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16. Abstract

This report presents an evaluation of the need for priority treatment for high-occupancy vehicles on the North PanAm Freeway (I-35) in San Antonio, Texas. The study addresses an 8.5 mile section of roadway from the Fratt Interchange to the interchange of I-35 and I-37. Applicable priority treatments and the effectiveness of those treatments to the year 2000 were identified.

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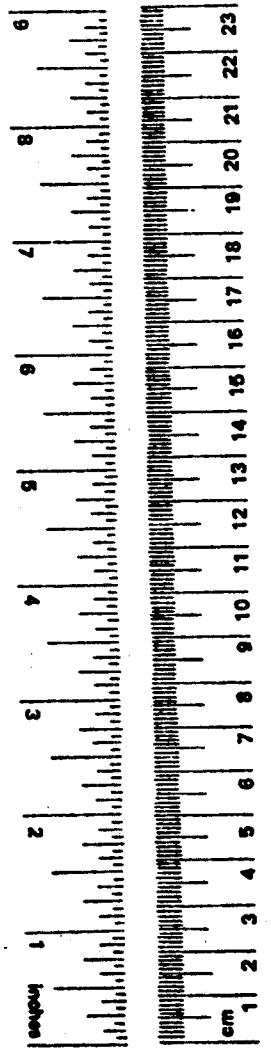
METRIC CONVERSION FACTORS

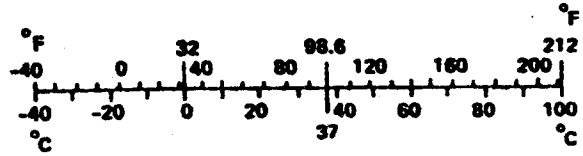
Approximate Conversions to Metric Measures

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	0.96	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



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



* 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.

PRIORITY TREATMENT FOR HIGH-OCCUPANCY VEHICLES ON THE NORTH PANAM FREEWAY, SAN ANTONIO

A Feasibility Study

by

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Research Report 205-12

Priority Use of Transportation Facilities

Research Study Number 2-10-74-205

Sponsored by

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Texas Transportation Institute
The Texas A&M University System
College Station, Texas 77843

July 1980

ABSTRACT

This report presents an evaluation of the need for priority treatment for high-occupancy vehicles on the North PanAm Freeway (I-35) in San Antonio, Texas. The study addresses an 8.5 mile section of roadway from the Fratt Interchange to the interchange of I-35 and I-37. Applicable priority treatments and the effectiveness of those treatments to the year 2000 were identified.

Key Words: Priority Treatment, High-Occupancy Vehicles, Priority Entry, Exclusive Busways

SUMMARY

This study evaluates the need for priority treatment for high-occupancy vehicles on the North PanAm Freeway in San Antonio. Given present operating conditions, a need for priority measures does not exist.

By the mid-1980's, a need for low-cost, short implementation time alternatives is anticipated. Priority entry for buses and carpools appears to represent the preferred action. The suggested approach, which involves ramp metering and providing bypass opportunities at 4 ramp locations, would cost approximately $200,000 and require 6 months to implement.

Once the freeway begins operating at level-of-service E (projected to occur in the mid-1990's), a one-lane, median, high-occupancy vehicle lane may be effective. Such a lane would be used by buses and carpools. This priority measure will provide increased travel speed, reduced travel time, improved schedule reliability, and increased capacity. As part of a major freeway reconstruction, such a lane could be incorporated into the existing 6-lane cross section with minimal problems. If the cross section is expanded to 8 lanes, more serious design and construction problems are encountered. The one-lane median facility would cost approximately $17 million to implement and require 5 to 10 years to become operational.

Due to the implementation times associated with the priority improvements and the projected times until those improvements are needed, the Department does not need to take any immediate actions. This report documents what improvements may be needed, but sufficient time exists to allow the Department to wait to see if the need does, indeed, develop. If so, to the extent possible, provision of the HOV priority measures should be undertaken in conjunction with other improvements planned by the Department for the North PanAm Freeway.

IMPLEMENTATION STATEMENT

The intent of Project 205 has been to assist the Department in planning and implementing priority treatment on roadways in Texas. Historically, priority treatment has been considered as an alternative after the traffic situation has already become critical. The question then becomes what is there that can be done as quickly as possible.

In the North PanAm corridor, the situation is not yet critical. The opportunity exists to identify what improvements might be needed and at what point in time those improvements may be needed. With that information, high-occupancy vehicle improvements can be planned for, and coordinated with, other improvement planned by the Department. This report is intended to assist District 15 in that planning process.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the opinions, findings, and conclusions 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.

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INTRODUCTION

Since the inception of this project in 1974, the primary intent has been to assist the State Department of Highways and Public Transportation in planning for and implementing priority treatments for high-occupancy vehicles on roadways in Texas. As part of this assistance, the Institute has begun to perform feasibility studies concerning high-occupancy vehicle treatments for specific urban freeways in Texas.

The Project 205 Committee, comprised of 6 District Engineers and 3 Division Heads, has assisted the Institute in selecting the specific facilities to be evaluated. This feasibility study, which addresses the North PanAm Freeway (Interstate 35) in San Antonio, is the second of a series of such studies to be undertaken by Texas Transportation Institute. Figures 1 and 2 identify the North PanAm corridor study area. Throughout most of the 8.5 mile intensive study area, which extends from the San Antonio central business district (the interchange of I-35 with I-37) to the Fratt Interchange (the interchange of I-35N with I-410N), the North PanAm Freeway is a 6-lane (3 lanes in each direction) facility.

The intent of the feasibility studies is to evaluate what priority treatments, if any, should be considered for the time and funding levels listed below.

- Immediate implementation, low cost. Priority measures such as signal preemption and priority entry for high-occupancy vehicles are representative of this type of improvement.
- Moderate implementation time, moderate cost. Priority measures in this category would include contraflow lanes and one-lane median busways.
- Long implementation time, very high cost. Multilane HOV facilities would be representative of this type of improvement.

Each of these time and funding levels is considered in this research report.

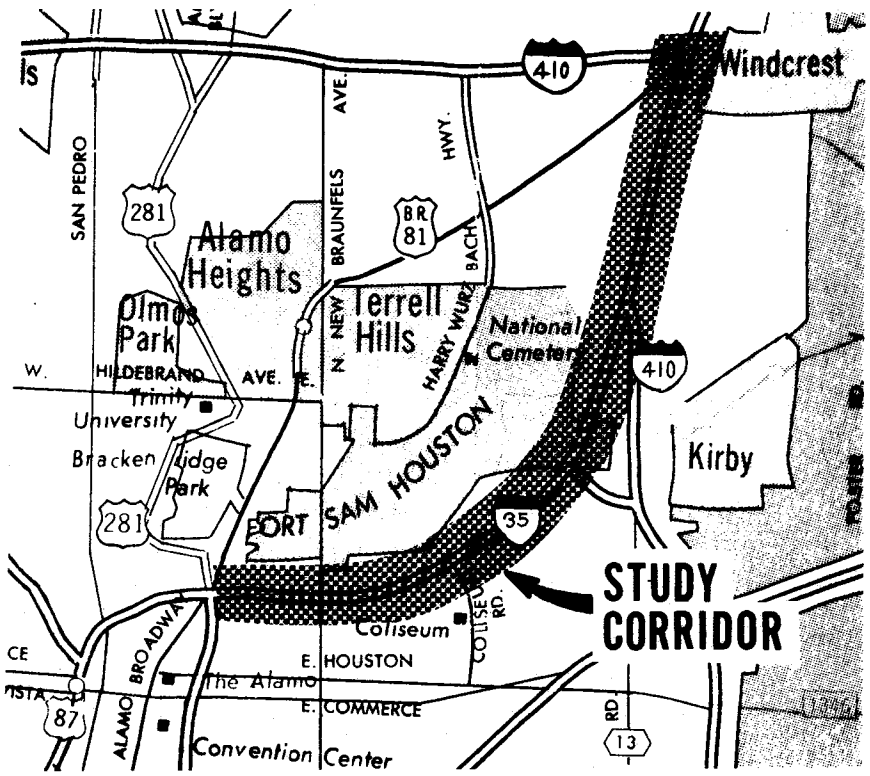

Figure 1: General Location of North PanAm Freeway Study Corridor

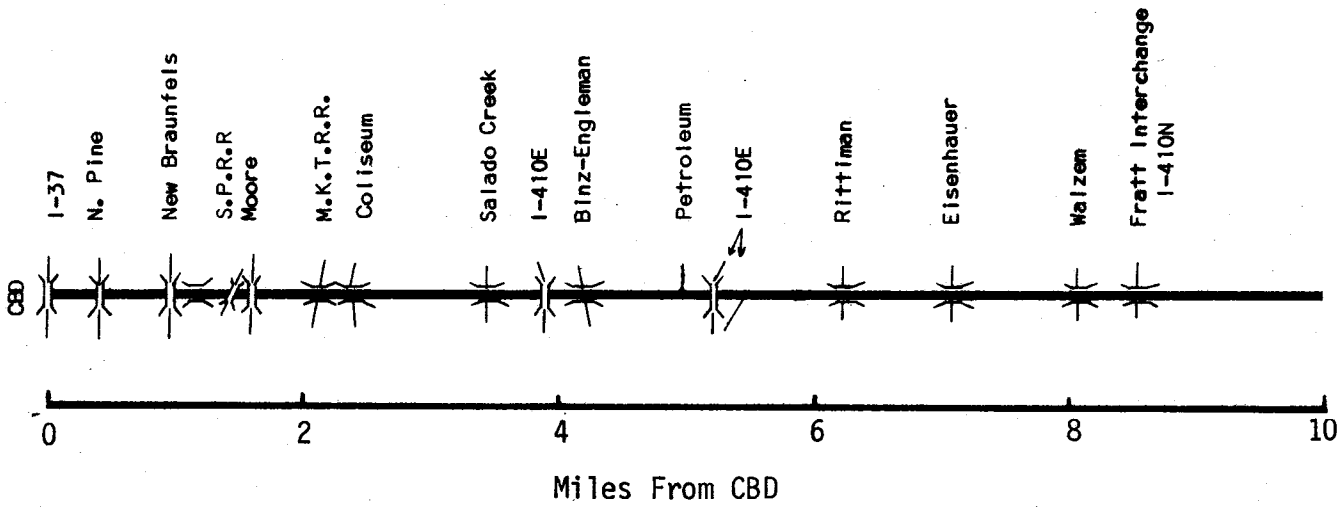

Figure 2: North PanAm Study Corridor and Major Intersecting Roadways

In addition to this introductory section, this report is presented in 5 sections. The initial section defines the extent and characteristics of both existing and projected traffic congestion in the Interstate 35 study corridor, and the implications this traffic congestion has concerning priority treatment. The second section reviews available priority treatments and identifies those that appear applicable, based on physical design and traffic operating patterns, for implementation in the study corridor. The third section identifies the number of high-occupancy vehicles that can be expected to use the priority treatment. The fourth section presents conceptual designs for the improvements; cross sections and renderings of both existing and possible future conditions are presented. The final section presents the major study findings and recommendations.

TRAFFIC CONSIDERATIONS

The North PanAm Freeway (I-35) is a major interstate highway serving travel demands from northeast San Antonio, which is growing rapidly, to the San Antonio central business district (CBD). Some travel demands to Fort Sam Houston also are served by I-35.

Daily traffic volumes in the study corridor, as shown on the 1978 State of Texas Traffic Map, vary from approximately 65,000 to 75,000. Travel demands in this corridor do not presently make it one of the more congested freeways in Texas. A recent report (Research Report 205-7) developed preliminary congestion indices for 19 radial freeways in Texas. Two separate indices were developed; of the 19 freeways studied, the North PanAm was rated as the 14th and the 16th most congested freeway in the state using those two indices. At this time, the traffic problems in the study corridor are not critical.

However, intensive study of this corridor is warranted for two reasons. First, a substantial lead time exists between the time a roadway improvement need is identified and the time at which that need becomes operational. Approximately 5 years were required to implement the contraflow lane on I-45N in Houston, and it is anticipated that at least 5 years will be required to implement the median busway on the Gulf Freeway in Houston. Thus, if there is reason to believe that a need for priority treatment may develop in the future, it is appropriate at this time to identify what those needs might be. And, second, there is reason to suspect that traffic problems in the study corridor are becoming worse at a rapidly increasing rate. For each of the 19 freeways evaluated in Research Report 205-7, the increase in daily traffic volumes per lane from 1972 to 1977 was determined; the 40 percent increase experienced on the North PanAm Freeway was the third greatest increase identified in the

state. This type of an increase in traffic volume is generally accompanied by an increase in public awareness of, and concern for, traffic problems and improvement needs.

Traffic Volumes

Historical and projected traffic volumes in the study corridor are shown in Figure 3.[1] At present, 70,000 represents a "typical" average daily traffic value. Assuming a 10 percent peak-hour factor and a 60/40 peak-hour directional split, this corresponds to a peak-hour, peak-direction flow rate of 4200 vehicles. Such a volume on a 6-lane freeway represents a freeway operation of approximately level-of-service (LOS) C.[2] Operating speeds in the range of 45 to 50 mph would be expected to characterize a freeway operating at LOS C; as shown subsequently, those speeds are representative of peak-hour travel on the North PanAm Freeway.

Traffic growth rates, both historical and projected, are relatively large. From 1970 to 1978, annual increases in traffic volumes of approximately 9 percent were recorded on I-35. Between 1980 and 2000, annual increases of between 1.6 percent and 4 percent are being projected. Daily traffic volumes in the range of 150,000 to 160,000 are projected to occur in the year 2000 along the North PanAm Freeway.

Previous research reports (Research Reports 205-8 and 205-10) have suggested that, as long as peak-period travel speeds in the vicinity of 45 mph

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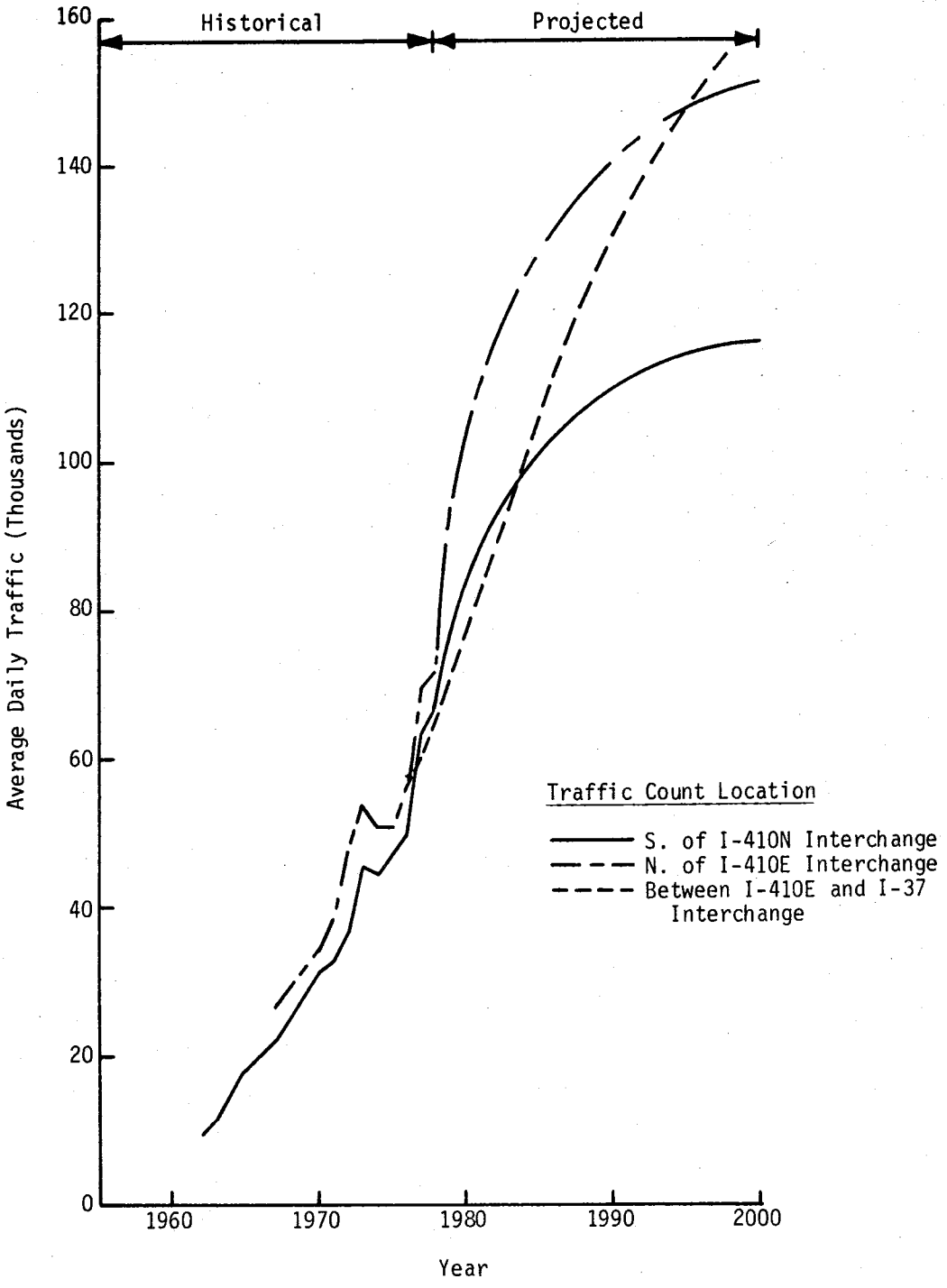
[1]There is no permanent count station located in the study corridor. Estimates of hourly flow rates in the study corridor are developed using daily traffic volumes and adjusting those volumes using factors obtained from permanent count stations on other San Antonio freeways.
[2]From Table 9.1, page 252, Highway Capacity Manual.



Source: State Department of Highways and Public Transportation

Figure 3: Historical and Projected Average Daily Traffic Volumes, North PanAm Freeway

exist, little benefit can be gained from priority treatment (unless such treatment would noticeably increase schedule reliability). Thus, at this time, there does not appear to be an immediate need for priority treatment in the study corridor.

However, with the present 6-lane roadway, the projected traffic volumes suggest that a need for priority treatment can be expected to develop. Near the end of the Department's current 20-year plan, expansion of I-35N from 6 to 8 lanes is anticipated. Even at this 8-lane cross section, it appears that some priority treatment may be justified to complement the roadway expansion.

It might be assumed that low capital, short implementation time alternatives might begin to become effective when peak-period travel volumes result in LOS D. Intermediate cost, intermediate implementation time alternatives should begin to be effective as LOS E is reached. That LOS E operation would need to exist for a period of at least one hour. Such improvements can then provide significant travel time advantages for high-occupancy vehicles (HOV's) as well as increase effective roadway capacity.[3] If the intermediate range improvements cannot accommodate the projected travel demands, consideration needs to be given to long-range, high-cost alternatives. Based on the projections shown in Figure 3, Figure 4 provides an estimate of the year in which different priority treatments may be effective, based on the cross section for the study freeway.[4]

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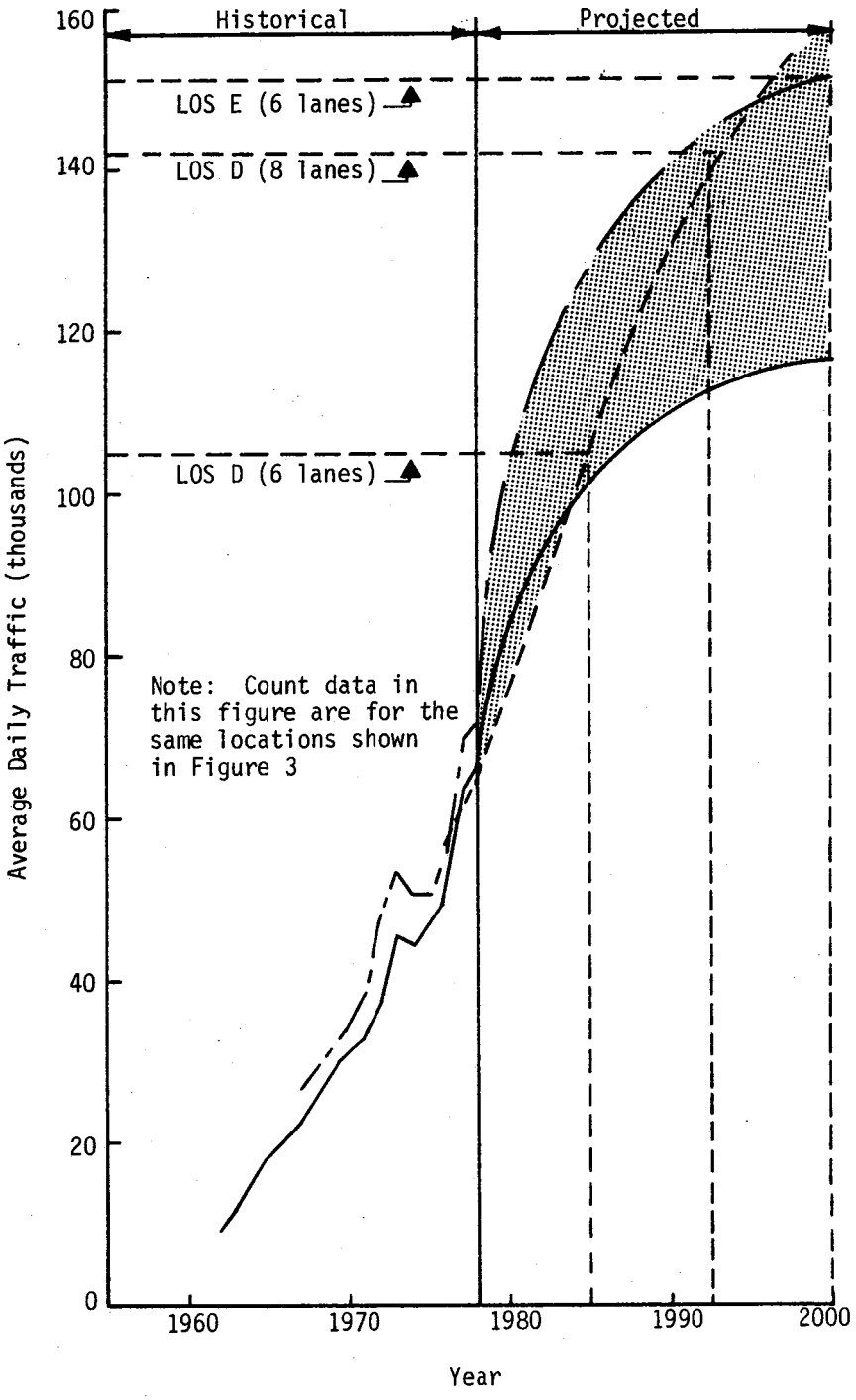
[3]Recent work performed for the U.S. Department of Transportation suggests that, for an HOV improvement to be highly "successful," it needs to provide approximately 1 minute of travel time savings per mile of improvement. Assuming a 50 mph speed in the priority lane, the general traffic lanes would need to be operating at about 27 mph, or LOS E, to be "successful."

[4]Table 9.1, Page 252, of the Highway Capacity Manual was used to develop these estimates. For LOS D, a peak-hour factor of 8 percent and a 58/42 directional split were assumed. For LOS E, a 7 percent peak-hour factor and a 55/45 directional split were assumed.



Source of Count Data: State Department of Highways and Public Transportation

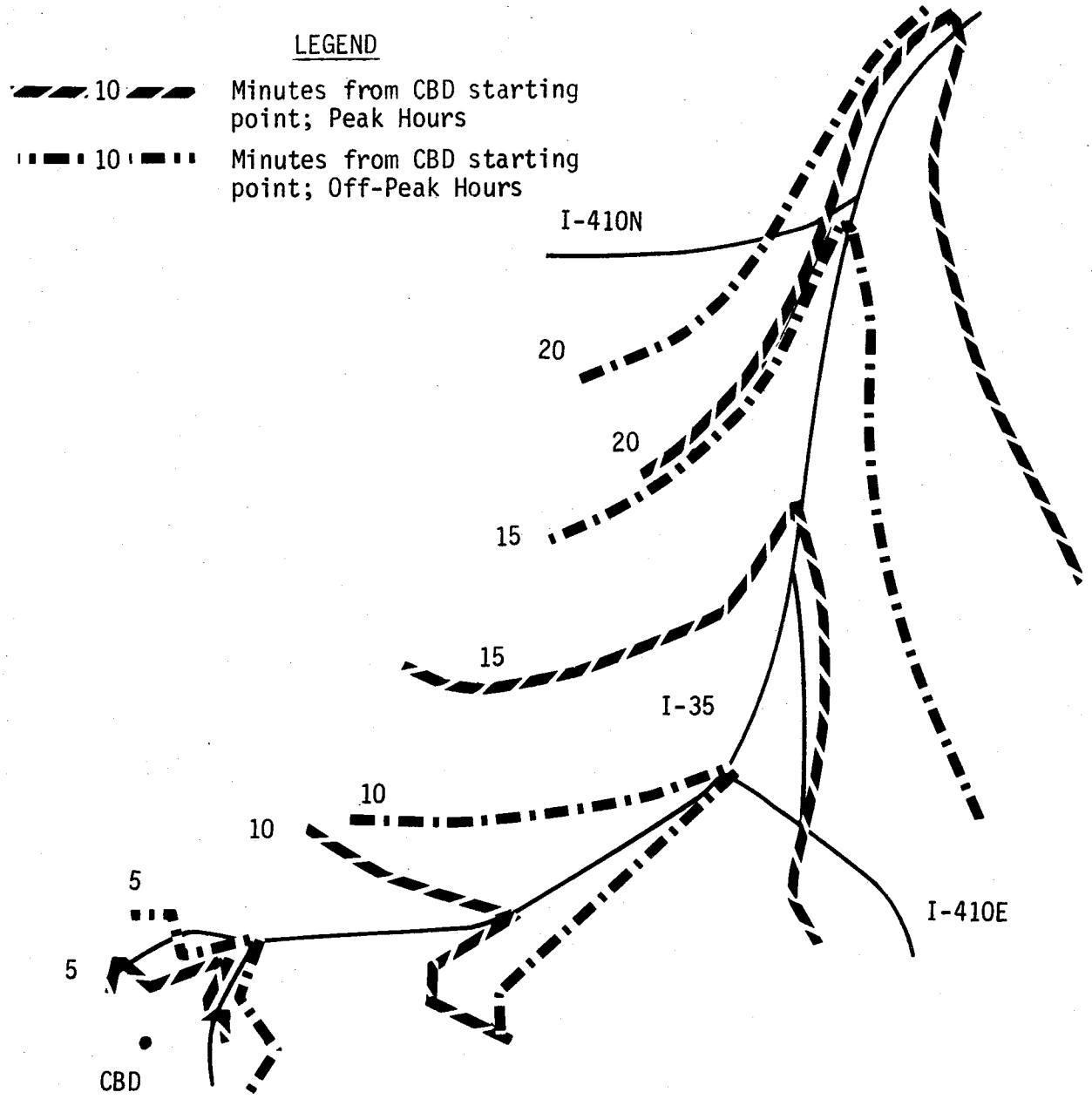
Figure 4: Relationship Between Daily Traffic Volumes and Projected Priority Improvement Needs, North PanAm Freeway

Based on the estimates shown in Figure 4, if the 6-lane cross section continues to exist, a need for low-cost, short implementation time priority measures may develop in the North PanAm Freeway corridor by the mid-1980's. It appears that more costly priority measures may not be needed on the 6-lane cross section until the mid- to late 1990's. If the roadway is expanded to 8 lanes, sufficient additional general traffic capacity will be generated to reduce the urgency of need for priority measures. While some form of low-cost, short implementation time priority alternative may be appropriate by the early 1990's, sufficient roadway capacity should exist until the end of this century to preclude the need for more extensive improvements (e.g., median HOV lane); LOS E will not exist for the 8-lane cross section prior to the year 2000. However, as shown subsequently, if an 8-lane cross section is developed, it may be desirable to also construct, or at least reserve space to subsequently construct, a high-occupancy vehicle improvement at the same time.

Travel Time and Delay

Afternoon peak and off-peak travel time data were collected by the State Department of Highways and Public Transportation in San Antonio in 1977. Travel time contours, as determined in those surveys, are shown in Figure 5.

As shown in that figure, during the p.m. peak it required approximately 18 minutes to drive from the CBD to the Fratt Interchange. Approximately 12 minutes were required to drive the 8.5 mile study corridor (from the I-37 and I-35 interchange to the Fratt Interchange), representing an average speed of approximately 40 mph. This agrees with the LOS C to D estimate made previously in this section. Off-peak travel-time data indicate that approximately 10 minutes



Source: State Department of Highways and Public Transportation Travel Time Studies

Figure 5: 1977 Travel Times on the North PanAm Freeway

were required to traverse the study section, resulting in an average speed of approximately 50 mph. Peak-period delay, the difference between peak and off-peak travel times, was about 2 minutes in 1977.

Implications of Traffic Data

Congestion is not a major problem in the North PanAm study corridor at this time; an immediate need to implement priority measures for high-occupancy vehicles does not exist. However, traffic volumes have been, and are projected to continue, increasing at a rapid rate. Given the existing 6-lane cross section, a need for low-cost priority measures for HOV's may exist by the mid-1980's, with the need for more extensive HOV improvements developing in the 1990's. If I-35 is expanded to 8 lanes, the urgency of providing priority measures is delayed but not eliminated; low-cost, short implementation time improvements might be warranted by the early 1990's.

OVERVIEW OF APPLICABLE PRIORITY TREATMENTS

In evaluating the potential for priority treatment on the North PanAm Freeway, a number of alternative improvements justify consideration. The primary issue addressed in this report concerns what priority treatments, if any, should be considered for incorporation into the facility.

The intent of this section of the report is to screen the available priority treatment techniques. This section of the report identifies those priority treatments that appear to be technically feasible.

Previous research reports (205-1, 205-8, and 205-10) have identified and reviewed alternative priority techniques as those techniques relate to specific Texas freeways. Those preliminary evaluations have identified the general types of improvements that appear to be applicable in the North PanAm Freeway Study Corridor.

The applicability of the following 5 priority treatments to Texas Freeways was considered in previous reports.

1. Exclusive Busway - lanes that are physically separated from other traffic;
2. Contraflow lane - a lane reserved for buses on the left-hand side of the median barrier;
3. Reserved Lane-Concurrent Flow - a lane reserved for high-occupancy vehicles in the normal direction of flow that is not physically separated from other lanes;
4. Freeway Control with Priority Entry - a situation where total freeway traffic volumes are controlled by traffic signals at entry ramps, with high-occupancy vehicles provided special entry ramps; and
5. Use of Frontage Roads - the use of signal preemption, reserved lanes, or other devices to expedite the movement of buses along freeway frontage roads or other surface streets.

Each of these techniques requires a different set of design and operational characteristics in order to be applicable to a specific freeway. A

set of design and operational characteristics considered critical to the implementation of each of the 5 techniques was developed as part of previous research. In developing those characteristics, the underlying assumptions set forth below were utilized. If different underlying assumptions are considered, different guidelines will result.

1. Negative effects on existing traffic capacity available to the general public should be minimized.

   a. To be effective and enforceable, all of the techniques implemented must have the support of the general public. An episode similar to the Los Angeles "Diamond Lane" controversy would be highly undesirable.

   b. Removal of emergency parking shoulders would probably be acceptable as would narrowing of lane widths along short sections of roadway. Removal of an existing lane of travel in a congested portion of the freeway probably would not be acceptable.

2. The application of priority treatment to any segment of freeway should result either in improved HOV travel speeds or in improved bus schedule reliability.

   a. Priority treatment along portions of freeways that are operating at 45 mph or better in mixed flow would yield little if any benefit. Such projects could not be justified unless there is strong evidence that the "free-flow" conditions will be short-lived, and that early implementation of priority treatment would be beneficial. This is an especially critical consideration in the study of the North PanAm Freeway since, at present, mixed flow operating speeds during the peak hour are in the range of 45 mph or better.

   b. No consideration is given to trying to force a reduction in Vehicle-Miles-of-Travel (VMT) through the implementation of priority treatment. The primary objective of priority treatment techniques is to increase the effective capacity of the existing facilities and also to permit improved transit schedule reliability.

Design and Operational Characteristics

For each type of priority improvement, the design and operational characteristics of a freeway which are critical to implementation of that

technique are presented in this section. It should be noted that these characteristics are divided into two sets: those considered to be "Required Attributes," and those considered to be "Desired Attributes." If a specific freeway does not meet all of the "Required Attributes" for a certain priority treatment technique, then that particular technique is considered technically infeasible for application to the freeway being evaluated. The "Desired Attributes" are to be considered only if all "Required Attributes" are satisfied. If all desired characteristics are not met, the improvement may be undesirable but not necessarily infeasible.

Exclusive Busway

Different types of exclusive busways might be considered. One type might consist of an elevated guideway with adequate lane and shoulder widths to assure optimal operation. This might be considered as a long implementation time, very high cost alternative. The other type might be considered more of an "intermediate" range improvement; a busway that might be implemented primarily at-grade in the median. Such an improvement would require less implementation time than would an entirely grade-separated, multilane, high-occupancy vehicle facility. It is recognized that several design and operational aspects of this latter design, although "workable," may not be optimal.

As long as the intermediate approach -- that is, a one-lane, median, reversible HOV facility -- offers sufficient capacity to serve demands and does not unduly compromise the operation of the general traffic lanes, such an approach appears to be the preferred course of action. Even if a multilane busway appears to be needed at some time in the future, initially, it would appear to be more reasonable to provide the intermediate type facility and

then, if necessary, make a transition to the higher capacity, higher cost facility. This approach is suggested for the following reasons.

- Congestion. At the present time, congestion in the North PanAm Study Corridor is not sufficiently bad to justify a separate HOV facility. Estimates developed later in this report suggest that the one-lane facility will provide adequate capacity until the end of this century.

- Implementation Time. The intermediate range improvement, since it does not require large-scale construction activity, could be implemented in 3 to 5 years. In all likelihood, 10 to 20 years would be required to develop an elevated exclusive busway facility. If the intermediate solution is applicable, no action will need to be taken until that need is more imminent or until the necessary construction can be performed in conjunction with a major freeway reconstruction or expansion.

- A Test of Demand. Although San Antonio has a history of good, local transit service, it does not have a history of large-scale, express bus operations. Thus, even though estimates of potential usage are presented in subsequent sections of this report, those estimates must be viewed as being only approximations. A one-lane HOV facility would provide a means of testing demand to assess whether possible justifications for more elaborate facilities exist. If a median HOV lane proved not to be successful, such a lane can be easily converted to many other uses (e.g., emergency storage space) at a minimal cost.

- Benefit-Cost. This particular study does not develop detailed cost-benefit values for the two alternatives. However, as part of a study undertaken for the Gulf Freeway in Houston ("Cost Effectiveness Analysis of Alternatives for Gulf Freeway Busway," prepared by Houston Urban Office), the one-lane, at-grade busway had a benefit/cost ratio of 7.6 while the two-lane, elevated busway had a benefit/cost ratio of 2.4. In that congestion on the Gulf Freeway is presently more intense than the congestion that is projected to occur on the North PanAm Freeway in the year 2000, if the one-lane alternative is superior to the multilane alternative on the Gulf Freeway, it is reasonable to assume that an extensive benefit/cost study would result in a similar conclusion for the North PanAm Freeway.

As a consequence, the following exclusive busway guidelines pertain primarily to the construction of busways that are primarily at-grade and only one-lane wide (busways that can be built in existing freeway medians). A two-lane, at-grade busway cannot be built in the space available without either severe impacts on other freeway traffic or massive construction costs to rebuild structures. As a result, this study primarily pertains to priority treatment techniques that can be implemented in the intermediate time range.

As shown subsequently, such an improvement is sufficient to serve projected long-range demands in the North PanAm study corridor.

Required Attributes. The following attributes are considered essential for application of an exclusive busway to an existing freeway.

- Continuous wide median section (∿20 feet wide) available along most of the critical segment.

  Note: Some occasional discontinuities can be accommodated at reasonable costs. For example, a short stretch of narrow median might be spanned by an elevated section or an extremely narrow cross section. Also, discontinuities at overpass structures can sometimes be handled by decking between the two roadway structures (this type of improvement is necessary along the North PanAm Freeway) or by the elimination of shoulders on the main travel lanes. In the case of the North PanAm Freeway, some freeway widening may be desirable in conjunction with the busway improvement in order to continue to have emergency shoulders adjacent to the inside traffic lanes. Without freeway widening in conjunction with the provision of a median HOV lane, general traffic operations on the North PanAm Freeway will be unduly compromised.

- Buses are able to reach the exclusive lane expeditiously.

  Note: This can probably be accomplished at-grade if the desired entry point for buses is upstream of the congested section. If the improvement is several miles in length, opportunities for midpoint entry should exist. For a variety of reasons (listed in subsequent sections), midpoint entry is an essential feature of the North PanAm median HOV lane.

- No left-hand entrances or exits that cannot be grade-separated within available right-of-way. Such a grade separation is required on the North PanAm Freeway at the I-410E Interchange.

- No existing underpasses with center columns that cannot be negotiated by restriping lanes or some device other than eliminating the columns.

Desired Attributes. The following attributes are considered desirable for application of an exclusive busway to an existing freeway.

- Minimum median clutter requiring relocation (Luminaire posts, sign structures, drainage inlets, etc.).

- Minimum grade differentials between roadways on each side of the median.

- Continuous median shoulders across existing overpass structures.

Contraflow Lane

Required Attributes. The following attributes are considered absolute requirements for applicability of a contraflow lane.

- Minimum of three through lanes in the off-peak direction.

  Note: At least two remaining travel lanes must be available to the general public in the off-peak direction for the roadway to continue to function as a freeway.

- A directional split high enough that the resulting flow rates in the off-peak direction will not exceed 1700 vehicles per hour per lane after the lane is removed.

  Note: Flow rates as high as 1700 vehicles per hour per lane result in level-of-service E (speeds of 30-40 mph) and can easily deteriorate into level-of-service F (Stop-and-Go).

- No left-hand entrance and exit ramps without bypass opportunities.

  Note: Obviously, these ramps would cause traffic conflict problems.

- An opportunity to design a safe entrance to, and exit from, the contraflow lane on each side of the congested portion.

  Note: Safety considerations include sufficient sight distance, adequate weaving opportunity, and opportunity for police to enforce the restrictions.

Desired Attributes. The following attributes are considered desirable for a contraflow lane.

- A directional split such that the resulting flow rates in the off-peak direction would be less than 1500 vehicles per hour per lane after the lane is removed.

- An available median shoulder over most of the route for stalled vehicles.

- Acceptable sight distances along the freeway for safe operation during periods of infrequent bus traffic.

- Continuous freeway lighting over the entire contraflow segment.

- Opportunities for designing intermediate entries to, and exits from, the contraflow lane, thereby increasing the flexibility of operations.

Note: This attribute probably requires a wide median (at least 20 feet wide) in those locations where entry and exit points are desired.

Reserved Lane-Concurrent Flow

Evaluation of problems encountered concerning safety, public acceptance, operation, and enforcement of concurrent flow lanes have led to a recommendation against further implementation of this technique when that implementation involves taking a lane away from the general traffic. If a new lane is added to the facility to function as the concurrent flow lane, this treatment becomes less unattractive although probably not as desirable as other priority treatments that might be implemented if the space were available to add an extra lane. However, short segments of concurrent flow lanes, designed to connect with and provide transitions to other forms of priority treatment, may represent a means of greatly enhancing the flexibility associated with new freeway construction as well as the effectiveness of the other priority treatments; for example, a short section of concurrent flow lane is being evaluated as a possible approach to the I-45N contraflow lane in Houston. As a result, this is not considered as a separate technique for evaluation in this report.

Freeway Control and Priority Entry

Required Attributes. The following attributes are considered to be absolute requirements for implementing this priority technique.

- Capability to control the total volume of traffic on the freeway sufficiently to assure no worse than level-of-service D in the critical segment.

  Note: It is considered highly undesirable if freeway-to-freeway traffic must be reduced sufficiently to back the queue onto the other freeway in order to meet this requirement.

- Adequate queueing space available at each control location.

  Note: If isolated ramps fail to meet this criterion, they should either be closed completely or dedicated totally to high-occupancy vehicles (HOV's).

- Available HOV entry ramp locations to permit HOV's to bypass queued vehicles to enter the freeway.

Desired Attributes. The following attributes are considered desirable for implementation of freeway control with priority entry.

- Continuous frontage roads--at least to an intersection with a suitable arterial street that could be used as a diversionary route.

  Note: This feature would permit cars to enter the ramp queue and remain long enough for the drivers to estimate how long it would require to enter the freeway and then divert to the frontage road if they so desire.

- The ability to control the traffic without obviously placing more severe restrictions on traffic entering at certain ramps.

  Note: Such cases of obvious discrimination may result in intense protests from those neighborhoods affected.

Use of Frontage Roads

Required Attributes. The following attributes are considered to be absolute requirements for implementing this priority technique.

- Continuous frontage roads over the length of the critical segment (or a combination of frontage roads and suitable parallel surface arterial streets).

- The ability to clear the queue ahead of the bus whenever signal preemption is used.

Desired Attributes. The following attribute is considered desirable for implementation of priority treatment on frontage roads.

- At least three approach lanes to each high volume intersection so that the buses will not be impeded by turning movements.

Applicability to the North PanAm Freeway

Research Report 205-8 compared the guidelines presented previously in this section to the design and operational features of the North PanAm Freeway. The conclusions, as set forth in Research Report 205-8, are documented in this section. Additional information concerning the applicability of these priority

measures to the North PanAm Freeway is also presented. The section of the North PanAm Freeway from North Pine Street to the Fratt Interchange is considered in this section.

Exclusive HOV Lane. The following analysis summarizes the applicability of a 22 foot wide (center of median barrier to center of median barrier) exclusive HOV facility to the North PanAm Freeway.

Attributes	Peak Period	
	A. M.	P. M.
Required		
Wide Median	1.5 miles of 44 ft. median and 7.0 miles of 20 ft. median	
Entry Locations	Yes	Yes
Left-hand Ramps	One @ I-410E Intchg., can be tunnelled under in existing R.O.W.	
Center Columns	5 locations	5 locations[1]
Desired		
Median Clutter	Some luminaires & sign bridges	
Grade Differentials	None	None
Median Shoulders	Discontinuous @ 8 overpasses[2]	

[1]The locations are I-410E, S.P. Railroad tracks near Moore, Moore, New Braunfels, and North Pine (refer to Figure 2).
[2]The locations are Walzem, Eisenhauer, Rittiman, Binz-Engleman, Coliseum, Salado Creek, an abandoned rail track, and M-K-T Railroad (refer to Figure 2).

Conclusions Concerning Exclusive, Median HOV Facility. Such a facility could be built in the existing median. That construction would require making a continuous structure at the 8 locations where two separate structures presently exist, eliminating the inside shoulders, and slightly narrowing traffic lanes. If the freeway is widened by 8 to 10 feet on both sides, the emergency inside

shoulder is allowed to remain and traffic lanes do not need to be narrowed. Consequently, it appears that it would be desirable, if a median HOV facility is to be provided, to provide that facility at the same time a major freeway reconstruction (either a resurfacing or the addition of a lane in each direction, as called for in the 20-year plan) is undertaken. As shown previously, the median facility would not be needed for at least 10 years and, consequently, opportunities for staging its construction to coincide with major freeway reconstruction should exist. A more detailed evaluation of this treatment is provided in subsequent sections of this report.

Contraflow Lane. The following analysis summarizes the applicability of a contraflow lane to the North PanAm Freeway.

Attributes	Peak Period	
	A. M.	P. M.
Required		
Minimum of 3 lanes	Yes	Yes
Flow Rates Per Lane in off-peak direction[1]	1,400	1,400
Left-Hand Ramps	At I-410E, but space exists for a bypass	
Safe Ends	Reasonable alternatives exist	
Desired		
Flow Rates <1500	Yes, but probably not in 5 years	
Median Shoulder	Yes, over most of the distance	
Sight Distance	Good	
Intermediate Entries	Possibly @ I-410E	

[1]Estimated from daily traffic volumes. A 70,000 ADT with a 10 percent PHF and a 60/40 directional split was assumed.

Conclusions Concerning Contraflow. Given existing flow rates, a contraflow lane might be successful. However, given projected growth rates, within 5 years it appears that off-peak direction traffic volumes would preclude the attractiveness of this approach. Also, a contraflow lane might be viewed as an "emergency" technique that is used when a situation has already reached a critical stage, and no major freeway reconstruction is imminent. It is doubtful that a contraflow lane would be developed as the result of a long-range planning study. Additional comparison of the relative benefits of an exclusive median facility as opposed to a contraflow lane is provided subsequently in this report.

Freeway Control With Priority Entry. The following analysis summarizes the applicability of freeway control with priority entry to the North PanAm Freeway.

Attributes	Peak Period	
	A. M.	P. M.
Required		
Total Control	Would require metering freeway to freeway traffic @ I-410E/I-35, I-410N/I-35, and I-37/US 281 & I-35.	
Queueing Space	Yes	Yes
HOV Ramps	Yes	Yes
Desired		
Continuous Frontage Rd.	Yes	Yes except I-410E Intchg.
Nondiscriminatory Metering	Yes	Yes

Conclusions Concerning Priority Entry. Priority entry can be viewed in two manners. The most effective approach involves control at all ramps to assure

an acceptable level-of-service on the main lanes and combines that with preferential entry for high-occupancy vehicles to the main lanes. Without metering freeway to freeway movements (at the interchanges of I-37/US 281, I-410E and I-410N with I-35), which must be considered as undesirable, this "total" approach does not appear feasible.

However, metering can be installed at certain high-volume ramps, and high-occupancy vehicles could be given priority at those locations. Such an approach is similar to what has been implemented on East R.L. Thornton (I-30) at Ferguson Road in Dallas. That approach represents a reasonably low cost, short implementation time alternative for the North PanAm Freeway. In comparison to an exclusive HOV lane, this concept does not provide the schedule reliability, travel time improvement, or increase in vehicular capacity that an exclusive lane can provide.

Use of Frontage Roads. The following analysis summarizes the applicability of using frontage roads as a priority treatment technique on the North PanAm Freeway.

Attributes	Peak Period	
	A. M.	P. M.
Required		
Continuous Frontage Roads	Yes	Not @ I-410E Intchg.[1]
Clear Queue	Yes	Yes
Desired		
3 Lanes @ Intersections	No, but pavement could be widened	

[1]A possible bypass, using Seguin Road, exists

Conclusions Concerning Use of Frontage Roads. Although the physical conditions would allow utilization of frontage roads as a low cost, short implementation time alternative, such an approach on the North PanAm Freeway appears inferior to priority entry. Signal preemption systems benefit buses and, quite possibly, disadvantage general traffic. As is shown in subsequent sections of this report, in considering HOV improvements in San Antonio, buses represent a very small percentage of total high-occupancy vehicles; in San Antonio, HOV improvements should be designed to also serve carpools. If significant bus volumes did use the frontage roads and had preemption capabilities, serious disruption of traffic flow on major cross streets might result.

Also, as was the case with contraflow lanes, using frontage roads for priority treatment really becomes attractive only after intense congestion exists on the main lanes. As long as acceptable travel conditions exist on the main lanes, it is reasonable to encourage the long-distance trips by HOV's to use those lanes. As travel conditions on the main lanes become congested, other HOV improvements (median lane, contraflow, etc.) provide more effective improvements. Such improvements serve more types of HOV's, provide higher travel speeds, schedule reliability, and capacity than does using frontage roads for priority treatment.

Findings Concerning Applicable Priority Treatments

Since congestion on the North PanAm Freeway has not reached critical levels, the issue that needs to be answered is what type of priority treatment should, desirably, be provided in the future. This is distinctly different from the issue being faced in cities such as Houston where the question has

become what, if anything, can be done immediately, given that situation is already critical.

Previous portions of this section have discussed numerous technical features that affect the applicability of the various priority treatments to the North PanAm Freeway. Some additional considerations are summarized in Table 1.

Low-cost, short implementation time alternatives considered in this section included priority entry and priority use of frontage roads. Of those two choices, priority entry appears the most desirable. Unlike priority use of frontage roads, it offers benefits to all high-occupancy vehicles (a very important consideration in San Antonio where bus volumes are relatively low) and does not disrupt traffic on major cross streets. Also, all HOV's can benefit regardless of their destination. Since total freeway metering is difficult due to the I-37/US-281, I-410E and I-410N interchanges with I-35, this concept remains viable only as long as mixed flow on the main lanes continues to operate at LOS D or better. Once traffic conditions deteriorate below that point, other priority treatments that provide greater capacity, schedule reliability, and capacity should be made available.

As intermediate cost, intermediate implementation time improvements, this section considered contraflow lanes and a one-lane, reversible, median busway. Given a choice between operating on an exclusive HOV lane or a contraflow lane, the exclusive lane represents a preferable alternative for the reasons listed below.

- Operational Cost. It is costing the Metropolitan Transit Authority in Houston $2000 to $3000 per day to set up, take down, and enforce the contraflow lane on I-45N. Costs of operating a busway would be a small fraction of that cost.

- Positive Separation of Flow. An exclusive HOV lane would allow median barriers to continue to provide a positive separation of traffic flow during all times of day.

Table 1: Comparison of Alternative Priority HOV Improvements[1]

Parameter	Alternative HOV Improvement			
	1-lane Median Busway	2-lane Elevated Busway[2]	Use of Frontage Roads	Freeway Control w/Priority Entry
Quality of bus Service				
Avg. Speed, mph	50	50	30	40[3]
Schedule Reliability	Excellent	Excellent	Poor	Good-Fair
Carpools Included	No/Yes[4]	Yes	No	Yes
Impact on Other Traffic	Minor	Minor	Major	Moderate-Major
Cost, Thousands/Mile[5]	$2,000	$9,000	$130	$400
Maximum Capacity				
Buses, Veh./Hr.	400[6]	400[6]	60[8]	200[9]
Carpools, Veh./Hr.	0	800[7]	0	400[9]
Total, Persons/Hr.	20,000	24,000	3,000	12,000

[1]Based on a similar table presented in "Cost-Effectiveness Analysis of Alternatives for Gulf Freeway Busway," Prepared by Houston Urban Office, June 11, 1979.
[2]For numerous reasons listed previously in this section, this does not appear to represent a needed improvement in the North PanAm corridor. As considered in this matrix, this facility would operate with one-lane in each direction.
[3]Attainable only with sufficient enforcement to control ramp violation rates.
[4]Operationally, it may be undesirable to allow carpools onto a facility one-lane wide without continuous shoulders. Realistically, it may be necessary to allow carpool utilization to generate an "acceptable" level of total vehicular utilization. Continuous shoulders greatly reduce this potential problem.
[5]Does not include costs required to provide "support" facilities such as park-and-ride lots.
[6]This value based on the flow volume that could return in mixed flow in the off-peak direction. At this flow level, carpools would be undesirable on the one-lane busway since they would adversely impact schedule reliability for the high bus volume.
[7]Sufficient carpools added to obtain level-of-service D.
[8]At 60 buses per hour, every cycle would be preempted by buses, destroying the capability of cross streets to serve traffic demands.
[9]This capacity is a function of the volume of traffic the freeway can serve. It is assumed in this table that no more than half the capacity of one freeway lane will be available for HOV use.

- Penalty to Off-Peak Traffic. The exclusive lane will not penalize traffic moving in the off-peak direction through removal of a travel lane.

- Eligible Vehicles. The exclusive HOV lane would permit less concern to occur over the types of vehicles and drivers eligible to use the lane. Again, this is a major consideration in San Antonio.

- Midpoint Entry. Due to the length of the improvement contemplated in this study, it is essential that midpoint access to the HOV lane exist. This is much easier to accomplish if an exclusive median lane is devoted to use by HOVs.

As shown subsequently in this report, a median HOV lane provides the capacity needed to serve projected demands in the North PanAm Freeway corridor. As a result, higher cost alternatives do not appear necessary in the next 15 to 20 years.

Thus, the following priority measures warrant more comprehensive evaluation.

- Low Cost, Short Implementation Time. Priority entry at selected high-volume ramps.

- Intermediate Cost, Intermediate Implementation Time. A one-lane, reversible, median HOV lane.

- Very High Cost, Very Long Implementation Time. A need for this type of improvement is not identified for the time period evaluated in this study (20-year planning horizon).

UTILIZATION AND COST OF PRIORITY MEASURES

Two alternative priority measures, priority entry and a one-lane, reversible, median HOV lane were identified in the previous section as warranting more extensive evaluation. This section presents estimates of the number of HOV's that would utilize the improvements as well as the benefits that would accrue to those vehicles. Design aspects of the priority measures are discussed in the subsequent section of this report.

Analysis Data

Extensive traffic and design data collected by the Department were made available as part of this study. As necessary to evaluate the need for priority treatment, other pertinent data were developed during the course of the study.

Vehicle Occupancy

A San Antonio occupancy survey of vehicles entering the CBD found the average peak-period vehicle occupancy to be approximately 1.4 persons per vehicle. Based on occupancy data characteristic of major urban areas in Texas, the following vehicle occupancy distribution is assumed.

- Single occupant - 73%
- Two occupants - 21%
- Three occupants - 4%
- Four or more occupants - 2%

Ramp Entry Data

As part of an ongoing traffic counting process, 24-hour counts of ramp volumes are routinely collected by the Department. Entry volumes at ramps in the study corridor for 1979 are shown in Table 2.

Table 2. 1979 Daily Traffic Volumes on Ramps Entering the North PanAm Freeway

Ramp Location	Daily Volume	Percentage	Cumulative
I-410N	14,780	22	22
Walzem	8,680	13	35
Eisenhauer	5,150	7	42
Rittiman	11,100	16	58
N. of Binz-Engleman	550	1	59
I-410E	5,470	8	67
N. of Salado Creek	3,620	5	72
N. of Moore	7,220	10	82
S. of Moore	4,720	7	89
New Braunfels	7,760	11	100
Total	69,050		

Source: State Department of Highways and Public Transportation

Downtown Travel Data

Although some trips destined to Fort Sam Houston will take advantage of a priority measure on the North PanAm Freeway, the primary benefit will be to persons travelling to downtown San Antonio. Thus, to estimate the effectiveness of an HOV improvement, an estimate of CBD work trip patterns on the North PanAm Freeway is needed.

Origin-destination data are not available for use in such an estimate. As a consequence, secondary data concerning travel patterns in major Texas cities were used to estimate work trip patterns on the North PanAm Freeway. The results of that estimate are shown in Figure 6. The procedures used to develop Figure 6 are documented in Appendix A.

The trips shown in Figure 6 represent daily auto work trips to the CBD that use the North PanAm Freeway. It is assumed that approximately 50 percent of those trips occur during the peak hour.

Utilization of Priority Entry

Based on analyses presented previously in this report, it appears that some form of low-cost, short implementation time priority measure might be needed on the North PanAm Freeway by the mid- to late 1980's. It also appears that priority entry represents the most desirable form of low-cost priority treatment for the North PanAm Freeway.

Priority entry, in conjunction with freeway metering, can be considered in two manners. In the first, which is similar to the operation on certain Los Angeles freeways, all freeway ramps are metered to help assure a satisfactory operating condition in the main lanes and, in addition, at some ramp locations high-occupancy vehicles are provided with preferential entry ramps to allow those vehicles to bypass the queue at the metered ramp. For the I-35 study corridor, however, this is not the approach suggested as a low-cost, short implementation time priority measure. Thirty percent of the traffic entering the North PanAm Freeway in the study section does so at freeway-to-freeway interchanges (Table 2). Metering freeway-to-freeway ramps could result in forcing traffic to back up in the main lanes, a situation that would not be considered desirable.

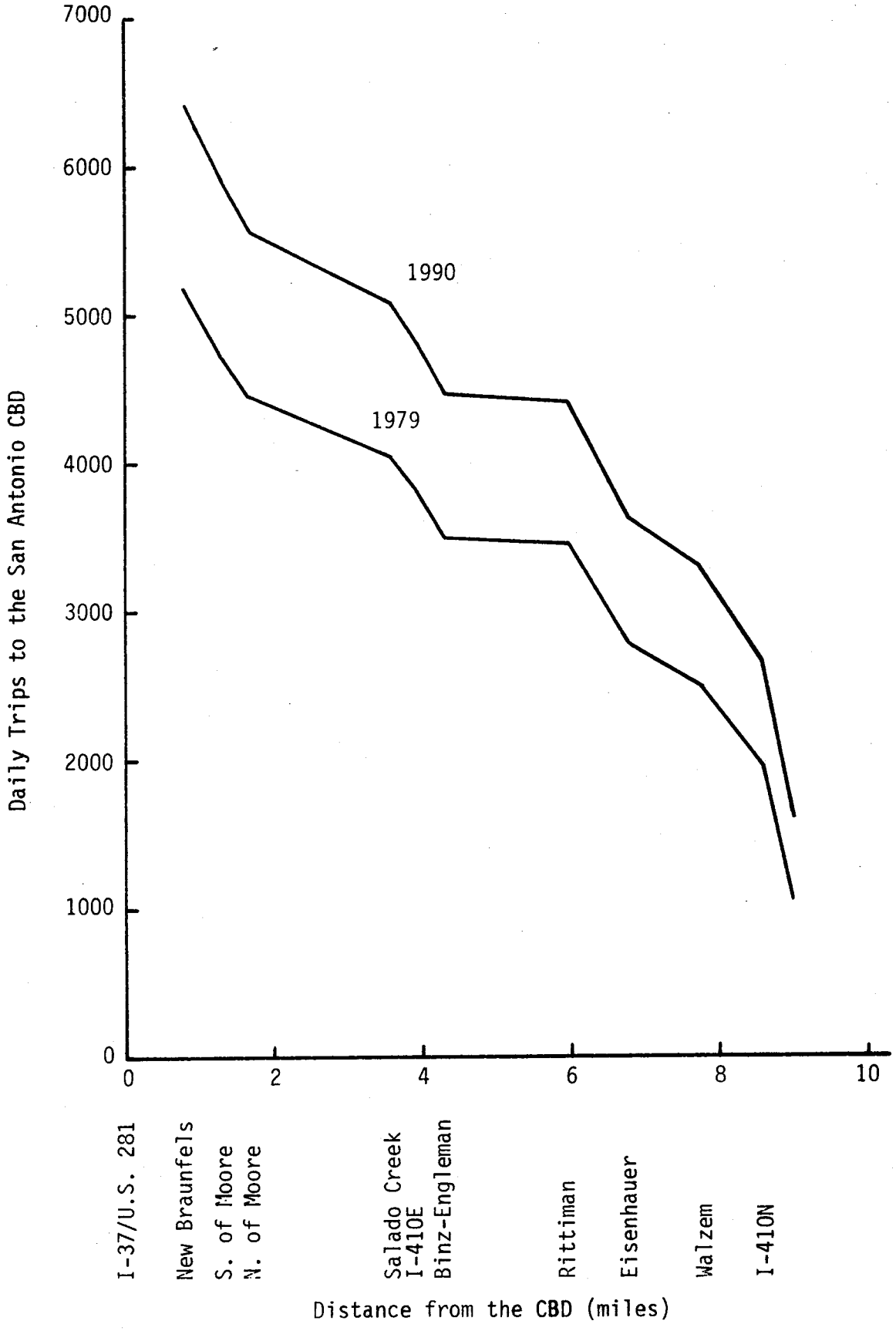


Figure 6. Estimated Daily Auto Work Trips to the San Antonio CBD on I-35N

The second approach involves taking actions such as have been taken in Dallas on I-30 at Ferguson Road. With this approach, certain high-volume ramps are identified, those ramps are metered, and priority entry for high-occupancy vehicles is provided at those locations. Other freeway ramps are not metered. As considered in this study, priority entry would not be the desired priority treatment to provide once main lane operation slipped below LOS D. Thus, this second approach appears applicable to the North PanAm Freeway as a low-cost, short implementation time action. Once freeway operations approach LOS E, an exclusive median HOV lane should be considered.

Impact of Priority Entry Ramps

Most of the experience with priority entry has been in Los Angeles. Nearly 150 bypass ramps are operational in that city. In Texas, 4 bypass ramps are presently operational (2 on Southwest Freeway in Houston, 1 on North Central Expressway in Dallas, 1 on I-30 in Dallas). While the Los Angeles ramps are used by both buses and carpools, with the exception of the I-30 ramp in Dallas, all the Texas ramps are for buses only. Fewer than 20 buses per hour would use a priority system on the North PanAm Freeway; as a result, carpools should be allowed to use a priority entry approach on the North PanAm Freeway. For this type of operation, a carpool is commonly defined as 2 or more persons per vehicle.

Selected data for the Los Angeles operations are shown in Table 3. The utilization and effectiveness of these lanes can be expected to be somewhat higher than will be experienced in San Antonio. The Los Angeles freeways are typically operating at capacity, while it is anticipated the North PanAm Freeway will be at LOS D when priority entry is provided. A travel time savings of 2 minutes will not result in San Antonio; indeed, on I-30 in Dallas,

the travel time savings in the bypass ramp were 3 seconds. As a result, the values for San Antonio that are shown in Table 3 are assumed to be approximately half of the corresponding Los Angeles values. A 20 percent increase in carpools in San Antonio will result in about a 5 percent increase in average occupancy at those locations where priority entry is provided.

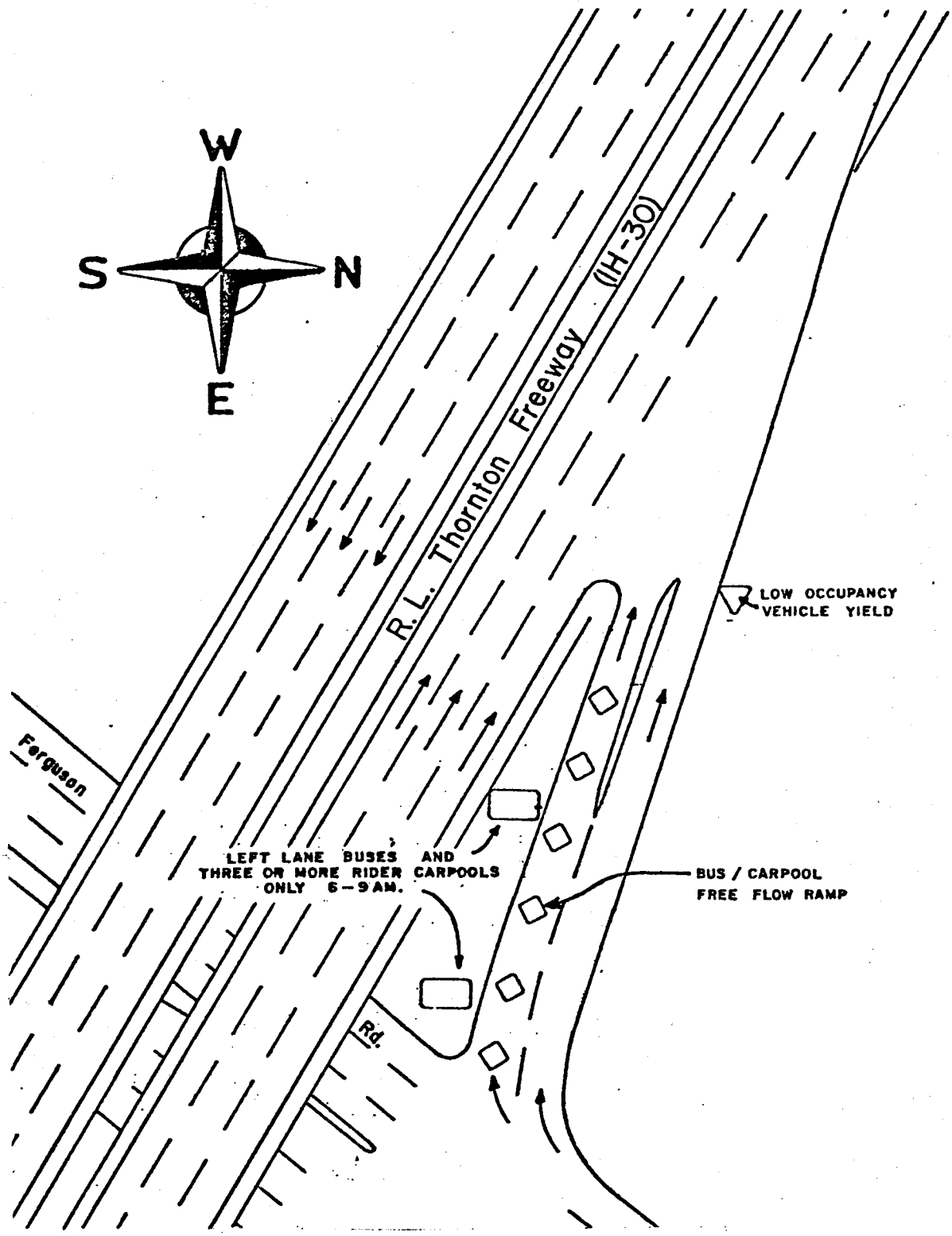
Table 3: Effects of Priority Entry in Los Angeles and Estimated Impacts in San Antonio

City	Avg. Travel Time Savings	Percentage Increase in Carpools	Violation Rate[1]
Los Angeles	2 min.	38%	35%
San Antonio	<1 min.	20%	25%

[1]The percentage of vehicles using the priority ramp that are not eligible to do so.

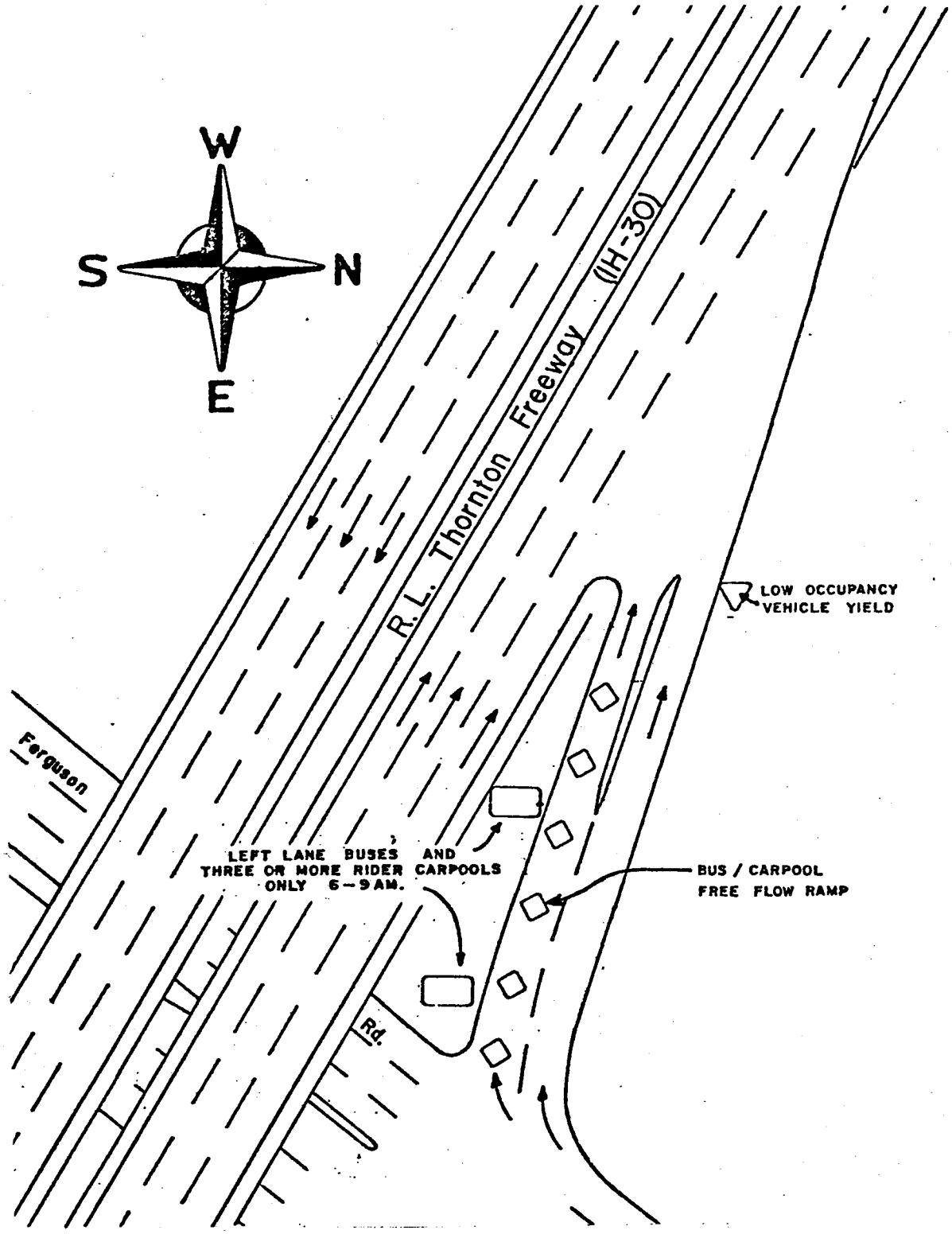
Priority entry ramps would not be provided at each ramp location. Los Angeles provides such facilities on about every second ramp. On the North PanAm Freeway, it would appear appropriate to provide those facilities only at the high-volume entry locations, which also results in priority entry at about every second ramp. Based on data in Table 2, priority entry might be considered at, as a maximum, 4 ramp locations -- namely Walzem, Rittiman, north of Moore, and New Braunfels. Fifty percent of the traffic entering I-35 in the study corridor enters at those ramps. Such improvements could be phased in to evaluate effectiveness and acceptance; if that approach is used, Rittiman would appear to be the best location for initial development due to both its high volume and distance from downtown.

The bypass ramp in Dallas (Figure 7) is similar to the type of treatment that might be implemented along the North PanAm Freeway. That installation



Source: "Bus and Carpool Bypass Ramp Operations in Dallas," prepared by Office of Transportation Programs, City of Dallas, July 1979

Figure 7: Priority Entry Ramp on East R.L. Thornton at Ferguson Road, Dallas



Source: "Bus and Carpool Bypass Ramp Operations in Dallas," prepared by Office of Transportation Programs, City of Dallas, July 1979

Figure 7: Priority Entry Ramp on East R.L. Thornton at Ferguson Road, Dallas

cost approximately $50,000; a similar per ramp cost should be incurred in San Antonio. Consideration needs to be given to queueing space, as it will not be unusual for 15 to 20 cars to be queued at the ramp meter during the height of the peak period. The high violation rate (Table 3) also makes enforcement a major concern; personnel need to be available (on a random basis after the first several weeks of operation), and procedures must exist to permit the identification and safe apprehension of violators.

If ramp metering with priority entry is provided at the four locations identified previously, assuming that the priority entry is provided in 1985, peak-hour utilization of the priority entry facility is estimated in Table 4. Based on the values in Table 4, approximately one-third of the peak-hour vehicles would use the priority lane, and those vehicles would move 53 percent of the persons. The average occupancy in the priority ramp lanes would be 2.3 persons per carpool.

Table 4: Estimated 1985 Peak Hour Usage of Priority Entry Ramps on the North PanAm Freeway

Ramp Location	Est. Volume Without Priority Entry	Est. Volume With Priority Entry[1]	
		Non-Priority Lane	Priority Lane[2]
Walzem	970	715	355
Rittiman	1,240	910	450
N. of Moore	810	595	295
New Braunfels	870	640	320

[1]In Los Angeles, half the carpools using the priority ramp were new carpools. This would be 10 percent in San Antonio (Table 3). It is assumed that this is a 10 percent increase in total volume using the ramp as a result of the priority measure.
[2]Vehicles with 2 or more occupants (buses plus carpools).

Utilization of a Median HOV Lane

If the North PanAm Freeway remains as a 6-lane facility, information presented previously suggests that, by the early to mid-1990's, an exclusive, median HOV lane may represent a needed improvement. Such an improvement provides considerable gains in capacity, travel speeds, and schedule reliability over the priority entry improvement. This section develops estimates of 1990 utilization of a median HOV lane for the North PanAm Freeway. That is the earliest date at which such a facility may be needed (Figure 4). The estimates are for the morning peak hour. The 1990 estimates are formulated assuming that buses, carpools, and vanpools are allowed to use the HOV lane. Considerations regarding the types of vehicles that might actually be allowed to use the lane are discussed in the subsequent part of this section.

Work trip data shown in Figure 6 are used to develop this information. It is assumed that the high-occupancy vehicle lane will be utilized by both buses and carpools (for this type of treatment, carpools are defined as 3 or more persons per vehicle).

Bus Usage

Information is not available to obtain a highly accurate estimate of bus usage of a median HOV lane. Based on the VIA route structure in effect in 1978, it appears that, at most, 6 buses would currently use the priority lane (3 buses from the Windsor Park Express and 3 diverted from Route 15). The opening of a park-and-ride facility at the Fratt Interchange might add at most, 6 more peak-hour bus trips. Assuming that this number of total bus trips might double by 1990 (a 7+ percent increase per year), perhaps 25 peak-hour VIA buses

might use the median HOV facility in 1990[1]. This estimate, if anything, should be high; fewer than 40 buses per 2.5 hours are currently using the I-45N contraflow lane in Houston.

Carpool Usage

The data shown in Figure 6 are used to estimate potential carpool usage of the lane. It is assumed that carpools will be defined as 3 or more persons per vehicle.

At the greatest load point on the North PanAm Freeway in 1990, 6400 CBD auto work trips are using that facility (Figure 6). The following analysis is used to estimate utilization of an exclusive median HOV lane.

- 6400 auto trips, assume 50 percent occur in the peak hour yields 3200 peak-hour CBD auto work trips.
- Of these, 6 percent have 3 or more occupants per vehicle (based on data presented previously). Thus, approximately 190 vehicles are immediately eligible to use the lane.
- Work performed by the Transportation System Center has noted that designating a preferential lane for carpools increases carpools by some 70 percent. Thus, some 320 carpools could be expected to use the lane.

Total Usage

If the lane were operational in 1990, approximately 345 vehicles could be expected to use that lane for CBD work trips. Perhaps 35 additional vehicles would use the facility for trips to Fort Sam Houston. Thus, at the greatest load point, perhaps 380 vehicles would use a priority lane in the peak hour. That high of a volume would exist over only about 1 mile of the 8.5 mile HOV lane.

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[1]Data provided by VIA Metroplitan Transit suggest that perhaps as many as 100 buses per hour would use the lane. That increased volume would not change the conclusions determined in this study regarding applicable priority treatments.

Capacity/Utilization Considerations

The following considerations are pertinent in evaluating utilization of the priority lane.

- Total flow volume should remain low (probably less than 400 vph at an average lead point) to assure that a high level-of-service typically exists on the priority lane. This low of a flow rate applies to the facility in general and not necessarily to the highest load point. One lane exclusive HOV facilities in the U.S. currently serve volumes as high as 800 vph. It is doubtful if the value at the maximum load point should be allowed to serve more trips than this level in order to assure high HOV travel speeds and schedule reliability.

- A sufficient number of vehicles should be using the lane so that the public perception is that the lane is being highly utilized (probably at least one vehicle every 30 to 60 seconds during peak periods). A minimum flow rate of 100 vehicles per hour is necessary to be sure that the lane is used by at least one vehicle each minute. Based on the travel patterns shown in Figure 6, if 380 vehicles are using the lane its highest load point, approximately 95 would be using the facility at its lowest load point.

Conclusions Regarding Utilization/Capacity

Due to the low bus volumes, it is essential that the lane be designed for use by carpools in order to generate sufficient usage to justify the facility. This requires provision of emergency shoulder space over most of the length of the priority lane.

The utilization estimates developed in this section confirm the analyses presented previously; that is, an exclusive HOV lane is not needed until at least 1990. Minimum acceptable levels of utilization can nearly be attained at that time, and maximum levels will not be exceeded at any point along the HOV lane.

The volume at the maximum load point could double from the projected 1990 level and still not exceed the 800 vph currently being served by some HOV lanes in the United States. For the 1990 value to double by the year 2000, an annual increase in travel volumes in excess of 7 percent would be required. The

estimated annual rate of increase in auto trips to the CBD between 1979 and 1990 was less than 2 percent. Thus, it is highly doubtful that the demand for the median HOV lane would exceed the capacity of that lane. Thus, it is concluded in this study that a one lane, median facility will be all that is needed to serve travel needs in the North PanAm corridor until at least the year 2000. At this time there is no need to consider more costly, higher capacity alternatives.

Cost and Implementation Time

The cost and implementation time for the two priority measures evaluated in this study are shown in Table 5.

Table 5: Estimated Cost and Implementation Time Associated With Priority Measures Evaluated in this Report

Description of Measure	Implementation Time	Cost (1979 dollars)
4 Priority Entry Ramps	6 mo. to 1 yr.	$ 200,000
8.5 mile priority, median HOV lane	5 yr. to 10 yr.[1]	17,000,000

[1]This improvement would logically be performed in conjunction with a major freeway reconstruction. The planning, design, and implementation should all correspond to the freeway reconstruction schedule.

CONCEPTUAL DESIGN AND OPERATION OF PRIORITY MEASURES

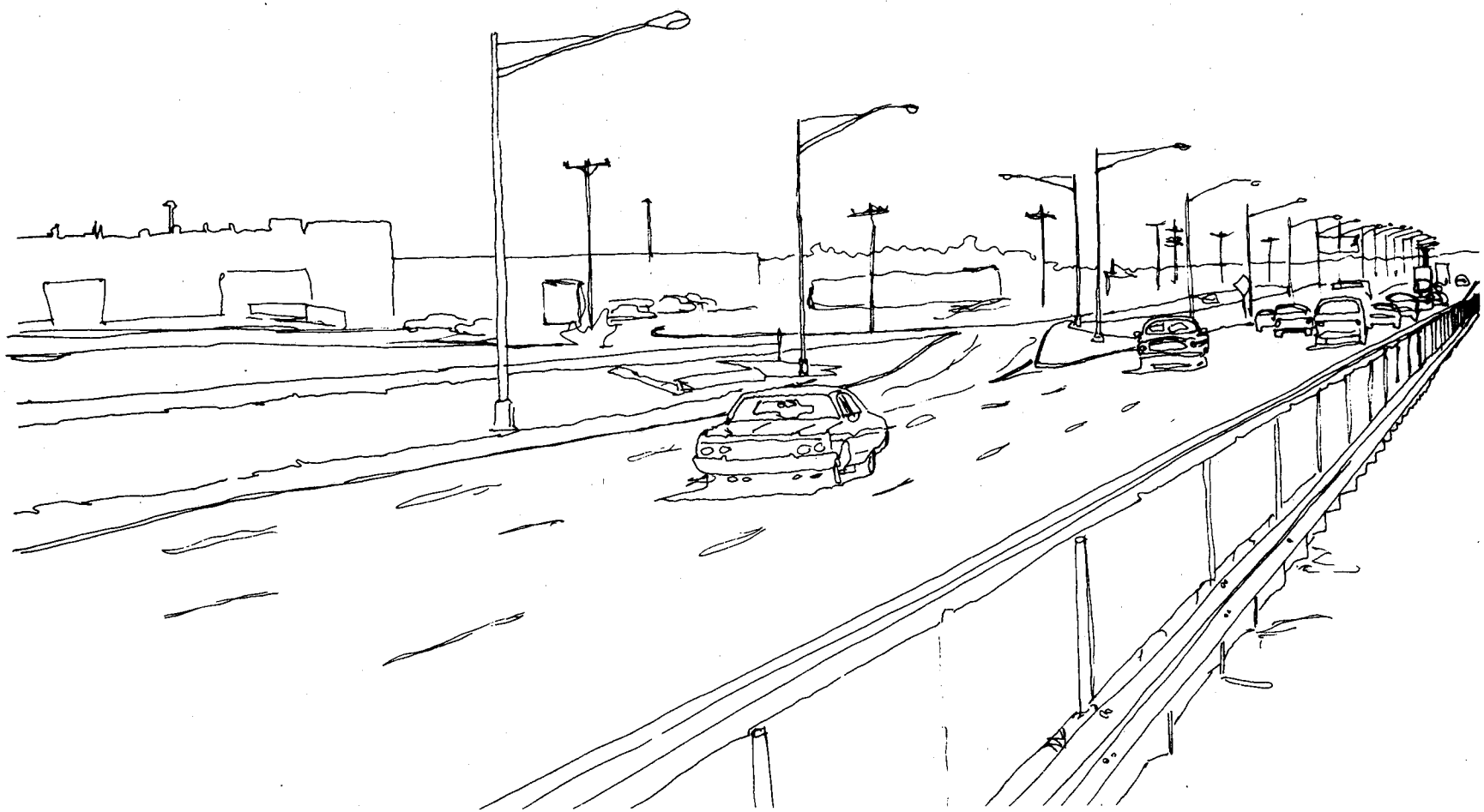
The design and operation of the priority entry ramps are not extremely complicated. A typical layout (Figure 7) was shown in the previous section as were cost estimates and estimates of utilization. A rendering of an HOV entry ramp on the North PanAm Freeway is shown in Figure 8.

This section primarily focuses on design and operational concerns associated with incorporating a one-lane, reversible, median HOV lane into the North PanAm Freeway. That type of improvement appears to provide sufficient capacity to accommodate projected HOV travel needs until at least the year 2000.

Design and operational considerations discussed in this section should be viewed as conceptual only. Many trade-offs are involved in laying out transportation improvements within the confines of restricted rights-of-way. It is the intent of this report to show a manner in which the suggested HOV improvement could be designed and operated. More detailed design studies, which are necessary prior to implementation, may identify better designs and/or operational procedures for the median HOV lane.

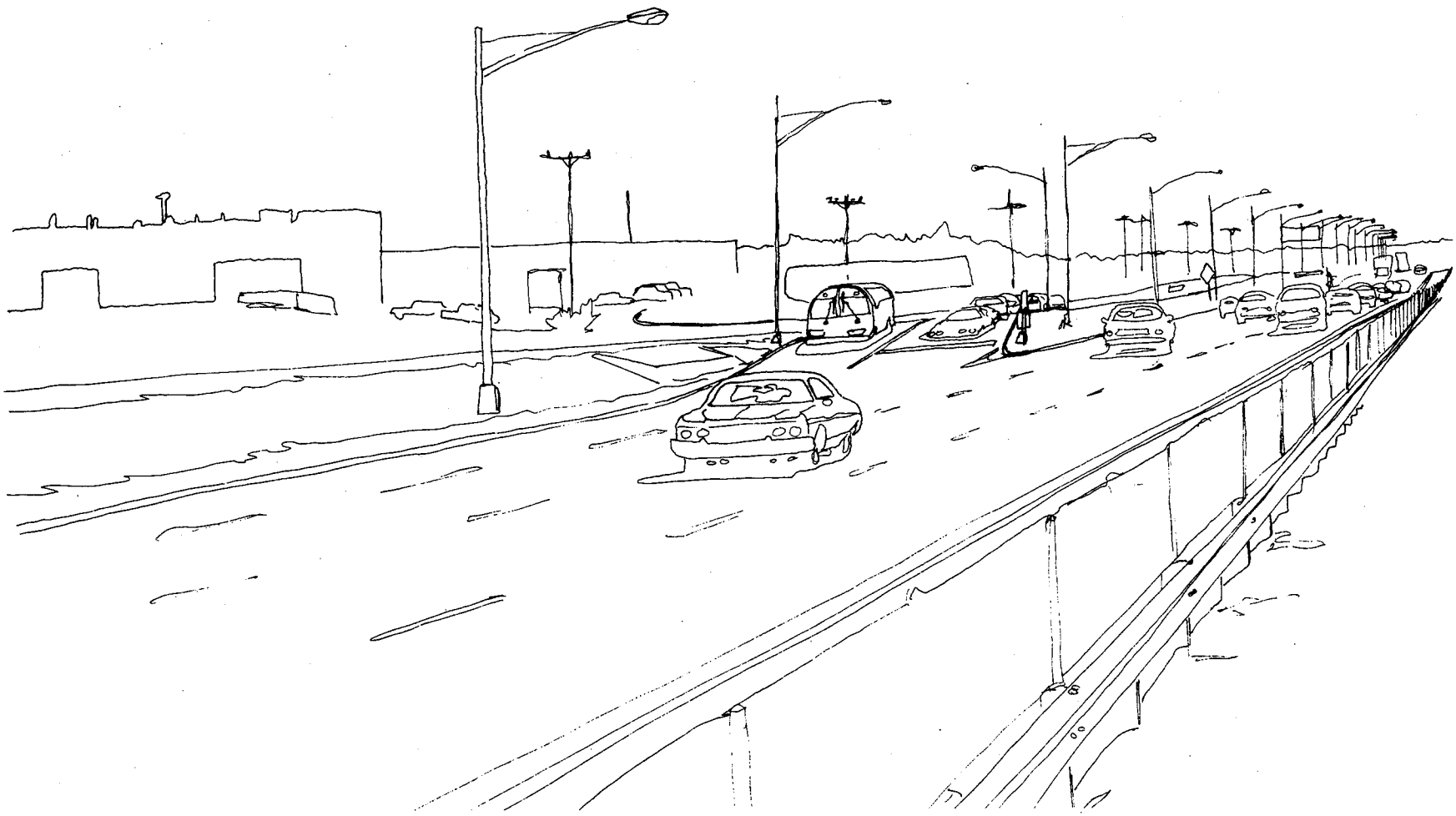
Compatibility With Department Plans

The need for a median HOV lane is not critical at this time; indeed, that need will not arise until the early 1990's. The HOV lane does require widening of the existing freeway cross section. As a result, it appears that all planning, design, and construction of the median facility should be done in conjunction with other Department plans for the study freeway. The median facility could be provided as part of a major freeway reconstruction or as part of a proposed freeway widening; the addition of one lane in each direction is



Location: South of I-410E (North Interchange), looking south
Existing

Figure 8: Manner in Which a Priority Entry Ramp
Would Be Added to an Existing Ramp



Location: South of I-410E (North Interchange), looking south
Possible Future

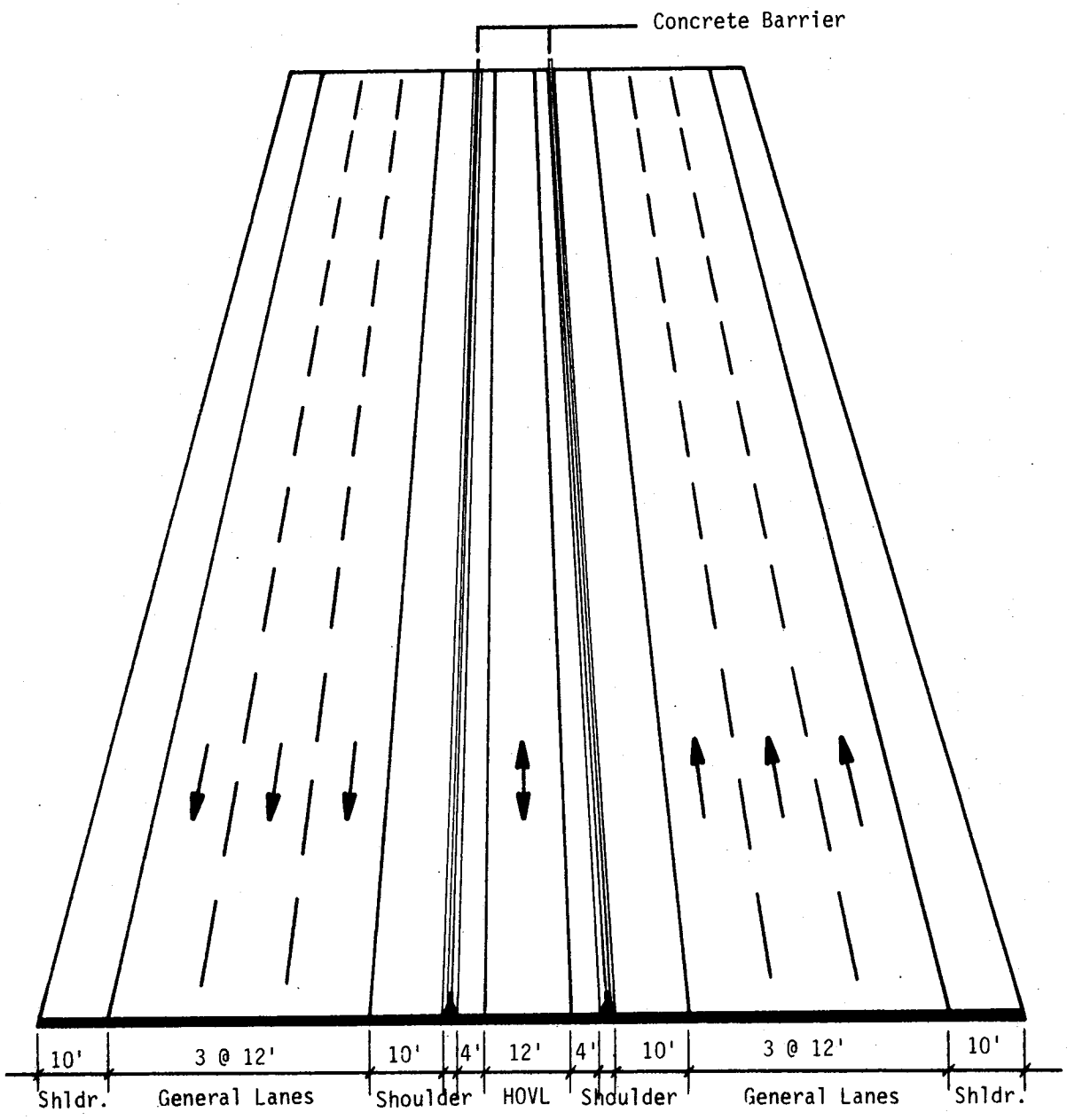
Figure 8: (Continued)

included in the later stages of the Department's current 20-year plan. The HOV improvement should be viewed as being complementary to other planned Department improvements in the corridor. Incorporating a median HOV lane into the freeway does not preclude the possibility of expanding North PanAm Freeway to an 8-lane facility, although it does necessitate some operational and design compromises. At Moore Street and the railroad overpass just south of Moore Street (Figure 2), either the existing overpasses will need to be rebuilt to eliminate the center column or, alternatively, the HOV lane will need to be elevated above Moore and the S.P. railroad, two levels above freeway grade level. Also, for one direction of travel on I-35, only 3 lanes can be carried through the I-410E interchange; a lane drop at an exit ramp with a lane added at the subsequent entrance ramp will be required. At the 8 locations where I-35 goes over cross streets, the space between the existing structures will need to be paved and about 8 feet of widening will be required. Otherwise no unusual problems exist in expanding the facility to 8 lanes.

HOV Median Lane Operation

Pavement width restrictions at structures place limitations on the roadway width that can be devoted to a median HOV lane. As a consequence, only a one-lane HOV facility can be provided. However, that one-lane design is adequate to serve HOV travel needs on I-35. A cross section of a "typical" roadway section is shown in Figure 9. A continuous emergency shoulder, which is highly desirable since carpool operation is anticipated on the HOV lane, can be incorporated into the entire length of the median HOV lane (with the exception of these locations where overpasses exist).

The HOV lane will be a reversible facility. It will operate inbound in the morning and outbound in the evening. Buses circulating in the off-peak direction will need to use the main freeway lanes. With the addition of one



Note: This cross section requires approximately 20 feet of widening.

Figure 9: Typical Cross Section, Median HOV Lane on North PanAm Freeway

lane in each direction (a part of the 20-year plan), off-peak direction speeds should not unduly impede necessary bus circulation in that directional splits of approximately 65/35 should result. Even if an additional lane is not added, off-peak direction speeds should remain sufficiently high to not greatly impede bus operations. Freeway metering can be used, if necessary, to assure satisfactory off-peak direction travel speeds.

Location of HOV Improvement

The HOV median lane will begin at the Fratt Interchange. Access to the lane at that location will be possible from I-35, I-410N, and the park-and-ride lot being constructed in the Fratt Interchange (Figure 10). North of Fratt Interchange, I-35 is in the process of being widened. As a result, capacity deficiencies are not anticipated north of the Fratt Interchange and, as a result, the Fratt Interchange represents the northern terminus of the HOV lane. A rendering of a possible flyover ramp to the median lane is shown in Figure 11.

The priority lane primarily is designed to serve traffic destined to the CBD. It is suggested that the median HOV lane conclude at the southern terminus with an at-grade intersection with the North Pine Street overpass (Figure 12), or, alternatively, a new overpass south of North Pine Street. This approach permits the lane to be out of the I-35 median prior to the intersection with I-37, and also permits traffic destined to the CBD to use any of several existing streets to gain access to downtown San Antonio from either the north or the east.

Midpoint Entry Possibilities

For a number of reasons, including those listed below, it will be necessary to develop midpoint access to the median HOV lane.

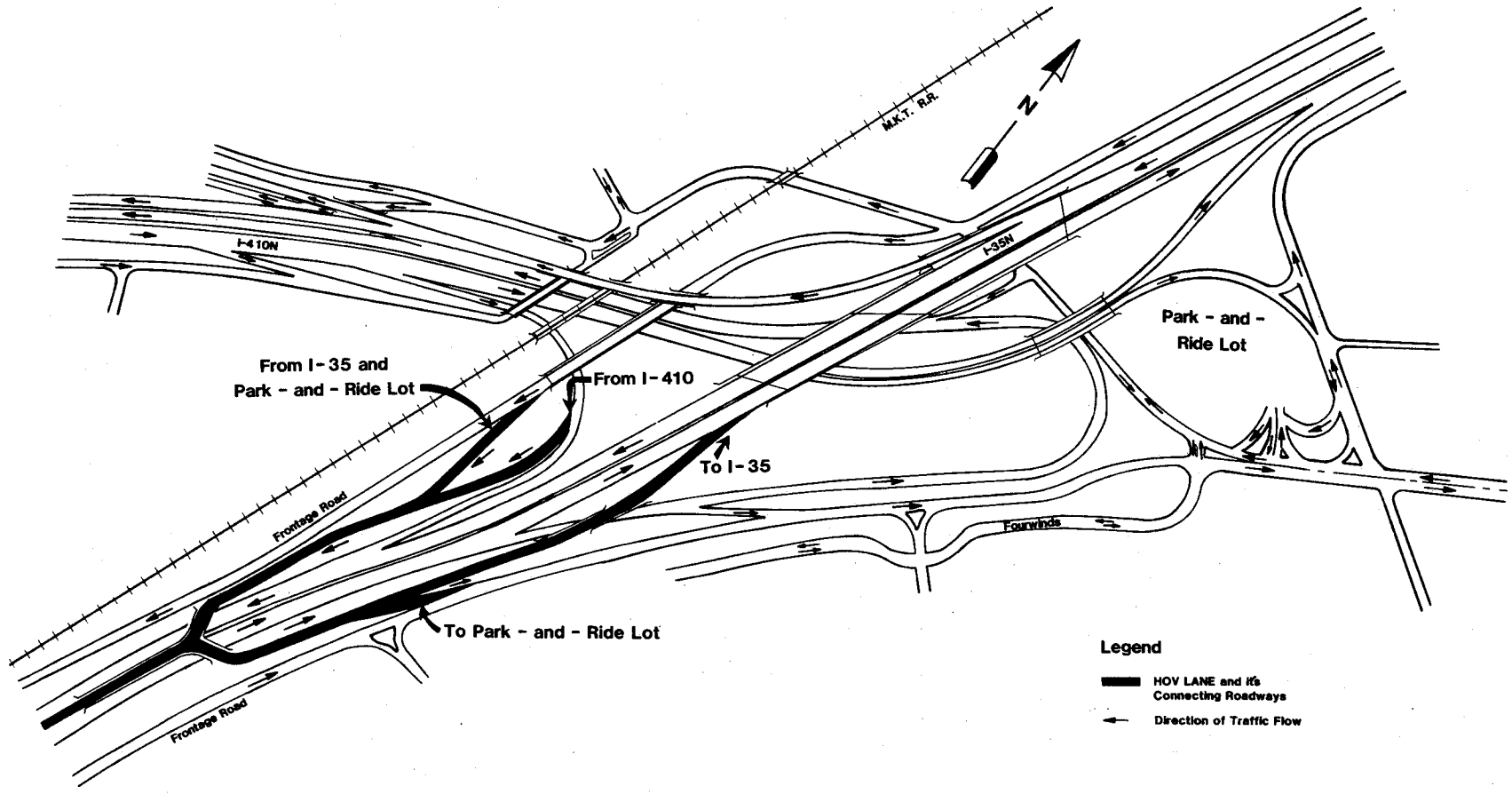
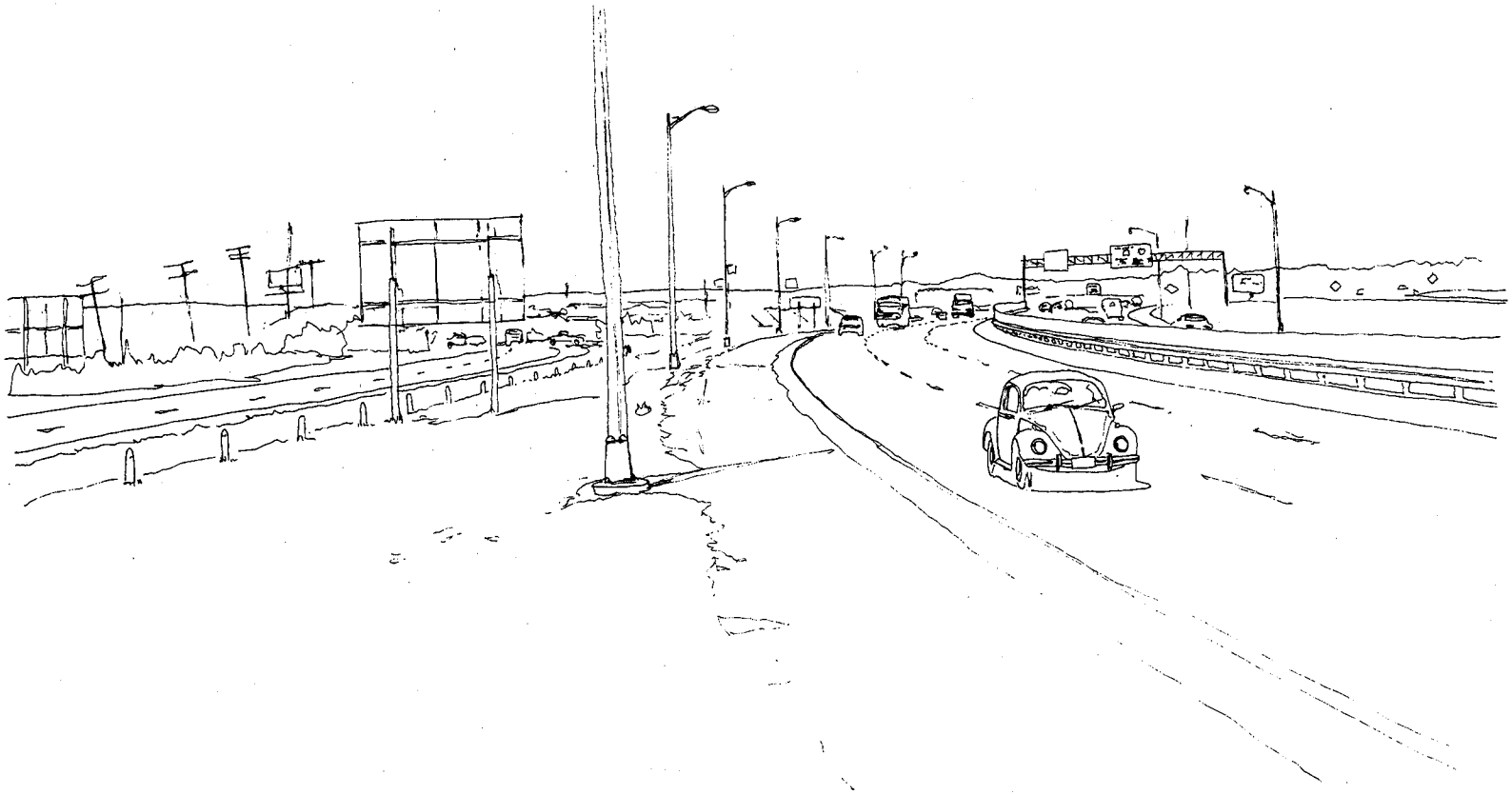
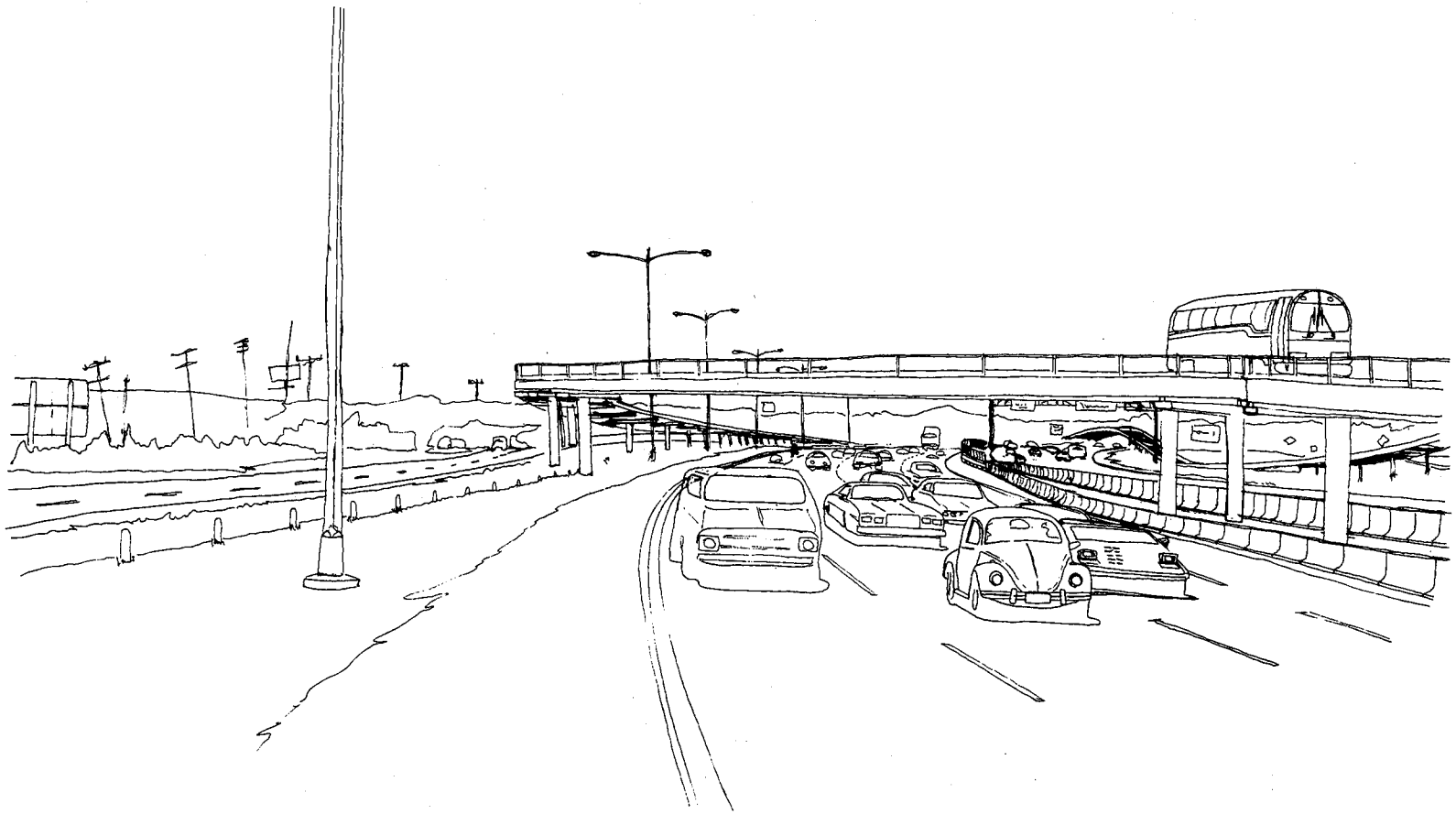


Figure 10: Proposed Fratt Interchange With Ramp Connections to a Median HOV Lane



Location: South of I-410N Interchange (Fratt Interchange), looking north
Existing

Figure 11: A Manner in Which Flyover Ramps Can Be Used to Provide Access to the Median HOV Lane



Location: South of I-410N Interchange (Fratt Interchange), looking north
Possible Future

Figure 11: (Continued)

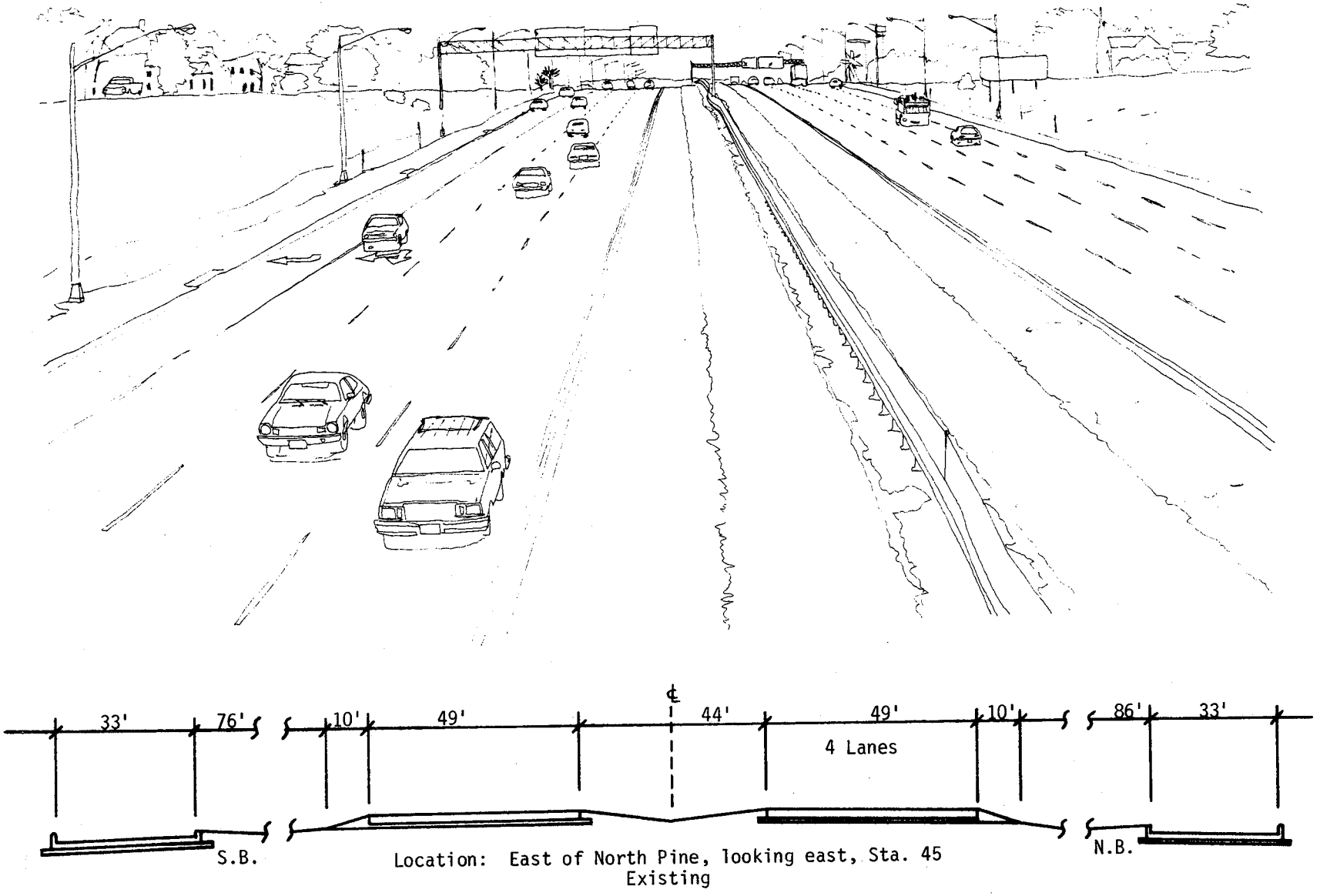
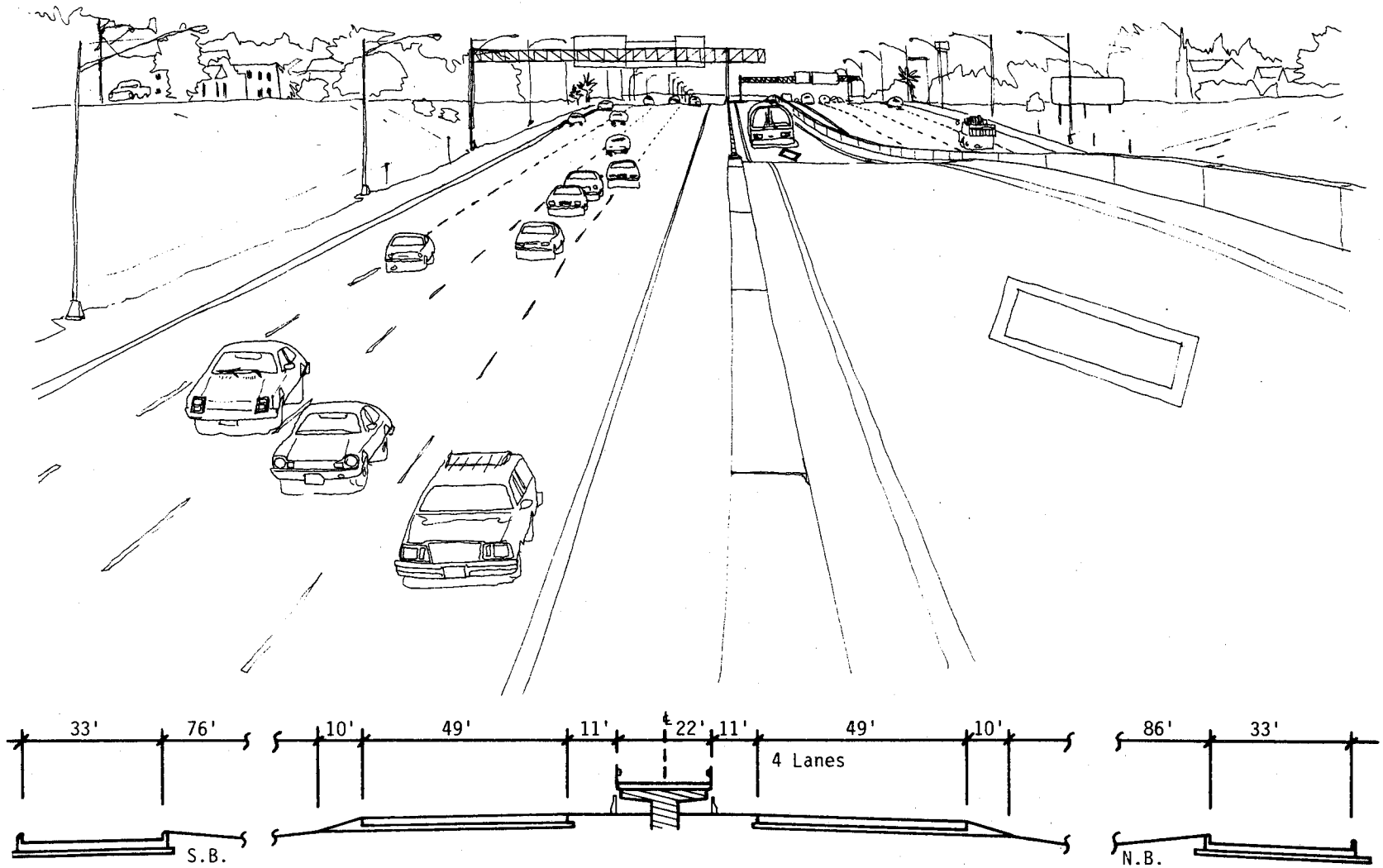


Figure 12: Example of a Manner in Which the Median HOV Lane and Pine Street Could Intersect, Providing Access to the San Antonio CBD



Location: East of North Pine, looking east, Sta. 45
Possible Future

Figure 12: (Continued)

- Length of Improvement. The improvement originates upstream of the traffic congestion, 8.5 miles from the CBD. Insufficient utilization of the lane would result if that were the only access point.

- Alternative Destinations. Although downtown San Antonio will be the primary destination point served, the lane also has the capability to serve some trips to Fort Sam Houston. That traffic would enter and exit the lane prior to the southern terminus of the HOV lane at North Pine Street.

- Emergency Operation. The HOV improvement will be one lane wide. Midpoint entries may be necessary both to provide emergency vehicle access to stalled vehicles and to use as a means of getting traffic off of the HOV lane if that lane becomes blocked for an extended period of time.

Possible Designs and Locations

The median HOV lane will, for most of the length of the improvement, be at the same elevation as the main freeway lanes. This will be true except for those locations where midpoint access to the HOV lane is provided. At those locations, the median HOV lane will be elevated, and flyover ramps will be used to provide access/egress to the HOV lane. Alternatively, ramps from the median HOV lane can be developed to intersect with existing overpass structures, such as at New Braunfels. Access and egress treatments at the terminal points of the lane have been discussed previously.

Again, it is not the intent of this study to determine the specific locations at which midpoint entries will be provided. A number of locations at which it appears feasible to provide such access are identified in this section; however, none of these possibilities are necessarily optimal in all respects, nor do they represent the only possibilities available.

Midpoint access to the median HOV lane might be considered at the following locations.

- New Braunfels. A ramp could be provided from the median HOV lane to the existing overpass at New Braunfels. This could serve as the connection to Fort Sam Houston.

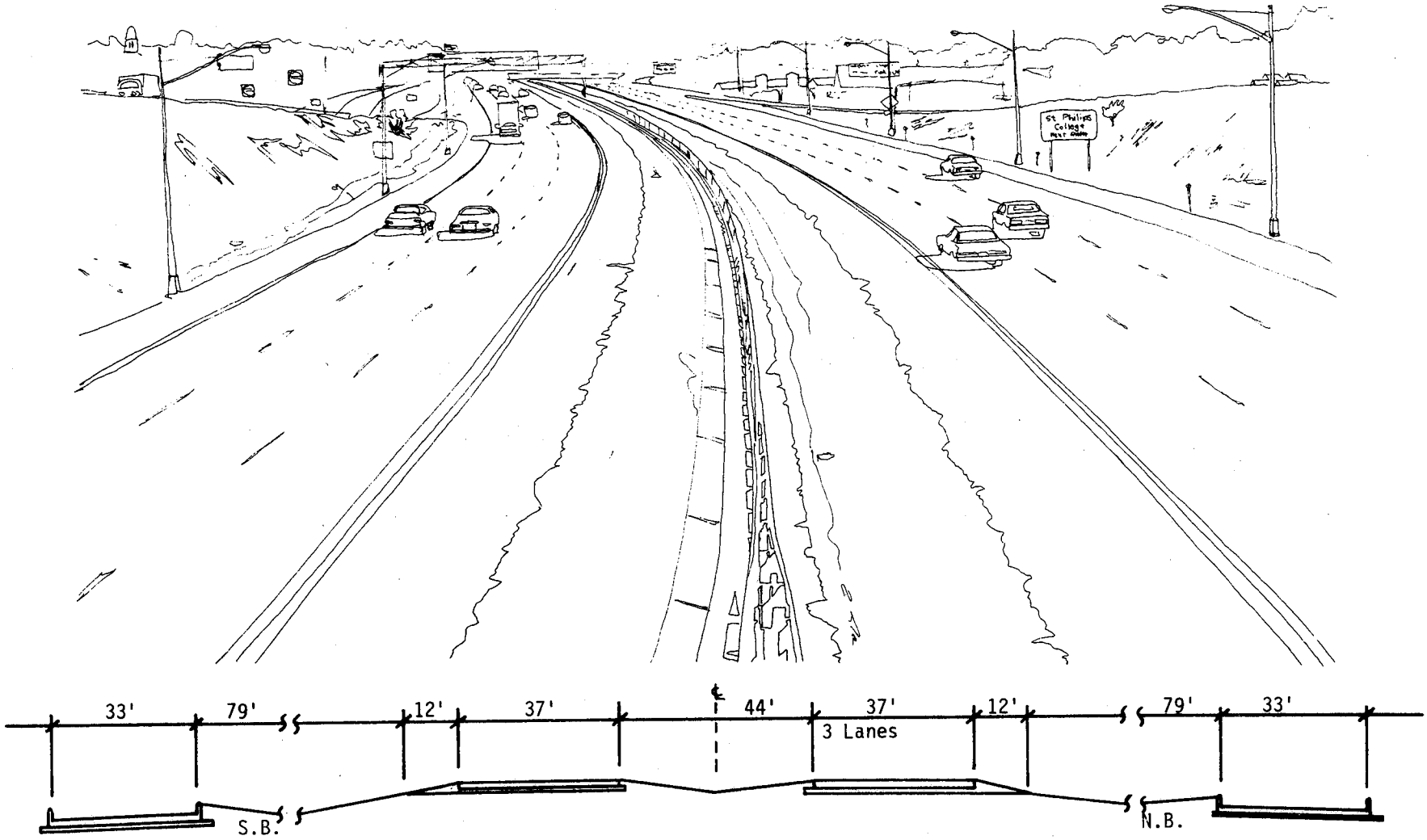
- Petroleum Drive. A flyover ramp could intersect with an elevated portion of the HOV lane, providing additional access to Fort Sam Houston.

- Vicinity of Rittiman and Eisenhauer. A flyover ramp to an elevated section of the HOV lane in this general location would serve a large volume of entering traffic destined to downtown San Antonio (Figure 6). A number of alternative locations exist at which such access could be developed. Railroad track clearance poses a possible design problem.

Additional Cross Sections and Critical Segments

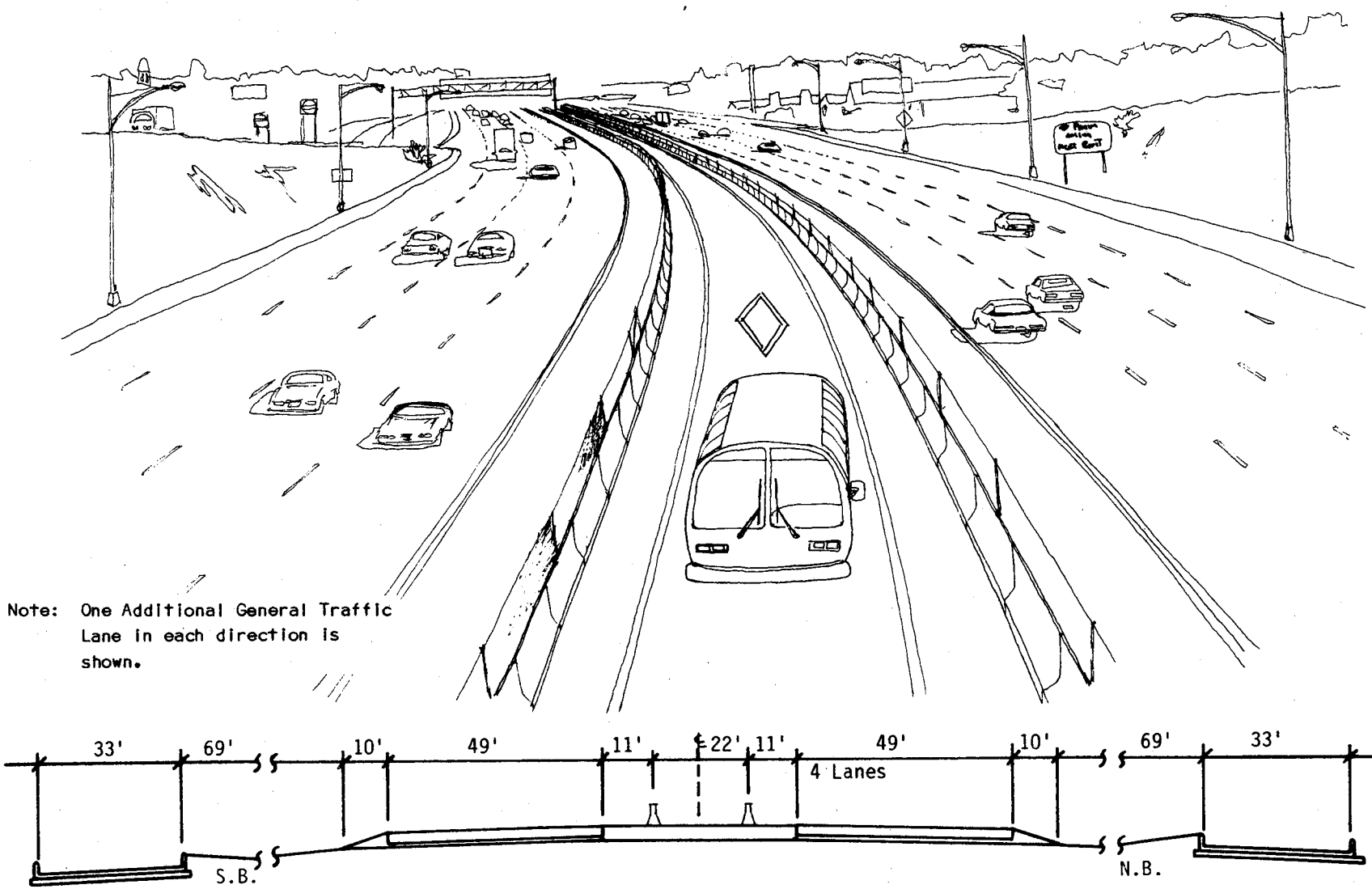
A number of cross sections and renderings have been presented in previous portions of this section. All renderings presented in this section relate to the provision of a one-lane, median HOV lane. Renderings that depict other alternative priority measures are included in Appendix B of this report.

Figures 13, 14, and 15 show three additional views of the one-lane median HOV facility. A tunnel will be needed to stay in the median and go under the ramp from I-35 (southbound) to I-410E (Figure 16). These cross sections cause no particular problems except at those locations where overpasses with center columns in the I-35 median exist. To maintain inside shoulders and desirable lane widths, widening will be required throughout the length of the improvement as will filling in the opening between existing freeway structures in the median. A description of the geometric constraints that are created at each cross street overpass is presented in Table 6; since the HOV lane will exist only on one side of the center column of the overpass, one direction of travel on I-35 will be unaffected by the provision of a one-lane, median HOV facility.



Location: East of New Braunfels, looking east, Sta. 83
Existing

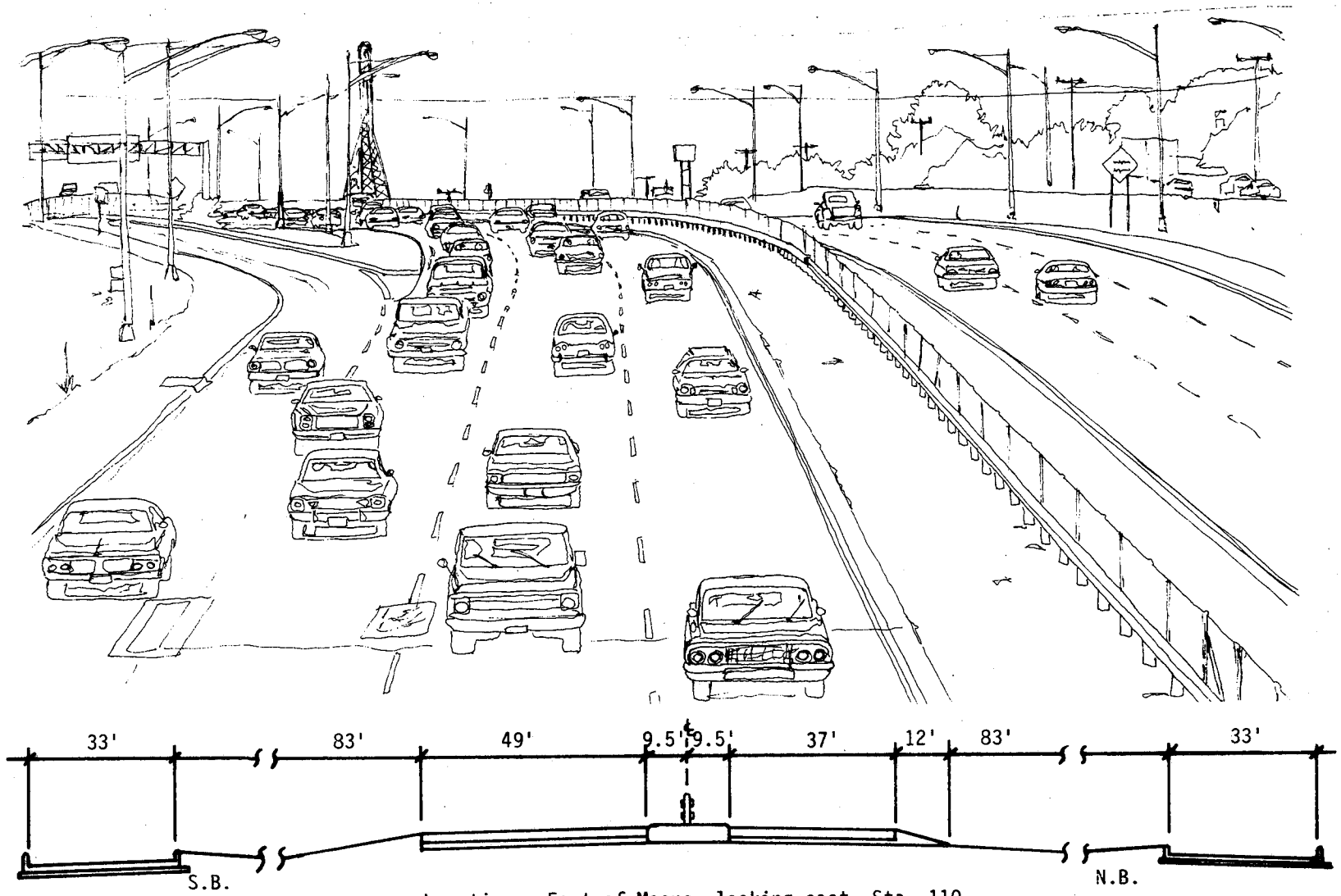
Figure 13: "Typical" Section of Possible One-Lane Median HOV Lane in a Wide Median



Note: One Additional General Traffic Lane in each direction is shown.

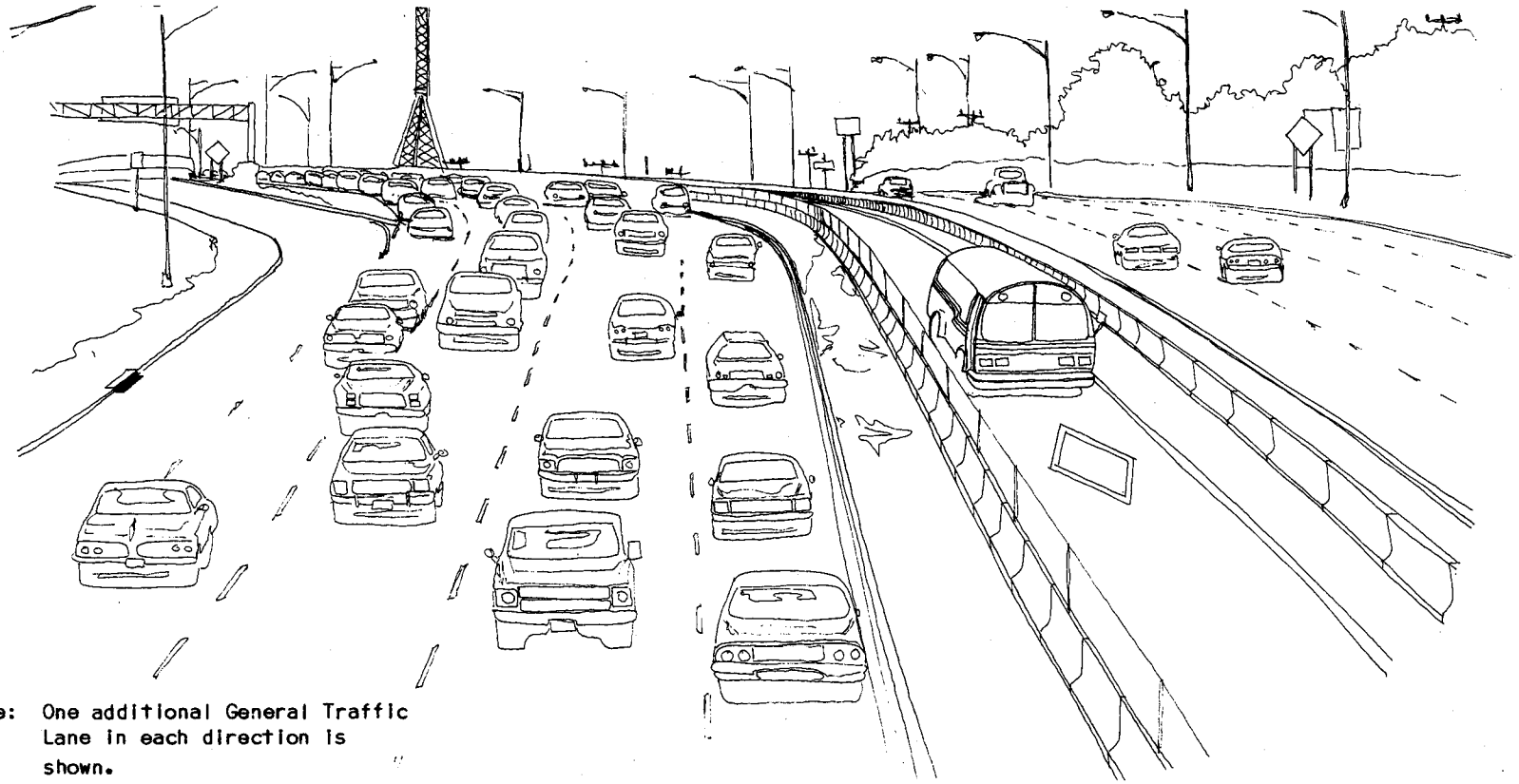
Location: East of New Braunfels, looking east, Sta. 83
Possible Future

Figure 13: (Continued)

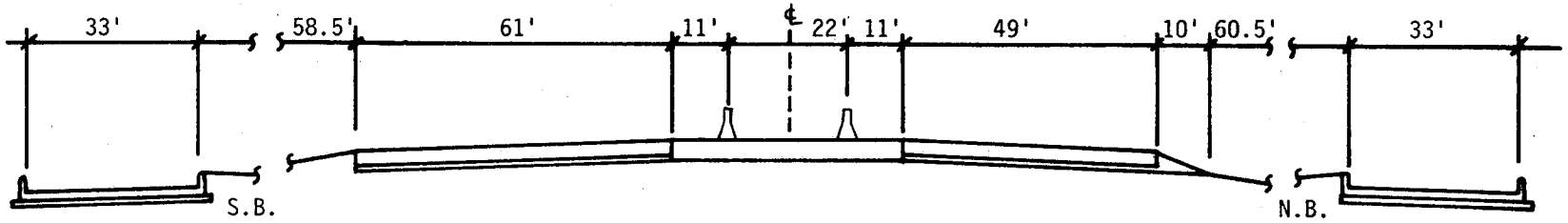


Location: East of Moore, looking east, Sta. 110
Existing

Figure 14: "Typical" Section of Possible One-Lane Median HOV Lane in a Standard Median



Note: One additional General Traffic Lane in each direction is shown.



Location: East of Moore, looking east, Sta. 110
Possible Future

Figure 14: (Continued)

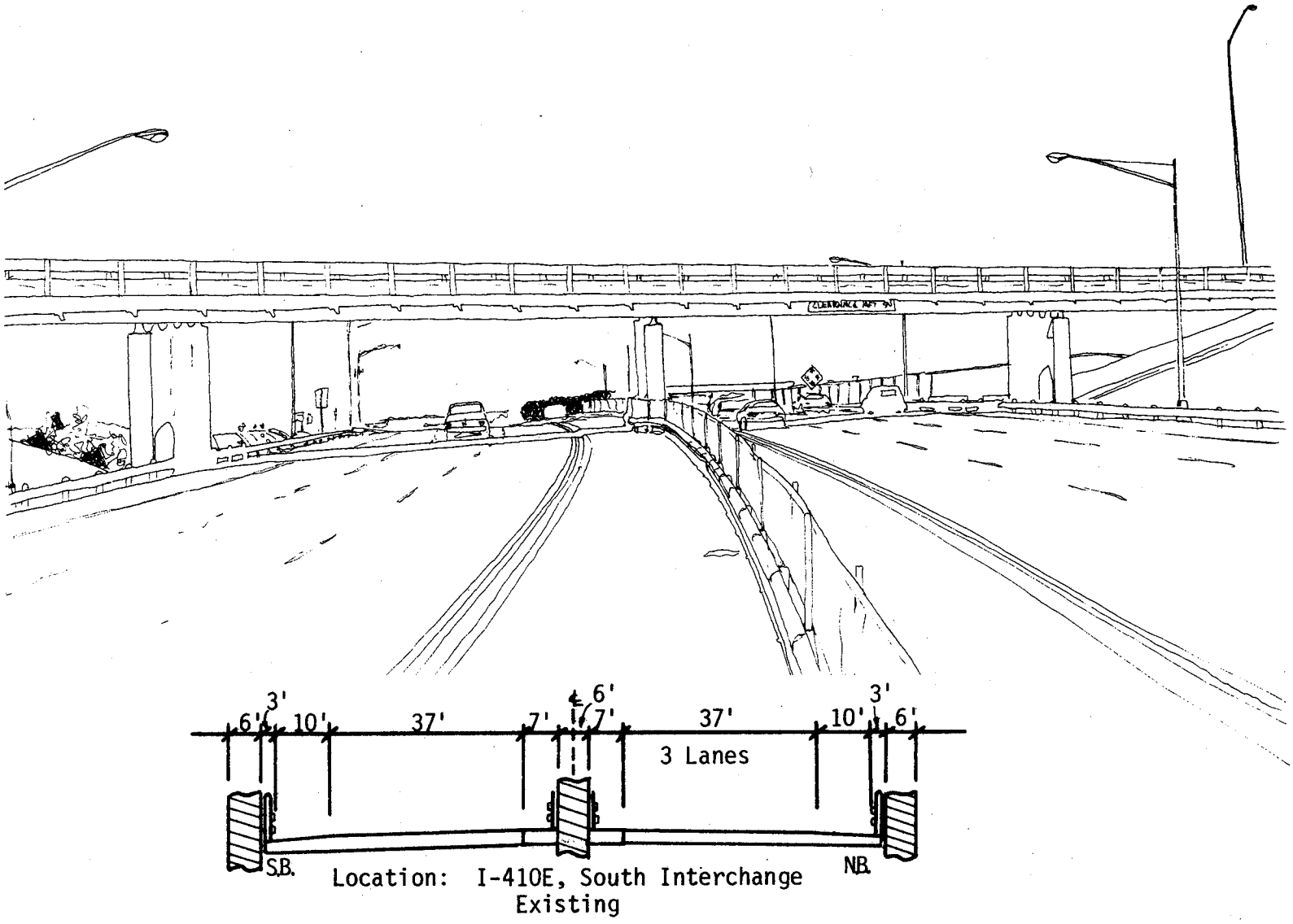
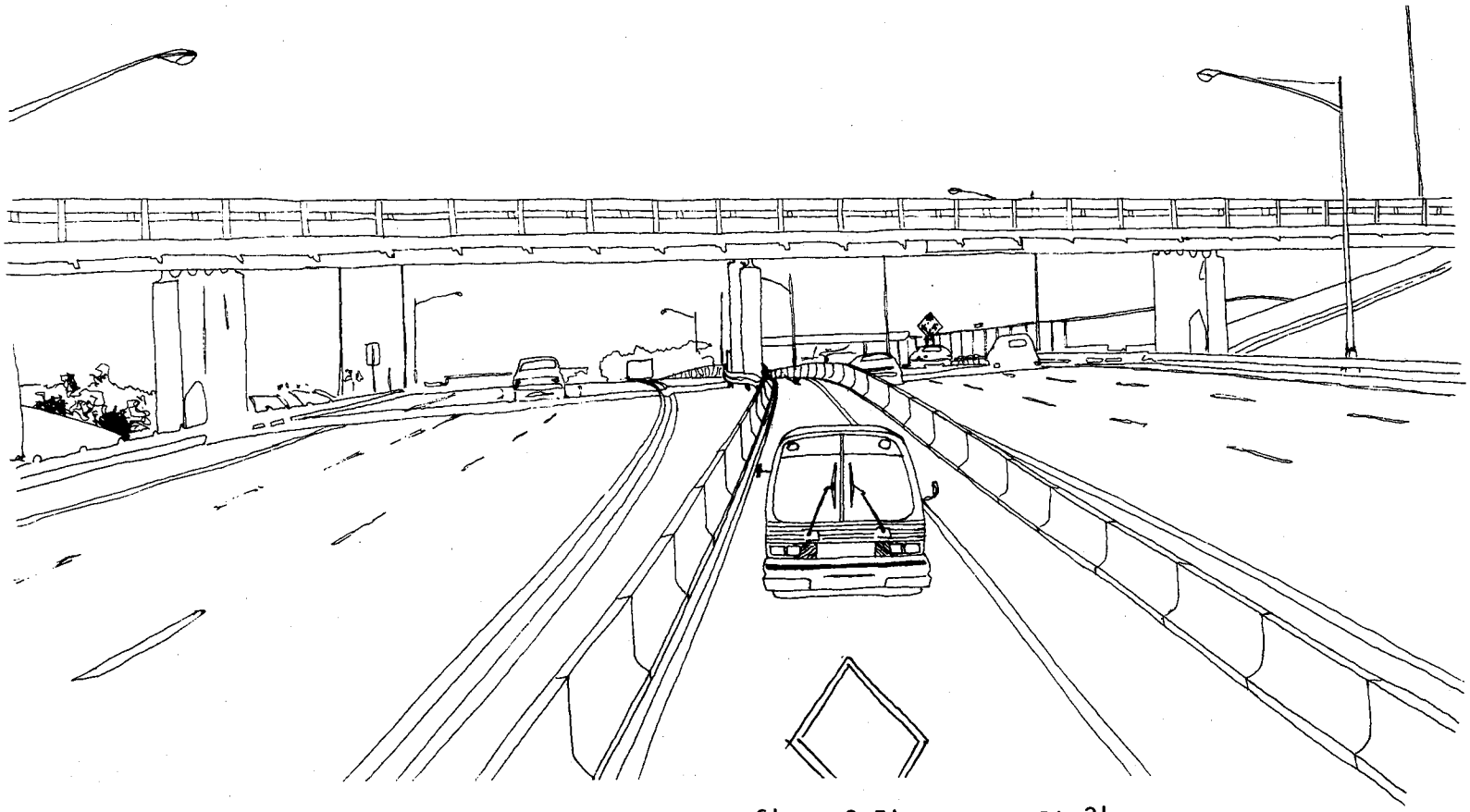
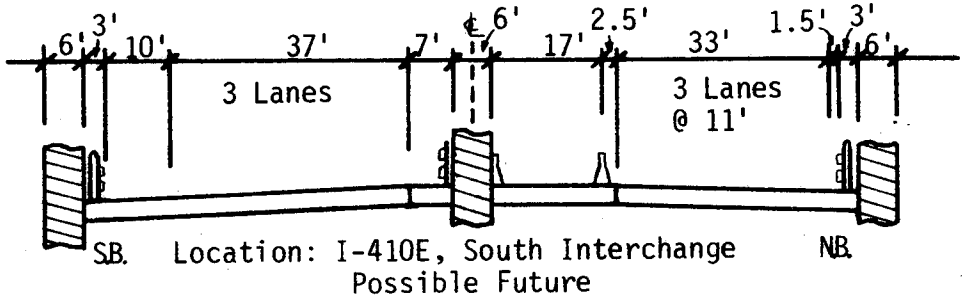


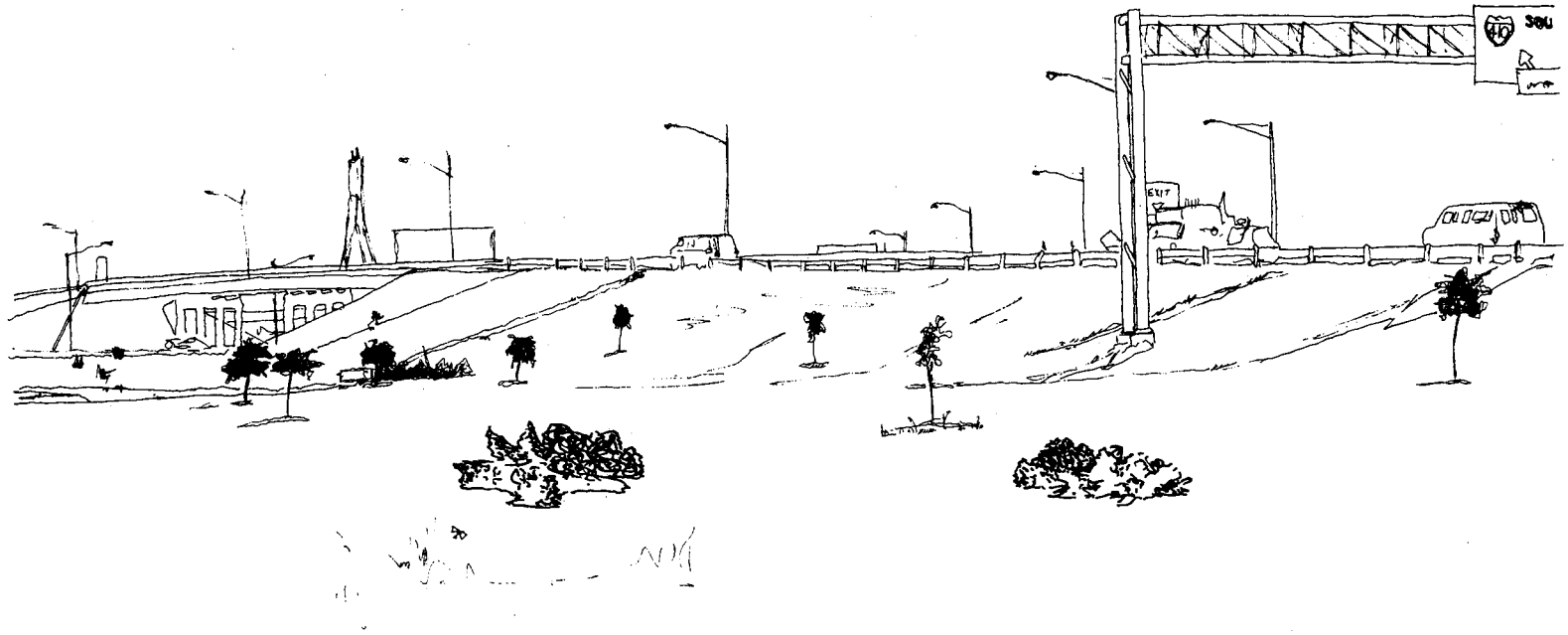
Figure 15: A Manner in Which the One-Lane Median HOV Lane Could Be Continued Through the I-410E Interchange (South Section)





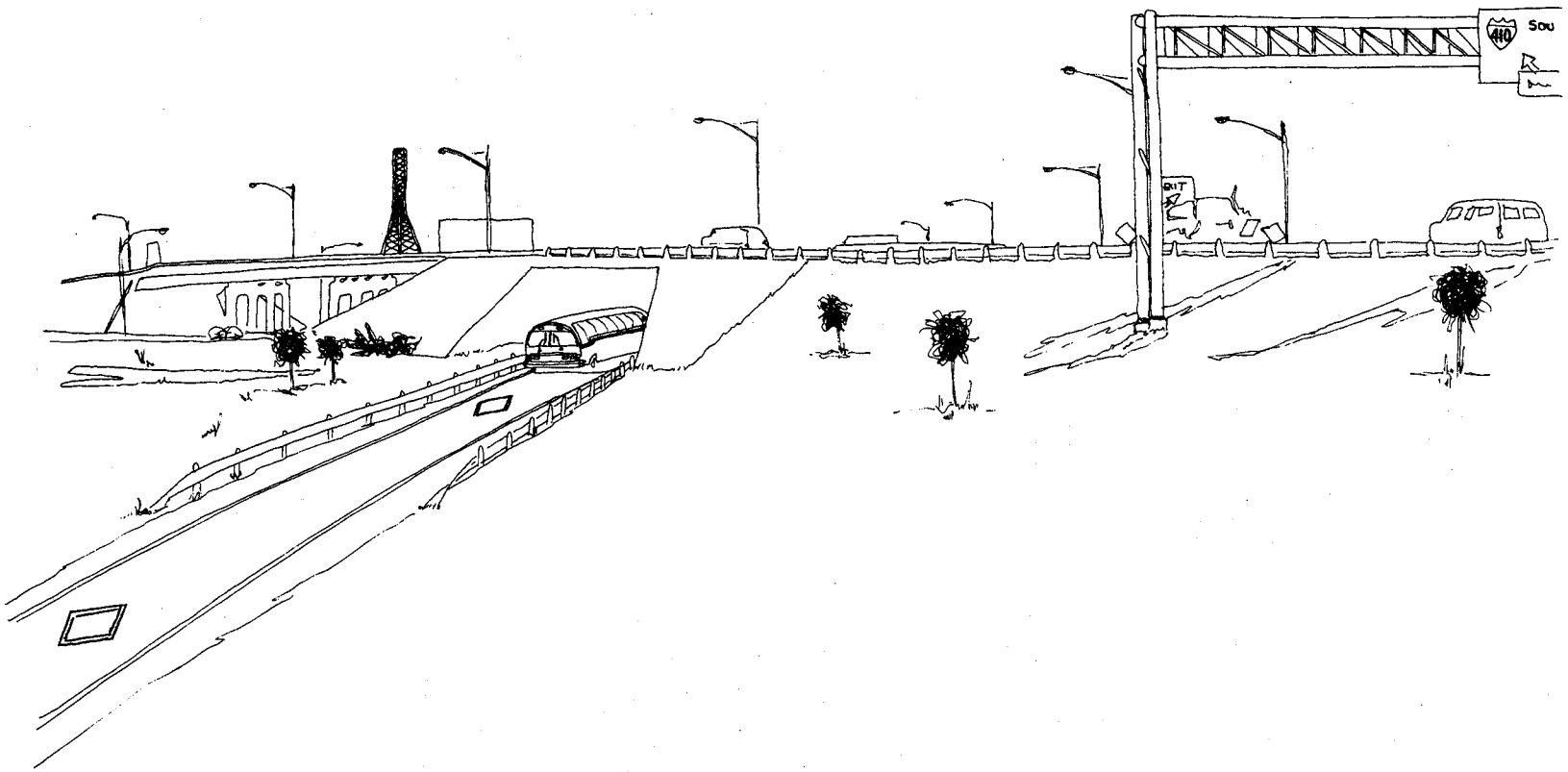
Location: I-410E, South Interchange
Possible Future

Figure 15: (Continued)



Location: I-410E Interchange, (North Section)
Existing

Figure 16: A Manner in Which the One-Lane Median HOV Lane Could Be Continued Through the I-410E Interchange (North Section)



Location: I-410E Interchange (North Section)
Possible Future

Figure 16: (Continued)

Table 6: Cross Section Constraints Created By Cross Street Overpass Structures

Overpass Location	Approx. Fwy. Width Between Structures	Freeway Cross Section[1]			
		6 Lanes		8 Lanes	
		HOV Lane Width	Fwy. X-Section	HOV Lane Width	Fwy. X-Section
Pine	77'	2	2	2	2
New Braunfels	65'	17.5	Ins. Shldr=2.5' Main Lanes=3@12' Out. Shldr.=10'	17'	Ins. Shldr.=2.5' Main Lanes 4@11' Out. Shldr.=3'
Moore & S.P.R.R.	54'	16'	Ins. Shldr.=2.5' Main Lanes=3@11' Out. Shldr.=2.5'	3	3
I-410E Intchg.	54'	17'	Ins. Shldr.=2.5' Main Lanes=3@11' Out. Shldr.=1.5'	3	3

[1] At locations other than overpasses, the existing freeway width will need to be expanded in order to provide a median HOV lane and inside shoulders in both travel directions. However, this expansion, in conjunction with a major freeway reconstruction, should pose no major problems except at existing overpasses. At locations other than overpasses, the HOV lane will be 22 feet wide (center of median barrier to center of median barrier).

[2] As described in this study, the HOV lane will terminate at an intersection with the Pine Street overpass and will not pass under that structure, although sufficient space is available to do so.

[3] Due to available median width and the presence of bridge columns, if an at-grade median HOV lane is provided, 8 lanes of freeway cannot be provided at either Moore or the I-410E interchange. At Moore, either the overpass structures would need to be rebuilt to eliminate center columns or the HOV lane would need to be elevated two levels. At the I-410E interchange, for the direction of travel in which the median HOV lane is included, a lane will need to be dropped at the I-410E exit ramp and added at the subsequent entrance ramp. Only 3 through lanes can be provided in that direction through the interchange.

CONCLUSIONS

This study evaluated the needs for priority treatment for high-occupancy vehicles on an 8.5 mile section of the North PanAm Freeway (I-35) from the I-37 Interchange to the I-410N Interchange (Fratt Interchange). At present, there is not an immediate need to implement any priority measures. During peak periods the study freeway operates at approximately level-of-service (LOS) C.

However, due to the lead time involved in implementing certain priority measures, the need for such measures should be anticipated in order to permit the improvement to be operational at the time the need for that improvement has developed. Some of the most rapid increases in traffic volumes in the state have occurred along I-35, and year 2000 traffic projections in the range of 150,000 suggest that a need for priority treatment may develop.

The needs, if any, for priority treatment were evaluated for the time and funding levels listed below.

- Immediate implementation, low cost. Priority measures such as signal preemption and priority entry for high-occupancy vehicles are representative of this type of improvement.
- Moderate implementation time, moderate cost. Priority measures in this category would include contraflow lanes and one-lane median busways.
- Long implementation time, very high cost. Multilane HOV facilities would be representative of this type of improvement.

Due to the relatively low bus volumes in San Antonio, any priority measure implemented should be capable of also serving carpools.

It was estimated that, given the present 6-lane cross section, a need for a low-cost, short implementation time improvement might develop by the mid-1980's. Priority entry was identified as being the most applicable technique. A need for a moderate implementation time, moderate cost improvement may develop by the mid-1990's; a one-lane, reversible, median high-occupancy

vehicle lane represents the most applicable technique. If the freeway is expanded to 8 lanes, as called for in the current 20-year plan, the need for priority treatment improvements is delayed but not eliminated. Within the 20-year planning horizon considered in this study, a need for a long implementation time, very high cost priority improvement was not identified.

Priority Entry

Once freeway operation approaches LOS D, provision of priority entry ramps at selected locations warrants consideration; that condition should exist in the mid-1980's. As applied to the North PanAm Freeway, no attempt would be made to meter all traffic entering the study freeway, since 30 percent of that traffic enters at freeway-to-freeway ramps. Rather, priority entry ramps might be provided at 4 locations -- Walzem, Rittiman, Moore, and New Braunfels. Buses plus carpools (2 or more persons per vehicle) would be allowed to use the priority ramps. In 1985, some 1400 vehicles would use the priority ramps during the peak hour; 33 percent of total traffic at the priority ramp locations would use the priority lane, and that traffic would move 53 percent of the person volume.

Priority entry at the 4 ramps would require a capital expenditure of approximately $200,000 (1979 dollars). Since the implementation time would be about 6 months, no action needs to be taken at this time. Once it becomes evident that the need exists for the improvement, that improvement can be implemented rather rapidly. Enforcement is a major concern in planning and implementing this priority measure.

Median HOV Lane

Once main lane traffic begins to operate at LOS E, the priority entry improvement will lose some of its effectiveness. A one-lane, reversible, median HOV lane offers considerable improvement over priority entry in terms of travel speed, travel time, capacity, and schedule reliability. As a result, once LOS E is approached, this improvement becomes attractive.

The median lane would be used by buses and carpools (3 or more persons per vehicle). Travel demands to both the CBD and Fort Sam Houston could be served. The lane would generally be at the same grade as the freeway, except at those locations where midpoint entry is needed; at midpoint entry locations the median lane would be elevated, and flyover ramps would be used to provide midpoint access. The lane would operate from the Fratt Interchange to Pine Street.

With the 6-lane facility, a median HOV lane (22 feet wide) can be provided without major problems. Some freeway widening would be required and, as a result, implementation of this improvement should be done in conjunction with a major freeway reconstruction. If the freeway is expanded to 8 lanes, existing overpass structures at 3 locations pose problems due to center columns.

In 1990, perhaps 400 vph would use the exclusive lane at the maximum load point. Those vehicles would experience about an 8 minute time savings if they travelled the length of the priority lane. The capacity of the lane should be sufficient to serve travel demands until at least the year 2000.

An implementation time of 5 to 10 years would be required. The improvement will cost approximately $17 million (1979 dollars).

Concluding Observation

Due to the implementation times associated with the improvements and the projected time until those improvements are needed, the Department does not need to take any immediate actions. This report documents what improvements may be needed, but sufficient time exists to allow the Department to wait to see if the need does, indeed, develop. If so, to the extent possible, provision of the HOV priority measures should be undertaken in conjunction with other improvements planned by the Department for the North PanAm Freeway.

APPENDICES

- Appendix A. Auto Work Trip Estimate
- Appendix B. Additional Renderings

APPENDIX A

Estimating CBD Auto Work Trips Entering the Southbound North PanAm Freeway.

This analysis is based on past research conducted by TTI in Houston. Two independent estimates are formulated, and the average of the two estimates was used to find the number of auto work trips to the San Antonio CBD made via I-35N.

Work Trips, Estimate 1

It has been found that the work trips into the CBD can be estimated as 9.5 percent of the ADT count closest to the CBD (Table A-1). The 1979 AADT at I-35N and North Pine Street (the AADT closest to the CBD) is given as 65,000 vehicles (State Traffic Map). Therefore:

65,000 Vehicles x 9.5% auto work trips = 6175 auto work trips to CBD on I-35N.

Table A-1: CBD Work Trips as a Percent of ADT for Houston Radial Freeways

Freeway	1975 Auto Work Trips to CBD	1975 ADT Closest to CBD	Work Trips as a Percent of ADT
Eastex	8,100	107,570	7.5%
Gulf	13,800	165,330	8.4
Southwest	15,800	134,720	11.7
Katy	11,500	105,940	10.9
North	11,200	120,480	9.2
Weighted Average			9.5%

Work Trips, Estimate 2

The City of San Antonio estimated that 1979 CBD employment was 39,957. Several factors are applied to this figure to arrive at an estimate for auto work trips to the CBD via the freeways.

- Assume that, on any given workday, approximately 5 percent of the workers will be absent from work (sickness, travel, etc.).

- Using information from a TTI study performed in Houston, and recognizing that freeways in Houston are more intensely congested than those in San Antonio, it is estimated that 80 percent of the CBD workers arrive in downtown via the freeway system. (The corresponding value in Houston is 67 percent).

- Auto occupancy for urban travel is estimated at 1.3 persons per vehicle. Therefore:

CBD employment	X	Percent of workers on job any day	X	Percent of freeway users to CBD	÷	Auto Occupancy	=	Auto work trips to the CBD via the freeway
39,957	X	95%	X	80%	÷	1.3	=	23,359 trips

- Using the Department's Traffic Volume Maps, it was found that North PanAm carried 18 percent of the total freeway volume entering the CBD (based on ADT values).

Trips to CBD	X	Percent of trips on I-35N	=	Auto work trips on I-35N
23,359	X	18%	=	4205

4200 auto-work trips to the CBD on I-35N.

Work Trips, Final Estimate

Estimates 1 and 2 are averaged to obtain a value for use in this study

Estimate 1					6,175	
+Estimate 2					+ 4,200	
Total	÷	2	=	Average	10,375	÷ 2

There are approximately 5200 daily auto work trips to the CBD using the North PanAm Freeway.

Distribution of 1979 Auto Work Trips on I-35N

Knowing the number of vehicles entering the CBD on the North PanAm Freeway and given an estimate of the number of vehicles entering that freeway before

the Fratt Interchange and destined for downtown, it is assumed that the remaining trips may be factored to the entrance ramps based on the overall ramp volume. Research in Houston found that, at 8.5 miles (the distance from the CBD to the Fratt Interchange) from the CBD, approximately 40 percent of the CBD-bound vehicles were on the freeway. It is assumed that 20 percent would be a more appropriate estimate for the I-35N corridor since intense urban development does not exist as far from downtown San Antonio as it does from downtown Houston. The following procedure was used to determine the number of CBD work trips entering at each ramp.

Number of Total CBD work-trips	X	Percent of CBD trips on I-35N before Fratt Interchange	=	CBD work trips on I-35N before Fratt Interchange

5200 X 20% = 1040

The number of trips to distribute to the ramps is then:

5200 - 1040 = 4160 CBD auto work-trips

The total of all entrance ramp volumes was computed, and then used to find the percentage of the total that each ramp represented. This percentage was applied to the number of work trips to achieve an estimate of the number of CBD work trips entering at each ramp. Table 2 in the main text shows ramp volume by ramp location.

CBD Work Trips for 1990

In order to achieve an estimate of entrance ramp volumes in the future, the yearly increases of employment in the CBD and AADT on North PanAm are averaged.

Estimate 1 - Employment

The City of San Antonio supplied TTI with a forecast for CBD employment in the year 2000.

1979 = 39,957 jobs
2000 = 45,815 jobs employment increase = 14.7%

The projected average yearly increase in employment is 0.65 percent.

Estimate 2 - AADT

The Department made estimates of AADT at three places along North PanAm for the year 2000. Those estimates are shown below along with their average yearly percentage increase.

Location	1976 AADT	2000 AADT	Percent Change per year
Coliseum Road	73,800	162,800	+ 3.35%
South of Rittiman Road	74,500	152,500	+ 3.03%
Fratt Interchange	53,100	116,500	+ 3.33%

The projected average yearly increase in AADT is 3.24 percent.

Average of Two Estimates

Estimate 1		3.24
+Estimate 2		+0.65
Total ÷ 2	= Average	3.89 ÷ 2

The factor that is applied to the 1979 total ramp volume to obtain a 1990 estimate is a yearly increase of 1.95 percent. It is foreseen that development in San Antonio will have changed somewhat by 1990 (more development outside of I-410N), so the amount of CBD work trips on the freeway at the Fratt Interchange is raised to 25 percent. A procedure similar to that followed in 1979 is used to calculate the entrance ramp volumes.

Final estimates are shown in Figure 6 in the main text.

APPENDIX B

Renderings of Alternative HOV improvements

This report identified two HOV priority improvements -- priority entry and a one-lane median HOV lane -- as warranting consideration for implementation on the North PanAm Freeway. Renderings of those improvements are included in the text. Renderings of other possible improvements, considered in this study but not recommended for implementation, are included in this appendix. The following renderings are included.

- Contraflow Lane at the I-410E interchange
- Two-Lane, Median HOV facility
  - I-410E interchanges (north and south)
  - Moore Street (looking north)
  - New Braunfels (looking north)
  - Pine Street

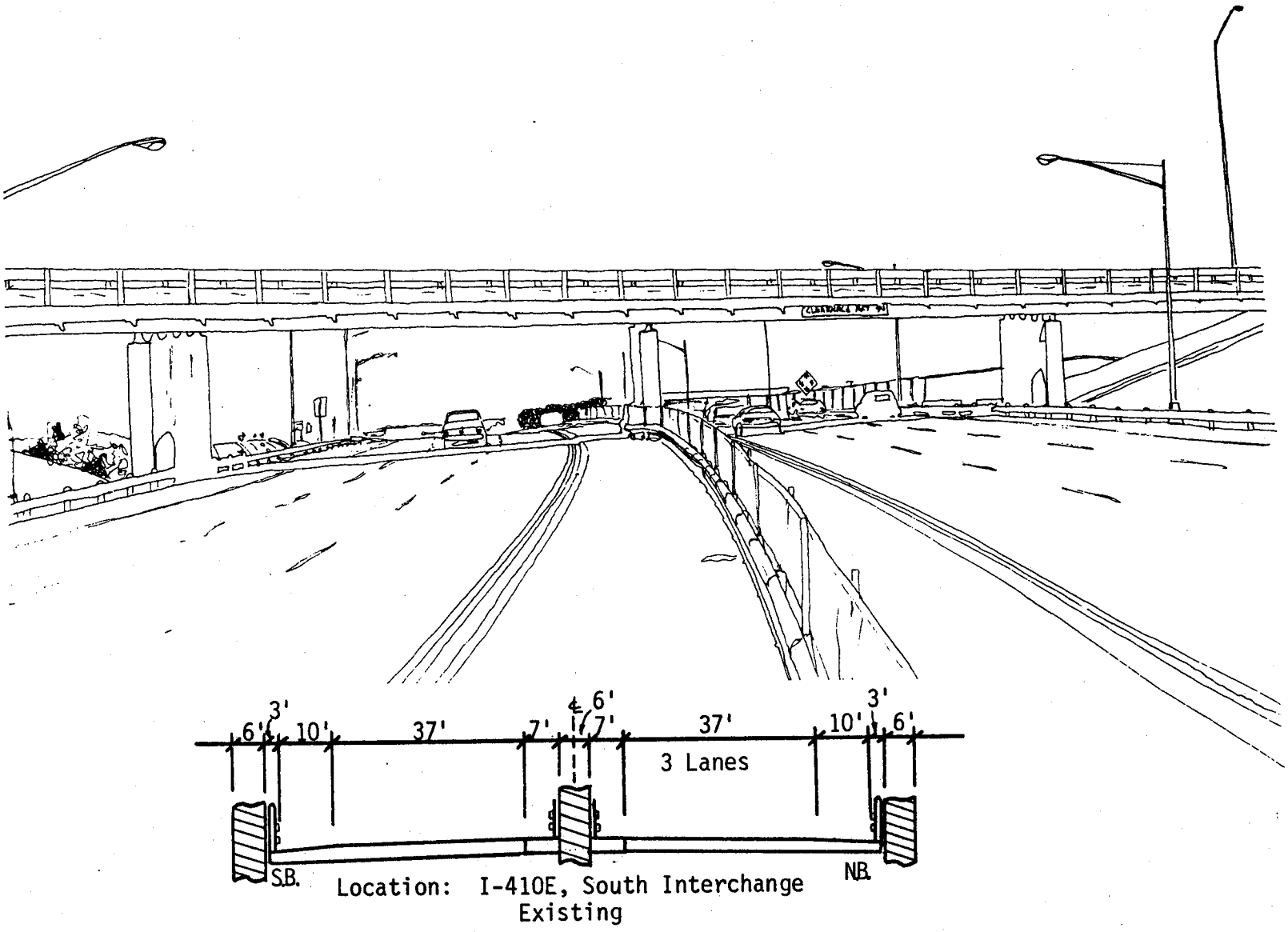
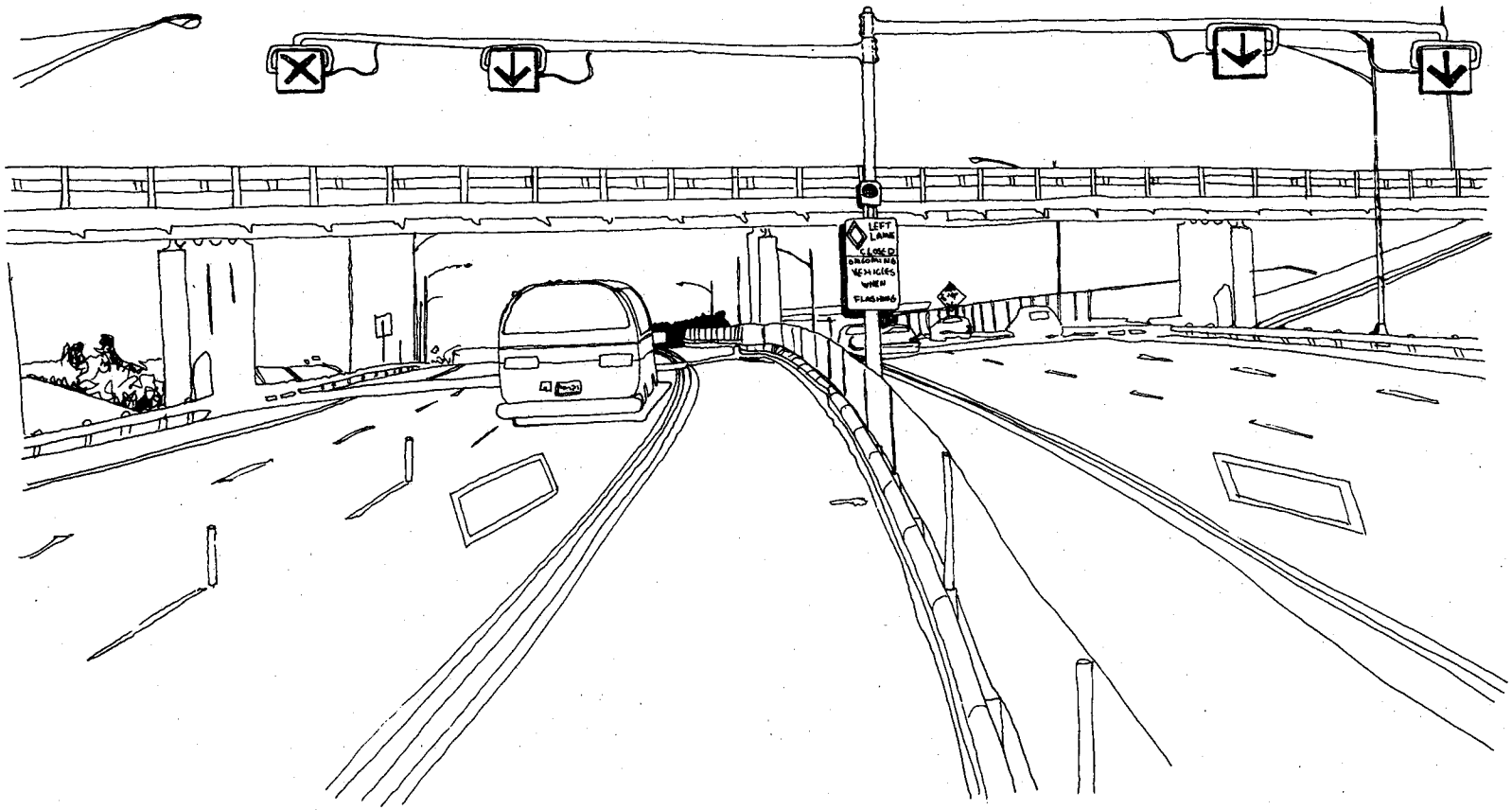
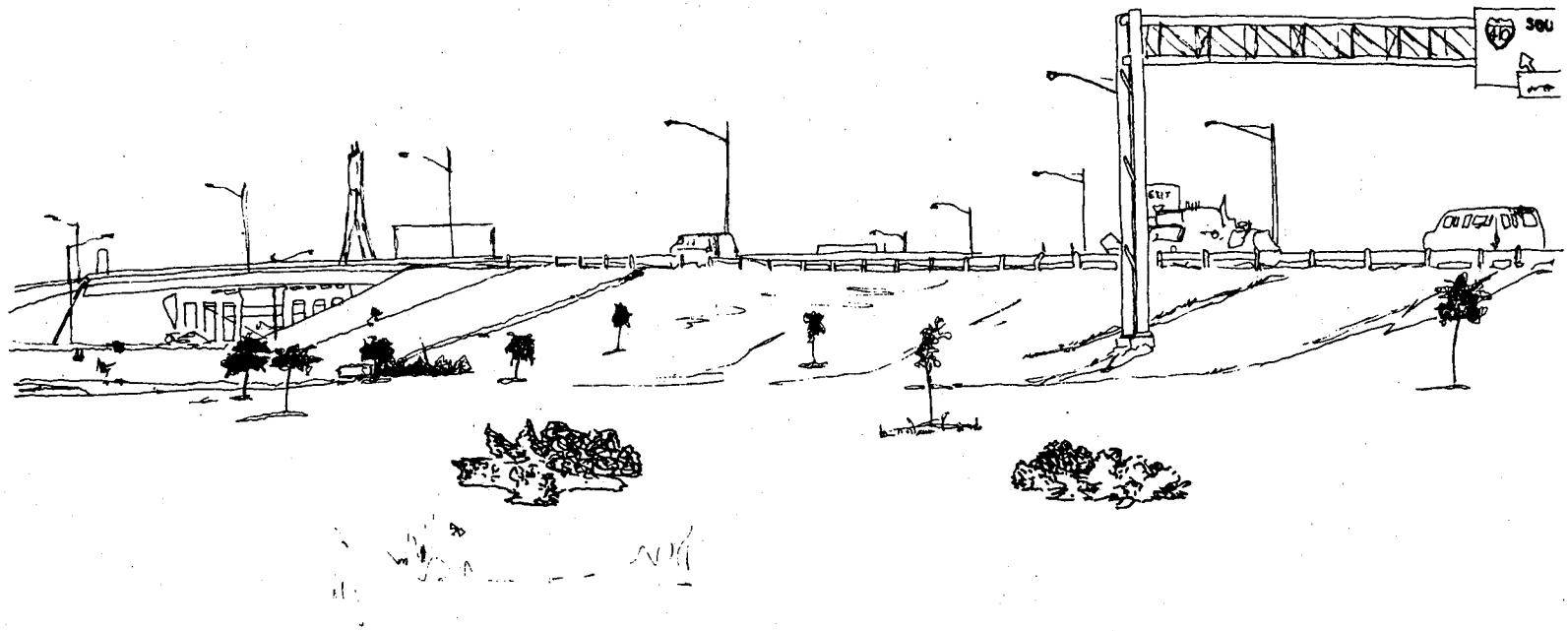


Figure B-1: A Manner in Which a Contraflow Lane Could Be Continued Through the I-410E Interchange (South Section)



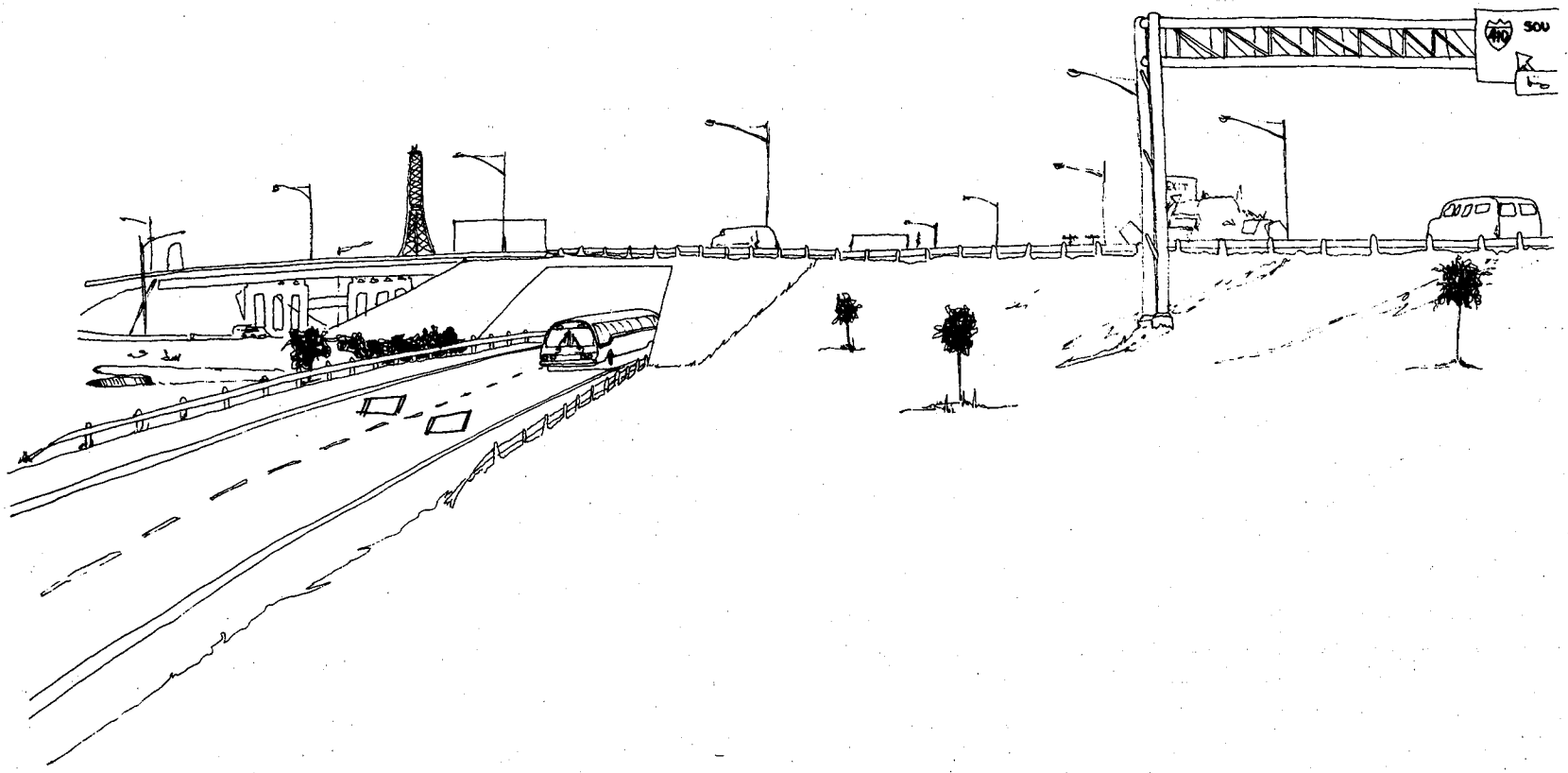
Location: I-410E, South Interchange
Possible Future

Figure B-1: (Continued)



Location: I-410E Interchange, (North Section)
Existing

Figure B-2: A Manner in Which the Two-Lane Median HOV Lane Could Be Continued Through the I-410E Interchange (North Section)



Location: I-410E Interchange, (North Section)
Possible Future

Figure B-2: (Continued)

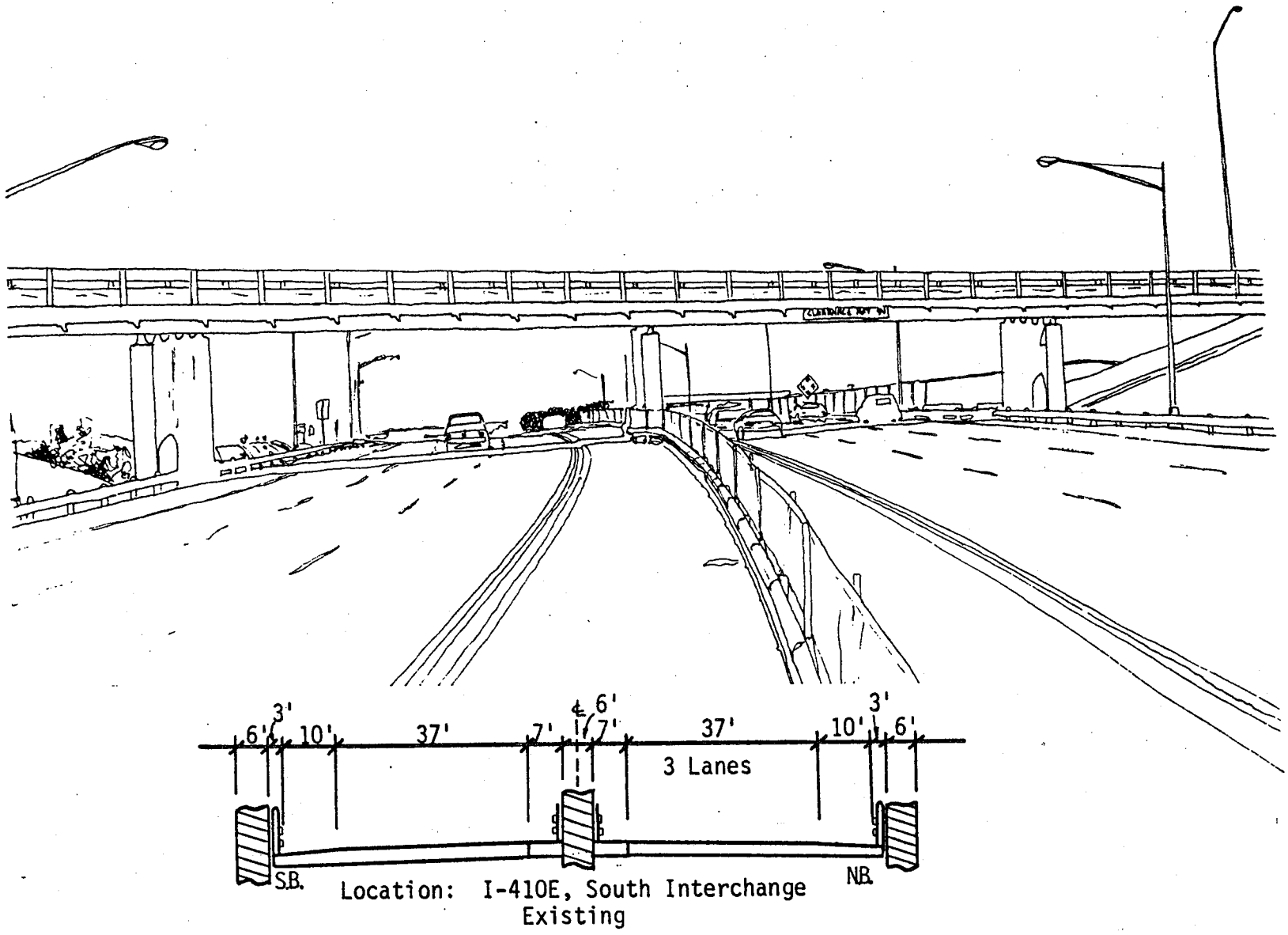
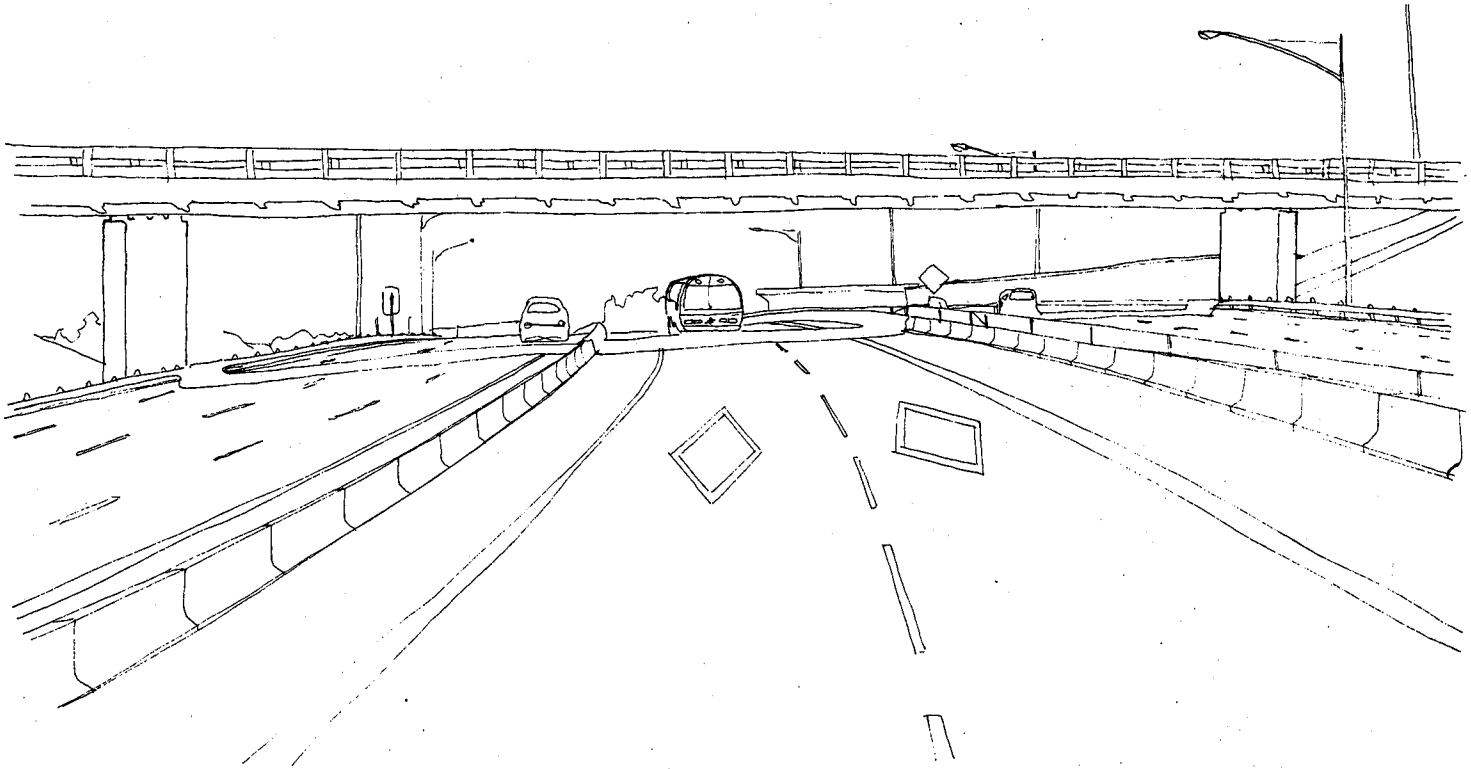
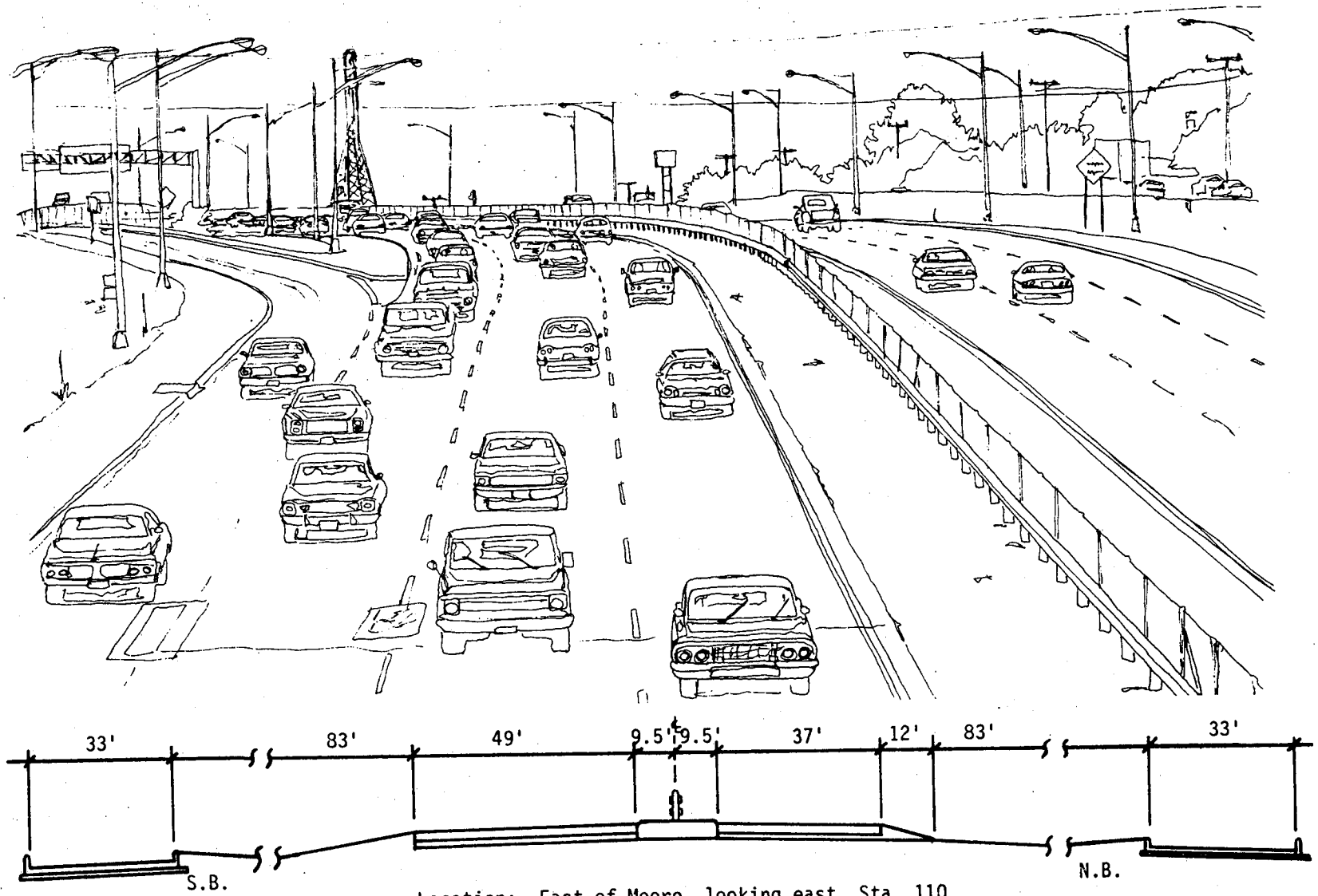


Figure B-3: A Manner in Which the Two-Lane Median HOV Lane Could Be Continued Through the I-410E Interchange (South Section)



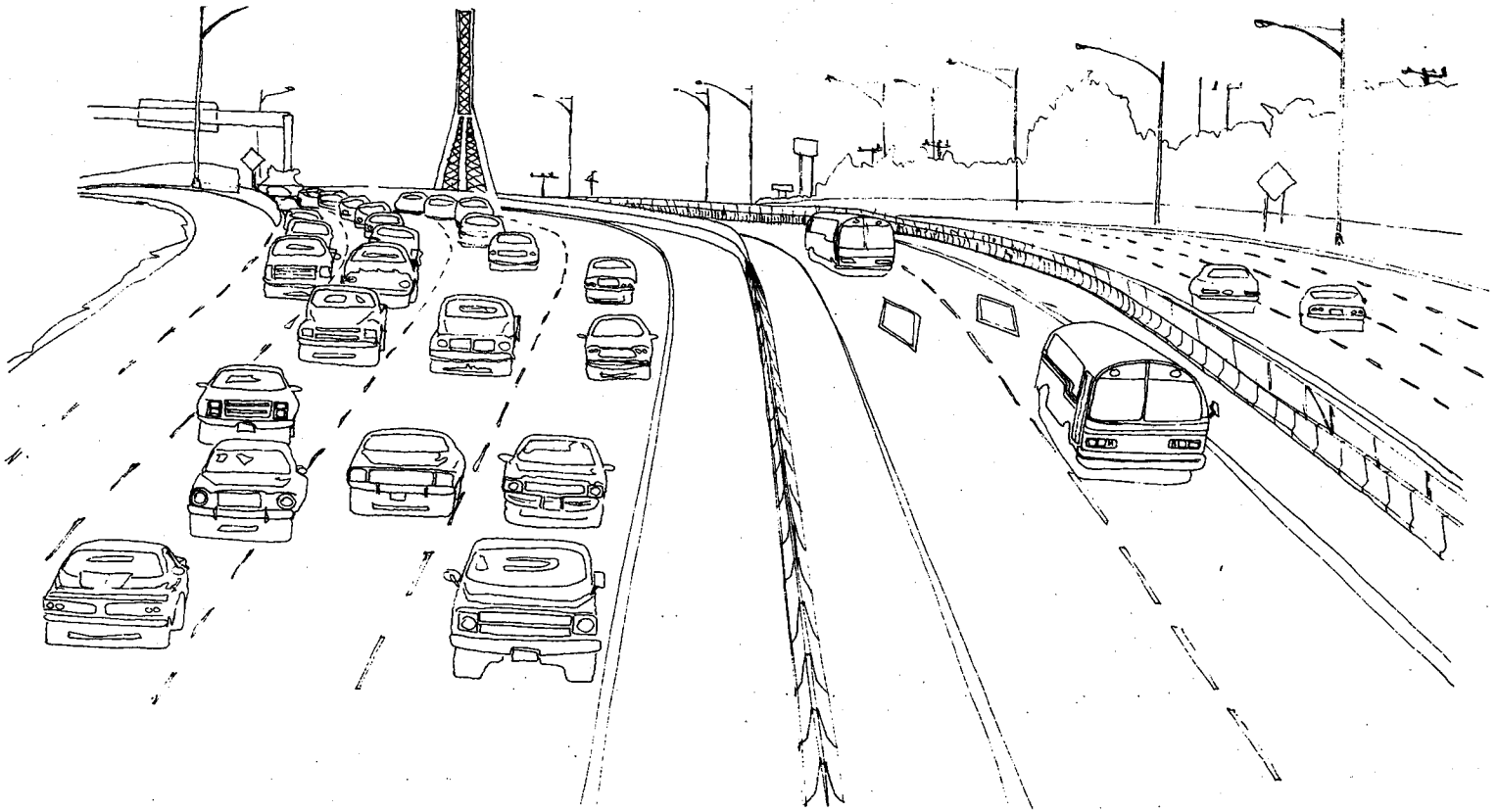
Location: I-410E, South Interchange
Possible Future

Figure B-3: (Continued)



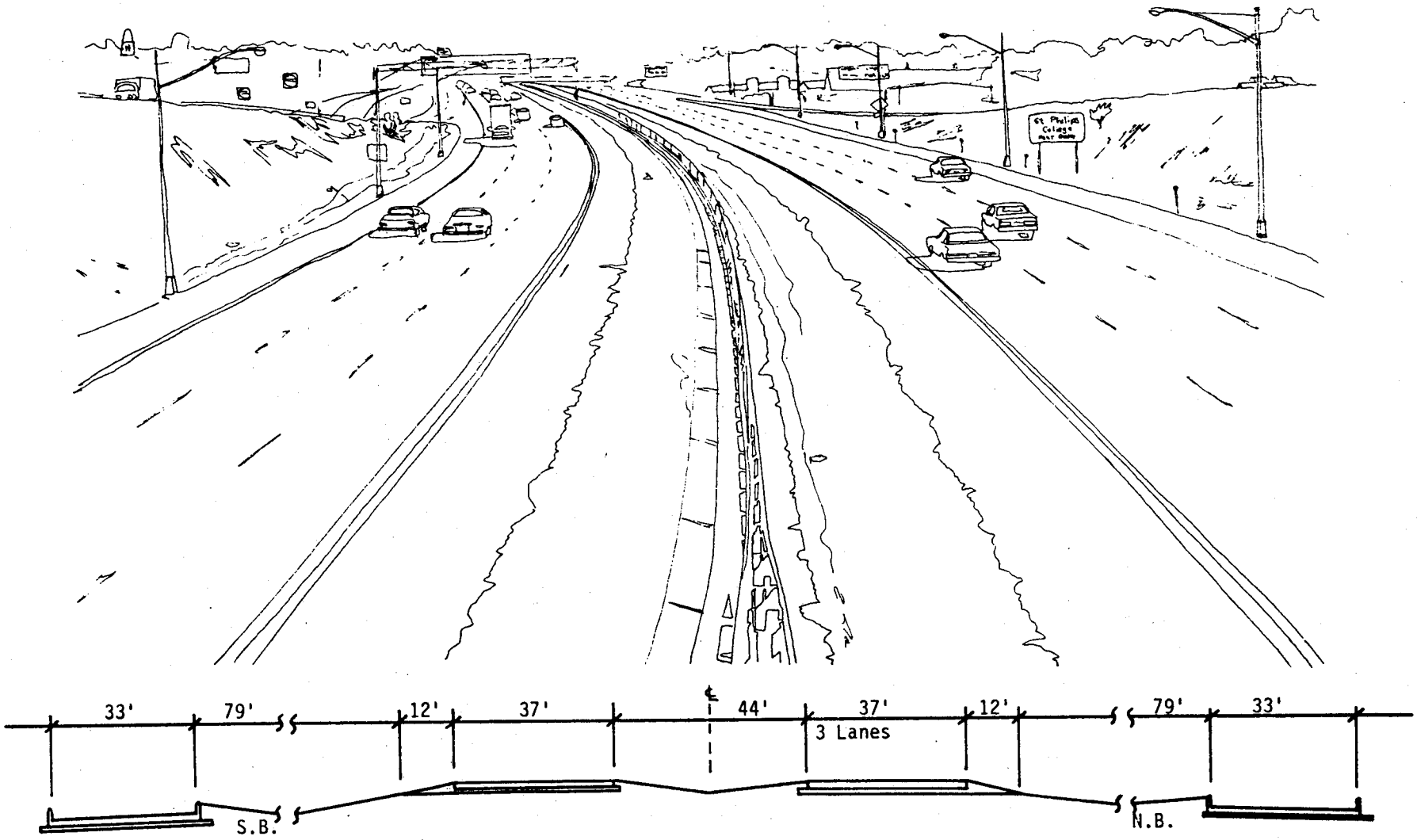
Location: East of Moore, looking east, Sta. 110
Existing

Figure B-4: "Typical" Section of Possible Two-Lane Median HOV Lane in a Standard Median



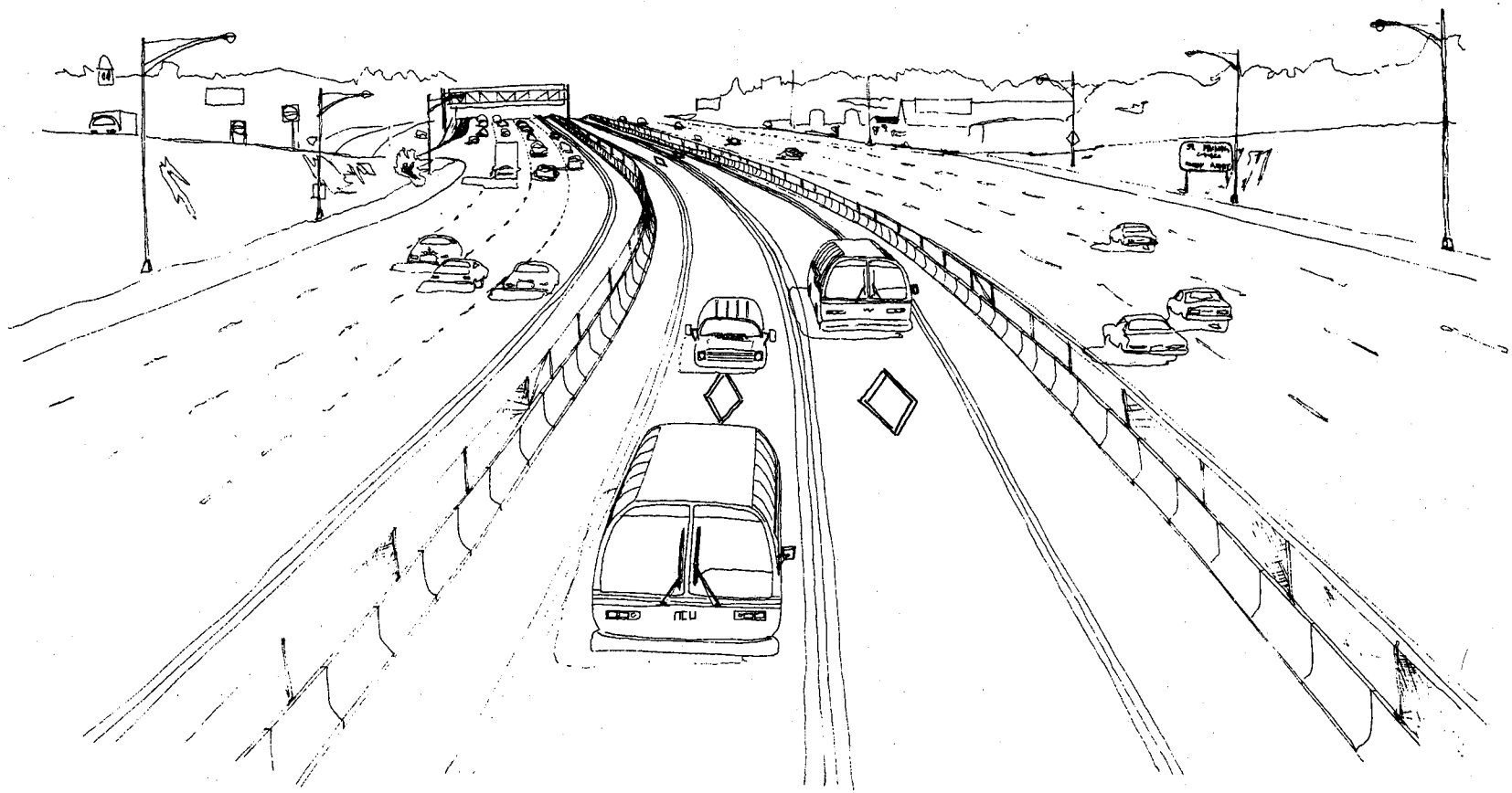
Location: East of Moore, looking east, Sta. 110
Possible Future

Figure B-4: (Continued)



Location: East of New Braunfels, looking east, Sta. 83
Existing

Figure B-5: "Typical" Section of Possible Two-Lane Median HOV Lane in a Wide Median



Location: East of New Braunfels, looking east, Sta. 83
Possible Future

Figure B-5: (Continued)