Vehicles Entering When Flashing (VEWF) Evaluation

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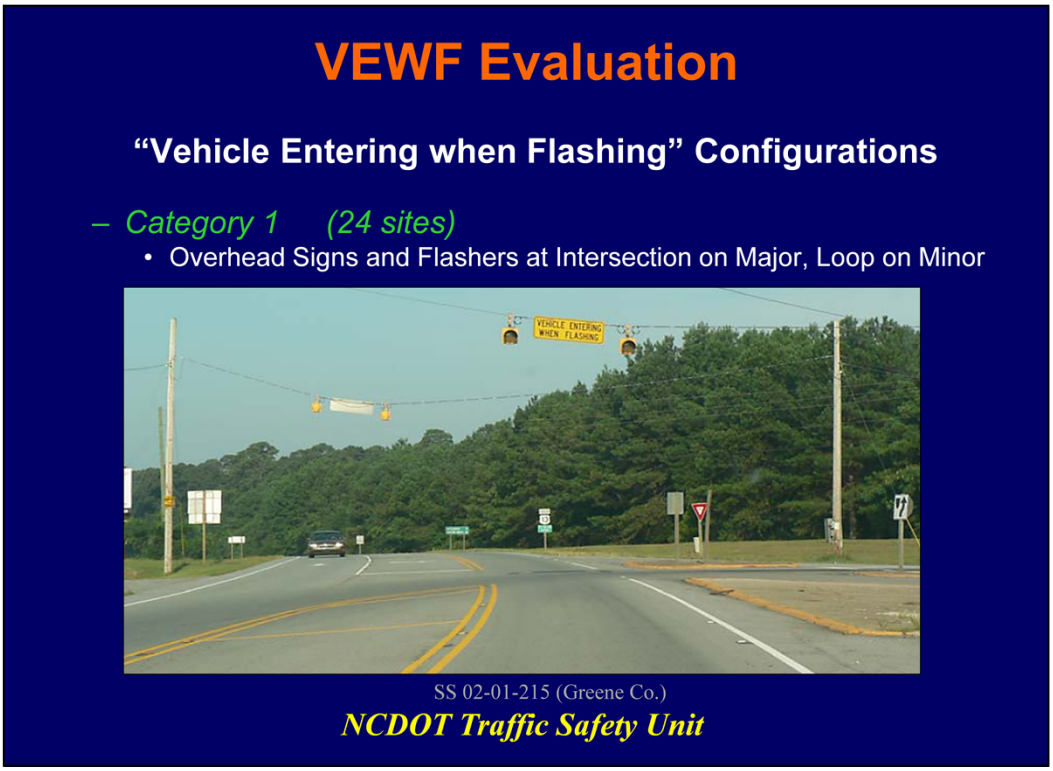
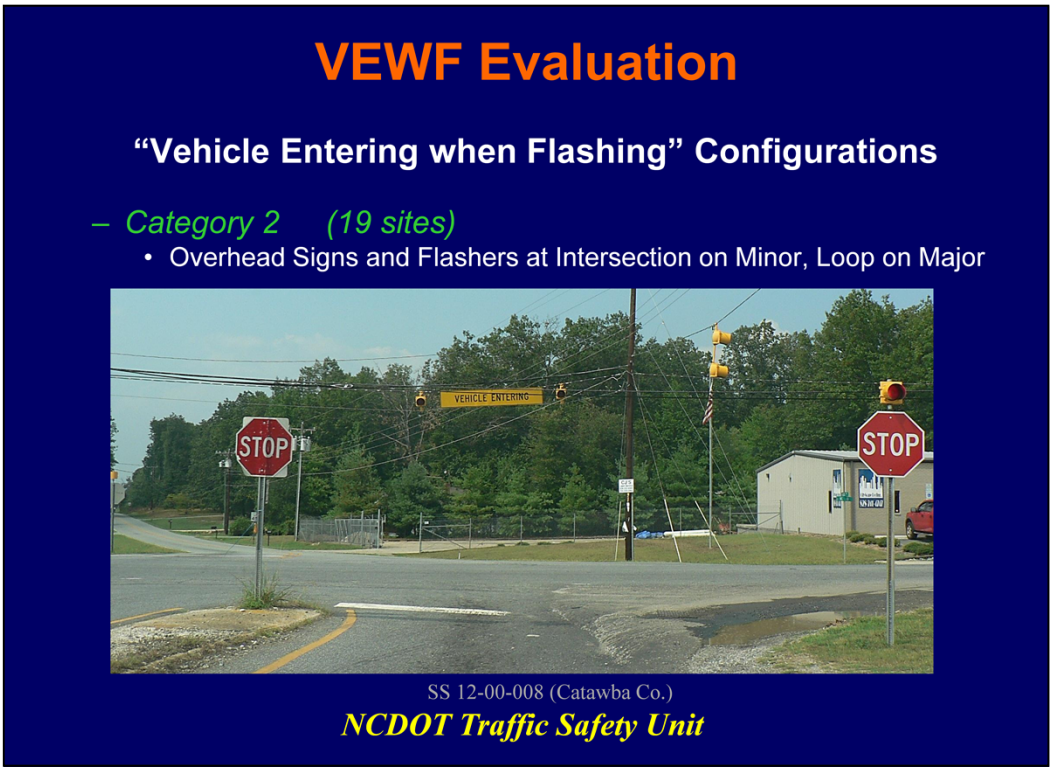


Four categories of actuated signs and flashers are currently used in North Carolina. All of the warnings depend upon detection of vehicle presence via inductive loops and activate flashing beacon(s) in conjunction with a static sign.

Category 1 utilizes an overhead sign and flasher assembly used to provide drivers on the through road with a warning of vehicle presence on the minor road. The system operates through loop detector activation on the side-street to activate the signs. At least one loop is placed on the minor road at the stop bar and in some cases an additional loop is placed up to 960 feet before the intersection on the minor road based on location characteristics. The system flashes for the duration of time a side-street vehicle is present.



Category 2 has an overhead sign and flasher assembly used to provide drivers on the minor road with a warning of vehicle presence on the major road. The system operates through loop detector activation on the major road to activate the signs. Detection is placed 300-1,000 feet before the intersection. The location for mainline detection is selected based on speeds and stopping sight distances. Depending on the location characteristics, the system flashes up to 6-13 seconds after a mainline vehicle initially crosses the sensor in either direction. Each subsequent vehicle then resets the timer. This flashing period is based on the time it should take a vehicle traveling at the speed limit to clear the intersection after triggering the sensor.

VEWF Evaluation

"Vehicle Entering when Flashing" Configurations

– *Category 3 (23 sites)*
  - Post Mounted Signs and Flashers on Major in Advance of Intersection, Loop on Minor

SS 06-01-213 (Bladen Co.)

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Category 3 operates similarly to Category 1, with the loop detector activation on the minor road to activate the signs. At least one loop is placed on the minor road at the stop bar and in some cases an additional loop is placed up to 1,000 feet before the intersection on the minor road based on location characteristics. In this configuration, the signs and flashers are post mounted and located 350-975 feet in advance of the intersection. The system flashes for the duration of time a side-street vehicle is present.

VEWF Evaluation

"Vehicle Entering when Flashing" Configurations

- *Category 4 (8 sites)*
  - Combination of Category 1 through Category 3

SS 08-06-217 (Randolph Co.)

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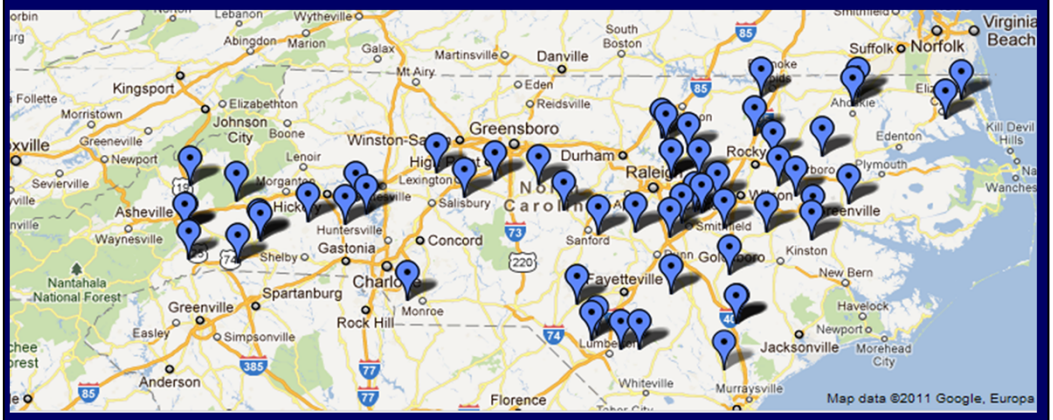
VEWF Evaluation

"Vehicle Entering when Flashing" Configurations



TOTAL = 74 SITES

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VEWF Evaluation

Project Scope

Specific evaluation goals include:

- Development of **Overall CMFs** for VEWF systems
- Determine the safety effectiveness of various **Categories** of VEWF systems
- Determine the impact of **Major Road Cross Section** on treatment effectiveness
- Determine the impact of **Other Key Factors** on treatment effectiveness

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VEWF Evaluation

Site Selection

- Reviewed completed projects in Spot Safety Database
- Mainline approach speed limits range from 35 mph - 55 mph, although majority are rural, isolated, high speed facilities.
- Intersection AADT range from approx. 3,000 - 30,000 veh/day.
- Flashing beacon present in the before period at 23 locations.
- Intersection geometry includes 2-lane at 2-lane, 4-lane divided at 2-lane, and multilane (3 -5 lanes) undivided at 2-lane.

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A majority of the treatment sites were selected by searching the NCDOT Spot Safety Program Database. Many of the VEWF systems were completed through this program, which is used to develop smaller improvement projects to address safety and operational issues.

Treatment sites were located in urban and rural areas with mainline approach speed limits ranging from 35 mph to 55 mph, although the majority of sites were rural, isolated, high speed facilities. The intersection annual average daily traffic (AADT) ranged from approximately 3,000 to 30,000 vehicles entering per day. The type of mainline facilities varied with the intersection geometry including two-lane at two-lane, multilane (3 -5 lanes) undivided at two-lane, and four-lane divided at two-lane sites.

VEWF Evaluation

Crash Reduction Factors – All Sites (67)
Empirical Bayes Method with Traffic Factor

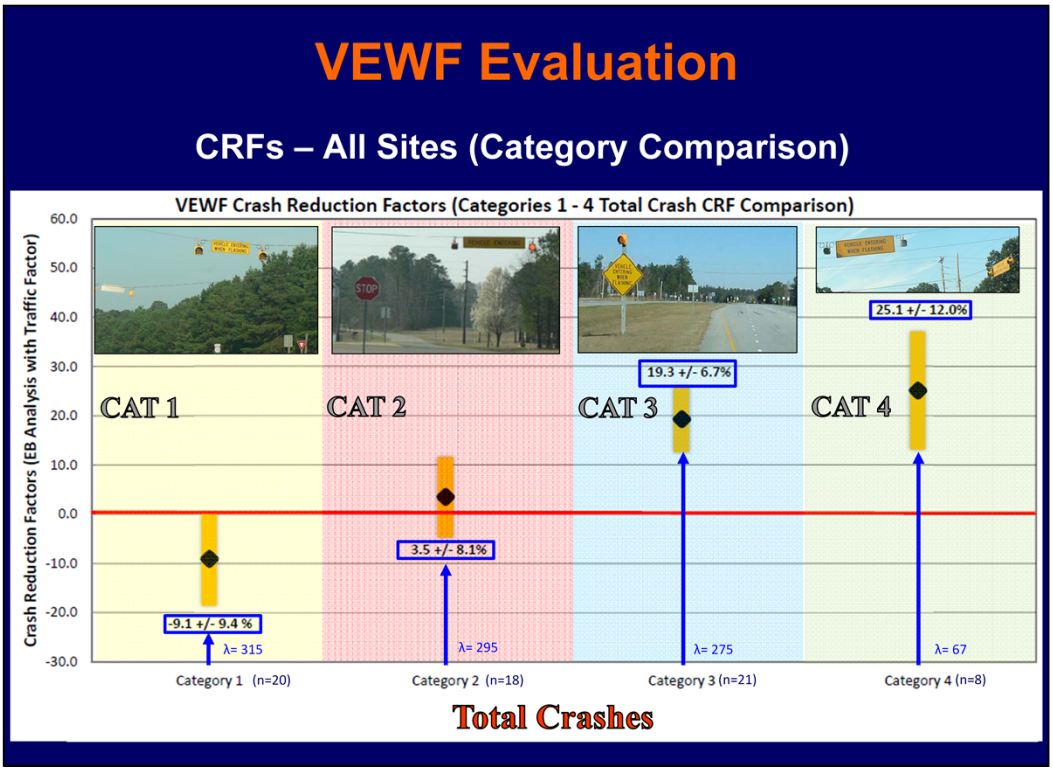
	All Sites (n=67)
Total	6.8 (+/-4.3%)
Target	3.2 (+/-5.0)%
Injury	6.4 (+/-5.5)%
K+A Injury	16.4 (+/-15.9)%

*Note: Negative Results Mean an Increase in Crashes.

	Cat 1 (n=20)	Cat 2 (n=18)	Cat 3 (n=21)	Cat 4 (n=8)
Total	-9.1 (+/-9.4)%	3.5 (+/-8.1)%	19.3 (+/-6.7)%	25.1 (+/-12.0)%
Target	-9.6 (+/-10.5)%	-4.3 (+/-9.7)%	17.3 (+/-7.6)%	20.3 (+/-14.4)%
Injury	5.0 (+/-10.4)%	2.4 (+/-10.5)%	11.0 (+/-9.0)%	13.0 (+/-18.7)%
K+A Injury	31.1 (+/-24.2)%	14.1 (+/-28.2)%	6.8 (+/-27.9)%	75.8 (+/-21.2)%

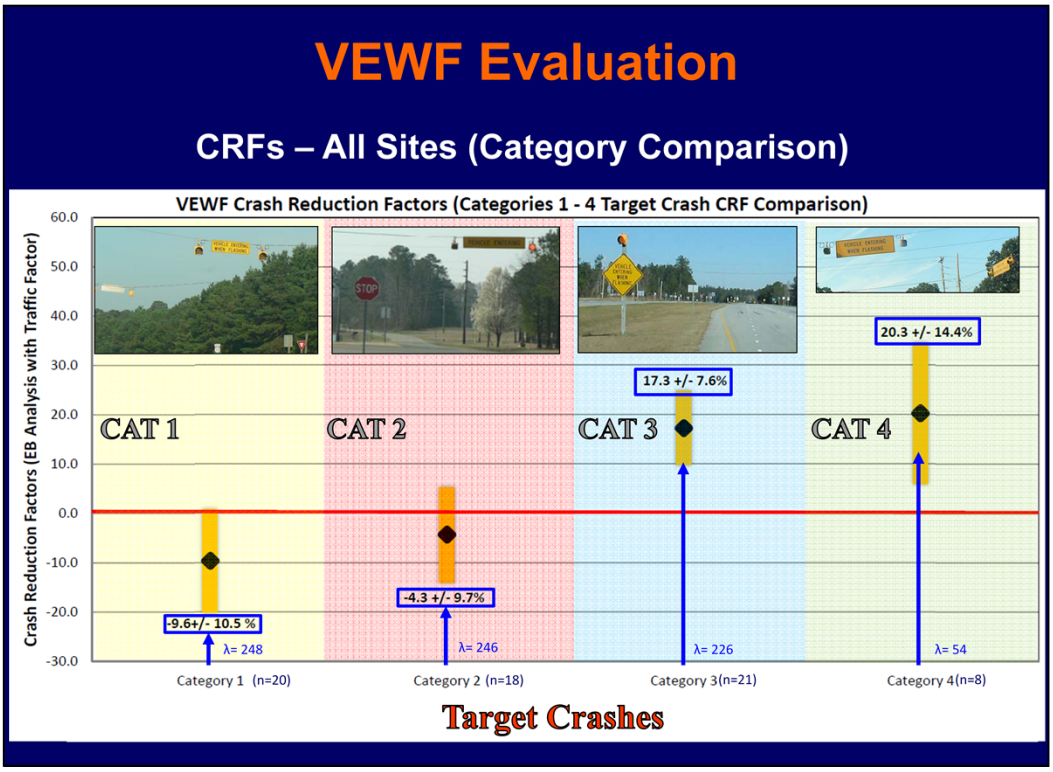
The safety estimates are provided separately by category because the categories demonstrated a range of effectiveness at reducing crashes. The factors were calculated using the Empirical Bayes method with consideration for traffic increase at 67 treatment sites (excluded multi-lane undivided in EB method due to sample sizes).

The results yielded a 7% (+/- 4%) reduction in total crashes, a 3% (+/- 5%) reduction in frontal impact crashes, a 6% (+/- 6%) reduction in injury crashes, and a 16% (+/- 16%) reduction in severe injury crashes. Note that the Category 4 results, as well as the results for severe injury crashes for all categories, should be viewed with some reserve due to the small sample sizes.

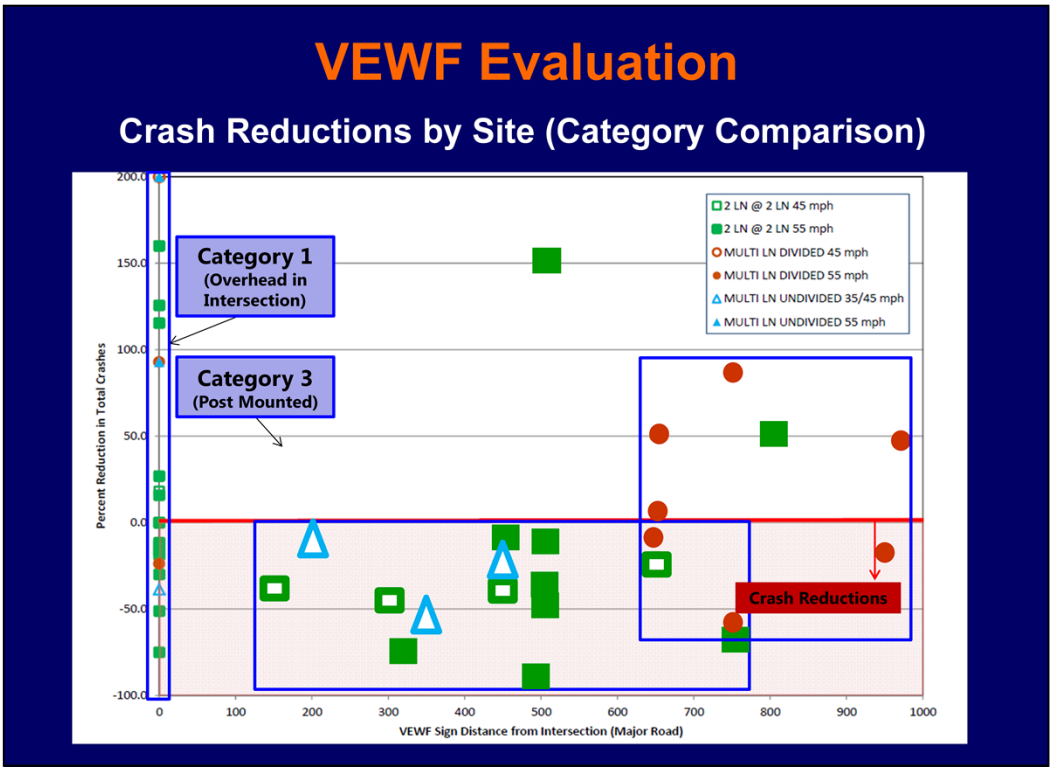


This slide provides a graphical view of the CRFs calculated using the Empirical Bayes method for **TOTAL** crashes in Categories 1-4.

Note that a positive CRF estimate indicates a reduction in crashes. As shown in the figure, there was a noticeably greater reduction in total crashes for Categories 3 and 4 than Categories 1 and 2. Category 1 actually showed an increase in total crashes.



This slide provides a graphical view of the CRFs calculated using the Empirical Bayes method for **TARGET** crashes in Categories 1-4.



This slide plots the percent reduction in total crashes as it relates to VEWF sign placement on the major road on a site by site basis. The symbols vary by mainline road type and speed limits.

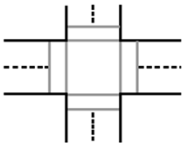
The results indicate the two-lane at two-lane sites with post mounted signs generally experienced the greatest reductions in crashes.

VEWF Evaluation

Crash Reduction Factors – Intersection Type Comparison
Empirical Bayes Method with Traffic Factor

2 Ln @ 2 Ln

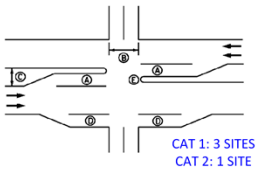
	All Sites (n=56)
Total	10.3 (+/-4.7)%
Target	7.1 (+/-5.5)%
Injury	12.2 (+/-5.9)%
K+A Injury	30.3 (+/-15.9)%



4 Ln Divided @ 2 Ln

	All Sites (n=11)
Total	-6.7 (+/-10.8)%
Target	-10.0 (+/-12.1)%
Injury	-14.9 (+/-14.3)%
K+A Injury	-16.9 (+/-39.3)%

*Note: Negative Results Mean an Increase in Crashes.



The data set is comprised of 56 two-lane at two-lane intersections, 11 four-lane divided at two-lane intersections, and 7 multi-lane undivided at two-lane intersections. Due to sample sizes, we were only able to compare the group of two-lane at two-lane intersections and four-lane divided at two-lane intersections in the data set.

When analyzing all two-lane at two-lane sites combined, the results demonstrate a reduction in crashes for all of the crash types analyzed.

On the other hand, the combined crash analysis results for four-lane divided at two-lane sites show no apparent reduction in crashes at these sites. Overall, the locations with this intersection geometry did not experience a reduction in total, target, injury or severe injury crashes.

VEWF Evaluation

Other Treatments Implemented After VEWF

2 Lane @ 2 Lane	All Sites	Sites with Additional Treatments Implemented after					Percent of All Sites
		Signal	All-Way Stop	Geometric Revisions*	Additional VEWF Signs	Total	
Category 1	17	3	1	0	1	5	29%
Category 2	17	2	2	2	1	7	41%
Category 3	14	0	0	0	0	0	0%
Category 4	8	1	0	0	0	1	13%
Total	**56**	**6**	**3**	**2**	**2**	**13**	**23%**

4 Lane Divided @ 2 Lane	All Sites	Sites with Additional Treatments Implemented after					Percent of All Sites
		Signal	All-Way Stop	Geometric Revisions*	Additional VEWF Signs	Total	
Category 1	3	2	0	0	0	2	67%
Category 2	1	0	0	1	0	1	100%
Category 3	7	0	0	4	0	4	57%
Category 4	0	0	0	0	0	0	N/A
Total	**11**	**2**	**0**	**5**	**0**	**7**	**64%**

Multilane Undivided @ 2 Lane	All Sites	Sites with Additional Treatments Implemented after					Percent of All Sites
		Signal	All-Way Stop	Geometric Revisions*	Additional VEWF Signs	Total	
Category 1	4	2	0	1	0	3	75%
Category 2	1	0	0	0	0	0	0%
Category 3	2	1	0	0	0	1	50%
Category 4	0	0	0	0	0	0	N/A
Total	**7**	**3**	**0**	**1**	**0**	**4**	**57%**

This slide presents the number of sites with known treatment implemented after the VEWF treatment was installed.

Seven of 11 (64%) of the four-lane divided locations are known to have had additional safety countermeasures installed within several years after the VEWF was completed, which is an indicator that the VEWF system was not effective at these sites.

The use of VEWF systems at four-lane divided at two-lane intersections may be more a “band-aid” treatment that does not address the root cause of crashes in this situation and a geometric change (i.e. directional crossover, offsetting minor road legs, or crossover closure) may be a more appropriate solution to address crash patterns likely related to gap-acceptance. Although the number of treatment sites is relatively low, based on the crash analysis results and our experience with the treatment locations, we believe the installation of VEWF systems is not an appropriate treatment for most intersections with a four-lane divided roadway experiencing a strong frontal impact crash pattern.

VEWF Evaluation

Crash Reduction Factors – 2 Ln @ 2 Ln (56)
Empirical Bayes Method with Traffic Factor

2 Ln @ 2 Ln

	Cat 1 (n=17)	Cat 2 (n=17)	Cat 3 (n=14)	Cat 4 (n=8)
Total	-5.9 (+/-9.8)%	4.7 (+/-8.4)%	32.5 (+/-7.6)%	25.1 (+/-12.0)%
Target	-7.4 (+/-11.2)%	-0.1 (+/-9.6)%	32.1 (+/-8.8)%	20.3 (+/-14.4)%
Injury	8.3 (+/-10.8)%	6.6 (+/-10.6)%	26.8 (+/-10.2)%	13.0 (+/-18.7)%
K+A Injury	38.7 (+/-23.6)%	23.9 (+/-26.8)%	30.1 (+/-30.1)%	75.8 (+/-21.2)%

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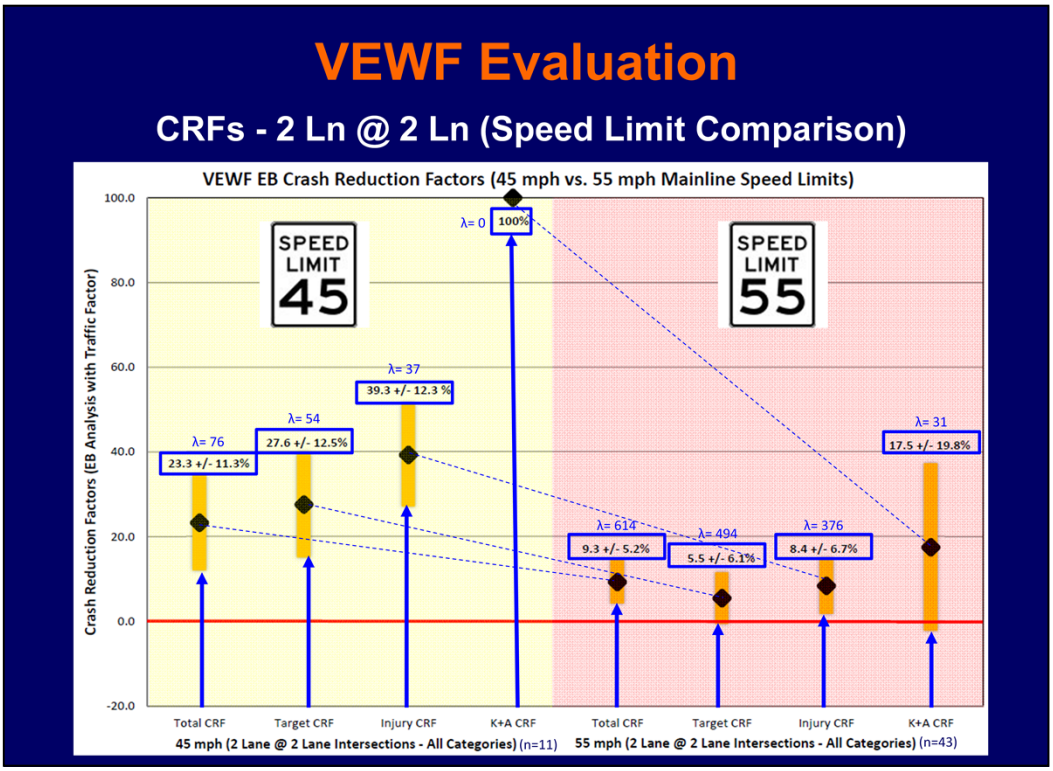
The number of available sites within each intersection configuration limited further study solely to the group of two-lane at two-lane intersections. These are the recommended CRF estimates for installation of a VEWF system SPECIFICALLY at a two-lane at two-lane stop-controlled intersection.

Certain categories of VEWF systems show more promise for two-lane at two-lane intersections than others based on the crash analysis results. The results indicate Category 3 and 4 locations generally experienced the greatest reductions in crashes for two-lane at two-lane intersections. The Category 3 group shows the largest reduction in total, target and injury crash types. (The Category 4 results, as well as the results for severe injury crashes for all categories, should be viewed with some reserve due to the small sample sizes.)

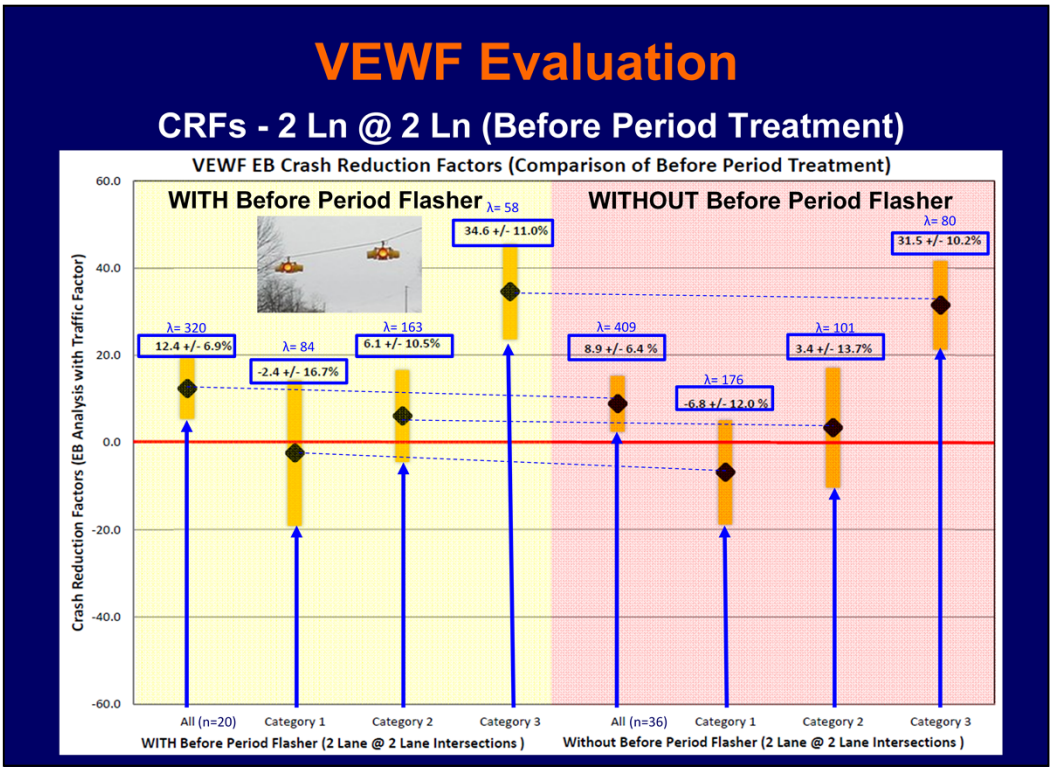
It appears motorists may benefit more from the advance warning prior to the intersection that Category 3 signage provides. It may be the advanced signing on the major road gives motorists more time to be prepared for a vehicle to enter from the minor road, and allows for more defensive actions such as taking the foot off the gas. The use of Category 4 signing, most of which utilize a combination of both major road and minor road signing and detection, also shows promise in reducing crashes at two-lane at two-lane intersections.

It makes sense that more benefit is achieved when providing both major and minor road vehicles with alerts rather than if major road only or minor road only alerts are provided. We are unable to determine what impact specific combinations of signs had on crash reductions due to the large amount of signing variability within this category. There were six variations within the eight sites in this category. Future research should refine Category 4 signing and determine the optimal design when using alerts for both approaches.



This slide provides a comparison of the CRF estimates calculated for two-lane at two-lane treatment intersections with mainline speed limits of 45 mph and 55 mph. The results are provided for total, target, injury, and K+A injury crashes, regardless of category. Approximately 77% (43 of 56) of the two-lane at two-lane treatment sites have 55 mph mainline speed limits. The percentage of sites within each category was relatively similar for both speed limit groups.

The results demonstrate the two-lane at two-lane treatment sites show a reduction in crashes regardless of the mainline speed limit. However, the treatment sites with a 45 mph mainline speed limit may have been more effective at reducing crashes than sites with a 55 mph mainline speed limit. The results suggest that VEWF systems may provide more benefit for intersections with a lower mainline speed limit, although a larger sample of sites with 45 mph mainline speed limits should be analyzed to validate these results. Providing a warning directed at mainline motorists (in 3 of 4 categories) in conjunction with lower mainline speed limits, may create a situation that gives through vehicles a split second more time to avoid vehicles entering the intersection from the minor road.



This slide compares CRFs for sites where a standard flasher WAS present in the before period to sites where a standard flasher was NOT present in the before period. The results may suggest that at sites where a standard flasher was present prior to VEWF, the standard flasher did not effectively treat the existing crash pattern.

VEWF Evaluation

Items for Future Research

- Determine how the following contribute to VEWF effectiveness:
  - Sign message & size
  - Combined messaging on both major and minor approaches
  - Distance on major approach from intersection to signs (for sites with advance post mounted signs)
  - Distance on major and/or minor approaches from intersection to loops
  - Number of loops on the minor approach (some have lead in loops)
  - Variability of detector timing setting
  - Other safety treatments used in conjunction with VEWF
  - Sight distance
  - Roadway grade on major and minor approaches
  - Traffic volume thresholds
  - Additional analysis of intersection lane geometry (i.e. 4-lane divided at 2-lane and multilane undivided at 2-lane)

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This is a list of items that should be addressed in future research. We are not able to account for all of the different location conditions and sign configurations (such as sign placement, message set, dynamic elements, etc.) in this study because of the number of variations within the data.

It will be beneficial to determine the role each of these items play in improving VEWF effectiveness. These items should be investigated when more locations are available for analysis.

The following slides demonstrate the variability of the treatment sites.

VEWF Evaluation

Variability in Intersection Geometry & Sign/Flasher Treatments

Category 1 – Overhead Signs and Flashers on Major, Loop on Minor (24 sites)

CATEGORY 1

	Sign Message			Total
	"Vehicle Entering When Flashing"	"Vehicle Entering"	"Watch for Approaching Vehicles"	
Intersection Geometry				
3 Leg - 2 Ln @ 2 Ln	1	0	0	**1**
4 Leg - 2 Ln @ 2 Ln	15	1	0	**16**
3 Leg - Multilane Divided @ 2 Ln	1	0	0	**1**
4 Leg - Multilane Divided @ 2 Ln	2	0	0	**2**
3 Leg - Multilane Undivided @ 2 Ln	1	0	0	**1**
4 Leg - Multilane Undivided @ 2 Ln	2	0	1	**3**
Total	**22**	**1**	**1**	**24**
Number of Sites using Sign Size				
66" X 20"	1	0	0	**1**
72" X 12"	1	0	0	**1**
114" X 36"	15	1	1	**17**
168" X 48"	2	0	0	**2**
Unknown	3	0	0	**3**
Number of Sites using Additional Treatments				
Additional Flasher on Stop Ahead Sign	2	0	0	**2**
Additional Flasher on Intersection Warning Sign	1	0	0	**1**
Continuous Flasher in Before Period	4	0	0	**4**

***Note: VEWF characteristics based on original signal plan designs. Not field verified.**

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This slide represents site variability for **Category 1** locations.

VEWF Evaluation

Variability in Intersection Geometry & Sign/Flasher Treatments

Category 2 – Overhead Signs and Flashers on Minor, Loop on Major (19 sites)

CATEGORY 2

	Sign Message				Total
	"Vehicle Entering When Flashing"	"Vehicle Entering"	"Watch for Approaching Vehicles"	"Vehicle Entering from Left when Flashing"	
Intersection Geometry					
3 Leg - 2 Ln @ 2 Ln	1	0	0	0	**1**
4 Leg - 2 Ln @ 2 Ln	6	9	1	0	**16**
4 Leg - Multilane Divided @ 2 Ln	0	0	0	1	**1**
4 Leg - Multilane Undivided @ 2 Ln	1	0	0	0	**1**
Total	**8**	**9**	**1**	**1**	**19**
Number of Sites using Sign Size					
114" X 36"	8	4	0	1	**13**
125" X 24"	0	1	0	0	**1**
144" X 24"	0	1	0	0	**1**
Unknown	0	3	1	0	**4**
Number of Sites using Additional Treatments					
Additional Flasher on Stop Sign	5	3	1	0	**9**
Additional Flasher on Intersection Warning Sign	0	0	0	1	**1**
Continuous Flasher in Before Period	3	5	1	0	**9**

***Note: VEWF characteristics based on original signal plan designs. Not field verified.**

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This slide represents site variability for **Category 2** locations.

VEWF Evaluation

Variability in Intersection Geometry & Sign/Flasher Treatments

Category 3 – Post Mounted Signs and Flashers on Major, Loop on Minor (23 sites)

CATEGORY 3

	Sign Message			Total
	"Vehicle Entering When Flashing"	"Vehicle Entering"	"Watch for Approaching Vehicles"	
Intersection Geometry				
4 Leg - 2 Ln @ 2 Ln	10	3	1	**14**
4 Leg - Multilane Divided @ 2 Ln	4	0	0	**4**
4 Leg - Multilane Undivided @ 2 Ln	2	3	0	**5**
Total	**16**	**6**	**1**	**23**
Number of Sites using Sign Size				
48" x 48"	14	6	1	**21**
Unknown	2	0	0	**2**
Number of Sites using Additional Treatments				
Additional Flasher on Stop Sign	1	1	0	**2**
Additional Flasher on Stop Ahead Sign	1	0	0	**1**
Continuous Flasher in Before Period	8	0	0	**8**

***Note: VEWF characteristics based on original signal plan designs. Not field verified.**

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This slide represents site variability for **Category 3** locations.

VEWF Evaluation

Variability in Intersection Geometry & Sign/Flasher Treatments

Category 4 – Locations with Combination of Category 1 through Category 3 (8 sites)

CATEGORY 4

	Sign Messages						Total
	Overhead Major: "Vehicle Entering When Flashing" Overhead Minor: "Watch for Approaching Vehicle"	Overhead Major: "Vehicle Entering" Overhead Minor: "Watch for Approaching Vehicle"	Overhead & Post Mounted Major: "Vehicle Entering when Flashing" Overhead Minor: "Watch for Approaching Vehicle"	Overhead & Post Mounted Major: "Vehicle Entering When Flashing"	Overhead Major: "Vehicle Entering When Flashing" Overhead Minor: "Vehicle Entering When Flashing"	Post Mounted Major: "Vehicle Entering When Flashing" Post Mounted Minor: "Watch for Approaching Vehicle"	
Intersection Geometry							
3 Leg - 2 Ln @ 2 Ln	0	0	0	1	0	1	**1**
4 Leg - 2 Ln @ 2 Ln	2	2	1	1	1	0	**7**
Total	**2**	**2**	**1**	**1**	**1**	**1**	**8**
Number of Sites using Sign Size							
48" x 48" (Post)	0	0	1	1	0	1	**3**
72" X 12" (Overhead)	0	0	0	1	0	0	**1**
114" X 36" (Overhead)	1	2	1	0	1	0	**5**
Unknown	1	0	0	0	0	0	**1**
Number of Sites using Additional Treatments							
Additional Flasher on Stop Sign	1	0	0	0	1	0	**2**
Additional Flasher on Stop Ahead Sign	0	1	0	0	0	0	**1**
Continuous Flasher in Before Period	1	1	0	0	0	0	**2**

*Note: VEWF characteristics based on original signal plan designs. Not field verified.

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This slide represents site variability for **Category 4** locations.

VEWF Evaluation

Variability in Loop Placement & Detector Timing

Category 3 – Post Mounted Signs and Flashers on Major, Loop on Minor (23 sites)

	# Sites	Minor Distance from Intersection to First Loop (ft)	Detector Timing (extension in sec)	Minor Distance from Intersection to Second Loop (ft)	Detector Timing (extension in sec)	Major Distance from Intersection to Sign (ft)	Intersection AADT Range (entering veh/day)
35 mph	1	450	15	0	3	350	10,600
45 mph	5	0-495	5-14	0-5	0-5	150-450	2,900-28,600
55 mph	17	0-1000	3-17	0-6	0-5	325-975	2,800-10,200

***Note: VEWF characteristics based on original signal plan designs. Not field verified.**

This slide represents loop placement and detector timing variability for **Category 3** locations. Such variability was found in all Category types.

VEWF Evaluation

Treatment Toolbox

COMPARISON OF SEVERAL LOW COST TREATMENTS FOR 2 LN @ 2 LN INTERSECTIONS	TOTAL CRF	INJURY CRF	AVERAGE COST*	INTERSECTION AADT**
All Way Stop (Installed with Overhead Flashing Beacons)	82 (+/-4)%	87 (+/-4)%	$20,000	1,400-9,900
All Way Stop (Signs Only)	61 (+/-3)%	72 (+/-4)%	$5,000	680 - 15,100
VEWF Category 3	32 (+/-8)%	27 (+/-10)%	$21,200	2,800-9,700
VEWF Category 4	25 (+/-12)%	13 (+/-19)%	$28,000	2,400-9,300
Overhead Flashing Beacon	12 (+/-6)%	9 (+/-8)%	$20,000	1,100-14,000
VEWF Category 2	5 (+/-8)%	7 (+/-11)%	$21,900	3,200-12,100
VEWF Category 1	-6 (+/-10)%	8 (+/-11)%	$22,800	1,500-12,200

*VEWF costs obtained from sites with available project information in spot safety files. All way stop and flasher costs obtained from prior Statewide evaluations.
** Range of intersection AADTs for locations used in study

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The results suggest VEWF systems to be limited to either Category 3 or Category 4 with major road signing in advance of the intersection at 2-lane at 2-lane intersections.

That being said, the magnitude of effectiveness for VEWF systems should be viewed within context of other low-cost safety countermeasures available for 2-lane at 2-lane intersections.

Category 3 and 4 signing may have a niche at 2-lane at 2-lane intersections, but they are one of several low cost countermeasures used by NCDOT to treat lower volume stop controlled two-lane at two-lane intersections experiencing severe angle crash patterns. This table provides a summary of several low cost safety treatments used by traffic engineers to treat locations with this type of crash pattern. The total CRF, Injury CRF, average cost of installation, and intersection AADT range for locations used in past NCDOT evaluations are provided for conversion to all way stop control, installation of standard overhead flashing beacons, as well as installation of each VEWF Category. While installation of either category 3 or 4 VEWF may provide a sound reduction in total and injury crashes, conversion to all-way stop control may provide a bigger safety benefit at a slightly lesser installation cost for low volume two-lane at two-lane intersections.