire in the Motor Vehicle Act (MVA) dated back to 1979, and did not clearly define a winter tire.

Figure 8 – R-047 Winter Tire Sign

Winter tire related recommendations from the Safety and Speed Review included:

1. A legislative update to the winter tire definition
2. An update to regulations to modernize requirements for studded tires or chains
3. New winter tire signs to clarify requirements for winter tire and chain use
4. Increase resources to promote and improve winter safety through the multi-agency Shift into Winter campaign

The winter tire definition has been clarified as those tires labelled with either the winter mountain/snowflake symbol or the mud and snow (M+S) designation. Winter tires must also be in good condition with a minimum tread depth of 3.5 mm. This definition was updated in legislation in summer 2015, in time for the 2015/16 winter driving season.

Along with the definition of winter tires, the requirements for chains and studded tires were updated. The Motor Vehicle Act Regulations were updated to include definitions for chains as well as all other acceptable "traction devices" such as automatic tire chains, cable chains, wheel sanders, and textile tire covers.

In total, 389 winter tire and chain signs have been posted throughout the province. Additionally, the ministry has increased its commitment and funding in support of the multi-agency Shift into Winter campaign. This partnership with the Winter Driving Safety Alliance reminds motorists to prepare their vehicles, check DriveBC and to drive to the conditions of the road.

3.2 Slower Moving Vehicles

By working to resolve speed differential (discussed in Section 2.0), the Ministry reviewed best practices relating to management of slower moving vehicles and the following recommendations were developed:

1. Improved Keep Right signs that emphasize that drivers shall let others pass
2. Updated passing/climbing lane pavement marking to direct drivers to the right lane
3. Update legislation to clarify Keep Right Except to Pass requirements
4. Pilot signs requiring Slow Traffic Delaying 5 Vehicles Must Use Pullout on Highway 4, Parksville to Tofino

300 new Keep Right signs were installed throughout B.C. on multilane highways and at the beginning of passing or climbing lanes. The new signs, along with 357 updated pavement markings for passing and climbing lanes were introduced in September 2014. Left lane legislation came into effect in June 2015 to clarify rules regarding travelling in the left lane:

Drivers on multi-lane highways where the speed is at least 80 km/h must stay to the right unless they are:

- Overtaking and passing another vehicle
- Moving left to allow traffic to merge
- Preparing for a left hand turn
- Moving left to pass an official vehicle displaying a flashing light

During periods of congestion, if the operating speed drops to 50 km/h or less, drivers are encouraged to use the left-most lane to keep traffic flowing.

Slow moving vehicle pullouts were upgraded along Highway 4 in the summer of 2014. Substantial work was completed, including conversion of some existing pullouts to passing lanes, removal of substandard pullouts and construction of a new pullout. In the end, Highway 4 now has improved passing opportunities as well as three eastbound and three westbound pullouts between Port Alberni and the Tofino junction. The corridor has signs which requiring drivers to use the pullouts if they are delaying five (or more) vehicles.

3.3 Wildlife Detection System

Ground surveillance sensors supplement infrared and Pan-Tilt-Zoom (PTZ) network cameras. The cameras are programmed to record and track animals when the radar detects their presence. These images are used to verify results and calibrate the system to minimize false detection.

Figure 10 – Wildlife Detection System, Elko BC

The Rural Highway Safety and Speed Review made recommendations to pilot a wildlife detection system (WDS) in corridors known to have a higher history of wildlife collisions. Two corridors in the East Kootenays along Highway 3 were chosen for this pilot. Data collected in the ministry's Wildlife Accident Reporting system marked these locations as having some of the highest frequency of wildlife accidents on Highway 3.

Table 11 Wildlife Detection System Locations

Location	Segment	Length	Species
Hwy 3 (Elko)	1 km east of Elko	3 km	Deer & Sheep
Hwy 3 (Michel)	1 km east of Sparwood	5 km	Elk

The WDS system uses radar and infrared camera technology to detect wildlife. Upon detection of wildlife, the system begins tracking the animal and activates gateway and confirmatory warning signs to bring attention to drivers of the presence of an animal. These signs stay active during and immediately after the animal is in the detection zone.

Construction of the Wildlife Detection System is complete. The system was configured and field tested, and went live in April 2016. Early analysis shows wildlife present on or near the highway 6-8 hours per day

The ministry has also implemented new Wildlife Corridor Gateway signs on highways which experience frequent and varying wildlife incidents. These signs provide additional warning of the presence of wildlife, supplementing location specific warning signs.

Figure 11 Gateway Wildlife Signs

4.0 Conclusions

A number of significant actions were implemented from the 2014 Rural Highway Safety and Speed Review. The speed limit review used internationally accepted practices to review and recommend changes across the province. Speed limits were changed on the recommended highway segments in the summer and fall of 2014.

Operating speeds were measured after the speed limit changes and found that, on average, the increase in operating speed (as represented by the 85th percentile speed), was 2 km/h. This represents good compliance and acceptance of speed limits within the Province. Speed differential saw a nominal increase of 1 km/h. This is expected to decrease over time. Segments where the speed limit was changed will continue to be closely monitored and reviewed in the coming years.

A review of individual changed highway segments showed that 19 of the 33 segments saw a reduction or no change in the collision rate since the speed limit changes occurred. 7 segments saw an increase in collision rate, despite also having a decrease in 85th percentile speed. Only 7 of the 33 segments had an increase in 85th percentile speed and an increase in collision rate. Although this information is based on limited data, the ministry is taking early mitigation measures to address the safety of these corridors by undertaking improvements, and education.

A review of the Ministry's collision data showed that factors such as driver inattentiveness, road condition (snow, slush, ice), and driving too fast for conditions remain the top contributing factors to collisions on provincial rural highways. The proportion of collisions attributed to driver inattentiveness has increased, while driving too fast for conditions has decreased. These issues are being addressed through further initiatives presented in this review as well as in BC On the Move.

A third party modelling of preliminary safety data conducted by UBC estimated an aggregated 11% increase in severe collisions when comparing changed segments to comparison segments. This modelling is based on a relatively short period of post implementation data and could not develop performance data on individual highway segments. The UBC study recommends repeating the analysis when more data is available for a longer post-treatment period.

In addition to the speed limit review, the Ministry has successfully implemented the other recommendations of the 2014 report:

- Variable speed limit systems have been installed on segments of Highway 1, 5, and 99. These systems became operational in June 2016 and establish regulatory speed limits that reflect current road conditions.
- Winter tires and chains are clearly defined in the Motor Vehicle Act Regulations. Their use has been updated on new signs installed throughout the province.
- Legislation on the appropriate use of the left-most lane on highways has been clarified. New signs were developed and installed on multi-lane highways and the start of passing/climbing lanes.
- Wildlife Detection Systems have been installed at two sites on Highway 3 and were operational in April 2016. These sites provide advance warning to drivers of the presence of wildlife on and near the roadway.

The results in this report are based on one year post implementation collision and speed data which cannot alone suggest any safety trends as a result of speed limit changes. The ministry will continue to closely monitor corridors throughout the province to maintain a safe and reliable highway network.

References

1. National Safety Council - http://www.nsc.org/NewsDocuments/2016/mv-fatality-report-1215.pdf1
2. European Transport Safety Council - http://etsc.eu/9th-annual-road-safety-performance-index-pin-report
3. Australian Government Department of Infrastructure and Regional Development https://bitre.gov.au/publications/ongoing/road_deaths_australia_monthly_bulletins.aspx

APPENDIX A: SPEED LIMIT CHANGES BY HIGHWAY

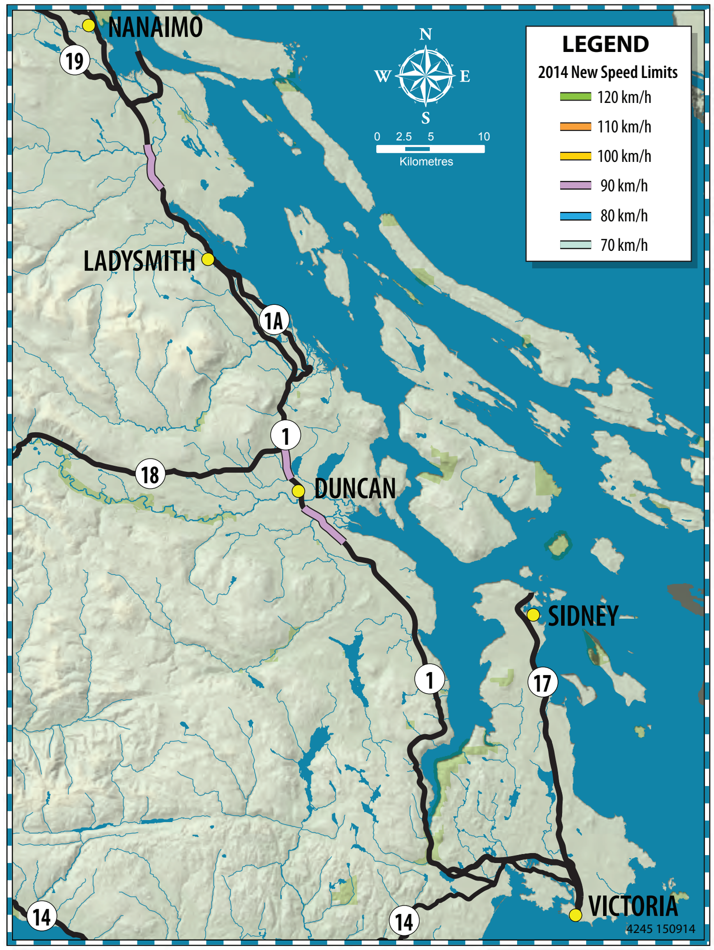
Cowichan Bay to Nanaimo

Physical Characteristics

Start Point 1: Bench Road
End Point 1: Allenby Rd
Length . . . . 2.7 km
Start Point 2: North of Sherman Rd
End Point 2: Sprott Rd
Length . . . . 3.6 km
Start Point 3: Timberlands Rd
End Point 3: Nanaimo River Bridge
Length . . . . 3.1 km
Total length . . . . 9.4 km
Number of Lanes. 4
Divided. . . . . Yes

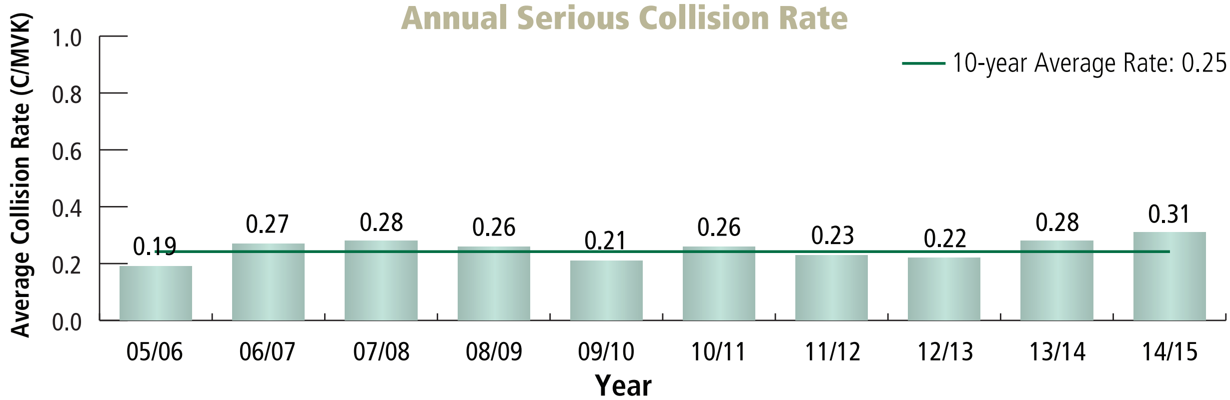
Operational Characteristics

Average Daily Traffic 22,000
% Trucks. 4%
Previous Speed Limit. . . . . 80/90 km/h
Previous 85th Percentile Speed . . . . 100 km/h
New Speed Limit. . . . . 90 km/h
Implementation Date . . . . Aug. 29, 2014
Current 85th Percentile Speed. . . . . 100 km/h
Change in 85th Percentile Speed. 0

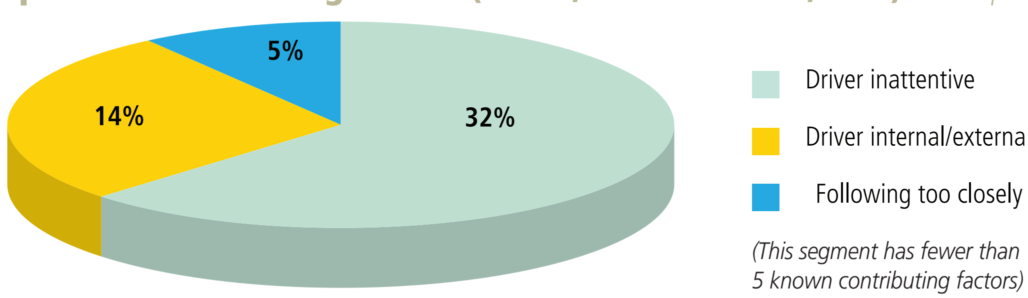


Safety Trends

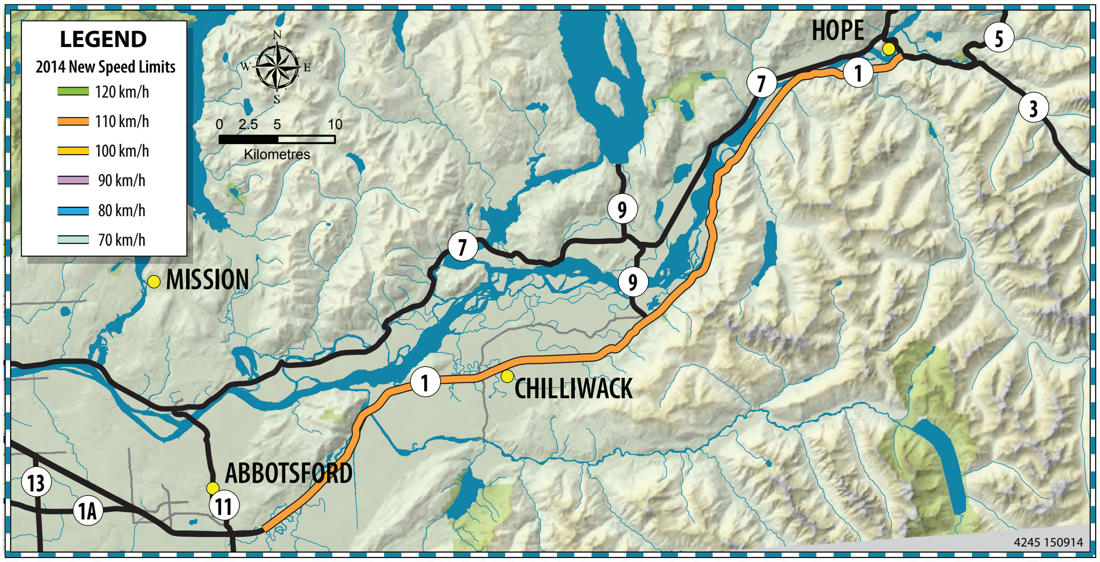
Annual Serious Collision Rate



Top 5 – 1st Contributing Factors (Nov. 1, 2014 to Oct. 31, 2015) *Post Implementation*



* These values may not add up to 100% as there are other contributing factors.



Whatcom Rd to Hope

Physical Characteristics

Start Point: Whatcom Rd (Exit 95)

End Point: Highway 3 Junction (Exit 170)

Length . . . . .74 km

Number of Lanes. 4

Divided . . . . Yes

Operational Characteristics

Average Daily Traffic 17,000

% Trucks. 18%

Previous Speed Limit. . . . . 100 km/h

Previous 85th Percentile Speed . . . . 116 km/h

New Speed Limit . . . . .110 km/h

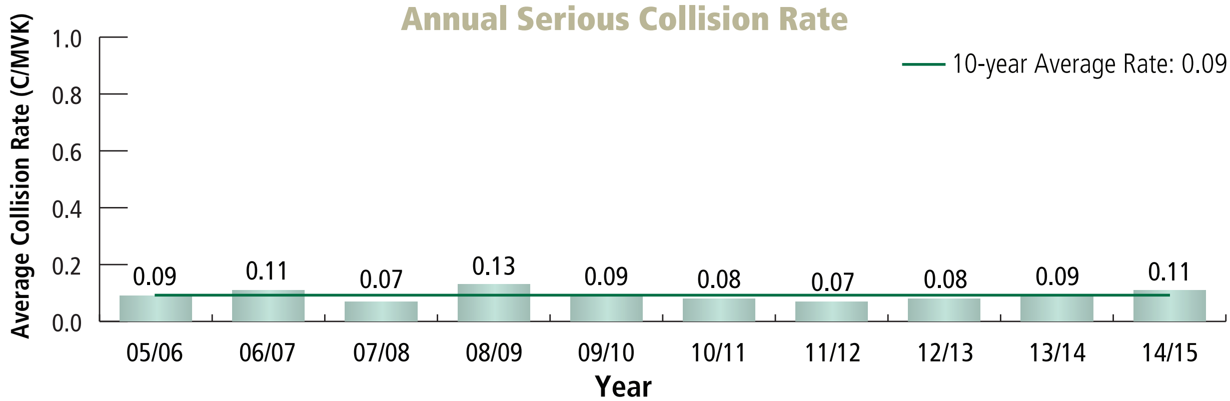
Implementation Date . . . . July 2, 2015

Current 85th Percentile Speed. . . . . 119 km/h

Change in 85th Percentile Speed. . . . .+3 km/h

Safety Trends

Annual Serious Collision Rate



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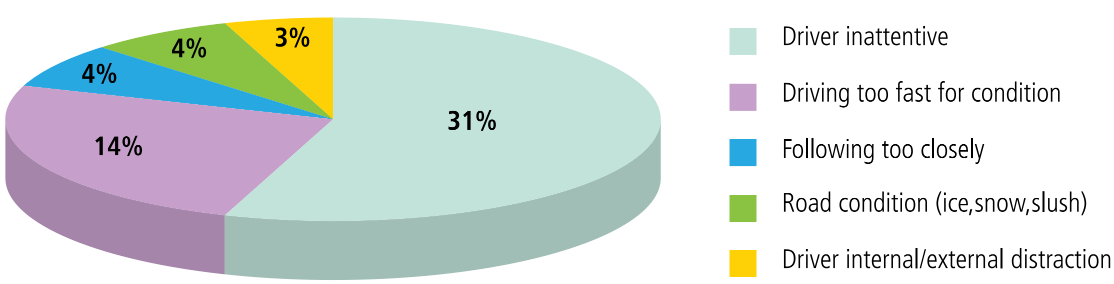


* These values may not add up to 100% as there are other contributing factors.

Hope to Boston Bar

Physical Characteristics

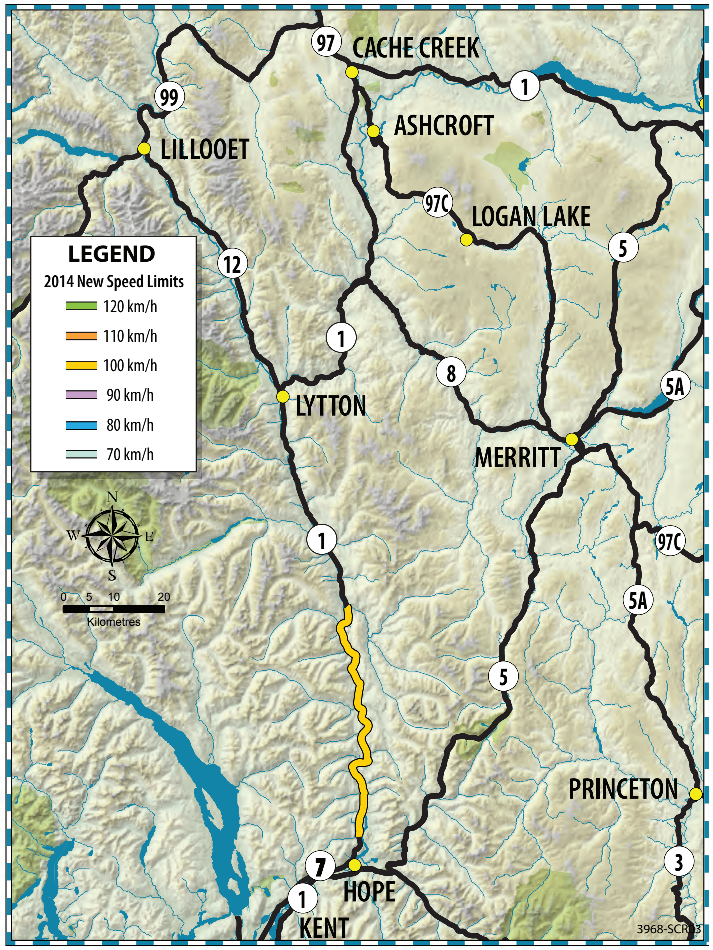
Start Point: 1 km east of Lake of the Woods Rest Area

End Point: 1.2 km west of Maintenance Yard in Boston Bar

Length .... 55 km
Number of Lanes 3
Divided .... No

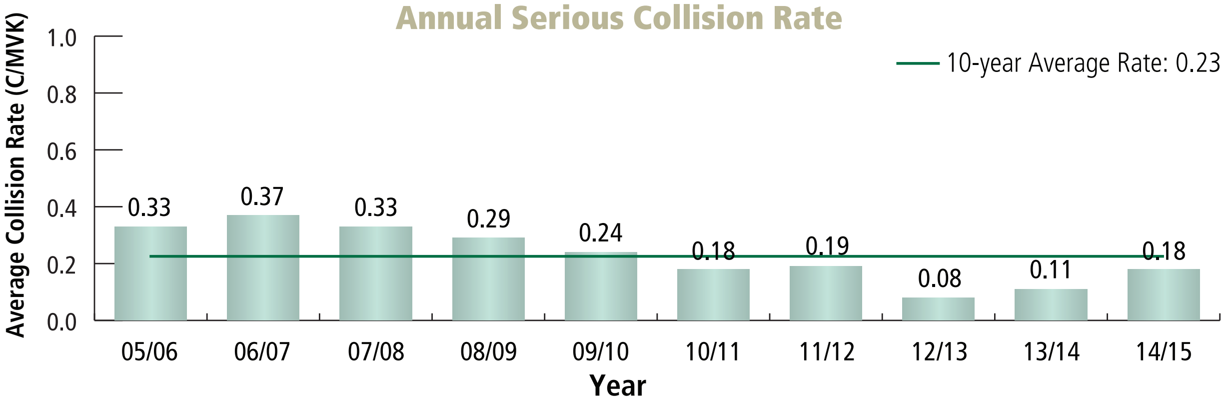
Operational Characteristics

Average Daily Traffic 3,000
% Trucks 30%
Previous Speed Limit .... 80/90 km/h
Previous 85th Percentile Speed .... 107 km/h
New Speed Limit .... 100 km/h
Implementation Date .... September 5, 2014
Current 85th Percentile Speed .... 112 km/h
Change in 85th Percentile Speed .... +5 km/h

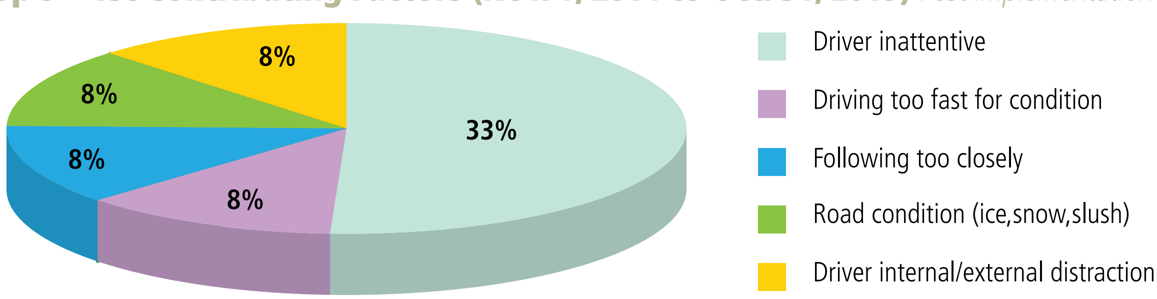


Safety Trends

Annual Serious Collision Rate



Top 5 – 1st Contributing Factors (Nov. 1, 2014 to Oct. 31, 2015) *Post Implementation*



* These values may not add up to 100% as there are other contributing factors.

Boston Bar to Jackass Mountain

Physical Characteristics

Start Point: 420 m east of Northbend Ferry Rd

End Point: 820 m east of Falls Creek

Length . . . . .24 km

Number of Lanes. 2/4

Divided . . . . No

Operational Characteristics

Average Daily Traffic 3,000

% Trucks. 30%

Previous Speed Limit. . . . . 90 km/h

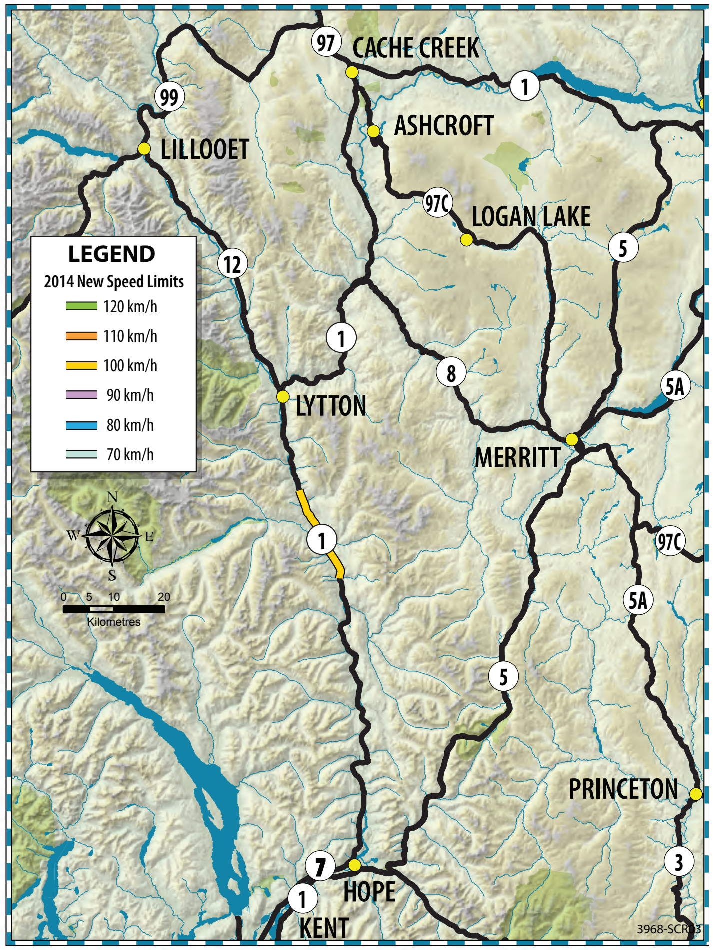
Previous 85th Percentile Speed . . . . 116 km/h

New Speed Limit . . . . 100 km/h

Implementation Date . . . . July 2, 2014

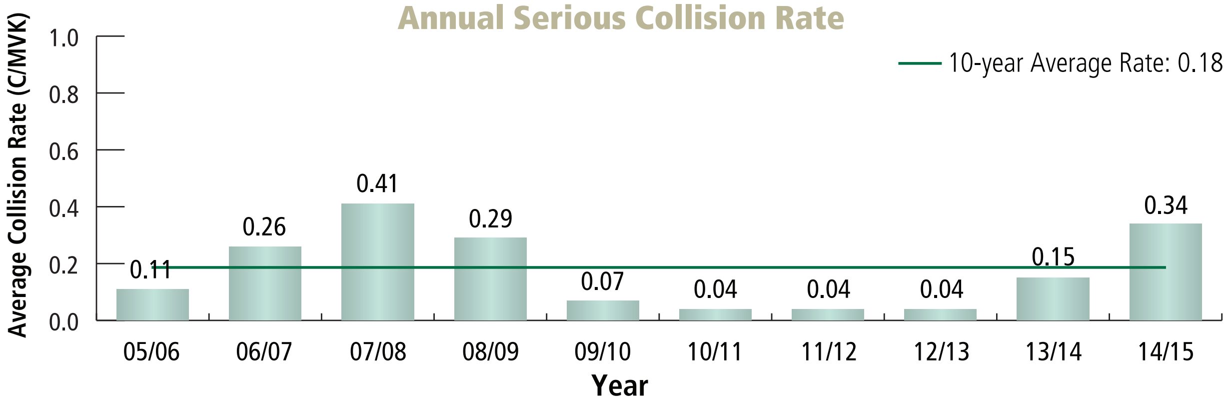
Current 85th Percentile Speed. . . . . 114 km/h

Change in 85th Percentile Speed. . . . . -2 km/h

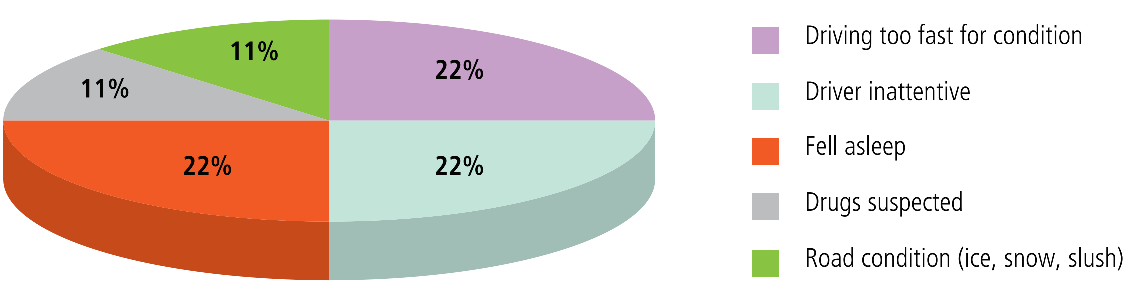


Safety Trends

Annual Serious Collision Rate



Top 5 – 1st Contributing Factors (Nov. 1, 2014 to Oct. 31, 2015) *Post Implementation*



* These values may not add up to 100% as there are other contributing factors.

Tobiano to Savona

Physical Characteristics

Start Point: Savona Station Rd

End Point: Six MIle Rest Area

Length .... 12 km

Number of Lanes.......... 2

Divided .... No

Operational Characteristics

Average Daily Traffic 3,500

% Trucks.......... 17%

Previous Speed Limit.......... 90 km/h

Previous 85th Percentile Speed .... 104 km/h

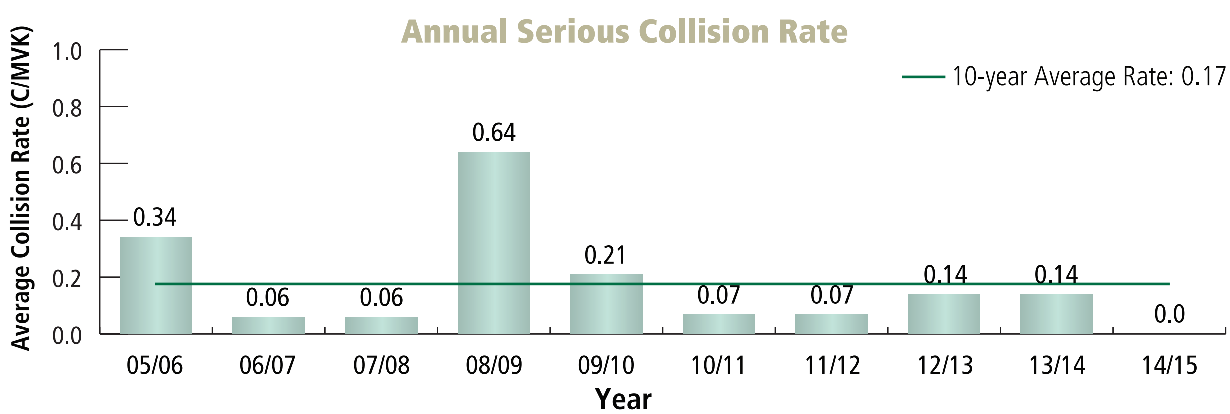
New Speed Limit .... 100 km/h

Implementation Date .... August 24, 2014

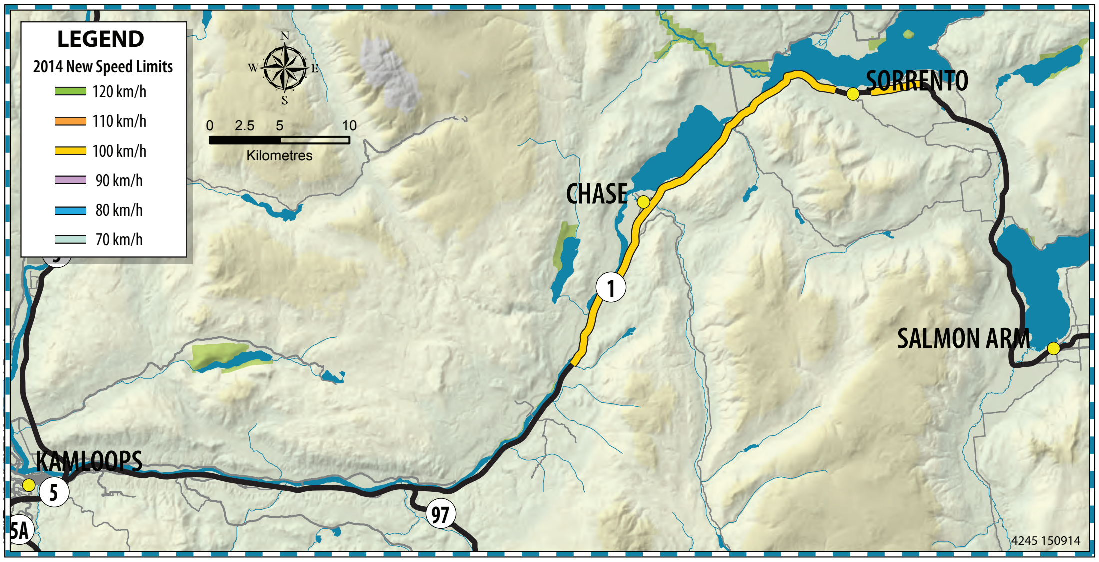
Current 85th Percentile Speed.......... 107 km/h

Change in 85th Percentile Speed.......... +3 km/h

Safety Trends



No crashes reported in 2014/15 – post implementation period.



Chase to Sorrento (Hilltop)

Physical Characteristics

Start Point: Willow Rd

End Point: Hilltop Rd

Length ....25 km

Number of Lanes........................... 2

Divided .... No

Operational Characteristics

Average Daily Traffic 9,000

% Trucks..................................18%

Previous Speed Limit................... 90 km/h

Previous 85th Percentile Speed .... 105 km/h

New Speed Limit ....100 km/h

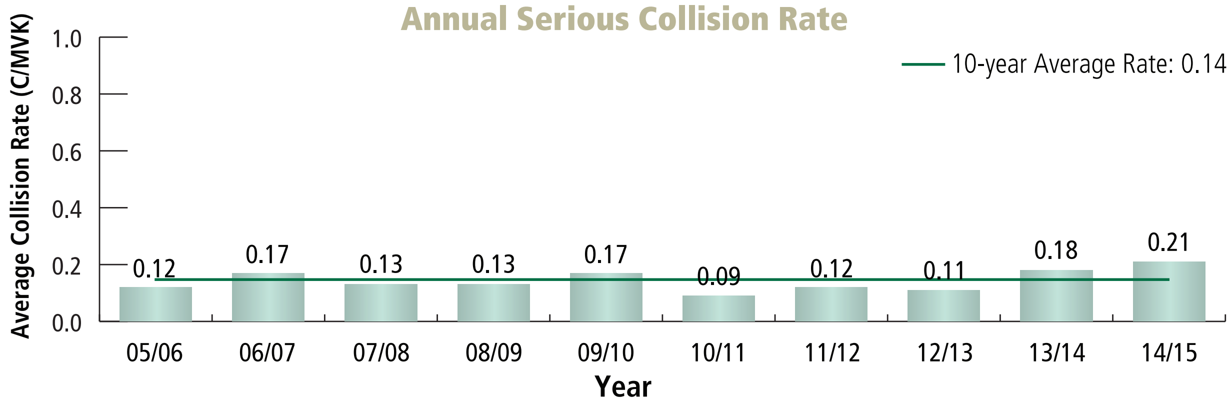
Implementation Date ....September 15, 2014

Current 85th Percentile Speed........... 111 km/h

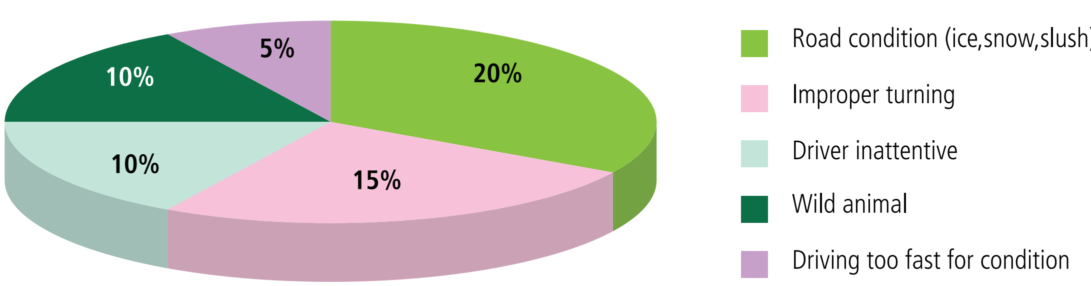
Change in 85th Percentile Speed..........+6 km/h

Safety Trends

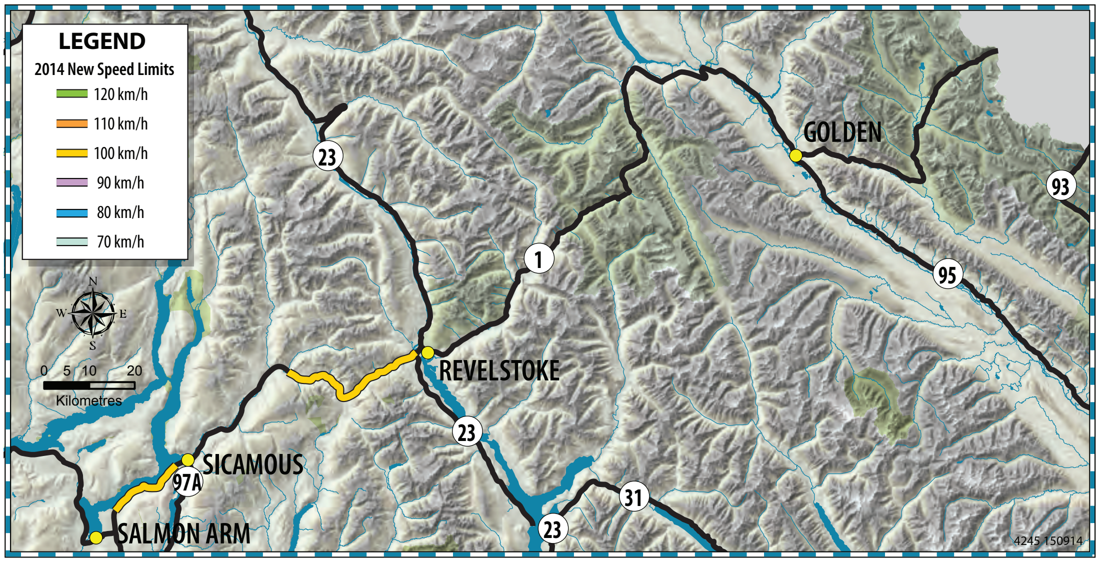
Annual Serious Collision Rate



Top 5 – 1st Contributing Factors (Nov. 1, 2014 to Oct. 31, 2015) *Post Implementation*



* These values may not add up to 100% as there are other contributing factors.



Salmon Arm to Revelstoke

Physical Characteristics

Start Point: Canoe (70th St. NE)

End Point: Hwy 23S

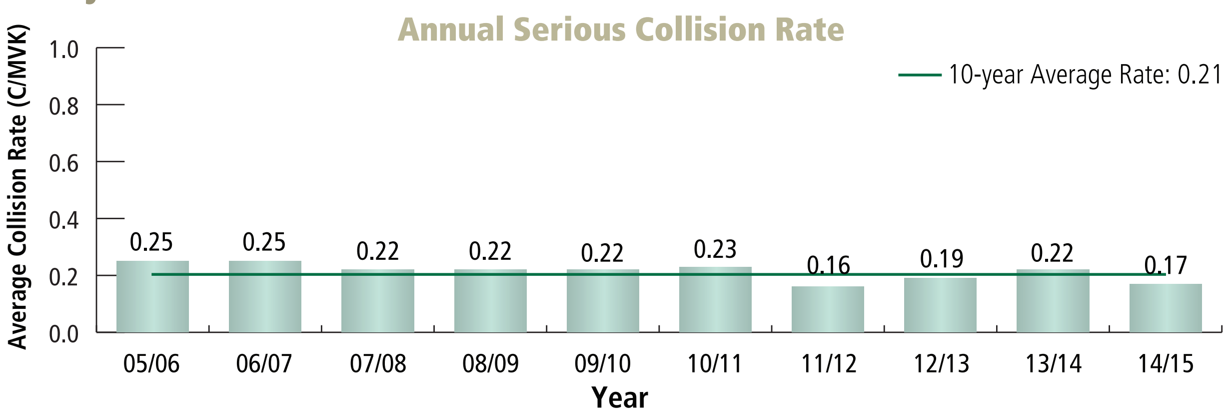
Length	58 km
Number of Lanes	2/4
Divided	No

Operational Characteristics

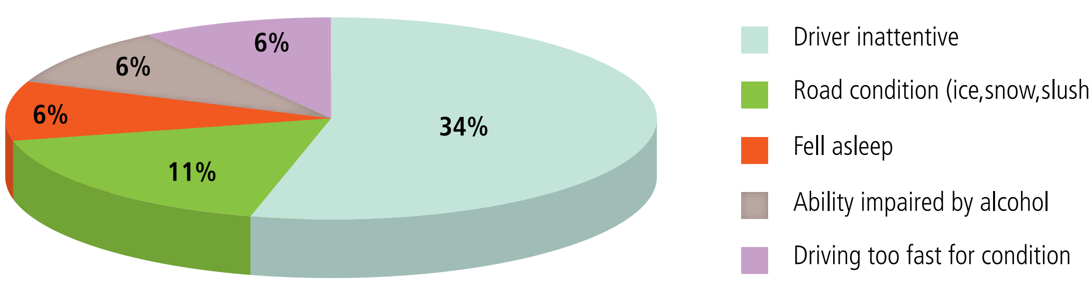
Average Daily Traffic	6,000
% Trucks	24%
Previous Speed Limit	90/100 km/h
Previous 85th Percentile Speed	106 km/h
New Posted Speed Limit	**100 km/h**
Implementation Date	September 19, 2014
Current 85th Percentile Speed	106 km/h
Change in 85th Percentile Speed	0

Safety Trends

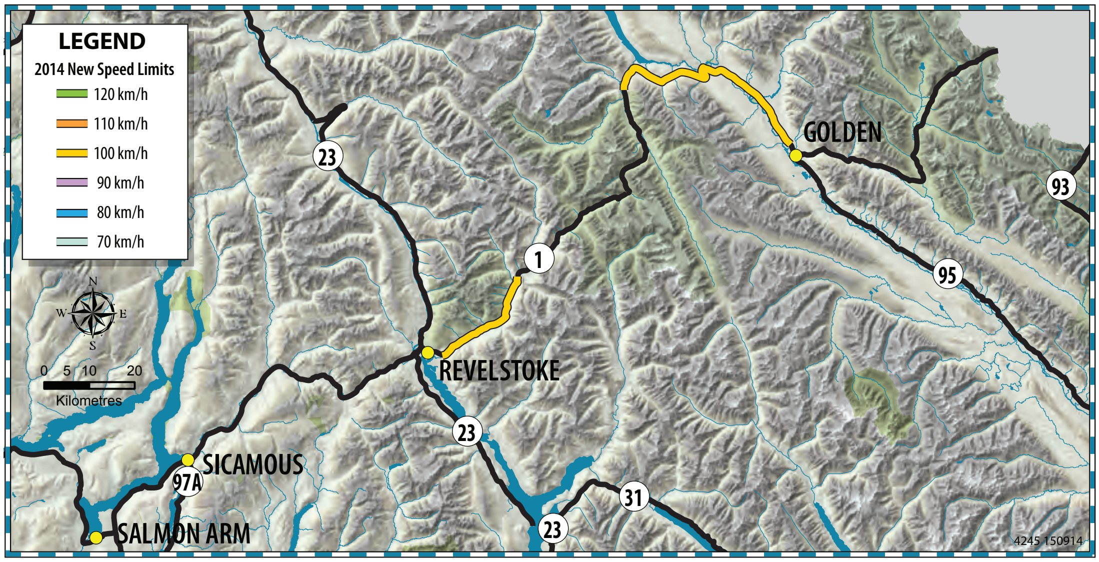
Annual Serious Collision Rate



Top 5 – 1st Contributing Factors (Nov. 1, 2014 to Oct. 31, 2015) *Post Implementation*



* These values may not add up to 100%, as there are other contributing factors.



Revelstoke to Golden

Physical Characteristics

Start Point: Hwy 23N

End Point: Golden (Anderson Rd)

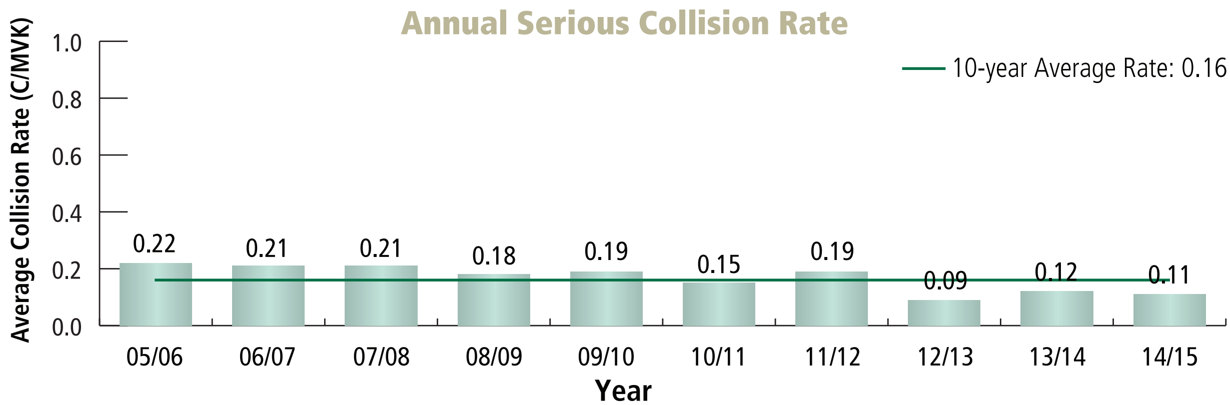
Length	101 km
Number of Lanes	2
Divided	No

Operational Characteristics

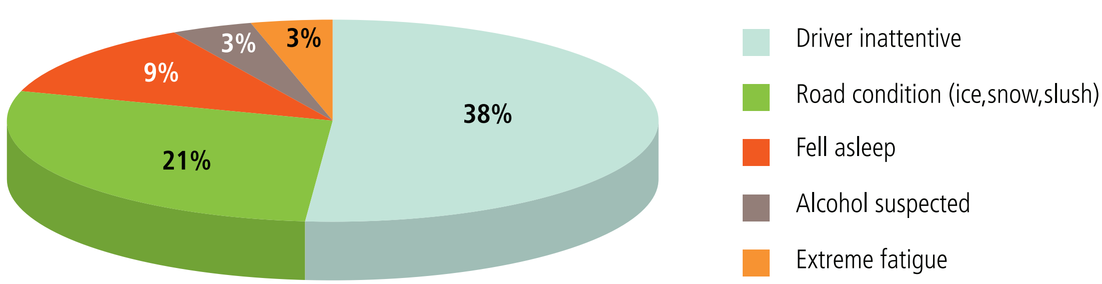
Average Daily Traffic	5,400
% Trucks	26%
Previous Speed Limit	90 km/h
Previous 85th Percentile Speed	103 km/h
New Speed Limit	**100 km/h**
Implementation Date	September 18, 2014
Current 85th Percentile Speed	109 km/h
Change in 85th Percentile Speed	+6 km/h

Safety Trends

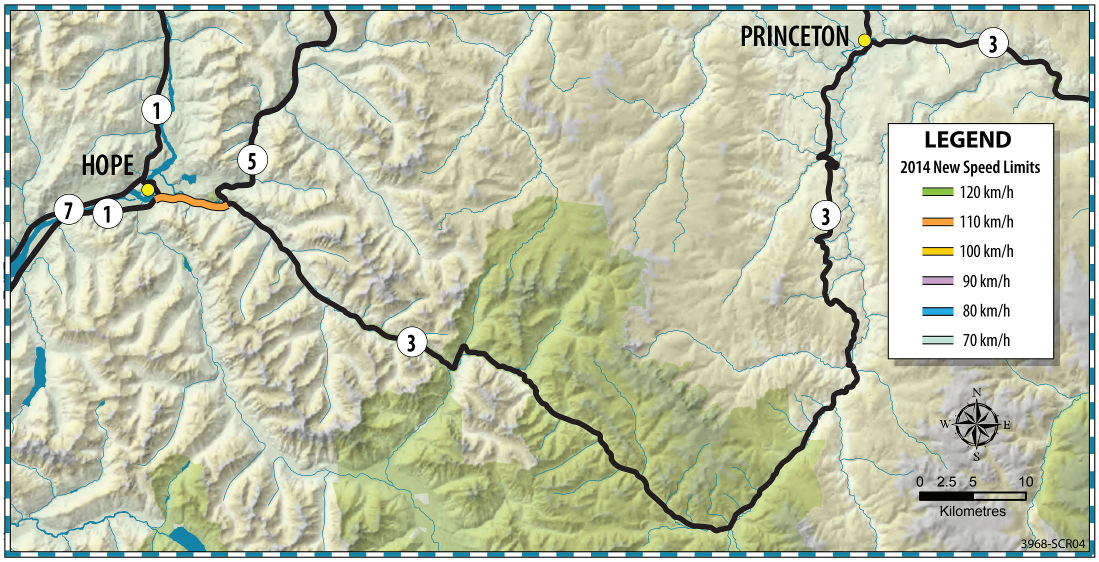
Annual Serious Collision Rate



Top 5 – 1st Contributing Factors (Nov. 1, 2014 to Oct. 31, 2015) *Post Implementation*



* These values may not add up to 100%, as there are other contributing factors.



Hope to Coquihalla

Physical Characteristics

Start Point: Start of Hwy 3 (Exit 170)

End Point: Hwy 5 Junction (Exit 177)

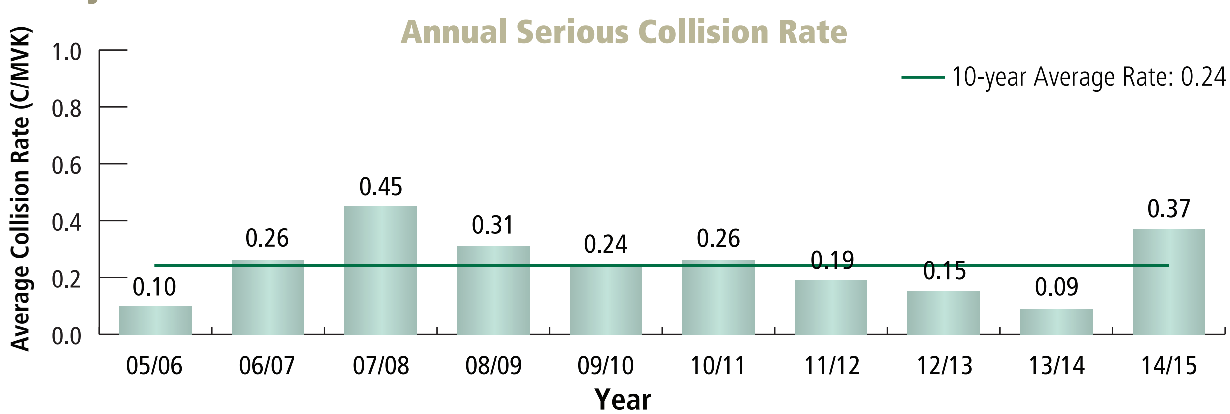
Length	7 km
Number of Lanes	6
Divided	Yes

Operational Characteristics

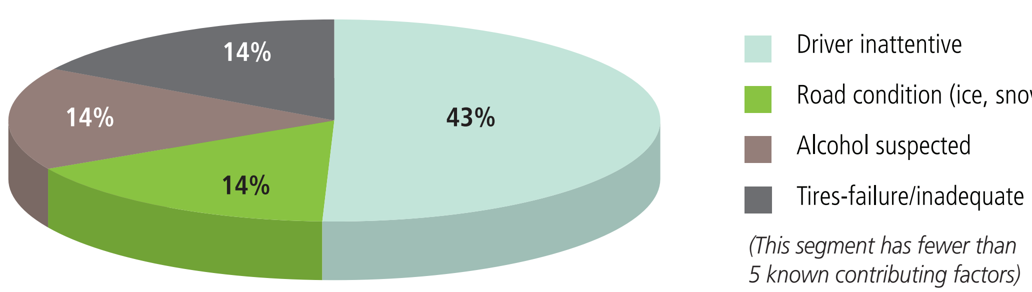
Average Daily Traffic	13,700
% Trucks	20%
Previous Speed Limit	100 km/h
Previous 85th Percentile Speed	114 km/h
New Speed Limit	**110 km/h**
Implementation Date	July 2, 2014
Current 85th Percentile Speed	120 km/h
Change in 85th Percentile Speed	+6 km/h

Safety Trends

Annual Serious Collision Rate

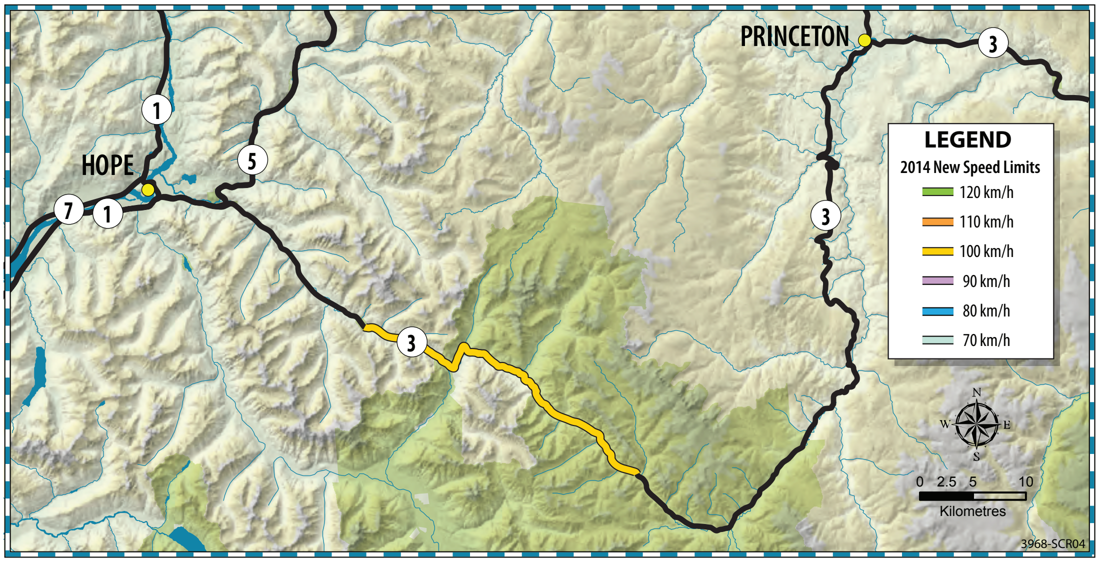


Top 5 – 1st Contributing Factors (Nov. 1, 2014 to Oct. 31, 2015) *Post Implementation*



(This segment has fewer than 5 known contributing factors)

* These values may not add up to 100%, as there are other contributing factors.



Sunshine Valley to Manning Park East Boundary

Physical Characteristics

Start Point: End of 4 Lane (1.2 km west of Manning Park West Gate)

End Point: 500 m East of Allison Pass Maintenance Yard

Length ....33 km

Number of Lanes.......................... 2

Divided .... No

Operational Characteristics

Average Daily Traffic 2,300

% Trucks...............................13%

Previous Speed Limit................ 80/90 km/h

Previous 85th Percentile Speed .... 103 km/h

New Speed Limit................... 100 km/h

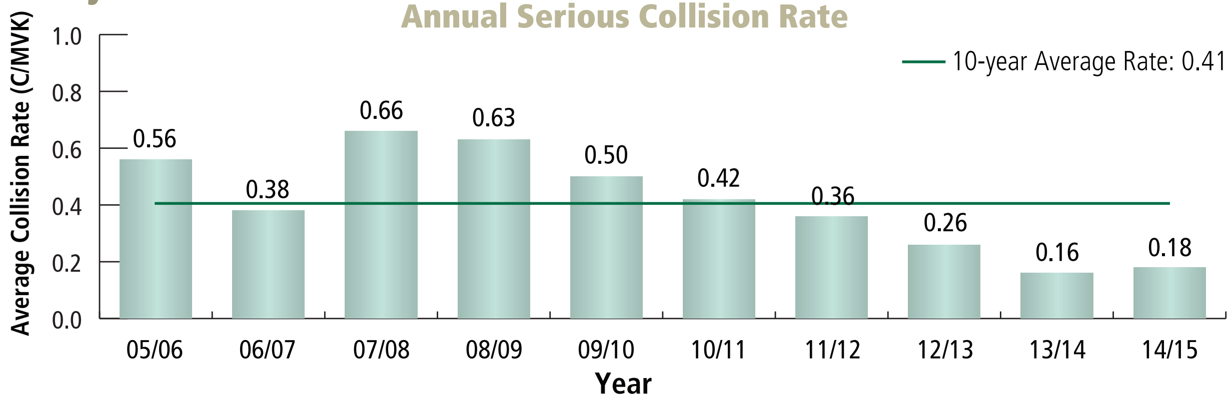
Implementation Date ....September 12, 2014

Current 85th Percentile Speed........... 109 km/h

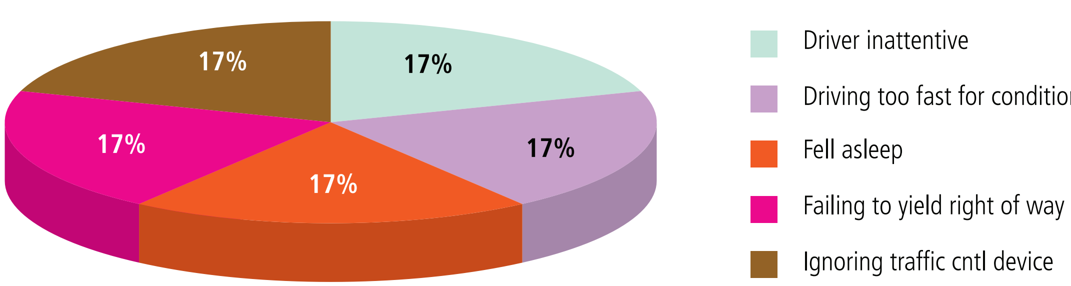
Change in 85th Percentile Speed..........+6 km/h

Safety Trends

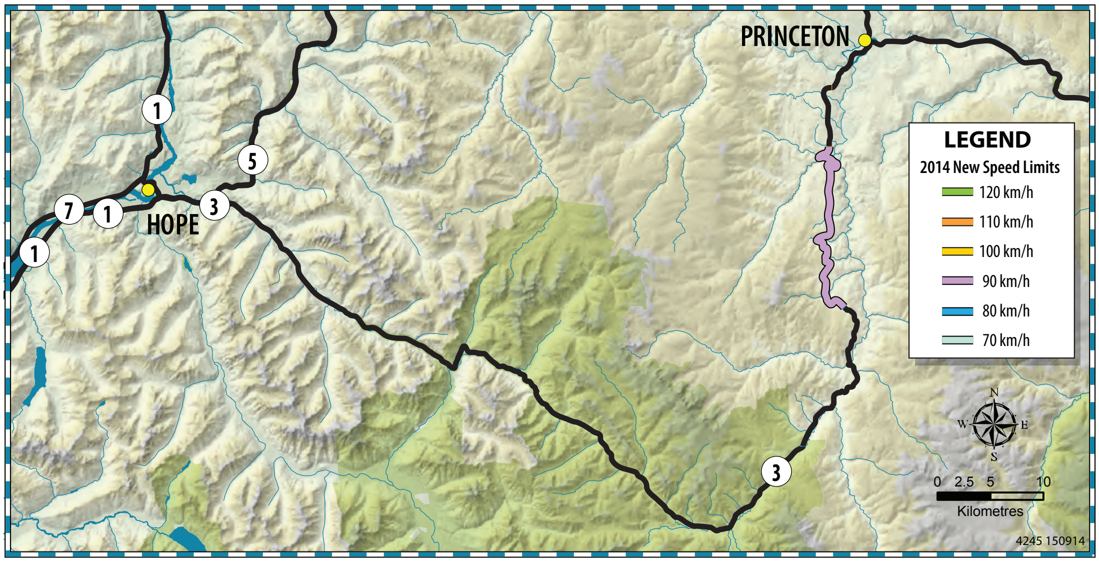
Annual Serious Collision Rate



Top 5 – 1st Contributing Factors (Nov. 1, 2014 to Oct. 31, 2015) *Post Implementation*



* These values may not add up to 100%, as there are other contributing factors.



Sunday Summit to Princeton

Physical Characteristics

Start Point: Sunday Summit

End Point: Whipsaw Creek

Length . . . . .22 km

Number of Lanes. 2

Divided . . . . No

Operational Characteristics

Average Daily Traffic 2,300

% Trucks. 13%

Previous Speed Limit. . . . . 80 km/h

Previous 85th Percentile Speed . . . . 103 km/h

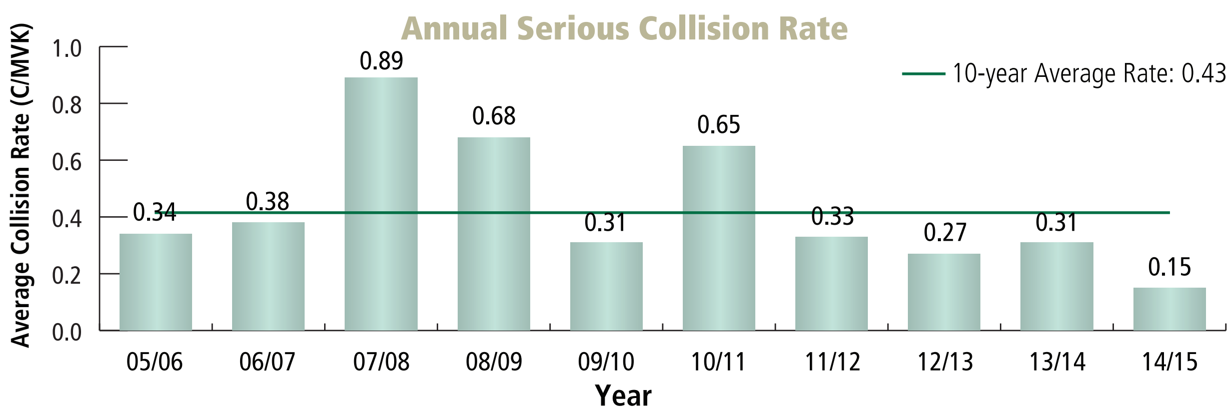
New Speed Limit . . . . .90 km/h

Implementation Date . . . . .September 12, 2014

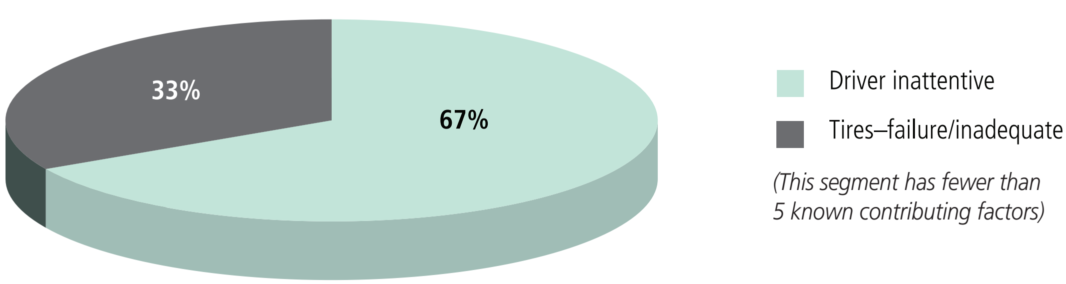
Current 85th Percentile Speed. 100

Change in 85th Percentile Speed. . . . .-3km/h

Safety Trends



Top 5 – 1st Contributing Factors (Nov. 1, 2014 to Oct. 31, 2015) *Post Implementation*



* These values may not add up to 100% as there are other contributing factors.

Hope to Kamloops

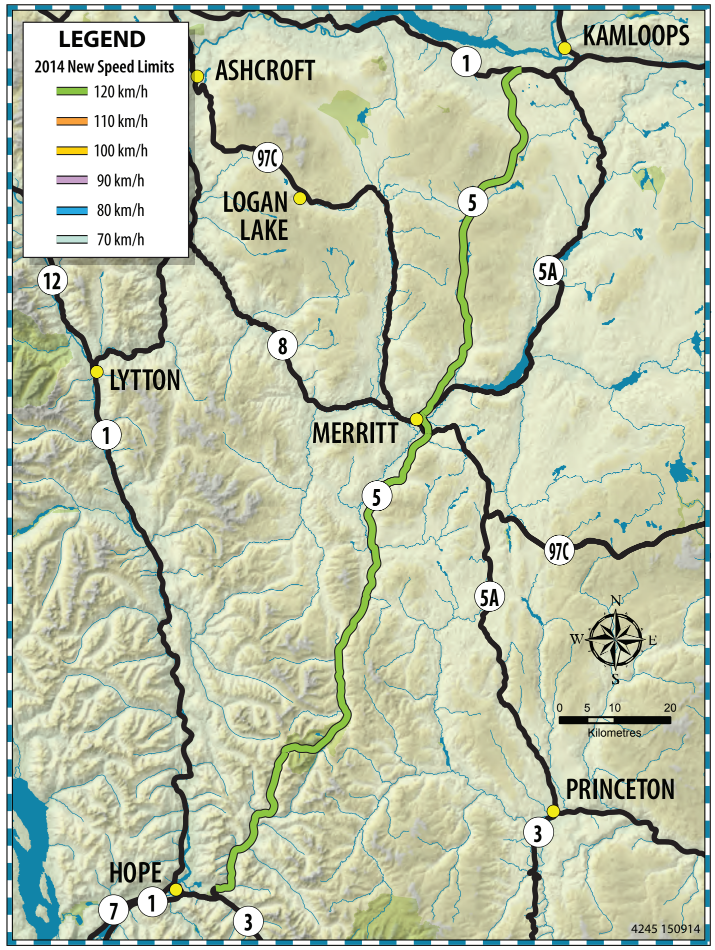
Physical Characteristics

Start Point: Othello Interchange
End Point: Hwy 1 junction

Length	180 km
Number of Lanes	4
Divided	No

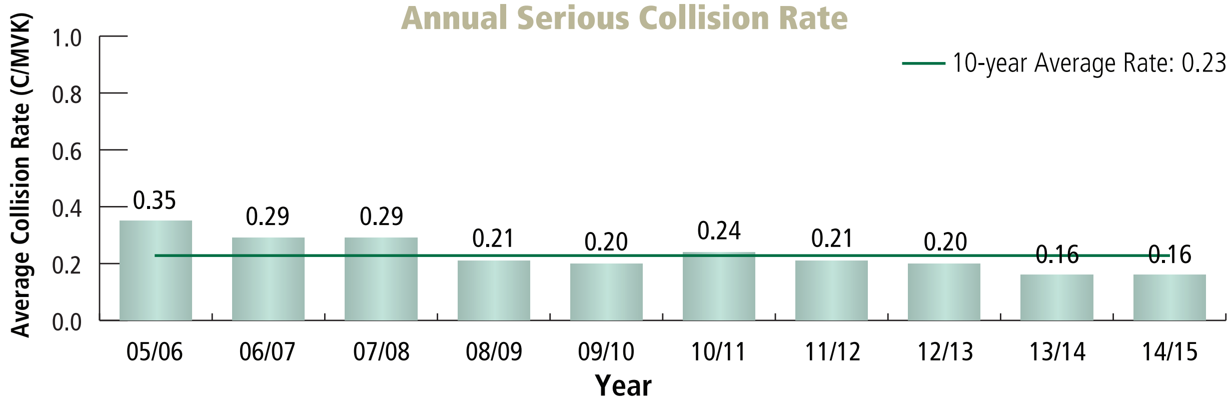
Operational Characteristics

Average Daily Traffic–Hope to Merritt	10,600
% Trucks	22%
Average Daily Traffic–Merritt to Kamloops	7,800
% Trucks	22%
Previous Speed Limit	110 km/h
Previous 85th Percentile Speed	127 km/h
New Speed Limit	**120 km/h**
Implementation Date	July 2, 2014
Current 85th Percentile Speed	127 km/h
Change in 85th Percentile Speed	0

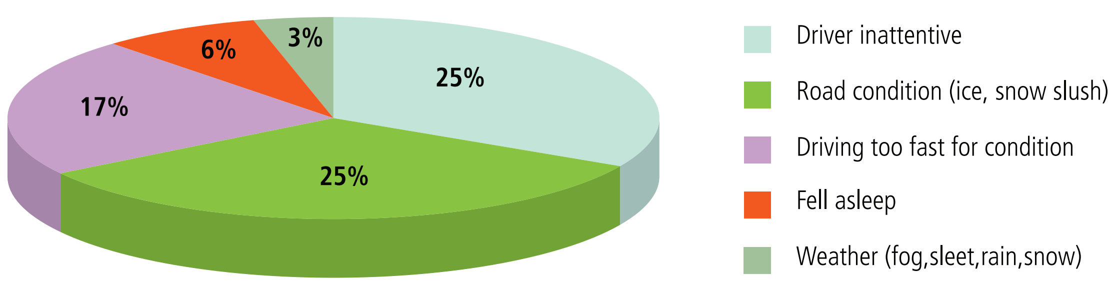


Safety Trends

Annual Serious Collision Rate



Top 5 – 1st Contributing Factors (Nov. 1, 2014 to Oct. 31, 2015) *Post Implementation*



* These values may not add up to 100%, as there are other contributing factors.

Heffley to Little Fort

Physical Characteristics

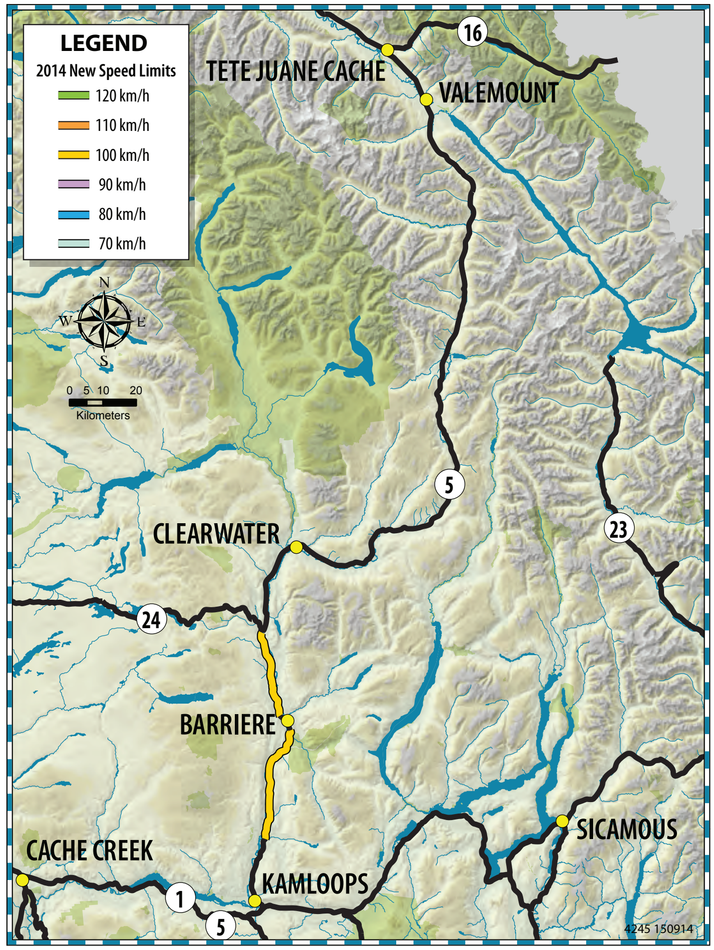
Start Point: Tod Mountain Rd

End Point: Hwy 24 junction

Length	67 km
Number of Lanes	2
Divided	No

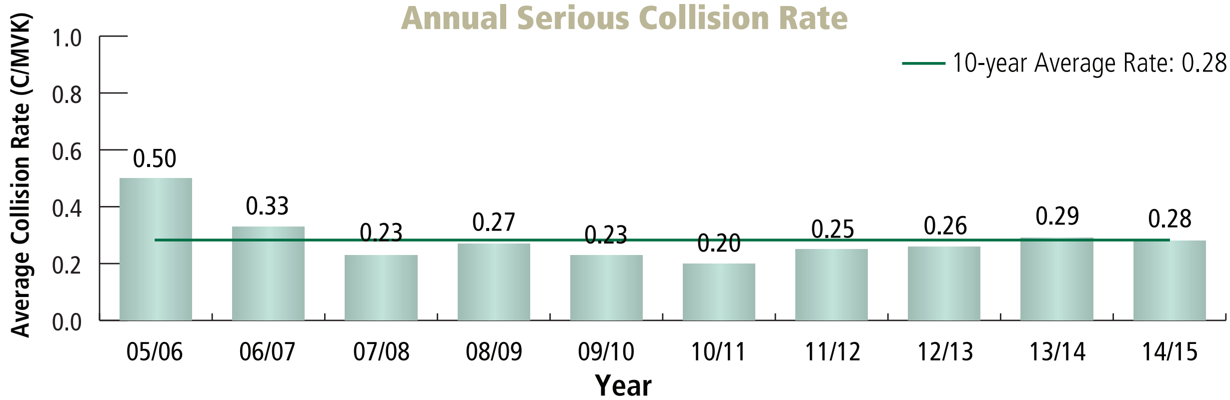
Operational Characteristics

Average Daily Traffic	5,000
% Trucks	15%
Previous Speed Limit	90 km/h
Previous 85th Percentile Speed	102 km/h
New Speed Limit	**100 km/h**
Implementation Date:	August 29, 2014
Current 85th Percentile Speed	111km/h
Change in 85th Percentile Speed	+9 km/h

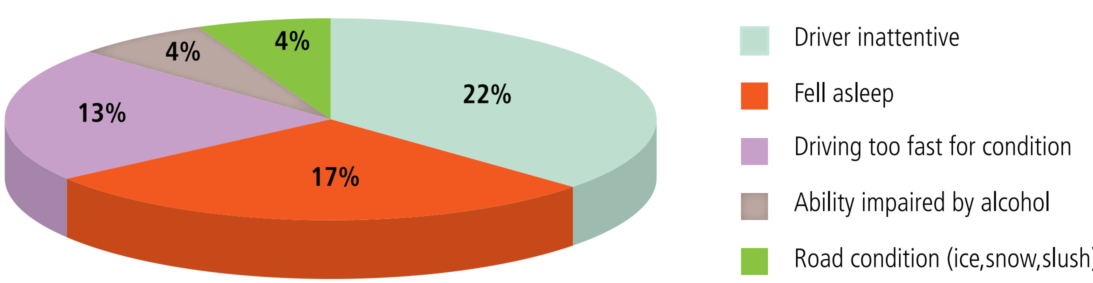


Safety Trends

Annual Serious Collision Rate



Top 5 – 1st Contributing Factors (Nov. 1, 2014 to Oct. 31, 2015) *Post Implementation*



* These values may not add up to 100%, as there are other contributing factors.

Princeton to TN Boundary (south of Aspen Grove)

Physical Characteristics

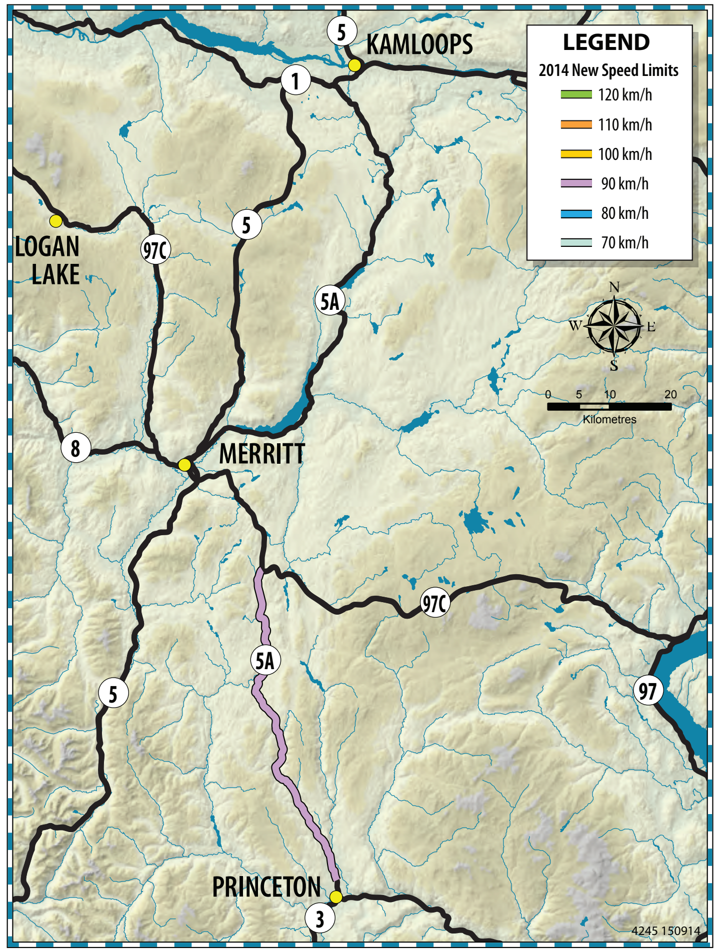
Start Point: Old Hedley Rd

End Point: Hwy 97C junction

Length	36 km
Number of Lanes	2
Divided	No

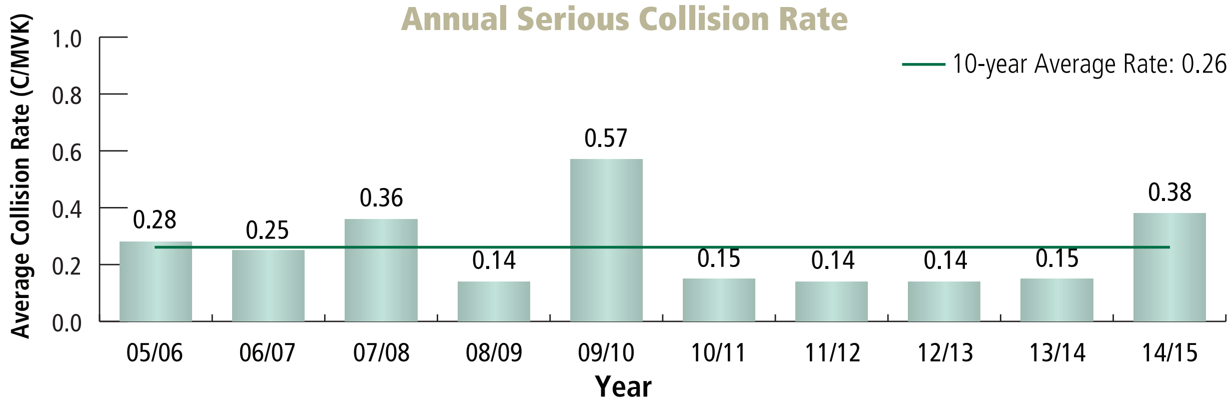
Operational Characteristics

Average Daily Traffic	1,200
% Trucks	n/a
Previous Speed Limit	80 km/h
Previous 85th Percentile Speed	99 km/h
New Speed Limit	**90 km/h**
Implementation Date	November 12, 2014
Current 85th Percentile Speed	104 km/h
Change in 85th Percentile Speed	+5 km/h

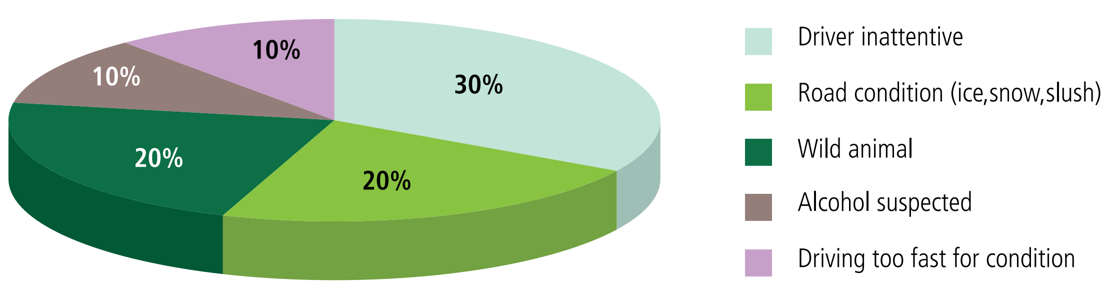


Safety Trends

Annual Serious Collision Rate



Top 5 – 1st Contributing Factors (Nov. 1, 2014 to Oct. 31, 2015) *Post Implementation*



* These values may not add up to 100%, as there are other contributing factors.

New Denver to Hills

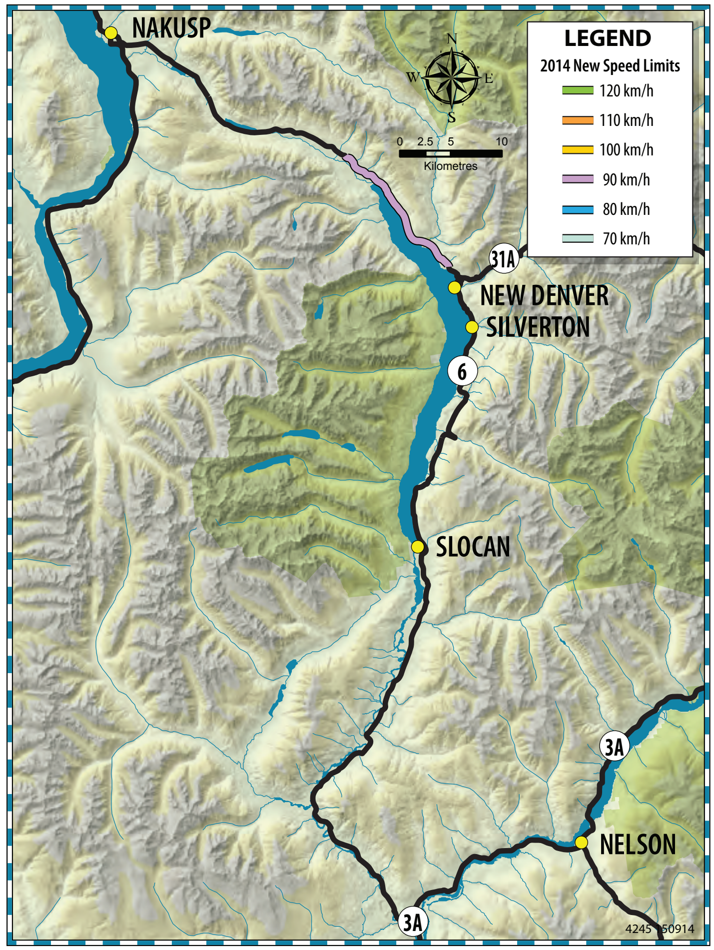
Physical Characteristics

Start Point: Golf Course Rd
End Point: Purdy Rd (Excluding 70 km/h through Hills)

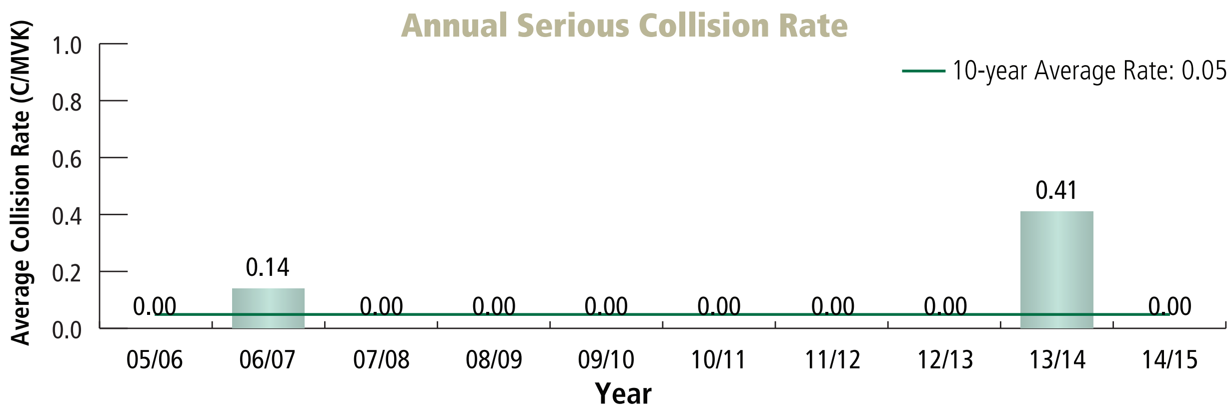
Length	15 km
Number of Lanes	2
Divided	No

Operational Characteristics

Average Daily Traffic	1,500
% Trucks	9%
Previous Speed Limit	80 km/h
Previous 85th Percentile Speed	99 km/h
New Speed Limit	**90 km/h**
Implementation Date	September 8, 2014
Current 85th Percentile Speed	97 km/h
Change in 86th Percentile Speed	-2 km/h



Safety Trends



No crashes reported in 2014/15 – post implementation period.

Summit Lake to Nakusp

Physical Characteristics

Start Point: Purdy Rd

End Point: Upper Brouse Rd

Length . . . . 22 km

Number of Lanes. 2

Divided . . . . No

Operational Characteristics

Average Daily Traffic 1,500

% Trucks. 9%

Previous Speed Limit. . . . . 90 km/h

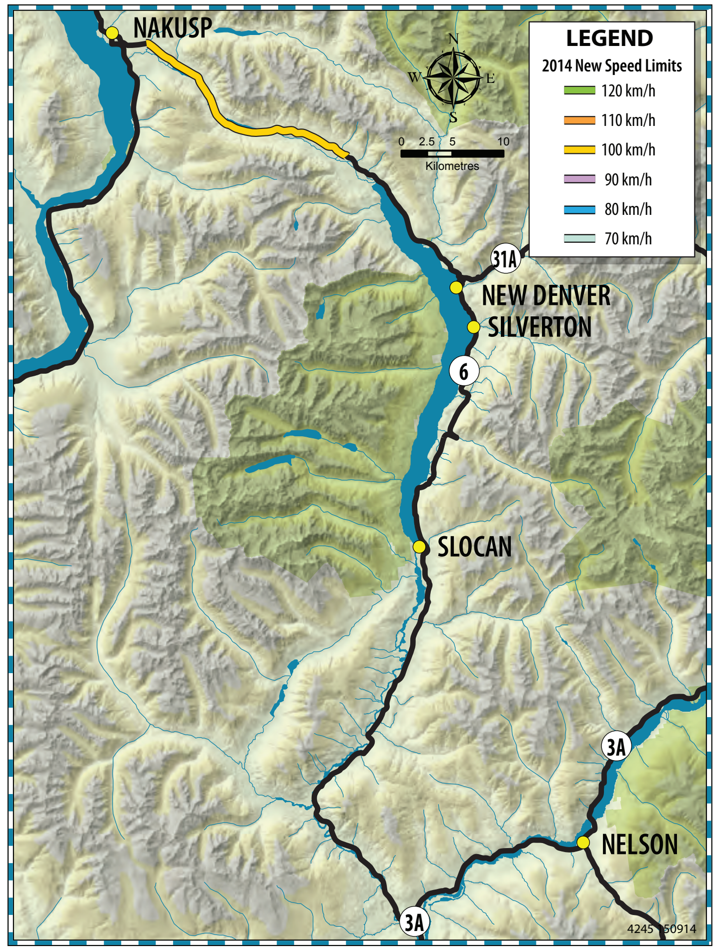
Previous 85th Percentile Speed . . . . 110 km/h

New Speed Limit . . . . 100 km/h

Implementation Date . . . . September 8, 2014

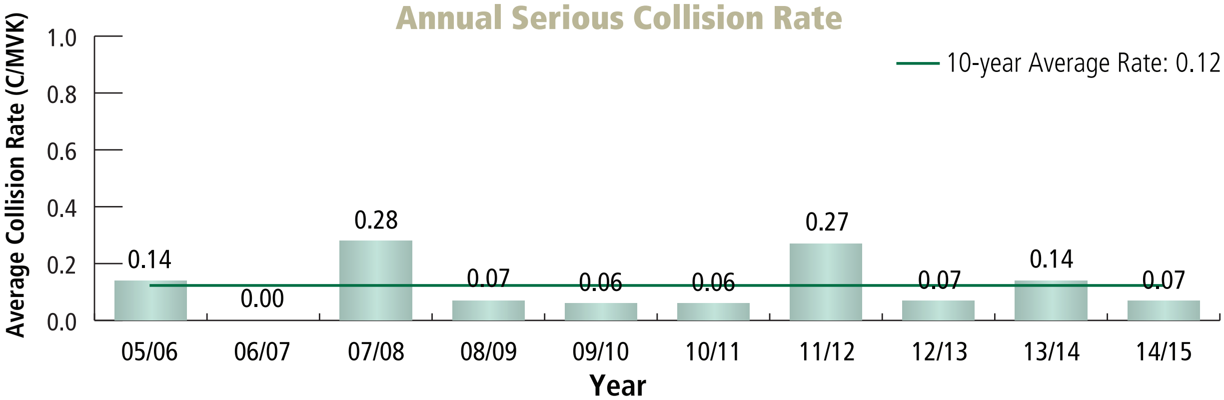
Current 85th Percentile Speed. . . . . 110 km/h

Change in 85th Percentile Speed. 0

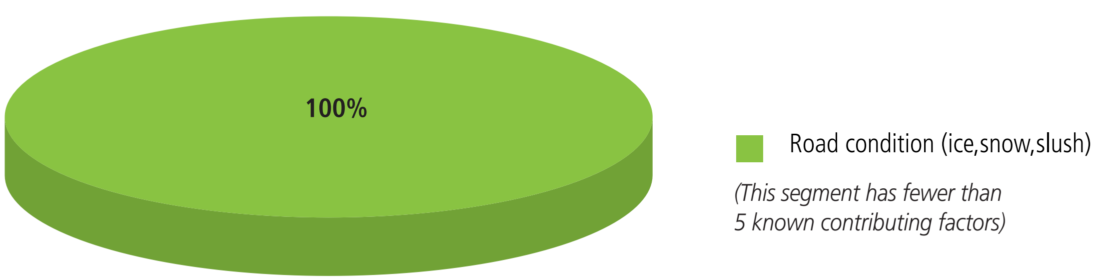


Safety Trends

Annual Serious Collision Rate



Top 5 – 1st Contributing Factors (Nov. 1, 2014 to Oct. 31, 2015) *Post Implementation*



(This segment has fewer than 5 known contributing factors)

* These values may not add up to 100%, as there are other contributing factors.

Agassiz to Hope

Physical Characteristics

Start Point: Pull Out west of Haigh Scale

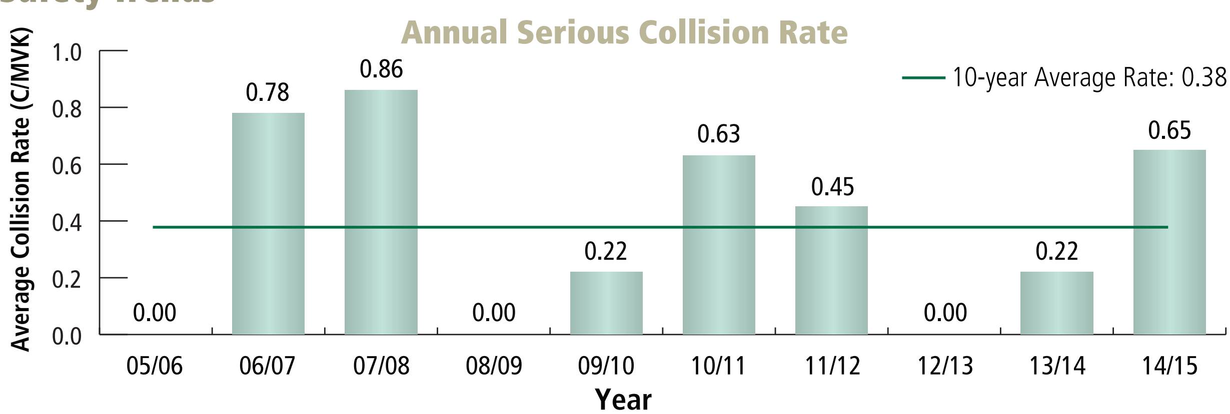
End Point: Junction with Hwy 1

Length	5 km
Number of Lanes	2
Divided	No

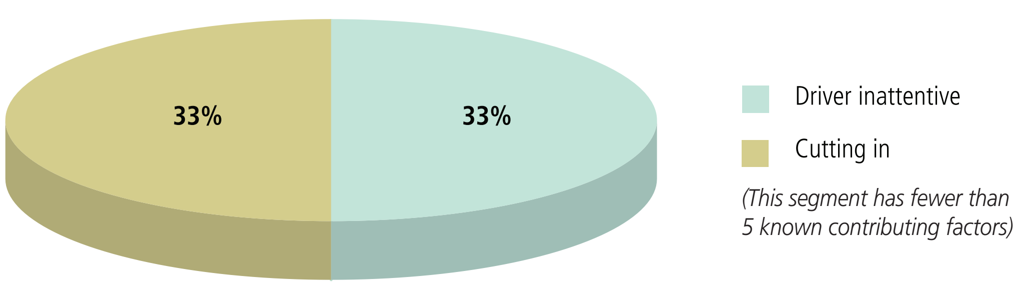
Operational Characteristics

Average Daily Traffic	4,900
% Trucks	9%
Previous Speed Limit	90/100 km/h
Previous 85th Percentile Speed	107 km/h
New Speed Limit	**100 km/h**
Implementation Date	September 12, 2015
Current 85th Percentile Speed	107 km/h
Change in 85th Percentile Speed	0

Safety Trends



Top 5 – 1st Contributing Factors (Nov. 1, 2014 to Oct. 31, 2015) *Post Implementation*



* These values may not add up to 100%, as there are other contributing factors.

Parkesville to Campbell River

Physical Characteristics

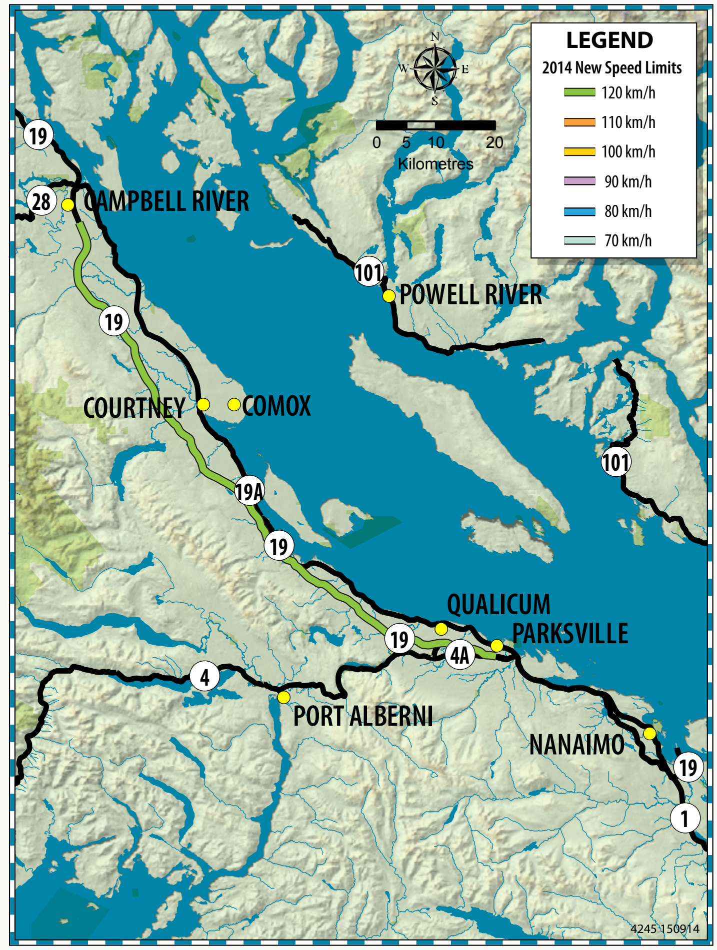
Start Point: 1 km north of exit to Parksville/Weigh Scale

End Point: South of Willis Rd

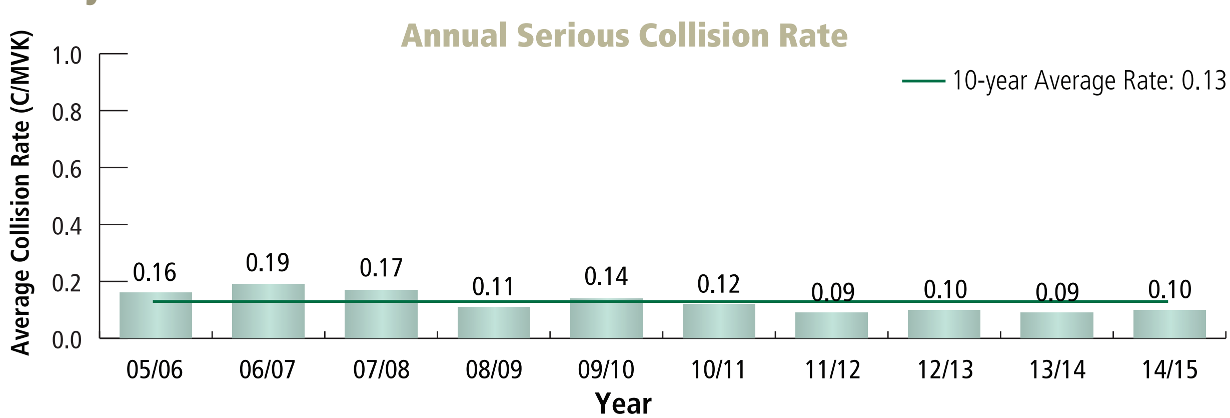
Length	114 km
Number of Lanes	4
Divided	Yes

Operational Characteristics

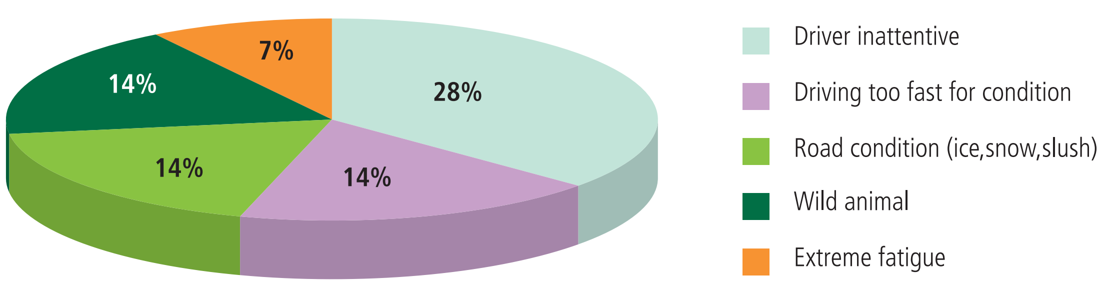
Average Daily Traffic	9,400
% Trucks	8%
Previous Speed Limit	90/110 km/h
Previous 85th Percentile Speed	121 km/h
New Speed Limit	**120 km/h**
Implementation Date	July 15, 2014
Current 85th Percentile Speed	125 km/h
Change in 85th Percentile Speed	+4 km/h



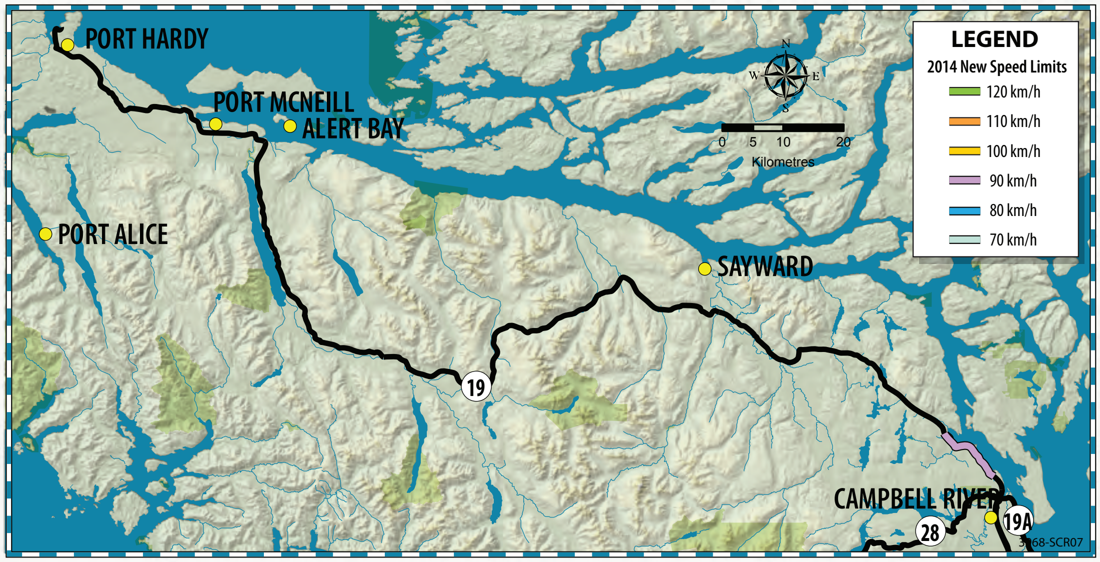
Safety Trends



Top 5 – 1st Contributing Factors (Nov. 1, 2014 to Oct. 31, 2015) *Post Implementation*



* These values may not add up to 100%, as there are other contributing factors.



Campbell River to Bloedel

Physical Characteristics

Start Point: North of Duncan Bay Rd

End Point: North of Mohun Creek Bridge

Length ....10 km

Number of Lanes.... 2

Divided .... No

Average Daily Traffic 1,200

% Trucks....7%

Operational Characteristics

Previous Speed Limit.... 80 km/h

Previous 85th Percentile Speed .... 95 km/h

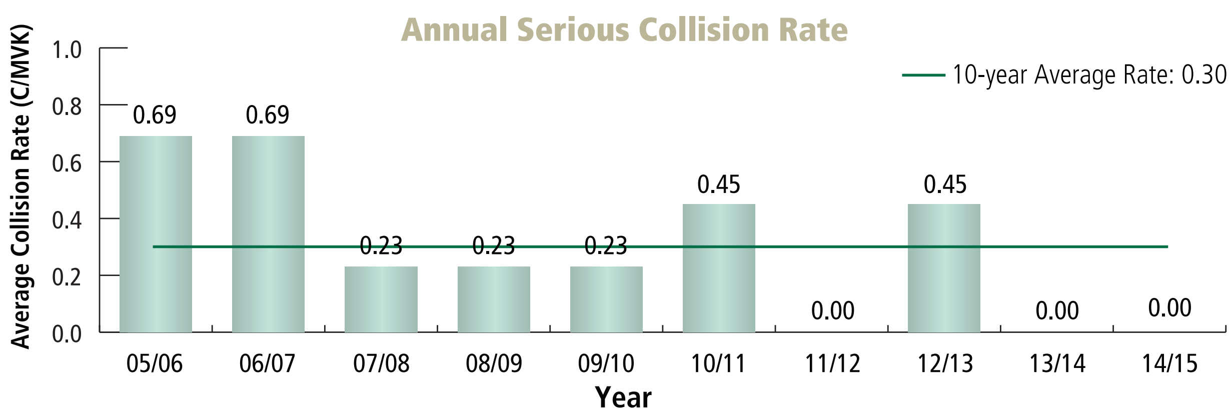
New Speed Limit ....90 km/h

Implementation Date .... August 28, 2014

Current 85th Percentile Speed.... 97 km/h

Change in 85th Percentile Speed....+2 km/h

Safety Trends



No crashes reported in 2014/15 – post implementation period.

Bloedel to Sayward

Physical Characteristics

Start Point: North of Mohun Creek Bridge

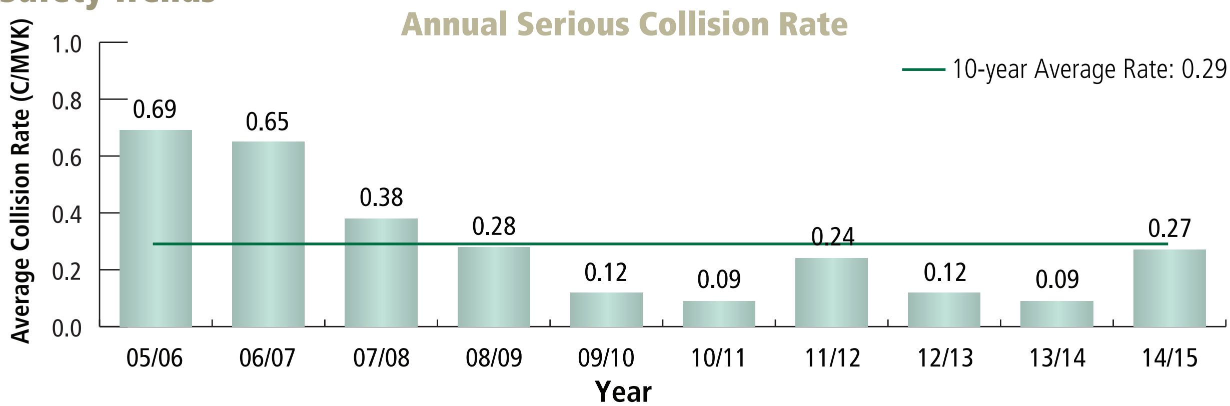
End Point: Gentry Rd

Length	44 km
Number of Lanes	2
Divided	No
Average Daily Traffic	1,200
% Trucks	7%

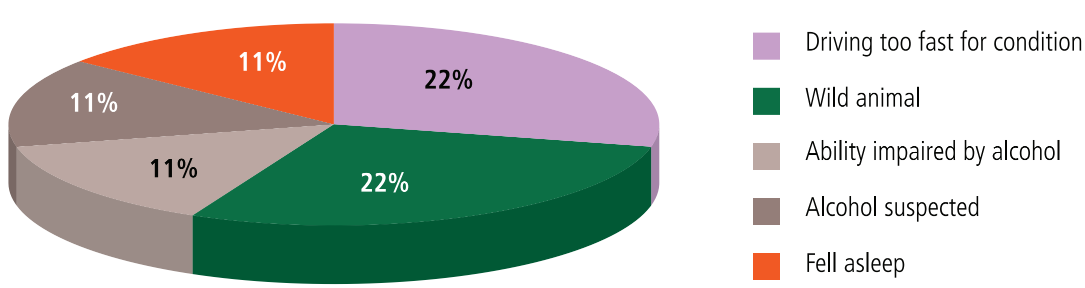
Operational Characteristics

Previous Speed Limit	90 km/h
Previous 85th Percentile Speed	106 km/h
New Speed Limit	**100 km/h**
Implementation Date	August 28, 2014
Current 85th Percentile Speed	107 km/h
Change in 85th Percentile Speed	+1 km/h

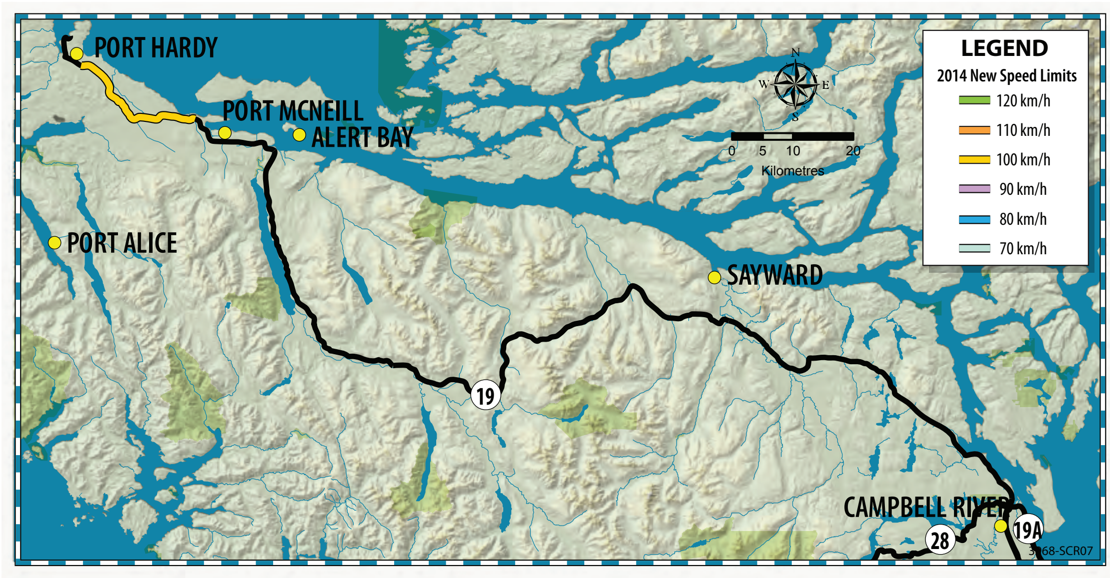
Safety Trends



Top 5 – 1st Contributing Factors (Nov. 1, 2014 to Oct. 31, 2015) *Post Implementation*



* These values may not add up to 100%, as there are other contributing factors.



Port McNeill to Port Hardy

Physical Characteristics

Start Point: Cluxewe Bridge

End Point: Douglas St

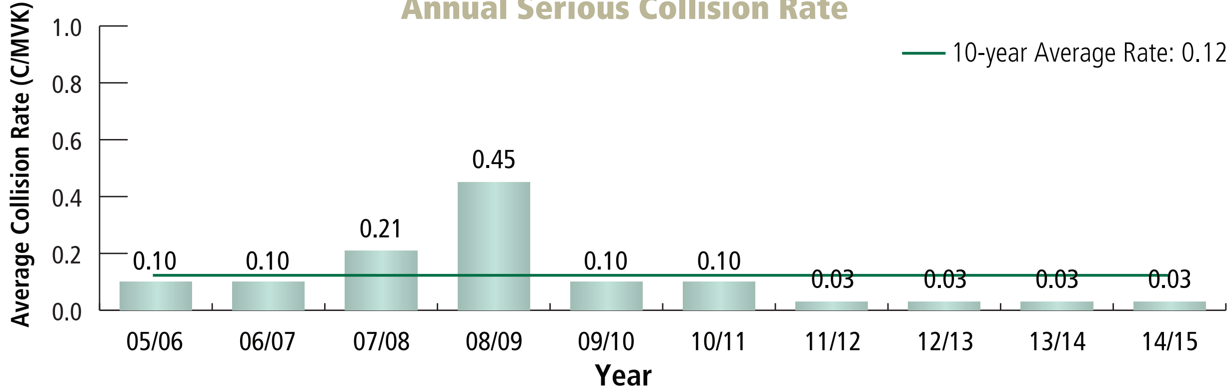
Length	25 km
Number of Lanes	2
Divided	No
Average Daily Traffic	1,200
% Trucks	7%

Operational Characteristics

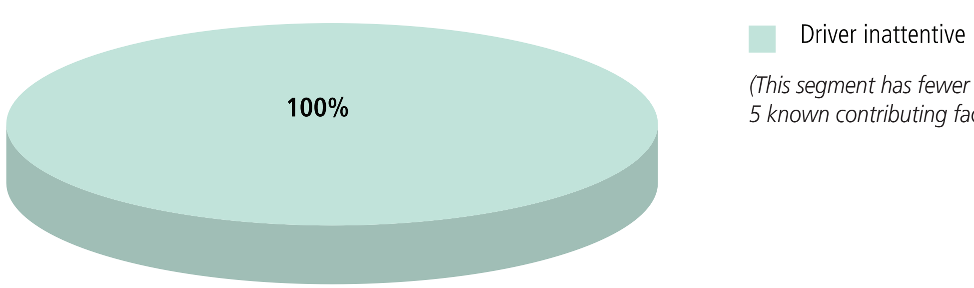
Previous Speed Limit	80/90 km/h
Previous 85th Percentile Speed	96 km/h
New Speed Limit	**100 km/h**
Implementation Date	August 28, 2014
Current 85th Percentile Speed	100 km/h
Change in 85th Percentile Speed	+4 km/h

Safety Trends

Annual Serious Collision Rate



Top 5 – 1st Contributing Factors (Nov. 1, 2014 to Oct. 31, 2015) *Post Implementation*



(This segment has fewer than 5 known contributing factors)

* These values may not add up to 100%, as there are other contributing factors.

Black Mountain to McCulloch Rd (District Boundary)

Physical Characteristics

Start Point: South of Brentwood Rd

End Point: North of Big White

Length . . . . .28 km

Number of Lanes. 2

Divided . . . . No

Operational Characteristics

Average Daily Traffic 2,000

% Trucks. . . . . .n/a

Safety: Overall Rock Creek to Kelowna corridor serious summer crashes trending down by 57%

Previous Speed Limit . . . . 90 km/h

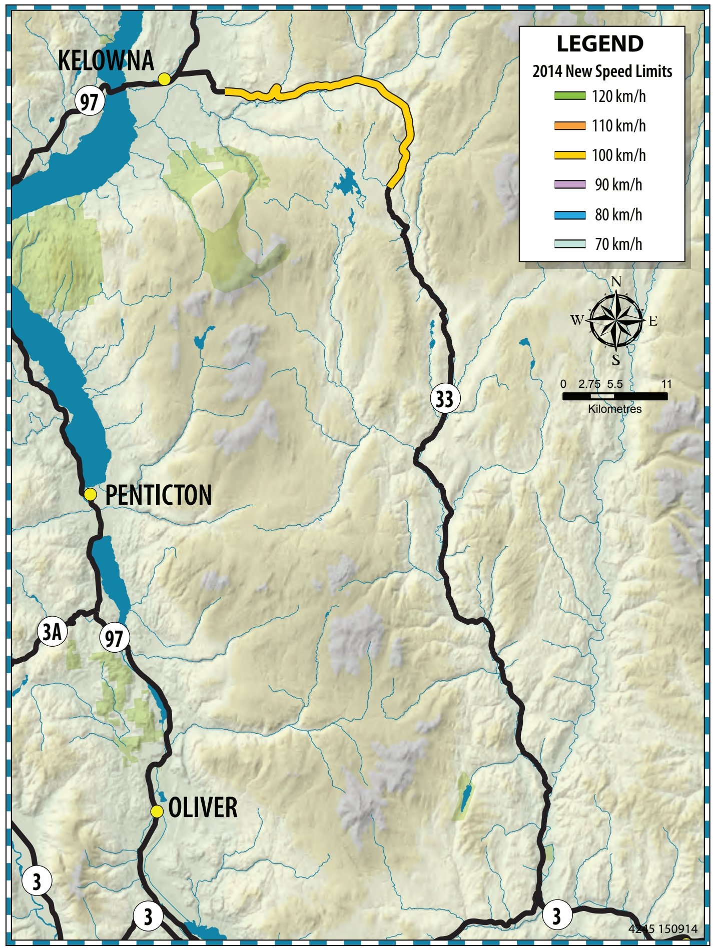
Previous 85th Percentile Speed . . . . 101 km/h

New Speed Limit . . . . .100 km/h

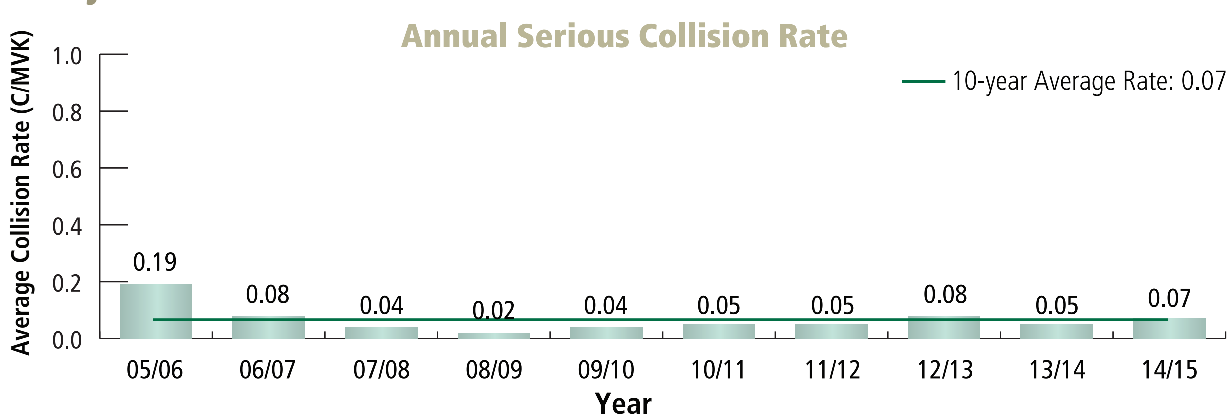
Implementation Date . . . . August 31, 2014

Current 85th Percentile Speed . . . . 106 km/h

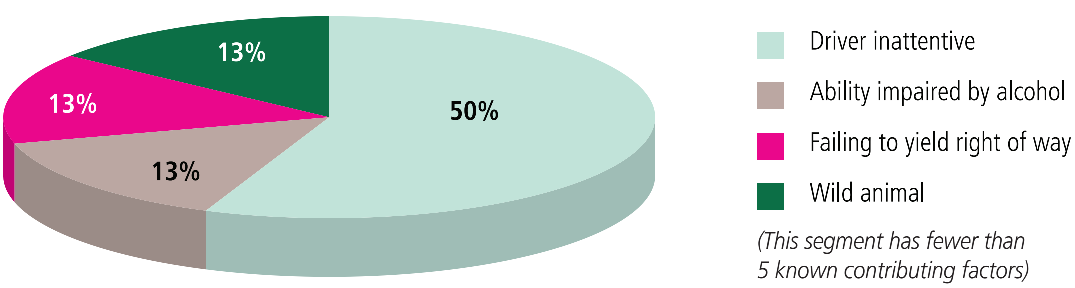
Change in 85th Percentile Speed . . . .+5 km/h



Safety Trends



Top 5 – 1st Contributing Factors (Nov. 1, 2014 to Oct. 31, 2015) *Post Implementation*



(This segment has fewer than 5 known contributing factors)

* These values may not add up to 100%, as there are other contributing factors.

Rock Creek to Westbridge

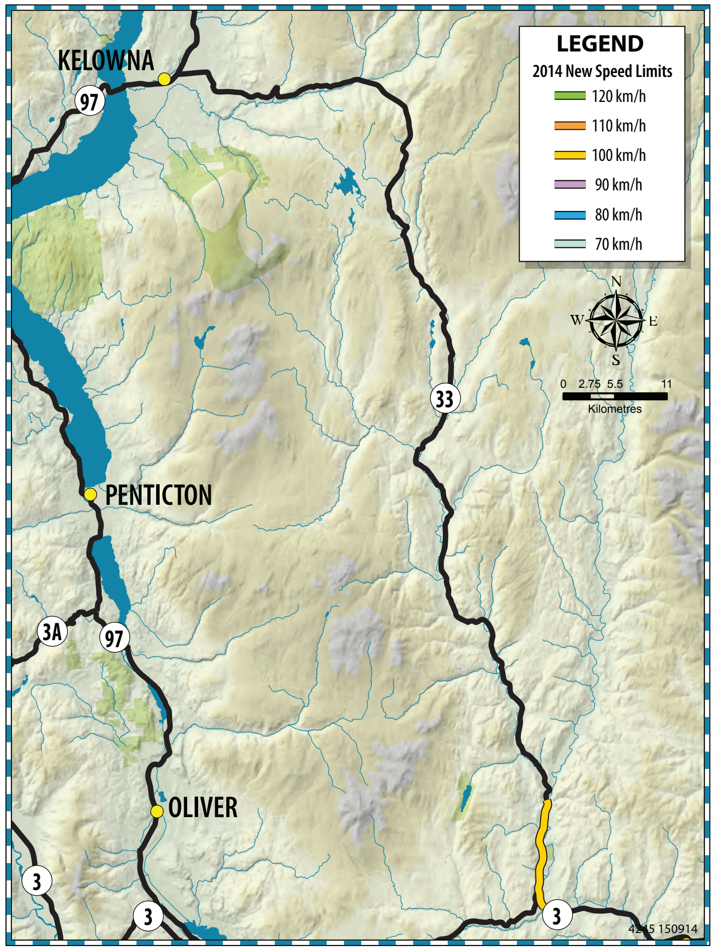
Physical Characteristics

Start Point: 1 km North of Junction with Hwy 3
End Point: 1 km south of Christian Valley Rd

Length	12 km
Number of Lanes	2
Divided	No

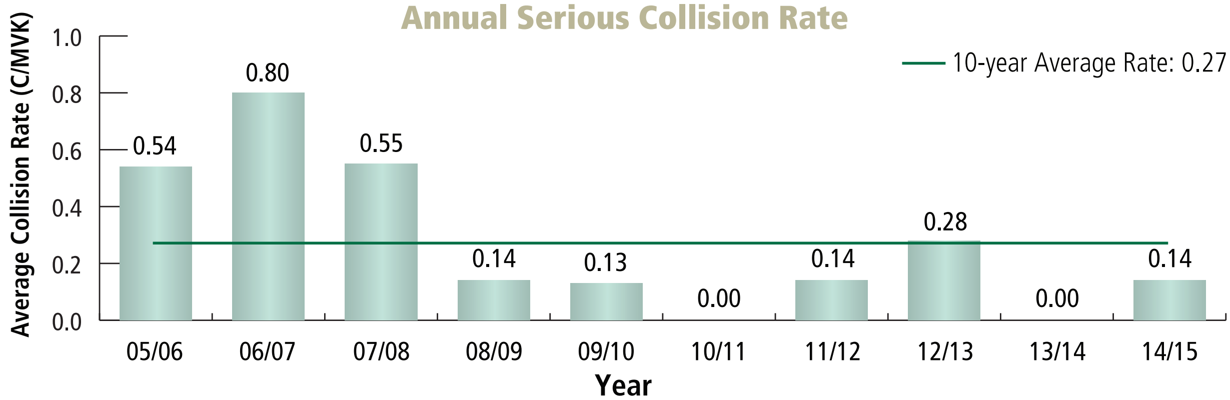
Operational Characteristics

Average Daily Traffic	2,000
% Trucks	n/a
Previous Speed Limit	90 km/h
Previous 85th Percentile Speed	110 km/h
New Speed Limit	**100 km/h**
Implementation Date	August 31, 2014
Current 85th Percentile Speed	108
Change in 85th Percentile Speed	-2 km/h

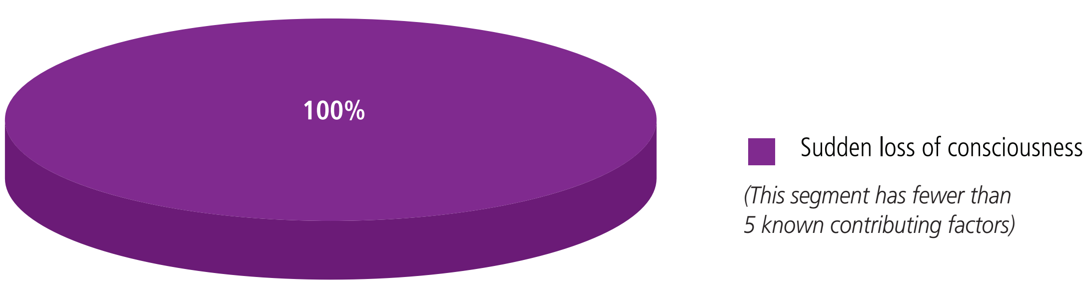


Safety Trends

Annual Serious Collision Rate



Top 5 – 1st Contributing Factors (Nov. 1, 2014 to Oct. 31, 2015) *Post Implementation*



(This segment has fewer than 5 known contributing factors)

* These values may not add up to 100%, as there are other contributing factors.

Cache Creek to 100 Mile House

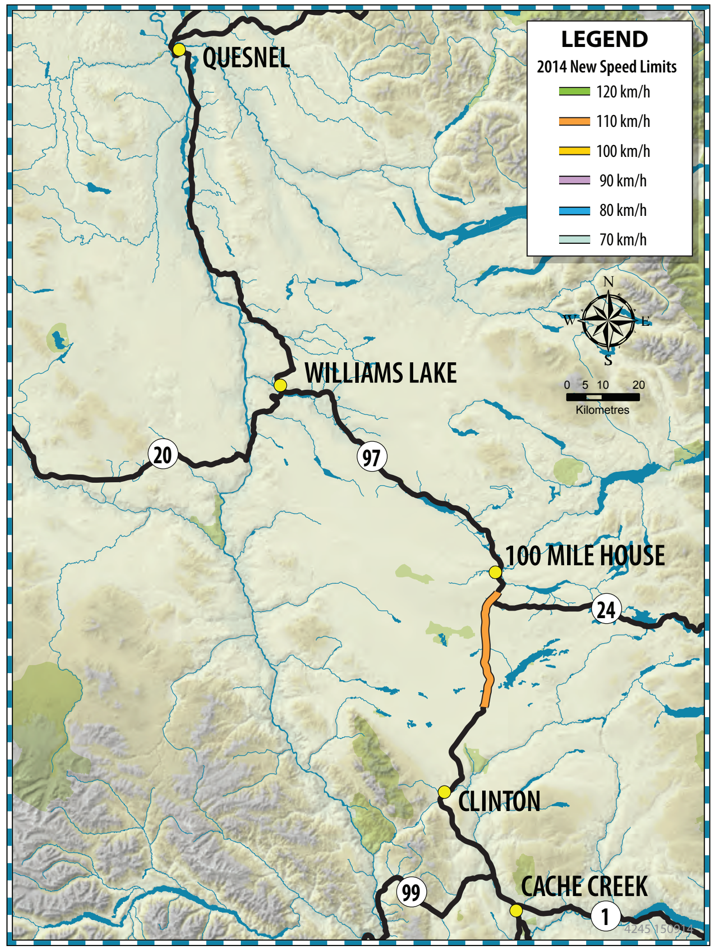
Physical Characteristics

Start Point: 1 km north of Willow Dr (70 Mile)
End Point: BCR Overpass (100 Mile)

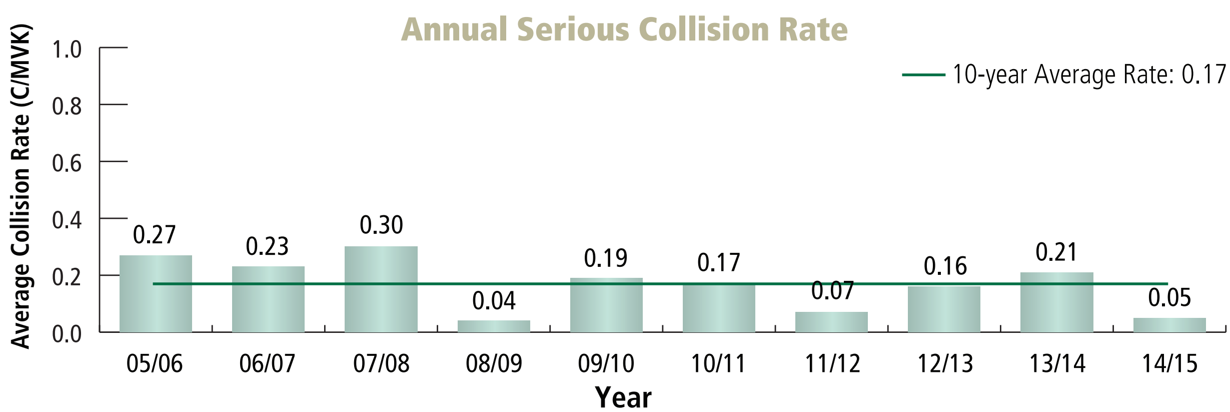
Length	37 km
Number of Lanes	4
Divided	No

Operational Characteristics

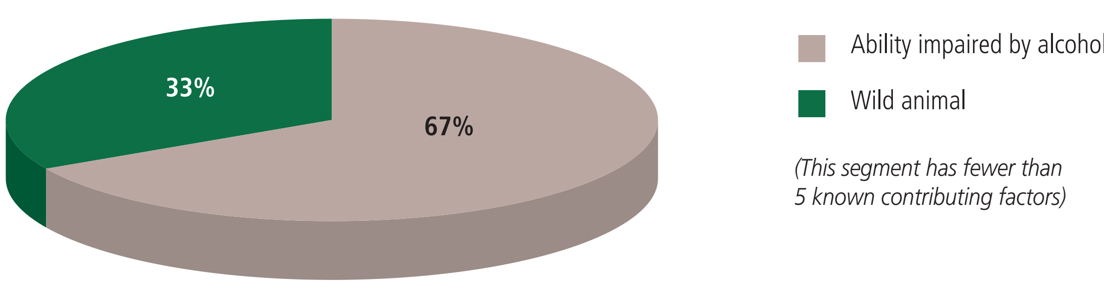
Average Daily Traffic	4,000
% Trucks	20%
Previous Speed Limit	100 km/h
Previous 85th Percentile Speed	114 km/h
New Speed Limit	**110 km/h**
Implementation Date	September 5, 2014
Current 85th Percentile Speed	117 km/h
Change in 85th Percentile Speed	+3 km/h



Safety Trends

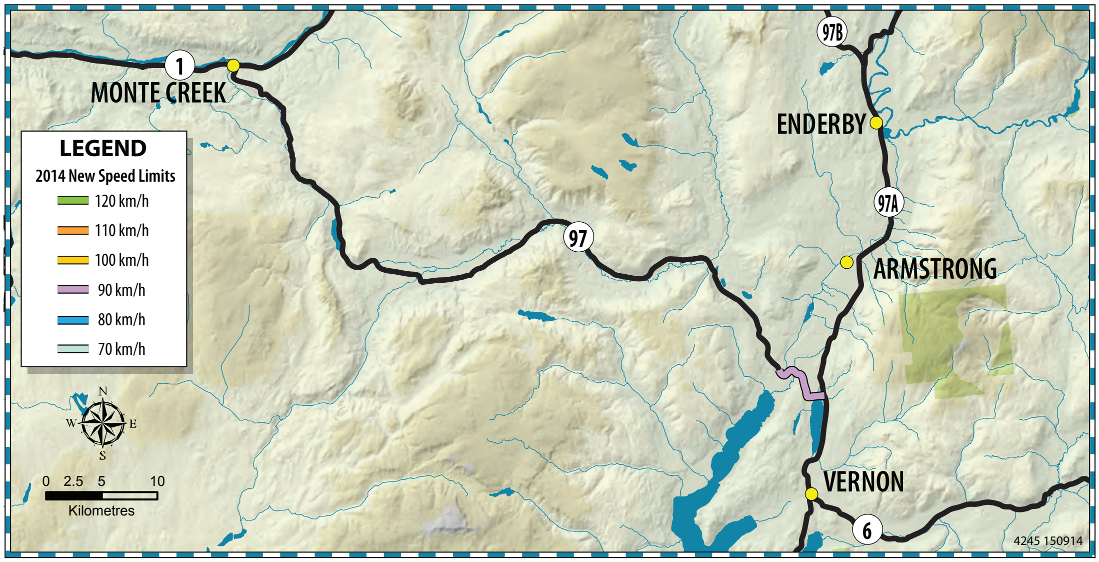


Top 5 – 1st Contributing Factors (Nov. 1, 2014 to Oct. 31, 2015) *Post Implementation*



(This segment has fewer than 5 known contributing factors)

* These values may not add up to 100%, as there are other contributing factors.



Swan Lake to Monte Creek

Physical Characteristics

Start Point: Hwy 97A junction (Swan Lake)

End Point: Westside Rd

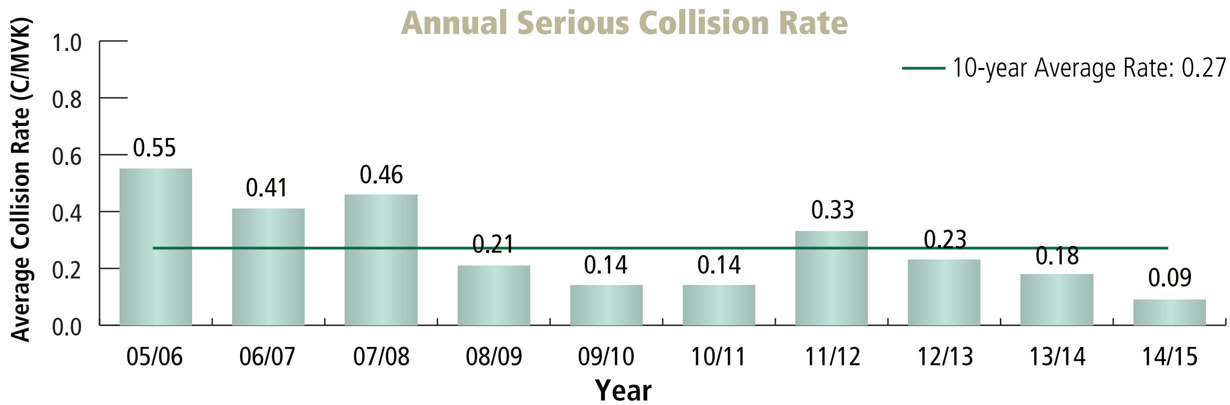
Length	6 km
Number of Lanes	2
Divided	No

Operational Characteristics

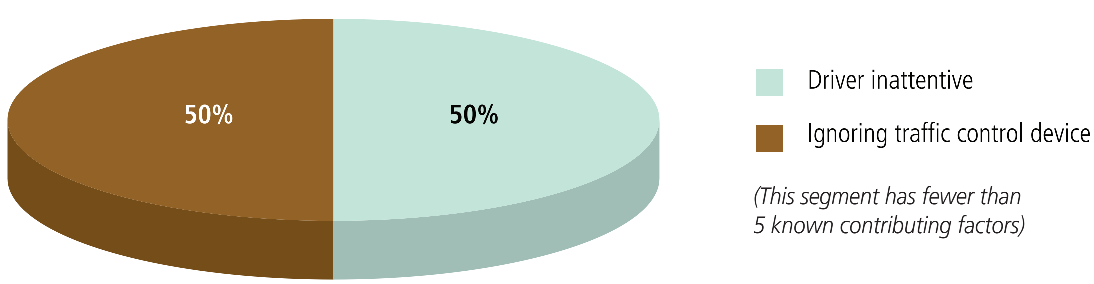
Average Daily Traffic	4,000
% Trucks	15%
Previous Speed Limit	80 km/h
Previous 85th Percentile Speed	91 km/h
New Speed Limit	**90 km/h**
Implementation Date	September 30, 2014
Current 85th Percentile Speed	97 km/h
Change in 85th Percentile Speed	+6 km/h

Safety Trends

Annual Serious Collision Rate



Top 5 – 1st Contributing Factors (Nov. 1, 2014 to Oct. 31, 2015) *Post Implementation*



(This segment has fewer than 5 known contributing factors)

* These values may not add up to 100%, as there are other contributing factors.

Armstrong to Enderby

Physical Characteristics

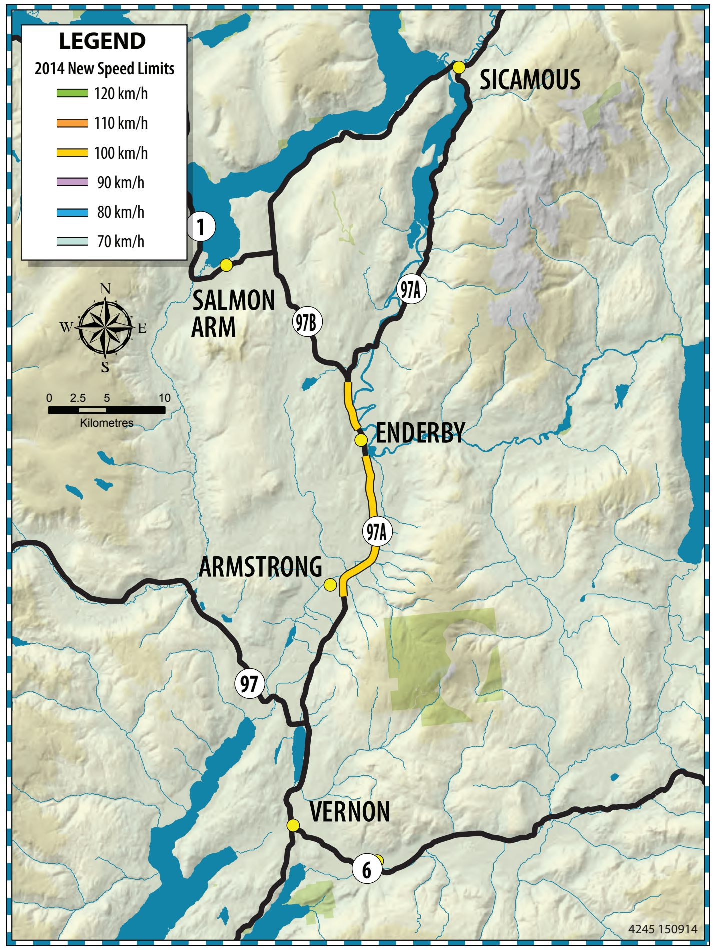
Start Point: North of Smith Dr

End Point: Hwy 97B junction (excluding 50 km/h in Enderby)

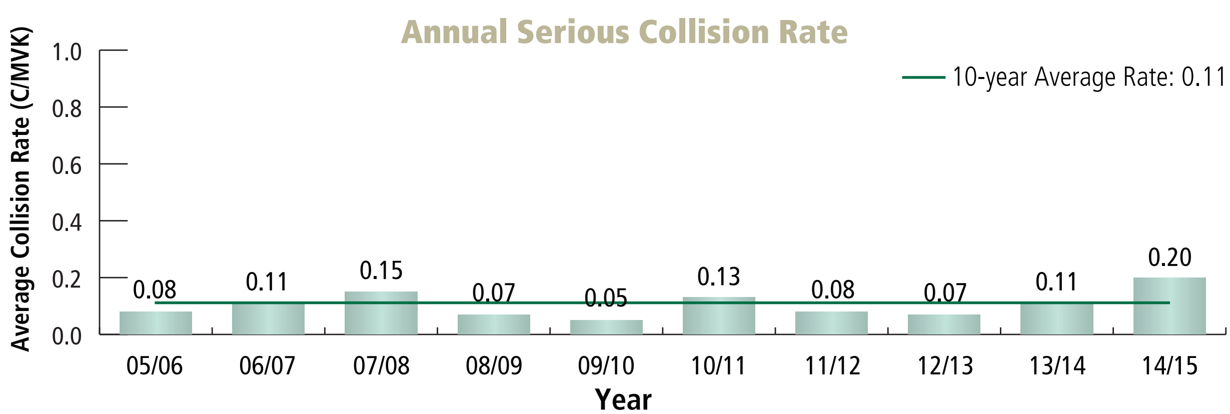
Length	18 km
Number of Lanes	2
Divided	No

Operational Characteristics

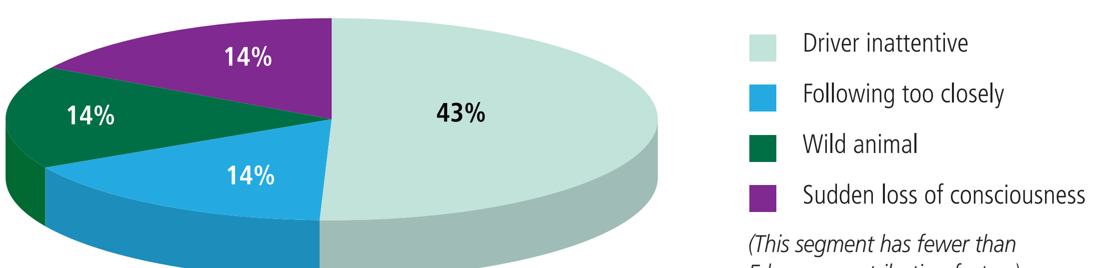
Average Daily Traffic	11,000
% Trucks	5%
Previous Speed Limit	90 km/h
Previous 85th Percentile Speed	101 km/h
New Speed Limit	**100 km/h**
Implementation Date	September 5, 2014
Current 85th Percentile Speed	98 km/h
Change in 85th Percentile Speed	-3 km/h



Safety Trends



Top 5 – 1st Contributing Factors (Nov. 1, 2014 to Oct. 31, 2015) *Post Implementation*



(This segment has fewer than 5 known contributing factors)

* These values may not add up to 100%, as there are other contributing factors.

Grindrod to Sicamous

Physical Characteristics

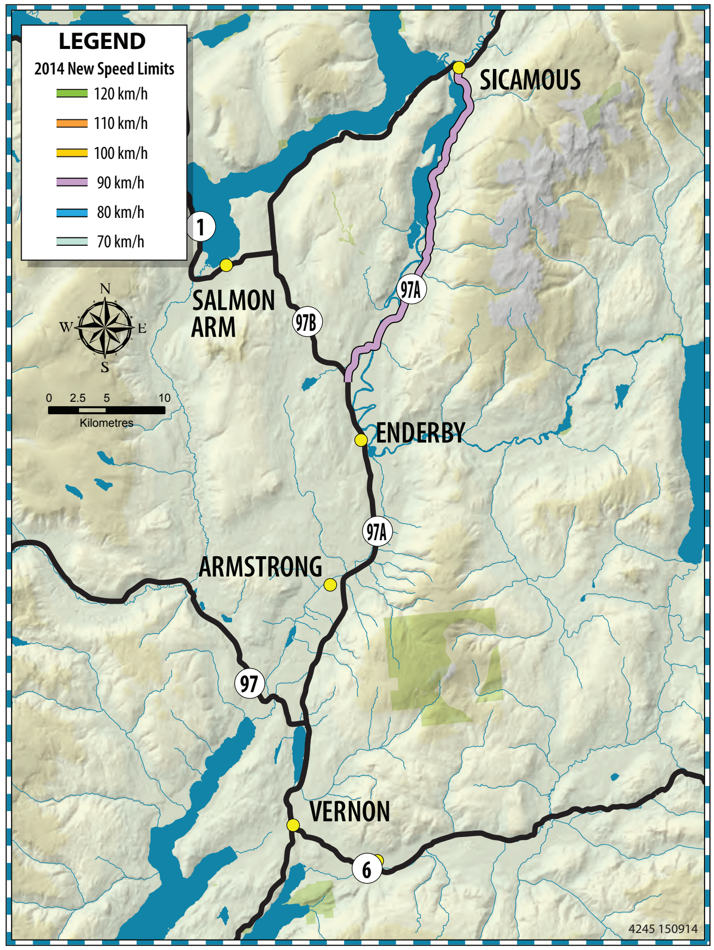
Start Point: Hwy 97B junction

End Point: Sicamous Creek Bridge
(excluding 50 km/h in Grindrod)

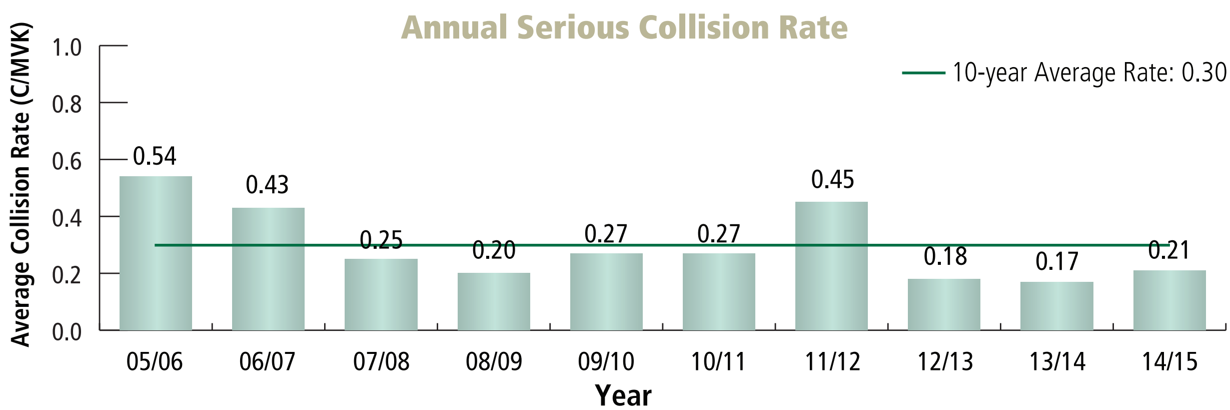
Length	33 km
Number of Lanes	2
Divided	No

Operational Characteristics

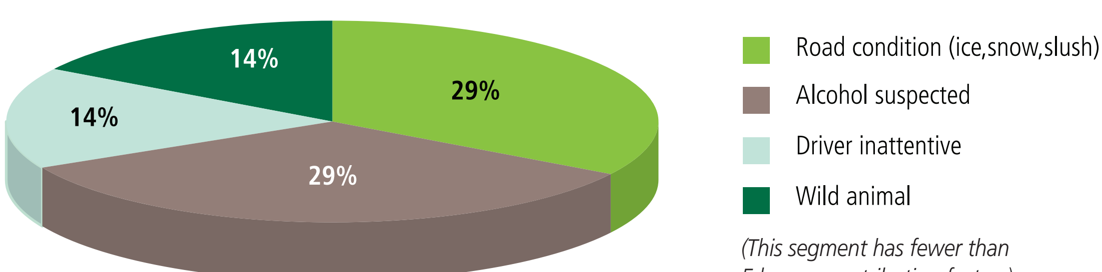
Average Daily Traffic	4,000
% Trucks	n/a
Previous Speed Limit	80 km/h
Previous 85th Percentile Speed	95 km/h
New Speed Limit	**90 km/h**
Implementation Date	September 30, 2014
Current 85th Percentile Speed	94 km/h
Change in 85th Percentile Speed	-1 km/h



Safety Trends

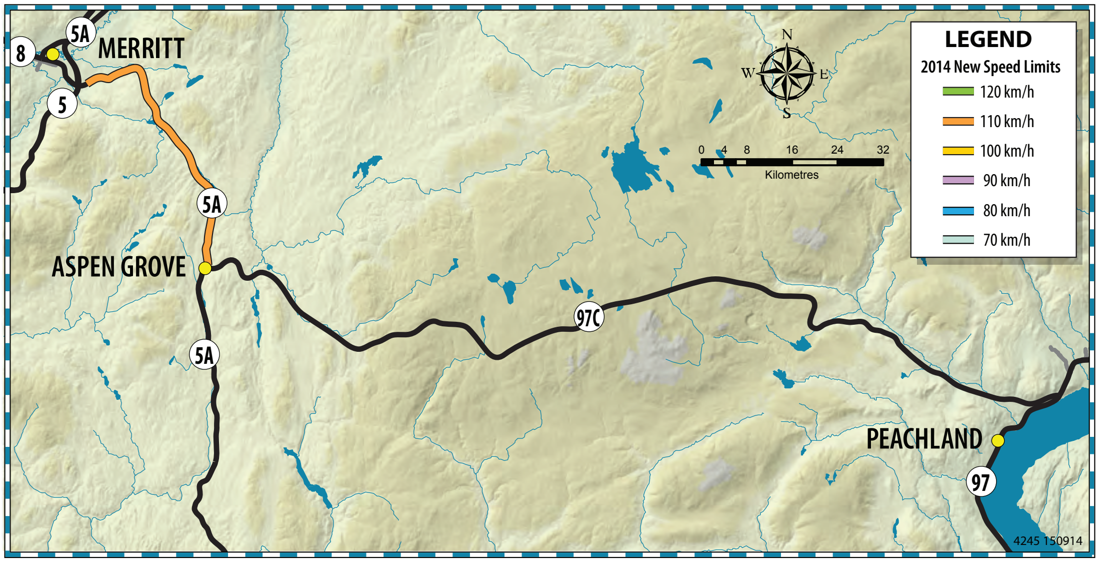


Top 5 – 1st Contributing Factors (Nov. 1, 2014 to Oct. 31, 2015) *Post Implementation*



(This segment has fewer than 5 known contributing factors)

* These values may not add up to 100%, as there are other contributing factors.



Merritt to Aspen Grove

Physical Characteristics

Start Point: Junction with Hwy 5 Coquihalla (Coldwater Interchange)

End Point: Junction with Hwy 5A (Aspen Grove Interchange)

Length . . . . 22 km

Number of Lanes. 4

Divided. . . . . No

Operational Characteristics

Average Daily Traffic 5,500

% Trucks. 15%

Previous Speed Limit. . . . . 100 km/h

Previous 85th Percentile Speed . . . . 123 km/h

New Speed Limit . . . . 110 km/h

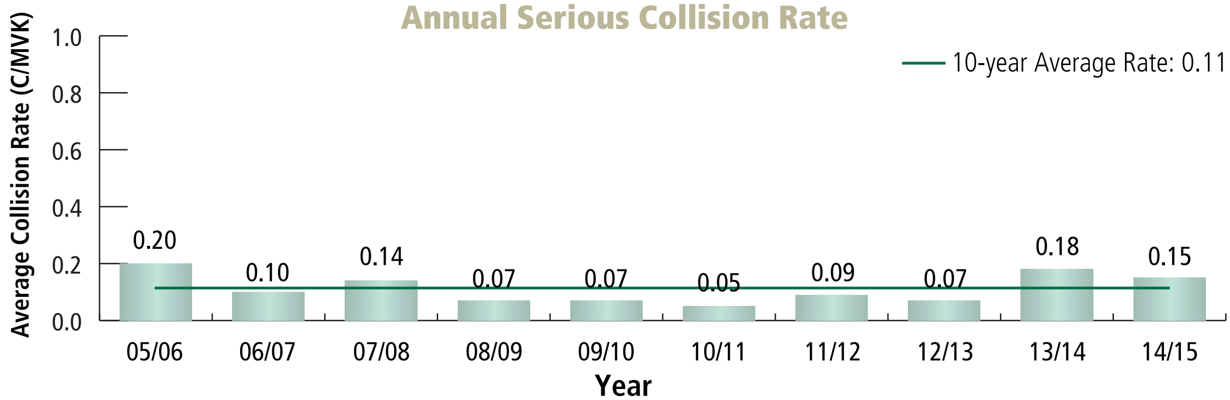
Implementation Date . . . . July 2, 2014

Current 85th Percentile Speed. . . . . 123 km/h

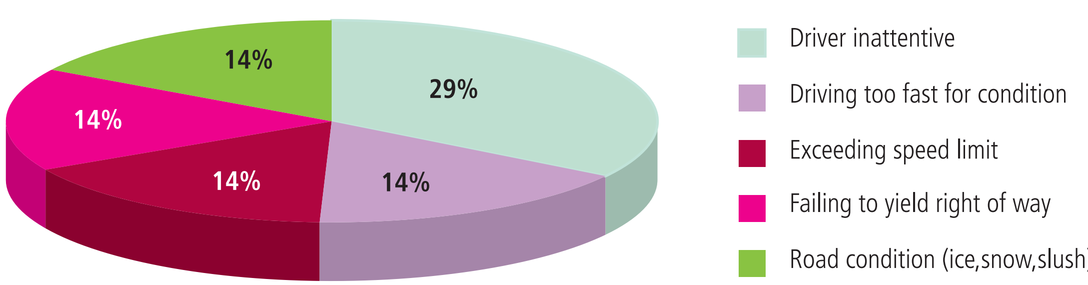
Change in 85th Percentile Speed. 0

Safety Trends

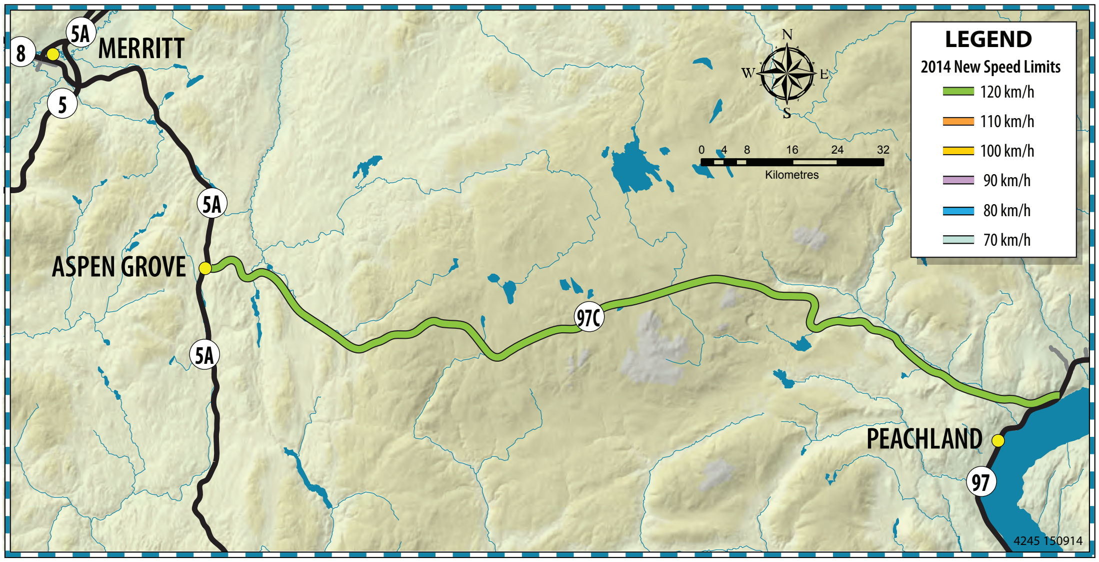
Annual Serious Collision Rate



Top 5 – 1st Contributing Factors (Nov. 1, 2014 to Oct. 31, 2015) *Post Implementation*



* These values may not add up to 100%, as there are other contributing factors.



Aspen Grove to Peachland

Physical Characteristics

Start Point: Junction with Hwy 5A (Aspen Grove)

End Point: Junction with Hwy 97 (Drought Hill Interchange)

Length . . . . .78 km

Number of Lanes. 4

Divided . . . . .Yes

Operational Characteristics

Average Daily Traffic 6,000

% Trucks. 15%

Previous Speed Limit. . . . . 110 km/h

Previous 85th Percentile Speed . . . . 126 km/h

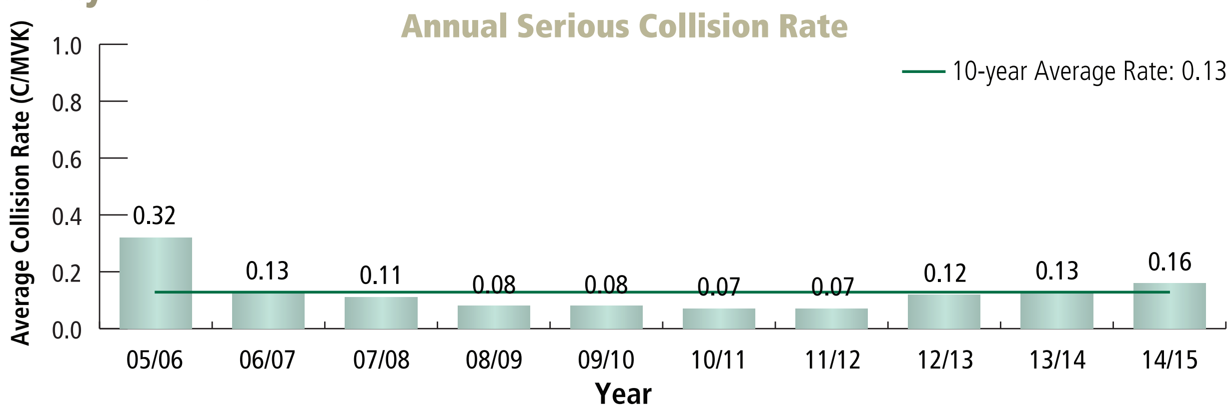
New Speed Limit . . . . .120 km/h

Implementation Date . . . . July 2, 2014

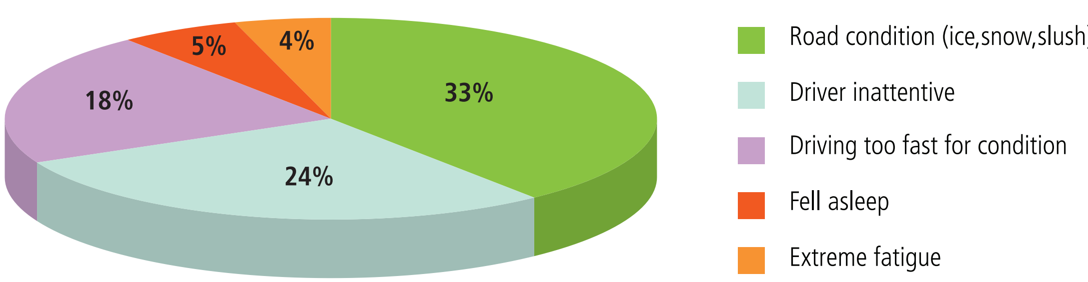
Current 85th Percentile Speed. . . . . 126 km/h

Change in 85th Percentile Speed. 0

Safety Trends



Top 5 – 1st Contributing Factors (Nov. 1, 2014 to Oct. 31, 2015) *Post Implementation*



* These values may not add up to 100%, as there are other contributing factors.

Horseshoe Bay to Squamish

Physical Characteristics

First Start Point: Eagle Ridge Interchange

End Point: South of Stawamus River Bridge

Length . . . . .35 km

Number of Lanes. 4

Divided . . . . Yes

Operational Characteristics

Average Daily Traffic 10,800

% Trucks. 2%

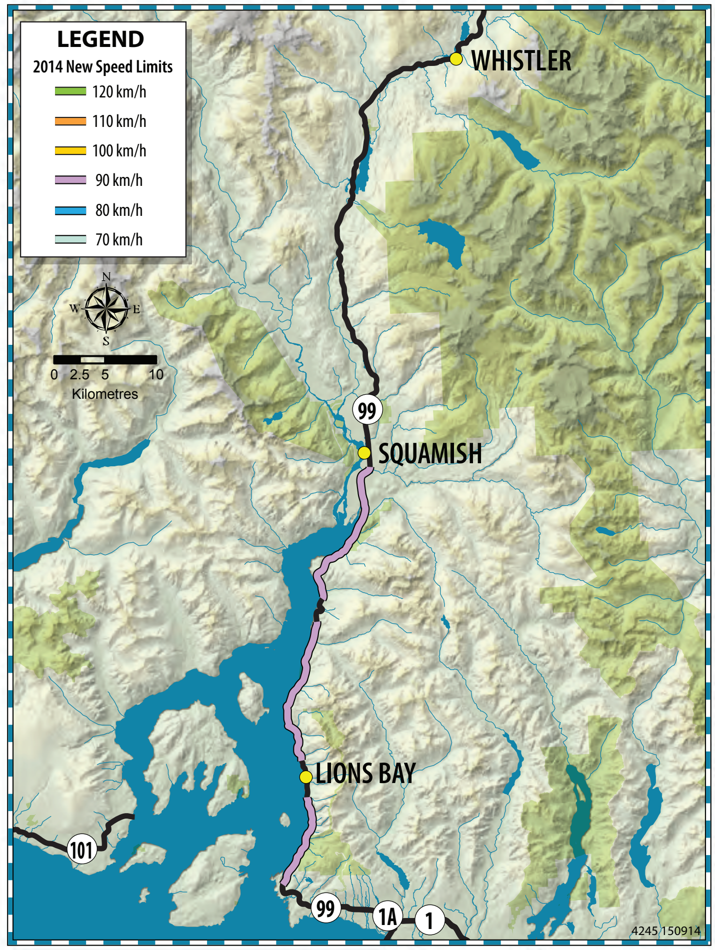
Previous Speed Limit. . . . . 80 km/h

Previous 85th Percentile Speed . . . . 102 km/h

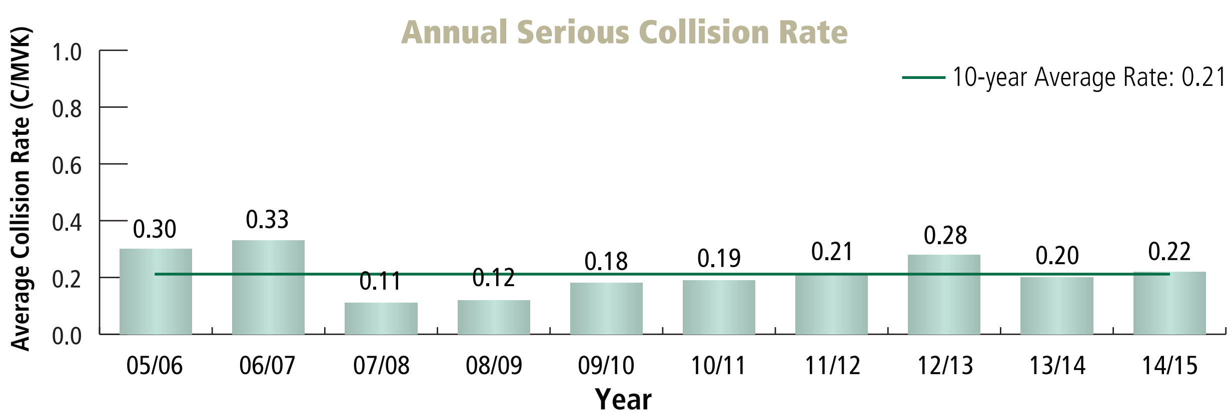
New Speed Limit . . . . .90 km/h

Implementation DateSeptember 12, 2014 Current 85th Percentile Speed . . . . 104 km/h

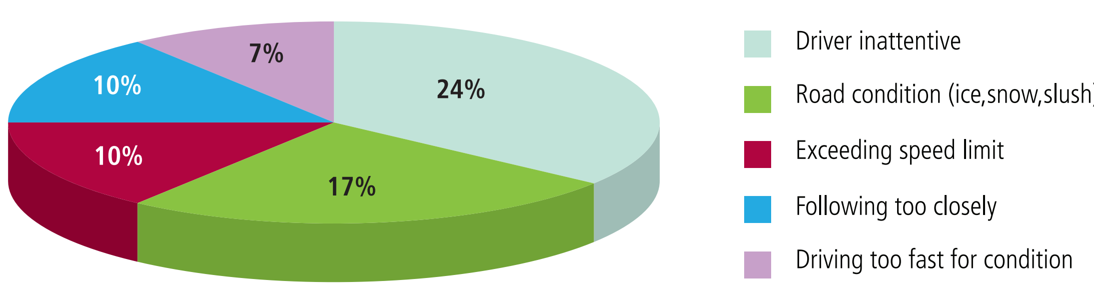
Change in 85th Percentile Speed. . . . .+2 km/h



Safety Trends



Top 5 – 1st Contributing Factors (Nov. 1, 2014 to Oct. 31, 2015) *Post Implementation*



* These values may not add up to 100%, as there are other contributing factors.

Squamish to Whistler

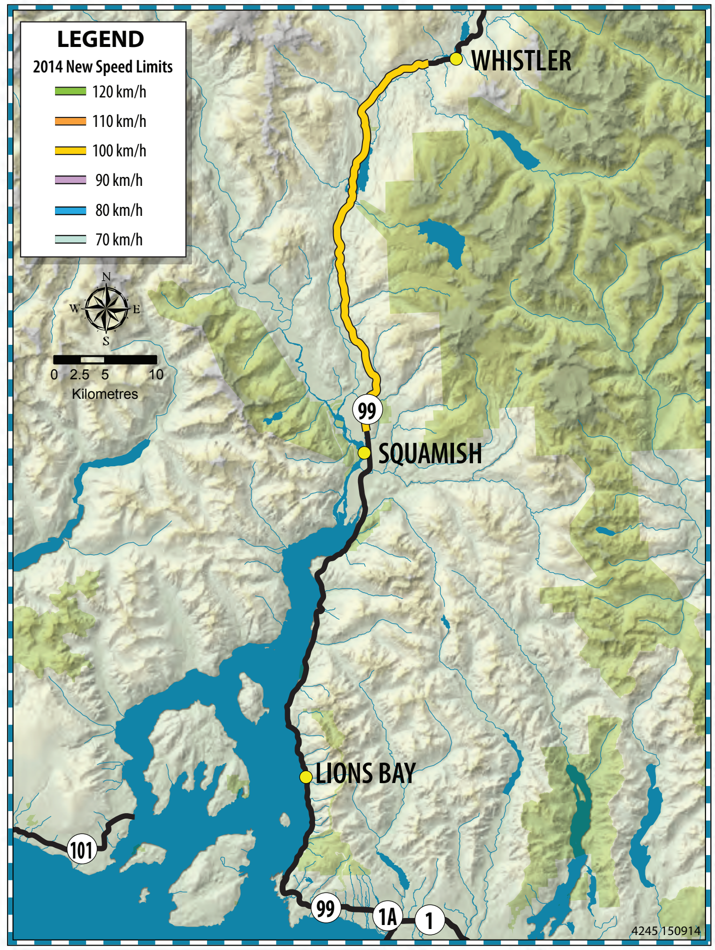
Physical Characteristics

Start Point: North of Depot Rd
End Point: Alpha Lake Rd (Function Junction)

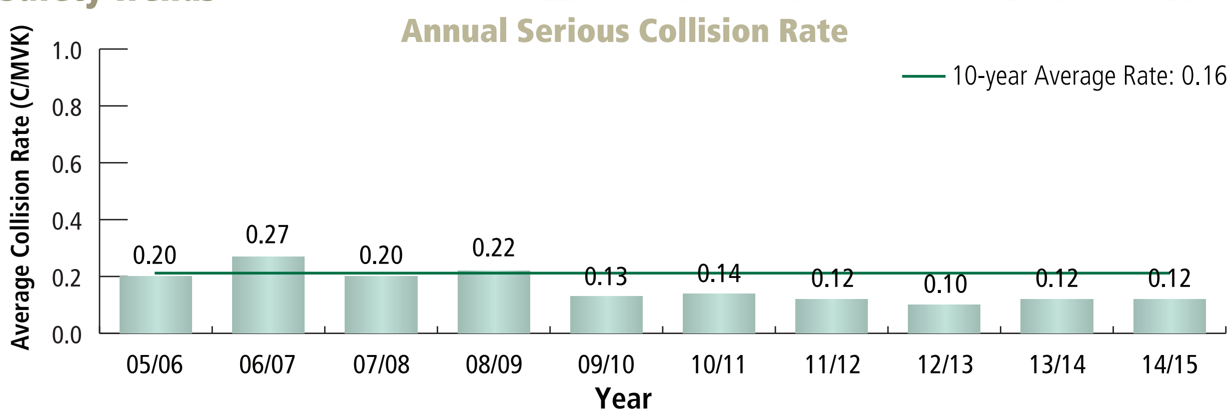
Length	45 km
Number of Lanes	3/4
Divided	No

Operational Characteristics

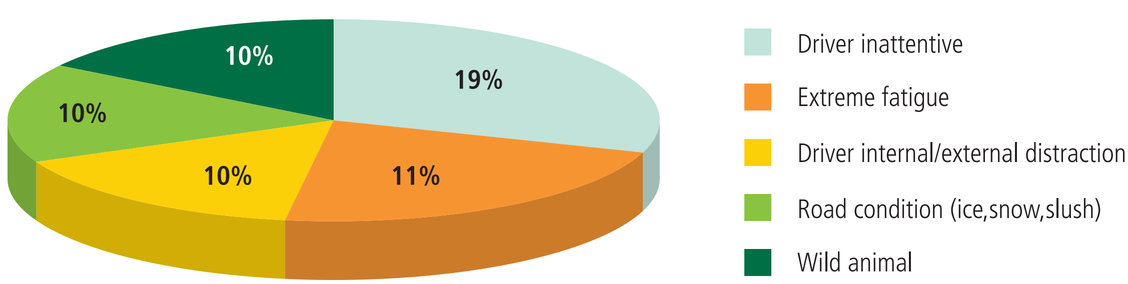
Average Daily Traffic	9,200
% Trucks	2%
Previous Speed Limit	80/90 km/h
Previous 85th Percentile Speed	105 km/h
New Speed Limit	**100 km/h**
Implementation Date	September 12, 2014
Current 85th Percentile Speed	106 km/h
Change in 85th Percentile Speed	+1 km/h



Safety Trends



Top 5 – 1st Contributing Factors (Nov. 1, 2014 to Oct. 31, 2015) *Post Implementation*



* These values may not add up to 100%, as there are other contributing factors.

Whistler to Pemberton

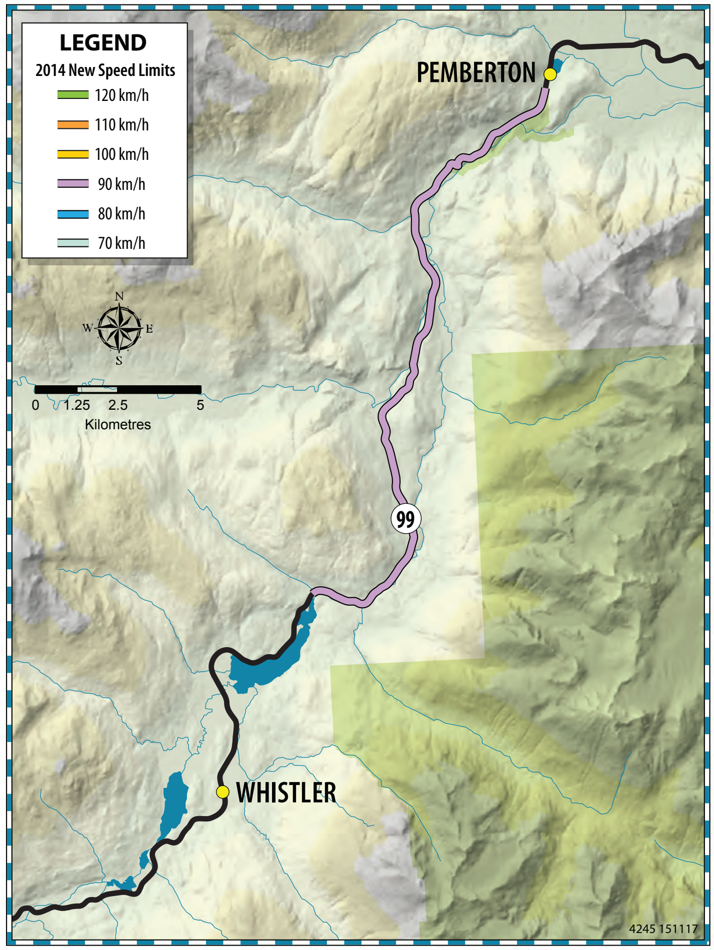
Physical Characteristics

Start Point: South of Whistler Heliport Rd
End Point: Pemberton Boundary

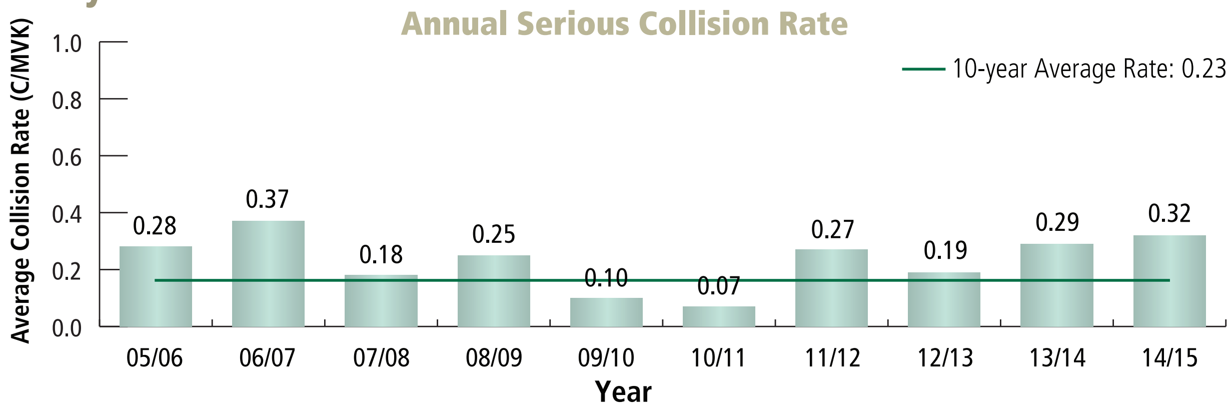
Length	21 km
Number of Lanes	2/3
Divided	No

Operational Characteristics

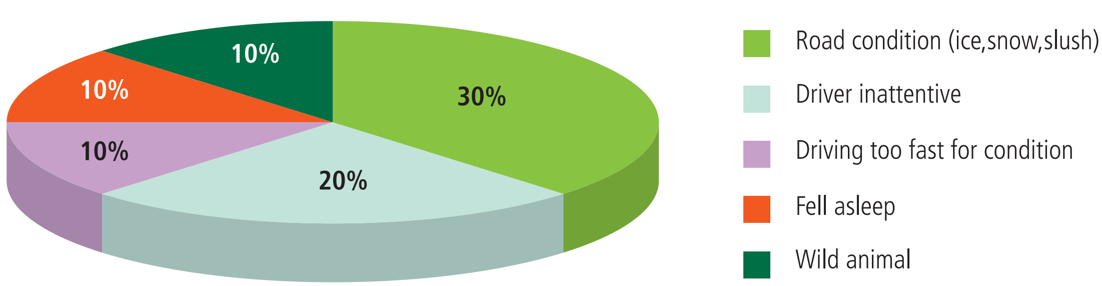
Average Daily Traffic	3,700
% Trucks	2%
Previous Speed Limit	80 km/h
Previous 85th Percentile Speed	102 km/h
New Speed Limit	**90 km/h**
Implementation Date	August 29, 2014
Current 85th Percentile Speed	97 km/h
Change in 85th Percentile Speed	-5 km/h



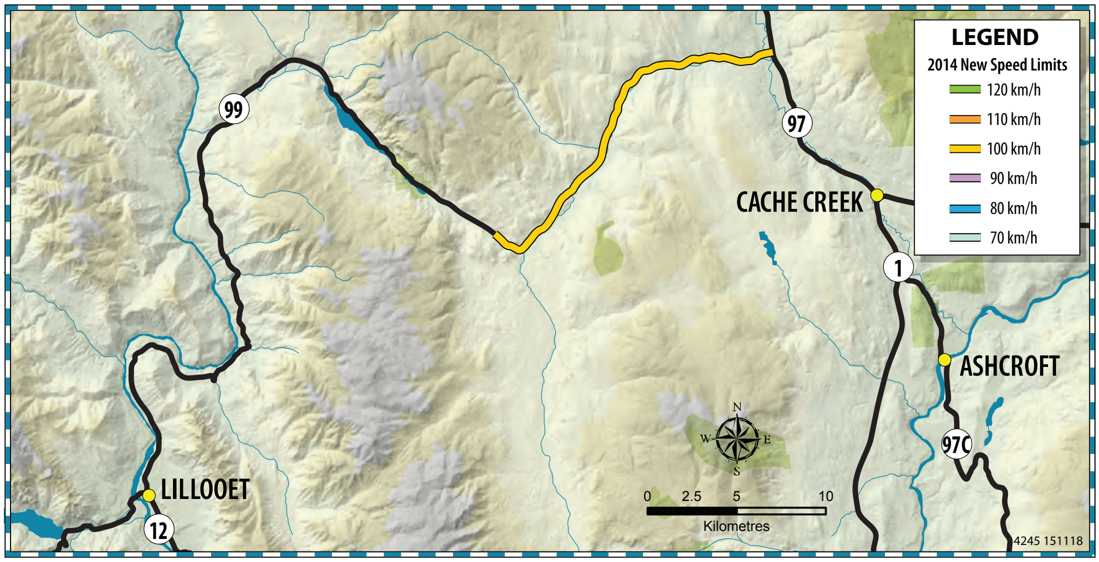
Safety Trends



Top 5 – 1st Contributing Factors (Nov. 1, 2014 to Oct. 31, 2015) *Post Implementation*



* These values may not add up to 100%, as there are other contributing factors.



Lillooet to Cache Creek

Physical Characteristics

Start Point: 2.4 km north of Marble Canyon Provincial Park

End Point: Hwy 97 junction

Length ....22 km

Number of Lanes........................... 2

Divided .... No

Operational Characteristics

Average Daily Traffic 1500

% Trucks................................ 13

Previous Speed Limit.................... 90 km/h

Previous 85th Percentile Speed .... 102 km/h

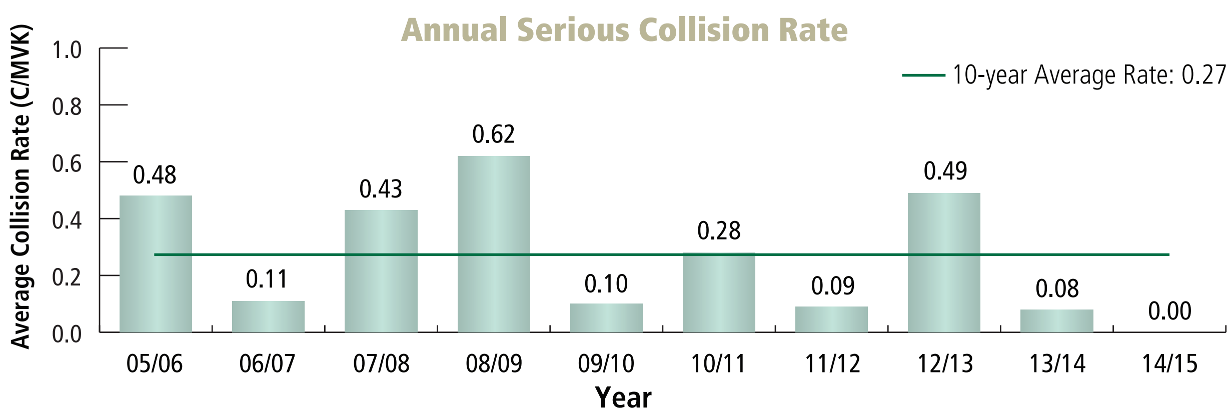
New Speed Limit ....100 km/h

Implementation Date ....September 5, 2014

Current 85th Percentile Speed........... 110 km/h

Change in 85th Percentile Speed..........+8 km/h

Safety Trends



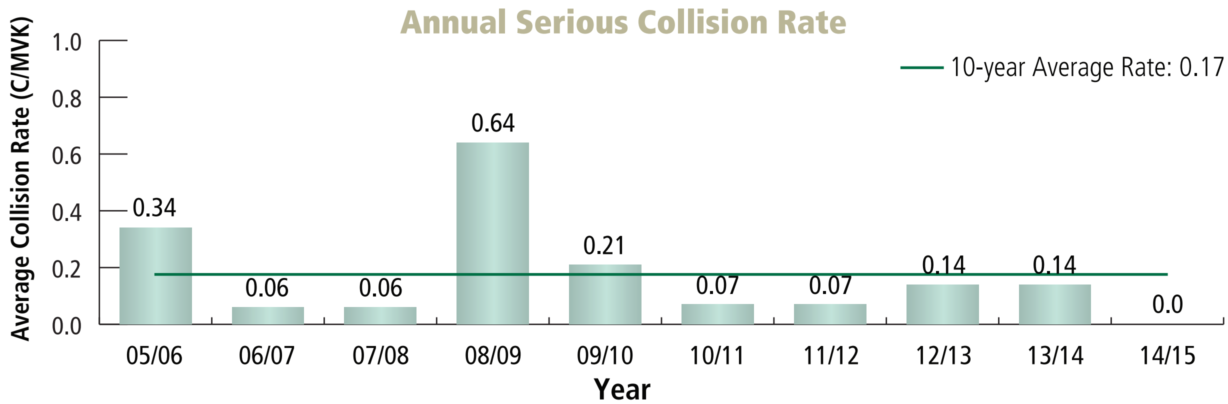
No crashes reported in 2014/15 – post implementation period.

APPENDIX B: COLLISION RATES BY HIGHWAY SEGMENT

APPENDIX B1 – Speed Increased and Collision Rate Decreased

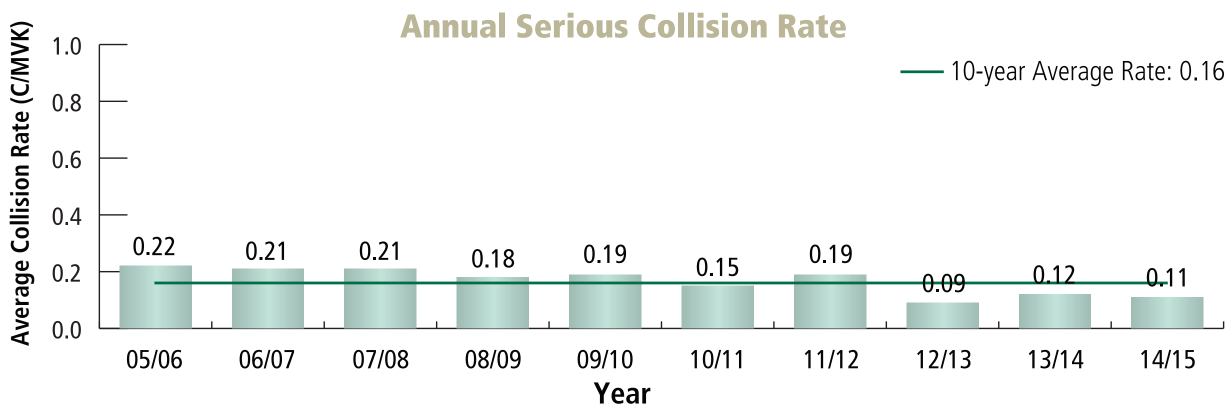
New Posted Speed Limit: 100 km/h
Current 85th Percentile Speed: 107 km/h
Change in 85th Percentile Speed: +3 km/h

Highway 1 Cache Creek to Kamloops



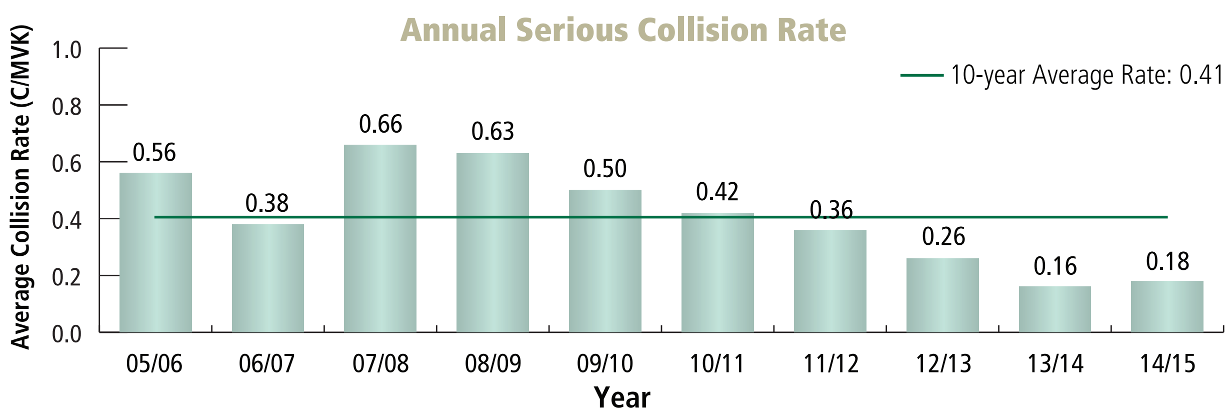
New Posted Speed Limit: 100 km/h
Current 85th Percentile Speed: 109 km/h
Change in 85th Percentile Speed: +6 km/h

Highway 1 Salmon Arm to Alberta Border (Revelstoke to Golden)



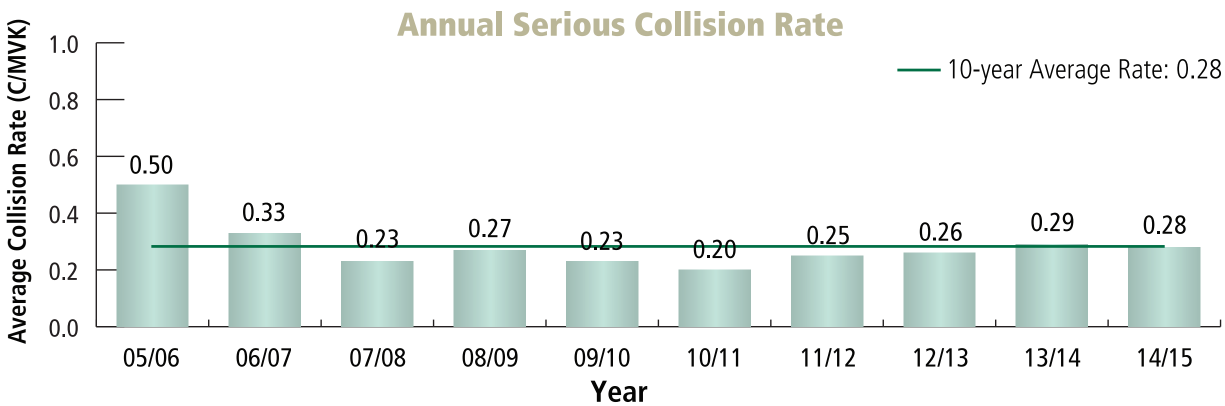
New Posted Speed Limit: 100 km/h
Current 85th Percentile Speed: 109 km/h
Change in 85th Percentile Speed: +6 km/h

Highway 3 Hope to Princeton (Sunshine Valley to Manning Park East Boundary)



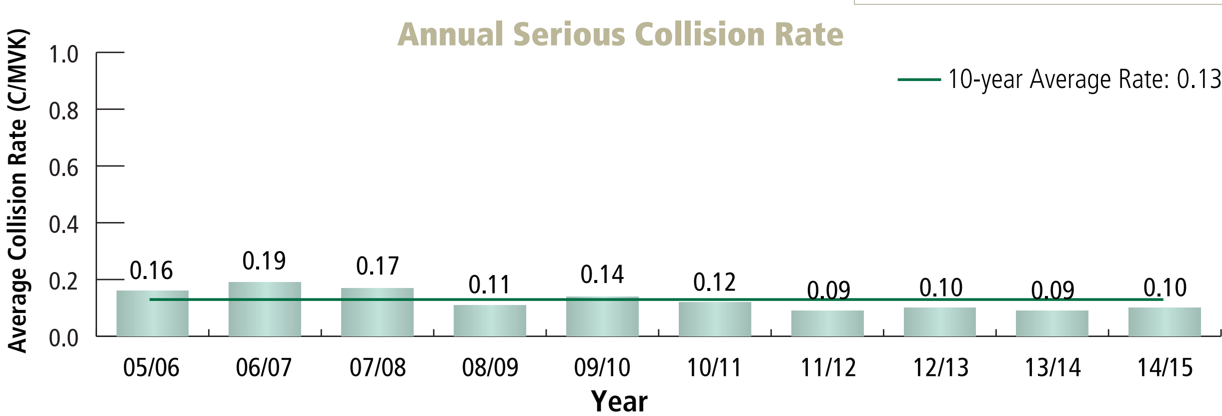
New Posted Speed Limit: 100 km/h
Current 85th Percentile Speed: 111 km/h
Change in 85th Percentile Speed: +3 km/h

Highway 5 Kamloops to Tête Jaune Cache



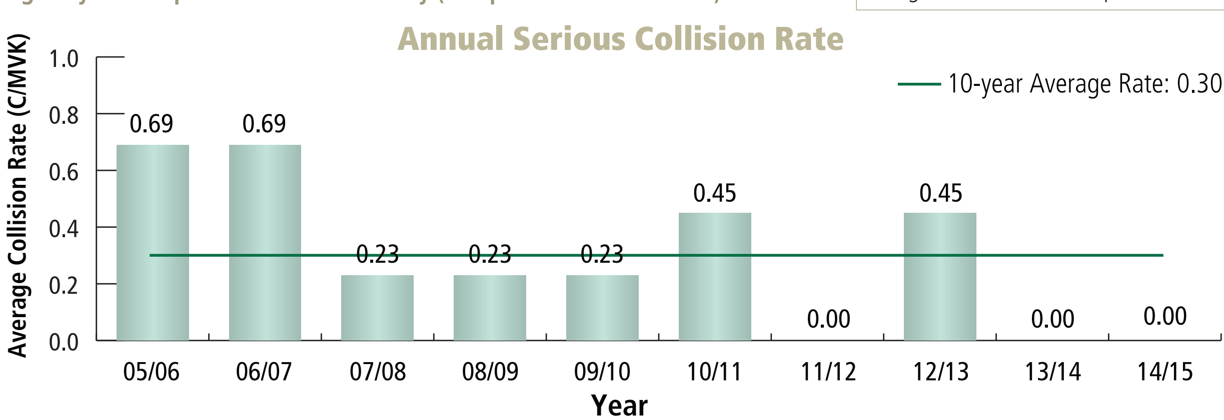
New Posted Speed Limit: 120 km/h
Current 85th Percentile Speed: 125 km/h
Change in 85th Percentile Speed: +4 km/h

Highway 19 Nanaimo to Campbell River



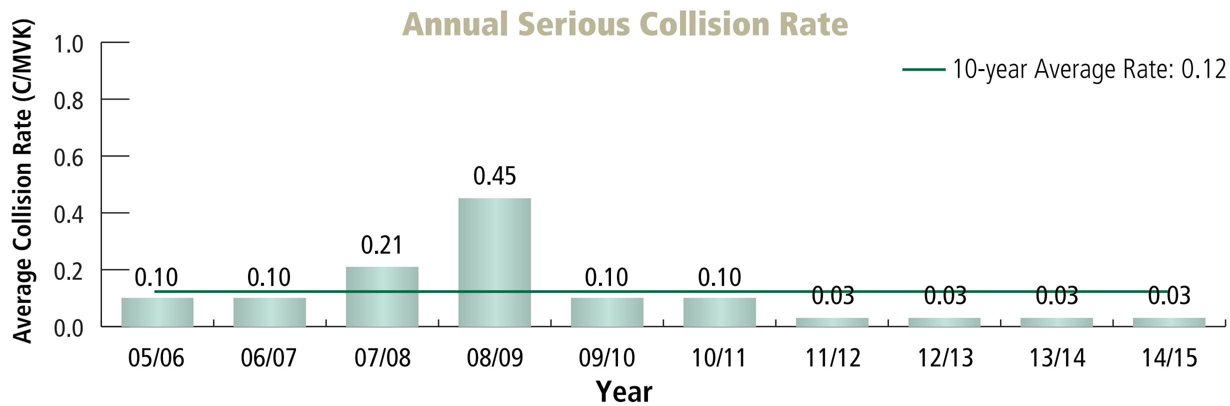
New Posted Speed Limit: 90 km/h
Current 85th Percentile Speed: 97 km/h
Change in 85th Percentile Speed: +2 km/h

Highway 19 Campbell River to Port Hardy (Campbell River to Bloedel)



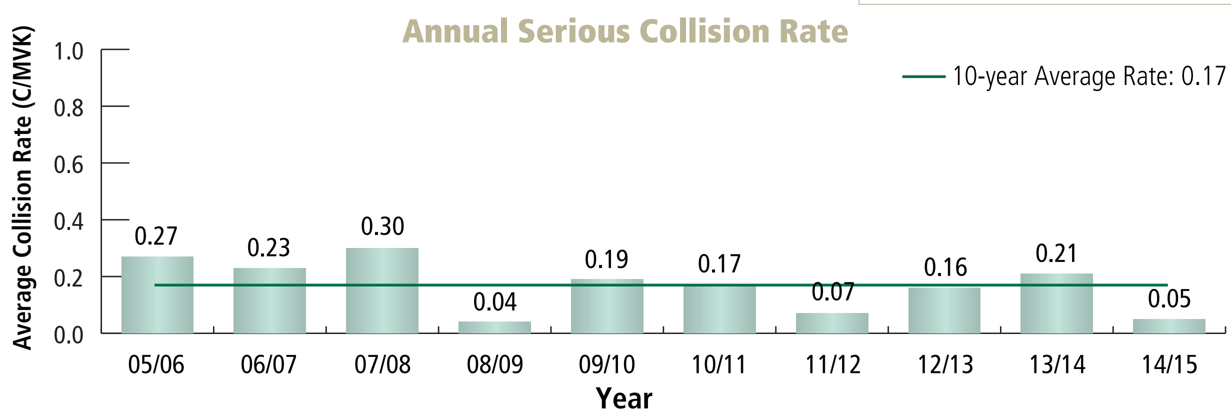
New Posted Speed Limit: 100 km/h
Current 85th Percentile Speed: 100 km/h
Change in 85th Percentile Speed: +4 km/h

Highway 19 Campbell River to Port Hardy (Port McNeill to Port Hardy)



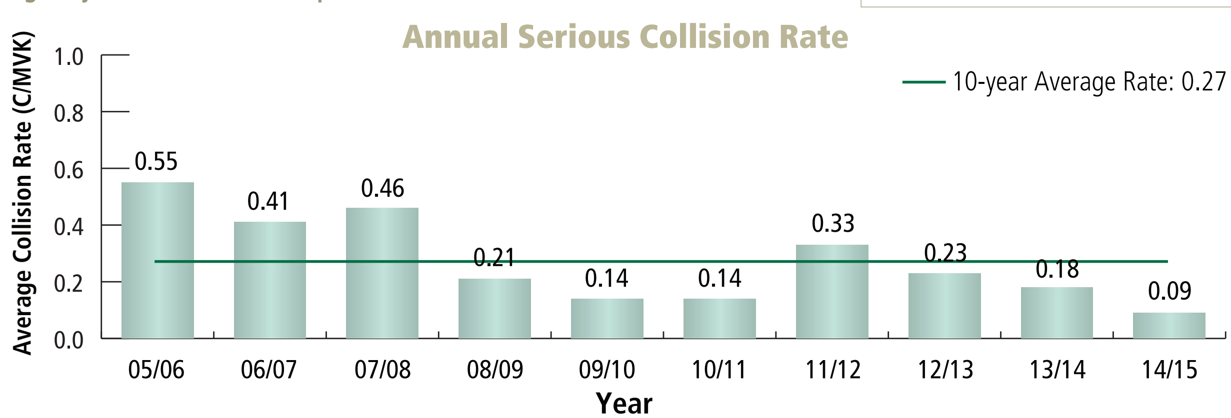
New Posted Speed Limit: 110 km/h
Current 85th Percentile Speed: 117 km/h
Change in 85th Percentile Speed: +3 km/h

Highway 97 Cache Creek to Williams Lake



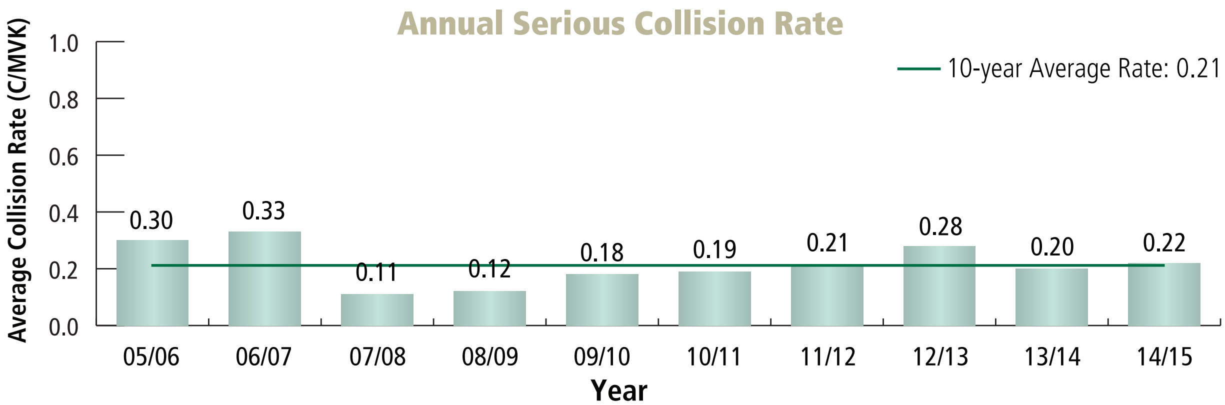
New Posted Speed Limit: 90 km/h
Current 85th Percentile Speed: 97 km/h
Change in 85th Percentile Speed: +6 km/h

Highway 97 Vernon to Kamloops



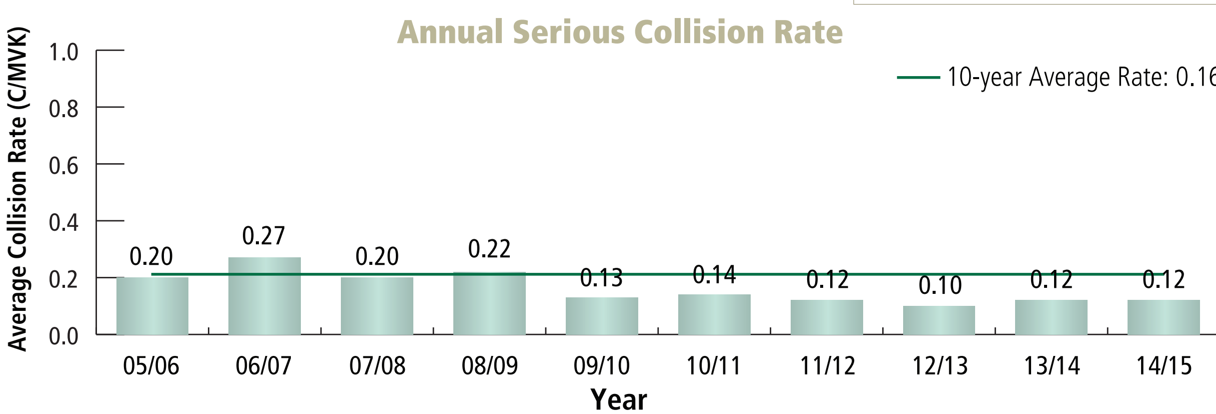
New Posted Speed Limit: 90 km/h
Current 85th Percentile Speed: 104 km/h
Change in 85th Percentile Speed: +2 km/h

Highway 99 Sea-to-Sky Highway (Horseshoe Bay to Squamish)



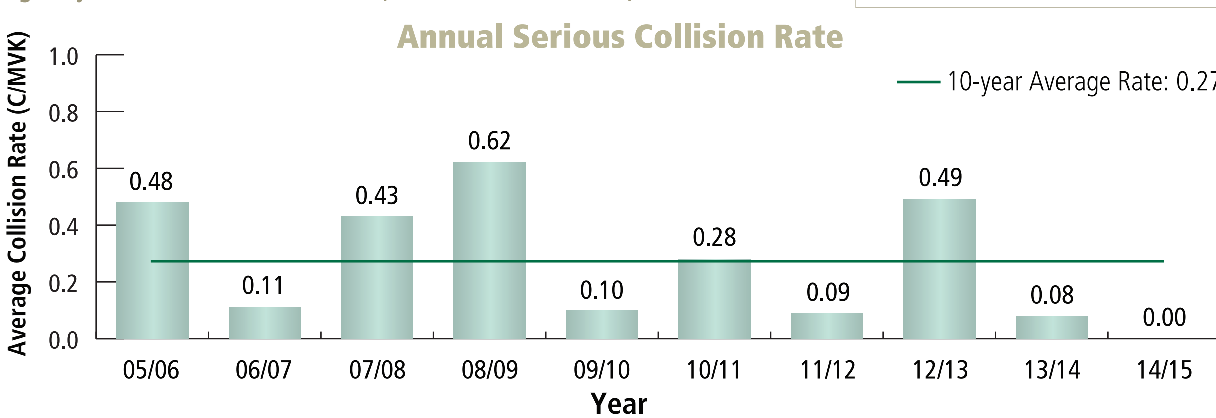
New Posted Speed Limit: 100 km/h
Current 85th Percentile Speed: 106 km/h
Change in 85th Percentile Speed: +3 km/h

Highway 99 Sea-to-Sky Highway (Squamish to Whistler)



New Posted Speed Limit: 100 km/h
Current 85th Percentile Speed: 110 km/h
Change in 85th Percentile Speed: +8 km/h

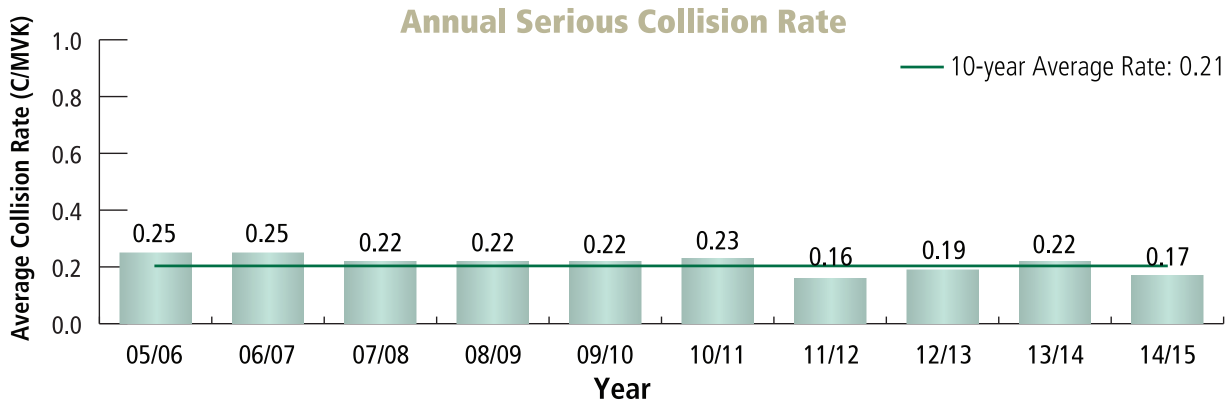
Highway 99 Whistler to Cache Creek (Lillooet to Cache Creek)



APPENDIX B2 – Speed Decreased and Collision Rate Decreased

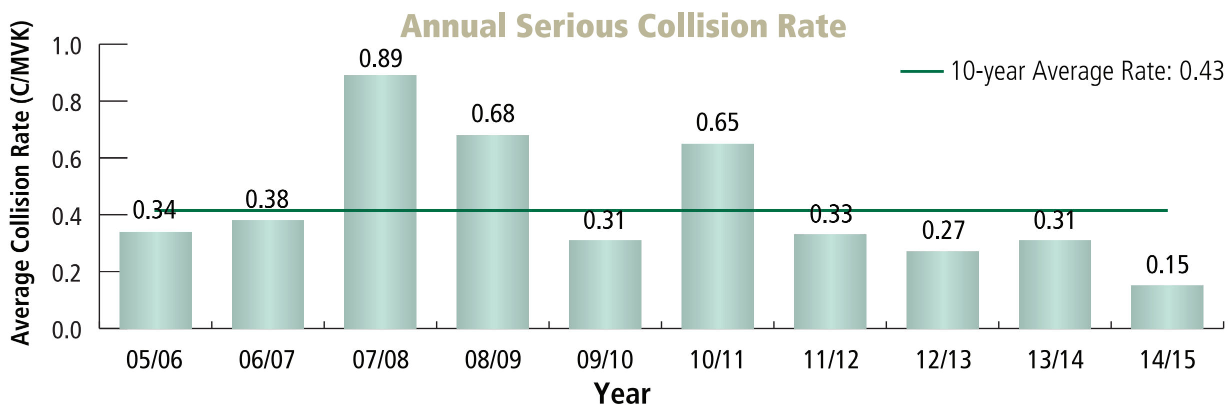
New Posted Speed Limit: 100 km/h
Current 85th Percentile Speed: 106 km/h
Change in 85th Percentile Speed: 0 km/h

Highway 1 Salmon Arm to Alberta Border



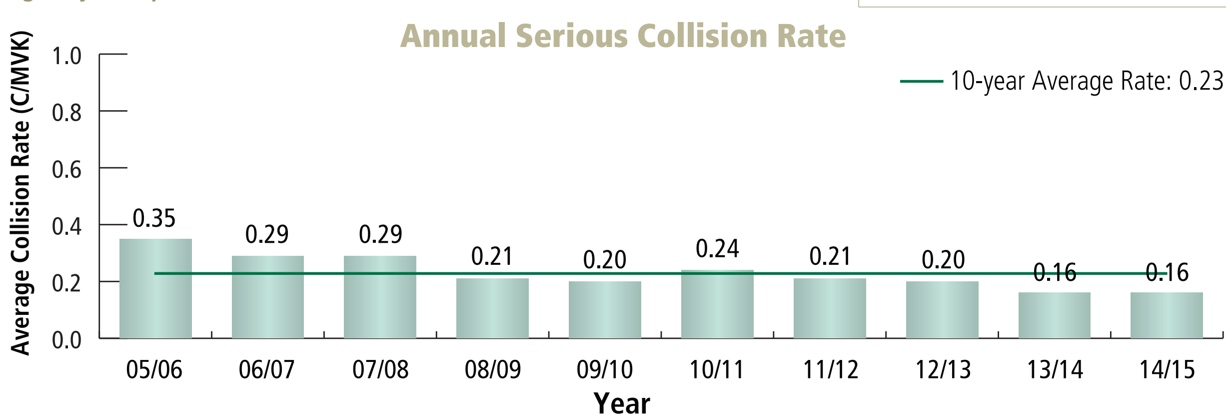
New Posted Speed Limit: 90 km/h
Current 85th Percentile Speed: 100 km/h
Change in 85th Percentile Speed: -3 km/h

Highway 3 Hope to Princeton (Sunday Summit to Princeton)



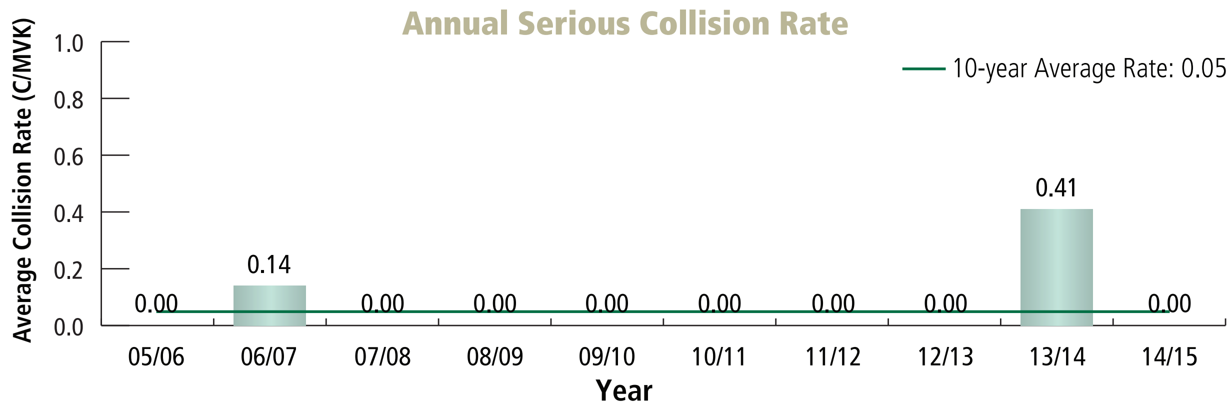
New Posted Speed Limit: 120 km/h
Current 85th Percentile Speed: 127 km/h
Change in 85th Percentile Speed: 0 km/h

Highway 5 Coquihalla



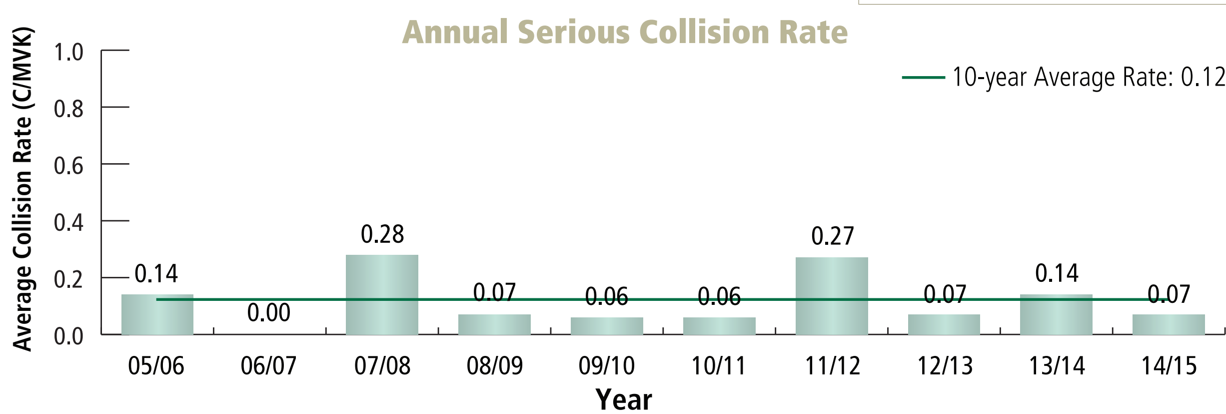
New Posted Speed Limit: 90 km/h
Current 85th Percentile Speed: 97 km/h
Change in 85th Percentile Speed: -2 km/h

Highway 6 Nelson to Nakusp (New Denver to Hills)



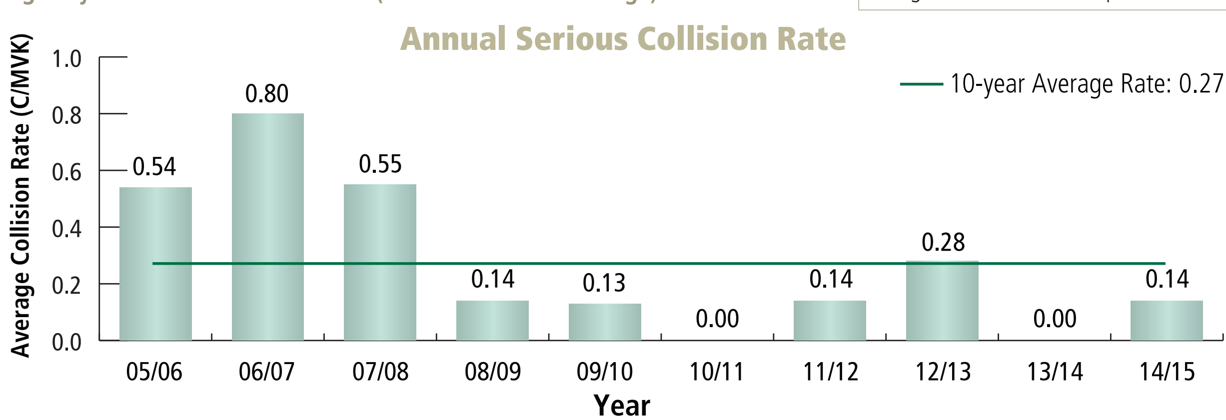
New Posted Speed Limit: 100 km/h
Current 85th Percentile Speed: 110 km/h
Change in 85th Percentile Speed: 0 km/h

Highway 6 Nelson to Nakusp (Summit Lake to Nakusp)



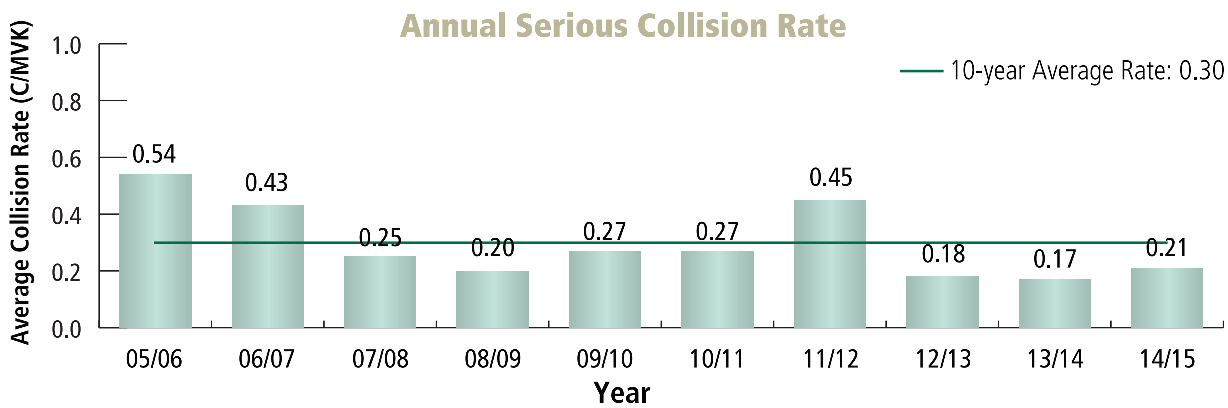
New Posted Speed Limit: 100 km/h
Current 85th Percentile Speed: 108 km/h
Change in 85th Percentile Speed: -2 km/h

Highway 33 Rock Creek to Kelowna (Rock Creek to Westbridge)



New Posted Speed Limit: 90 km/h
Current 85th Percentile Speed: 94 km/h
Change in 85th Percentile Speed: -1 km/h

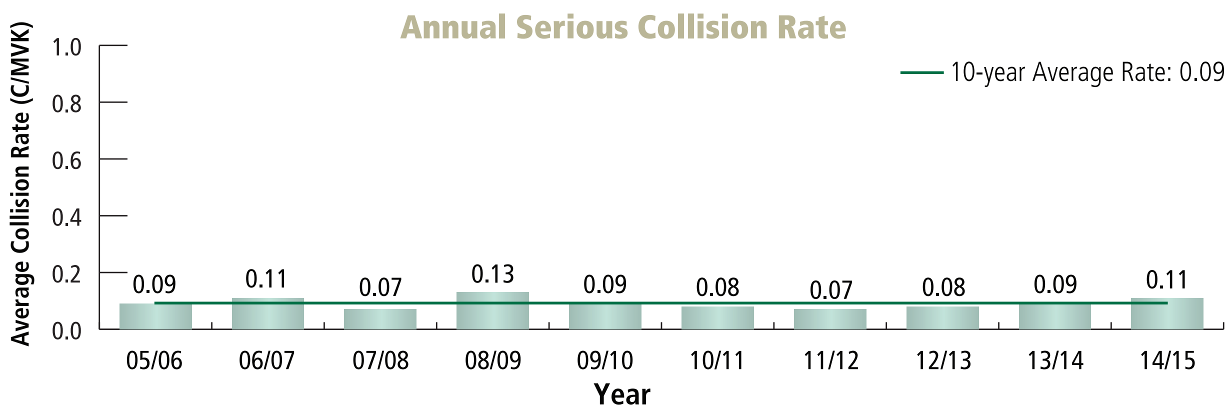
Highway 97A Vernon to Sicamous (Grindrod to Sicamous)



APPENDIX B3 – Speed Increased and Collision Rate Increased

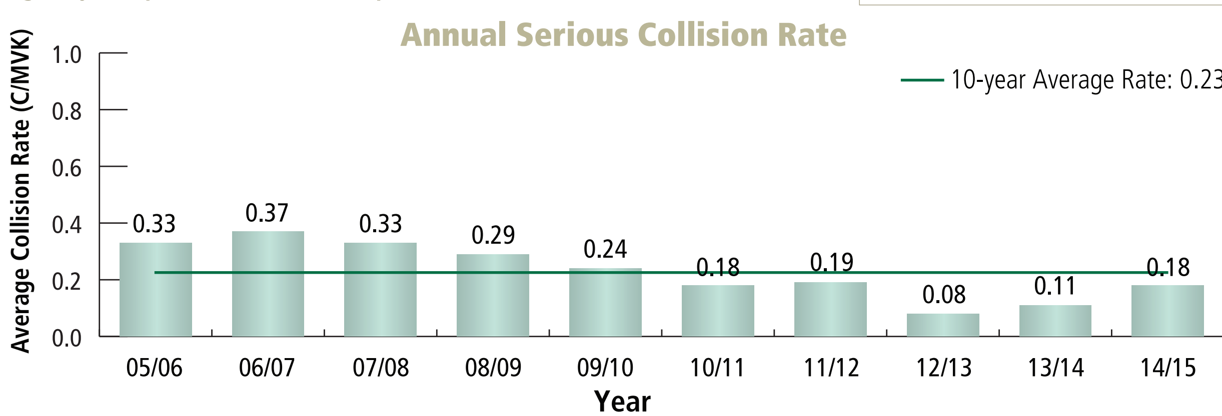
New Posted Speed Limit: 110 km/h
Current 85th Percentile Speed: 119 km/h
Change in 85th Percentile Speed: +3 km/h

Highway 1 Abbotsford to Hope



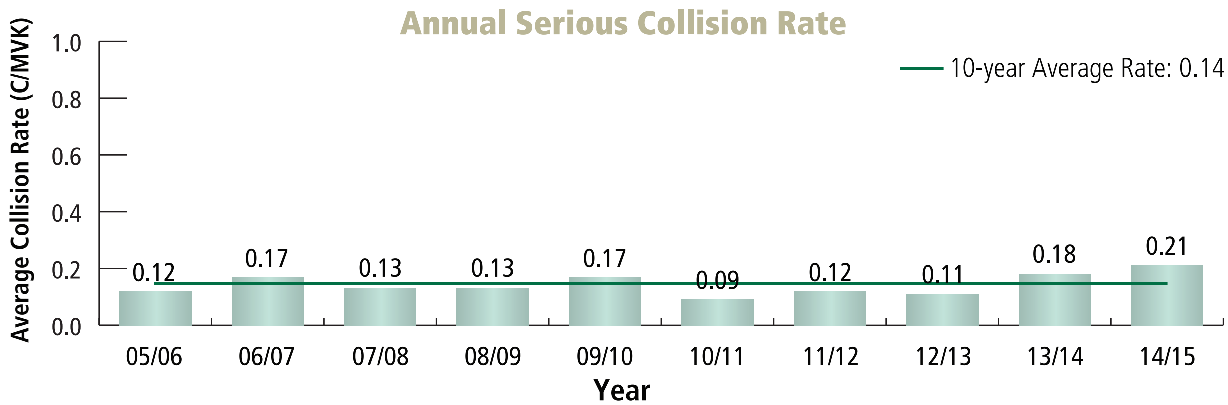
New Posted Speed Limit: 100 km/h
Current 85th Percentile Speed: 112 km/h
Change in 85th Percentile Speed: +5 km/h

Highway 1 Hope to Cache Creek (Hope to Boston Bar)



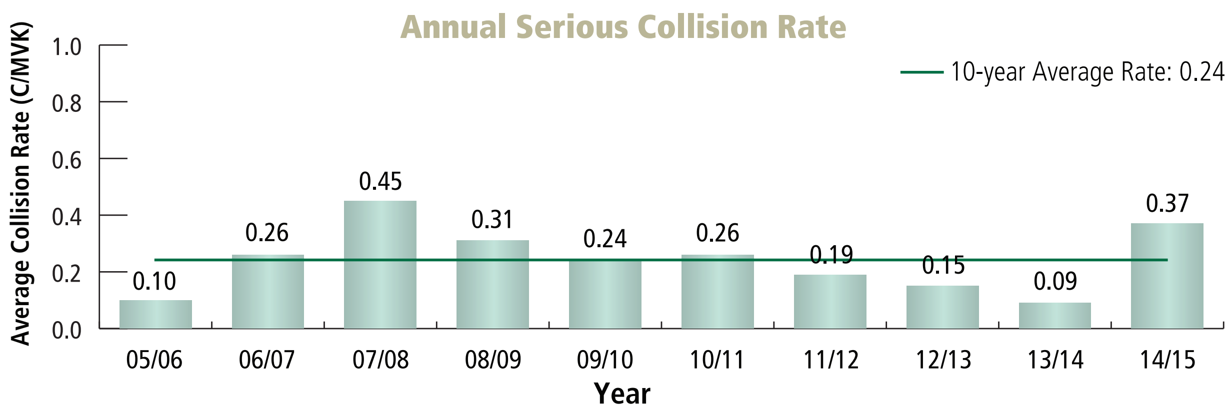
New Posted Speed Limit: 100 km/h
Current 85th Percentile Speed: 111 km/h
Change in 85th Percentile Speed: +6 km/h

Highway 1 Kamloops to Salmon Arm



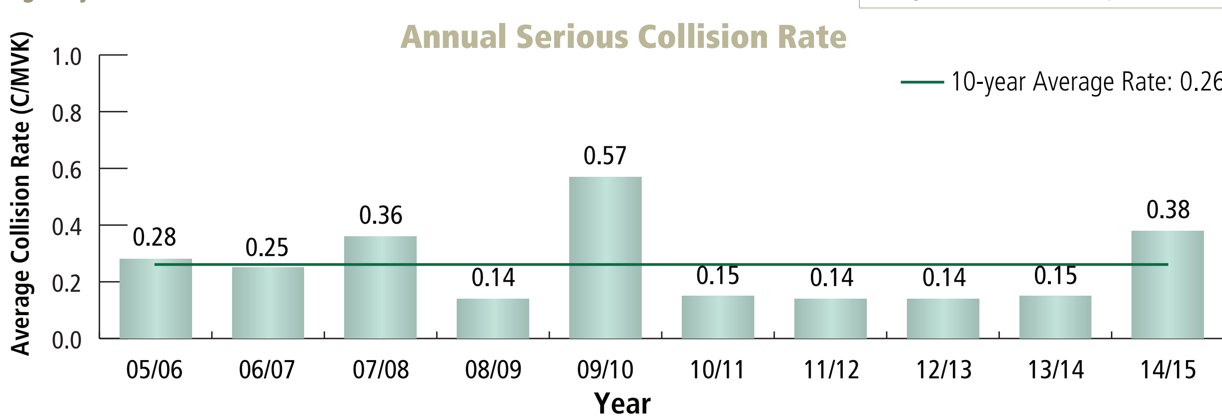
New Posted Speed Limit: 110 km/h
Current 85th Percentile Speed: 120 km/h
Change in 85th Percentile Speed: +6 km/h

Highway 3 Hope to Princeton (Hope to Coquihalla)



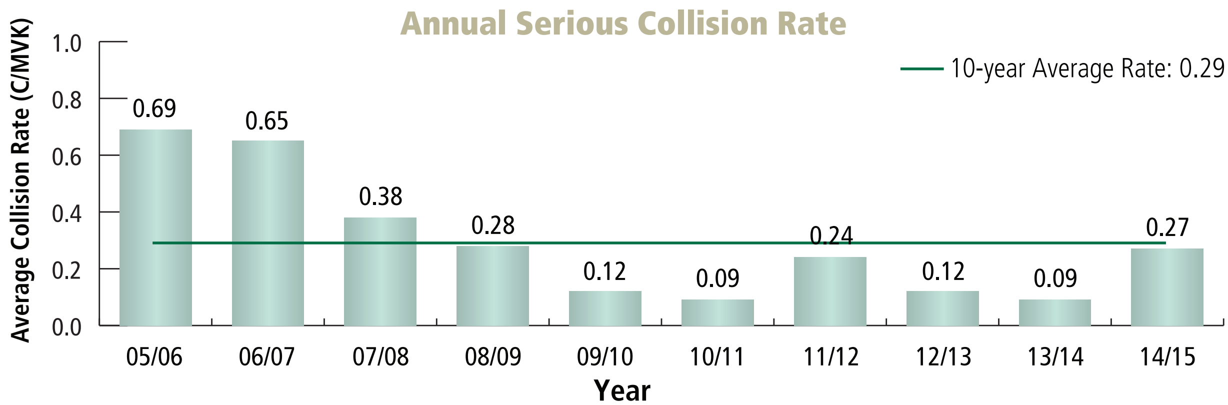
New Posted Speed Limit: 90 km/h
Current 85th Percentile Speed: 104 km/h
Change in 85th Percentile Speed: +5 km/h

Highway 5A Princeton to Merritt



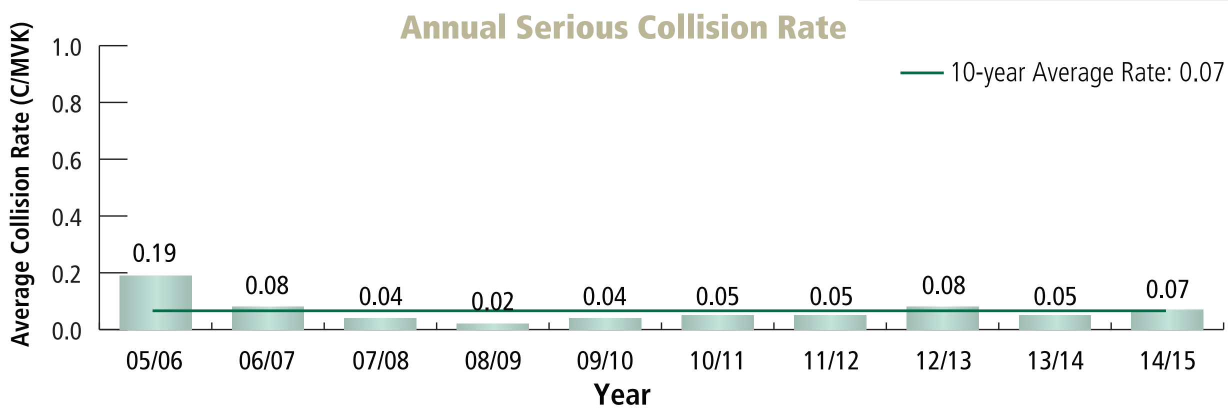
New Posted Speed Limit: 100 km/h
Current 85th Percentile Speed: 107 km/h
Change in 85th Percentile Speed: +1 km/h

Highway 19 Campbell River to Port Hardy (Bloedel to Sayward)



New Posted Speed Limit: 110 km/h
Current 85th Percentile Speed: 106 km/h
Change in 85th Percentile Speed: +5 km/h

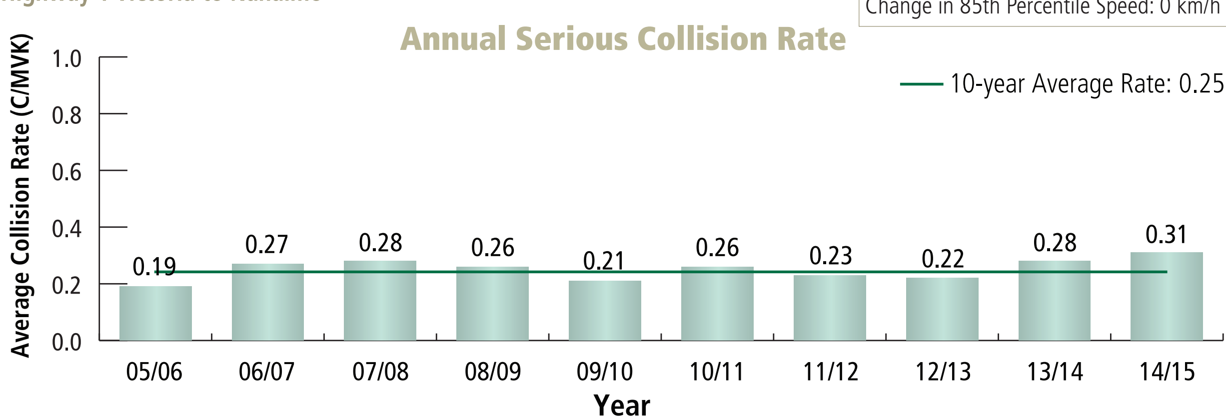
Highway 33 Rock Creek to Kelowna (Black Mountain to McCulloch Road)



APPENDIX B4 – Speed Decreased and Collision Rate Increased

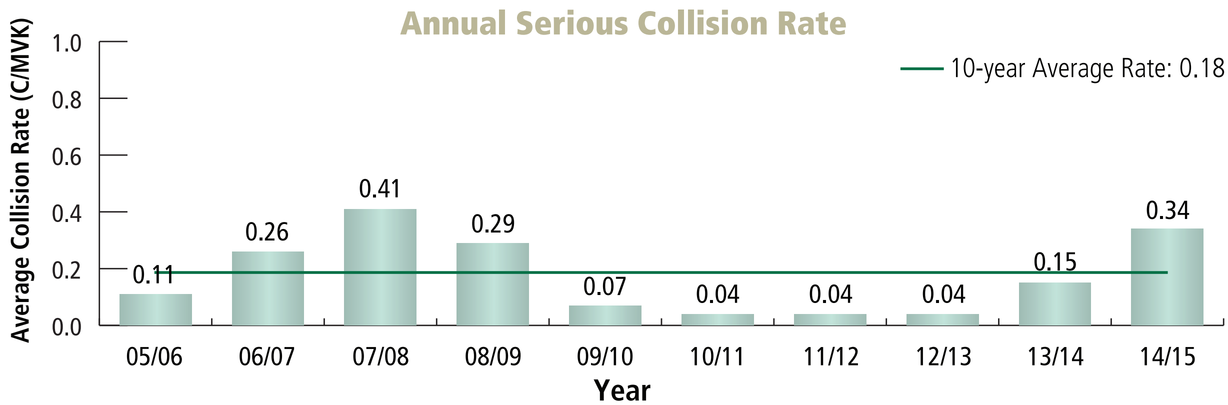
New Posted Speed Limit: 90 km/h
Current 85th Percentile Speed: 100 km/h
Change in 85th Percentile Speed: 0 km/h

Highway 1 Victoria to Nanaimo



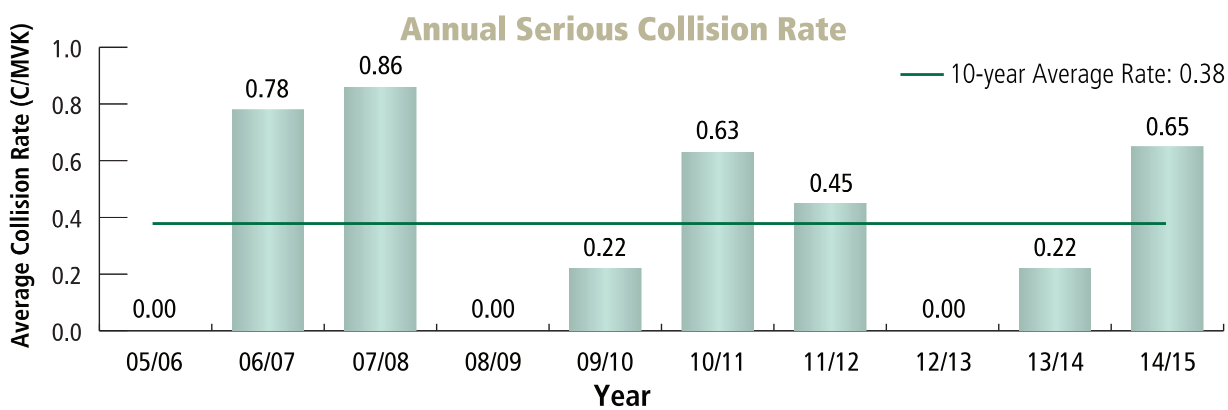
New Posted Speed Limit: 100 km/h
Current 85th Percentile Speed: 114 km/h
Change in 85th Percentile Speed: -2 km/h

Highway 1 Hope to Cache Creek (Boston Bar to Jackass Mountain



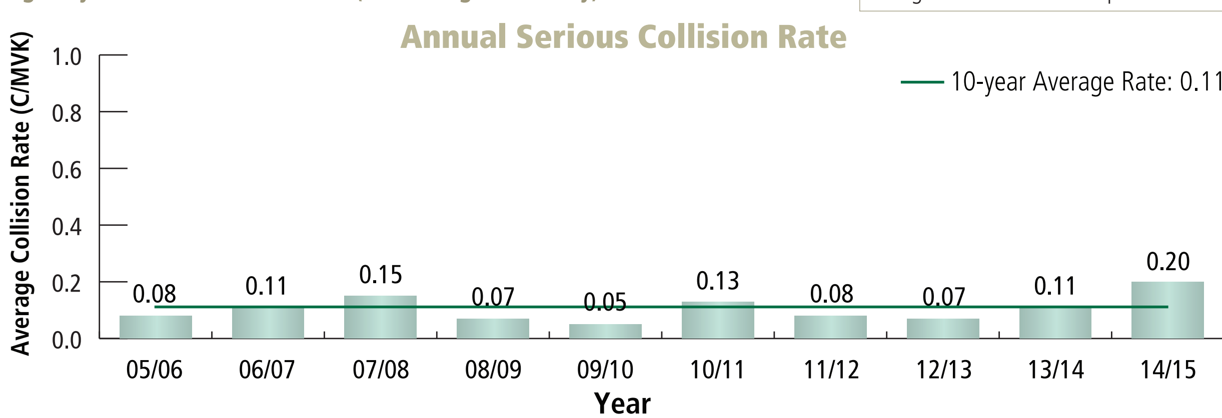
New Posted Speed Limit: 100 km/h
Current 85th Percentile Speed: 107 km/h
Change in 85th Percentile Speed: 0 km/h

Highway 7 Mission to Hope



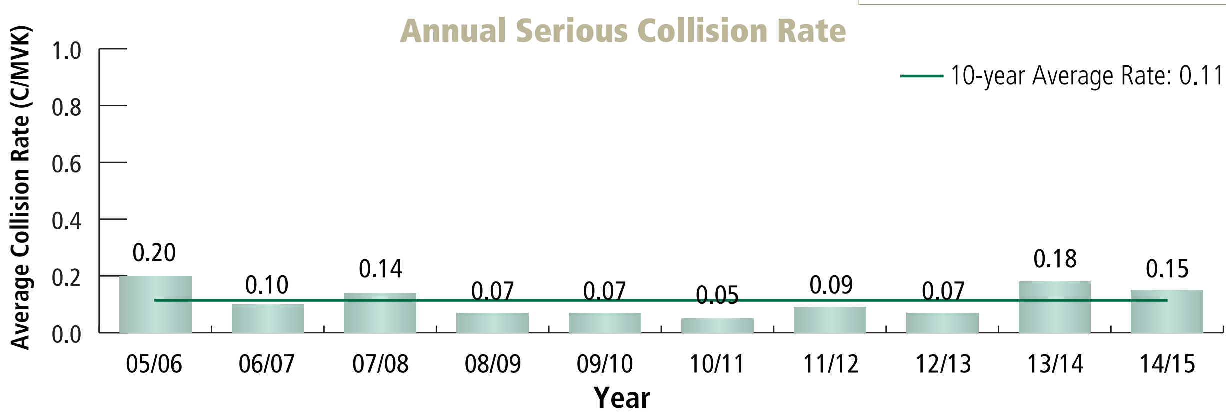
New Posted Speed Limit: 100 km/h
Current 85th Percentile Speed: 98 km/h
Change in 85th Percentile Speed: -3 km/h

Highway 97A Vernon to Sicamous (Armstrong to Enderby)



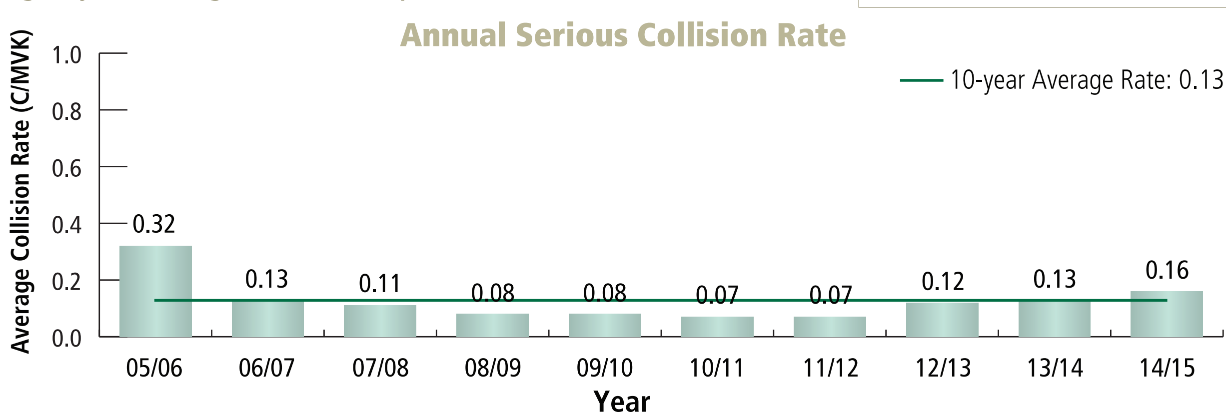
New Posted Speed Limit: 110 km/h
Current 85th Percentile Speed: 123 km/h
Change in 85th Percentile Speed: 0 km/h

Highway 97C Okanagan Connector (Merritt to Aspen Grove)



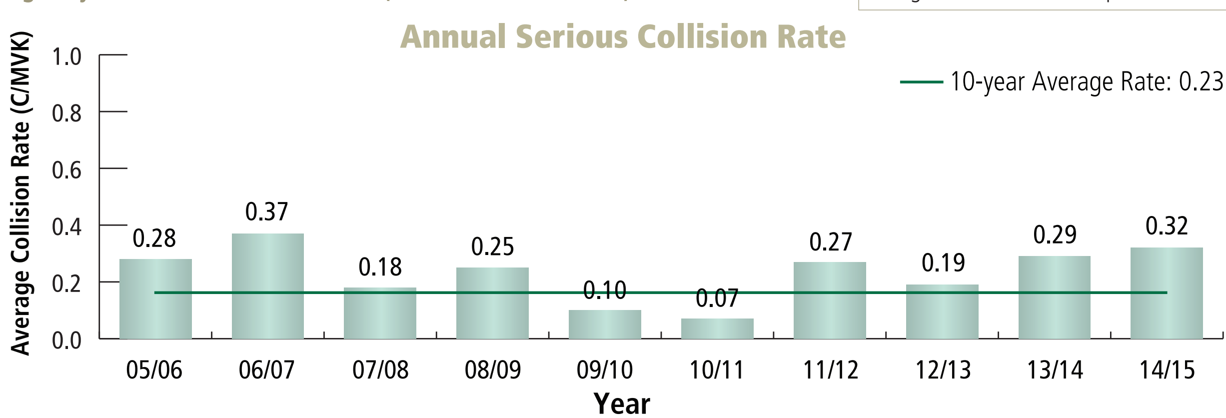
New Posted Speed Limit: 120 km/h
Current 85th Percentile Speed: 126 km/h
Change in 85th Percentile Speed: 0 km/h

Highway 97C Okanagan Connector (Aspen Grove to Peachland)



New Posted Speed Limit: 90 km/h
Current 85th Percentile Speed: 97 km/h
Change in 85th Percentile Speed: -5 km/h

Highway 99 Whistler to Cache Creek (Whistler to Pemberton)



APPENDIX C: Safety Analysis of Changed Speed Limits on Rural Highways in British Columbia (UBC Report)

Safety Analysis of Changed Speed Limits on

Rural Highways in British Columbia

Report prepared for the BC Ministry of Transportation and Infrastructure

February 15, 2016

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TABLE of CONTENTS

List of Tables

List of Figures

Executive Summary

E-1 Introduction

In the fall of 2013, the British Columbia Ministry of Transportation and Infrastructure (MoTI) initiated a safety and speed review on approximately 9,100 km of stretches of provincial rural highways. A technical team conducted over 300 speed surveys with measurement of the 85th percentile operating speed, a measure used by many jurisdictions for establishing speed limits. It was found that the 85th percentile speed on these highways was upwards of 10 km/h higher than corresponding posted speed limits. It was also noticed that serious crashes were trending down significantly since 2003. These observations led to consideration of speed limit increases, and, after a public consultation was conducted, approximately 1,300 km of highway segments were recommended for higher speed limits.

The increased speed limits were implemented in the second-half of 2014. Rural divided highways had a maximum posted speed limit increase to 120 km/h and rural undivided highways to 100 km/h with some 4-lane sections up to 110 km/h.

As speed plays an important role in road safety, and traffic operations is enhanced when appropriate speed limits are set, the main objective of this project was to estimate the safety effects of the changed speed limits on rural highways after the first year of implantation, with particular focus on the most severe crashes (fatal plus injury).

E-2 Overview of Before-After Evaluations

The study design used to estimate the safety effects of the changed speed limits is a time-series analysis, which is often referred to as a before-after (BA) analysis. This approach attempts to measure the change in safety over time due to the implementation of a safety initiative. For BA analyses, Bayesian methods are commonly used within an odds-ratio (OR) analysis for their ability to: a) ensure that a noted change in the safety performance is caused by the safety initiative and not by other “confounding” factors or causes external to the initiative, b) treat unknown parameters such as predicted crash frequency as random variables having their own probability distributions.

Examples of Bayesian evaluation techniques include the empirical Bayes (EB) and full Bayes (FB) method, which are commonly used in traffic safety analyses. The FB approach was employed for this evaluation as it offers several methodological and data advantages. In terms of methodological advantages, the FB approach has the ability to account for most uncertainty in the data, to provide more detailed inference, and to allow inference at more than one level for hierarchical models, among others. In terms of data requirements, the FB approach efficiently integrates the estimation of the crash prediction model (CPM) and treatment effects in a single step thereby negating the need for a reference group data and reducing the data requirements.

A FB technique with advanced CPMs (i.e., non-linear intervention functions) was used for this evaluation.

E-3 Data Evaluation

This task was carried out through the use of crash and traffic records made available by MoTI. The sites (highway segments) with increased speed limits were reviewed in detail to create a subset of homogeneous locations. A total of 60 treatment segments were used for this analysis. Furthermore, the selection of comparison sites was a key step to control for potential confounding factors that may affect the accuracy of the evaluation. The number of available comparison sites was equal to 95 segments.

Crash data was available for all treated and comparison sites for approximately 3.8 years, from January 2012 to October 2015. As the new speed limits were implemented in mid-2014, a time period (time unit) of four months was selected in order to obtain a wider range of post-treatment time frames (i.e., 4 periods of 4 months in total). Therefore, the before period ran from March 2012 to June 2014 (i.e., 7 periods of 4 months) and the after period from July 2014 to October 2015 (i.e., 4 periods of 4 months), with July-October 2014 as a transition period. Fatal-plus-injury (F+I) crash records were used to estimate the effect of increased speed limits. After a thorough review, property-damage-only crash records were found to be incomplete and were not used in the analysis. Finally, traffic volume information was obtained from existing records.

E-4 Results

As mentioned before, a FB technique with advanced non-linear intervention function was applied to estimate the resulting crash frequency change. Overall, the results showed that the sections of roadway where new speed limits were imposed, experienced an increase in the number of severe (fatal and injuries) crashes of 11.1%, following the implementation of speed limit increases (see Table E-4.1). This increase was found statistically significant at the 95% confidence level (CL).

Table E-4.1 Change from the before to the after period for F+I crashes

Odds Ratio	5% CL	95% CL	Change*
1.11±0.070	1.002	1.228	+11.1%

* Positive sign means increase of crashes

It should also be noted that although the FB technique can produce crash change estimations by site, the individual site results were not provided in this report for the following reasons:

- the after study period in this study was relatively short (i.e., approximately 1.3 years only); this caused the individual site results to be less reliable and not statistically significant;
- as the FB technique matches treatment sites with appropriate comparison sites, the results for individual locations will become sensitive to the safety performance of the smaller matched comparison group with short after period.

E-5 Comparison to Similar Studies Worldwide

Many studies conducted worldwide have investigated the relationship between speed and safety showing the important role of speed management. Generally, the results indicate that the higher the travel speed, the greater the probability of crashes and the higher severity of the crashes. Similar to the model form used in this study, a number of meta-analysis studies revealed that the relationship between speed and accidents is best represented by a power model:

$$\textit{Accident Ratio} = (\textit{Mean Speed Ratio})^{\textit{Power}}$$

where the "Accident Ratio" is the ratio between accident frequency after and before the speed change; and the "Mean Speed Ratio" is the ratio between the means of driving speeds (after to before). A study by Elvik in 2009 concluded the power parameter to have values of 4.1, 2.6, 1.1 and 1.5 for fatal, serious injury, slight injury and PDO crashes, respectively, on rural roads. Using an average exponent value from Elvik, the fatal and injury crash increase reported in this study (11.1%) can be obtained from about 3 km/h increase in the mean operating speed for a segment with initial mean speed of 90 km/h.

A case study from Hong Kong evaluated the increase of speed limits that occurred from 1999 to 2002 on major roadways from 50 to 70 km/h and 70km/h to 80 km/h for other highways. Overall, the relaxation of the speed limit from 50 to 70 km/h caused an increase of 15% for fatal-plus-injury crashes. The relaxation of speed limits from 70 to 80 km/h was found to increase fatal-plus-injury crashes by 18% and fatal plus serious-injury only crashes by 36%. It should be noted that although this study was carried out in an urban environment, the comparison may be relevant for the stretches of highways with higher speed limits.

In North America, a before-after study accounting for confounding factors was conducted on the increase of the speed limits on several Utah highways (urban, rural and high-speed highway segments). Overall, the results showed a significant increase in both total crash rates on urban interstate segments, and fatal crash rates on high-speed rural non-interstate segments. However, total, fatality, and injury crash rates on rural interstate segments; fatality and injury crash rates on urban interstate segments; and total and injury crash rates on high-speed non-interstate segments were substantially unchanged.

Farmer *et al.* in 1999 investigated the trends in fatalities over 8 years for 24 states that raised interstate speed limits and 7 states that did not. The study revealed an increase of 15% in motor vehicle occupant deaths for the 24 states that raised speed limits. After accounting for changes in vehicle miles of travel, fatality rates were 17% higher following the speed limit increases. Another US study (Shafi and Gentilello, 2007) reported that, after the repeal of the national maximum speed limit law, there was a 13% increase in the risk of traffic fatalities in 29 states that increased speed limits on roadways with speed limits greater than 65 mph compared to states that did not increase speed limits.

E-6 Conclusions and Study Limitations

Overall, the impact of increasing speed limits resulted in an increase of crashes on BC rural highways, where speed limits have been changed. In details, the full Bayes evaluation technique showed a statistically significant increase of crash frequency of 11.1%. The results are consistent with similar studies conducted worldwide in showing an increase in fatal and injury crash frequency after raising the speed limit. However, it should be noted that the post-treatment period for this evaluation was relatively short. As such, although the results are statistically significant at the 95% confidence level, it is recommended that the evaluation is repeated when more crash data becomes available for a longer post-treatment period. It should also be noted that the robustness of the evaluation results highly depends on the quality of the crash data provided.

1 Introduction

1.1 Background

In 2013, the British Columbia (BC) Ministry of Transportation and Infrastructure (MoTI) initiated a review of several potential challenges affecting safety and traffic operations on rural provincial highways. The review included several areas: speed limits, winter tire regulations, passing lanes for slower-moving vehicles and wildlife hazards.

For the speed limits review, throughout the fall of 2013, a technical team conducted over 300 speed surveys on approximately 9,100 km of stretches of highways with measurements of the mean and 85th percentile operating speeds. After these surveys were carried out, it was found that the 85th percentile speed on these highways was 10 km/h higher than corresponding posted speed limits, as shown in Table 1.1. It was also noticed that, overall, serious crashes were trending down significantly since 2003.

These considerations led to the option of increasing speed limits on BC rural highways. Therefore, after a public consultation process was conducted, approximately 1,300 km of rural provincial highway segments were recommended for higher speed limits. The increased speed limits took effect in the second-half of 2014. Rural divided highways had a maximum posted speed limit increase to 120 km/h and rural undivided highways to 100 km/h with some 4-lane sections up to 110 km/h.

Table 1.1 Summary of Speed Surveys Results on Key Corridors (Source: MoTI, 2014)

Highway Segment	Current Speed Limit	85th percentile operating speed
Hwy 1: Abbotsford to Hope	100	116
Hwy 1: Revelstoke to Golden	90	103
Hwy 3: Sunshine Valley to Manning Park	80, 90	103
Hwy 5: Hope to Kamloops	110	127
Hwy 19: Parksville to Campbell River	110	121
Hwy 97C: Aspen Grove to Peachland	110	126
Hwy 99: Horseshoe Bay to Squamish	80	102
Hwy 99: Squamish to Whistler	80, 90	105

1.2 Project Objectives

Driving speed is perhaps the most studied indicator for crash risk. Speed plays an important role in road safety, and traffic operations are enhanced when appropriate speed limits are set. Therefore, it is important to evaluate the safety impact of changing speed limits.

The main objective of this study was to estimate the effect of increased speed limits on crash occurrence and severity during the period of post-implementation (approximately 1.3 years). The methodology used to evaluate the safety impact of increased speed limits utilized state-of-the-art knowledge and experience in field road safety evaluation. In particular, before-after (BA) evaluations were undertaken with the full Bayesian (FB) technique, which is a well-established statistical methodology with considerable literature available to provide guidance for its application for safety evaluations. It has been shown in several studies that the FB analysis has many advantages over other safety evaluation methodologies.

1.3 Report Structure

Chapter 1 of this report has provided a short introduction to the evaluation objective, establishing background information of the main motivation of MOTI for the speed limit change. Chapter 2 describes different safety evaluation methods with particular focus on the full Bayesian (FB) before-after (BA) analysis, which was selected for this evaluation. Chapter 3 presents the data for the selected treatment and comparison sites used in the evaluation including crash and traffic volume data. Chapter 4 discusses the results of the evaluation and changes in the safety level of subject roadways after implementing the speed limit increases. To compare results of this study with similar studies worldwide, Chapter 5 provides a thorough review of BA evaluation studies covering the safety impact of speed limit changes in other jurisdictions. Chapter 6 contains the conclusions of the study along with the study limitations. At the end of the report, a comprehensive reference list and several appendices are also provided.

2 Overview of Before-After Evaluations

2.1 Safety Evaluation Methods

Time-series and cross-sectional studies are two techniques that are frequently used to estimate the effect of specific road safety interventions. The most common method to estimate the effectiveness of safety initiatives is a time-series analysis, which is often referred to as a before-after (BA) analysis as mentioned earlier. This approach attempts to measure the change in safety over time due to the implementation of a safety initiative. A cross-sectional study compares the expected crash frequencies of a group of locations having a specific component of interest (treatment) to the expected crash frequency of a group of similar locations that lack the presence of this specific component. Any differences in crash frequency between the two groups are attributed to the change in conditions, representing the safety effect of the treatment. Cross-sectional studies are generally considered inferior to time-series analysis (before-after studies) since no actual change has taken place. Cross-sectional studies were also shown by many researchers to have several statistical shortcomings (see for instance Hauer, 2010). BA studies are known as observational when countermeasures have been implemented and treatment sites are selected where concerns about crash frequency were raised. Observational studies are much more common in road safety literature than experimental studies, i.e., studies where treatments have been implemented randomly in some locations to specifically estimate their effectiveness. Indeed, random selection in assigning treatments is an impractical and uneconomical solution for traffic agencies to undertake (Highway Safety Manual, 2010). An observational before-and-after study is generally perceived to be an effective way to estimate the safety effect of changes in traffic and roadway characteristics.

An observational BA study, where the treatment effect is naively evaluated as the change in observed crash frequency between the before and the after period, is known as a simple BA evaluation. The simple BA evaluation has many shortcomings; the crash frequency observed at a road location during a certain period of time is a biased measure that does not correctly reflect the location level of safety during that time period. The reason is that traffic crashes are events that have a random component. Crash frequency is a stochastic variable and the single number of crashes observed represents only one realization of its true (expected) value. Therefore, determining treatment effect should deal with the difference between the true safety levels, estimated with the use of statistical techniques, rather than the observed safety levels available in crash records.

For these reasons, other study types are preferred over a simple BA evaluation. For BA analyses, Bayesian methods are commonly used within an odds-ratio (OR) analysis for their ability to treat unknown parameters such as predicted crash frequency as random variables having their own probability distributions. Examples of Bayesian evaluation techniques include the Empirical Bayes (EB) (Hauer, 1997) (Sayed *et al.*, 2004) and fully Bayes (FB) (Persaud *et al.*, 2009) (El-Basyouny & Sayed, 2011), which are commonly used in traffic safety analyses. A typical EB before-after study requires the collection of data for three distinct sets of data: i) treatment sites, ii) comparison sites, and iii) reference sites. The comparison group is used to correct time-trend effects and other unrelated effects and includes sites that have not been treated but experience similar traffic and environmental conditions. The reference group is used to correct the regression-to-the-mean (RTM) artifact. Usually, the reference group includes a larger number of sites that are similar to the treatment sites and is used to develop a crash prediction model (CPM). The EB approach is used to refine the estimate of the expected number of crashes at a location by combining the observed number of crashes (at the location) with the predicted number of crashes from the CPM.

Alternatively, the FB approach has been proposed in the road safety literature to conduct before-after studies. The FB approach is appealing for several reasons, which can be categorized into methodological and data advantages. In terms of methodological advantages, the FB approach has the ability to account for all uncertainty in the data, to provide more detailed inference, and to allow inference at more than one level for hierarchical models, among others (El-Basyouny & Sayed, 2011). In terms of data requirements, the FB approach efficiently integrates the estimation of the CPM and treatment effects in a single step, whereas these are separate tasks in the EB method thereby negating the need for a reference group and reducing the data requirement.

To benefit from the additional advantages of the FB approach, several researchers have proposed the use of intervention models in the context of a before-after safety evaluation. Crash prediction models have been proposed to conduct crash intervention analysis by relating the crash occurrence on various road facilities as a function of time, treatment, and interaction effects. These intervention models acknowledge that safety treatment (intervention) effects do not occur instantaneously but are spread over future time periods and are used to capture the effectiveness of safety interventions.

2.2 Confounding Factors

As mentioned earlier, the evaluation process should ensure that a noted change in the safety performance measured is caused by the safety initiative and not by other "confounding" factors or causes. If other factors are allowed to contribute to the noted change, then sound conclusions about the effect of the countermeasure cannot be made. This report will focus on the main factors that are most relevant to road safety evaluations.

The regression-to-the-mean (RTM) artifact is considered one of the most important confounding factors since a countermeasure is not typically assigned randomly to sites but to locations with high-crash frequency. This high-crash frequency may regress toward the mean value in the post-treatment period regardless of the effect of the treatment. This condition will lead to an overestimation of the treatment effect in terms of the crash reduction. Usually, a group of reference sites are used to correct the RTM phenomenon by developing CPMs, i.e., a calibrated relationship between crash frequency and annual average daily traffic (AADT) volumes. The reference group includes an adequate number of sites that are similar to the treatment sites but have not undergone any improvements from the before to the after periods. Full Bayes techniques have been shown to account for the regression to the mean-using comparison groups (Persaud *et al.*, 2009) (El-Basyouny & Sayed, 2012).

Other confounding factors, theorized to have an effect on the frequency of crashes attributed to a road safety measure, are: the exposure effect, unrelated effect, and trend effects (maturation).

- **Exposure effect:** the most common measure of exposure is traffic volume, which can be represented in a number of ways (such as the total volume entering the location in a set period, or be separated into major or minor entering traffic volumes, or even be separated down to the particular movement). Traffic volume can vary over time because of various reasons such as increased demand of travel, population growth, or a change in the capacity of the intersection. It is important that the applied methodology accounts for exposure.

- **Unrelated effect:** refers to the possibility that factors other than the treatment being investigated caused all or part of the observed change in crashes. For example, traffic and driver composition, enforcement level, weather conditions, etc. can be changed from the before period to the after period.

- **Maturation:** refers to changes in long-term crash trends. Comparing crashes before and after implementing a specific countermeasure may indicate a reduction attributed to the countermeasure. However, it is possible that the crash reduction could be attributed to a continuing decreasing trend (e.g., caused by improvements to vehicle performance).

To account for unrelated effects and maturation, a group of comparison sites, which are similar facilities for geographic proximity and comparability (mainly traffic and geometry) to the treatment sites, are normally used. This is done with the assumption that the unknown factors should affect the comparison group in the same manner that they influence the treatment group. By comparing the change in crashes in the comparison group to the change in crashes in the treated sites, the treatment effect can be calculated.

2.3 Full Bayes Approach

Researchers have recently introduced the use of the full Bayesian (FB) approach to evaluate the effect of road safety countermeasures (Li *et al.*, 2008)(Persaud *et al.*, 2009) (El-Basyouny & Sayed, 2010, 2012). As discussed earlier, the FB method has several advantages including the ability to:

a) Conduct multivariate analysis. Crashes of different severity and types can be strongly correlated, thus, multivariate modeling can lead to more accurate and precise estimations.

b) Allow inference at more than one level for hierarchical (multi-level) models. It has been proposed that aside from being correlated across different severities and types, crash data exhibit a multi-level structure.

c) Treat each time period as an individual data point; that is, if the time period selected for the analysis is by month, then each month of the year represents a separate data point in the FB analysis, while the EB method typically deals with the entire study period as a single data point (either total or calculated as per year). This has two advantages: the ability to account for seasonal changes throughout the year and to look for changes in treatment effects with respect to time.

d) Integrate the estimation of the CPM and treatment effects in a single step. The FB method differs in that the model parameters have prior distributions and, therefore, the posterior distribution integrates and includes both prior information and all available data. Then, the expected crash frequency is a distribution of likely values rather than a point estimate.

Therefore, if we consider a BA study where crash data are available for a reasonable period of time before and after the intervention and, in addition, we also consider the availability of a comparison/reference group for the before and after period of the intervention at treatment sites, it is possible to write the foundational model for FB analysis of crash data in the form of a Poisson-lognormal (PLN) model. Different forms for the PLN model can be adopted. The full model form used in this evaluation can be found in appendix A.1.

By implementing the models in statistical software, the FB method provides the output of the odds ratio (OR) and regression coefficients in a seamless integration. This is done by computing B_i and D_i which are the predicted crash counts for the i^{th} treated site averaged over appropriate years during the before and after periods, respectively, and A and C the corresponding quantities for the specific site comparison group where the predicted crash counts are averaged over all sites in the matching comparison group and years. Then, the OR can be computed as:

$$OR_i = \frac{A/C}{B_i/D_i}$$

or

$$\ln(OR_i) = \ln(\mu_{TAi}) + \ln(\mu_{CB}) - \ln(\mu_{TBi}) - \ln(\mu_{CA})$$

where μ_{TB} and μ_{TAi} are the predicted crash counts for the ith treated site averaged over appropriate years during the before and after periods, respectively, and μ_{CB} and μ_{CA} are the corresponding quantities for the comparison group where the predicted crash counts are averaged over all sites in the matching comparison group and years. Finally, the overall index can be calculated from the following equation where NT is the number of traded sites:

$$\ln(OR) = \frac{1}{NT} \sum_{i=1}^{NT} \ln(OR_i).$$

The statistical software WinBUGS (Spiegelhalter *et al.*, 2005) was selected as the modeling platform to obtain FB estimates. The final part of the project consisted of calculating the treatment effectiveness indexes for the different points outlined above. After the results were obtained, it was possible to discuss and draw conclusions regarding the speed limit change intervention as a whole.

3 Evaluation Data

3.1 Treatment Sites

The sites (i.e., segments of highways) with increased speed limits were reviewed in detail to create a subset of treatment locations needed for the time-series (BA) analysis. A total of 60 treatment segments were selected along the stretches of highways with changed speed limits (see Table 3.1).

Table 3.1 Available Highways with Changed Speed Limits

Highway #	City/Town
1	Abbotsford to Hope
5	Hope to Kamloops
19	Nanaimo to Campbell River
97C	Merritt to Peachland
1	Hope to Cache Creek
3	Hope to Princeton
7	Mission to Hope
99	North Vancouver to Cache Creek
1	Victoria to Nanaimo
19	Campbell River to Port Hardy
1	Tobiano to Savona
1	Salmon Arm to Golden
3	Sunday Summit to Princeton
5	Heffley to Little Fort
6	New Denver to Nakusp
33	Black Mountain to Big White
33	Rock Creek to Westbridge
97	Swan Lake to Monte Creek
97A	Armstrong to Enderby
97A	Grindrod to Sicamous

3.2 Comparison Sites Selection

The selection of comparison sites is a key step to control confounding factors, such as maturation and unrelated effects, to ensure they do not influence the number of crashes attributed to change of speed limits. Therefore, a lack of proper control groups may be considered a flaw in the analysis and could affect the accuracy of the final results.

In this regard, some specific criteria were developed in order to ensure a systematic process for the selection of control group sites, which include the following:

- The potential control group sites must be a rural highway segment;
- The potential control group site must be in relatively close proximity to the treatment site;
- The potential control group site must have reliable crash data and traffic volume data available to support the evaluation;
- The potential control group site should be reasonably similar in design and operation, and stable over the evaluation timeframe to the treatment site: for example, there should be no major changes to the potential control group site such as significant construction.

With regard to the group size, the number of control sites should be large enough to avoid being subject to large random fluctuations which will consequently lead to a large standard error. For this study, the number of available comparison sites was equal to 95 segments which belonged to 35 matched-pair groups.

3.3 Crash and Traffic Data

Crash data was available for all treated and comparison sites for approximately 3.8 years, from January 2012 to October 2015. As the new speed limits were implemented in mid-2014, a study period of four months was selected in order to obtain a wider range of post-treatment time frames (i.e., 4 periods of 4 months in total).

Specifically, the three 4 month time periods used were:

- March to June;
- July to October;

- November to February.

Therefore, the before period ran from March 2012 to June 2014 (i.e., 7 periods of 4 months) and the after period from July 2014 to October 2015, with July-October 2014 as a transition period. Fatal-plus-injury (F+I) crash records were used to estimate the effect of increased speed limits. After a thorough review, property-damage-only crash records were found to be incomplete and were not employed for the analysis. Finally, traffic volume information, in the form of annual average daily traffic (AADT), was obtained both for treatment and comparison sites from existing MoTI records.

4 Results

4.1 Treatment Effectiveness Estimates

The resulting output of the model, i.e., the Odds Ratios (OR), which represents an average index of treatment effectiveness across the treated locations, is showed in Table 4.1. The full set of estimated model parameters was found in line with the ones obtained in similar studies (see for instance Sacchi *et al.,* 2014). The estimated effectiveness of the treatment in reducing crashes "C.R." can easily be estimated from the following equation:

$$C.R. = 100\times(1 - OR)$$

Overall, the resulting CR showed that the sections of roadway where new speed limits were changed, experienced an increase in the number of severe (fatal and injuries) crashes equal to 11.1% following the implementation of speed limit increases (see Table 4.1). This increase was found statistically significant at the 95% confidence level (CL).

Table 4.1 Change From the Before to the After Period for F+I Crashes

Odds-Ratio ± Standard Deviation	5% CL	95% CL	Estimated Crash Change (C.R.)*
1. 111±0.070	1.002	1.228	+11.1%

* Positive sign means increase of crashes

It should also be noted that although the FB technique can produce crash change estimations by site, the individual site results were not provided in this report for the following reasons:

- the after study period in this study was relatively short (i.e., approximately 1.3 years only); this caused the individual site results to be less reliable and not statistically significant;
- as the FB technique matches treatment sites with appropriate comparison sites, the results for individual locations will become sensitive to the safety performance of the smaller matched comparison group with short after period.

4.2 Time-Varying Crash Modification Function

The FB technique also allowed for the estimation of a crash modification function that varies over time (El-Basyouny and Sayed, 2012) (Sacchi *et al.*, 2014). In fact, the OR provided in Table 4.1 describe the effect of the speed limit change as point estimate. However, the intervention (i.e., speed limit change) effects do not always occur instantaneously but are spread over future time periods. Therefore, a crash modification function can be more adequate to explain how an intervention affects crash frequency over time. Within the FB context of technique, a crash modification function was developed as shown in Figure 4.1. The model form to obtain this curve is described in the Appendix A.1.6.

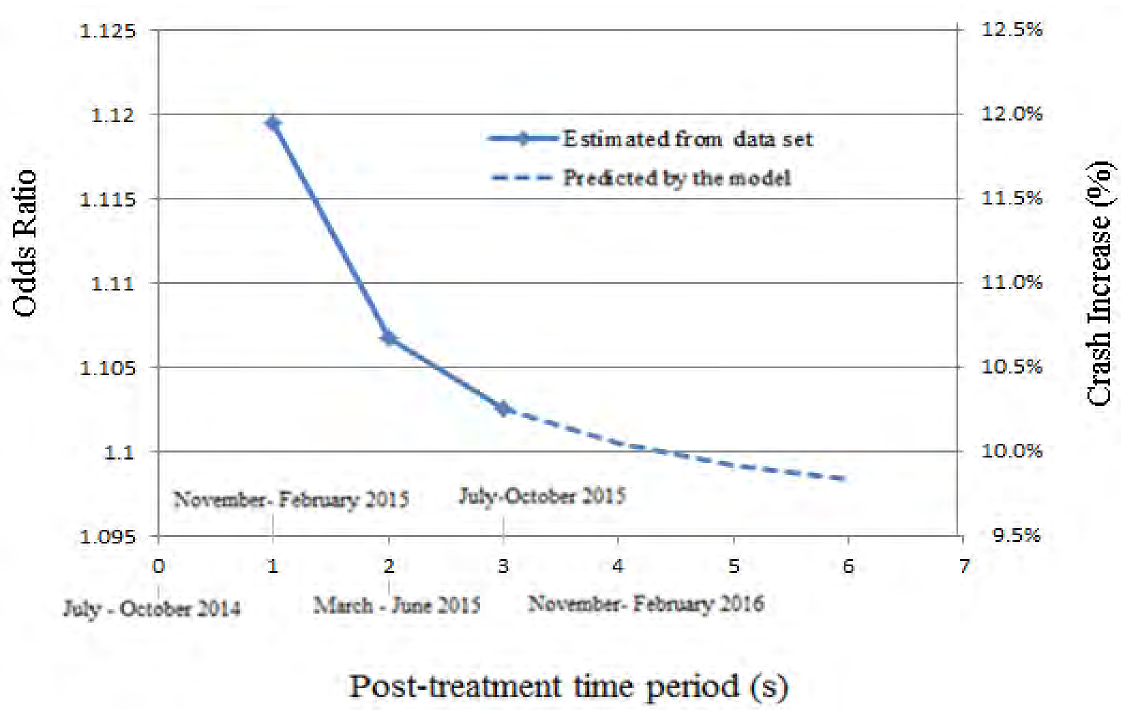

Figure 4.1 Crash Frequency Change over Time

Overall, it appears that the initial increase may be further reduced over time, as predicted by the model (dashed line in Figure 4.1).

5 Comparison to Similar Studies Worldwide

To test the results of the current study, a review of the available peer-reviewed published literature was made on the subject of speed limit changes and the safety effects that have resulted from their implementation. The review focused on information that would be considered the most reliable, including studies that deployed a robust methodology that accounted for some confounding factors, as well as studies that were supported with the availability of good quality data.

5.1 Safety Evaluations of Speed Limit Change

Many studies conducted worldwide have investigated the relationship between speed and safety showing the important role of speed management. Generally, the results indicate that the higher the travel speed, the greater the probability of crashes and the higher severity of the crashes.

In the US, for instance, several authors studied the effect on road safety of relaxing speed limits after the repeal of the national maximum speed limit law. Farmer *et al.* (1999) investigated the trends in fatalities over 8 years for 24 states that raised interstate speed limits and 7 states that did not. The study revealed an increase of 15% in motor vehicle occupant deaths for the 24 states that raised speed limits. After accounting for changes in vehicle miles of travel, fatality rates were 17% higher following the speed limit increases. Vernon *et al.* (2004) focused their attention on Utah highways (urban, rural and high-speed highway segments). The methodology used for the evaluation was an autoregressive integrative moving average (ARIMA) intervention time series analysis. The study only indicated statistically significant increase/decrease in collisions but did not provide the magnitude of the increase/decrease. Overall, the results showed a significant increase in both total crash rates on urban interstate segments, and fatal crash rates on high-speed rural non-interstate segments. However, 1) total, fatality, and injury crash rates on rural interstate segments, 2) fatality and injury crash rates on urban interstate segments and 3) total and injury crash rates on high-speed non-interstate segments were substantially unchanged. Finally, Shafi and Gentilello (2007) reported that, after the repeal of the national maximum speed limit law, there was a 13% increase in the risk of traffic fatalities in 29 states that increased speed limits on roadways with speed limits greater than 65 mph compared to states that did not increase speed limits. The researcher estimated that approximately 2,985 lives may be saved per year with a nationwide speed limit of 65 mph or less.

Another major study from Hong Kong evaluated the increase of speed limits that occurred from 1999 to 2002 on different highways. Nineteen sections were major roadways with increases in speed limits from an initial 50 km/h limit to a higher 70 km/h limit (Wong et al., 2005). Overall, the relaxation of the speed limit from 50 to 70 km/h caused an increase of 15% for fatal-plus-injury crashes. The relaxation of speed limits from 70 to 80 km/h was found to increase fatal-plus-injury crashes by 18% and fatal plus serious-injury only crashes by 36%. It should be noted that although this study was carried out in an urban environment, the comparison may be relevant for the stretches of highways with higher speed limits.

5.2 The Power Model of the Relationship between Speed and Safety

A number of meta-analysis studies (e.g., Elvik, 2009) revealed that the relationship between speed and safety (accident frequency) is best represented by a power model which was first introduced by Nilsson (1984):

$$\text{Accidents}_{\text{after}} = \text{accidents}_{\text{before}} \left(\frac{\text{speed}_{\text{after}}}{\text{speed}_{\text{before}}}\right)^{\text{Power}}$$

These meta-analysis have suggested that the estimates of the exponents ("Power") are generally higher for fatal and major injuries than minor injuries and property-damage-only (PDO) crashes. Moreover, the coefficient has been found higher for inter-urban highways than urban roads. For example, the power parameters were calibrated by Elvik (2009) as illustrated in Table 5.1.

Table 5.1 Summary Estimates of Exponents by Traffic Environment (Source: Elvik, 2009)

Rural roads/Freeways		
	Best Estimate ("Power")	**95% Confidence Interval**
Fatal crashes	4.1	(2.9, 5.3)
Serious injury crashes	2.6	(-2.7, 7.9)
Slight injury crashes	1.1	(0.0, 2.2)
Injury crashes - all	1.6	(0.9, 2.3)
Property-damage-only crashes	1.5	(0.1, 2.9)

Using average exponent values from Table 5.1, the fatal and injury crash increase reported in this study can be obtained from about 3 km/h increase in the mean operating speed for a segment with initial mean speed of 90 km/h.

6 Conclusions

Overall, the impact of increasing speed limits caused a statistically significant increase of crashes on rural highways in BC where the speed limits have been changed. The full Bayes evaluation technique adopted for this evaluation showed an increase 11.1% that was statistically significant at the 95% confidence level. The results are consistent with similar studies conducted worldwide in showing an increase in fatal and injury crash frequency after raising the speed limit

However, it should be noted that the post-treatment period for this evaluation was relatively short. As such, although the results are statistically significant, it is recommended that the evaluation is repeated when more crash data becomes available for a longer post-treatment period. It should also be noted that the robustness of the evaluation results highly depend on the quality of the crash data provided.

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Appendix

A.1 Theoretical Background for Full Bayes Models

The methodology employed to evaluate the effects on safety of the speed limit change was a full-Bayes BA study with advanced non-linear intervention functions.

Let Y_{it} denote the collision count recorded at site i (i = 1, 2, …, n) during time-period t (t = 1,2, …, m) (e.g., year, month, etc.). It is assumed that accidents at the n sites are independent and that

$$Y_i \mid \lambda_i \sim Poisson(\lambda_i) \tag{1}$$

To address over-dispersion for unobserved or unmeasured heterogeneity, it is assumed that

$$\lambda_i = \mu_i \exp(\varepsilon_i)\,, \tag{2}$$

where, μ_i is determined by a set of covariates representing site-specific attributes and a corresponding set of unknown regression parameters; whereas, the term $\exp(\varepsilon_i)$ represents a multiplicative random effect. The Poisson-lognormal (PLN) regression model is obtained by the assumption:

$$\exp(\varepsilon_i) \mid \sigma_\varepsilon^2 \sim Lognormal(0,\sigma_\varepsilon^2) \text{ or } \varepsilon_i \mid \sigma_\varepsilon^2 \sim Normal(0,\sigma_\varepsilon^2)\,. \tag{3a,b}$$

A.1.2 Non-Linear Intervention (Koyck) Model

A way to define μ_{it} is using the so-called "intervention" model, which has been available in the literature for some time (Li et al., 2008) (El-Basyouny and Sayed, 2011). An intervention model is a piecewise linear or non-linear function of the covariates designed to accommodate a possible change in the slope of crash frequency on time at treatment sites, which might be attributable to the intervention. El-Basyouny & Sayed (2012a, 2012b) advocated the use of the nonlinear "Koyck" intervention model (Koyck, 1954) to represent the lagged treatment effects that are distributed over time. The Koyck model is an alternative dynamic regression form involving a first-order autoregressive (AR1) CPM that is based on distributed lags. The model affords a rich family of forms (over the parameter space) that can accommodate various profiles for the treatment effects. Therefore, the Koyck model is used as an alternative nonlinear intervention model to estimate the effectiveness of safety treatments in BA designs. Recently, a comparison of several Bayesian evaluation techniques has shown the advantages of using the nonlinear intervention model for BA studies (Sacchi & Sayed, 2015).

Apart from the logarithm of the total circulating AADT and the length of the stretch of highway analyzed, $V_{,it}$ and L_i respectively, there are other covariates for crash frequency that can be included in the model: an indicator of whether the site was an intervention site or a comparison site (a treatment indicator T_i equal to 1 for treated sites, 0 for comparison sites), a time indicator for a sudden drop in crash frequency at the time of the intervention (I_{it} equal to 1 in the after period, 0 in the before period), and a two-way interaction to allow a different intervention slope across the treated and comparison sites. Moreover, the treatment effects can be modeled using distributed lags along with the AR1 model as a proxy for the time effects (Judge et al., 1988) (Pankratz, 1991). The regression equation for the rational distributed lag model is given by (El-Basyouny & Sayed, 2012a):

$$\ln(\mu_{it}) = \alpha_0 + \alpha_1 T_i + [\omega/(1-\delta B)] I_{it} + [\omega^*/(1-\delta B)] T_i I_{it} + \beta_1 \ln(V_{it}) + \beta_2 \ln(L_i) + \nu_t, \qquad (6)$$

where *B* denotes the backshift operator $(B Z_t = Z_{t-1})$, $|\delta| < 1$ and ν_t satisfies the following stationary AR1 equation

$$\nu_t = \phi \nu_{t-1} + e_t, \qquad |\phi| < 1, \qquad e_t \sim N(0, \sigma_\nu^2), \qquad t = 2, 3, ..., m. \qquad (7)$$

Consider the expansion $(1-\delta B)^{-1} I_{it} = I_{it} + \delta I_{i,t-1} + \delta^2 I_{i,t-2} + ...$, and note that the rational distributed lag model depicts an everlasting treatment effect as $\ln(\mu_{it})$ is tacitly assumed to be a function of the infinite distributed lags $(I_{it}, I_{i,t-1}, I_{i,t-2}, ...)$. The parsimonious model (6) is known as the Koyck model (Koyck, 1954) in which the lag weights $\omega\delta^k$ and $\omega^*\delta^k$ decline geometrically for $k = 0, 1, 2, ...$. Consequently, the earlier time frames following the intervention are more heavily weighted than distant years. It should also be noted that although the weights never reach zero, they will eventually become negligible. The two parameters ω (the intervention effect) and ω^* (intervention effects across treated and comparison sites) are impact multipliers, whereas δ is a decay parameter controlling the rate at which the weights decline.

A.1.3 Index of Treatment Effectiveness

To estimate the index of effectiveness of the countermeasure, let μ_{TBi} and μ_{TAi} denote the predicted collision counts for the i^{th} treated site averaged over appropriate years during the before and after periods, respectively, and let μ_{CBi} and μ_{CAi} denote the corresponding quantities for the matching comparison group where the predicted collision counts are averaged over appropriate sites (all sites in the matching comparison group) and time periods. The ratio μ_{CAi} / μ_{CBi} can be used to adjust the prediction for general trends between the before and after periods at the i^{th} treated site. Thus, the predicted crashes in the after period for the i^{th} treated site had the countermeasures not been applied is given by $\pi_{TAi} = \mu_{TBi} \; (\mu_{CAi} / \mu_{CBi})$. The index of effectiveness of the countermeasures at the i^{th} treated site is given by the ratio μ_{TAi} / π_{TAi}, which reduces to

$$\theta_i = \mu_{TAi} \, \mu_{CB} / \mu_{TBi} \, \mu_{CA} \tag{8}$$

or

$$\ln(\theta_i) = \ln(\mu_{TAi}) + \ln(\mu_{CB}) - \ln(\mu_{TBi}) - \ln(\mu_{CA}) \tag{9}$$

The overall index can be computed from

$$\ln(\theta) = \frac{1}{NT} \sum_{i=1}^{NT} \ln(\theta_i). \tag{10}$$

where NT is the total number of treatment sites. The overall treatment effect is calculated from $(\theta - 1)$, while the overall percentage of reduction in predicted collision counts is given by $(1 - \theta) \times 100$.

A.1.4 Parameters used for posterior estimates

The statistical software WinBUGS (Spiegelhalter *et al.*, 2005) was selected as the modeling platform to obtain full Bayes estimates of the unknown parameters (e.g., α_j and β_j). First, it is required to specify prior distributions for the parameters. To do so, prior distributions for all parameters are assumed and then the posterior distributions are sampled using Markov Chain Monte Carlo (MCMC) techniques available in WinBUGS. The most commonly used priors are diffused normal distributions (with zero mean and large variance) for the regression parameters and Gamma(ε, ε) or Gamma(1, ε) for the precision (inverse variance) parameters, where ε is a small number (e.g., 0.01 or 0.001).

Second, the whole set of parameters were assumed as non-informative with normal distribution with zero mean and large variance, i.e., normal (0, 10^3), to reflect the lack of precise knowledge of their value (prior distribution). Moreover, since comparison sites were selected to be as similar to treatment sites as possible, this may generate a correlation in collisions between sites within comparison-treatment pairs; hence, the variation due to comparison-treatment pairing was represented by allowing the model coefficients to vary randomly from one pairs to another, such that:

$\alpha_{p(i),j} \sim N(\alpha_j, \sigma^2_j)$,

$\beta_{p(i),j} \sim N(\beta_j, \sigma^2_j)$,

where the only difference in the PLNI model is the additional subscript $p(i)=1,2,\ldots, NC$ which denotes which treatment group the regression coefficient belongs to (with NC equal to the number of comparison groups) (El-Basyouny & Sayed, 2012).

Finally, to implement the Koyck model in WinBUGS, Equation 6 was rewritten and decomposed in three different equations (for t=1, t=2, and t≥3). The regression models obtained are showed in the next section (A.1.5).

The BUGS code produced draws from the posterior distribution of the parameters and, given those draws, MCMC techniques was used to approximate the posterior mean and standard deviation of the parameters. Hence, the posterior summaries in this study were computed by running two independent Markov chains for each of the parameters in the models for 40,000 iterations. Chains were thinned using a factor of 100 and the first 10,000 iterations in each chain were discarded as burn-in runs. The convergence was monitored by reaching ratios of the Monte Carlo errors relative to the standard deviations for each parameter less than 5% using the BGR statistics of WinBUGS and also using visual approaches such as observing trace plots.

A.1.5 Derivations of the Koyck model for WinBUGS

Rewriting Equation 6 as $\ln(\mu_{it}) = C_{it} + \nu_t$, the AR1 Equation 7 implies that $\nu_t = \phi[\ln(\mu_{i,t-1}) - C_{i,t-1}] + e_t$. Substituting this last expression in (6) leads to

$$\ln(\mu_{it}) = (1-\phi)\alpha_0 + (1-\phi)\alpha_1 T_i + [\omega/(1-\delta B)] I^*_{it} + [\omega^*/(1-\delta B)] T_i I^*_{it}$$
$$+ \beta_1 X_{1it} + (1-\phi)\beta_2 X_{2i} + \phi \ln(\mu_{i,t-1}) + e_t, \qquad (11)$$

where $I^*_{it} = I_{it} - \phi I_{i,t-1}$, $X_{1it} = \ln(V_{it}) - \phi \ln(V_{i,t-1})$, and $X_{2i} = ln(L_i)$.

Applying the operator $(1-\delta B)$ to both sides of (11) yields

$$\ln(\mu_{it}) = (1-\phi)(1-\delta)\alpha_0 + (1-\phi)(1-\delta)\alpha_1 T_i + \omega I^*_{it} + \omega^* T_i I^*_{it}$$
$$+ \beta_1 X^*_{1it} + (1-\phi)(1-\delta)\beta_2 X_{2i} + (\phi+\delta)\ln(\mu_{i,t-1}) - \phi\delta \ln(\mu_{i,t-2}) + e_t, \qquad (12)$$

where $X^*_{1it} = X_{1it} - \delta X_{1i,t-1}$.

Equation 12 holds for $t = 3, 4, \ldots, m$. The regression model for t=1 (with no lags) is obtained from Equation 11 as follows

$$ln(\mu_{i1}) = \alpha_0 + \alpha_1 T_i + \beta_1 ln(V_{i1}) + \beta_2 ln(L_i) + \nu_1,\ \nu_1 \sim N(0, \sigma^2_\nu/(1-\phi^2)),$$

whereas the regression model for t=2 (with one lag) is obtained from Equation 11 as follows

$$ln(\mu_{i2}) = (1-\phi)\alpha_0 + (1-\phi)\alpha_1 T_i + \beta_1 [ln(V_{i2}) - \phi ln(V_{i1})] + (1-\phi)\beta_2 X_{2i} + \phi \ln(\mu_{i1}) + e_2$$

To derive the variance of ν_1, the AR1 Equation 7 implies that $\text{var}(\nu_t) = \phi^2 \text{var}(\nu_{t-1}) + \sigma^2_\nu$. For $|\phi| < 1$ (stationary AR1), $\text{var}(\nu_t) = \sigma^2_\nu/(1-\phi^2)$, for all t.

It is important to check the appropriateness of such models for a given dataset by monitoring in WinBUGS the posterior probabilities of the stationary conditions $(|\hat{\delta}| \le 1)$ and

$(|\hat{\phi}| \leq 1)$. For posterior probability of non-stationarity $(|\phi| \geq 1)$, a $N(0, \tau)$ prior can be used (stationarity is not imposed) where τ is small, e.g., 1 or 0.5 (Congdon, 2006).

A.1.6 Time-Varying Crash Modification Function under the Koyck Model

The components of a time-varying crash modification function under the Koyck model (estimated in section 5.2) can be obtained from the following equation as shown in (El-Basyouny & Sayed, 2012):

$$\theta_{is} = K_1(i,s) K_2(i,s) K_3(i,s) \ , \tag{13}$$

where

$$K_1(i,s) = [\theta_{i,s-1}]^{\phi} = [\theta_{i1}]^{\phi^{s-1}} , \tag{14a}$$

$$K_2(i,s) = \exp\{c + d(1-\delta^s)/s\}, \quad c = \omega^*(1-\phi)/(1-\delta), \quad d = \omega^*(\phi-\delta)/(1-\delta)^2 , \tag{14b}$$

$$K_3(i,s) = [\theta(V_{1is})]^{\beta_1} / [\theta(V_{1i,s-1})]^{\phi\beta_1} , \tag{14c}$$

The component $K_1(i,s)$ corresponds to the time (novelty) effects. After the first time period of intervention (s=1), the subsequent novelty component would either grow or decline exponentially at a rate of ϕ according to whether $\theta_{i1} < 1$ or $\theta_{i1} > 1$. In both cases, $K_1(i,s)$ converges to 1 (since $|\phi| < 1$).

The treatment component of the crash modification function (14b) describes a non-linear relation of s involving the impact multiplier ω^* along with the AR1 parameter ϕ and the decay parameter δ. In the long-run $K_2(i,s)$ converges to $\exp\{c\}$, which corresponds to the everlasting (permanent) treatment (ELT) impact.

The component $K_3(i,s)$ represents the effects of the total circulating traffic volume. The numerator is the current traffic volume index raised to a fractional power (β_1) and thereby would be close to 1. Yet, the denominator would be even closer to 1 as the power of the previous year's index is much smaller ($\phi\beta_1 < \beta_1$). Thus, unless the traffic volume is subject to significant annual fluctuations, this component is expected to be near 1. $K_3(i,s)$ is inversely related to the indirect (through traffic volumes) local impact under the Koyck model.

APPENDIX D: 2015 Speed Surveys

Highway Description	Length (km)	Speed Limit (km/h)		85th Percentile speeds (km/h)		
		Old	New	Before	After (2015)	Change
Hwy 1, Victoria to Nanaimo						
Three sections between Bench Road and Nanaimo River Bridge	9	80, 90	90	100	100	0
Hwy 1, Abbotsford to Hope						
Whatcom Rd (Exit 95) to Junction with Highway 3 (Exit 170)	74	100	110	116	119	+3
Hwy 1, Hope to Cache Creek						
1 km east of the Lake of the Woods Rest Area to 1.2 km west of the Highway Maintenance Yard in Boston Bar	55	80, 90	100	107	112	+5
420 m east of Northbend Ferry road to 820 m east of Falls Creek	24	90	100	116	114	-2
Hwy 1, Cache Creek to Kamloops						
Six Mile Rest Area to Savona Station Rd	12	90	100	104	107	+3
Hwy 1, Kamloops to Salmon Arm						
Willow Rd (5 km East) to Hilltop Rd (Excluding 60 km/h through Sorrento)	25	90	100	105	111	+6
Hwy 1, Salmon Arm to Golden						
Canoe (70th St NE) to Revelstoke (Highway 23S) (Excluding existing 60 km/h through Sicamous)	58	90, 100	100	106	106	0
Revelstoke (Highway 23N) to Golden (Anderson Rd) Excluding Parks	101	90	100	103	109	+6
Hwy 3, Hope to Princeton						
Start of Highway 3 (Exit 170) to Junction with Highway 5 Coquihalla (Exit 177)	7	100	110	114	120	+6
End of 4 Lane (1.2 km West of Manning Park West Gate) to 500 m East of Allison Pass Highway Maintenance Yard	33	80, 90	100	103	109	+6
Sunday Summit to Whipsaw Creek	22	80	90	103	100	-3
Hwy 5, Hope to Kamloops						
Othello Rd to Junction Hwy 1	180	110	120	127	127	0
Hwy 5, Kamloops to Tête Jaune Cache						
Tod Mountain Rd to Junction Hwy 24 (Excluding 60 km/h through Barriere)	67	90	100	102	111	+9
Hwy 5A, Princeton to Merritt						
Old Hedley Rd to Hwy 97C Junction (excluding existing 70 km/h through Aspen Grove)	36	80	90	99	104	+5
Hwy 6, Nelson to Nakusp	15	80	90	99	97	-2
Golf Course Rd (North of New Denver) to Purdy Rd (North of Hills) (Excluding 70 km/h through Hills)						
Purdy Rd (North of Hills) to Upper Brouse Rd (Nakusp)	22	90	100	110	110	0

Highway Description	Length (km)	Speed Limit (km/h) Old	Speed Limit (km/h) New	85th Percentile speeds (km/h) Before	85th Percentile speeds (km/h) After (2015)	85th Percentile speeds (km/h) Change
Hwy 7, Mission to Hope						
Pullout West of Haigh Scale to Junction with Hwy 1	5	90, 100	100	107	107	0
Hwy 19, Nanaimo to Campbell River						
1 km north of Parksville Exit/Weigh Scale to 300 m south of Willis Road	114	110	120	121	125	+4
Hwy 19, Campbell River to Port Hardy						
200 m north of Duncan Bay Road to 500 m north of Mohun Creek Bridge	10	80	90	95	97	+2
500 m north of Mohun Creek Bridge to Gentry Road	44	90	100	106	107	+1
Cluxewe Bridge to Douglas Street	25	80, 90	100	96	100	+4
Hwy 33, Rock Creek to Kelowna						
South of McCulloch Rd to Gallagher Rd	32	90	100	101	106	+5
1 km North of Junction with Hwy 3 to 1 km south of Christian Valley Rd	12	90	100	110	108	-2
Hwy 97, Cache Creek to Williams Lake						
1 km North of Willow Drive (70 Mile House) to BCR Overpass (100 Mile House)	37	100	110	114	117	+3
Hwy 97, Vernon to Kamloops						
Junction Hwy 97A (Swan Lake) to Westside Rd	6	80	90	91	97	+6
Hwy 97A, Vernon to Sicamous						
North of Smith Drive to Hwy 97B Junction (Excluding 50 km/h through Enderby)	18	90	100	101	98	-3
Junction with Hwy 97B to Sicamous Creek Bridge (Excluding 50 km/h through Grindrod)	33	80	90	95	94	-1
Hwy 97C, Merritt to Peachland						
Junction with Hwy 5 Coquihalla (Coldwater Interchange) to Junction with Hwy 5A (Aspen Grove)	22	100	110	123	123	0
Junction with Hwy 5A (Aspen Grove) to Junction with Hwy 97 (Drought Hill Interchange)	78	110	120	126	126	0
Hwy 99, North Vancouver to Whistler						
Eagle Ridge Interchange to 150 m South of the Stawamus River Bridge	35	80	90	102	104	+2
400 m North of Depot Rd to Alta Lake Rd	45	80, 90	100	105	106	+1
Hwy 99, Whistler to Cache Creek						
400 m South of Whistler Heliport Rd to Pemberton Boundary	21	80	90	102	97	-5
1.4 km North of Lime Plant to Hwy 97 Junction	22	90	100	102	110	+8