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16. Abstract This research evaluated the effectiveness of a vehicle-activated strobe light and supplemental sign as enhancements to the W10-1 sign (enhanced sign system) at passive highway-railroad grade crossings. Three study methods were developed for evaluating the effectiveness of the enhanced sign system including a <i>before</i> and <i>after</i> speed study, a driver survey, and a driver observation study. The study results can be summarized as follows: <ul style="list-style-type: none"> <li>• The enhanced sign system appears to increase driver awareness of the passive highway-railroad grade crossing;</li> <li>• The enhanced sign system caused some drivers to approach the passive highway-railroad grade crossing with additional caution;</li> <li>• Reductions in average speed on both the east and west approach to the passive highway-railroad grade crossing were observed after the installation of the enhanced sign system;</li> <li>• The strobe light was effective in directing drivers' attention to the railroad advance warning (W10-1) and supplemental signs; and</li> <li>• The enhanced sign system did not cause any adverse driver reaction.</li> </ul> The results of this research indicate that the enhanced sign system can be an effective traffic control device. It offers promise of increased safety at passive highway-railroad grade crossings and appears worthy of additional investigation and implementation.					
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**ENHANCED TRAFFIC CONTROL DEVICES AND RAILROAD  
OPERATIONS FOR HIGHWAY-RAILROAD GRADE CROSSINGS:  
THIRD-YEAR ACTIVITIES**

by

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## IMPLEMENTATION STATEMENT

This report describes activities completed during the third year of a three-year study focusing on improving safety at highway-railroad grade crossings. The primary activity of the third year of the study was the field implementation of a vehicle-activated strobe light and “Look For Trains At Crossing” supplemental sign as enhancements to the W10-1 sign (enhanced sign system) at a passive highway-railroad grade crossing in Temple, Texas. The results of this investigation were positive, and the enhanced sign system shows promise for improving safety at passive grade crossings.

The experimental set-up was changed to include loop detector technology for detecting vehicles on the approach to the passive highway-railroad grade crossing. Loop detectors are commonly used for vehicle detection and provide a simple and effective method for installing the enhanced sign system at other locations. The primary components of the field set-up include the flashing yellow strobe light, loop detector wire, loop detector amplifier, single shot relay, wire from the strobe light to the power source, and a D.C. power source with recharging capabilities (12-volt battery with solar panel or equivalent) or a direct A.C. connection.

To implement this enhanced sign system, excluding labor and maintenance costs, would require approximately \$2,000 per crossing. All of these components, with exception of the buried wire and in-pavement loop detector, can be reused at a new location when the passive highway-railroad grade crossing is upgraded to an active highway-railroad grade crossing. It is conceivable that this enhanced sign system could be applied to between 50 and 100 passive grade crossings, slated for upgrade to active grade crossings, throughout the state of Texas each year. To implement this enhanced sign system at 100 passive grade crossings in Texas would require approximately \$200,000 plus labor costs for installation and maintenance of the enhanced sign system.



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## **DISCLAIMER**

The contents of this report reflect the views of the authors who are responsible for the facts, opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the Texas Department of Transportation (TxDOT) or the Federal Highway Administration (FHWA). This report does not constitute a standard, specification, or regulation and is not intended for construction, bidding, or permit purposes. The engineers in charge of preparing this report were Daniel B. Fambro, P.E. No. 47535 (Texas), and David A. Noyce, P.E. No. 25726 (Wisconsin).

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The authors wish to acknowledge the contributions of the Technical Advisory Committee which includes Herbert Bickley (Lufkin), David Greer (Traffic Operations Division), Gerald Jackson (Waco), and Mark Thorp (Traffic Operations Division) of TxDOT, and Ken Rouse of the Union Pacific Railroad. The committee provided technical input and suggestions on the field implementation which were greatly appreciated. The authors would also like to acknowledge Cindy Parks of TxDOT (Waco) for her assistance in coordinating the field work and Lee Anne Dixon and Jon Collins of TTI for their assistance in the field set-up and preparation of this report.



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## SUMMARY

The objective of this study was to determine the effectiveness of a vehicle-activated strobe light and supplemental sign as enhancements to the railroad advance warning (W10-1) sign at passive highway-railroad grade crossings. Three study methods were developed for evaluating the effectiveness of the *enhanced sign system*. First, a spot speed study was designed using a *before* and *after* methodology to determine if the implementation of the enhanced sign system led to a more cautious approach to the highway-railroad grade crossing. Second, a driver survey was developed to evaluate the conspicuity of the flashing strobe light and supplemental sign and to evaluate drivers' comprehension of the enhanced sign system. Third, a driver observation study was developed to evaluate drivers' reaction to the flashing strobe light and the associated driving patterns between the enhanced sign system location and the highway-railroad grade crossing.

The results of the *before* and *after* speed study indicated that average speeds on the approaches to the highway-railroad grade crossing were slightly lower after the installation of the enhanced sign system. During night driving conditions, this reduction in average speeds was found at all data collection locations. It is difficult to predict how much of the speed reduction is attributable to the enhanced sign system; however, it can be concluded that the warning sign had a positive contribution in reducing speed on each approach to the highway-railroad grade crossing.

The results of the driver survey found drivers responding favorably to the addition of the vehicle-activated strobe light and supplemental sign. The number of drivers who recalled observing the supplemental sign was encouraging, especially the number of drivers who were able to recall the exact wording of this unfamiliar sign. Further, by adding the strobe light and supplemental sign to the existing W10-1 sign, some drivers implied this to mean that this location was an unsafe highway-railroad grade crossing and approached the crossing with additional caution.

The final two driver surveys conducted, just before complete darkness set in, found that the drivers did not recall seeing the flashing strobe light but did see the supplemental sign with the last driver able to correctly recall the wording of the supplemental sign. Since the purpose of the flashing strobe light is to draw the driver's attention to the warning signs, not to the strobe light itself, it would appear that the enhanced sign system performed desirably in these two instances. None of the drivers surveyed indicated that they correlated the flashing strobe light with the presence of a train at the crossing.

The results of the driver observation study found no adverse driver reactions at the onset of the flashing strobe light. Drivers appeared to be exercising more caution by braking earlier, switching to their hi-beam headlights, and crossing the railroad at lower speeds.

Based on the summary of research findings described above, the following conclusions can be drawn:

- The enhanced sign system appears to increase driver awareness of the passive highway-railroad grade crossing;

- 
- The enhanced sign system caused some drivers to approach the passive highway-railroad grade crossing with additional caution;
  - A reduction in average speed on both the east and west approach to the passive highway-railroad grade crossing was observed after the installation of the enhanced sign system;
  - The strobe light was effective in directing drivers' attention to the railroad advance warning (W10-1) and supplemental signs; and
  - The enhanced sign system did not cause any adverse driver reaction.

The results of this research indicate that the enhanced sign system can be an effective traffic control device and is worthy of additional investigation and implementation. Study results were positive, and the enhanced sign system shows promise for improving safety at passive highway-railroad grade crossings. It is recommended that the enhanced sign system be applied to rural passive highway-railroad grade crossings, specifically those slated for future improvements. It is feasible that this enhanced sign system could be applied to between 50 and 100 passive highway-railroad grade crossings throughout the state of Texas each year.

## 1.0 INTRODUCTION

In its simplest form, a highway-railroad grade crossing is nothing more than an intersection that handles two conflicting streams of traffic; however, the grade crossing is unique in the transportation system in that two different modes of transportation compete for the same physical space. This attribute and the different operating characteristics of motor vehicles and trains create potential safety problems at highway-railroad grade crossings. The operating characteristics of trains inhibit their ability to stop quickly. Unlike cars, trains move on a fixed path or guideway, and cannot swerve to miss a car to avoid an impending accident. Therefore, cars must yield right-of-way to trains at highway-railroad grade crossings or conflicts will occur. Texas law clearly states that the motorist should always “slow, look, and listen, and be prepared to yield the right of way to an approaching train” at a highway-railroad grade crossing.

According to 1993 Federal Highway Administration (FHWA) reports, the state of Texas had 13,235 public highway-railroad grade crossings. This number is greater than in any other state; Illinois ranks second with 10,364 crossings. Approximately 4,500 (34 percent) of Texas public grade crossings are classified as *active* crossings. Active crossings provide warning of the approach or presence of a train. A detection circuit in the railroad track senses the presence of an approaching train and activates the warning devices at the crossing. Examples of active warning devices include mast- and cantilever-mounted flashing light signals, automatic gates, wigwag signals, and bells. Crossings that lack train-activated warning devices are classified as *passive* crossings. Passive crossings employ signs and markings to identify the location of the crossing and to direct the attention of the motorist, bicyclist, or pedestrian toward it. Passive devices provide static messages; the message conveyed by the signs or markings remain constant regardless of the presence or absence of a train. Both types of crossings use the same advance warning signs and pavement markings to alert roadway users that a highway-railroad grade crossing is nearby.

### 1.1 PROBLEM STATEMENT

Driver error is frequently cited as a factor in highway-railroad grade crossing crashes; however, these errors may be compounded by engineering and human factors issues. Driver error may result from failure to perceive that a train is in hazardous proximity to the grade crossing. Alternatively, the driver may detect the train but decide erroneously that adequate time is available to clear the crossing ahead of the train. Explanations for the driver’s failure to detect the train or faulty decision-making process are many. It is suggested that a leading cause of bad decisions is violation of driver expectancy. If a driver is only familiar with active highway-railroad grade crossings, he or she may not understand his or her responsibilities at a passive grade crossing. Further, the driver who has had experience at a grade crossing with infrequent trains may not pay adequate attention at unfamiliar locations with higher train volumes.

Another possible source of confusion to drivers encountering highway-railroad grade crossings is the current system of visual communication. The advance warning sign and railroad crossbuck sign do not differentiate between active and passive crossings, thereby complicating the drivers decision-making task. National statistics show that more than 50 percent of all collisions between

motor vehicles and trains occur at active crossings, which in theory should have substantially fewer crashes or no crashes at all. One potential explanation is that the warning device technologies and the warning time they provide might contribute to the frequency of crashes at these crossings. Methods for improving communication between railroad advance warning signs and the driver are needed to reduce driver confusion, minimize violations of driver expectancy, and improve overall safety at highway-railroad grade crossings.

## 1.2 RESEARCH OBJECTIVE

The objective of this study is to develop, test, evaluate, and recommend improved methods for communicating with drivers at both active and passive highway-railroad grade crossings. Proposed new devices should demonstrate compliance with the *Manual on Uniform Traffic Control Devices* (MUTCD), high conspicuity and target value, adequate comprehension by the Texas driver population, and relatively low implementation cost versus alternative measures. To accomplish the research objective, the research team formulated a work plan consisting of nine tasks:

1. Assess driver behavior and causes of driver error;
2. Assess warning device activation technologies;
3. Assess railroad operating rules and practices;
4. Conduct a statewide grade crossing accident study;
5. Monitor experimental passive sign systems at test crossings;
6. Develop and evaluate enhanced traffic control devices;
7. Create and convene a public education advisory committee;
8. Develop a comprehensive plan for highway-rail safety awareness; and
9. Prepare and submit a final report documenting the research findings and recommendations.

This report documents the results from the study's third-year activities. The third-year activities consisted of Tasks 5, 6, and 9 and focused on the field implementation of a vehicle-activated strobe and supplemental sign enhancement at a passive highway-railroad grade crossing in Temple, Texas.

## 1.3 ORGANIZATION

This report documents the activities and findings of research activities completed within the third year of this three-year study. The report on first-year activities contained a review of the literature on driver behavior at highway-railroad grade crossings, a study of train detection technologies for highway-railroad application, a study of railroad operating rules and practices at grade crossings, and an analysis of factors contributing to grade crossing crashes in Texas.

The report on the second-year activities contained driver comprehension surveys related to highway-railroad traffic control devices, an in-vehicle observations of driver behavior at highway-railroad grade crossings, a field study of "Yield To Trains" and "Look for Trains" advance warning signs, and the development and evaluation of a vehicle-activated strobe light enhancement to the railroad advance (W10-1) warning sign.

This report of third-year research activities contains six sections, including this introductory section. Section 2.0 discusses the background and study design for the field placement of the



enhanced sign system. Section 3.0 discusses the study results of the *before* and *after* speed study conducted on each approach to the passive highway-railroad grade crossing. Section 4.0 presents the findings of a driver survey designed to evaluate drivers' detection and comprehension of the strobe light and supplemental sign. Section 5.0 describes the results of a driver observation study completed during night driving conditions. Section 6.0 summarizes the conclusions and recommendations from the third-year activities.



## 2.0 BACKGROUND AND STUDY DESIGN

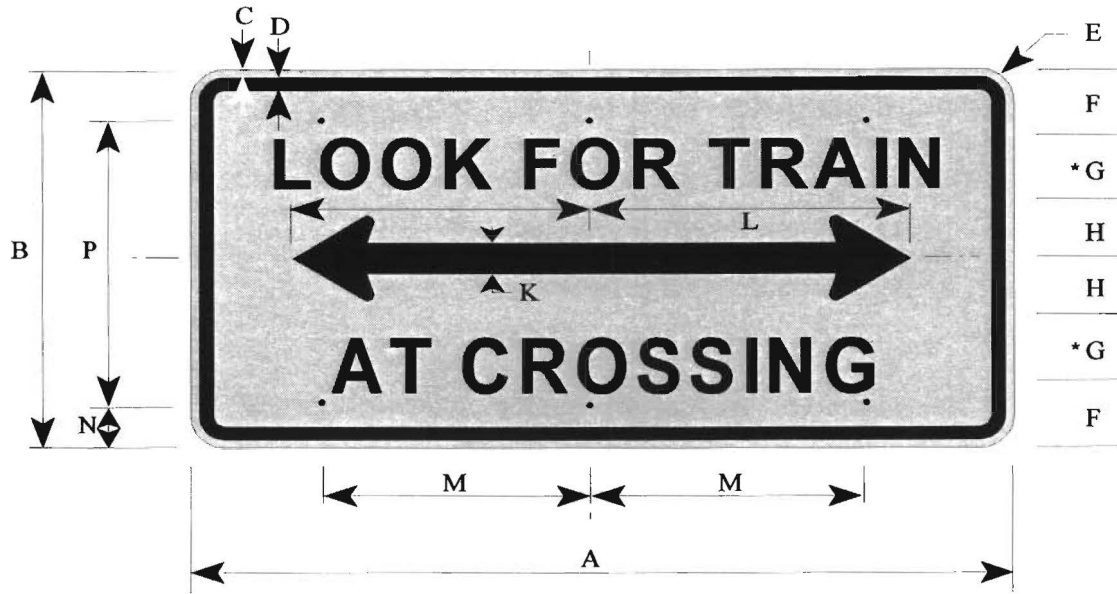
### 2.1 BACKGROUND

In October 1995, a focus group and closed-course driving study were undertaken to determine driver response to enhancements to the standard railroad advance warning (W10-1) sign. As part of this investigation, three enhancements to the W10-1 sign were explored, including an increase in sign reflectorization through improved sheeting, the addition of a continuously flashing yellow beacon, and the addition of a vehicle-activated strobe light. The flashing beacon and vehicle-activated strobe light were intended for use at passive highway-railroad grade crossings with the purpose of attracting drivers' attention and directing it to the W10-1 sign, increasing driver awareness of the presence of a highway-railroad grade crossing. Focus group comments concerning both flashing light alternatives were generally positive, and no adverse driver behavior was observed when drivers encountered either alternative in a closed-course driving study. Both the continuously flashing beacon and the vehicle-activated strobe light were identified as effective methods of increasing driver awareness of the railroad advance warning sign; however, the uniqueness of the vehicle-activated strobe light led participants to conclude that it may be more effective at attracting drivers' attention. Given these results, a field study of the vehicle-activated strobe light at a passive highway-railroad grade crossing was recommended.

One of the concerns raised in the focus group study was how drivers would interpret the meaning of flashing yellow lights at passive highway-railroad grade crossings. Some focus group participants indicated that they assumed the flashing light meant a train was at the crossing. This interpretation created a potential safety problem since the flashing light was designed to attract drivers' attention rather than to indicate the presence of a train at the crossing. This problem was found to be greater with the continuously flashing beacon than with the vehicle-activated strobe light.

To address this problem, the research team and the Texas Department of Transportation (TxDOT) developed a "LOOK FOR TRAIN AT CROSSING" supplemental sign to be installed directly below the W10-1 sign. This supplemental sign provided the driver with a written message consistent with the desired action at the crossing and minimized the potential of a driver misunderstanding the meaning of the flashing strobe light. The sign contained 10-centimeter letters, using a 122-centimeter (48-inch) sign width. This letter height was based on a ratio of legibility distance to letter height of 7:1 assuming 20/20 Snellen vision. The final design and sizing requirements for the supplemental sign are presented in Figure 2.1. In July 1996, after thoroughly evaluating the proposed vehicle-activated strobe and supplemental sign design, TxDOT granted permission to undertake a field implementation and evaluation of these enhancements at a passive highway-railroad grade crossing.

The focus of this section is a description of the study design used in the field evaluation of the vehicle-activated strobe light and supplemental sign as enhancements to the W10-1 sign (enhanced sign system). The first section described the objectives for the field evaluation. The second section described the study site selection process and the reasons for selecting the Blackland Road site. The third section describes the *before* and *after* speed study design used to test the effectiveness of the



\* CONDENSE SPACING 15%

**COLORS - Border, Legend & Symbol - BLACK; Background - YELLOW (Refl)**

Sign	Dimensions (Inches)													
	A	B	C	D	E	F	G	H	J	K	L	M	N	P
Special	36	18	3/8	5/8	1½	3	3D	3	3½	1½	13½	-	2½	13
Special	48	24	3/8	5/8	1½	4	4D	4	5¼	2	18	16	3	20

1 inch = 2.54 centimeters

**Figure 2.1. Supplemental Sign Design**

enhanced sign system including a depiction of the field layout. The third section also summarizes the process and equipment used to develop the vehicle-activated strobe light system for field application.

## 2.2 OBJECTIVE

The objective of this study was to develop, test, and evaluate an improved method for communicating with drivers at passive highway-railroad grade crossings. Specifically, this research was formulated to evaluate the effectiveness of a vehicle-activated strobe and supplemental sign as enhancements to the railroad advance warning sign at passive highway-railroad grade crossings. To be effective, the enhanced sign system should increase driver awareness of the highway-railroad grade crossing and result in more cautious behavior. At the same time, drivers should understand the meaning of the enhanced sign system, and the enhancements should not result in unsafe driver behavior on the approach to the highway-railroad grade crossing. Reduced vehicle approach speeds combined with increased looking for an approaching train would be indicative of a more cautious approach to the crossing.

## 2.3 SITE SELECTION

TxDOT's Waco District, in cooperation with Bell County officials, offered the opportunity to test the enhanced sign system at a passive highway-railroad grade crossing within their jurisdiction. After reviewing a number of passive grade crossings in Bell County, the Blackland Road crossing on the Union Pacific Railroad Line in Temple, Texas was selected (Crossing Number 416201T). Although all the sites considered contained traffic volumes below 1,000 vehicles-per-day (vpd), the Temple site provided the largest average daily traffic volumes estimated at 650 vpd. The railroad was active with up to 15 train crossings per day, and the site was easily accessible to the research team. Additionally, this site provided the following desirable characteristics:

- The city of Temple, Bell County, and TxDOT supported the selection of this location;
- Both approaches to the Blackland Road crossing were of adequate length to study the deceleration effects of traffic approaching a highway-railroad grade crossing;
- The crossing had experienced several accidents, none of which were fatal;
- Blackland Road was used by a mix of familiar and unfamiliar drivers; and
- The Blackland Road crossing was scheduled for upgrade to active warning devices.

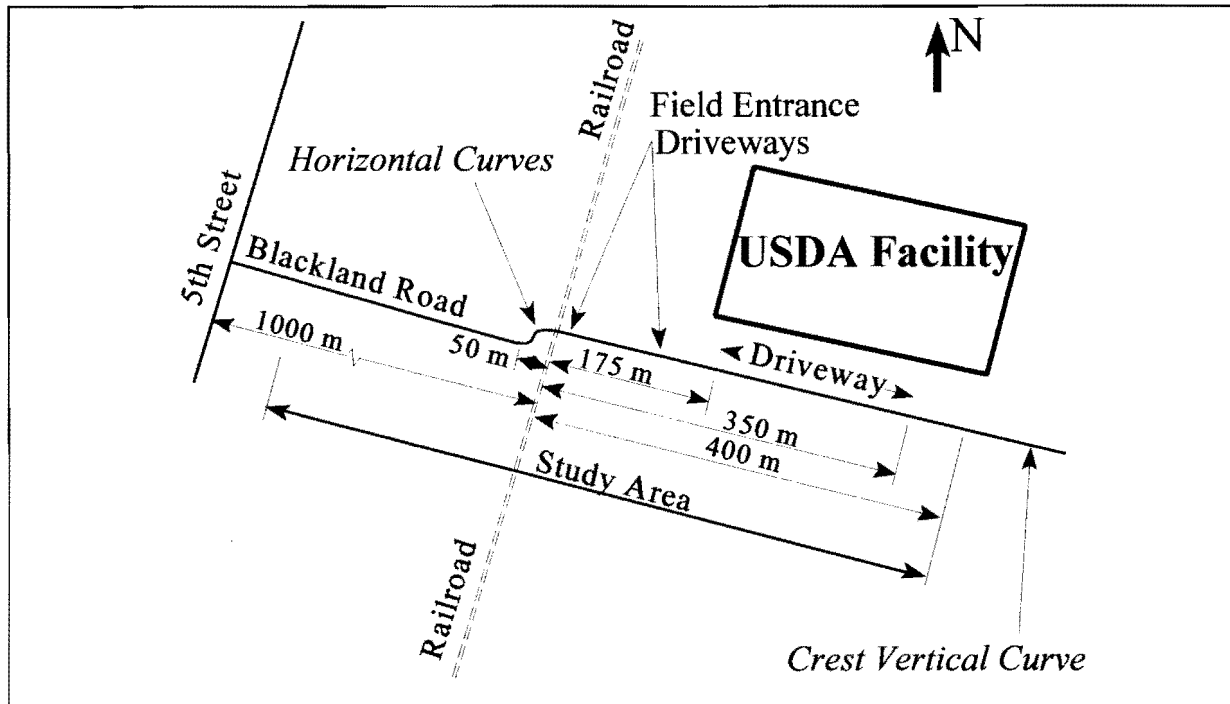
The Blackland Road study site contained a number of prominent geometric features. The west approach to the railroad crossing contained two short-radius horizontal curves forming a reverse or S-curve roadway alignment approximately 50 m from the grade crossing. This horizontal curvature created limited sight distance near the grade crossing. The approach roadway west of the horizontal curves was straight and flat and contained sufficient sight distance.

The east approach to the railroad crossing contained a crest vertical curve approximately 400 m from the grade crossing. This vertical curve had limited sight distance blocking the drivers' view of the grade crossing and corresponding railroad advance warning sign until the driver and vehicle were approximately 380 m from the crossing. Two driveway entrances to a United States Department of Agriculture (USDA) facility were located on the north side of the east approach at approximately 175 m and 350 m from the crossing. Field entrances for the USDA farm machinery were located on the north side of this approach approximately 125 m from the crossing and on the south side of this approach at approximately 25 m and 125 m from the crossing. Within 20 m of the railroad crossing on both approaches, the vertical grade of the roadway increased sharply to meet the grade of the railroad tracks forming a hump in the roadway profile. Figure 2.2 presents a schematic drawing of the study site. A map showing Blackland Road and the study site area is included in Appendix A.

None of the geometric features of Blackland Road were considered to be detrimental to the selection of this location as a study site. In addition, the study methods selected, as described in the following section, were not sensitive to the geometry of the roadway.

## 2.4 STUDY DESIGN

The most effective way to determine if the enhanced sign system improved safety at passive highway-railroad grade crossings would be to evaluate the crash rates at the crossing *before* and *after* installation. Since crash rates were not a viable measure for short term evaluation, three surrogate



**Figure 2.2 Blackland Road Study Site**

study methods were developed. First, a spot speed study was designed using a *before* and *after* methodology. Although railroad warning signs do not require drivers to reduce speed unless a train is present, the comparison of *before* and *after* speed profiles provided an effective means of determining if the objective of a more cautious approach to the highway-railroad grade crossing was achieved. The research team hypothesized that an effective warning system would result in a speed reduction on the approach near the location of the enhanced sign system with little speed differential near the crossing. Second, a driver survey was designed to evaluate the conspicuity (detection) of the flashing strobe light and supplemental sign. The survey was also used to determine drivers' comprehension of the enhanced sign system. Third, a driver observation study was conducted during night driving conditions. The driver observation study was designed to evaluate drivers' reaction to the flashing strobe light and the associated driving patterns between the enhanced sign system and the highway-railroad grade crossing. The remaining discussion in this section pertains to the study design of the *before* and *after* study. Details of the driver survey and driver observation studies are contained in Sections 4.0 and 5.0 of this report.

### **Before Study**

The *before* speed study was undertaken prior to any changes to the existing signs and traffic control on Blackland Road. TxDOT personnel inspected the existing traffic control devices on both approaches to the highway-railroad grade crossing and confirmed that current standards were met. Vehicle speeds were recorded by traffic classifiers placed 400, 200, 150, 100, 50, and 10 m from the railroad, measured from the closest rail at the highway-railroad grade crossing. The classifiers placed between the grade crossing and the 200-m location collected speed data to determine the speed profiles of vehicles approaching the highway-railroad grade crossing. The classifier placed

400 m from the crossing was used as a control site since it was outside the influence area of the strobe light and beyond the visual range of the supplemental sign. Classifier spacings and the field layout are presented in Figure 2.3.

The traffic classifiers used for data collection in this study were the TCC-500 (version 3.19), Unicorn (version 2.30), and Phoenix (version 2.10). Each classifier was attached to two piezo sensors placed exactly 3.05 m (10 ft) apart in one lane of the roadway. Traffic classifiers measured both the axle length and speed of the vehicle traversing the sensors. Vehicles traveling in the opposite direction over the sensors registered as a *miss* in the classifiers and did not detrimentally affect the speed data. Classifiers were placed in the field for a minimum of three days to assure that a sufficient number of speed measurements were obtained.

Speed data were collected first on the east approach to the grade crossing and then the west approach. This two-phase data collection process was used because of limitations in equipment availability but provided for better management of the experimental set-up. At the conclusion of the *before* speed study, speed data obtained by the traffic classifiers was downloaded to a computer software package for computation and analysis.

In an effort to validate the speed results obtained by the traffic classifiers, laser guns were used to measure the first 30 vehicle speeds that were recorded. Additionally, a test vehicle entered the traffic flow at a uniform 30 mph speed by use of the vehicle's cruise control device. Each time the test vehicle passed a data collection site, the time and speed were recorded for later comparison to the classifiers and laser gun. The results of this comparison are reported in Section 3.0 of this report.

### **Enhanced Devices Installation**

After the data collection for the *before* speed study was complete, the enhanced sign system was installed. The "LOOK FOR TRAIN AT CROSSING" supplemental sign was installed by TxDOT personnel and placed under the W10-1 sign on both approaches to the grade crossing. This supplemental sign was manufactured specifically for this study by the sign shop at TxDOT's Waco District Office since it was a unique design not previously used on Texas roadways. The research team then installed the vehicle-activated strobe light and associated loop detector equipment on the east approach. The strobe light was operated for a two-week period prior to the commencement of the *after* speed data collection. Allowing the strobe light to operate for a short period of time prior to data collection provided an opportunity for the research team to observe and confirm the operation of the strobe light. This two-week period of time also provided an opportunity for drivers to become familiar with the strobe light, reducing its *novelty* effect. The dynamic nature of the strobe, as compared to static devices, was also believed to reduce the novelty effect. Figure 2.4 illustrates the enhanced sign system.

The strobe light used in this study was a Tri-Light Mars model ST-2 full size strobe measuring 16.5 cm in height by 13.7 cm in diameter. The strobe light flashed at one million candle power and 90 flashes-per-minute. A magnetic mount held the strobe light to the top of the warning sign post. A shield was placed in back of the strobe light limiting the visibility of the flash to 180 degrees in the direction of the approaching traffic. The flashing strobe light was not visible to drivers traveling in the opposing direction.

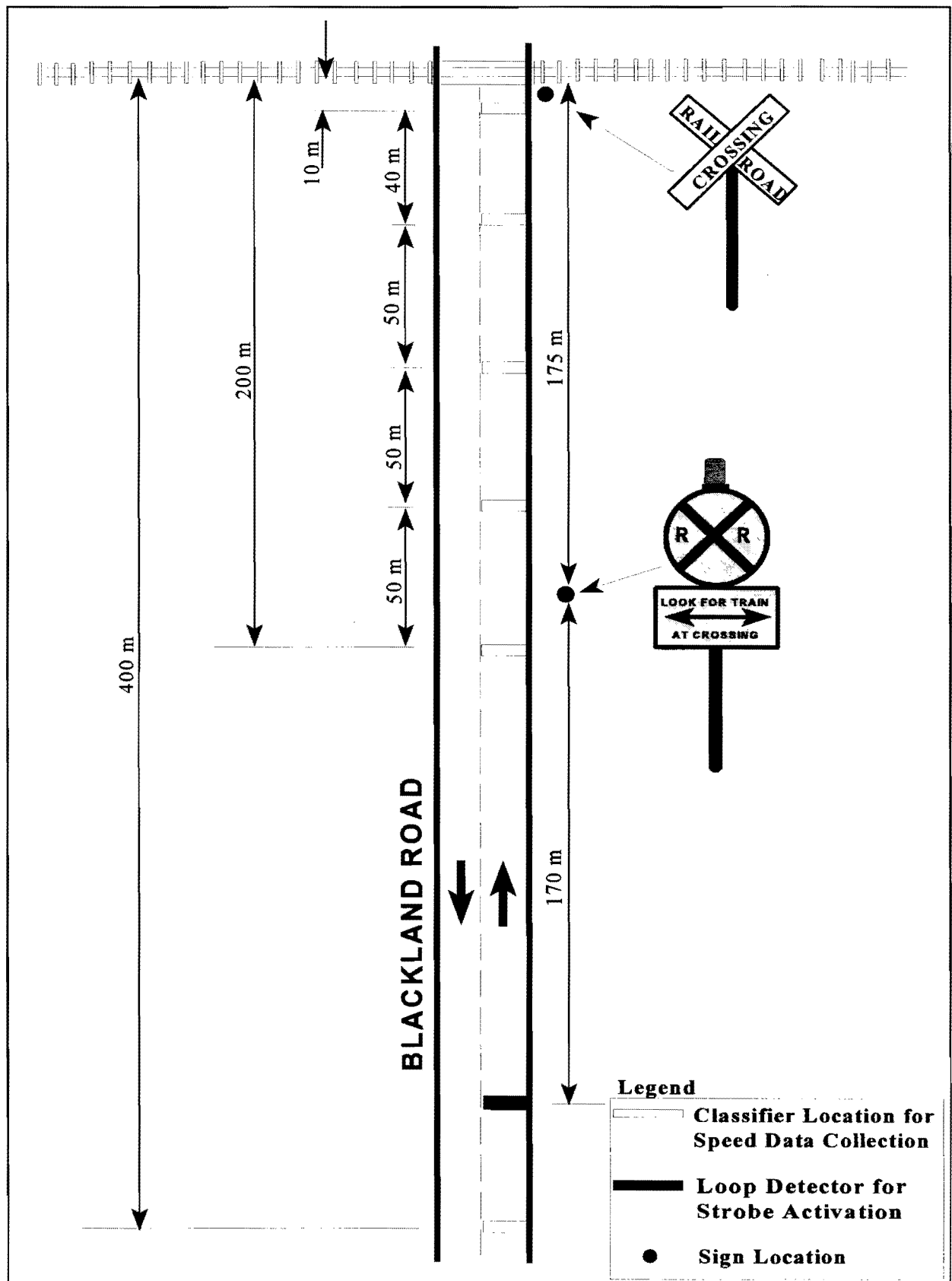


Figure 2.3. Field Layout for Data Collection





**Figure 2.4. Strobe Light and Supplemental Sign Enhancement**

The original design of the strobe light's activation mechanism called for an Invisible Beam Entry Alert device. This device sent an infrared beam across the roadway to a reflector which reflected the beam back to the source. When an object *broke* the beam, the device triggered a six-second electrical flow which provided power to the strobe light. Although this device worked effectively in the closed-course field experiments, it proved to be cumbersome and sensitive to precise positioning in the field leading the research team to question the effectiveness of this device for both this study and future field implementations.

A number of other problems were discovered with the Invisible Beam Entry Alert device. To *disguise* the device's location along the roadway while placing it close enough to the travel lanes to be effective, a customized mailbox was developed to support the device; however, the mailbox provided safety concerns and was susceptible to vandalism. The research team was also concerned with the possibility of postal service and other delivery personnel mistakenly placing items in the mailbox and disrupting the aim of the device. Further, vehicles traveling in *both* directions would

activate the strobe light which would reduce the effectiveness of the enhanced sign system. The device was not weather proof nor was it cost-effective to replace. To overcome these problems, the research team developed a new activation system for the strobe light using loop detector technology.

A loop detector was found to be an effective and relatively easy means of strobe light activation. The loop detectors were placed approximately 170 m upstream of the enhanced sign system to assure that the strobe light was operating for a sufficient period of time before the driver was in visual range of the warning signs. A distance of 170 m was selected using a combination of expected perception-reaction time and approximate sign legibility distance. Drivers were allocated five seconds of perception-reaction time based on vehicle speeds of 45 mph. This speed was consistent with the findings in the *before* speed study and resulted in 100 m of perception-reaction distance.

The 1.8-m square loop detector was constructed using four turns of 14 gauge wire. Both the loop and strobe light received electrical power from a standard 12-volt battery. A solar panel was attached to the battery which acted as a battery charger to maintain the voltage throughout the study period. The loop detector was wired to a 12-volt DC loop detector amplifier (IDC Detector Systems-326 Series) which produced an electrical pulse when the inductance of the loop was altered. This pulse was dispatched to a single-shot relay device which, by use of a timer, controlled the eight second duration of electricity sent to the strobe light. The solar panel, 12-volt battery, loop detector amplifier, and single-shot relay assembly is shown in Figure 2.5. Note that all of this equipment is contained within a 30-cm wide, by 36-cm high, by 15-cm deep metal container.

The "LOOK FOR TRAIN AT CROSSING" sign contained 10-cm letters and was designed using the 122-cm (48-in) sign dimensions presented in Figure 2.1. A ratio of legibility distance to letter height of 7:1 was used assuming 20/20 Snellen vision. This ratio resulted in the equivalent of 70 m of legibility distance. Drivers with less than 20/20 Snellen vision require shorter legibility distances, but would benefit from the additional observation time provided by the 70 m distance. The combination of perception-reaction distance and legibility distance added to 170 m as depicted in Figure 2.6. The complete set-up on the east approach, including the piezo sensors and sign enhancements, is presented in Figure 2.7. As a vehicle passed over the loop detector, the strobe light was activated and flashed for a period of approximately eight seconds. Eight seconds provided sufficient time for the driver to observe the strobe light and to focus attention on the railroad advance warning and supplemental signs.

### **After Study**

Two weeks passed between the installation of the enhanced sign system and the commencement of the *after* speed study. As mentioned, this time allowed the research team to evaluate the operation of the system as well as provided time for drivers to become familiar with the vehicle-activated strobe light and supplemental sign. The *after* speed study was conducted using the same study methodology as the *before* speed study, including the same data collection equipment placed at the 400-, 200-, 150-, 100-, 50-, and 10-m locations. As with the *before* speed study, data collection was completed first on the east approach and then on the west approach. Every effort was made to assure consistency between data collection periods and procedures. At the conclusion of the *after* speed study, speed data obtained by the traffic classifiers was downloaded to a computer software package for computation and analysis. Figure 2.8 depicts the field component of the data download process.



Figure 2.5. Loop Detector Assembly

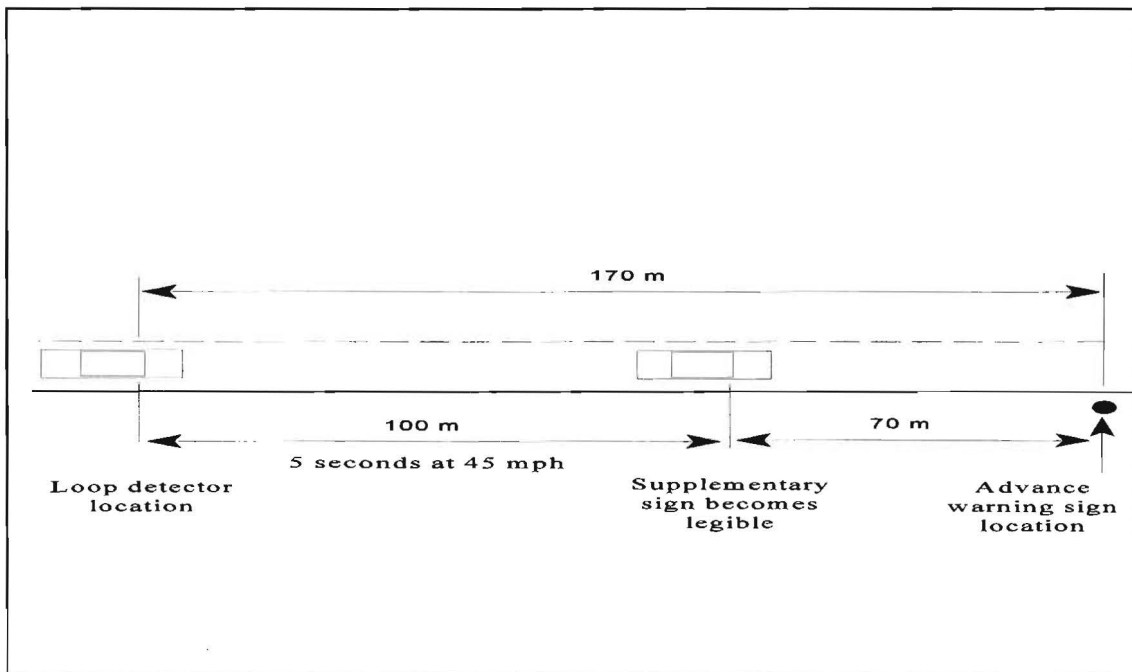
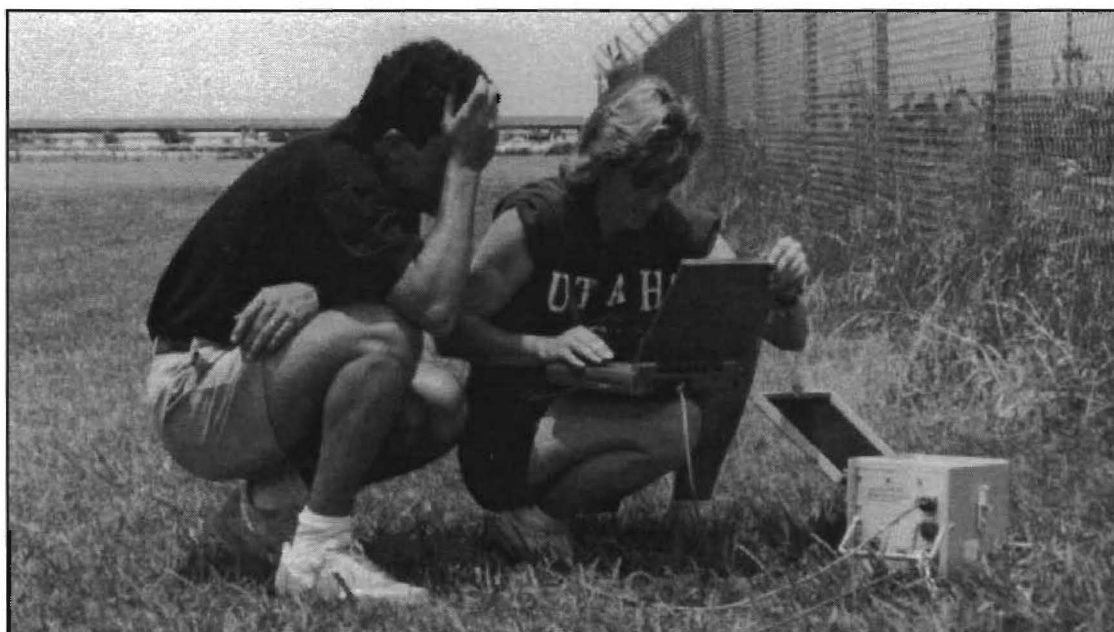


Figure 2.6. Loop Detector Placement



**Figure 2.7. Completed Experimental Set-Up on East Approach**



**Figure 2.8. Field Data Collection**

## 3.0 SPEED STUDY RESULTS

### 3.1 INTRODUCTION

This section presents the results of the *before* and *after* speed study. This speed study was completed to determine the effectiveness of the enhanced sign system. First, the results of the *before* speed study along with a description of the procedure to check the accuracy of the traffic classifiers is presented. Next, the *after* speed study data are presented. The last section provides a comparison between the *before* and *after* data.

### 3.2 BEFORE STUDY

The *before* speed study was undertaken prior to any changes to the existing signs and traffic control on Blackland Road. Vehicle speed data was collected over an eight-week period between November of 1996 and February of 1997. After completing the *before* speed study data collection, speed data was transferred from the traffic classifiers to a laptop computer for computation and analysis. The speed data was carefully reviewed to assure that no erroneous speeds were included in the database.

To assure the accuracy of the traffic classifiers used for this study, a subset of vehicle speeds were collected using a laser gun. The laser gun was used at each location where a different classifier model was used. This provided a means of determining the accuracy of the classifiers and if the laser gun and classifier produced consistent speed results. Further, a test vehicle, traveling at a uniform speed, was used to evaluate the consistency of the speed results obtained by the laser gun and traffic classifiers. The speedometer reading of the test vehicle, the laser gun speed reading, and the exact time of vehicle passage were recorded and compared with the results of the classifiers.

The results of the speed comparison indicated that each type of traffic classifier and the laser gun produced speed results within a one mile-per-hour range of the known test vehicle speed and within a one mile-per-hour range of each other. A statistical analysis using a paired t-test methodology found that there was no statically significant difference between the speed results obtained from the classifier and laser gun. The research team concluded that the traffic classifiers used for speed data collection provided sufficient accuracy for this study.

Table 3.1 presents a summary of the speed data during all time periods on both the east and west approaches to the highway-railroad grade crossing. Data obtained during night driving conditions, assumed to be 7:00 p.m. to 7:00 a.m., is presented in Table 3.2. Speed profiles for the east and west approach to the grade crossing are shown in Figures 3.1 and 3.2, respectively.

One of the interesting findings in the *before* speed study data was that average speeds on the east approach were less during daylight hours than nighttime hours. This difference in average speed values was attributed to the effects of vehicle acceleration and deceleration at the driveway entrances to the USDA facility. As previously mentioned, the USDA facility has two driveway entrances on the east approach located at approximately 175 m and 375 m from the crossing. Vehicles accelerating to and from these driveway locations traveled at speeds lower than the speeds of most

**Table 3.1. Average Speed Results (Day and Night Conditions)**

Approach and Location from Crossing (meters)	Number of Observations	Speeds (mph)						
		Average	Variance	Low	High	15 <sup>th</sup> Percentile	85 <sup>th</sup> Percentile	
<b>East</b>	400	2058	41.2	80.9	10	77	30.6	49.7
	200	1994	39.3	72.9	10	70	31.3	47.7
	150	3145	37.6	86.7	4	85	29.3	46.3
	100	3262	35.6	58.6	3	70	27.9	43.6
	50	1364	30.8	29.7	10	51	25.9	36.1
	10	1355	18.9	23.0	4	42	14.3	23.1
<b>West</b>	400	2556	38.4	48.5	11	70	31.3	45.6
	200	2093	35.2	45.9	5	70	28.6	42.2
	150	2254	34.6	37.4	5	63	28.6	40.9
	100	2252	32.0	32.2	5	49	26.5	37.5
	50	2580	29.0	25.6	5	48	24.5	34.0
	10	6283	18.2	21.7	3	40	13.6	22.5

**Table 3.2. Average Speed Results (Night Conditions)**

Approach and Location from Crossing (meters)	Number of Observations	Speeds (mph)						
		Average	Variance	Low	High	15 <sup>th</sup> Percentile	85 <sup>th</sup> Percentile	
<b>East</b>	400	377	42.0	63.0	10	77	35.4	49.7
	200	384	39.1	61.0	15	70	32.0	46.3
	150	526	39.1	48.0	13	71	32.7	45.6
	100	493	37.2	44.3	9	70	31.3	43.6
	50	173	33.1	26.0	15	50	28.5	38.1
	10	174	20.2	24.6	8	42	15.6	23.8
<b>West</b>	400	413	37.8	55.2	15	70	30.6	45.0
	200	357	34.7	50.5	5	58	27.5	41.9
	150	364	33.6	48.2	5	63	27.2	40.2
	100	327	31.0	33.3	14	48	25.2	36.8
	50	413	28.4	23.9	16	45	23.1	33.4
	10	1156	17.8	24.0	4	39	12.9	22.5

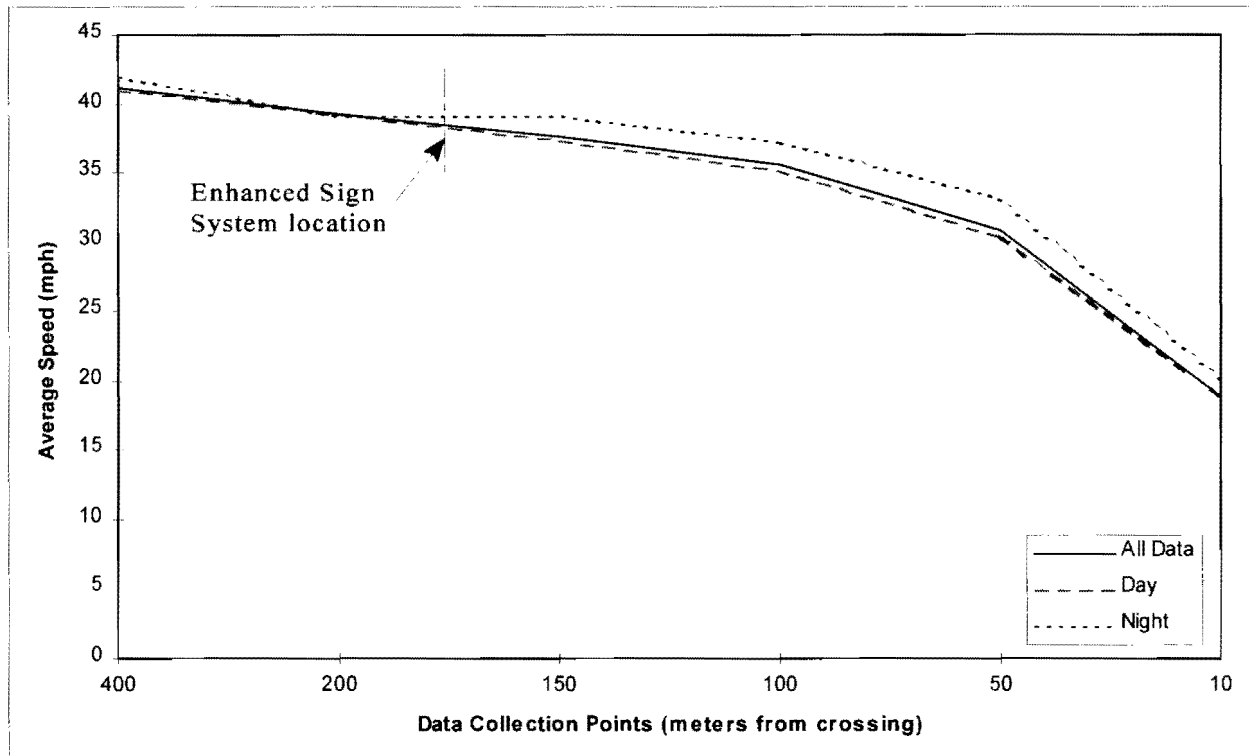


Figure 3.1. Speed Profile for East Approach

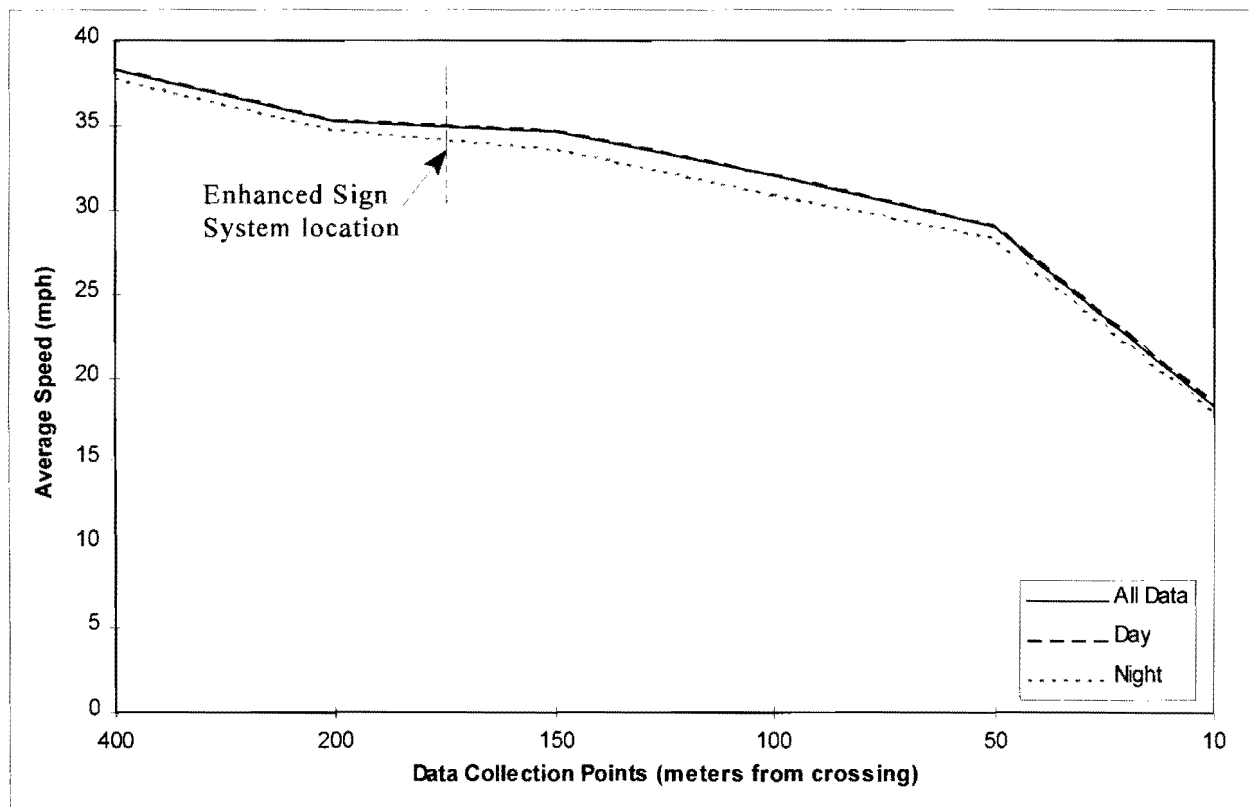


Figure 3.2. Speed Profile for West Approach

through vehicles. These results can be observed in Table 3.2 and Figure 3.4. On the west approach, night speeds were consistently less than day speeds.

### 3.3 AFTER STUDY

The purpose of the *after* speed study was to determine speed conditions after the installation of the enhanced sign system and to determine how speeds changed from the *before* conditions. The enhanced sign system was installed approximately four-weeks after the *before* speed study was completed and approximately four-weeks prior to the commencement of the *after* speed data collection. The vehicle-activated strobe light was operated for a two-week period prior to the *after* study. This time was minimized since many drivers used Blackland Road on a daily basis.

The *after* speed study was conducted over a four-week period in April and May of 1997 using the same study methodology as the *before* speed study, including the same data collection equipment and locations. Speed data was transferred from the classifiers to a laptop computer for computation and analysis. Speed data was carefully reviewed to assure no erroneous speeds were included in the database. Table 3.3 presents the speed data obtained during all time periods, and Table 3.4 presents the speed data obtained during night driving conditions, assumed to be 8:00 p.m. to 7:00 a.m. Note that the beginning of night driving conditions was changed from 7:00 p.m. in the *before* study to 8:00 p.m. in the *after* study to account for the change in sunset times over the duration of this study. Speed profiles for the east and west approaches are shown in Figures 3.3 and 3.4.

During the time of the *before* and *after* speed study, the city of Temple and the Union Pacific Railroad began preparation for improvements to Blackland Road. Blackland Road was scheduled for reconstruction in the fall of 1997, and the railroad was installing the equipment for an active crossing. As part of this work, the city of Temple placed 30 mph speed limit signs on each end of Blackland Road. Unfortunately, these speed limit signs were placed during the final days of data collection for the *after* speed data. A careful review of the data, along with the observation of many vehicles, indicated that the speed limit signs had no apparent effect on vehicle operating speed in either day or night conditions. In fact, as was observed at the 400-m control location on the east approach, some vehicle speeds increased in the *after* speed study. No adjustments to the data were made as a result of this speed limit sign placement.

As in the *before* speed study, night speeds on the east approach were found to be slightly higher than day speeds. Again, this anomaly is attributed to the effects of slow vehicles at the driveway entrances to the USDA facility. Except within 50 m of the crossing, night speeds on the west approach were found to be less than day speeds. The traffic classifiers placed at 10 m and 50 m on the west approach were disturbed by Union Pacific construction activities at the grade crossing and by heavy rains during data collection. The classifier at 10 m was found to *miss* speeds less than 12 mph, and as a result, the average speed recorded by the classifier was higher than the actual average speed at this location. One of the two piezo sensors necessary for speed determination at the 50-m location was shifted slightly during a heavy rain storm. The spacing of the classifier's piezo sensors narrowed resulting in recorded speeds that were higher than actual vehicle speeds.



**Table 3.3. Average Speed Results (Day and Night Conditions)**

Approach and Location from Crossing (meters)	Number of Observations	Speeds (mph)						
		Average	Variance	Low	High	15 <sup>th</sup> Percentile	85 <sup>th</sup> Percentile	
East	400	1505	42.7	69.0	6	72	34.0	51.1
	200	630	37.8	77.1	10	66	28.6	46.3
	150	666	35.4	96.2	3	65	25.9	45.0
	100	1982	35.8	56.2	3	59	27.9	43.6
	50	1997	30.4	31.5	7	55	25.2	36.1
	10	1728	19.1	23.5	4	40	14.3	23.8
West	400	931	36.7	54.5	15	70	29.3	44.3
	200	845	35.4	42.7	15	70	29.3	42.2
	150	946	32.9	38.4	6	64	26.5	39.5
	100	461	29.8	28.9	12	46	24.5	35.4
	50	325	28.8	26.7	7	50	23.8	33.4
	10	135	21.2	16.7	12	38	17.7	25.2

**Table 3.4. Average Speed Results (Night Conditions)**

Approach and Location from Crossing (meters)	Number of Observations	Speeds (mph)						
		Average	Variance	Low	High	15 <sup>th</sup> Percentile	85 <sup>th</sup> Percentile	
East	400	243	41.9	58.5	34	67	34.0	48.4
	200	132	38.1	77.3	29	61	29.1	46.3
	150	119	38.3	57.6	30	57	29.8	45.8
	100	267	36.7	45.1	10	57	30.5	43.6
	50	270	31.7	29.8	10	48	26.5	37.5
	10	248	19.9	25.4	6	39	15.0	24.5
West	400	178	35.7	49.3	20	63	28.3	42.9
	200	171	34.1	49.8	18	70	27.2	40.6
	150	186	31.6	42.9	11	64	25.7	37.5
	100	71	27.0	26.7	12	45	23.0	32.0
	50	39	29.6	31.7	20	50	24.3	25.3
	10	27	21.3	19.0	14	35	18.4	23.8

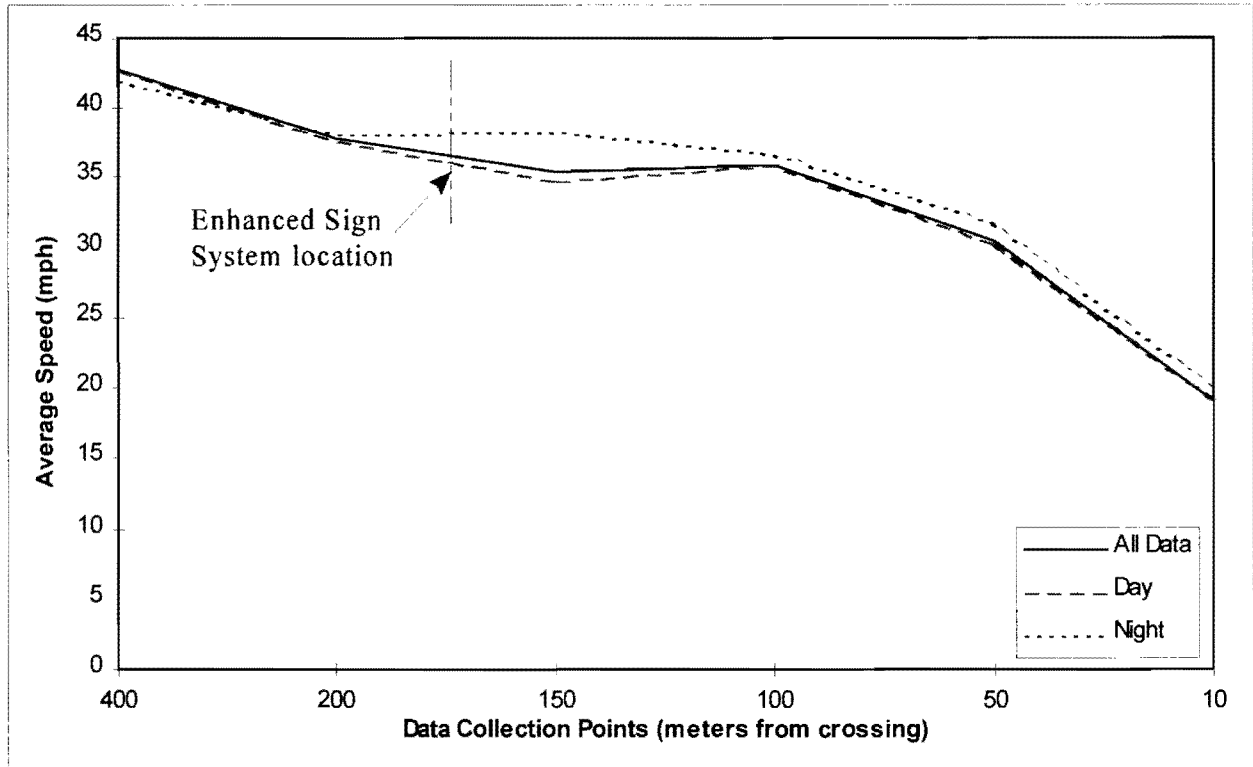


Figure 3.3. Speed Profile for East Approach

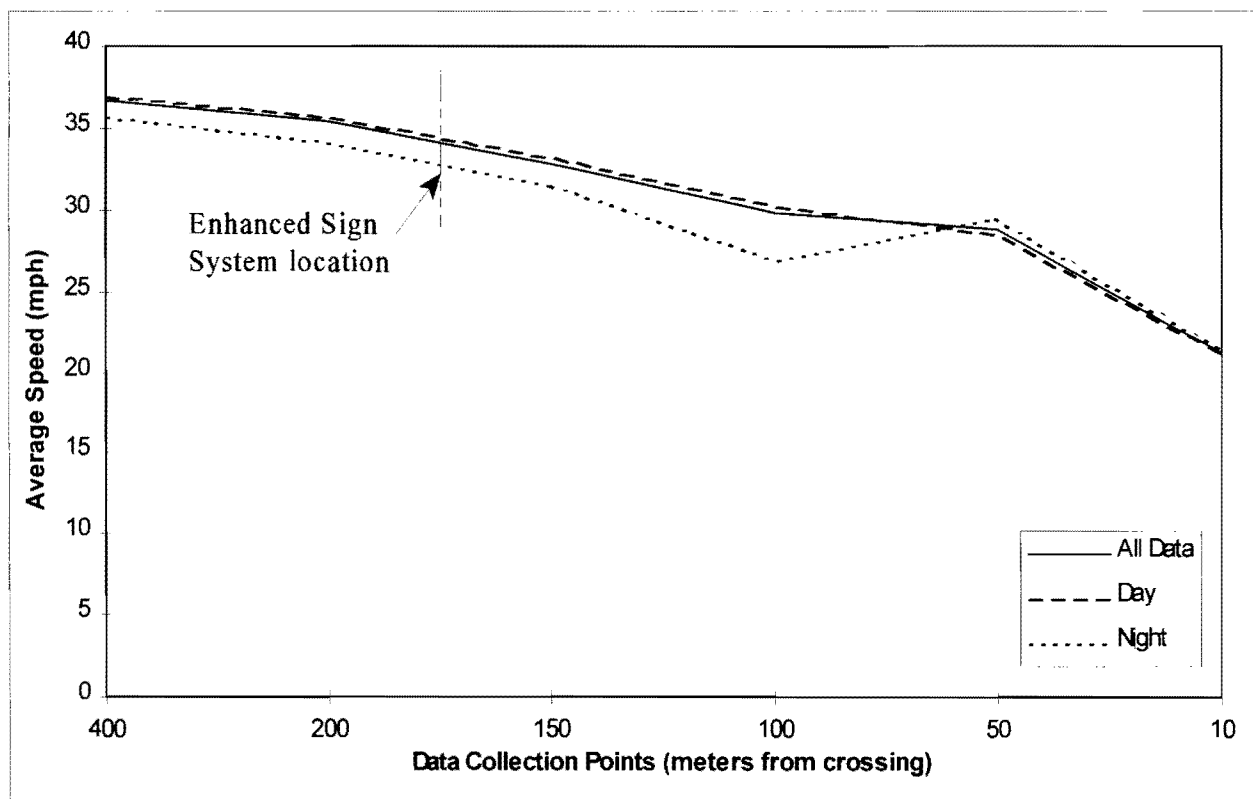


Figure 3.4. Speed Profile for West Approach

The erroneous speeds were eliminated from the data set; however, speeds still appeared to be higher than expected especially during night conditions. Further, due to the problems with the classifiers at 10 m and 50 m, the number of observations is much smaller than at other locations. Given the above mentioned factors on the west approach, the malfunction of the classifiers suggests that the accuracy of the results at 10 m and 50 m is questionable and should be used with caution. Construction activities by Union Pacific, including the installation of an active grade crossing, eliminated the opportunity to repeat the speed measurements at the 10-m and 50-m locations.

### 3.4 COMPARISON OF BEFORE AND AFTER STUDY

Figures 3.5 and 3.6 present a speed profile comparison of the *before* and *after* average speed results on the east approach to the highway-railroad grade crossing. Figure 3.5 shows the average speeds for all data (day and night), and Figure 3.6 shows the average speeds obtained during night driving conditions. The vertical line at 175 m on both Figures 3.5 and 3.6 represents the location of the enhanced sign system. As shown in Figure 3.5, average speeds after the enhanced sign system was placed in the field were slightly higher at the 400-m control location. Speeds were lower at the 200- and 150-m locations and approximately the same at the 100-, 50- and 10-m locations. Average night speeds were nearly identical at the 400-m control location and slightly lower at all of the other data collection locations.

Figures 3.7 and 3.8 present a comparison of the *before* and *after* average speed results on the west approach to the grade crossing. Figure 3.7 shows the average speed for all data, and Figure 3.8 shows the average speeds at night. The vertical line at 175 m on both Figures 3.7 and 3.8 represents the location of the enhanced sign system. As shown in Figure 3.7, average speeds in the *after* speed study were somewhat lower at the 400-m control location and at the 150- and 100-m locations. Average speeds were approximately the same at the 200- and 50-m locations. The results at 10-m show higher average speeds values in the after study; however, the questionable accuracy of 50- and 10-m location values has been noted. Average night speeds were lower in the *after* speed study at the 400-, 200-, 150- and 100-m locations.

A statistical analysis comparing the *before* and *after* speeds at each location was completed, using a two-sample t-test, to determine the significance of the speed differences. The results are presented in Tables 3.5 and 3.6. A significant increase in average speeds was found at the 400-m location on the east approach while a significant decrease in average speeds was found at the 200-, 150-, and 50-m locations. Significant decreases in average speed were found at the 400-, 150-, and 100-m locations on the west approach.

Only the 50-m location on the east approach showed a significant decrease in average night speed. All other locations on the east approach showed decreases in average night speed but not at a statistically significant level. Average night speeds on the west approach showed significant speed decreases at the 400-, 150- and 100-m locations. A decrease in average night speed was also observed at the 200-m location but not at a significant level. The significant increase in night speed at the 10-m location was attributed to the questionable accuracy of the speed data as noted in Section 3.3.

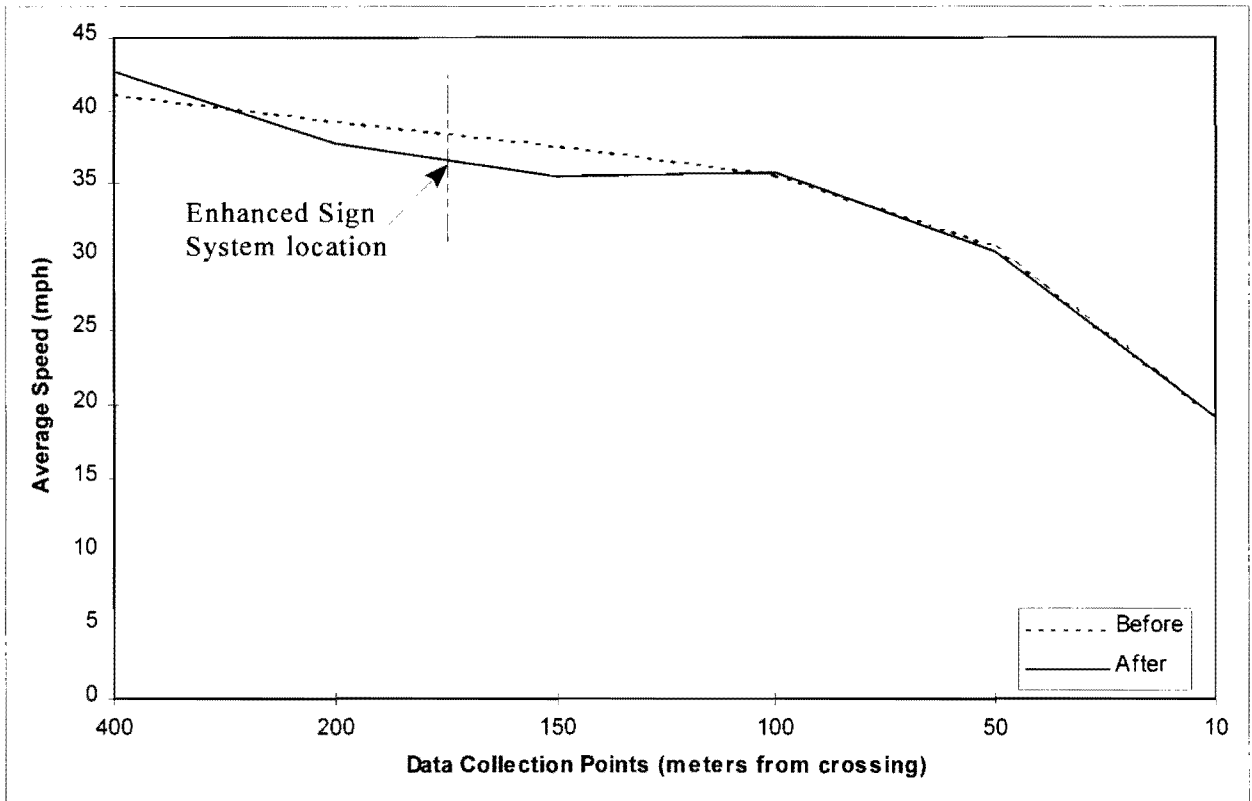


Figure 3.5. Average Speed on East Approach (Day and Night Conditions)

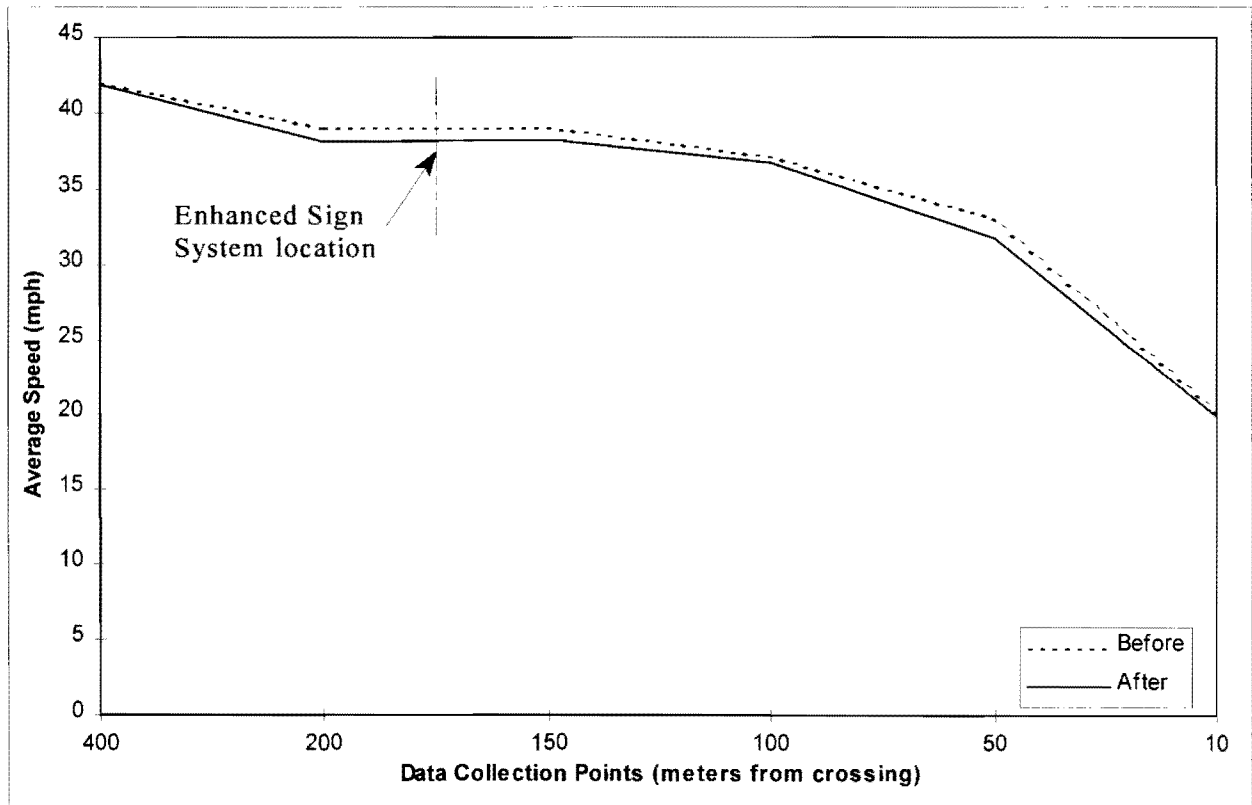


Figure 3.6. Average Speed on East Approach (Night Conditions)

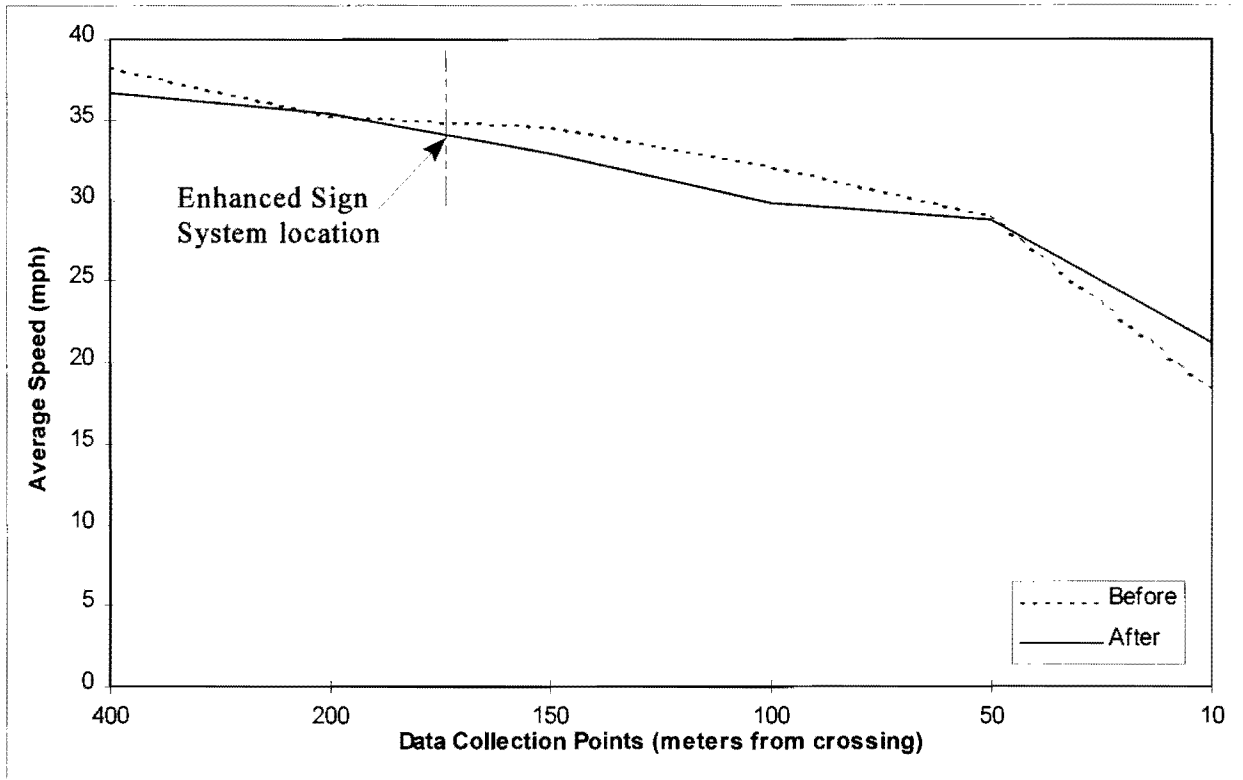


Figure 3.7. Average Speed on West Approach (Day and Night Conditions)

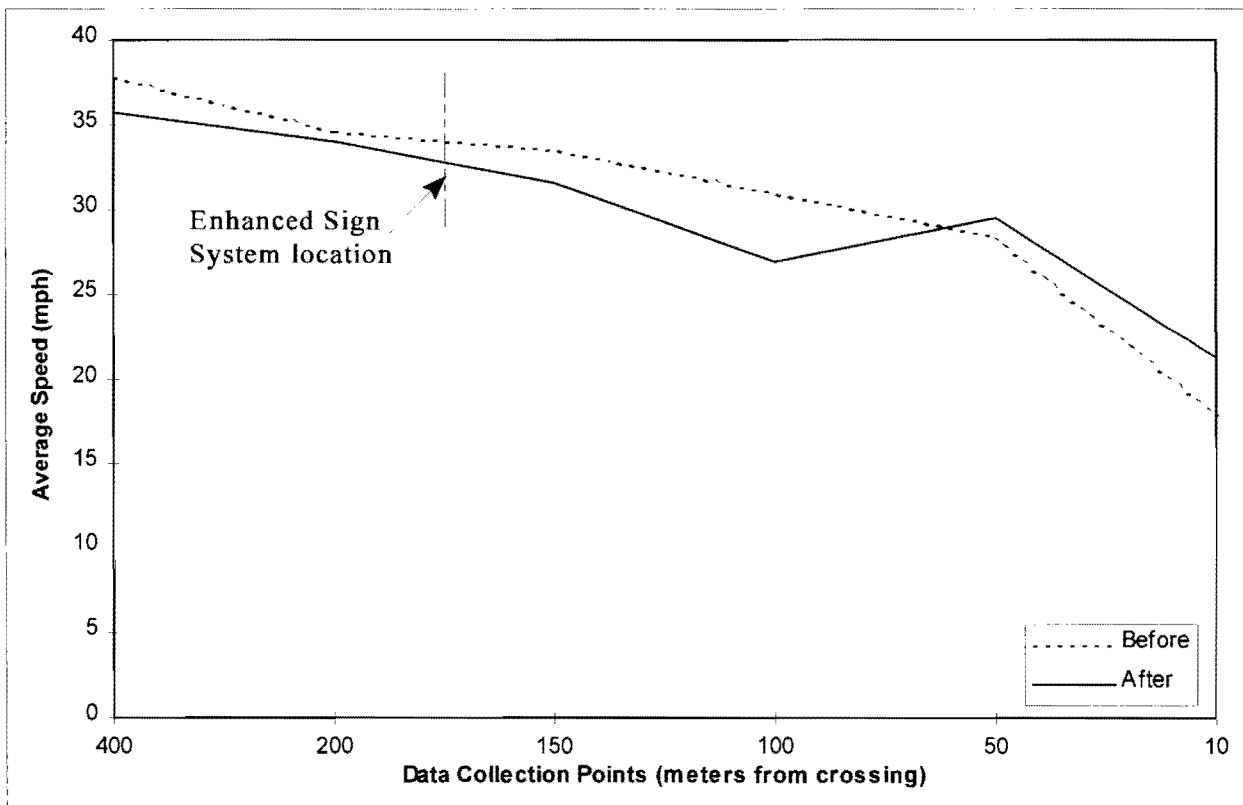


Figure 3.8. Average Speed on West Approach (Night Conditions)

**Table 3.5. Comparison of *Before* and *After* Average Speed (Day and Night Conditions)**

Approach and Location from Crossing (meters)	Average Speed (mph)			Z Value	Significant @ $\alpha = 0.05$	
	Before	After	Difference			
East	400	41.2	42.7	-1.5	-5.1	Yes
	200	39.3	37.8	1.5	3.8	Yes
	150	37.6	35.4	2.2	5.3	Yes
	100	35.6	35.8	-0.2	-0.9	No
	50	30.8	30.4	0.4	2.1	Yes
	10	18.9	19.1	-0.2	-1.1	No
West	400	38.4	36.7	1.7	6.1	Yes
	200	35.2	35.4	-0.2	-0.7	No
	150	34.6	32.9	1.7	7.1	Yes
	100	32.0	29.8	2.2	7.9	Yes
	50	29.0	28.8	0.2	0.7	No
	10	18.2	21.2	-3.0	-8.4	Yes

**Table 3.6. Comparison of *Before* and *After* Average Speed (Night Conditions)**

Approach and Location from Crossing (meters)	Average Speed (mph)			Z Value	Significant @ $\alpha = 0.05$	
	Before	After	Difference			
East	400	42.0	41.9	0.1	0.2	No
	200	39.1	38.1	1.0	1.2	No
	150	39.1	38.3	0.8	1.1	No
	100	37.2	36.7	0.5	1.0	No
	50	33.1	31.7	1.4	2.7	Yes
	10	20.2	19.9	0.3	0.6	No
West	400	37.8	35.7	2.1	3.3	Yes
	200	34.7	34.1	0.6	0.9	No
	150	33.6	31.6	2.0	3.3	Yes
	100	31.0	27.0	4.0	5.8	Yes
	50	28.4	29.6	-1.2	-1.3	No
	10	17.8	21.3	-3.5	-4.1	Yes

The results of the *before* and *after* speed study suggest that the addition of the enhanced sign system lowered vehicle speeds on the approach to the grade crossing. The significant increase in average speed on the east approach at the 400-m location, followed by a significant decrease at the 200-, 150- and 50-m locations, provides some indication that the enhanced sign system caused drivers to reduce speed as they approach the grade crossing. A reduction in average speeds was observed at all locations during night conditions.

Similar reductions in average speeds were observed on the west approach. Significant reductions in average speed were found at the 400-, 150- and 100-m locations in both day and night driving conditions. These findings include a four mile-per-hour reduction at the 100-m location during night conditions. Although the accuracy of the 10- and 50-m locations are of question, the results obtained at the other data collection locations suggest that speed reductions would have been observed throughout the west approach if the classifiers had operated properly.

The study locations located 100 m from the grade crossing on each approach provided the last speed measure before an approaching vehicle entered the nonrecovery zone. This zone is defined in the Federal Highway Administration's (FHWA) *Railroad-Highway Grade Crossing Handbook* as the area on the approach where the amount of roadway is insufficient to avoid a collision if the stop/go decision has not been made. The beginning of the nonrecovery zone coincides with the stopping sight distance point or the minimum visible distance required to see an object in the roadway necessitating a stop and to safely stop the vehicle. Actual stopping distances vary with approach speed, reaction time, pavement friction, tire conditions, and deceleration rates, but can be considered to be between 50 m and 100 m given the prevailing conditions on Blackland Road.

Average speeds on the west approach at the 100-m location decreased approximately 7 percent from 32.0 mph in the *before* study to 29.8 mph in the *after* study. Average night speeds decreased approximately 13 percent from 31.0 mph in the *before* study to 27.0 mph in the *after* study. The average speeds on the east approach remained consistent in both the *before* and *after* conditions. The findings on the west approach were consistent with the research hypothesis and suggest that the enhanced sign system was effective in reducing vehicle speeds as drivers entered the nonrecovery zone. This reduction in average speeds also reduces stopping sight distance requirements which may have a positive effect on safety at the grade crossing.

The reasons why average speeds on the east approach did not change can probably be attributed to the existing geometric features of the roadway. The crest vertical curve on the east approach located 400 m from the crossing and the USDA driveway and field entrances may cause drivers to enter the study site at a slower speed, minimizing the need for significant speed reduction and minimizing the potential speed impact of the enhanced sign system. Also, westbound drivers had ample time to reach their desired operating speed on Blackland Road minimizing the need for significant speed reductions on the railroad approach.





## **4.0 DRIVER SURVEYS**

### **4.1 INTRODUCTION**

This section presents the results of the driver surveys. The purpose of the interview style survey was to evaluate the conspicuity (detection) of the vehicle-activated strobe light and supplemental sign as enhancements to the existing (W10-1) sign on the approach to the highway-railroad grade crossing. The survey was also used to evaluate drivers' comprehension of the enhanced sign system. This section begins by presenting the study design for the driver surveys. Next, the survey results are described. This section concludes with a discussion of the significant findings.

### **4.2 STUDY DESIGN**

On May 20, 1997, a driver survey was conducted at the Blackland Road study site. Westbound drivers were surveyed as they stopped at the intersection of Blackland Road and 5<sup>th</sup> Street. The survey was conducted from 6:30 p.m. to 8:30 p.m. during the period of mesopic vision (dusk) conditions. Although it would be desirable to have all survey data obtained during scotopic vision (dark) conditions, safety concerns prevented data collection during this time period.

Drivers were flagged to a stop during their approach to the intersection with 5<sup>th</sup> Street. After stopping, each driver was asked if they were willing to participate in the survey. Those who agreed to participate were asked to respond to a series of questions regarding the grade crossing that they had just passed. Each survey began by recording the arrival time of the vehicle at the survey location. The driver was first asked to recall the approach to the railroad tracks they just crossed and if they had noticed anything different or unique as compared to other similar crossings. If the driver answered yes, he or she was asked what it was that they had noticed. Drivers that mentioned the strobe light were asked how they reacted. Drivers that did not mention the strobe light were asked if they noticed a yellow flashing light on the railroad warning sign. Drivers answering yes to this question were asked how they reacted to it. Each driver was then asked what they thought the strobe light meant and if they felt a flashing strobe light would bother them during night driving conditions.

The second part of the survey focused on the supplemental sign. Drivers who did not mention the supplemental sign as part of the first question were told that there was an additional sign under the railroad warning sign. They were then asked if they recalled seeing this sign. Drivers that answered yes to this question were asked to recall what was on the sign. Drivers answering no to the question of observing the supplemental sign were told what was written on the sign. In both cases, drivers were asked what they thought the sign meant. Finally, drivers were asked how frequently they use Blackland Road. The age and gender of each driver were recorded by the interviewer. A copy of the survey form is included in Appendix B.

### **4.3 SURVEY RESULTS**

A total of 37 vehicles stopped at the survey location during the two-hour study period, resulting in 33 useable surveys. The first two surveys were used as a beta test which allowed the interviewers to review the survey questions and make any necessary refinements. Two drivers declined to

participate in the survey. Of the 33 drivers surveyed, 23 were male and 10 were female. Six of the male drivers were between the ages of 16 and 25, eleven were between 26 and 55, and six were over 55. One of the female drivers was between 16 and 25 years of age and nine were between 26 and 55. No female drivers were over 55 years old. Ten drivers indicated that they drove this section of Blackland Road several times per day, 15 drivers drove Blackland Road several times per week, and 5 drivers used Blackland Road less than once a month. Frequency data was not collected for 3 of the drivers. The 82 percent of drivers who indicated that they used Blackland Road on a regular basis was consistent with the researcher's expectations.

When asked if they noticed anything unique or different about the railroad crossing, 52 percent of the drivers indicated that they had. This response rate was a significant improvement over previous studies where only 20 percent of drivers were able to recall standard railroad warning signs. Of the drivers who indicated that they noticed something unique or different, 88 percent (15 of 17) identified the strobe light and 71 percent (12 of 17) identified the supplemental sign.

There appeared to be a distinct trend in the frequency of positive responses. Before 7:45 p.m., 29 percent (5 of 17) of the drivers indicated that they noticed something unique or uncommon while after 7:45 p.m., 75 percent (12 of 16) of the drivers reported noticing something unique about the crossing. Although the reasons for this trend are not completely obvious, it would appear that there was a relationship between the degree of darkness and the conspicuity of the strobe light. In other words, the strobe light became more obvious as it became darker.

Nearly 64 percent (21 of 33) of the drivers recalled seeing the flashing strobe light, including six drivers who did not notice anything unique or different on the approach to the grade crossing. Again, there was a distinct trend in the frequency of positive responses with respect to time as only 47 percent (8 of 17) of the drivers recalled seeing the strobe light prior to 7:45 p.m. while 81 percent (13 of 16) of the drivers recalled seeing the strobe light after 7:45 p.m.

The strobe light elicited two general responses. Some drivers indicated that the strobe light caused them to use additional caution at the grade crossing while others indicated that they had no response to the strobe light. Using additional caution usually included performing one or more of the following actions: brake/slow down, read sign, looked for trains, or stopped at crossing. This group accounted for 58 percent of the responses (19 of 33). The remaining 42 percent of the drivers (14 of 33) did nothing, many because they did not notice the flashing strobe light. Drivers were asked if they felt that the strobe light would bother them during night driving conditions. Of the 26 respondents who were asked, 26 (100 percent) reported that the flashing strobe light would not bother them when driving at night.

When drivers were asked what they thought the strobe light meant, eight of the responding drivers thought that the strobe light meant to use extra caution at the grade crossing. Additionally, three drivers believed the strobe light meant to slow down and eight drivers believed that the strobe light meant pay attention, be careful, read the sign, or look for train. The remaining responses to the meaning of the strobe light were varied; however, none of the drivers related the flashing strobe light to the presence or lack of presence of a train at the grade crossing. All of the drivers responding to the survey question related the meaning of the strobe light to the need for exercising some form of additional caution on the approach to the grade crossing.

The next section of the survey focused on the supplemental sign placed below the railroad advance warning (W10-1) sign which stated, "LOOK FOR TRAIN AT CROSSING." Overall, 55 percent (18 of 33) of the drivers indicated that they observed the supplemental sign. Of the 18 drivers who observed the sign, five were able to correctly recall the sign wording, six recalled similar wording, and seven were not able to recall the words. The remaining 15 survey respondents did not recall seeing the supplemental sign. The responses followed a pattern similar to those for the vehicle-activated strobe light. Prior to 7:45 p.m., 47 percent (8 of 17) of the drivers recalled seeing the sign, although only 18 percent (3 of 17) recalled the wording on the sign (all three correctly identified the wording). After 7:45 p.m., 63 percent (10 of 16) of the drivers recalled seeing the sign, and 50 percent (8 of 16) knew the exact or similar wording on the sign, compared to the 33 percent (11 of 33) of the respondents who knew the exact or similar wording on the sign. In addition to the survey questions, a number of drivers indicated that the supplemental sign caused them to drive with additional caution because they assumed that transportation officials would not have placed the additional sign in the field if the crossing was not unsafe.

Drivers who did not recall seeing the supplemental sign or did not recall the wording of the sign were told that the sign said "LOOK FOR TRAIN AT CROSSING" and asked what they thought the sign meant. Nearly all of the drivers indicated that the sign meant exactly what it said, look for trains at the crossing. Drivers further associated the meaning of this supplemental sign with taking extra care and stopping at the grade crossing.

Figure 4.1 shows the distribution of those drivers who saw the flashing strobe light before and after 7:45 p.m. with respect to the frequency that they traveled Blackland Road. Before 7:45 p.m., none of the drivers who used Blackland Road on a daily basis recalled seeing the flashing strobe light, although 86 percent (6 of 7) of the daily drivers recalled seeing the strobe after 7:45 p.m. A similar pattern was observed in the drivers who reported using Blackland Road approximately once per week as 60 percent (6 of 10) of the drivers recalled seeing the strobe light before 7:45 p.m., and 100 percent (5 of 5) observed the strobe light after 7:45 p.m. Both of the unfamiliar drivers that traveled Blackland Road prior to 7:45 p.m. recalled seeing the strobe light while only one of the three unfamiliar drivers after 7:45 p.m. recalled seeing the strobe light.

Figure 4.2 shows the distribution of those drivers who recalled the exact or similar wording of the supplemental sign before and after 7:45 p.m. with respect to the frequency that they used the grade crossing. Before 7:45 p.m., none of the daily drivers recalled the wording of the sign. After 7:45 p.m., 43 percent (3 of 7) of the daily drivers recalled the exact or similar wording of the sign. Of the weekly drivers, 20 percent (2 of 10) recalled the wording of the sign before 7:45 p.m. and 40 percent (2 of 5) recalled the wording of the sign after 7:45 p.m. Only one of the two infrequent or unfamiliar drivers that passed the crossing before 7:45 p.m. recalled the wording of the sign, and two of the three drivers after 7:45 p.m. recalled the wording.

Figure 4.3 shows driver reactions to the flashing strobe light with respect to the time of survey (i.e., light conditions). Nearly 59 percent (10 of 17) of the drivers showed no reaction in the first half of the study. In the second half, 69 percent (11 of 16) of the drivers indicated that they used additional caution at the crossing. Figure 4.4 summarizes overall response to the enhanced sign system. All combinations of the following are shown, including observed strobe light, did not observe strobe light, recalled the wording of sign, and/or did not recall the wording of sign. Prior

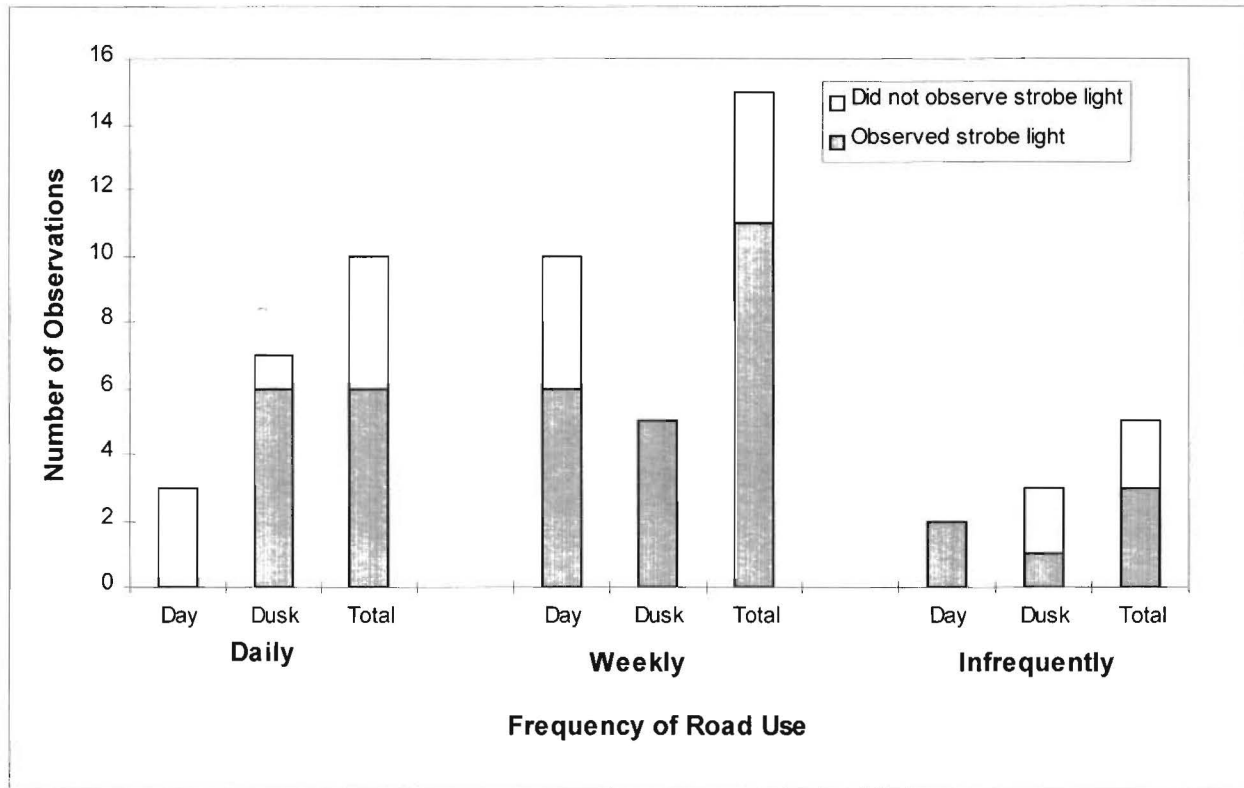


Figure 4.1. Driver Observance of Strobe Light by Frequency of Road Use

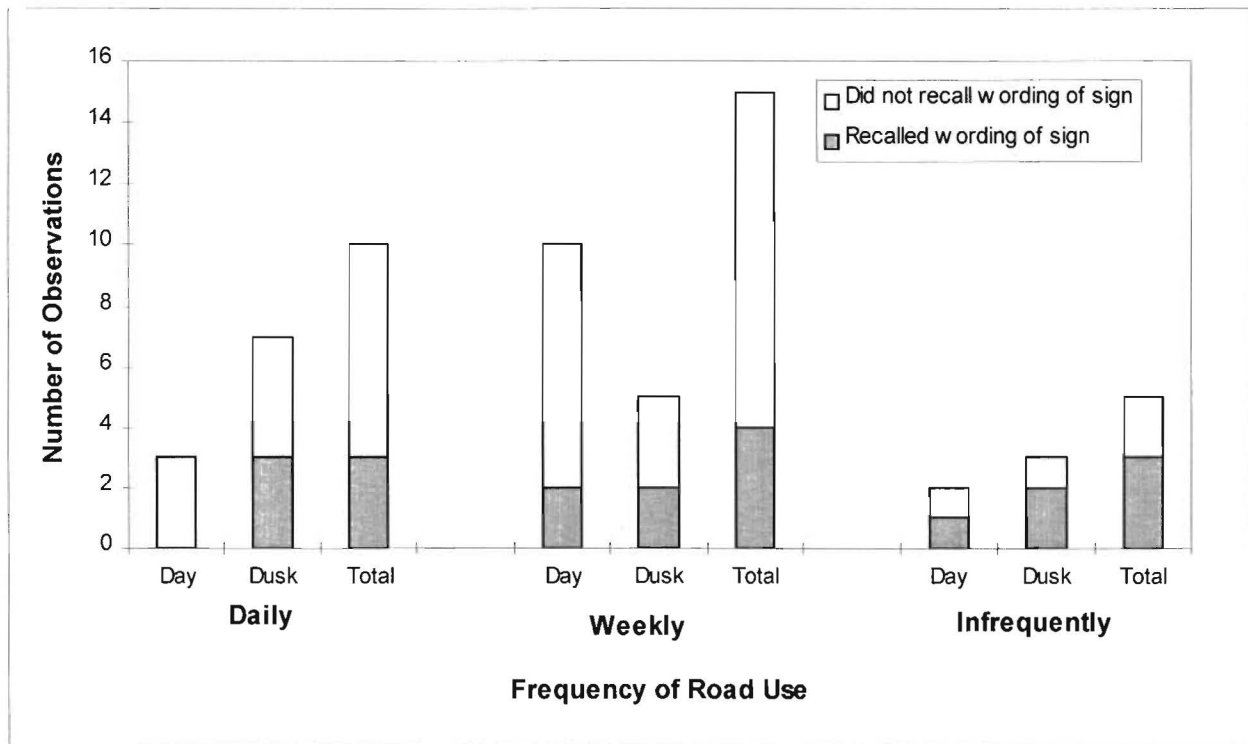


Figure 4.2. Driver Observance of Supplementary Sign by Frequency of Road Use

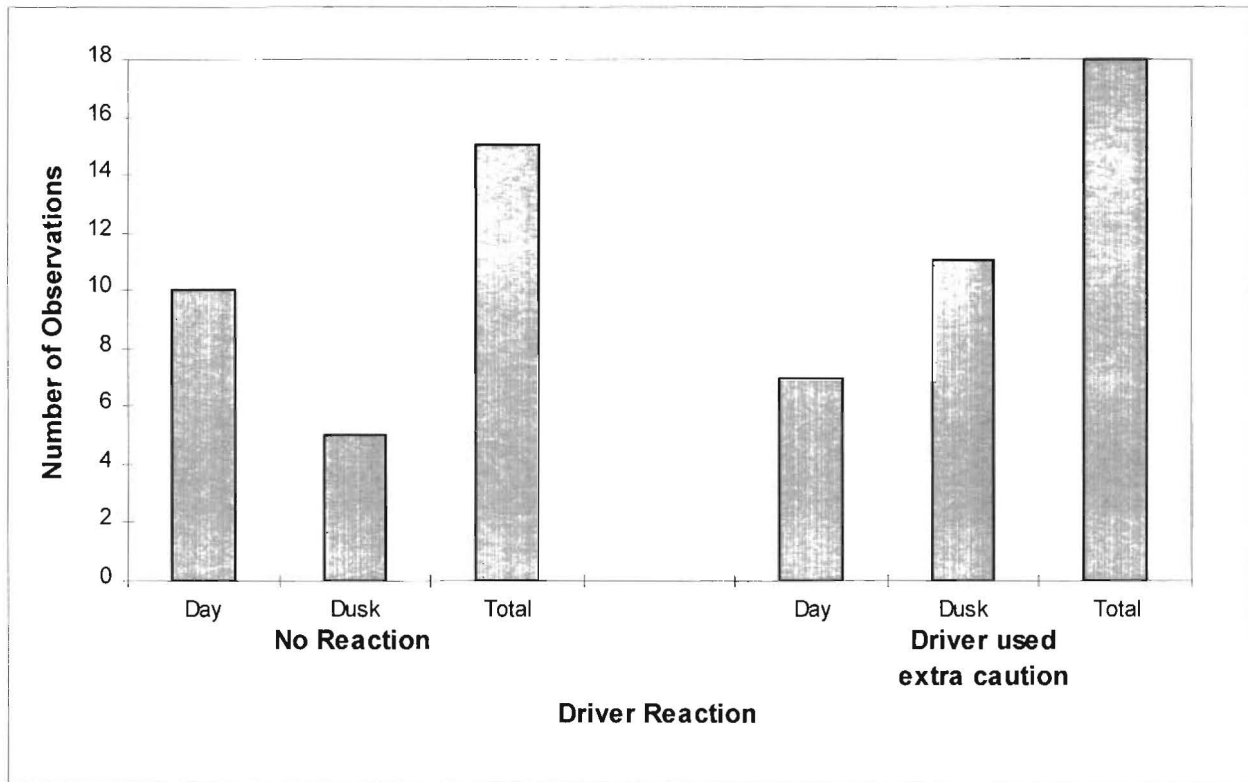


Figure 4.3. Driver Reaction to Strobe Light by Time Period

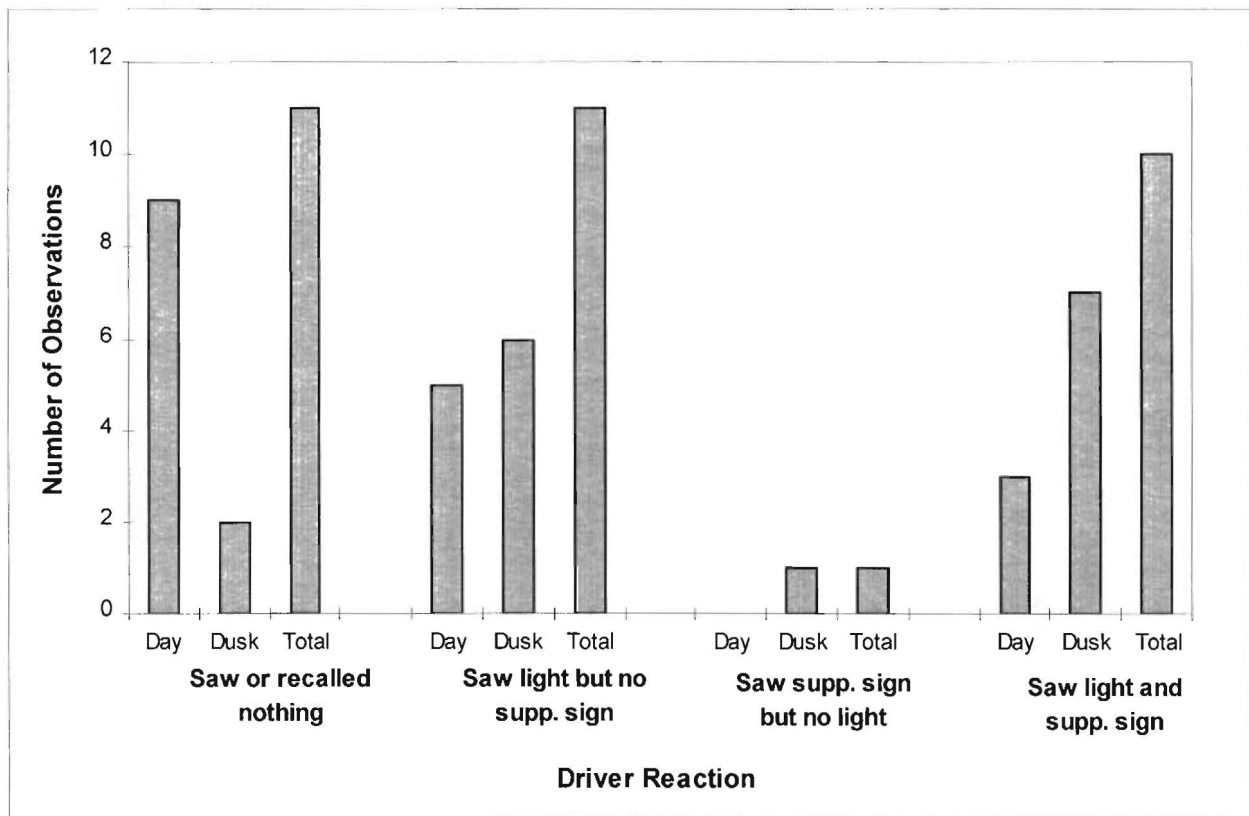


Figure 4.4. Driver Reaction to Strobe and Supplemental Sign

to 7:45 p.m., 82 percent (9 of 11) of the drivers reported seeing neither the flashing strobe light nor the supplemental sign. After 7:45 p.m., 70 percent (7 of 10) of the drivers recalled seeing the flashing strobe light and could recall the wording of the supplemental sign.

#### **4.4 DISCUSSION OF RESULTS**

A number of conclusions can be drawn from these survey results. First, it is apparent that the flashing strobe light is more effective at gaining drivers' attention during scotopic vision conditions than photopic or mesopic vision conditions. This result is not surprising since the flashing strobe light can be difficult to notice in bright sunlight. Nevertheless, this result is significant as the strobe light is fulfilling its desired purpose, that is gaining drivers' attention during night driving conditions. Second, there appears to be a relationship between the frequency of roadway use and the observance of the warning signs. Drivers who used Blackland Road daily were less likely to notice the flashing strobe light and supplemental sign than the unfamiliar drivers. Third, 9 of the 11 drivers who recalled the wording of the supplemental sign chose to use additional caution at the grade crossing. Of the 22 drivers who did not recall the wording of the supplemental sign, 10 indicated that they used additional caution and 12 stated that they did nothing different. The supplemental sign appears to increase the caution used by drivers at the Blackland Road grade crossing. Finally, three out of the five unfamiliar drivers surveyed stated that they observed the flashing strobe light, observed the supplemental sign, and were able to recall the exact or similar wording of the sign.

The enhanced sign system appears to be effective in gaining the attention of both familiar and unfamiliar drivers. The last two drivers surveyed indicated that they observed the supplemental sign but did not recall seeing the strobe light. Since the primary purpose of the flashing strobe light is not to be seen in itself but to draw the attention of drivers to the railroad warning sign(s), the enhanced sign system worked perfectly in these two instances.

## **5.0 DRIVER OBSERVATION STUDY**

### **5.1 INTRODUCTION**

This section presents the results of the driver observation study. Driver behavior was observed on the approach to the highway-railroad grade crossing before, during, and after the activation of the strobe light to address the concern that adverse driver reaction may be caused by the flashing strobe light. This section begins by presenting the study design. The results of the driver observation study is then presented.

### **5.2 STUDY DESIGN**

The driver reaction observations were made during night driving conditions when the flashing strobe light has maximum contrast luminance. An observer was positioned approximately 180 m upstream of the enhanced sign system. The observer was provided with survey forms on which to record the arrival time and reaction to the strobe exhibited by each approaching vehicle. Refer to Appendix C for a sample of the survey form. The reaction of each vehicle was monitored in the zone starting at the point at which the vehicle activated the flashing strobe light (detector location) and ending at the grade crossing. Driver reaction was considered to be anything visible to the observer including braking, weaving, swerving, and related vehicle maneuvers. Because this study was completed at night, driver looking behavior and associated head movements at the approach to the grade crossing could not be observed.

### **5.3 STUDY RESULTS**

Eighteen drivers were observed over a three-hour period on the evening of May 20, 1997. The weather conditions were clear and warm, and the pavement was dry. The results of the survey are summarized in Table 5.1. Of the 18 drivers observed, 12 (67 percent) exhibited no noticeable reaction to the strobe light. In this instance, no reaction or normal behavior was deemed to be braking between 100 m to 75 m from the crossing and crossing the railway line at a reasonable speed (< 30 mph).

Six drivers exhibited changes in behavior due to the strobe light although their observed reactions were not considered severe. On the contrary, their reactions indicated that they were exercising additional caution on the approach to the grade crossing. Three of the drivers applied the vehicle's brakes in the vicinity of the warning sign and flashing strobe light, and one driver switched on their hi-beam headlights, presumably to read the warning signs. One driver stopped at the grade crossing, another driver applied brakes the moment the strobe light was activated, and a driver crossed the railway line at a speed below 10 mph with hi-beam headlights. No adverse driver reaction to the strobe light was observed.

**Table 5.1. Summary of the Driver Reaction Results**

Observation	Time (pm)	Driver Reaction to Strobe Light					
		No Reaction	Brakes Applied at Sign	Stopped Vehicle at Crossing	Applied Brakes when Strobe Activated	Changed to Hi-Beam to Read Sign	Passed Crossing Cautiously
1	8:38	1					
2	8:40	1					
3	8:43	1					
4	8:44	1					
5	8:47	1					
6	8:54	1					
7	8:55		1				
8	8:56		1				
9	9:06			1			
10	9:11				1		
11	9:13	1					
12	9:18	1					
13	9:19		1			1	
14	9:20	1					
15	9:23					1	1
16	9:40	1					
17	9:46	1					
18	9:49	1					
Total		12	3	1	1	2	1
Percentage		67%	17%	6%	6%	11%	6%



## 6.0 CONCLUSIONS AND RECOMMENDATIONS

### 6.1 INTRODUCTION

This section summarizes the evaluation of the vehicle-activated strobe light and supplemental sign enhancements (enhanced sign system) at passive highway-railroad grade crossings. The first section provides the conclusions and key findings of the research and reviews the experimental set-up. The last section provides recommendations related to the research results.

### 6.2 CONCLUSIONS

The objective of this study was to determine the effectiveness of the vehicle-activated strobe light and supplemental sign as enhancements to the W10-1 sign (enhanced sign system) at passive highway-railroad grade crossings. Three study methods were developed for evaluating the effectiveness of the enhanced sign system. First, a spot speed study was designed using a *before* and *after* methodology to determine if the placement of the enhanced sign system led to a more cautious approach to the grade crossing. Second, a driver survey was designed to evaluate the conspicuity (detection) and drivers' comprehension of the enhanced sign system. Third, a driver observation study was conducted during night driving conditions to evaluate drivers' reaction to the flashing strobe light and the associated driving patterns between the railroad advance warning (W10-1) sign location and the highway-railroad grade crossing.

The results of this research indicate that the enhanced sign system can be effective at reducing speeds and attracting drivers' attention on the approach to passive highway-railroad grade crossings. Average speeds on the approaches to the grade crossing were found to be slightly lower after the installation of the enhanced sign system with the greatest speed reduction near the advance warning sign. These speed reductions may result in improved safety on the approach to the crossing.

Reduction in average speed was found at all study locations during night driving conditions. Average night speeds were reduced by four miles-per-hour between *before* and *after* speed study conditions at the 100-m study location on the west approach to the highway-railroad grade crossing. It is difficult to predict how much of the speed reduction is attributable to the enhanced sign system; however, it is safe to conclude that the enhanced sign system contributed to reducing speeds on each approach to the grade crossing.

Drivers responded favorably to the addition of the enhanced sign system. The number of familiar and unfamiliar drivers who recalled seeing the supplemental sign was encouraging, especially the number of drivers who were able to recall the exact wording of this unfamiliar sign. Further, the addition of the strobe light and supplemental sign to the existing W10-1 sign indicated to some drivers that transportation officials considered this location to be an unsafe grade crossing. These same drivers indicated that they approached the grade crossing with more caution than in the past. None of the drivers surveyed indicated that they implied the meaning of the flashing strobe light to be correlated to the presence of a train at the crossing. Also, no adverse driver reactions were reported or observed at the onset of the flashing strobe light.

Just before complete darkness, the two drivers surveyed claimed that they did not observe the flashing strobe light but did see the supplemental sign, the last of which was able to correctly recall the wording of the supplemental sign. Since the purpose of the flashing strobe light is to attract the drivers' attention to the warning sign(s), not to the strobe light itself, it would appear that the enhanced sign system performed desirably in these two instances.

Based on the summary of research findings described above, the following conclusions can be drawn:

- The enhanced sign system appears to increase driver awareness of the passive highway-railroad grade crossing;
- The enhanced sign system caused some drivers to approach the passive highway-railroad grade crossing with additional caution;
- Reductions in average speed on both the east and west approach to the passive highway-railroad grade crossing were observed after the installation of the enhanced sign system;
- The strobe light was effective in directing drivers' attention to the railroad advance warning (W10-1) and supplemental signs during low light conditions; and
- The enhanced sign system did not cause any adverse driver reaction.

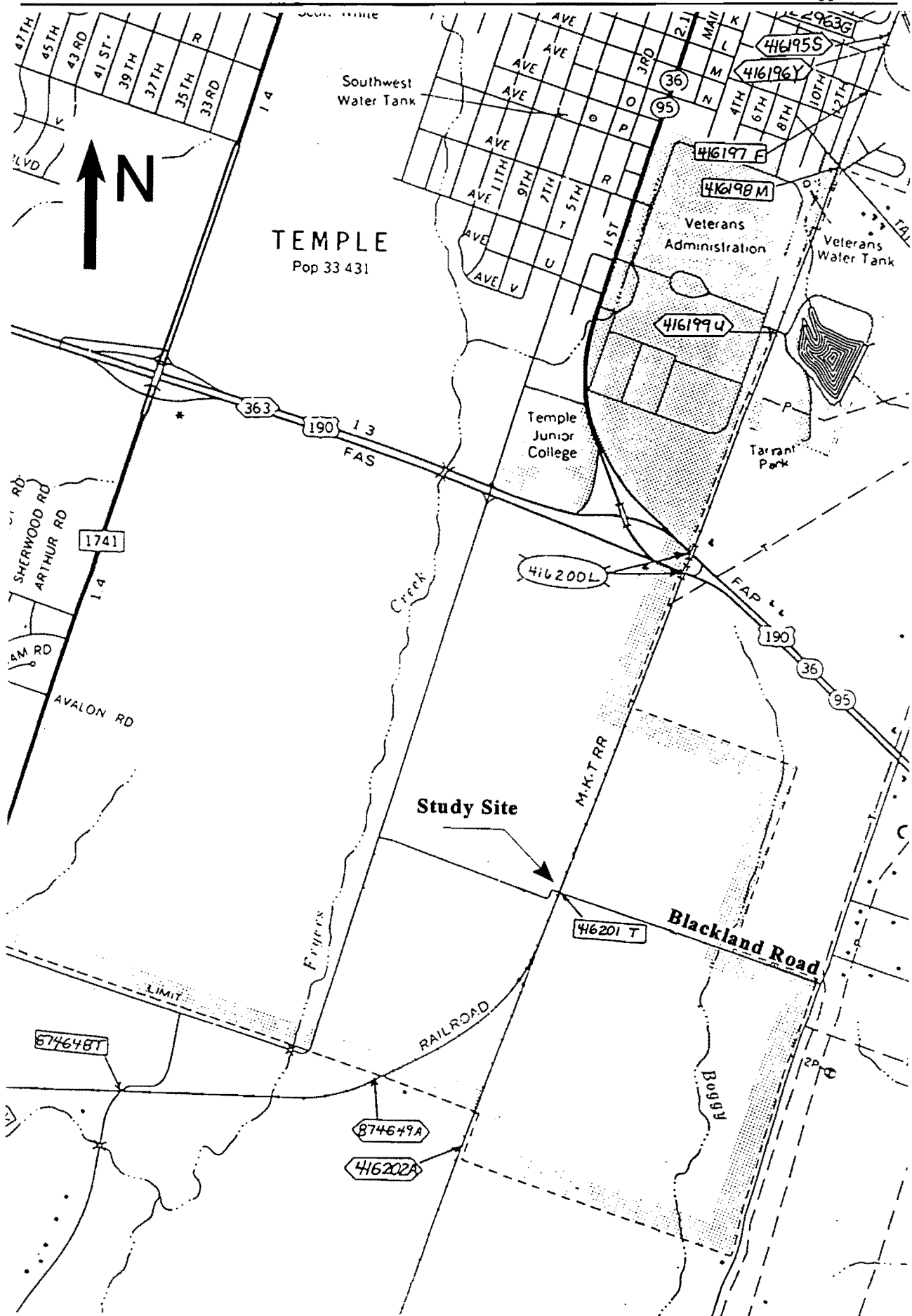
### **6.3 RECOMMENDATIONS**

The results of this research indicate that the enhanced sign system can be an effective traffic control device at passive highway-railroad grade crossings. All of the results were positive, and the enhanced sign system shows promise for improving safety at passive grade crossings. In addition, the enhanced sign system appears to be effective at conveying to the driver that they are approaching a passive grade crossing and additional caution is required as the driver looks for on-coming trains. Thus, the enhanced sign system appears worthy of additional investigation and implementation.

Additional research is required to validate the results of this study and to further document the effectiveness of the enhanced sign system. If further testing is completed, it is recommended that the enhanced sign system be implemented at rural passive highway-railroad grade crossings, specifically those slated for future improvements. It is conceivable that this enhanced sign system could be applied to between 50 and 100 passive grade crossings throughout the state of Texas each year.

**APPENDIX A:**  
**BLACKLAND ROAD STUDY SITE**  
**LOCATION MAP**







**APPENDIX B:**  
**DRIVER SURVEY FORM**





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**Driver Survey**  
**SPR 0-1469**  
**“Enhanced Traffic Control Devices and Railroad Operations**  
**for Highway-Railroad Grade Crossings”**  
**May 20, 1997**

1. As you approached the railroad crossing, did you notice anything different from other similar railroad crossings?

- NO (Go to question 2)     YES

If yes, what did you notice? \_\_\_\_\_  
(If the answer is strobe light, go to question 3)

2. Did you notice a yellow strobe light on the railroad warning sign?

- NO (Go to question 6)     YES

3. How did you react to the strobe light?

- brake/slow vehicle  
 read sign  
 looked for trains  
 startled  
 wasn't sure what to do  
 did nothing  
 accelerate  
 other \_\_\_\_\_

4. What do you think the strobe light meant?

\_\_\_\_\_

5. Do you think that the strobe light will bother you at night?

- NO                       YES

**Driver Survey**  
**SPR 0-1469**  
**“Enhanced Traffic Control Devices and Railroad Operations**  
**for Highway-Railroad Grade Crossings”**  
**May 20, 1997**  
**Page 2**

6. Below the railroad warning sign was another sign.  
Do you recall observing this additional sign?

- NO (*Go to question 7*)     YES

(If yes) Do you recall what the sign said?

- NO (*Go to question 7*)     YES

(If yes) What did the sign say?

- CORRECT RESPONSE     Other

What were you suppose to do? \_\_\_\_\_

\_\_\_\_\_  
(*Go to question 8*)

7. The sign said **look for train at crossing**. What do you think that this sign means?

\_\_\_\_\_  
\_\_\_\_\_

8. How many times have you passed over this railroad crossing?

- 1     2-10     Many \_\_\_\_\_

***END SURVEY - Thank You!***

9. Gender

- Male                       Female

10. Age

- 16-25     26-55     Over 55

Notes: \_\_\_\_\_  
\_\_\_\_\_

**APPENDIX C:**  
**DRIVER REACTION FORM**



**Driver Observation Study**  
**SPR 0-1469**  
**“Enhanced Traffic Control Devices and Railroad Operations**  
**for Highway-Railroad Grade Crossings”**  
**May 20, 1997**

Observation Number: \_\_\_\_\_

Time: \_\_\_\_\_

Vehicle reaction to the strobe light:

- No observed reaction
- Brakes applied
- Sudden deceleration
- Vehicle swerved
- Vehicle stopped at crossing
- Other: \_\_\_\_\_
- \_\_\_\_\_