EVALUATION OF INNOVATIVE SAFETY TREATMENTS

Volume 6: A Study of the Effectiveness of In-roadway Lights

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16. Abstract

The Florida Department of Transportation (FDOT) District 4 Traffic Operations Office installed a series of in-roadway lights in November 2004 along the off-ramp from southbound I-95 to westbound State Road 84 (SR 84), in an effort to reduce travel speeds and improve motorist safety. The exit ramp is relatively long, approximately 2000 feet in length. As such, drivers tend to travel at a relatively high speed even after exiting the interstate. This one-lane ramp operates as a free-flow right-turn-only lane, which then merges with westbound SR 84. The turning radius for this right turn is very small requiring drivers to slow down to 10 miles per hour. A total of 41 crashes occurred at this intersection during the three-year period from 2001 to 2003. It appears that some southbound drivers on the ramp approach this intersection at a high rate of speed, often misjudge the ramp geometry, miss the merge lane due to the wide turn associated with excessive speed and encroach into the path of oncoming westbound traffic on SR 84. The in-roadway lights were installed to alert motorists of the approaching sharp right turn at SR 84, so that drivers would reduce their speed in order to negotiate the right turn safely. The in-roadway lights were linked with a speed detection system, which would detect the speed of the approaching vehicle and activate the in-roadway lights when the detected speed is above the pre-set speed of 50 miles per hour (mph). The in-roadway lights were operated in such a way that they create a 'strobing' effect towards the approaching driver to give the motorist the perception that he/she is speeding. It is anticipated that in-roadway lights would reduce vehicular speeds, which in turn would reduce the potential for crashes.

A before/after study was conducted to determine the effectiveness of in-roadway lights on travel speeds and crashes. Crash data for the three-year before period (2001 to 2003) and the three-year after period (2004 to 2006) were collected. Speed data were collected at four locations (200, 500, 600 and 900 feet north of SR 84) along the ramp during the before condition (without in-roadway lights) and the after condition (with in-roadway lights). A total of 76 speed studies were conducted, of which 44 studies were conducted during the before condition and 32 were conducted during the after condition. Several statistical tests were conducted to determine whether the changes observed in the measures of effectiveness (mean speed, speed distribution and crash frequency) are attributable to the installation of the in-roadway lights or simply due to chance.

Based on the results of this study, the use of in-roadway lights resulted in statistically significant speed reductions. Mean vehicular speeds reduced by 2 to 7 mph. However, the in-roadway lights did not generally have a substantial impact on crashes. The before and after crash frequencies were statistically similar at a 95% confidence level, although there was an increase in crashes during the after period. Additional traffic safety measures may need to be implemented at this location to further reduce travel speeds and associated potential for crashes.

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Executive Summary

The Nation's freeway systems are generally built to the highest mobility and safety standards. The wider lanes, sufficient lateral clearances and appropriate geometric characteristics are provided on freeways to achieve higher levels of service. Such features, however, promote faster driving behavior in motorists. Although speeding on freeways during uncontested time periods are common occurrences, safety is not often compromised. However, the freeway connection to other roadways, at interchanges, presents a set of challenges to motorists. The interchanges often require drivers to reduce their speed significantly due to horizontal curves, grades and traffic control measures that are distinctly different from normal freeway conditions. Some drivers under such circumstances fail to reduce their speed sufficiently to be able to safely negotiate through this change in driving environment, which sometimes leads to serious crashes.

The intersection of southbound I-95 off-ramp and westbound State Road 84 is a T-intersection located in Fort Lauderdale, Florida. The exit ramp is relatively long, approximately 2000 feet in length. As such, drivers tend to travel at a relatively high speed even after exiting the interstate. The exit ramp consists of one-lane and operates as a free-flow right-turn-only lane, which then merges with westbound SR 84. The turning radius for this right turn is very small requiring drivers to slow down to 10 miles per hour.

A total of 41 crashes occurred at this intersection during the three-year period from 2001 to 2003. A majority of these crashes (71%) involved southbound vehicles from the off-ramp and westbound vehicles traveling in the rightmost through lane. Based on crash history at this location, it appears that some southbound drivers on this exit ramp approach the intersection of SR 84 at a high rate of speed, often misjudge the ramp geometry, miss the merge lane due to the wide turn associated with excessive speed and encroach into the path of oncoming westbound traffic on SR 84 or travel straight into the barrier wall located on the south side of SR 84.

In an effort to reduce the frequency of crashes at this intersection, the Florida Department of Transportation (FDOT) District 4 Traffic Operations Office installed a series of in-roadway lights in November 2004 along the off-ramp, starting from SR 84 to a point 600 feet north of SR 84. The intention was to alert motorists to the approaching sharp right turn at SR 84, so that drivers would reduce their speeds in order to negotiate the turn safely. The in-roadway lights were linked with a speed detection system, which would illuminate the lights when the approaching vehicle's speed was detected to be greater than the pre-set speed of 50 mph. The in-roadway lights were operated in such a way that they create a 'strobing' effect towards the approaching driver to give the motorist the perception that he/she is speeding. The 'strobe' effect starts at the beginning of each group of lights, and progresses with each unit in the group illuminating until all are illuminated, then off, and starting the sequence over again. As such, in-roadway lights are expected to reduce travel speeds. It is anticipated that the reduction in vehicular speeds would reduce the potential for crashes.

The goal of this research was to determine the effectiveness of in-roadway lights in reducing travel speeds and associated crash frequency and severity. A before/after evaluation plan was utilized to determine the effectiveness of in-roadway lights. The Measures of Effectiveness (MOEs) for the before and after evaluation study were as follows:

- Change in the crash frequency
- Change in average speed
- Change in speed distribution

Crash data were collected for a three-year before period (2001, 2002 and 2003) and a three-year after period (2004, 2005 and 2006). The before period specifically began on January 1, 2001 and continued through December 31, 2003. The after period began on December 1, 2004 and continued through August 10, 2006. During the after period, Hurricane Wilma interrupted the performance of the in-roadway lights between October of 2005 and March of 2006. Therefore, crash data for this period were not considered in the analysis.

Speed data were collected at four locations (200, 500, 600 and 900 feet north of SR 84) along the ramp during the before condition (without in-roadway lights) and after condition (with in-roadway lights). A total of 76 speed studies were conducted during four different time periods (AM, Noon, PM and Evening). Forty-four studies (44) were conducted during the before condition and thirty-two (32) were conducted during the after condition.

Several statistical tests were conducted to determine whether the changes observed in the measures of effectiveness (mean speed, speed distribution and crash frequency) are attributable to the installation of the in-roadway lights. A summary of the findings is as follows:

- The total crash frequencies for the before condition (without in-roadway lights) and the after condition (with in-roadway lights) were not significantly different at a 95% confidence level.

- For the AM and Noon periods at the 600-foot location, the speed distributions for the before condition were significantly different from those for the after condition. This indicates that in-roadway lights positively impacted travel speeds.
- For the AM, Noon, PM and Evening periods at the 600-foot speed study location, the mean speeds between the before and after conditions were significantly different at a 95% confidence level. Overall, the travel speeds were lower (by 2 to 7 mph based on time of day) during the after condition than those observed during the before condition. This indicates that the installation of in-roadway lights reduced the overall speed.
- The mean speeds for the AM, Noon, PM and Evening periods at the 200-foot location were significantly lower (by 2 to 4 mph) at a 95% confidence level in the after condition. This indicates that motorists reduced their speeds in response to the in-roadway lights.
- The mean speeds for the Noon, PM and Evening periods at the 500-foot location were significantly lower (by 2 to 3 mph) at a 95% confidence level in the after condition, while the AM period mean speed was similar.
- For the 900-foot speed study location, the Noon, PM and Evening period mean speeds between the before and after conditions were similar at a 95% confidence level, which means that speeds prior to approaching the study area were similar. Therefore, the reductions in speed at 200 foot and 500 foot locations can be attributed to in-roadway lights.

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1.0 INTRODUCTION

The Nation's freeway systems are generally built to the highest mobility and safety standards. The wider lanes, sufficient lateral clearances and appropriate geometric characteristics are provided on freeways to achieve higher levels of service. Such features, however, promote faster driving behavior in motorists. Although speeding on freeways during uncongested time periods are common occurrences, safety is not often compromised. The connection to other roadways at interchanges, however, presents a different set of challenges. The interchanges often require drivers to confront horizontal curves, grades and traffic control measures that are distinctly different from normal freeway conditions. Such changes in the driving environment at interchanges require reduction in speed. Some drivers under such circumstances fail to reduce their speed sufficiently to be able to safely negotiate through this change in driving environment, which sometimes leads to serious crashes.

The intersection of southbound I-95 off-ramp and westbound State Road 84 is a T-intersection located in the City of Fort Lauderdale, Broward County, Florida. The exit ramp is relatively long, approximately 2000 feet in length. As such, drivers tend to travel at a relatively high speed even after exiting the interstate. The exit ramp consists of one-lane and operates as a free-flow right-turn-only lane onto SR 84, which then merges with westbound SR 84 approximately 500 feet west of the intersection. The turning radius for this right turn is very small requiring drivers to slow down to 10 miles per hour. Figure 1 is an aerial view of the southbound I-95 off-ramp at SR 84. Figure 2 depicts the off-ramp configuration and existing signing/pavement marking approaching the intersection at SR 84. Figure 3 shows the intersection view from SR 84 looking north.

A total of 41 crashes occurred at this intersection during the three-year period from 2001 to 2003. A majority of these crashes (71%) involved southbound vehicles from the off-ramp and westbound vehicles traveling in the rightmost through lane. Based on crash history at this location, it appears that some southbound drivers on the exit ramp approach the SR 84 intersection at a high rate of speed, often misjudge the ramp geometry, miss the merge lane due to the wide turn associated with excessive speed and encroach into the path of oncoming westbound traffic on SR 84 or travel straight into the barrier wall located on the south side of SR 84 (see Figure 3). A total of 6 collision with barrier wall crashes were reported during the referenced three-year period.

In an effort to improve motorist safety at this intersection, the Florida Department of Transportation (FDOT) District 4 Traffic Operations Office installed a series of in-roadway lights in

November 2004 along both sides of the off-ramp, starting at the gore area between the ramp and SR 84 to a point 600 feet north of SR 84 (see Figure 4). The intention was to alert motorists of the approaching sharp right turn at SR 84, so that drivers would reduce their speeds in order to negotiate the turn safely. The in-roadway lights were linked with a speed detection system, which would illuminate the lights when the approaching vehicle's speed was detected to be greater than the pre-set speed of 50 mph. The in-roadway lights were operated in such a way that they create a 'strobing' effect towards the approaching driver to give the motorist the perception that he/she is speeding. The 'strobe' effect starts at the beginning of each group of lights, and progresses with each unit in the group illuminating until all are illuminated, then off, and starting the sequence over again. As such, the in-roadway lights are expected to reduce vehicle speeds. It is anticipated that the reduction in vehicular speeds would reduce the potential for crashes.

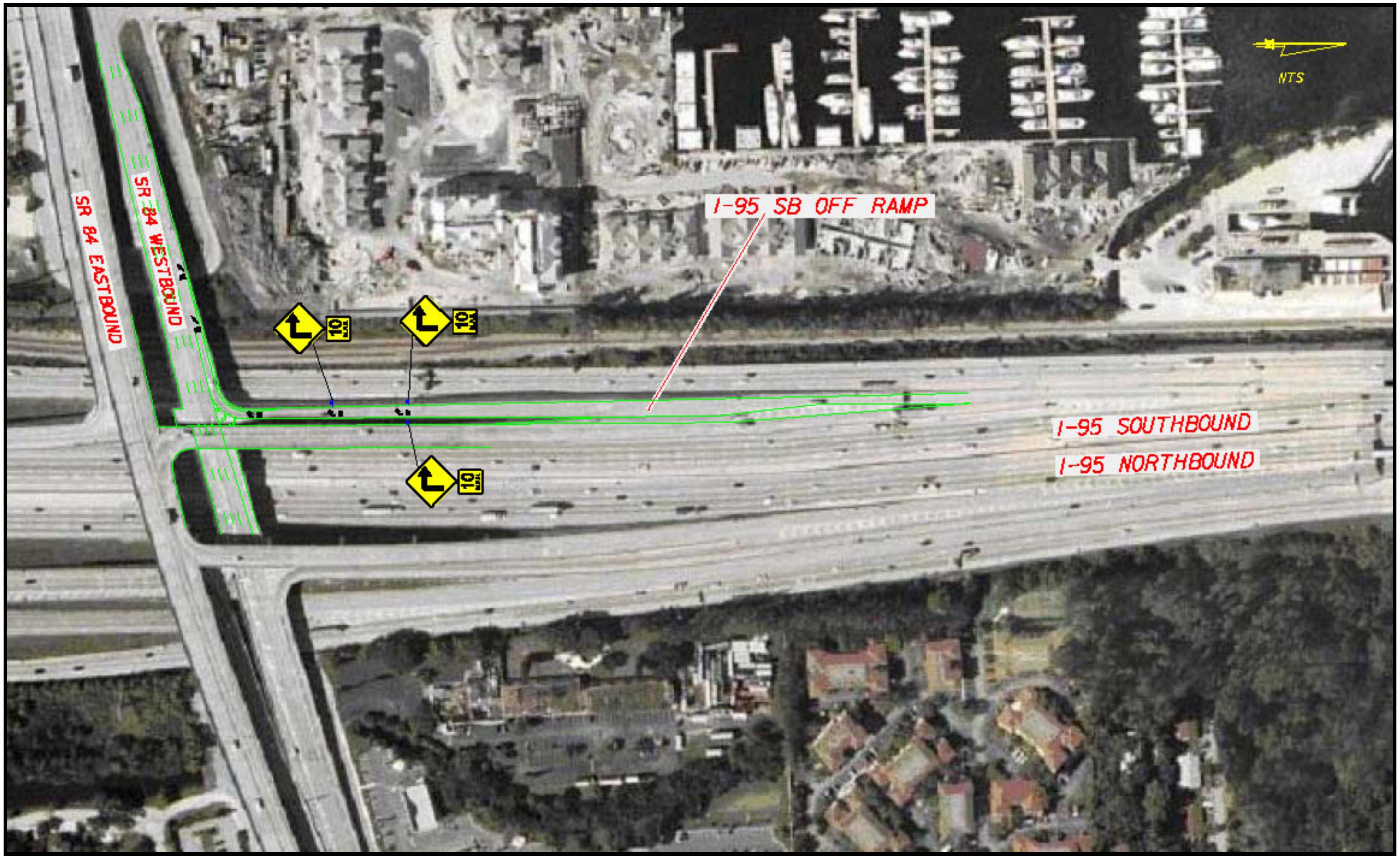

Figure 1. Aerial View of the I-95 and SR 84 Interchange

Figure 2. Existing Signing and Pavement Markings along the Ramp Approaching SR 84 (Looking South).

Figure 3. Looking north into the intersection of SB I-95 off-ramp at SR 84. Note damaged concrete wall on the south side.

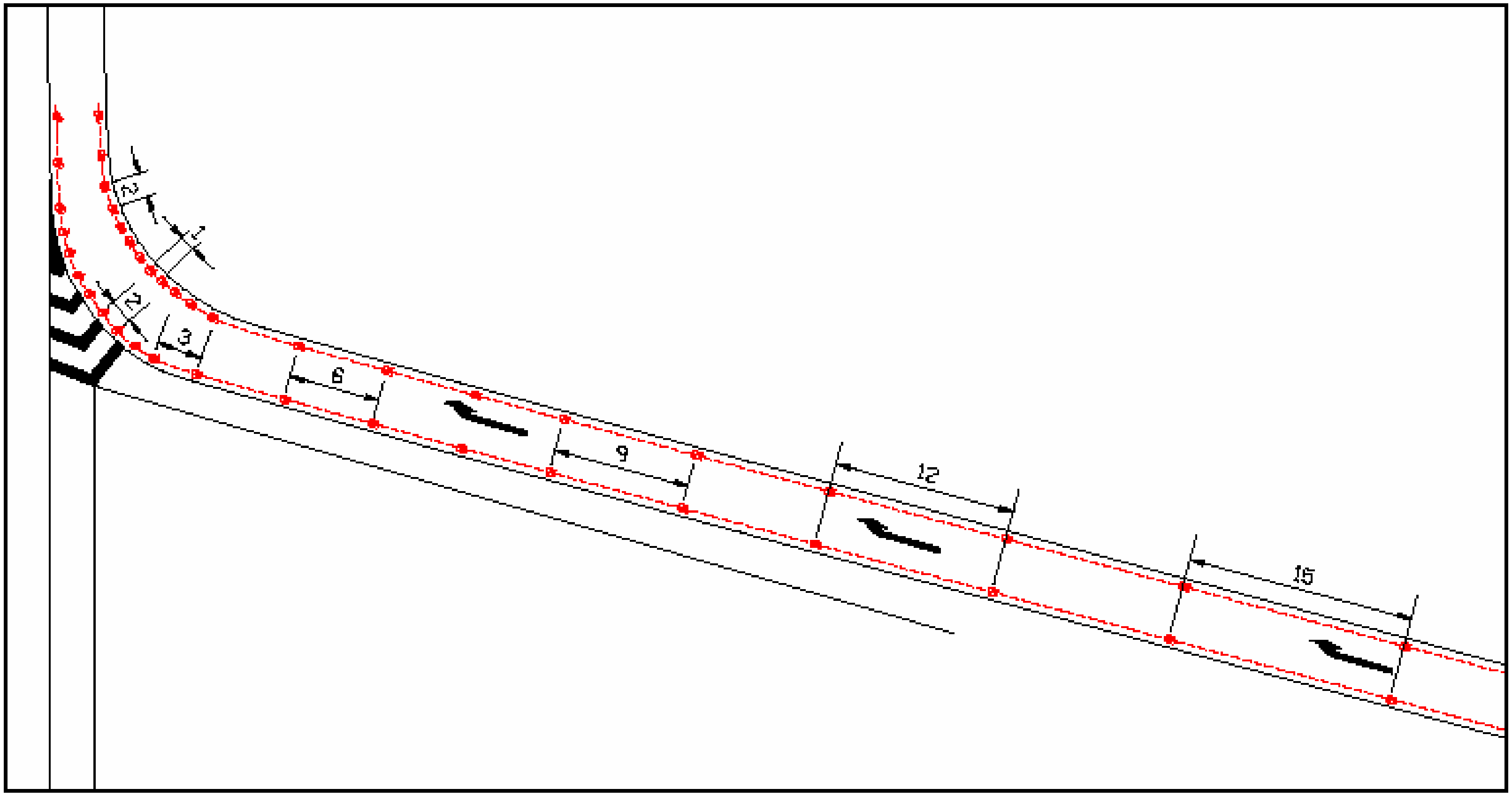

Figure 4. In-Roadway Light Spacing Configuration

2.0 STUDY OBJECTIVES

The goal of this research was to determine the effectiveness of in-roadway lights in reducing travel speeds and associated crash frequency and severity. The effectiveness of in-roadway lights was determined through a field experiment conducted at the intersection of southbound I-95 off-ramp and westbound State Road 84.

3.0 STUDY METHODOLOGY

The study site was selected by FDOT based on the number of crashes. Therefore, a before and after with control group evaluation plan could not be used since that evaluation design depends on random selection of treatment and control groups prior to the implementation of the treatment. A preliminary review of potential control sites indicated that there are few sites where the geometric conditions were similar, however, the ramps at these similar sites were signalized whereas the study site was not. Without similar geometric or traffic control conditions, the crash history at the various sites cannot be considered comparable. Therefore, the before and after evaluation plan was utilized to determine the effectiveness of in-roadway lights.

Measures of Effectiveness

The number of crashes related to speeding is expected to be positively impacted by the presence of in-roadway lights, as a direct effect of the expected reduction in speeds. Due to concerns about obtaining adequate sample size in terms of crash frequency, the reduction in speeds was considered as a surrogate measure for crash reduction. Therefore, a comparison was made between vehicle speeds measured at various points along the exit ramp with and without in-roadway lights. Changes in travel speed were evaluated in several ways, such as changes in mean speed, speed distribution, and variance.

Thus, the proposed measures of effectiveness (MOEs) for the before and after evaluation study were as follows:

- Change in the crash frequency
- Change in average speed
- Change in speed distribution

Several statistical tests were conducted to determine whether the changes observed in the measures of effectiveness are attributable to the use of in-roadway lights or simply due to chance. Statistical tests performed to test the effectiveness of in-roadway lights were as follows:

- Poisson Test of Significance: to determine if differences in the before and after crash frequencies are significant.
- Kolmogorov-Smirnov and Shapiro-Wilk Tests: to determine if the speed data are normally distributed.
- Z-scores for skewness and kurtosis with the Kolmogorov-Smirnov Test: to determine if there are changes in the speed distributions for the before and after periods.
- Student's t-test or Analysis of Variance (ANOVA): to determine if differences in mean speeds are statistically significant.
- F-test: to determine if differences in the variance of the mean speed are different.

Given that outliers in the speed values of the distribution might artificially impact the average speed and its variance, tests were conducted to detect changes in the shape of the speed distributions for the before and after groups. That is, if the distribution is skewed to the left or positive skew, it will be an indication of reduction in travel speeds.

4.0 DATA COLLECTION

Crash Data

Crash data were collected for a three-year before period (2001, 2002 and 2003) and a three-year after period (2004, 2005 and 2006). The before period specifically began on January 1, 2001 and continued through December 31, 2003. The after period began on December 1, 2004 and continued through August 10, 2006. During the after period, Hurricane Wilma interrupted the performance of the in-roadway lights between October of 2005 and March of 2006. Therefore, crash data for this period were not considered in the analysis.

To ensure the before and after crash data were obtained under similar conditions, data from the three-year before period were removed for those months which correspond to the months where the data was removed for the three-year after period due to Hurricane Wilma. This procedure ensured that the crash data were utilized for an identical number of similar months under both the before and after conditions.

For the first year of each before and after condition, the crash analysis included the month of December. For the second year of each before and after condition, the crash analysis included nine months (between January and September). For the third year of the before and after condition, the crash analysis included six months (between March and August). The crash data for the before condition are summarized in Table 1. The crash data for the after condition are summarized in Table 2. The collision diagrams for the before and after conditions are included in Appendix A.

Table 1. Before Condition Crash Data Summary

Crash Type	2001 (1 Month)	2002 (9 Months)	2003 (6 Months)	16-Month Analysis Period Total
Right Turn	0	10	5	15
Rear End	0	0	1	1
Sideswipe	0	0	1	1
Impact with Concrete Barrier Wall	0	1	2	3
Total Crashes	0	11	9	20
Fatal Crashes	0	0	0	0
Injury Crashes	0	7	5	12
Daylight Crashes	0	6	7	13
Nighttime Crashes	0	5	2	7
Dry Roadway Surface Crashes	0	7	7	14
Wet Roadway Surface Crashes	0	4	2	6

Table 2. After Condition Crash Data Summary

Crash Type	2004 (1 Month)	2005 (9 Months)	2006 (6 Months)	16-Month Analysis Period Total
Angle	0	2	2	4
Right Turn	2	12	5	19
Rear End	0	1	0	1
Impact with Concrete Barrier Wall	0	1	0	1
Total Crashes	2	16	7	25
Fatal Crashes	1	1	0	2
Injury Crashes	2	6	6	14
Daylight Crashes	1	9	6	16
Nighttime Crashes	1	7	1	9
Dry Surface Crashes	0	9	7	16
Wet Surface Crashes	2	7	0	9

Speed Studies

Observers collected speed data using a radar gun, and the speed of each individual vehicle was recorded. Observers also recorded the date and time of day for each observational period, as well as any other information (such as weather, road surface condition, traffic incidents or other events) that could affect the behavior of motorists along the exit ramp.

Speed studies were initially conducted at a position 600 feet north of SR 84 during four different time periods: AM (7:00 to 8:00 AM), Noon (12:00 to 1:00 PM), PM (4:45 to 5:45 PM) and evening (7:00 to 8:00 PM) periods. A total of 16 studies were conducted between January 2004 and April 2005, of which eight were conducted prior to the installation of in-roadway lights and eight were conducted after the installation of in-roadway lights.

To better evaluate changes in travel speeds in response to in-roadway lights at various points, additional speed studies were conducted at three different positions along the ramp, approximately 200 feet, 500 feet and 900 feet from SR 84. The in-roadway lights were installed along the ramp, beginning at SR 84 north up to a point approximately 600 feet north of SR 84. Therefore, the studies conducted at 200 foot and 500 foot locations indicate travel speeds after motorists encountered the in-roadway lights, whereas the studies conducted at the 900 foot location indicate travel speeds prior to encountering in-roadway lights. A total of 24 speed studies were conducted during the after period at these three different positions during AM, Noon, PM and Evening periods.

As part of a FDOT resurfacing project, the subject ramp was resurfaced and the in-roadway lights were taken out on August 10, 2006. To date, in-roadway lights have not been completely replaced (only a few lights are working). Therefore, researchers have not been able to conduct additional speed studies for the after condition (with in-roadway lights) with new pavement surface. However, researchers utilized this opportunity and collected additional speed studies (without in-roadway lights) at 200 feet, 500 feet and 900 feet north of SR 84 after the ramp had been resurfaced, for possible consideration as the before data.

The data collected for the before and after conditions at the location 600 feet north of SR 84 are summarized in Table 3. The data collected for the before condition (with a resurfaced pavement) at the locations 200, 500 and 900 feet north of SR 84 are summarized in Table 4. The data collected for the after condition at 200, 500 and 900 feet north of SR 84 are summarized in Table 5.

Table 3. Summary of Before/After Speed Studies Conducted 600 feet North of SR 84

Type of Study	Time of Study	Date	No. of Vehicles Observed	Mean Speed (MPH)	Standard Deviation (MPH)	Variance (MPH)
Before Condition (Without In-roadway Lights)	AM Period	1/22/2004	252	55.07	5.74	32.95
		2/21/2004	126	49.57	6.42	41.17
		Summary	378	53.24	6.51	37.33
	Noon Period	1/22/2004	193	51.06	6.13	37.62
		2/21/2004	174	48.39	6.76	45.65
		Summary	367	49.79	6.57	43.10
	PM Period	1/22/2004	186	47.75	5.58	31.18
		2/21/2004	129	48.84	6.2	38.43
		Summary	315	48.20	5.86	34.33
	Evening Period	2/17/2004	135	44.99	6.4	41.01
		2/21/2004	90	46.86	6.07	36.84
		Summary	225	45.74	6.33	40.01
	Overall	Summary	1285	49.71	6.86	37.08
After Condition (With In-roadway Lights)	AM Period	3/17/2005	178	47.51	6.23	38.80
		4/2/2005	137	45.39	5.83	33.96
		Summary	315	46.59	6.14	37.70
	Noon Period	3/17/2005	231	48.67	6.84	46.74
		3/19/2005	180	45.12	5.48	30.07
		Summary	411	47.11	6.52	42.57
	PM Period	3/19/2005	156	47.27	6.56	43.02
		4/14/2005	159	45.13	6.08	36.91
		Summary	315	46.19	6.40	40.96
	Evening Period	3/19/2005	91	46.23	6.76	45.67
		4/14/2005	151	43.05	6.7	45.88
		Summary	242	44.25	6.93	45.99
	Overall	Summary	1283	46.22	6.55	42.92

Table 4. Summary of the Before Condition Speed Studies Conducted at 200, 500, and 900 feet North of SR 84 with a New Pavement Surface (continues on next page)

Type of Study	Time of Study	Date	No. of Vehicles Observed	Mean Speed (MPH)	Standard Deviation (MPH)	Variance (MPH)
Before Condition (Without In-roadway Lights) **at 200 Feet**	AM Period	8/17/2006	105	36.52	3.72	13.92
		8/26/2006	100	37.60	4.59	21.11
		Summary	205	37.05	4.20	17.63
	Noon Period	8/17/2006	102	36.32	4.64	21.55
		8/23/2006	111	36.04	5.60	31.34
		8/26/2006	100	39.28	5.10	26.02
		10/26/2006	170	36.45	4.94	24.40
		Summary	483	36.91	5.20	27.06
	PM Period	8/17/2006	102	36.65	4.23	17.91
		8/26/2006	100	39.80	5.30	28.10
		10/26/2006	166	38.37	4.77	22.71
		Summary	368	38.28	4.91	24.09
	Evening Period	8/17/2006	102	37.49	5.03	25.26
		9/23/2006	55	35.78	5.21	27.14
		10/26/2006	116	38.97	6.24	39.00
		Summary	273	37.78	5.72	32.70
	Overall	Summary	1329	37.49	5.12	26.23
Before Condition (Without In-roadway Lights) **at 500 Feet**	AM Period	8/17/2006	105	45.55	5.14	26.44
		8/26/2007	100	45.99	5.98	35.81
		Summary	205	45.77	5.56	30.91
	Noon Period	8/17/2006	102	44.98	6.28	39.39
		8/23/2006	111	45.84	6.36	40.46
		8/26/2007	100	47.03	6.53	42.60
		10/26/2006	170	45.56	6.14	37.68
		Summary	483	45.81	6.32	39.92
	PM Period	8/17/2006	102	44.33	4.75	22.52
		8/26/2006	100	47.90	6.55	42.84
		10/26/2006	166	46.78	6.13	37.56
		Summary	368	46.40	6.04	36.50
	Evening Period	8/17/2006	102	46.93	6.01	36.14
		9/23/2006	55	45.31	6.90	47.62
		10/26/2006	116	46.37	6.07	39.79
		Summary	273	46.37	6.23	38.78
	Overall	Summary	1329	46.08	6.11	37.36

Table 4. Summary of the Before Condition Speed Studies Conducted at 200, 500, and 900 feet North of SR 84 with a New Pavement Surface (continued)

Type of Study	Time of Study	Date	No. of Vehicles Observed	Mean Speed (MPH)	Standard Deviation (MPH)	Variance (MPH)
Before Condition (Without In-roadway Lights) at 900 Feet	AM Period	8/17/2006	105	52.76	5.15	26.47
		8/26/2006	100	53.77	5.87	34.42
		Summary	205	53.25	5.52	30.45
	Noon Period	8/17/2006	102	54.47	6.39	40.81
		8/23/2006	111	54.97	6.59	43.41
		8/26/2006	100	54.87	7.07	49.97
		10/26/2006	170	52.88	6.02	36.19
		Summary	483	54.11	6.50	62.27
	PM Period	8/17/2006	102	53.01	5.19	26.94
		8/26/2006	100	55.65	6.82	46.49
		10/26/2006	166	54.40	6.28	39.43
		Summary	368	54.36	6.22	38.64
	Evening Period	8/17/2006	102	54.83	6.59	43.49
		9/23/2006	55	53.27	8.08	65.24
		10/26/2006	116	52.99	6.14	37.66
		Summary	273	53.74	6.76	45.75
	Overall	Summary	1329	53.97	6.34	40.21

Table 5. Summary of the After Condition Speed Studies Conducted at 200, 500, and 900 feet North of SR 84 (continues on next page)

Type of Study	Time of Study	Date	No. of Vehicles Observed	Mean Speed (MPH)	Standard Deviation (MPH)	Variance (MPH)
After Condition (With In-Roadway Lights) at 200 Feet	AM Period	3/16/2006	103	32.92	6.56	42.97
		3/18/2006	101	33.07	5.29	27.97
		Summary	204	33.00	5.95	35.37
	Noon Period	3/16/2006	124	33.89	5.09	25.91
		3/18/2006	101	33.41	5.39	29.08
		Summary	225	33.67	5.22	27.27
	PM Period	3/16/2006	105	35.39	5.24	27.47
		3/18/2006	103	36.23	4.24	17.98
		Summary	208	35.81	4.78	22.84
	Evening Period	3/16/2006	105	35.34	5.62	31.54
		3/18/2006	105	35.34	4.77	22.73
		Summary	210	35.34	5.2	27.00
	Overall	Summary	847	34.45	5.73	32.79

Table 5. Summary of the After Condition Speed Studies Conducted at 200, 500, and 900 feet North of SR 84 (continued)

Type of Study	Time of Study	Date	No. of Vehicles Observed	Mean Speed (MPH)	Standard Deviation (MPH)	Variance (MPH)
After Condition (With In-Roadway Lights) at **500 Feet**	AM Period	3/16/2006	103	44.25	5.85	34.25
		3/18/2006	101	45.44	5.32	28.31
		Summary	204	44.84	5.61	31.51
	Noon Period	3/16/2006	124	43.98	5.62	31.54
		3/18/2006	101	43.91	5.06	25.62
		Summary	225	43.95	5.36	28.78
	PM Period	3/16/2006	105	43.02	6.35	40.31
		3/18/2006	103	46.82	5.25	27.52
		Summary	208	44.90	6.12	37.43
	Evening Period	3/16/2006	105	43.07	5.13	26.35
		3/18/2006	105	44.69	6.26	39.22
		Summary	210	43.88	5.77	33.29
	Overall	Summary	847	44.38	5.73	32.79
After Condition (With In-Roadway Lights) at **900 Feet**	AM Period	3/16/2006	103	52.96	6.26	39.19
		3/18/2006	101	56.75	5.69	32.37
		Summary	204	54.84	6026	39.25
	Noon Period	3/16/2006	124	52.31	6.29	39.60
		3/18/2006	101	54.43	4.93	24.35
		Summary	225	53.26	5.81	33.73
	PM Period	3/16/2006	105	52.55	6.44	41.44
		3/18/2006	103	46.82	5.25	27.52
		Summary	208	54.38	6.13	37.55
	Evening Period	3/16/2006	105	51.46	5.38	28.92
		3/18/2006	105	53.86	6.30	39.72
		Summary	210	52.66	5.97	35.60
	Overall	Summary	847	53.76	6.09	37.07

The number of observations, or sample size, was reviewed to ensure that Type I and Type II errors were minimized. For a detailed discussion of Type I and Type II errors, refer to the Statistical Evaluation Section of this report. In order to ensure a statistically valid study that is representative of the population, the following formula was used to estimate minimum sample size:

$$n = \frac{Z^2 \times \sigma^2}{\varepsilon^2}$$

Where:

n = estimated sample size

Z = 1.96, the two-tailed value of the standardized normal deviate associated with the desired level of confidence, 95%

σ = standard deviation of the population

ε = minimum detectable difference

The formula listed above only requires the knowledge of the standard deviation of the population and the level of confidence or alpha level, which corresponds to the Type I error. However, the power of the test, 1-β, is not specified nor controlled, which may result in a severe problem associated with Type II error. Another formula for sample size, provided by Hinkle, et al [2], allows protection from both Type I and Type II errors.

The formula is as follows [2]:

$$n = \frac{(Z_\beta - Z_{\alpha/2})^2 \times \sigma^2}{\varepsilon^2}$$

Where:

Z_β = distance from the critical value to mean in H_a (in standard deviation units); for β= 0.2, Z_β = -0.842

$Z_{\alpha/2}$= distance from the critical value to mean in H_o (in standard deviation units); for a two-tailed test and α= 0.05, $Z_{\alpha/2}$= 1.96

Table 6 summarizes the sample size requirements for various time periods based upon detectable difference between before and after speeds. In practical terms, this table illustrates the sample size required to detect a 1 mph or 2 mph difference in average speed. For example, based upon the data collected at 600 foot location during the AM period, a sample size of 101 vehicles would allow for the detection of a 2 mph difference and increasing the sample size to 402 vehicles would allow for the detection of a 1 mph difference. In order to achieve a power of 80 % (beta equal to 0.20), the sample size requirements listed in Table 6 must be met. Based upon these requirements, the data for the before and after conditions collected at each of the locations (200, 500, 600 and 900 feet north of SR 84), were sufficient to maintain the power and robustness of the statistical analysis.

Table 6. Sample Size Requirements

Time Period and Location	Minimum Sample Size Required	
	1 mph Error Level	2 mph Error Level
AM Period at 600 Feet	402	101
Noon Period at 600 Feet	351	88
PM Period at 600 Feet	303	76
Evening Period at 600 Feet	351	88
Before AM Period at 200, 500 or 900 Feet	551	138
Before Noon Period at 200, 500 or 900 Feet	673	169
Before PM Period at 200, 500 or 900 Feet	598	150
Before Evening Period at 200, 500 or 900 Feet	641	160
After AM Period at 200, 500 or 900 Feet	402	101
After Noon Period at 200, 500 or 900 Feet	351	88
After PM Period at 200, 500 or 900 Feet	303	76
After Evening Period at 200, 500 or 900 Feet	351	88

5.0 STATISTICAL EVALUATION

It is customary to use statistical analysis in the effectiveness evaluation process. Such analysis ensures that the observed differences in the before and after conditions are in fact due to the treatment/countermeasure, in this case in-roadway lights, and not due to chance.

A number of before/after speed comparisons were made to evaluate the impact of in-roadway lights on travel speed as follows:

- AM Period at 200, 500, 600 and 900 feet.
- Noon Period at 200, 500, 600 and 900 feet.
- PM Period at 200, 500, 600 and 900 feet.
- Evening Period at 200, 500, 600 and 900 feet.

All statistical analyses require certain assumptions, and the validity of the assumptions is critical to the appropriateness of the statistical analysis. Therefore, several tests were performed as a part of this study and are summarized below.

Poisson Test for Crash Frequency

The Poisson Test was performed to analyze the significance of the differences in crash frequency between the before and after periods. The Poisson Test plots expected crash frequency without treatment versus the percent change at the same location/time frame with treatment, for a specified level of confidence. The actual data point being tested must fall above the specified level of confidence curve in order to be considered significant. If the result is significant, then the null hypothesis stating that there was no difference would be rejected, indicating a significant difference in the crash frequencies for the before and after conditions.

Tests for Normality

In order to determine if the speed data utilized for the Student's t-test are normally distributed, the skewness and kurtosis of the speed distribution were examined. The skewness and kurtosis can be tested by dividing the variable by the standard error of the variable to determine a calculated z-score [3]. The calculated z-score is compared to a z-critical value of 1.96. If the calculated value is greater than z-critical, then the data are considered to have deviated from the normal distribution. Two other tests that determine the normality of the data are the Kolmogorov-Smirnov and the Shapiro-Wilk tests which compare the observations in the sample to a normally distributed set of samples with the same mean and standard deviation [3].

Tests for Speed Distribution

The Kolmogorov-Smirnov test examines the distributions of two independent groups to determine if the distributions are similar [4].

Student's t-test for Mean Speed Differences

In order to test the effectiveness of the in-roadway lights in reducing vehicular speeds, the Student's t-test was used to determine if the differences in the mean speeds were statistically significant. Before the Student's t-test can be used, the data need to meet two underlying assumptions. The data must exhibit a distribution that is approximately normal with variances that are equal between the two groups being tested. For the Student's t-test, a two-tailed analysis was used in which the null hypothesis states that there is no difference between the two means. The alternative hypothesis states that the means are not similar. A one-tailed test requires the direction of the difference to be specified prior to the analysis. The two-tailed test was used for this research because the effectiveness of in-roadway lights on travel speeds was not known.

There is a possibility of two potential errors involved in any statistical analysis, a Type I error or a Type II error. A Type I error indicates that a particular treatment has an impact on dependent variables, when in fact there is none [2]. A Type II error indicates that the treatment does not have an impact on the dependent variables, when in fact there is an impact [2]. The Type I error can be reduced by selecting a small alpha level, but this increases the probability of a Type II error. Therefore, the selection of the level of confidence is critical. Traffic engineering professionals have consistently used a level of confidence of 95% for evaluations of various treatments.

The Student t-test was used to compare the mean speed for before condition with the mean speed for after condition. The following equations were utilized to calculate the t-statistic and the degrees of freedom (k'), assuming unequal sample sizes. If the calculated t-value is greater than the critical t-value obtained from available statistical tables, then the difference in mean speeds is considered to be statistically significant. The t-value was calculated using the following equation for [NB + NA – 2] degrees of freedom [2]:

$$t_{calc} = \frac{\overline{X_B} - \overline{X_A}}{\sqrt{\sigma^2\left(\frac{1}{N_B} + \frac{1}{N_A}\right)}}$$

Where:

$\overline{X_B}$	=	sample mean of data collected at before locations
$\overline{X_A}$	=	sample mean of data collected at after locations
N_B	=	number of before locations
N_A	=	number of after locations
σ	=	common standard deviation

In cases where the assumptions of normality and equal variances were not met, the F Max test was utilized to test the homogeneity of the variance.

If the data follow a normal distribution, but the variances are not equal, the Welch's test, or modified Student's t-test, can be utilized to test the differences in the mean speeds of the before and after groups. The Welch's test statistic is as follows [4]:

$$W = \frac{\left(\overline{X}_B - \overline{X}_A\right)}{\sqrt{\left(\frac{\hat{\sigma}_B^2}{N_B} + \frac{\hat{\sigma}_A^2}{N_A}\right)}}$$

$$k' = \frac{\left(\frac{\hat{\sigma}_B^2}{N_B} + \frac{\hat{\sigma}_A^2}{N_A}\right)^2}{\frac{\left(\frac{\hat{\sigma}_B^2}{N_B}\right)^2}{N_B - 1} + \frac{\left(\frac{\hat{\sigma}_A^2}{N_A}\right)^2}{N_A - 1}}$$

Where:

$\overline{X}_B$ = sample mean of data collected at before locations

$\overline{X}_A$ = sample mean of data collected at after locations

N_B = number of before locations

N_A = number of after locations

σ_B = standard deviation of data for before locations

σ_A = standard deviation of data for after locations

k' = degrees of freedom

ANOVA for Mean Speed Differences

In order to compare several means simultaneously, a one-way analysis of variance (ANOVA) was utilized to determine if the means for the various locations (200, 500 and 900 feet north of SR 84) were similar. Although a Student's t-test could have been conducted on the same data, several iterations of the t-test would be required in order to compare all possible scenarios; however, the ANOVA can maintain an alpha level of 0.05 while the Student's t-test alpha level decreases substantially with each additional test performed. The assumptions for the ANOVA are similar to those for the Student's t-test. The data must be continuous, independent, follow the normal distribution and have equal variances. Violations of these assumptions impact the results of the test; however, the ANOVA is considered a very robust test even with the violation of normality, unless the variances and sample sizes are unequal. To perform the ANOVA, an F-statistic is calculated which is equal to the mean squares between the groups divided by the mean squares within the groups. If F-calculated is greater than the F-critical obtained from statistical tables, the difference in the means is considered statistically significant. The equations used to perform this test are as follows:

$$SS_T = \sum_{k=1}^{K} \sum_{i=1}^{n_k} X_{ik}^2 - \frac{T^2}{N}$$

Where:

SS_T = Total sum of squares

$\sum_{k=1}^{K} \sum_{i=1}^{n_k} X_{ik}^2$ = squared scores summed across all individuals and groups

K = Number of groups

n = Number of observations

T = sum of scores summed across all observations and groups

N = total number of scores

$$SS_B = \sum_{k=1}^{K} \frac{T_k^2}{n_k} - \frac{T^2}{N}$$

Where:

SS_B = Sum of squares between-groups

T_k= sum of observations for k^{th} group

$$SS_W = \sum_{k=1}^{K} \sum_{i=1}^{n_k} X_{ik}^2 - \sum_{k=1}^{k} \frac{T_k^2}{n_k}$$

Where:

SS_W = Sum of squares within-groups

$$MS_B = \frac{SS_B}{K - 1}$$

$$MS_W = \frac{SS_W}{N - K}$$

$$F_{calc} = \frac{MS_B}{MS_W}$$

Where:

MS_B = Mean sum of squares between-groups

MS_W = Mean sum of squares within-groups

6.0 RESULTS OF THE STATISTICAL TESTING

Poisson Test for Crash Frequency

To determine if the crash frequencies for the before period were similar to the crash frequencies for the after period, the expected after period crash frequency and the percent change between the expected and actual after crash frequencies were calculated.

The Poisson Test was utilized to examine differences in crash frequencies for total, injury, day/night, and wet/dry crash groups between the before and after periods. The results of the analysis are summarized in Table 7 and plotted in Figure 5. The analysis indicates that the before condition and the after condition crash frequencies were similar at a level of confidence of 95% or alpha equal to 0.05. Although the crash frequency during the after period increased, this increase is not statistically significant at a 95% confidence level.

Table 7. Results of the Poisson Test for Crashes

	Total Crashes	Injury Crashes	Daytime Crashes	Nighttime Crashes	Wet Roadway Crashes
Expected After Crash Frequency Without Treatment	20	12	13	7	6
Actual After Crash Frequency	25	14	16	9	9
Percent Change	-25.00	-16.67	-23.08	-28.57	-50.00
Test Result	Accept Null	Accept Null	Accept Null	Accept Null	Accept Null

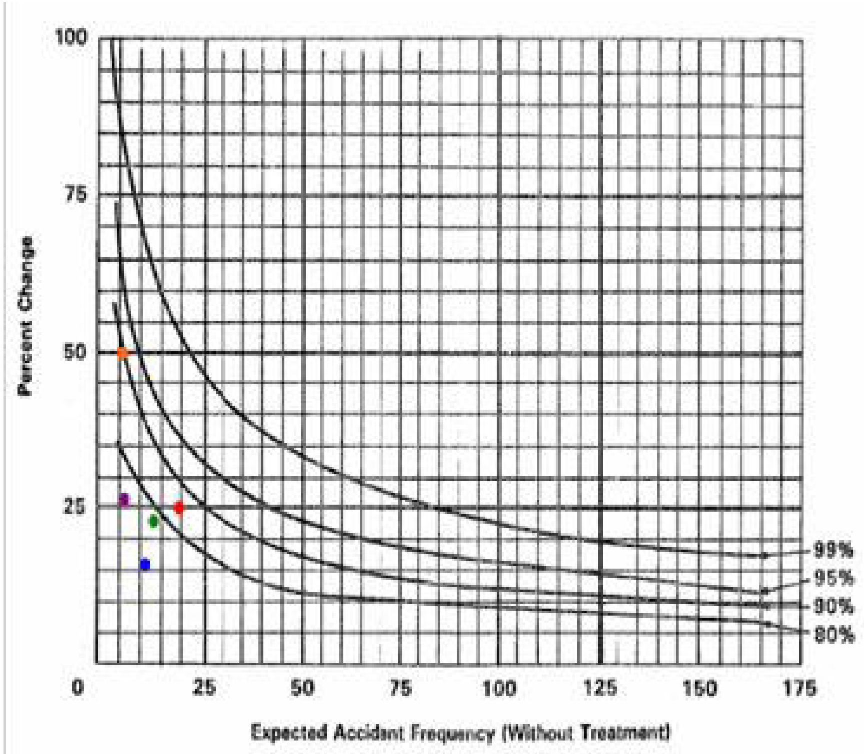

Figure 5. Graphic Results of the Poisson Test for Crash Frequencies

Tests for Normality of the Speed Data

Each dataset was analyzed for normality as described in the previous section. It was determined that the vast majority of the individual data sets were normally distributed. However, it was found that the data associated with the Noon period at 200 foot, the PM and the Evening periods at 900 foot locations deviated from normality. However, the deviation from normality was not sufficient to significantly impact the results of the analysis.

Tests for Speed Distribution

The Kolmogorov-Smirnov test was performed to determine if there were differences in the speed distributions for the before and after conditions. The Kolmogorov-Smirnov test indicated statistically significant differences at a 95% confidence level between the speed distributions for the before and after conditions for the AM and Noon periods at the 600-foot location. The PM and Evening distributions for the before and after conditions were similar.

The AM period and Noon period speed distributions for the before condition exhibited a negative skew. The distributions for the after condition were positively skewed. This indicates that the distribution of speeds shifted due to in-roadway lights and the examination of the mean for each distribution confirms that the speeds were reduced in both instances, further indicating a positive change in the speed characteristics.

Student's t-test for Differences in Mean Speed at the 600-foot location

Prior to conducting statistical analyses using the Student's t-test, the assumption of equal variances was tested using the F Max test. Through the F Max test, it was found that each of the test groups exhibited similar variances with a calculated F Max value less than the critical value of 1.73.

The null hypothesis that states the mean speed of the before condition was similar to the mean speed of the after condition was not accepted for each of the comparison groups of AM, Noon, PM and Evening. This indicates that there was a statistically significant difference between the mean speeds at a 95% confidence level. The mean speeds with in-roadway lights were lower than those observed without in-roadway lights. Table 8 summarizes the statistical results of the Student's t-test. The extent of the effect size describes the practical significance between the two speeds [2]. Effect size is valuable in statistical analysis, as any difference between two means can be found to be significantly different when the sample sizes are large. A very small difference in mean speed, such as 0.1 mph, may be statistically different; however, there is practically no difference between the mean speeds. To circumvent this issue, effect size is utilized to provide a measure of the magnitude of the difference between the two mean speeds in terms of the number of standard deviation units from zero [2]. Therefore, a large effect size would indicate a practical difference in mean speeds [2]. For the AM and Noon periods, a medium effect size indicated that a practical difference was apparent, while for the PM and Evening periods the practical difference was not as apparent.

Table 8. Student's t-test Results of the Speed Studies

Analysis Period	$t_{calculated}$	$t_{critical}$	Degrees of Freedom	Effect Size	Test Results
AM Period at the 600-foot location	13.75	$\pm$1.96	691	0.46	Reject Null
Noon Period at the 600-foot location	5.71	$\pm$1.96	776	0.20	Reject Null
PM Period at the 600-foot location	4.11	$\pm$1.96	628	0.16	Reject Null
Evening Period at the 600-foot location	2.421	$\pm$1.96	465	0.11	Reject Null

ANOVA test for Differences in Mean Speeds

As discussed in the Data Collection section of the report, the speed studies conducted at 200 feet, 500 feet, and 900 feet north of SR 84 in the before condition (without in-roadway lights) had a new pavement surface, whereas the speeds conducted in the after condition (with in-roadway lights) had the old pavement surface, since these studies were conducted prior to the resurfacing project. Although the pavement surface was different in both scenarios (i.e. with and without in-roadway lights), the trend in the speed reduction should be different if the in-roadway lights were impacting vehicle speeds. Therefore, speed plots were developed (see Figures 5, 6, 7, and 8) for the mean speeds at the three locations to graphically represent speed reductions for both the before condition with a new pavement surface and the after condition without new pavement surface.

As the motorists approach SR 84, their speeds seem to decrease in both the before and after conditions. However, the speed reduction between the 900 and 200 foot intervals is more pronounced with the in-roadway light scenario (see Table 9).

Table 9. Before and After Mean Speeds at Various Locations along the Ramp

Speed Observation Location	Before Speeds (in mph)				After Speeds (in mph)			
	AM	Noon	PM	Evening	AM	Noon	PM	Evening
200 feet north of SR 84	37.05	36.91	38.28	37.78	33.00	33.67	35.81	35.34
500 feet north of SR 84	45.77	45.81	46.40	46.37	44.84	43.95	44.90	43.88
900 feet north of SR 84	53.25	54.11	54.36	53.74	54.84	53.26	54.38	52.66
Speed Reduction between 900 and 200 foot intervals	16.20	17.20	16.08	15.96	21.84	19.59	18.57	17.32
Speed Observation Location	**Tukey Pairwise Comparison**				**Test Results**			
	AM	**Noon**	**PM**	**Evening**	**AM**	**Noon**	**PM**	**Evening**
200 feet north of SR 84	8.07	7.70	5.88	4.87	Reject Null	Reject Null	Reject Null	Reject Null
500 feet north of SR 84	1.68	3.95	2.84	4.52	Accept Null	Reject Null	Reject Null	Reject Null
900 feet north of SR 84	-2.78	1.71	-0.037	1.85	Reject Null	Accept Null	Accept Null	Accept Null

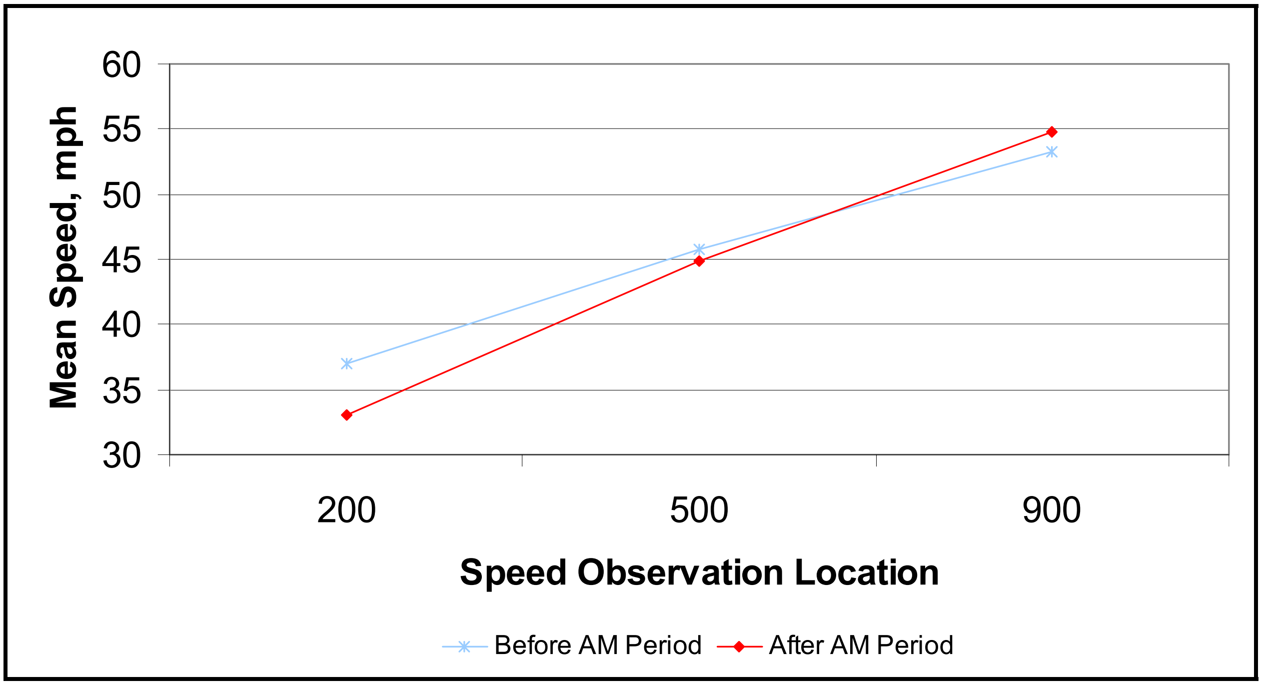

Figure 6. Average Speeds at 200, 500 and 900 feet North of SR 84 During AM Peak Period

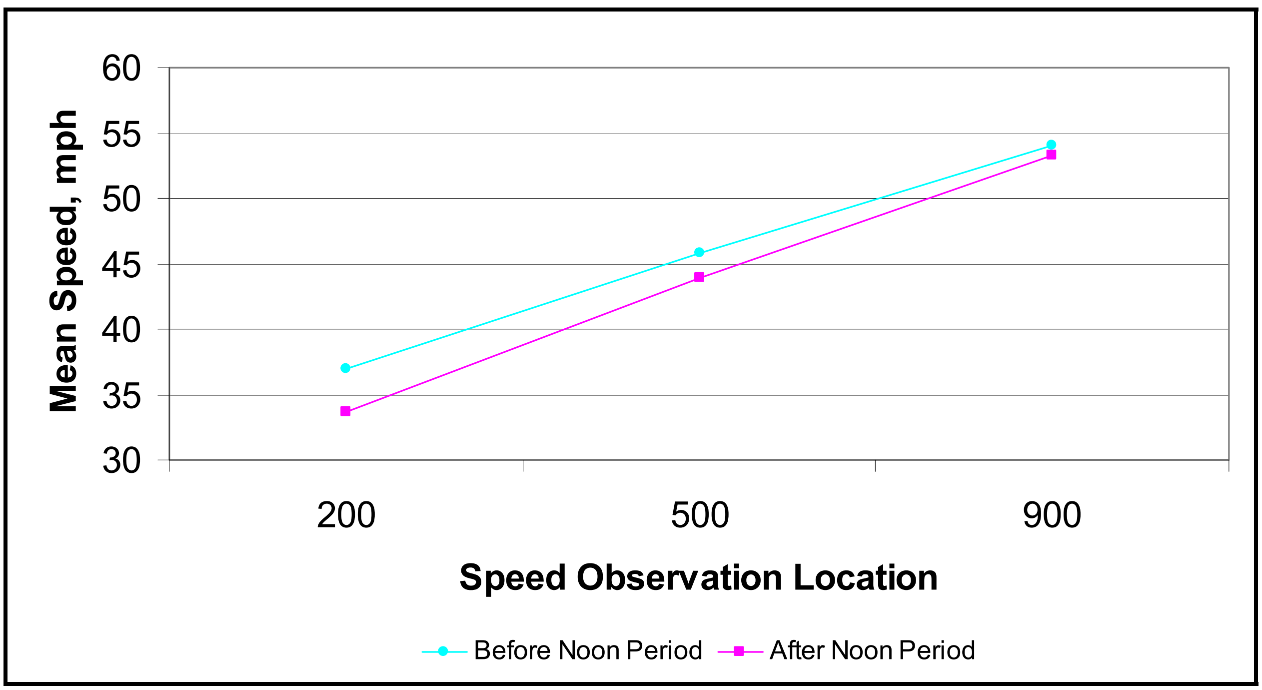

Figure 7. Average Speeds at 200, 500 and 900 feet North of SR 84 During Noon Period

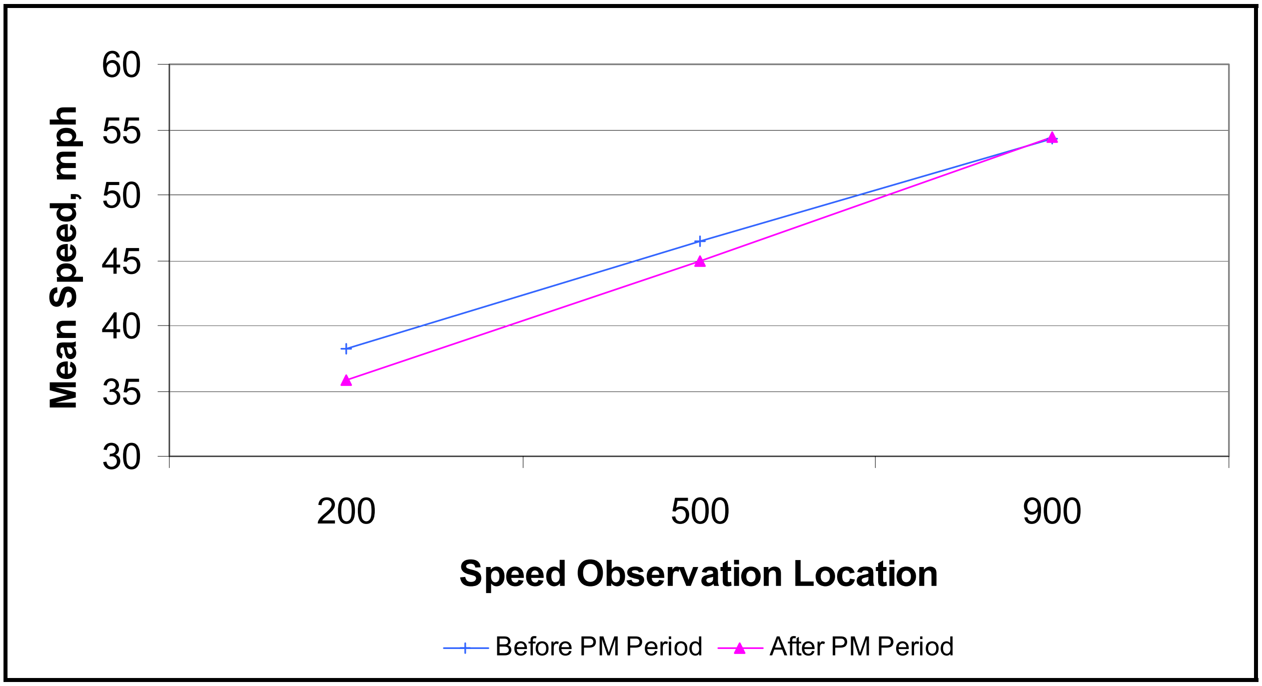

Figure 8. Average Speeds at 200, 500 and 900 feet North of SR 84 during PM Period

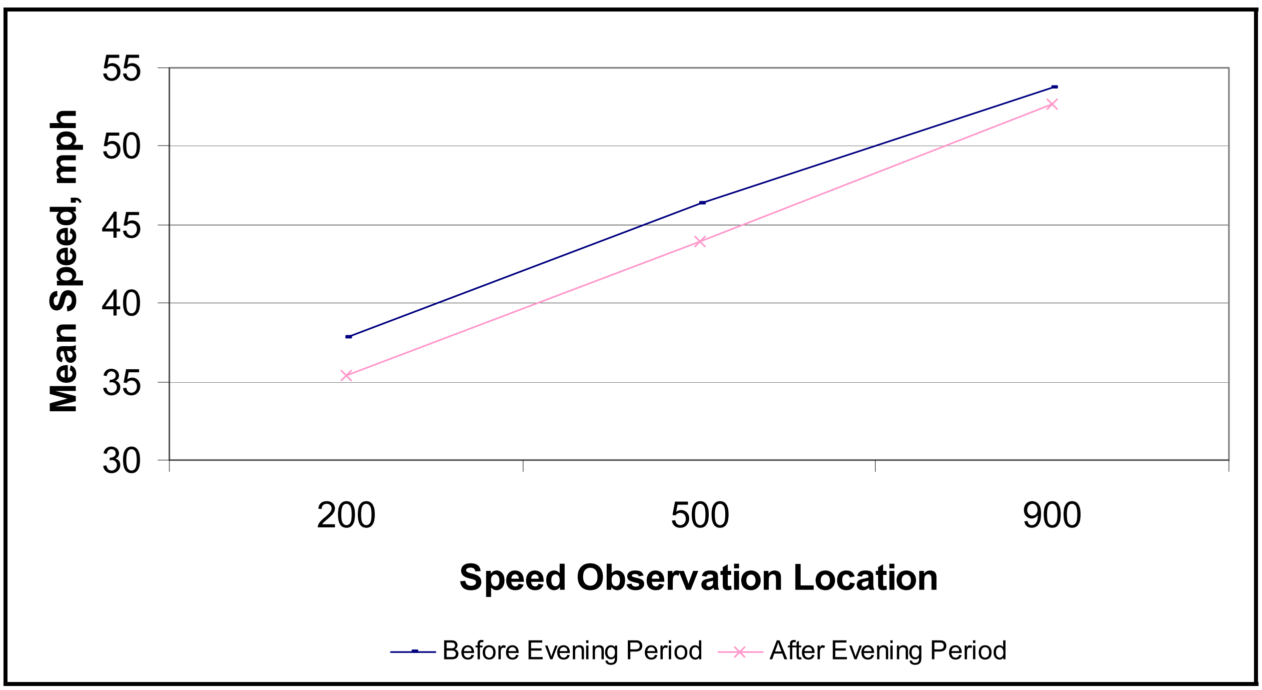

Figure 9. Average Speeds at 200, 500 and 900 feet North of SR 84 during Evening Period

The null hypothesis stating that the mean speeds were similar for the before and after conditions was rejected for all four analysis periods (AM, Noon, PM and Evening) for the 200-foot location, and three analysis periods (Noon, PM and Evening) for the 500-foot location. The null hypothesis was accepted for the AM period for the 500-foot location and three of the four periods for the 900-foot location.

In other words, the speeds were statistically different between the before and after conditions for all four time periods at the 200-foot location and for three time periods (Noon, PM and Evening) at the 500- foot location. Although the mean speed during the AM peak period was lower in the after condition at the 500-foot location, the difference was statistically similar. In general, at both the 200-foot and 500-foot locations, the in-roadway lights provided consistent speed reductions between 2 and 4 mph.

The mean speeds were similar at the 900 foot location for three of the four analysis periods (Noon, PM, and Evening), as expected, since the 900 foot location is outside of the area where the in-roadway lights were installed (the in-roadway lights only extend up to 600 feet north of SR 84). This finding also confirms that mean speeds prior to approaching the area with in-roadway lights were similar under both the before and after periods, and therefore, the reductions in speed at 200 foot and 500 foot locations can be attributed to in-roadway lights.

7.0 CONCLUSIONS

The objective of this study was to determine the effectiveness of in-roadway lights in reducing travel speeds with the ultimate goal of reducing crashes. The Florida Department of Transportation District 4 Traffic Operations Office installed a series of in-roadway lights along both sides of the southbound I-95 exit ramp to westbound SR 84, starting at the gore area between the ramp and SR 84 to a point 600 feet north of SR 84. The in-roadway lights were linked with a speed detection system, which would illuminate the lights when the approaching vehicle's speed was detected to be greater than the pre-set speed of 50 mph. A Before/After evaluation plan was utilized to determine the effectiveness of in-roadway lights on travel speeds and crashes.

Crash data for a three-year before period (2001 to 2003) and a three-year after period (2004 to 2006) were collected from the FDOT Crash Analysis and Reporting System. Speed data were collected at four locations (200, 500, 600 and 900 feet north of SR 84) along the ramp during the before condition (without in-roadway lights) and after condition (with in-roadway lights). A total of 76 speed studies were conducted during four different time periods (AM, Noon, PM and Evening). Forty-four studies (44) were conducted in the before condition and thirty-two (32) were conducted in the after condition. Several statistical tests were conducted to determine whether the changes observed in the measures of effectiveness (mean speed, speed distribution and crash frequency) are attributable to the installation of the in-roadway lights. A summary of the findings is as follows:

- The total crash frequencies for the before condition (without in-roadway lights) and the after condition (with in-roadway lights) were not significantly different at a 95% confidence level.
- For the AM and Noon periods at the 600-foot location, the speed distributions for the before condition were significantly different from those for the after condition. This indicates that in-roadway lights positively impacted travel speeds.
- For the AM, Noon, PM and Evening periods at the 600-foot speed study location, the mean speeds between the before and after conditions were significantly different at a 95% confidence level. Overall, the travel speeds were lower (by 2 to 7 mph based on time of day) during the after condition than those observed during the before condition. This indicates that the installation of in-roadway lights reduced the overall speed.
- The mean speeds for the AM, Noon, PM and Evening periods at the 200-foot location were significantly lower (by 2 to 4 mph) at a 95% confidence level in the after condition. This indicates that motorists reduced their speeds in response to in-roadway lights.
- The mean speeds for the Noon, PM and Evening periods at the 500-foot location were significantly lower (2 to 3 mph) at a 95% confidence level in the after condition, while the AM period mean speed was similar.
- For the 900-foot speed study location, the Noon, PM and Evening period mean speeds were similar at a 95% confidence level between the before and after conditions, which means that speeds prior to approaching the study area were similar.

In summary, the use of in-roadway lights reduced vehicular speeds by 2 to 7 mph and did not have a substantial impact on crashes at the study intersection. It should be noted that the in-roadway lights were not working continuously throughout the study period. The system was not 100% functional due to erratic operation of the loop detector card caused by lightening strikes and/or other reasons. The before and after crash frequencies were statistically similar at a 95% confidence level, although there was an increase in crashes during the after period. Additional traffic safety measures may need to be implemented at the study intersection to further reduce travel speeds and associated potential for crashes.

8.0 REFERENCES

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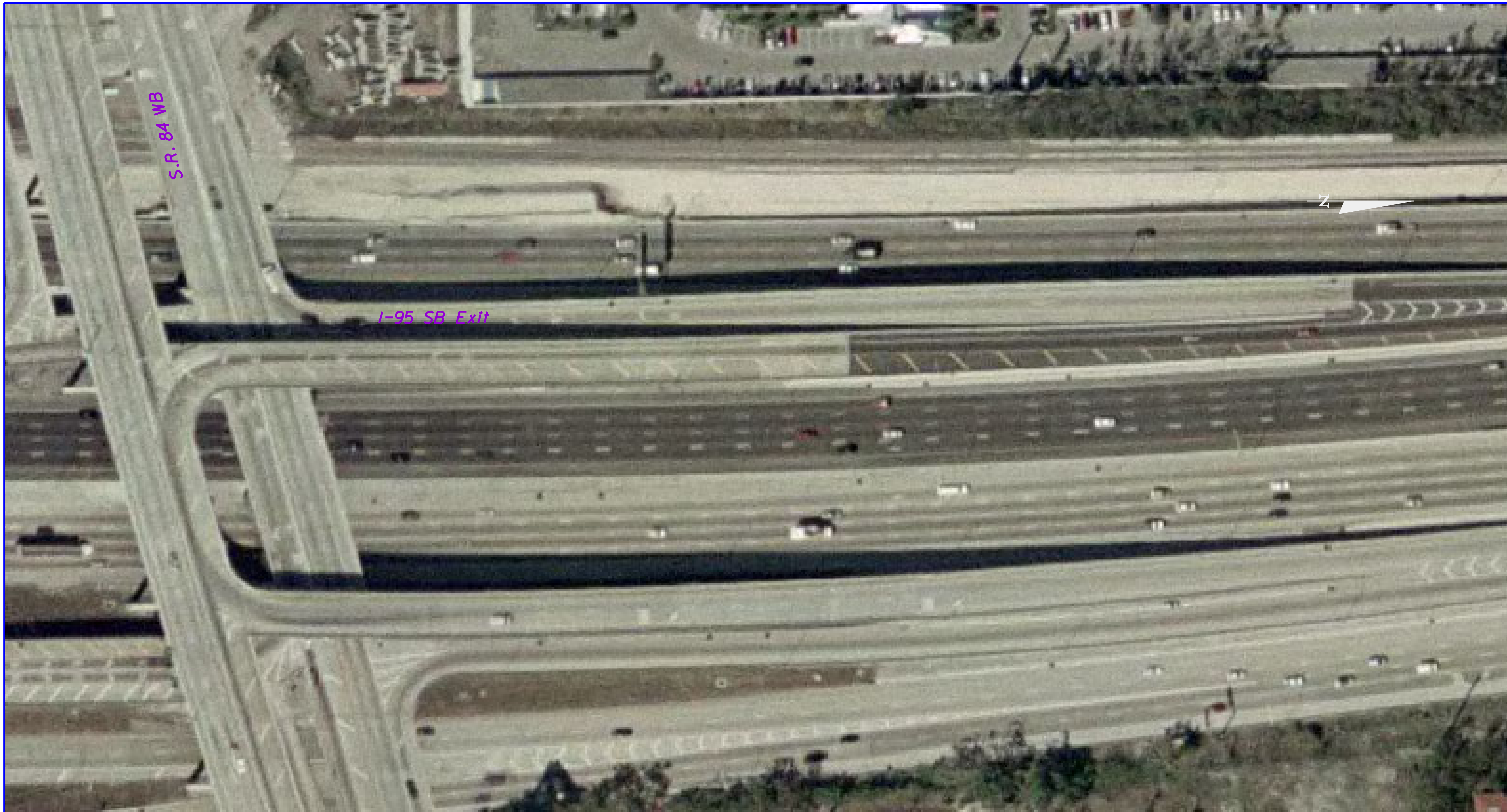
4. Wilcox, Rand. *Statistics for the Social Sciences, Fifth Edition*. Academic Press, San Diego, CA, 1996.

APPENDIX A

Collision Diagrams for Before and After Conditions



REAR-END COLLISION
SIDESWIPE
ANGLE COLLISION
COLLISION W/ PEDESTRIAN
COLLISION W/ BICYCLE

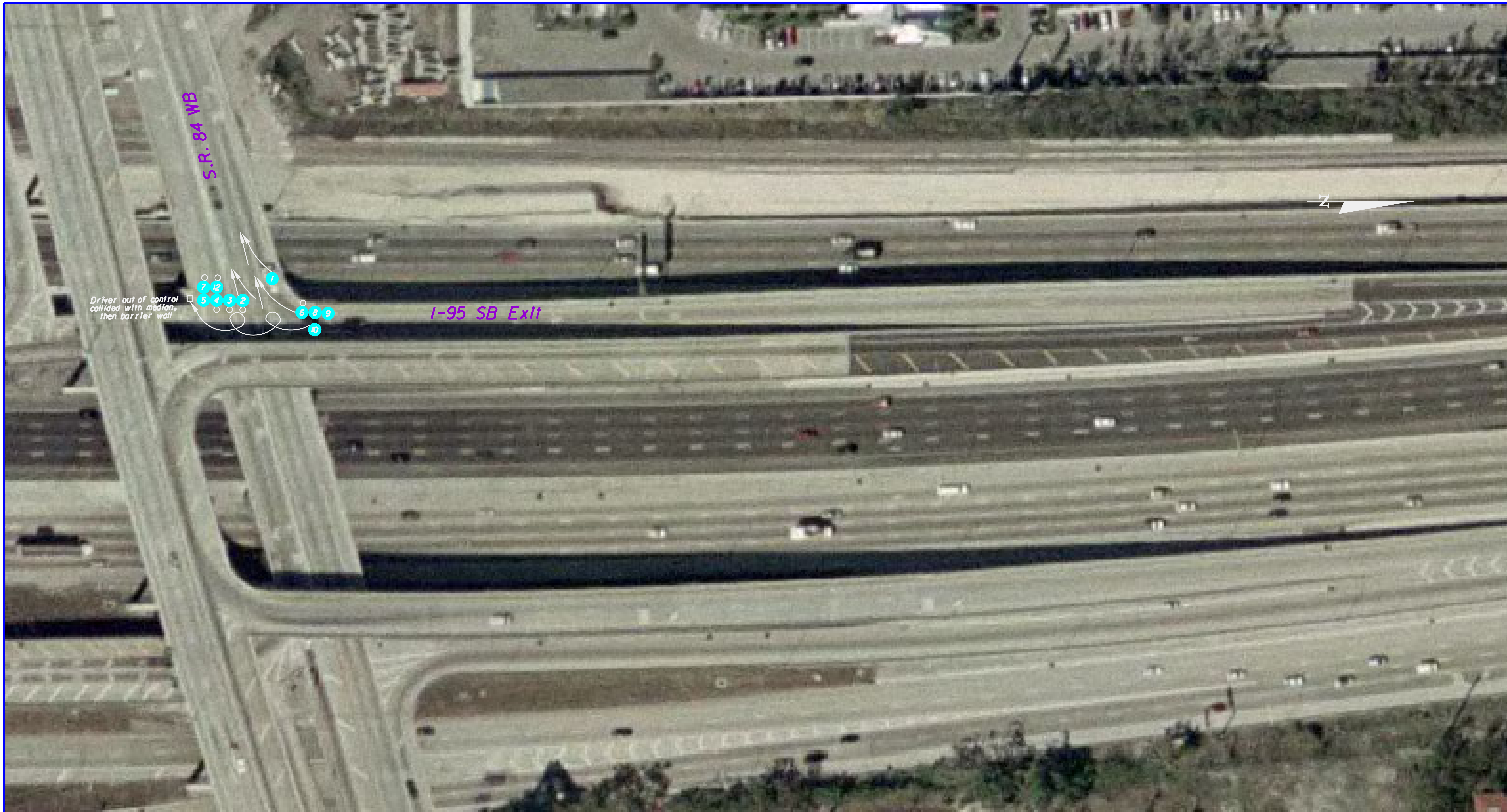
SYMBOLS:

HIT FIXED OBJECT
OUT OF CONTROL
LEFT TURN COLLISION
RIGHT TURN COLLISION
DISREGARDED TRAFFIC SIGNAL
PERSONAL INJURY
FATALITY

HNTB
6363 NW 6TH WAY, SUITE 420,
FORT LAUDERDALE, FL 33309
(954) 486-2880

2001 (DECEMBER ONLY)
COLLISION DIAGRAM
WB SR 84 AT SB I-95 Exit Ramp

$FILE$



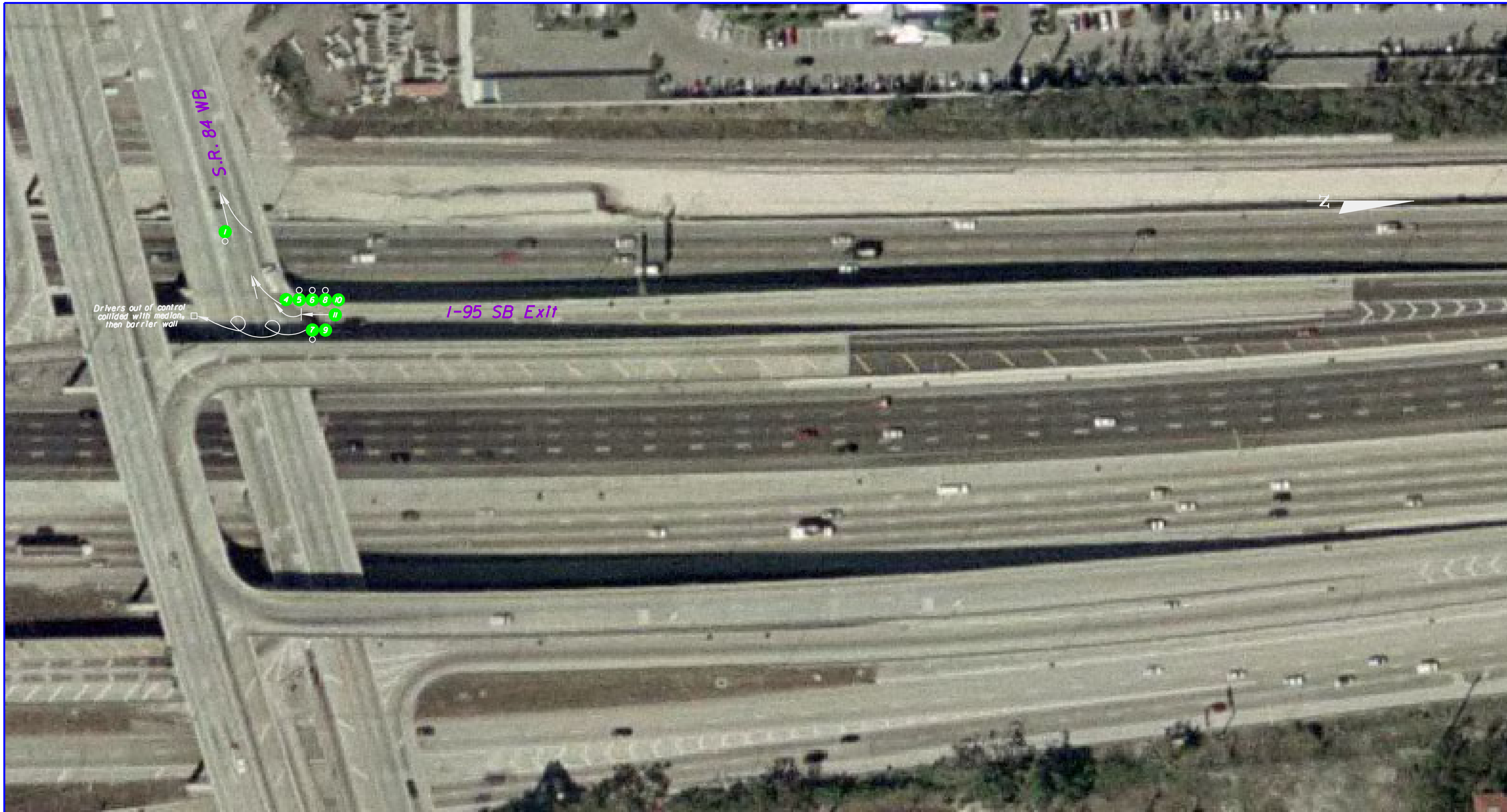
REAR-END COLLISION
SIDESWIPE
ANGLE COLLISION
COLLISION W/ PEDESTRIAN
COLLISION W/ BICYCLE

SYMBOLS:
HIT FIXED OBJECT
OUT OF CONTROL
LEFT TURN COLLISION
RIGHT TURN COLLISION
DISREGARDED TRAFFIC SIGNAL
PERSONAL INJURY
FATALITY

HNTB
6363 NW 6TH WAY, SUITE 420,
FORT LAUDERDALE, FL 33309
(954) 486-2880

2002 (JANUARY TO SEPTEMBER)
COLLISION DIAGRAM
WB SR 84 AT SB I-95 Exit Ramp

$FILE$



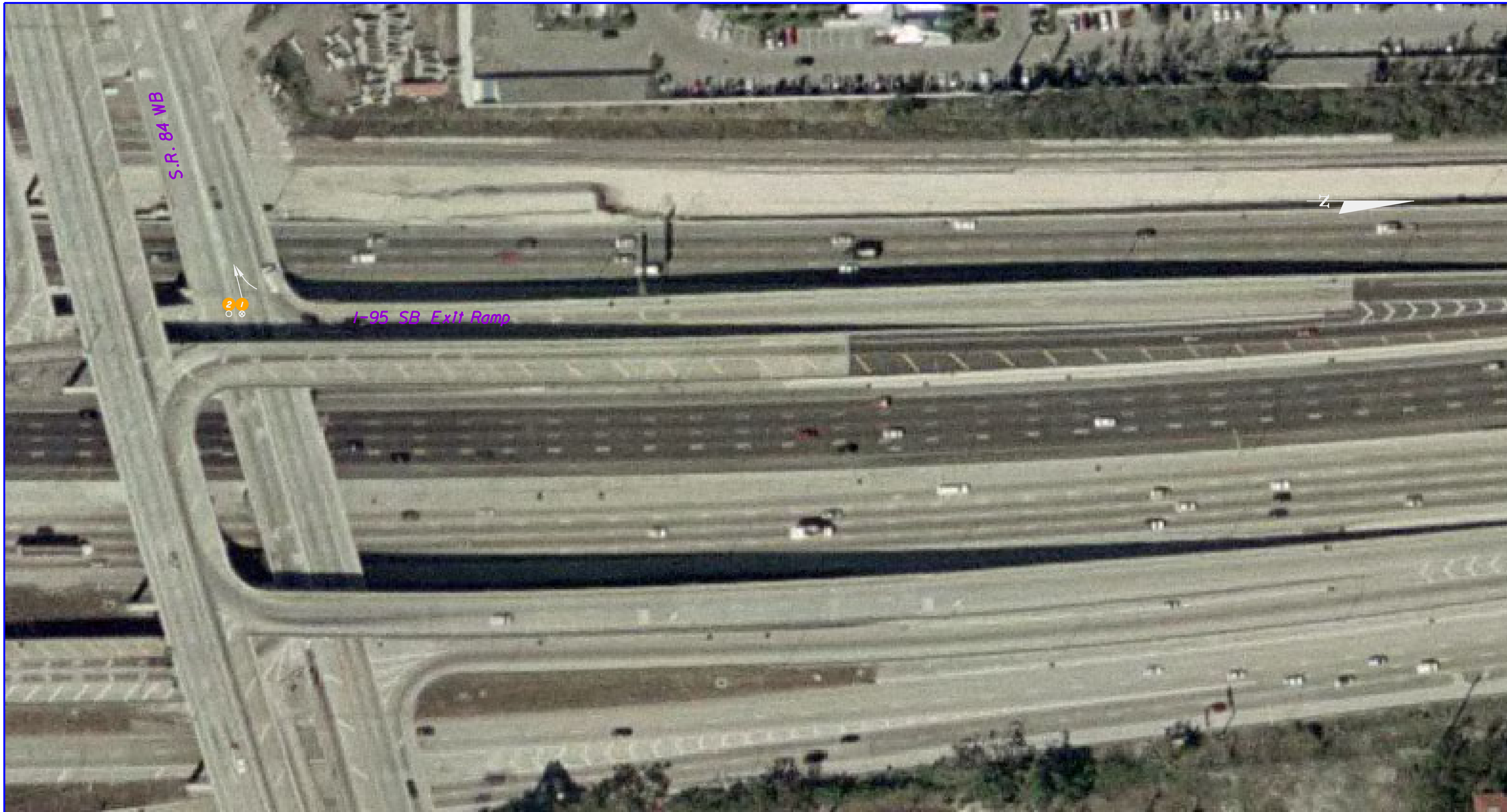
REAR-END COLLISION
SIDESWIPE
ANGLE COLLISION
COLLISION W/ PEDESTRIAN
COLLISION W/ BICYCLE

SYMBOLS:
HIT FIXED OBJECT
OUT OF CONTROL
LEFT TURN COLLISION
RIGHT TURN COLLISION
DISREGARDED TRAFFIC SIGNAL
PERSONAL INJURY
FATALITY

HNTB
6363 NW 6TH WAY, SUITE 420,
FORT LAUDERDALE, FL 33309
(954) 486-2880

2003 (MARCH TO AUGUST)
COLLISION DIAGRAM
WB SR 84 AT SB I-95 Exit Ramp

$FILE$



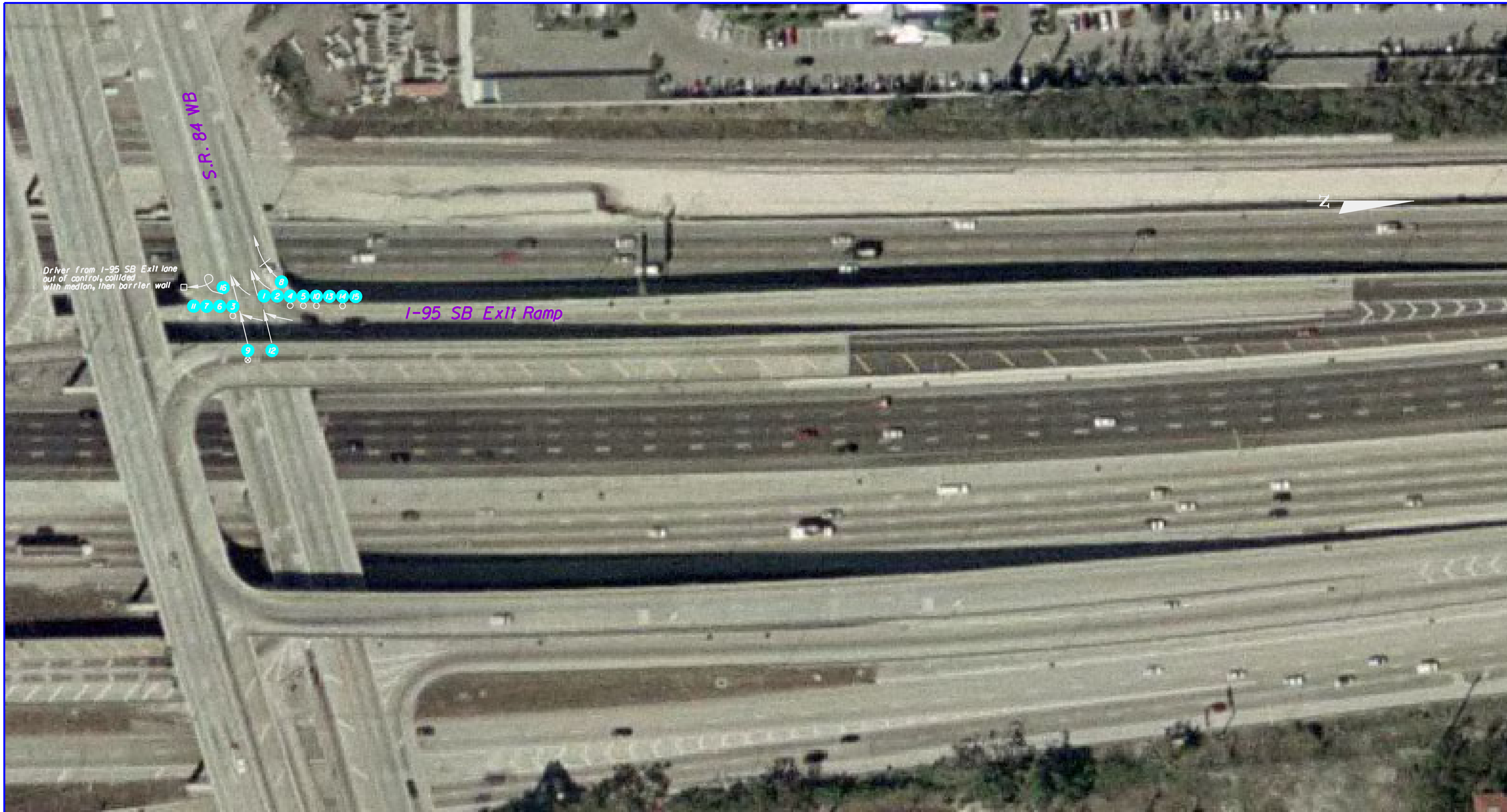
REAR-END COLLISION
SIDESWIPE
ANGLE COLLISION
COLLISION W/ PEDESTRIAN
COLLISION W/ BICYCLE

SYMBOLS:
HIT FIXED OBJECT
OUT OF CONTROL
LEFT TURN COLLISION
RIGHT TURN COLLISION
DISREGARDED TRAFFIC SIGNAL
PERSONAL INJURY
FATALITY

HNTB
6363 NW 6TH WAY, SUITE 420,
FORT LAUDERDALE, FL 33309
(954) 486-2880

2004 (DECEMBER ONLY)
COLLISION DIAGRAM
WB SR 84 AT SB I-95 Exit Ramp

$FILE$



REAR-END COLLISION
SIDESWIPE
ANGLE COLLISION
COLLISION W/ PEDESTRIAN
COLLISION W/ BICYCLE

SYMBOLS:

HIT FIXED OBJECT
OUT OF CONTROL
LEFT TURN COLLISION
RIGHT TURN COLLISION
DISREGARDED TRAFFIC SIGNAL
PERSONAL INJURY
FATALITY

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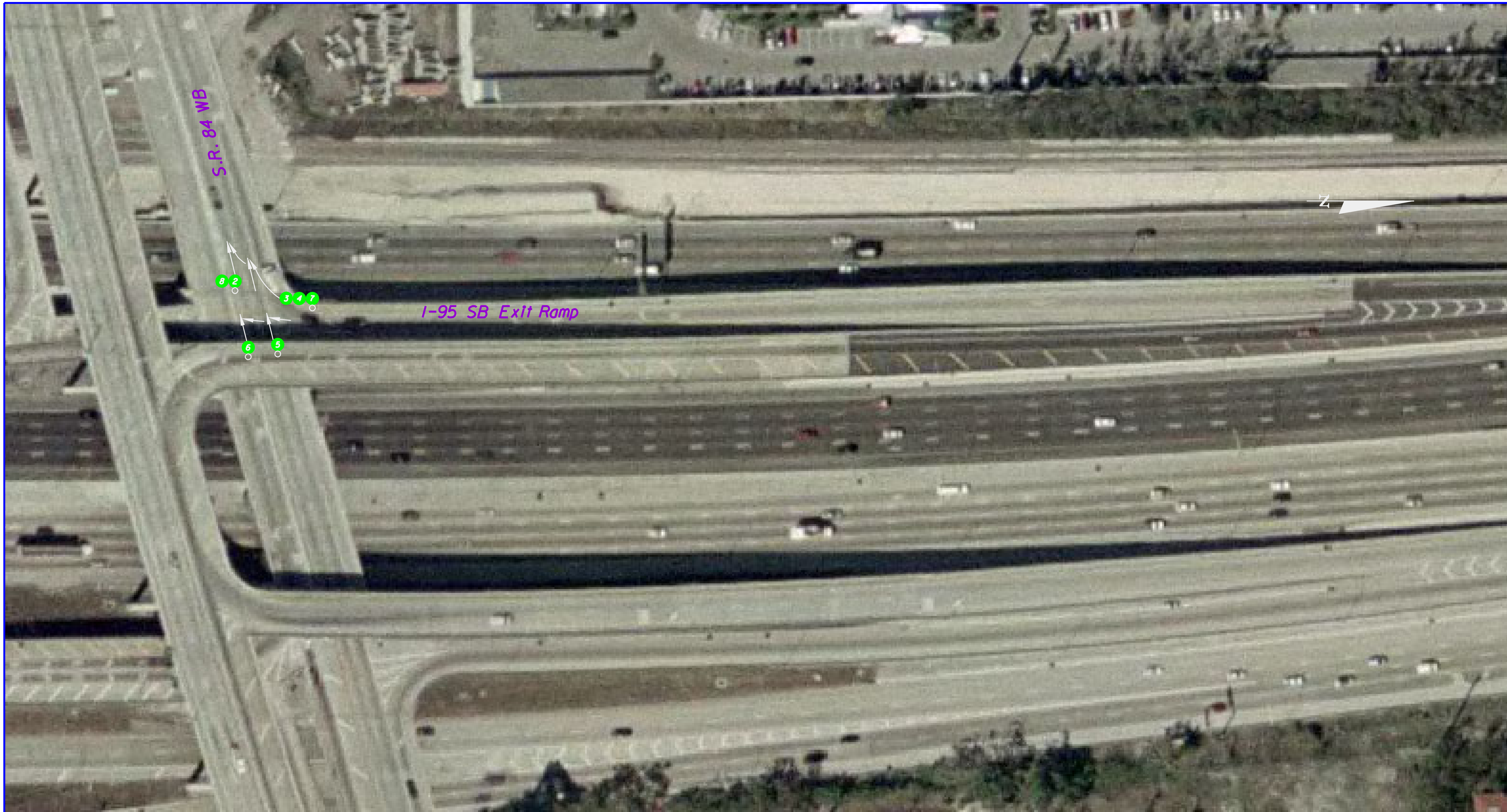
2005 (JANUARY TO SEPTEMBER)
COLLISION DIAGRAM
WB SR 84 AT I-95 SB Exit Ramp

$FILE$



SYMBOLS:

REAR-END COLLISION
SIDESWIPE
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2006 (MARCH TO AUGUST)
COLLISION DIAGRAM
WB SR 84 AT I-95 SB Exit Ramp

$FILE$