STATE OF NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION

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GOVERNOR

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SECRETARY

August 9, 2004

MEMORANDUM

To: J.S. (Steve) Kite, PE
Project Engineer

From: Stephen D. Lowry, PE
Traffic Safety Project Engineer

Subject: Traffic Safety Evaluation of the Wet Pavement Detection System Utilized on TIP Project Number R-2248

The Safety Evaluation Section of the Traffic Safety Systems Management Unit has completed a safety evaluation of the temporary on-site detour area along I-85 in western Mecklenburg County. The attached report presents the findings of a Before and After Comparison Analysis for the time period of July 1, 2002 to October 31, 2003.

If you have any further questions, please contact me at your convenience at (919) 733-7020.

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Attachments

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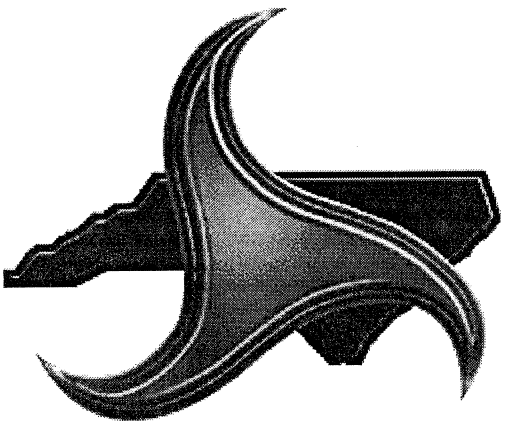
Traffic Safety Effects of a Wet Pavement Detection System Installed on a North Carolina Interstate

A Statistical Summary of Crash Data for a Temporary On-Site Detour inside an I-485 Construction Zone in Mecklenburg County



Document Prepared By:

Safety Evaluation Section
Traffic Safety Systems Management Unit
Traffic Engineering and Safety Systems Branch
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Principal Investigator

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EXECUTIVE SUMMARY

This report summarizes the traffic safety effects of a wet pavement detection system (WPDS) installed at an interstate construction zone. A temporary detour section was outfitted with WPDS, because standing water was creating a hazardous situation for motorists. This study examines the "wet" crashes prior to and after the installation of the WPDS. A comparison of the two time periods yield the following results:

- **The evaluation indicates that the WPDS reduced the yearly wet crash rate by 39 percent and the yearly injury crash rate by 35 percent.**
- **The average daily rainfall increased 71% from the "before" to the "after" period.**
- **The WPDS had very little or no effect during "dry" days. Examining days with no or little precipitation, the crash frequencies with and without WPDS were very similar.**
- **The average daily crashes on "heavy precipitation" days decreased from 2.59 to 1.09 crashes per day, a 58% drop.**
- **The WPDS appeared to reduce crashes on days with "heavy precipitation". Before the WPDS installation, there were 22 study days with 0.5 inches or more of precipitation. Only 5 of these 22 study days were accident free in the "before" period. After the WPDS installation, there were 33 study days with 0.5 inches or more of precipitation. Sixteen of those 33 days were accident free in the "after" period.**

INTRODUCTION

The purpose of this study is to report the safety effects of installing a Wet Pavement Detection System (WPDS). An I-85 bridge construction project in western Mecklenburg County required a temporary detour around the construction zone. This new eight-lane, three-quarter mile, asphalt section opened up in June 2002. When the traffic detour was opened, large sections of standing water were observed on the roadway during heavy rains. The standing water was a factor in several hydroplane crashes. NCDOT contacted Quixote Transportation Safety, Inc. to help alleviate the impacts of this temporary hazardous situation.

A WPDS was installed on the detour in March 2003. Northbound and southbound pavement sensors were installed in the roadway to measure water depth. Two roadside control units were equipped with precipitation sensors to detect rainfall. Also, Variable Message Signs (VMS) were placed in advance of the sensor locations. An automated monitoring system collected real-time data from these sensors and selected the display message. If the pavement was dry, the VMS had a blank display. If the pavement was wet and the water level was below 6 mm, the VMS message was "Wet Pavement Ahead; Observe Speed Limit". When the water depth rose above 6 mm, the VMS displayed "Standing Water Ahead; Reduce Your Speed". NCDOT rerouted I-85 traffic back to the permanent section in November 2003.

While this analysis includes a detailed look at the crash statistics for the detour area, it did not include any comprehensive field investigations or operational review. This analysis quantifies the differences in crash experience due to the installation of the WPDS. This analysis will help guide future traffic safety decisions for roadways sections that are experiencing an unusually large frequency of "wet" road crashes.

SCOPE OF PROJECT

This study is broken into two time periods. The "Before" study period is from July 1, 2002 to March 27, 2003. These dates represent a time period between the opening of the detour and the installation of the Wet Pavement Detection System (WPDS). The "After" study period is from March 29, 2003 to October 31, 2003. These dates represent a time period between the WPDS installation and the closure of the temporary on-site detour *(See Appendix A)*.

The Variable Message Signs (VMS) were placed approximately 0.5 mile on each side prior to the 0.75-mile detour. Thus, a 2.5-mile study section was chosen for the crash analysis to account for the drivers who slow down when they see the highway-warning message *(See Appendix B)*.

CRASH ANALYSIS METHOD

Crash data was obtained from the Traffic Engineering Accident Analysis System (TEAAS) database. This database contains all reported motor vehicle crashes in North Carolina. Volume data for this study was obtained from the 2002 NCDOT AADT maps. The annual average daily traffic along this section of I-85 was 103,000 vehicles per day.

NAÏVE BEFORE AND AFTER ANALYSIS

The "Before" data clearly shows that this area was experiencing an extreme number of "Wet" crashes (*See Table 1*). The 2.5-mile study section experienced 73 "wet" crashes in 270 days; 18 of the 73 "wet" crashes were reported to have "standing/moving water" as the roadway surface condition. "Wet" crashes made up 65.2% of the total crashes. This compares to the 21.66% percent "wet" crashes listed on the *2000-2002 Three-Year Crash Rate for Mecklenburg County* for rural interstates. Furthermore, eleven crashes were reported on August 31, 2002 and September 26, 2002. Seven crashes were reported on August 15, 2002 and September 15, 2002. A local weather station reported heavy rainfall amounts for these four days.

The "Before" study period and "After" study period are 270 days and 217 days, respectively. Therefore, the data was converted to a yearly crash rate for comparison purposes. The Yearly Total Crash Rate dropped 4.5% while the Yearly Wet Crash Rate fell 16.5%. However, the Naïve Before and After evaluation methods do not account for changes in weather conditions and other sundry factors. Comparison studies are often used to account for weather and other changing factors that can influence traffic safety.

CRASH SUMMARY	Before Period	After Period
Total Crashes	112	86
Total Injury Crashes	41	21
PDO Crashes	71	65
Wet Crashes	73	49

CRASH SUMMARY	Before Period	After Period	% Change	Statistically Significant*
Yearly Total Crash Rate	151.4	144.7	-4.5%	NO
Yearly Injury Crash Rate	55.4	35.3	-36.3%	YES
Yearly PDO Crash Rate	96.0	109.3	13.9%	NO
Yearly Wet Crash Rate	98.7	82.4	-16.5%	NO

Table 1. Crash Data for Treatment Area

* Statistical significance tested at the 85% confidence interval using the *T Test* methodology.

COMPARISON GROUP ANALYSIS

A 2.5-mile section of I-85 in eastern Gaston County was selected as a comparison section. This comparison section was chosen because it is near the treatment section, thus the weather conditions, traffic volumes, vehicle fleet and other factors are very similar. (*See Table 2*)

The crash data of the comparison section was utilized to calculate the expected yearly crash rate for the treated study section during the after period. Odds ratio calculations show that the "wet" crash rate decreased by 39.0% and the injury crash rate shrunk by 35.1% (*See Table 3*).

CRASH SUMMARY	Before Period	After Period
Total Crashes	40	31
Total Injury Crashes	19	15
PDO Crashes	21	16
Wet Crashes	10	11

CRASH SUMMARY	Before Period	After Period	% Change	Statistically Significant*
Yearly Total Crash Rate	54.1	52.1	-3.6%	NO
Yearly Injury Crash Rate	25.7	25.2	-1.8%	NO
Yearly PDO Crash Rate	28.4	26.9	-5.2%	NO
Yearly Wet Crash Rate	13.5	18.5	36.9%	NO

Table 2. Crash Data for Comparison Area

* Statistical significance tested at the 85% confidence interval using the *T Test* methodology.

CRASH SUMMARY	Predicted Treatment	Actual Treatment	% Change	Statistically Significant*
Yearly Total Crash Rate	146.0	144.7	-0.9%	NO
Yearly Injury Crash Rate	54.4	35.3	-35.1%	YES
Yearly PDO Crash Rate	91.0	109.3	20.2%	NO
Yearly Wet Crash Rate	135.1	82.4	-39.0%	YES

Table 3. Odds Ratio Calculations

Statistical significance tested at the 85% confidence interval using the *T Test* methodology.

CRASH FREQUENCY BY DAILY PRECIPITATION

The Charlotte weather station for the National Weather Service is located approximately 3 miles southeast of the construction zone. The meteorological data was collected for this station to determine the approximate amount of daily precipitation in the study area. Based on this data, the total precipitation during the "before" period and "after" period was 35.33" and 48.53", respectively. The calculated average daily rainfall increased from 0.131" to 0.224" (71%). Such an increase in daily precipitation has a definite impact on "wet" crash rates.

The daily precipitation totals were classified into the four groups shown below:

Precipitation Level	**Amount**
None	0" or Trace
Slight	0.01 to 0.10"
Moderate	0.11 to 0.50"
Heavy	> 0.50"

The twenty-two "heavy" precipitation days during the "before" period averaged 2.59 crashes per day. In comparison the thirty-three "heavy" precipitation days during the "after" period average only 1.09 crashes per day. This represents a 58% decrease (*See Table 4*).

Precipitation Level	Ave. Daily Crashes	
	Before	After
None	0.18	0.20
Slight	0.21	0.28
Moderate	0.43	0.57
Heavy	2.59	1.09

Table 4. Crashes By Precipitation Level

The daily crash frequencies at the study section were very similar during days with moderate precipitation or less. The "before" study period and "after" study period included 22 and 33 days of "heavy" precipitation, respectively. Only 5 of 22 (23%) "heavy" precipitation days were accident free in the "before" period. In comparison, 16 of 33 (48%) "heavy" precipitation days were accident free in the "after" period (*See Table 5 and 6*).

accident free in the "before" period. In comparison, 16 of 33 (48%) "heavy" precipitation days were accident free in the "after" period (*See Table 5 and 6*).

Number of Days with Crash Total (% of total)

	Number of Days by Crash Frequency							
Daily Precipitation	**0**	**1**	**2**	**3**	**4**	**5**	**>5**	**All**
none	149 (85.6%)	20 (11.5%)	4 (2.3%)	1 (0.6%)				174 (100%)
slight	27 (79.4%)	7 (20.6%)						34 (100%)
moderate	29 (72.5%)	8 (20.0%)	1 (2.5%)	1 (2.5%)	1 (2.5%)			40 (100%)
heavy	5 (22.7%)	6 (27.3%)	6 (27.3%)	1 (4.5%)			4 (18.2%)	22 (100%)

Table 5. Crash Frequency by Precipitation Level (Before Period)

Number of Days with Crash Total (% of total)

	Number of Days by Crash Frequency							
Daily Precipitation	**0**	**1**	**2**	**3**	**4**	**5**	**>5**	**All**
none	104 (85.2%)	13 (10.7%)	4 (3.3%)	1 (0.8%)				122 (100%)
slight	24 (75.0%)	7 (21.9%)	1 (3.1%)					32 (100%)
moderate	20 (66.7%)	7 (23.3%)	1 (3.3%)	1 (3.3%)		1 (3.3%)		30 (100%)
heavy	16 (48.5%)	8 (24.2%)	3 (9.1%)	4 (12.1%)		2 (6.1%)		33 (100%)

Table 6. Crash Frequency by Precipitation Level (After Period)

RECOMMENDATIONS

APLLICATION OF STUDY RESULTS

Based upon this study, the Wet Pavement Detection System (WPDS) was effective in preventing crashes at this location during periods of heavy precipitation. When compared to a similar location, the estimated reduction of yearly wet crash rate was 39%. However, it should be noted that such a dramatic decrease might not be replicated for WPDS applications that have adequate roadway drainage.

REFERENCES

1. http://www.highwayinfo.com/news/11-03_quixote_intellizone.php

2. http://www.erh.noaa.gov/er/gsp/climate/climate.htm

3. Ezra Hauer "Observational Before-After Studies in Road Safety", Pergamon, Elsevier Science Ltd, Tarrytown, New York, 1997

APPENDIX A – Crash Count & Precipitation by Day

Before Period

DATE	# of Crashes	Rainfall Amount
7/1/2002	0	0.08
7/2/2002	0	0.02
7/3/2002	0	0
7/4/2002	0	0
7/5/2002	0	0
7/6/2002	0	0
7/7/2002	0	0
7/8/2002	0	0
7/9/2002	0	0
7/10/2002	0	0
7/11/2002	0	0
7/12/2002	0	0
7/13/2002	1	0.41
7/14/2002	1	0.17
7/15/2002	3	0.32
7/16/2002	0	0
7/17/2002	0	0
7/18/2002	1	0
7/19/2002	0	0
7/20/2002	0	0.02
7/21/2002	0	0
7/22/2002	0	0
7/23/2002	0	0
7/24/2002	1	0.01
7/25/2002	0	0.12
7/26/2002	0	0.05
7/27/2002	0	0
7/28/2002	0	0
7/29/2002	0	0
7/30/2002	0	0
7/31/2002	0	0
8/1/2002	0	0
8/2/2002	0	0
8/3/2002	0	0
8/4/2002	0	0
8/5/2002	0	0
8/6/2002	0	0
8/7/2002	2	0
8/8/2002	0	0
8/9/2002	0	0
8/10/2002	0	0
8/11/2002	0	0

DATE	# of Crashes	Rainfall Amount
8/12/2002	0	0
8/13/2002	0	0
8/14/2002	0	0
8/15/2002	**7**	**0.89**
8/16/2002	1	0.4
8/17/2002	0	0.21
8/18/2002	0	0
8/19/2002	0	0
8/20/2002	0	0
8/21/2002	0	0
8/22/2002	0	0
8/23/2002	0	0
8/24/2002	1	0.33
8/25/2002	0	0.33
8/26/2002	0	0.34
8/27/2002	1	0.03
8/28/2002	1	0.09
8/29/2002	0	0.04
8/30/2002	0	0.04
8/31/2002	**11**	**1.62**
9/1/2002	0	0.06
9/2/2002	0	0
9/3/2002	0	0
9/4/2002	0	0
9/5/2002	1	0
9/6/2002	0	0
9/7/2002	0	0
9/8/2002	0	0
9/9/2002	0	0
9/10/2002	1	0
9/11/2002	0	0
9/12/2002	1	0
9/13/2002	0	0
9/14/2002	0	1.4
9/15/2002	**7**	**0.99**
9/16/2002	0	0.03
9/17/2002	0	0.01
9/18/2002	0	0
9/19/2002	0	0
9/20/2002	0	0
9/21/2002	1	0
9/22/2002	1	0.01

DATE	# of Crashes	Rainfall Amount
9/23/2002	0	0
9/24/2002	0	0
9/25/2002	0	0.09
9/26/2002	**11**	**0.78**
9/27/2002	4	0.17
9/28/2002	0	0
9/29/2002	0	0
9/30/2002	0	0
10/1/2002	1	0
10/2/2002	0	0
10/3/2002	0	0
10/4/2002	0	0
10/5/2002	2	0
10/6/2002	0	0
10/7/2002	0	0
10/8/2002	0	0.06
10/9/2002	0	0.02
10/10/2002	0	0.01
10/11/2002	2	2.24
10/12/2002	0	0
10/13/2002	0	0.62
10/14/2002	0	0
10/15/2002	1	0.9
10/16/2002	1	0.45
10/17/2002	0	0
10/18/2002	1	0
10/19/2002	0	0
10/20/2002	0	0.03
10/21/2002	0	0.12
10/22/2002	0	0.03
10/23/2002	0	0
10/24/2002	0	0
10/25/2002	0	0.16
10/26/2002	0	0
10/27/2002	0	0
10/28/2002	1	0.53
10/29/2002	0	0.25
10/30/2002	0	0.01
10/31/2002	0	0
11/1/2002	0	0
11/2/2002	0	0
11/3/2002	0	0

DATE	# of Crashes	Rainfall Amount
11/4/2002	0	0.03
11/5/2002	1	0.97
11/6/2002	0	0.16
11/7/2002	0	0
11/8/2002	0	0
11/9/2002	2	0
11/10/2002	1	0.01
11/11/2002	0	0.38
11/12/2002	1	1.54
11/13/2002	0	0
11/14/2002	0	0
11/15/2002	0	0
11/16/2002	0	1.13
11/17/2002	0	0.16
11/18/2002	0	0
11/19/2002	0	0
11/20/2002	0	0
11/21/2002	0	0
11/22/2002	0	0
11/23/2002	0	0
11/24/2002	0	0
11/25/2002	0	0
11/26/2002	1	0
11/27/2002	0	0
11/28/2002	0	0
11/29/2002	1	0
11/30/2002	0	0
12/1/2002	0	0
12/2/2002	0	0.01
12/3/2002	0	0
12/4/2002	2	0.65
12/5/2002	0	0.49
12/6/2002	0	0
12/7/2002	0	0
12/8/2002	0	0
12/9/2002	0	0
12/10/2002	0	0.13
12/11/2002	0	0.44
12/12/2002	0	0
12/13/2002	1	1
12/14/2002	0	0
12/15/2002	0	0
12/16/2002	0	0
12/17/2002	1	0
12/18/2002	0	0
12/19/2002	0	0.01
12/20/2002	1	0.36
12/21/2002	0	0

DATE	# of Crashes	Rainfall Amount
12/22/2002	0	0
12/23/2002	1	0
12/24/2002	2	1.47
12/25/2002	0	0.4
12/26/2002	0	0
12/27/2002	0	0
12/28/2002	0	0
12/29/2002	0	0
12/30/2002	0	0
12/31/2002	1	0
1/1/2003	1	0.24
1/2/2003	0	0.05
1/3/2003	0	0.22
1/4/2003	3	0
1/5/2003	1	0
1/6/2003	0	0
1/7/2003	0	0
1/8/2003	0	0
1/9/2003	0	0
1/10/2003	0	0
1/11/2003	1	0
1/12/2003	0	0
1/13/2003	0	0
1/14/2003	0	0
1/15/2003	0	0
1/16/2003	0	0.15
1/17/2003	0	0
1/18/2003	1	0
1/19/2003	0	0
1/20/2003	0	0
1/21/2003	0	0.13
1/22/2003	0	0
1/23/2003	0	0.18
1/24/2003	1	0
1/25/2003	0	0
1/26/2003	0	0
1/27/2003	0	0
1/28/2003	0	0
1/29/2003	0	0.14
1/30/2003	0	0.85
1/31/2003	0	0
2/1/2003	0	0
2/2/2003	0	0
2/3/2003	0	0
2/4/2003	0	0.23
2/5/2003	0	0
2/6/2003	0	0.43
2/7/2003	0	0.13

DATE	# of Crashes	Rainfall Amount
2/8/2003	0	0
2/9/2003	1	0
2/10/2003	1	0.22
2/11/2003	2	0
2/12/2003	0	0
2/13/2003	0	0
2/14/2003	0	0.25
2/15/2003	0	0.04
2/16/2003	2	0.41
2/17/2003	0	0.01
2/18/2003	0	0
2/19/2003	0	0
2/20/2003	1	0.04
2/21/2003	0	0.03
2/22/2003	0	0.98
2/23/2003	0	0.05
2/24/2003	0	0
2/25/2003	0	0
2/26/2003	0	0.44
2/27/2003	0	0.35
2/28/2003	0	0
3/1/2003	1	0.55
3/2/2003	0	0.05
3/3/2003	0	0
3/4/2003	0	0.02
3/5/2003	0	0.12
3/6/2003	3	1.3
3/7/2003	0	0
3/8/2003	0	0
3/9/2003	0	0
3/10/2003	0	0
3/11/2003	0	0
3/12/2003	0	0
3/13/2003	0	0
3/14/2003	1	0
3/15/2003	2	0.56
3/16/2003	0	0.39
3/17/2003	0	0.13
3/18/2003	0	0.16
3/19/2003	2	0.57
3/20/2003	2	1.99
3/21/2003	1	0.01
3/22/2003	1	0
3/23/2003	0	0
3/24/2003	0	0
3/25/2003	1	0
3/26/2003	0	0.08
3/27/2003	0	0

After Period

DATE	# of Crashes	Rainfall Amount
3/29/2003	0	0
3/30/2003	3	1.13
3/31/2003	0	0
4/1/2003	0	0
4/2/2003	0	0
4/3/2003	2	0
4/4/2003	0	0
4/5/2003	0	0.19
4/6/2003	3	0.67
4/7/2003	0	1.31
4/8/2003	0	0.66
4/9/2003	0	0.91
4/10/2003	3	1.98
4/11/2003	0	0.06
4/12/2003	0	0
4/13/2003	0	0
4/14/2003	0	0
4/15/2003	0	0
4/16/2003	0	0
4/17/2003	1	0.21
4/18/2003	1	1.59
4/19/2003	0	0.12
4/20/2003	0	0
4/21/2003	0	0.09
4/22/2003	0	0
4/23/2003	0	0
4/24/2003	0	0
4/25/2003	0	0.26
4/26/2003	0	0.19
4/27/2003	0	0
4/28/2003	0	0
4/29/2003	0	0.01
4/30/2003	0	0
5/1/2003	0	0.01
5/2/2003	1	0.28
5/3/2003	0	0
5/4/2003	0	0
5/5/2003	0	0.24
5/6/2003	2	1.08
5/7/2003	1	0.03
5/8/2003	0	0
5/9/2003	0	0
5/10/2003	0	0
5/11/2003	0	0.01
5/12/2003	0	0

DATE	# of Crashes	Rainfall Amount
5/13/2003	3	0
5/14/2003	0	0
5/15/2003	0	1.56
5/16/2003	0	0
5/17/2003	0	0
5/18/2003	1	0.48
5/19/2003	0	0.03
5/20/2003	0	0
5/21/2003	0	1.51
5/22/2003	5	3.5
5/23/2003	1	0.07
5/24/2003	0	0.26
5/25/2003	2	0.55
5/26/2003	1	0.82
5/27/2003	0	0
5/28/2003	0	0
5/29/2003	0	0.01
5/30/2003	1	0
5/31/2003	5	0.25
6/1/2003	0	0
6/2/2003	0	0
6/3/2003	1	0.72
6/4/2003	0	0.18
6/5/2003	0	0
6/6/2003	1	0.56
6/7/2003	1	2.19
6/8/2003	1	0.32
6/9/2003	1	0
6/10/2003	0	0
6/11/2003	0	0.05
6/12/2003	0	0.13
6/13/2003	0	0
6/14/2003	0	0
6/15/2003	1	0.15
6/16/2003	1	0.09
6/17/2003	1	0.01
6/18/2003	0	0.23
6/19/2003	0	0.18
6/20/2003	0	0.01
6/21/2003	0	0
6/22/2003	0	0
6/23/2003	0	0
6/24/2003	2	0
6/25/2003	1	0
6/26/2003	0	0

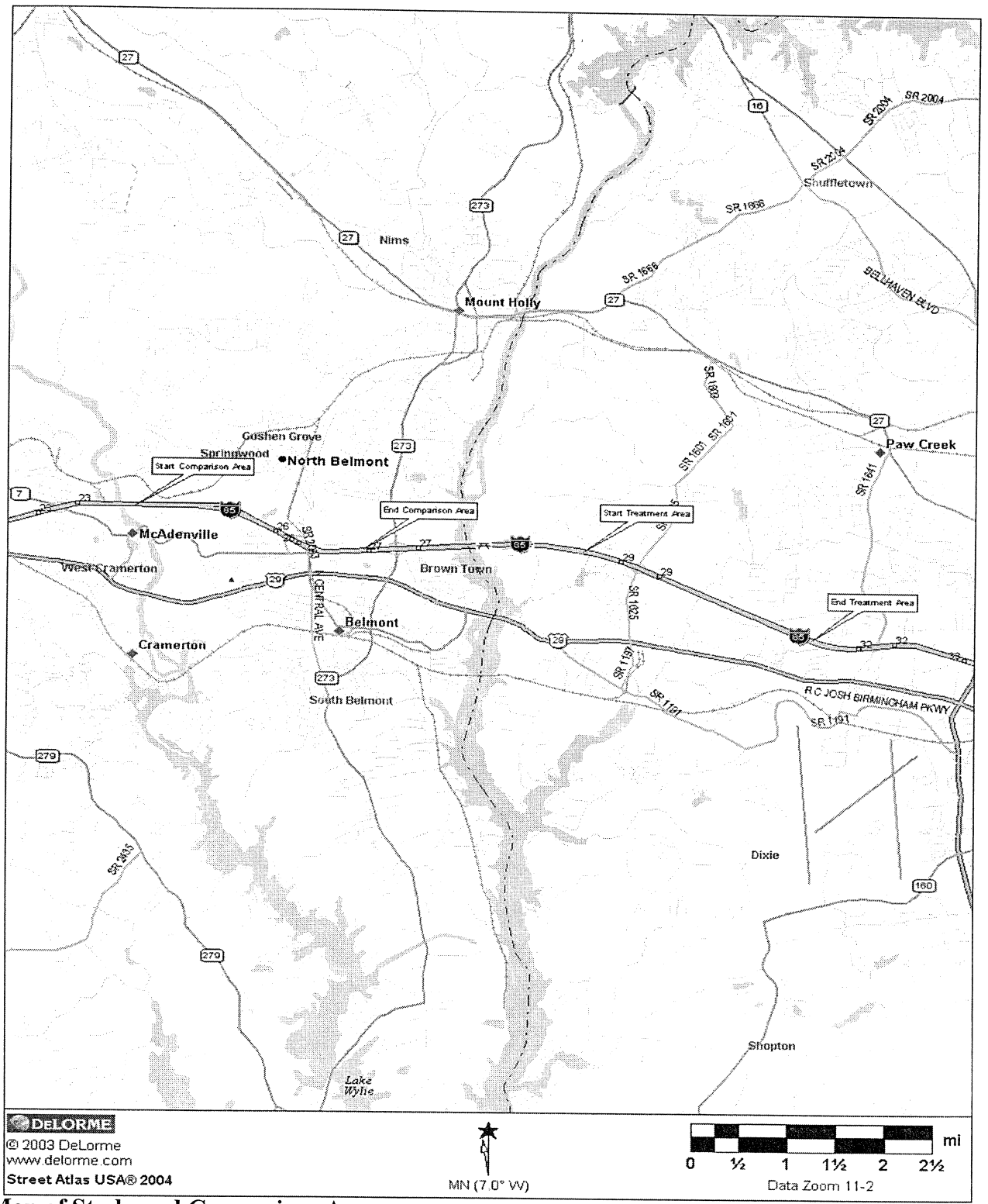
DATE	# of Crashes	Rainfall Amount
6/27/2003	0	0
6/28/2003	1	0.19
6/29/2003	0	0
6/30/2003	0	0.05
7/1/2003	0	0.48
7/2/2003	2	1.07
7/3/2003	0	0
7/4/2003	0	0
7/5/2003	0	0
7/6/2003	0	0
7/7/2003	0	0.01
7/8/2003	0	0
7/9/2003	0	0.45
7/10/2003	0	0.02
7/11/2003	0	0.39
7/12/2003	0	0.53
7/13/2003	0	0.75
7/14/2003	0	0
7/15/2003	0	0
7/16/2003	0	0.01
7/17/2003	0	0.69
7/18/2003	0	0.06
7/19/2003	0	0.17
7/20/2003	0	0
7/21/2003	1	1.56
7/22/2003	0	0
7/23/2003	3	0.21
7/24/2003	0	0
7/25/2003	0	0
7/26/2003	0	0.77
7/27/2003	0	0
7/28/2003	0	0
7/29/2003	0	0.59
7/30/2003	2	0.03
7/31/2003	1	0.5
8/1/2003	0	0.03
8/2/2003	0	0
8/3/2003	0	0.45
8/4/2003	0	2.48
8/5/2003	0	0.01
8/6/2003	0	0.03
8/7/2003	0	0.05
8/8/2003	0	0.98
8/9/2003	0	0.41
8/10/2003	3	1.41

DATE	# of Crashes	Rainfall Amount
8/11/2003	0	0
8/12/2003	0	0.1
8/13/2003	0	0
8/14/2003	1	1.74
8/15/2003	0	0
8/16/2003	0	0
8/17/2003	0	0.08
8/18/2003	1	0
8/19/2003	0	0
8/20/2003	0	0
8/21/2003	0	0
8/22/2003	0	1.38
8/23/2003	0	0
8/24/2003	0	0
8/25/2003	1	0
8/26/2003	0	0
8/27/2003	0	0
8/28/2003	0	0.5
8/29/2003	0	0
8/30/2003	0	0
8/31/2003	0	0.7
9/1/2003	0	0.02
9/2/2003	0	0
9/3/2003	0	0
9/4/2003	0	0.17
9/5/2003	0	0
9/6/2003	0	0
9/7/2003	0	0

DATE	# of Crashes	Rainfall Amount
9/8/2003	1	0.03
9/9/2003	0	0
9/10/2003	1	0
9/11/2003	0	0
9/12/2003	0	0
9/13/2003	0	0
9/14/2003	0	0
9/15/2003	0	0.69
9/16/2003	0	0
9/17/2003	0	0
9/18/2003	0	0
9/19/2003	0	0
9/20/2003	0	0
9/21/2003	0	0
9/22/2003	5	1.48
9/23/2003	1	0.06
9/24/2003	0	0
9/25/2003	0	0
9/26/2003	0	0
9/27/2003	0	0.24
9/28/2003	0	0
9/29/2003	1	0
9/30/2003	0	0
10/1/2003	0	0
10/2/2003	0	0
10/3/2003	2	0
10/4/2003	0	0
10/5/2003	1	0

DATE	# of Crashes	Rainfall Amount
10/6/2003	0	0
10/7/2003	0	0
10/8/2003	1	0.8
10/9/2003	1	0.01
10/10/2003	0	0.09
10/11/2003	2	0.17
10/12/2003	0	0
10/13/2003	0	0
10/14/2003	1	0
10/15/2003	0	0
10/16/2003	2	0
10/17/2003	1	0
10/18/2003	1	0
10/19/2003	0	0
10/20/2003	0	0
10/21/2003	0	0
10/22/2003	0	0
10/23/2003	0	0
10/24/2003	1	0
10/25/2003	0	0
10/26/2003	0	0.26
10/27/2003	0	0.7
10/28/2003	0	0.03
10/29/2003	0	0.01
10/30/2003	1	0
10/31/2003	0	0

Appendix B



Map of Study and Comparison Area

STATE OF NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION

MICHAEL F. EASLEY
GOVERNOR

LYNDO TIPPETT
SECRETARY

August 9, 2004

MEMORANDUM

To: J.S. (Steve) Kite, PE
Project Engineer

From: Stephen D. Lowry, PE
Traffic Safety Project Engineer

Subject: Traffic Safety Evaluation of the Wet Pavement Detection System Utilized on TIP Project Number R-2248

The Safety Evaluation Section of the Traffic Safety Systems Management Unit has completed a safety evaluation of the temporary on-site detour area along I-85 in western Mecklenburg County. The attached report presents the findings of a Before and After Comparison Analysis for the time period of July 1, 2002 to October 31, 2003.

If you have any further questions, please contact me at your convenience at (919) 733-7020.

SDL: sdl

Attachments

Cc: J. K. Lacy, PE, CPM
J. Stuart Bourne, PE
Joseph Ishak, PE
Tawana Brooks, PE
Thomas Thrower
A. D. (Tony) Wyatt, PE
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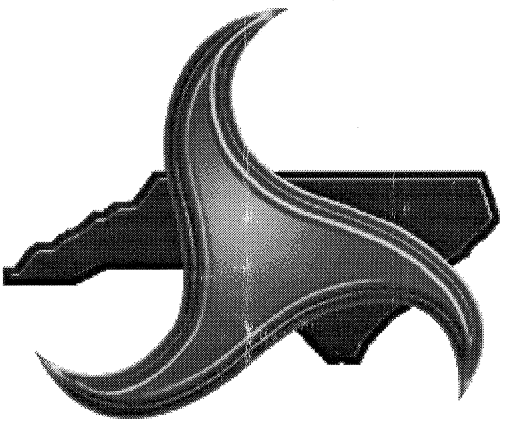
LOCATION:
THOMPSON BUILDING
122 NORTH MCDOWELL STREET
RALEIGH, NORTH CAROLINA 27603

Traffic Safety Effects of a Wet Pavement Detection System Installed on a North Carolina Interstate

A Statistical Summary of Crash Data for a Temporary On-Site Detour inside an I-485 Construction Zone in Mecklenburg County



Document Prepared By:

Safety Evaluation Section
Traffic Safety Systems Management Unit
Traffic Engineering and Safety Systems Branch
North Carolina Department of Transportation

August 2004

Traffic Safety Effects of a Wet Pavement Detection System Installed on a North Carolina Interstate

A Statistical Summary of Crash Data for a Temporary On-Site Detour inside an I-485 Construction Zone in Mecklenburg County

Document Prepared By:

Safety Evaluation Section
Traffic Safety Systems Management Unit
Traffic Engineering and Safety Systems Branch
North Carolina Department of Transportation

Principal Investigator

Stephen D. Lowry, PE

Traffic Safety Project Engineer

TABLE OF CONTENTS

Safe Speed

Photo Enforcement - Charlotte Mecklenburg

Can give a citation every 1/2 second

Laser based Radar 600mm camera

"Li-Dar" Based system - very precise

Peak Traffic was selected vendor

System is "housed" in a marked Van

$50.00 citation (NO POINTS (~~Citation~~ Civil Action Only)

Ticket displays a color wide angle & a black/white close up of tag

- Written in English & Spanish
- Program allows for "online" payment
- can appeal over the phone or adjudicator
- Can get access over the internet to view the picture of the car & tags

1 Lane Enforcement
Laser Pointed in 1 Lane

No revenue for city ... All goes to the ~~City~~ School System

Had to get legislation change to allow the use of Photo Speed Enforced ... used it as "Pilot Program"

- Large Public Info. Campaign. 3 PSAs, Billboards, Print Ads, Internet, Went to Community Mtgs

- No Negative Emails from this System

Limit set @ 5mph above speed limit

Enforcement Limited to 12 roadways
Locations identified w/ advance signing

Sunset on Legislation = 6/30/06
All proceeds goto school system
uniform officer ~~not~~ monitor system

EXECUTIVE SUMMARY

This report summarizes the traffic safety effects of a wet pavement detection system (WPDS) installed at an interstate construction zone. A temporary detour section was outfitted with WPDS, because standing water was creating a hazardous situation for motorists. This study examines the "wet" crashes prior to and after the installation of the WPDS. A comparison of the two time periods yield the following results:

- **The evaluation indicates that the WPDS reduced the yearly wet crash rate by 39 percent and the yearly injury crash rate by 35 percent.**
- **The average daily rainfall increased 71% from the "before" to the "after" period.**
- **The WPDS had very little or no effect during "dry" days. Examining days with no or little precipitation, the crash frequencies with and without WPDS were very similar.**
- **The average daily crashes on "heavy precipitation" days decreased from 2.59 to 1.09 crashes per day, a 58% drop.**
- **The WPDS appeared to reduce crashes on days with "heavy precipitation". Before the WPDS installation, there were 22 study days with 0.5 inches or more of precipitation. Only 5 of these 22 study days were accident free in the "before" period. After the WPDS installation, there were 33 study days with 0.5 inches or more of precipitation. Sixteen of those 33 days were accident free in the "after" period.**

INTRODUCTION

The purpose of this study is to report the safety effects of installing a Wet Pavement Detection System (WPDS). An I-85 bridge construction project in western Mecklenburg County required a temporary detour around the construction zone. This new eight-lane, three-quarter mile, asphalt section opened up in June 2002. When the traffic detour was opened, large sections of standing water were observed on the roadway during heavy rains. The standing water was a factor in several hydroplane crashes. NCDOT contacted Quixote Transportation Safety, Inc. to help alleviate the impacts of this temporary hazardous situation.

A WPDS was installed on the detour in March 2003. Northbound and southbound pavement sensors were installed in the roadway to measure water depth. Two roadside control units were equipped with precipitation sensors to detect rainfall. Also, Variable Message Signs (VMS) were placed in advance of the sensor locations. An automated monitoring system collected real-time data from these sensors and selected the display message. If the pavement was dry, the VMS had a blank display. If the pavement was wet and the water level was below 6 mm, the VMS message was "Wet Pavement Ahead; Observe Speed Limit". When the water depth rose above 6 mm, the VMS displayed "Standing Water Ahead; Reduce Your Speed". NCDOT rerouted I-85 traffic back to the permanent section in November 2003.

While this analysis includes a detailed look at the crash statistics for the detour area, it did not include any comprehensive field investigations or operational review. This analysis quantifies the differences in crash experience due to the installation of the WPDS. This analysis will help guide future traffic safety decisions for roadways sections that are experiencing an unusually large frequency of "wet" road crashes.

SCOPE OF PROJECT

This study is broken into two time periods. The "Before" study period is from July 1, 2002 to March 27, 2003. These dates represent a time period between the opening of the detour and the installation of the Wet Pavement Detection System (WPDS). The "After" study period is from March 29, 2003 to October 31, 2003. These dates represent a time period between the WPDS installation and the closure of the temporary on-site detour *(See Appendix A)*.

The Variable Message Signs (VMS) were placed approximately 0.5 mile on each side prior to the 0.75-mile detour. Thus, a 2.5-mile study section was chosen for the crash analysis to account for the drivers who slow down when they see the highway-warning message *(See Appendix B)*.

CRASH ANALYSIS METHOD

Crash data was obtained from the Traffic Engineering Accident Analysis System (TEAAS) database. This database contains all reported motor vehicle crashes in North Carolina. Volume data for this study was obtained from the 2002 NCDOT AADT maps. The annual average daily traffic along this section of I-85 was 103,000 vehicles per day.

NAÏVE BEFORE AND AFTER ANALYSIS

The "Before" data clearly shows that this area was experiencing an extreme number of "Wet" crashes (*See Table 1*). The 2.5-mile study section experienced 73 "wet" crashes in 270 days; 18 of the 73 "wet" crashes were reported to have "standing/moving water" as the roadway surface condition. "Wet" crashes made up 65.2% of the total crashes. This compares to the 21.66% percent "wet" crashes listed on the *2000-2002 Three-Year Crash Rate for Mecklenburg County* for rural interstates. Furthermore, eleven crashes were reported on August 31, 2002 and September 26, 2002. Seven crashes were reported on August 15, 2002 and September 15, 2002. A local weather station reported heavy rainfall amounts for these four days.

The "Before" study period and "After" study period are 270 days and 217 days, respectively. Therefore, the data was converted to a yearly crash rate for comparison purposes. The Yearly Total Crash Rate dropped 4.5% while the Yearly Wet Crash Rate fell 16.5%. However, the Naïve Before and After evaluation methods do not account for changes in weather conditions and other sundry factors. Comparison studies are often used to account for weather and other changing factors that can influence traffic safety.

CRASH SUMMARY	Before Period	After Period
Total Crashes	112	86
Total Injury Crashes	41	21
PDO Crashes	71	65
Wet Crashes	73	49

CRASH SUMMARY	Before Period	After Period	% Change	Statistically Significant*
Yearly Total Crash Rate	151.4	144.7	-4.5%	NO
Yearly Injury Crash Rate	55.4	35.3	-36.3%	YES
Yearly PDO Crash Rate	96.0	109.3	13.9%	NO
Yearly Wet Crash Rate	98.7	82.4	-16.5%	NO

Table 1. Crash Data for Treatment Area

* Statistical significance tested at the 85% confidence interval using the *T Test* methodology.

COMPARISON GROUP ANALYSIS

A 2.5-mile section of I-85 in eastern Gaston County was selected as a comparison section. This comparison section was chosen because it is near the treatment section, thus the weather conditions, traffic volumes, vehicle fleet and other factors are very similar. (*See Table 2*)

The crash data of the comparison section was utilized to calculate the expected yearly crash rate for the treated study section during the after period. Odds ratio calculations show that the "wet" crash rate decreased by 39.0% and the injury crash rate shrunk by 35.1% (*See Table 3*).

CRASH SUMMARY	Before Period	After Period
Total Crashes	40	31
Total Injury Crashes	19	15
PDO Crashes	21	16
Wet Crashes	10	11

CRASH SUMMARY	Before Period	After Period	% Change	Statistically Significant*
Yearly Total Crash Rate	54.1	52.1	-3.6%	NO
Yearly Injury Crash Rate	25.7	25.2	-1.8%	NO
Yearly PDO Crash Rate	28.4	26.9	-5.2%	NO
Yearly Wet Crash Rate	13.5	18.5	36.9%	NO

Table 2. Crash Data for Comparison Area

* Statistical significance tested at the 85% confidence interval using the *T Test* methodology.

CRASH SUMMARY	Predicted Treatment	Actual Treatment	% Change	Statistically Significant*
Yearly Total Crash Rate	146.0	144.7	-0.9%	NO
Yearly Injury Crash Rate	54.4	35.3	-35.1%	YES
Yearly PDO Crash Rate	91.0	109.3	20.2%	NO
Yearly Wet Crash Rate	135.1	82.4	-39.0%	YES

Table 3. Odds Ratio Calculations

Statistical significance tested at the 85% confidence interval using the *T Test* methodology.

CRASH FREQUENCY BY DAILY PRECIPITATION

The Charlotte weather station for the National Weather Service is located approximately 3 miles southeast of the construction zone. The meteorological data was collected for this station to determine the approximate amount of daily precipitation in the study area. Based on this data, the total precipitation during the "before" period and "after" period was 35.33" and 48.53", respectively. The calculated average daily rainfall increased from 0.131" to 0.224" (71%). Such an increase in daily precipitation has a definite impact on "wet" crash rates.

The daily precipitation totals were classified into the four groups shown below:

Precipitation Level	**Amount**
None	0" or Trace
Slight	0.01 to 0.10"
Moderate	0.11 to 0.50"
Heavy	> 0.50"

The twenty-two "heavy" precipitation days during the "before" period averaged 2.59 crashes per day. In comparison the thirty-three "heavy" precipitation days during the "after" period average only 1.09 crashes per day. This represents a 58% decrease (*See Table 4*).

Precipitation Level	Ave. Daily Crashes	
	Before	After
None	0.18	0.20
Slight	0.21	0.28
Moderate	0.43	0.57
Heavy	2.59	1.09

Table 4. Crashes By Precipitation Level

The daily crash frequencies at the study section were very similar during days with moderate precipitation or less. The "before" study period and "after" study period included 22 and 33 days of "heavy" precipitation, respectively. Only 5 of 22 (23%) "heavy" precipitation days were accident free in the "before" period. In comparison, 16 of 33 (48%) "heavy" precipitation days were accident free in the "after" period (*See Table 5 and 6*).

accident free in the "before" period. In comparison, 16 of 33 (48%) "heavy" precipitation days were accident free in the "after" period (*See Table 5 and 6*).

Number of Days with Crash Total (% of total)

	Number of Days by Crash Frequency							
Daily Precipitation	**0**	**1**	**2**	**3**	**4**	**5**	**>5**	**All**
none	149 (85.6%)	20 (11.5%)	4 (2.3%)	1 (0.6%)				174 (100%)
slight	27 (79.4%)	7 (20.6%)						34 (100%)
moderate	29 (72.5%)	8 (20.0%)	1 (2.5%)	1 (2.5%)	1 (2.5%)			40 (100%)
heavy	5 (22.7%)	6 (27.3%)	6 (27.3%)	1 (4.5%)			4 (18.2%)	22 (100%)

Table 5. Crash Frequency by Precipitation Level (Before Period)

Number of Days with Crash Total (% of total)

	Number of Days by Crash Frequency							
Daily Precipitation	**0**	**1**	**2**	**3**	**4**	**5**	**>5**	**All**
none	104 (85.2%)	13 (10.7%)	4 (3.3%)	1 (0.8%)				122 (100%)
slight	24 (75.0%)	7 (21.9%)	1 (3.1%)					32 (100%)
moderate	20 (66.7%)	7 (23.3%)	1 (3.3%)	1 (3.3%)		1 (3.3%)		30 (100%)
heavy	16 (48.5%)	8 (24.2%)	3 (9.1%)	4 (12.1%)		2 (6.1%)		33 (100%)

Table 6. Crash Frequency by Precipitation Level (After Period)

RECOMMENDATIONS

APLLICATION OF STUDY RESULTS

Based upon this study, the Wet Pavement Detection System (WPDS) was effective in preventing crashes at this location during periods of heavy precipitation. When compared to a similar location, the estimated reduction of yearly wet crash rate was 39%. However, it should be noted that such a dramatic decrease might not be replicated for WPDS applications that have adequate roadway drainage.

REFERENCES

1. http://www.highwayinfo.com/news/11-03_quixote_intellizone.php

2. http://www.erh.noaa.gov/er/gsp/climate/climate.htm

3. Ezra Hauer "Observational Before-After Studies in Road Safety", Pergamon, Elsevier Science Ltd, Tarrytown, New York, 1997

APPENDIX A – Crash Count & Precipitation by Day

Before Period

DATE	# of Crashes	Rainfall Amount
7/1/2002	0	0.08
7/2/2002	0	0.02
7/3/2002	0	0
7/4/2002	0	0
7/5/2002	0	0
7/6/2002	0	0
7/7/2002	0	0
7/8/2002	0	0
7/9/2002	0	0
7/10/2002	0	0
7/11/2002	0	0
7/12/2002	0	0
7/13/2002	1	0.41
7/14/2002	1	0.17
7/15/2002	3	0.32
7/16/2002	0	0
7/17/2002	0	0
7/18/2002	1	0
7/19/2002	0	0
7/20/2002	0	0.02
7/21/2002	0	0
7/22/2002	0	0
7/23/2002	0	0
7/24/2002	1	0.01
7/25/2002	0	0.12
7/26/2002	0	0.05
7/27/2002	0	0
7/28/2002	0	0
7/29/2002	0	0
7/30/2002	0	0
7/31/2002	0	0
8/1/2002	0	0
8/2/2002	0	0
8/3/2002	0	0
8/4/2002	0	0
8/5/2002	0	0
8/6/2002	0	0
8/7/2002	2	0
8/8/2002	0	0
8/9/2002	0	0
8/10/2002	0	0
8/11/2002	0	0

DATE	# of Crashes	Rainfall Amount
8/12/2002	0	0
8/13/2002	0	0
8/14/2002	0	0
8/15/2002	**7**	**0.89**
8/16/2002	1	0.4
8/17/2002	0	0.21
8/18/2002	0	0
8/19/2002	0	0
8/20/2002	0	0
8/21/2002	0	0
8/22/2002	0	0
8/23/2002	0	0
8/24/2002	1	0.33
8/25/2002	0	0.33
8/26/2002	0	0.34
8/27/2002	1	0.03
8/28/2002	1	0.09
8/29/2002	0	0.04
8/30/2002	0	0.04
8/31/2002	**11**	**1.62**
9/1/2002	0	0.06
9/2/2002	0	0
9/3/2002	0	0
9/4/2002	0	0
9/5/2002	1	0
9/6/2002	0	0
9/7/2002	0	0
9/8/2002	0	0
9/9/2002	0	0
9/10/2002	1	0
9/11/2002	0	0
9/12/2002	1	0
9/13/2002	0	0
9/14/2002	0	1.4
9/15/2002	**7**	**0.99**
9/16/2002	0	0.03
9/17/2002	0	0.01
9/18/2002	0	0
9/19/2002	0	0
9/20/2002	0	0
9/21/2002	1	0
9/22/2002	1	0.01

DATE	# of Crashes	Rainfall Amount
9/23/2002	0	0
9/24/2002	0	0
9/25/2002	0	0.09
9/26/2002	**11**	**0.78**
9/27/2002	4	0.17
9/28/2002	0	0
9/29/2002	0	0
9/30/2002	0	0
10/1/2002	1	0
10/2/2002	0	0
10/3/2002	0	0
10/4/2002	0	0
10/5/2002	2	0
10/6/2002	0	0
10/7/2002	0	0
10/8/2002	0	0.06
10/9/2002	0	0.02
10/10/2002	0	0.01
10/11/2002	2	2.24
10/12/2002	0	0
10/13/2002	0	0.62
10/14/2002	0	0
10/15/2002	1	0.9
10/16/2002	1	0.45
10/17/2002	0	0
10/18/2002	1	0
10/19/2002	0	0
10/20/2002	0	0.03
10/21/2002	0	0.12
10/22/2002	0	0.03
10/23/2002	0	0
10/24/2002	0	0
10/25/2002	0	0.16
10/26/2002	0	0
10/27/2002	0	0
10/28/2002	1	0.53
10/29/2002	0	0.25
10/30/2002	0	0.01
10/31/2002	0	0
11/1/2002	0	0
11/2/2002	0	0
11/3/2002	0	0

DATE	# of Crashes	Rainfall Amount
11/4/2002	0	0.03
11/5/2002	1	0.97
11/6/2002	0	0.16
11/7/2002	0	0
11/8/2002	0	0
11/9/2002	2	0
11/10/2002	1	0.01
11/11/2002	0	0.38
11/12/2002	1	1.54
11/13/2002	0	0
11/14/2002	0	0
11/15/2002	0	0
11/16/2002	0	1.13
11/17/2002	0	0.16
11/18/2002	0	0
11/19/2002	0	0
11/20/2002	0	0
11/21/2002	0	0
11/22/2002	0	0
11/23/2002	0	0
11/24/2002	0	0
11/25/2002	0	0
11/26/2002	1	0
11/27/2002	0	0
11/28/2002	0	0
11/29/2002	1	0
11/30/2002	0	0
12/1/2002	0	0
12/2/2002	0	0.01
12/3/2002	0	0
12/4/2002	2	0.65
12/5/2002	0	0.49
12/6/2002	0	0
12/7/2002	0	0
12/8/2002	0	0
12/9/2002	0	0
12/10/2002	0	0.13
12/11/2002	0	0.44
12/12/2002	0	0
12/13/2002	1	1
12/14/2002	0	0
12/15/2002	0	0
12/16/2002	0	0
12/17/2002	1	0
12/18/2002	0	0
12/19/2002	0	0.01
12/20/2002	1	0.36
12/21/2002	0	0

DATE	# of Crashes	Rainfall Amount
12/22/2002	0	0
12/23/2002	1	0
12/24/2002	2	1.47
12/25/2002	0	0.4
12/26/2002	0	0
12/27/2002	0	0
12/28/2002	0	0
12/29/2002	0	0
12/30/2002	0	0
12/31/2002	1	0
1/1/2003	1	0.24
1/2/2003	0	0.05
1/3/2003	0	0.22
1/4/2003	3	0
1/5/2003	1	0
1/6/2003	0	0
1/7/2003	0	0
1/8/2003	0	0
1/9/2003	0	0
1/10/2003	0	0
1/11/2003	1	0
1/12/2003	0	0
1/13/2003	0	0
1/14/2003	0	0
1/15/2003	0	0
1/16/2003	0	0.15
1/17/2003	0	0
1/18/2003	1	0
1/19/2003	0	0
1/20/2003	0	0
1/21/2003	0	0.13
1/22/2003	0	0
1/23/2003	0	0.18
1/24/2003	1	0
1/25/2003	0	0
1/26/2003	0	0
1/27/2003	0	0
1/28/2003	0	0
1/29/2003	0	0.14
1/30/2003	0	0.85
1/31/2003	0	0
2/1/2003	0	0
2/2/2003	0	0
2/3/2003	0	0
2/4/2003	0	0.23
2/5/2003	0	0
2/6/2003	0	0.43
2/7/2003	0	0.13

DATE	# of Crashes	Rainfall Amount
2/8/2003	0	0
2/9/2003	1	0
2/10/2003	1	0.22
2/11/2003	2	0
2/12/2003	0	0
2/13/2003	0	0
2/14/2003	0	0.25
2/15/2003	0	0.04
2/16/2003	2	0.41
2/17/2003	0	0.01
2/18/2003	0	0
2/19/2003	0	0
2/20/2003	1	0.04
2/21/2003	0	0.03
2/22/2003	0	0.98
2/23/2003	0	0.05
2/24/2003	0	0
2/25/2003	0	0
2/26/2003	0	0.44
2/27/2003	0	0.35
2/28/2003	0	0
3/1/2003	1	0.55
3/2/2003	0	0.05
3/3/2003	0	0
3/4/2003	0	0.02
3/5/2003	0	0.12
3/6/2003	3	1.3
3/7/2003	0	0
3/8/2003	0	0
3/9/2003	0	0
3/10/2003	0	0
3/11/2003	0	0
3/12/2003	0	0
3/13/2003	0	0
3/14/2003	1	0
3/15/2003	2	0.56
3/16/2003	0	0.39
3/17/2003	0	0.13
3/18/2003	0	0.16
3/19/2003	2	0.57
3/20/2003	2	1.99
3/21/2003	1	0.01
3/22/2003	1	0
3/23/2003	0	0
3/24/2003	0	0
3/25/2003	1	0
3/26/2003	0	0.08
3/27/2003	0	0

After Period

DATE	# of Crashes	Rainfall Amount
3/29/2003	0	0
3/30/2003	3	1.13
3/31/2003	0	0
4/1/2003	0	0
4/2/2003	0	0
4/3/2003	2	0
4/4/2003	0	0
4/5/2003	0	0.19
4/6/2003	3	0.67
4/7/2003	0	1.31
4/8/2003	0	0.66
4/9/2003	0	0.91
4/10/2003	3	1.98
4/11/2003	0	0.06
4/12/2003	0	0
4/13/2003	0	0
4/14/2003	0	0
4/15/2003	0	0
4/16/2003	0	0
4/17/2003	1	0.21
4/18/2003	1	1.59
4/19/2003	0	0.12
4/20/2003	0	0
4/21/2003	0	0.09
4/22/2003	0	0
4/23/2003	0	0
4/24/2003	0	0
4/25/2003	0	0.26
4/26/2003	0	0.19
4/27/2003	0	0
4/28/2003	0	0
4/29/2003	0	0.01
4/30/2003	0	0
5/1/2003	0	0.01
5/2/2003	1	0.28
5/3/2003	0	0
5/4/2003	0	0
5/5/2003	0	0.24
5/6/2003	2	1.08
5/7/2003	1	0.03
5/8/2003	0	0
5/9/2003	0	0
5/10/2003	0	0
5/11/2003	0	0.01
5/12/2003	0	0

DATE	# of Crashes	Rainfall Amount
5/13/2003	3	0
5/14/2003	0	0
5/15/2003	0	1.56
5/16/2003	0	0
5/17/2003	0	0
5/18/2003	1	0.48
5/19/2003	0	0.03
5/20/2003	0	0
5/21/2003	0	1.51
5/22/2003	5	3.5
5/23/2003	1	0.07
5/24/2003	0	0.26
5/25/2003	2	0.55
5/26/2003	1	0.82
5/27/2003	0	0
5/28/2003	0	0
5/29/2003	0	0.01
5/30/2003	1	0
5/31/2003	5	0.25
6/1/2003	0	0
6/2/2003	0	0
6/3/2003	1	0.72
6/4/2003	0	0.18
6/5/2003	0	0
6/6/2003	1	0.56
6/7/2003	1	2.19
6/8/2003	1	0.32
6/9/2003	1	0
6/10/2003	0	0
6/11/2003	0	0.05
6/12/2003	0	0.13
6/13/2003	0	0
6/14/2003	0	0
6/15/2003	1	0.15
6/16/2003	1	0.09
6/17/2003	1	0.01
6/18/2003	0	0.23
6/19/2003	0	0.18
6/20/2003	0	0.01
6/21/2003	0	0
6/22/2003	0	0
6/23/2003	0	0
6/24/2003	2	0
6/25/2003	1	0
6/26/2003	0	0

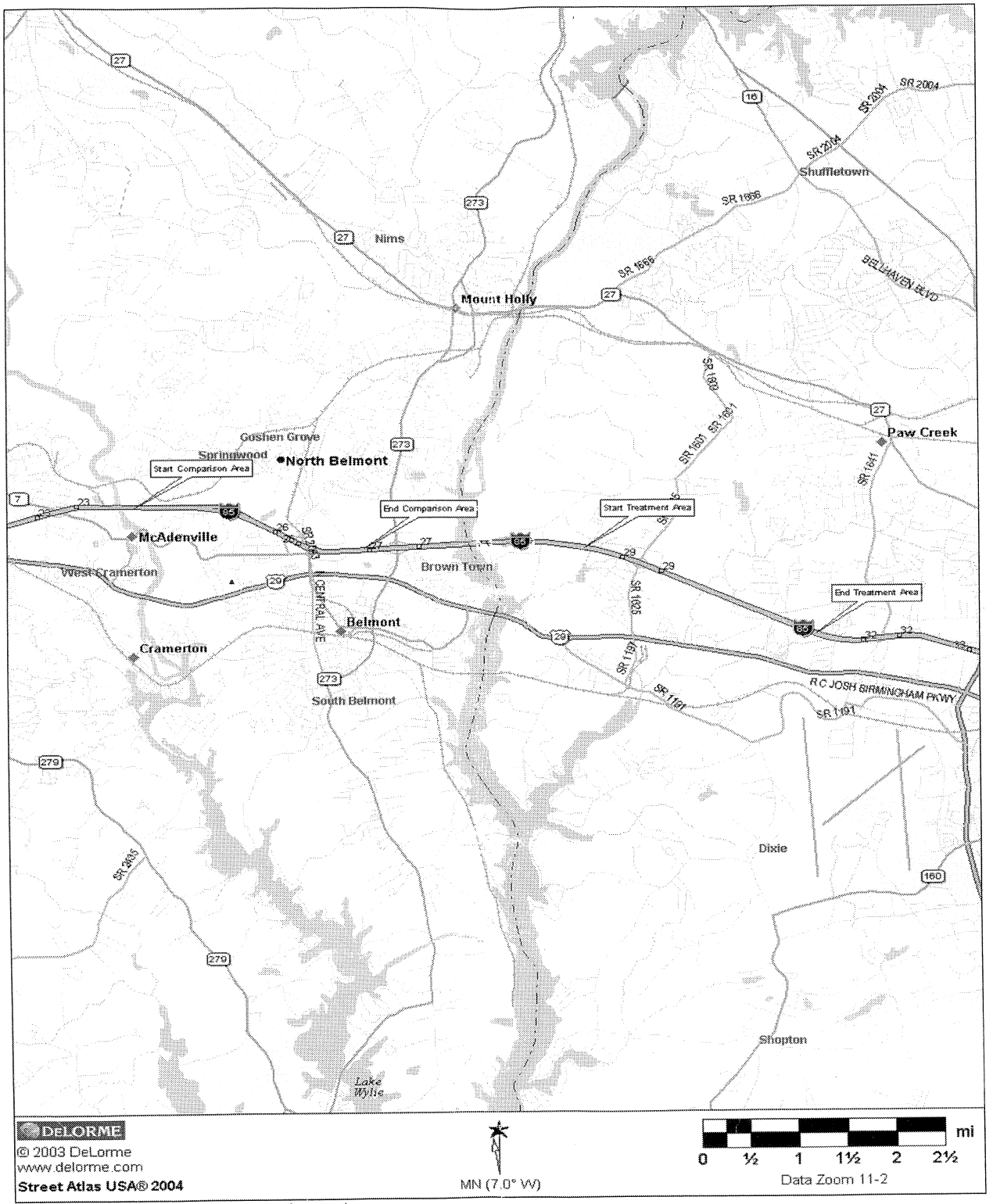
DATE	# of Crashes	Rainfall Amount
6/27/2003	0	0
6/28/2003	1	0.19
6/29/2003	0	0
6/30/2003	0	0.05
7/1/2003	0	0.48
7/2/2003	2	1.07
7/3/2003	0	0
7/4/2003	0	0
7/5/2003	0	0
7/6/2003	0	0
7/7/2003	0	0.01
7/8/2003	0	0
7/9/2003	0	0.45
7/10/2003	0	0.02
7/11/2003	0	0.39
7/12/2003	0	0.53
7/13/2003	0	0.75
7/14/2003	0	0
7/15/2003	0	0
7/16/2003	0	0.01
7/17/2003	0	0.69
7/18/2003	0	0.06
7/19/2003	0	0.17
7/20/2003	0	0
7/21/2003	1	1.56
7/22/2003	0	0
7/23/2003	3	0.21
7/24/2003	0	0
7/25/2003	0	0
7/26/2003	0	0.77
7/27/2003	0	0
7/28/2003	0	0
7/29/2003	0	0.59
7/30/2003	2	0.03
7/31/2003	1	0.5
8/1/2003	0	0.03
8/2/2003	0	0
8/3/2003	0	0.45
8/4/2003	0	2.48
8/5/2003	0	0.01
8/6/2003	0	0.03
8/7/2003	0	0.05
8/8/2003	0	0.98
8/9/2003	0	0.41
8/10/2003	3	1.41

DATE	# of Crashes	Rainfall Amount
8/11/2003	0	0
8/12/2003	0	0.1
8/13/2003	0	0
8/14/2003	1	1.74
8/15/2003	0	0
8/16/2003	0	0
8/17/2003	0	0.08
8/18/2003	1	0
8/19/2003	0	0
8/20/2003	0	0
8/21/2003	0	0
8/22/2003	0	1.38
8/23/2003	0	0
8/24/2003	0	0
8/25/2003	1	0
8/26/2003	0	0
8/27/2003	0	0
8/28/2003	0	0.5
8/29/2003	0	0
8/30/2003	0	0
8/31/2003	0	0.7
9/1/2003	0	0.02
9/2/2003	0	0
9/3/2003	0	0
9/4/2003	0	0.17
9/5/2003	0	0
9/6/2003	0	0
9/7/2003	0	0

DATE	# of Crashes	Rainfall Amount
9/8/2003	1	0.03
9/9/2003	0	0
9/10/2003	1	0
9/11/2003	0	0
9/12/2003	0	0
9/13/2003	0	0
9/14/2003	0	0
9/15/2003	0	0.69
9/16/2003	0	0
9/17/2003	0	0
9/18/2003	0	0
9/19/2003	0	0
9/20/2003	0	0
9/21/2003	0	0
9/22/2003	5	1.48
9/23/2003	1	0.06
9/24/2003	0	0
9/25/2003	0	0
9/26/2003	0	0
9/27/2003	0	0.24
9/28/2003	0	0
9/29/2003	1	0
9/30/2003	0	0
10/1/2003	0	0
10/2/2003	0	0
10/3/2003	2	0
10/4/2003	0	0
10/5/2003	1	0

DATE	# of Crashes	Rainfall Amount
10/6/2003	0	0
10/7/2003	0	0
10/8/2003	1	0.8
10/9/2003	1	0.01
10/10/2003	0	0.09
10/11/2003	2	0.17
10/12/2003	0	0
10/13/2003	0	0
10/14/2003	1	0
10/15/2003	0	0
10/16/2003	2	0
10/17/2003	1	0
10/18/2003	1	0
10/19/2003	0	0
10/20/2003	0	0
10/21/2003	0	0
10/22/2003	0	0
10/23/2003	0	0
10/24/2003	1	0
10/25/2003	0	0
10/26/2003	0	0.26
10/27/2003	0	0.7
10/28/2003	0	0.03
10/29/2003	0	0.01
10/30/2003	1	0
10/31/2003	0	0

Appendix B



Map of Study and Comparison Area