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16. Abstract

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THE USE OF FREEWAY SHOULDERS TO INCREASE CAPACITY

A REVIEW

by

William R. McCasland
Research Engineer

Research Report Number 210-10

Evaluation of Urban Freeway Modifications

Research Study Number 2-18-77-210

Sponsored by
State Department of Highways and Public Transportation
In Cooperation with the
U.S. Department of Transportation
Federal Highway Administration

Texas Transportation Institute
Texas A&M University System
College Station, Texas

January 1984

ABSTRACT

Every sector of urban transportation faces the problems of rising costs, limited funds, and depleting resources with which to provide for increasing travel demands. Getting the greatest production out of the existing transportation facilities is the goal of every transportation agency. The Texas State Department of Highways and Public Transportation has been testing the concept of increasing roadway capacity on urban freeways by restriping the mainlane pavement with narrower lane widths and encroaching on the shoulder to create one additional lane for travel.

Two sections of U.S. 59 Southwest Freeway in Houston were modified for study. Before and after data were collected over a seven-year period to determine the effectiveness of reconfiguring the surface geometric of freeways, to provide an additional lane for travel 24 hours everyday. A second section was modified to provide the additional lane during peak periods only on weekdays. This "permissive" design was studied over a four-year period.

DISCLAIMER

Key Words: Narrow lanes, travel on freeway shoulders, freeway accident analysis, freeway operation.

SUMMARY

This report is concerned with the operational efficiency and safety of freeways with surface geometrics that have been modified to provide additional capacity. Every urban area in the country experiences traffic congestion to some extent. When the congestion becomes so extensive and repetitive, measures to increase the capacity or to reduce the demand should be undertaken. However, sufficient funds to make major changes to urban freeways may not be available and in some instances, space may be so limited as to rule out normal expansions in roadway width. One approach that many transportation agencies are considering is the downscoping of design standards to achieve greater capacity at lower cost.

The usual method to accomplish this is to reduce lane widths and to reduce or eliminate the roadway shoulders and create an additional lane for travel. The modification is considered to be temporary until sufficient funding is available for major reconstruction or until alternative modes or routes of travel are available to reduce the traffic demand.

The application of reduced standards should be undertaken with care to achieve the expected operational improvements without hazard to the public. This study evaluated two typical freeway sections that were modified to determine the operational effectiveness and safety experience over a seven-year period for one design and a four-year period for a different design.

The first design provided an extra lane continously in two bottleneck sections over 2.5 miles long. Peak period volumes in the modified sections were increased approximately 3000 vehicles, resulting in reduced travel times of 1000 vehicle-hours per day. The accident rates in the modified sections fell by 12 percent and remained at these lower levels while the traffic volumes increased. The cost of this installation was $38,700 per year. This annual

cost assumed that major pavement repair would be required within 10 years. Pavement was replaced in 1984, eight years after installation.

The second design, placed in the same section of freeway but in the opposite direction, employs a "permissive use" control during the peak periods only. The section was only 0.9 miles in length and was operational 3 hours per day on weekdays. However, the benefits were similar in magnitude to the first project. Peak period volumes increased by more than 2000 vehicles and travel time savings were calculated to be 785 vehicle hours per day. Accidents during the peak period were reduced by 50 percent while the non peak period accidents were increasing slightly. The cost to install the "permissive" lane was $28,000. The cost of maintenance was considered insignificant because of the low total volume of vehicles that use the lane.

IMPLEMENTATION STATEMENT

The primary purpose of this research project was to determine if a freeway cross section with narrow lanes and limited shoulders can produce travel benefits with safety. This report concludes that modifications of surface geometrics is an effective and safe way to increase capacity.

Several conditions are offered to agencies considering implementation of this solution: the modified section should be as short as possible; the section should be maintained at a level that will provide good lane delineation and rideability; the modification should be considered as a temporary solution to be returned to normal design standards when funds and conditions warrant; finally, some form of emergency parking should be provided in the modified section, if possible.

The "permissive" lane should be implemented if the problems of capacity are confined to short peak periods.

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INTRODUCTION

Faced with increasing traffic demands on urban freeways, the Houston District Office of the Texas State Department of Highways and Public Transportation in 1976 implemented a project on the Southwest Freeway (U.S. 59) to temporarily increase the capacity of a critical bottleneck section in the southbound lanes of the freeway by modifying the surface geometrics to develop an additional lane of travel. The lane widths were reduced and part of the paved shoulder on the right side was incorporated into a travel lane. The additional lane was available for travel 24 hours a day, seven days a week. The results of the modifications were documented in a Research Report 210-2 and proved to be very beneficial to the motorists. [1] The peak hour and peak period volumes were increased and the resultant reduction in travel time was estimated to be in excess of 1000 vehicle hours per day. The accident rates were reduced by 12 percent. The cost of the improvement was low since only a small amount of pavement reconstruction was involved. Additional money for the reconstruction of the shoulder lane in the future was included in determining the annual cost of $38,700 for providing the additional lane for a distance of 2.5 miles.

Despite the very positive results of the study, there was concern that lowering the design standards for lane widths and using shoulders to carry heavy traffic loads would result in increases in traffic accidents and maintenance costs as the traffic demands increased. Therefore, this project has been monitored for seven years to determine the impacts of increasing traffic loads.

An alternative design was implemented in February 1981 on the northbound lanes of the Southwest Freeway which addressed the problems of pavement wear on the shoulder lane and the elimination of shoulders for emergency

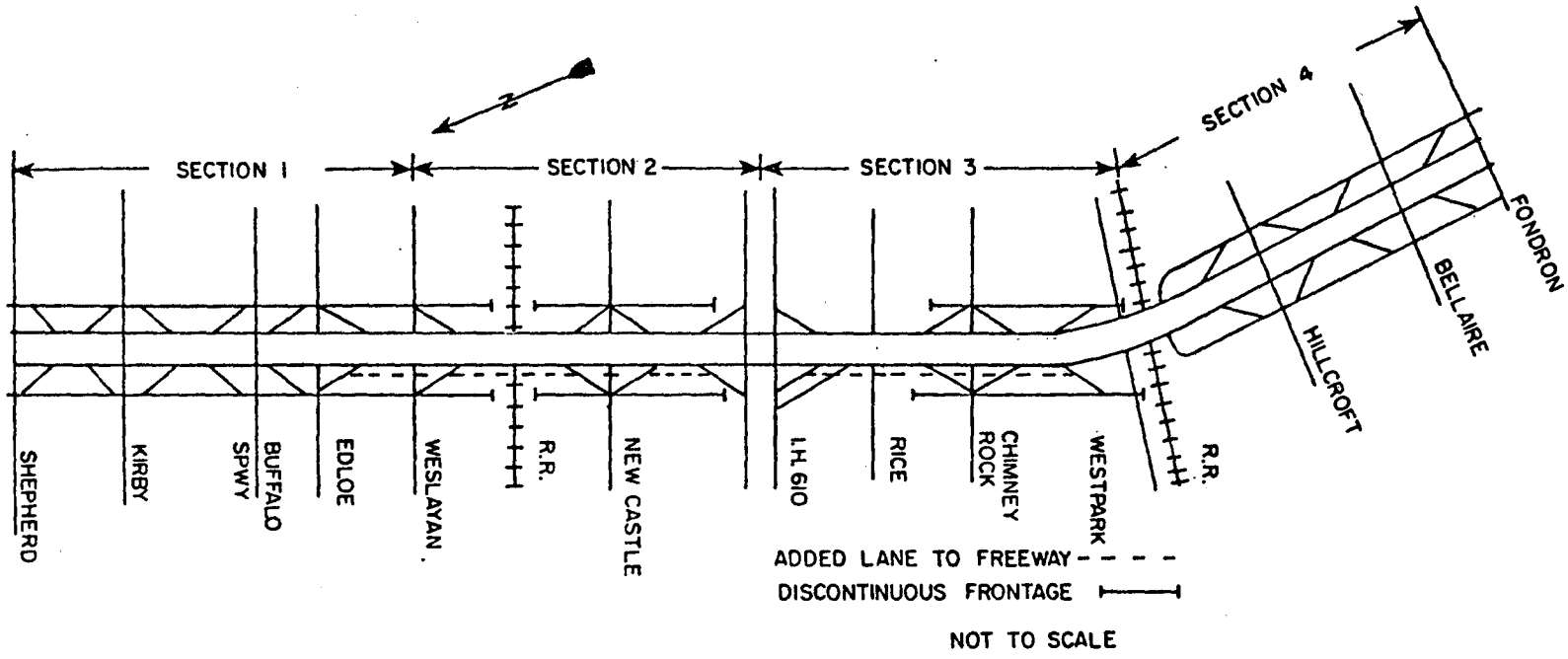
parking. In this design traffic is permitted to use the extra lane only during the morning peak period (6:00 - 9:00 A.M.) on weekdays for travel. The lane is used as a shoulder for the remainder of the time. This design provides the additional capacity when the traffic demands are high, while providing the benefits of the shoulder for parking for the majority of the time. This type of operation reduces the traffic loads on the shoulder lane by over 80 percent which lowers the maintenance requirements.

This report reviews the 7 years of operation of the southbound "Continuous Use" shoulder lane and presents the results of 2 years of operation of the northbound "Permissive Use" shoulder lane on U.S. 59 Southwest Freeway in Houston. Similar projects have been implemented in the nation and the results are documented in a Federal Highway Administration Document. (2)

REVIEW OF "CONTINUOUS USE" SHOULDER LANES

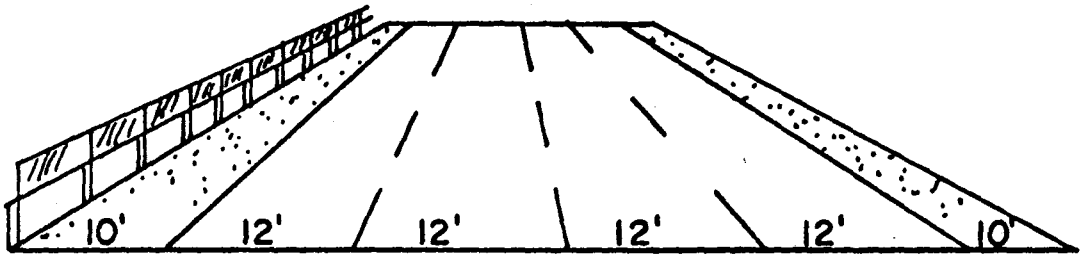
Description of Project

On May 1, 1976 the right shoulder from Weslayan entrance ramp to the I-610 interchange and from the I-610 interchange to the Westpark exit ramp was converted to a 24-hour travel lane (Figure 1). The width of the lanes was reduced to 10.5 feet and a part of the right shoulder was striped as a travel lane (Figure 2 and 3). In August 1978 the shoulder lane was extended to the north to the Edloe entrance ramp to increase the potential for use by traffic using that ramp. Signs were placed in advance of the modified sections to advise motorists that there was no paved shoulder for a specified distance (Figure 4). In the design of the freeway in this section, the width of the shoulder lane was sufficient to permit a disabled vehicle to park partially on the paved shoulder and the outer separation to clear the traveled way, except at overpass structures at the cross streets and the railroad crossing (Figure 5). The pavement in the shoulder from I-610 to Westpark was replaced to improve the strength and rideability. Other modifications consisted of the removal of paint stripes and restriping of the narrow lanes, and placing the static signing in the modified area.

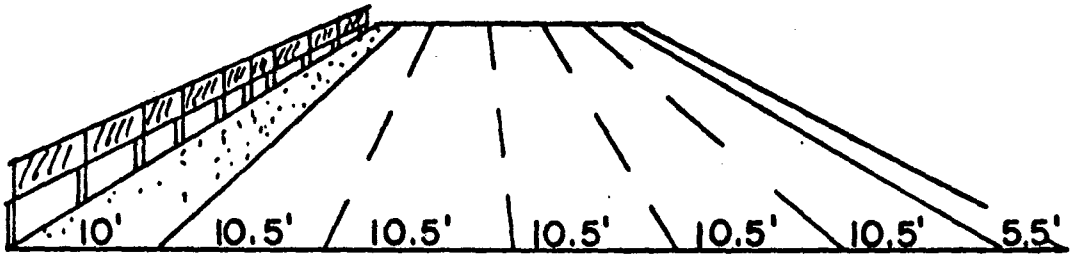


Study Site - Continuous Use Shoulder Lane
U. S. 59 Southwest Freeway - Southbound

Figure 1



BEFORE
(FOUR LANES)

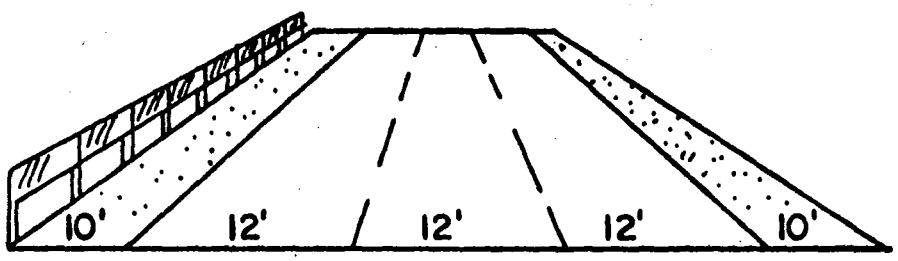


AFTER
(FIVE LANES)

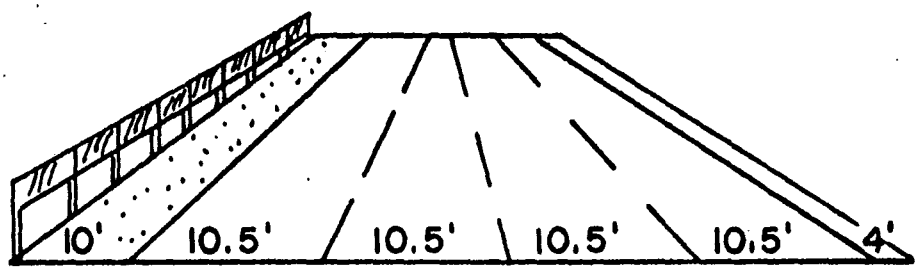
(1 foot = 0.3 metres)

Cross Section Reconfiguration
Four Lanes to Five Lanes

Figure 2



BEFORE
(THREE LANES)

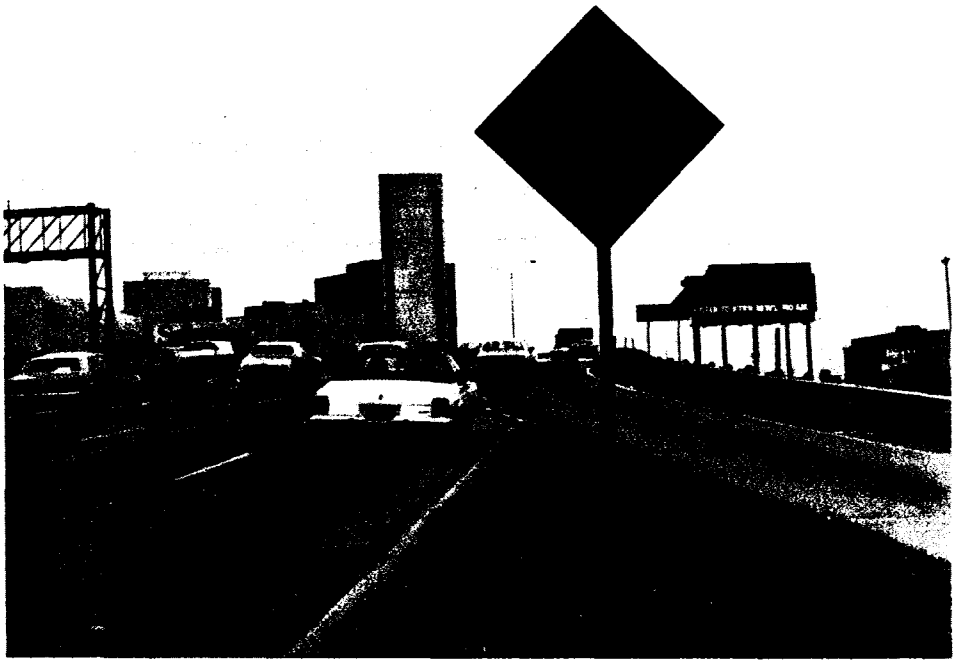


AFTER
(FOUR LANES)

(1 foot = 0.3 metres)

Cross Section Reconfiguration
Three Lanes to Four Lanes

Figure 3



Warning Sign - No Paved Shoulder

Figure 4

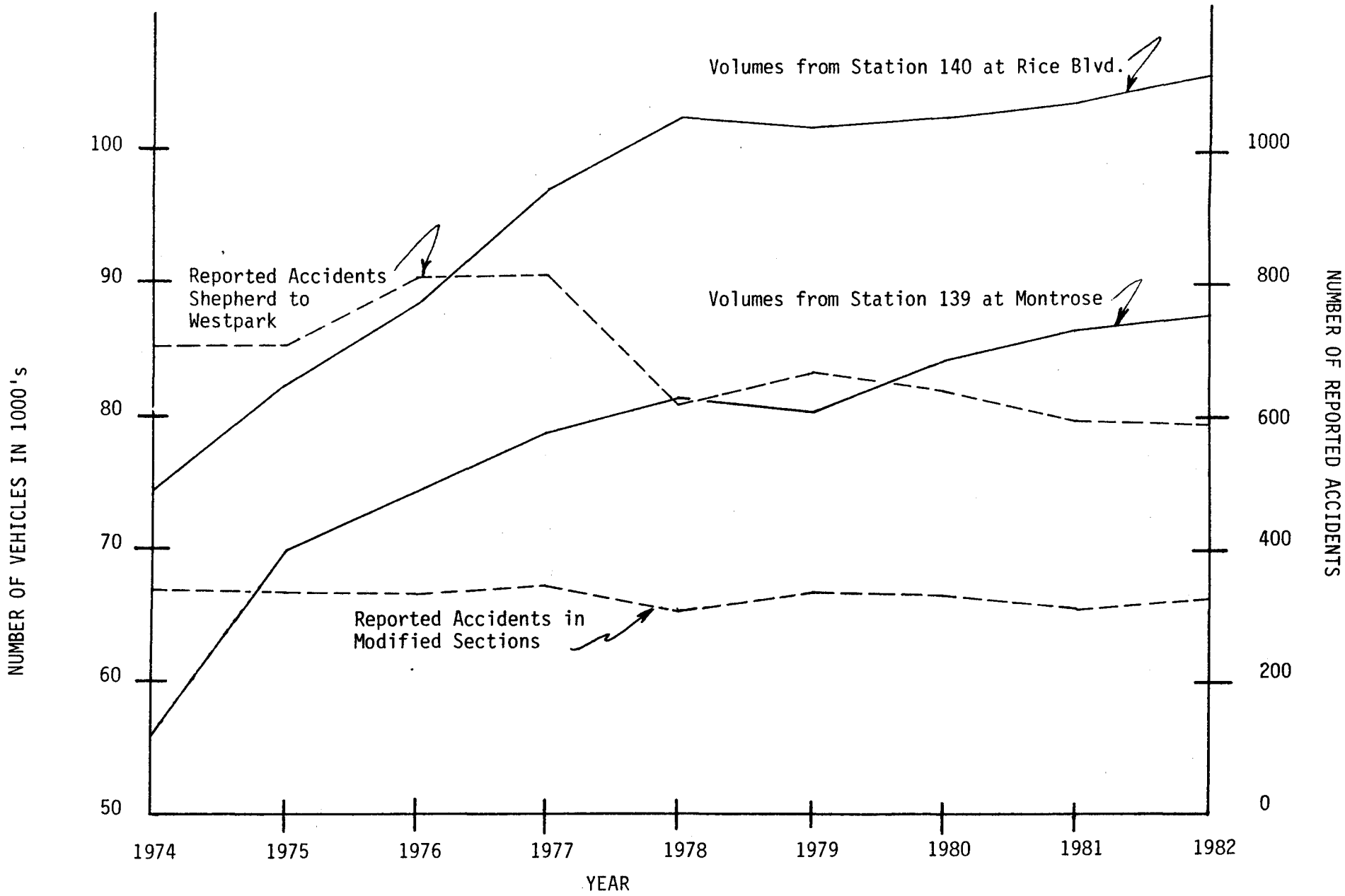
Width of Paved Shoulder Lane

Figure 5

Results of Modifications

Traffic Volumes - Traffic demands for the Southwest Freeway have increased (Figure 6). The average growth rates are 6.4 percent from 1974 to 1978 and 1.6 percent from 1978 to 1982. The usage of the shoulder lane represents the increase in the mainlane "throughput" in the bottleneck section. The study was divided into four sections for analysis (Figure 1). The two modified sections, 2 and 3 have experienced increases in volumes during the seven years (Table 1). In section 2 the volume at Newcastle has increased an average of 15 percent for the two hour peak period and 6.4 percent for the 24-hour period. In section 3 the volume at Rice has not changed during the two-hour peak, reflecting the high usuage that was achieved during the first two years after the restriping. The 24-hour volumes, however have increased an average rate of 4.3 percent.

These results indicate an increasing acceptance of the shoulder lane as a travel lane, even though the lateral clearance, lane width and rideability are less than desirable. The need for the increase in capacity out weighs the quality of the trip - at least for short distances.



Annual Average Daily Volumes and Accident Frequencies
Southbound U.S. 59 Southwest Freeway

Figure 6

Table 1

Usage of the Shoulder Lane
U.S. 59 Southwest Freeway Southbound

Year	Section 2 at Newcastle	Section 3 at Rice
	Peak 2-Hour Volumes	
1976	1,550	2,800
1983	2,950	2,820
	ADT Volumes	
1976	8,155	13,445
1983	11,300	16,930

Accident Experience - The number of reported accidents in the modified sections have remained relatively constant while the number in the overall study area decreased (Figure 6 and Table 2). When expressed as a rate, the accident experience in all sections decrease until 1978 and have remained relatively constant until 1982 (Figure 7 and Table 3).

These data indicate that the small rise in total volumes have not caused a similar rise in accidents. Other factors that influence the analysis of accidents during this time period are the changes in accident reporting requirements. On January 1, 1978, the value of accident damage that required the filing of a report was raised from $50 to $250. On April 1, 1980, the Houston Police Department (HPD) announced that they would not investigate minor accidents, but that motorist must still file a report. On October 1, 1981, the HPD announced that patrol units would clear the roadway of accidents as soon as possible, but minor accidents would still not be investigated.

These factors tend to reduce the number of reported accidents. Therefore, some of the reduction from 1978 must be attributed to the rising percentage of minor accidents not reported.

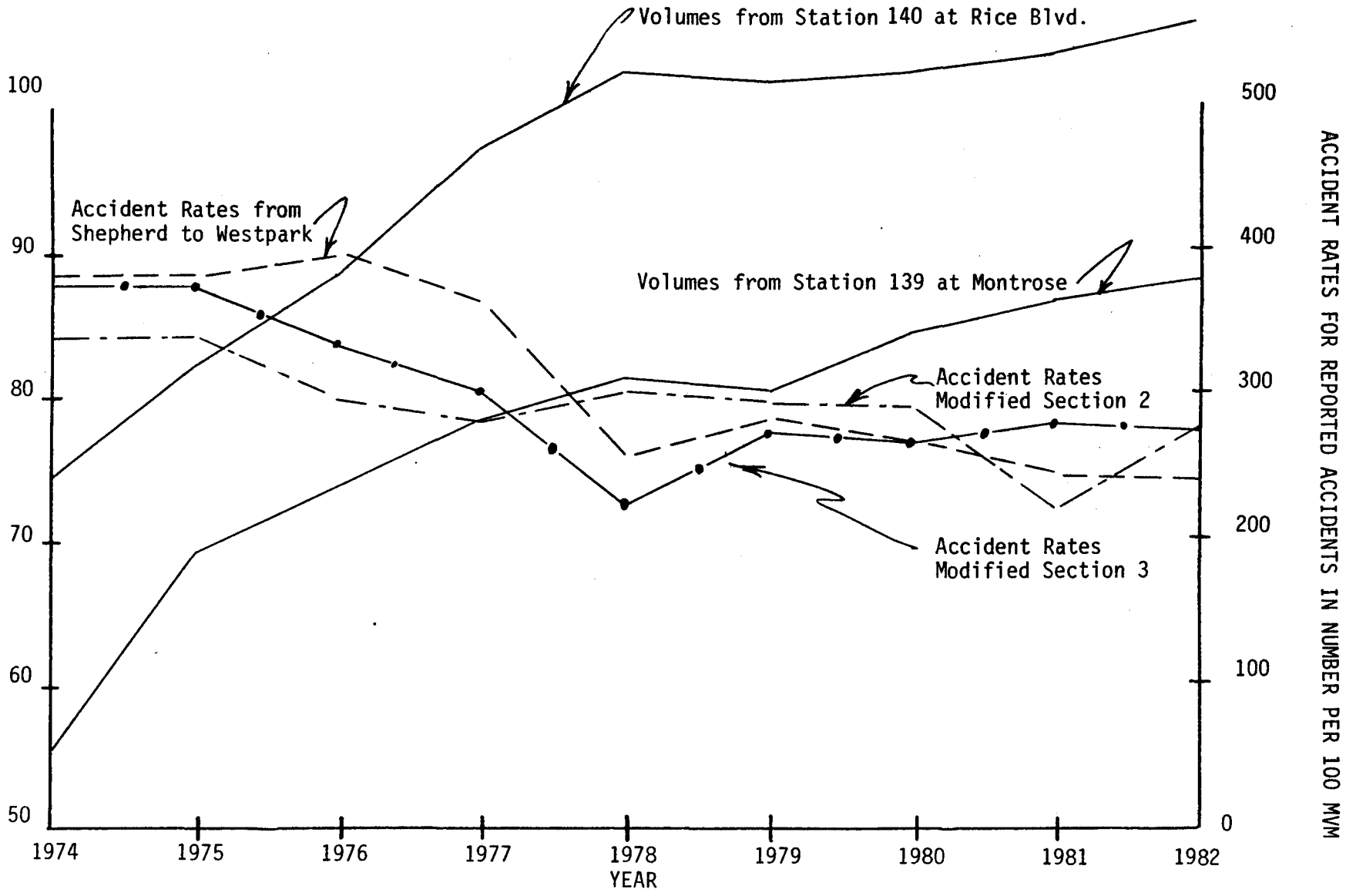
Table 2

Frequency of Reported Accidents

Southwest Freeway - Southbound
Shepherd to Westpark

Total 24-Hour Period

Section	Number of Accidents Per Year							
	Before Restriping	After Restriping						
		1976	1977	1978	1979	1980	1981	1982
1	259	313	259	172	165	168	148	109
2	129	127	156	149	145	143	111	138
3	205	207	190	159	194	190	200	199
4	109	162	213	138	163	142	137	146
TOTAL	702	809	818	618	667	643	596	592



Annual Average Daily Traffic and Accident Rates

Southbound U.S. 59 Southwest Freeway

Figure 7

Table 3

Rates of Reported Accidents

Southwest Freeway - Southbound
Shepherd to Westpark

Total 24-Hour Period

Section	Accidents/100 Million Vehicle Miles							
	Before Restriping	After Restriping						
		1976	1977	1978	1979	1980	1981	1982
1	595	609	476	305	295	286	246	180
2	342	298	282	302	295	291	222	271
3	378	338	303	224	274	268	278	271
4	237	312	373	230	271	237	224	234
AVERAGE	384	397	364	257	283	266	244	240

DISCUSSION OF "PERMISSIVE USE" SHOULDER LANES

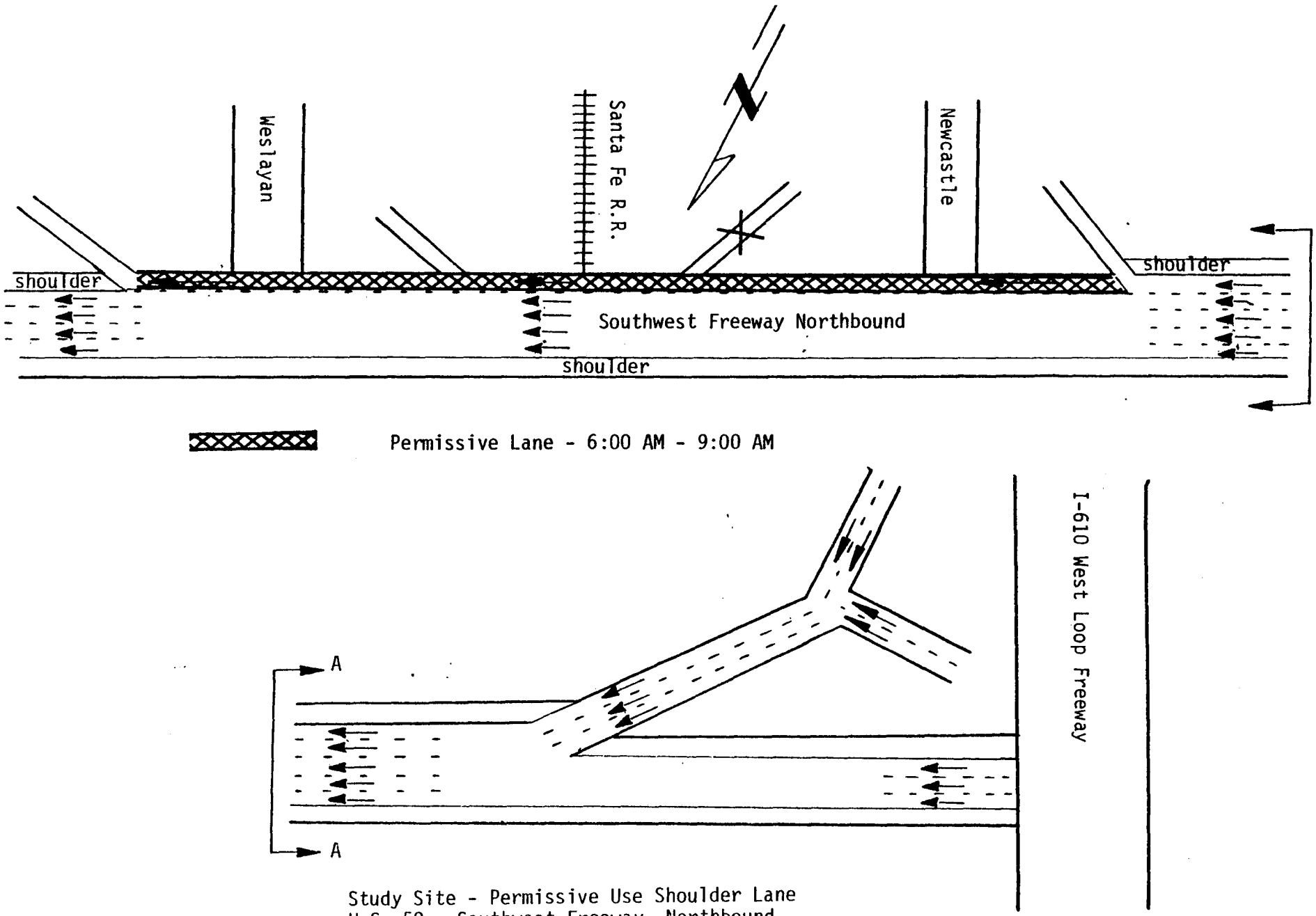
Description of Project

On February 2, 1981 the Houston District Office of the State Department of Highways and Public Transportation (SDHPT) converted the right shoulder to a travel lane during the morning peak period from 6:00 to 9:00 a.m. on weekdays from the Newcastle exit ramp to the Edloe exit ramp on northbound Southwest Freeway, a distance of 0.9 miles (Figure 8). The Newcastle entrance ramp to the northbound Southwest Freeway is closed to traffic during the time of operation by a time clock operated railroad barrier gate (Figure 9). Ramp traffic is diverted along the frontage road or arterial streets to entrance ramps downstream of the Edloe Street interchange. The ramp metering rates on these entrance ramps are adjusted to permit higher volumes of traffic to enter the freeway without delay.

The purpose of the shoulder lane conversion and the ramp closure are to permit greater thruput over the Santa Fe Railroad Crossing on the freeway mainlanes and the frontage road, and to improve traffic operations upstream of the Newcastle entrance ramp.

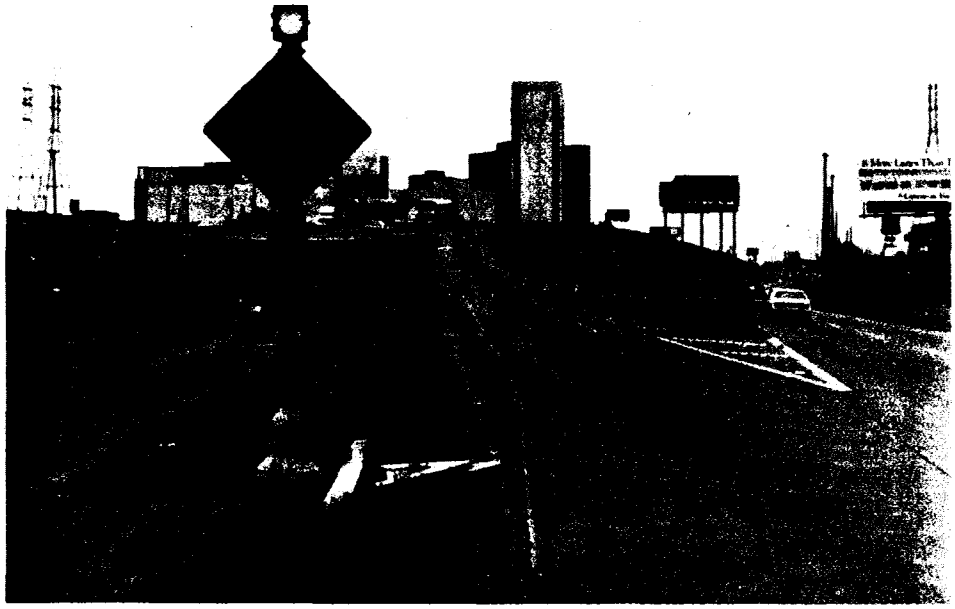
The closure of the Newcastle entrance ramp is critical to the project because of several factors: (Figure 10)

1. The ramp merging area on the upgrade approaching the bridge section is eliminated.
2. The interference at the frontage road and Newcastle intersection, caused by ramp queues at the metered ramp, is eliminated.
3. Over 500 vph are diverted from the freeway bottleneck at the Santa Fe Railroad Overpass to alternate routes.
4. Traffic demands originating upstream of the bottleneck replace the diverted traffic, thus reducing total travel time.



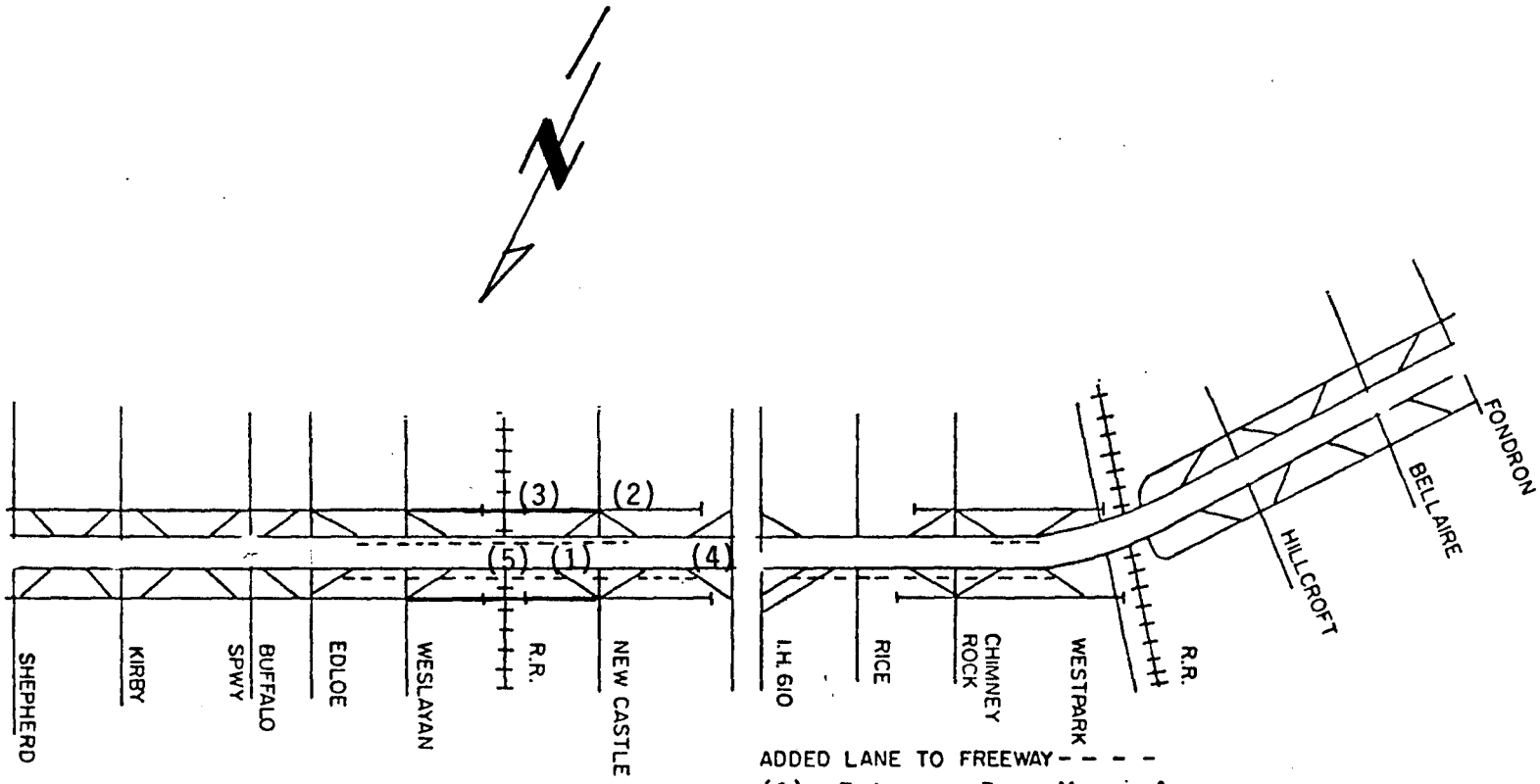
Study Site - Permissive Use Shoulder Lane
U.S. 59 - Southwest Freeway- Northbound

Figure 8



Newcastle Entrance Ramp Barrier Gate

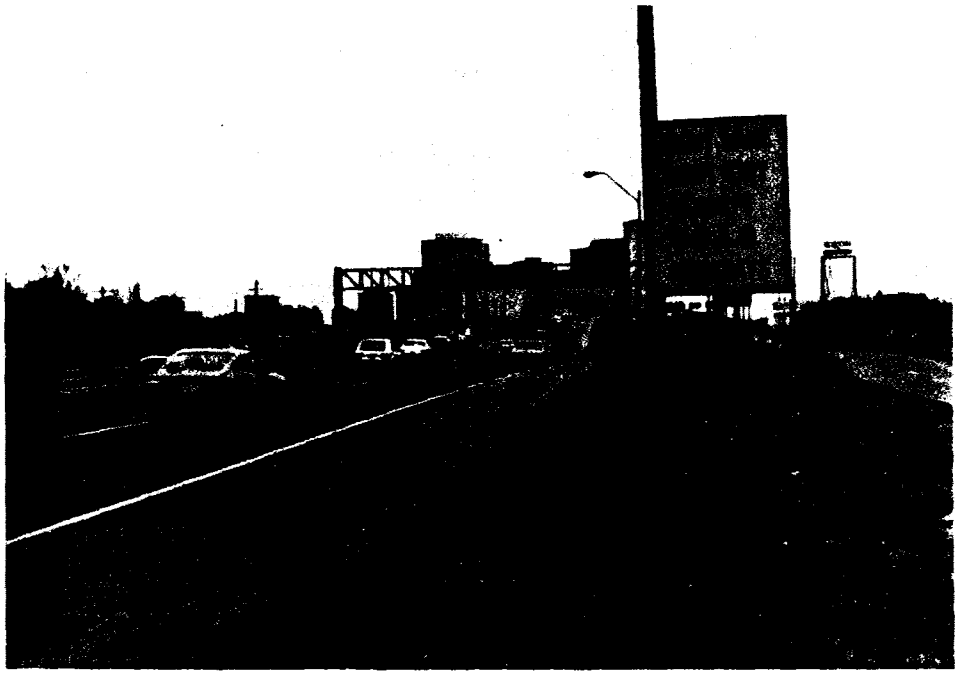
Figure 9



Impact of Newcastle Entrance Ramp Closure

Figure 10

5. Eliminating the entrance ramp merging area permitted the establishment of an additional lane of travel through the bottleneck. The right shoulder is designed as a "permissive" travel lane during the morning peak period only by the use of static roadside signs (Figure 11).



Static Signing for Designating
Use of Permissive Shoulder Lane

Figure 11

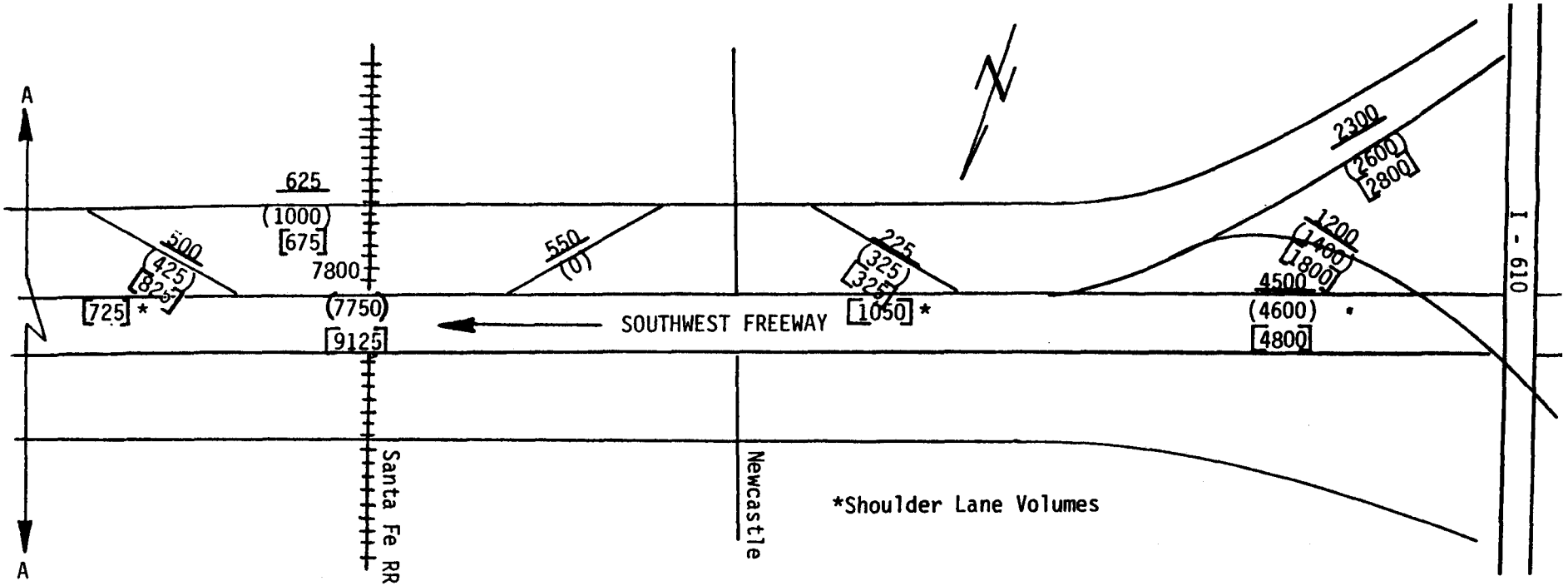
Results of Modifications

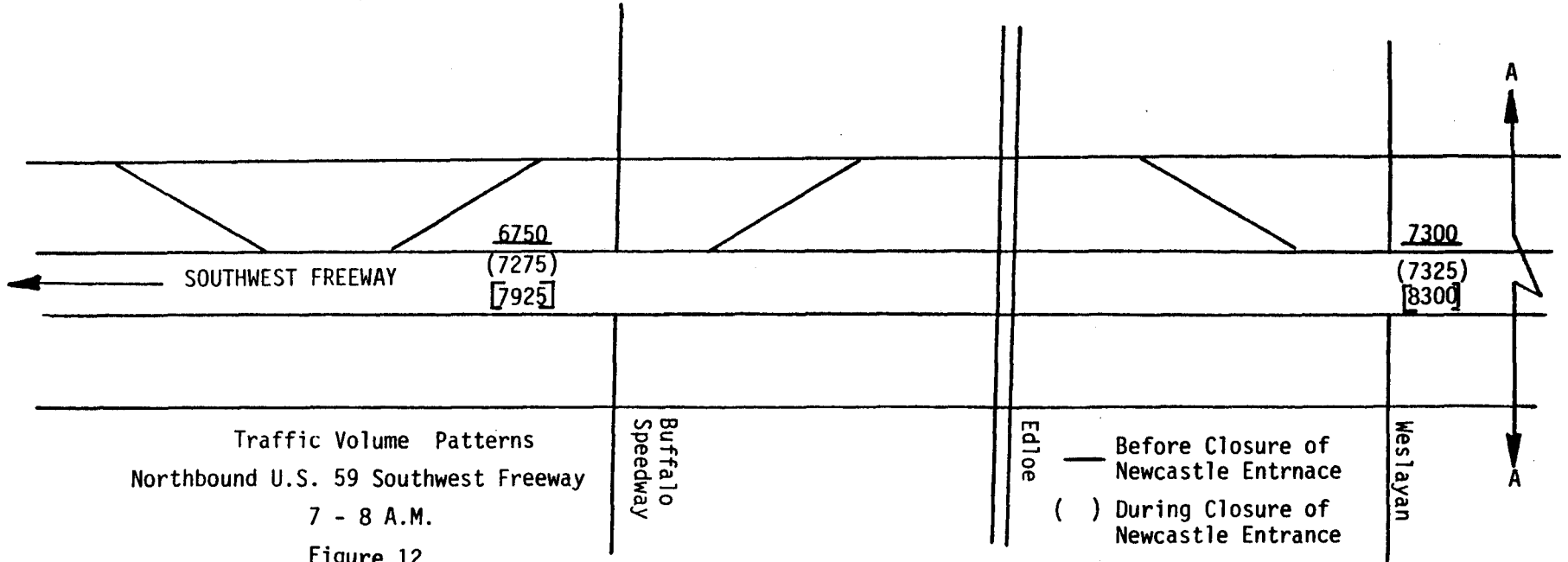
Traffic Volumes - Volume studies were made to study the changes on traffic patterns as a result of the closure of the Newcastle entrance ramp (Figure 12 and 13). Vehicle counts on the ramps and mainlanes of the freeway at Santa Fe railroad overpass indicate that the closure of the Newcastle entrance ramp did not change the freeway hourly volumes. When the permissive lane was established on the freeway shoulder, traffic volumes over the railroad overpass increased by 1300 vph during the peak period, and the traffic flow along the frontage road decreased, indicating that the Newcastle entrance ramp traffic used other alternate routes to the freeway. The total volume over Santa Fe railroad crossing has increased by 1375 vph during the peak hour and 2,800 vehicles during the 2-hour peak period as a result of the modifications.

Shoulder Lane Usuage and Violations - The usage of the converted shoulder lane was increased as total traffic demands increased and drivers became accustomed to the operations (Table 4). These data indicate that the lane is operating at approximately 60 percent capacity.

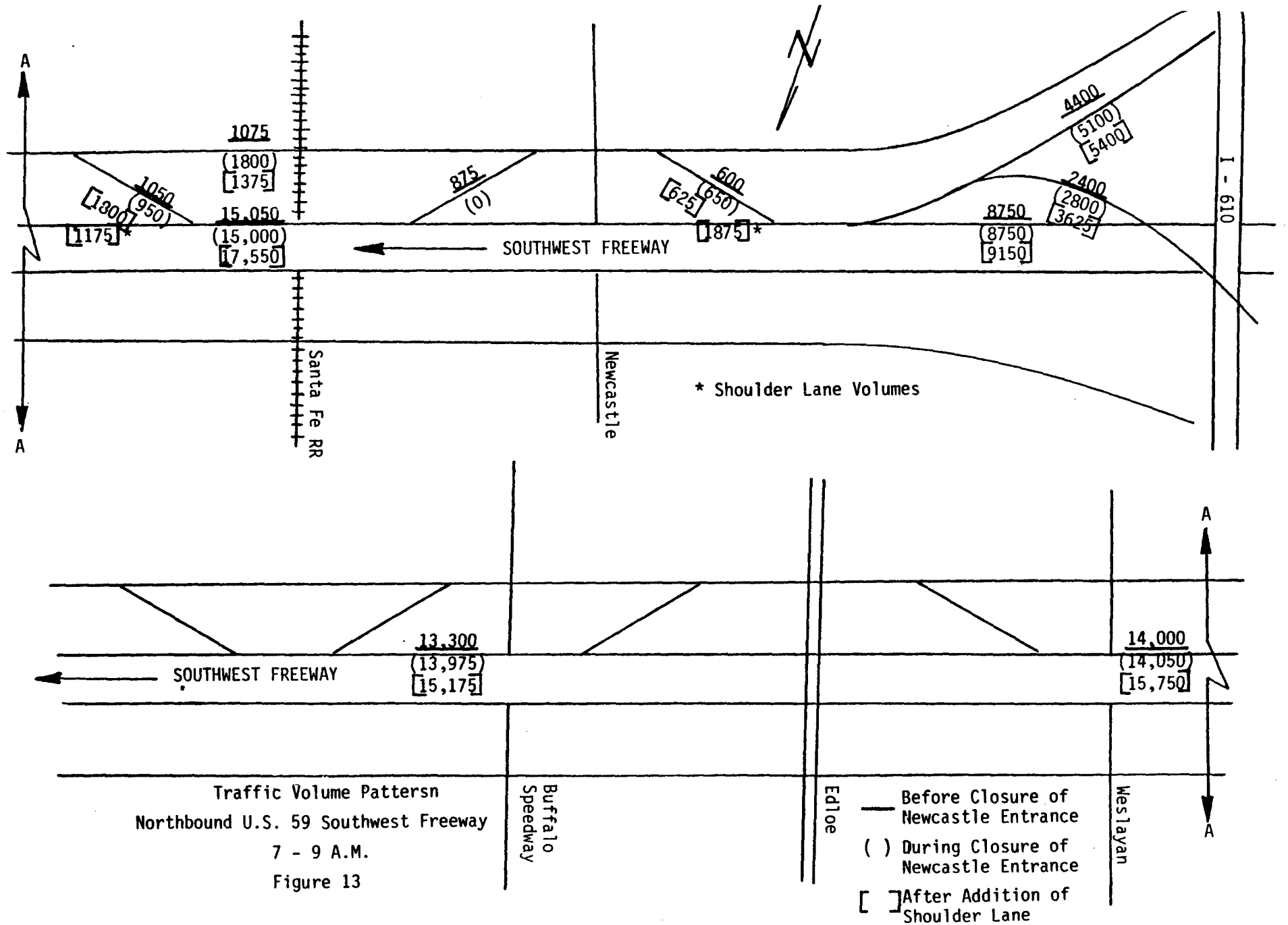
Violations of the permissive lane time limits were 4 percent of the total traffic that used the shoulder lane. No special traffic enforcement has been applied to this operation, and no safety problems have been observed.

Accident Experience - The frequency of reported accidents for the freeway section I.H. 610 to Weslayan, a distance of 1.6 miles, was determined for the morning peak period of 6 to 9 a.m. on weekdays when the shoulder lane was operational (Table 5). The results indicated a reduction in numbers of accidents of approximately 50 percent during the two years after the installation of the permissive lane and a reduction in the accident rate of 57 percent.





Traffic Volume Patterns
Northbound U.S. 59 Southwest Freeway
7 - 8 A.M.
Figure 12



Traffic Volume Patternsn
Northbound U.S. 59 Southwest Freeway
7 - 9 A.M.
Figure 13

Table 4

Use of Permissive Lane

From Newcastle Exit to Edloe Exit

Northbound U.S. 59 Southwest Freeway

Location of Counts	6 - 9 A.M.	Peak Hour	Violations 5 - 6 A.M. and 9 - 10 A.M.
Newcastle Exit to Weslayan Exit			
March 1981	1673	754	13
March 1983	2525	1058	116
Weslayan Exit to Edloe Exit			
March 1981	1792	733	19
March 1983	1920	1022	77

Table 5

Accident Frequency and Accident Rates

From I-610 to Weslayan Interchange (1.6 Miles)

Northbound U.S. 59 Southwest Freeway

6:00 A.M. - 9:00 A.M. Weekdays

(3 Hours - Peak Period Only)

	Two Years Before 1979 - 1980	Two Years After 1981 - 1982	Percent Change
Frequency in Number of Accidents	58	29	- 50
Rate in Accidents/100 Million Veh Miles	441	189	- 57

An analysis was conducted for the same 4-year period, with accident records for the non peak period, that is, the 21 hours from 9:00 am to 6:00 am for 7 days a week (Table 6). The frequency of accidents fell only 2 percent and the accident rate by 5 percent.

These results indicate that the safety of the modified freeway section is improved by the addition of the shoulder lane during the peak period.

Table 6

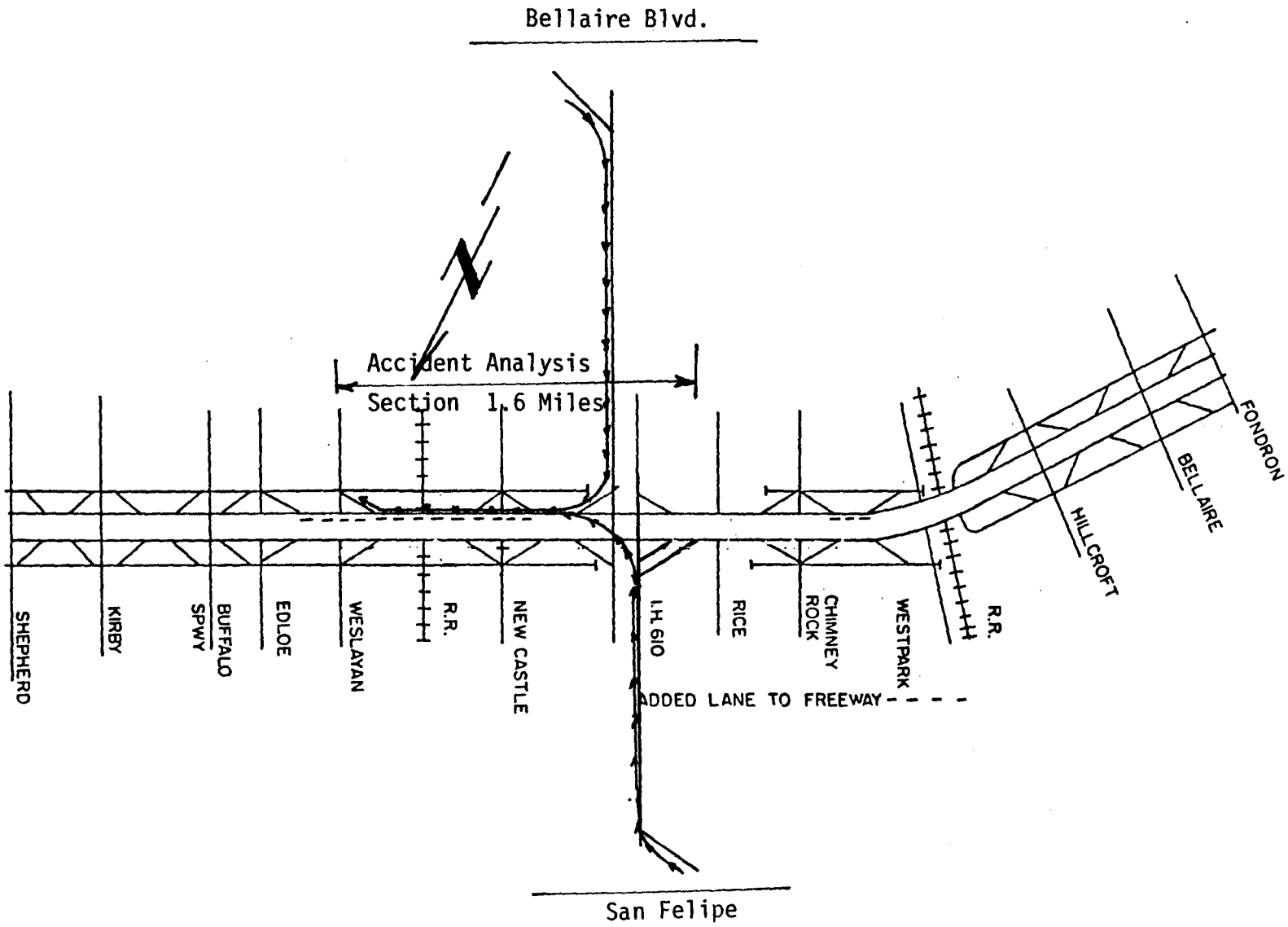
Accident Frequency and Accident Rates
From I-610 to Weslayan Interchange (1.6 Miles)
Northbound U.S. 59 Southwest Freeway
9:00 A.M. - 6:00 A.M. Daily
(21 Hours - Off Peak Period)

	Two Years Before 1979 - 1980	Two Years After 1981 - 1982	Percent Change
Frequency in Number of Accidents	307	301	- 2
Rate in Accidents/100 Million Veh Miles	314	299	- 5

Travel Time Studies - The addition of the permissive lane provides major benefits to the traffic interchanging from I-610 to U.S. 59 northbound. Travel runs were made on the I-610 approaches to a point adjacent to the Weslayan exit ramp, a distance of 2.4 miles for the northbound I-610 traffic and 2.3 miles for the southbound I-610 traffic (Figure 14). The average speeds are 45 mph on the approaches with no traffic congestion, but a 40 mph speed is used in the analysis as the basis for the calculation of delay.

Figures 15 and 16 indicate the travel times on the two I-610 approaches to U.S. 59 before and after the installation of the permissive lane. Travel times in excess of the 40 mph speed level, were multiplied by the ramp volumes to calculate total delay (Table 7), and the average delay vehicle (Table 8). The results indicate a daily reduction in delay of 385 vehicle hours while accommodating 1646 additional vehicles during the two-hour peak period each weekday. The small delay measured on the northbound approach after the modifications was due primarily to the weaving volumes between Bellaire and I-610 interchange. There were no speed reductions encountered on the permissive lane, or on the U.S. 59 mainlanes adjacent to the permissive lane.

Traffic operations on the mainlanes of the Southwest Freeway upstream of the I-610 interchange were also improved by the modifications. The two-hour peak period volume through the interchange was increased by 400 vehicles, which resulted in travel time reductions of 400 vehicle hours per day, and the average savings per vehicle 2.6 minutes. The traffic diverted from the Newcastle entrance ramp by the ramp closure has several alternate routes. For the first few weeks, most traffic used the southbound frontage road to approach downstream entrance ramps. However, traffic counts taken two years after the ramp closure was started, indicate that other routes on arterial streets such as Westpark and Richmond are now being used. This shift to other routes indicates that shorter travel times were available. The increase in total delay to the diverted traffic



Study Sites for I-610 EntranceRamp
Travel Time Analyses

Figure 14

Table 7

Total Travel Delay on I-610 Entrance Ramps
to U.S. 59 Southwest Freeway N.B.
7 - 9 A.M.

	Before (Vehicle Hours)	After (Vehicle Hours)	Difference* (Vehicle Hours)
I-610 NB Approach	315	42	- 273
I-610 SB Approach	112	0	- 112
TOTAL	427	42	- 385

* Negative differences represents savings in travel time to the motorists.

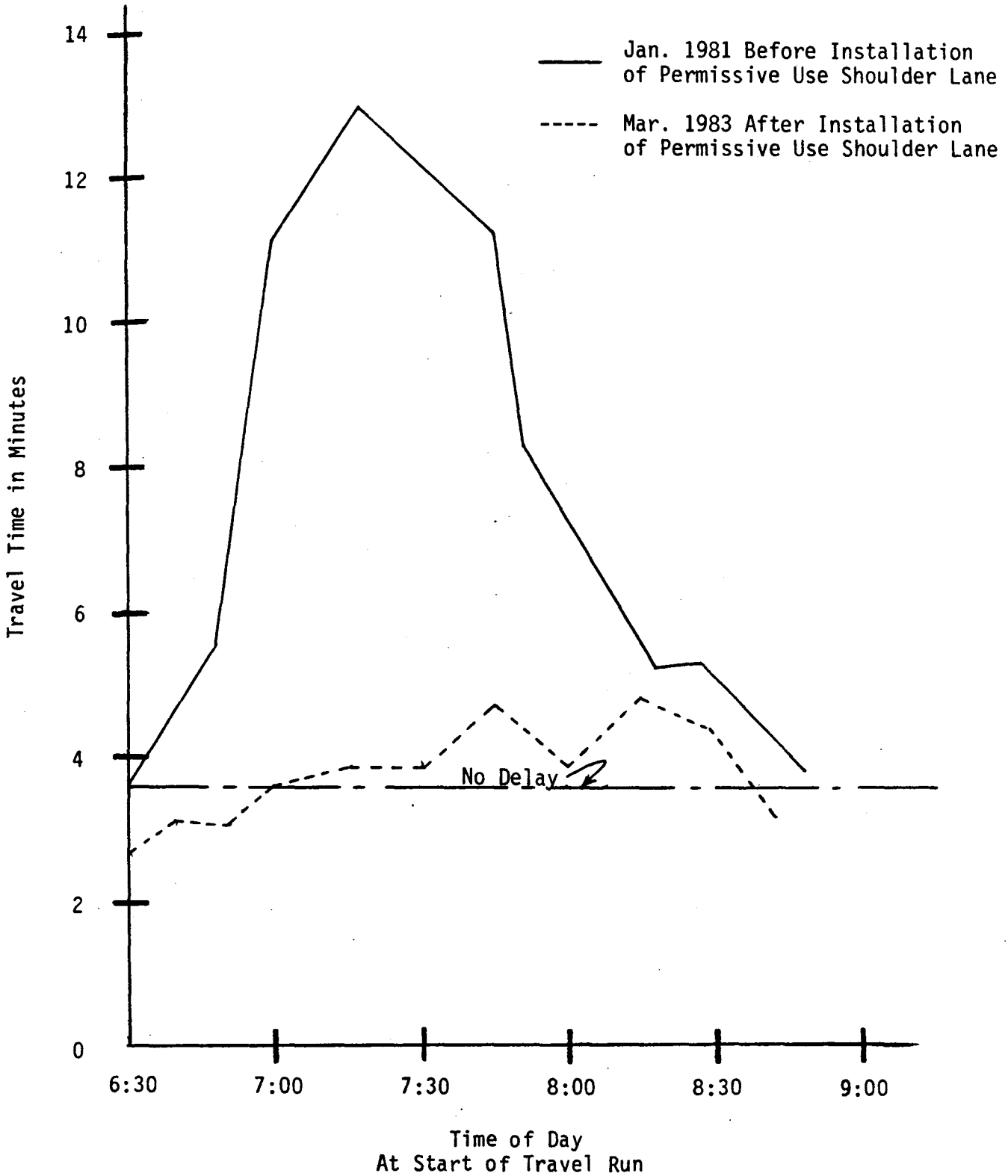
Table 8

Average Vehicle Delay on I-610 Entrance Ramps
to U.S. 59 Southwest Freeway N.B.
7 - 9 A.M.

	Before		After		Difference *	
	2-Hr. Volume (Veh)	Average Delay (Min/Veh)	2-Hr. Volume (Veh)	Average Delay (Min/Veh)	2-Hr. Volume (Veh)	Average Delay (Min/Veh)
-610 NB Approach	4400	4.30	5365	0.47	+ 965	- 3.83
-610 SB Approach	2880	2.33	3561	0	+ 691	- 2.33
OTAL	7280	3.52	8926	0.28	+1646	- 3.24

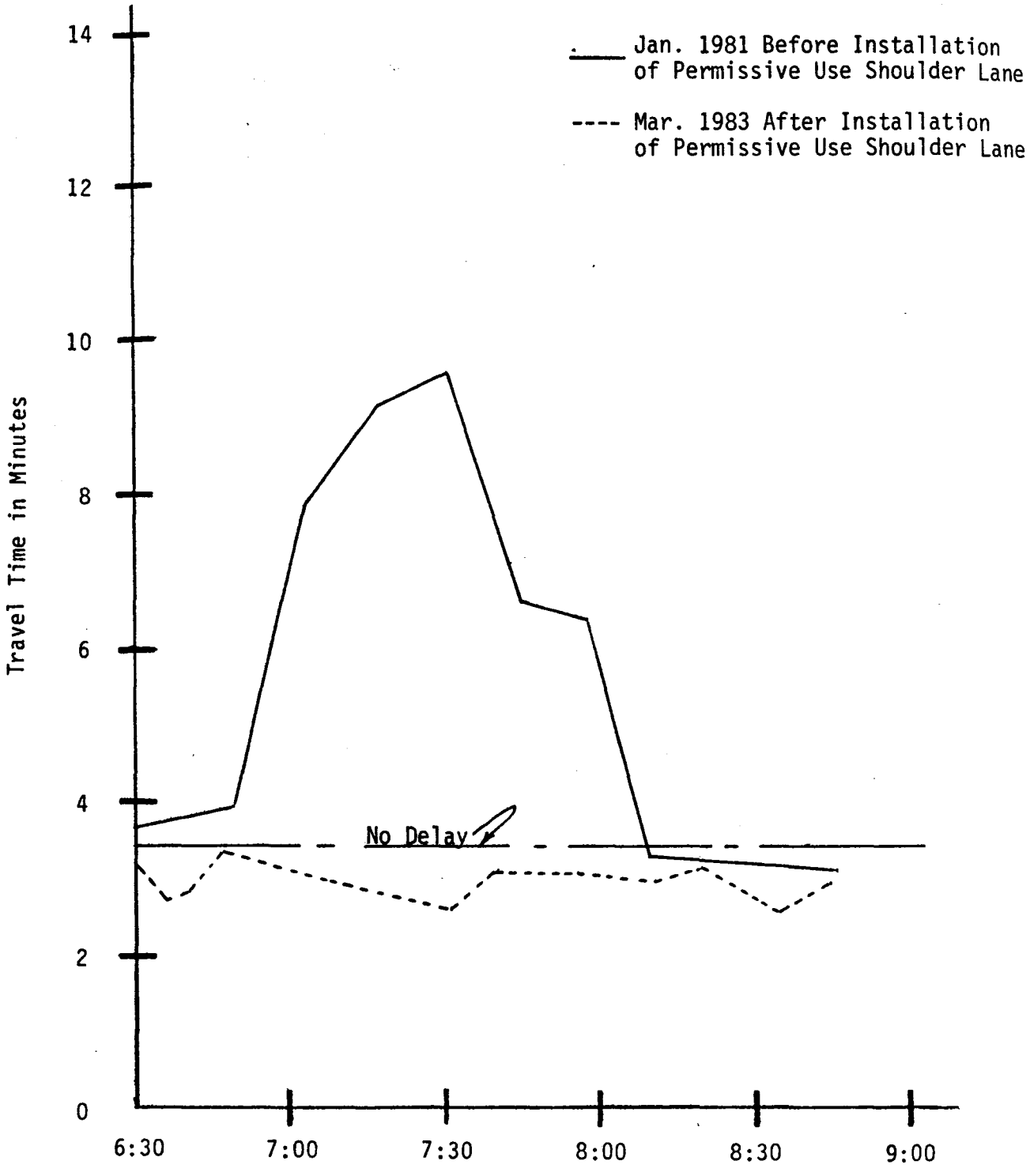
* Negative difference represent savings in travel time to the motorist.

when using the frontage roads is not significant because the ramp traffic was encountering delays of one to two minutes at the ramp metering signal at Newcastle entrance ramp when it was open.



Travel Times For I - 610 Northbound Entrance Ramp Traffic

Figure 15



Travel Times for I - 610 Southbound Entrance Ramp Traffic

Figure 16

Benefits-Costs - The closure of the Newcastle entrance ramp and the conversion of the shoulder for travel during the morning peak period was highly cost effective to traffic using the Southwest Freeway corridor. Approximately 785 vehicle hours of travel time are saved each weekday. Using $7.80 per person-hour for the 1982 estimate of the value of time, an annual costs savings of $2 million can be credited to the project that cost 26,000 to implement. There are other savings, such as the cost of accidents and vehicle operating costs, but these are insignificant compared to time. There are also other savings to traffic on the I-610 mainlane not destined for the Southwest Freeway. The reduction of queues on the approached to the Southwest Freeway have been eliminated or substantially reduced.

Because of the low volumes using the lane; no costs for maintenance are included in the analysis. The calculated loads on the shoulder lane are 500,00 vehicle miles per year, with the volume of trucks less the 0.5 percent.

CONCLUSIONS

The use of paved shoulders on urban freeways for travel is an effective and inexpensive method of increasing capacity in critical bottleneck sections. Accident experiences have not increased as a result of the reduction in lane widths, elimination or reduction of shoulders for parking and the reduction of lateral clearances.

Average speeds have increased and total travel times have decreased on the freeways that have implemented shoulder lanes.

The use of the "Permissive" shoulder lane has the advantage of reducing the maintenance requirements. However, the placement of a strong pavement in the shoulder prior to its conversion for travel, either continuously or by specified time periods, is advisable.

The implementation of shoulder lanes should be limited to short bottleneck sections.

The shoulder lane should be fully replaced by a normal lane with full pavement strength as soon as practical. Lane widths should be increased a minimum of 11 feet and lateral obstructions clearances increased as much as possible up to six feet.

REFERENCES

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3. Texas Department of Highways and Public Transportation, Programmer's Supplement to Highway Economic Evaluation Model, Austin, Texas June 1976.