City of Hamilton

Roadside Safety Assessment

Red Hill Valley Parkway

Final Report
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1. Introduction

1.1. Background

The City of Hamilton (The City) has resurfacing works scheduled for the Red Hill Valley Parkway (RHVP) in 2019 and has identified the need to complete a roadside safety assessment of the facility, including mainline and all on- and off-ramps. The main purpose of the study is to provide recommendations to reduce roadside related collision frequency and/or severity by correcting deficiencies and/or upgrading roadside safety devices to current standards (new guidance was published in 2017 by the Transportation Association of Canada – TAC and by the Ministry of Transportation Ontario – MTO). The main focus of the study is on short-term improvements, although some medium-or long-term recommendations are also discussed when relevant.

CIMA+ has completed two previous studies on the RHVP. In 2013[1], a review of the portion of the RHVP between Dartnall Road and Greenhill Avenue was undertaken to determine the safety performance of the roadway since its opening in 2007 and to recommend measures to increase safety performance. The Mud Street interchange ramps were also included in the scope of the 2013 review. In 2015[2], a review of the entire length of the RHVP mainline was undertaken, with a focus on cross median collisions and a review of the need to provide median barrier along the facility.

The main findings from both studies that are applicable to roadside safety include:

- Atypically high proportions of Single Motor Vehicle (SMV) collisions, as well as wet surface and non-daylight conditions;
- High proportion of “lost control” apparent driver action;
- All locations with the highest collision frequencies located within, on approach to, or leaving horizontal curves;
- Particularly high concentration of collisions around the King Street interchange (31% of RHVP northbound collisions occurred over only 7.5% of its length; this number increases to 40% for median related collisions);
- High concentration of median related collisions, in the northbound direction, along a 600-m section around the King Street interchange (40% of collisions 7.5% of the RHVP length);
- High concentration of median related collisions, in the southbound direction, along a 1.1-km section around the King Street and Queenston Road interchanges (38% of collisions over 13.5% of the RHVP length);
- High operating speeds, with 85th percentile of 110 km/h and 115 km/h in the northbound and southbound directions, respectively; and with 34% and 48% of drivers at or exceeding the design speed of the road (100 km/h) in the northbound and southbound direction, respectively;[3] and

[1] Red Hill Valley Parkway Safety Review, CIMA+. October 2013.
[2] Red Hill Valley Parkway Detailed Safety Analysis, CIMA+. November 2015.
[3] The 2015 study report indicates 15% and 22% of drivers at or exceeding the design speed of the road (110 km/h) in the northbound and southbound direction, respectively. At the time, the design speed information had not been provided to CIMA+ and was assumed as 110 km/h based on operating speeds.

- High collision frequency at the Mud Street E-W On Ramp (40 collisions between October 2009 and October 2013, four times greater than the ramp with the second highest collision frequency).

Some of the main recommendations provided in the previous studies, applicable to roadside safety, included:

- Install oversized speed limit signs/speed feedback signs + regular speed enforcement;
- Install Slippery When Wet signs (potentially supplemented by rain activated flashing beacons);
- Install permanent recessed pavement markers;
- Conduct pavement friction testing;
- Install high-tension cable guide rail along median (long-term measure, with consideration for effectiveness of other measures);
- Install high-friction pavement on approach and through the curve on the Mud Street E-W On Ramp; and
- Install progressively larger chevron alignment signs, pavement marking text, and dynamic/variable speed warning sign/flashing beacons on the Mud Street E-W On Ramp.

The present study takes into account the findings and recommendations of the previous studies, in order to confirm or expand the recommendations to reduce roadside related collision frequency and severity.

1.2. Scope of Work

The study area of this assignment includes the entire length of the RHVP and all its ramps, as illustrated in **Figure 1**.

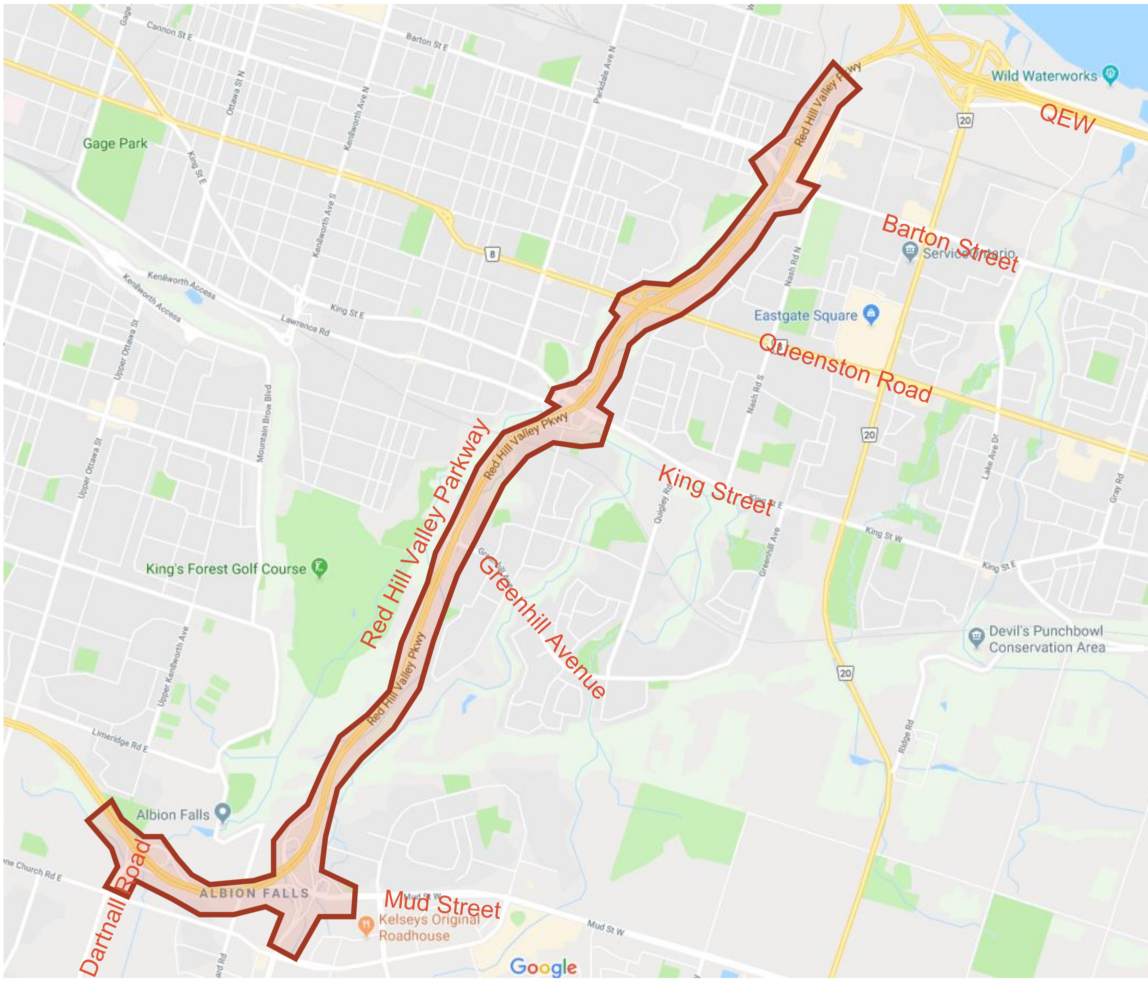

Figure 1: Study Area

The following tasks were undertaken for this assignment:

- Geometric design review to confirm curve radii and compatible design speeds of mainline and ramps, as well as requirement for median barrier;
- Collision history review to identify collision patterns associated with roadside hazards and roadway departures;
- Recommendation of safety countermeasures to reduce serious injuries and fatalities;
- Roadside safety devices field inventory and assessment based on current guidelines, and recommendations for maintenance, upgrades or new installations;
- Assessment of ramp/curve advisory speeds through ball bank tests;
- Review of shoulder condition through field inspection;
- Review of potential locations to build up emergency crossover locations; and
- Review of the feasibility to build up access to two wastewater facilities near Barton Street and Queenston Road.

The scope of this study is limited to short-term recommendations that can be implemented in conjunction with the planned resurfacing, although some long-term considerations may be provided where relevant.

2. Geometric Design Review

2.1. Design Speed and Curve Radii

CIMA+ completed a high-level review of the geometry of the RHVP mainline and ramps. The City provided design drawings for the RHVP mainline and ramps between the north end of the facility and the Greenhill Avenue interchange. The remaining locations were reviewed using satellite imagery (Google Earth) and approximate curve radii were measured. The review included curve radii and the compatible design speed (based on the 2017 TAC's Geometric Design Guide for Canadian Roads, which is the most conservative standard compared to the 1985 MTO Geometric Design Standards for Ontario Highways and to the 2017 MTO Supplement to the TAC Guide), and a subsequent comparison to operational speeds and posted ramp advisory speeds. The information reviewed was also used in the assessment of roadside safety devices (Section 4), to determine clear zone widths and guide rail length of need.

The RHVP has a posted speed limit of 90 km/h. According to the findings of a previous speed study (May 2013 Speed Study between Mud Street and Greenhill Avenue), operating speeds (85^{th} percentile) on the facility were 110 km/h for the northbound direction and 115 km/h in the southbound direction. Based on this, curve radii were reviewed for compatibility with a design speed of 110 km/h.

The RHVP was designed with maximum superelevations of 6%. **Table 1** summarizes minimum curve radii for various design speeds, based on TAC (2017).

Table 1: Minimum Curve Radii for 6% Maximum Superelevation (TAC, 2017)

Design Speed (km/h)	Minimum Radius (m)
120	750
110	600
100	440
90	340
80	250
70	190
60	130
50	90
40	55

The curves on the RHVP mainline present radii ranging between 420 m (between Greenhill Avenue and King Street) and 5,000 m (across the Greenhill Avenue interchange). Based on the values in Table 1, the following mainline locations have a compatible design speed lower than 110 km/h:

- RHVP Mainline north of Barton Street: R = 475 m; DS = 100 km/h;
- RHVP Mainline north of King Street: R = 450 m; DS = 100 km/h; and
- RHVP Mainline south of King Street: R = 420 m; DS = 90 km/h.

However, based on the 1985 Geometric Design Standards for Ontario Highways (MTO), the design standard at the time the RHVP was designed / constructed, a curve radius of 420 meters was compatible with a design speed of 100 km/h. This is also the case for the 2017 MTO Supplement to the TAC Guide (Exhibit 3-F – maximum speed at given superelevation for resurfacing projects). The City confirmed that the design speed of the Red Hill Valley Parkway is 100 km/h, therefore all curves were design with proper radii based on the then current design standards.

Curve radii compatible with a design speed lower than the operational speed, particularly around the King Street interchange, can be a contributing factor to collisions (refer to Section 3.1.5), especially when wet surface conditions are present. As previously noted, some sections of the RHVP present 85th percentile speeds up to 115 km/h, even though the posted speed limit (90 km/h) is lower than the compatible design speeds.

None of the ramps in the study area were found to have design speeds lower than the existing advisory speeds. The ramps listed in **Table 2** have compatible design speeds equal to the existing advisory speed.

Table 2: RHVP Ramps with Design Speed Equal to Existing Advisory Speed

Ramp	Curve Radius (m)	Compatible Design Speed (km/h)	Advisory Speed (km/h)
Barton Street N-E/W Off	65	40	40
Barton Street S-E/W Off	65	40	40
Barton Street E/W-N On	50	30	30
Barton Street E/W-S On	50	30	30
Queenston Road N-E/W Off	71	40	40
Queenston Road S-E/W Off	67	40	40
Queenston Road E/W-S On	43	30	30
King Street S-E/W Off	65	40	40
King Street E/W-N On	50	30	30
King Street E/W-S On	45	30	30
Mud Street E-W On	50	30	30
Upper RHVP S-W On	50	30	30
Dartnall Road S-W On	55	40	40

The advisory speeds equal to the design speeds could be a contributing factor to collisions on the ramps, since drivers may exceed the posted advisory speed of the road (refer to Section 5.1).

2.2. Median Barrier Warrant

The prevailing guidance in Ontario with respect to roadside barriers is the MTO's 2017 Roadside Design Guide (RDG). Based on the RDG, a median barrier is:

- Recommended where the median width is less than 10 metres;
- Optional where the median width is between 10 and 15 metres; and
- Not normally considered where the median width is more than 15 metres.

The RHVP median width varies between 15.0 and 22.7 metres. Under these conditions, a median barrier is not normally considered. However, the RDG also states that, for locations with median widths greater than 15 metres and with a history of cross-median collisions, a benefit-cost evaluation and an engineering study should be conducted to determine if barrier should be installed.[4] In the 2015 study, CIMA+ identified concerns with cross-median collisions and completed a benefit-cost evaluation, which concluded that providing a median barrier would be cost-effective.

A median barrier, however, would consist of a long-term countermeasure and would not be implemented in conjunction with the upcoming resurfacing of the RHVP. With the resurfacing and the implementation of other short-term countermeasures (refer to Section 3.4), it is possible that a reduction of median related collisions will be achieved by addressing speed and wet surface related collisions, which may change the benefit-cost relationship. The City should, therefore, monitor cross median collisions after the resurfacing is completed and other countermeasures are implemented, and re-evaluate the benefits of providing median barrier along the RHVP.

3. Collision History Review

3.1. Overview of Collisions

3.1.1. Collisions by Year

Collision records were provided by the City in digital format for the five-year period between 2013 and 2017. After removing collisions out of scope (e.g. occurring at intersections/ramp terminals) and duplicate records from the data set provided, a total of 939 collisions were reported to occur along the RHVP mainline, and a total of 231 collisions were reported to occur on ramps.

Figure 2 and **Figure 3** summarize collisions by year on the RHVP mainline and ramps, respectively, during the study period.

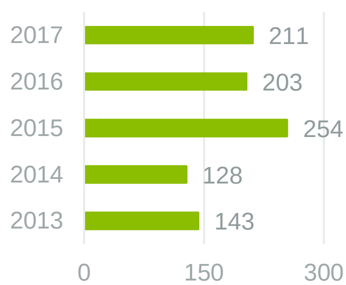

Figure 2: RHVP Collisions by Year (Mainline)

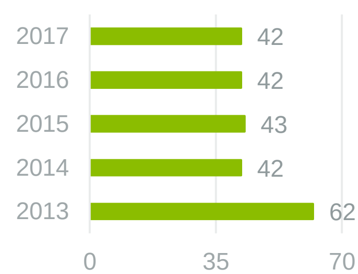

Figure 3: RHVP Collisions by Year (Ramps)

[4] Figure 2-13 of the RDG indicates that where the number of through lanes exceeds 3 lanes in both directions with centre median width less than 23 m, TL-3 barrier is recommended in the median. Although this would apply to the RHVP, the policy statement in the RDG makes reference to the figure in the context of freeway major capital expansion and reconstruction projects. The RHVP is not considered a freeway and the scope of the present study does not involve major capital expansion of reconstruction, therefore the recommendation does apply at this time.

The mainline presented a considerable increase in annual collisions between 2013 and 2017, from an approximate range of 130 to 140 collisions per year (2013 to 2014) to an approximate range of 200 to 250 (2015 to 2017). The ramps present a relatively constant number of collisions, with 42 or 43 collisions per year, except for 2013, when a relatively high number of collisions (62) were reported.

3.1.2. Collisions by Severity

Figure 4 and **Figure 5** summarize collisions by severity on the RHVP mainline and ramps, respectively, during the study period (2013 to 2017).

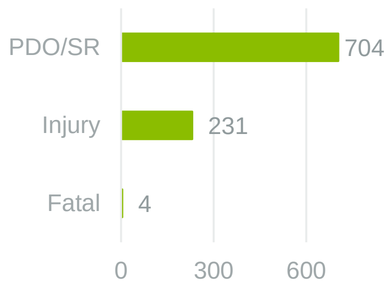

Figure 4: RHVP Collisions by Severity (Mainline)

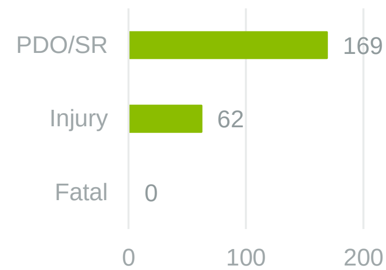

Figure 5: RHVP Collisions by Severity (Ramps)

The mainline presented 704 (75%) property damage only (PDO) collisions, which include self-reported (SR) collisions; 231 (24.6%) non-fatal injury collisions; and 4 fatal injury collisions (0.4%). The ramps presented 169 (73%) PDO/SR collisions and 62 (27%) non-fatal injury collisions. No fatal injuries were reported on the RHVP ramps during the study period.

The details of the fatal collisions on the RHVP are as follows:

- A head on collision occurred on May 5, 2015 at 11:27 p.m., in the northbound direction between Greenhill Avenue and King Street. The collision occurred with clear weather, wet surface and with dark conditions. A northbound vehicle lost control (skidding/sliding), ran off the road, and struck another vehicle in the southbound direction, resulting in two fatalities;
- A rear end collision occurred on July 23, 2015 at 10:10 p.m., in the northbound direction between Mud Street and Greenhill Avenue. The collision occurred with clear weather, dry surface and with dark conditions. A northbound vehicle changed lanes, struck another northbound vehicle and then struck a steel guide rail;
- A head on collision occurred on January 25, 2017 at 4:52 p.m., in the eastbound direction between Dartnall Road and Mud Street. An eastbound vehicle lost control, ran off the road and struck another vehicle in the westbound direction; and
- A sideswipe (same direction) collision occurred on February 21, 2017 at 11:00 p.m., in the northbound direction between Greenhill Avenue and King Street.

3.1.3. Collisions by Light, Environment and Road Surface Conditions

Figure 6 through **Figure 11** summarize the collisions in the study area, for mainline and ramps, broken down by light, environment and road surface conditions. For all of these factors, 42% of mainline collisions and 32% of ramp collisions have “unknown” values. These correspond to self-reported collisions, which do not contain this information.

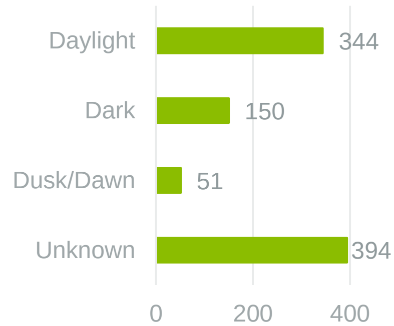

Figure 6: RHVP Collisions by Light Condition (Mainline)

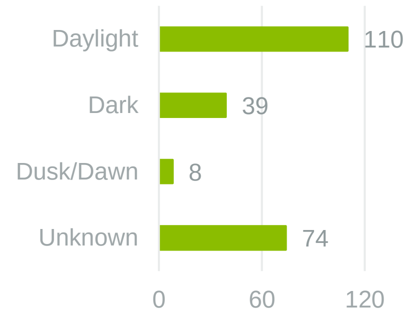

Figure 7: RHVP Collisions by Light Condition (Ramps)

Out of the 545 mainline collisions that include light condition information, 344 (63%) occurred during daylight periods, 150 (28%) during dark periods, and 51 (9%) during dusk/dawn periods; out of the 157 ramp collisions that include this information, 110 (70%) occurred during daylight periods, 39 (25%) during dark periods, and 8 (5%) during dusk/dawn periods. The 37% non-daylight collisions on the mainline is consistent with the review completed in the 2015 review.

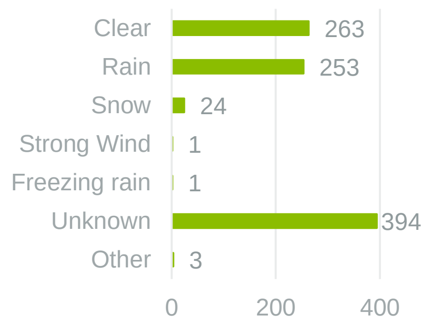

Figure 8: RHVP Collisions by Environment Condition (Mainline)

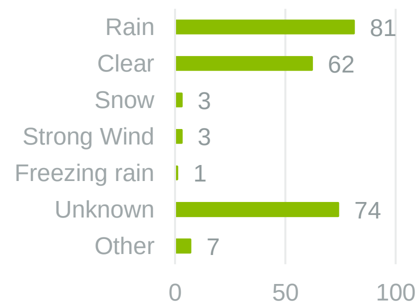

Figure 9: RHVP Collisions by Environment Condition (Ramps)

Out of the 545 mainline collisions that include environment condition information, 263 (48%) occurred with clear weather, 253 (46%) during rain, and 24 (4%) during snow conditions; out of the 157 ramp collisions that include this information, 81 (52%) occurred during rain, and 62 (27%) with clear weather. The proportion of rain environment condition is noticeably higher than what was found in the 2015 review (34%).

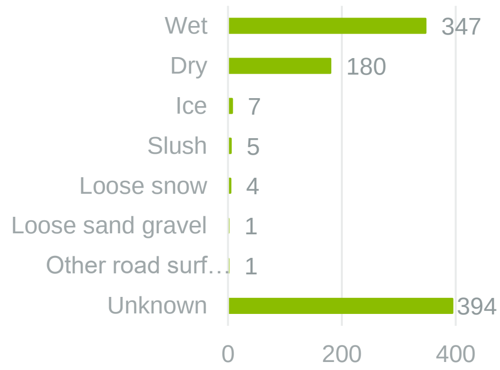

Figure 10: RHVP Collisions by Road Surface Condition (Mainline)

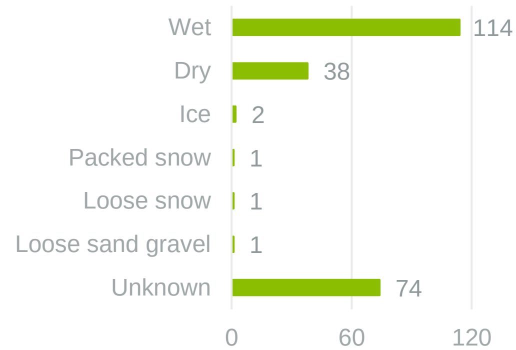

Figure 11: RHVP Collisions by Road Surface Condition (Ramps)

Out of the 545 mainline collisions that include road surface condition information, 347 (64%) occurred on wet surface and 180 (33%) on dry surface; out of the 157 ramp collisions that include this information, 114 (73%) occurred on wet surface and 38 (24%) on dry surface. The proportion of wet surface condition is noticeably higher than what was found in the 2015 review (50%), which, on that study, had already been found to be significantly higher than the Provincial and City averages of 17.6% and 22%, respectively.

3.1.4. Apparent Driver Action

Figure 12 and **Figure 13** summarize the number of drivers involved in collisions[5] by apparent driver action on the RHVP, for mainline and ramps, respectively.

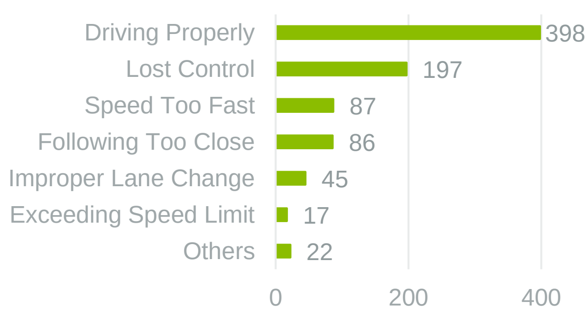

Figure 12: Apparent Driver Action (RHVP Mainline)

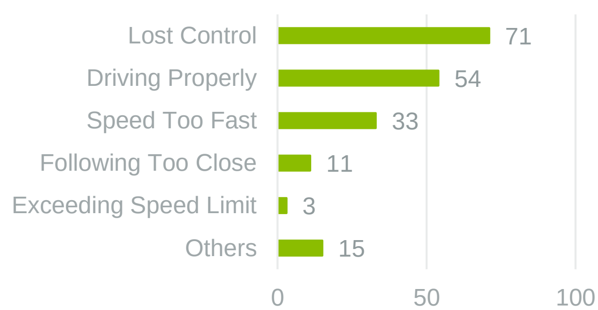

Figure 13: Apparent Driver Action (RHVP Ramps)

Out of 852 drivers with known apparent driver action for mainline collisions, 398 (47%) were reported to be driving properly; 197 (23%) were reported to have lost control; 87 (10%) were reported to be driving at a speed too fast for conditions; and 86 (10%) were reported to be following too close; only 17 drivers (2%) were reported to be exceeding the speed limit. For ramps, 71 out of 187 drivers (38%) were reported to have lost control; 54 (29%) were reported

[5] Self-reportable collisions excluded, since they do not include this information.

to be driving properly; 33 (18%) were reported to be driving at a speed too fast for conditions; but only 3 drivers (2%) were reported to be exceeding the speed limit.

When combined, lost control and speed too fast for conditions apparent driver actions represent 33% of drivers involved in a collision along the RHVP mainline, and 56% on ramps. These proportions increase to 44% on the mainline and to 68% on ramps for collisions involving wet surface conditions.

3.1.5. Collisions by Location

Figure 14 and **Figure 15** summarize total and fatal + injury (FI) collisions, respectively, by mainline location along the RHVP.

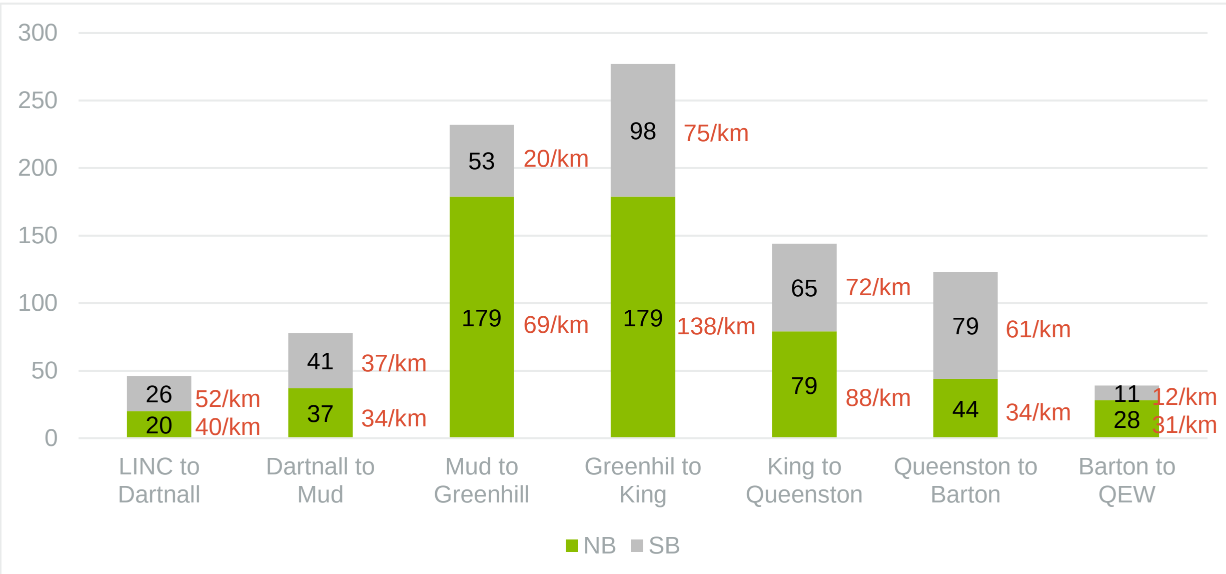

Figure 14: Total Collisions by Location (Mainline)

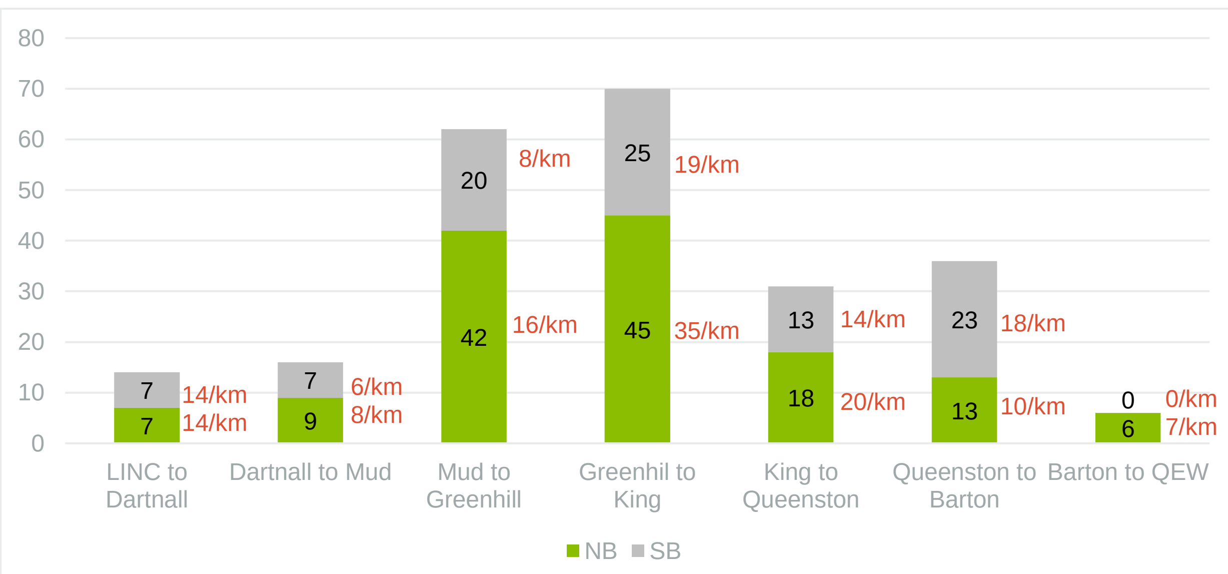

Figure 15: Fatal + Injury Collisions by Location (Mainline)

Both total and FI collisions follow a similar pattern with respect to the location of collisions, with the sections between Mud Street and Greenhill Avenue, and between Greenhill Avenue and King Street presenting the highest collision frequencies. This distribution is consistent with the findings from the 2015 review. When accounting for the length of each segment, the northbound segment between Greenhill Avenue and King Street presents the highest concentration of collisions, with 138 total and 35 FI collisions per kilometer. This is followed by the northbound section between King Street and Kingston Road (88 total and 20 FI collisions per km), the southbound section between Greenhill Avenue and King Street (75 total and 19 FI collisions per km), the southbound section between King Street and Queenston Road (72 total and 14 FI collisions per km), and the northbound section between Mud Street and Greenhill Avenue (69 total and 16 FI collisions per kim).

When wet surface conditions are reviewed by location (**Table 3**), the sections between Greenhill Avenue and Queenston Road stand out, with the proportion of wet surface collisions (self-reported records excluded) ranging between 69% and 88% for total collisions, and between 69% and 83% for FI collisions.

Table 3: Proportion of Wet Surface Collisions by Location

Mainline Section	Total	FI
LINC to Dartnall NB	25%	29%
LINC to Dartnall SB	40%	43%
Dartnall to Mud NB	26%	22%
Dartnall to Mud SB	33%	57%
Mud to Greenhill NB	58%	57%
Mud to Greenhill SB	36%	55%
Greenhill to King NB	88%	80%
Greenhill to King SB	69%	76%
King to Queenston NB	84%	83%
King to Queenston SB	71%	69%
Queenston to Barton NB	45%	46%
Queenston to Barton SB	48%	39%
Barton to QEW NB	38%	33%
Barton to QEW SB	60%	n/a

Although other sections also present atypically high proportions of wet surface collisions, it is possible that the sequence of curves with relatively small radii (as identified in the 2015 review) in the sections between Greenhill Avenue and Queenston Road contributes to these percentages.

Figure 16 summarizes collisions by ramp location, for the RHVP ramps with the highest collision frequencies (other ramps presented less than 10 total collisions).

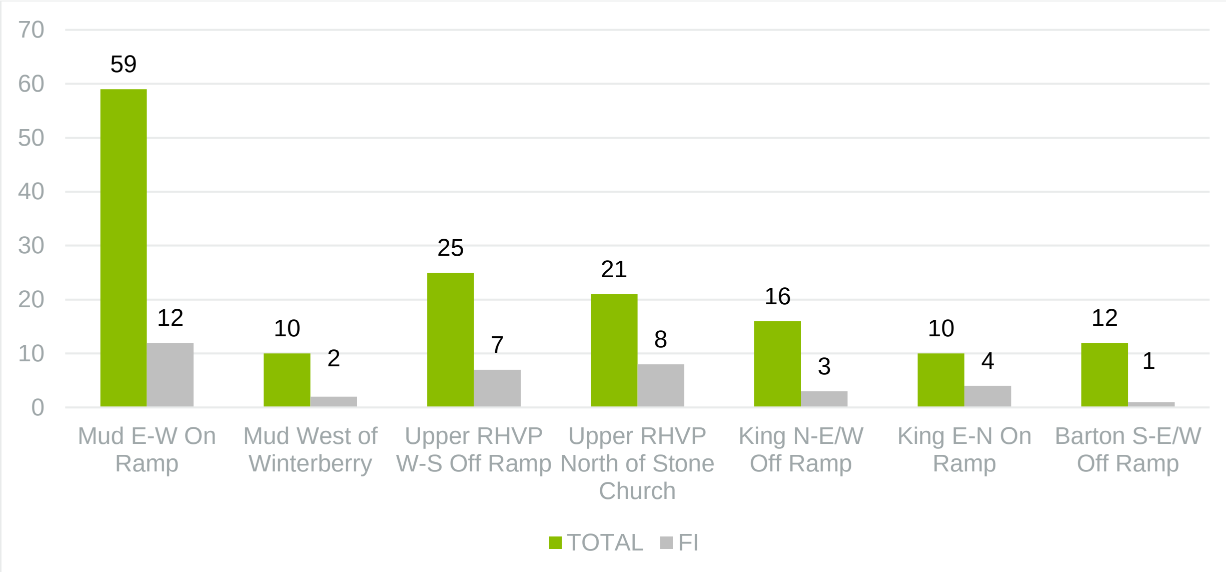

Figure 16: Collisions by Location (Ramps with 10 or More Collisions)

The Mud Street E-W On Ramp experienced the highest collision frequency of total and FI collisions, with 59 and 12, respectively, during the study period. Out of the 59 collisions, 52 (88%) were Single Motor Vehicle collisions. As noted in Section 2.1, this ramp has an advisory speed equal to the compatible design speed based on the curve radius. This could be a contributing factor to the high frequency of collisions compared to other ramps (although other factors may also be relevant, since, the same is the case for another 12 ramps in the study area).

The second and third highest collision frequency were observed on the Upper Red Hill Valley Parkway W-S Off Ramp (25 total and 7 FI collisions) and on the section of Upper red Hill Valley Parkway north of Stone Church Road (21 total and 8 FI collisions). **Figure 17** illustrates the location of these three ramps. The considerably higher collision frequency on the Mud Street E-W On Ramp, compared to other ramps in the study area, is consistent with the findings from the 2013 study, as mentioned in Section 1.1).

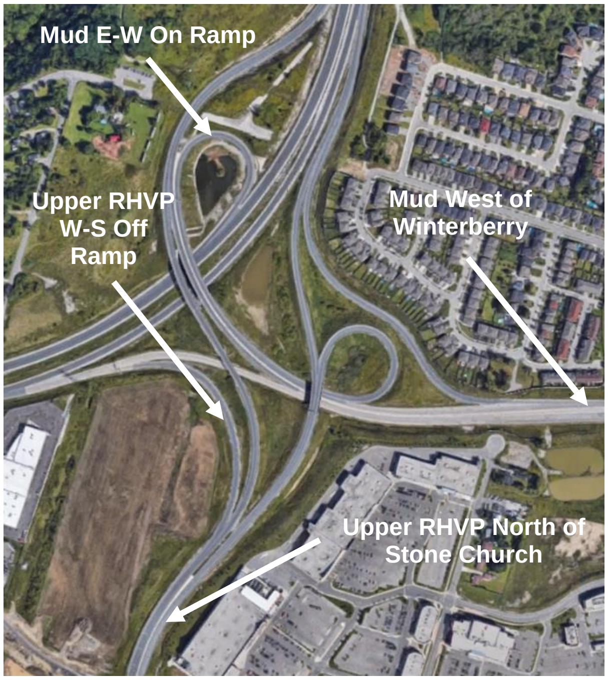

Figure 17: Mud Street and Upper Red Hill Valley Parkway Ramps

The proportions of wet surface collisions and combined lost control/speed too fast for conditions on these ramps are summarized in **Table 4**. These proportions only include collisions where the information was available (i.e. excludes self-reported collisions).

Table 4: Wet Surface and Lost Control/Speed Too Fast Collisions on Ramps

Ramp	Wet Surface (Total | FI)	Lost Control + Speed Too Fast (Total | FI)
Mud E-W On Ramp	78% | 75%	67% | 86%
Upper RHVP W-S Off Ramp	100% | 100%	80% | 86%
Upper RHVP North of Stone Church	50% | 50%	43% | 33%

All collisions on the Upper Red Hill Valley Parkway W-S Off Ramp occurred on wet surface, and 80% of drivers were reported to having lost control or being too fast for conditions (86% for FI collisions). Mud Street E-W On Ramp presented 78% of all collisions on wet surface, with 67% of drivers having lost control or being too fast for conditions (86% for FI collisions). On the Upper Red Hill Valley Parkway section north of Stone Church Road, 50% of collisions occurred on wet surface, and 43% of drivers lost control or were too fast for conditions (33% for FI collisions).

3.2. Collisions with Roadside Elements

Table 5 summarizes collisions with different roadside elements, as well as run off road collisions. In total, there were a total of 312 mainline collisions (121 FI) and 119 ramp collisions (44 FI) involving these elements.

Table 5: Summary of Collisions with Roadside Elements

Roadside Element	Mainline		Ramps	
	Total	FI	Total	FI
Concrete or Steel Barrier	197	68	49	16
Other Fixed Objects	22	7	17	3
Curb	13	6	9	6
Ditch	41	26	33	12
Run Off Road	106	44	46	15

Table 6 summarizes the relevant patterns found for collisions with roadside elements. Wet surface conditions were found to present high proportions, ranging from 54% for curbs to 86% for other fixed objects (including poles, fences, rock faces, trees, bridge supports, etc.) along mainline sections. For ramps, the proportion of wet surface collisions ranges from 65% for other fixed objects to 89% for curbs. Additionally, the northbound direction on the mainline presents the majority of collisions for all roadside elements reviewed, ranging from 54% for curbs to 69% for concrete or steel barriers.

Table 6: Relevant Patterns for Collisions with Roadside Elements

Roadside Element	Mainline		Ramps
	Wet Surface	NB Direction	Wet Surface
Concrete or Steel Barrier	76%	69%	84%
Other Fixed Objects	86%	68%	65%
Curb	54%	54%	89%
Ditch	76%	56%	88%
Run Off Road	70%	62%	83%
Any	**76%**	**64%**	**82%**

Figure 18 and **Figure 19** summarize total and fatal + injury (FI) collisions with roadside elements, respectively, by mainline location along the RHVP.

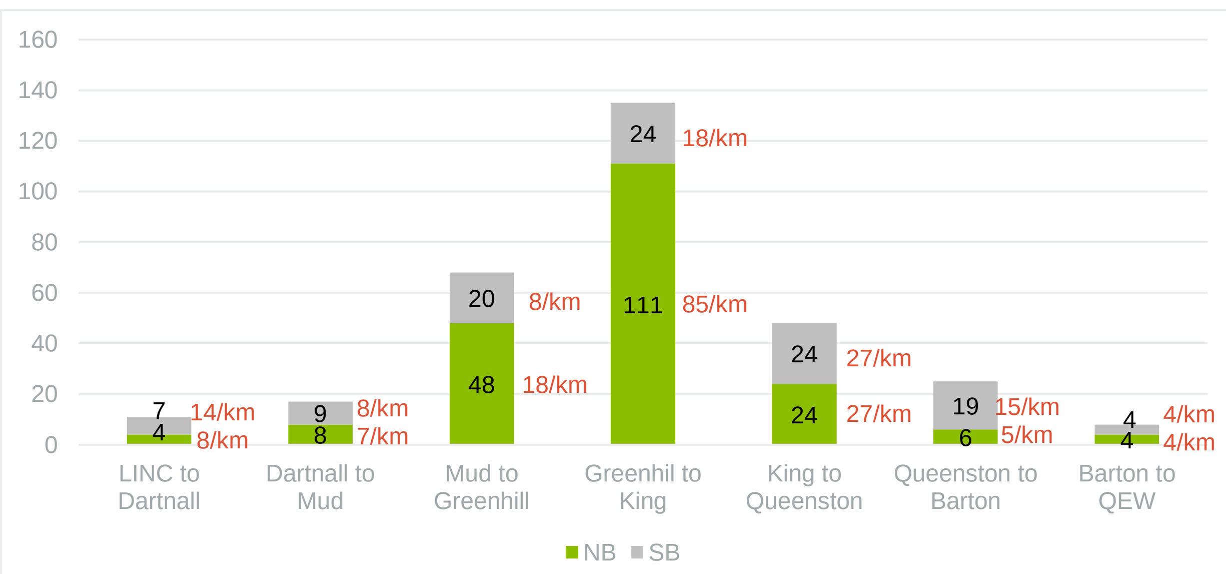

Figure 18: Total Collisions with Roadside Elements by Location (Mainline)

Figure 19: Fatal + Injury Collisions with Roadside Elements by Location (Mainline)

The section of the RHVP between Greenhill Avenue and King Street presents the highest frequency of collisions with roadside elements. In particular, the northbound direction along this segment experienced 111 collisions during the study period, almost five times the frequency of the southbound direction along the same section, and more than twice the frequency of the section between Mud Street and Greenhill Avenue northbound (the second highest frequency).

When accounting for the length of the segments, the northbound section between Greenhill Avenue and King Street presents 85 collisions per kilometre, three times higher than the second and third highest segments (northbound and southbound sections between King Street and Queenston Road, with 27 collisions per km each).

For fatal + injury collisions, the same sections of the RHVP stand out, however the difference between the sections with highest and second highest collision frequencies is not as high.

When wet surface conditions are reviewed by location (**Table 7**), the sections between Greenhill Avenue and Queenston Road stand out, with the proportion of wet surface collisions ranging between 75% and 96% for total collisions, and between 84% and 100% for FI collisions.

Table 7: Proportion of Wet Surface Collisions with Roadside Elements by Location

Mainline Section	Total	FI
LINC to Dartnall NB	50%	50%
LINC to Dartnall SB	14%	25%
Dartnall to Mud NB	38%	33%
Dartnall to Mud SB	44%	67%
Mud to Greenhill NB	67%	63%
Mud to Greenhill SB	60%	45%
Greenhill to King NB	90%	84%
Greenhill to King SB	96%	100%
King to Queenston NB	96%	100%
King to Queenston SB	75%	75%
Queenston to Barton NB	50%	75%
Queenston to Barton SB	58%	55%
Barton to QEW NB	25%	0%
Barton to QEW SB	75%	n/a

Figure 20 summarizes collisions with roadside elements by ramp location, for the RHVP ramps with the highest collision frequencies (other ramps presented 6 or less total collisions).

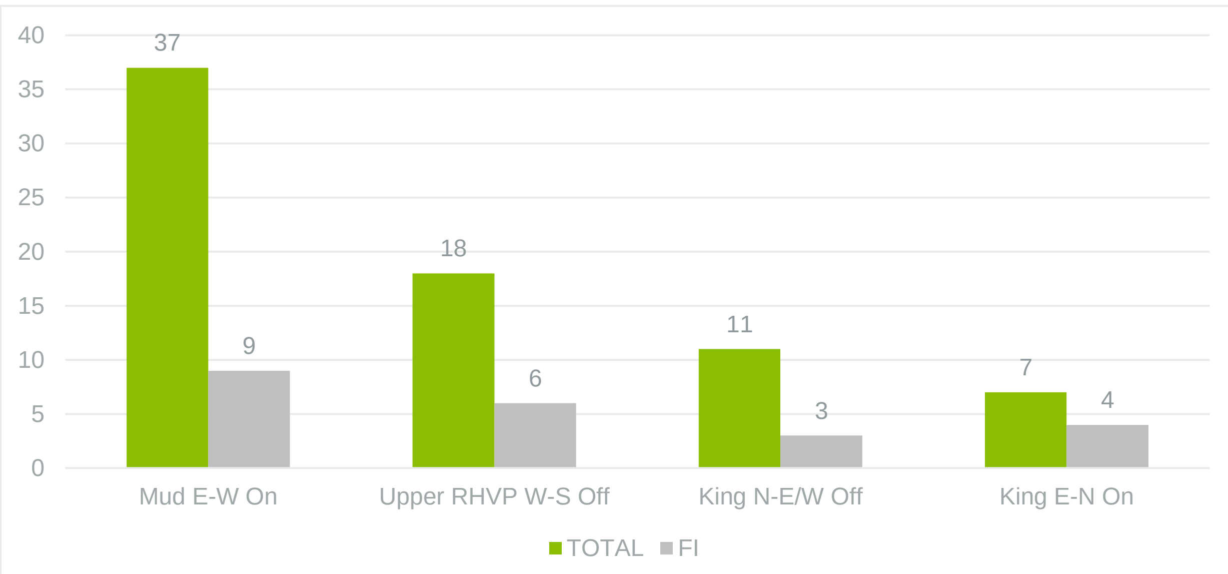

Figure 20: Collisions with Roadside Elements by Location (Ramps)

The Mud Street E-W On Ramp experienced the highest frequency of collisions with roadside elements for total and FI collisions, with 37 and 9, respectively, during the study period. The second and third highest collision frequency were observed on the Upper Red Hill Valley Parkway W-S Off Ramp (18 total and 6 FI collisions) and on the King Street N-E/W Off Ramp (11 total and 3 FI collisions).

The proportions of wet surface collisions and combined lost control/speed too fast for conditions on these ramps are summarized in **Table 4**. These proportions only include collisions where the information was available (i.e. excludes self-reported collisions).

Table 8: Wet Surface and Lost Control/Speed Too Fast Collisions on Ramps

Ramp	Wet Surface (Total | FI)	Lost Control + Speed Too Fast (Total | FI)
Mud E-W On Ramp	84% | 89%	67% | 86%
Upper RHVP W-S Off Ramp	100% | 100%	80% | 86%
King N-E/W Off Ramp	81% | 67%	43% | 33%

All collisions on the Upper Red Hill Valley Parkway W-S Off Ramp occurred on wet surface, and 80% of drivers were reported to having lost control or being too fast for conditions (86% for FI collisions). Mud Street E-W On Ramp presented 78% of all collisions on wet surface, with 67% of drivers having lost control or being too fast for conditions (86% for FI collisions). On the Upper Red Hill Valley Parkway section north of Stone Church Road, 50% of collisions occurred on wet surface, and 43% of drivers lost control or were too fast for conditions (33% for FI collisions).

3.3. Summary of Collision History Review

The findings from the collision history review for the period between 2013 and 2017 were consistent with the two previous studies completed by CIMA+ for the Red Hill Valley Parkway, as summarized below.

Overall Findings

- Wet surface collisions were found to represent 64% of mainline collisions and 73% of ramp collisions. The proportion of wet surface collisions on the mainline presented an increase compared with the 2015 study (50%);
- “Lost control” and “speed too fast for conditions” apparent driver actions were reported in 33% of mainline collisions (44% for wet surface collisions) and 56% of ramp collisions 68% for wet surface collisions); and
- These findings suggest that inadequate skid resistance (surface polishing, bleeding, contamination) and excessive speeds may be contributing factors to collisions;

Critical Locations

- The mainline sections with the highest collision frequencies in the study area are Mud Street to Greenhill Avenue, and Greenhill Avenue to King Street, particularly in the northbound direction;
- Mainline collisions involving wet surface condition present extremely high proportions between Greenhill Avenue and King Street, and between King Street and Queenston Road (up to 88%). In combination with potential skid resistance and excessive speed issues, curve radii compatible with a design speed of 100 km/h around the King Street interchange may explain this concentration of collisions (operational speed may exceed the design speed); and
- The Mud Street E-W On Ramp experienced the highest collision frequency among RHVP ramps, followed by the Upper RHVP W-S Off Ramp; the proportion of wet surface collisions on these two ramps are 78% and 100%, respectively, while the combined proportions of “lost control” and “speed too fast for conditions” apparent driver actions are 67% and 80%, respectively. The Mud Street E-W On Ramp presents a curve radius compatible with a design speed of 30 km/h, the same as the existing posted advisory speed; the Upper RHVP W-S Off Ramp has a curve radius compatible with a design speed of 50 km/h and posted

advisory speed of 40 km/h. It is possible that drivers are exceeding the design speed of these ramps.

3.4. Recommendations to Reduce Collision Frequency / Severity

Based on the findings presented in the previous sections, the following recommendations to reduce collision frequency and severity on the RHVP are provided:

- Ensure the pavement design for the upcoming resurfacing considers the history of wet surface collisions and investigates the need for higher friction surface;
- Consider installing oversized speed limit signs/speed feedback signs and conducting regular speed enforcement, particularly in the vicinity of the King Street and Queenston Road interchanges. The recommended locations and additional details for installing speed feedback signs are:
  - Eastbound, approximately 200 m west of Pritchard Road;
  - Northbound, approximately 550 m north of Greenhill Avenue;
  - Southbound, approximately 700 m north of Queenston Road;
  - Southbound, approximately 300 m north of King Street;

  It is recommended that the speed feedback signs be installed on their own post, on both right and left sides of the road at each location (i.e. a total of 8 signs), and in conjunction with oversize speed limit signs. Ideally, the size of the speed feedback sign should be consistent with the speed limit sign (this may depend on product availability); and

  It is suggested that speed feedback signs display the measured speeds up to 90 km/h, and a flashing “Slow Down” message when over 90 km/h, to prevent drivers attempting to “race” the sign.
- Immediately after the resurfacing is complete, and provided that adequate wet weather skid resistance is achieved, remove all Slippery When Wet signs along the RHVP (per guidance from Ontario Traffic Manual Book 6 – Warning Signs) and monitor collisions. If it is observed that more than one third of all collisions on a given section of the RHVP or its ramps occur on wet pavement, install Wc-105 (at intervals of 1 km or less if not a localized issue). If the proportion of collisions involving wet surface remains high, consideration may be given to supplementing the Slippery When Wet signs with rain activated flashing beacons;
- Consider installing high-friction pavement on approach and through the curve on the Mud Street E-W On Ramp (i.e. from approximately 65 m in advance of the existing overhead sign structure to the end of the curve – a total of approximately 330 m);
- Consider installing pavement marking text and/or peripheral transverse bars on the Mud Street E-W On Ramp and Upper RHVP W-S Off Ramp. The peripheral transverse bars should start approximately 10 metres in advance of the existing overhead sign structure and consist of 7 sets of bars spaced by 3 metres followed by 3 sets of bars spaced by 2 metres. “SLOW” text pavement marking can be installed 10 metres in advance of the start of the peripheral transverse bars. If not found to be effective, consider installing speed feedback signs or flashing beacons on the advisory speed signs; and
- Monitor the effect of the other countermeasures on median-related collision frequency and severity (particularly wet surface collisions, which may be reduced by improved pavement friction), and consider further investigating the need for installing median barrier in the long-term.

3.4.1. Discussion on Guide Rail Reflectors

After discussing the above recommendations with the City, the City requested CIMA+ to advise on the effectiveness of guide rail reflectors to improve delineation. According to the NCHRP Report 500, Volume 7 – A Guide for Reducing Collisions on Horizontal Curves (2004), the safety effect of enhanced delineation at a horizontal curve is difficult to assess because many of the research results are conflicting. The studies reviewed do not specifically refer to guide rail delineation, but to chevron alignment signs, post-mounted delineators and raised pavement markers. However, all these devices can be considered enhanced delineation and can be reasonably assumed to have a similar effect on drivers' understanding of the road geometry.

The Report only concludes that post-mounted delineators may improve safety at sharp curves and that chevrons are more effective than standard post-mounted delineators, however no quantitative estimates can be made. Some studies found increases in speeds when enhanced delineation is provided. The FHWA Low-Cost Treatments for Horizontal Curve Safety (2016) also indicates that there is no published research documenting the safety effects of installing delineators specifically on horizontal curves as of yet.

The use of guide rail reflectors is not uncommon and their application is seen in numerous Ontario municipalities, as well as on Provincial highways, including the 400-series. In CIMA+'s opinion, the ideal approach would be to delay installation of the guide rail reflectors until sufficient collision data is available after resurfacing (e.g. 3 years), and then install the reflectors in order to evaluate their effectiveness. Although we do not have objections to installing the guide rail reflectors immediately, this would prevent an accurate evaluation of their effect on collision frequency and/or severity, since it would not be possible to differentiate their contribution from the contribution of the resurfacing.

However, compared to raised or recessed pavement markers (which had been recommended in the 2013 and 2015 studies), the guide rail reflectors or other types of roadside mounted delineators have the benefit of preserving the integrity of the pavement.

4. Roadside Safety Devices Inventory and Condition Assessment

4.1. Inspection Procedure

CIMA+ completed site visits between October 29, 2018 and November 8, 2018, and an completed an inventory and condition assessment of roadside safety devices along the RHVP mainline and ramps, including steel beam guide rails, crash cushions, and unprotected hazards. Concrete barriers were not fully inventoried, however any significant evidence of barrier impacts were noted.

The condition assessment was based on the MTO's 2017 Roadside Design Guide (RDG) as the primary reference. For items not addressed by the RDG, TAC's 2017 Geometric Design for Canadian Roads (GDGCR) was used.

The following elements were reviewed as part of the inventory/condition assessment:

- **Hazard type and offset:** including type of hazard (embankment,[6] fixed object, water bodies, etc.), offset from travel lane, and offset of back of hazard;
- **Barrier type:** whether steel beam guide rail (SBGR), SBGR with channel, Type M SBGR, or other barrier type;
- **Barrier offset:** relative to the edge of the travel lanes;
- **Barrier height:** checked against the tolerances in Table 3-4 of the RDG (Acceptable Height at Completion of the Work – Top of Rail);
- **Post and blockout material and condition:** whether steel, wood or plastic, and number of damaged elements;
- **Approach and leaving end treatments:** type and condition of end treatments, including crash cushions. Extruder end treatments were also reviewed to identify whether they are regular 5-inch or substandard 4-inch extruders;
- **Approach and leaving end signage:** including object marker signs (presence, correct application and condition) and snow plow markers (presence and condition); and
- **Soil:** whether erosion or buildup was present.

In addition to the above, other items were also inspected as applicable, including the use of guide rails with barrier curb, presence of hazards behind the guide rail within the deflection distance, post spacing at structure connections, etc.

4.2. Roadside Safety Devices Recommendations

This section details the rationale used by CIMA+ in the development of recommendations associated with roadside safety devices. **Table 9** summarizes the types of deficiencies or concerns and the typical recommendation applied to each of them, including the rationale for the recommendations.

Table 9: Roadside Safety Devices Recommendations Rationale

Deficiency	Standard Recommendation	Rationale
4-inch Extruder Approach End Treatment (**Figure 21**)	Replace with MASH Sequential Kinking Terminal (MSKT).	4-inch extruder is a substandard energy attenuator end treatment (as opposed to 5-inch).
Eccentric Loader Approach End Treatment (**Figure 22**)	Replace with MASH Sequential Kinking Terminal (MSKT).	Eccentric Loader end treatment is an older technology.
SBGR height outside RDG tolerances	Replace section outside tolerances with Type M SBGR.	Proper mounting height is required for proper performance on impact.
Short length of need (LON) on approach end	Extend system with Type M SBGR to provide required LON (based on RDG).	Clear zone widths and encroachment lengths have been updated from previous standards, which may change LON requirements.

[6] Embankment hazards were evaluated using a simplified version of the method outlined in the RDG. Instead of a full benefit/cost analysis, the Severity Index (SI) of the embankment (considering slope, height, and surface condition) was compared to the SI of semi-rigid steel beam guide rails (3.6 for an assumed design speed of 110 km/h). If the SI for the embankment exceeded 3.6, the embankment was considered a hazard or area of concern.

Deficiency	Standard Recommendation	Rationale
SBGR adjacent to barrier curb (**Figure 23**)	If no channel or improper height, replace with Type M30 SBGR Adjacent to Concrete Curb; if SBGR with channel and proper height, system can remain, however in the long term, when major reconstruction occurs, removing the barrier curb is recommended.	Per 1993 MTO Roadside Safety Manual, only SBGR with channel was an appropriate use of guide rail with barrier curb.
Median concrete barrier approach ends (currently shielded by CAT-350 crash cushions) (**Figure 24**)	No immediate action required, however consider replacing with newer technology (e.g. QuadGuard, SMART, etc.) when necessary (e.g. after impact).	Upgrade to newer technology.
Sand Barrel Crash Cushions (**Figure 25**)	No action required in the short term beyond regular maintenance activities (i.e. replacing any damaged barrels, ensure proper alignment, etc.). In the long term, consider replacing with a different crash cushion based on practical maintenance considerations (e.g. City's parts inventory).	OPSD for this type of cushion no longer available; consideration for City's replacement parts inventory in the future.
Rock cuts (**Figure 26**)	Reviewed case by case, considering collision history.	RDG indicates severity index (SI) of semi-rigid barrier is 3.6 for DS = 110 km/h; SI for relatively smooth rock cut face is 3.2; and SI for jagged rock cut face is 6.3. The difference between smooth and jagged is not clearly defined. Because a guide rail would be closer to the road and likely to have higher frequency of impact than the rock cut face, installing a guide rail may be detrimental to safety if collisions with the rock cut face are not frequent.
Fixed objects protruding more than 100 mm above ground (**Figure 27**)	Fill ground around objects (illumination pole concrete base, culverts, etc).	Per RDG, objects protruding more than 100 mm are considered potential obstacles.

With respect to the use of guide rails with curbs, the GDGCR indicates that the installation of barrier curb in conjunction with barrier system is only permitted where operating speeds (85th percentile) are 60 km/h or less. For speeds over 60 km/h and up to 100 km/h, the use of semi-mountable and mountable curb is only permitted for certain offsets, and for speeds over 100 km/h, installation of curb in conjunction with barrier system is not recommended. Removal of the barrier curbs is not feasible in the context of the upcoming resurfacing, since drainage implications need to be considered, while removal of the guide rails is not recommended since this would leave road users exposed to potentially more severe hazards. However, in the long term, when major reconstruction occurs, the City should consider removing curbs at high-speed locations (e.g. mainline or off-ramps).

The 1993 MTO Roadside Design Guide, which was the current standard at the time of design and construction of the RHVP, states that curbs are undesirable on high speed roadways, although they may not be completely avoided. The Guide states that every effort should be made to design high speed roadways without curbs, and, if they cannot be avoided, only steel beam guide rail with channel is appropriate (when installed 250 mm behind the face of the curb). We note that it is not within the scope of this review to assess the need for curbs on the RHVP; only the appropriateness of the barrier type for the existing curb is reviewed, but it was found that some locations presented appropriate barriers (SBGR with channel) for the standards of the time, while others did not (SBGR without channel).

Figure 21: Substandard 4-inch Extruder

Figure 22: Eccentric Loader

Figure 23: SBGR with Barrier Curb

Figure 24: CAT-350 Crash Cushion

Figure 25: Sand Barrel Crash Cushion

Figure 26: Rock Cut

Figure 27: Fixed Objects Protruding More than 100 mm Above Ground

The detailed recommendations relating to roadside safety devices maintenance and upgrades are provided in a separate GIS file (Geodatabase), which includes the location of all roadside safety devices, a summary of the different elements assessed, and a recommendation for replacements, extensions, maintenance, etc. **Table 10** summarizes the Ontario Provincial Standard Drawings associated with each type of guide rail recommended.

Table 10: Ontario Provincial Standard Drawings (OPSD)

Type of Guide Rail	OPSD	Application
SBGR / SBGR with Channel	912.130	Partial replacements at mid-section of guide rails (particularly replacement of damaged sections)
Type M20 SBGR	912.185	Normal guide rail applications (extensions, full replacements, and partial replacements at ends of guide rails)
Type M20 SBGR Adjacent to 2H:1V Slope	912.186	Narrow shoulder applications (too close to slope)
Type M30 SBGR Adjacent to Concrete Curb	912.188	Guide rail + barrier curb applications
Type M Transition Rail	912.124	Transitions between standard and Type M guide rails
Steel Beam Leaving End Treatment (SBLET)	912.235	Leaving end treatments for standard guide rails
Type M Steel Beam Leaving End Treatment (Type M SBLET)	912.255	Leaving end treatments for Type M guide rails
Structure Connection with Channel Termination	912.430	Connections with bridge structures
Concrete Barrier Connection	912.480	Connections with Jersey barriers
MASH Sequential Kinking Terminal (MSKT)	922.186	Approach end treatments
Approach End Delineation	984.201	Wa-33 + plow marker installation at approach ends

Table 11 provides a summary of recommendations and associated costs, for mainline and ramps, including guide rails and MSKT end treatments. The estimated cost presented were based on the following unit costs provided by the City:

- $90 per metre for new guide rail installation or replacement;
- $4,500 for MASH Sequential Kinking Terminal (MSKT) end treatment; and
- $15,000 for crash cushion or barrel system.

The cost for sign (i.e. Wa-33 Object Marker + plow marker) installation was assumed as $250.

Table 11: Summary of Roadside Safety Recommendations and Costs

Type of Recommendation	Mainline	Ramps	Cost
SBGR (m)	4,479	5,516	$ 899,550
MSKT (units)	50	24	$ 333,000
SMART Crash Cushion (units)	0	2	$ 30,000
Wa-33 / plow marker signs (sets)	61	45	$ 26,500
	TOTAL COST		**$ 1,289,050**

We note that the recommendations provided correspond to “ultimate” improvements (i.e. recommendations were provided for all deficiencies identified), however the City may consider prioritizing these improvements based on available funds, focusing on locations with the highest collision frequencies (as identified in Section 3) for implementation with the upcoming resurfacing works. The remaining recommendations may be deferred, for example, until other maintenance is required for specific systems (for example, after an impact).

In addition to roadside safety devices, recommendations are also provided to mitigate potential hazards identified. This includes clearing denser vegetation on slopes or filling the ground around fixed objects protruding more than 100 mm. These recommendations are provided in the

GIS Shapefile, and it is assumed that they will be undertaken through regular operations and maintenance activities.

5. Curve Advisory Speeds

5.1. Curve Advisory Speed Assessment

According to Ontario Traffic Manual (OTM) Book 6 – Warning Signs, ball-bank indicator tests are the most common, available and practical way of determining advisory speeds. The ball-bank indicator test provides a combined measure of centrifugal force, vehicle roll and superelevation.

Table 12 provides the angle thresholds defined in the 5th Edition of the Institute of Transportation Engineers (ITE) Traffic Engineering Handbook (TEH), published in 1999. These thresholds consisted of the current guidance at the time the RHVP was designed and built.

Table 12: Summary of Roadside Safety Devices Maintenance and Upgrades

Speed (km/h)	TEH 5th Edition Threshold (Degrees)
20	14
30	12
40	12
50	12
60	10
70	10
80	10
90	10

CIMA+ completed a review of curve advisory speed signs on all RHVP ramps using a digital inclinometer, which provides maximum ball bank angle readings. Most of the existing curve advisory speed on the Red Hill Valley Parkway vary between 30 km/h for the 'loop' on-ramps (e.g. King Street, Queenston Road, Barton Street) and 50 km/h for off-ramps (e.g. Mud Street). The highest existing advisory speed in the study area is 60 km/h, for the Upper Red Hill Valley Parkway S-N On Ramp. The Greenhill Avenue ramps and the Queenston Road E/W-N Ramp were not reviewed in detailed since they do not present curved geometry. Multiple runs (minimum of 3 per ramp) were completed on each ramp, at the existing advisory speeds, and the average readings were compared with the ITE thresholds.

Only the Queenston Road S-E/W Off Ramp and the Dartnall Road S-E On Ramp failed the test (12.1 and 12.6, respectively). However, the maximum readings on the Queenston Road S-E-W Off Ramp typically occurred 30 to 40 m in advance of the stop bar at the signalized ramp terminal, where speeds are likely to be lower as drivers prepare to complete a right- or left-turn; the maximum readings along the Dartnall Road S-E On Ramp typically occurred where the pavement presented some unevenness, which may be addressed with the upcoming resurfacing. Furthermore, no collisions were reported to occur on this ramp between 2013 and 2017.

5.2. Curve Advisory Speed Recommendations

Considering the findings described above, none of the ramps require modifications from the existing curve advisory speeds. The two Greenhill Avenue Off Ramps have posted advisory speeds of 40 km/h, however they do not present curved geometry. The ramps end at stop-controlled intersections, and right-side Stop Ahead (Wb-1) warning signs are provided. The advisory speed signs should be removed from the Greenhill Avenue Off Ramps, and the City may consider installing additional, left-side Stop Ahead warning signs to reinforce the need to reduce speed.

6. Shoulder Condition

CIMA+ completed a brief review of shoulder conditions along the RHVP mainline and ramps. The review consisted of a drive-by/windshield review and focused on noticeable failures or areas where the shoulder condition was considerably more deteriorated in comparison with the travel lanes.

Overall, the review of shoulder condition did not indicate major concerns. Some isolated failures were identified that should be addressed in the short term, as listed in **Table 13** and illustrated in **Figure 28** through **Figure 30**. Occasional areas also present some alligator cracking, however the shoulders appeared to be stable. These should be monitored as part of regular patrolling and maintenance activities, as they can lead to the formation of potholes.

Table 13: Shoulder Issues

Location	Issue	Approximate Length
RHVP SB, approximately 460 m north of Barton Street (right shoulder)	Small depression on pavement	6 m
RHVP SB, approximately 540 m north of Queenston Road (right shoulder)	Pavement drop-off	10 m
RHVP SB, approximately 660 m south of Greenhill Avenue (right shoulder)	Gravel Shoulder Erosion	10 m
RHVP NB, approximately 560 m north of Mud Street (right shoulder)	Gravel Shoulder Erosion	10 m
Mud Street W-E Off Ramp, approximately 330 m east of Pritchard Road (right shoulder)	Pavement drop-off	10 m

Figure 28: Shoulder Depression

Figure 29: Pavement Edge Drop-off

Figure 30: Shoulder Erosion

CIMA+ also reviewed the presence of shoulder rumble strips, which may help prevent run-of-road collisions, along the RHVP mainline. The entire length of the RHVP presents rumble strips on both right- and left-side shoulders, with the following exceptions:

- Along the bridge between Mud Street and Greenhill Avenue: no rumble strips on either right- or left-side shoulders; and
- Along acceleration and deceleration lanes and along weaving sections near interchanges.

This type of application is consistent with the MTO "Highway Shoulder Rumble Strip Application and Installation Policy".

7. Emergency Crossover Locations

Section 2.3.7 of the MTO Roadside Design Guide (RDG) provides guidance with respect to the implementation of crossovers for emergency vehicles. These crossovers are normally provided where interchange spacing exceeds 8 km, and should only be provided where desirable stopping sight distances are provided. The guide states that these crossovers are unacceptable on freeways with medians less than 15 m wide, and that they should not be located closer than

450 m to the end of a speed change lane of a ramp or to any structure. Additionally, they should not be located on superelevated curves.

CIMA+ reviewed the Red Hill Valley Parkway Median on site to identify candidate crossover locations for emergency vehicles. The criteria used to select the candidate locations included the absence of drainage elements (such as catch basins) and maximum possible visibility to traffic approaching from both directions. Our review consisted of a simple visual inspection, from inside a passenger car, and no detailed measurements (e.g. sight distances) were undertaken.

Table 14 lists the candidate locations determined in our field review. The table also identifies potential concerns with these locations, in accordance with the RDG.

Table 14: Candidate Crossover Locations

Approximate Location	Potential Concerns
230 m north of Barton Street	• 50 m from end of speed change lane • 220 m from structure • Median < 15 m (unless shoulder is included)
540 m south of Barton Street	• 160 m from end of speed change lane • Median < 15 m (unless shoulder is included)
430 m south of Queenston Road	• 380 m from structure • Median < 15 m (unless shoulder is included)
480 m north of Greenhill Avenue	• 330 m from structure • Median < 15 m (unless shoulder is included)
660 m south of Greenhill Avenue	• Median < 15 m (unless shoulder is included)
220 m east of Pritchard Road	• 110 m from structure • At end of speed change lane • Visibility may be restricted by horizontal curves + tall vegetation on median
420 m west of Dartnall Road	• 420 m from structure • 180 m from end of speed change lane

As indicated in the table above, all locations present potential concerns when evaluated against the RDG requirements. Based on these findings, the construction of emergency crossover locations is not recommended along the Red Hill Valley Parkway.

In addition to the potential crossover locations, Hamilton Police Service requested to build up an existing unpaved service access located on the right side of the northbound lanes approximately 600 metres north of Greenhill Avenue. Hamilton Police Service reports that there's a drop-off between the shoulder and the unpaved access due to erosion. Since this is an existing access, there are no safety concerns and the access can be paved and leveled with the existing paved shoulder.

Figure 31: Unpaved Access North of Greenhill Avenue

8. Access to Wastewater Facilities

The City requested a review of the potential to improve access to two wastewater facilities located off the Red Hill Valley Parkway: HCS07B, located on the east side of the Red Hill Valley Parkway, approximately 200 m north of Queenston Road (**Figure 32**); and HCS07C, also located on the east side east of the Red Hill Valley Parkway, approximately 400 m north of Barton Street (**Figure 33**).

Figure 32: HCS07B near Queenston Road

Figure 33: HCS07C near Barton Street

City staff visit these sites monthly, when the operator drives past the station and pulls off to the gravel shoulder of the road. They then reverse against the flow of traffic and park behind guardrail/barriers for protection. The City is considering widening and extending the gravel portion of the shoulder to allow the service vehicle to better manoeuvre and park safely behind the guide rail, preferably from the south side to avoid reversing.

CIMA+ visited the two locations to assess whether the suggested improvements can be accommodated. Our review consisted of a preliminary, visual assessment to determine if there are any major physical impediments. If the City decides to carry out the suggested improvements, a more detailed topographic survey and design should be undertaken.

The site near Barton Street is shielded, from its south side, by a guide rail that extends continually towards the Barton Street overpass structure. Its function is to shield an embankment hazard along this section of road. Providing an opening on the south side of the facility would require the installation of an energy attenuator end treatment, which introduces a potential for frontal collisions, which are typically more severe than lateral collisions with a continuous guide rail. As such, providing an access to this facility from the south side is not recommended. The north side of the facility appears to be clear of any obstacles such as culverts and utility boxes, therefore can potentially be improved to accommodate the desired access. However, the north side of the facility presents a slope approximately 1.5-metre deep (**Figure 34**), which would require a considerable fill section.

Figure 34: Slope Height North of HCS07C

The site near Queenston Road presents a shorter guide rail on the south side, which shields the facility itself. However, a catch basin located on the south side (**Figure 35**) would prevent building up the access. On the north side, a culvert and some utility inspection boxes (**Figure 36**) are present, however the ditch is not as deep as the one at the Barton Street location (approximately 0.5 m). The culvert can potentially be extended further north to accommodate the require improvements, however the utility inspection boxes may be damaged if vehicles drive over them due to insufficient width.

Figure 35: Catch Basin South of HCS07B

Figure 36: Culvert/Utilities North of HCS07B

In conclusion, our preliminary assessment indicates that the suggested improvements to the two wastewater facilities can be accommodated on the north side, pending a topographic survey and detail design. The location near Queenston Road may require extending a culvert and the location of utility inspection boxes will need to be carefully assessed during detail design.

9. Summary of Findings and Recommendations

The City of Hamilton (The City) has resurfacing works scheduled for the Red Hill Valley Parkway (RHVP) in 2019 and has identified the need to complete a roadside safety assessment of the facility, including mainline and all on- and off-ramps. The main purpose of the study is to provide recommendations to reduce roadside related collision frequency and/or severity by correcting deficiencies and/or upgrading roadside safety devices to current standards. The following sections summarize the findings and recommendations resulting from this study.

9.1. Geometric Design Review

9.1.1. Design Speed and Curve Radii

CIMA+ completed a high-level review of the geometry of the RHVP mainline and ramps, including curve radii and the compatible design speed based on the 2017 TAC's Geometric Design Guide for Canadian Roads, and a subsequent comparison to operational speeds and posted ramp advisory speeds.

The following mainline locations have a compatible design speed lower than the operating speeds of the road (85th percentiles of 110 to 115 km/h):

- RHVP Mainline north of Barton Street: R = 475 m; DS = 100 km/h;
- RHVP Mainline north of King Street: R = 450 m; DS = 100 km/h; and
- RHVP Mainline south of King Street: R = 420 m; DS = 90 km/h.

Curve radii compatible with a design speed lower than the operational speed, particularly around the King Street interchange, can be a contributing factor to collisions, especially when wet surface conditions are present.

However, based on the 1985 Geometric Design Standards for Ontario Highways (MTO), the design standard at the time the RHVP was designed / constructed, a curve radius of 420 meters was compatible with a design speed of 100 km/h, which was confirmed by the City to be the design speed of the facility, therefore all curves were design with proper radii based on the then current design standards.

None of the ramps in the study area were found to have design speeds lower than the existing advisory speeds, however, 13 ramps (detailed in Section 2.1) have compatible design speeds equal to the existing advisory speed, which could be a contributing factor to collisions on the ramps, since drivers may exceed the posted advisory speed of the road.

9.1.2. Median Barrier Warrant

The RHVP median width varies between 15.0 and 22.7 metres. Under these conditions, a median barrier is not normally considered based on the MTO's 2017 Roadside Design Guide (RDG). However, the RDG also states that, for locations with median widths greater than 15 metres and with a history of cross-median collisions, a benefit-cost evaluation and an engineering study should be conducted to determine if barrier should be installed. In a previous study (2015), CIMA+ identified concerns with cross-median collisions and completed a benefit-cost evaluation, which concluded that providing a median barrier would be cost-effective.

However, with the resurfacing and the implementation of other short-term countermeasures (Section 3.4), it is possible that a reduction of median related collisions will be achieved by addressing speed and wet surface related collisions, which may change the benefit-cost relationship. The City should monitor cross median collisions after the resurfacing is completed and other countermeasures are implemented, and re-evaluate the benefits of providing median barrier along the RHVP.

9.2. Collision History Review

9.2.1. Findings

Collision records were provided by the City in digital format for the five-year period between 2013 and 2017. A total of 939 collisions were reported to occur along the RHVP mainline, and a total of 231 collisions were reported to occur on ramps. The findings from the collision history review for the period between 2013 and 2017 are summarized below.

Overall Findings

- Wet surface collisions were found to represent 64% of mainline collisions and 73% of ramp collisions. The proportion of wet surface collisions on the mainline presented an increase compared with the 2015 study (50%);
- “Lost control” and “speed too fast for conditions” apparent driver actions were reported in 33% of mainline collisions (44% for wet surface collisions) and 56% of ramp collisions 68% for wet surface collisions); and
- These findings suggest that inadequate skid resistance (surface polishing, bleeding, contamination) and excessive speeds may be contributing factors to collisions;

Critical Locations

- The mainline sections with the highest collision frequencies in the study area are Mud Street to Greenhill Avenue, and Greenhill Avenue to King Street, particularly in the northbound direction;
- Mainline collisions involving wet surface condition present extremely high proportions between Greenhill Avenue and King Street, and between King Street and Queenston Road (up to 88%). In combination with potential skid resistance and excessive speed issues, curve radii compatible with a design speed of 100 km/h around the King Street interchange may explain this concentration of collisions (operational speed may exceed the design speed); and
- The Mud Street E-W On Ramp experienced the highest collision frequency among RHVP ramps, followed by the Upper RHVP W-S Off Ramp; the proportion of wet surface collisions on these two ramps are 78% and 100%, respectively, while the combined proportions of “lost control” and “speed too fast for conditions” apparent driver actions are 67% and 80%, respectively. The Mud Street E-W On Ramp presents a curve radius compatible with a design speed of 30 km/h, the same as the existing posted advisory speed; the Upper RHVP W-S Off Ramp has a curve radius compatible with a design speed of 50 km/h and posted advisory speed of 40 km/h. It is possible that drivers are exceeding the design speed of these ramps.

9.2.2. Recommendations

Based on the findings from the collision history review, the following recommendations to reduce collision frequency and severity on the RHVP are provided:

- Ensure the pavement design for the upcoming resurfacing considers the history of wet surface collisions and investigates the need for higher friction surface;
  Consider installing oversized speed limit signs/speed feedback signs and conducting regular speed enforcement, particularly in the vicinity of the King Street and Queenston Road interchanges.
- Immediately after the resurfacing is complete, and provided that adequate wet weather skid resistance is achieved, remove all Slippery When Wet signs along the RHVP and monitor collisions. If it is observed that more than one third of all collisions on a given section of the RHVP or its ramps occur on wet pavement, install Wc-105 signs per OTM Book 6 guidance (if still not effective, consideration may be given to supplementing the Slippery When Wet signs with rain activated flashing beacons);
- Consider installing high-friction pavement on approach and through the curve on the Mud Street E-W On Ramp;
- Consider installing pavement marking text and/or peripheral transverse bars on the Mud Street E-W On Ramp and Upper RHVP W-S Off Ramp; and
- Monitor the effect of the other countermeasures on median-related collision frequency and severity (particularly wet surface collisions, which may be reduced by improved pavement friction), and consider further investigating the need for installing median barrier in the long-term.

Additional details are provided in Section 3.4.

9.3. Roadside Safety Devices

CIMA+ completed an inventory and condition assessment of roadside safety devices along the RHVP mainline and ramps, including steel beam guide rails, crash cushions, and unprotected hazards. The condition assessment was based on the MTO's 2017 Roadside Design Guide (RDG) as the primary reference. For items not addressed by the RDG, TAC's 2017 Geometric Design for Canadian Roads (GDGCR) was used.

A series of recommendations were provided to upgrade or replace guide rails and end treatments where necessary due to substandard conditions or the need to extend existing systems or install new systems. In addition to roadside safety devices, recommendations are also provided to mitigate potential hazards identified (e.g. clearing denser vegetation on slopes or filling the ground around fixed objects protruding more than 100 mm). The estimated cost to implement all recommended roadside improvements is $1.3M. These improvements, which are detailed in Section 4.2 and in a separate GIS file (Geodatabase) are expected to be implemented during the upcoming resurfacing project.

In the long-term, when major reconstruction occurs on the Red Hill Valley Parkway, the City should consider removing curbs at high-speed locations (e.g. mainline or off-ramps), since, based on guidance from the TAC Geometric Design Guide for Canadian Roads, the installation of barrier curb in conjunction with barrier system is only permitted where operating speeds (85^{th} percentile) are 60 km/h or less.

9.4. Curve Advisory Speeds

CIMA+ completed a review of curve advisory speed signs on all RHVP ramps using a digital inclinometer, which provides maximum ball bank angle readings. The ball bank results were compared to the thresholds outlined in the 5th Edition of the Institute of Transportation Engineers (ITE) Traffic Engineering Handbook (TEH), published in 1999, which was the current guidance at the time the RHVP was designed and built.

The results of our review indicated that none of the ramps require modifications from the existing curve advisory speeds. The two Greenhill Avenue Off Ramps have posted advisory speeds of 40 km/h, however they do not present curved geometry. The ramps end at stop-controlled intersections, and right-side Stop Ahead (Wb-1) warning signs are provided. The advisory speed signs should be removed from the Greenhill Avenue Off Ramps, and the City may consider installing additional, left-side Stop Ahead warning signs to reinforce the need to reduce speed.

9.5. Shoulder Condition

CIMA+ completed a brief review of shoulder conditions along the RHVP mainline and ramps. The review consisted of a drive-by/windshield review and focused on noticeable failures or areas where the shoulder condition was considerably more deteriorated in comparison with the travel lanes. The review of shoulder condition did not indicate major concerns. Some isolated failures were identified that should be addressed in the short term, as detailed in Section 6.

9.6. Emergency Crossover Locations

CIMA+ reviewed the Red Hill Valley Parkway Median on site to identify candidate crossover locations for emergency vehicles based on Section 2.3.7 of the MTO Roadside Design Guide (RDG), which provides guidance with respect to the implementation of crossovers for emergency vehicles.

All locations reviewed present potential concerns when evaluated against the RDG requirements, including proximity to structures and to speed change lanes. Therefore, the construction of emergency crossover locations is not recommended along the Red Hill Valley Parkway.

9.7. Access to Wastewater Facilities

A review of the potential to improve access to two wastewater facilities located off the Red Hill Valley Parkway was completed. The two locations are HCS07B, located on the east side of the Red Hill Valley Parkway, approximately 200 m north of Queenston Road, and HCS07C, also located on the east side east of the Red Hill Valley Parkway, approximately 400 m north of Barton Street.

Our review assessment indicates that the suggested improvements to the two wastewater facilities can be accommodated on the north side, pending a topographic survey and detail design. The location near Queenston Road may require extending a culvert and the location of utility inspection boxes will need to be carefully assessed during detail design.

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