MEMORANDUM

State of Alaska

Department of Transportation & Public Facilities
Design and Engineering Services – Central Region

TO: Mark Neidhold, P.E., Chief
Design and Construction
Standards

DATE: ~~January 30~~ March 6, 2019

THRU: Wolfgang Junge, P.E.
Preconstruction Engineer
Central Region

TELEPHONE NO: 907-269-0639

FROM: Scott Thomas, P.E.
Regional Traffic & Safety
Engineer

SUBJECT: Set aside RSAP for Calibration
Use ROADSIDE in interim

Central Region requests tabling RSAP as DOTPF's cost-effective analysis program until it can be acceptably calibrated to resolve significant and common roadside safety problems.

We recommend returning to DOTPF's previous ROADSIDE version 1.2 in the interim. This program was demonstrated to meet AASHTO prior to RSAP issuance.

Highway Preconstruction Manual page 1100-10, and sections, 1130.2 and 1130.6 are affected.

It is a major concern RSAP is unable to conclude guardrail for high volume, high speed, high risk roadsides when used uncalibrated as "out of the box" software. RSAP places a low severity on rollover crashes and tall slopes or water hazards. ROADSIDE allows user input of severity with engineering judgment and more frequently addresses public and legislative concerns.

TESTED PROBLEMS (High and low volume, significant slopes)

		Guardrail Recommended?		
		RSAP 3.1	ROADSIDE 1.2	CZ? = No
1	2 lanes, 16,000 vpd, 65 MPH, 2 ft shldrs, 30 ft tall slope, 2:1, 1000 ft long	No	Yes	50'
	Add deep water	No	Yes	
	Add steep hill 7%, sharp curve -5 degr	No	Yes	50'
2	2 lanes, 1000 vpd, 65 MPH, 2 ft shldrs, 30 ft tall slope, 2:1, 1000 ft long	No	Yes	25'
	Add deep water	No	Yes	38'
	Add steep hill 7%, sharp curve -5 degr	No	Yes	34'-47'*
3	2 lanes, 500 vpd, 65 MPH, 2 ft shoulders, 10 ft short slope, 2:1, 1000 ft long	Not run	No	N/A
	Add deep water	Not run	Yes	30'
	Add steep hill 7%, sharp curve -5 degr	Not run	Yes	24'-45'*
4	2 lanes, 2000 vpd, 55 MPH, 6 ft shldr, 10 ft, barn roof, 30 ft CZ, 2:1 slope	Not run	No	N/A
	Add deep water	Not run	Yes	28'
	30 ft tall barn roof	Not run	Yes	20' – 29'*

*with deep water

The above table shows tall, severe slopes of concern under high speed, high volume traffic, do not trigger guardrail concerns under RSAP. However, ROADSIDE will trigger guardrail for major slopes of concern. To further check for overemphasis, ROADSIDE is shown to trigger less and less guardrail as clear zone CZ is increased or slopes are flattened (a "no" condition).

Kinney Engineering has also verified these same RSAP concerns in their spring 2018 RSAP training for DOTPF. They have spent a good deal of time exploring the method. Kinney Engineering tested calibration of overturn crash severity using Alaska data and found it changed RSAP's conclusion. Attached is a paper they presented at WesternITE. This demonstrates RSAP needs work in order to be used in Alaska.

RSAP results are not acceptable without Alaska calibration. This may be true in many states given how low the crash severity values are estimated. Calibration cannot be efficiently performed on a project by project basis. It requires a statewide analysis. Several crash type calibrations are in order: overturning crash severity, trees, culverts, guardrail, and other roadside features for example. Once RSAP can be shown to acceptably solve the examples above and is calibrated for Alaska, it could be reinstated.

In the interim, ROADSIDE is requested. It has served Central Region well, for example:

- ROADSIDE resolved contractor and DOTPF concerns with the design of tall slopes at interchanges along Minnesota Drive interchanges, without having to treat slopes at 3:1 or flatter along lower volume ramps.
- ROADSIDE resolved many "gravel to black" concerns raised by the public and officials where there were very tall steep roadsides.
- Application to 81 miles of Kodiak's main road system led to systemic analysis and preventive treatments along about 10 percent of the roadside. ROADSIDE did not miss any sites identified by residents familiar with the area or impacted by crashes harmful to friends and relatives. Using RSAP as tested above, no guardrail would be warranted on Kodiak, not an acceptable solution.

(ROADSIDE, RSAP files available to provide backup to summaries.)

Attachments:
RSAP/ROADSIDE Analysis of Options 1 through 4
Kinney Engineering Presentation at WesternITE

cc: Pat Carroll P.E., Regional Preconstruction Engineer, Southcoast Region
Sarah Schacher, P.E. Regional Preconstruction Engineer, Northern Region
Jim Amundsen, P.E., Chief, CRHighway Design
Joel St. Aubin, P.E., Chief, CR Construction
Luke Bowland, P.E., Chief, Statewide Aviation Design
Eric Miyashiro, P.E., Chief, CR Preliminary Design & Environmental Section
Todd Vanhove, Chief, CR Planning and Administrative Services
Charles Wagner, P.E., Chief, CR Maintenance and Operations

2019 ROADSIDE RUNS - Common Slopes of Concern

3-4-19 set

1 Two Lanes, Hi Vol, Hi Speed, Tall Slope

	ADT	Speed	Shldr	Height	Water	Steep curve, grade	Guardrail	ROADSIDE	Choice	
1						SI=6		$ 2,315,000		No rail requirement?
2					Deep Water	SI=8.6		$ 9,563,000		50' clear zone
3							Yes, SI=3	$ 188,000	Barrier for tall slopes	No deep water
4	16000	65	2	30 ft		Yes, SI=6		$ 11,636,000		50' clear zone
5					Deep Water	Yes, SI=8.6		$ 48,104,000		Not feasible even w/cz
6						Yes	Yes, SI=3	$ 923,000	Barrier at tall slopes on curve/grade	

2 Two Lanes, Low Vol, Lower Speed, Tall Slope

	ADT	Speed	Shldr	Height	Water	Steep curve, grade	Guardrail	ROADSIDE		
1						SI=4.9		$ 50,000		25' clear zone
2					Deep Water	SI=5.8		$ 148,000		38' clear zone
3							Yes, SI=2.2	$ 9,000	Barrier for tall slopes	
4	1000	45	2	30 ft		Yes, SI=4.9		$ 261,000		34' clear zone
5					Deep Water	Yes, SI=5.8		$ 769,000		47' clear zone
6						Yes	Yes, SI=2.2	$ 23,000	Barrier at tall slopes on curve/grade	

3 Two Lanes, Lower Vol, Lower Speed, Short Slope

	ADT	Speed	Shldr	Height	Water	Steep curve, grade	Guardrail	ROADSIDE		
1						SI=4		$ 8,000	No CZ ok at short slopes, low vol	OK as is, within 10%
2					Deep Water	SI=5.8		$ 42,000		30' clear zone
3							Yes, SI=2.2	$ 7,000		
4	500	45	2	10 ft		Yes, SI=4		$ 40,000		24' clear zone
5					Deep Water	Yes, SI=5.8		$ 216,000		45' clear zone
6							Yes, SI=2.2	$ 11,000	Barrier at short slopes on curve/grade	

4 Two Lanes, Lower Vol, Lower Speed,Barn Roof

	ADT	Speed	Shldr	Height	Water	Steep curve, grade	Guardrail	ROADSIDE		
1						SI=4		$ 12,000	Clear zone ok short slopes	OK as is
2				10 ft	Deep Water	SI=5.8		$ 52,000		28' clear zone
3	2000	55	6				Yes, SI=2.6	$ 14,000		No rail
4						SI=4.9		$ 24,000		20' clear zone
5				30 ft	Deep Water	SI=5.8		$ 64,000		29' clear zone
6							Yes, SI=2.6	$ 14,000	Barrier at tall slopes	

2019 RSAP RUNS - Common Slopes of Concern

3-4-19 set

1 Two Lanes, Hi Vol, Hi Speed, Tall Slope

	ADT	Speed	Shldr	Height	Water	Steep curve, grade	Guardrail	RSAP	Choice
1								$ 1,272	No barrier
2					Deep Water			$ 1,272	
3	16000	65	2	30 ft			Yes	$ 1,898	
4						Yes		$ 9,167	No barrier w/curve-grade
5					Deep Water	Yes			
6						Yes	Yes	$ 13,464	

2 Two Lanes, Low Vol, Lower Speed, Tall Slope

	ADT	Speed	Shldr	Height	Water	Steep curve, grade	Guardrail	RSAP	
1								$ 2,155	No barrier
2					Deep Water				
3	1000	45	2	30 ft			Yes	$ 3,881	
4						Yes		$ 15,441	
5					Deep Water	Yes			
6						Yes	Yes	$ 28,858	

2019 RSAP RUNS - Common Slopes of Concern

3-4-19 set

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3	16000	65	2	30 ft			Yes	$ 1,898	
4						Yes		$ 9,167	No barrier w/curve-grade
5					Deep Water	Yes			
6						Yes	Yes	$ 13,464	

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1								$ 2,155	No barrier
2					Deep Water				
3	1000	45	2	30 ft			Yes	$ 3,881	
4						Yes		$ 15,441	No barrier w/curve-grade
5					Deep Water	Yes			
6						Yes	Yes	$ 28,858	

A discussion paper on the calibration of RSAP for embankment hazards

Problem Summary

Roadside Safety Analysis Program (RSAP) consistently selects a do-nothing treatment for steep and high embankment slopes when presented with an array of less-severe alternatives. This choice contradicts engineering judgement as well as past roadside evaluation methodologies that would select barriers or slope flattening instead of steep, high slopes.

This paper presents severity calibrations that should be applied to RSAP hazards to reflect observed severity conditions in Alaska.

RSAP Embankment Hazards

A lane departure of a single vehicle would sustain damage on a steep high embankment if the vehicle overturns, or if the vehicle strikes an obstacle/hazard while traversing the slope or at the slope bottom. RSAP will model slope and selection obstacle hazards selected from a menu by the modeler.

RSAP models guardrail as well. However, guardrail has a severity associated with it, and because it is positioned between the edge of travel way and the slope hazard it protects, it may experience a higher frequency of collisions than the slope it protects. Moreover, RSAP allows the vehicle to completely traverse or stop on steep slopes, without a rollover or collision with a hazard. As such, an encroachment onto the slope and beyond will not necessarily result in a crash with a severity. We have observed that barriers in a RSAP model typically experiences more, low-severity hits, while the slope has fewer collisions with higher severities.

RSAP's computations and results often concludes that the status quo of a steep slope is more cost effective than a barrier or slope flattening. To determine if that is outcome reasonable, rollover/overturn frequencies and severity of the overturn crashes are evaluated since lower values of either result in lower overturn/rollover life-cycle costs.

Embankment Overturn/Rollover Frequency and Alaska Severity

Absent of any other hazard on an embankment slope (e.g. trees, rocks, poles, etc.) a rollover crash is only hazard within the slope itself. Even so, an encroachment onto the slope does not always result in an overturn. In fact, RSAP's rollover model uses these rollover probabilities for slopes.

Sideslope H:V	Probability of Rollover (%)
2:1	13.23%
3:1	8.99%
4:1	5.82%
Flat	3.61%
-10:1	5.03%
-6:1	5.82%
-4:1	6.82%
-3:1	12.04%
-2:1	18.52%

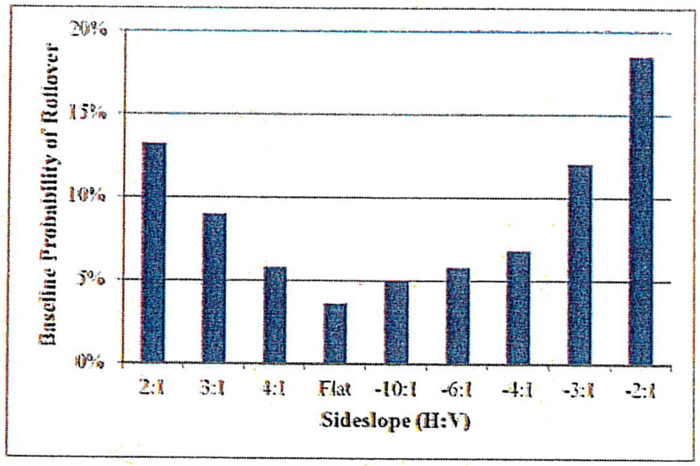

Figure 1- Probability of rollover model implemented in RSAPv3, Rollover Adjustment Factors for Various Roadway Characteristics (Source: RSAP Engineer's Manual)

There is no discernable data within Alaska crash database on slope-rollover probabilities. As such, the RSAP model is not modified for rollover probability.

However, severities for crash types can be determined from the crash database, and this will be the focus of the remainder of this section.

Hazards within RSAP are assigned an equivalent fatal crash cost ratio at 65 mph (EFCCR65). RSAP's default EFCCR65 severity for rollover crashes is 0.022. This rollover EFCCR65 applies to all vehicle types even though authors of the User's Manual and Engineer's Manual acknowledge severity is variable for each vehicle (e.g. trucks are likely to sustain higher property damage, but passenger cars usually have more occupants. The EFCCR65 value can be converted to a crash cost (needed for economic analyses) using these KABCO values found at:

http://www.dot.alaska.gov/stwddes/dcspubs/assets/pdf/directives/attach/2015/attach_071415_kabco_values.pdf

- K, Fatality = Value of Statistical Life (VSL), $9.5 Million in 2016
- A, Incapacitating Injury= 0.0692 x VSL=$660,000
- B, Non-Incapacitating Injury= 0.0138 x VSL=$130,000
- C, Possible Injury=0.00731 x VSL=$70,000
- O, Property Damage Only= 0.000769 x VSL=$7,300

Using the current (2016) fatality value of $9.5 million in the KABCO cost severity scale, RSAP's rollover cost is $209,000 (0.022 x $9,500,000) indicating a severity between non-incapacitating injury at and incapacitating injury.

Alaska rollovers were evaluated to determine if the RSAP rollover default severity of EFCCR65= 0.022 would apply.

Alaska crash experience was evaluated between 2000 and 2014 using a statewide 2000 to 2012 database, statewide 2013 database, and statewide 2014 database. The crash database changed significantly after 2012 with significant differences in reported fields, crash type descriptions, and other reporting attributes and values. There was a second change in field titles between 2013 and 2014, but data content was largely unchanged. Nevertheless, all three databases were required to be individually evaluated.

Crash data does not provide information on specific highway speeds, or estimated speeds of the vehicle involved in a crash (other than as a qualitative contributing factor statement). As stated earlier, the severity factor EFCCR65 for RSAP severities is that occurring at 65 mph. To screen lane departure crashes that may have occurred at very high speeds, data filters were set for:

- Functional class=interstate: because of these are the highest mobility roadways of which high speed limits are likely to be posted
- Area type= rural: because of increased likelihood of high speed limits
- Crash type= single vehicle
- Vehicle damage= total loss or disabling damage: because crashes on higher posted speed limits are more likely to result in high vehicle damage across all injury severity levels.

These factors are presumed to be surrogate filters for 65 mph crashes and related severity profiles for overturn crashes.

The following figures depict crash proportions by type and severity with these filters for the 971 crashes occurring during the 13-year 2000-2012 period, 216 crashes occurring during the 2013 period, and the 205 crashes occurring during the 2014 period.

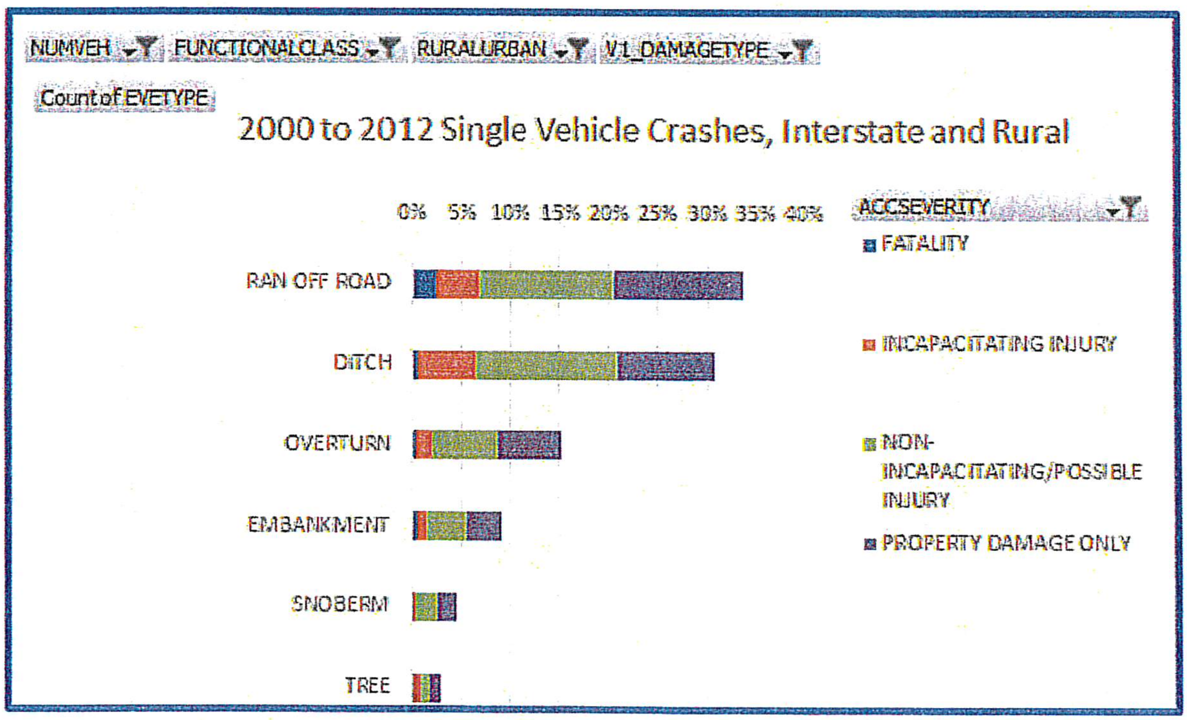

Figure 2- Top 6 Single Rural, Interstate Lane Departure Crashes, 2000 to 2012

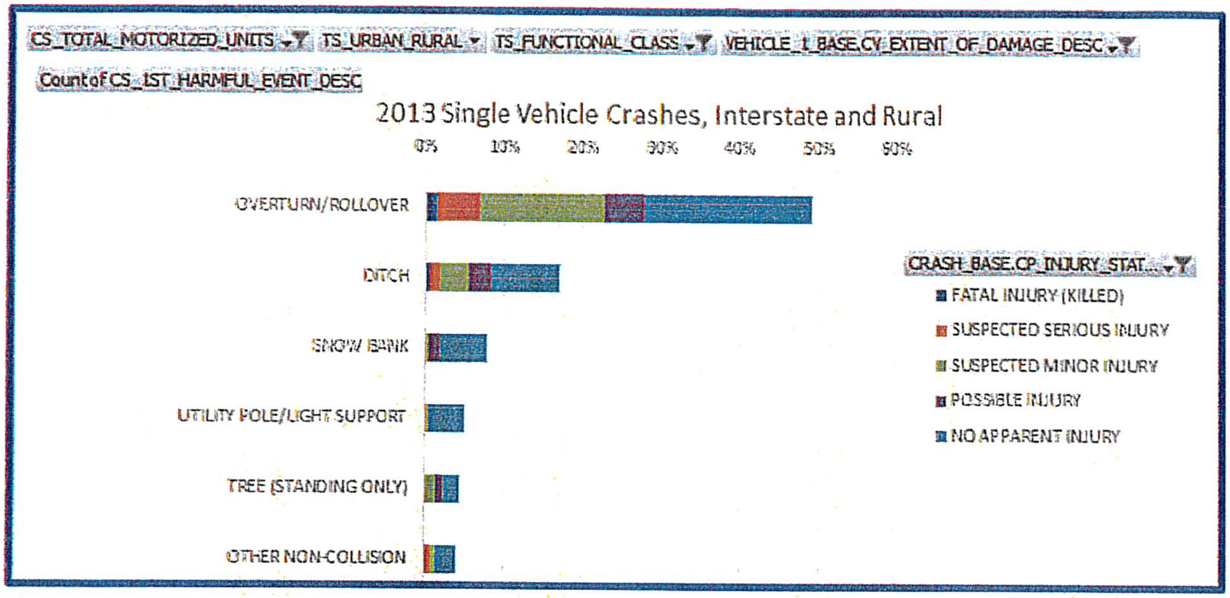

Figure 3- Top 6 Single Rural, Interstate Lane Departure Crashes, 2013

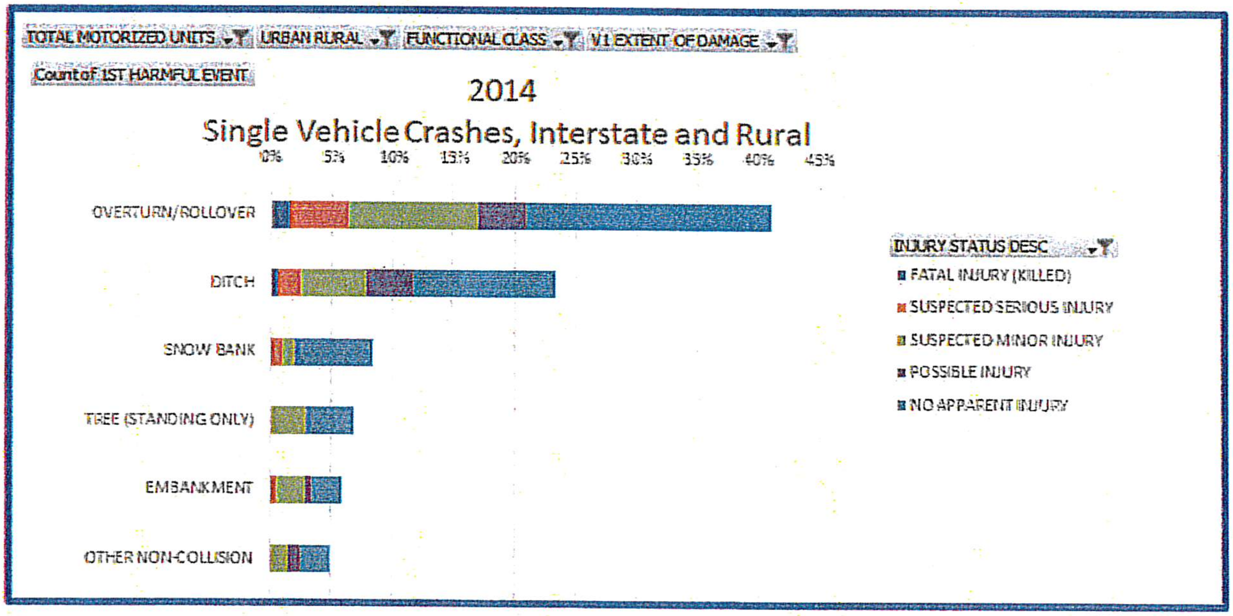

Figure 4- Top 6 Single Rural, Interstate Lane Departure Crashes, 2014

In exploring this data, we find that there is a discernable shift in the crash type order patterns. The 2000 to 2012 data included "ran off road" (ROR) as a crash type which was the highest type for the filtered data during that time period. ROR was not carried forward as type in the subsequent 2013 and 2014 data bases revisions. Also, while ROR crashes dominate the 2000-2012 single vehicle data, overturn/rollover type crashes, which ranked third in 2000-2012, were highest in 2013 and 2014. Moreover, the ROR and overturn collisions percentages together in 2000 to 2012 are about the same as the percentages of the overturn/rollover categories in 2013 and 2014 (40 to 50%). As such, it was likely that ROR reported crashes in the 2000-2012 period probably included a very high proportion of overturn collisions.

Year by year ROR and overturn crashes for the period between 2010 and 2012, and overturn/rollover collisions only during 2013 and 2014 are further evaluated with the same filters as discussed above. An additional filter was used that restricts overturns to shoulders and roadsides, and removed those occurring in medians, pathways, parking lots, etc. from consideration. Table 1 summarizes year by year occurrences and frequencies.

Table 1- High Speed Overturn Crash and Severity

Annual Crashes (2010-2012 Overturn & ROR, 2013-2014 Overturn)					
Severity Class- 2016 Values	**2010**	**2011**	**2012**	**2013**	**2014**
K- $9.5 Million	4	3	5	2	2
A- $650,000	5	5	0	8	9
*B&C- Avg.= $100,000	40	20	8	24	23
O- $7,300	46	43	25	30	32
Total	**95**	**71**	**38**	**64**	**66**

**Combined because 2010-2012 severity classes only included fatality, major injury, minor injury, and property damage only. Post 2012 data is based on the KABCO severity (K=fatality, A=Incapacitating Injury, B=Non- Incapacitating Injury, C= Possible Injury, O=Property Damage Only). KABCO categories B and C in 2013 and 2014 were combined to compare with 2010-2012 minor injury occurrences.*

The year-to-year variance in severity and totals are evaluated with a Two-Way Analysis of Variance. presented in Table 2.

Table 2- Two-way ANOVA Table of Overturn Crash Severity and Year

Alpha	0.05						
ANOVA							
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*	*Statistical Significance?*
Rows (severity)	3459.4	3	1153.133	28.46657066	9.69943E-06	3.490294819	Significant, P<=0.05
Columns (Year)	412.7	4	103.175	2.547006789	0.093969314	3.259166727	Not Significant, P>0.05
Error	486.1	12	40.50833				
Total	4358.2	19					

This analysis confirms that there is significant difference in severity frequency which is expected, but no statistical difference between the years evaluated, that is the same severity patterns are repeated year by year. As such, this may justify the combining of ROR and overturn crashes between 2010 and 2012, with the overturn only data from the 2013 and 2014 databases, and we can conclude no statistical difference over the duration between 2010 and 2014. These years are used to determine an average severity cost for the high-speed overturn events. The following table presents the EFCCR65 computed with an average of annual costs.

Table 3- Annual Crash Costs for High Speed Overturn Crashes

Year	Crash Cost
2010	$ 480,000
2011	$ 480,000.00
2012	$ 1,276,000.00
2013	$ 420,000
2014	$ 416,000
Wtd Avg	$ 614,000
EFCCR65	
$614K/$9.5 M=	0.065

A second computation methodology pools the severities over the entire 5-year duration together and computes the weighted average as shown in the following table.

Table 4- Crash Costs by Severity (2010 to 2014) for High Speed Overturn Crashes

Class	2010-2014 Crashes	Severity Cost	2010-2014 Class Cost
K	16	$9,500,000.00	$152,000,000
A	27	$660,000.00	$17,820,000
B&C	115	$100,000.00	$11,500,000
C	176	$7,300.00	$1,284,800
Total	334		$182,604,800
		Average	$ 547,000
		EFCCR65	
		$547K/$9.5 M=	0.058

Calibration of Alaska Rollover Severity

RSAP hazard's EFCCR65 values can be overwritten by users. For the rollover hazard, a value of 0.058 was entered and iteratively evaluated with a number of slope and ADT scenarios at a speed of 65 MPH. It was determined from examination of outputs that to produce an output rollover severity = 0.058, the rollover EFCC65 in the hazard worksheet needs to be **0.145**.

Note that the EFCCR65 is highly sensitive to heavy vehicle mix. The 0.145 EFCCR65 rollover input works well with 10% trucks. Lower or no trucks in the vehicle mix require higher EFCCR65 rollover input values, on the order of 0.18 or more for an output rollover severity of 0.058. Conversely, high proportion of trucks, say 30% would require a reduction to EFCCR65 of 0.08 to obtain rollover severity of 0.058.