TNS
TRUE NORTH SAFETY GROUP

RED HILL VALLEY PARKWAY INQUIRY
HIGHWAY DESIGN AND ASSESSMENT REPORT

Your File: 96189
TNS File No.: 220007

Prepared For:

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November 1, 2022

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1.0 INTRODUCTION

Paliare Roland Rosenberg Rothstein LLP retained True North Safety Group as an independent contractor to provide transportation safety expert consulting services to the Red Hill Valley Parkway Inquiry, Justice Herman Wilton-Siegel, Commissioner.

We were asked to prepare an expert report regarding the following:

- Reviewing the compliance of the Red Hill Valley Parkway ('RHVP') design with the 1985 Geometric Design Standards for Ontario Highways, Ministry of Transportation of Ontario[1] (the '1985 MTO Design Guide').
- Commenting on design consistency and motorist expectancy in relation to the above geometric review.
- Defining the scope and components of a highway safety review and determining if the 2015 CIMA Report[2] evaluated those components.
- Providing comment on the most likely contributing factors to an over-representation of wet road collisions on a highway.
- Reviewing the City of Hamilton historic collision reports to determine any trends in collision frequency/proportions and type on the Red Hill Valley Parkway.

1.1 Scope

Our assessment is based on a review of the materials provided, readily accessible industry-guidance and our March 9, 2022 report related to Principal Design and Maintenance Standards, Guidelines and General Practices for Ontario Highways (the 'March 2022 TNS report'). A copy of the March 2022 TNS report is appended (**Appendix A**) for completeness and ease of reference. **Appendix B** includes the documents that were reviewed and/or relied upon in the preparation of this report.

We have not been asked to complete independent research to respond to the above requests. A number of geometric design evaluations of the RHVP design noted above cannot be accurately undertaken from the information provided. In-vehicle field investigations were undertaken by TNS Group on October 2, 2022, to review the overall character and nature of the highway and conduct ball bank tests[3] of the horizontal curves along the RHVP.

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[1] Geometric Design Standards for Ontario Highways, Ministry of Transportation of Ontario, 1985.

[2] HAM0056684_0001, Red Hill Valley Parkway Detailed Safety Analysis, CIMA, 2015.

[3] A ball bank indicator device is used to measure the combined effect of the body roll angle of the test vehicle, the centrifugal force on the vehicle, and the roadway superelevation as a vehicle is driven around a horizontal curve. A further discussion regarding the method and its use are included in the body of this report.

2.0 HIGHWAY DESIGN

2.1 Roadway Function and Speed

The RHVP was planned as a divided urban freeway. The 1985 MTO Design Guide provides general guidance and ranges for selecting design speeds and posted speeds for various classifications of roadway facilities; however, it does not provide prescriptive guidance on selecting or posting speed limits. The RHVP was planned to have a posted speed of 90 km/h and a design speed of 100 km/hr.

Generally, the overall design criteria are specified at the outset of the design process including the design speed. Once the design speed is selected, the highway features are designed, at a minimum, to the prevailing guidance.

Typically, common practice is to select a design speed of 10 to 20 km/h over the posted speed limit for a paved roadway. The design speed is applied in decision-making regarding the appropriate road design features (i.e., road/shoulder widths, horizontal curves and vertical curves, and roadside design and protection) and traffic control devices.

In determining the appropriate design speed of the RHVP, the following should be considered:

- The 1985 MTO Design Guide allows a design speed range of 90 to 120 km/h to be selected for freeways, with a 90 km/h design speed to be considered only in the instance of urban freeways.
- The 1985 MTO Design Guide indicates that:
    - Design speed should desirably be set at 20 km/h over the posted limit.
    - There may be instances on lower functioning classes of highways (i.e., secondary highways) with lower volumes, where it is acceptable to apply a design speed equal to the posted speed.
    - Every effort should be made to provide the desirable standard on freeways as they are generally the important links and more heavily travelled components in the highway system.
    - Urban environments and challenging topography are two of the reasons provided in which desirable design speeds may not be accommodated.
    - Consistency and uniformity of design standards place the driver in an environment which is fundamentally safer because it is more likely to compensate for the driving errors that unfortunately are inevitably made.

Based on our experience, the majority of Ontario freeway facilities were posted with 100 km/h maximum speed limits and had mainline design speeds of 120 km/h.

The Red Hill Creek Expressway/Queen Elizabeth Way Preliminary Design Report[4] (a design report prepared for the addition of the Red Hill Creek interchange to the QEW alignment) noted a 110 km/h design speed was chosen, which differed from the 'normal standard' of 120 km/h applicable to other sections of the QEW. Further, a number of RHVP safety-related reports prepared for the City of Hamilton by CIMA between 2013 and 2018, refer to a posted speed of 90 km/h and an 'assumed' design speed of 110 km/h[5], based on industry practice. The latter two instances support the 1995 MTO Design Guide guidance of designing freeways to 20 km/h over the posted speed. In 2019, however, the City clarified that the design of the RHVP was 100 km/h during the preparation of the CIMA's Roadside Safety Assessment report[6].

From the early planning stages through to the preliminary design criteria for the RHVP, a design speed of 100 km/h was consistently documented. This decision was within the range of acceptable design standards; however, the selection of minimum design standards for one or more geometric components would need to be undertaken with caution knowing that the RHVP would have an operating environment that might be an expectancy violation for the users of a freeway facility in Ontario. Road users have priori expectations of acceptable operating speeds based on observations and experiences of driving on a range of highway classes, including freeways. Aspects of highway design or operating characteristics that are in accordance with these prevalent expectations aid motorist decision making; whereas, situations that violate user expectations lead to slower reaction times, and poor decision-making regarding an appropriate operating speed. In this case, a design speed of 100 km/h on a controlled access freeway facility would be an expectancy violation to some road users, notwithstanding the 90 km/h posted speed.

The 2015 CIMA report[7] documented operating speeds on the RHVP and noted that 85% speeds were approximately 110 km/h and 115 km/h in the northbound and southbound directions respectively. Figure 1 shows the partial results of 2013 speed studies undertaken on the RHVP. Notwithstanding the 90 km/h posted speed, the 2013 speed study results suggest that road users were adopting operating speeds consistent their expectations of an appropriate speed for an Ontario freeway environment.

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[4] Red Hill Creek Expressway/Queen Elizabeth Way Preliminary Design Report, McCormick Rankin Corporation, 2002 (HAM0000180).

[5] Image 2 of HAM0056684_0001, Red Hill Valley Parkway Detailed Safety Analysis, CIMA, 2015; Image 21 of HAM0056683_001, Lincoln Alexander Parkway Median Safety Study, November 2015, CIMA; and Image 36 of CIM0015106, Hamilton LINC and RHVP Speed Study, October 2018, CIMA.

[6] Image 38 of HAM0054495_0001, Roadside Safety Assessment, CIMA, 2019.

[7] Image 30 of HAM0056684_0001, Red Hill Valley Parkway Detailed Safety Analysis, CIMA, 2015.

Applying the assumed design speed of 110 km/h, the 2015 CIMA report indicated 15% to 22% of the road users were travelling at or exceeding the design speed of the RHVP in the northbound and southbound directions, respectively. Based on the actual design speed, 34 to 48% of vehicle speeds were at or exceeding the design speed. Had CIMA been advised of the actual design speed of 100 km/h on the RHVP, they would have identified the significant disparities between the posted, design and operating speeds, and potentially adjusted their assessment scope, assumptions, or range and/or immediacy of potential remedial actions.

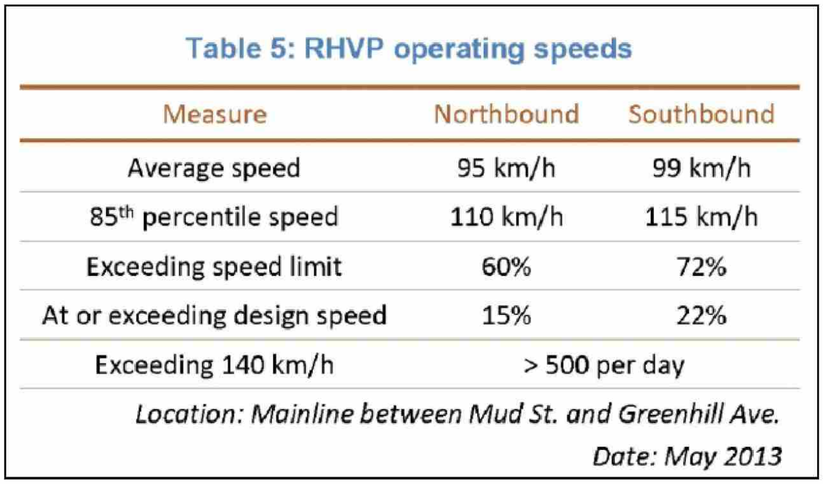


Table 5: RHVP operating speeds

Measure	Northbound	Southbound
Average speed	95 km/h	99 km/h
85th percentile speed	110 km/h	115 km/h
Exceeding speed limit	60%	72%
At or exceeding design speed	15%	22%
Exceeding 140 km/h	> 500 per day	

Location: Mainline between Mud St. and Greenhill Ave.

Date: May 2013

Figure 1: RVHP operating speeds (CIMA, 2015).

2.2 Lane/Shoulder Widths and Pavement Crossfall

RHVP was designed as a four-lane divided highway and a six-lane divided section in the more southerly sections. **Figure 2** is an excerpt from the 1985 MTO Design Guide which outlines the design standards for four and six-lane divided highways and indicates that a minimum lane width of 3.75 m should be applied for a 100 km/h design speed. A median lane width of 3.5 m is permitted on a six-lane highway.

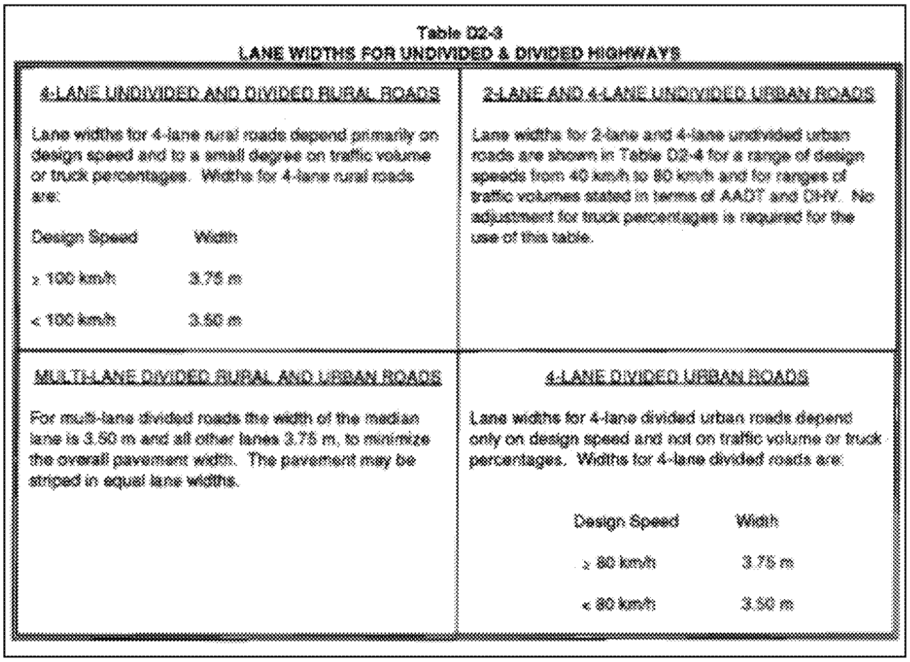


Table D2-3
LANE WIDTHS FOR UNDIVIDED & DIVIDED HIGHWAYS

4-LANE UNDIVIDED AND DIVIDED RURAL ROADS

Lane widths for 4-lane rural roads depend primarily on design speed and to a small degree on traffic volume or truck percentages. Widths for 4-lane rural roads are:

Design Speed	Width
≥ 100 km/h	3.75 m
< 100 km/h	3.50 m

2-LANE AND 4-LANE UNDIVIDED URBAN ROADS

Lane widths for 2-lane and 4-lane undivided urban roads are shown in Table D2-4 for a range of design speeds from 40 km/h to 80 km/h and for ranges of traffic volumes stated in terms of AADT and DHV. No adjustment for truck percentages is required for the use of this table.

MULTI-LANE DIVIDED RURAL AND URBAN ROADS

For multi-lane divided roads the width of the median lane is 3.50 m and all other lanes 3.75 m, to minimize the overall pavement width. The pavement may be striped in equal lane widths.

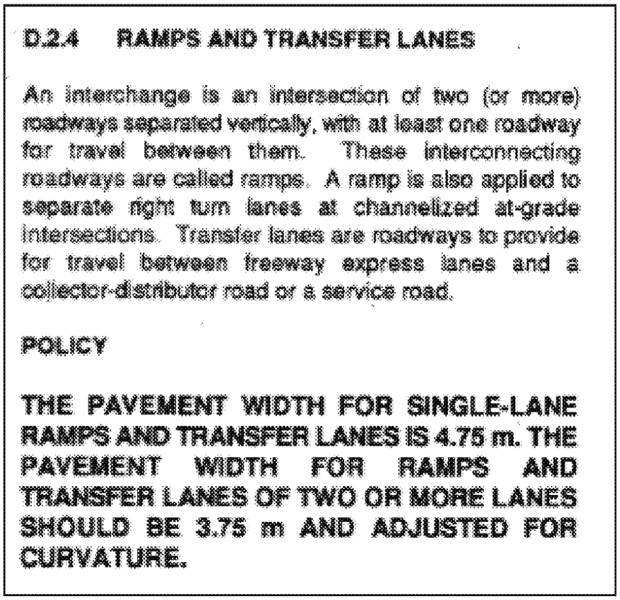
4-LANE DIVIDED URBAN ROADS

Lane widths for 4-lane divided urban roads depend only on design speed and not on traffic volume or truck percentages. Widths for 4-lane divided roads are:

Design Speed	Width
≥ 80 km/h	3.75 m
< 80 km/h	3.50 m

Figure 2: Highway lane widths (1985 MTO Design Guide).

Figure 3 is an excerpt from the 1985 MTO Design Guide and notes ramp lane widths of 4.75 m for a single lane ramp and 3.75 m for multilane ramps.



D.2.4 RAMPS AND TRANSFER LANES

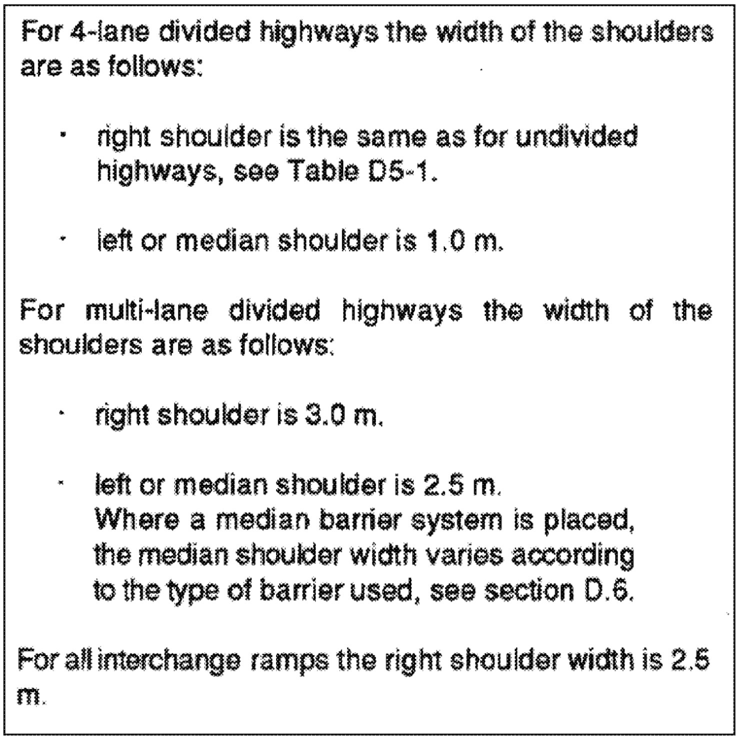
An interchange is an intersection of two (or more) roadways separated vertically, with at least one roadway for travel between them. These interconnecting roadways are called ramps. A ramp is also applied to separate right turn lanes at channelized at-grade intersections. Transfer lanes are roadways to provide for travel between freeway express lanes and a collector-distributor road or a service road.

POLICY

THE PAVEMENT WIDTH FOR SINGLE-LANE RAMPS AND TRANSFER LANES IS 4.75 m. THE PAVEMENT WIDTH FOR RAMPS AND TRANSFER LANES OF TWO OR MORE LANES SHOULD BE 3.75 m AND ADJUSTED FOR CURVATURE.

Figure 3: Lane widths for ramp and transfer (1985 MTO Design Guide).

Figure 4 is an excerpt from the 1985 MTO Design Guide which outlines the design standards for right and left (median) shoulders applicable to four lane divided highways. Table D5-1 is referenced in the **Figure 4** standards and is included in **Figure 5**. Based on this guidance, a minimum of a 2.5 m right shoulder and a 1.0 left shoulder should be provided for higher volume 4-lane divided highways. Six-lane divided highways should have a 3.0 m right shoulder and a 2.5 m left shoulder where median barriers exist.



For 4-lane divided highways the width of the shoulders are as follows:

- right shoulder is the same as for undivided highways, see Table D5-1.
- left or median shoulder is 1.0 m.

For multi-lane divided highways the width of the shoulders are as follows:

- right shoulder is 3.0 m.
- left or median shoulder is 2.5 m.
  Where a median barrier system is placed, the median shoulder width varies according to the type of barrier used, see section D.6.

For all interchange ramps the right shoulder width is 2.5 m.

Figure 4: Shoulder widths for four and six-lane divided highways (1985 MTO Design Guide).

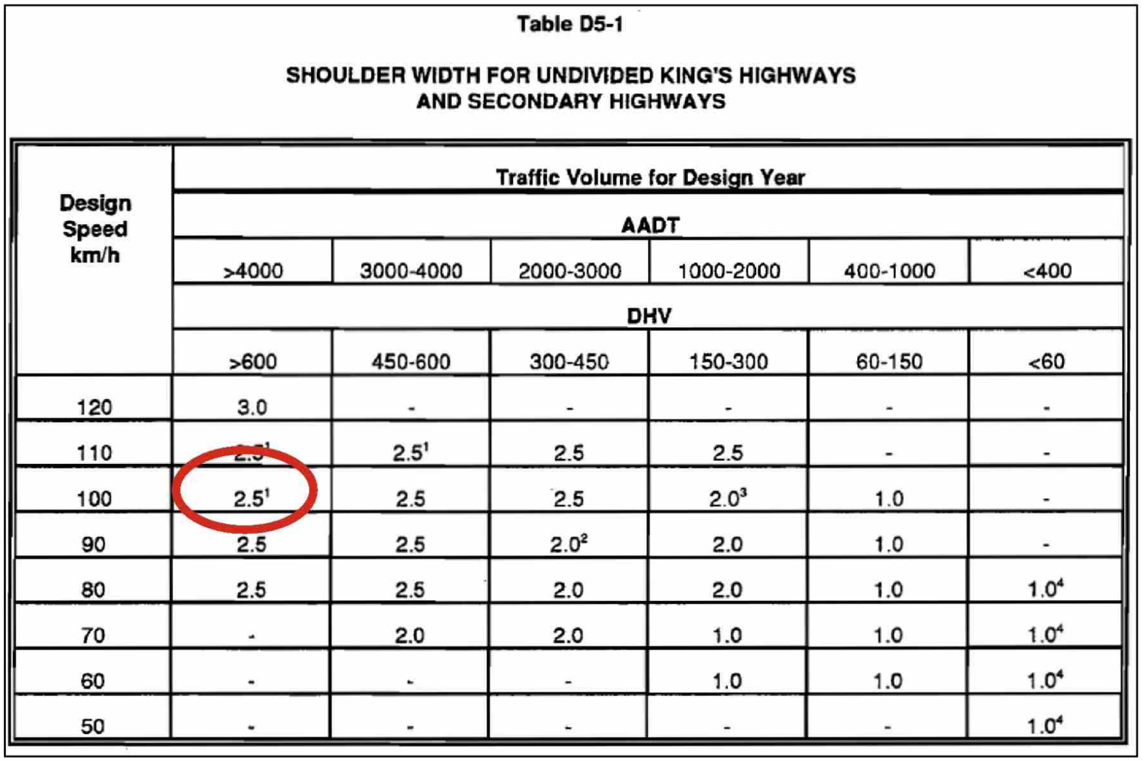


Table D5-1

SHOULDER WIDTH FOR UNDIVIDED KING'S HIGHWAYS
AND SECONDARY HIGHWAYS

Design Speed km/h	Traffic Volume for Design Year					
	AADT					
	>4000	3000-4000	2000-3000	1000-2000	400-1000	<400
	DHV					
	>600	450-600	300-450	150-300	60-150	<60
120	3.0	-	-	-	-	-
110	2.5[1]	2.5[1]	2.5	2.5	-	-
100	2.5[1]	2.5	2.5	2.0[3]	1.0	-
90	2.5	2.5	2.0[2]	2.0	1.0	-
80	2.5	2.5	2.0	2.0	1.0	1.0[4]
70	-	2.0	2.0	1.0	1.0	1.0[4]
60	-	-	-	1.0	1.0	1.0[4]
50	-	-	-	-	-	1.0[4]

Figure 5: Highway shoulder widths (1985 MTO Design Guide).

Pavement crossfall is the slope of the roadway from the pavement surface towards the edges of the highway to facilitate surface water drainage off the roadway. Section D.4 of the 1985 MTO Geometric Design Guide indicates a standard pavement crossfall is 2% with superelevation[8] incorporated into horizontal curves. The latter will be evaluated in the horizontal curve assessment in **Section 2.5**.

Based on a review of the detailed design drawings[9] produced for the three design sections, there do not appear to be any lane width, shoulder width or cross-fall deviations in the RHVP designs when compared to the 1985 MTO Design Guide.

2.3 Median Widths

Figure 6 is an excerpt from the 1985 MTO Design Guide which outlines the design standards for median widths on urban divided freeways. The standards indicate that urban freeways would typically be 6.0 m for 4-lane freeways and 7.5 m for six-lane freeways and would have some type of median barrier. The southerly 6-lane section of the RHVP[10] was constructed with

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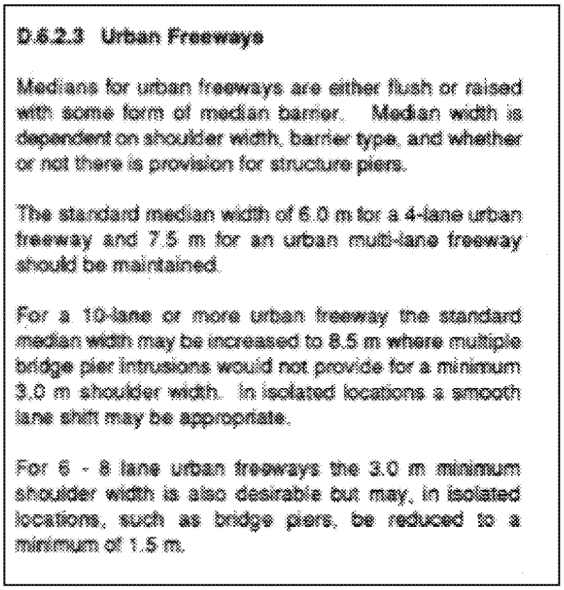
[8] Superelevation is a design feature that incorporates the outside road edge of the roadway to be higher than the inside road edge to counteract the horizontal forces on a vehicle around a curve.

[9] DUF0002534.001, DUF0002535.001, DUF0002536.001 and DUF0002537.001.

[10] Between the south terminus of the RHVP at the Lincoln M. Alexander Parkway (LINC) and approximately 1.400 kms north of the Mud Street interchange and 1.1 kms south of the Greenhill interchange (Station 23+500).

a concrete barrier and had standard median shoulder widths, and therefore was not subjected to a further detailed review.



D.6.2.3 Urban Freeways

Medians for urban freeways are either flush or raised with some form of median barrier. Median width is dependent on shoulder width, barrier type, and whether or not there is provision for structure piers.

The standard median width of 6.0 m for a 4-lane urban freeway and 7.5 m for an urban multi-lane freeway should be maintained.

For a 10-lane or more urban freeway the standard median width may be increased to 8.5 m where multiple bridge pier intrusions would not provide for a minimum 3.0 m shoulder width. In isolated locations a smooth lane shift may be appropriate.

For 6 - 8 lane urban freeways the 3.0 m minimum shoulder width is also desirable but may, in isolated locations, such as bridge piers, be reduced to a minimum of 1.5 m.

Figure 6: Urban freeway median standards (1985 MTO Design Guide).

The northerly 4-lane section[11] was constructed with a grass median with steel beam guiderail barriers provided at fixed hazards such as bridge piers. A depressed grassed median is generally provided in a rural divided highway environment and shown in **Figure 7**. A rural cross-section is not consistent with an urban freeway design. It cannot be determined from the information provided, why a rural cross-section design was provided for the majority of RHVP, when the design criteria specified an urban design.

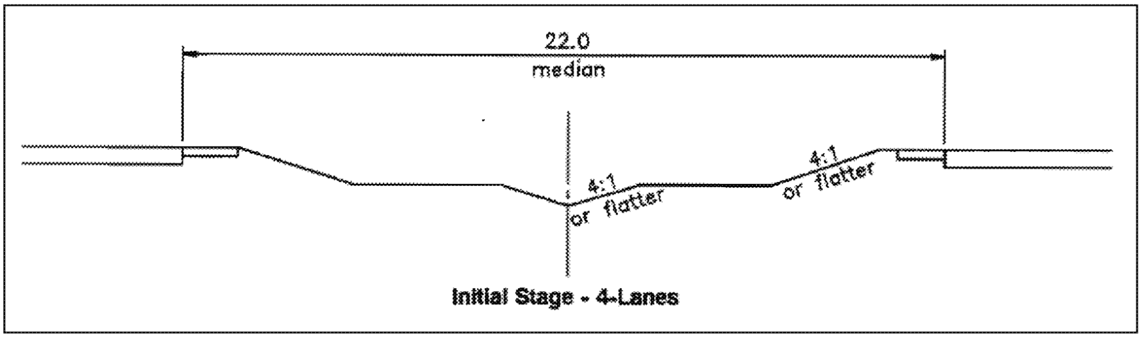


Figure 7: Typical rural freeway depressed grass median with 22.0 width (1985 MTO Design Guide).

The median standards for a rural freeway indicate that when warranted, an appropriate longitudinal barrier system shall be selected, and the designer is referred to the 1993

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[11] Station 23+550 to the north terminus of the three RVHP design contracts, north of Barton Street.

Roadside Safety Manual, Ministry of Transportation of Ontario[12] (the '1993 MTO RSM'). **Figure 8** shows the median barrier warrant in the 1993 MTO RSM for divided highways and indicates that a barrier was not required for median widths[13] of 15 to 20 m. Based on our review of the detailed designs[14], median widths were greater than 15 m in width, and a median barrier was not required. A similar rural median design is present along the majority of the LINC.

The 2015 CIMA Report[15] completed a review of median related collisions between January 1, 2008 and July 2015 and concluded that:

- 28% of all collisions in the RHVP study area were median related.
- Wet surface conditions were present in 53% of median related collisions.
- 17 crossover collisions[16] occurred, with one fatality and nine injury collisions.
- The locations with the high median-related collision frequency were in the vicinity of the King Street and Queenston road interchanges. At these locations, wet surface conditions were present in 74% of median related collisions and crossover collisions were more severe.

A median barrier eliminates more severe crossover collisions; however, its presence results in a higher frequency of property damage only collisions (PDO) when vehicles strike the median barrier, as opposed to those instances when the vehicle would otherwise have come to rest in the grass median.

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[12] Roadside Safety Manual, Ministry of Transportation of Ontario, 1993.

[13] Median widths are measured from the edges of the two travel lanes and include the shoulders.

[14] DUF0002534.001, DUF0002535.001, DUF0002536.001 and DUF0002537.001

[15] Images 19 through 25 of HAM0056684_0001, Red Hill Valley Parkway Detailed Safety Analysis, CIMA, 2015.

[16] Collisions crossing over the median where vehicles travelled across the centre median and entered the opposing lanes of traffic lanes.

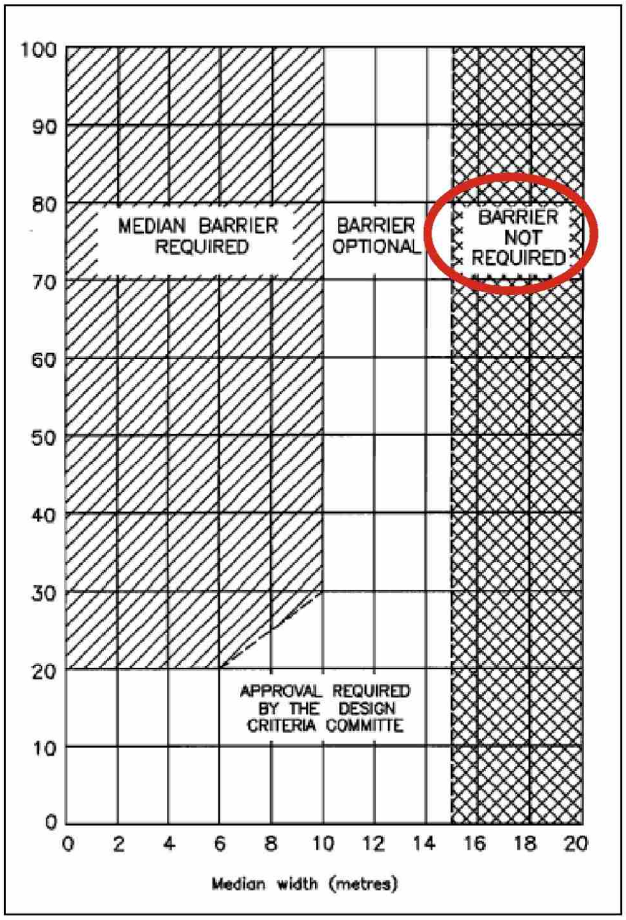

Figure 8: Median barrier warrant for divided highways (1985 MTO Design Guide).

The 2015 CIMA Report[17] concluded that a high-tension median cable barrier system would eliminate severe crossover collisions, would have an overall benefit to cost ratio (B/C ratio) of 5.26 and was a cost-effective option. The report recommended that a range of short-term and lower cost countermeasure be implemented and that the RHVP safety performance be subsequently reassessed to determine if there continued to be potential benefit (i.e., a positive B/C ratio) of providing a median barrier system. Installation of a median barrier system was not part of the short-term recommendations in the 2015 CIMA Report.

2.4 Vertical Alignment and Grades

Vertical curves represent the hills (i.e., crests) and valleys (i.e., sags) experienced as you travel along the highway alignment. **Figure 9** outlines the minimum “k” factors (i.e., rate of change in grade[18]) for crest and sag curves specified in the 1985 MTO Design Guide. For a 100

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[17] Images 50, 51 and 55 of HAM0056684_0001, Red Hill Valley Parkway Detailed Safety Analysis, CIMA, 2015.

[18] A “k” factor represents the horizontal distance required to achieve a 1% change in the slope of the vertical curve. A lower “k” value represents a more abrupt change in grade through the vertical curve, whereas, a higher value represents a more gradual change in grade.

km/h design speed, the minimum “k” factors for a crest and sag curves are 70 and 45, respectively. This minimum “k” values were reflected in the project design criteria[19].

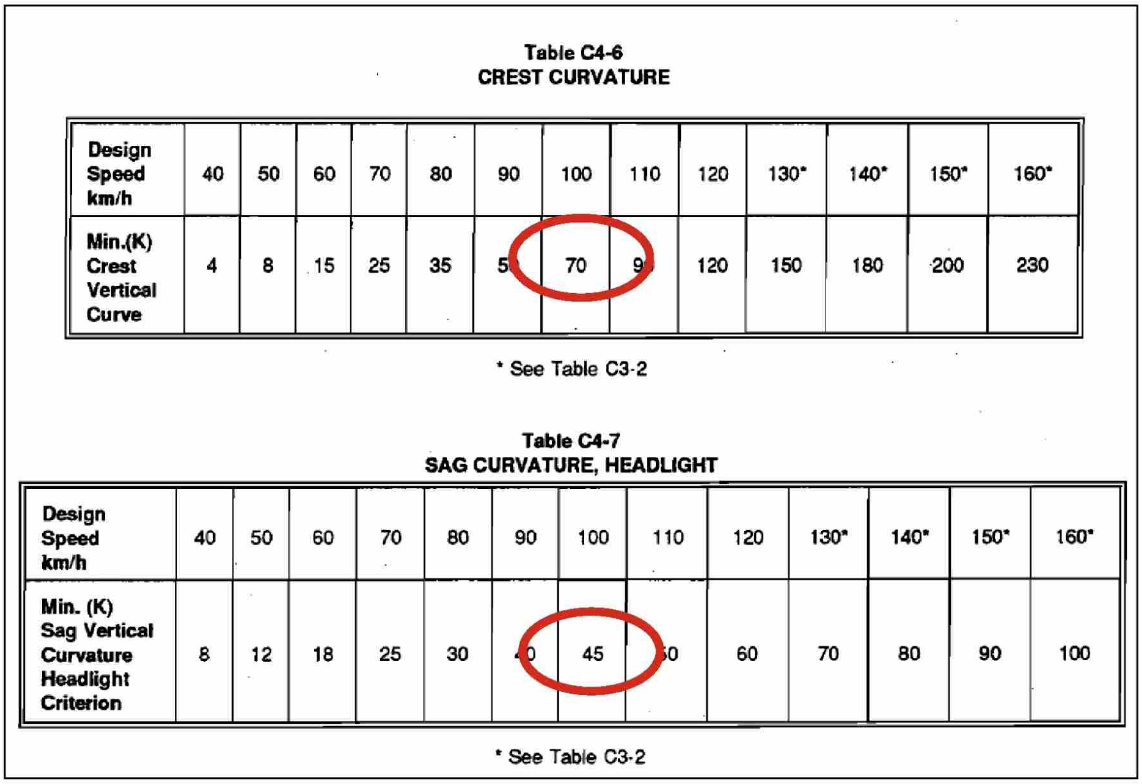

Table C4-6
CREST CURVATURE

Design Speed km/h	40	50	60	70	80	90	100	110	120	130*	140*	150*	160*
Min.(K) Crest Vertical Curve	4	8	15	25	35	5	70	9	120	150	180	200	230

* See Table C3-2

Table C4-7
SAG CURVATURE, HEADLIGHT

Design Speed km/h	40	50	60	70	80	90	100	110	120	130*	140*	150*	160*
Min. (K) Sag Vertical Curvature Headlight Criterion	8	12	18	25	30	40	45	0	60	70	80	90	100

* See Table C3-2

Figure 9: Minimum “K’ factors for crest and sag curves (1985 MTO Design Guide).

Roadway grades are the overall uphill (i.e., rise) and downhill (i.e., fall) of the highway surface. Roadway grades are positive if rising in the direction of travel and negative if falling in the direction of travel. The grade along a roadway is expressed as a percentage; that is rise or fall in metres over a horizontal length of 100 m. **Figure 10** provides the maximum longitudinal design grade range of 3 to 4% for freeway, as outlined in the 1985 MTO Design Guide.

Based on our review of the detailed design drawings[20], we concluded the following:

- Minimum “k” factors for crest curves (i.e., 70) and sag curves (i.e., 45) were met or exceeded for the three project design areas of the RHVP roadway profile. The values generally ranged from 150 to 250 and greatly exceeded the minimum values. A minimum “k” of 45 for a sag vertical curve was noted at the CN Rail underpass, north of Barton Street; however, the curve has a short length of 176 m and based on our field observations had no substantial impact on forward visibility along the highway at the design speed.

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[19] HAM0032182_0001, Red Hill Valley Project Design Report (Draft), January 31, 2006
[20] DUF0002534.001, DUF0002535.001, DUF0002536.001 and DUF0002537.001

- Maximum grades noted in the RHVP detailed design profiles met but did not exceed those specified for a 100 km/h design speed.

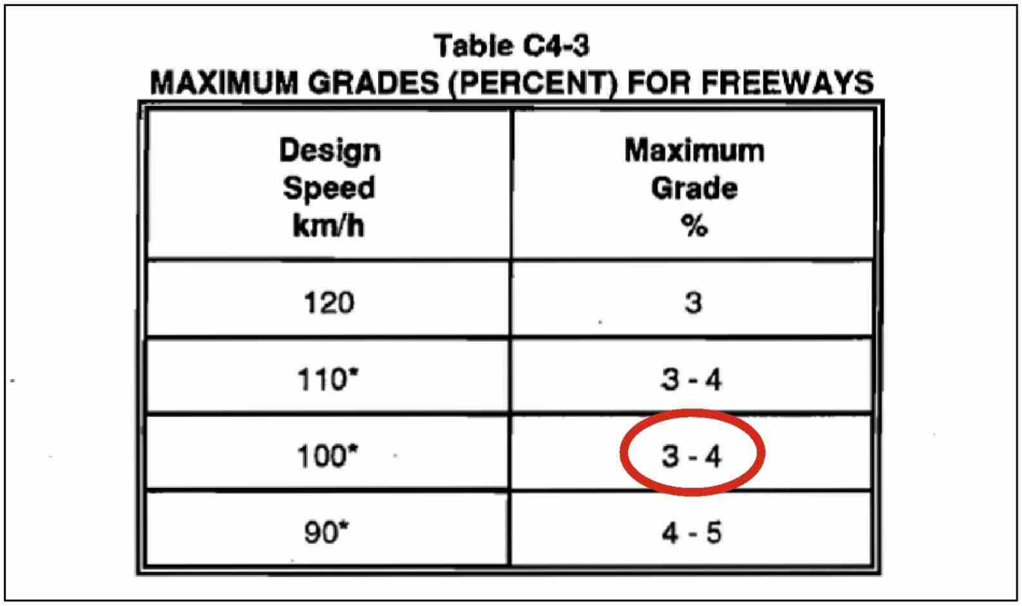


Table C4-3
MAXIMUM GRADES (PERCENT) FOR FREEWAYS

Design Speed km/h	Maximum Grade %
120	3
110*	3 - 4
100*	3 - 4
90*	4 - 5

Figure 10: Maximum longitudinal grades for freeways (1985 MTO Design Guide).

2.5 Horizontal Alignment

The horizontal alignment of a freeway (i.e., curves and turns in the highway alignment) includes:

- Circular curves – with a design speed related to the curve radius, wet weather friction values and superelevation;
- Spiral curves – a curve with a constantly varying radius, to provide a smooth transition between a tangent road section and the circular curve; and
- Superelevation – design with the outside road edge to be higher than the inside road edge to counteract the horizontal forces on a vehicle around a curve.

Figures 11 and 12 provided the minimum radius (i.e., 420 m) and spiral curve value (i.e., 190) for a horizontal curve with a 100 km/h design speed and a superelevation of 6%.

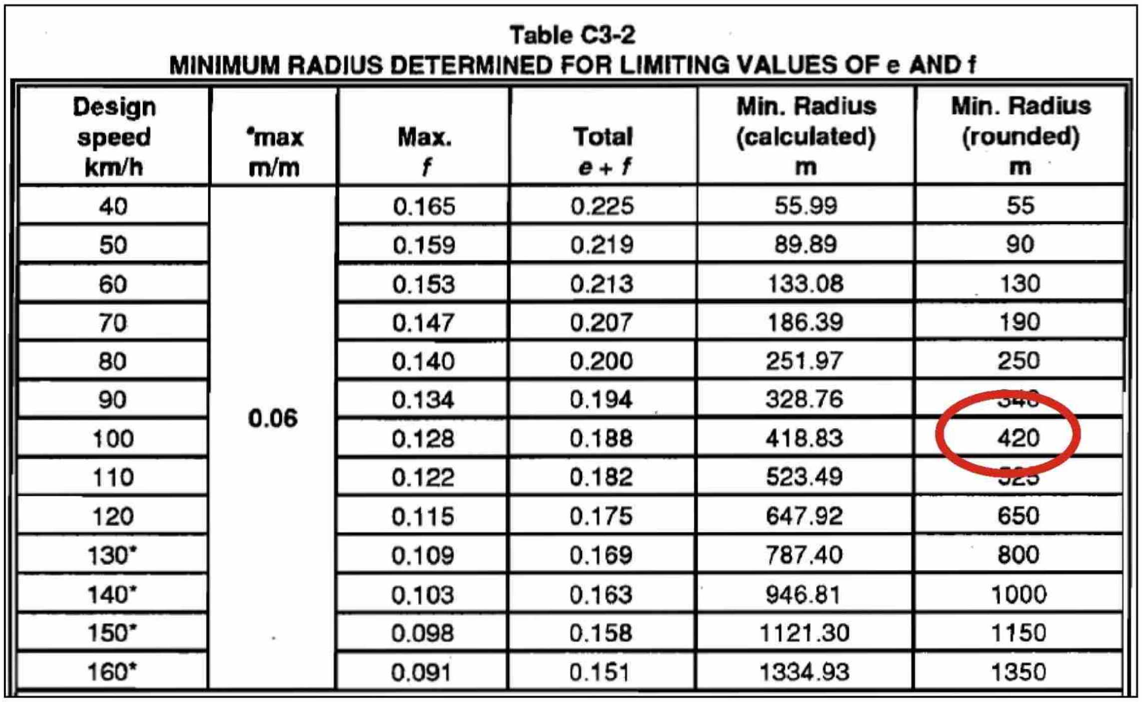
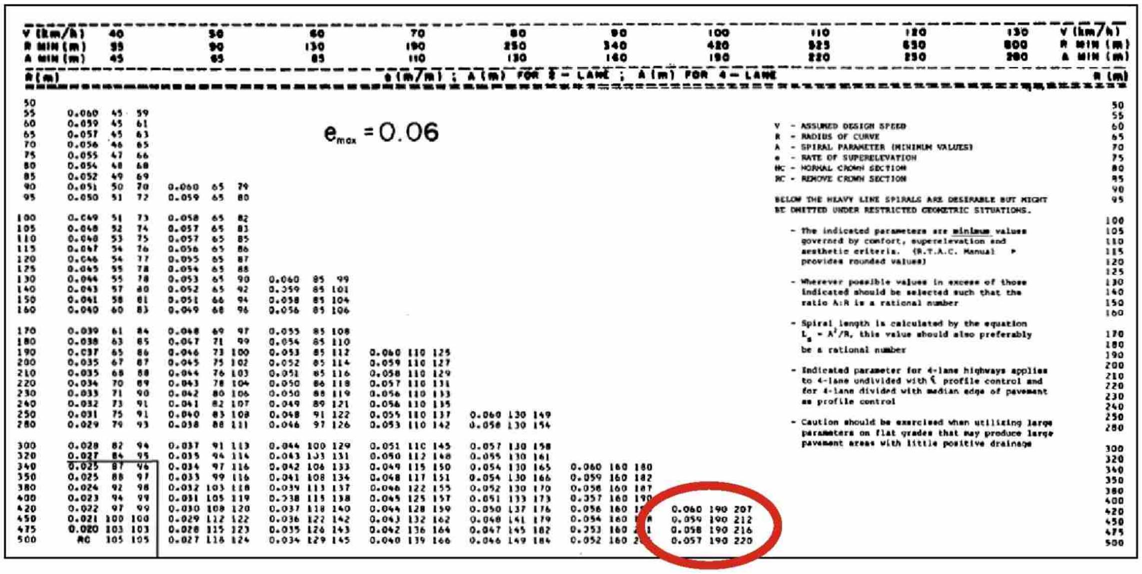


Table C3-2
MINIMUM RADIUS DETERMINED FOR LIMITING VALUES OF e AND f

Design speed km/h	*max m/m	Max. f	Total e + f	Min. Radius (calculated) m	Min. Radius (rounded) m
40	0.06	0.165	0.225	55.99	55
50		0.159	0.219	89.89	90
60		0.153	0.213	133.08	130
70		0.147	0.207	186.39	190
80		0.140	0.200	251.97	250
90		0.134	0.194	328.76	340
100		0.128	0.188	418.83	420
110		0.122	0.182	523.49	525
120		0.115	0.175	647.92	650
130*		0.109	0.169	787.40	800
140*		0.103	0.163	946.81	1000
150*		0.098	0.158	1121.30	1150
160*		0.091	0.151	1334.93	1350

Figure 11: Minimum radius for the design of horizontal curves (1985 MTO Design Guide).



$e_{max} = 0.06$

V (km/h)	40			50			60			70			80			90			100			110	120	130	V (km/h)
R MIN (m)	55			90			130			190			250			340			420			525	650	800	R MIN (m)
A MIN (m)	45			65			85			110			130			160			190			220	250	280	A MIN (m)
R (m)	e (m/m) ; A (m) FOR 2 - LANE ; A (m) FOR 4 - LANE																								R (m)
50																									50
55	0.060	45	59																						55
60	0.059	45	61																						60
65	0.057	45	63																						65
70	0.056	46	65																						70
75	0.055	47	66																						75
80	0.054	48	68																						80
85	0.052	49	69																						85
90	0.051	50	70	0.060	65	79																			90
95	0.050	51	72	0.059	65	80																			95
100	0.049	51	73	0.058	65	82																			100
105	0.048	52	74	0.057	65	83																			105
110	0.048	53	75	0.057	65	85																			110
115	0.047	54	76	0.056	65	86																			115
120	0.046	54	77	0.055	65	87																			120
125	0.045	55	78	0.054	65	88																			125
130	0.044	55	78	0.053	65	90	0.060	85	99																130
140	0.043	57	80	0.052	65	92	0.059	85	101																140
150	0.041	58	81	0.051	66	94	0.058	85	104																150
160	0.040	60	83	0.049	68	96	0.056	85	106																160
170	0.039	61	84	0.048	69	97	0.055	85	108																170
180	0.038	63	85	0.047	71	99	0.054	85	110																180
190	0.037	65	86	0.046	73	100	0.053	85	112	0.060	110	125													190
200	0.035	67	87	0.045	75	102	0.052	85	114	0.059	110	127													200
210	0.035	68	88	0.044	76	103	0.051	85	116	0.058	110	129													210
220	0.034	70	89	0.043	78	104	0.050	86	118	0.057	110	131													220
230	0.033	71	90	0.042	80	106	0.050	88	119	0.056	110	133													230
240	0.032	73	91	0.041	82	107	0.049	89	121	0.056	110	135													240
250	0.031	75	91	0.040	83	108	0.048	91	122	0.055	110	137	0.060	130	149										250
280	0.029	79	93	0.038	88	111	0.046	97	126	0.053	110	142	0.058	130	154										280
300	0.028	82	94	0.037	91	113	0.044	100	129	0.051	110	145	0.057	130	158										300
320	0.027	84	95	0.035	94	114	0.043	103	131	0.050	112	148	0.055	130	161										320
340	0.025	87	96	0.034	97	116	0.042	106	133	0.049	115	150	0.054	130	165	0.060	160	180							340
350	0.025	88	97	0.033	99	116	0.041	108	134	0.048	117	151	0.054	130	166	0.059	160	182							350
380	0.024	92	98	0.032	103	118	0.039	113	137	0.046	122	155	0.052	130	170	0.058	160	187							380
400	0.023	94	99	0.031	105	119	0.038	115	138	0.045	125	157	0.051	133	173	0.057	160	190							400
420	0.022	97	99	0.030	108	120	0.037	118	140	0.044	128	159	0.050	137	176	0.056	160	[illegible]	0.060	190	207				420
450	0.021	100	100	0.029	112	122	0.036	122	142	0.043	132	162	0.048	141	179	0.054	160	[illegible]	0.059	190	212				450
475	0.020	103	103	0.028	115	123	0.035	126	143	0.042	136	164	0.047	145	182	0.053	160	[illegible]	0.058	190	216				475
500	RC	105	105	0.027	118	124	0.034	129	145	0.040	139	166	0.046	149	184	0.052	160	[illegible]	0.057	190	220				500

V - ASSUMED DESIGN SPEED
R - RADIUS OF CURVE
A - SPIRAL PARAMETER (MINIMUM VALUES)
e - RATE OF SUPERELEVATION
NC - NORMAL CROWN SECTION
RC - REMOVE CROWN SECTION

BELOW THE HEAVY LINE SPIRALS ARE DESIRABLE BUT MIGHT BE OMITTED UNDER RESTRICTED GEOMETRIC SITUATIONS.

- The indicated parameters are minimum values governed by comfort, superelevation and aesthetic criteria. (R.T.A.C. Manual ▸ provides rounded values)
- Wherever possible values in excess of those indicated should be selected such that the ratio A:R is a rational number
- Spiral length is calculated by the equation $L_s = A^2/R$, this value should also preferably be a rational number
- Indicated parameter for 4-lane highways applies to 4-lane undivided with ℄ profile control and for 4-lane divided with median edge of pavement as profile control
- Caution should be exercised when utilizing large parameters on flat grades that may produce large pavement areas with little positive drainage

Figure 12: Minimum radius and spiral curve factors for the design of horizontal curves with a 6% or less superelevation (1985 MTO Design Guide).

Maps of the study curves were provided in the Overview Document #3.1: RHVP Design & Geometry and are reproduced in **Appendix C** for ease of reference. **Table 1** provides a summary of the horizontal curve designs incorporated into the RHVP detailed design[21].

Table 1: Summary of RVHP mainline horizontal curve designs as per the detailed design drawings[22].

Part	Drawing Reference Document and Station	Beginning of Curve (SC) Linear Reference	Radius, Spiral and Superelevation	Meets or Exceeds 1985 MTO Design Guide
A	DUF0002534.001 at image 2	20+998.957 South of the Mud Street interchange[23]	Radius: 700 m Superelevation: 4.9% Spiral Curve Parameter: 243	Yes
A	DUF0002534.001 at image 2	22+717.978 North of the Mud Street interchange[24]	Radius: 700 m Superelevation: 4.9% Spiral Curve Parameter: 243	Yes
A	DUF0002534.001 at image 2	23+463 South of the Greenhill Avenue interchange[25]	Radius: 800 m Superelevation: 4.7% Spiral Curve Parameter: 252	Yes
B	DUF0002535.001 at image 7	25+450.392 South of the King Street interchange[26]	Radius: 420 m Superelevation: Unspecified Spiral Curve Parameters[27]: 339/311	Undetermined[28]

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[21] We have excluded the 5,000 m radius curve design in the vicinity of the Greenhill Avenue interchange, as it is nominally tangent and greatly exceeds the design speed of the highway.

[22] DUF0002534.001, DUF0002535.001, DUF0002536.001 and DUF0002537.001

[23] Overview Document #3.1: RHVP Design & Geometry, Doc 4219637, Image 10

[24] Overview Document #3.1: RHVP Design & Geometry, Doc 4219637, Image 10

[25] Overview Document #3.1: RHVP Design & Geometry, Doc 4219637, Image 10

[26] Overview Document #3.1: RHVP Design & Geometry, Doc 4219637, Image 13

[27] The spiral parameter to the south of the curve is 339; whereas, the spiral parameter to the north is 311. Both parameters exceed the minimum values specified.

[28] The superelevation provided in the design cannot be determined from the information provided. A design speed of 100 km/h requires a radius of 420 m and a superelevation of 6%. Assuming a typical superelevation of 4.9 to 6.0%, this curve may not have a design speed of 100 km/h or greater.

Part	Drawing Reference Document and Station	Beginning of Curve (SC) Linear Reference	Radius, Spiral and Superelevation	Meets or Exceeds 1985 MTO Design Guide
B	DUF0002535.001 at image 8	25+862.215 North of the King Street Interchange[29]	Radius: 450 m Superelevation: 6% Spiral Curve Parameter: 212	Yes
B	DUF0002535.001 at image 10	26+416.504 South of the Queenston Road interchange[30]	Radius: 690 m Superelevation: Unspecified Spiral Curve Parameter: 243	Yes[31]
B	DUF0002535.001 at image 11	27+132.765 North of the Queenston Road interchange[32]	Radius: 525 m Superelevation: 6% Spiral Curve Parameter: 223	Yes
C	DUF0002536.001 at image 3	27+815.899 South of the Barton Road interchange[33]	Radius: 1000 m Superelevation: 6% Spiral Curve Parameter: 266	Yes
C	DUF0002536.001 at image 3	28+680.950 North of the Barton Road interchange[34]	Radius: 575 m Superelevation: Unspecified Spiral Curve Parameter: 229	Yes[35]

Based on the above review, the majority of the horizontal curves and the associated spiral curves had design speeds equal to or greater than the 100 km/h design speed. The horizontal curves north and south of the King Street interchange had radii of 450 and 420 m, were at or slightly above the design minimums.

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[29] Overview Document #3.1: RHVP Design & Geometry, Doc 4219637, Image 13.
[30] Overview Document #3.1: RHVP Design & Geometry, Doc 4219637, Image 13.
[31] Assuming a typical superelevation of 4.9 to 6.0%, this curve would have a design speed of 100 km/h or greater.
[32] Overview Document #3.1: RHVP Design & Geometry, Doc 4219637, Image 13.
[33] Overview Document #3.1: RHVP Design & Geometry, Doc 4219637, Image 16.
[34] Overview Document #3.1: RHVP Design & Geometry, Doc 4219637, Image 16.
[35] Assuming a typical superelevation of 4.9 to 6.0%, this curve would have a design speed of 100 km/h or greater.

The horizontal curve south of the King Street interchange was the only curve designed to the minimum radius of 420 m. The superelevation provided in the design cannot be determined from the information provided. A design speed of 100 km/h requires a radius of 420 m and a superelevation of 6%. Assuming a typical superelevation of 4.9 to 6.0%, this curve may not have a design speed of 100 km/h or greater, i.e., a 420 m radius curve with a superelevation of 4.9% would have a design speed less than 100 km/h. Further, traffic travelling in the northbound direction would be navigating this right turn while travelling a downhill grade, which would reduce the effect of the superelevation and require greater friction between the vehicle tires and the pavement surface compared to the same curve on a level road section.

In general, an advisory speed is posted on a horizontal curve or ramp when the design speed of that geometric design feature is less than (or in some cases equal to) the posted speed of the roadway, i.e., motorists are advised with warning signs that a lower operating speed is recommended to negotiate a specific curve.

A common method of determining the appropriate advisory speed is through ball bank tests. A ball bank indicator device is used to measure the combined effect of the body roll angle of the test vehicle, the centrifugal force on the vehicle, and the roadway superelevation as a vehicle is driven around a horizontal curve. The ball bank reading is then compared to an industry accepted threshold value. The highest vehicle speed at which an acceptable ball bank reading[36] is attained, is then rounded down to the nearest 10 km/h and represents the advisory speed.

Ball bank field tests undertaken by CIMA[37] in 2015 indicated that lower radius curves in the vicinity of the King Street and Queenston Road interchanges had advisory speeds of at least 100 km/h, which were equal to the design speed of the RHVP and greater than the 90 km/h posted speed. Field tests undertaken by TNS Group in October 2022 produced similar results, with all mainline horizontal curves having acceptable ball bank readings at the 100 km/h design speed.

While the ball bank readings produced acceptable readings at the intended design speed of 100 km/h, motorist expectations regarding an appropriate operating speed through a horizontal curve on a freeway facility during wet surface conditions appear to have been violated on the RHVP by the posted-design speed differential, design speed differentials between successive curves, and the lower available pavement friction. **Sections 3.0 and 5.0** provide a discussion regarding these interrelated contributory factors.

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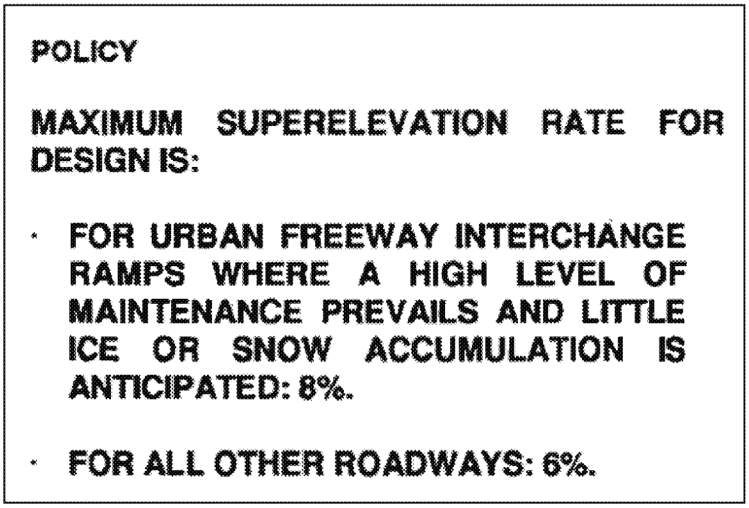
[36] An acceptable ball bank reading occurs when the field value is less than the threshold value at the vehicle test speed.

[37] Image 30 of HAM0056684_0001, Red Hill Valley Parkway Detailed Safety Analysis, CIMA, 2015.

2.6 Ramp Designs and Advisory Speeds

Given that freeway ramps to the local road network generally transition between different vertical grades and horizontally separate alignments over a relatively short distance, it is relatively rare that their vertical and horizontal alignments are constructed to the freeway design speed. As such, the designer relies on curve warning signs, delineation, advisory speed tabs and/or ramp speed signs to convey the appropriate speed at which the ramp design can be negotiated. Ramps are typically designed with 6% to 8% slopes, with 6% being more common. **Figure 13** provide the MTO policy for freeway ramps.



POLICY

MAXIMUM SUPERELEVATION RATE FOR DESIGN IS:

- **FOR URBAN FREEWAY INTERCHANGE RAMPS WHERE A HIGH LEVEL OF MAINTENANCE PREVAILS AND LITTLE ICE OR SNOW ACCUMULATION IS ANTICIPATED: 8%.**
- **FOR ALL OTHER ROADWAYS: 6%.**

Figure 13: MTO superelevation policy (1985 MTO Design Guide).

In their 2019 Roadside Safety Assessment for the RHVP[38], CIMA completed a desktop review of the theoretical design speed of the RHVP ramps and compared them to the advisory speed posted on the ramps. **Figure 14** provides a summary of the 2019 CIMA findings. We have reviewed the curve radii and ramp speed sign content assumptions of the 2019 CIMA evaluation and have confirmed the input values to be correct.

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[38] HAM0054495_0001 - Roadside Safety Assessment - Red Hill Valley Parkway, CIMA, January 2019.

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

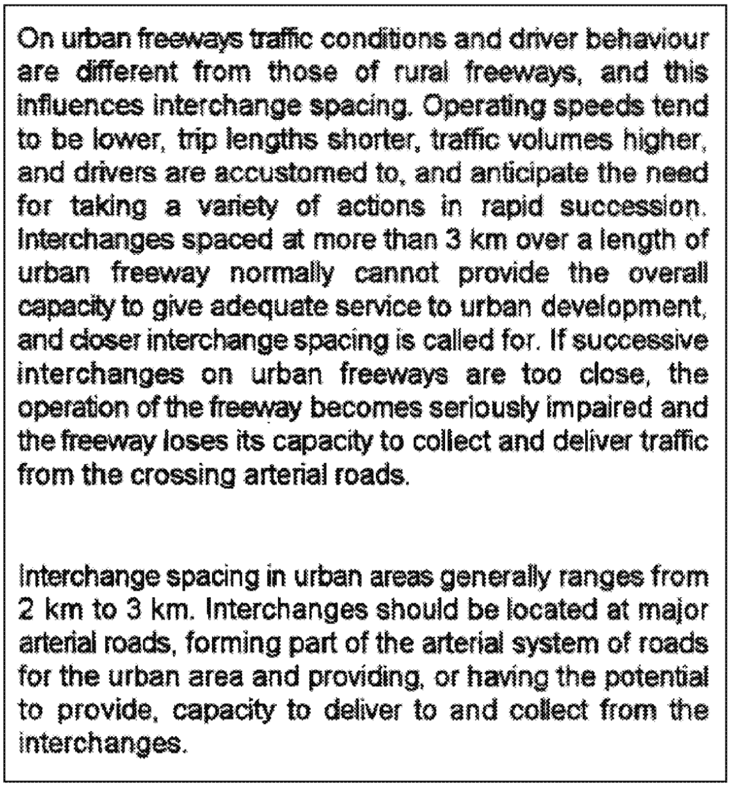
Figure 14: RHVP ramp design evaluation summary (CIMA, 2019).

Based on our experience, the compatible design speed calculation incorporated in the above assessment is generally a reasonable approximation of the appropriate posted advisory speed assuming that the superelevation provided is a minimum of 6% and the ramp does not have a significant downhill vertical grade. Actual recommended advisory speeds are assessed in the field using ball bank testing prior to the roadway being opened to traffic and would consider any sight line obstructions present on the inside of the curve.

Based on CIMA assessment, the posted advisory speeds on the RHVP ramps were appropriate for their equivalent design speeds.

2.7 Interchange Spacing

The 1985 MTO Design Guide provides guidance related to minimum interchange spacing. **Figure 15** provides the guidance related to urban freeway interchange spacing.



On urban freeways traffic conditions and driver behaviour are different from those of rural freeways, and this influences interchange spacing. Operating speeds tend to be lower, trip lengths shorter, traffic volumes higher, and drivers are accustomed to, and anticipate the need for taking a variety of actions in rapid succession. Interchanges spaced at more than 3 km over a length of urban freeway normally cannot provide the overall capacity to give adequate service to urban development, and closer interchange spacing is called for. If successive interchanges on urban freeways are too close, the operation of the freeway becomes seriously impaired and the freeway loses its capacity to collect and deliver traffic from the crossing arterial roads.

Interchange spacing in urban areas generally ranges from 2 km to 3 km. Interchanges should be located at major arterial roads, forming part of the arterial system of roads for the urban area and providing, or having the potential to provide, capacity to deliver to and collect from the interchanges.

Figure 15: Urban freeway interchange spacing (1985 MTO Design Guide).

The Red Hill Valley Parkway Inquiry Overview Document #3.1: RHVP Design & Geometry[39] included an evaluation of interchange spacing. We have reviewed this assessment and confirm the interchange separation distances in the RHVP design are as outlined in **Table 2**. The majority of the interchanges on the RHVP were spaced less than specified, with the distance between the King Street and Queenston Road interchanges being the least and less than half the minimum value outlined in the 1985 MTO Design Guide for urban freeways.

Table 2: Interchange spacing on the RHVP.

Adjacent Interchanges on RHVP	Distance Between Interchanges (km)	Compliance with 1985 MTO Design Guide (2 km minimum)
Dartnall Road to Mud Street	1.152	No
Mud Street to Greenhill Avenue	2.522	Yes
Greenhill Avenue to King Street	1.292	No
King Street to Queenston Road	0.832	No
Queenston Road to Barton Street	1.334	No

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[39] Overview Document #3.1: RHVP Design & Geometry

2.8 Sight Distances

Geometric design guidance for highways includes the following primary components of sight distance:

- Stopping sight distance to allow motorists to perceive, react and stop for an object in their path at the design speed, i.e., sufficient sight distance over a hill to observe and react to an object or stopped vehicle in the travel lane on the far side of the hill.
- Decision sight distance to allow motorists sufficient time to make a decision regarding maneuvering their vehicle or adjusting their speed in complex situations[40] where information may be perceived incorrectly, decisions are required, or control actions are required (as opposed to stopping sight distance which involves a complete stop for an obstacle).
- Sight lines approaching and at the at-grade intersections to observe and react to the traffic control and conflicting road users, i.e., a vehicle stopped at an intersection attempting to pick a gap in traffic to make a turn at or cross the intersection.

Designing a freeway to meet the minimum horizontal, vertical and clear zone components of the highway for the specified design speed should generally provide for appropriate stopping sight along the highway in most instances.

In general, based on the detailed design plan and profile drawings we are unable to complete an accurate assessment of the available sight distances for many components of the RVHP mainline alignment or approaching and along the ramp terminals. Factors that preclude an assessment include, but are not limited to:

- The combination of horizontal and vertical alignment that is present at a number of the critical areas of the roadway and ramp designs.
- The presence of vertical features which represent sight line obstructions such as vegetation, bridge abutments and columns, retaining walls, rock cuts, guiderail and/or concrete barriers.

Based on a cursory review during our in-vehicle field tests, sight distances appear to be sufficient along the tangent and larger radius alignments of the mainline lanes and the relatively tangent ramps of the Greenhill Avenue interchanges. These sections are located to the south of the King Street interchange and in and or around the Barton Street interchange. Available sight lines in or around the King Street and Queenston Road interchanges are more constrained; however, we cannot definitively determine if they are deficient for the 100 km/h design speed. **Figure 16** provides an example of a location where the sightlines are constrained along the exit ramp, along the mainline freeway lanes, and approaching the conflict zone of an on-ramp (which is located on the inside of the curve beyond the vegetation).

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[40] For example, complex intersections or interchanges, unusual or unexpected changes in the roadway environment, construction zones, demanding driver workload areas due to a heavy traffic/conflict, advertising, and/or traffic control devices.

A detailed review of available sight distances could be completed in the field; however, this could not be undertaken without lane closures on the RHVP. Alternatively, a three-dimensional scan and plot of the highway right-of-way and its roadside features would permit a relatively accurate assessment of available sight distances on the RHVP.

Figure 16: Southbound RHVP approaching the King Street (Google Maps, 2022).

3.0 DESIGN CONSISTENCY AND MOTORIST EXPECTATIONS

It is well documented in the transportation industry, that the motorist is the primary contributor to collisions with the road-vehicle-motorist system. Some estimates suggest that human error and decision-making is a primary or contributory factor in 95% of motor vehicle collisions.

It is also well-established fact in transportation research that individuals react faster and more accurately to events, conditions and hazards that are “expected” compared to those that are unexpected or a surprise. Expectancy relates to a motorist’s readiness to respond to events, conditions and hazards successfully. Motorists have longer term expectations that are primarily based on education, training, and past driving experiences, and shorter-term expectations from conditions experienced on a particular trip or along a specific road section.

It is estimated that the road design, operations, and maintenance is a contributing factor in approximately one quarter of motor vehicle collisions. This significant contribution suggests that the infrastructure must be designed, operated, and maintained so that motorists understand the system they are using and make rapid and appropriate decisions in selecting speed and path. Consistency and uniformity of design standards is a primary means of facilitating motorist comprehension, expectancy and prudent decision-making. Based upon the above geometric review, the following are potential expectancy violations within the RHVP design that may singularly or collectively challenge motorist expectation and proper decision-making:

- Design Speed: Road users have priori expectations of acceptable operating speeds based on observations and experiences of driving on a range of freeways including 400-series highways that are generally designed to 20 km/h or more over the posted limit. Specific freeway elements that reflect a minimum design speed of 100 km/h on a controlled access freeway facility would be an expectancy violation to some road users, notwithstanding the 90 km/h posted speed.
- Horizontal Curve Design: While many of the horizontal curves approaching and within the RHVP corridor have alignments which reflect design speeds well in excess of the 100 km/h design speed of the RHVP, the two mainline section curves in or around the King Street interchange were designed at or near the minimum values.
- Interchange Spacing: The majority of the interchanges on the RHVP were spaced less than specified in the 1985 MTO Design Guide, with the distance between the King Street and Queenston Road interchanges being the least and less than half the minimum value. This latter road section corresponded with a number of the lower design speed horizontal curves. Motorists may be ill-prepared to react to the conflicts, speed differentials and periodic congestion associated with closely spaced ramps.
- Pavement Friction: While the majority of motorists have little or no knowledge regarding pavement friction design values, they continually make decisions regarding an appropriate speed and path of their vehicle based on prior experiences of relative friction/traction abilities while accelerating, decelerating and/or turning their vehicle on paved road surfaces under a range of geometric design features and surface conditions (i.e., dry, wet, snow, slush, and ice). It would be an expectancy violation for a motorist to experience lower traction abilities under routine dry and wet surface conditions encountered on a regular basis.

4.0 HISTORIC COLLISION TRENDS

The City of Hamilton's annual citywide collision reports between 2017 to 2021[41] were analyzed to determine if there were any discernable collision trends along the RHVP corridor. The City issues an annual collision report that summarizes collision trends over the past five years (i.e., the 2021 report summarizes collisions that were recorded between 2017 to 2021). The reports summarized collisions that occurred across the City with a separate section for collisions on the RHVP and LINC. The reports provided a summary of temporal trends (e.g., year, month, day, hour) and collision attributes (e.g., road surface condition, impact type, driver action), identified trends over the analysis periods.

The annual collision reports provided a summary of the changes that have occurred along the RHVP over the course of each period that may impact collision performance, some of which are listed below:

- The 2019 Annual Collision Report notes that posted speed limits were reduced from 90 km/h to 80 km/h between the Greenhill and Barton interchanges in February 2019[42].

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[41] RHV0000596 (2017), RVH0000597 (2018), RHV0000609 (2019), RHV0000908 (2020), and RHV0001001 (2021).
[42] 2019 Annual Collision Report, 2019, RHV0000609, Image 38.

- In May 2021, the posted speed limits were reduced from 90 km/h to 80 km/h for the entire length of the RHVP[43].
- Resurfacing, guide rail upgrades, addition of rumble strips, curve delineation signage, and lane marking upgrades were completed in the summer of 2019. The associated construction effort led to closures of various sections of the RHVP over three months[44].
- The Hamilton Police Services conducted a targeted enforcement program along the RHVP in conjunction with City education campaigns in March 2019 and April 2020. A total of 4,300 additional hours of enforcement were used on the RHVP and resulted in 6,554 Provincial Offence Notices being issued, a majority of which were for speeding[45]. Based on our experience, this program represented a concerted enforcement effort with a significant amount of police resources being deployed over a long period of time. During the concerted enforcement effort, operating speeds may have been reduced; however, it has been our experience (and the experience of the transportation industry), that vehicle speeds generally return to their "pre-enforcement" levels once the motoring public becomes aware that targeted enforcement efforts have been suspended

We have limited our analysis to comparison of collision attribute proportions (as opposed to collision frequencies) to exclude and account for some of the effects of lower traffic volumes experienced across North America during the COVID-19 pandemic. We are unaware of any industry research or practice that has been established to account for and normalize traffic volume and collision trends during the pandemic. The 2020 Annual Collision Report noted that across the province, "the total collisions in 2020 decreased by 26% compared to 2019 but the number of fatalities increased by 22% in 2020 compared to 2019. The OPP believes that the increase in fatalities is attributable to careless driving and dangerous driving (speeding)."[46].

4.1 Road Surface Condition

Road surface condition is a collision field contained within collision reports that provides information related to the road surface condition recorded by the investigating officer (e.g., dry, wet, snow, ice, slush, etc.) The previous CIMA reports[47] [48] found that there was a much higher proportion of wet road surface conditions that occurred on the RHVP compared to the Provincial and City averages. The 2015 CIMA report noted that 50.4% of collisions were recorded to have wet road surface collisions, compared to Provincial and municipal averages of 17.6% and 22%, respectively.

Figure 17 shows the proportion of collisions that were reported to have wet road surface conditions in each annual collision report's reporting period. Actual proportion differences

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[43] Speed limit reduction on the RHVP starting May 17, Ward 8 Hamilton. Retrieved October 25, 2022, from https://ward8hamilton.ca/speed-limit-reduction-on-the-rhvp-starting-may-17/, RHV0001029.
[44] 2019 Annual Collision Report, 2019, RHV0000609, Image 38.
[45] Annual Collision Report 2020, RHV0000908, Image 3
[46] Annual Collision Report 2020, RHV0000908, Image 7.
[47] Red Hill Valley Parkway Safety Review, October 2013, HAM0041871_0001, Image 23-24.
[48] Red Hill Valley Parkway Detailed Safety Analysis, November 2015, HAM0056684_0001, Image 13.

year over year will be less pronounced given that a five-year rolling average is employed, which spans the pre- and post-resurfacing periods, the pandemic, targeted enforcement, and a number of the remedial actions undertaken by the City. For example, the 2020 collision report aggregates collisions that were recorded between 2016 to 2020. If RHVP was resurfaced in summer 2019, the rolling average would consist of approximately 3.5 years (i.e., 2016 to mid-2019) where RHVP had the old pavement surface, and 1.5 years (i.e., mid 2019 to the end of 2020) with the new pavement surface.

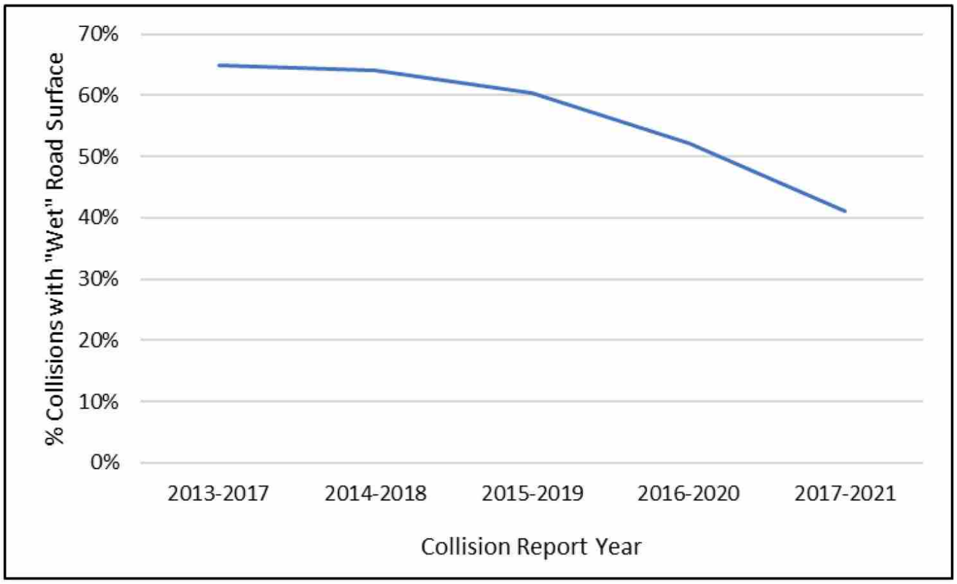

Figure 17: Proportion of Collisions with Wet Road Surface Condition[49].

Figure 17 shows that the proportion of RHVP collisions with wet road surface conditions slightly decreased between 2017 to 2019, and experienced larger decreases in 2020 and 2021.

It was noted that the RHVP was resurfaced in the Summer of 2019, and subsequent testing in September 2019 found that the friction values were higher compared to friction values collected in 2014[50]. While wet road surface collisions can be impacted by other external factors (i.e., active weather conditions and operating speeds), the proportion of collisions during wet road surface conditions appears to be significantly lower in Q4 of 2019 compared to previous years[51] [52]. This trend generally aligns with the findings shown **Figure 17**.

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[49] RHV0000596 (2017), RVH0000597 (2018), RHV0000609 (2019), RHV0000908 (2020), and RHV0001001 (2021).

[50] Review of Red Hill Valley Parkway Friction Test Results, May 2020. CIM0022320, Image 10-11. I have also reviewed the report of Gerardo Flintsch submitted for the Inquiry which covers this issue in depth.

[51] Red Hill Valley Parkway Analysis, April 28, 2020. CIM0022143, Image 45-46.

[52] The report notes that while the frequency and proportion of wet road surface collisions in Q4 2019 were lower compared to previous years, collisions are random occurrences; therefore, definitive conclusions cannot be drawn based on four months of collision data.

4.2 Impact Type

The CIMA reports also noted that there was a high proportion of single motor vehicle (SMV) collisions in their pre-2019 reporting[53] [54]. This impact type represents incidents where only one vehicle was involved, and typically occurs when a motorist loses control and collides with a stationary object or other roadside hazard. The historic proportion of SMV collisions was higher compared to provincial and City averages and resulted in SMV collisions being the most prominent impact type on RHVP, which is usually not typical for a freeway facility. Generally, rear-end collisions are the most prominent impact type on freeway facilities since they are associated with congestion and start-stop behavior.

Figure 18 shows the proportion of the prominent impact types that occurred on RHVP, obtained from the annual collision reports.

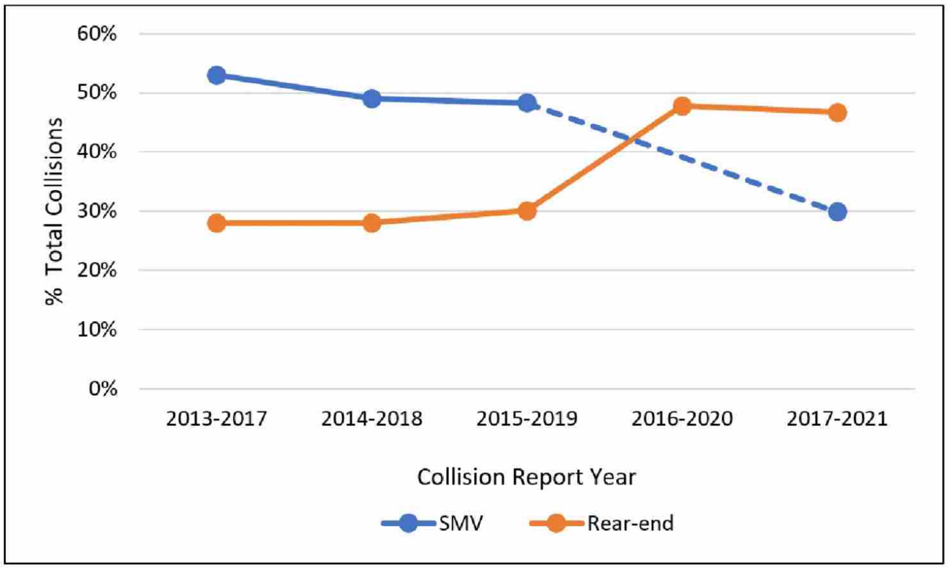

Figure 18: Impact Type Distribution.[55]

Figure 18 shows that the prominent impact type for the 2017 to 2019 annual collision reports was SMV collisions. However, in 2020, the prominent impact type changed to rear-end collisions; it was noted that SMV collisions were the second most prominent type, but the proportion of those collisions was not provided in the City's 2020 annual report. In 2021, the proportion of rear-end and SMV collisions was provided; the missing value in the 2020 Annual Collision report is interpolated in **Figure 18** based on values provided in the 2019 and 2021 reports. Poor road surface conditions, including lower pavement friction, is one of the primary contributory factors to an over-representation of SMV collisions on urban freeways.

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[53] Red Hill Valley Parkway Safety Review, October 2013. HAM 0041871_0001, Image 22.

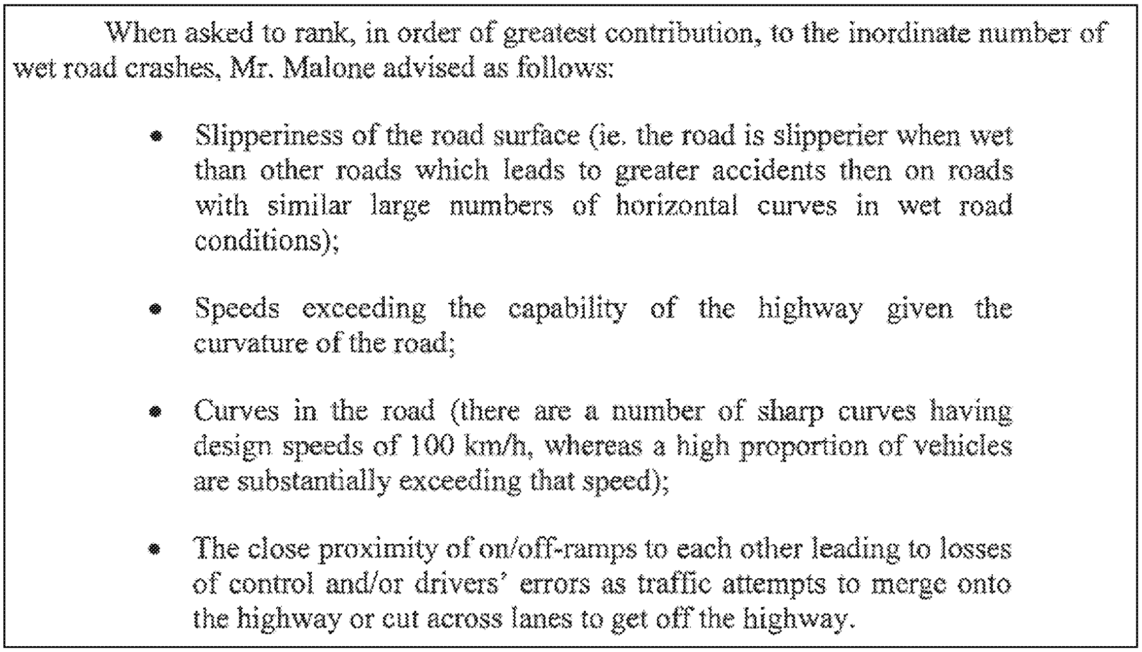
[54] Red Hill Valley Parkway Detailed Safety Analysis, November 2015. HAM0056684_0001, Image 13.

[55] SMV collisions were noted to be the second most prominent impact type in 2020, but the collision report did not provide specific proportions of those collisions. The proportion of SMV collisions was provided in the 2021 Annual Collision Report; the 2020 value was approximated based on the proportion of SMV collisions in 2019 and 2021.

The change in prominent collision types also takes place in the 2020 annual collision report, the first full year after the RHVP was resurfaced, and other safety initiatives to mitigate SMV collisions were implemented such as reduced speed limits, rumble strips, restriped lane markings, reflective delineators on curves, and installation of "Slippery When Wet" and oversized maximum speed signs. These factors can all impact driver behavior and safety performance, but it is difficult to isolate the individual impacts of each improvement that was implemented over the analysis period.

5.0 CONTRIBUTORY FACTORS IN WET ROAD COLLISIONS

In a Boghosian & Allen LLP letter to the City of Hamilton[56], Mr. David Boghosian documented a question and answer of Mr. Brian Malone of CIMA in relation to potential contributory causes of an inordinate number of wet road crashes. **Figure 19** outlines the summary of the response.



When asked to rank, in order of greatest contribution, to the inordinate number of wet road crashes, Mr. Malone advised as follows:

- Slipperiness of the road surface (ie. the road is slipperier when wet than other roads which leads to greater accidents then on roads with similar large numbers of horizontal curves in wet road conditions);
- Speeds exceeding the capability of the highway given the curvature of the road;
- Curves in the road (there are a number of sharp curves having design speeds of 100 km/h, whereas a high proportion of vehicles are substantially exceeding that speed);
- The close proximity of on/off-ramps to each other leading to losses of control and/or drivers' errors as traffic attempts to merge onto the highway or cut across lanes to get off the highway.

Figure 19: Excerpt from Boghosian & Allen LLP letter[57].

It should be noted that during his inquiry testimony on October 31, 2022, Mr. Malone clarified that the above noted contributory factors are consistent with the CIMA reports and his opinion; however, he did not agree they were conveyed to Mr. Boghosian in a ranked order from greatest to least contribution to wet road crashes.

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[56] HAM0064331_0009.

[57] Image 8 of HAM0064331_0009.

We were asked if we agreed with what Mr. Boghosian reported as being Mr. Malone's answers and reported relative ranking. Provided below is my response.

It is my experience and opinion that reduced road surface friction would be the primary (i.e., highest ranking) contributory cause of an over-representation[58] of wet road crashes.

Of the above bulleted responses, I would agree that the close proximity of on/off ramps would generally be the lowest ranking contributory factor of the four responses given.

The second and third bullet point responses in **Figure 19** are interrelated as they both "implicate" motorist operating speed choice and the design speed of horizontal curves. The former appears to place greater contribution on motorist speed choice; whereas, the latter appears to suggest a greater contribution of the presence and/or design of horizontal curves.

The presence of a horizontal curve creates a higher risk of collision when compared to a tangent road section. In our experience, the primary contributory factors causing loss of control incidents at curves generally relate to motorist entry speed choice which is a function of the visibility of the curve alignment and its severity, advance warning of the curve design, the presence/absence of delineation and/or dark conditions. In general, compromised road surface conditions due to recognizable conditions such as gravel, snow, slush, ice or wet road surfaces conditions are not over-represented in long-term collision trends at curves, as road users will adjust their operating speeds in response. The majority of loss of control collisions at horizontal curves occur during clear dry conditions.

Therefore, I am of the opinion that the two speed/curve design factors recorded by Mr. Boghosian as being noted by Mr. Malone are the second most important factors in the over-representation of wet road collisions, when combined with and exacerbated by the primary factor of reduced road friction; the latter generally being a condition that would not be readily apparent to the motoring public.

6.0 HIGHWAY SAFETY REVIEW SCOPE

The Transportation Association of Canada (TAC) defines a safety review as:

> *"An in-depth engineering study of an existing road using road safety principles with the purpose of identifying cost-effective countermeasures that would improve road safety and operations for all road users. In-service reviews can be conducted for any road section, intersection, or interchange, and are generally most effective when conducted at locations where a high collision risk has been identified."*[59]

Several industry guidelines were examined to identify tasks and technical elements that are typically included within the scope of a highway safety review. Three industry-accepted

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[58] A road safety term used to describe an inordinate frequency of a specific collision attribute when compared to peer transportation facilities.

[59] The Canadian Guide to In-service Road Safety Reviews, Transportation Association of Canada, 2004. Image #11.

guidelines (hereafter collectively referred to as 'industry guidelines') were referred to and are listed below:

- TAC Guide to In-Service Road Safety Reviews (2004)[60]
- MTO Guidelines for Operational Performance Reviews (2015)[61]
- FHWA Road Safety Audit Guidelines (2006)[62]

It should be noted that the FHWA document provides guidance for road safety audits, which differ from a traditional in-service safety review. Road safety audits can be performed for an existing roadway facility (i.e., in-service safety review), or for a future facility design that has yet to be constructed (i.e., safety audit. To remain consistent between the documents, FHWA guidance for in-service roadway facilities was applied.

Table 3 provides a summary of the tasks that could be included in a highway safety review based on guidance provided in each document and compares the tasks to those that were completed as part of the 2015 CIMA study[63]. While the tasks shown are typically included in the scope of a highway safety review, the scope of specific studies may vary based on client objectives, requirements, budget, and availability of data.

Table 3: Typical Highway Safety Scope Tasks.

Task	Industry Guidelines	2015 CIMA Study[64]
Stakeholder Consultation	✓	✓
Site Visit / Field Investigation	✓	✓
Collision Analysis	✓	✓
Geometric Analysis	✓	X
Operational Analysis	✓	✓
Human Factors Analysis	✓	✓
Identification of Issues	✓	✓
Countermeasure Selection	✓	✓
Documentation	✓	✓

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[60] The Canadian Guide to In-service Road Safety Reviews, Transportation Association of Canada, 2004.
[61] Guidelines for Operational Performance Reviews, Ministry of Transportation of Ontario, 2015.
[62] Road Safety Audit Guidelines, Federal Highway Administration, 2006.
[63] HAM0056684_0001, Red Hill Valley Parkway Detailed Safety Analysis, CIMA, 2015.
[64] Red Hill Valley Parkway Detailed Safety Analysis, 2015, HAM00056684_0001.

Based on a review of **Table 3**, the tasks included in the 2015 CIMA study generally aligned with the tasks contained within the industry accepted guidelines for a typical highway safety study. However, an analysis of the geometry of the roadway was not undertaken in the 2015 CIMA study although it is generally a primary component of a highway safety study. There was no rationale provided for its exclusion.

In their 2013 Red Hill Valley Safety Review[65], CIMA noted that the RHVP had already undergone many design refinements and assessments through the planning and design phases, and therefore geometric analysis was not included as part of the 2013 study scope.

Table 4 provides a summary of the various analysis elements that may be included as part of road safety studies, using the same documents that were previously compared.

Table 4: Road Safety Analysis Elements

Analysis Element	Industry Guidelines	2015 CIMA Study
Traffic Control Devices	✓	✓
Traffic Volumes	✓	✓
Speed Studies	✓	✓
Traffic Operations	✓	**X**
Collision Diagram	✓	**X**
Collision Attribute Analysis	✓	✓
Illumination	✓	✓
Horizontal Alignment	✓	X
Superelevation	✓	X
Sight Distances	✓	X
Vertical Alignment	✓	X
Cross Sectional Elements	✓	✓
Drainage	✓	**X**
Design Consistency	✓	✓

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[65] Red Hill Valley Parkway Safety Review, October 2013, HAM0041871_0001, Image 15.

The following are the highway safety review elements that were not included in the 2015 CIMA study:

- Traffic operations analysis.
- Collision diagrams: these are not always required and are generally more beneficial when applied in an intersection context, where collisions are geographically distributed and other relevant information (i.e., impact type, severity, road surface condition, etc.) are presented. The 2015 CIMA study graphed the spatial distribution by direction along the RHVP[66] and conducted collision attribute analysis along the study area.
- Horizontal alignment, superelevation, sight distance, vertical alignment, and drainage: these elements are typically included within the scope of geometric analysis.

As outlined in **Sections 3.0 and 5.0**, the interaction between design consistency and motorist expectations, operating speed choice, and the geometric design of curves and interchanges are contributory factors in the over-representation of wet road collisions.

7.0 CLOSING WORDS

We trust that the above assessment responds to your request. Should additional information become available, we reserve the right to amend our opinion.

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[66] Red Hill Valley Parkway Detailed Safety Analysis, November 2015, HAM0056684_0001. Image 17-18.

APPENDIX A: MARCH 2022 TNS REPORT

TNS
TRUE NORTH SAFETY GROUP

RED HILL VALLEY PARKWAY INQUIRY

PRINCIPAL DESIGN AND MAINTENANCE STANDARDS, GUIDELINES AND GENERAL PRACTICES FOR ONTARIO HIGHWAYS

Your File: 96189
TNS File No.: **220007**

Prepared For:

Mr. Robert A. Centa
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March 9, 2022

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1.0 INTRODUCTION

Paliare Roland Rosenberg Rothstein LLP retained True North Safety Group as an independent contractor to provide transportation safety expert consulting services to the Red Hill Valley Parkway Inquiry, Justice Herman Wilton-Siegel, Commissioner.

On February 1, 2022, we were asked to prepare an expert report regarding the principal design and maintenance standards, guidelines and general practices for highways in Ontario related to the following:

- Pavement friction.
- Posted, operating and design speeds.
- Sightlines.
- Lane and shoulder widths.
- Roadway alignment and grades.
- Crossfall and drainage.
- Traffic control devices.
- Roadside safety.
- Road maintenance.

2.0 PRINCIPAL DESIGN AND MAINTENANCE STANDARDS, GUIDELINES, AND GENERAL PRACTICES

2.1 Scope

The Ontario Highway Traffic Act (HTA)[1] defines a "highway" to include "*a common and public highway, street, avenue, parkway, driveway, square, place, bridge, viaduct or trestle, any part of which is intended for or used by the general public for the passage of vehicles and includes the area between the lateral property lines thereof*".

For the purposes of this report, the term "*highway*" will be used to define a free flow facility with grade-separated interchanges, restricted access, and prohibition of pedestrians and cyclists, i.e., controlled access highway, freeway, or expressway. All other road facilities noted above in the HTA definition will be referred to in this report as local or municipal roads.

As previously discussed, we do not have extensive expertise in pavement design or friction testing. Therefore, we have limited our discussion of pavement friction to the requirements/guidance outlined in geometric design manuals.

2.2 Assessment Period

An assessment period of 2002 to 2020 was established to generally encompass the design, operations, and maintenance periods of the Red Hill Valley Parkway. Where applicable, we have made reference to a range of standards/guidance that may have changed during the assessment period.

2.3 Highway Design

2.3.1 Standards, Guidelines and Policies

Highway geometric design guidance includes the following primary components:

- Sight distances
    - Stopping sight distance to allow motorists to perceive, react and stop for an object in their path at the design speed, i.e., sufficient sight distance over a hill to observe and react to an object or stopped vehicle in the travel lane on the far side of the hill.
    - Decision sight distance to allow motorists sufficient time to make a decision regarding maneuvering their vehicle or adjusting their speed in

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[1] Highway Traffic Act, R.S.O. 1990, CHAPTER H.8.

complex situations[2] where information may be perceived incorrectly, decisions are required, or control actions are required (as opposed stopping sight distance which involves a complete stop for an obstacle).

    - Sight lines approaching and at the at-grade intersections to observe and react to the traffic control and conflicting road users, i.e., a vehicle stopped at an intersection attempting to pick a gap in traffic to make a turn at or cross the intersection;

- Lane and shoulder widths;
- Vertical curves representing the hills and valleys experienced as you travel along the highway alignment;
- Grades - Overall uphill (i.e., rise) and downhill (i.e., fall) of the highway surface. Roadway grades are positive if rising in the direction of travel and negative if falling in the direction of travel. The grade along a roadway is expressed as a percentage; that is rise or fall in metres over a horizontal length of 100 m;
- Pavement crossfall which is the slope of the roadway from the pavement surface towards the edges of the highway to facilitate surface water drainage off the roadway;
- Horizontal curves including:
    - Circular curves – with a design speed related to the curve radius, wet weather friction values[3] and superelevation;
    - Spiral curves – a curve with a constantly varying radius, to provide a smooth transition between a tangent road section and the circular curve; and
    - Superelevation – design with the outside road edge to be higher than the inside road edge to counteract the horizontal forces on a vehicle around a curve.
- Interchange design; and
- Roadside safety including ditches, fixed hazards, and protection[4].

The principal design standards/guidelines for the design of highways in Ontario are:

- **1985 Geometric Design Standards for Ontario Highways, Ministry of Transportation of Ontario[5] (the '1985 MTO Design Guide')** – The 1985 MTO Design Guide was developed for use on Provincial highways and roadways; however, some municipal entities have adopted it for the design and contract specifications of their roadways. It has been our experience, that this latter group included mostly

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[2] For example, complex intersections or interchanges, unusual or unexpected changes in the roadway environment, construction zones, demanding driver workload areas due to a heavy traffic/conflict, advertising, and/or traffic control devices.

[3] Pavement friction design values will be address in a subsequent section of this report.

[4] Roadside design will be addressed in a subsequent section of this report.

[5] Geometric Design Standards for Ontario Highways, Ministry of Transportation of Ontario, 1985.

counties, smaller rural communities, and indigenous road authorities that may have received their technical knowledge transfer from regional MTO offices.

- **1999 Transportation Association of Canada's Geometric Design Guide for Canadian Roads[6] (the '1999 TAC Guide') including the 2017 update[7] (the '2017 TAC Guide')** – The 1999 TAC Guide and 2017 TAC Guide were developed to achieve design consistency amongst Canadian federal, provincial, territorial, and municipal road authorities. In 2017, the MTO adopted the entirety of the 2017 TAC Guide except the roadside design chapter. It has been our experience that most major cities and towns, and many counties, applied the 1999 and 2017 TAC guides.

2.3.2 Compliance and Application

Ontario municipalities are not legally bound to follow any of the above design standards or guidelines. Industry good practice is to apply either the 1985 MTO Design Guide or the 1999/2017 TAC Guide, with jurisdictional design exceptions. **Table 1** provides the intent and context for application of the TAC guides.

In general, it has been our experience that major cities in Ontario applied and specified the 1999/2017 TAC Guide for highway design, unless they were making modifications to a provincial highway within their jurisdiction that was the subject of a connecting link agreement[8] with MTO. In these latter instances, MTO practices would be specified.

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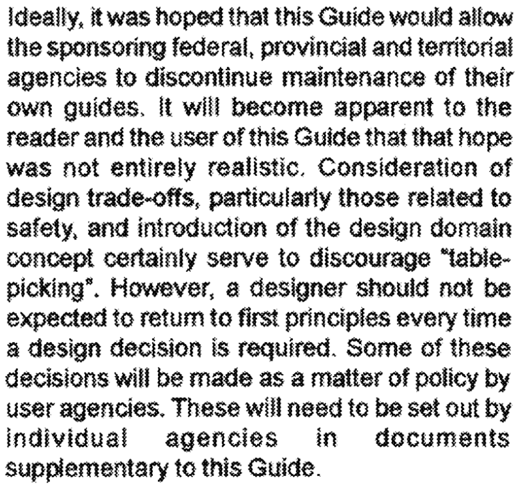
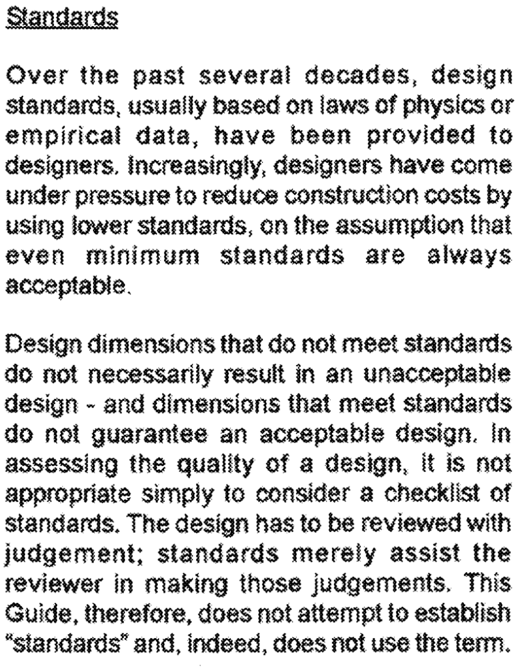
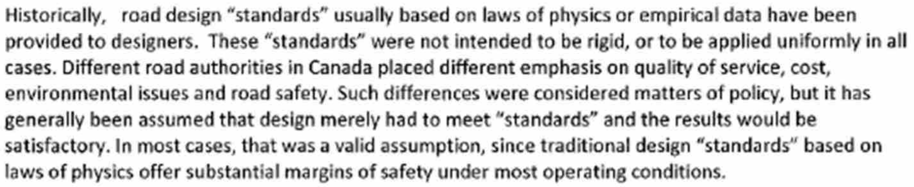
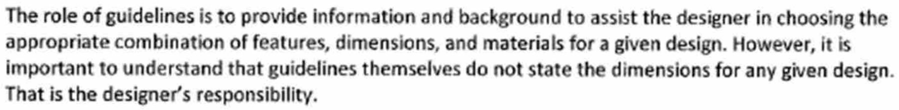
[6] Geometric Design Guide for Canadian Roads, Transportation Association of Canada, 1999.

[7] Geometric Design Guide for Canadian Roads, Transportation Association of Canada, 2017.

[8] Under a connecting link agreement, a local municipality operates and maintains an MTO roadway through a build-up area of a community. When infrastructure or operational modifications are required to the connecting link, they are generally modified based on MTO requirements, as MTO is the facility owner. This circumstance will be inherently applicable to other standard/guideline areas discussed in this report.

Table 1: 1999/2017 TAC Guide application guidance.

Reference	Application
1999 TAC Guide	 Ideally, it was hoped that this Guide would allow the sponsoring federal, provincial and territorial agencies to discontinue maintenance of their own guides. It will become apparent to the reader and the user of this Guide that that hope was not entirely realistic. Consideration of design trade-offs, particularly those related to safety, and introduction of the design domain concept certainly serve to discourage "table-picking". However, a designer should not be expected to return to first principles every time a design decision is required. Some of these decisions will be made as a matter of policy by user agencies. These will need to be set out by individual agencies in documents supplementary to this Guide.
1999 TAC Guide	 Standards Over the past several decades, design standards, usually based on laws of physics or empirical data, have been provided to designers. Increasingly, designers have come under pressure to reduce construction costs by using lower standards, on the assumption that even minimum standards are always acceptable. Design dimensions that do not meet standards do not necessarily result in an unacceptable design - and dimensions that meet standards do not guarantee an acceptable design. In assessing the quality of a design, it is not appropriate simply to consider a checklist of standards. The design has to be reviewed with judgement; standards merely assist the reviewer in making those judgements. This Guide, therefore, does not attempt to establish "standards" and, indeed, does not use the term.

Reference	Application
2017 TAC Guide	 Historically, road design "standards" usually based on laws of physics or empirical data have been provided to designers. These "standards" were not intended to be rigid, or to be applied uniformly in all cases. Different road authorities in Canada placed different emphasis on quality of service, cost, environmental issues and road safety. Such differences were considered matters of policy, but it has generally been assumed that design merely had to meet "standards" and the results would be satisfactory. In most cases, that was a valid assumption, since traditional design "standards" based on laws of physics offer substantial margins of safety under most operating conditions.
2017 TAC Guide	 The role of guidelines is to provide information and background to assist the designer in choosing the appropriate combination of features, dimensions, and materials for a given design. However, it is important to understand that guidelines themselves do not state the dimensions for any given design. That is the designer's responsibility.

2.4 Pavement Friction Design

2.4.1 Standards, Guidelines and Policies

The pavement friction value, represented by the coefficient of friction ('f'), represents the available friction between vehicle tires and the roadway. Friction values used in highway design have measured values either longitudinally (i.e., the design friction value assumed between the road and tire for a vehicle to stop within the stopping sight distance) or laterally (i.e., the lateral friction required for a vehicle to travel around a curve in the roadway). **Figure 1** shows the lateral friction concept associated with a vehicle travelling around a high-speed curve with the roadway superelevated to the inside of the curve.

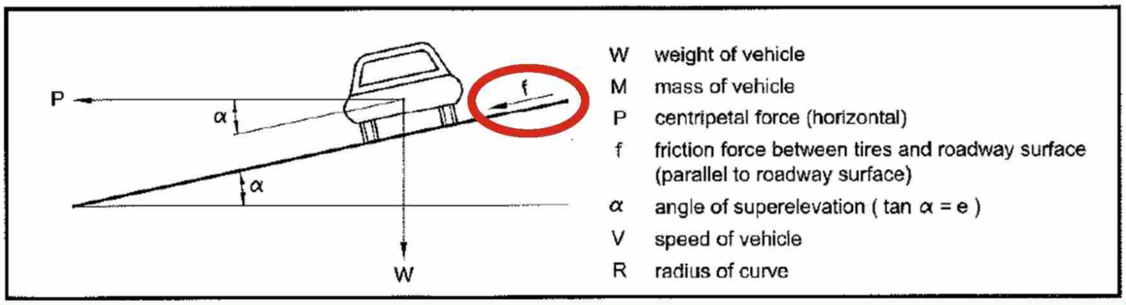


Figure 1: Dynamics of a vehicle on a horizontal curve (TAC, 1999/2007).

The 1999/2017 TAC Guide and the 1985 MTO Design Guide recommend conservative design values[9] for available friction based on worn pavement, worn tires and wet

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[9] Friction values assumed in design do not represent the available (i.e., actual) friction between the tires and road, but a much lower value with safety and driver comfort factors considered.

pavement conditions. The highway design does account for intermittent reduced friction conditions due to snow, slush or icy road surface conditions. Pavement friction is required to maintain traction around curves and allow for acceptable braking, as required for stopping sight distance. **Figure 2** shows the rounded friction value assumptions for stopping sight distance on level pavement[10] outlined in the 1999 TAC Guide[11] (i.e., longitudinal friction).

The 1999 TAC Guide applies a range of friction values between 0.28 to 0.38 as a function of the design speed to calculate stopping sight distance. The 2017 TAC Guide applies a constant 3.4 m/s^2 deceleration rate, which is approximately equivalent to a constant friction value of 0.343. The effect of the assumption of a constant deceleration value in the 2017 TAC Guide is marginally lower stopping sight distance requirements at higher design speeds (80 to 120 km/h) under the current standards.

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[10] Stopping sight distances are adjusted for uphill or downhill grades/slopes.

[11] Similar lateral friction values are assumed in Table C2-1 (Minimum Stopping Sight Distance on Wet Pavement) in the 1985 MTO Design Guide.

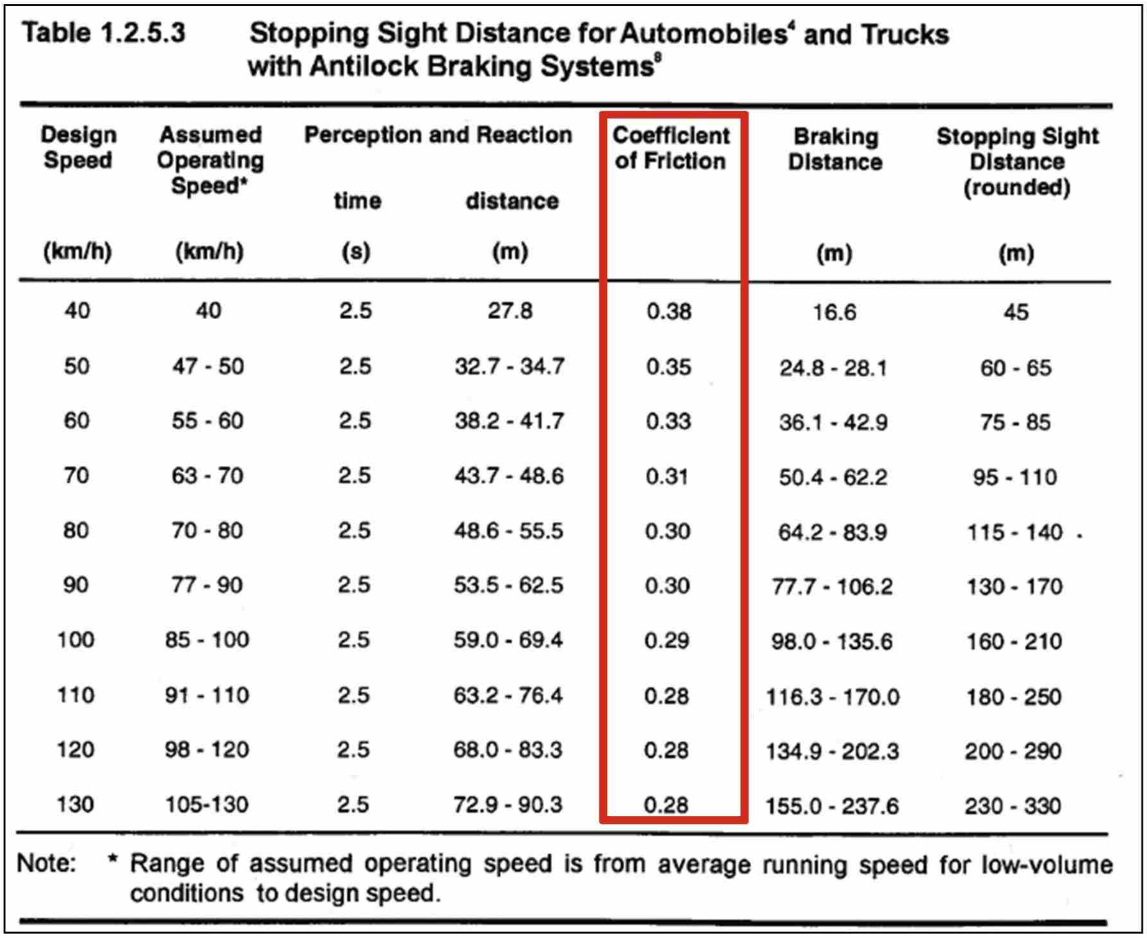

Table 1.2.5.3 Stopping Sight Distance for Automobiles[4] and Trucks with Antilock Braking Systems[8]

Design Speed (km/h)	Assumed Operating Speed* (km/h)	Perception and Reaction time (s)	Perception and Reaction distance (m)	Coefficient of Friction	Braking Distance (m)	Stopping Sight Distance (rounded) (m)
40	40	2.5	27.8	0.38	16.6	45
50	47 - 50	2.5	32.7 - 34.7	0.35	24.8 - 28.1	60 - 65
60	55 - 60	2.5	38.2 - 41.7	0.33	36.1 - 42.9	75 - 85
70	63 - 70	2.5	43.7 - 48.6	0.31	50.4 - 62.2	95 - 110
80	70 - 80	2.5	48.6 - 55.5	0.30	64.2 - 83.9	115 - 140
90	77 - 90	2.5	53.5 - 62.5	0.30	77.7 - 106.2	130 - 170
100	85 - 100	2.5	59.0 - 69.4	0.29	98.0 - 135.6	160 - 210
110	91 - 110	2.5	63.2 - 76.4	0.28	116.3 - 170.0	180 - 250
120	98 - 120	2.5	68.0 - 83.3	0.28	134.9 - 202.3	200 - 290
130	105-130	2.5	72.9 - 90.3	0.28	155.0 - 237.6	230 - 330

Note: * Range of assumed operating speed is from average running speed for low-volume conditions to design speed.

Figure 2: Stopping sight distance for automobiles and trucks with antilock braking systems (1999 TAC Guide).

Figure 3 shows the maximum lateral friction value assumptions for the design of horizontal curves in the 1999 TAC Guide[12]. These lateral friction values are based on a tolerable degree of occupant discomfort and provide a reasonable margin of safety against skidding under normal driving conditions. Road curves are designed to avoid skidding conditions; therefore, the lateral friction factors for roadway design are substantially less than the available coefficient of friction between vehicle tires and the roadway. The 1999 TAC Guide lateral friction values shown in **Figure 3** are consistent with existing design guidance in the 2017 TAC Guide.

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[12] A similar range and magnitude of lateral friction values are assumed in the 1985 MTO Design Guide; however, there are slight variations in actual values.

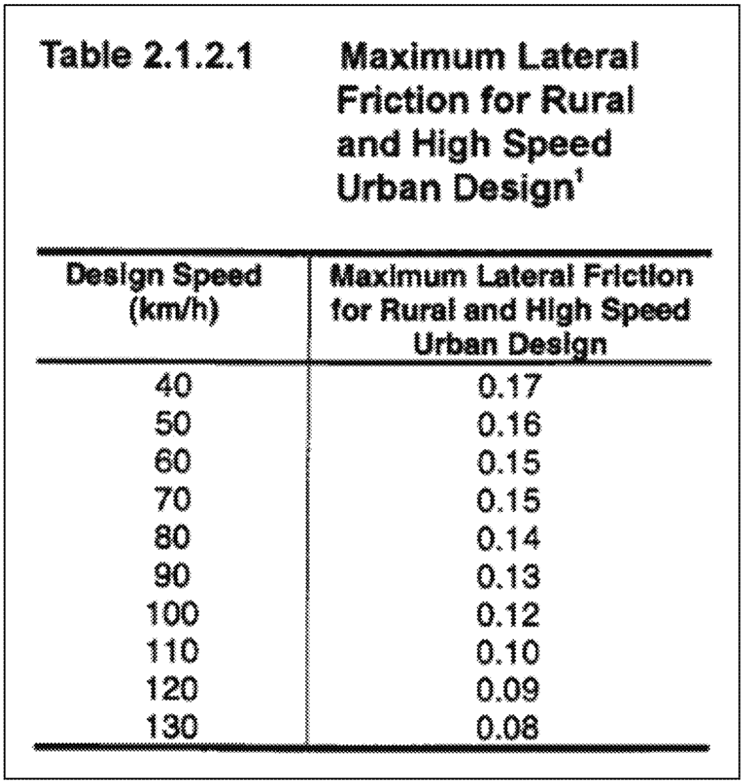

Table 2.1.2.1 Maximum Lateral Friction for Rural and High Speed Urban Design[1]

Design Speed (km/h)	Maximum Lateral Friction for Rural and High Speed Urban Design
40	0.17
50	0.16
60	0.15
70	0.15
80	0.14
90	0.13
100	0.12
110	0.10
120	0.09
130	0.08

Figure 3: Maximum lateral friction for design (1999 TAC Guide).

2.4.2 Compliance and Application

Ontario municipalities are not legally bound to follow any of the above design standards or guidelines. Industry good practice is to apply either the 1985 MTO Design Guide or the 1999/2017 TAC Guide for pavement friction and the associated geometric design components noted above. In general, it has been our experience that major cities in Ontario applied and specified the 1999/2017 TAC Guide for highway design during the assessment period.

2.5 Traffic Control Devices

2.5.1 Standards, Guidelines and Policies

Traffic control devices include signs, markings, and delineation on our highways. The principal designs standards/guidelines for the design of highways in Ontario are:

- **Ontario Traffic Manual**[13] - The purpose of the Ontario Traffic Manual (OTM) is to provide information and guidance for transportation practitioners and to promote uniformity of treatment in the design, application and operation of traffic control devices and systems across Ontario. **Table 2** provides the primary OTM books applicable to highways. It has been our experience that the OTM is the primary resource applied by MTO and most municipalities in Ontario.
- **1985/1995 Manual of Uniform Traffic Control Devices for Canada (MUTCDC)** [14] **including the 2014**[15] **and 2021**[16] **updates** – The purpose of the MUTCDC is to provide national standardization for the user of traffic control devices for the control of traffic and the provision of information to drivers and other road users. It had been our experience that some Ontario municipalities have applied the entirety of, or specific guidance/signs outlined in the MUTCDC; however, these are the exception.

Table 2: Ontario Traffic Manual (OTM) books applicable to highways.

OTM Book	Traffic Control Device	Publication Date
1	Introduction	2001
2	Sign Patterns and Fabrication	2004
5	Regulatory Signs	2000
6	Warning Signs	2001
7	Temporary Conditions	2014
8	Guide and Information Signs	2010
10	Dynamic Message Signs	2007
12	Traffic Signals	2012

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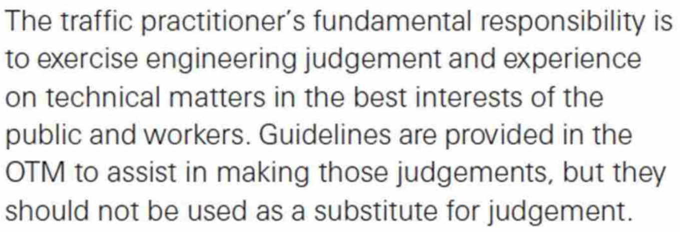
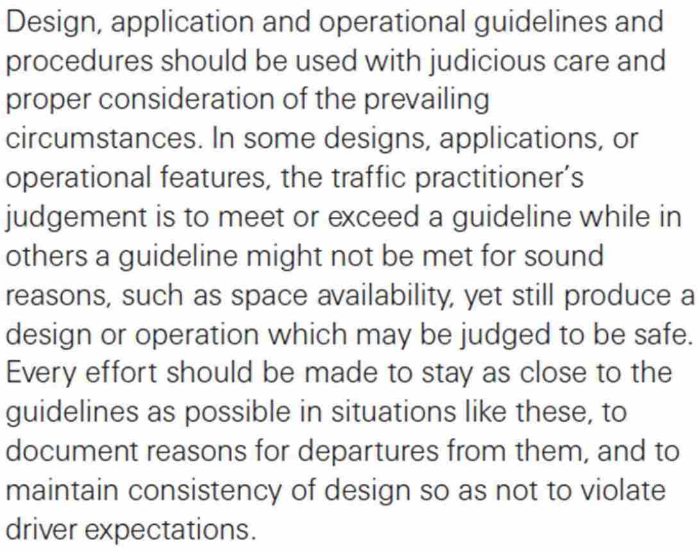
[13] Ontario Traffic Manual, Ministry of Transportation of Ontario, 2000.
[14] Manual of Uniform Traffic Control Devices for Canada, Transportation Association of Canada, 1985-1995.
[15] Manual of Uniform Traffic Control Devices for Canada, Transportation Association of Canada, 2014.
[16] Manual of Uniform Traffic Control Devices for Canada, Transportation Association of Canada, 2021.

2.5.2 Compliance and Application

In general, it has been our experience that major municipalities in Ontario apply the OTM for traffic control device guidance. Ontario municipalities are not legally bound to follow OTM as noted in **Table 3**; however, it has been applied as industry good practice by Ontario municipalities for the past two decades.

Table 3: OTM application guidance.

Application Guidance
 The traffic practitioner's fundamental responsibility is to exercise engineering judgement and experience on technical matters in the best interests of the public and workers. Guidelines are provided in the OTM to assist in making those judgements, but they should not be used as a substitute for judgement.
 Design, application and operational guidelines and procedures should be used with judicious care and proper consideration of the prevailing circumstances. In some designs, applications, or operational features, the traffic practitioner's judgement is to meet or exceed a guideline while in others a guideline might not be met for sound reasons, such as space availability, yet still produce a design or operation which may be judged to be safe. Every effort should be made to stay as close to the guidelines as possible in situations like these, to document reasons for departures from them, and to maintain consistency of design so as not to violate driver expectations.

2.6 Design Speed and Posted Speeds

2.6.1 Standards, Guidelines and Policies

The principal standards/guidelines for the selection of design speed and posting of speed limits on Ontario highways are:

- **The Highway Traffic Act**[17] – provides regulations related to unposted statutory rates of speed[18] in Ontario (i.e., 50 km/h within a local municipality or urban built-up areas and 80 km/h for rural and high-speed environments), and the ability and general provisions for provincial and municipal road authorities to prescribe a rate of speed different from the statutory rates.
- **OTM Book 5: Regulatory Signs** – provides guidance on the design and placement of maximum speed limit signs once a road authority determines the applicable rate of speed to post.
- **OTM Book 6: Warning Signs** – provides guidance on determining and posting advisory and ramp speeds for specific roadway attributes that require advance warning as they may not meet the intended operating, design or posted speed of the overall highway.
- **1985 MTO Design Guide and the 1999/2017 TAC Guides** – provide general guidance and ranges for selecting design speeds and posted speeds for various classifications of roadway facilities; however, they to do not provide prescriptive guidance on selecting or posting speed limits.
- **Methods and practices for setting speed limits: An informational report**[19] **(the 'FHWA speed report')** - a guideline produced by the Federal Highway Administration describes three approaches for setting speed limits including an engineering approach, expert system approach, and safe systems approach.
- **Canadian Guidelines for Establishing Posted Speed Limits**[20] **(the 'TAC Speed Guide')** - provides recommendations to assist transportation practitioners to determine speed limit management procedures, which enhances the effectiveness and credibility of posted speed limits. The guidelines provide an evaluation tool to assess appropriate posted speed limits based on the classification, function, and physical characteristics of a roadway. An automated spreadsheet is provided to facilitate the evaluation of posted speed limits.

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[17] Highway Traffic Act, R.S.O. 1990, c. H.8

[18] All unposted roadways are assumed to have a 50 or 80 km/h rate of speed based on their location and environment noted above. This speed is inferred and can be enforced by police services. If a road authority wishes to post a speed on a roadway different than the statutory speeds outlined in the HTA, it may do so through regulation (for provincial highways) or by-law (for municipal roadways), and it must be explicitly posted.

[19] Methods and practices for setting speed limits: An informational report (No. IR-133). Federal Highway Administration, 2012.

[20] Canadian Guidelines for Establishing Posted Speed Limits, Transportation Association of Canada, 2009.

2.6.2 Compliance and Application

There is no commonly applied standard/guideline establishing posted speed limits on highways in Ontario, beyond the statutory speed outlined by the HTA. There are no legal or regulatory requirements for establishing the appropriate design speed or posted speed on Ontario roadways.

Typically, common practice is to select a 'design speed' of 10 to 20 km/h over the posted speed limit for a paved roadway. The design speed is applied in decision-making regarding the appropriate road design features (i.e., road/shoulder widths, horizontal curves and vertical curves, and roadside design and protection) and traffic control devices. The 1985 MTO Design Guide allows a design speed range of 90 to 120 km/h to be selected for highways, with a 90 km/h design speed to be considered only in the instance of urban freeways.

Based on our experience, the design speed of a planned highway is generally selected as a function of the roadway classification and the intended posted speed. We are unaware of any instances where a road authority has proactively and explicitly applied one of the speed limit setting/assessment tools noted above (i.e., the FHWA Speed Report or the TAC Speed Guide) at the planning and design stages of a highway. Generally, the overall design criteria are specified at the outset of the design process including the design speed.

Once the design speed is selected, the highway features are designed, at a minimum, to the prevailing guidance outlined in **Section 2.3**. Where specific highway features or operations cannot be provided to meet the design speed criteria and/or motorist expectations of the posted speed, regulatory and warning traffic control devices are used to set expectations for appropriate operating speeds, i.e., the application of OTM Book 5 and 6 guidance.

It is our experience that Ontario road authorities apply a range of methods to assess the posted speed limits along their existing roadways[21] with the most common being the 85th percentile method[22] or the application of the TAC Speed Guide methodology. The assessment of the posted speed of an existing roadway is generally undertaken based on collision history, speed compliance issues, speeding complaints or substantial changes to the nature and function of the roadway compared to when it was designed and constructed.

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[21] Roadways that have been constructed and are in operations.

[22] Setting the posted speed limit at or within 5 to 10 km/h of the 85th percentile speed. The 85th percentile speed is measured in the field and represents the speed at which 85 percent of the traffic is travelling at or below.

2.7 Illumination

2.7.1 Standards, Guidelines and Policies

The principal guidelines for highway illumination on Ontario municipal highways are:

- **2006 Guide for the Design of Roadway Lighting[23] (the 'TAC Illumination Guide').**
- **2001 Illumination of Isolated Rural Intersections[24] (the 'TAC Rural Illumination Guide').**
- **2000 Roadway Lighting, ANSI/IESNA RP-8-00[25] ('RP-8-00') and update in 2014[26] ('RP-8-14').**
- **2012 FHWA Lighting Handbook**[27].

The MTO applies the Ministry Policy for Highway Illumination[28] for its highways; however, we do not have experience with municipal road authorities applying the MTO policies.

2.7.2 Compliance and Application

In general, it has been our experience that major municipalities in Ontario apply the TAC Illumination Guide and/or RP-8-00/RP-814 guidelines. We have applied these illumination guidelines in consulting work and legal liability matters, as they are the primary guidelines we see referenced in municipal design guidance, tenders, and contracts.

Ontario municipalities are not legally bound to follow any of the above illumination guidelines, warranting criteria, or specifications. **Table 4** provides application guidance excerpts from the TAC Illumination Guide and RP-8-00. The TAC Illumination Guide and RP-8-00/RP-814 guidelines represent industry good practice regarding recommended lighting levels once the decision is made to illuminate a municipal highway.

Table 4: TAC Illumination Guide application guidance.

Reference	Application Guidance
TAC Illumination Guide	The contents of this Guide have no legislative authority and are not to be interpreted as minimum standards by which road authorities are to be judged. Similarly, this manual is not intended to be used as a basis for establishing civil liability.

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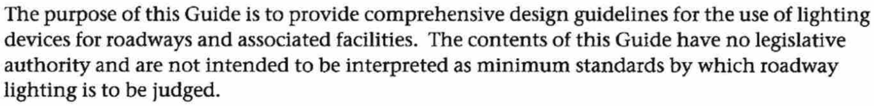
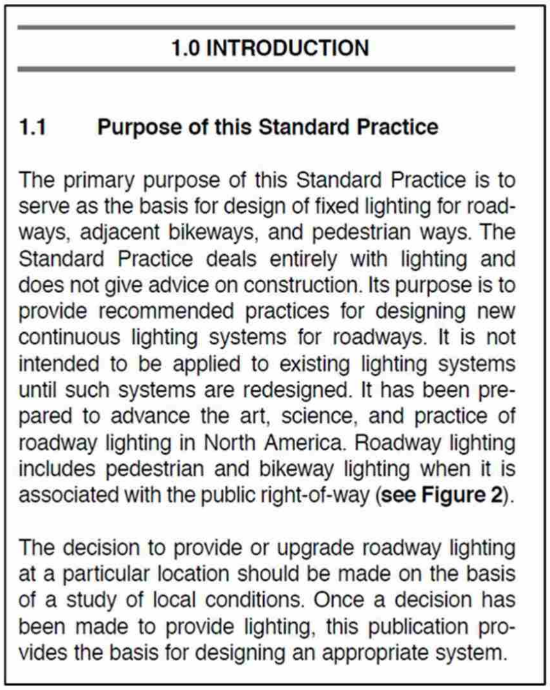
[23] Guide for the Design of Roadway Lighting, Transportation Association of Canada, 2006.
[24] Illumination of Isolated Rural Intersections, Transportation Association of Canada, 2001.
[25] Roadway Lighting, ANSI/IESNA RP-8-00, 2000.
[26] Roadway Lighting, ANSI/IESNA RP-8-00, 2014.
[27] FHWA Lighting Handbook, Transportation Research Board (TRB), 2012.
[28] Ministry Policy for Highway Illumination, Policy, Planning and Standards Division, Directive #PLNG-B-05, 2002.

Reference	Application Guidance
TAC Illumination Guide	 The purpose of this Guide is to provide comprehensive design guidelines for the use of lighting devices for roadways and associated facilities. The contents of this Guide have no legislative authority and are not intended to be interpreted as minimum standards by which roadway lighting is to be judged.
RP-8-00	 **1.0 INTRODUCTION** **1.1 Purpose of this Standard Practice** The primary purpose of this Standard Practice is to serve as the basis for design of fixed lighting for roadways, adjacent bikeways, and pedestrian ways. The Standard Practice deals entirely with lighting and does not give advice on construction. Its purpose is to provide recommended practices for designing new continuous lighting systems for roadways. It is not intended to be applied to existing lighting systems until such systems are redesigned. It has been prepared to advance the art, science, and practice of roadway lighting in North America. Roadway lighting includes pedestrian and bikeway lighting when it is associated with the public right-of-way (**see Figure 2**). The decision to provide or upgrade roadway lighting at a particular location should be made on the basis of a study of local conditions. Once a decision has been made to provide lighting, this publication provides the basis for designing an appropriate system.

2.8 Road Maintenance

2.8.1 Standards, Guidelines and Policies

The principal standards/guidelines for highway maintenance of Ontario municipal highways are:

- **Minimum Maintenance Standards for Municipal Roadways (MMS)**[29] – Establishes maintenance standards for highway maintenance related to roadway and shoulder surface conditions, winter maintenance, illumination, traffic signs, and traffic signals. The standards are non-prescriptive regarding the methods or materials for maintenance and do not include pavement friction.

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[29] Minimum Maintenance Standards for Municipal Roadways, O. Reg. 239/02, and its amendments, 2007, 2010, 2013 and 2018.

- **The 2003 Ministry of Transportation of Ontario Maintenance Manual**[30] **(the 'MTO Maintenance Manual')** - The MTO Maintenance Manual is the MTO's governing document for addressing inspection maintenance and repair activities for summer and winter highway maintenance operations. It provides a province-wide reference of MTO's current maintenance standards, practices, and technologies. The MTO Maintenance Manual includes maintenance quality standards (MQS) and maintenance best practices (MBP) for a range of infrastructure elements.

Some municipalities undertake road needs studies[31] on a regular cycle and commonly refer to one or more of the following in undertaking these studies:

- Inventory Manual for Municipal Roads, MTO, 1999.
- Flexible Pavement Condition Rating – Guidelines for Municipalities (SP-022), MTO, 1989.
- Manual for Condition Rating of Flexible Pavements – Distress Manifestations (SP-024), MTO, 2016.

2.8.2 Compliance and Application

The MMS is applied by many municipal road authorities. Municipalities are not required to adopt the MMS; however, once adopted it provides the basis for establishing the state of repair of a roadway. The MMS requirements are non-prescriptive regarding the methods or materials for undertaking maintenance on a highway.

There are many highway and roadside municipal maintenance responsibilities that are not included in the MMS. It has been our experience that municipalities apply jurisdiction-specific policies/practices for many of these other maintenance needs, and there are no commonly applied standards/guidelines for the maintenance of Ontario municipal highways in this regard. While we have observed the occasional municipal road authority reference the MTO maintenance manual, its application/adoption is not commonplace.

2.9 Roadside Design

2.9.1 Standards, Guidelines and Policies

Roadside design relates to the road safety concepts, quantitative analysis of risk and evaluation of forgiving, mitigating and protective devices once a vehicle leaves the travelled portion of the roadway. The clear zone is a fundamental concept applied through the provision of an appropriate road/roadside cross-section and drainage elements to allow errant vehicles to recover safely within the roadside.

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[30] Maintenance Manual, Ministry of Transportation of Ontario, 2003.

[31] A Road Needs Study is undertaken to provide an overview of the overall condition of a municipality's road system for project planning and budgeting. The study provides a rating of the general condition of the road system by road section, including such factors as structural adequacy, drainage, and surface condition, and may include a high-level review of horizontal and vertical geometric alignment elements.

The principal standards/guidelines for roadside design on Ontario highways are:

- **1993 Roadside Safety Manual, Ministry of Transportation of Ontario[32] (the '1993 MTO RSM') and its 2017 update (the '2017 MTO RDM')[33]** - the MTO guidance is issued primarily for the direction and guidance of MTO staff and engineering consultants for design of provincial highway projects, and it may also be used as a design guideline by other road authorities in Ontario.
- **The 1999/2017 TAC guides[34]** – provide guidance for Canadian road authorities related to roadside design and protection.
- **Ontario Provincial Standards (OPS)**[35] - The OPS organization produces a comprehensive set of standards and design drawings for use by provincial and municipal road authorities throughout Ontario. OPS specifications and drawings are updated to current practice on a regular cycle of 3 to 5 years.

2.9.2 Compliance and Application

Ontario municipalities are not legally bound to follow any of the above roadside design guidelines, specifications, or design standards.

The 1993 MTO RSM was considered industry good practice in Ontario when released; however, it was not updated for more than two decades, and many Ontario municipal road authorities looked to more current guidance in the 1999 TAC Guide and other North American research for their roadside safety needs. In general, the 1999 TAC Guide guidance reflected more current US research/guidance documented in the Roadside Design Guide, American Association of State Highway and Transportation Officials (AASHTO) guidelines[36] (AASHTO RDG).

In 2017, MTO and TAC released updated guides/manuals, which generally reflect the AASHTO RDG guidance, including recommended clear zone areas. It has been our experience that the majority of the larger municipal road authorities on Ontario applied the TAC guides over the assessment period.

Once the decision was made to provide mitigation or protection of roadside hazards, the majority of Ontario municipalities referenced the OPS in their tender design specifications and contracts.

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[32] Roadside Safety Manual, Ministry of Transportation of Ontario, 1993.

[33] Roadside Design Manual, Ministry of Transportation of Ontario (MTO), 2017.

[34] Geometric Design Guide for Canadian Roads, Transportation Association of Canada, 1999 and 2017.

[35] Ontario Provincial Standards (OPS and OPSD), Ministry of Transportation of Ontario available through www.library.mto.gov.on.ca. Various dates.

[36] Roadside Design Guide, American Association of State Highway and Transportation Officials (AASHTO), 2011.

3.0 CLOSING WORDS

We trust that the above assessment responds to your request. Should additional information become available, we reserve the right to amend our opinion.

APPENDIX B: PROVIDED DOCUMENTS

DOCUMENTS PROVIDED & REVIEWED	
Title/Description	**Document ID or No.**
RHVPI Overview Document #3.1: RHVP Design & Geometry	Inquiry Exhibit #3, Doc 4219637
Red Hill Valley Parkway Safety Review, October 2013, CIMA	HAM0041871_0001
Red Hill Valley Parkway Detailed Safety Analysis, November 2015, CIMA	HAM0056684_0001
Lincoln Alexander Parkway Median Safety Study, November 2015, CIMA	HAM0056683_0001
Lincoln Alexander Parkway / Red Hill Valley Parkway Collision Rates Memo, January 12, 2018, CIMA	HAM0001095_0001
Hamilton LINC and RHVP Speed Study, October 2018, CIMA	CIM0015106
Detailed LINC/RHVP Illumination Review: Executive Summary, December 2018, CIMA	HAM0012346_0001
Detailed LINC/RHVP Illumination Review, January 2019, CIMA	HAM0054314_0001
Lincoln Alexander Parkway / Red Hill Valley Parkway Collision Rates Memo, January 18, 2019, CIMA	HAM0054494_0001
Roadside Safety Assessment: Red Hill Valley Parkway, January 2019, CIMA	HAM0054495_0001
Red Hill Valley Parkway – Pavement Friction Testing Results Review Memo, February 4, 2019, CIMA	HAM0012842_0001
Red Hill Valley Parkway – Review of MTO Pavement Friction Data 2008-2014 Memo, February 26, 2019	HAM0036336_0001
Red Hill Valley Parkway Analysis, April 28, 2020, CIMA	CIM0022143
Review of Red Hill Valley Parkway Friction Test Results, May 2020, CIMA	CIM0022320
City of Hamilton, 2017 Annual Collision Report	RHV0000596
City of Hamilton, 2018 Annual Collision Report	RHV0000597
City of Hamilton, 2019 Annual Collision Report	RHV0000609
City of Hamilton, 2020 Annual Collision Report	RHV0000908
City of Hamilton, 2021 Annual Collision Report	RHV0001001
‘City will drop speed limit on Red Hill Valley Parkway starting Monday’, CBC News, May 13, 2021	RHV0001031
‘Speed limit on entirety of Hamilton’s Red Hill Valley Parkway to be lowered to 80 km/h’, Global News, May 13, 2021	RHV0001030
‘Speed limit reduction on the RHVP stating May 17’, Councillor John-Paul Danko (Ward 8) News Release	RHV0001029
Hamilton re: Red Hill Valley Parkway Legal Opinion, Letter of David Boghosian (Boghosian & Allen LLP), February 4, 2019	HAM0064331_0001
RHVP Mainline Paving Contract, Part A – Mud Street Interchange to South of Greenhill Avenue [Issued for Tender]	DUF0002534.001
RHVP Mainline Paving Contract, Part B – South of Greenhill Ave. to Queenston Road [Issued for Tender]	DUF0002535.001
RHVP Mainline Paving Contract, Part C – Queenston Road to QEW Interchange [Issued for Tender]	DUF0002536.001
RHVP Mainline Paving Contract, Part D – Mud Street Interchange to QEW Interchange [Issued for Tender]	DUF0002537.001
Mountain East-West and North-South Transportation Corridor, Environmental Assessment Submission Volume I, Regional Municipality of Hamilton-Wentworth, December 1982	CIM0016205

Mountain East-West and North-South Transportation Corridor, Environmental Assessment Submission Volume II (Exhibits), Regional Municipality of Hamilton-Wentworth, December 1982	CIM0016206
Mountain East-West and North-South Transportation Corridor Project, Preliminary Design Investigation Executive Summary, Regional Municipality of Hamilton- Wentworth, 1990	CIM0016107
Preliminary Design Report, January 31, 1990	HAM0008905_0001
Technical Memorandum No. 2, Impact Assessment of Alternatives, McCormick Rankin, July 1994	HAM0002099_0001
Red Hill Creek Expressway/ Queen Elizabeth Way Preliminary Design Report, McCormick Rankin, November 2002	HAM0000180_0001
Red Hill Creek Expressway Preliminary Design Report, February 2003 draft	HAM0050707_0001
Email chain attaching February 2003 draft Preliminary Design Report	HAM0050706_0001
Red Hill Creek Expressway Preliminary Design Report, November 2003 draft	HAM0031758_0001
Red Hill Valley Project Design Report – Section 1 (Introduction), January 2006 draft	HAM0032181_0001
Red Hill Valley Project Design Report – Section 2 (Engineering Design), January 2006 draft	HAM0032182_0001
Red Hill Valley Project, Impact Assessment and Design Process Summary Report, July 2003	HAM0058767_0001
Red Hill Valley Parkway, Performance Review After Six Years in Service, January 2014, Golder Associates	GOL0002981
Friction Testing Survey Summary Report, Lincoln Alexander & Red Hill Valley Parkways, November 2013, Tradewind Scientific Ltd.	GOL0001113

APPENDIX C: REFERENCE MAPS OF RHVP STUDY CURVES

Part A – Stantec

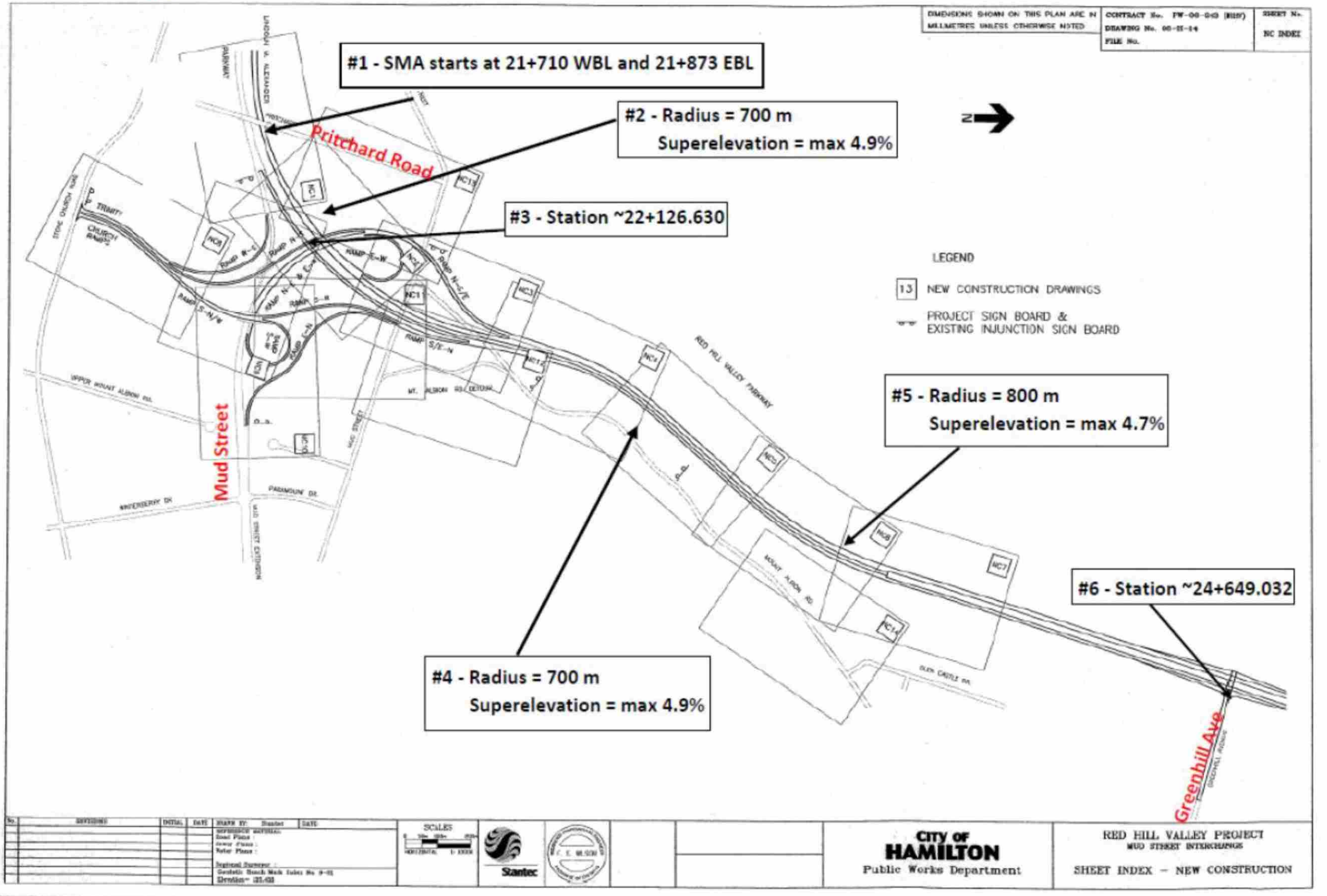

Figure C1: Overview Document #3.1: RHVP Design & Geometry, Doc 4219637, Image 10.

Part B – Philips

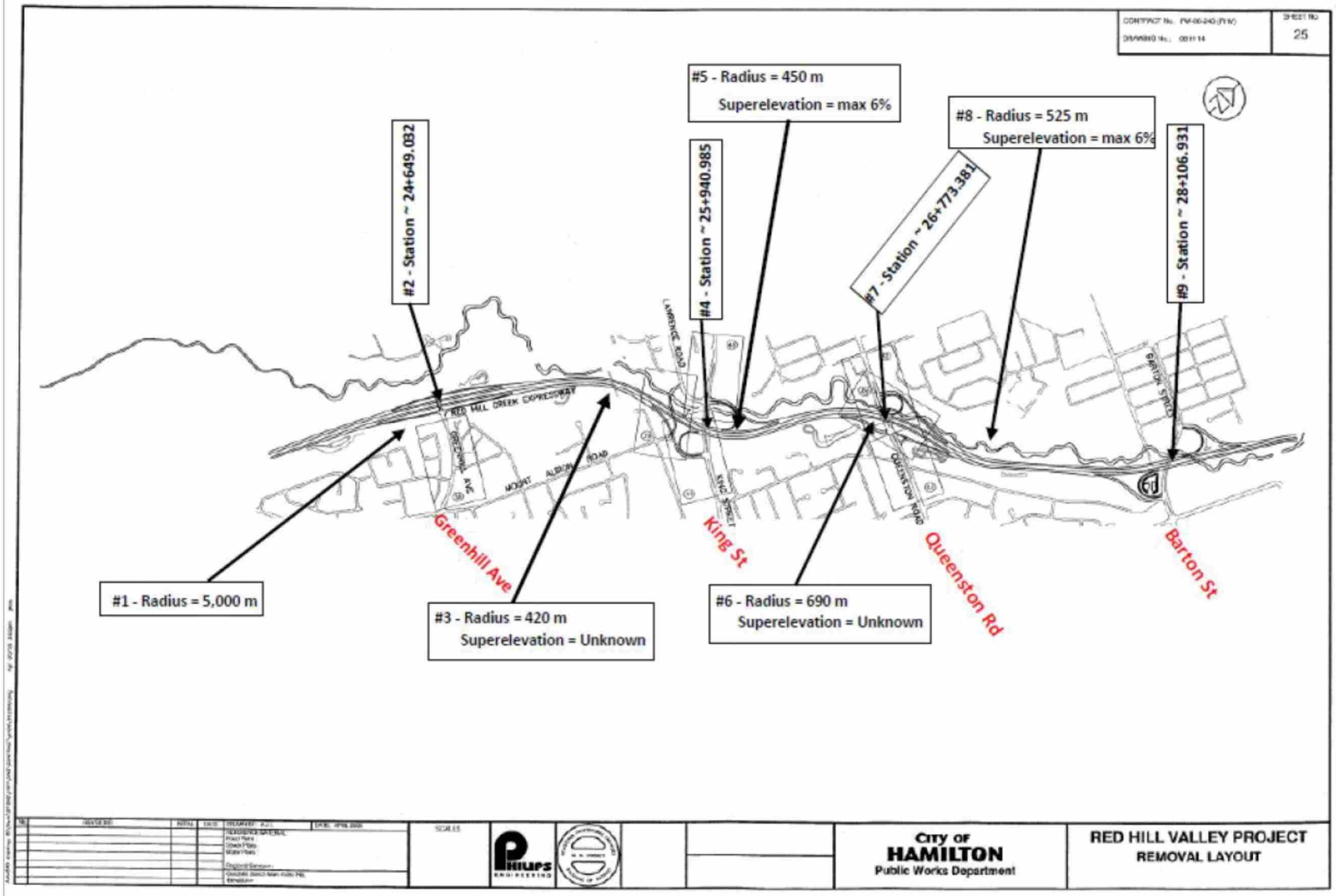

Figure C2: Overview Document #3.1: RHVP Design & Geometry, Doc 4219637, Image 13.

Part C – McCormick Rankin

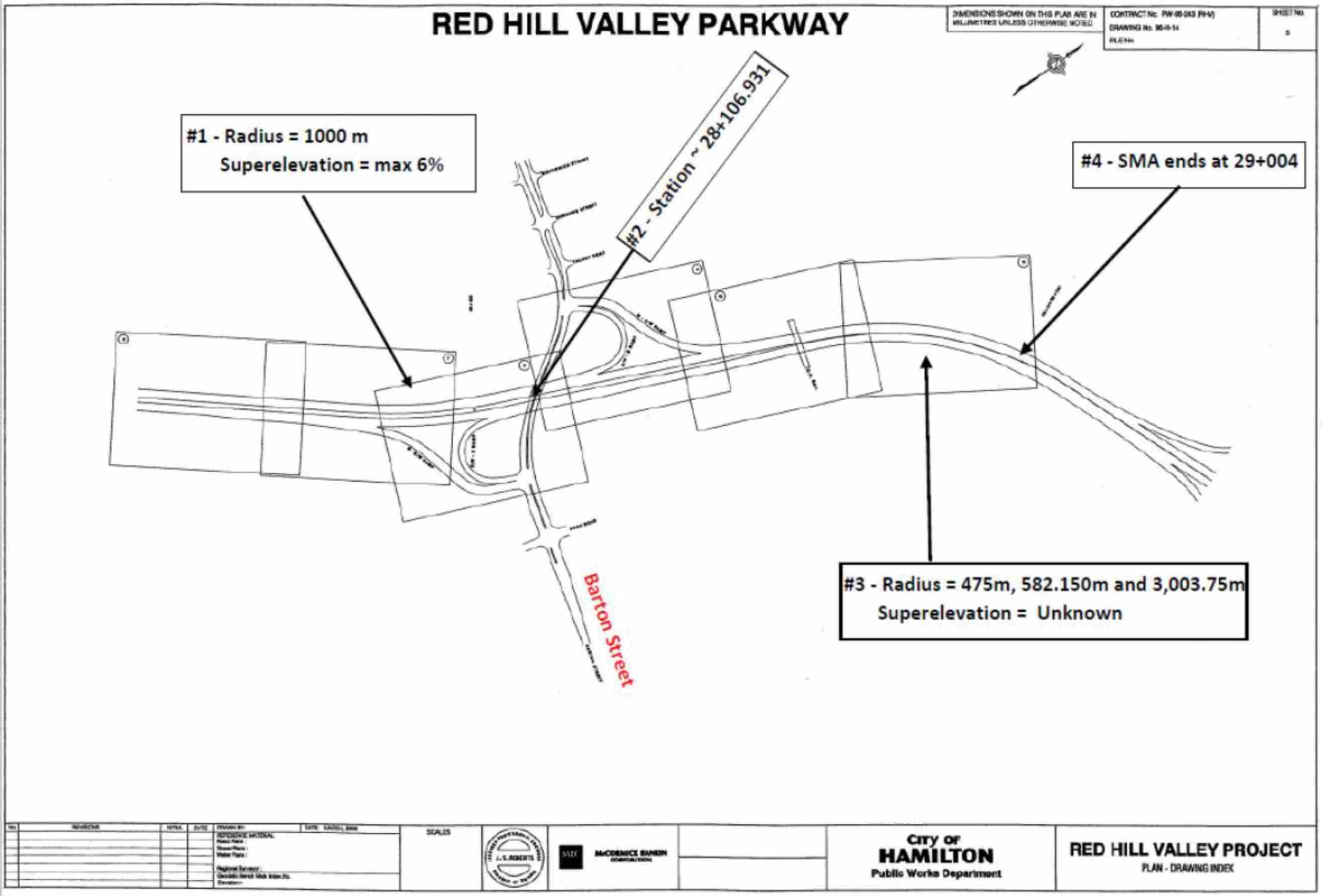

Figure C3: Overview Document #3.1: RHVP Design & Geometry, Doc 4219637, Image 16.