FIELD EVALUATION OF THE MYRTLE CREEK ADVANCED CURVE WARNING SYSTEM

Final Report

SPR 352

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by

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400 Seventh Street SW
Washington, DC 20590

June 2006

1. Report No. FHWA-OR-RD-06-13	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Field Evaluation of the Myrtle Creek Advanced Curve Warning System		5. Report Date June 2006 6. Performing Organization Code
7. Author(s) Robert L. Bertini, Christopher M. Monsere, Casey Nolan, Peter Bosa, and Tarek Abou El-Seoud Department of Civil & Environmental Engineering Portland State University -- PO Box 751 -- Portland, OR 97207		8. Performing Organization Report No.
9. Performing Organization Name and Address Oregon Department of Transportation Research Unit 200 Hawthorne Ave. SE, Suite B-240 Salem, Oregon 97301-5192		10. Work Unit No. (TRAIS) 11. Contract or Grant No. SPR 352
12. Sponsoring Agency Name and Address Oregon Department of Transportation Research Unit and 200 Hawthorne Ave. SE, Suite B-240 Salem, Oregon 97301-5192	Federal Highway Administration 400 Seventh Street SW Washington, D.C. 20590	13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

As part of a larger study focusing on determining optimum countermeasures for speed related crashes, this report presents the results of a quantitative and qualitative before and after evaluation of a dynamic curve warning system deployed at one site on northbound and southbound Interstate 5 in Myrtle Creek, Oregon. The system displays directed messages on two dynamic message signs to drivers based on the detected speed of approaching vehicles. For the evaluation, three measures of effectiveness were selected: 1) the change in mean speed for passenger cars and commercial vehicles; 2) the change in the speed distribution for both passenger cars and trucks; and 3) public response to the dynamic message signs. Speed samples were taken of vehicles with a laser ranging and detection device, recording both speed and distance information over seven days – four in the before period and three in the after period. The quantitative evaluation indicated that the advanced curve warning system was effective in reducing the mean speeds of passenger cars and trucks by approximately 3 mph for the southbound direction and 2 mph for the northbound direction. After the system was installed, the distribution of vehicle speeds was statistically different with a lower number of vehicles in the higher speed bins. Crash reduction impacts of the system have not yet been evaluated, as the system was only recently installed. Intercept surveys of motorists at nearby rest areas revealed a positive perception of the system. Overall, the results of the evaluation indicate that the advanced curve warning system is effective.

17. Key Words Traffic control devices, Before and after studies, Highway curves, Interstate highways, Measures of effectiveness, Public opinion, Speed distribution, Variable message signs, Warning systems.		18. Distribution Statement Copies available from NTIS, and online at http://www.oregon.gov//ODOT/TD/TP_RES/	
19. Security Classification (of this report) Unclassified	20. Security Classification (of this page) Unclassified	21. No. of Pages 50	22. Price

Technical Report Form DOT F 1700.7 (8-72) Reproduction of completed page authorized Printed on recycled paper

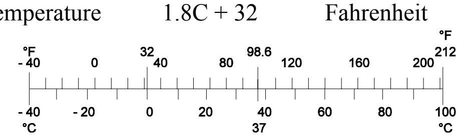
SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9	Celsius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius temperature	1.8C + 32	Fahrenheit	°F



* SI is the symbol for the International System of Measurement

(4-7-94 jbp)

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the financial support provided by the Oregon Department of Transportation (ODOT). In particular, the technical advisory committee has provided helpful oversight: Edward Anderson, Ann Holder, Scott McCanna, Galen McGill, David McKane, and Tim Burks (ODOT) as well as Nick Fortey and Nathaniel Price of the Federal Highway Administration (FHWA). In particular, Edward Anderson assisted greatly by providing details of the project design. Rob Edgar (ODOT) was particularly committed to this project and assisted with data collection while serving as the research coordinator for most of the project. Mark Joerger (ODOT) managed the final phases of this project. The contents of this report reflect the views and opinions of the authors, who are responsible for the facts and the accuracy of the data presented here.

DISCLAIMER

FIELD EVALUATION OF THE MYRTLE CREEK ADVANCED CURVE WARNING SYSTEM

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EXECUTIVE SUMMARY

As part of a larger study focusing on determining optimum countermeasures for speed related crashes, this report presents the results of a quantitative and qualitative before and after evaluation of a dynamic curve warning system deployed at one site on northbound and southbound Interstate 5 in Myrtle Creek, Oregon. The system displays directed messages on two dynamic message signs to drivers based on the detected speed of approaching vehicles.

For the evaluation, three measures of effectiveness were selected: 1) the change in mean speed for passenger cars and commercial vehicles; 2) the change in the speed distribution for both passenger cars and trucks; and 3) public response to the dynamic message signs. Speed samples were taken of vehicles with a laser ranging and detection device, recording both speed and distance information over seven days – four in the before period and three in the after period.

The quantitative evaluation indicated that the advanced curve warning system was effective in reducing the mean speeds of passenger cars and trucks by approximately 3 mph for the southbound direction and 2 mph for the northbound direction. After the system was installed, the distribution of vehicle speeds was statistically different with a lower number of vehicles in the higher speed bins. Crash reduction impacts of the system have not yet been evaluated, as the system was only recently installed. Intercept surveys of motorists at nearby rest areas revealed a positive perception of the system. Overall, the results of the evaluation indicate that the advanced curve warning system is effective.

1.0 INTRODUCTION

Interstate highways, with their high design standards, are the safest facilities for highway travel in the United States, as measured on a per mile driven basis. Using the most recent data available for Oregon (2002), the fatality rates for urban interstates and rural interstates were 0.31 and 0.32 per 100 million vehicle miles traveled (MVMT), respectively. By comparison, the fatality rate for rural highways in Oregon was 2.67 per 100 MVMT. Total crash rates (including fatal, injury and property damage only crashes) are also lower for freeway facilities (*ODOT 2003*).

Interstate facility designs rarely violate driver expectations, which is one key factor that contributes to their safe performance. However, when drivers encounter highway segments that have substantially different design features than adjacent freeway sections, their expectations are likely to be violated. In general, expectancy violations produce driver errors, longer reaction times, and are often associated with crash prone locations (*AASHTO 2001; Ogden 1996*). These locations typically require additional guidance for the driver, in terms of warning signs and other traffic control devices, to maintain adequate safety performance. When excessive or inappropriate speed is combined with these unusual geometric features, the crash problem can be compounded.

Geographic and economic constraints have often required unusual geometry on some sections of the Interstate system. Despite additional warning signs and other modifications, some curve and downgrade locations continue to exhibit higher than expected crash frequencies, particularly for large trucks. In response, states have deployed Intelligent Transportation System (ITS) technologies to enhance the effectiveness of static warning devices on the Interstate system (*Harwood, et al. 2003; Robinson, et al. 2002*). Many of these deployments have been directed at improving truck safety for long downgrades or reducing rollover potential on curves (*Mounce, et al. 2000; Baker, et al. 2001; Janson 1999; Bell and Montagne 2000; Lee, et al. 1999; Strickland and McGee 1998*). At curve locations, typical Dynamic Curve Warning Systems are capable of directly measuring approaching vehicle speeds, weight, or height and then displaying a targeted message to the driver via a Dynamic Message Signs (DMS).

The relative success of these systems in other states encouraged the Oregon Department of Transportation (ODOT) to design and implement an Advanced Curve Warning System (ACWS) on northbound and southbound Interstate 5 in an area known locally as the “Myrtle Creek Curves.” This location consists of a series of curves which have continually been a notable crash problem, especially for trucks. Using existing sign bridge structures, ODOT designed a system that measures speeds of oncoming vehicles using radar and displays a customized warning message to vehicles approaching the curve based on these detected speeds. A series of messages is displayed to the driver based on the measured speed.

This paper presents the results of a quantitative and qualitative evaluation that a) examined the before and after speed conditions at the Myrtle Creek site; and b) implemented motorist surveys to gauge public perception of the signs' effectiveness. Because the systems were installed less than three years ago (March 2004), crash reduction has not yet been evaluated. In the following sections of the paper, brief summaries of previous applications of similar deployments are presented, followed by a site description of the Myrtle Creek curves. The paper then describes the study design, evaluation methodologies, and results of the before and after speed evaluation and motorist survey.

2.0 LITERATURE REVIEW – DYNAMIC MESSAGE SYSTEMS

Many of the ITS-type warning systems deployed on Interstates have been directed at improving the safety of large trucks (*Harwood, et al. 2003*). One type of system that has been deployed is aimed at reducing truck rollover crashes, and a second system type is one aimed at reducing the speeds of trucks on long downgrades. Automatic truck rollover warning systems can vary, but most are designed to estimate the probability of a rollover based on real-time vehicular and environmental conditions and display a warning if necessary. The most basic systems use speed as the only variable to determine the likelihood of a rollover. More advanced systems integrate truck speed, weight, and height into the rollover equation. Systems that incorporate more variables have been shown to be more effective and reliable in providing accurate warnings of potential rollovers (*Baker, et al. 2001*).

Five dynamic warning systems were installed by the California Department of Transportation (Caltrans) on a section of Interstate 5 in the Sacramento River Canyon. These systems are similar to the Myrtle Creek system in that they also use a radar-based speed sensor and a DMS to relay warnings to speeding motorists. In a comprehensive evaluation, speed reductions were found at 3 of the 5 locations. Approximately 72% of truck drivers surveyed indicated they found the system helpful.

Other state agencies have installed dynamic warning devices on freeway off ramps. Texas installed a system on a freeway to freeway loop ramp and found it to be effective in reducing the speeds of those vehicles in the higher speed ranges (*Lee, et al. 1999*). Maryland and Virginia deployed a system that used weigh-in-motion, loop detection, and height sensors to provide directed warnings to trucks. A reduction in the number of crashes, from 10 to 0, in the three year period following installation, and a 25% reduction in speeds was found (*Strickland and McGee 1998*).

Downhill speed warning systems, designed to warn trucks of appropriate downhill speeds for long grades have also been deployed. Colorado installed a system in the Eisenhower tunnel on Interstate 70 prior to 5–7% downgrades. Using loop detectors and weigh-in-motion sensors, the system displays an appropriate downhill speed to heavy trucks based on their weight. The system appeared to significantly reduce downhill truck speeds (*Janson 1999*).

In Oregon, ODOT designed and installed a dynamic downhill warning system on Interstate 84 in the northeast portion of the state. The system uses a DMS to display recommended speeds to trucks based on their weight, which is measured by a weigh-in-motion system. A motor carrier who participates in the state's electronic screening and credentialing program, *Green Light* sees a customized message, based on information read from a transponder in the truck. An evaluation has apparently not yet been conducted (*Bell and Montagne 2000*). Based on these experiences, ODOT implemented its first Dynamic Curve Warning System in 2004. This evaluation is an integral part of the system implementation.

The Minnesota DOT used a radar detection system in conjunction with a DMS to study the difference between static and dynamic signs in the ability to reduce the speed of high-speed vehicles. Researchers found the overall effect of a dynamic curve warning sign on vehicle speed to be somewhat small. However, the dynamic sign did have a strong effect on high speed vehicles and improved their ability to navigate through a curve (*Preston and Schoenecker 1999*).

Researchers at the Texas Transportation Institute analyzed a series of Dynamic Speed Display Signs (DSDS) at various locations (school zones, signalized intersections, and sharp horizontal curves). The study was set up similarly to what was conducted for the Myrtle Creek study described below. Data was collected before the signs were installed, one week after installation, and again after four months.

Researchers used a data collection method that allowed for tracking of vehicles at two specified locations in the study site. This allowed researchers to correlate initial approach speeds to speeds at the DSDS and thus assess how the sign impacted motorists' speed-changing behavior. Furthermore, researchers analyzed the influence of the DSDS upon passenger vehicles and large trucks separately at the horizontal curves location, just as was done at the Myrtle Creek study.

The signs were most effective in school speed zones, where speeds were reduced by 9 miles per hour. At the two horizontal curve sites, small decreases in speeds were evident in passenger vehicles approaching those curves. In general, motorists traveling faster than the posted speed reduced their speed more significantly than other motorists. (*Robinson, et al. 2002*)

3.0 SITE DESCRIPTION

The Myrtle Creek Advanced Curve Warning System project is located in Douglas County, Oregon on Interstate 5 between milepost 107 and 109, a location regionally known as the "Myrtle Creek Curves," as shown in Figure 3.1.

As shown in Figure 3.2, the curved section of Interstate 5 is tightly constrained by an embankment on one side and the South Umpqua River on the other. The curves are located in a 50 mile per hour (mph) speed zone and are posted with an advisory speed of 45 mph for all vehicles in both directions. Approximately 0.5 mile upstream and downstream of the signs the posted speed is 65 mph for passenger cars and 55 mph for trucks.

In 2002, the average daily traffic was 16,750 vehicles northbound and 15,700 vehicles southbound. Trucks constitute 27 percent of total vehicles for both directions.

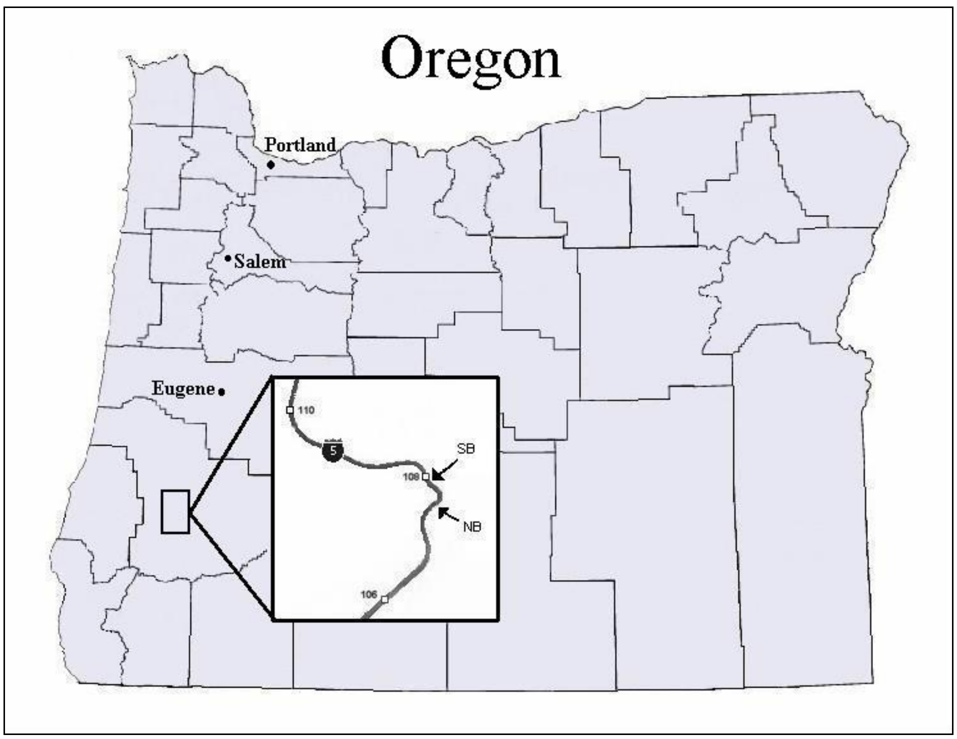


Figure 3.1: Myrtle Creek location

Figure 3.2: Aerial photograph of Myrtle Creek curves

The static warning signing in place prior to the installation of the ACWS consisted of dual overhead horizontal alignment/advisory speed combination sign assemblies (MUTCD W1-2a) with 4 flashing beacons. A ground mounted truck rollover warning sign was also present (Oregon OW8-12) slightly upstream of the sign bridge in the northbound direction and on the sign bridge support pole in the southbound direction. There are chevrons (MUTCD W1-8) installed through the curves in the northbound direction but there are no chevrons in the southbound direction. The “before” sign conditions are visible in Figure 3.3 and 3.4.

Before **After**

Figure 3.3: Northbound sign bridge, I-5 Milepost 108.00, before and after ACWS installation

Before **After**

Figure 3.4: Southbound sign bridge, I-5 Milepost 108.35, before and after ACWS installation

Topographical constraints, specifically the canyon formed by the South Umpqua River, necessitated the current alignment when Interstate 5 was designed. The plan layout of the site is shown in Figure 3.5. All data shown in the figure use SI units. There are three horizontal curves through the project area—two transition curves on either end of the main curve. The main curve has a radius of 648.68 feet (198.98 meters) in the northbound direction and 616.47 feet (189.10 meters) in the southbound direction. The maximum superelevation is 10 percent and there are spiral transitions for all curves.

An interchange with OR-99 to Myrtle Creek is incorporated in the curve area. The southbound interchange is a partial trumpet; and the southbound on-ramp includes a 12 foot wide acceleration lane for approximately 700 feet beyond the sign bridge. Throughout the curves, the cross section consists of two 12-foot lanes, a 6-foot paved left shoulder with a single slope concrete median barrier separating traffic, and an average paved outside shoulder width of 12 feet (8 feet in the section with acceleration lane). Both outside shoulders have a single slope concrete barrier through the entire length of the curve.

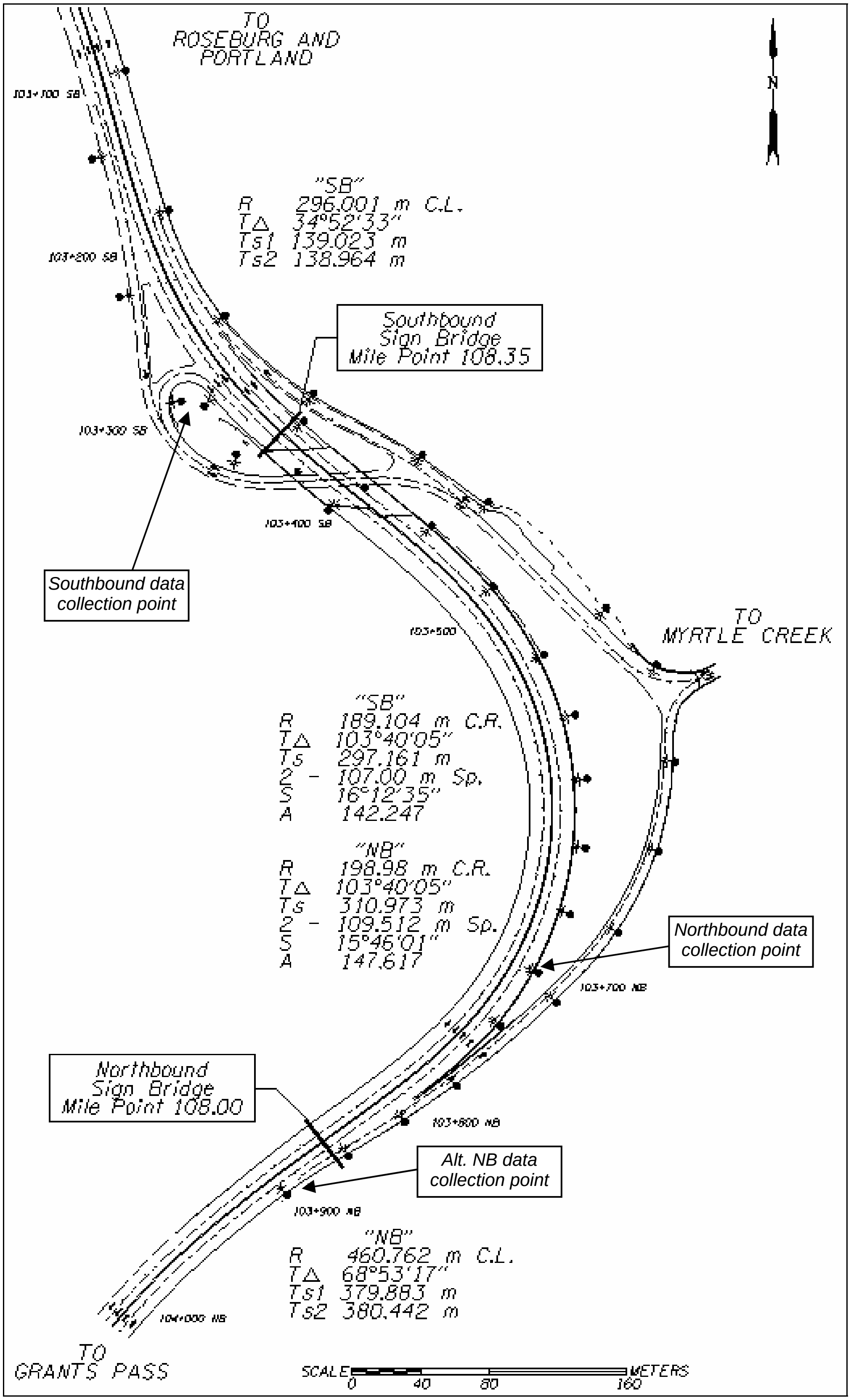


Figure 3.5: Plan view of I-5, Myrtle Creek curves area

According to the ODOT statewide crash database, there were 33 reported crashes for 1998–2002. The number per year increased each year over the previous one. Of these, 13 of the crashes occurred on the sharper southbound curve and 20 crashes occurred on the northbound curve. Twelve of the total crashes involved injuries three of which were severe. No fatalities were reported. Nearly 70% of the crashes involved only one vehicle and accordingly, the most common crash-type was fixed-object (45%) followed by 24% non-collision (i.e., overturning). Weather conditions were not an obvious contributing factor, as the crashes were equally split between dry and wet conditions. Only one snow-ice related crash was reported.

A summary of a number of crash parameters is shown in Figure 3.6. The crash rate for the short 0.5 mile section of the curves is 1.18 per MVMT over the five year period, well above the state average for rural freeways of 0.22 per MVMT. These results were strongly considered by ODOT when the decision was made to implement the Advanced Curve Warning System at this location.

More detailed data were obtained from the ODOT Motor Carrier Division for crashes relating to trucks between 1999 and 2003. These records, which include additional crashes not recorded in the statewide crash database, indicated a total of 27 truck crashes during this five year period with substantially more crashes in the southbound direction (17) than in the northbound direction (10). The principal crash type was listed as overturning with inappropriate or excessive speed as the primary contributing factor. The southbound direction, with the sharper alignment, had 11 overturning incidents.

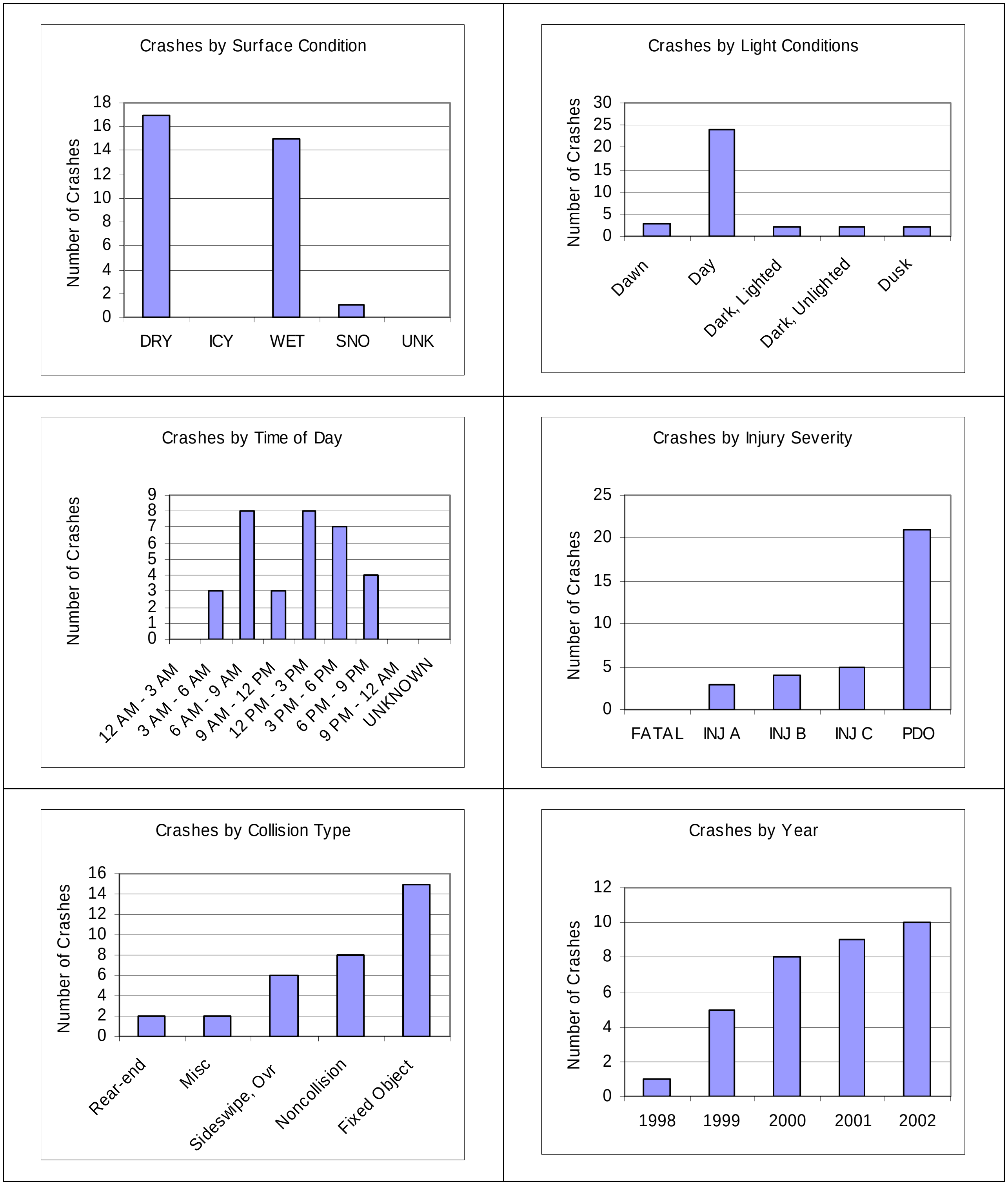


Figure 3.6: Summary of crash data, 1998-2002, I-5 – milepost 107.00-109.00

4.0 ADVANCED CURVE WARNING SYSTEM

The ACWS was installed for both northbound and southbound traffic. The system was installed in March 2004 and, following field testing, was made operational. The ACWS, as originally conceived, was to focus on trucks. Budget limitations, however, dictated that the system could only be designed to measure the speeds of all approaching vehicles without discerning between autos and trucks. As such, the system as deployed is designed to convey messages to all vehicles and is similar in concept to the system deployed by Caltrans in Shasta County, California.

The Myrtle Creek ACWS consists of the following key elements at each sign location: a dynamic message sign (DMS), a radar unit for speed measurement, a controller unit and computer software to manage the speed inputs and (locally) modify the sign message. Fortunately, the existing sign bridges were of sufficient structural capacity to accommodate the DMS without modifications. For the northbound sign bridge one of the W1-2a assemblies was removed to provide sufficient space for the DMS. The DMS were installed overhead on existing sign bridges as shown in Figures 3.3 and 3.4.

For speed measurement a radar unit was used. The radar units were pole-mounted near the sign bridges on the right shoulders at heights of 20 feet above the pavement. The sensors use Doppler technology to detect vehicle speeds and travel direction, which is important for filtering vehicles traveling in the opposite direction. The devices have two detection modes: strongest and fastest. Initially, it was desired for the radar unit to measure the speed of the strongest target with the hope that the larger vehicles (trucks) would be targeted. However, during field tests and after consultation with the manufacturer (MPH Industries, Inc.), the setting was switched to detect the fastest target. Throughout the duration of this study, the fastest mode was consistently selected for display on the DMS.

The DMS consists of 3 lines capable of displaying 12 characters each and were manufactured and integrated with the radar units by Daktronics, Inc.[1] Characters are formed by a 5 x 7 matrices of light emitting diodes (LEDs) and are 18 inches high. The signs display three messages depending on the prevailing speed detected. The messages are: 1) default message; 2) warning message; and 3) excessive speed message.

Table 4.1 shows the DMS messages for each panel, which are displayed for 2 seconds. The default message is displayed continuously when there are no vehicles detected traveling at or above 50 mph. The warning message is displayed when one or more vehicles are traveling at or above 50 mph but below 70 mph, and the excessive speed message is displayed when one or more vehicles are traveling at or above 70 mph. The system displays the speed of the fastest vehicle in the detection range and as such, the possibility exists that a motorist will see a message that displays the speed of a nearby faster vehicle. How often this occurred was not studied as part of this research.

[1] Brookings, South Dakota

Table 4.1: Possible advisory messages for DMS

Panel	**Default Message** *Detected Vehicle Speeds Less than 50 mph*	**Warning Message** *Detected Vehicle Speeds 50 to 70 mph*	**Excessive Speed Message** *Detected Vehicle Speeds over 70 mph*
1	CAUTION	SLOW DOWN	SLOW DOWN
2	SHARP CURVES AHEAD	YOUR SPEED IS XX MPH	YOUR SPEED IS OVER 70 MPH

5.0 DATA COLLECTION

Quantitative and qualitative evaluation techniques were used to conduct this evaluation. Three measures of effectiveness were selected: 1) the change in mean speed for passenger cars and commercial vehicles; 2) the change in the speed distribution for both passenger cars and trucks; and 3) public response to the sign. The impacts on crash performance are not reported here because the system was only recently implemented. As part of the ongoing performance evaluation of the Advanced Curve Warning System, it is recommended that assessment of crash performance at this site continue.

Speed measurements were obtained in the field using an UltraLyte[2] laser speed detection and ranging device. The UltraLyte device detects vehicle speeds as well as the distance between the device and the target. The ODOT Research Unit provided two laser units and Hewlett Packard 48 calculators running SpeedStat DC software for data collection (*Laser Technology 1995*). Speed measurements were taken separately for passenger vehicles (including light trucks and SUVs) and heavy trucks. Buses, motorcycles, single unit trucks and recreational vehicles were not sampled.

For southbound traffic, data were collected from a vehicle parked in the ramp gore area. This location was less than ideal because it was clearly visible to approaching traffic and has been used by Oregon State Police for enforcement purposes. The physical constraints of the site, however, provide few safe data collection location options. For northbound traffic, data were collected from behind the concrete barrier approximately 420 feet downstream from the sign. Some data were also collected at a location 114 feet upstream of the sign. In both locations, the person collecting data was relatively inconspicuous to drivers. Also, the data collection locations were exactly the same for both the before and after analysis in order to avoid any bias.

Data collectors were instructed to select a target as far from their location as possible, acquire the target with the speed detection device, record on the HP calculator whether the vehicle was passenger or commercial vehicle, and follow the vehicle through the curves, obtaining a minimum of three speed and distance samples. For each positive return, the speed of the observed vehicle and the distance from laser unit was recorded. As soon as the vehicle was out of range, data collectors were instructed to acquire the next feasible target. An attempt was made to balance target selection between passenger vehicles and trucks.

There were seven total data collection trips made to the site over the duration of the study. Details of each data collection day are shown in Table 5.1. Prior to installation of the ACWS, the research team made four visits to the site to collect baseline speed data in October, November, and December of 2003. After the system was installed, researchers made three visits to collect comparison data in May and July of 2004. All data were collected during daylight hours between 10:00 am and 2:00 pm on Wednesday, Thursday, or Friday. Weather was

[2] Laser Technology, Inc., Centennial, CO

essentially similar for all data collection days with the exceptions of light scattered showers on December 12, 2003. A total of 11 hours of data were collected for the before period and 17 hours for the after period. As shown in the data in Table 5.1, a nearly equal number of commercial vehicle and passenger car samples were collected (sample refers to speed and distance entry, there are multiple samples per vehicle).

Table 5.1: Data collection summary

Date	Day of Week	Weather Conditions	Direction	Hours Sampled (hh:mm:ss)	Number of Samples	
					Trucks	**Cars**
Before ACWS Installation						
10/08/2003	Wednesday	Clear, cool	NB	00:27:09	149	156
			SB	01:53:48	342	649
10/24/2003	Friday	Clear, cool	NB	02:27:57	916	844
			SB	02:46:03	775	885
11/13/2003	Thursday	Clear, cool	NB	-	-	-
			SB	00:42:08	161	232
12/12/2003	Friday	Scattered showers, cool	NB	00:47:15	352	275
			SB	02:02:36	510	517
		Total Each Direction	NB	03:42:21	1,417	1,275
			SB	07:24:35	1,788	2,283
			Total Before Installation	**11:06:56**	**3,205**	**3,558**
After ACWS Installation						
05/07/2004	Friday	Clear, warm	NB	02:37:38	577	635
			SB	03:01:05	1,044	1,273
05/21/2004	Friday	Clear, warm	NB	02:28:36	723	504
			SB	02:44:41	1,439	1,284
07/22/2004	Thursday	Clear, warm	NB	02:29:17	670	630
			SB	03:54:14	1,144	1,668
		Total Each Direction	NB	07:35:30	1,970	1,769
			SB	09:39:59	3,627	4,225
			Total After Installation	**17:15:29**	**5,597**	**5,994**
			Grand Total Before & After Installation	**28:22:25**	**8,802**	**9,552**

Subsequent to the field work, speed data were retrieved from the HP calculators with the SpeedStat DC software and transferred to a spreadsheet for analysis. All speed and distance calculations were cosine corrected based on the geometry of the data collection point. All distances were converted relative to the location of the ACWS. During the data collection phase, some of the initially targeted vehicles exited the freeway or were obstructed by other vehicles as they traversed the curve. For this reason, any vehicle record that had fewer than three speed samples through the curve was removed from the data set. Following this data cleaning phase, approximately 6,800 samples remained in the “before” set and 11,600 samples remained for the “after” conditions.

As part of the qualitative portion of this evaluation, an intercept survey of motorist perceptions of the ACWS was conducted at the closest rest areas during the last three data collection days (only after the system was operational). For southbound traffic, the nearest rest stop downstream of the curves was located at milepost 82, approximately 26 miles from the curve. For northbound traffic, the closest rest area was closed for construction, so surveys were collected at the next available rest area at milepost 143, approximately 35 miles from the ACWS.

Surveyors set up a table in the rest area and had willing motorists fill out the survey, clarifying questions when needed. The survey consisted of 11 questions and took less than 2 minutes to complete. Questions asked about the recognition, importance, placement, and visibility of the ACWS. A total of 40 surveys were collected at the northbound rest area and 47 surveys were collected at the southbound area.

6.0 EVALUATION

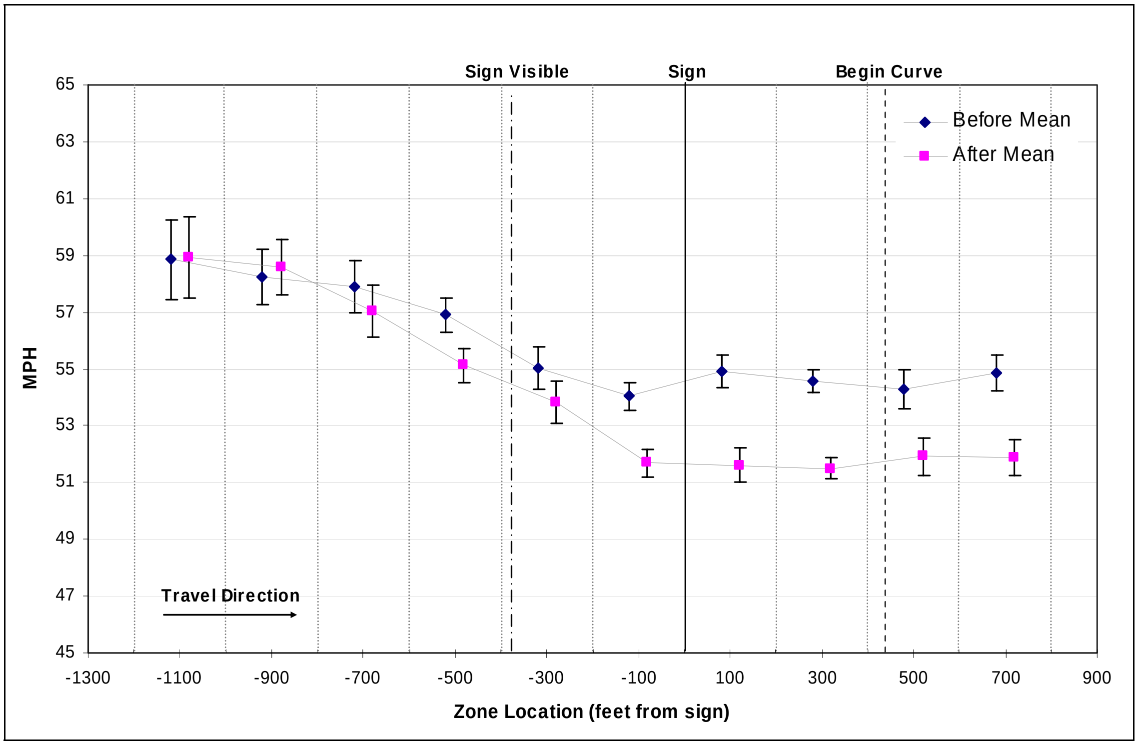
The following sections describe the analysis and results for the three measures of effectiveness.

6.1 CHANGE IN MEAN SPEEDS

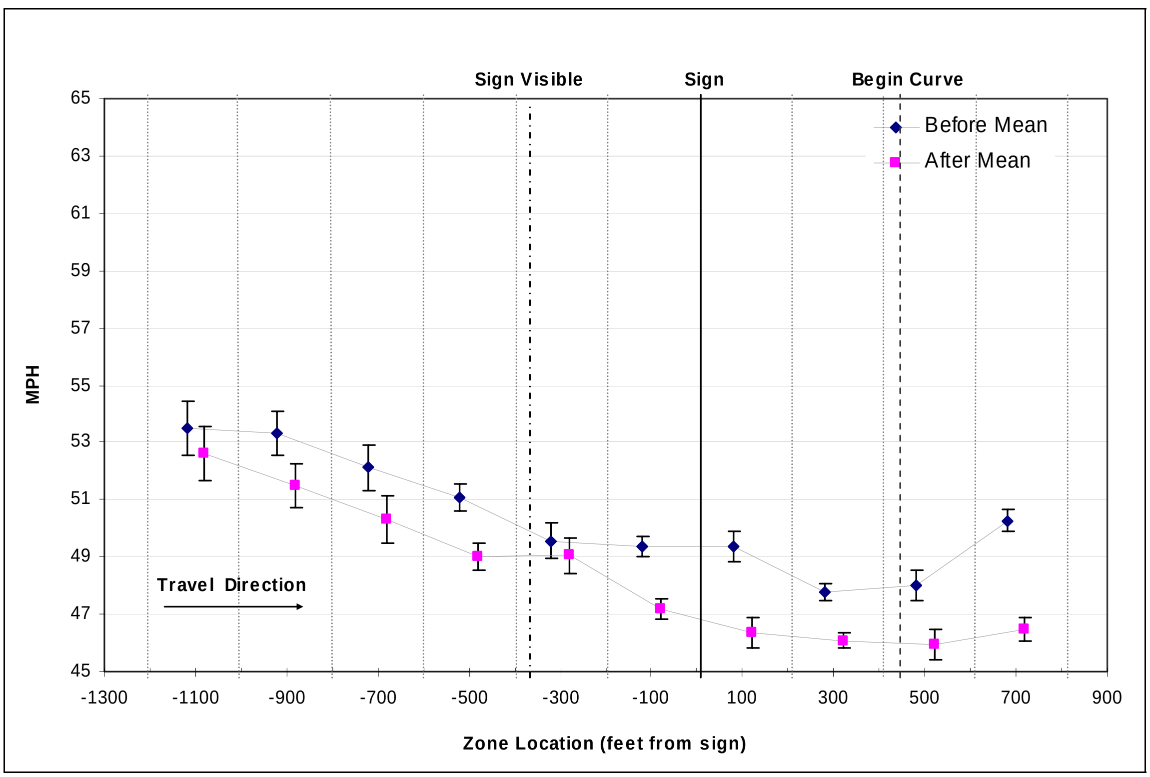
Subsequent to data cleaning, all speed measurements were aggregated into 200-foot zones for commercial vehicles and passenger cars by direction. The number of samples obtained for each vehicle was not necessarily consistent, since each time a target was acquired a data record for that particular location and vehicle speed was recorded. Other data treatments were tested, but given the data collection technique, 200-foot zones kept the number of multiple vehicle records in each zone to a minimum (desirable to avoid biasing a zone with multiple samples from slower speed vehicles) while providing sufficient sample resolution for the analysis. In addition, the 200-foot zone provided sufficient fidelity to observe driver speed choice after the sign installation. For each zone, the mean speed, the standard deviation, and the 95th percentile confidence intervals were calculated. These data are plotted for commercial and passenger vehicles for both directions in Figures 6.1 and 6.2.

As shown in the figures, distances upstream of the sign are displayed as negative numbers. For purposes of display, the mean speed for each speed zone is plotted at the midpoint of that zone. For example, the mean speed for the zone that includes all speed samples with distances from the sign to 200 feet downstream is plotted at +100 feet. The before and after speed midpoints are slightly offset for plotting purposes.

For each direction, the location of the beginning of the curve, as measured from the ACWS was determined from the plan drawings. This distance is shown approximately on each chart in Figures 6.1 and 6.2. The ODOT digital video log, updated June 24, 2004, was used to determine the approximate distance from which the ACWS would first be visible to most drivers. This is a subjective measurement and was conservatively estimated. No adjustment or consideration was made for trucks and their higher heights of driver’s eye which affords them longer sight distances. However, this provides an indication of when the data could be expected to show changes in driver behavior.

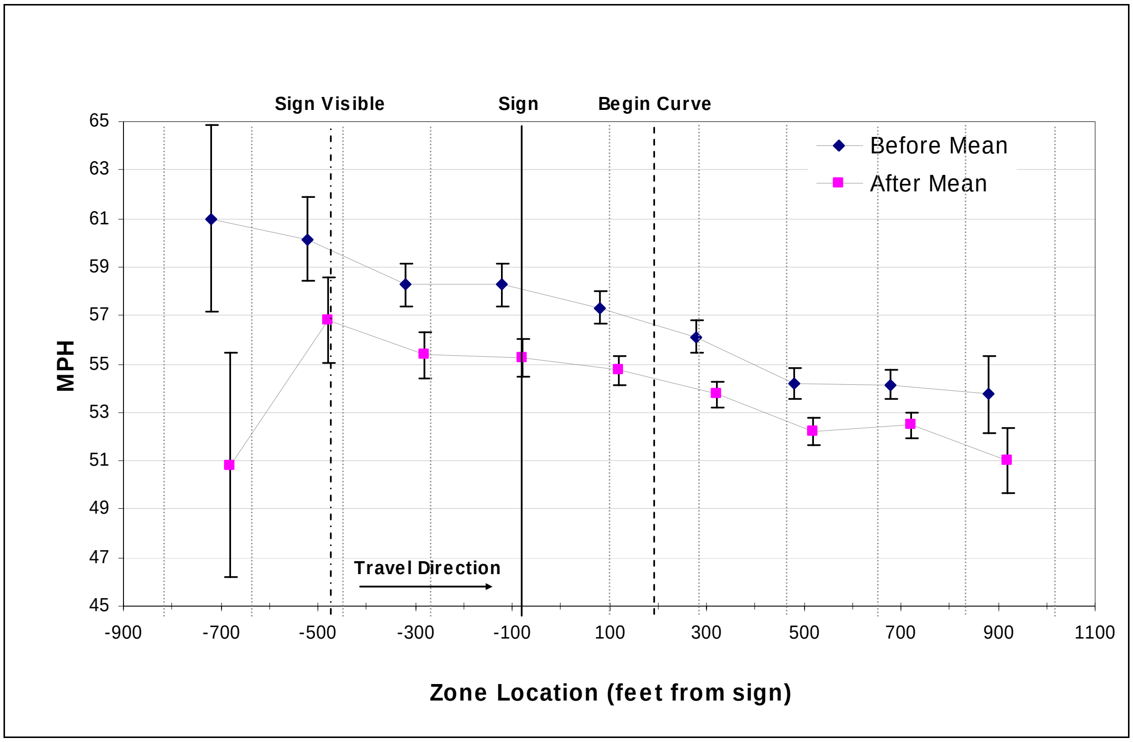


(a) Passenger Vehicles

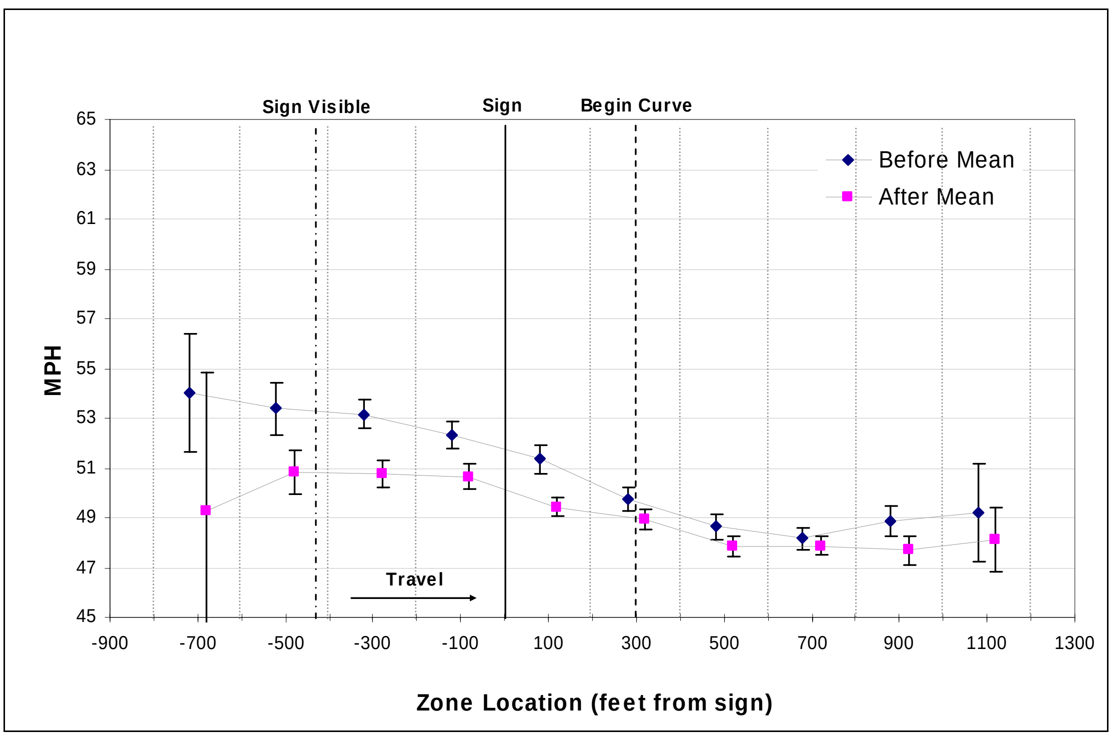


(b) Commercial Vehicles

Figure 6.1: Before and after comparison of mean speeds, southbound



(a) Passenger Vehicles



(b) Commercial Vehicles

Figure 6.2: Before and after comparison of mean speeds, northbound

The equality of means for the speeds of each vehicle class for each zone was tested using the *t*-test for significance. Results of the test are displayed in Table 6.1. For both directions, shown in Figure 6.1 and 6.2, the critical location for speed reduction is the location between the "sign visible" line and the "begin curve" line. It should be noted that all mean observed speeds lie above the posted advisory speed of 45 mph for the curve.

The plots in Figure 6.1 for the sharper southbound curve clearly show a change in vehicle speed for both passenger cars and commercial trucks. For the farthest upstream zones, the before and after mean speeds are not statistically significantly different, as indicated by *t*-tests in zone −1100, −900, and −700 in Table 6.1 for passenger cars. As drivers approached the sign, however, there was a statistically significant reduction in the mean speeds that appears to be associated with the presence of the ACWS (because the before speeds are similar when the sign is not visible).

For commercial vehicles, the same speed trend is evident; however, the results are not as conclusive statistically. Only in the −1100 and −300 zone are the differences in speeds not significant. After the sign, starting in zone −100, all of the differences are statistically different. The maximum mean speed reduction occurred in the zone immediately following the sign location and is 3.3 mph for passenger cars and 3.0 mph for commercial vehicles.

The plots in Figure 6.2 for the northbound curve also display reductions in the mean speeds after ACWS implementation, but the clear driver reaction to the sign observed in the southbound direction is not evident. The after speeds are statistically significantly lower in all zones expect two (−700 commercial vehicles, and 700 commercial vehicles) making it difficult to conclude that speed reductions are attributable only to the ACWS.

Part of the difficulty is related to the availability of data. Unlike the southbound direction, the data collection point was downstream of the ACWS, and as a result, data points in advance of the sign were not as easy to collect. For example, in the −700 zone, only 21 before and 10 after samples were collected. However, the data in Figure 6.2 show speed reductions after the ACWS deployment. There were maximum speed reductions of 2.6 mph for passenger cars and 1.9 mph for commercial vehicles. This is consistent with the southbound direction.

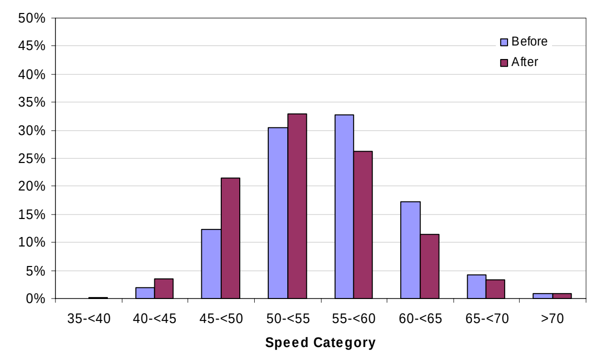
Though these reductions in speed are small, they are statistically significant, as Table 6.1 clearly shows. For all vehicles, appropriate speed prior to the beginning of the curve has been related to the ability to safely navigate the curve (*Preston and Schoenecker 1999*). The reductions are important in the southbound direction, where 11 overturning truck crashes were recorded over the past five years. Rollover crashes are particularly sensitive to speed and the loading configuration of the payload.

Table 6.1: Tests of significance

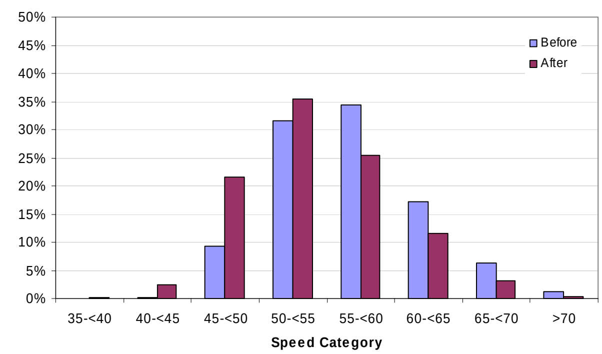
Direction	Vehicle	Zone	Before			After			*t*-Statistic * = significant at 95% confidence
			Sample	Mean	Standard Deviation	Sample	Mean	Standard Deviation	
Northbound	Passenger	−700	11	61.0	5.70	3	50.8	1.70	2.950 *
		−500	35	60.1	5.00	50	56.8	6.20	2.660 *
		−300	148	58.3	5.40	160	55.4	6.00	4.470 *
		−100	150	58.3	5.50	210	55.3	5.90	4.910 *
		100	244	57.3	5.30	349	54.7	5.62	5.650 *
		300	203	56.1	4.82	274	53.7	4.67	5.426 *
		500	190	54.2	4.53	256	52.2	4.59	4.586 *
		700	223	54.1	4.44	285	52.5	4.69	4.102 *
		900	41	53.7	5.00	29	51.0	3.54	2.534 *
	Commercial	−700	10	54.0	3.33	7	49.3	6.02	2.079
		−500	48	53.4	3.60	78	50.9	3.82	3.699 *
		−300	142	53.2	3.53	194	50.8	3.91	5.809 *
		−100	185	52.3	3.80	239	50.7	3.80	4.460 *
		100	209	51.3	4.04	398	49.4	3.76	5.779 *
		300	208	49.7	3.63	309	48.9	3.74	2.430 *
		500	205	48.7	3.64	282	47.9	3.27	2.528 *
		700	232	48.2	3.49	291	47.9	3.27	1.026
		900	154	48.9	3.93	138	47.7	3.37	2.715 *
		1100	21	49.2	4.31	21	48.1	2.84	0.967
Southbound	Passenger	−1100	68	58.8	5.90	120	58.9	5.34	−0.092
		−900	151	58.2	5.62	357	58.6	5.74	−0.581
		−700	209	57.9	5.48	529	57.0	5.72	1.864
		−500	327	56.9	5.44	715	55.1	5.24	5.030 *
		−300	236	55.0	5.29	282	53.8	5.37	2.557 *
		−100	291	54.1	5.39	541	51.7	5.06	6.283 *
		100	291	54.9	5.29	675	51.6	4.89	9.416 *
		300	346	54.6	5.21	488	51.5	4.73	8.880 *
		500	287	54.3	4.80	376	51.9	4.56	6.466 *
		700	46	54.9	5.46	95	51.9	5.00	3.207 *
	Commercial	−1100	61	53.5	3.77	108	52.6	4.02	1.416
		−900	104	53.3	4.22	280	51.5	3.98	3.939 *
		−700	156	52.1	3.87	445	50.3	3.72	5.103 *
		−500	241	51.1	4.10	568	49.0	3.41	7.380 *
		−300	201	49.6	3.74	322	49.1	3.55	1.559
		−100	242	49.4	4.07	489	47.2	3.44	7.590 *
		100	223	49.4	4.10	510	46.4	3.20	10.661 *
		300	294	47.8	3.52	421	46.1	3.22	6.635 *
		500	233	48.0	3.74	366	46.0	3.37	6.924 *
		700	28	50.3	5.39	116	46.5	3.65	4.459 *

6.2 CHANGE IN SPEED DISTRIBUTION

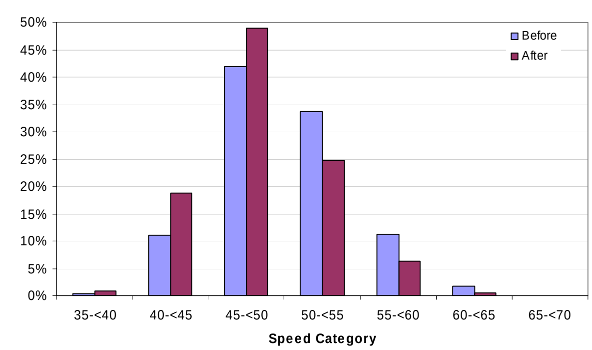
The speed distributions were tabulated as a percentage of vehicles in each five-mile-per-hour speed bin and are shown as histograms in Figure 6.3. The frequency distributions were compared with the chi-square test for goodness of fit. Examination of the speed distributions shown in Figure 6.3 indicates that there was a shift to the left in the after distributions relative to before distributions for all four graphs. This shift represents a lower number of vehicles in the higher speed bins and at least for commercial vehicles, a higher concentration of vehicles near the mean speed. The chi-square test indicated that all of these distribution shifts were statistically significant at a 95th percent confidence level.



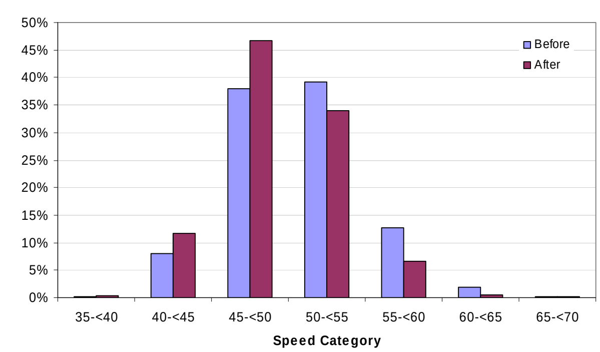
(a) Southbound, Passenger Vehicles



(b) Northbound, Passenger Vehicles



(c) Southbound, Commercial Vehicles



(d) Northbound, Commercial Vehicles

Figure 6.3: Before and after comparison of speed distributions

7.0 PUBLIC RESPONSE

The motorist survey revealed a positive reaction to the ACWS. Figure 7.1 displays a sample of the survey form used for data collection. Table 7.1 shows the detailed survey results for both northbound and southbound data collection.

Results of the northbound and southbound surveys were similar. Nearly all survey participants (85%) were driving a passenger vehicle. The majority of participants (80%) drive through the curves less than once per month and were on a pleasure trip (68%). Nearly every driver noticed the ACWS (95%), and 76% said it displayed their speed, and 84 % of those thought that the sign information aided in safe navigation through the curves. Given that this survey was conducted nearly 30 minutes after drivers encountered the sign, the large percentage recalling the ACWS is noteworthy.

Perhaps as expected, the majority of drivers claimed to have actually slowed down as a result of the ACWS (76%). Nearly half of those who did not slow down indicated that they were already traveling below the advised speed.

A majority of drivers noted the sign was placed in an adequate location (79%). The majority those who thought otherwise (86%) thought the location was too close to the curve. Motorists thought the visibility of the message was adequate. A small percentage thought the text size was too small.

Myrtle Creek Advanced Curve Warning Sign- Motorist Survey

Date: ________ / ______ / 2004 ________ Weather: Clear Cloudy Raining Snowing Fog

Time: ______________________ Road Conditions: Dry Wet Snowy Icy

Direction of Travel: North South Interviewer: ______________________

1. What type of vehicle are you driving today?
   _____ Car/Pick-up/Van
   _____ Commercial truck
   _____ RV/Bus
   _____ Other

2. What is the purpose of your trip on I-5 today?
   _____ Buisness
   _____ Commuting to work
   _____ Pleasure
   _____ Other

3. How often do you drive this section of I-5?
   _____ Less than 1/month
   _____ 1-3/month
   _____ More than 3/month

4. Did you notice the overhead warning sign (with the lighted message) just before the sharp curves?
   _____ Yes (Go to question 5)
   _____ No (Go to question 11)
   _____ Not sure (Go to question 11)

5. Did it display your vehicle speed?
   _____Yes _____No _____Not sure

6. Do you think the sign information was useful to you in driving safely through the curve?
   _____Yes _____No _____Not sure

7. Was this the first time you noticed it?
   _____Yes _____No

8. Did you respond and adjust your travel speed through the curve as advised? Mark multiple answers if necessary.
   _____Yes _____No _____Not sure
   _____Was already below advised speed

9. Was the location of the lighted message sign adequate for you to respond?
   _____Yes _____No _____Not sure

   If no, what was your difficulty with the sign location?
   ______Too close to curve
   ______Too far from curve
   ______Other (explain)

10. Was the visibility of the lighted message sign adequate for you to respond?
    _____Yes _____No _____Not sure

    If no, what was your difficulty with the sign visibility?
    _____Too bright _____Too dim
    _____Sign angle _____Text size
    _____Other (explain)

11. Personal Information:
    _____ Age ___M___F___ Sex

Additional driver comments (continue on the back of this survey if needed):

Thank you for your time !

This survey is being conducted by Portland State University for the Oregon Department of Transportation (503-986-2846).

Figure 7.1: Sample form for Myrtle Creek ACWS motorist survey

Table 7.1: Survey results

	NORTHBOUND		SOUTHBOUND	
Vehicle type				
Passenger	34	85.0%	42	89.4%
Commercial Truck	3	7.5%	2	4.3%
RV/Bus	3	7.5%	3	6.4%
Total	40	100.0%	47	100.0%
Purpose of trip				
Work	8	20.0%	8	17.0%
Pleasure	27	67.5%	31	66.0%
Other	5	12.5%	8	17.0%
Total	40	100.0%	47	100.0%
How often drive I-5?				
<1/month	32	80.0%	40	85.1%
1-3/month	4	10.0%	3	6.4%
>3/month	4	10.0%	4	8.5%
Total	40	100.0%	47	100.0%
Did you notice the DMS?				
Yes	38	95.0%	38	80.9%
No	2	5.0%	9	19.1%
Total	40	100.0%	47	100.0%
Did it display your speed?				
Yes	29	76.3%	29	76.3%
No	4	10.5%	1	2.6%
Not sure	5	13.2%	8	21.1%
Total	38	100.0%	38	100.0%
Was info useful for safe driving?				
Yes	32	84.2%	34	89.5%
No	3	7.9%	3	7.9%
Not sure	3	7.9%	1	2.6%
Total	38	100.0%	38	100.0%

	NORTHBOUND		SOUTHBOUND	
First time noticed it?				
Yes	28	73.7%	23	60.5%
No	10	26.3%	15	39.5%
Total	38	100.0%	38	100.0%
Did you adjust your speed?				
Yes	29	76.3%	30	78.9%
No	3	7.9%	4	10.5%
Not sure	2	5.3%	1	2.6%
Already slow	4	10.5%	3	7.9%
Total	38	100.0%	38	100.0%
Was location adequate?				
Yes	34	79.1%	30	78.9%
No	7	16.3%	7	18.4%
Too close to curve?	6	85.7%	6	85.7%
Too far from curve?	0	0.0%	1	14.3%
Not sure	2	4.7%	1	2.6%
Total	43	100.0%	38	100.0%
Was the visibility adequate?				
Yes	35	92.1%	35	94.6%
No	2	5.3%	2	5.4%
Text size?	2	100.0%	0	0.0%
Sign angle?	0	0.0%	2	100.0%
Not sure	1	2.6%	0	0.0%
Total	38	100.0%	37	100.0%

8.0 CONCLUSIONS

The results of the evaluation indicate that the Myrtle Creek Advanced Curve Warning System is effective at reducing the speeds of the majority of vehicles entering the curve area. All three measures of effectiveness yielded positive results in this evaluation. In terms of mean speeds of vehicles traversing the curve, in the location between when the sign became visible and the beginning of the curve, both directions had statistically significant differences. Mean speeds of passenger cars and trucks were lower by approximately 3 mph for the southbound direction and 2 mph for the northbound direction. The speed distributions of both passenger cars and trucks were statistically different and there were lower proportions of higher speed vehicles.

The study results may be limited in that temporal variations were not adjusted for in the before and after days. Experience with ODOT speed monitoring stations indicate that that speeds in the summer months are generally higher (after condition) than the winter months (Before condition). In addition, there was a systematic reduction in speed for all zones, suggesting perhaps that some of the speed reductions attributed to the ACWS were due to other factors such as the presence of the radar detection device or increased volumes. Because lower profile, faster cars were hard to acquire as targets, some bias may have been introduced to the sample collection. Rather than aggregate analysis of mean speeds, future analysis may consider the individual speed profiles of vehicles.

Overall, the primary motivation for installation was crash reduction. It is assumed that these speed reductions will translate to an actual reduction in crashes over time. With this in mind, it is suggested that the system be monitored for its impact in crash performance when sufficient data become available.

Some improvements to the system could include supplemental variable messages for inclement weather. Currently, the system is not accessible remotely and is not part of the traffic management network. All changes to messages displayed by the DMS must be done at the site. Future implementation with central management capabilities is recommended.

At this time, speed observations do not suggest that the upper bound for the default message should be changed. A small percentage of vehicles were traveling over 70 mph. A customized speed message is displayed for the majority of drivers and may help promote better speed compliance.

The Oregon DOT should consider similar deployments at other hazardous curves and develop a robust methodology to identify candidate locations. Some of these potential methodologies are discussed in *Comparison of Identification and Ranking Methodologies for Speed-Related Crash Locations*, a companion to this report (*Monsere, et al. 2006*).

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APPENDIX

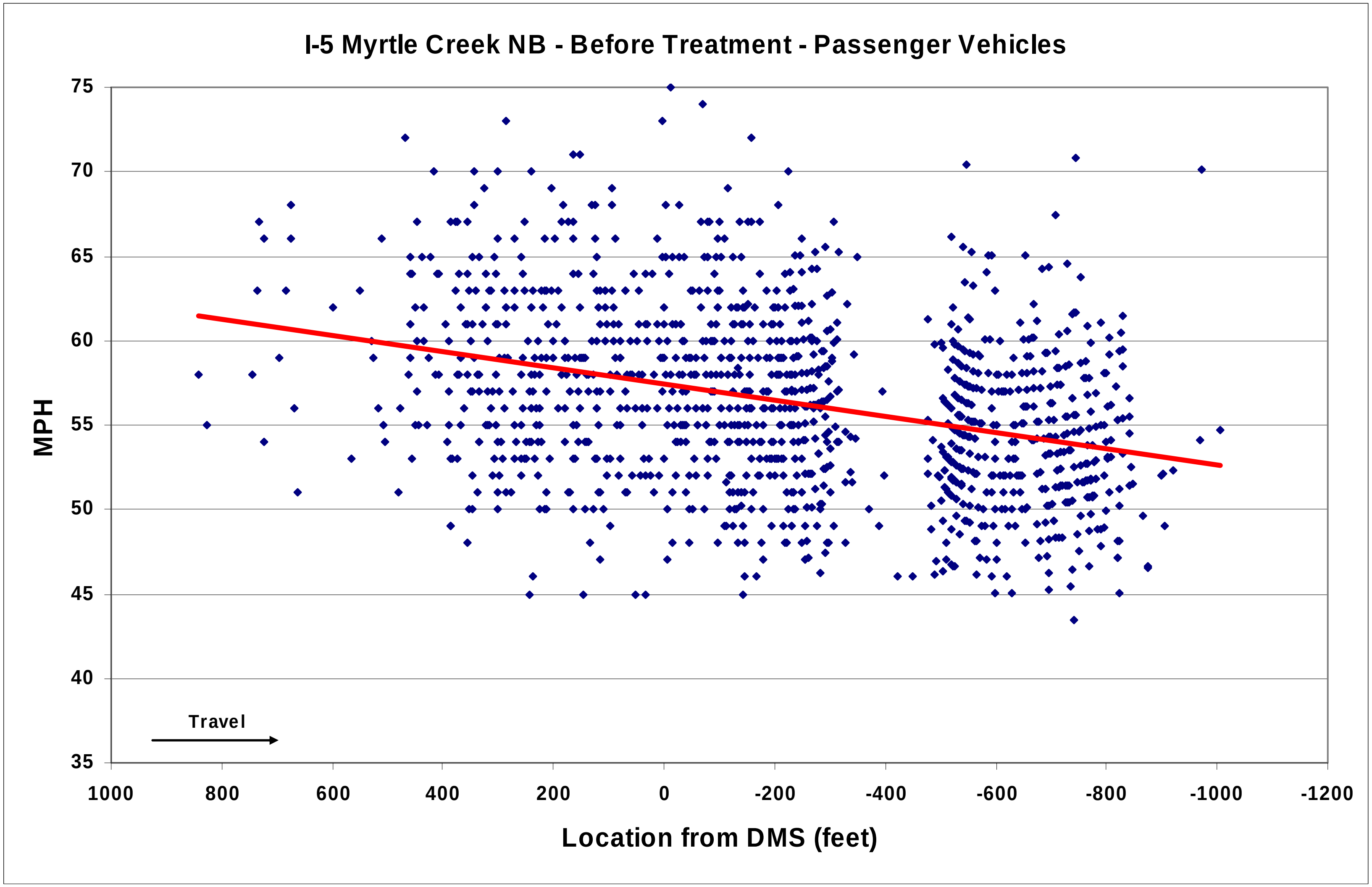

Figure A1: Before data – northbound passenger vehicles

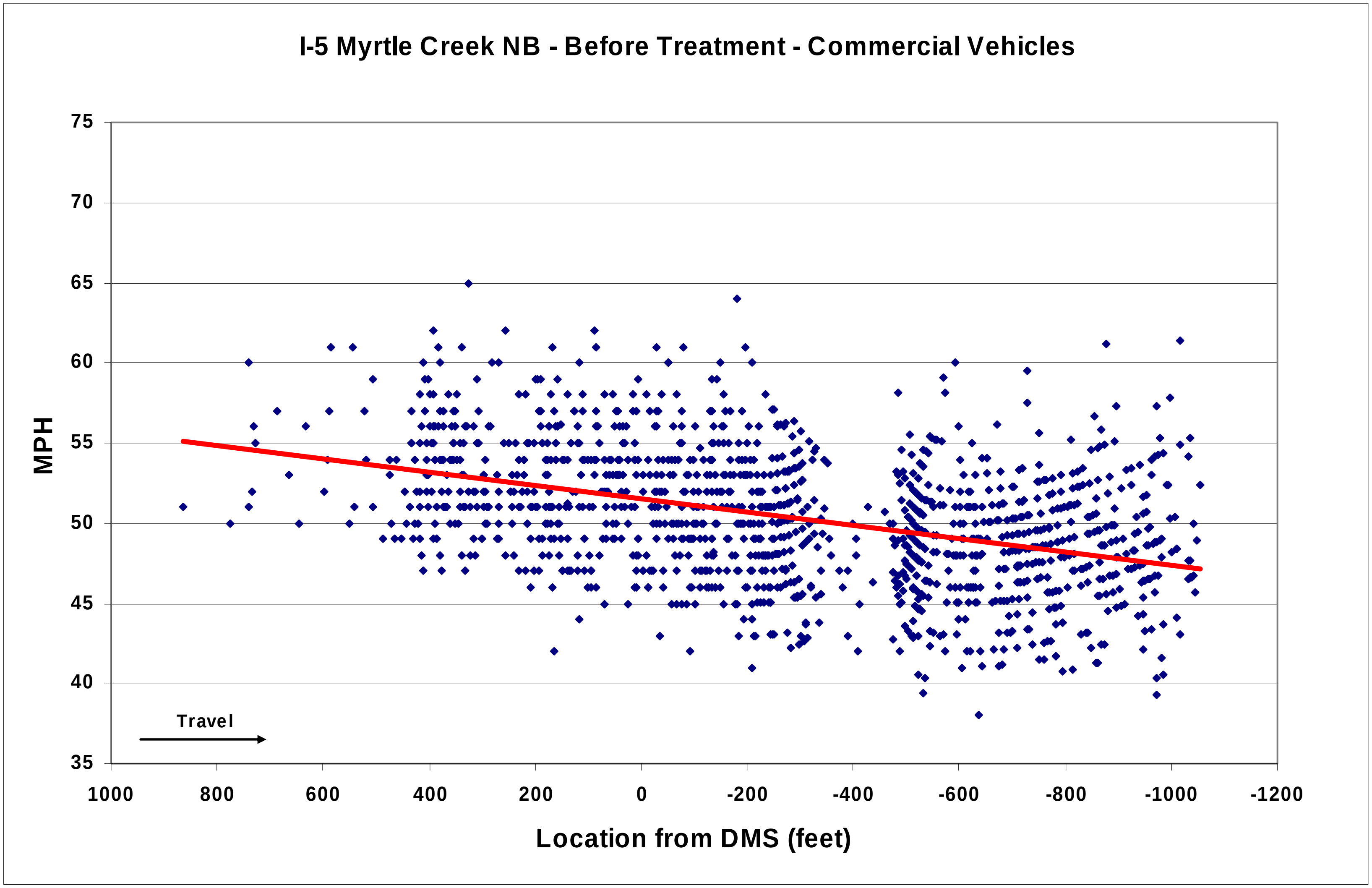

Figure A2: Before data – northbound commercial vehicles

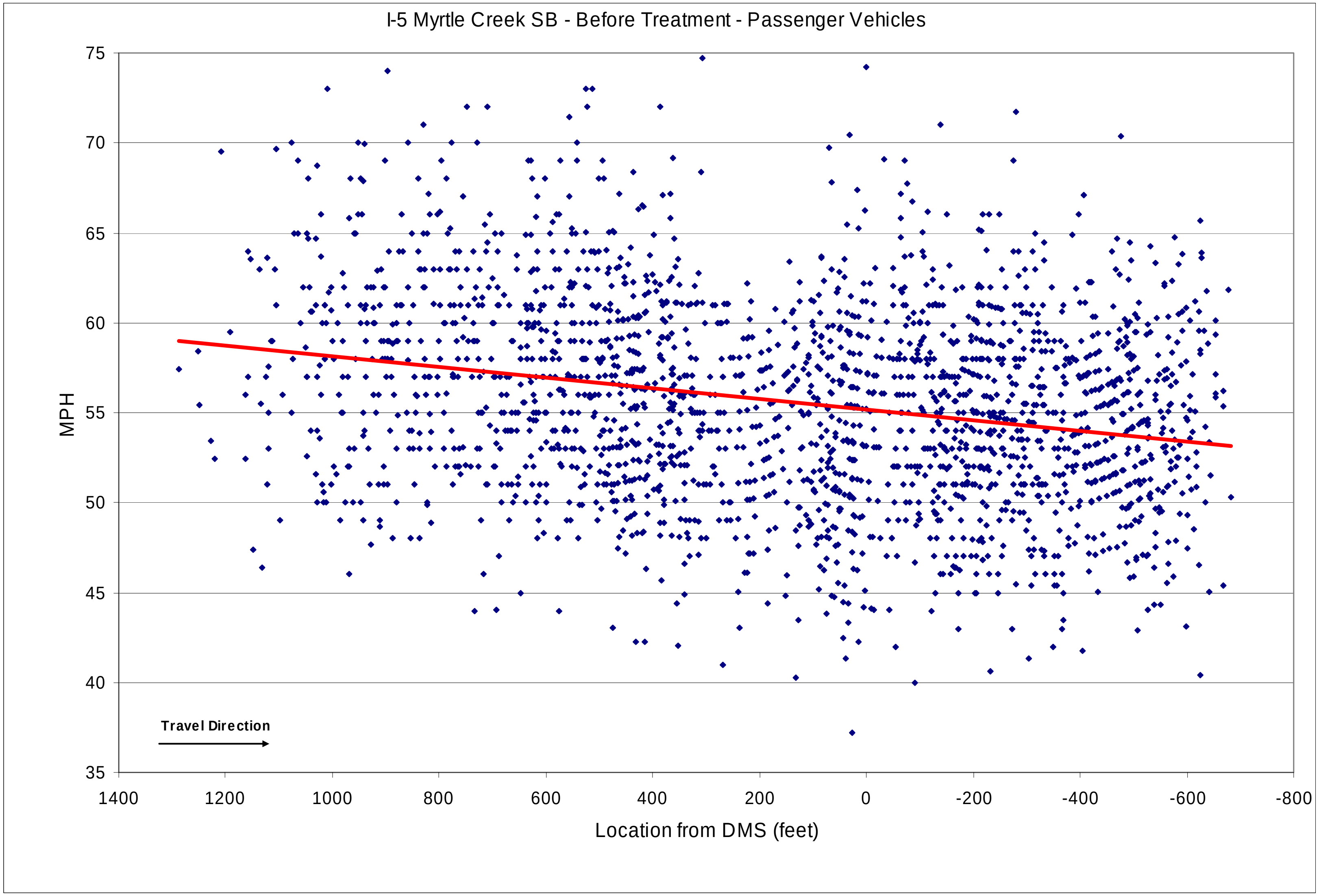

Figure A3: Before data – southbound passenger vehicles

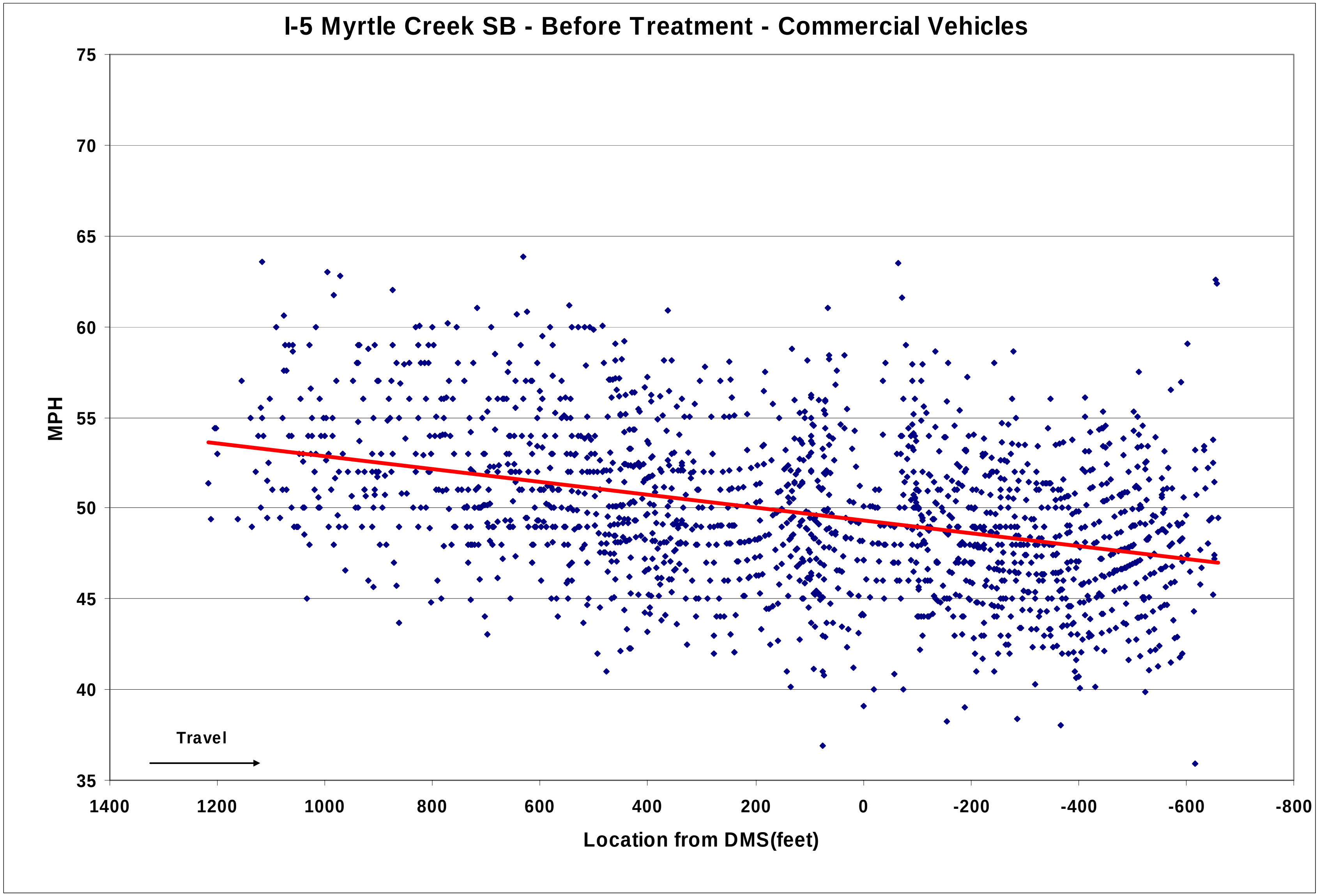

Figure A4: Before data – southbound commercial vehicles

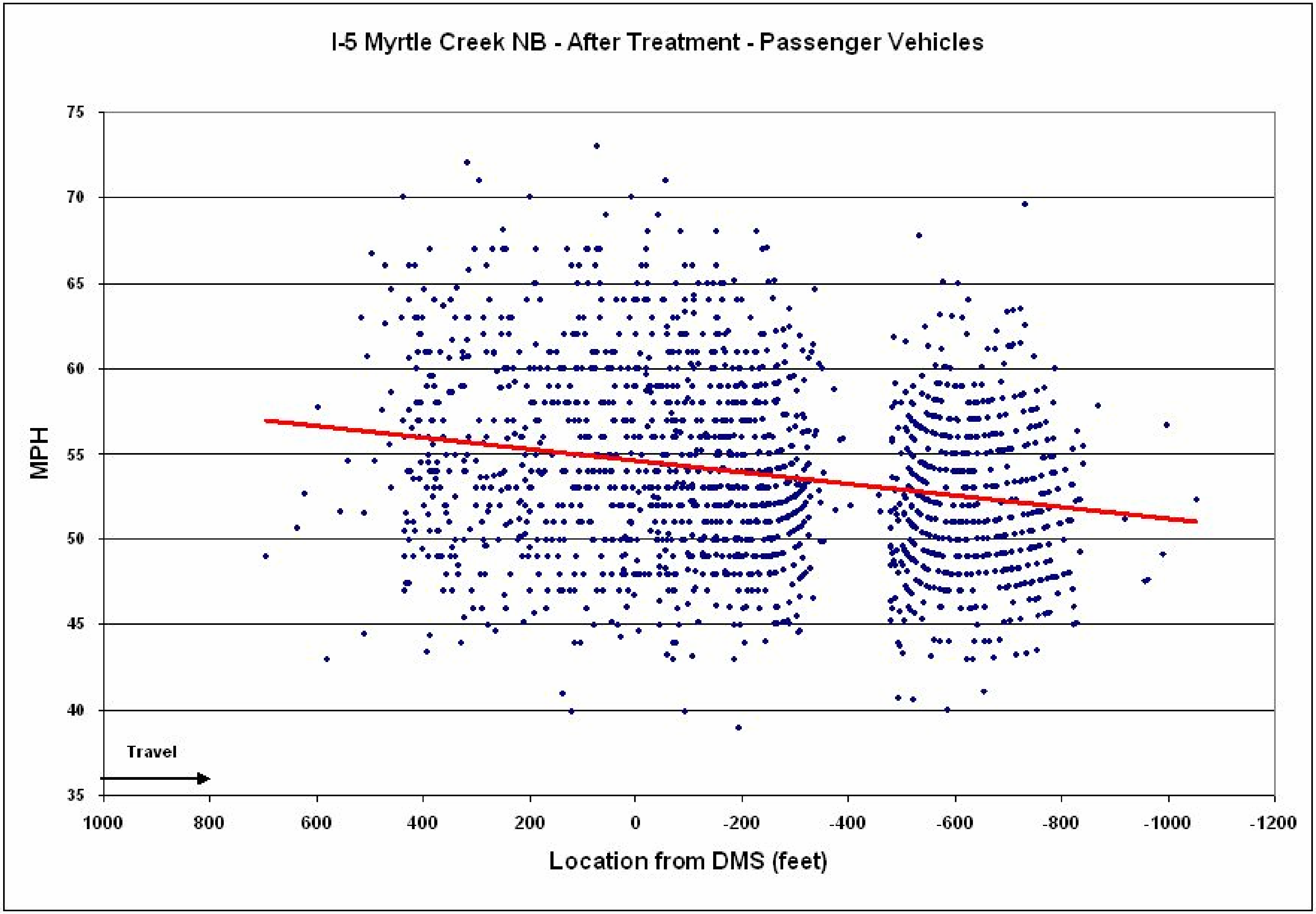

Figure A5: After data – northbound passenger vehicles

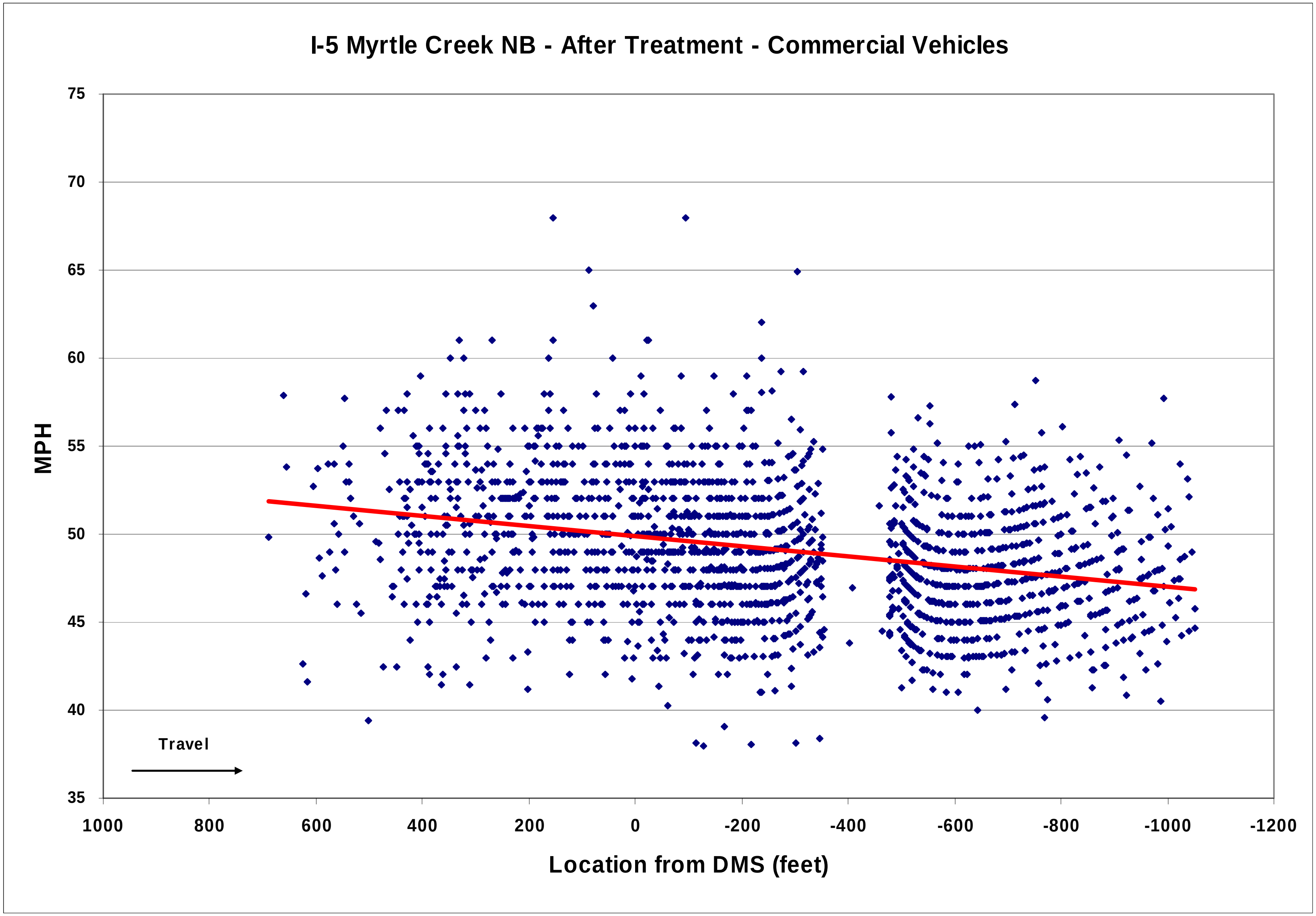

Figure A6: After data – northbound commercial vehicles

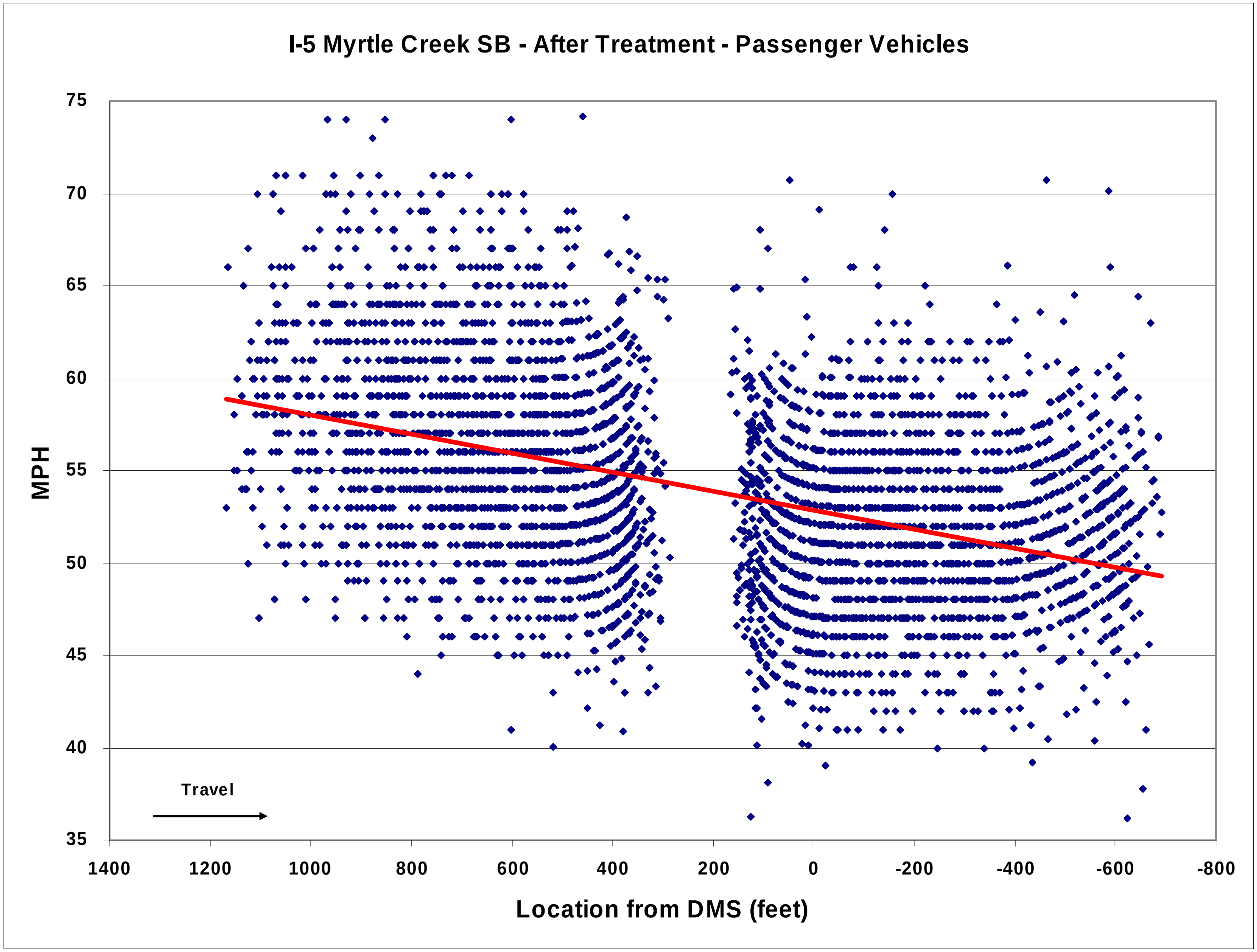

Figure A7: After data – southbound passenger vehicles

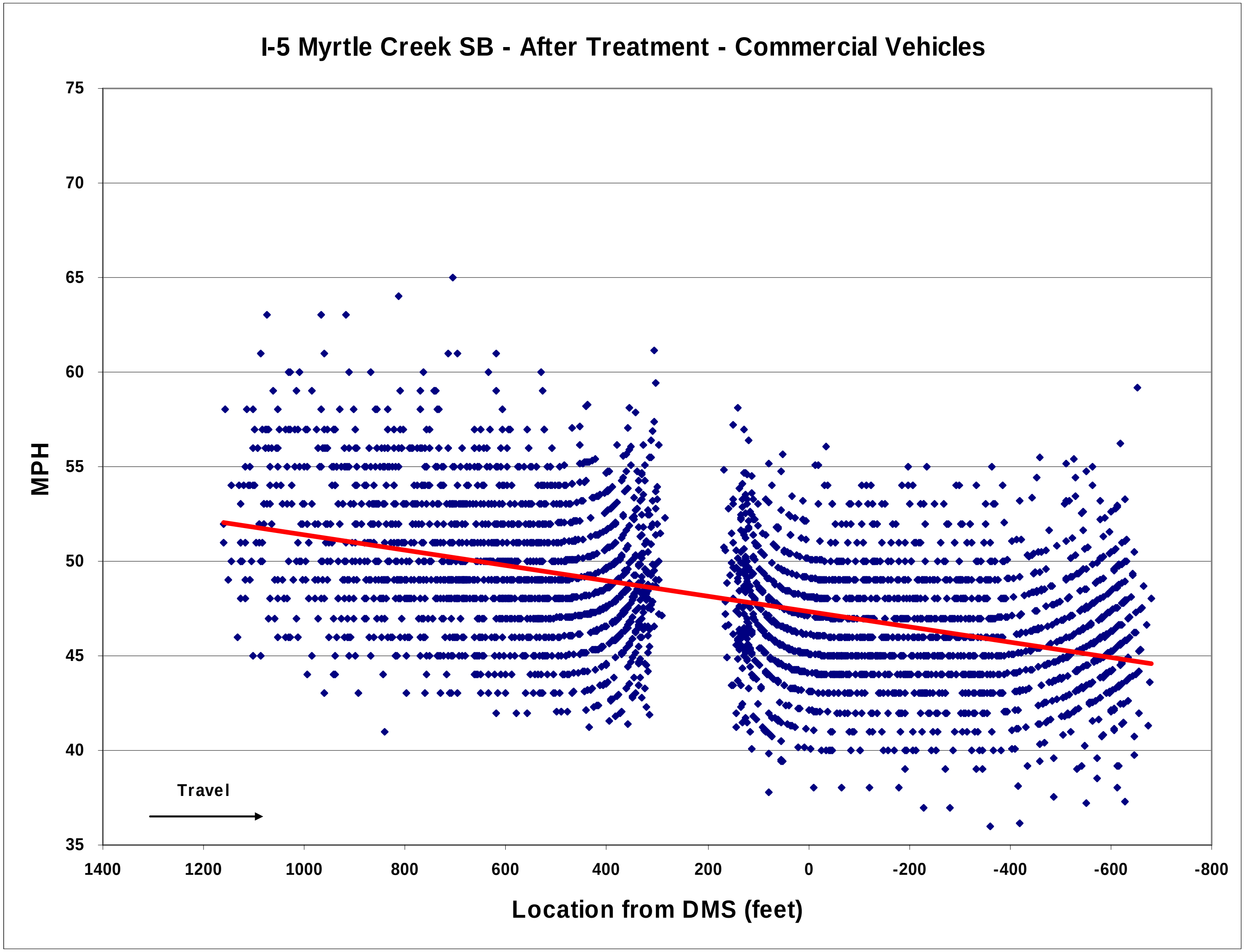

Figure A8: After data – southbound commercial vehicles