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16. Abstract

Field studies have been conducted at a limited number of Texas Sites to investigate and evaluate speed zoning procedures 1) at speed zones in rapidly developing urban fringe areas, 2) at transition section speed zones on highway approaches to cities or towns, and 3) at speed zones recently lowered below the 85th percentile speed in response to local community pressure. Posting speed limits below the 85th percentile speed in rapidly developing areas had no conclusive effect on speeds or accidents. Studies at transition section speed zones showed that fewer speed limit signs could be used to adjust between rural and urban speed limits without adversely affecting traffic speeds. Studies at speed zones recently lowered after considerable community pressure showed that overall speeds were also not lowered by reduced speed limits. These results come from a limited number of studies, and should not be taken as totally conclusive.

The studies do not support a departure from the 85th percentile speed criteria currently used in Texas speed zoning procedures. It is recommended, however, that the procedures emphasize that fewer speed limit signs may be used in transition sections.

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SPEED ZONING AND CONTROL

by

C. L. Dudek

and

G. L. Ullman

Research Report 334-2F
Research Study Number 2-18-84-334

Sponsored by

Texas State Department of Highways and Public Transportation
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The Texas A&M University System
College Station, Texas 77843

August 1987

METRIC CONVERSION FACTORS

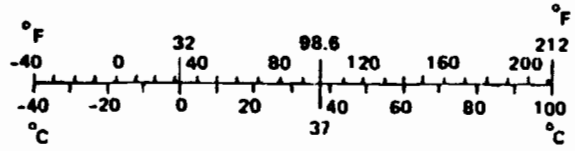
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

IMPLEMENTATION STATEMENT

The results of this study do not support a change from the use of the 85th percentile speed criteria as the major determinant for establishing speed zones in the state of Texas.

However, it is recommended that current Department speed zoning procedures give additional emphasis to the statement that distances between consecutive non-identical speed limit signs be as long as possible in transition sections on highway approaches to cities or towns. Field studies indicated that speed limit signs need not reflect every 5 mph change in the 85th percentile speed through the transition, but rather only the 10 and 15 mph changes need be represented with a new speed limit sign. Effectively, two to four speed limit signs, costing between 60 and 75 dollars each to install and maintain, may be eliminated at a vast number of transition section speed zones statewide.

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SUMMARY

This report documents the result of a 3-year study to gather current data on the effects of speed zoning on traffic operations and safety. The scope of the study has been to examine existing procedures for speed zoning in rapidly developing urban fringe areas and for transition speed zoning section on highway approaches to cities or towns and, if possible, to develop improved procedures for these situations. In addition, the study has examined how local citizens respond to speed zoning changes demanded by their community.

Field studies at a limited number of sites conducted as part of this research have shown that speed zoning below the 85th percentile speed of traffic does not consistently or effectively reduce vehicle speeds, standard deviations of speeds, or speed-changing activity in rapidly developing urban fringe areas. Also, the speed limit reductions did not have a conlclusive effect on accident rates at the few sites that were examined in this study. Similarly, studies at sites where speed zones were lowered below the 85th percentile speed because of local community pressure also indicate that speeds were not reduced. In addition, the reductions in speed zones may increase differences in speeds between vehicles and degrade the safety of the highway.

Studies at the transition section speed zones indicate that, in many instances, fewer speed limit signs may be needed. The studies show that traffic operation was not affected at sites where fewer speed limit signs were in effect and speed limits were changed in 10 or 15 mph steps, rather than in 5 mph steps.

Because these studies have not found justifiable cause for change from the use of the 85th percentile speed, it is recommended that this criteria continue to be the primary determinant in Department speed zoning procedures. However, it is recommended that the procedures emphasize that fewer speed limit signs in transition sections (with larger changes in speed and distances between signs) may be used. The reader is cautioned that the results reported herein come from a limited number of study sites. Changes in weather, vehicle mix, roadside development or other factors could have influenced these results, so care must be taken in their interpretation.

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1. INTRODUCTION

Background

Policies and procedures for speed zoning on Texas highways are contained in the Texas State Department of Highways and Public Transportation SDHPT document "Procedures for Establishing Speed Zones" (1). This publication describes in detail procedures for setting regulatory, advisory, and special speed zones. It also discusses the need for speed zoning, and reviews Texas speed laws and legal opinions on speed law questions.

The speed zoning procedures currently used in Texas are based largely upon research conducted 20 to 30 years ago. Since that time, the State has experienced several changes, including:

1. The adoption of the 55 mph maximum speed limit on all highways.

2. A large population increase, resulting in rapid urban development in the fringe areas of major cities.

3. Changes in the performance characteristics of passenger vehicles and trucks, as well as in the mix of these vehicles on the highways.

Consequently, there was a recognized need to gather new information about the effectiveness of speed limits and existing speed zoning procedures. It was possible that the procedures would need to be modified or expanded to accommodate the many changes that have occurred. In light of this need, HPR Study 334, "Speed Zoning and Control," was initiated in August 1983.

Scope

The Study was designed to examine speed zoning effects on traffic safety and operations as related to the following areas of concern: 1) speed zoning in rapidly developing areas, 2) speed zoning in transition areas, and 3) citizen compliance to locally requested speed zoning changes.

Speed Zoning in Rapidly Developing Areas

The fringe areas surrounding many major Texas cities experienced rapid development over the last few years. These fringe areas, with a mixture of urban and rural characteristics, present a driving environment considerably different than pure rural areas. However, current speed zoning procedures, based on the 85th percentile speed, generally dictate a 55 mph speed limit in the fringe areas--the same speed limit as for pure rural areas. In effect, no distinction in speed limits is made between the urban fringe and rural areas. Because of concern for existing and potential accident problems, it was felt that speed zoning below the 85th percentile speed may be beneficial in urban fringe areas to indicate to motorists that additional attention and caution is needed.

Speed Zoning in Transition Sections

On every highway approach to a city or town, a transition section in the inbound direction provides a gradual change from a rural speed limit (i.e., 55 mph) to a lower urban speed limit (e.g., 30 mph), and vice versa in the outbound direction. The speed limit transition into a city or town is commonly made by posting lower speed limits in increments of 5 mph (i.e., 55, 50, 45, 40, etc.) until the final urban speed limit is reached. Likewise, the transition out of the city is normally made by increasing the speed limit in increments of 5 mph. It was hypothesized that the speed transition into and out of city or town could be made within the same distance but using 10 or 15 mph increments. If no operational or safety problems occur with the larger speed change increments, then the number of signs could be reduced throughout the State resulting in considerable savings in initial and maintenance costs to the Highway Department.

Citizen Compliance to Locally Requested Speed Zoning Changes

Local communities often request that speed limits be lowered in a particular speed zone, even though a reduction is not warranted based on Department speed zoning procedures. Information as to whether citizens in the communities that make these requests actually comply with the lower posted speed limits would be extremely useful to Department personnel when responding to requests for lower speed limits in the future.

Objectives

Specifically, the objectives of this Study were as follows:

1. Determine whether speed zoning below the 85th percentile speed in rapidly developing urban fringe areas has a positive impact upon traffic safety and operation.

2. Determine whether fewer speed limit signs can be used in transition sections without adversely affecting traffic safety and operations.

3. Determine local citizen compliance to lower speed limits requested by the local communities.

Report Format

A review of past highway speed-related research is presented in Chapter 2. Field study and accident analysis results for studies concerned with 1) speed zoning in rapidly developing urban fringe areas, 2) speed zoning in transition sections, and 3) local citizen compliance to requested speed zone changes are presented in chapters 3, 4, and 5.

2. REVIEW OF PAST SPEED-RELATED RESEARCH

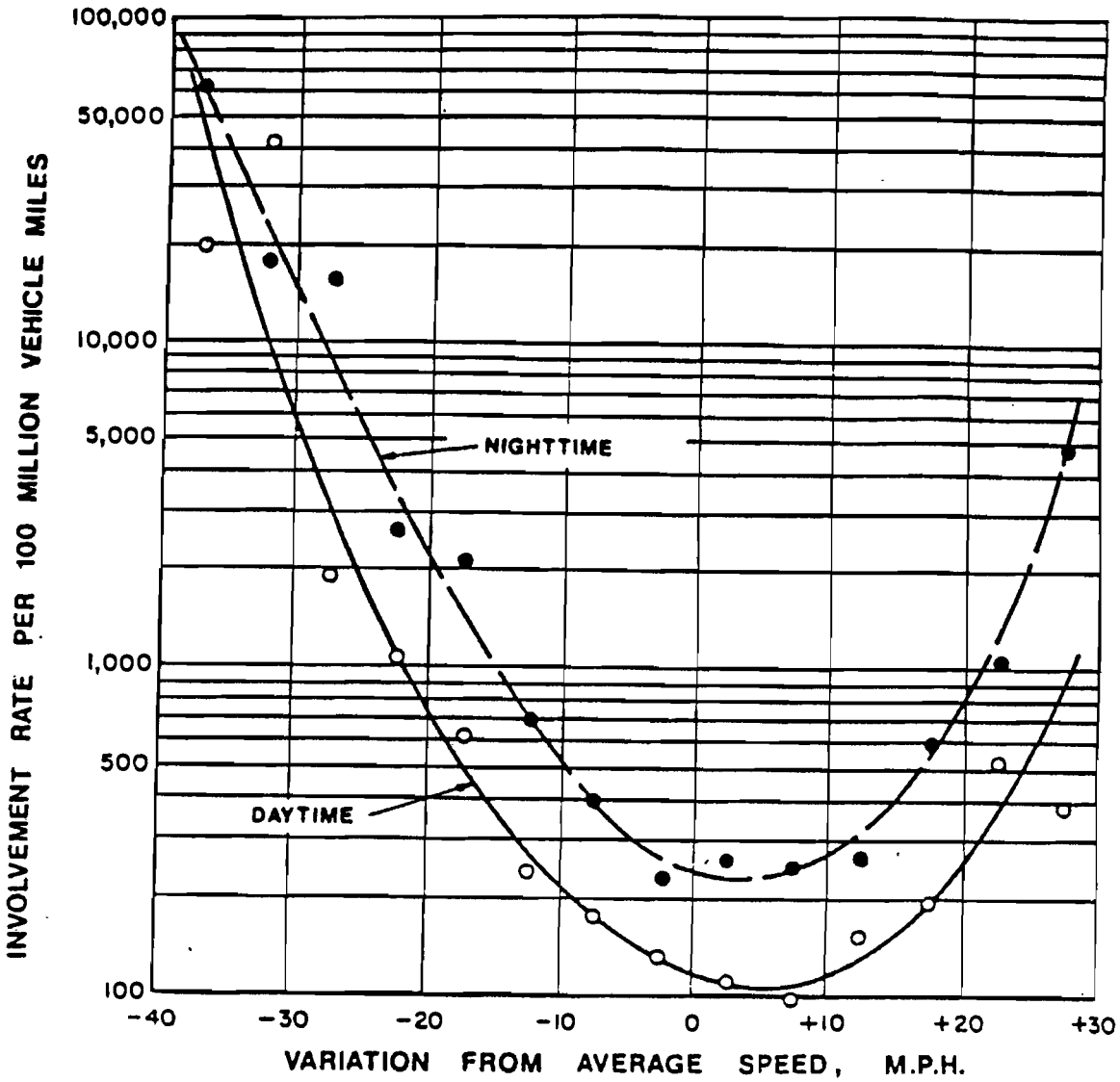
This chapter summarizes the findings of a literature review of previous research on highway speeds and speed zoning. One of the most comprehensive summaries was prepared by Warren (2) which covered most speed-related research through 1981. This publication was used as a primary source of information and supplemented with other publications. The findings are presented in three sections: 1) the relationships between speed and safety, 2) factors that affect drivers' choices of speed, and 3) the effects of speed zoning and speed limits on speed.

The Relationship between Speed and Safety

One of the primary goals of speed zoning is to inform drivers of the maximum speed that is safe and reasonable on a section of highway where speeds need to be reduced below the statewide maximum speed limit. Consequently, the relationship between speed and accidents is of particular interest.

The literature documents a direct relationship between speed and accident severity. This relationship would be expected since a vehicle traveling fast has considerable kinetic energy to dissipate in the event of an accident. The deceleration of a high-speed vehicle (and consequently, its occupants) would be more severe than for a low-speed vehicle and would have a higher probability of resulting in a fatality or an injury (2). It stands to reason, then, that a reduction in speeds on a facility should also reduce the severity of accidents occurring on the facility. Data collected by Dart (3) suggests that such a relationship does exist, showing that a 10 mph drop in speed on Interstates highways corresponded to a 20 percent reduction in fatalities, and that a 5 mph drop in speed on State highways corresponded to a 41 percent reduction in fatalities.

In contrast to accident severity, accident involvement rates not appear to be related to absolute speed. Instead, large differences in travel speeds between vehicles seem to affect the number of accidents that occur. In a 1964 study by Solomon (4), deviation in speed from the average speed of traffic was compared to accident involvement rate. His results, shown in Figure 2-1, revealed a relationship between accident involvement rate and speed deviation that was U-shaped, indicating that accident involvement rates were much higher for vehicles traveling above and below the average speed of traffic. More recent studies by West and Dunn (5) and Joksch (6) have found similar relationships. To pursue this issue further, then, a relationship should exist between accident rates and the variability of speeds on a highway, since the variability or dispersion of spot speed data on a highway is a measure of the magnitude and number of speed deviations occuring. This has been shown to be the case, as both Michaels and Schnieder (7) and Dart (3) found accident involvement rates were directly related to spot speed variability (measured as the standard deviations of speeds or as the proportion of observed speeds in the 10-mph pace).



Note: 1 mph = 1.61 kmph

Source: Solomon, D.: Accidents on Main Rural Highways; U.S. Bureau of Public Roads, 1964.

Figure 2-1. Relationship between accident involvement rate and variation from average speed

As a final note, some researchers have suggested a link between accident involvement rates and the shape of the speed distribution curve. Both Taylor (8) and Krzemski (9) found highway sites where the speed distributions were skewed from a Normal distribution generally had higher accident rates.

Factors That Affect Speed

Many investigators have also studied the factors that affect a driver's choice of speed. In a case study in the late 1950s Rowan and Keese (10) measured speeds on five different Texas highways. This study concluded that roadway geometry, sight distance, the presence of curbs, and degree of continuous roadside development were significant speed-influencing factors. The speeds of vehicles that began and ended their trip within the developed area were consistently lower than the speeds of through vehicles. It was noted that the presence of a traffic policeman decreased mean speeds by about 5 to 7 mph. In 1963, Oppenlander (11) investigated 48 potential traffic, geometric and environmental factors influencing speed. He concluded that speeds were higher with higher values of the following factors:

1. out-of-state vehicles,
2. combination trucks,
3. minimum sight distance, and
4. lane width.

Speeds were found to be lower for higher values of the following factors:

1. degree of curve,
2. gradient,
3. number of roadside establishments, and
4. total volume.

In recent years, the economic factors that influence speed have also been investigated. Jondrow et al (12) suggested that the individual driver considers both costs (additonal fuel consumption, potential accidents) and benefits (reduced travel time, comfort and enjoyment) when choosing his/her speed. In another study, Brackett and Carnahan (13) investigated the economic effects of fuel pricing on speed and developed a formula for predicting compliance with the highway speed limit based on fuel prices. In general, the formula predicts that compliance increases with increasing gasoline prices and decreases with steady or decreasing prices. The drop in gas prices in the early 1980's resulted in increased non-compliance in Texas, as predicted by the equation.

Finally, the possibility of being ticketed for speeding by law enforcement appears to have an effect on speed. As an example, Richards, Wunderlich and Dudek (14) found a relationship between speeds and the presence of enforcement at highway work zones. However, enforcement must continue to be present in order for speeds to remain affected; if the enforcement is removed, speeds eventually return to their original levels (2).

Effect of Speed Zoning

Traditionally, research efforts in the United States have focused on the effects that a change in a speed limit has on traffic speeds and accidents. Several early studies (2) examined the effects of raising or lowering speed limits on vehicle speeds. Most found little or no change in speed, regardless of whether the limits were increased or decreased. Recently, Spitz (15) examined speed zone changes at several California sites and also found little or no change in speeds.

In 1974, the national 55 mph speed limit was adopted. Several sources, including AASHTO (16) and Michaels and Schnieder (8), documented speed reductions after the national speed limit was put into effect. In fact, Heckard et al. (17) found that average speeds dropped 4 to 8 mph, depending on the road type. However, these reductions cannot be attributed solely to the change in speed limits, since other factors, including increased gasoline prices and increased law enforcement efforts also influenced speeds. In actuality, driver compliance with the 55 mph limit is actually very poor, with an estimated 75 percent of drivers exceeding this speed limit on rural Interstates (18).

While the data collected nationally suggests that a speed limit change (raising or lowering) does not affect speeds, it does not indicate whether the presence or absence of speed limits affect speeds and/or accident rates, as all streets and highways in the United States have posted or implied speed limits in effect. Experience in other countries, however, shows that speed limits do indeed serve a useful purpose. In several instances, the posting of a speed limit on a highway previously without a speed limit resulted in reductions in average speeds and in accident rates (2).

Summary

Previous research indicates that speed has a definite impact upon the safety of a highway. Several studies, dating back to the work by Solomon, have identified a link between accident frequency and the variability of speeds on a highway, while the severity of those accidents occurring appears to be a function of absolute speeds.

Research also indicates that drivers select their speeds based on personal characteristics and on cues from the driving environment. Speed limits serve only as one type of cue, and do not appear to have the ability to control speeds. Early research efforts which showed that speeds are not affected by changes in speed limits (up or down) has been supported by recent studies. It should be noted that comparison between studies, such as these is difficult, as differences between site specific factors and study designs may influence the results obtained. One must be careful when stating any of the above-mentioned relationships and trends as "fact".

The literature search, while useful in updating and synthesizing current knowledge about speeds and speed limits, failed to uncover much information directly relating to speed limits and speed zoning at the specific types of locations of interest in this study. No recent research was identified which dealt with reduced speed limits in areas of rapid urban development, with the number of speed limit signs necessary to transition between urban and rural speed limits, or with local citizen reaction and compliance to speed limits reduced because of local community pressure to do so. Consequently, field studies conducted at each of these types of locations and documented in the following chapters should be useful to both traffic engineers and those concerned with speed zoning policies and procedures.

3. SPEED ZONING IN RAPIDLY DEVELOPING URBAN FRINGE AREAS

In recent years, the fringes of many major cities in Texas have been experiencing rapid urban development. The driving environment on highways in these areas has become more complex as traffic volumes increased, commercial and residential units were constructed nearby, and new and additional forms of traffic control were installed during a very short period of time. At many locations, accidents and accident rates increased significantly. Due to the high speeds still present on these highways, many of these accidents were quite severe.

Current speed zoning procedures (1), which rely primarily on the 85th percentile speed of traffic on a facility, may not be adequate for these rapidly developing urban fringe areas. Even though the areas develop some urban characteristics, the 85th percentile speed usually indicates that a speed limit no lower than 55 mph be posted, the same as that posted in rural areas. In effect, no distinction in speed limits is made between highway sections in rural areas and highway sections undergoing rapid development in urban fringe areas.

Traffic safety and operations might be improved by posting a speed limit below the 85th percentile speed in these rapidly developing urban fringe areas. A speed limit lower than 55 mph may indicate to motorists that the driving environment is more complex and that additional attention and caution are needed. To test this hypothesis, studies were conducted at several locations in Texas to examine the effectiveness of implementing speed zones below the 85th percentile speeds on highways in rapidly developing urban fringe areas.

Study Methodology

Before and After speed and accident data were collected to evaluate the effectiveness of implementing speed zones below the 85th percentile speed. Six study sites on 2- and 4-lane undivided highways were identified where 1) rapid development was occurring in urban fringe areas that had been primarily rural in nature, and 2) 55 mph speed limits were still posted. Speed and accident data were collected at each site and then the speed limits were reduced to 45 mph. Speed zones of 45 mph were selected for study because it was felt that 50 mph may not present the same sense of urbanization to motorists, while zones of 40 mph or below would be too inconsistent with existing speeds on the facility and may be dismissed by drivers as unreasonable and unrealistic. Speed and accident data were collected again after the speed limits were lowered. The two sets of data were then analyzed and compared.

Study Site Selection

The six study sites, selected with the help of Texas SDHPT personnel, were in Districts 12 (Houston), 14 (Austin), and 2 (Fort Worth). Table 3-1 identifies each study site location. Several combinations of 1) roadway cross section, 2) degree and type of development existing in the area, 3) traffic volumes, and 4) accident history were represented by the sites. Table 3-2 provides this information for each site. The type of development that existed at each site before the study began was classified by the authors as 1) residential, or 2) commercial. The amount of development that had already occurred at the sites prior to the studies was categorized as either 1) low, 2) moderate, or 3) high.

TABLE 3-1. RAPIDLY DEVELOPING HIGHWAY STUDY SITES

Site	Highway	From	To	Site Boundary Mile Points
1	FM 529	Barker-Cypress Rd.	SH 6	10.5 - 12.8
2	FM 1093	County Line	SH 6	0.0 - 3.1
3	FM 1960	Rayford Rd.	Lee Rd.	18.3 - 21.9 21.9 - 22.2
4	SH 6	FM 1093	Harris-Ft. Bend County Line	13.0 - 16.3
5	FM 1325	IBM Entrance #5	Oak Creek Rd.	2.4 - 4.4
6	SH 26	Mustang St.	Hardage St.	11.2 - 13.5

TABLE 3-2. SUMMARY OF STUDY SITE CHARACTERISTICS

Site	Location	Length (mi.)	Cross-Section	Development		1983 AADT	Accidents /MVM 1983
				Degree	Type		
1	Houston	2.3	2-lane, 2-way	Low	Residential	14,100	3.9
2	Houston	3.1	2-lane, 2-way	Low	Residential	10,700	1.2
3	Houston	3.9	4-lane, Undivided	Moderate	Residential	30,400	0.9
4	Houston	3.3	4-lane, Undivided	High	Commercial, Residential	29,000	4.7
5	Austin	2.0	4-lane, Undivided	Moderate	Commercial, Residential	25,000	8.2
6	Ft. Worth	2.3	4-lane, Undivided	Low	Commercial, Residential	11,500	3.7

AADT = Annual Average Daily Traffic

MVM = Million-Vehicle-Miles

Data Collection and Reduction

Spot speed data were collected at three locations which were one-quarter, one-half, and three quarters of the way through each study site. In each direction at each location, the speeds of at least 125 free-flowing vehicles were measured using a speed radar gun from within a vehicle parked in as inconspicuous a location as possible. Care was taken not to choose locations near intersections, major driveways, or other features that may affect normal driving speeds. Several statistics of interest were computed from the spot speed data, including:

1. average speed,
2. 85th percentile speed,
3. proportion of recorded speeds exceeding 60 mph,
4. standard deviation of speeds, and
5. skewness index of the distribution of speeds.

In addition to spot speeds, speed profile data were also collected. A car-following technique was employed with an instrumented vehicle to obtain measurements of speed every 500 feet through the sites. Twenty vehicles selected at random were followed through each direction of travel at each site. A measure of speed changing activity was computed from the profile data, based on the acceleration noise concept originally introduced by Jones and Potts (19), and successfully used by TTI in previous studies (20) for describing the quality of traffic flow in quantitative terms. Acceleration noise is defined as the standard deviation of the accelerations and decelerations of an individual vehicle as it travels over a particular section of road. It represents the disturbance of the vehicle's speed from a uniform speed, and provides a measure of the frequency and degree of speed changes for that vehicle.

Accident data from the Master Accident File maintained by the Texas Department of Public Safety were obtained for each site for the one-year period prior to and for the one-year period immediately after the installation of the 45 mph speed zones. Because the study sites were located in urban fringe areas experiencing ongoing development, significant changes in traffic volumes occurred over the two-year study period, as shown in Table 3-3. Therefore, accident rates (accidents/million vehicle miles) were used in this analysis. Both total and severe (fatal and injury) accidents were compared.

TABLE 3-3. CHANGES IN TRAFFIC VOLUMES

Site	Traffic Volumes (AADT)		
	Before	After	Change
1	14,000	16,200	+16%
2	10,300	10,600	+3%
3	33,000	35,000	+6%
4	22,000	19,800	-10%
5	27,000	31,000	+15%
6	16,800	18,000	+7%

The degree of law enforcement used at a location has been proven to have a dramatic effect on vehicle speeds (2). The law enforcement agencies responsible for patrolling and enforcing the speed limits at the various study sites were requested to maintain the same level of enforcement efforts after

the installation at the 45 mph speed limits as they did before the speed limit change so as not to bias the results. Although all agencies did agree to maintain their current enforcement level efforts, objective data (such as the number of speeding tickets given during the before and after time periods) were not available to check whether enforcement levels did remain constant. As will be discussed, possible variations in law enforcement at each site may have affected the study results.

Results

Spot Speeds

Overall, the installation of 45 mph speed zones at the study sites in rapidly developing urban fringe areas appears to have had little effect on vehicle speeds. A summary of the average speeds and 85th percentile speeds, are presented in Table 3-4 for the middle data collection location at each site. Results for the other two data collection locations where spot speed data were taken are included in Appendix A.

Although slight location-to-location variation did exist at the sites, the overall changes between the before and after speed data were similar at all locations. As can be seen in Table 3-4, average and 85th percentile speeds at most of the sites, were not affected to any practical degree. There were exceptions, however. Site 5 (Austin) did experience a 4 to 6 mph reduction in the average and 85th percentile speeds. Also, the site 6 (Ft. Worth) also dropped 3 mph average speed in the southbound direction. Conversely, the eastbound direction at site 3 (Houston) experienced a 3 mph increase in average speed after the lower limits were installed. While the reduced speed zones may have been responsible for the reductions in speeds, it is also possible that extraneous factors were responsible for the changes that were measured. For instance, the level of law enforcement at these sites may have increased once the 45 mph speed limits were installed. Another possible explanation is that the traffic volumes were significantly different between the before and after studies, which could have had an effect on speeds. Unfortunately, traffic volumes were not collected during the field studies to investigate this possibility. Whatever the reasons, it does appear that the reduced speed limits did not have a consistent effect in lowering vehicle speeds at the study sites.

Examination of the standard deviation and skewness index statistics, presented in Table 3-5, also suggests that the lower 45 mph speed zones had little or no effect on the speed distributions at the study sites. No statistical differences in standard deviations were detected, and skewness indexes for all of the sites were very close to a value of 1.0, which represents a non-skewed distribution of speeds.

TABLE 3-4. EFFECT OF 45 MPH SPEED ZONES ON VEHICLE SPEEDS

Site	Average Speed (mph) Before	After	Change	85th Percentile Speed (mph) Before	After	Change
1						
EB	47.3	47.0	-0.3	53	52	-1
WB	47.8	48.3	+0.5	54	53	-1
2						
EB	53.2	52.3	-0.9	61	58	-3
WB	53.2	52.8	-0.4	59	59	0
3						
EB	48.5	52.3	+3.8*	59	57	-2
WB	49.2	49.9	+0.7	54	54	0
4						
NB	42.9	43.4	+0.5	49	49	0
SB	44.8	43.6	-1.2	50	48	-2
5						
NB	53.1	47.2	-6.1*	58	53	-5
SB	51.1	46.9	-4.2*	56	52	-4
6						
NB	52.9	51.9	-1.0	59	57	-2
SB	54.2	49.9	-3.3*	59	56	-3

*Statistically significant change from Before Condition (Level of Confidence = 95%)

TABLE 3-5. EFFECT OF 45 MPH SPEED ZONES ON THE DISTRIBUTION OF SPEEDS

Site	Standard Deviation (mph) Before	After	Change	Skewness Index[a] Before	After
1					
EB	5.2	5.1	-0.1	1.0	1.0
WB	5.2	4.9	-0.3	1.0	1.0
2					
EB	7.3	6.4	-0.9	0.9	1.0
WB	5.6	6.1	+0.5	0.9	1.1
3					
EB	4.8	4.7	-0.1	0.9	0.9
WB	5.8	5.1	-0.7	1.1	0.8
4					
NB	6.3	6.3	0.0	1.0	0.9
SB	5.3	6.0	+0.7	1.0	0.9
5					
NB	5.9	5.5	-0.4	0.9	0.9
SB	6.0	5.3	-0.7	0.9	0.9
6					
NB	5.8	6.1	+0.3	1.1	1.0
SB	4.8	5.6	+0.8	0.9	0.9

[a]Skewness index was computed as:

$$\frac{2(93\text{rd \%tile speed} - 50\text{th \%tile speed})}{(93\text{rd \%tile speed} - 7\text{th \%tile speed})}$$

*Statistically Significant Change from Before Condition (Level of Confidence = 95%)

The only consistent impact that the lower speed limits did have was to dramatically increase the amount of motorist non-compliance with the posted limit. As presented in Table 3-6, the percent of vehicles exceeding the posted limit was dramatically higher at each location, the increases ranging from 31 to 87 percent. Non-compliance levels exceeded 50 percent at five of the six locations. These increases, of course, occurred because the speed limits were lowered below the speeds most of the drivers were already travelling.

Speed Profiles

Plots of the mean speed profiles from each site did not reveal any major changes as a result of the lower 45 mph speed limits. Only at site 6 (Ft. Worth) did the average speed profile for the after study show any decrease from the average before profile, as illustrated in Figure 3-1. The rest of the sites showed only minor changes in speed between the before and after profiles. Plots of the remaining speed profiles are found in Appendix A.

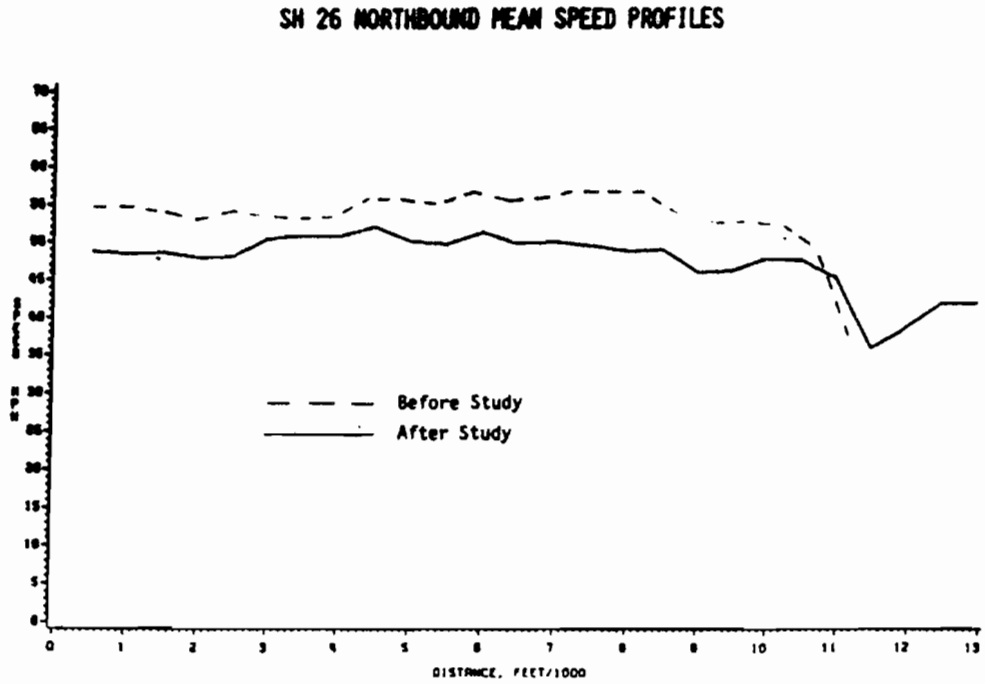
Acceleration Noise

The comparison of the estimated acceleration noise values was also non-conclusive. An estimate of acceleration noise was computed for each speed profile obtained in the before and after studies. Lacking information about the statistical distributions of the estimated acceleration noise values, a Before-After analysis of the estimates at each site was conducted using a non-parametric (Wilcoxon Two-Sample) test. The test ranked the acceleration noise values of the profiles from both the before and after studies together in ascending order. The rank of the values from each before and after study were then summed separately and compared. Based on the rank test of the samples from each study, statistically significant reductions did occur in both directions of travel at site 3, and in one direction of travel only at sites 1 and 5. However, the remaining sites were not significantly affected. In addition, the averages of these samples were computed as a summary of their values at each site. These averages are shown in Table 3-7.

TABLE 3-6. EFFECT OF LOWER SPEED LIMITS ON MOTORIST NON-COMPLIANCE

Site	Percent Exceeding the Posted Speed Limit:		
	Before (55 mph)	After (45 mph)	Increase
1			
EB	7.2	56.0	48.8*
NB	7.2	68.0	60.8*
2			
EB	34.4	86.9	52.5*
WB	36.0	89.2	53.2*
3			
EB	5.6	92.2	86.6*
WB	14.4	86.7	72.3*
4			
NB	3.2	36.0	32.8*
SB	2.4	38.3	35.9*
5			
NB	30.4	61.5	31.1*
SB	23.2	63.1	39.9*
6			
NB	33.6	82.8	49.2*
SB	39.2	86.7	47.5*

* Statistically Significant Increase from Before Condition (Level of Confidence = 95%)



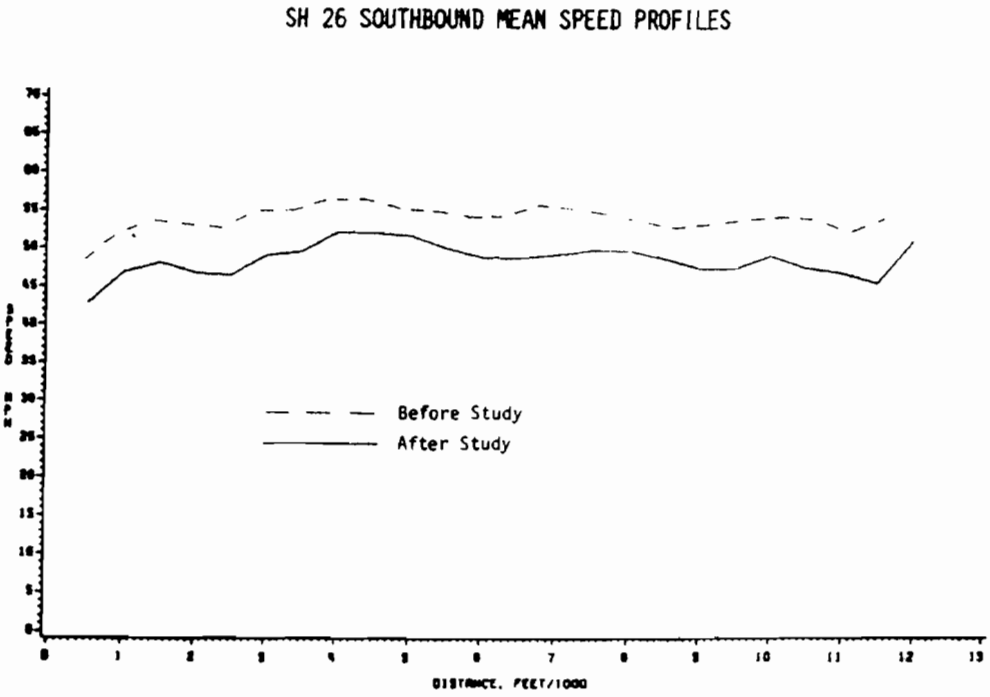


Figure 3-1. Before and After Mean Speed Profiles from Site 6

TABLE 3-7. COMPARISON OF ESTIMATED ACCELERATION NOISE

Site	Average Acceleration Noise (ft/sec^2) Before	After	Change
1			
EB	1.10	1.04	0.06
WB	1.28	0.99	0.29*
2			
EB	0.88	0.86	-0.02
WB	0.73	0.63	-0.10
3			
EB	1.20	0.87	-0.33*
WB	1.32	1.07	-0.25*
4			
NB	1.12	1.20	+0.08
SB	1.05	1.08	+0.03
5			
NB	1.09	1.28	+0.19
SB	1.26	0.93	-0.33*
6			
NB	0.97	0.90	-0.07
SB	0.66	0.76	+0.10

*Statistically Significant Changes were based on a rank test of the before and after samplesat each site(95% level of confidence).

Accidents

A comparison of the accident rates at the six sites is presented in Table 3-8. While sites 1 and 3 did experience a statistically significant reduction in total accidents rates, no statistically significant changes were found at the other four sites. Similarly, severe (fatal and injury) accidents rates did not change statistically, which the exception of an increase in the severe accident rate at site 6. These data represent only a one-year period before and after the reduction in speed limits; the reader is cautioned not to interpret these results as completely conclusive in and of themselves.

TABLE 3-8. COMPARISON OF ACCIDENT RATES (Accident/MVM)

Site	Total Accidents Rate Before	Total Accidents Rate After	Total Accidents Change	Severe (Fatal & Injury) Accidents Rate Before	Severe (Fatal & Injury) Accidents Rate After	Severe (Fatal & Injury) Accidents Change
1	4.1	2.6	-1.5*	1.5	1.5	NC
2	1.1	1.1	NC	0.3	0.6	+0.3
3	2.0	1.2	-0.8*	0.8	0.5	-0.3
4	7.3	9.1	+1.8	3.0	3.0	NC
5	7.1	7.0	+0.1	3.2	3.0	-0.2
6	2.4	3.0	+0.6	0.9	1.7	+0.8*

MVM = Million-Vehicle-Miles
NC = No Change
*Significant Change in Accident Rate based on Poisson Comparison of Means Test (Level of Confidence = 95%)

As a final comparison, accidents in the Master Accident File with either 1) exceeding the posted limit, or 2) exceeding a safe speed coded as a contributing factor were identified, and the rates of these accidents were computed for the Before and After time periods. In some cases, the choice between which of these factors was coded was most likely made arbitrarily by the officer or other person filling out the accident form. In some cases, it is possible that a vehicle exceeding a posted limit is also exceeding a safe speed for that road. In other cases where speed limits have been set arbitrarily low, motorists may exceed the posted limits without exceeding a safe speed. However, in conditions which are poorer than normal (i.e. rain,

darkness), the maximum safe speed could be less than the posted limit. These rates are shown in Table 3-9. Again, no particular trend is evident towards lower rates. No significant changes were detected in the rates of the accidents in which speeds exceeding the posted limit were a contributing factor to the accidents. The rate of accidents in which a safe speed was exceeded decreased at site 3, but increased at site 4. The remaining sites were not significantly affected. It should be remembered that the accident reports are made after-the-fact; estimates of speed and/or its role in the accident are made somewhat arbitrarily by the officer or other individual filing the report. Nevertheless, the available data does not suggest that speed-related accidents were reduced after lower speed zones were posted at the rapidly developing study sites.

TABLE 3-9. EFFECT OF LOWER SPEED ZONES ON SPEED-RELATED ACCIDENTS (Accident/MVM)

Site	Posted Speed Limit Exceeded			Safe Speed Exceeded		
	Rate Before	Rate After	Change	Rate Before	Rate After	Change
1	0.4	0.2	-0.2	0.8	0.8	NC
2	0.1	0.1	NC	0.2	0.3	+0.1
3	0.1	0.1	NC	0.8	0.5	-0.3*
4	0.2	0.1	-0.1	1.7	2.3	+0.6*
5	0.1	0.0	-0.1	2.2	2.0	-0.2
6	0.1	0.0	-0.1	0.6	0.7	+0.1

MVM = Million-Vehicle-Miles
NC = No Change in Accident Rates
*Significant change in Accident Rate Based on Poisson Comparison of Means Test (Level of Confidence = 95%)

Summary of Findings

These studies have examined the effectiveness of installing speed zones with limits that are below the 85th percentile speed of traffic at locations in rapidly developing urban fringe areas. Tabel 3-10 presents a tabular summary of the effects of the reduced speed limits on the various measures-of-effectiveness examined. Overall, a reduction in the speed limits at the six study sites from 55 mph to 45 mph had no conclusive effect on absolute speeds, speed distributions, or speed-changing activity. Likewise, the lower limits were not effective in reducing the frequency of accidents, nor did they reduce the severity of accidents that were occurring. Changes that were detected were isolated, and generally inconsistent across the rest of the measures. For instance, accidents appeared to decrease at site 3 even though speeds increased. On the other hand, speeds decreased significantly at site 5, but accident rates were generally unaffected. Again, caution should be exercized in interpreting the accident dates, as this represents only a one-year sample before and after.

The study results do not support a departure from the 85th percentile speed zoning criteria at this time. Additional research into other means of differentiating between the speed limits that are used in rapidly developing urban fringes and those in purely rural areas should be considered. A review of the before data shows that speeds of all six sites were normally distributed. In addition, the standard deviations of the speed distributions generally fell in the 5-7 mph range, very close to typical standard deviations (17) for highway speeds. Consequently, these favorable initial speed characteristics may suggest that drivers at the sites were already correctly evaluating and reacting to conditions, and so the studies did not detect any improvements as a result of posting speed limits below the 85th percentile speed. Perhaps reduced speed limits should be tried and tested at sites with a skewed distribution of speeds and/or a high variability of speeds to determine if traffic safety and operation are improved.

TABLE 3-10. SUMMARY OF STUDY RESULTS

Site	Changes in the Following Measure-of-Effectiveness							
	Average Speed	85th %-tile Speed	Standard Deviation	Percent Non-Compliance	Acceleration Noise	Accidents		
						Total	Severe	Speed-Related
1								
EB	-----	Decrease	------	Increase	------	Decrease	----	--------
WB	-----	Decrease	------	Increase	Decrease			
2								
EB	-----	Decrease	------	Increase	------	-------	----	--------
WB	-----	--------	------	Increase	------			
3								
EB	Increase	Increase	------	Increase	Decrease	Decrease	----	Decrease
WB	-----	--------	------	Increase	Decrease			
4								
NB	-----	--------	------	Increase	--------	--------	----	Increase
SB	-----	Decrease	------	Increase	--------			
5								
NB	Decrease	Decrease	------	Increase	--------	--------	----	--------
SB	Decrease	Decrease	------	Increase	Decrease			
6								
NB	-----	Decrease	------	Increase	--------	--------	Increase	--------
SB	Decrease	Decrease	------	Increase				

4. SPEED ZONING IN TRANSITION SECTIONS

Speed transition sections are needed on highways at the edges of cities or towns so that drivers can adjust between high speed rural travel and lower speed urban travel. Within the transition section, speed zones must be adjusted from a 55 mph rural speed limit to a lower limit (e.g., 30 mph) in the urban area. This is accomplished in steps, i.e., short speed limit segments of 50 mph, then 45 mph, then 40 mph, then 35 mph, and 30 mph through the remainder of the city or town.

The current Texas procedures specify three requirements to establishing speed zones in transition sections (1):

1. Speed zones should follow the 85th percentile speed of traffic (measured at several points along the highway) as closely as possible.

2. The minimum distance between two different speed limit signs should not be less than 0.2 miles.

3. The maximum difference between consecutive speed limit signs should not be greater than 15 mph.

In practice, the first two requirements above often results in a large number of speed limit signs within a relatively short transition section. Sometimes, several different speed limit signs may be visible to drivers as they approach or leave an urban area. Studies have shown (2, 11) that drivers rely on cues from the driving environment, including the closeness and amount of development adjacent to the road, when selecting their driving speed. Speed limits appear to play only a secondary role in this process. Thus, it may be possible to reduce the number of speed limit signs within a transition section by combining two or more short speed limit segments that differ by 5 mph, into one longer speed limit segment with a 10 or 15 mph change. To test this possibility, studies were conducted at highway transition sections in three small Texas cities. If a reduction in the number of speed limit signs used in transition sections was possible, then the Department would benefit from savings in sign installation and maintenance costs.

Study Methodology

A Before and After study design was selected for this analysis. Comparisons would be made between speed data collected before and after altering the speed zone through the transition.

The actual study involved covering two speed limit signs, one in each direction of travel, within each transition section under investigation. As shown in Figure 4-1, the covered signs altered the speed limit through a portion of the transition section. By covering the signs, the change between the two speed limits was increased from 5 mph to 10 or 15 mph. Furthermore,

the distance between two visible speed limit signs was increased. Speed limit sign locations were not changed for those that remained uncovered during the study.

Study Site Selection

Four sites in District 17 (Bryan) were identified from speed zoning strip maps as potential study sites. Each of these had at least one segment that could be altered from two consecutive 5 mph speed limit changes to one 10 mph change.

The transition sections were located within the legal boundaries of an urban area. Thus, cooperation and permission to conduct these studies was needed from the responsible local officials. Of the four potential locations, three were finally used. Officials at the fourth location declined to participate in the study, fearing the possible legal ramifications of the speed zone change in the event of an accident.

Table 4-1 summarizes the characteristics of the three sites, along with the particular speed zone section that was changed. Speed limit signs of 50 mph were covered at site 1, 45 mph at site 2, and 40 mph and site 3. The study sections at the sites were fairly short, approximately 0.2 mile at sites 1 and 2, and 0.4 mile at site 3.

TABLE 4-1. SUMMARY OF TRANSITION SECTION CHARACTERISTICS

Site	Roadway Cross-Section	Original Limit Sign Sequence (Before)	Covered Speed Limit Sign	Speed Limit Sign Sequence (After)
1	2-lane, 2-way	Inbound: 55-50-45-35-30	50 mph	55---45-35-30
		Outbound: 30-35-45-50-55	50 mph	30-35-45---55
2	2-lane, 2-way 4-lane thru study section	Inbound: 55-50-45-40-30	45 mph	55-50---40-30
		Outbound: 30-40-45-50-55	45 mph	30-40---50-55
3	2-lane, 2-way 4-lane thru study section	Inbound: 55-45-40	40 mph	55-45---30
		Outbound: 30-40-45-55	40 mph	30---45-55

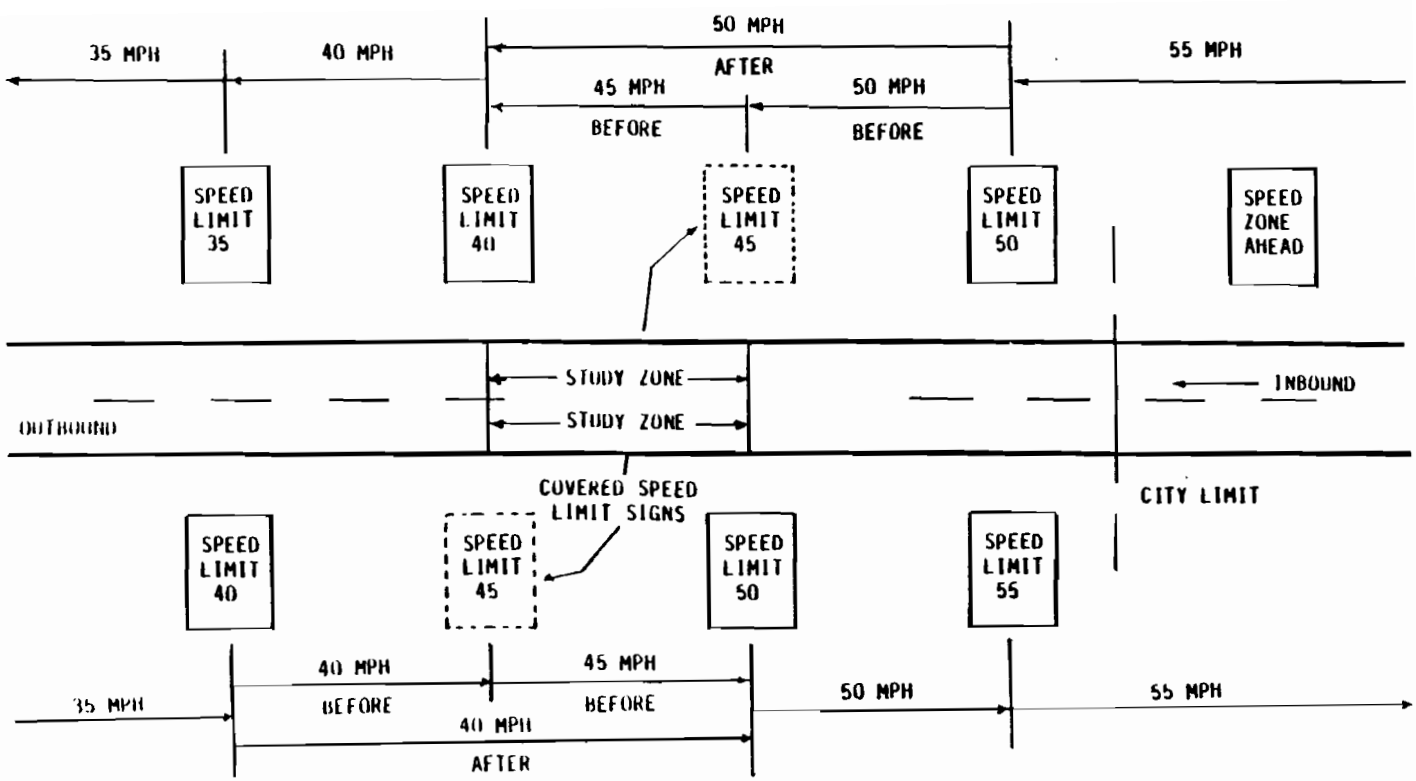


Figure 4-1. Schematic Drawing of a Typical Field Study File

Data Collection and Reduction

Spot speed data were collected in both inbound and outbound directions at stations prior to, within, and beyond the specific speed limit segments that were altered. The stations upstream and downstream were located a sufficient distance from the study section so as not to be directly influenced by the covered speed limit signs. For each station, 125 free-flowing vehicle speeds were recorded. Of the three stations where spot speed data were collected within each site, the data taken within the study section (i.e., the middle station) were used as the basis of comparison. Data from the stations upstream and downstream from the study section were used as "controls" to determine if any observed changes in speeds were due to reasons other than the covered speed limits.

To supplement the spot speed data, ten speed profiles were collected in both the inbound and outbound directions. An automobile instrumented with a time-distance-speed recorder followed random vehicles through the transition study section in both directions of travel. The speed of the vehicle was recorded every 250 ft through the sites.

Results-Inbound Direction

Spot Speeds

Table 4-2 summarizes the changes in speeds in the inbound direction of travel at the three sites. At site 1, where a 50 mph speed limit sign was covered, a statistically significant increase (2 mph) in average speeds was detected at the spot speed station within the study section. The 85th percentile speed echoed the change that occurred in the average speed. No changes were found at the upstream and downstream stations. It appears that covering the speed limit sign did raise speeds at this site. However, the 2 mph increase may not represent a practical difference in speeds. At site 2, where the 45 mph speed limit sign was covered, the average and 85th percentile speeds at all three spot speed stations were higher for the after study. Since speeds at all of the stations were significantly different, the increase at the middle station (situated within the study section) could not be attributed solely to the covered speed limit sign, but rather some extraneous factors causing speeds on the particular day the after studies were conducted to be higher. At site 3, where a 40 mph sign was covered, no change in average speed was found at any of the three spot speed stations. The 85th percentile speed was also unaffected.

TABLE 4-2. SUMMARY OF CHANGES IN AVERAGE AND 85TH PERCENTILE SPEEDS

Inbound Direction of Travel

	"Control" Station Upstream	"Test" Station Study Section	"Control" Station Downstream
CHANGES IN AVERAGE SPEEDS (MPH)			
SITE 1:	0.0	+2.0*	-0.9
SITE 2:	+4.8*	+3.0*(a)	+2.4*
SITE 3:	-1.4	+0.2	-0.3
CHANGES IN 85TH PERCENTILE SPEED (MPH)			
SITE 1:	0	+2	0
SITE 2:	+6	+3	+2
SITE 3:	-2	-1	0

*Statistically significant increase in average speed at this station (Level of Confidence = 95%)

[a]This significant change could not be attributed to the covered speed limit sign at this site since increases were also recorded at the "control" stations.

Next, the standard deviations of the spot speed data were compared at all sites to investigate whether the covered speed limit signs resulted in a higher variation in traffic speeds. The results of these comparisons are shown in Table 4-3. Standard deviations at site 1 did increase within the study section (from 5.3 mph to 6.4 mph). This increase was not evident at the first spot speed station, indicating that the covered speed limit sign may be responsible for "spreading out" the distribution of speeds. The third spot speed station also showed increased dispersion (although the increase was not statistically significant at a 95% level of confidence), indicating that the additional variation in speeds continued downstream for a considerable distance from the study section. Meanwhile, sites 2 and 3 showed no significant changes in standard deviations after covering the speed limit signs.

TABLE 4-3. SUMMARY OF STANDARD DEVIATIONS:

INBOUND DIRECTION OF TRAVEL

	"Control" Station Upstream	"Test" Station Study Section	"Control" Station Downstream
Site 1:			
Before Data (mph)	5.7	5.3	4.5
After Data (mph)	4.9	6.4*	5.3
Site 2:			
Before Data (mph)	5.1	4.9	3.9
After Data (mph)	5.4	5.0	3.7
Site 3:			
Before Data (mph)	7.0	5.4	4.9
After Data (mph)	6.9	5.2	5.2

*Significant increase in standard deviation at this station (Level of Confidence = 95%)

Speed Profiles

Next, the results of spot speed comparisons are supplemented by the speed profile results. Figure 4-2 is the Before and After average inbound speed profiles for site 1. Speeds through the study section profile seem to be higher after the 50 mph speed limit sign was covered. The average profile for the after data upstream of the study section is at about the same speed as the average for the before data. Through the study section, the profile for the after study remains at the same speed, whereas the profile for the before study decreases gradually. Once beyond the study section, the after profile decreases rapidly until the two profiles come together again. Based on the limited sample of speed profiles, it appears that the after study drivers waited longer before beginning to slow down.

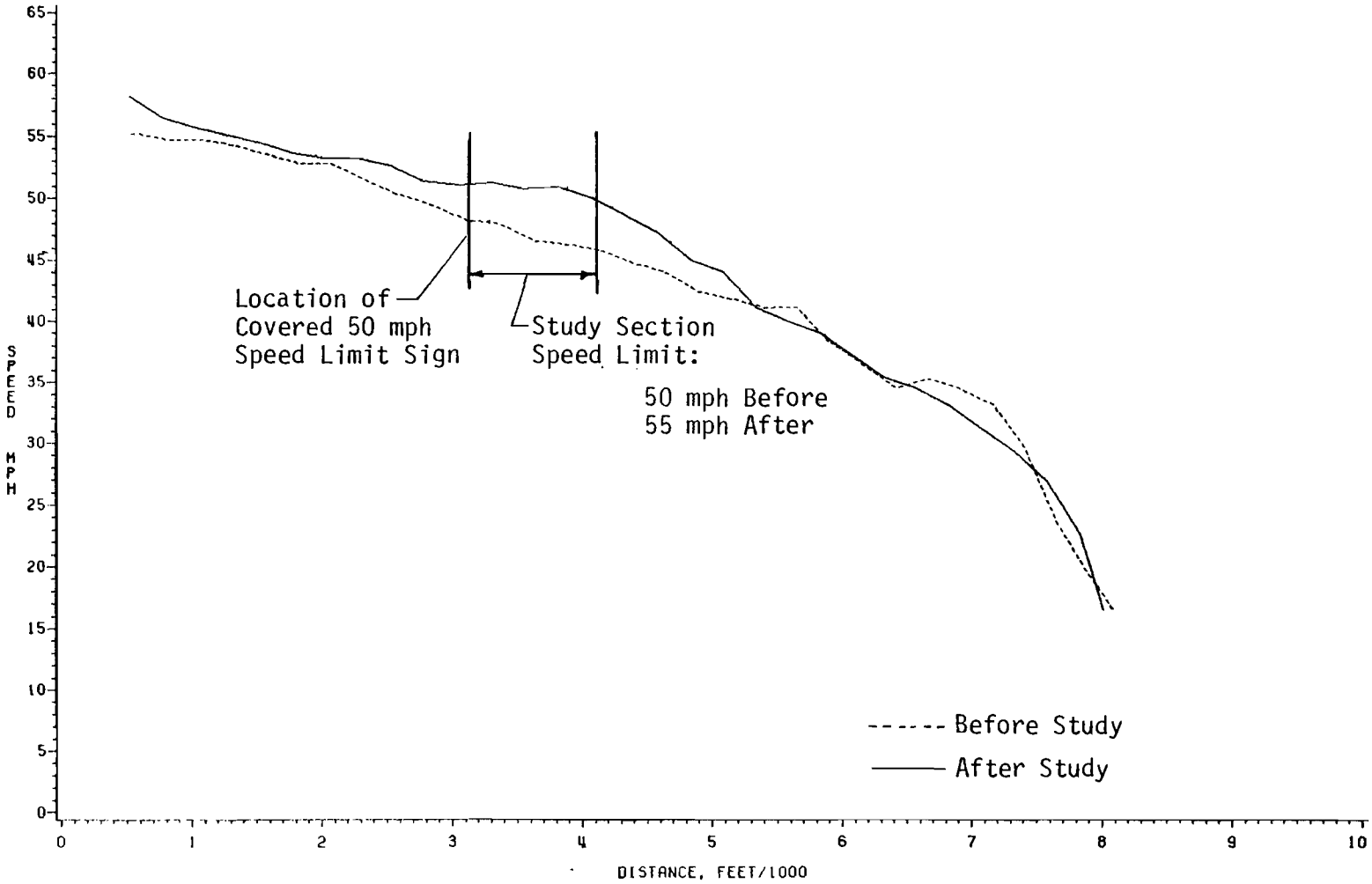


Figure 4-2. Average Inbound Speed Profiles for Site 1

The speed profiles at the two remaining sites did not suggest changes occured in speeds as a result of covered speed limit signs. The profile from site 2 showed relatively little difference in profiles for the before and after conditions. The site 3 profile suggested that speeds were actually much lower through the altered segment after the speed limit sign was covered, not higher as seen in the spot speed data. As only a few speed profiles were collected at these sites, the average profiles can be expected to have considerable variation. In any event, the profile did suggest that speeds through the altered segment at site 3 did not increase. These figures may be found in Appendix B.

Summary-Inbound Direction

These results from site 1 suggest that drivers may use the first speed limit sign in a transition zone as an indication of when they should begin their deceleration to an urban speed. Without this sign, some drivers continue to travel at high speeds until the next speed limit sign is seen, at which time they begin to decelerate. Consequently, average speeds and the speed variance through the affected speed limit section increases.

The results from sites 2 and 3 suggest that once drivers are within the transition section and have started to decelerate, their driving speeds are more influenced by other cues in the driving environment. It does not appear necessary to post every 5 mph change in speed limits; 10 and 15 mph changes work just as well.

Results-Outbound Direction

Spot Speeds

In the outbound direction of travel, Site 1 did not experience changes in average or 85th percentile speed at any of the three spot speed stations. However, the spot speed data collected before and after the speed limit signs were covered differed significantly at sites 2 and 3. As shown in Table 4-4, average speeds at the test station decreased 3.6 mph at site 2 and 1.7 mph at site 3. However, significant changes in average speeds were also detected at the "control" station upstream and downstream from the altered segment at site 2, which does suggest that speeds may have been affected by factors other than the covered speed limit sign.

The standard deviations of the spot speed data in the outbound direction were also compared at all sites. As documented in Table 4-5, none of the three sites show any significant changes in standard deviations. Thus, the variability of speeds at the sites was not affected by covering the speed limit signs.

TABLE 4-4. SUMMARY OF CHANGES IN AVERAGE AND 85TH PERCENTILE SPEEDS

Outbound Direction Of Travel

	"Control" Station Upstream	"Test" Station Study Section	"Control" Station Downstream
CHANGES IN AVERAGE SPEED (MPH)			
SITE 1:	-1.2	-0.4**	-1.3**
SITE 2:	+2.7*	-3.6**	-3.6**
SITE 3:	0.0	-1.7**	-0.7
CHANGES IN 85TH PERCENTILE SPEED (MPH)			
SITE 1:	-2	0	-1
SITE 2:	+2	-3	-5
SITE 3:	0	-2	-1

*Significant increase in average speed at this station (Level of Confidence = 95%)

**Significant decrease in average speed at this station (Level of Confidence = 95%)

TABLE 4-5. SUMMARY OF STANDARD DEVIATIONS:

OUTBOUND DIRECTION OF TRAVEL

	"Control" Station Upstream	"Test" Station Study Section	"Control" Station Downstream
Site 1:			
Before Data (mph)	5.0	5.1	5.7
After Data (mph)	5.1	5.3	5.5
Site 2:			
Before Data (mph)	5.8	4.0	4.4
After Data (mph)	5.2	4.0	3.7
Site 3:			
Before Data (mph)	6.7	5.4	5.8
After Data (mph)	7.0	5.1	5.2

*Significant Change from before condition (Level of Confidence = 95%)

Speed Profiles

The Before and After outbound average speed profiles all suggested that none of the covered signs at any of the sites had much effect on speeds. At site 2, where the spot speed data seemed somewhat inconclusive, the after speed profile was lower than the before profile throughout the entire transition section and not just the study segment, suggesting that the covered speed limit sign was not solely responsible for the change in traffic speeds. The average speed profiles for the outbound direction are found in Appendix B.

Summary-Outbound Direction

In the outbound direction, the covering of speed limit signs appears to have had little or no effect on speeds. Only site 3 showed a decrease in average speed that could be attributed to the covered speed limit sign. The decrease was less than 2 mph. In addition, none of the sites showed increased variation in speeds through the study sections.

Summary of Findings

The field studies conducted at three different transition sections were designed to determine if it was necessary to post every 5 mph change in the speed limit that corresponded to a change in the 85th percentile speed. The studies have shown that:

1. Speeds, and variations in speed were generally not affected by reducing the number of speed limit signs in a transition section.

2. When traveling inbound to an urban area, the first lower speed limit sign within a transition does seem to affect speeds by indicating to drivers exactly where the transition begins and that deceleration to lower speeds are necessary.

3. In the outbound direction, driving speeds were not affected by covering a speed limit sign within the transition.

These studies have shown that it is possible to use fewer speed limit signs in transition sections without seriously affecting traffic speeds. The use and location of the first speed limit sign inbound is critical, so it should be posted as soon as the 85th percentile speed indicates its placement, or at the beginning of the incorporated city or town as specified currently in the procedures (1). As for additional speed limit signs within the transition, the studies suggest that decreasing or increasing speed limits in 10 or 15 mph increments, even when 5 mph increments of shorter segment lengths would better approximate the 85th percentile speed, results in satisfactory traffic operation. Texas speed zoning procedures already state that speed zone segments should be as long as possible. It is recommended that more emphasis be given to this statement and an additional statement be added to allow some flexibility with regards to posting limits as close as possible to the 85th percentile speed.

5. LOCAL CITIZEN COMPLIANCE TO REQUESTED SPEED ZONE CHANGES

Dealing with the public over a dispute about a speed zone is a very difficult task. In most situations, the public accepts Department speed zoning activities without comment or incident. However, instances arise where citizens do not approve of a speed zone on a particular section of highway or street. Believing that a direct relationship exists between speed and safety, citizens often demand that lower speed limits be posted in order to slow down the speed of traffic.

Speed zoning procedures, with their basis in driver behavior characteristics, legal concerns, accident statistics, etc., cannot be readily understood by the public. Referring to past research and experience which show traffic speeds are not lowered by imposing lower speed limits is usually ineffective as citizens often feel that they base their own driving speeds on posted speed limits. It would be useful to have speed information on citizens who live a disputed speed zone (who are aware of and possibly involved in the dispute), and determine if and to what degree these local citizens actually alter their driving speeds in response to a reduction in speed limits. In order to gain this type of information, studies were conducted at two Texas highway sites where speed limits lower than the 85th percentile speed were implemented in response to local community pressure to do so.

Study Methodology

Before and After speed and license plate studies were conducted at sites where the local community had pressured the Department into reducing the speed limit, even though such a reduction was not warranted according to Department speed zoning procedures. The license plate data were used to categorize recorded speeds according to whether the drivers lived local or non-local to the area. The two categories of data were analyzed and compared to determine the effect of the speed limit reduction on speeds, compliance rates, and quality of traffic operation.

Study Site Selection

Two sites were chosen for the study. Site 1 was a 0.3 mile stretch on FM 1638 in Nacogdoches, Texas (District 11). The highway is a 2-lane, 2-way facility with 10 ft lanes and either narrow turf shoulders or no shoulders at all. Several residences have direct access to the highway. The speed limit posted through the section was 50 mph, representing the 85th percentile speed of traffic. The director of a day care center located in the middle of the study section felt that this speed was too high for the roadway, and expressed concern for both the small children who played around the center as well as for the vehicles entering and exiting the center to pick up and drop off children. This concern over the posted limit had been expressed on several occasions since 1980. In 1983, she circulated a petition among the local residents to support her concerns and demanded a lower speed limit. In

January, 1986, District 11 approved a reduction in the speed limit on FM 1638 immediately adjacent to the day care center. The original limit was reduced from 50 mph to 45 mph. Further into town the limit was also reduced from 35 mph to 30 mph. Although this latter change was not situated within the study section, it may have affected driving speeds through the site.

The second site was a 0.8 mile segment of FM 1825 near Pflugerville, Texas (District 14). FM 1825 is a 4-lane undivided facility which connects IH-35 to Pflugerville, and is traveled by about 13,000 vehicles per day. A small residential trailer park, a small shopping mall, and a local tavern were located within the study section. Throughout the section, a 55 mph speed limit was posted. The citizens and local politicians of Pflugerville had demanded a lower speed limit be posted to slow vehicle speeds. Eventually, the Department agreed to lower the speed limit on that portion of FM 1825 from 55 to 50 mph.

Data Collection and Reduction

Spot speeds were collected at three stations within each site. At site 1 (FM 1638), the middle station was directly in front of the day care center. The two other locations were about 650-750 ft. on either side of the middle station. At site 2 (FM 1825), the middle station was directly across from the shopping mall, with the other two stations about 0.4 mile to each side.

Speed traps (200 ft.) were used to collect the speed data. Data collection personnel at each station communicated with one another by two-way radios. In order to maximize the strength of the experimental design, vehicles approaching in either direction were identified at the lead station and its speed recorded at each station downstream. Simultaneously, the license plate number of each study vehicle was also recorded. The plate numbers provided the means (via accessing the Department's vehicle registration database) to determine the registered address of each vehicle. Vehicles (and by inference, drivers) were segregated by address as being local or non-local. If an address could not be positively defined as local or non-local it was discarded from analysis. Data for each before and after study were collected on a clear, dry weekday during the a.m. and p.m. off-peak periods. Table 5-1 presents the sample sizes of each study for each site. Local drivers were found to represent approximately 15 to 25 percent of the total driving population at both sites, based on the vehicle registration information.

TABLE 5-1. SAMPLE SIZES FOR EACH STUDY SITE

	Site 1		Site 2	
	Before	After	Before	After
Inbound				
Local	19 (24%)	23 (21%)	13 (19%)	15 (16%)
Non-Local	59 (76%)	89 (79%)	55 (81%)	81 (84%)
Total	78	112	68	96
Outbound				
Local	14 (22%)	27 (25%)	11 (16%)	25 (23%)
Non-Local	49 (78%)	79 (75%)	56 (89%)	86 (77%)
Total	63	106	67	111

( ) represents percent of total sample size for each study at each site.

Results

Appendix C contains summaries of the averages and standard deviations of the speed data collected. This information is arranged by study, site, station, direction of travel, and driver type.

Table 5-2 summarizes the changes in average and standard deviations of speeds at each site for all driving speeds sampled. While site 2, station 2 experienced 3 and 7 mph reductions in travel speeds, (in the inbound and outbound directions, respectively), speeds at the other two stations experienced little or no change (0 to 2 mph reduction). The standard deviations in speeds were similarly unaffected, with only one statistically significant change occurring at one site (that being an increase).

The data were then sorted by driver type (local or non-local) and reanalyzed. The changes in average speeds and the standard deviation of speeds are shown in Table 5-3. The effect of the lower speed limits on local drivers was mixed. Inbound, local drivers did appear to reduce their speeds 2 to 4 mph at both sites after the speed zones were lowered 5 mph, although these reductions were not always statistically significant. The data were less consistent in the outbound direction. The average speed of local drivers at site 1, station 2 decreased by nearly 9 mph, even though the speed zone had been changed only 5 mph. Conversely, average local driving speeds at site 2 actually increased at two stations.

TABLE 5-2. EFFECT OF SPEED ZONING CHANGE ON TRAFFIC SPEEDS

All Drivers

	Changes in:		
	Speed Limit (mph)	Average Speed (mph)	Standard Deviation (mph)
Site 1			
Inbound			
Station 1	-5	-1.4	+0.7
2	-5	-2.6*	+0.1
3	NC	-0.1	-0.1
Outbound			
Station 1	-5	-0.3	+2.2*
2	-5	-7.3*	-1.1
3	NC	-1.9	+0.3
Site 2			
Inbound			
Station 1	-5	-1.8	0.0
2	-5	-1.2	-0.7
3	-5	-1.9*	+0.4
Outbound			
Station 1	-5	-1.7*	-0.7
2	-5	+0.5	+0.2
3	-5	+1.7*	-0.7

*Statistically Significant change from Before Condition (Level of Confidence = 95%)

Examination of speeds of non-local drivers suggests that they were generally unaffected by the reduced speed zones. Nearly 7 mph decrease in average speed did occur at site 1, station 2, and a less than 3 mph reduction at site 2, station 1, (see Table 5-3) but the remaining stations did not experience significant changes in speed. The researchers are unsure of the reason for the large decreases in speed at site 1, station 2.

The standard deviation of local and non-local driving speeds did not appear to be affected by the speed zone changes. Only two statistically significant changes did occur in the local driving speeds, as shown in Table 5-3. As with the average speeds, the standard deviations of speeds for non-local drivers were also not affected. No practical or statistically significant changes in the standard deviation of speeds were found at any of the study locations.

TABLE 5-3. CHANGES IN TRAVEL SPEEDS BETWEEN STUDIES

	Changes in:			
	Average Speed (mph)		Standard Deviation (mph)	
Site 1	Local	Non-Local	Local	Non-Local
Inbound				
Station 1	-3.7*	+0.3	+0.7	+0.5
2	-3.9*	-2.1	-1.8	+0.4
3	-2.4	+0.6	+1.1	-0.5
Outbound				
Station 1	0.0	-0.4	+5.4*	+1.0
2	-8.7*	-6.8*	-0.4	-1.4
3	-3.4	-1.3	+0.9	0.0
Site 2				
Inbound				
Station 1	-3.3	-0.5	-0.7	+0.3
2	-2.0	-1.0	-2.4*	-0.4
3	-3.7*	-1.4	-1.7	+0.8
Outbound				
Station 1	+1.4	-2.6*	+0.3	-1.1
2	+4.3*	-0.6	+0.1	+0.1
3	+4.7*	+0.9	-1.2	-0.7

*Statistically Significant Change from Before Condition (Level of Confidence = 95%)

Table 5-4 presents the differences in average speeds and standard deviations in speeds that exist between driver types both before and after the speed zones were lowered. Differences in average speeds were insignificant at both sites before the speed zones were lowered, with actual differences ranging from 0 to 3 mph. It is interesting to note that inbound local drivers at both sites traveled slightly slower than non-local drivers (as shown by the negative differences in average speeds), but traveled slightly faster than those in the outbound direction. Differences in average speeds between driver type after the speed zones were lowered do not follow this same pattern. A few statistically significant differences were found at each site. It appears that the lower speed zones may have actually worsened the quality of traffic operation at the sites somewhat, by causing differences in driving speeds between driver types to increase.

TABLE 5-4. DIFFERENCES IN TRAVEL SPEEDS BETWEEN DRIVER TYPE (LOCAL VERSUS NON-LOCAL)

Differences in Average Speeds (mph)[a]

	Before Study	After Study
Site 1		
Inbound		
Station 1	+1.4	+2.6
2	+0.1	-1.7
3	+0.3	-2.7
Outbound		
Station 1	-0.2	+0.2
2	-0.2	-2.1
3	-1.4	-3.5*
Site 2		
Inbound		
Station 1	+2.7	+0.9
2	+1.6	+0.6
3	+3.0	+0.7
Outbound		
Station 1	-1.0	+3.0*
2	-2.6	+3.3*
3	-1.1	+2.7*

[a] Computed as (Local - Non-Local)

*Statistically Significant Difference Between Driver Type (Level of Confidence = 95%)

As a final measure of the effects of the reduced speed zones, Table 5-5 (both directions combined) summarizes the percentages of drivers exceeding the posted limits at each site before and after the speed zones had been changed. As can be seen, both sites experienced large increases in the percentages of drivers exceeding the posted speed limit as a result of lower speed limits being posted. At site 1, where local drivers did appear to decrease their speeds to some degree (Table 5-3), non-compliance remained fairly constant at about 30 percent. Non-local violation of the posted limits increased from 29 to 41 percent. Non-compliance rose sharply for both driver types at site 2, with percentages jumping from 25 percent to 51 percent for local drivers, and from 18 percent to 39 percent of non-local drivers.

TABLE 5.5. EFFECT OF REDUCED SPEED LIMITS ON DRIVER NON-COMPLIANCE

	Percent of Drivers Exceeding the Posted Speed Limit:			
	Local Drivers		Non-Local Drivers	
	Before	After	Before	After
Site 1	29	31	29	41
Site 2	25	51	18	39

Summary of Findings

The previous discussion has summarized the results of field studies at two sites where speed zones were changed after local citizen pressures. Based on this limited study, the following findings about local and non-local driver response to the speed zone changes have been noted:

1. Overall, the speed zoning changes had only a small effect upon the driving population as a whole. One site did experience a speed reduction, but it is not certain that external factors were not at least partially responsible for the change. Otherwise, changes that did occur were of small magnitude (up to 2 mph).

2. Data from site 1 suggest that local drivers may reduce their speeds slightly after speed zones are lowered. Data at site 2 were less conclusive, showing decreases in local driving speeds in the inbound direction, but increases for those local drivers travelling outbound.

3. Non-local driving speeds were not affected to any significant degree by the reduction in speed limits at either site.

4. The reduction in speed zones had a detremental affect on driver compliance to the speed limits for both driver types. Reducing the speed limit by only 5 mph resulted in an additional 10 to 30 percent of drivers exceeding the posted limit. Non-compliance of non-local drivers was consistently higher, near 40 percent, at both sites after speed zones were reduced, while non-compliance of local drivers varied, with no change at site 1 and a large increase at site 2.

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Appendix A: Spot Speed and Speed Profile Results from Studies on Rapidly Developing Urban Fringe Areas

TABLE A-1. EFFECT OF 45 MPH SPEED ZONES ON VEHICLE SPEEDS

LOCATION 1

Site	Average Speed (mph)			85th Percentile Speed (mph)			Proportion of Drivers Exceeding the Posted Speed Limit (%)		
	Before	After	Change	Before	After	Change	Before	After	Change
1									
EB	47.7	45.9	-1.8**	51	52	+1	12.8	65.6	+52.8*
WB	49.1	45.5	-3.6**	54	52	-2	11.2	73.6	+62.4*
2									
EB	55.2	53.8	-1.4	61	60	-1	10.4	78.1	+67.7*
WB	55.1	54.1	-1.0	60	60	0	6.4	77.3	+50.6*
3									
EB	46.8	48.9	+2.1*	53	53	0	49.6	90.0	+40.4*
WB	47.6	50.0	+2.5*	53	56	+3	43.2	93.8	+70.9*
4									
NB	53.2	50.2	-3.0**	59	56	-3	30.4	80.5	+50.1*
SB	52.3	50.5	-1.8**	58	58	0	28.0	75.0	+47.0*
5									
NB	51.5	48.3	-3.2**	57	53	-4	24.0	79.2	+55.2*
SB	51.0	46.8	-4.2**	56	52	-4	24.0	60.8	+36.8*
6									
NB	49.1	47.3	-1.8**	56	52	-4	19.2	64.8	+45.6*
SB	49.7	47.4	-2.2**	55	54	-1	14.4	64.1	+49.7*

*Statistically Significant Increase from Before Condition (Level of Confidence = 95%)
**Statistically Significant Decrease from Before Condition (Level of Confidence = 95%)

TABLE A-2. EFFECT OF 45 MPH SPEED ZONES ON THE DISTRIBUTION OF SPEEDS

LOCATION 1

Site	Standard Deviation (mph)			Skewness Index	
	Before	After	Change	Before	After
1					
EB	6.2	4.8	-1.4*	0.9	0.9
WB	6.3	5.0	-1.3*	1.1	1.0
2					
EB	5.9	6.2	+0.3	0.8	0.7
WB	5.4	6.0	+0.6	1.1	1.0
3					
EB	6.2	4.3	-1.9*	1.0	0.8
WB	6.1	5.6	-0.5	0.9	1.1
4					
NB	5.7	5.7	0.0	1.1	1.2
SB	6.2	6.8	+0.6	0.8	1.0
5					
NB	5.7	5.2	-0.5	1.1	0.8
SB	6.0	5.5	-0.5	0.9	0.9
6					
NB	6.8	4.8	-2.0*	0.8	0.9
SB	6.0	6.0	0.0	0.9	1.0

*Statistically Significant Decrease from Before Condition (Level of Confidence = 95%)

TABLE A-3. EFFECT OF 45 MPH SPEED ZONES ON VEHICLE SPEEDS

LOCATION 3

Site	Average Speed (mph)			85th Percentile Speed (mph)			Proportion of Drivers Exceeding the Posted Speed Limit (%)		
	Before	After	Change	Before	After	Change	Before	After	Change
1									
EB	41.3	44.8	+3.5*	47	50	+3	0.8	37.6	+36.8*
WB	44.3	45.2	+0.9	50	50	0	2.4	48.0	+45.6*
2									
EB	52.7	50.0	-2.7**	58	56	-2	36.0	92.2	+56.2*
WB	50.2	51.6	+1.4	55	58	+3	22.4	98.4	+78.0*
3									
EB	53.5	51.9	-1.6**	59	57	-2	34.4	84.6	+50.2*
WB	52.0	54.1	+2.1*	57	60	+3	36.0	83.1	+47.1*
4									
NB	47.1	48.4	+1.3	54	54	0	8.0	68.0	+60.0*
SB	46.3	48.4	+2.0*	52	54	+2	5.6	68.0	+62.4*
5									
NB	54.4	48.6	-5.8**	60	54	-6	43.2	70.0	+36.8*
SB	49.5	48.1	-1.4	55	54	-1	13.6	70.0	+56.4*
6									
NB	50.4	48.3	-2.1**	55	53	-2	12.8	84.4	+71.6*
SB	53.2	49.4	-3.9**	59	54	-5	34.4	76.6	+42.2*

*Statistically Significant Increase from Before Condition (Level of Confidence = 95%)
**Statistically Significant Decrease from Before Condition (Level of Confidence = 95%)

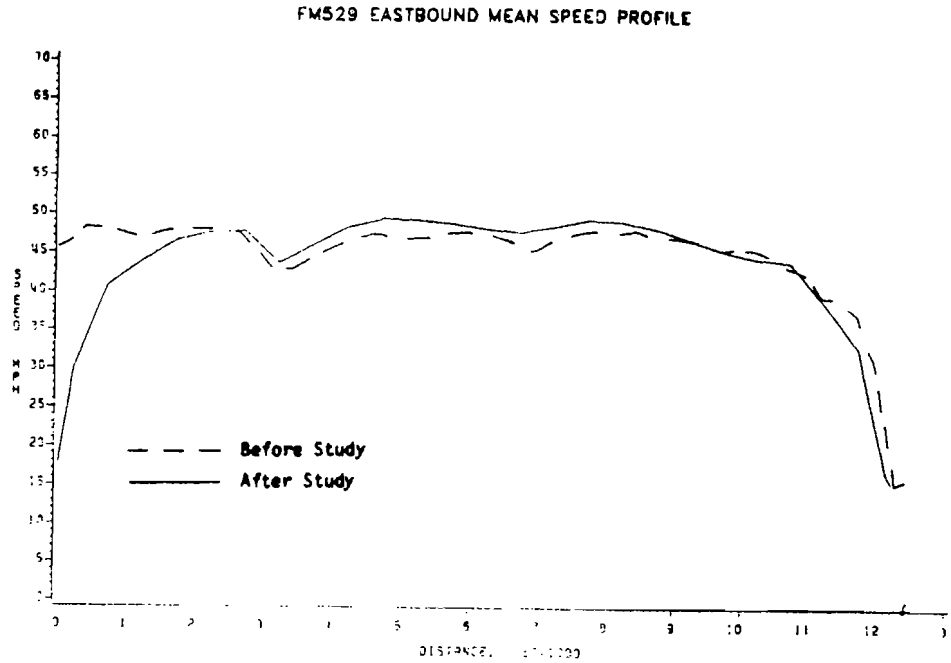
TABLE A-4. EFFECT OF 45 MPH SPEED ZONES ON THE DISTRIBUTION OF SPEEDS

LOCATION 3

Site	Standard Deviation (mph)			Skewness Index	
	Before	After	Change	Before	After
1					
EB	5.1	5.3	+0.2	0.8	1.3
WB	5.7	4.6	-1.1*	1.0	0.9
2					
EB	6.3	5.1	-1.2*	0.8	1.1
WB	4.7	6.9	+2.2**	1.0	0.9
3					
EB	5.8	4.5	-1.3*	1.1	0.9
WB	5.7	6.2	+0.5	0.9	1.0
4					
NB	5.9	5.1	0.8	1.1	1.1
SB	6.4	6.1	-0.3	0.8	1.0
5					
NB	5.4	5.7	+0.3	0.8	0.9
SB	6.2	6.3	+0.1	0.9	1.0
6					
NB	4.9	4.7	-0.2	0.9	0.9
SB	5.9	4.9	-1.0*	1.0	1.0

*Statistically Significant Decrease from Before Condition (Level of Confidence = 95%)

**Statistically Significant Increase from Before Condition (Level of Confidence = 95%)



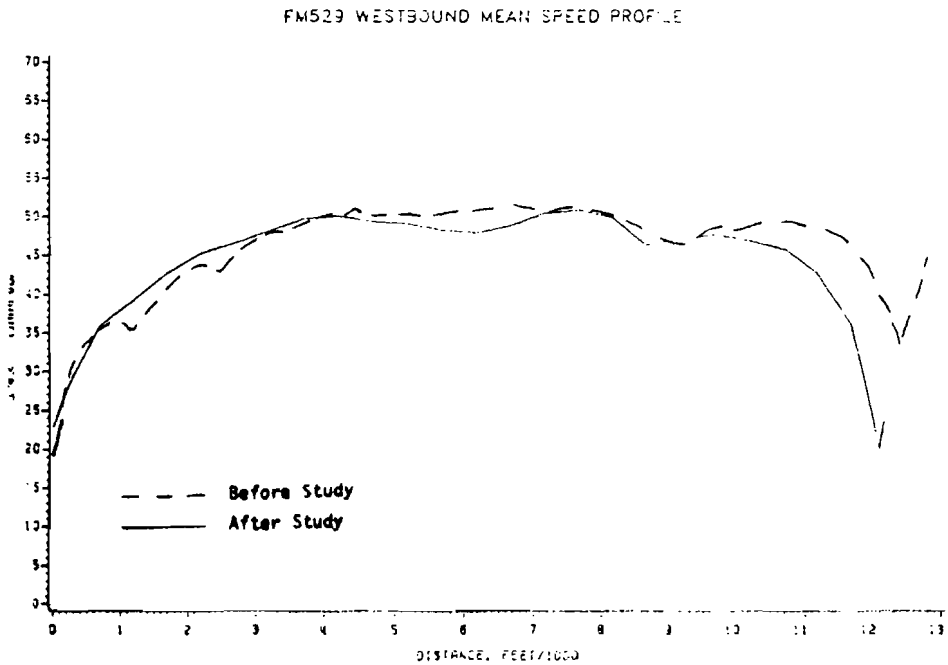
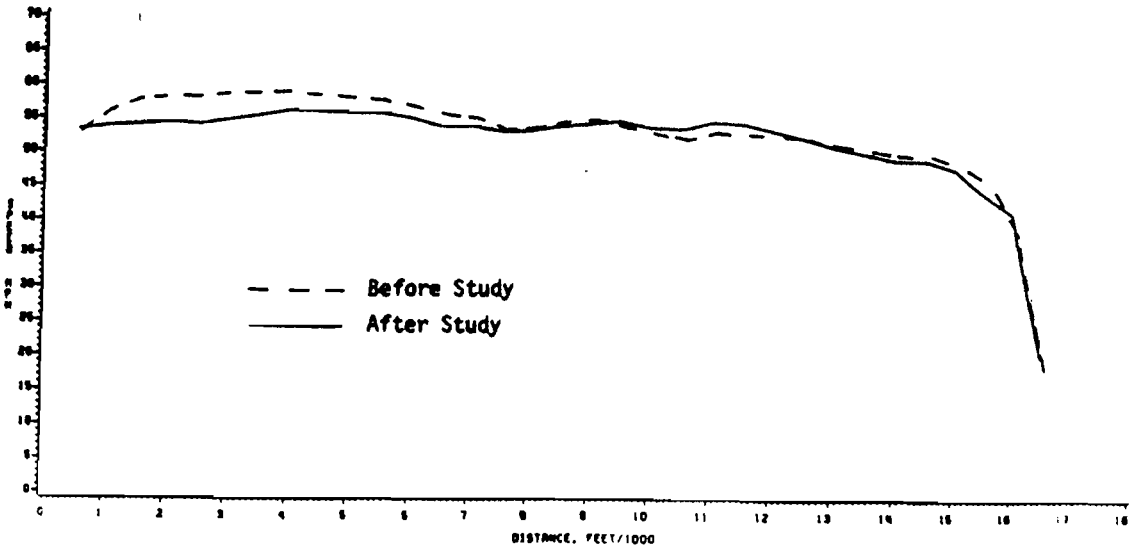


Figure A-1. Average Speed Profiles for Site 1

FM 1093 EASTBOUND MEAN SPEED PROFILES



FM 1093 WESTBOUND MEAN SPEED PROFILES

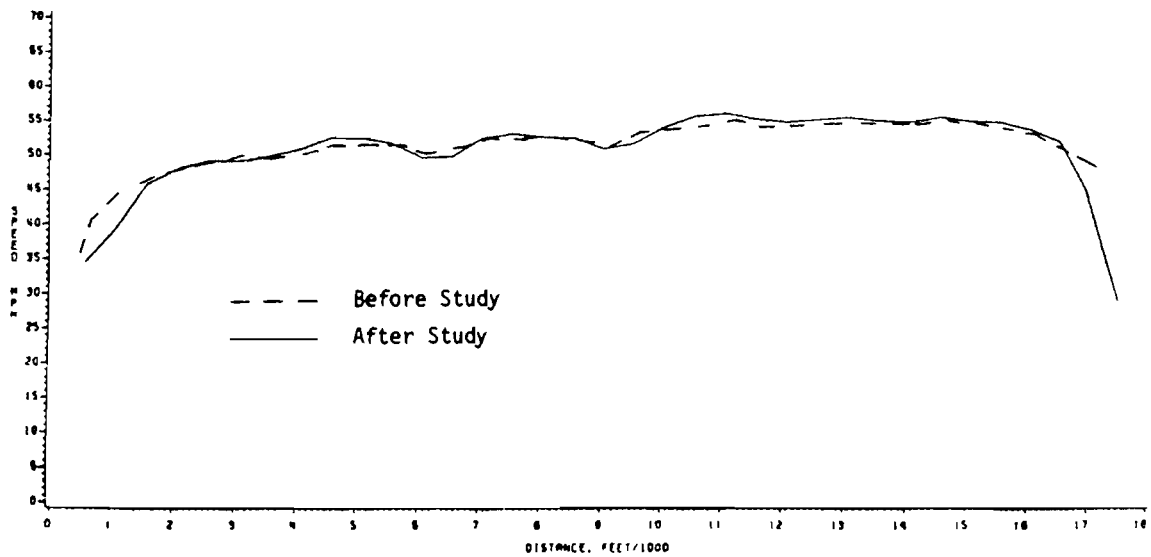
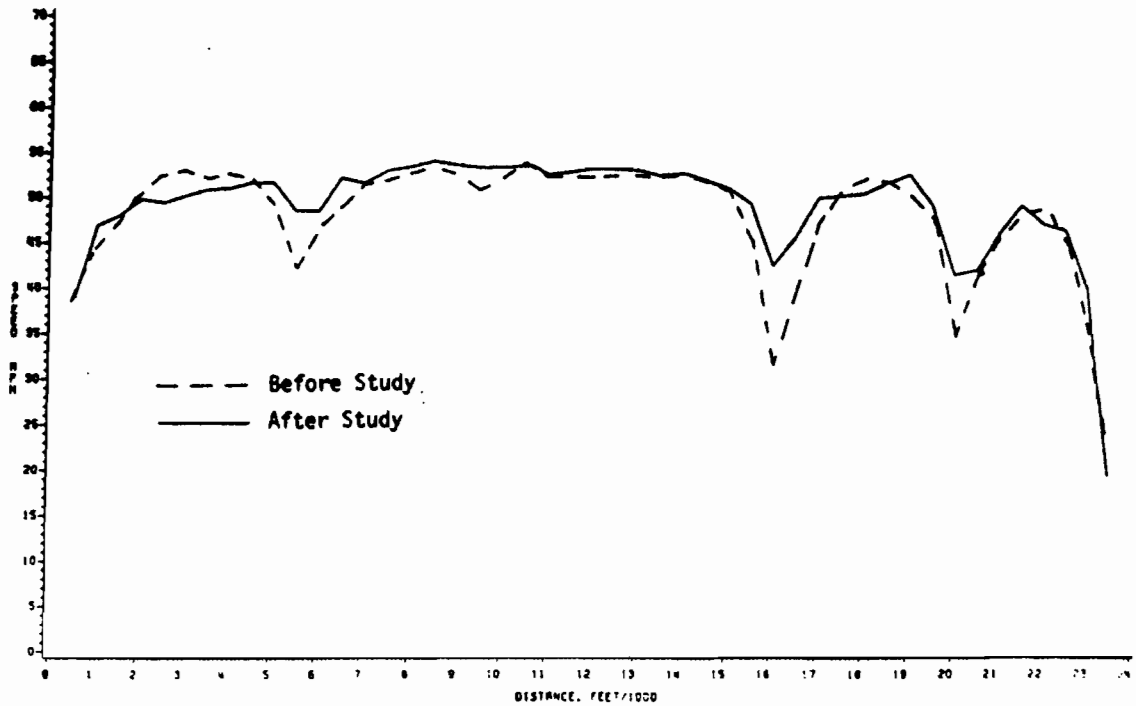


Figure A-2. Average Speed Profiles for Site 2

FM 1960 EASTBOUND MEAN SPEED PROFILES



FM 1960 WESTBOUND MEAN SPEED PROFILES

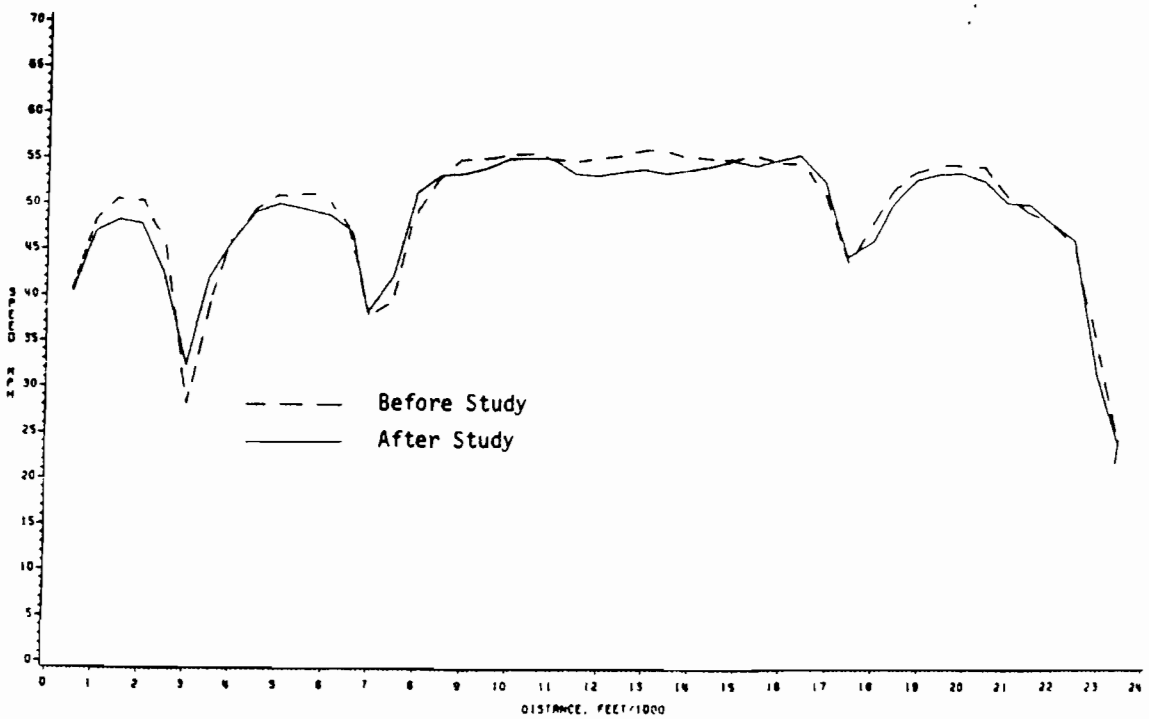
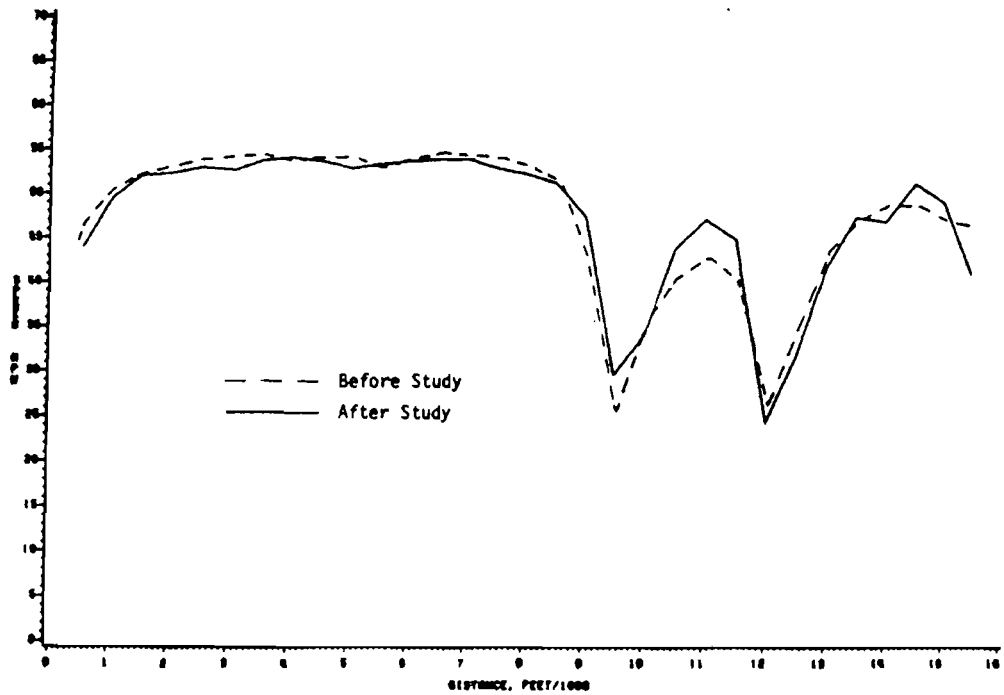


Figure A-3. Average Speed Profiles for Site 3

SH 6 NORTHBOUND MEAN SPEED PROFILES



SH 6 SOUTHBOUND MEAN SPEED PROFILES

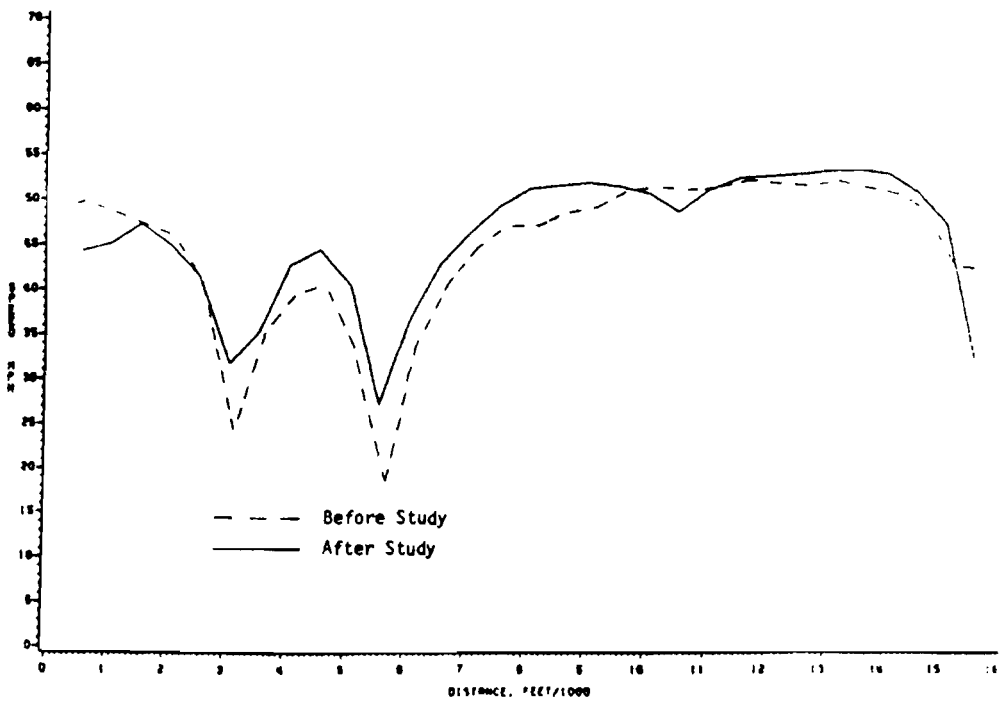
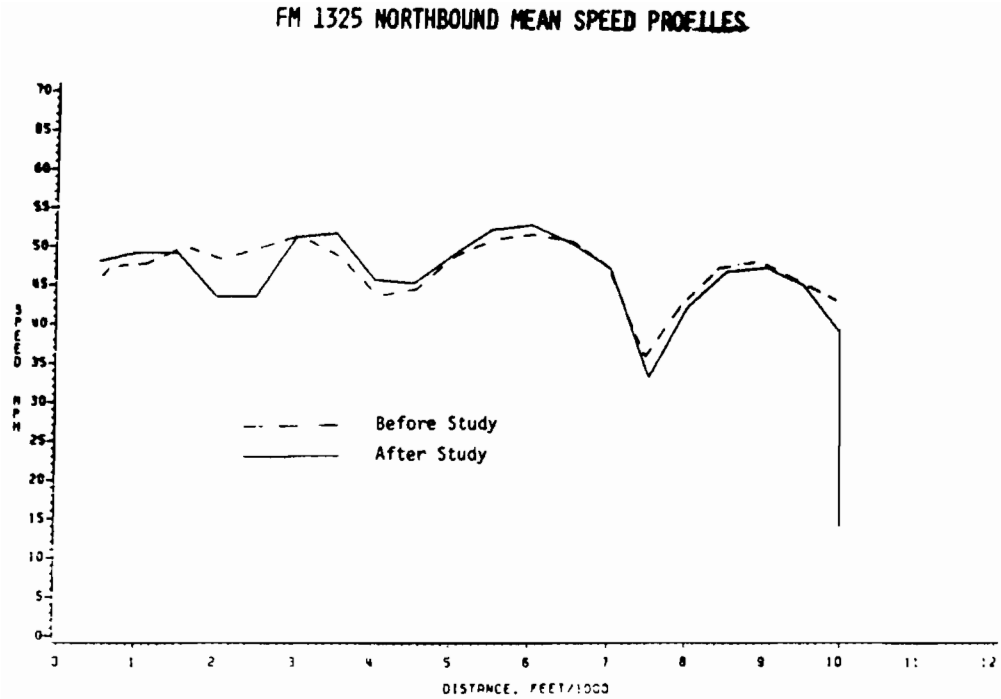


Figure A-4. Average Speed Profiles for Site 4



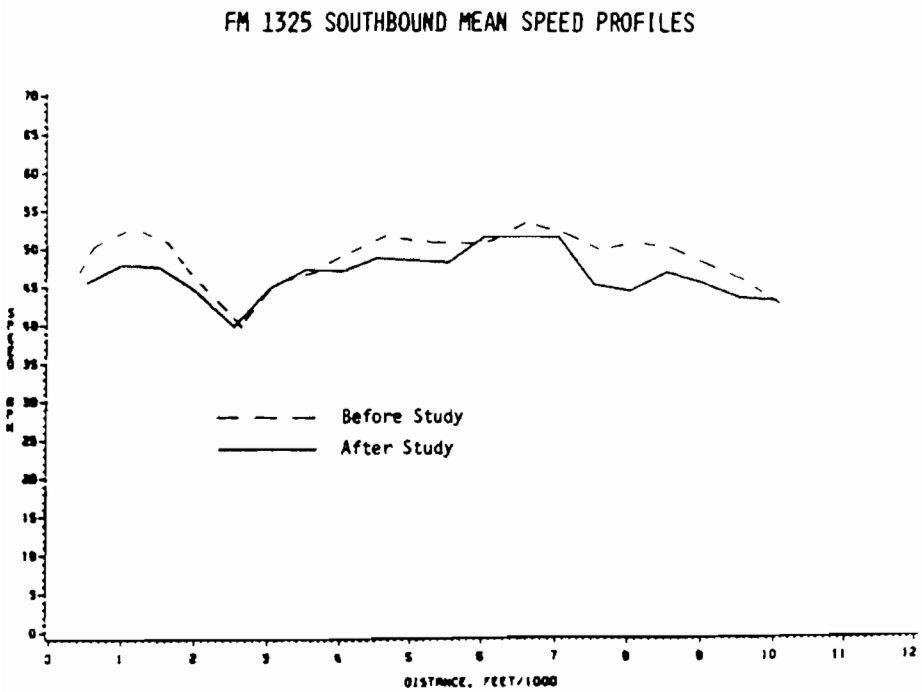


Figure A-5. Average Speed Profile for Site 5

Appendix B: Inbound and Outbound Speed Profiles for Transition Section Studies

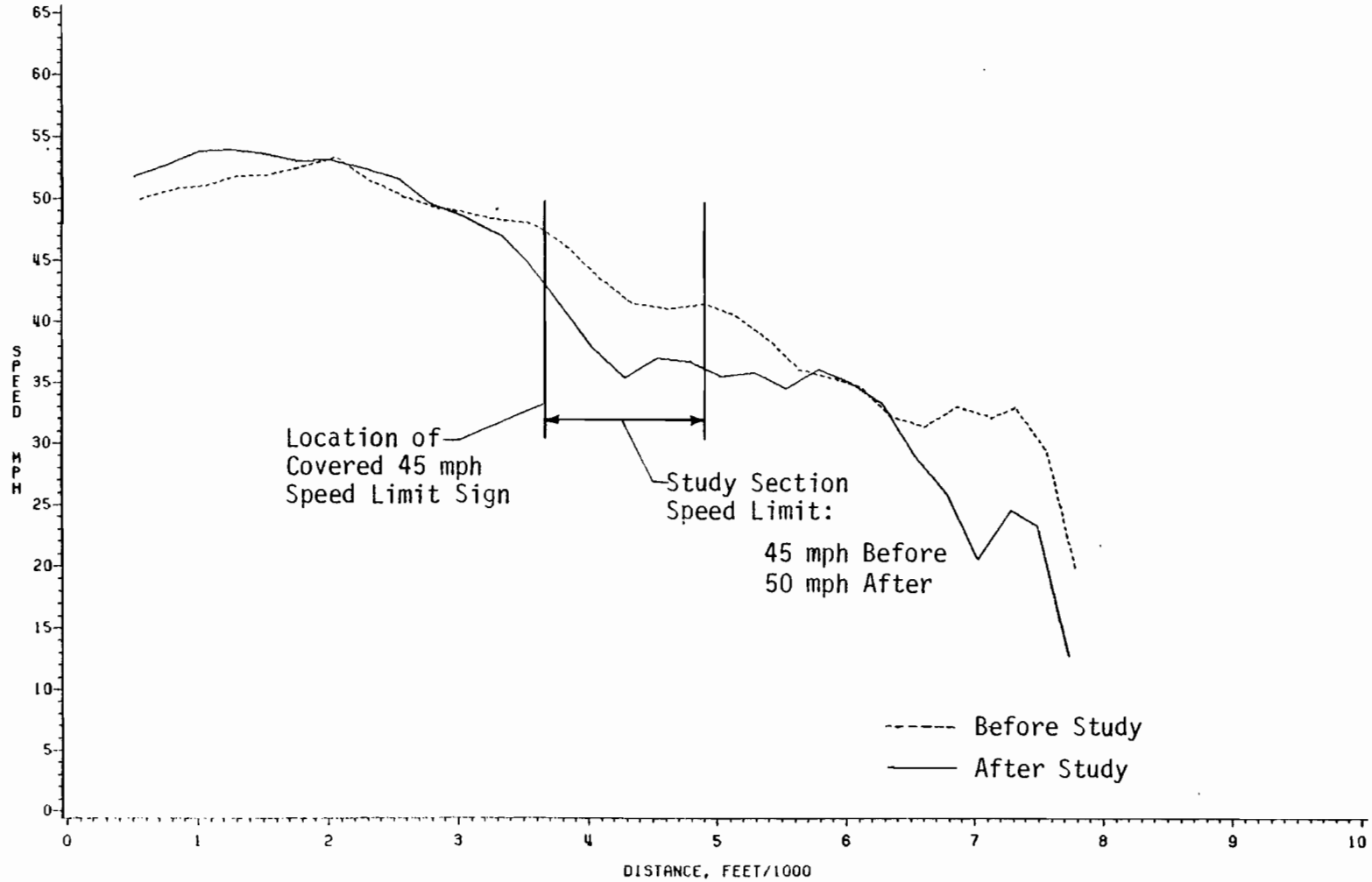


Figure B-1. Average Speed Profiles, Inbound, for Site 2

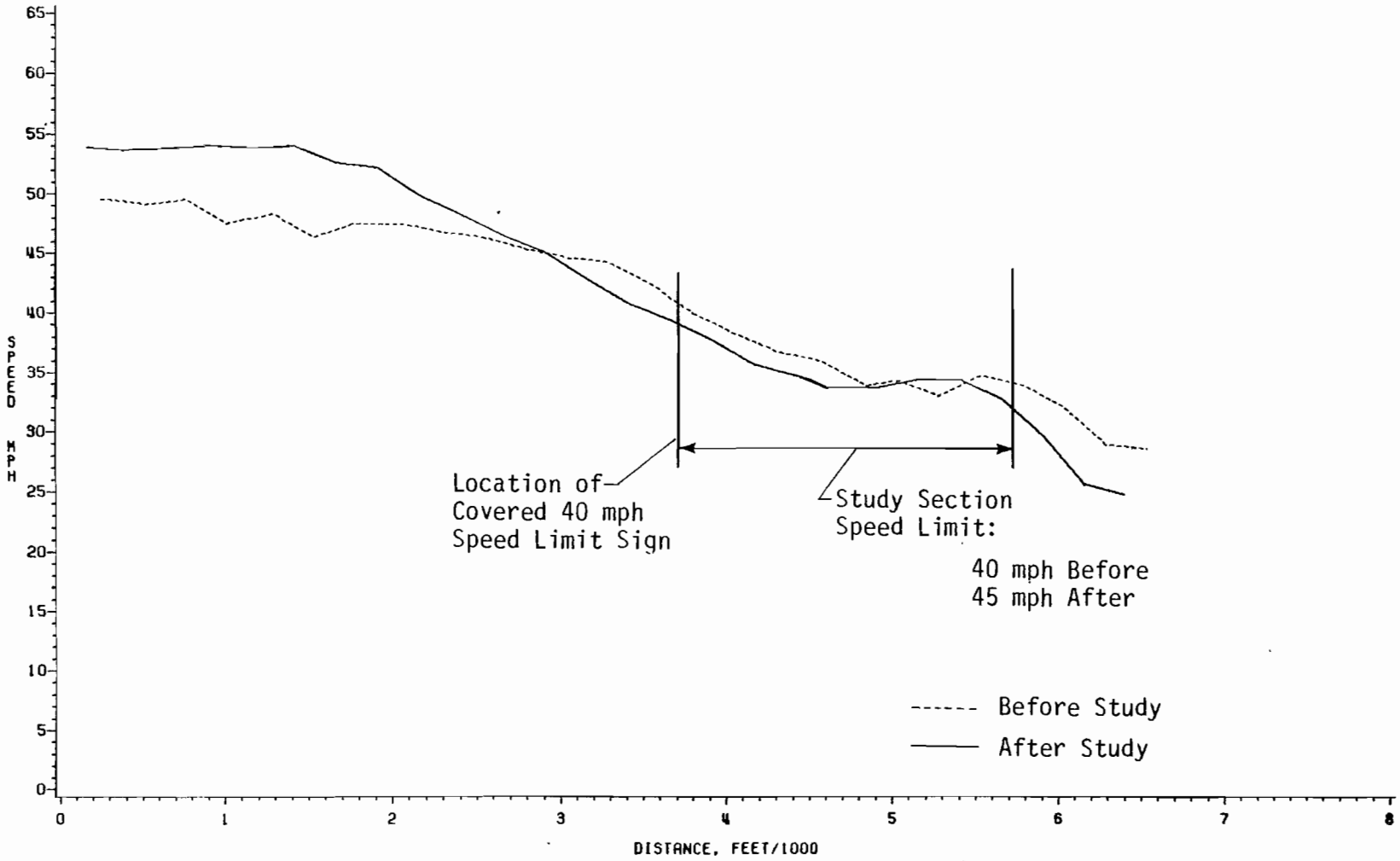


Figure B-2. Average Speed Profiles, Inbound, for Site 3

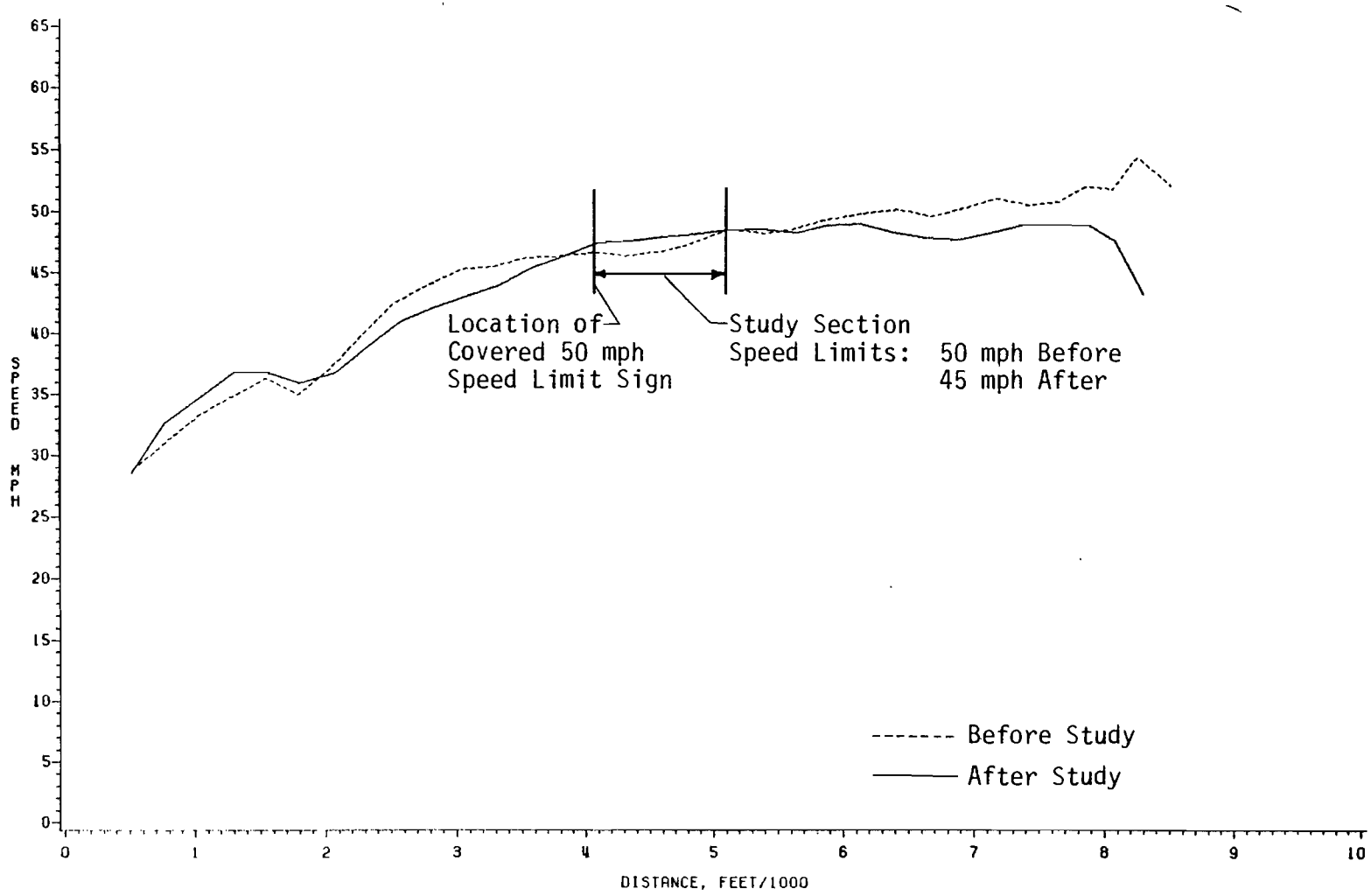


Figure B-3. Average Speed Profiles, Outbound, for Site 1

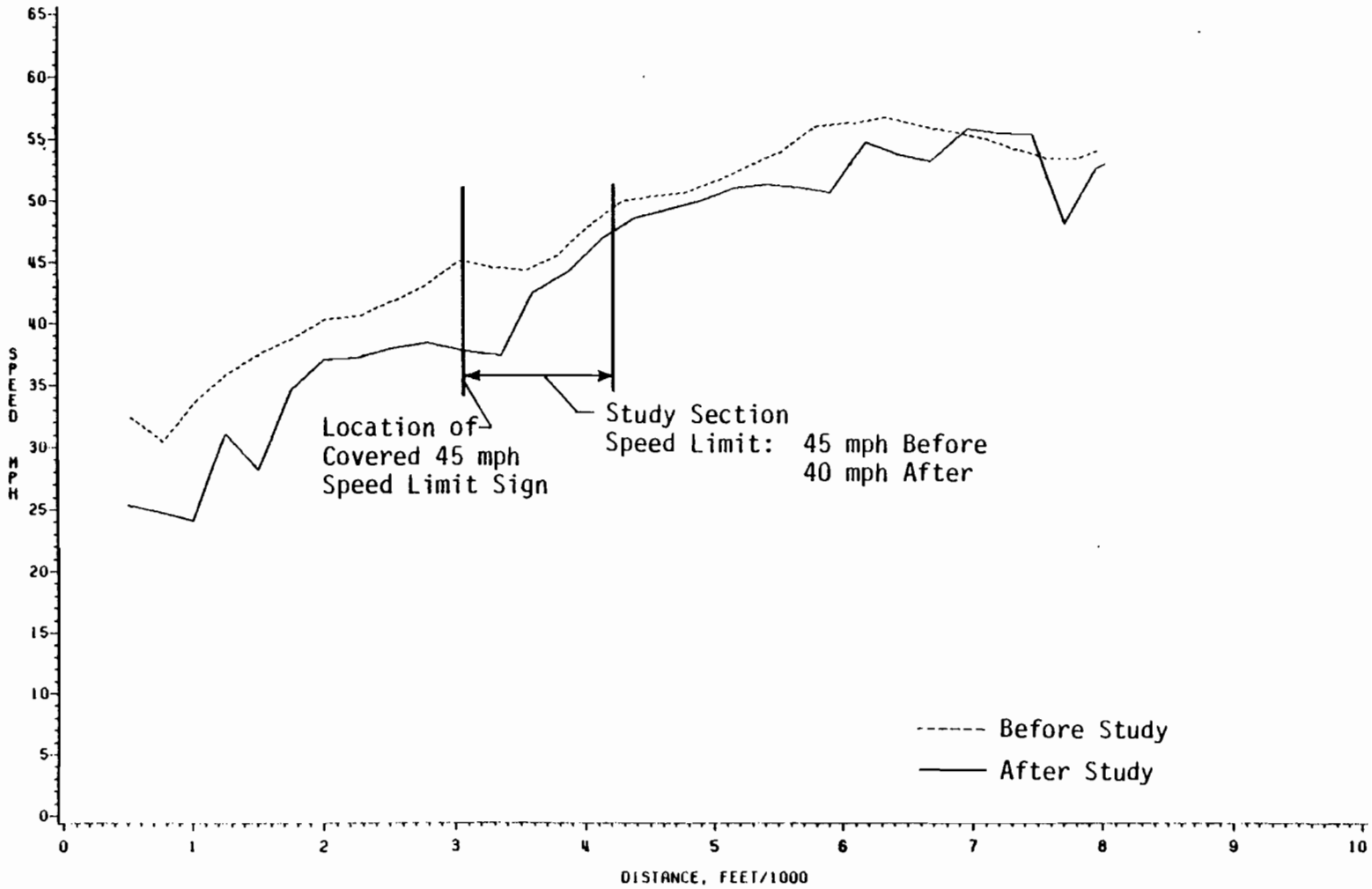


Figure B-4. Average Speed Profile, Outbound, for Site 2

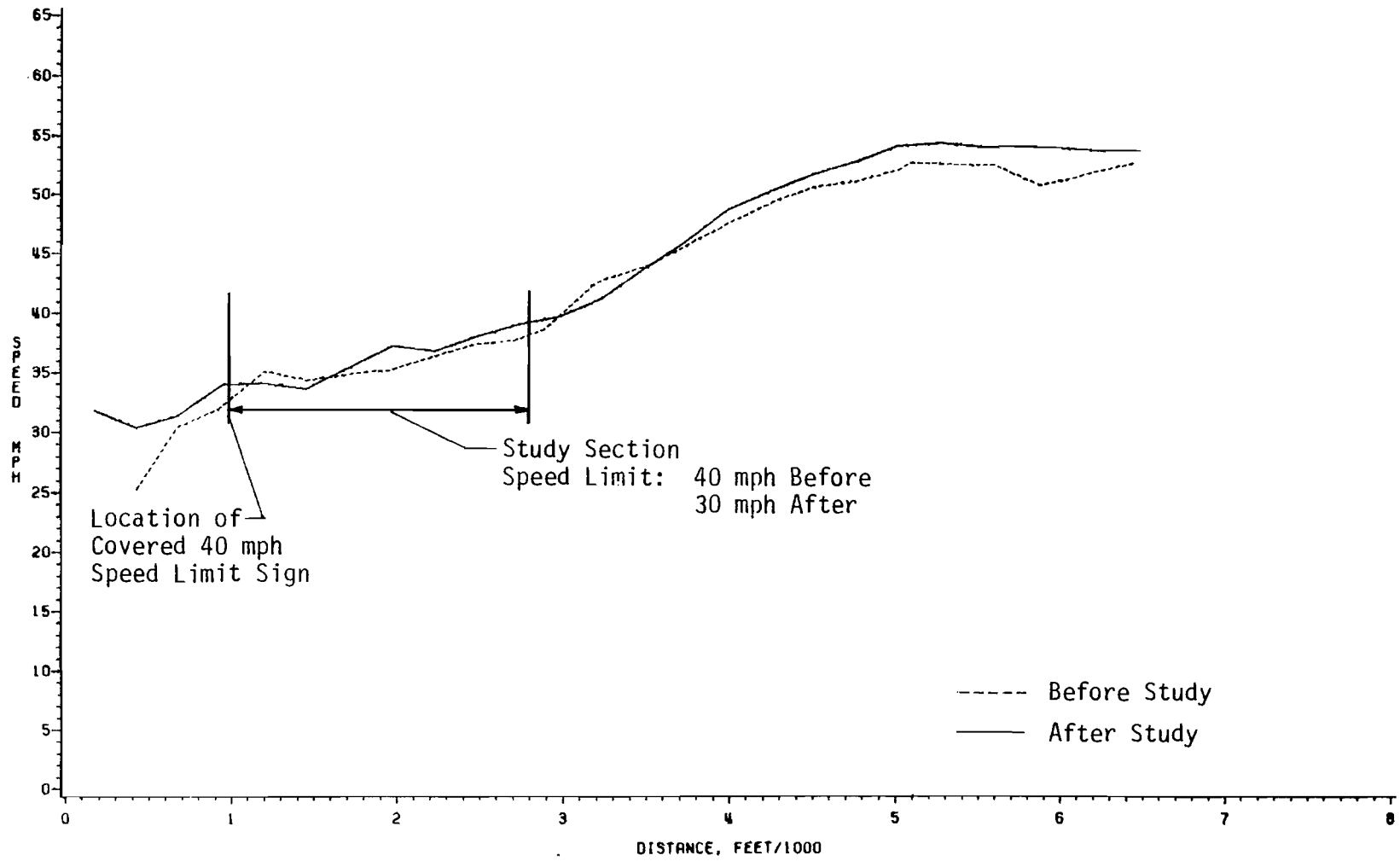


Figure B-5. Average Speed Profile, Outbound, for Site 3

Appendix C: Speed Data from Local Citizen Compliance Studies

TABLE C-1. SUMMARY OF SPEEDS: SITE 1

ALL DRIVERS

Location	Speed Limit (mph)		Average Speed (mph)			Standard Deviation (mph)		
	B	A	B	A	Diff	B	A	Diff
Station 1								
Inbound	50	45	42.3	41.9	-1.4	6.5	7.2	0.7
Outbound	50	45	38.6	38.3	-0.3	5.8	8.0	2.2*
Station 2								
Inbound	50	45	46.8	44.2	-2.6*	6.4	6.5	0.1
Outbound	50	45	43.8	36.5	-7.3*	6.5	5.4	-1.1
Station 3								
Inbound	50	50	44.6	44.5	-0.1	7.4	7.3	-0.1
Outbound	50	50	42.7	40.8	-1.9	6.6	6.9	0.3

B = Before Study
A = After Study
Diff = Difference between Before and After Studies
NC = No Change between Studies
*Statistically Significant Change from Before Condition
(Level of Confidence = 95%)

TABLE C-2. SUMMARY OF SPEEDS: SITE 2

ALL DRIVERS

Location	Speed Limit (mph)		Average Speed (mph)			Standard Deviation (mph)		
	B	A	B	A	Diff	B	A	Diff
Station 1								
Inbound	55	50	51.6	49.8	-1.8	6.1	6.1	NC
Outbound	55	50	53.5	51.8	-1.7	5.5	4.8	-0.7
Station 2								
Inbound	55	50	46.8	45.6	-1.2	6.3	5.7	-0.7
Outbound	55	50	48.9	49.4	+0.5	5.4	5.6	+0.2
Station 3								
Inbound	55	50	51.3	49.4	-1.9	5.2	5.6	+0.4
Outbound	55	50	50.9	52.6	+1.7	5.5	4.3	-0.7

B = Before Study
A = After Study
Diff = Difference between Before and After Studies
NC = No Change between Studies
*Statistically Significant Change from Before Condition
(Level of Confidence = 95%)

TABLE C-3. SUMMARY OF SPEEDS BY DRIVER TYPE: SITE 1

LOCAL DRIVERS

Station	Average Speed (mph)			Standard Deviation (mph)		
	B	A	Diff	B	A	Diff
Station 1						
Inbound	43.5	39.8	-3.7*	4.9	5.6	0.7
Outbound	38.5	38.5	NC	4.9	10.3	5.4*
Station 2						
Inbound	46.8	42.9	-3.9*	6.7	4.9	-1.8
Outbound	43.6	34.9	-8.7*	5.5	5.1	-0.4
Station 3						
Inbound	44.8	42.4	-2.4	5.8	6.9	1.1
Outbound	41.6	38.2	-3.4	5.8	6.7	0.9

NON-LOCAL DRIVERS

Station	Average Speed (mph)			Standard Deviation (mph)		
	B	A	Diff	B	A	Diff
Station 1						
Inbound	42.1	42.4	+0.3	7.0	7.5	0.5
Outbound	38.7	38.3	-0.4	6.2	7.2	1.0
Station 2						
Inbound	46.7	44.6	-2.1	6.4	6.8	0.4
Outbound	43.8	37.0	-6.8*	6.8	5.4	-1.4
Station 3						
Inbound	44.5	45.1	+0.6	7.9	7.4	-0.5
Outbound	43.0	41.7	-1.3	6.8	6.8	NC

B = Before Study
A = After Study
Diff = Difference Between Before and After Studies
NC = No Change Between Studies
*Statistically Significant Change Between Studies
(Level of Confidence = 95%)

TABLE C-4. SUMMARY OF SPEEDS BY DRIVER TYPE: SITE 2

LOCAL DRIVERS

Station	Average Speed (mph)			Standard Deviation (mph)		
	B	A	Diff	B	A	Diff
Station 1						
Inbound	53.8	50.5	-3.3	7.4	6.7	-0.7
Outbound	52.7	54.1	+1.4	4.7	5.0	+0.3
Station 2						
Inbound	48.1	46.1	-2.0	6.3	3.9	-2.4*
Outbound	46.7	52.0	+4.3*	5.6	5.7	+0.1
Station 3						
Inbound	53.7	50.0	-3.7*	4.9	3.2	-1.7
Outbound	50.0	54.7	+4.7*	5.7	4.5	-1.2

NON-LOCAL DRIVERS

Station	Average Speed (mph)			Standard Deviation (mph)		
	B	A	Diff	B	A	Diff
Station 1						
Inbound	51.1	49.6	-0.5	5.7	6.0	+0.3
Outbound	53.7	51.1	+2.6*	5.7	4.6	-1.1
Station 2						
Inbound	46.5	45.5	-1.0	6.3	5.9	-0.4
Outbound	49.3	48.7	-0.6	5.3	5.4	+0.1
Station 3						
Inbound	50.7	49.3	-1.4	5.1	5.9	+0.8
Outbound	51.1	52.0	+0.9	5.5	4.8	-0.7

B = Before Study
A = After Study
Diff = Difference Between Before and After Studies
NC = No Change Between Studies
*Statistically Significant Change Between Studies
(Level of Confidence = 95%)

TABLE C-5. SUMMARY OF SPEEDS BY STUDY: SITE 1

BEFORE STUDY

Station	Average Speed (mph)			Standard Deviation (mph)		
	Driver Type			Driver Type		
	L	NL	Diff	L	NL	Diff
Station 1						
Inbound	43.5	42.1	+1.4	4.9	7.0	2.1*
Outbound	38.5	38.7	-0.2	4.9	6.2	1.3
Station 2						
Inbound	46.8	46.7	+0.1	6.7	6.4	-0.3
Outbound	43.6	43.8	-0.2	5.5	6.8	1.3
Station 3						
Inbound	44.8	44.5	+0.3	5.8	7.9	2.1
Outbound	41.6	43.0	-1.4	5.8	6.8	1.0

AFTER STUDY

Station	Average Speed (mph)			Standard Deviation (mph)		
	Driver Type			Driver Type		
	L	NL	Diff	L	NL	Diff
Station 1						
Inbound	39.8	42.4	-2.6	5.6	7.5	1.9*
Outbound	38.5	38.3	+0.2	10.3	7.2	-3.1*
Station 2						
Inbound	42.9	44.6	-1.7	4.9	6.8	1.9*
Outbound	34.9	37.0	-2.1	5.1	5.4	0.3
Station 3						
Inbound	42.4	45.1	-2.7	6.9	7.4	0.5
Outbound	38.2	41.7	-3.5	6.7	6.8	0.1

L = Local Driver
NL = Non-Local Driver
Diff = Difference Between Driver Types
*Statistically Significant Difference Between Driver Type (Level of Confidence = 95%)

TABLE C-6. SUMMARY OF SPEEDS BY STUDY: SITE 2

BEFORE STUDY

Station	Average Speed (mph)			Standard Deviation (mph)		
	Driver Type			Driver Type		
	L	NL	Diff	L	NL	Diff
Station 1						
Inbound	53.8	51.1	+2.7	7.4	5.7	+1.7
Outbound	52.7	53.7	-1.0	4.7	5.7	-1.0
Station 2						
Inbound	48.1	46.5	+1.6	6.3	6.3	ND
Outbound	46.7	49.3	-2.6	5.6	5.3	+0.3
Station 3						
Inbound	53.7	50.7	+3.0	4.9	5.1	-0.2
Outbound	50.0	51.1	-1.1	5.7	5.5	+0.2

AFTER STUDY

Station	Average Speed (mph)			Standard Deviation (mph)		
	Driver Type			Driver Type		
	L	NL	Diff	L	NL	Diff
Station 1						
Inbound	50.5	49.6	+0.9	6.7	6.0	0.7
Outbound	54.1	51.1	+3.0*	5.0	4.6	0.4
Station 2						
Inbound	46.1	45.5	+0.6	3.9	5.9	-2.0*
Outbound	52.0	48.7	+3.3*	5.7	5.4	-0.3
Station 3						
Inbound	50.0	49.3	+0.7	3.2	5.9	-2.7*
Outbound	54.7	52.0	+2.7*	4.5	4.8	-0.3

L = Local Driver
NL = Non-Local Driver
Diff = Difference Between Driver Types
*Statistically Significant Difference Between Driver Type
(Level of Confidence = 95%)