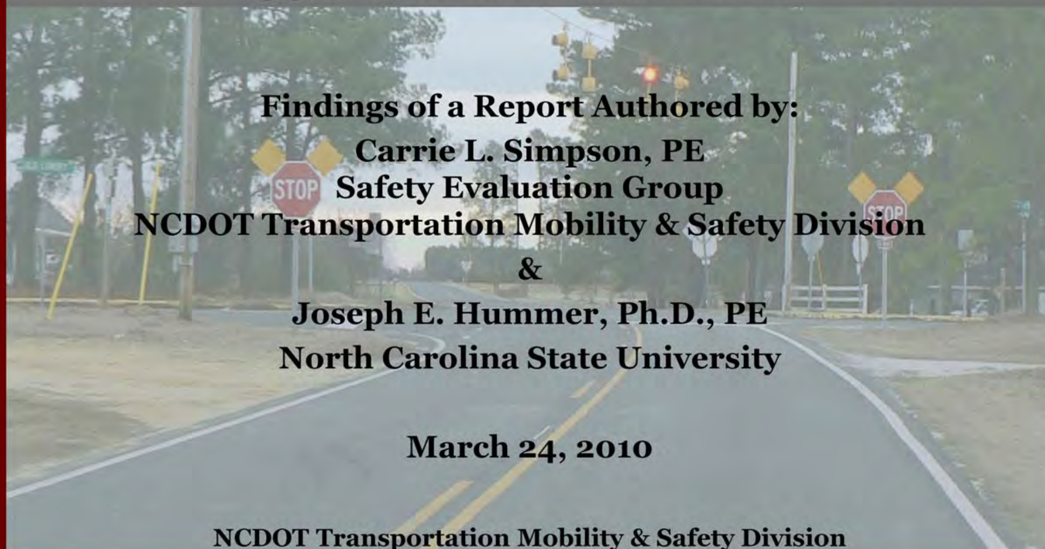
Evaluation of the Conversion from Two-Way Stop Sign Control to All-Way Stop Sign Control at 53 Locations Statewide



Findings of a Report Authored by:
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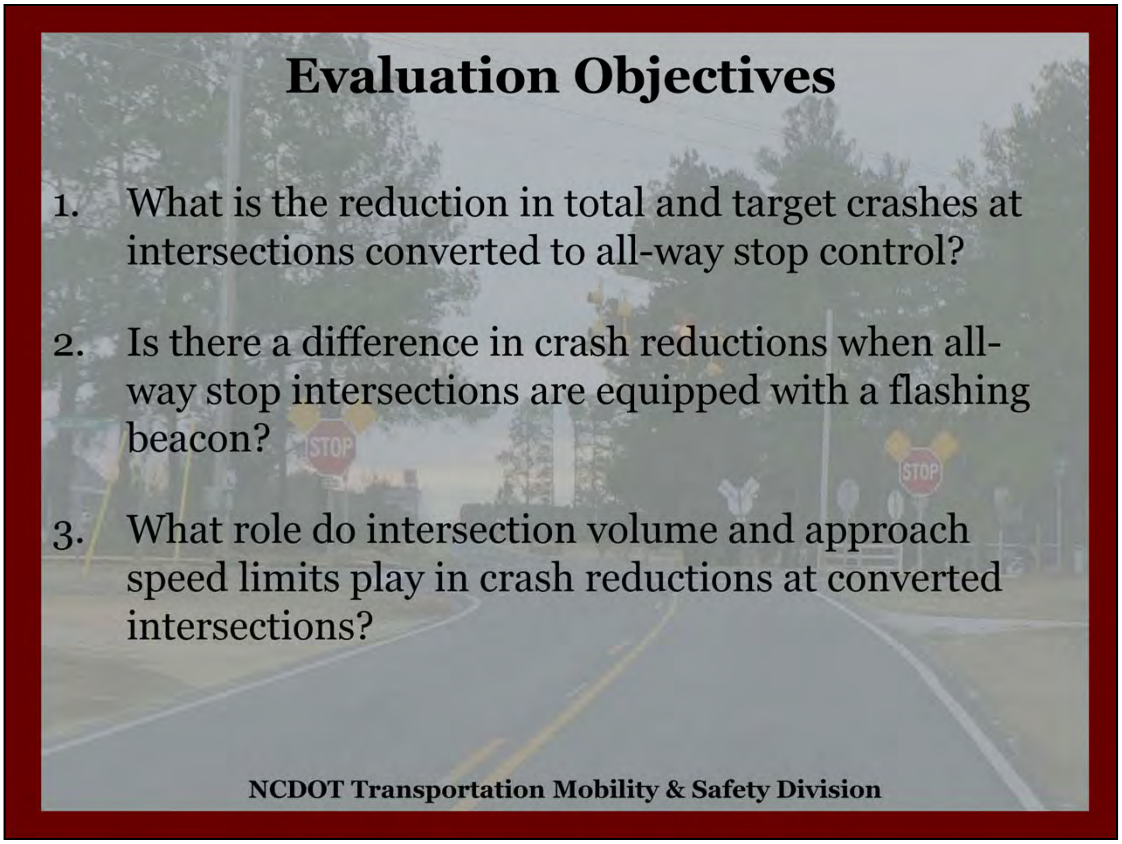
•There is growing interest in the conversion of intersections from two-way stop control to all-way stop control in both urban and rural areas in North Carolina.

•All-way stop control can be used at intersections with a pattern of high severity frontal impact crashes. It's a low cost countermeasure and quick to implement (granted there is no opposition from the community).

•There are few current, up-to-date studies quantifying their safety benefits. Our goal was to develop crash reduction factors that reflect North Carolina conditions and decision-making.

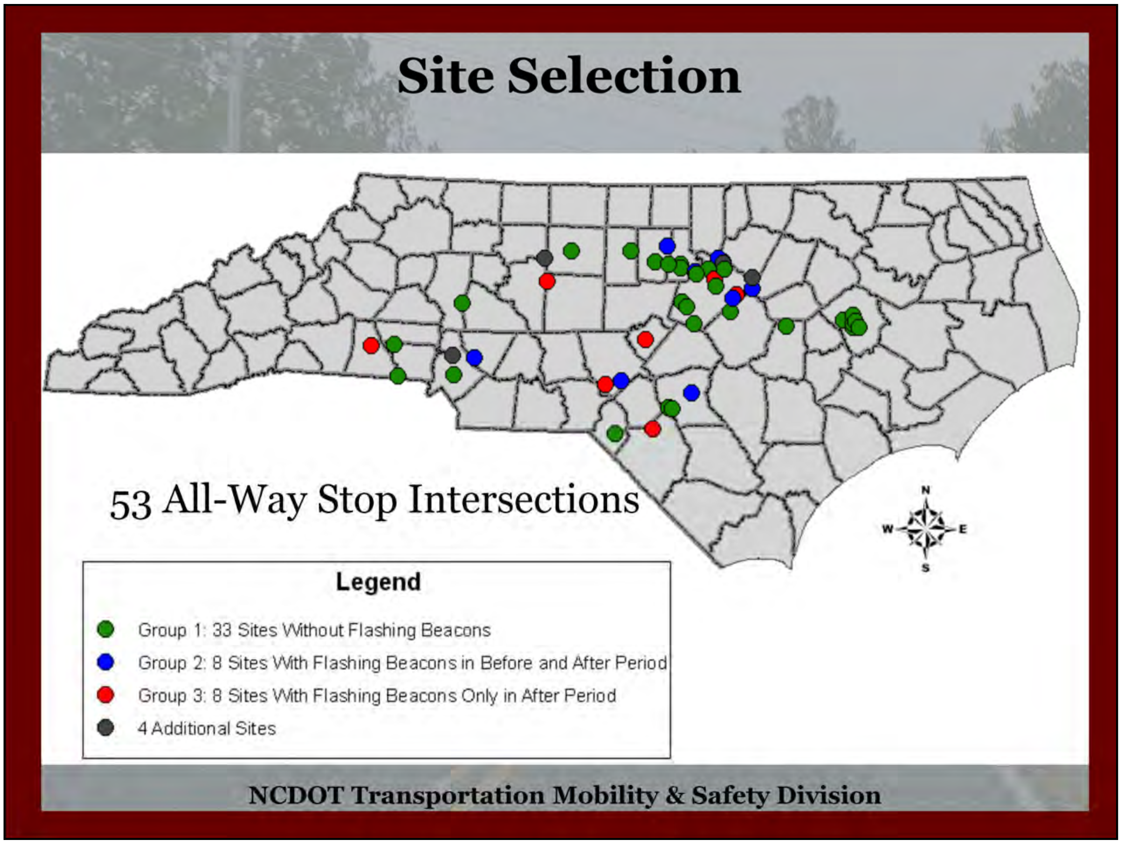


We had several evaluation objectives, which included:

1. Determining if there was a reduction in total and target crashes at intersections converted from two-way to all-way stop control

2. Determining if there was a difference in crash reductions when all-way stop control intersections are equipped with a flashing beacon; and

3. Determining if the intersection volume or approach speed limits played a role in crash reductions at converted intersections.



We obtained a statewide listing of known all-way stop installations from the Regions.

The Criteria for inclusion in our study was:

- An intersection of two roads with four approaches,
- Under two-way stop sign control in the before period,
- At least three years of 'before' crash data available, and
- At least one year of 'after' crash data available

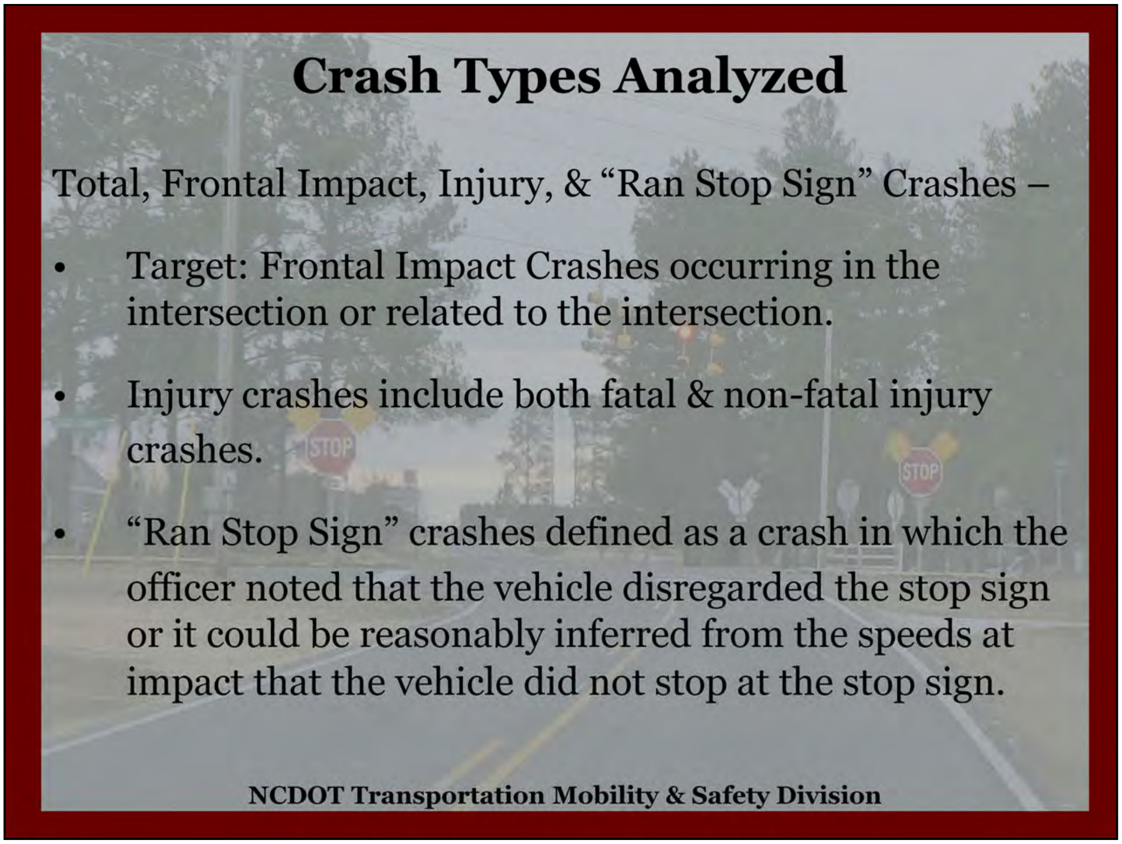
53 intersections met these criteria. Conversion dates varied from 1994 through 2008.

We had a Diverse Group of Intersections: with a range of volumes and approach speeds; located in urban, suburban, and rural areas; some sites with overhead or sign-mounted flashers; and the signing and marking varied

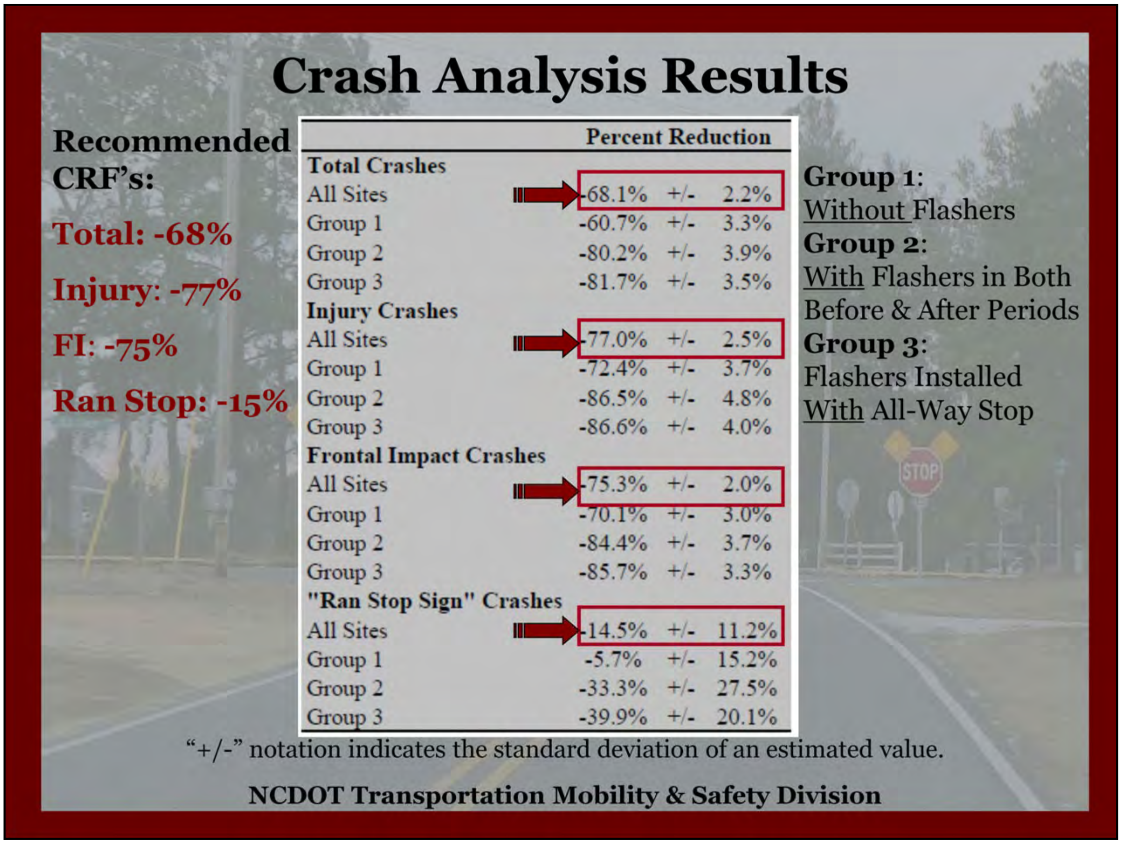
We saw combinations of oversized stop signs, dual stop signs, advanced warning signs, "stop ahead" pavement markings, stop bars, florescent markers on stop signs, and/or flags posted above stop signs. Because we are unable to determine installation dates on the signs and markings, we are unable to attribute specific crash reductions to these additional treatments.

The data was divided into 3 groups based upon presence of an overhead or sign mounted flasher:
Group 1 consisted of 33 intersections without a flasher;
Group 2 consisted of 8 intersections with a flasher in both the before and after period; and
Group 3 consisted of 8 intersections where the flasher was installed with the all-way stop control

- All intersections within the groups have 1 approach lane. 4 additional locations were analyzed but not included in one of the three groups because the intersection geometry was different, i.e. there were slip lanes, turn lanes, and/or median dividers.



- We analyzed Total, Injury, Frontal impact, & "Ran Stop Sign" crashes.
- Frontal impact crashes occurring in the intersection or related to the intersection were target crashes.
- Injury crashes include both fatal & non-fatal injury crashes.
- "Ran stop sign" crashes were defined as a crash in which the officer noted that the vehicle disregarded the stop sign or it could be reasonably inferred from the speeds at impact that the vehicle did not stop at the stop sign. We assumed vehicles traveling at or over 20 mph were stop sign runners.



These are the recommended Crash Reduction Factors (CRFs):

- 68% Reduction in Total Crashes, 77% Reduction in Injury Crashes, 75% Reduction in Frontal Impact Crashes. There was also a 15% reduction in Ran Stop Sign Crashes. We have a more precise idea of the true reduction with the first three point estimates than with Ran Stop Sign crashes due to the larger interval surrounding this estimate. The +/- notation indicates one standard deviation from the point estimates.

•Injury and frontal impact crashes especially benefited from the treatment. Due to the all-way stop condition, vehicles in crashes tended to travel at much lower speeds at impact. At the treatment sites, we specifically found a substantial decrease in vehicle speeds at impact in "ran stop sign" crashes.

•We used an EB analysis with Consideration for Traffic Increase, which accounted for an increase in volumes because of the long duration of before and after periods at some of the sites. The average change in volume at the treatment sites was approximately 15% from the middle of the before period to the middle of the after period.

•The numbers are also provided separately for Groups 1-3, sites with and without flashers. It appears that the Group 2 & 3 sites had greater crash reductions, which we will discuss more thoroughly in a moment.

Additional notes:

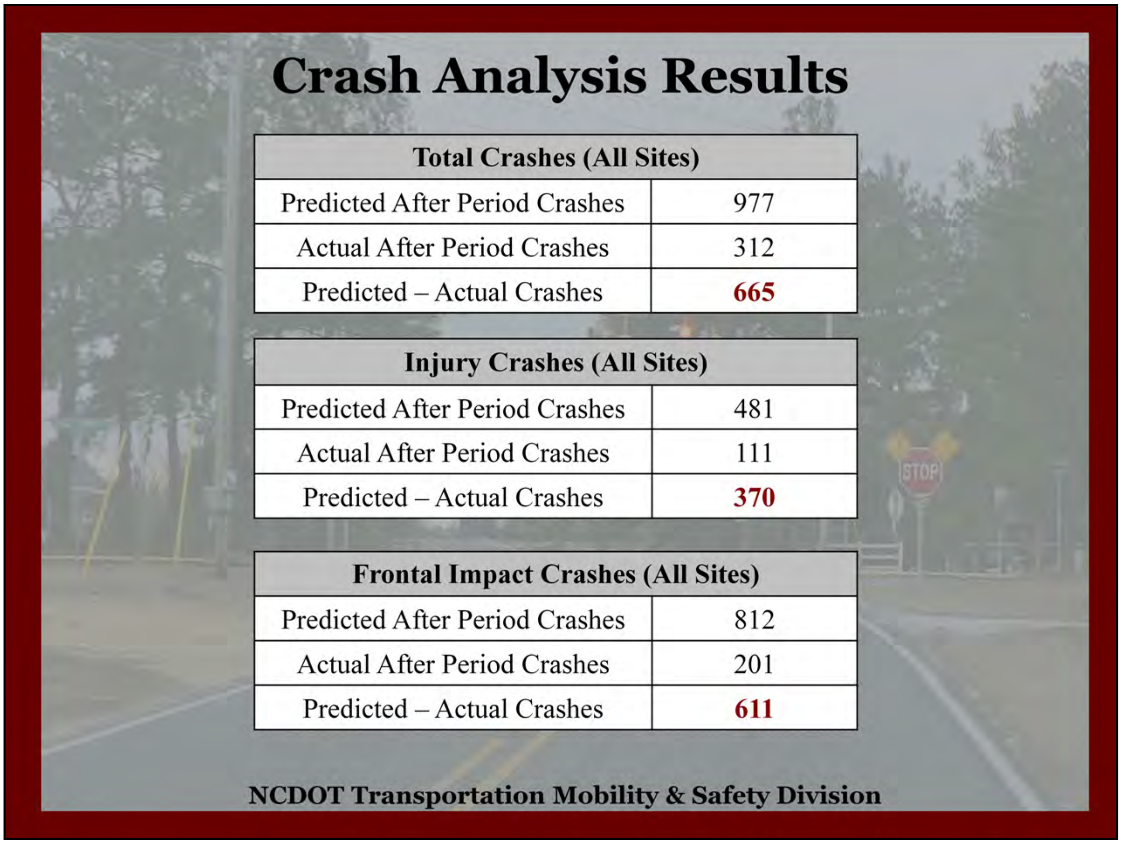
•The Group 2 & 3 results for injury, frontal impact, and "ran stop sign" crashes should be viewed with some reserve due to small sample size for these crash types.

•Total crashes = 954 before and 312 after (not adjusted for time)

•Injury crashes = 505 before and 111 after (not adjusted for time)

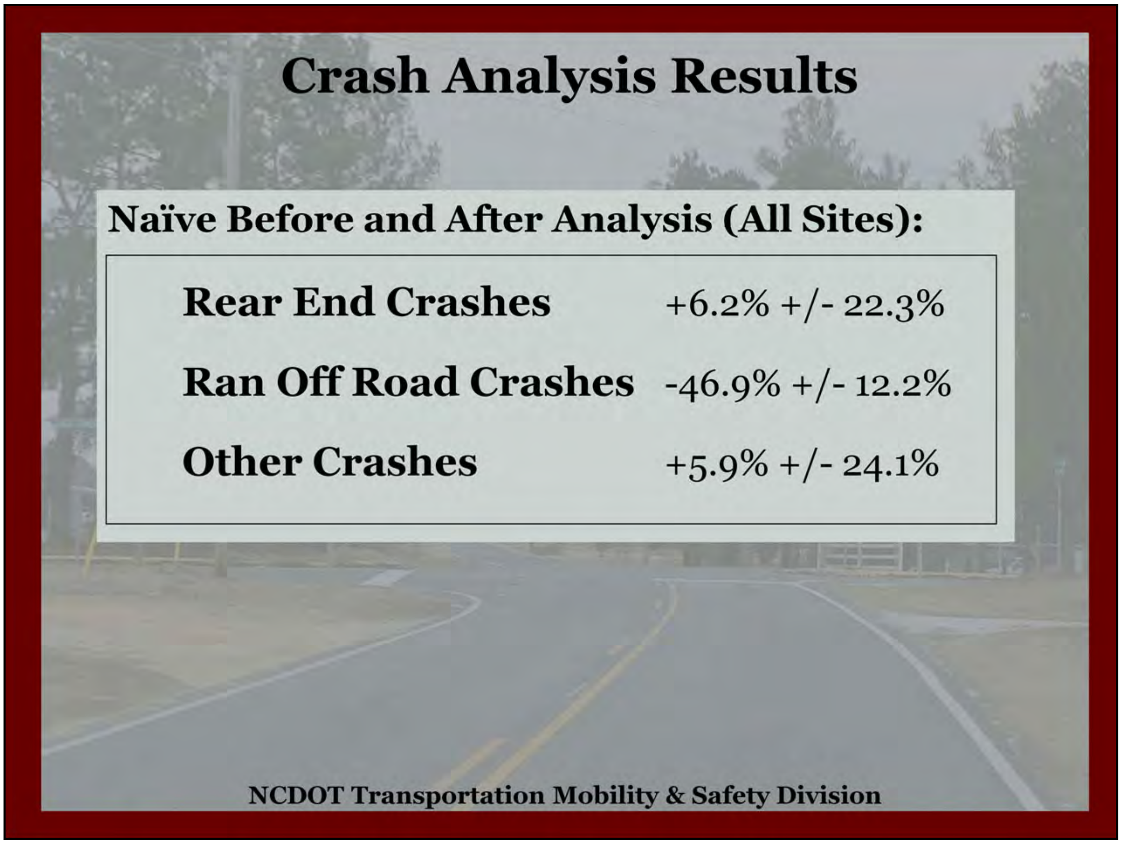
•Frontal Impact = 818 before and 201 after (not adjusted for time)

•Ran stop crashes = 151 before and 116 after (not adjusted for time)



These tables represent the number of total, injury, and frontal impact crashes that were predicted to happen in the after period but did not after the all-way stop projects were completed. At the 53 sites, there were 665 fewer total crashes than expected, 370 fewer injury crashes than expected, and 611 fewer frontal impact crashes than expected in the after period.

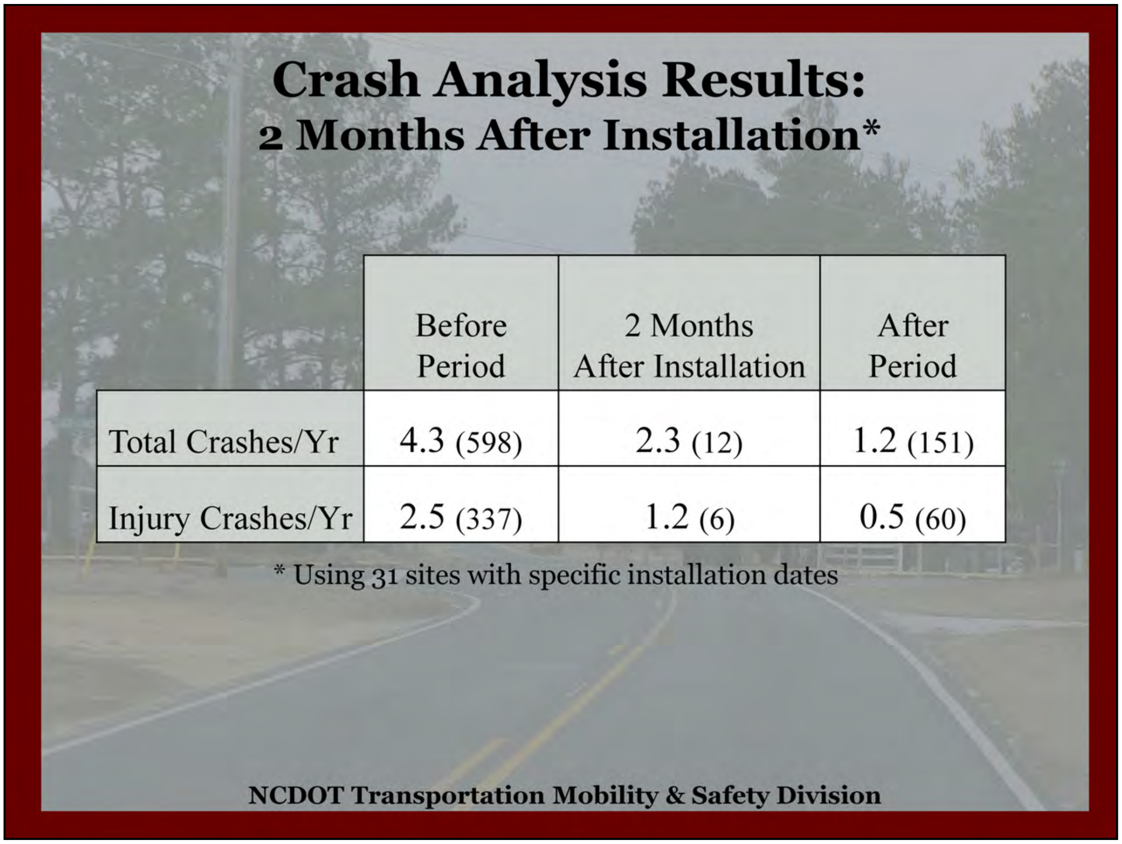
The before period, there were 10 fatalities at the 53 sites. In the after period, there were 0.



•We also looked at other non-target crash types using a simple before and after analysis. Overall, there was a 6% increase in Rear End Crashes, a 47% reduction in Ran Off Road Crashes, and a 6% increase in all other non-target crashes.

•The concern of creating a substantial increase in Rear End Crashes isn't showing itself – and we looked at a lot of sites. In the after period, there were only 45 Rear End Crashes at the 53 sites – and this is using about an average of 5 years after period.

•There was a substantial reduction in ran off road crashes, some of which may be attributed to a decrease in avoidance type crashes.



Crash Analysis Results:
2 Months After Installation*

	Before Period	2 Months After Installation	After Period
Total Crashes/Yr	4.3 (598)	2.3 (12)	1.2 (151)
Injury Crashes/Yr	2.5 (337)	1.2 (6)	0.5 (60)

* Using 31 sites with specific installation dates

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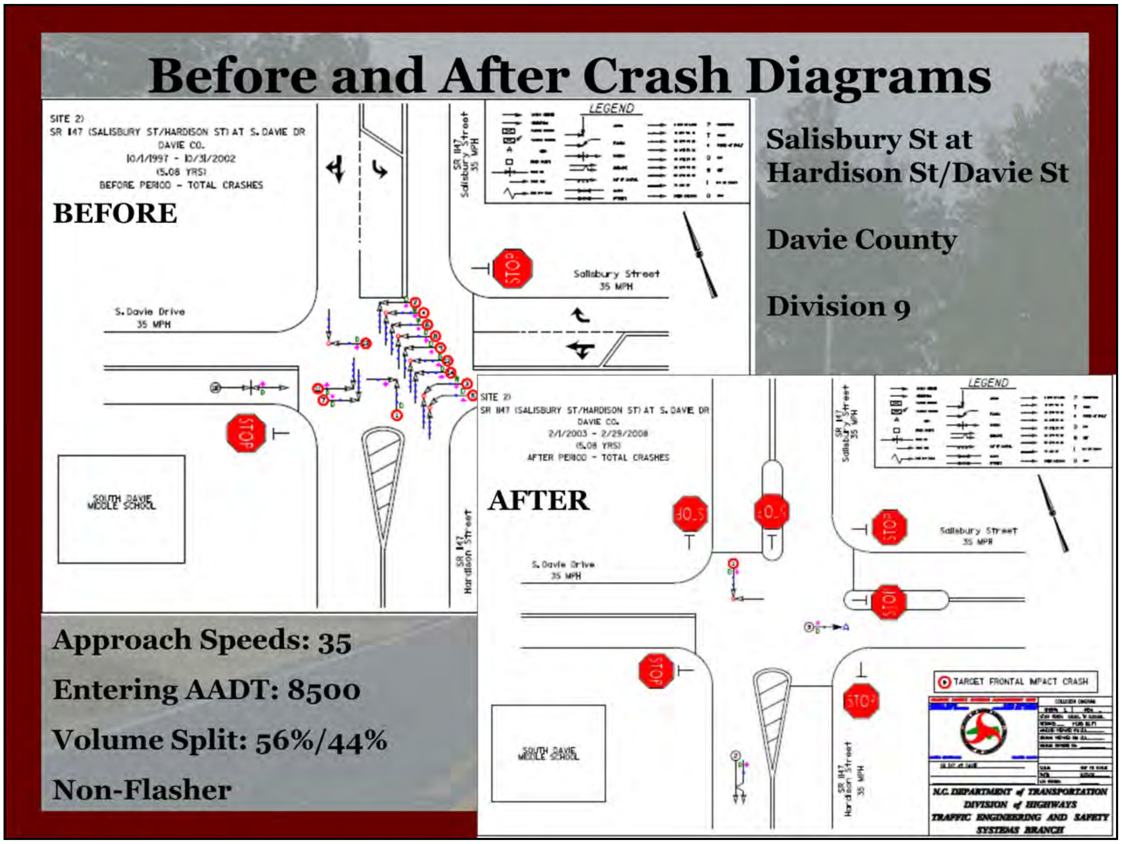
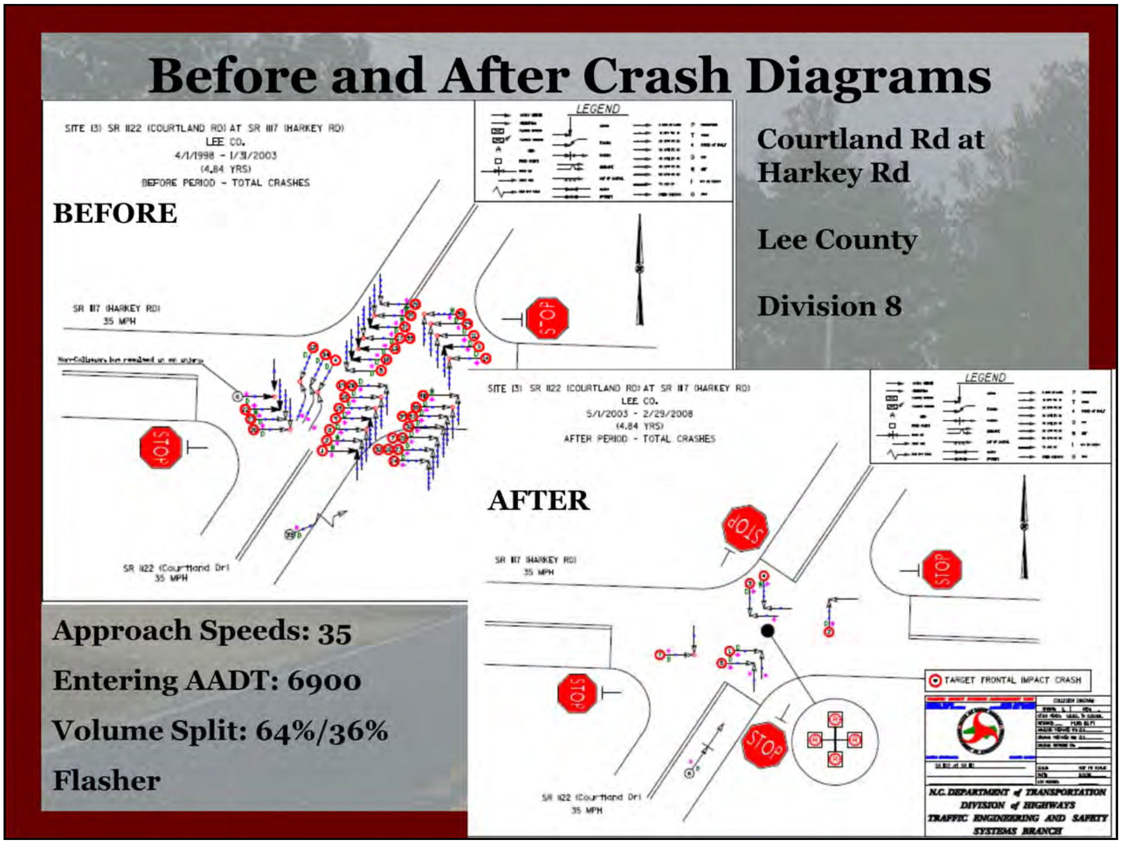
•We analyzed the number of total and injury crashes that occurred within two months after conversion to all way stop control. We looked to see if there was an increase in crashes immediately following the installation because there is a fear that the number of stop sign runners will increase and the number of crashes will increase in this period.

•We had 31 sites with specific installation dates that we could use. At these sites, we found that in this two-month period, the crashes rates were lower than the before period but higher than the remainder of the after period. It seems that there is an adjustment period immediately following conversion, but that the number of crashes in this period is still lower than that in the before period. I've also provided the total number of crashes in these time periods in parentheses to provide some perspective on the rates. The 2.3 total crashes per year during 2 months after installation only relates back to 12 total crashes.

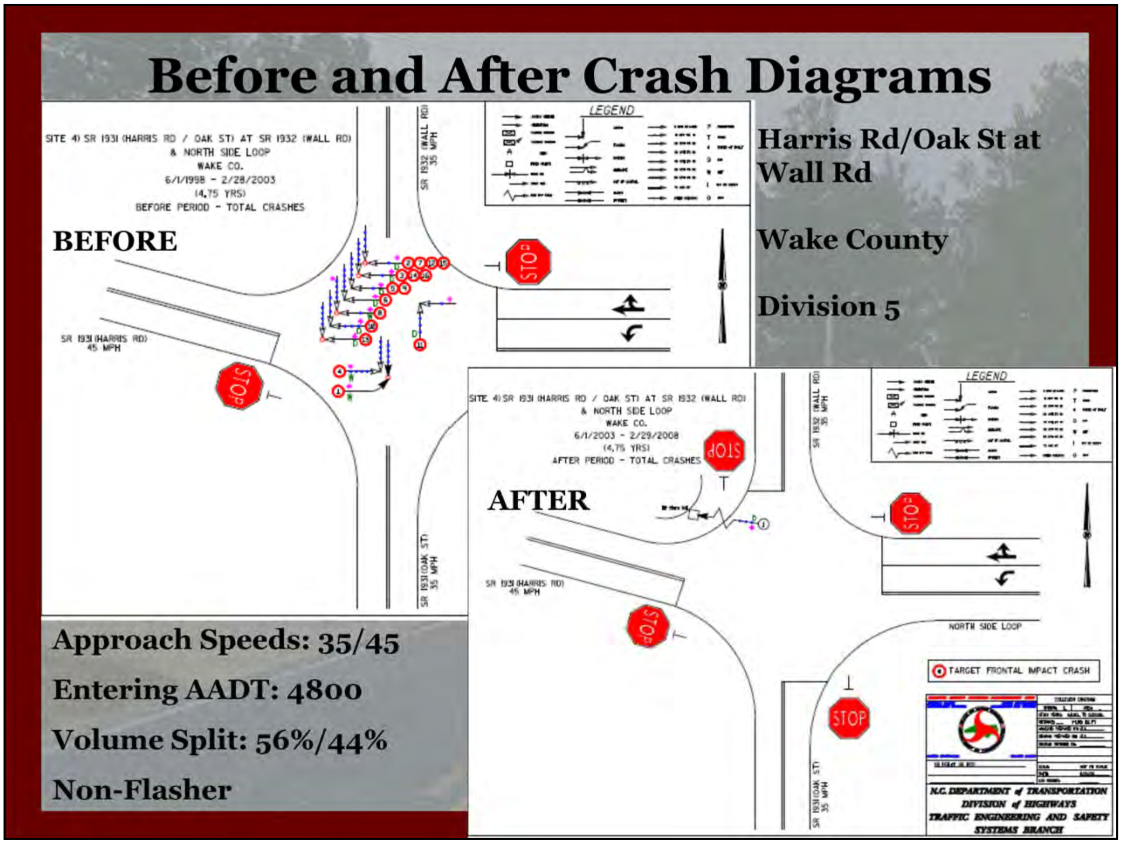


•As you'll see from this set of eight before and after crash diagrams, the pattern of angle crashes dramatically decreases but there is not a big increase in rear ends. I've noted the approach speeds, after period volume, and volume splits for each example. We'll start with the lower speed sites and work our way up to the higher speed sites.

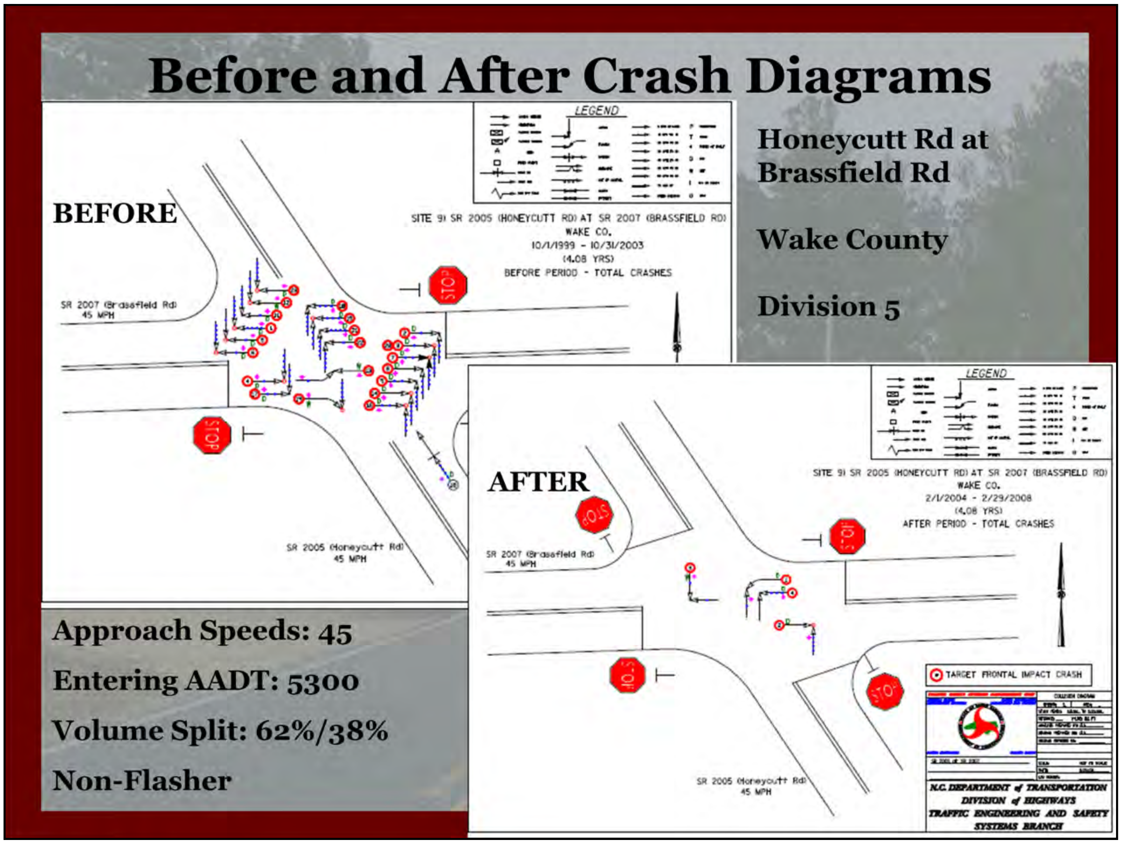
•This location is Salisbury St at Hardison & Davie St in Mocksville, which is in Davie County. It has approaching speed limits of 35 mph, an entering AADT of 8500, and a 56/44 volume split between the major and minor roads. There are no flashers here.



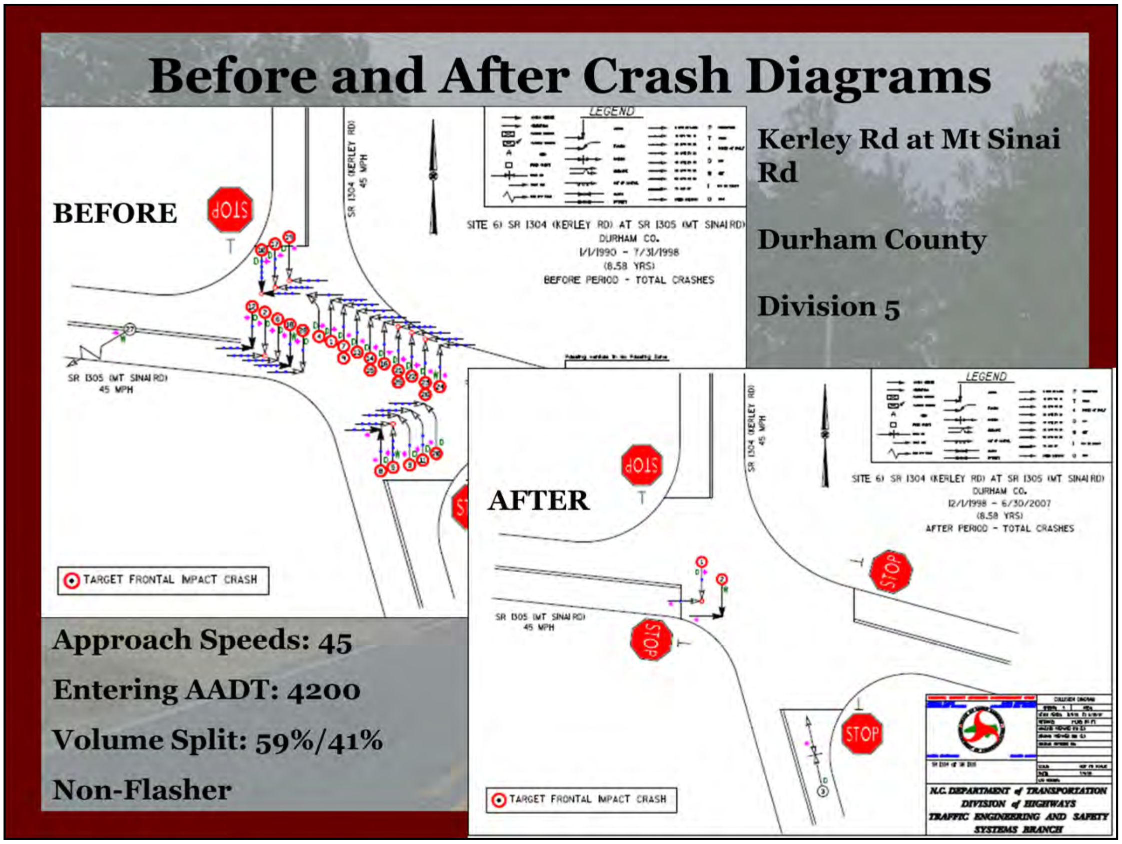
•This location is Courtland Rd at Harkey Rd in Sanford, which is in Lee County. It has approaching speed limits of 35 mph, an entering AADT of 6900, and a 64/36 volume split. An overhead flasher and two sign mounted flashers were installed with the project.



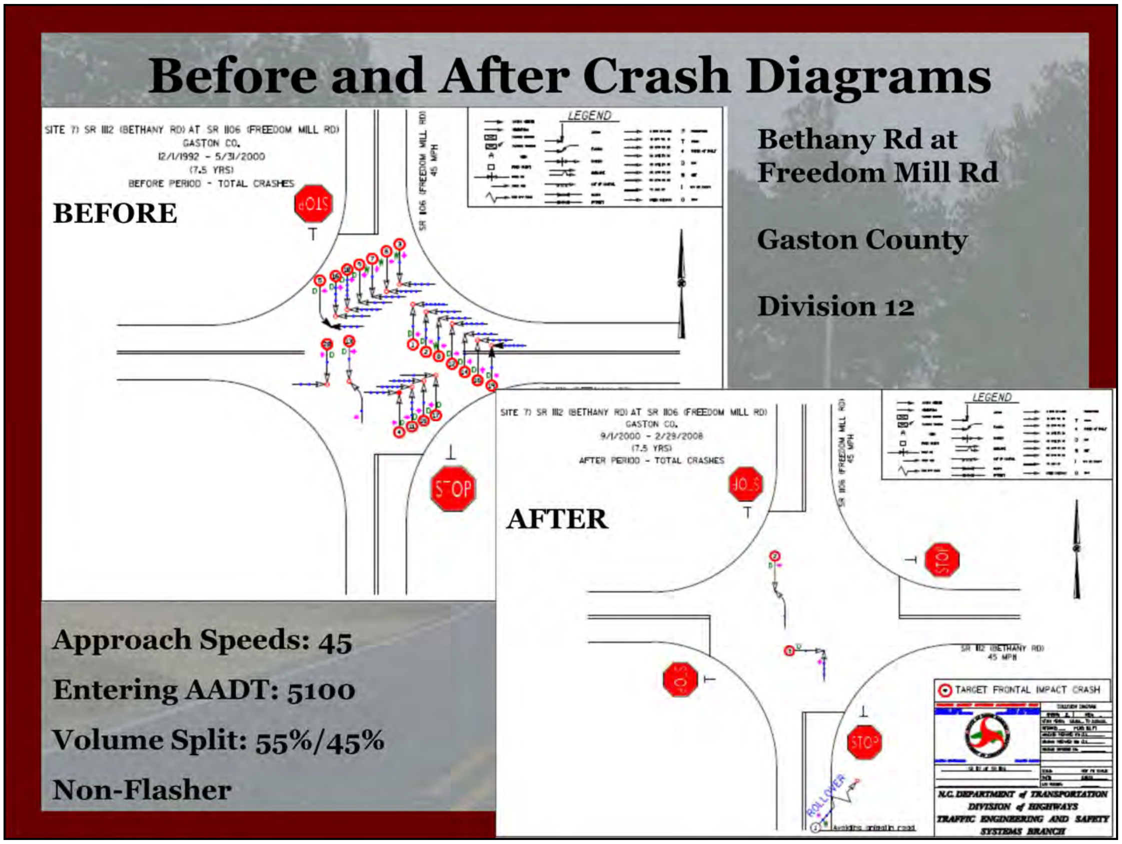
•This location is Harris Rd/Oak St at Wall Rd in Wake Forest, Wake County. It has approaching speed limits of 35-45 mph, an entering AADT of 4800, and a 56/44 volume split. There are no flashers here.



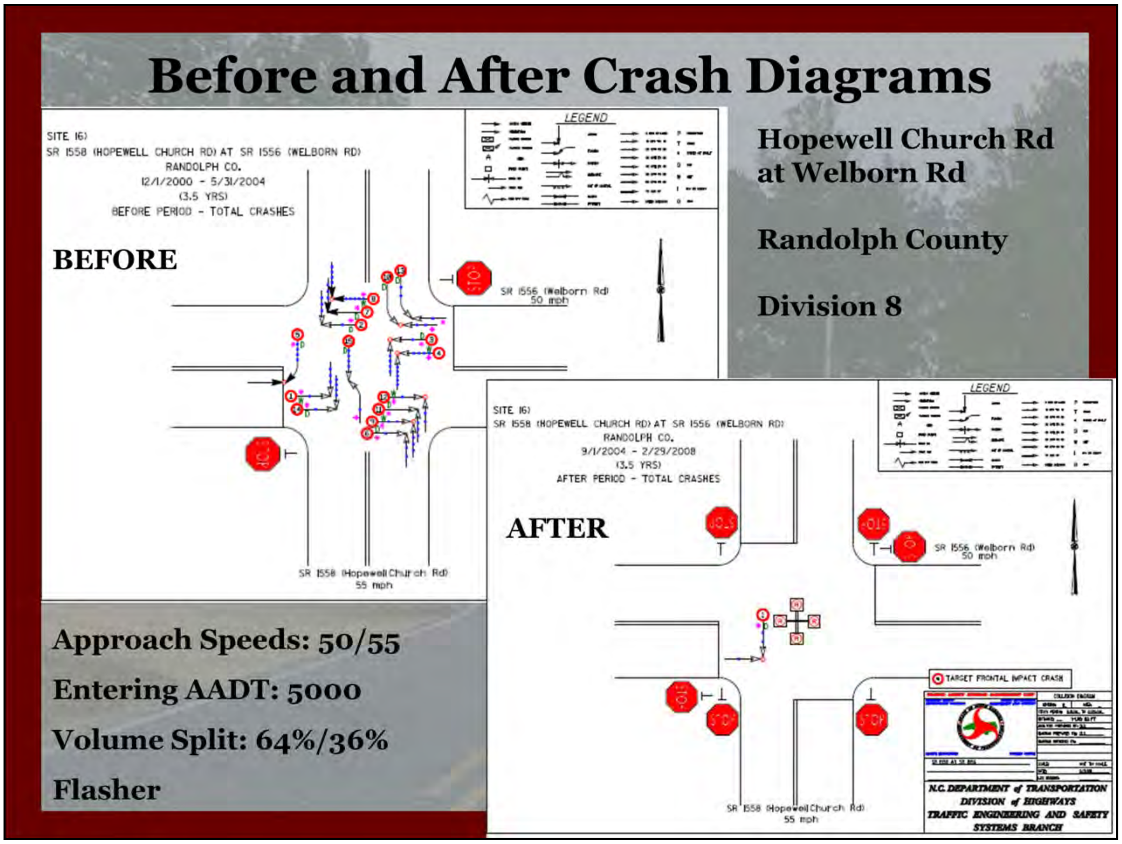
•This location is Honeycutt Rd at Brassfield Rd, north of Raleigh, Wake County. It has approaching speed limits of 45 mph, an entering AADT of 5300, and a 62/38 volume split. There are no flashers here. It's located adjacent to an elementary school.



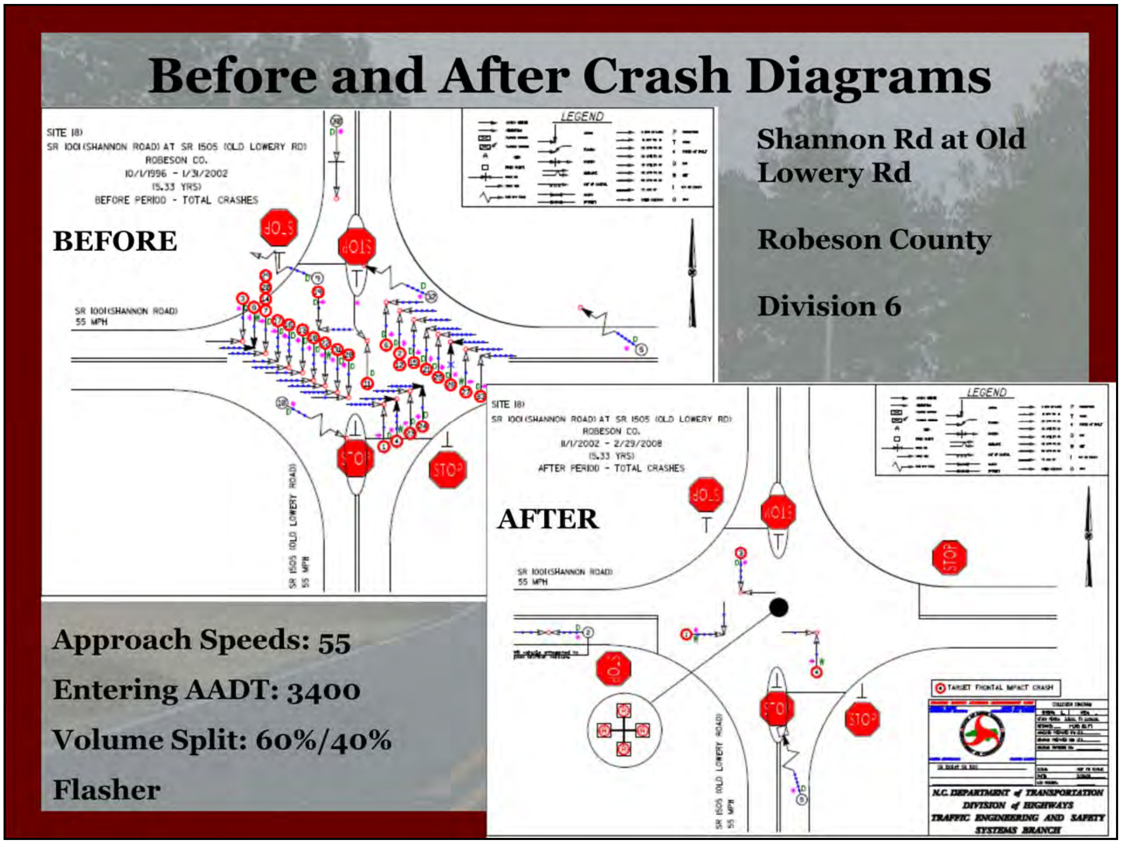
•This location is Kerley Rd at Mt Sinai Rd near Durham. It has approaching speed limits of 45 mph, an entering AADT of 4200, and a 59/41 volume split. There are no flashers here.



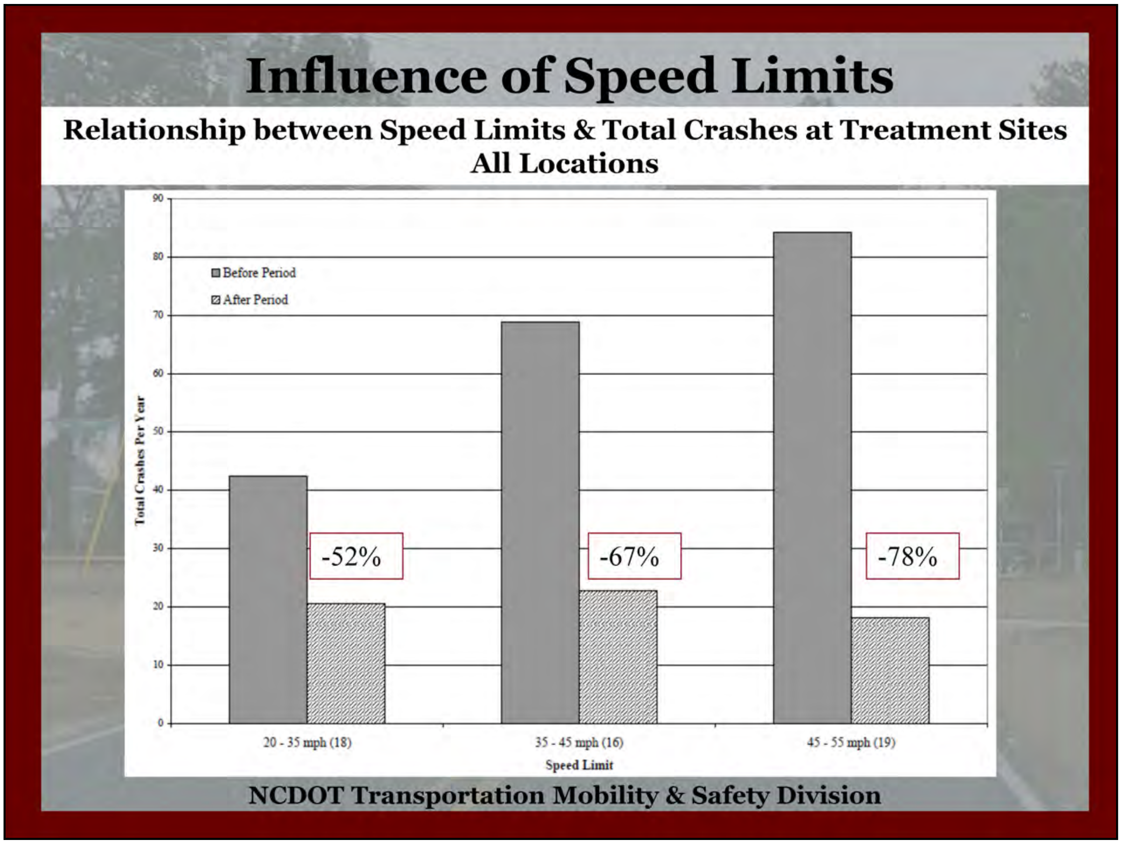
•This location is Bethany Rd at Freedom Mill Rd in a rural area of Gaston County. It has approaching speed limits of 45 mph, an entering AADT of 5100, and a 55/45 volume split. There are no flashers here.



•This location is Hopewell Church Rd at Welborn Rd near Trinity, which is in Randolph County. It has approaching speed limits of 50-55 mph, an entering AADT of 5000, and a 64/36 volume split. An overhead flasher was installed with the project. It's located adjacent to an elementary school.



•The last location is Shannon Rd at Old Lowery Rd in a rural area of Robeson County. It has approaching speed limits of 55 mph, an entering AADT of 3400, and a 60/40 volume split. An overhead flasher was installed several months after the all-way stop.



•One of our objectives was to determine what role speed limits approaching the intersection play in the crash reductions.

•We had 18 low speed sites, 16 moderate speed sites, and 19 high speed sites.

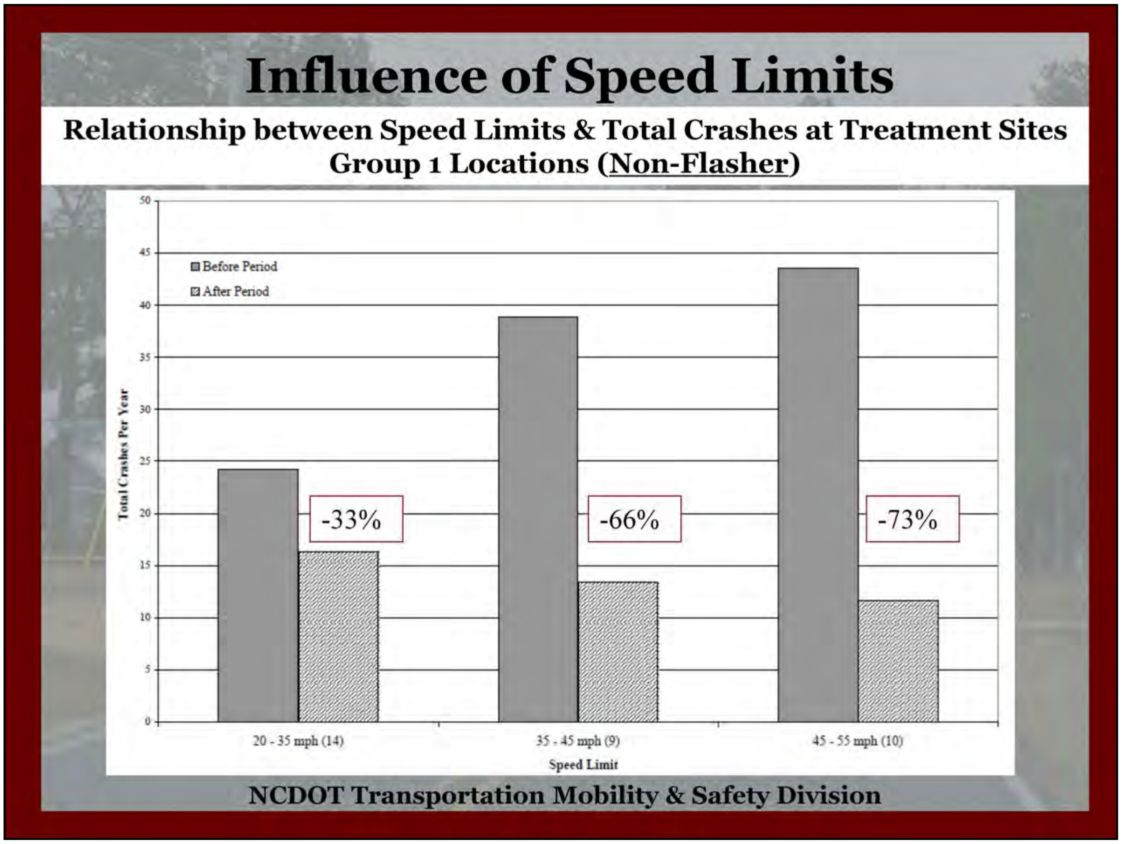
•When analyzing all sites, what we found was that the intersections with higher approach speeds were experiencing greater crash reductions after conversion to all-way stop. The crash reductions went from around 50 percent in the low speed sites to near 80 percent at the higher speed sites. We were curious why this was happening, so we checked to see if the presence of flashers was the skewing data, since a majority of sites with flashers were in the moderate/high speed limit ranges. So we next looked at the relationship between approach speeds and crash reductions just at sites without flashers.

Definition:

low speed sites (with speed limits of 20 to 35 mph on all approaches),

moderate speed sites (with speed limits of 35 to 45 mph on all approaches and at least one approach greater than 35 mph), and

high speed sites (with speed limits of 45 to 55 mph on all approaches and at least one approach greater than 45 mph).



•What we found is that the relationship between speed limits & crash reductions holds true for the non-flasher data set. So, it seems that it's not specifically presence of flashers that can explain why intersections with higher approach speeds experienced greater crash reductions.

•At non-flasher sites, the crash reductions went from around 30 percent in the low speed sites to around 70 percent at the higher speed sites.

We think some other intersection characteristics contributed to the difference in crash reductions between the higher & lower speed limit sites:

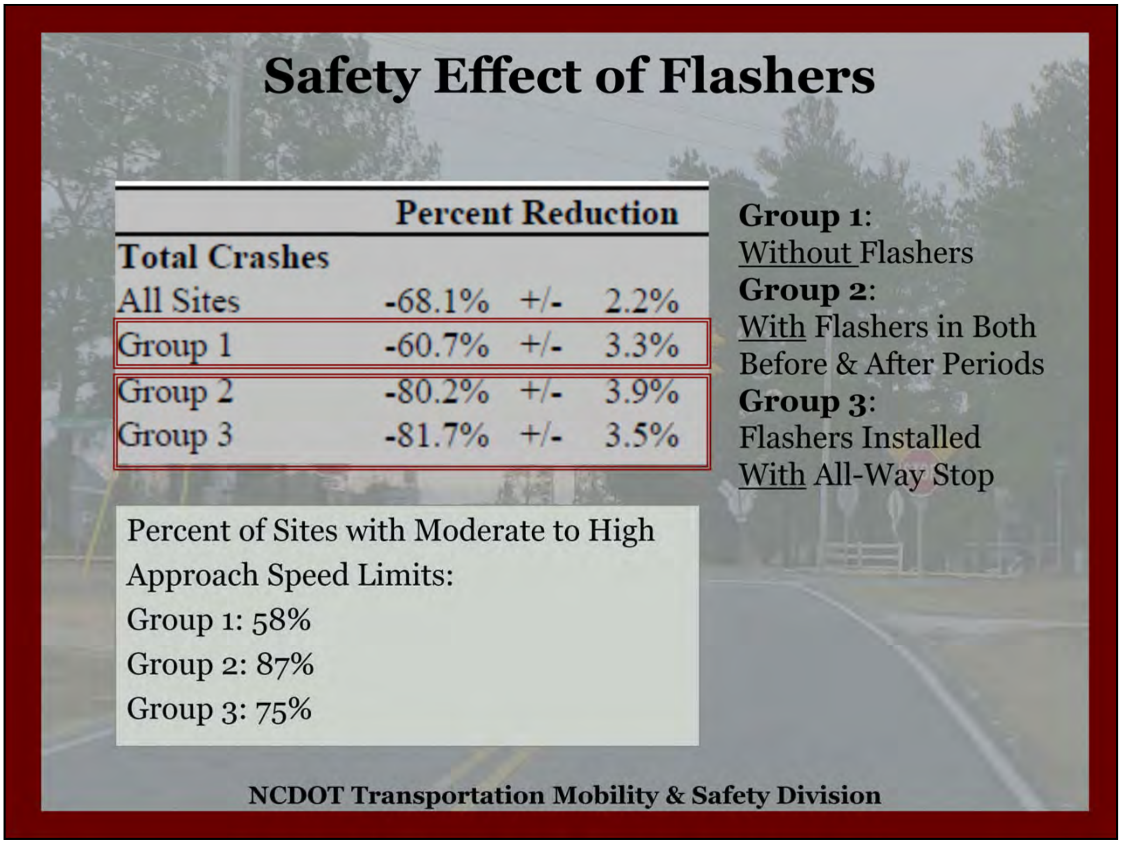
•A high percentage of the moderate to high speed sites had additional signing and marking treatments to supplement the stop signs. For example, all of the moderate and high speed limit sites had "stop ahead" signs, while only about half of the low speed sites had this treatment.

•Greater crash reductions at higher speed sites may be attributed to the more visible all-way stop condition created by a combination of treatments such as oversized stop signs, dual stop signs, advanced warning signs, "stop ahead" pavement markings, stop bars, etc.

•Here is a prime example of a rural, 45-mph non-flasher location with a very visible all-way stop condition created by additional signing and marking. These photos were taken 2 weeks after installation. At the time, the converted approaches had DMS, "New Traffic Pattern" Signs and two Sets of Stop Ahead Signs with flagging, Stop Ahead Pavement markings, stop bars, Stop marking, and dual stop signs.

•This site is Cornwallis at Josephine/ Shiloh in Johnston Co., which we will discuss in more detail later in the presentation.

•*(In 1 year, 3 months after conversion, there have been 3 crashes – none occurred within 2 months post installation.)*

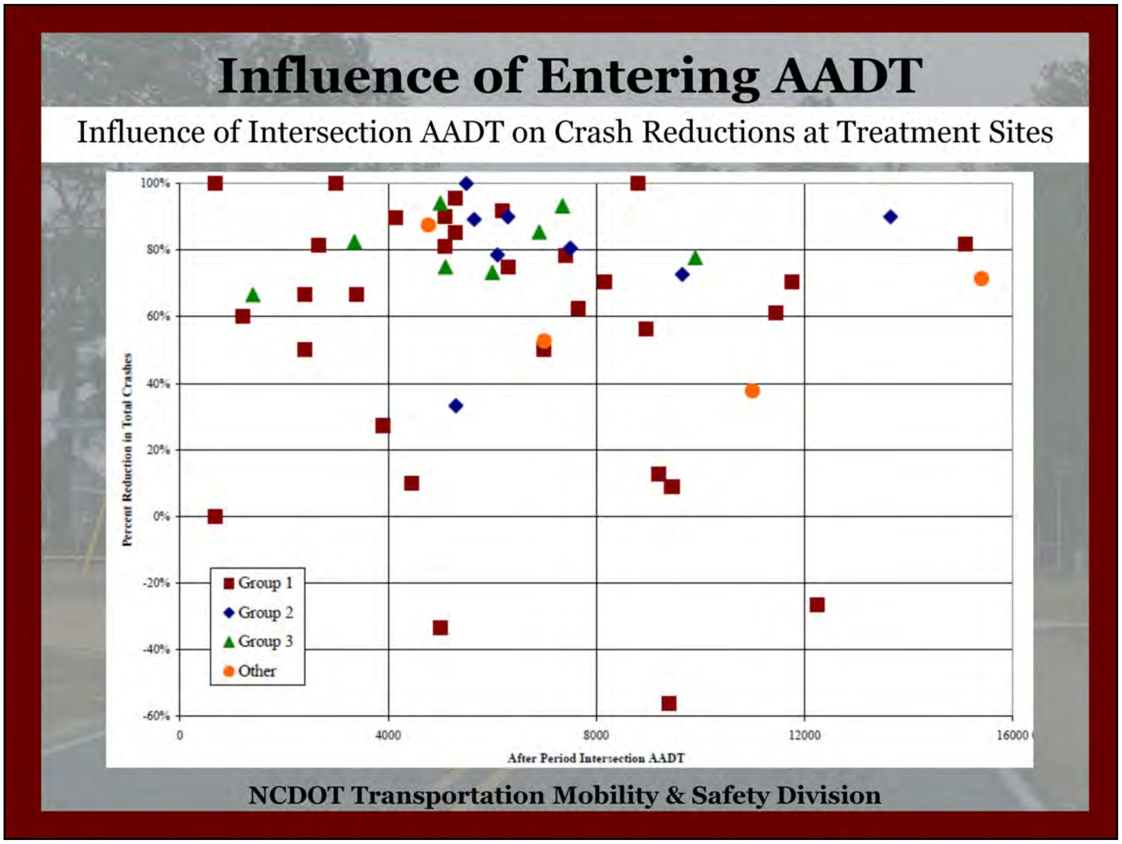


•Another objective was to determine if there was a difference in crash reductions when all-way stop intersections are equipped with a flasher.

•Looking at the crash data, it appears that the groups with flashers (Groups 2 and 3) performed much better than those without.

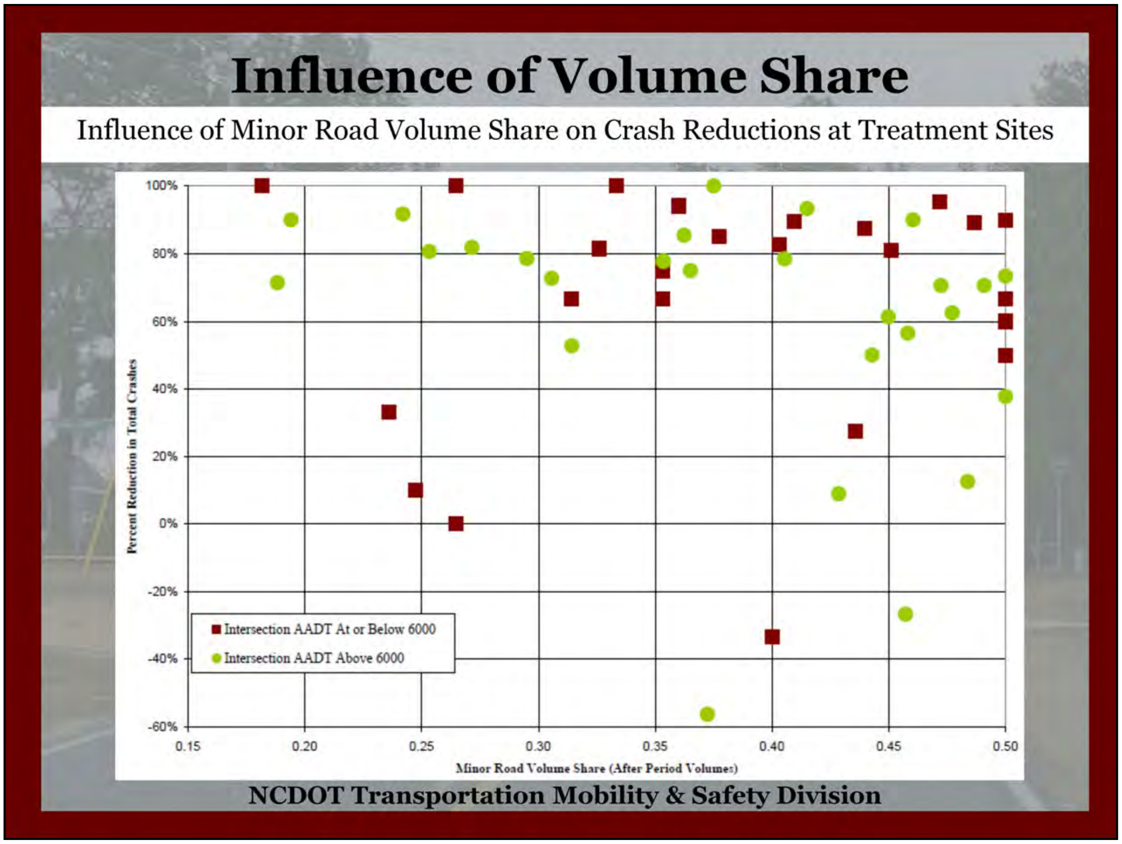
•However, this gap is likely affected by the higher percentage of high speed sites in Groups 2 and 3 that we just discussed (*87% of Group 2 sites and 75% of Group 3 sites had approach speed limits in the moderate and high ranges, while only 58% of Group 1 sites had approach speeds within these ranges*).

•We found that sites with higher speed limits generally had higher crash reductions due to an overall greater awareness of the all-way stop control through enhanced signing and marking. It seems plausible that differences in crash reductions at flasher vs. non-flasher sites may be influenced as much by these other factors. I don't think we can attribute all of the additional crash benefit exclusively to presence of flashers.



•Another objective was to determine at what ADT range conversion to all-way stop is effective. At our sites, intersection volumes varied from 680 - 15,400 entering vehicles/day in the after period, with the average ADT for all locations being about 6,400 entering veh/day.

•This figure is a scatter plot of the after period intersection ADT versus percent reduction in total crashes for all locations. There is no apparent trend between entering volumes and crash reductions. Our analysis shows all-way stop conversion is consistently effective at a wide range of intersection volumes, and can be just as effective at higher entering volumes as it is at lower.



•Another objective was to determine if all-way stop control has more safety benefit when the approach volumes are nearly equal.

•At our sites, the minor road volume share varied from 18 to 50% of the total entering volume.

•This figure shows that there is no evidence to suggest that approach volumes have to be nearly equal for the countermeasure to be effective.

•The sites are divided into higher and lower volume groups on the graph using 6,000 entering vehicles per day (The red squares are the lower volume sites and the green dots are the higher volume sites). The results were similar whether the intersection volumes are lower or higher. The all-way stop control was still effective when intersection volumes were unbalanced between the minor and major approaches.

Typical Installation Cost

ALL-WAY STOP INSTALLATION COST

SIGNING COST	Price/Unit	Unit	Total
Two Transportation Workers (per hour)	$55.10	4	$220
Sign Truck (per hour)	$32.13	4	$129
48" stop sign (per sign)	$119.45	4	$478
48" stop ahead sign (per sign)	$162.25	4	$649
36"x12" all-way plaque (per sign)	$27.21	8	$218
12 ft. U-channel post (per post)	$27.55	16	$441
			$2,134

MARKING COST	Price/Unit	Unit	Total
Labor	$55.10	4	$220
Equipment	$37.40	1	$37
Two Stop Bar Pack	$127.80	1	$128
Stop Symbols	$190.70	2	$381
Ahead Symbols	$264.60	2	$529
			$1,296

PE Cost	$1,000
NON-FLASHER TOTAL (LOW END)	**$4,430** **<= Round Up to $5,000**
FLASHER (INSTALLATION / UPGRADES) TOTAL (HIGH END)	**$20,000**

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We obtained cost estimates on current signing and markings from Division 5 staff. These are the prices they've used in recent projects.

For an all-way stop without flashers, the estimated cost is in the $5,000 range. This includes using dual oversized stop signs, stop ahead signs, and stop ahead pavement markings on the converted approaches. When talking about converting existing flashers or adding new flashers overhead or on signs (at the very high end of what a conversion can cost) recent spot safety projects have been set up with up to $20,000.

Assumptions:

•*typically takes 2 workers 4 hours for installation*

•*assuming 4 new stop signs (dual posted on two approaches)*

•*assuming 4 new stop ahead signs (dual posted on two approaches)*

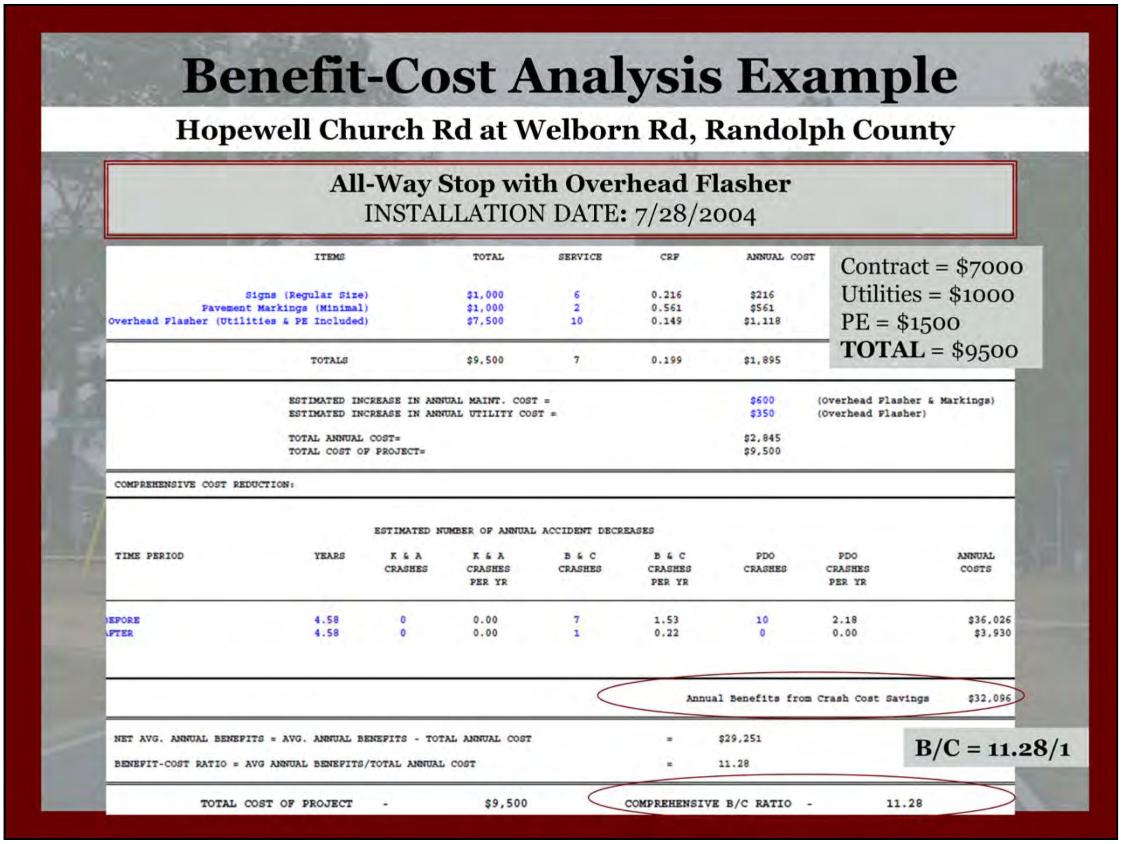
•*assuming 8 new all-way signs (dual posted on all approaches)*

•*assuming 8 new signs with 2 posts per sign (18 is number used on typical all-way stop installation)*

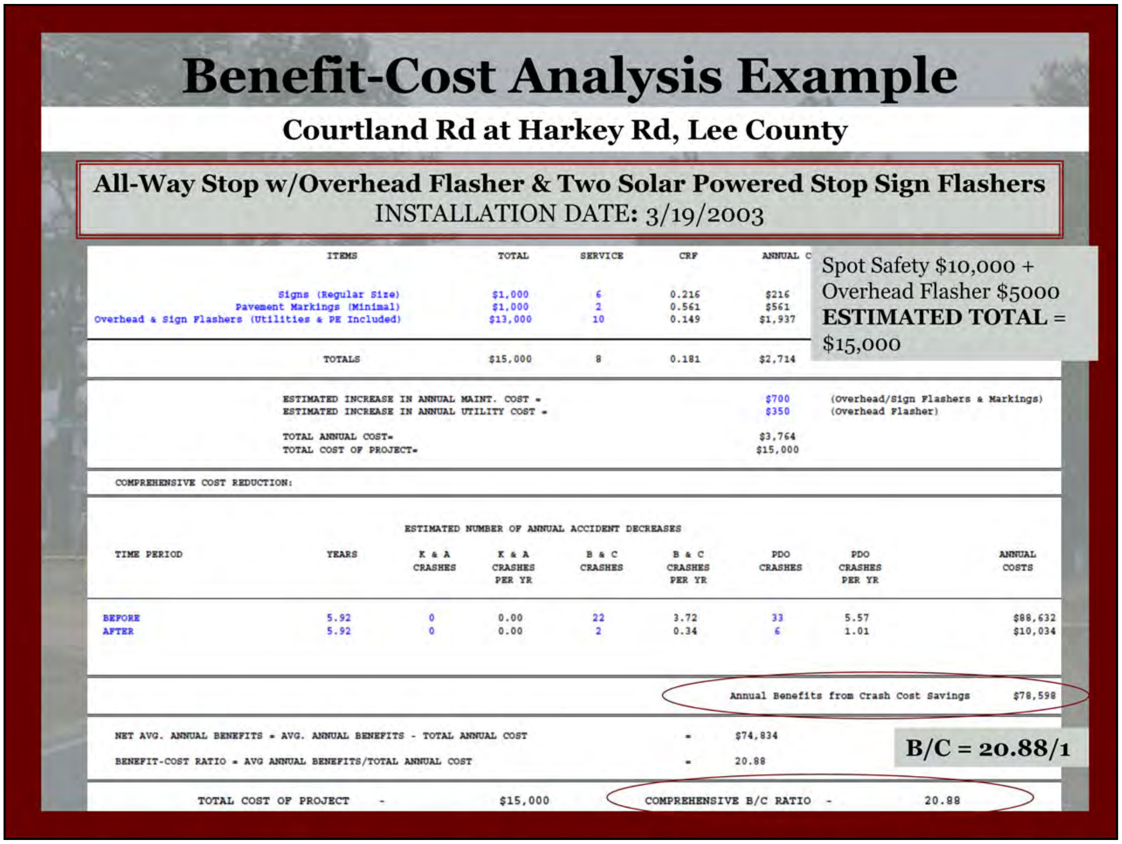
•*assuming stop bars needed for two approaches*

•*assuming stop ahead symbols needed on two approaches*

•*assuming stop ahead symbols needed on two approaches*



We ran benefit-cost examples using a few of the sites that we previously showed crash diagrams for. The first location we looked at is Hopewell Church Rd at Welborn Rd in Randolph County, which has approaching speed limits of 50-55 and an entering ADT of 5000. The treatment was to install an all-way stop with overhead flasher. It was completed in July 2004. From the spot safety project file, the estimated cost of signs, markings, and the flasher was $9500. There was a decrease in 6 injury crashes and 10 PDO crashes at the site, which gives us a B/C of about 11/1.



Benefit-Cost Analysis Example

Courtland Rd at Harkey Rd, Lee County

All-Way Stop w/Overhead Flasher & Two Solar Powered Stop Sign Flashers
INSTALLATION DATE: 3/19/2003

ITEMS	TOTAL	SERVICE	CRF	ANNUAL C
Signs (Regular Size)	$1,000	6	0.216	$216
Pavement Markings (Minimal)	$1,000	2	0.561	$561
Overhead & Sign Flashers (Utilities & PE Included)	$13,000	10	0.149	$1,937
TOTALS	$15,000	8	0.181	$2,714

Spot Safety $10,000 +
Overhead Flasher $5000
ESTIMATED TOTAL =
$15,000

ESTIMATED INCREASE IN ANNUAL MAINT. COST =	$700	(Overhead/Sign Flashers & Markings)
ESTIMATED INCREASE IN ANNUAL UTILITY COST =	$350	(Overhead Flasher)
TOTAL ANNUAL COST=	$3,764	
TOTAL COST OF PROJECT=	$15,000	

COMPREHENSIVE COST REDUCTION:

ESTIMATED NUMBER OF ANNUAL ACCIDENT DECREASES

TIME PERIOD	YEARS	K & A CRASHES	K & A CRASHES PER YR	B & C CRASHES	B & C CRASHES PER YR	PDO CRASHES	PDO CRASHES PER YR	ANNUAL COSTS
BEFORE	5.92	0	0.00	22	3.72	33	5.57	$88,632
AFTER	5.92	0	0.00	2	0.34	6	1.01	$10,034

Annual Benefits from Crash Cost Savings $78,598

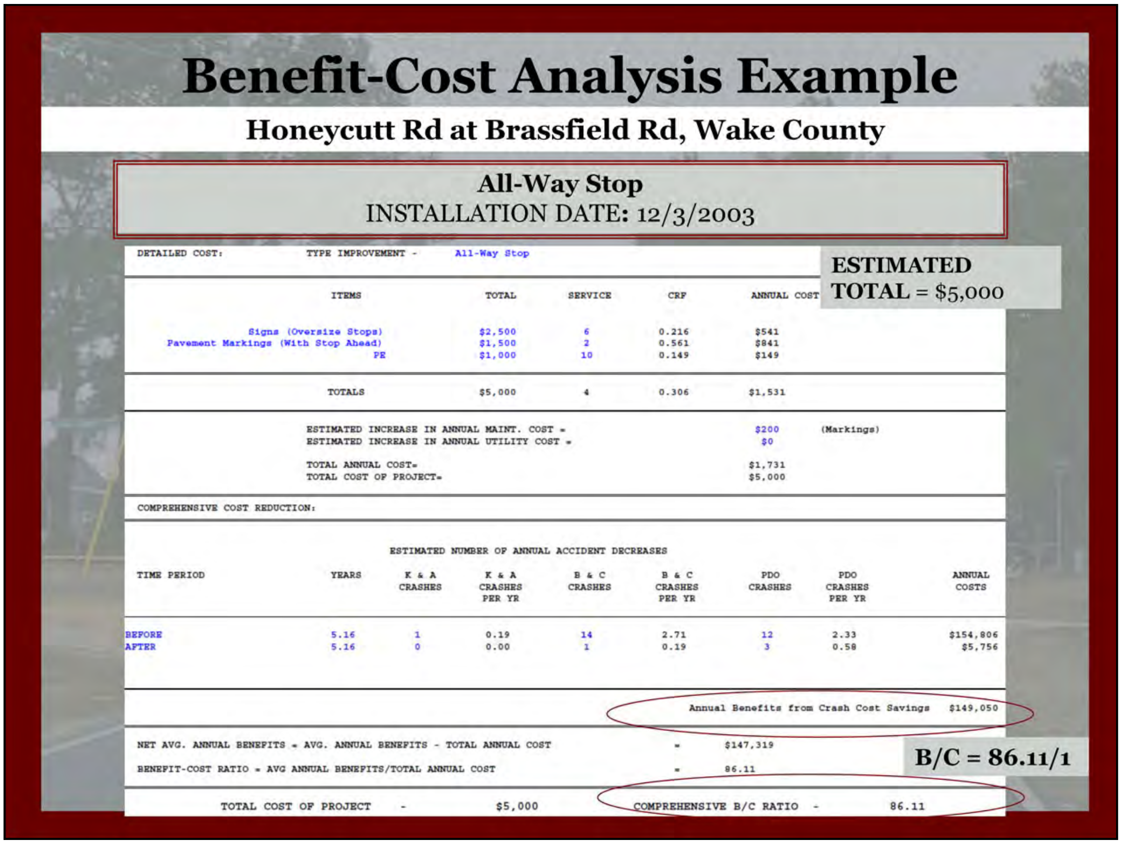
NET AVG. ANNUAL BENEFITS = AVG. ANNUAL BENEFITS - TOTAL ANNUAL COST = $74,834

BENEFIT-COST RATIO = AVG ANNUAL BENEFITS/TOTAL ANNUAL COST = 20.88

B/C = 20.88/1

TOTAL COST OF PROJECT - $15,000 COMPREHENSIVE B/C RATIO - 20.88

The next location is Courtland Rd at Harkey Rd in Lee County, which has approaching speed limits of 35 and an entering ADT of 6900. The treatment was to install an all-way stop with overhead flasher and two-solar powered stop sign flashers. It was completed in March 2003. From the spot safety project file, the estimated cost of Signs and Two Solar Powered Stop Sign Flashers was $6400, but was set up $10,000. There was no mention of funding the overhead flasher as part of the spot safety project, but I assumed an additional $5,000 for this – for a total cost of $15,000. There was a decrease in 20 injury crashes and 27 PDO crashes at the site, which gives us a B/C of almost 21/1.



The last location we did the B/C for is Honeycutt Rd at Brassfield Rd in Wake County, which has approaching speed limits of 45 and an entering ADT of 5300. The treatment was to install an all-way stop only, without flashers. It was completed in December 2003. I don't have the costs for this particular location, but used the $5,000 estimate from other recent non-flasher projects in Division 5. There was a decrease in 14 injury crashes and 9 PDO crashes at the site, which gives us a B/C of about 86/1.

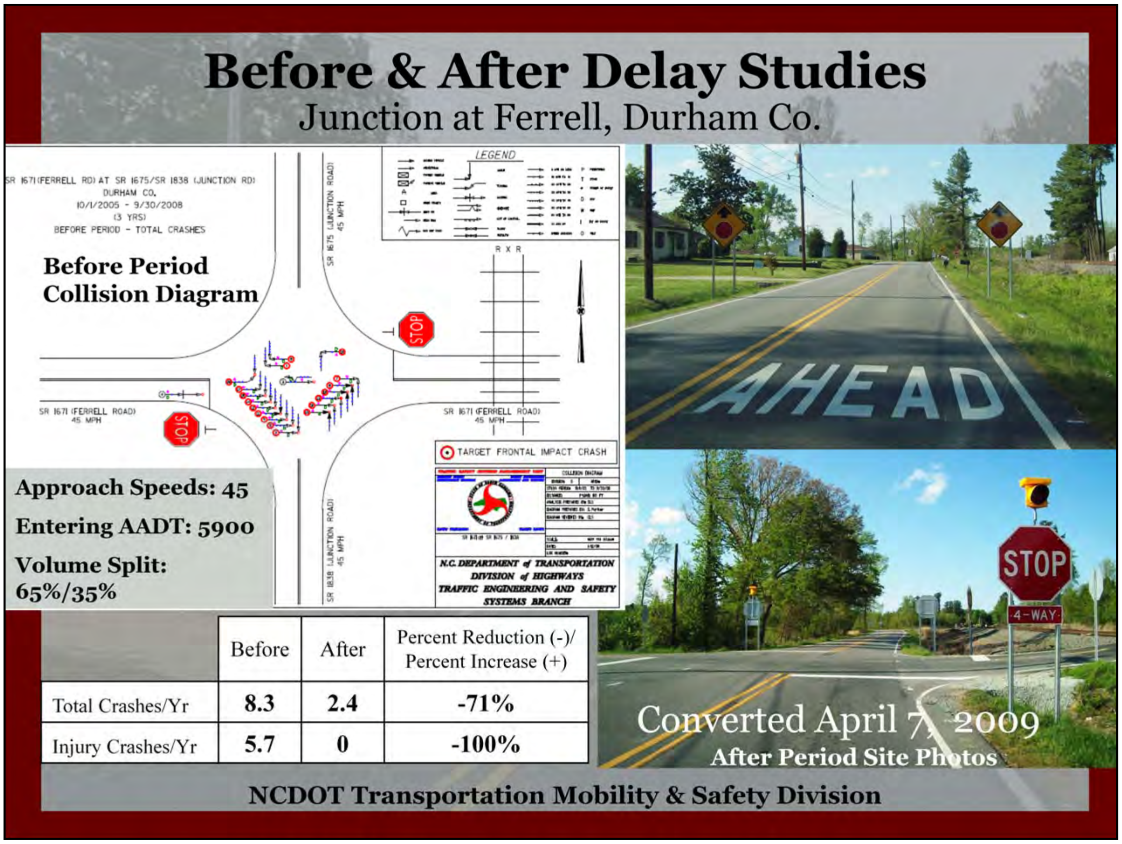
The benefit-cost analysis proves that these are extremely competitive projects. They can be funded quickly and hopefully implemented quickly as well.

We collected before and after field delay data at two locations that were recently converted:

•Junction at Ferrell in Durham Co. and

•Cornwallis at Josephine/ Shiloh in Johnston Co.

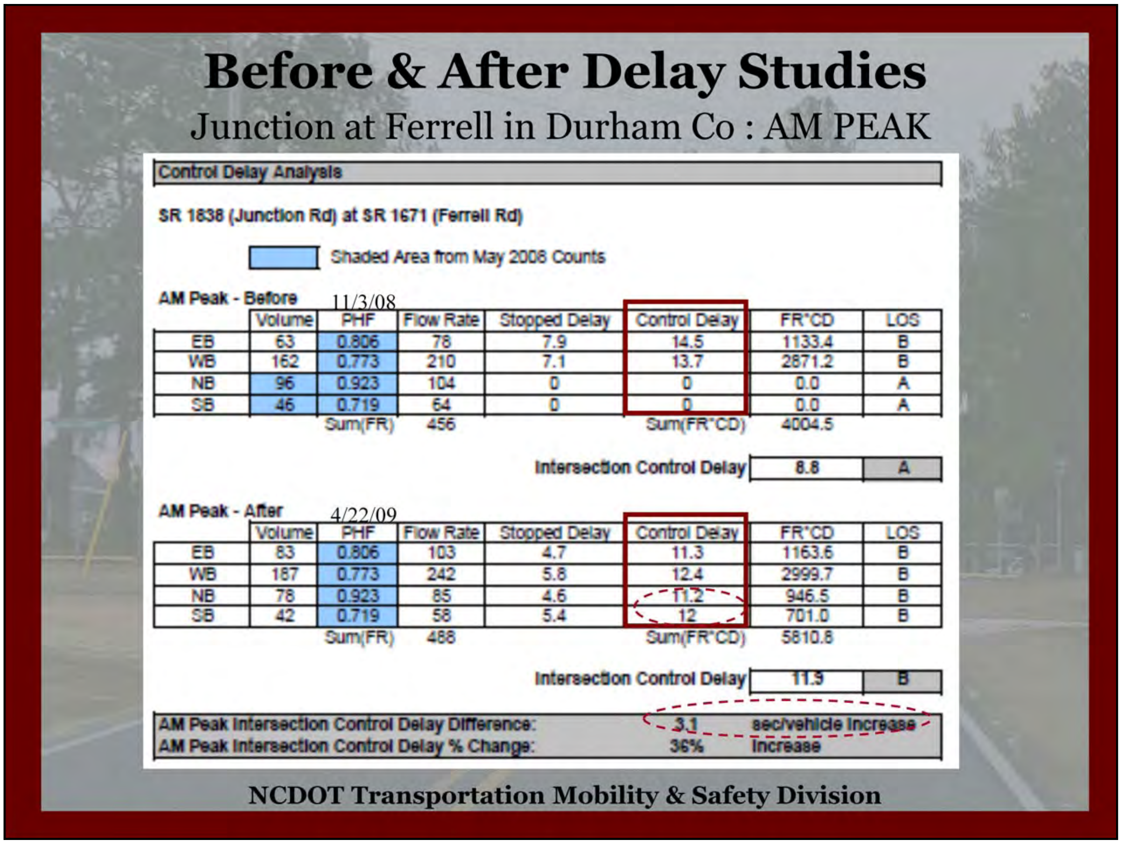
I want to note that these two locations were not a part of the 53-intersection evaluation because there was not enough after period data at the time to include them.



	Before	After	Percent Reduction (-)/ Percent Increase (+)
Total Crashes/Yr	8.3	2.4	-71%
Injury Crashes/Yr	5.7	0	-100%

The intersection of Junction at Ferrell was converted from two-way to all-way stop control on April 7, 2009. In the before period, there were 25 crashes in 3 years, or about 8.3 crashes per year (and included a fatality). In over 9 months after conversion, there have been 2 crashes, which equates to 2.4 crashes per year, for a 71 percent reduction in crashes. There were no injury crashes in the after period. The approach speeds are 45 mph, entering volume is 5900, and the minor road comprises 35% of the volume. (*With this location, the minor road was the through movement under two-way stop.)*

(Before: 3/1/06-2/28/09 and After: 4/7/08-1/31/10)



Before & After Delay Studies

Junction at Ferrell in Durham Co : AM PEAK

Control Delay Analysis

SR 1838 (Junction Rd) at SR 1671 (Ferrell Rd)

Shaded Area from May 2008 Counts

AM Peak - Before 11/3/08

	Volume	PHF	Flow Rate	Stopped Delay	Control Delay	FR*CD	LOS
EB	63	0.806	78	7.9	14.5	1133.4	B
WB	162	0.773	210	7.1	13.7	2871.2	B
NB	96	0.923	104	0	0	0.0	A
SB	46	0.719	64	0	0	0.0	A
		Sum(FR)	456		Sum(FR*CD)	4004.5	

Intersection Control Delay 8.8 A

AM Peak - After 4/22/09

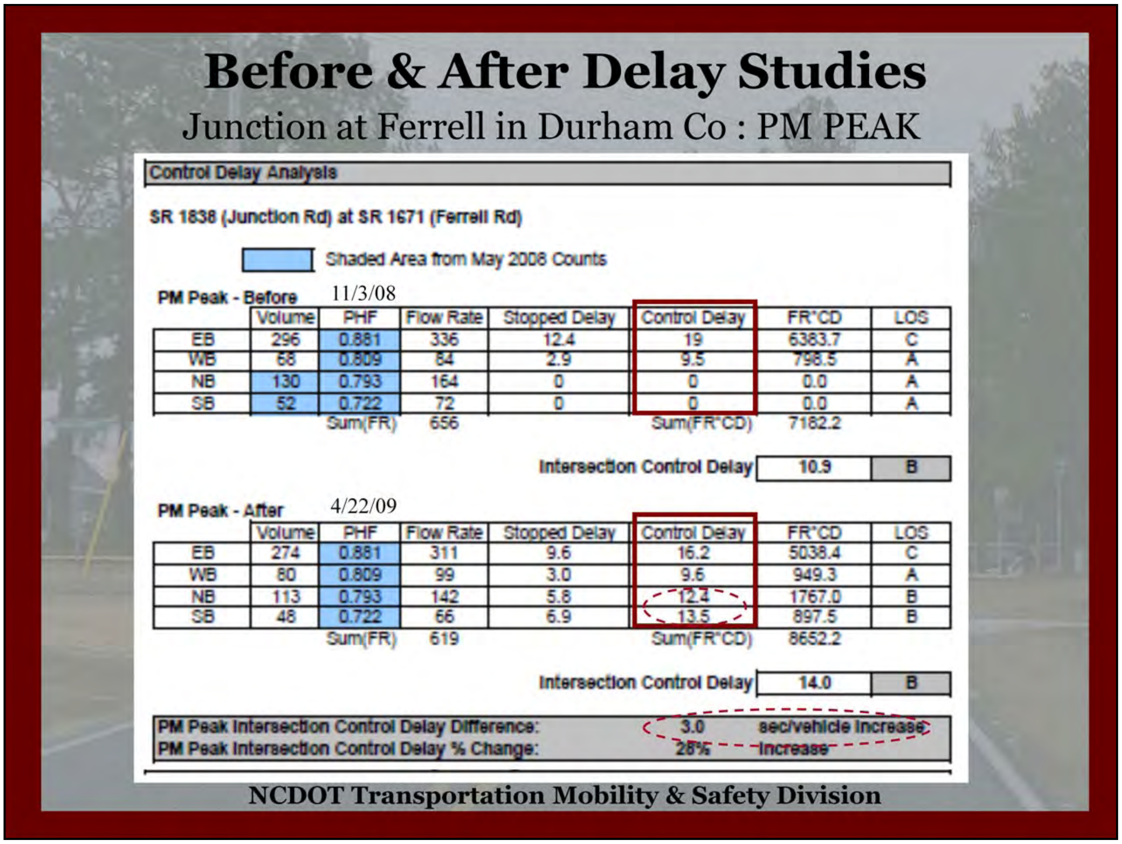
	Volume	PHF	Flow Rate	Stopped Delay	Control Delay	FR*CD	LOS
EB	83	0.806	103	4.7	11.3	1163.6	B
WB	187	0.773	242	5.8	12.4	2999.7	B
NB	78	0.923	85	4.6	11.2	946.5	B
SB	42	0.719	58	5.4	12	701.0	B
		Sum(FR)	488		Sum(FR*CD)	5810.8	

Intersection Control Delay 11.9 B

AM Peak Intersection Control Delay Difference: 3.1 sec/vehicle increase
AM Peak Intersection Control Delay % Change: 36% increase

NCDOT Transportation Mobility & Safety Division

In the after period, the all-way stop spread the delay across all approaches of the intersection. The average intersection delay increased by 3 seconds per vehicle. In the AM Peak there is a slight decrease in delay for the minor street but a 11-12 second delay for the major street approaches after conversion.



Before & After Delay Studies

Junction at Ferrell in Durham Co : PM PEAK

Control Delay Analysis

SR 1838 (Junction Rd) at SR 1671 (Ferrell Rd)

Shaded Area from May 2008 Counts

PM Peak - Before 11/3/08

	Volume	PHF	Flow Rate	Stopped Delay	Control Delay	FR*CD	LOS
EB	296	0.881	336	12.4	19	6383.7	C
WB	68	0.809	84	2.9	9.5	798.5	A
NB	130	0.793	164	0	0	0.0	A
SB	52	0.722	72	0	0	0.0	A
		Sum(FR)	656		Sum(FR*CD)	7182.2	

Intersection Control Delay 10.9 B

PM Peak - After 4/22/09

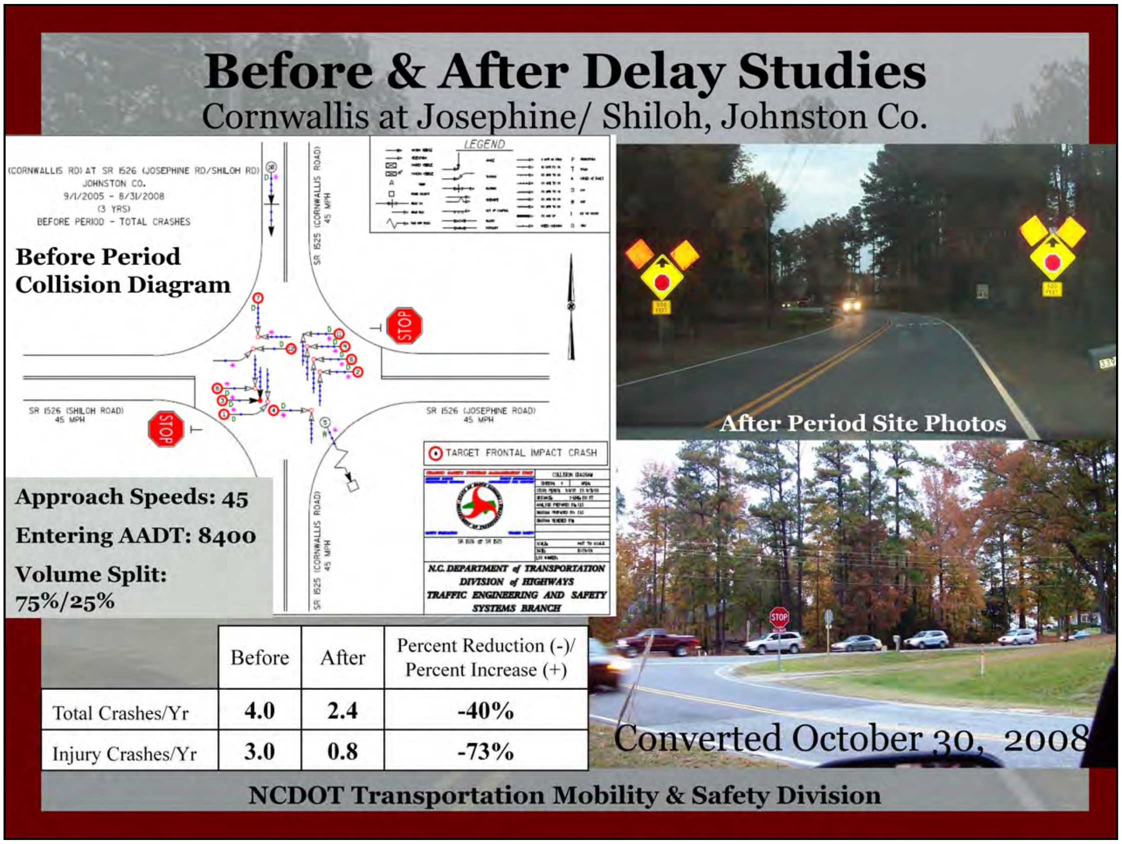
	Volume	PHF	Flow Rate	Stopped Delay	Control Delay	FR*CD	LOS
EB	274	0.881	311	9.6	16.2	5038.4	C
WB	80	0.809	99	3.0	9.6	949.3	A
NB	113	0.793	142	5.8	12.4	1767.0	B
SB	48	0.722	66	6.9	13.5	897.5	B
		Sum(FR)	619		Sum(FR*CD)	8652.2	

Intersection Control Delay 14.0 B

PM Peak Intersection Control Delay Difference:	3.0	sec/vehicle increase
PM Peak Intersection Control Delay % Change:	28%	increase

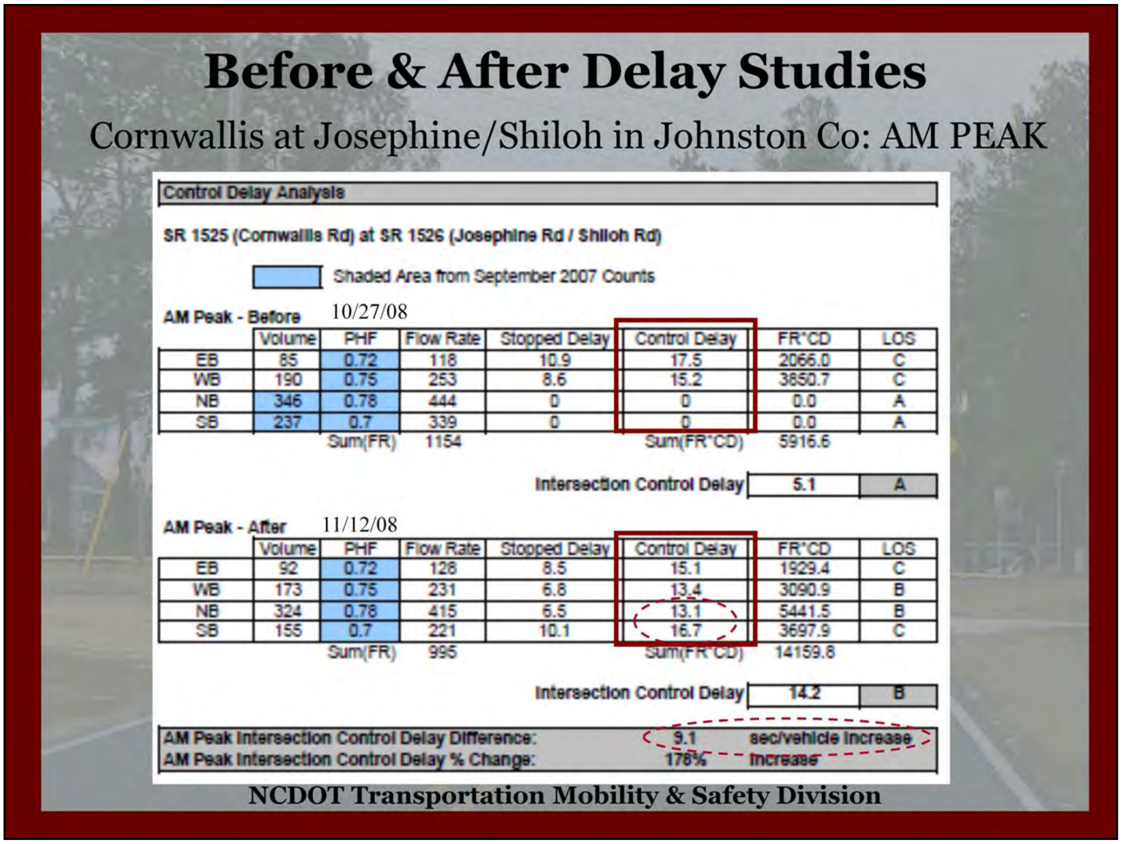
NCDOT Transportation Mobility & Safety Division

Again, in the PM Peak there is an increase in delay for the major street. And, the average intersection delay increased by 3 seconds per vehicle. But, we feel that in most cases, these small increases in delay are worth the substantially improved safety.



The intersection of Cornwallis at Josephine and Shiloh was converted from two-way to all-way stop control on October 30, 2008. In the before period, there were 12 crashes in 3 years, or 4 crashes per year (and included a fatality). In 1 year, 3 months after conversion, there have been 3 crashes, which equates to 2.4 crashes per year, for a 40 percent reduction in crashes. There was a 73% reduction in injury crashes, with 1 Class-C injury crash in the after period. The approach speeds are 45 mph, entering volume is 8400, and the minor road comprises 25% of the volume.

(Before: 9/1/05-8/31/08 and After: 10/30/08-1/31/10)



Before & After Delay Studies

Cornwallis at Josephine/Shiloh in Johnston Co: AM PEAK

Control Delay Analysis

SR 1525 (Cornwallis Rd) at SR 1526 (Josephine Rd / Shiloh Rd)

Shaded Area from September 2007 Counts

AM Peak - Before 10/27/08

	Volume	PHF	Flow Rate	Stopped Delay	Control Delay	FR*CD	LOS
EB	85	0.72	118	10.9	17.5	2066.0	C
WB	190	0.75	253	8.6	15.2	3850.7	C
NB	346	0.78	444	0	0	0.0	A
SB	237	0.7	339	0	0	0.0	A
		Sum(FR)	1154		Sum(FR*CD)	5916.6	

Intersection Control Delay 5.1 A

AM Peak - After 11/12/08

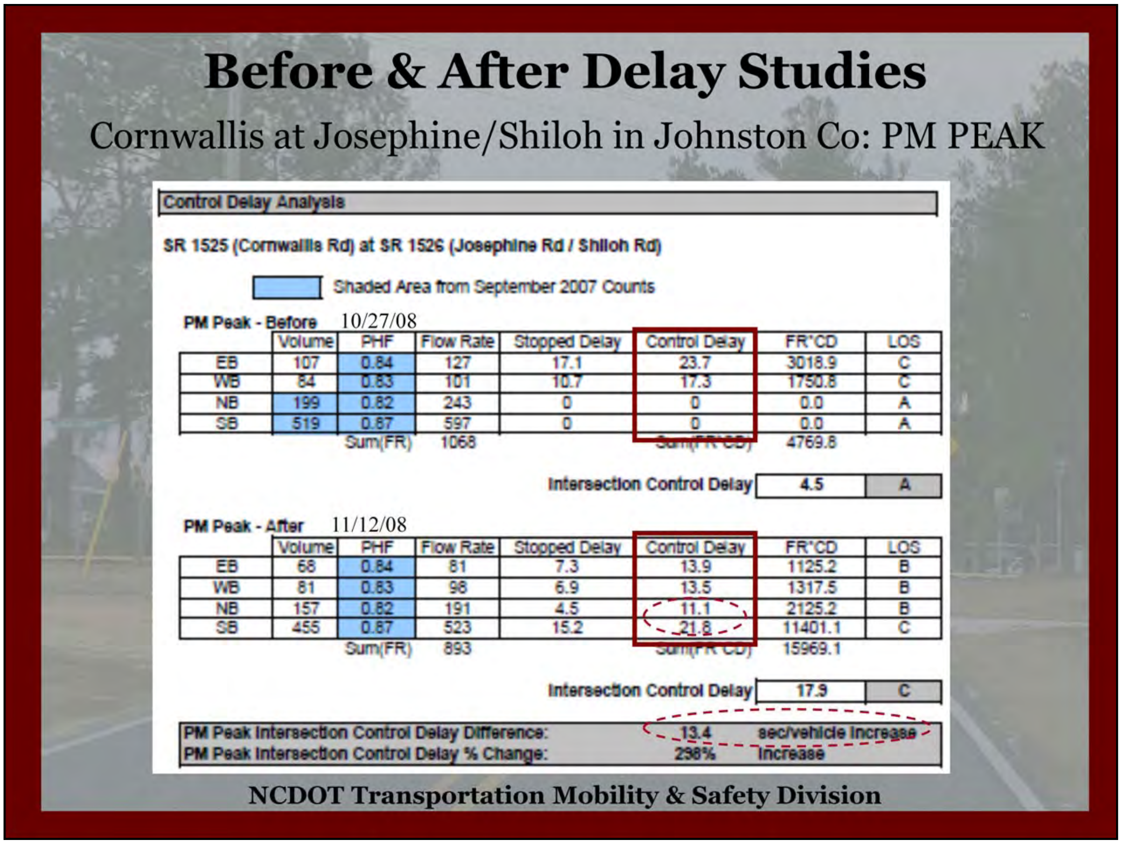
	Volume	PHF	Flow Rate	Stopped Delay	Control Delay	FR*CD	LOS
EB	92	0.72	128	8.5	15.1	1929.4	C
WB	173	0.75	231	6.8	13.4	3090.9	B
NB	324	0.78	415	6.5	13.1	5441.5	B
SB	155	0.7	221	10.1	16.7	3697.9	C
		Sum(FR)	995		Sum(FR*CD)	14159.8	

Intersection Control Delay 14.2 B

AM Peak Intersection Control Delay Difference:	9.1	sec/vehicle increase
AM Peak Intersection Control Delay % Change:	178%	increase

NCDOT Transportation Mobility & Safety Division

At this location, there was a greater increase in the average intersection delay, which increased by 9 seconds per vehicle. In the AM Peak there is a slight decrease in delay for the minor street but a 13-16 second delay for the major street after conversion.



Control Delay Analysis

SR 1525 (Cornwallis Rd) at SR 1526 (Josephine Rd / Shiloh Rd)

Shaded Area from September 2007 Counts

PM Peak - Before 10/27/08

	Volume	PHF	Flow Rate	Stopped Delay	Control Delay	FR*CD	LOS
EB	107	0.84	127	17.1	23.7	3018.9	C
WB	84	0.83	101	10.7	17.3	1750.8	C
NB	199	0.82	243	0	0	0.0	A
SB	519	0.87	597	0	0	0.0	A
		Sum(FR)	1068		Sum(FR*CD)	4769.8	
					Intersection Control Delay	4.5	A

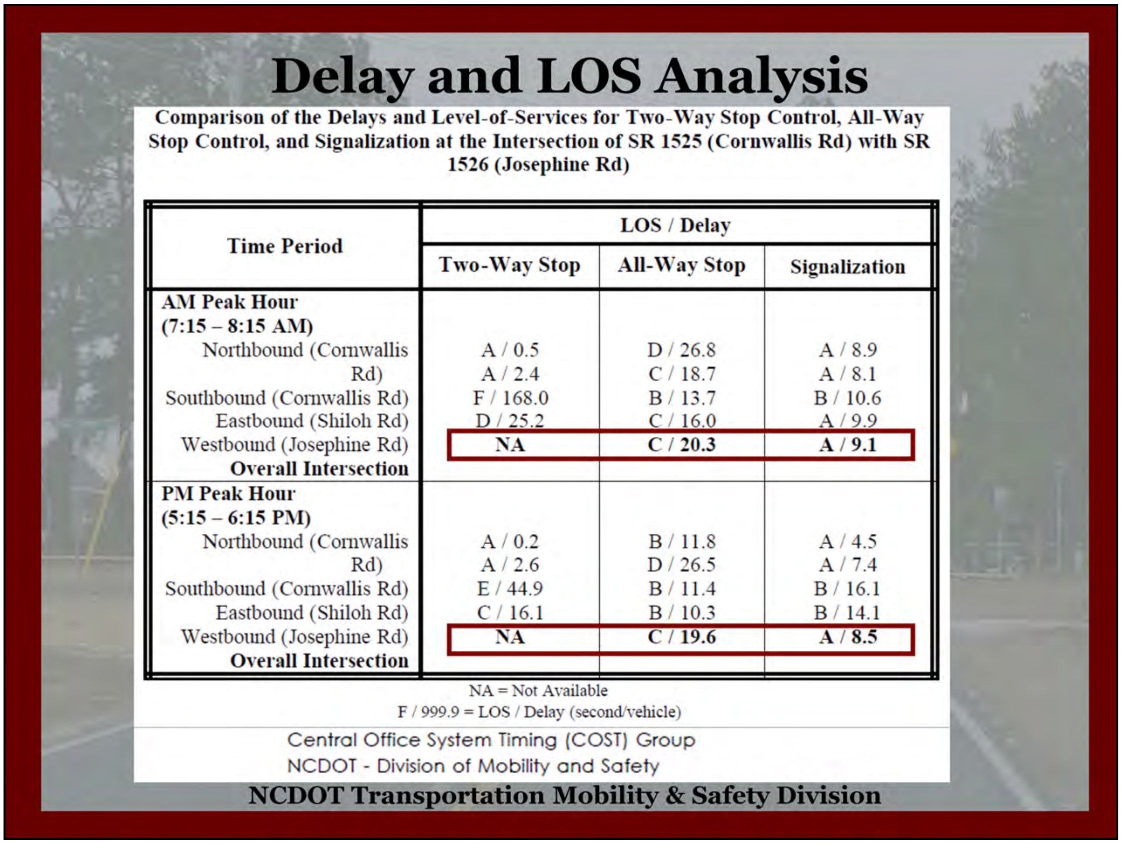
PM Peak - After 11/12/08

	Volume	PHF	Flow Rate	Stopped Delay	Control Delay	FR*CD	LOS
EB	68	0.84	81	7.3	13.9	1125.2	B
WB	81	0.83	98	6.9	13.5	1317.5	B
NB	157	0.82	191	4.5	11.1	2125.2	B
SB	455	0.87	523	15.2	21.8	11401.1	C
		Sum(FR)	893		Sum(FR*CD)	15969.1	
					Intersection Control Delay	17.9	C

PM Peak Intersection Control Delay Difference:	13.4	sec/vehicle Increase
PM Peak Intersection Control Delay % Change:	298%	Increase

•In the PM Peak there was a more substantial in decrease in delay for the minor street but an 11-22 second delay for the major street after converred. And, the average intersection delay increased by over 13 seconds per vehicle.

•Again, these are our observational data we collected by hand for two peak hours of the day.



Delay and LOS Analysis

Comparison of the Delays and Level-of-Services for Two-Way Stop Control, All-Way Stop Control, and Signalization at the Intersection of SR 1525 (Cornwallis Rd) with SR 1526 (Josephine Rd)

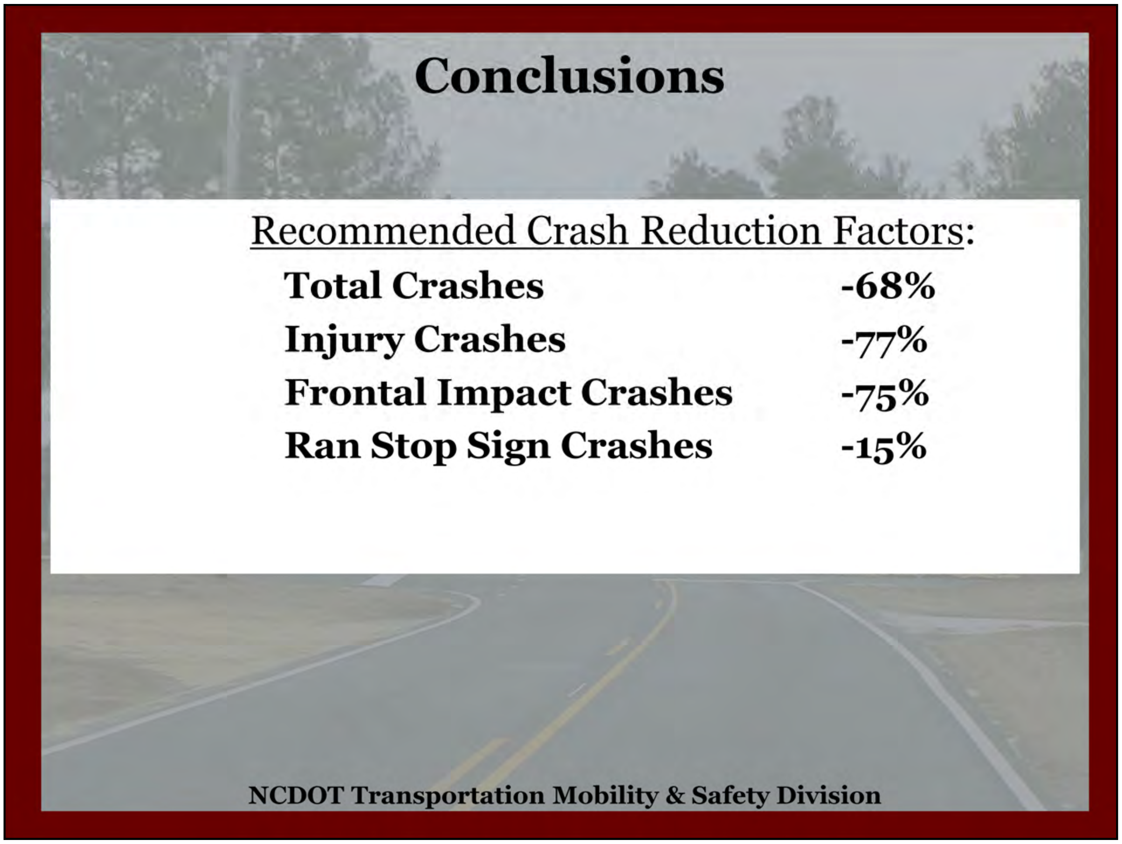
Time Period	LOS / Delay		
	Two-Way Stop	All-Way Stop	Signalization
AM Peak Hour (7:15 – 8:15 AM)			
Northbound (Cornwallis	A / 0.5	D / 26.8	A / 8.9
Rd)	A / 2.4	C / 18.7	A / 8.1
Southbound (Cornwallis Rd)	F / 168.0	B / 13.7	B / 10.6
Eastbound (Shiloh Rd)	D / 25.2	C / 16.0	A / 9.9
Westbound (Josephine Rd)	**NA**	**C / 20.3**	**A / 9.1**
Overall Intersection			
PM Peak Hour (5:15 – 6:15 PM)			
Northbound (Cornwallis	A / 0.2	B / 11.8	A / 4.5
Rd)	A / 2.6	D / 26.5	A / 7.4
Southbound (Cornwallis Rd)	E / 44.9	B / 11.4	B / 16.1
Eastbound (Shiloh Rd)	C / 16.1	B / 10.3	B / 14.1
Westbound (Josephine Rd)	**NA**	**C / 19.6**	**A / 8.5**
Overall Intersection			

NA = Not Available
F / 999.9 = LOS / Delay (second/vehicle)

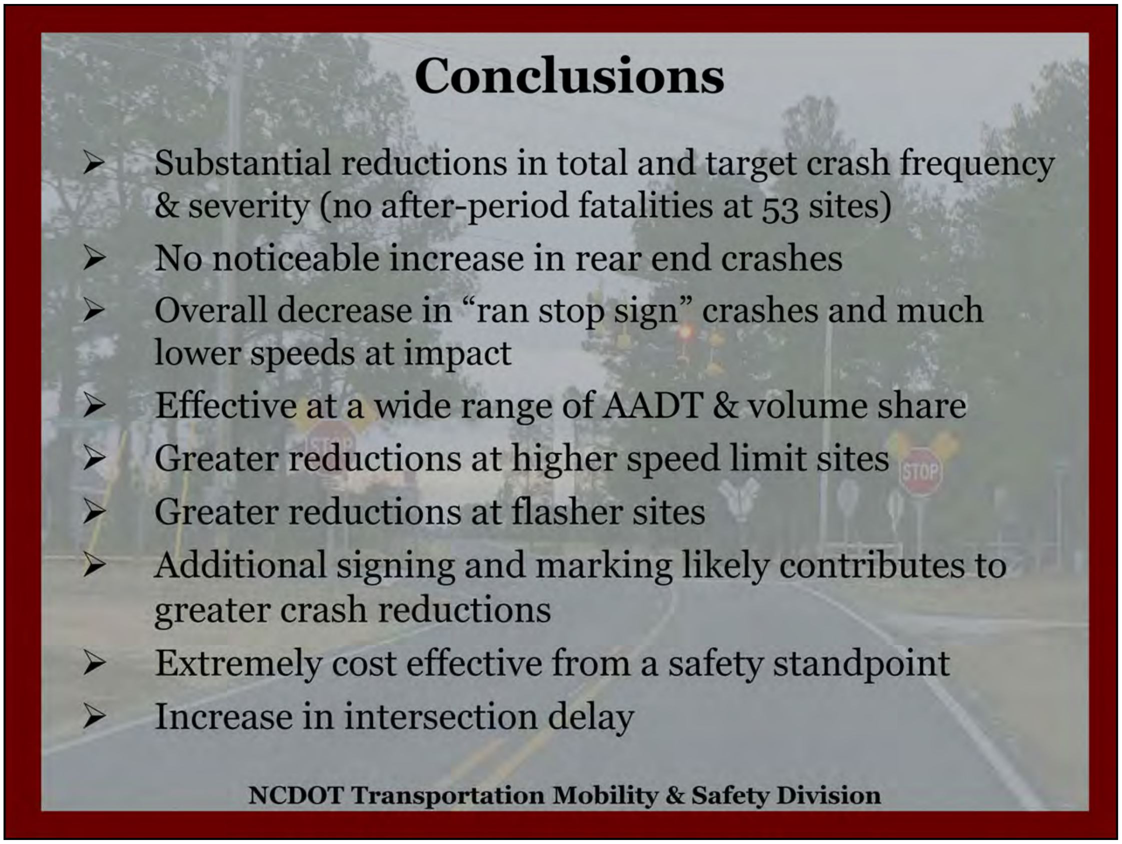
Central Office System Timing (COST) Group
NCDOT - Division of Mobility and Safety

NCDOT Transportation Mobility & Safety Division

•We wanted to also compare how this intersection would operate under signalized control. Using past traffic counts, we had the Central Office System Timing Section compare the delay and LOS of the intersection under two-way stop, all-way stop, and signalization using a modeled approach. Our field measurements for the all-way stop turned out better than these modeled estimates. As you can see, using the models, there is about 11 seconds more overall intersection delay under all-way stop control versus signalization for the two peak hours of the day.



Again, here are the recommended crash reduction factors. These numbers use data from the overall group of 53 locations, regardless of whether a flasher is present or whether the intersection is rural, low volume and high speed or urban, higher volume and low speed. The overall conclusion is based on the most expansive group to provide the widest scope possible.



- These are our conclusions from the study:
- Injury and frontal impact crashes especially benefited from the treatment. There were 10 fatal crashes before and none after at our treated sites.
- Based on our study findings, you'll not likely see a significant increase in rear end crashes.
- There was an overall decrease in ran stop sign crashes and we specifically found a substantial decrease in vehicle speeds at impact in "ran stop sign" crashes.
- The conversion to all-way stop control was consistently effective at a wide range of intersection volumes, and can be just as effective at higher entering volumes as it is at lower. It can also be as effective when intersection volumes are unbalanced between the minor and major approaches as when they are nearly equal. Of course, this does not mean that volumes play no part in the safety of all-way stop controlled intersections, only that in our sample there was no apparent trend between these volume characteristics and crash reductions.
- There were greater crash reductions at the higher speed treatment sites, which held true when analyzing sites with or without flashing beacons. We concluded that many more of the sites with moderate and high speed limits utilize a combination of additional signing and marking treatments to emphasize the all-way stop condition, which likely contributed to the greater crash reduction.
- There were greater reductions at the flasher sites, although all of the additional crash benefit may not be exclusively attributed to presence of flashers. Some of the difference in crash reductions may be attributed to the large percentage of high speed sites with additional signing and marking as much as to the presence of flashers.
- We're doing a great job of alerting motorists of the all-way stop condition and we need to keep it up. Additional signing and marking likely contributes to some of the greater crash reductions.
- As the Benefit Cost example prove, it is extremely cost effective from a safety standpoint.
- And finally, you'll most likely see an increase in the average intersection delay as the all-way stop spreads delay across all approaches of the intersection. We can investigate the delay aspect more if you provide us with locations before they are converted so we can do more before and after delay studies for a wider range of ADTs and volume share.


QUESTIONS?
Presentation & Report Soon Available at
http://www.ncdot.org/doh/preconstruct/traffic/safety/Reports/completed.html
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