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16. Abstract

The concept of exclusive high-occupancy vehicle priority treatment facilities (transitways) has been strongly endorsed by the Texas State Department of Highways and Public Transportation (SDHPT). There currently exists no unified set of accepted standards for the design of transitway facilities. The overall objective of this study is to develop a Texas manual of design guidelines for transitway facilities based upon a review of standards and operation of existing and proposed projects nationwide and in Texas. This report presents the details and summary of this information to be assessed subsequently for technical adequacy and applicability in Texas. Recommendations for the Transitway Design Manual will be forthcoming to be considered by both SDHPT and transit authority officials.

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DESIGN OF TRANSITWAYS: REVIEW OF CURRENT PRACTICE

Prepared for

Texas State Department of Highways
and Public Transportation
and
Federal Highway Administration
Department of Transportation

Under
HPR Study No. 2-10-84-425
Titled
"Preparation of Texas Manual
for Planning and Design of
High Occupancy Vehicle Priority
Facilities - Transitways"

Research Report 425-1

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August 1984

ABSTRACT

The concept of exclusive high-occupancy vehicle priority treatment facilities (transitways) has been strongly endorsed by the Texas State Department of Highways and Public Transportation (SDHPT). There currently exists no unified set of accepted standards for the design of transitway facilities. The overall objective of this study is to develop a Texas manual of design guidelines for transitway facilities based upon a review of standards and operation of existing and proposed projects nationwide and in Texas. This report presents the details and summary of this information to be assessed subsequently for technical adequacy and applicability in Texas. Recommendations for the Transitway Design Manual will be forthcoming to be considered by both SDHPT and transit authority officials.

DISCLAIMER

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1. INTRODUCTION

1.1 BACKGROUND

The concept of exclusive, physically separated high-occupancy vehicle priority treatment facilities (transitways) has been strongly endorsed by the Texas State Department of Highways and Public Transportation (SDHPT). As transit authorities in the metropolitan areas of Texas search for alternatives to relieve urban congestion and promote increased person-movement, transitways hold the attraction of being implementable both technically and fiscally in a relatively short time period within the existing infrastructure of the urban freeway system.

Several major transitway facilities have already been designed and are under construction, while numerous other facilities are in conceptual and planning stages. All of these efforts have been undertaken utilizing limited information obtained from relatively few successful projects nationwide. Furthermore, this limited information available on existing facilities has not been systematically analyzed to assess the adequacy and transferability of these designs. In short, there currently exists no unified set of accepted design standards which address the unique character of transitway facilities.

1.2 OBJECTIVES

The overall objective of this study is to develop a Texas manual of design guidelines for transitway facilities. Specific objectives for the first year of the study are :

(1) Review and summarize the design standards and operating plans of existing and proposed transitway facilities nationwide.

(2) Review transitway design standards and operational issues with key SDHPT personnel.

(3) Prepare a preliminary report documenting the information compiled from tasks outlined in objectives (1) and (2).

The purpose of this report is to present a summary of guidelines and current practice in the design of transitway facilities. Specifically, this report documents the results of the tasks undertaken to accomplish study objectives (1) and (2) as enumerated above.

The actual development of the "Transitway Design Manual" will be accomplished during the second year of the study. Specific objectives for the second year of the study are:

(1) Determine from the technical information summary and experience with on-going projects, the applicability of the identified guidelines and standards to Texas urban freeways.

(2) Develop preliminary guidelines and standards for transitway facilities to be formally considered by SDHPT personnel and officials of the major transit agencies in Texas.

1.3 ORGANIZATION OF THE REPORT

The report consists of five major sections. As read previously, Section 1 presents the background and objectives to this study. Section 2 is a summary of transitway design guidelines obtained from a review of published reports, project documentation, and a survey of operating agencies. Section 3 of the report presents a detailed discussion of the information assimilated in Section 2. Section 4 lists agencies and individuals contacted for information pertinent to this study. A list of general references on the subject of transitways and transitway design is given in Section 5.

Readers primarily interested in the results of this phase of the study are directed to Section 2. Those interested in the details of current practice and specific design features of individual projects may want to emphasize Section 3. From the total of this assimilation of information, a recommended set of design standards for transitways will be established which hold the optimum utility for application in Texas. These standards will be formatted into a "workable" manual of guidelines to be reviewed by an advisory committee of state and transit authority officials.

2. SUMMARY

Table 2-1 presents a summary of typical transitway design guidelines as obtained from a review of published reports and a survey of operating agencies. Those readers interested in the details of current state practices and/or specific features of individual projects are referred to Section 3 of this report.

The summary of guidelines in Table 2-1 has been categorized in three parts - transitway mainlanes, transitway ramps, and general including grades, clearances, curvature, and cross section slopes. Each design criteria element has also been referenced to source of information such as report, project, or operating agency.

The guidelines shown vary by project and state. Transitway widths for one lane, reversible facilities are typically 20-26 feet depending on selection of shoulder width. Two-lane, two-way transitway widths range from 34-52 feet with selection based on cross section constraints and placement either at grade or aerial. Transitway mainlane design speeds are consistent with a high level of service (50+ mph), while ramp speeds vary from 15-35 mph as allowed by geometric configuration. Criteria for both vertical and horizontal alignment follow as established for all high-type roadway facilities to insure safe operations.

Table 2-1. Summary of Typical Transitway Geometric Design Guidelines

DESIGN CRITERIA \ DESIGN SOURCE	AASHTO (1)	NCHRP (2)	CALIF (3)	CANADA (4)	MINN (5)	PENN (6)	TEXAS (7)	TEXAS (8)	TEXAS (9)	VIR (10)	WIS (11)
Transitway Mainlanes											
DESIGN SPEED (MPH)											
Desirable	60+	70	60	50	70	40	60	50-70	50+	50+	70
Minimum	---	--	--	--	--	--	40	30-50	--	--	--
LANE WIDTHS (FT)											
Desirable	12	13	12	12	12	12	12	13	13	12	13
Minimum	11	12	--	--	--	--	--	--	12	--	--
SHOULDER WIDTHS (FT)											
Professional Drivers											
Desirable	10	10	14	--	--	8	3	8-10	4	12	10
Minimum	2	8	2	2	--	2	--	3-8	--	--	8
Carpool Drivers											
Desirable	12	10	--	--	10	8	10	8-10	10	12	10
Minimum	4	8	--	2	5	2	8	6-8	8	--	8
TOTAL PAVEMENT WIDTH (FT)											
Narrow											
One Lane One Way Reversible	20	26	26	--	--	--	24	20	20-22	--	--
WIDE											
Two Lane, One Way	36*	36**	36	--	34	34	34	40	26-34	36	--
Two Lane, Two Way	48	44	52	--	39	40	48	48	34-40	--	50

(__) Source - See Section 3

* Minimum width of 26 feet with speeds less than 50 mph; desirable width of 40 feet.

** Width range of 24-44 feet for normal flow busways; width range of 30-36 feet for special and contraflow busways.

Table 2-1. Summary of Typical Transitway Geometric Design Guidelines Continued

DESIGN CRITERIA / DESIGN SOURCE	AASHTO (1)*	NCHRP (2)	CALIF (3)	CANADA (4)	MINN (5)	PENN (6)	TEXAS (7)	TEXAS (8)	TEXAS (9)	VIR (10)	WIS (11)
Transitway Ramps											
DESIGN SPEED (MPH)											
Desirable	--	30-35	--	30	--	--	--	30-35	25	--	35
Minimum	--	--	--	20	--	--	--	15-25	10	--	--
LANE WIDTHS (FT)											
Desirable	--	12	12	16	--	12	12	12	12	12	15
Minimum	--	--	--	--	--	--	--	12	--	--	--
PAVED SHOULDER WIDTHS (FT)											
Desirable	--	8	8	2	--	8	--	8-10	8	5	6
Minimum	--	--	2	--	--	2	--	8	--	--	--
TOTAL PAVED WIDTH (FT)											
Desirable With Shoulders	--	22	22	18	--	20	--	20	22-22	17	21
Minimum Without Shoulders	--	14	14	16	--	14	--	14	--	--	15

Table 2-1. Summary of Typical Transitway Geometric Design Guidelines Continued

DESIGN CRITERIA \ DESIGN SOURCE	AASHTO (1)*	NCHRP (2)	CALIF (3)	CANADA (4)	MINN (5)	PENN (6)	TEXAS (7)	TEXAS (8)	TEXAS (9)	VIR (10)	WIS (11)
Transitway (General)	36	36	36	--	34	34	34	40	26-34	36	15.0
VERTICAL CLEARANCE											
Desirable	--	18.0	16.5	--	--	--	--	14.5	--	--	--
Minimum	--	14.5	--	--	--	--	--	12.5	--	--	30.0
LATERAL CLEARANCE (FT)											
Left											
Desirable	--	3.5	9.0	--	--	--	--	3.5	--	--	3.5
Minimum	--	--	--	--	--	--	--	2.0	--	--	30.0
Right											
Desirable	--	6.0	11.0	--	--	--	--	6.0	--	--	8.0
Minimum	--	--	--	--	--	--	--	3.0	--	--	--
VERTICAL GRADES (%)											
Desirable	--	3.0	2.0	3.5	--	--	3.0	3.0	3.0	--	5.0
Maximum	--	8.0	3.0	6.0	--	--	6.0	6.0	6.0	--	--
ALIGNMENT CURVATURE CROSS SLOPE SUPERELEVATION	In conformance with adopted National and State standards for high-type roadway facilities.										

3. REVIEW OF CURRENT PRACTICE

This section presents details of transitway design guidelines as gleaned from published reports and a survey of operating agencies. The materials presented in this section have been extracted directly from the referenced reports.

3.1 GENERAL GUIDELINES

3.1.1 Source [1]: American Association of State Highway and Transportation Officials (AASHTO). Guide for the Design of High Occupancy Vehicle and Public Transfer Facilities, 1983.

3.1.1.1 General Considerations

A separate high occupancy vehicle (HOV) roadway may be located in the median of a freeway, adjacent to a freeway along one side, or on independent alignment. The best location in any particular set of circumstances will of course be dictated by available space within the existing freeway right-of-way or the availability of alternative rights-of-way such as abandoned railroads.

Where there is a choice of location, consideration should be given to factors such as traffic operations in interchange areas and on-ramps, pedestrian access to on-line terminals, the availability of parking areas at or near the terminals, and possible disruption of HOV operations during staging of maintenance and reconstruction activities on the adjoining regular use lanes.

3.1.1.2 Design Speeds

One purpose of HOV facilities is to provide a travel time savings for HOV's. It is conceivable that a seperate HOV facility could have a lower design speed than the adjoining freeway and still provide for higher operating speeds during the peak hour. This travel time advantage would diminish, however, as the HOV facilities become more congested.

It is preferable to use a design speed for the HOV facility which is comparable to the adjoining freeway. This is especially true if there is the possibility of it being used by non-HOVs during the off-peak hours or at some time in the future. AASHTO freeway standards should be used to provide for a high level of service.

If there is no possibility that a separate HOV facility will be used by general traffic, and use is to be further limited to a single vehicle type such as buses, the specific physical dimensions and operating characteristics of that vehicle type should be considered in design. For example, the difference in driver eye height or braking characteristics may require a different roadway geometry than if the facility was to be used by all vehicles.

3.1.1.3 Cross Section Widths

The roadway width that should be provided for separate facilities depends upon certain factors: the available width, the speed at which the vehicles are expected to operate, the type of vehicles that are to use the facility, i.e. buses only or buses and carpools, the presence or absence of barriers at the edge of the separate HOV facility, the number of lanes that are required, the provision for passing disabled vehicles and the type of operation (whether it is one-way or two-way). On facilities to be used only by buses (or perhaps buses and vanpools) and where volumes are low, the minimum width should be sufficient to allow for passing a disabled vehicle at very low speeds. For 8.5-foot wide buses, 20 feet is the practical minimum roadway width where barriers are present on both sides (Figure 3-1 (a)).

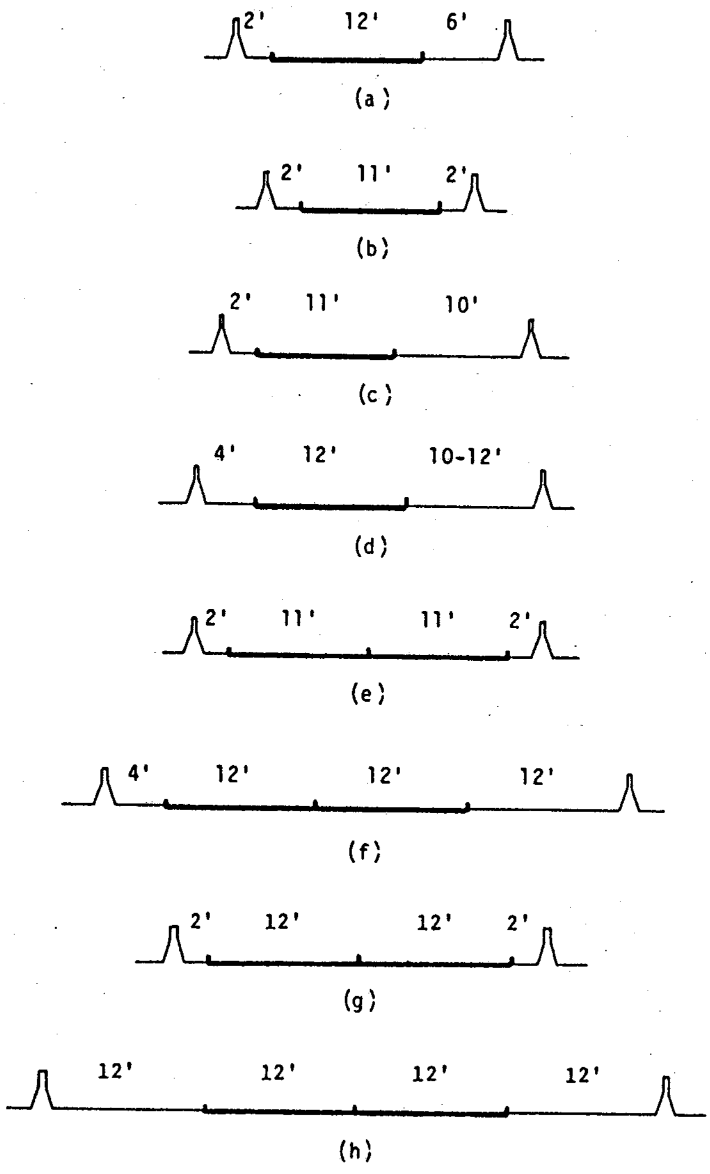


Figure 3-1. Typical AASHTO Transitway Cross-Section

Where barriers are not present, a slightly narrower cross section may suffice.

Provision for continuous passing of disabled vehicles may be omitted for short sections (less than 1 mile) where bus volumes are very low (less than 60 buses per hour). However, this situation should generally be regarded as temporary. An example cross section is shown in Figure 3-1 (b).

Where carpools are to use a facility, the cross sections shown in Figure 3-1 (a) and 3-1(b) are not adequate, as it is necessary to continuously provide for passing stalled vehicles at higher speeds. The minimum cross section should be that shown in Figure 3-1 (c).

The cross section in Figure 3-1 (c) provides sufficient space for one through lane, a usable shoulder wide enough to allow a disabled bus to stop completely off of the through lane pavement, and a 2-foot minimum offset between the lane or usable shoulder and adjacent traffic barriers. A usable shoulder on one side only is generally considered adequate for any one directional roadway of two lanes or less. However, if the roadway is to be used in a reversible manner, the width of the usable shoulder should be increased by 2 feet over the value given in the figure. This will allow persons to safely exit from the right side of a disabled bus parked on the left shoulder without encroaching on the through travel lane.

Where traffic barriers are not used, the 2-foot offset may be omitted. However, it is desireable to provide a minimum 2-foot paved shoulder at all times adjacent to a through travel lane.

Desirably where speeds are to be high (50 m.p.h. or above), and carpools are to use a facility, a cross section consisting of a 10- to 12-foot shoulder on one side and a 4-foot shoulder on the other side should be provided in addition to a 12-foot lane (total width 26 to 28 feet) as shown in Figure 3-1 (d).

Where two lanes are to be provided for one-way travel, a cross section consisting of two 11-foot lanes (12-foot desirable) plus 2-foot offsets to barriers (Figure 3-1 (e)), is the minimum that should be provided and should generally be restricted to facilities where speeds are low (less than 50 m.p.h.). Desirably, the roadway width for two lane operation should be increased to 40 feet, two 12-foot lanes plus one 12-foot shoulder, and one 4-foot shoulder as shown in Figure 3-1 (f). Where there are no barriers, such as at locations where a facility is constructed on completely separate right-of-way (not in conjunction with a freeway for general purpose traffic) slightly narrower shoulders may suffice. For a two-way busway, the roadway widths for each direction are similar to those for one directional travel with the exception of where a facility is to be designed with no median barrier. However, it is desirable to provide a median barrier to separate opposing traffic in all cases and it is essential for facilities that are to be used by carpools and higher speed facilities.

For bus only, two-way operation at lower speeds where there is no median barrier, a cross section width of 28 feet, (Figure 3-1 (g)), is the minimum that may be provided. However, it is desirable to provide a cross section width of 48 feet as shown in Figure 3-1 (h).

Where the facility is to be for high speed operation, or carpools and desirably for bus only operation, a median barrier should be provided. The minimum roadway widths for each direction of travel are as shown on Figure 3-1.

3.1.1.4 Access

Access to and egress from separate facilities may be provided in several ways. Stations or "on line terminals," may be provided along the facilities for pedestrian access or for transfers to and from other transportation modes. Ramps can be provided either from an adjacent freeway or a crossroad. Of course, access must be provided in some manner at both ends of the roadway.

Where "on line" stations are designed for large volumes, the connections should have high design standards. Tapers on entrance and exit ramps should be designed the same as for other freeway ramps except that special consideration should be given to the acceleration and deceleration characteristics of loaded buses. This is especially critical where ramp grades are significant. Very long, gradual tapers should be avoided on exit ramps as traffic may inadvertently follow the taper assuming it is the main roadway.

If traffic patterns warrant, separated HOV facilities should tie to the existing street system within the central business district (CBD). Direct ramps from a median HOV facility may be expensive and result in operational problems. However, they are preferable to merging HOV traffic with other freeway traffic in advance of the CBD provided conditions permit. Ramps that connect to adjacent facilities or to cross streets should be designed to the same standards as comparable facilities that connect freeways to crossroads. Designs of these type connections are described in the AASHTO "Policy on Geometric Design of Urban Highways and Arterial Streets" guidelines.

3.1.1.5 Operations

The operation of separate HOV roadways may be one direction, reversible, or two directional. The facility can be restricted to HOV's during peak periods only or throughout the day. The latter is safer when considering drivers' habits and is less difficult to sign.

3.1.1.6 Lane Markings and Control Devices

Signs and marking should conform to the Manual on Uniform Traffic Control Devices (MUTCD). Preferential lane markings should be used to indicate that the lanes are restricted to a specific class or classes of vehicles with supplemental signs or signals conveying specific restrictions. At the entrance to reversible facilities, particular attention must be paid to the control devices. In addition to the signs referred to above, special signing, including variable message signs may be necessary. These should be supplemented with gates or barriers to further prevent entry by vehicles going in the wrong direction, or to allow only authorized vehicles by special designation to enter the facility.

3.1.1.7 Enforcement

The enforcement of separate facilities is usually not a problem, particularly when the preferential treatment is limited to buses, or if full shoulders are provided adjacent the HOV lanes. The enforcement requirements should be coordinated with the enforcement personnel early in the design process. This permits them to become familiar with the concept of the project, to anticipate any additional requirements and make suggestions in the design which may make enforcement simpler, safer or more efficient. It may be desirable to provide special enforcement turnout areas at key locations. Up to several hundred feet of additional pavement 6 to 8 feet wide beyond the normal shoulder width may suffice. Where full shoulders are not provided,designs with longer approach tapers leading to a full width stopping area, up to 12 feet in width and 100 feet or more in length, may be desirable. These should be spaced as closely as possible,but not more than approximately 2,000 feet.

It may be necessary to initiate ordinances or laws that prescribe the intended restricted use of the lanes. The degree of public support is directly reflected in the degree of success of these treatments.

3.1.1.8 Terminal Facilities

A bus terminal,parking garage,or park and ride lot may be located adjacent to the terminal of a facility. Depending on the extent of the separation, there may also be a need for park and ride lots along the route providing exclusive access to and from the facility. Exclusive ramps to these facilities can be useful in attracting transit riders and in generating carpools.

The design of ramps serving these terminal facilities should be in accordance with AASHTO design policies. Where HOV facilities are located in the median, adequate space for vehicle parking will likely be limited or nonexistent and access for pedestrians may be difficult. This will be especially true in interchange areas where congestion already occurs. Many of these problems can be overcome by placing the exclusive HOV facilities to one side of the normal freeway lanes. Where the facility can be placed along a frontage road, ideal local access can be provided.

3.1.2 Source [2]: Levinson, H.S., C.L. Adams and W.F. Hoey. "Bus Use of Highways: Planning and Design Guidelines," National Cooperative Highway Research Program Rept. No. 155, 1975.

3.1.2.1 Busway Types

Busway designs can be grouped into several categories according to level of service, direction of flow, and arrangement of lanes. Design criteria and examples were prepared for two basic service levels and three basic busway configurations.

Class A Busways. Provide freeway or rail rapid transit levels of service and would be completely grade separated. They are generally applicable in large urban areas where express buses may operate nonstop at high speeds over long distances or for bypassing freeway sections that operate at a relatively low level of service (D, E, or F) throughout the peak period.

They should connect with freeways and provide access to downtown terminals or distributor busways.

Class B Busways. Provide service comparable to arterial streets or light rapid transit lines, and could incorporate some at-grade intersections. They would serve shorter-distance trips (3 to 6 miles), particularly in medium-sized urban areas, and provide relatively greater station frequency.

Busways also can be grouped by direction of flow and placement of shoulder as described below. The normal-flow busway should be used whenever vanpools and/or car pools might use the bus lanes.

Normal-flow busways provide a standard two-lane road with optional outside breakdown lanes. They are well suited for most busway applications, because they employ conventional right-hand operations with optional breakdown lanes on the outside.

Special-flow busways provide two one-lane roads and central breakdown lane. They afford economy of width where breakdown lanes are required.

Contra-flow busways provide two one-lane roads and a central breakdown lane. Buses keep to the left of the center line. This design permits common island station platforms, which minimize station security, supervision, maintenance, and vertical transportation requirements. It has potential applicability where stations are frequent, tunnel construction is not extensive, intermediate access is not essential, and strict control over use can be maintained.

3.1.2.2 Design Speeds

Mainlanes. Minimum design speeds of 50 mph for Class A busways and 30 mph for Class B buses should be used, with desirable speeds of 70 and 50 mph, respectively. A busway may incorporate various sections having different design speeds, but the changes should be few and gradual.

Ramps. Class A busway ramps should be designed for 30 to 35 mph and Class B busway ramps for 15 to 25 mph.

3.1.2.3 Cross Section Widths

Traveled way. Busway lanes should be 12 ft wide except for constricted areas and around terminals, where 11 ft lanes are acceptable. The present trend in bus design toward an 8.5 ft vehicle width calls for lane widths of at least 12 ft to achieve smooth flow at moderate speeds on two-lane two-way busways. On high-speed busways that do not have paved shoulders, 13 ft lanes should be provided. Pavement widening on curves should provide additional lateral width for maneuvering and for the overhang of various parts of the vehicle. Pavements should be widened 1.5 to 2 ft on curves having radii of 1,000 ft or less dependent on design speed and busway width (Table 3-1).

Shoulders. Buses should be able to pass stalled vehicles. This can be accomplished (a) by providing shoulders for disabled vehicles, (b) by providing narrow unpaved border (usually 2 to 4 ft wide) on both sides of the paved roadway, and/or by use of the opposite-direction lane. Busways can be developed with and without full width shoulders.

TABLE 3-1. Pavement Widening Recommended for Curves of Two-Way, Two-Lane Busway

Normal Roadway Width (Ft)	Design Speed (mph)	Pavement Widening[a] (Ft) for Curve With Radius of					
		500 Ft	750 Ft	1000 Ft	2000 Ft	3000 Ft	4000 Ft
24	30	1.5	1.0	0.5	0	0	0
	40	2.0	1.0	1.0	0	0	0
	50		1.5	1.0	0.5	0	0
	60			1.5	0.5	0	0
	70				1.0	0.5	0
22	30	2.5	2.0	1.5	1.0	0.5	0.5
	40	3.0	2.0	2.0	1.0	1.0	0.5

[a] Values less than 1.5 may be disregarded.
Source: [2]

Full-width design allows for buses to pull off the traveled way far enough to cause only minor disturbance to the flow of through traffic. This design is recommended only where the busway must be designed for possible use by private automobiles or trucks (e.g., car pools, and peak weekend traffic). Shoulders should be 6 to 8 ft wide for Class B busways and 8 to 10 ft wide for Class A busways.

Shoulders may be omitted where exclusive use of normal flow busways by buses is anticipated, or where extensive structure or tunnel sections are involved.

Ramps. Lanes should be 12 ft wide where shoulders are provided and 13 to 14 ft otherwise. Total paved ramp widths should range from 13 to 22 ft.

Minimum ramp designs should be used only for relatively short distances, although the unpaved border areas can provide a limited amount of additional width for maneuvering around stalled vehicles. Most urban buses are designed with minimum turning radii (inner rear wheel) as small as 17 ft. At this radius, the outer front wheel turns on a radius of 42 ft, producing a wheel path 25 ft wide. This path reduces in width as the inner radius increases, but is still a significant factor on many curved ramps.

The pavement widths required at various radii to include shoulders and traveled lanes are given in Table 3-2. Values are given for three cases: single-lane ramps, no passing; single lane ramps with provision for passing; and two-lane ramps.

Total paved width. Total paved width (between stations) ranges between 24 and 44 ft for normal-flow busways and between 30 and 36 ft for special-flow and contraflow busways. Minimum viaduct roadway widths are 28 ft and minimum tunnel envelope widths are 31 ft.

TABLE 3-2. Pavement Widths Recommended for Bus Ramps

Conditions	Pavement Width (Ft) for Inner Pavement Edge Radius of 50 Ft	75 Ft	100 Ft	150 Ft	200 Ft	300 Ft	500 Ft	1000 Ft	Tangent
Case 1 One-lane, one-way, no passing	22	19	17	16	16	15	15	14	12
Case 2 One-lane, one-way, with provision for passing stalled vehicle	39	31	28	25	24	23	22	22	20
Case 3 Two-lane, one-way, or two-way	45	37	34	31	30	29	28	27	24

Source: [2]

3.1.2.4 Vertical Clearances

Vertical clearances should be sufficient to accommodate buses plus any other vehicles that might ultimately use the facility. Where convertibility is anticipated or desired, rail car clearance requirements must be considered.

A minimum clearance of 16.0 ft should be used to allow for possible truck use as well as future increases in bus height. Clearances for existing rail systems vary from 14 ft for third rail systems up to 18 ft for overhead contact (catenary) systems. An absolute minimum vertical clearance of 12.5 ft for Class B busways would accommodate the maximum 11 ft height of most current urban buses.

3.1.2.5 Lateral Clearances

Lateral clearances to fixed obstructions reflect current highway standards. These values should apply to noncontinuous obstructions, such as bridge piers. Continuous obstructions, such as retaining walls or parapets, may tolerate closer clearances. Left-hand clearances should not be less than 2 ft for Class B busways and 3.5 ft for Class A busways. Right-hand clearances should be 4 and 6 ft, respectively.

3.1.2.6 Gradients

Maximum gradients should reflect current highway practice, except where convertibility to rail systems is desired. Long grades at or near the maximum values should be avoided wherever possible.

Where convertibility to rail is planned desirable grades should not exceed 3 to 4 percent. (The exception is where light rail systems are being considered for future installation.) Main-line grades should not exceed 5 to 6 percent, with an absolute maximum of 8 percent. Ramp grades should not exceed 8 percent, with an absolute maximum of 10 percent.

3.1.2.7 Vertical Curves

Criteria for vertical curvature should also conform to AASHTO practice. The length of vertical curvature should be determined by the requirements for minimum safe stopping distances, and be governed by (1) the algebraic sum of the gradients and (2) the design speed of the busway.

The adoption of AASHTO K-values for busway design is recommended. However, where substantial economies are essential, slightly lower values may be allowed. THE K-value could theoretically be reduced on crest vertical curves, when applied exclusively to buses, because the height of the driver's eye above the pavement is 6.5 to 7 ft for buses. A similar reduction in K-values for sag vertical curves might be made, considering the higher headlight mounting positions on buses. Counteracting these reductions, however, is the more critical nature of passenger safety - particularly for standees - during emergency stops, as well as the possibility of future bus vehicle designs with lower driver eye and headlight heights, and the use of busways by other HOV type vehicles.

3.1.2.8 Horizontal Curvature

Horizontal curvature should conform to AASHTO practice. Absolute minimum radii should be determined by bus vehicle capabilities and by the limitations of future rail systems. Most rail systems (excluding light rail systems) cannot negotiate curves of less than 250 ft radius. Horizontal curves of 250 ft radius should be provided for 30 mph; 750 ft, for 50 mph; and 1,600 ft, for 70 mph. Superelevation should not exceed 0.06 ft per foot where roadway icing is a factor and 0.08 ft per foot elsewhere. Transition curves should be provided where busways are located in freeway rights-of-way, and where transition curves follow those along the freeways.

3.1.2.9 Merging and Diverging Sections

Special design criteria should apply to busways where ramps enter or leave main-line busways or freeways and where turnout lanes are provided at busway stations.

Ramp exits should have a 12:1 taper ratio to assure adequate ramp identification and visibility. Beyond the point of lane divergence, the tangent section should be long enough to allow a comfortable rate of deceleration. Ramp entrances normally should have a 50:1 taper ratio; this may be reduced to as little as 20:1 where ramp bus speeds and volumes are low.

Turnout lane design at busway stations should be based on ease of negotiation by buses. Taper ratios of 30:1 are permissible on Class A busways and 20:1 on Class B busways.

3.1.2.10 Summary

Table 3-3 presents a summary of transitway design criteria suggested in NCHRP Report 155. Typical cross sections are shown in Figures 3-2 through 3-6.

3.2 CALIFORNIA GUIDELINES

3.2.1 Source [3]: California Dept. of Transportation. "Report on Design Criteria for Busways, Orange County Transit District Concept Design (Subtask A-6)," CALTRANS Cooperative Agreement No. 3607, April 8, 1982.

3.2.1.1 General

Freeway transit is a concept that attempts to maximize the efficiency of moving people for a variety of conditions. Located essentially within freeway rights-of-way, freeway transit development is conceived as being evolutionary in approach. It can be either a bus mode operating in mixed freeway traffic, an initial bus mode operating on an exclusive facility convertible to rail, or an initial rail mode facility.

Also by definition, freeway transit exclusive lanes used by an initial bus mode shall accommodate other high-occupancy vehicles (HOV's) such as carpools, vanpools, etc.

This design criteria will consider only the initial bus mode, operating as an exclusive facility, with other HOV vehicles. Facilities discussed will be referred to as "busways". These facilities will be designed on horizontal, vertical alignments and clearances so that they will be convertible to a rail mode. Basically, there are two potential uses of busways:

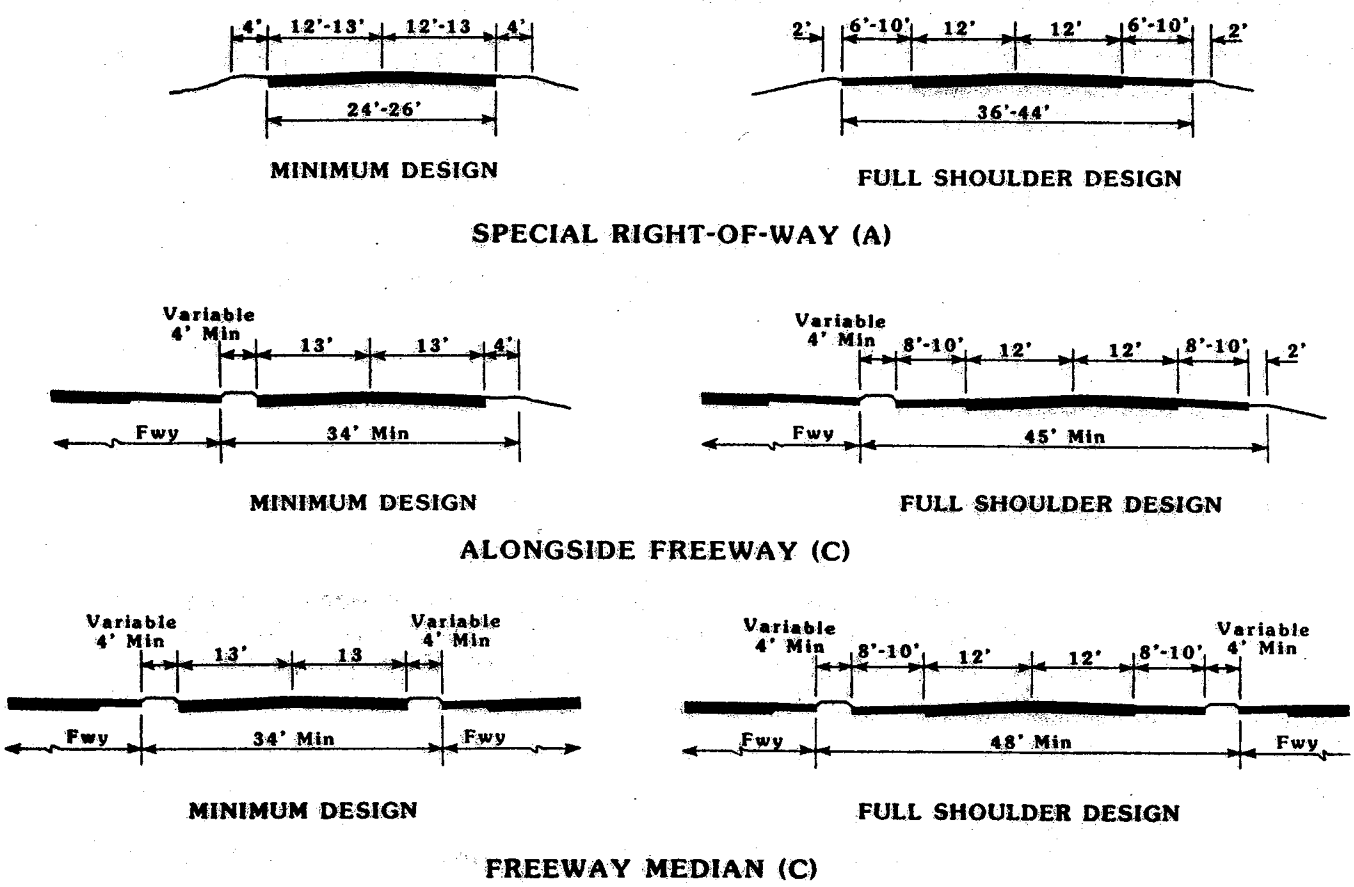
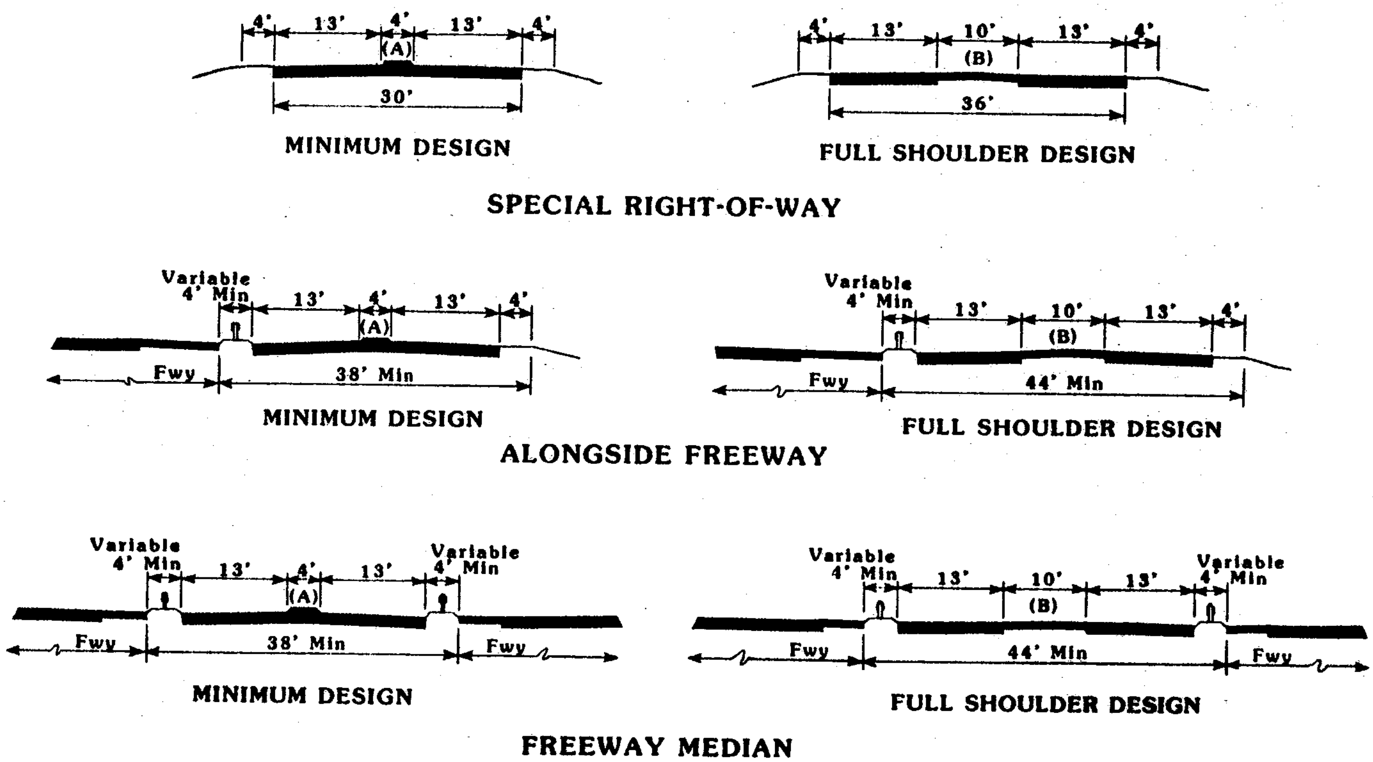


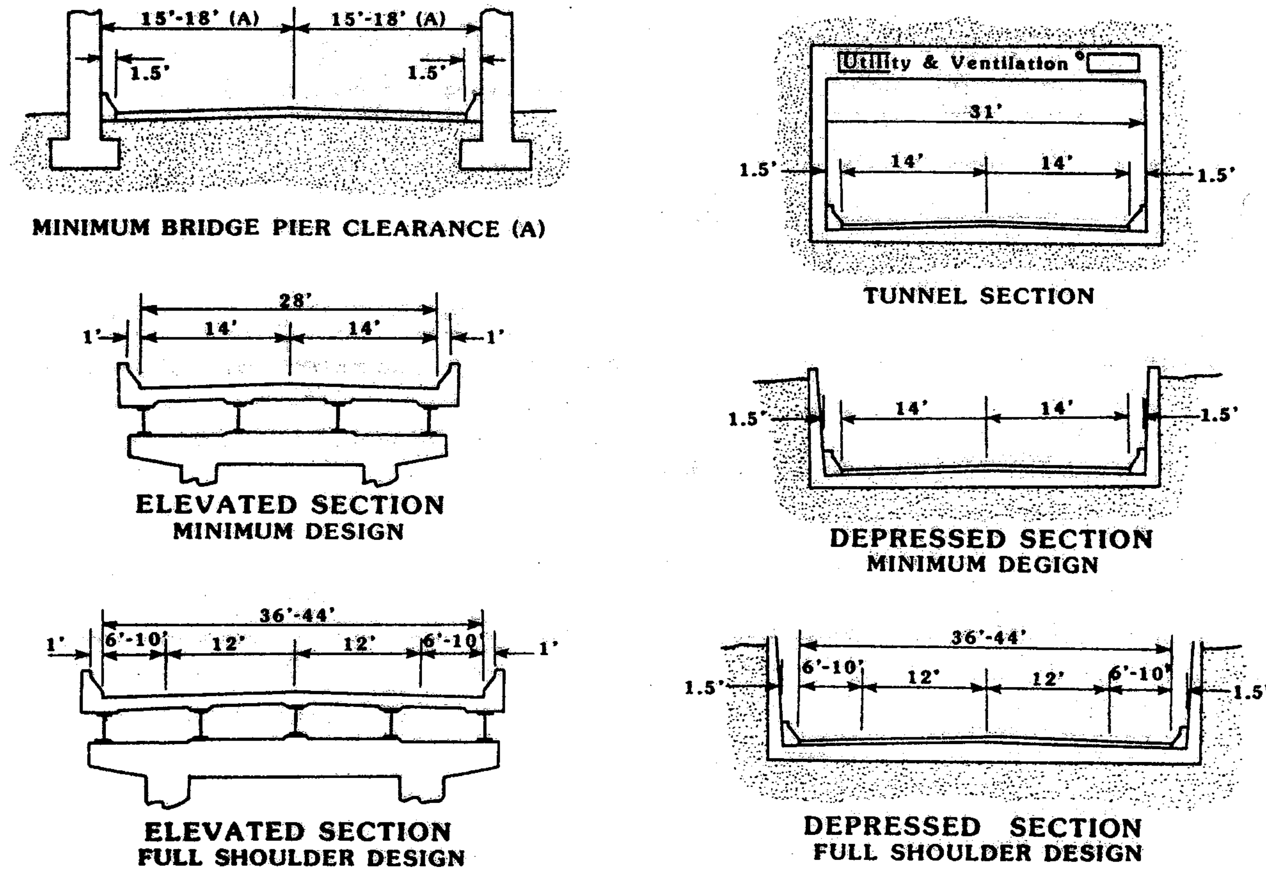
Figure 3-2. Typical Sections, Normal-Flow Busways



(A) Raised mountable median for contraflow; flush median for special flow
(B) Flush median

Notes: 1. Lane widths may be increased on curves.
2. Add 1 ft. to lane width where non-mountable curves are utilized adjacent to lane.

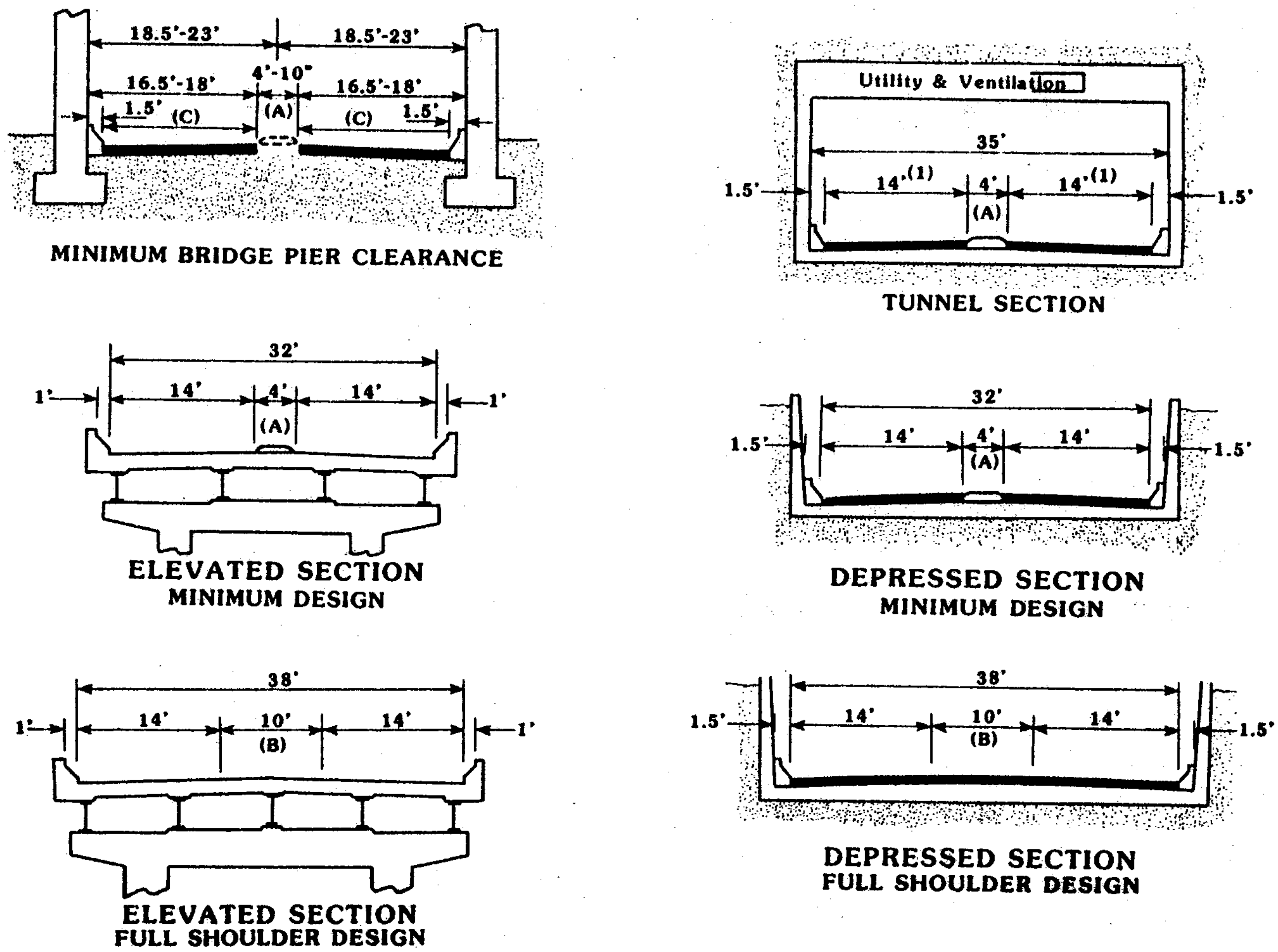
Figure 3-3. Typical Sections, Contraflow and Special Flow Busways



(A) Class 'A' busways - 36' between abutments;
Class 'B' busways - 30' between abutments.

Notes:
1. Lane width may be increased on curves.
2. Special construction sections for normal flow, class 'A' busways can also apply to special flow conditions.

Figure 3-4. Special Construction Sections, Normal-Flow Busways



(A) Raised median, mountable
(B) Flush median
(C) Contraflow 15' minimum lane width
Special flow 16.5' minimum lane width

Note: Lane width may be increased on curves.

Figure 3-5. Special Construction Sections, Contraflow and Special Flow Busways

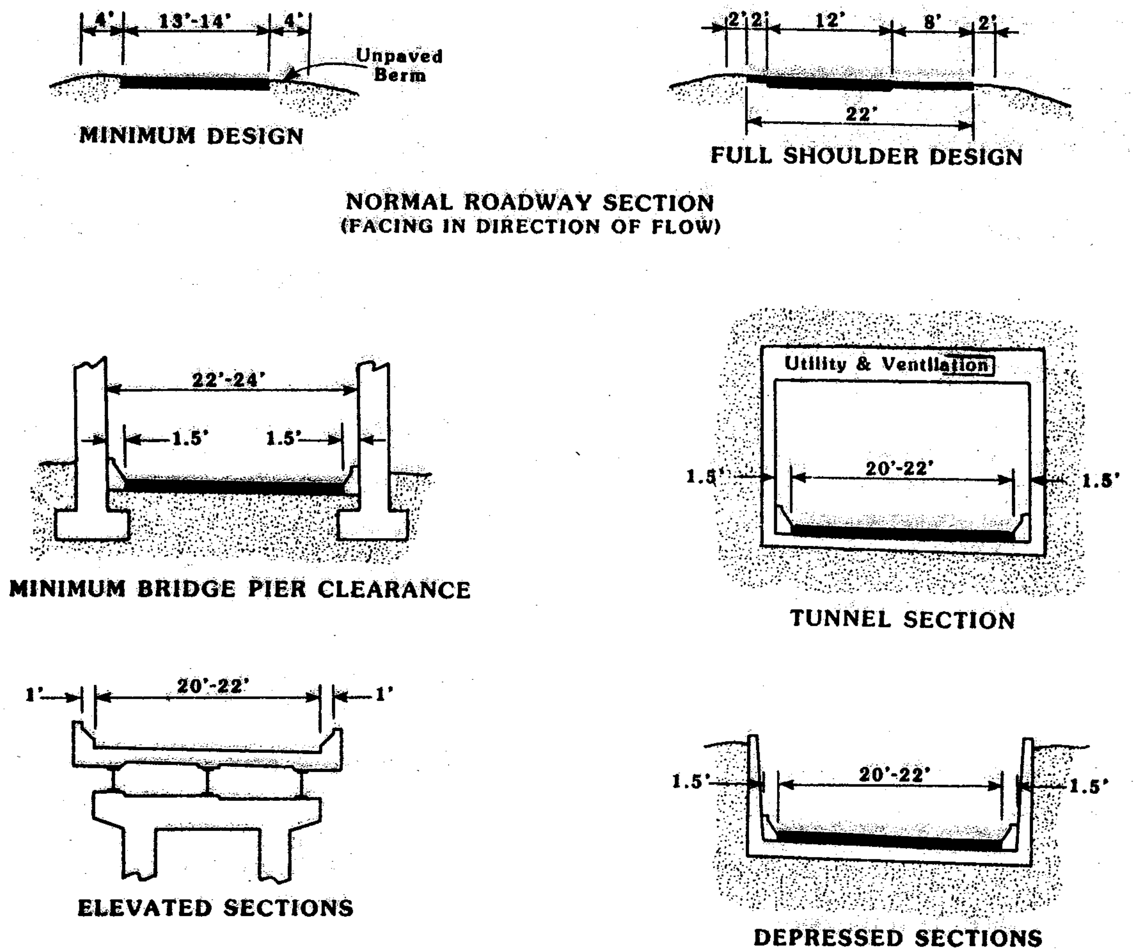


Figure 3-6. Busway Ramp Sections

TABLE 3-3. Suggested Busway Design Criteria

Item	Class A Busway	Class B Busway
Mainlanes		
Design Speed (mph):		
Desirable	70	50
Minimum	50	30
Lane width (ft):		
With paved shoulders	12	11-12
Without paved shoulders	13	12
Paved shoulder width (ft):	8-10	6-8
Total paved width (ft):		
Normal flow	26-44	24-40
Special flow	30-36	
Contra flow	30-36	
Minimum viaduct width (ft)	28	28
Minimum tunnel width (ft)	31	31
Minimum vertical clearance (ft)		
Desirable	14.5-18	14.5
Absolute minimum		12.5
Min. lat. dist. to fixed obstructions (ft):		
Left	3.5	2
Right	6	3
Maximum superelevation (ft/ft)	0.08	0.08
Min. radius of horiz. curves (ft):		
70 mph	1600	1600
60 mph	1150	1150
50 mph	750	750
40 mph	450	450
30 mph	250	250
Absolute min. radius (ft):		
Conv. to convention rail	250	250
Convertible to light rail	100	100
Nonconvertible	30	30
Maximum gradients (%):		
Desirable:		
Convertible to rail	3-4	4-4
Other	5	6
Ramps, up	6	7
Ramps, down	7	8
Absolute:		
Main line	8	8
Ramps	10	10
Ramps:		
Design speed (mph)	30-35	15-25
Lane width (ft):		
With paved shoulders	12'	12'
Without paved shoulders	14'	13'
Paved shoulders width (ft)	8	8
Total paved width (ft)	14-22	13-20

Source: [2]

Wide Busway with HOV's - A two-lane exclusive busway design for bi-directional operation for buses and other HOV's.

Narrow Busway with HOV's - A single lane exclusive busway designed for one-way reversible peak-direction operation for buses and other HOVs. The reverse or off-peak direction movement of buses or HOVs would be accommodated in mixed traffic along freeway or arterial lanes.

The general design criteria presented involves busways located within freeway rights-of-way and sited primarily along the median area. The busways are presented in both elevated and at-grade profiles.

3.2.1.2 Basis for Criteria

Bus Characteristics. Development of criteria relating to bus operations such as grades, acceleration and deceleration lanes, etc., relates to minimum requirements by the Urban Mass Transportation Administration (UMTA) for "StateoftheArtBuses".

HOV Characteristics. Criteria is based on the California Highway Design Manual and Federal Highway Administration Interstate Highway Standards.

3.2.1.3 General Design Criteria

The highway design practices of the California Department of Transportation (Caltrans), which also reflect those offered as "desirable" by AASHTO, shall govern in design criteria not set forth here.

The busways are established as high-speed facilities over which buses mixed with carpools, vanpools, etc., will travel. The additional class of vehicle with the inclusion of carpools and the consideration toward conversion to the rail mode have a pronounced effect on the design of busways.

Table 3-4 tabulates certain general design criteria for both the wide and narrow busways.

TABLE 3-4. Caltrans General Busway Design Criteria.

Design Vehicle:		
Driver's Eye Height	Bus	7 Ft.
	Car	3.75 Ft.
Operating Speed	Bus	55 MPH
	Car	55 MPH
Design Speed		60 MPH
Minimum Design Speed		60 MPH
Horizontal Curvature		
Minimum		1150 Ft.
Desirable Minimum		1600 Ft.
Superelevation		Depends on curve radii (0.12 ft/ft maximum)
Minimum Cross Slope		2.0%
Vertical Grade:		
Maximum Mainline		3.0% (1.0% at stations)
Desirable Mainline		2.0%
Maximum Ramps		6.0%
Minimum		0.25%
Stopping Sight Distance		25 Ft. for car at 60 MPH
Vertical Curves:		
Minimum Length (Desirable)		400 Ft. for car
Vertical Clearance (Minimum)		
State Highways		16-1/2 Ft.
Busways		16-1/2 Ft.
Horizontal Clearance (Minimum)		
Left of Traffic		9 Ft.
Right of Traffic		11 Ft. (Measured from Edge of Pavement)
Acceleration Lane		
Ramp Entrance		900 Ft.
Station Exit		1900 Ft.
Deceleration Lane		
Ramp Exit		400 Ft.
Station Entrance		1900 Ft.

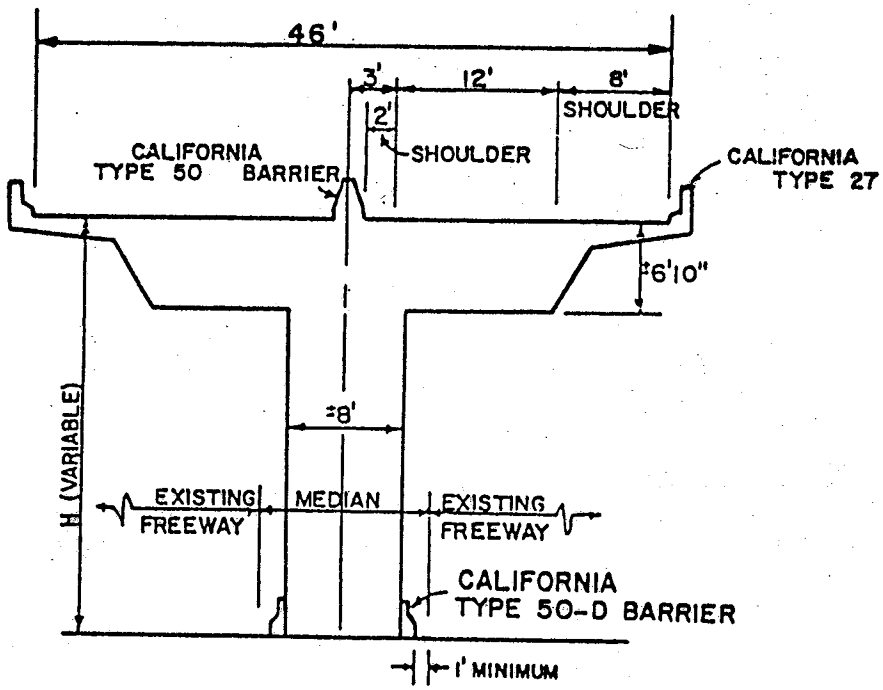
Source: [3]

Figure 3-7 and 3-8 indicate the control sections for the elevated wide and narrow busways. Figures 3-9 and 3-10 indicate the control sections for the at-grade wide and narrow busways. Figure 3-11 indicates the section for the elevated access ramps.

The size of the elevated wide busway has evolved from previous studies for busways by Caltrans. Concerns were based on the range of vehicles contemplated that will be using the facility such as, buses, autos, vans, etc., at fairly high rates of speeds. The increased exposure to breakdowns and potential for accidents over a bus-only professionally operated facility required the design features of the wide busway. The 46' roadway (Figure 3-7), will provide a divided two-lane facility incorporating a 12' lane in each direction with a 2' shoulder to the left and 8' shoulder to the right of traffic. While these clearances are narrower than Caltran's highway practice, they provide the bare minimum width needed for a bypass of a disabled bus by other vehicles. Construction procedures and costs were also underlying factors in the recommended wide busway width.

The at-grade wide busway, as depicted on Figure 3-9, has evolved from the same concerns as the elevated wide busway. The 64' median provides 12' lanes in each direction coupled with 14' common shoulders with mainline freeway traffic. The 12' center separation provides width for a concrete barrier and also for bypassing center column supports for overhead structures without shifting busway traffic.

The dimensions for the elevated and at-grade narrow busway (Figures 3-8 and 3-10) provide the narrowest width possible for one-way (reversible) operation while still retaining the flexibility of conversion to rail. The narrow busway with a 26' roadway width is adequate to provide a 12' lane with 6'and 8' shoulder. The at-grade narrow busway is separated from freeway traffic by concrete median barriers and 8' freeway shoulders. The lack of



NOTE: ALL ELEVATED STRUCTURES IN THIS REPORT ARE PRESTRESSED CONCRETE BOX GIRDERS WITH MAXIMUM SPANS OF 125' AND HEIGHTHS OF 55'.

Figure 3-7. Caltrans Wide Busway (elevated)

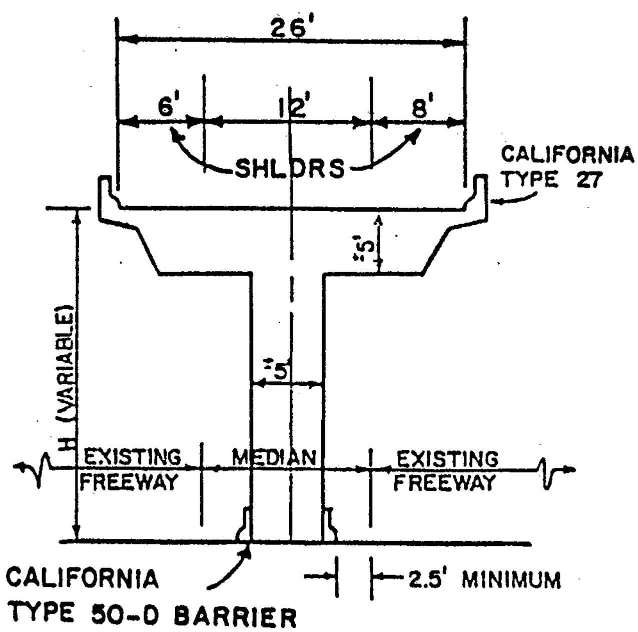


Figure 3-8. Caltrans Narrow Busway (elevated)

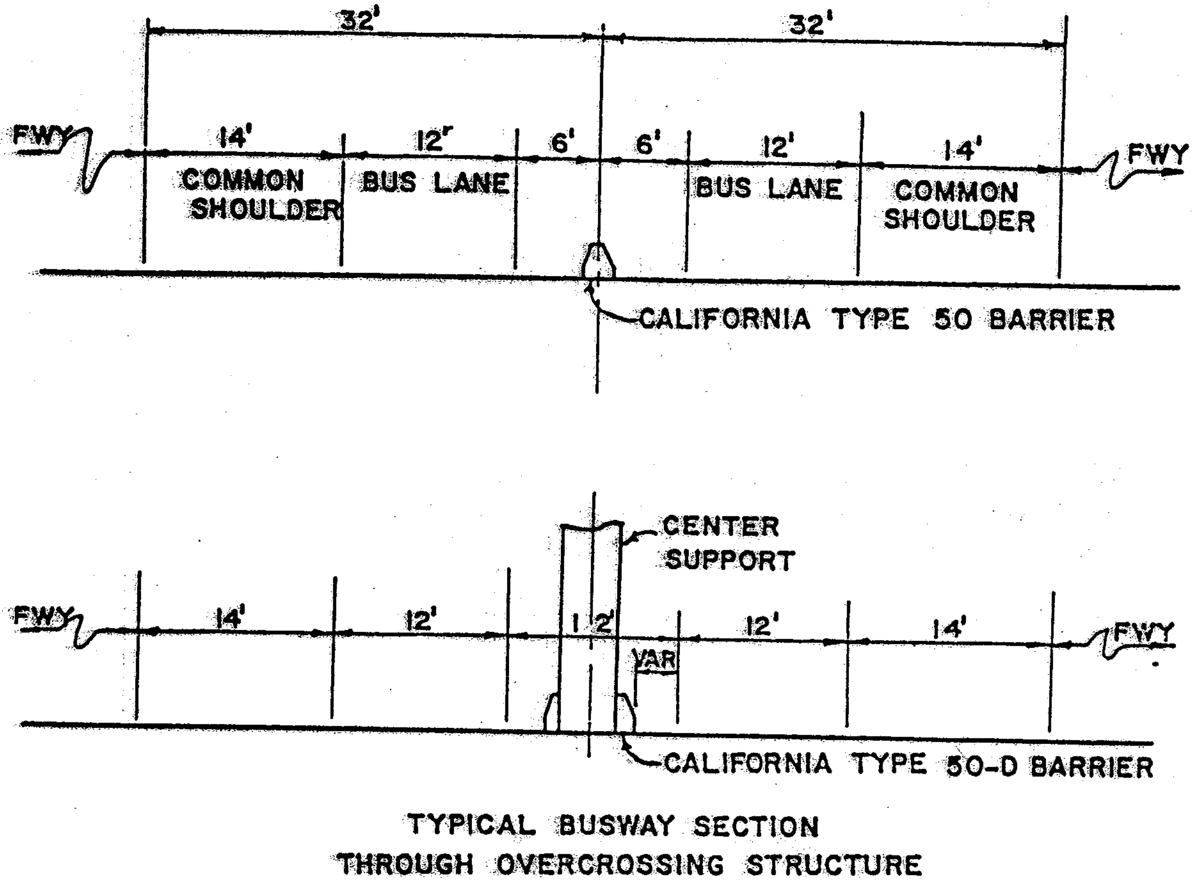
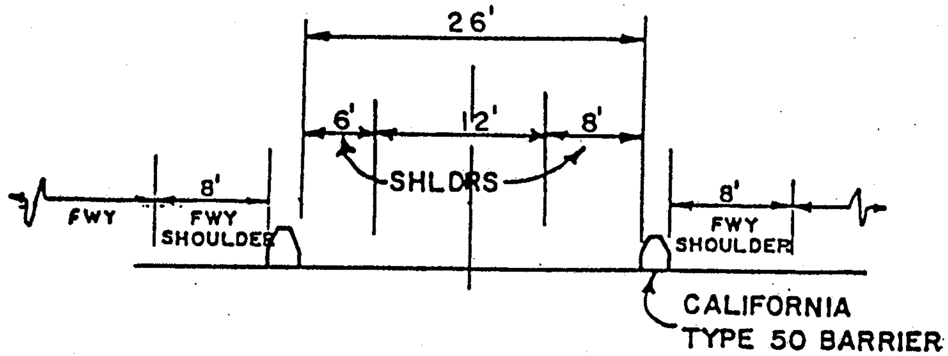
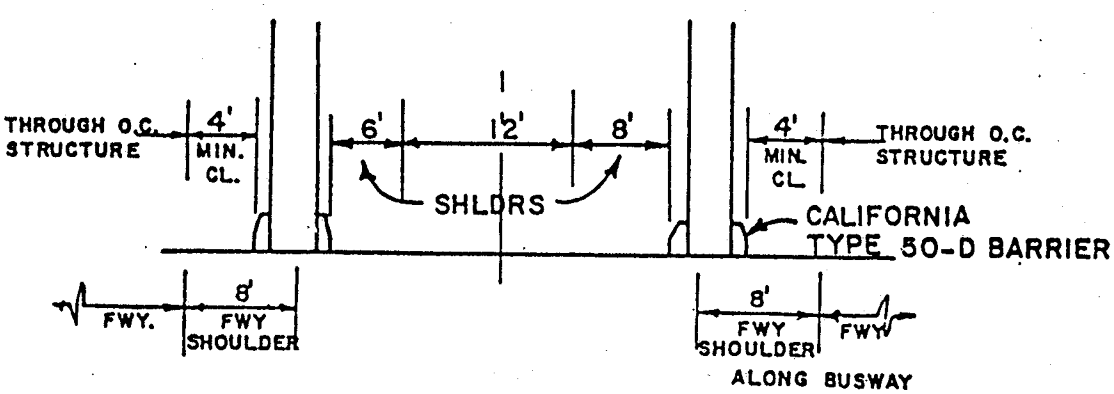


Figure 3-9. Caltrans Wide Busway (at-grade)





TYPICAL BUSWAY SECTION
THROUGH OVERCROSSING STRUCTURE

Figure 3-10. Caltrans Narrow Busway (at-grade)

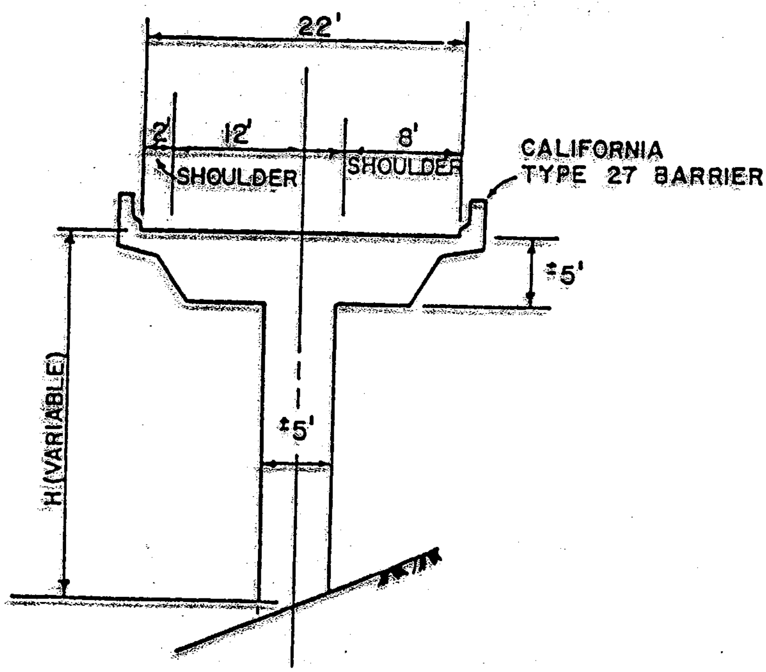


Figure 3-11. Caltrans Access Ramp (elevated)

ingress/egress directly to the freeway mainline is considered a serious deficiency for this design concept.

Figure 3-11 indicates the dimensions for the elevated ramp access. This sizing was developed from entrance/exit requirements as detailed in the California Highway Design Manual.

Figure 3-12 indicates the layout of the at-grade ingress/egress for the wide busway. The layout provides an additional 12' lane 1600' in length for weaving purposes by exiting and entering busway traffic. An ingress or egress lane for the at-grade narrow busway was not considered advisable due to the potential or wrong way moves.

3.3 CANADIAN GUIDELINES (Metric Units)

3.3.1 Source [4]: Regional Municipality of Ottawa-Carleton [Ontario]. Transitway Design Manual, 1982.

3.3.1.1 General

Description of the Transitway System

Initially, the transitways will operate as busways on exclusive rights of way. Outside the central area the transitways will be fully grade separated from other traffic and access will be restricted to buses and maintenance or emergency vehicles. Within the central area buses will not be seperated vertically from other traffic but will operate on exclusive bus lanes.

Conversion to Rail Transit

Provisions for conversion which are suggested in these guidelines are limited to:

1. Vertical clearances toaccommodatecurrentlightrail vehicles
2. Geometrics to accommodate current heavy rail vehicles
3. Structural loadings to accommodate current heavyrail vehicles

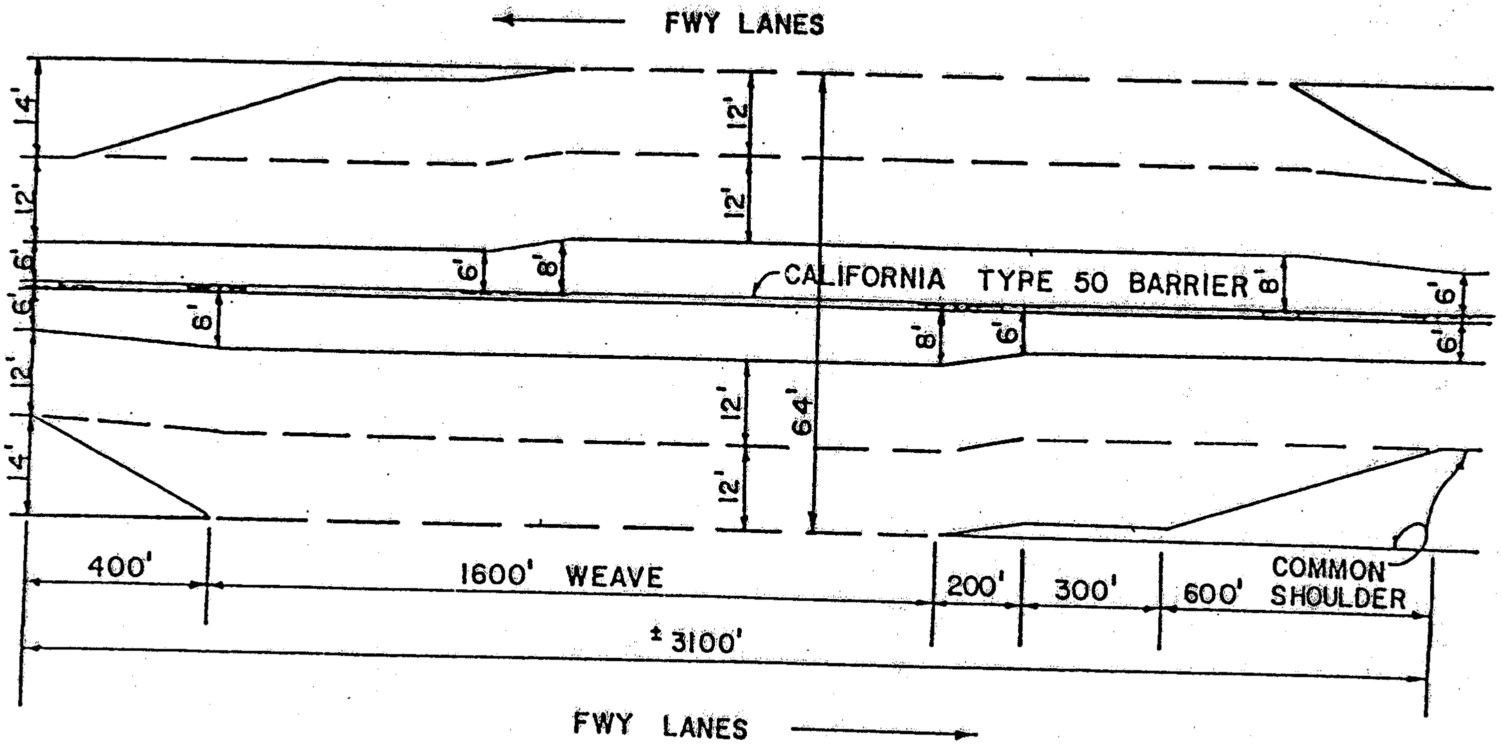


Figure 3-12. Caltrans Ingress/Egress for Wide Busway (at-grade)

3.3.1.2 Horizontal Curvature

For transitway design the following shall apply to the centerline control:

System	Operating Speed	Minimum Radius
Bus	80 km/h	250 m
Bus	50 km/h	90 m
Bus	35 km/h	42 m
Rail	80 km/h	420 m
Rail	62 km/h	250 m
Rail	50 km/h	165 m
Rail	37 km/h	90 m

3.3.1.3 Superelevation Rates

For transitway, ramps and access points the maximum superelevation shall be 6%. Spiral transition curves shall be provided. The relationship between operating speed and curvature is

$$e = 11.5 V^2 /R$$

where: e is superelevation in millimetres (175 mm max.)

V is velocity in km/h.

R is radius in meters.

3.3.1.4 Vertical Curvature

Sag curves, based on a headlight control of 1.0 m height, shall be as follows:

Standard for 80 km/h - k = 30

Standard for 50 km/h - k = 10

Crest curves, based on a driver eye height of 1.5 m and an object height of 150 mm, shall be as follows:

Standard for 80 km/h - k = 45

Standard for 50 km/h - k = 8

The desirable minimum length of vertical curve is 60 m. Vertical curvature for ramps and access routes shall be based on an appropriate design speed not to exceed 50 km/h. Transitway vertical curves for 80 km/h are satisfactory for conversion to rail transit.

3.3.1.5 Grades

The maximum gradient for transitway mainlines shall be desirably 3.5%. The desirable standard for maximum gradient is based on flexibility for conversion to rail system. The minimum gradient for transitway design to provide adequate drainage shall be 0.35%. The rail system minimum gradient can be level grade if adequate drainage grades of 0.35% are provided.

The maximum gradient for ramps and access points shall be desirably 6%. The use of ramp grades up to 8% may be considered in special situations. The designer shall ensure safe operation of user vehicles by providing flatter grades of adequate length at starting and stopping locations.

3.3.1.6 Operating Speeds

The transitway operating speed shall be 80 km/h maximum. The station area operating speed shall be 50 km/h maximum. Ramp and access route operating speeds shall be 35 km/h maximum. Minimum design speeds shall correspond to the above operating speeds. Greater design speeds shall be used wherever such higher standards do not result in significant increases in construction costs.

3.3.1.7 Speed Change Lanes

Speed change lanes shall be provided on the transitway for station lanes, access points and any other locations where operating speeds of various functions differ. Station area lanes are shown on Figure 3 - 13. The acceleration lane length of 150 m is based on theoretical performance curves for 50 km/h operating speed. The acceleration lane taper length of 50 m shall be provided in addition to acceleration lane length.

The deceleration lane length of 75 m is based on deceleration rate of 3.2 km/h/sec from 50 km/h, assuming deceleration on the taper. The deceleration lane taper length shall be 35 m. Where ramps are provided for accessing buses, the desirable arrangement is a "right on" and "right off" system. In situations precluding the desirable arrangement, a "jug handle" left turn may be considered as shown on Figure 3-14.

Tests and observations have indicated that a proportion of the current fleet of buses will not meet the theoretical acceleration performance described above. Consequently a reduced operating speed in these areas may be necessary. Where feasible, provision shall be made for the possible expansion of acceleration lane length.from 150 m to 220 m. Alternatively, signalization to control merging traffic may be desirable.

3.3.1.8 Transitway Sections

Lane widths are 3.5 m. Paved shoulder widths are 0.5 m. The remainder of the shoulder area as indicated on the drawings shall be surface treated with asphalt. Roundings are 0.6 m minimum. Maximum slopes, for both cut and fill, are 2:1. ROW offset from sectional features is 1.0 m.

3.3.1.9 Ramp Sections

Multiple lane ramps have 3.5 m lanes. Single lane ramps are 5.0 m wide. Paved shoulders are 0.5 m wide. The designer shall consider the use of ramps

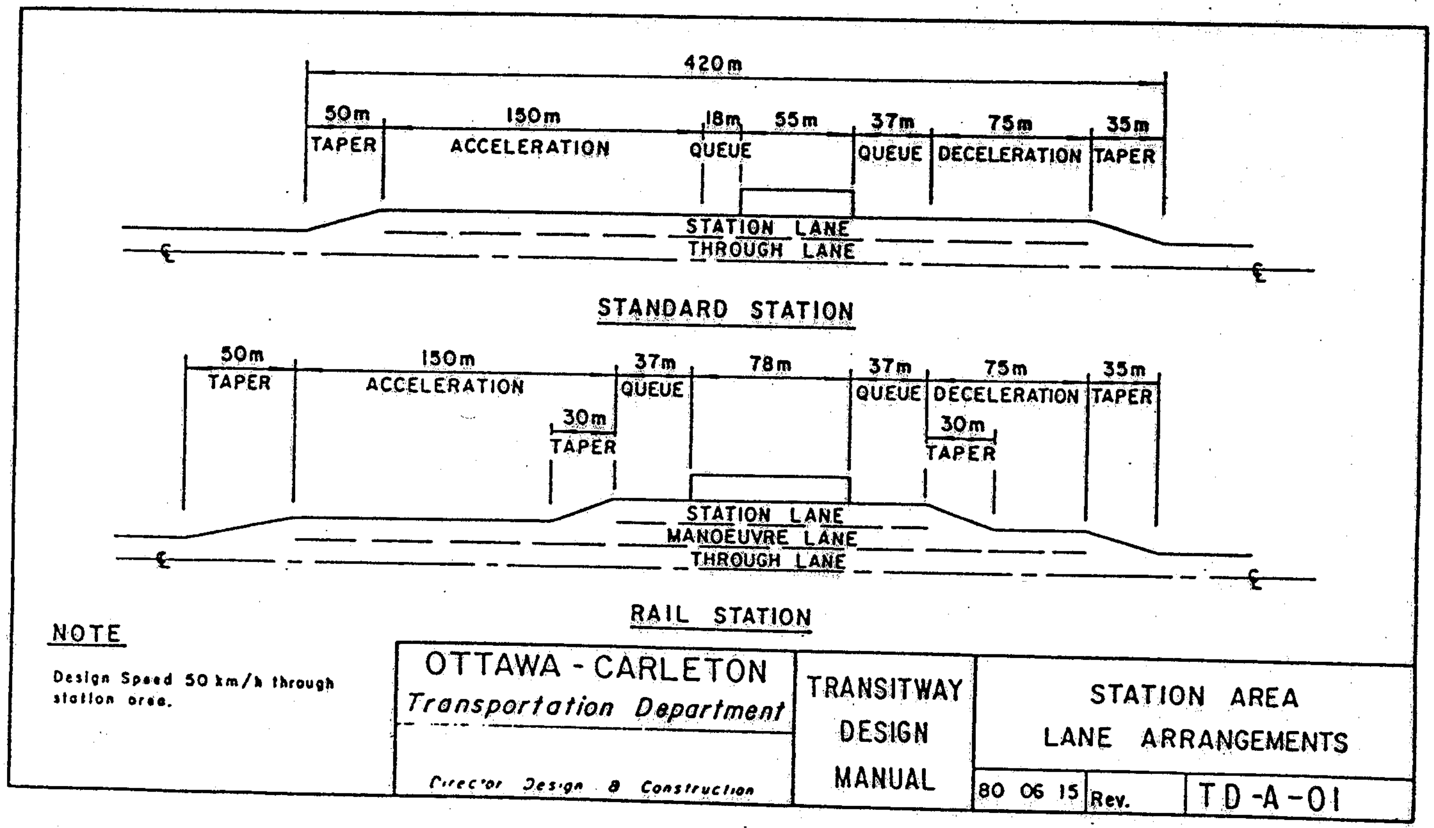

420m
50m
TAPER
150m
ACCELERATION
18m
QUEUE
55m
37m
QUEUE
75m
DECELERATION
35m
TAPER
STATION LANE
THROUGH LANE
STANDARD STATION
50m
TAPER
150m
ACCELERATION
30m
TAPER
37m
QUEUE
78m
37m
QUEUE
75m
DECELERATION
30m
TAPER
35m
TAPER
STATION LANE
MANOEUVRE LANE
THROUGH LANE
RAIL STATION
NOTE
Design Speed 50 km/h through station area.
OTTAWA - CARLETON
Transportation Department
Director Design & Construction
TRANSITWAY
DESIGN
MANUAL
STATION AREA
LANE ARRANGEMENTS
80 06 15
Rev.
TD-A-01

Figure 3-13

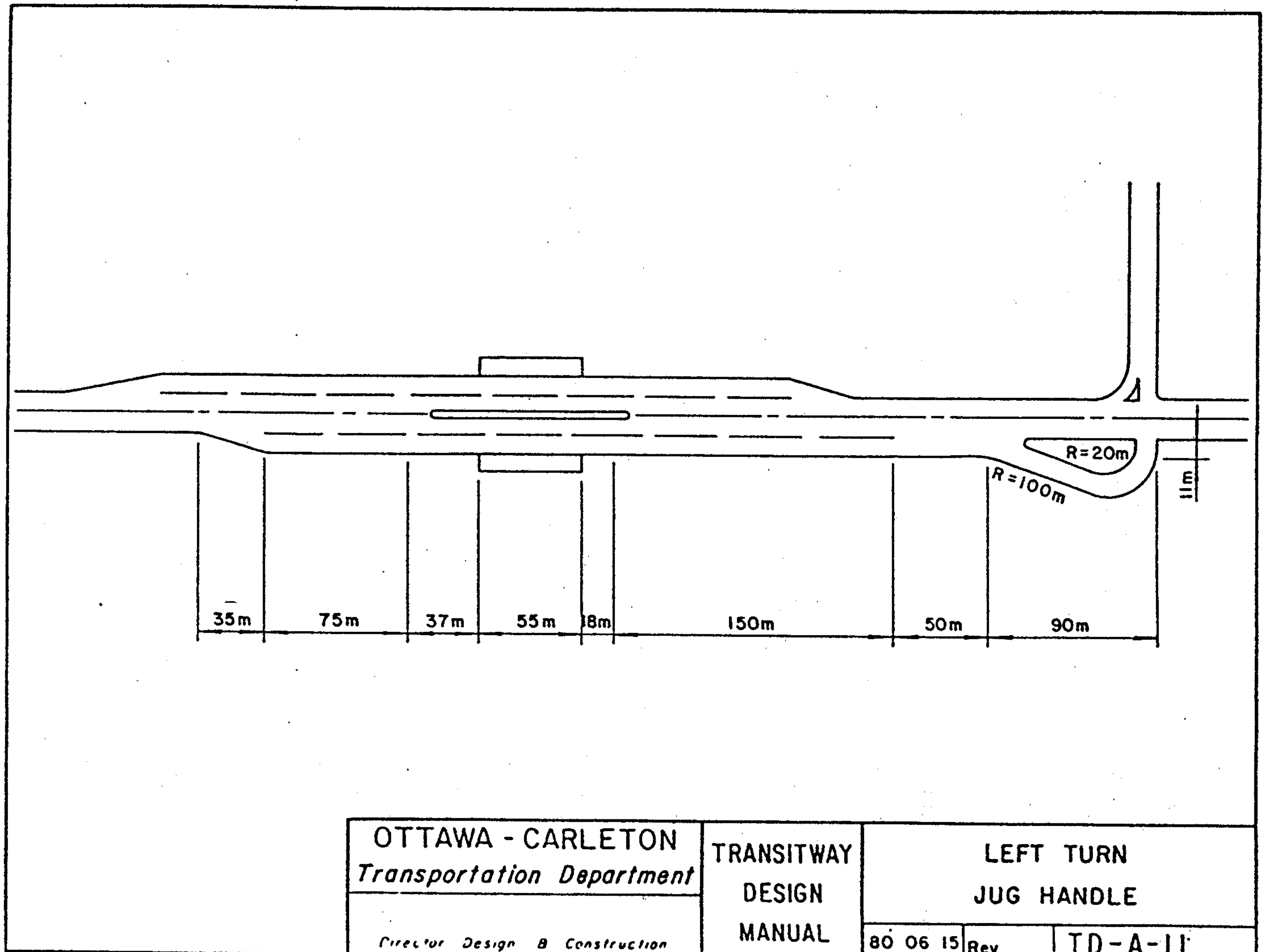

R=20m
R=100m
11m
35m
75m
37m
55m
18m
150m
50m
90m
OTTAWA - CARLETON
Transportation Department
Director Design & Construction
TRANSITWAY
DESIGN
MANUAL
LEFT TURN
JUG HANDLE
80 06 15
Rev.
TD-A-11

Figure 3-14

for maintenance access as well as transitway access. The designer shall consider the possibility of gating access points and the associated ducting for control.

3.3.1.10 Structure Sections

Standard transitway bridge cross section is shown in Figure 3 - 15. Horizontal and vertical clearances for bridges and underpasses shall conform to the standards in Figures 3 - 16 to 3 - 18.

3.4 MINNESOTA GUIDELINES

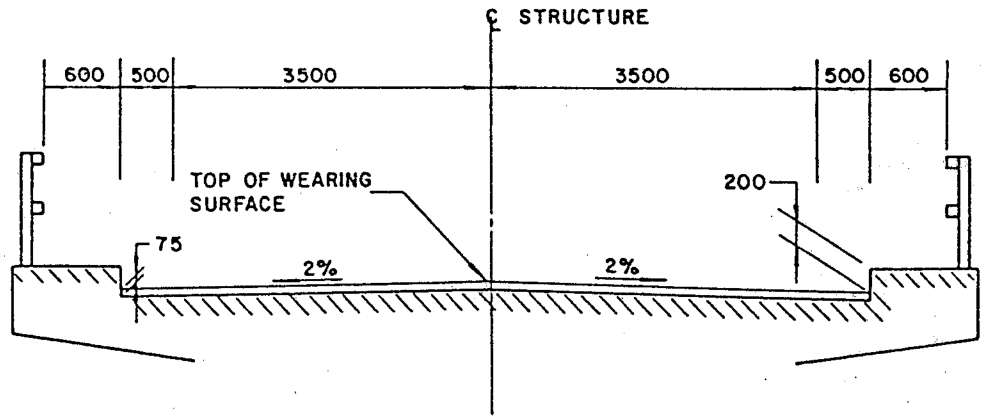
3.4.1 Source [5]: Minnesota Dept. of Transportation. Study Rept.: US-12/I-394 Between SR-101 and I-94 in Wayzata, Minnesota, Saint Louis Park, Golden Valley, and Minneapolis, Hennepin County, Minnesota. (not dated).

3.4.1.1 General

Six miles of the western segment of I-394 will have three lanes in each direction, with the inner lane in each direction marked as a diamond lane for the exclusive use of high occupancy vehicles during peak traffic hours. High-occupancy vehicles are defined as buses, vanpools, and carpools of two or more people. Only two and one-half miles of the eastern segment of I-394, near downtown Minneapolis, will have a physically separated transitway for these HOV's. This transitway will have two lanes and be reversible, operating inbound toward the city in the morning and outbound toward the suburbs in the evening. Alongside these lanes, I-394 will also consist of two general purpose lanes in each direction.

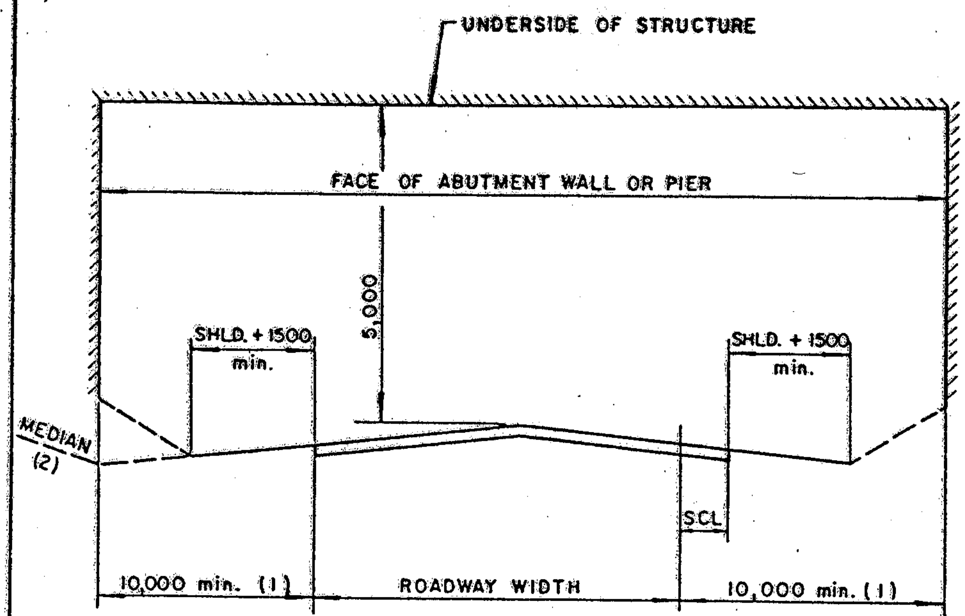
3.4.1.2 General Alignment

For most of their length the HOV lanes will be in the center of I-394, between the normal directional lanes, and at approximately the same grade.



OTTAWA - CARLETON *Transportation Department* Director Design & Construction	TRANSITWAY DESIGN MANUAL	TRANSITWAY BRIDGE STANDARD CROSS SECTION 80 06 15 Rev. TD-C-04

Figure 3-15



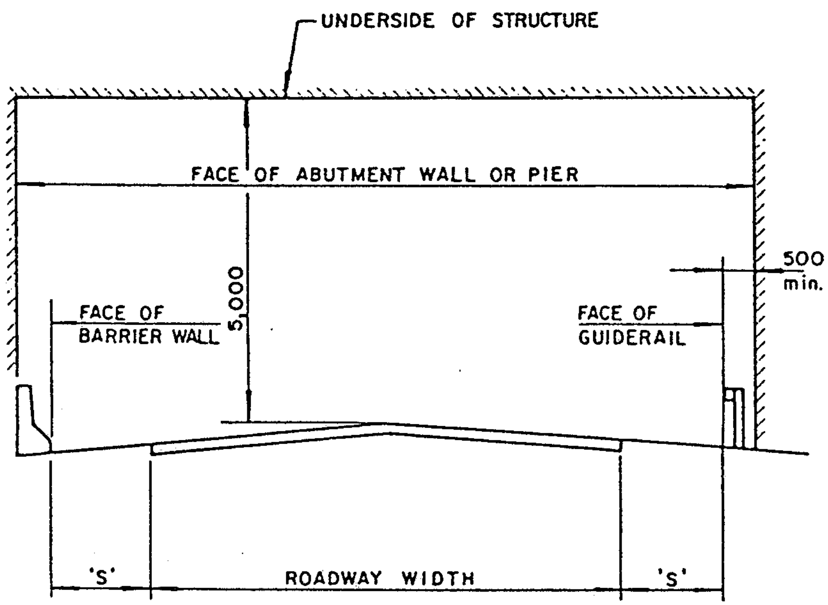
NOTES

(1) Measured, from the edge of thru' lane and may be reduced to 4·5m for pier only, subject to approval.

(2) For median widths less than 20m, median piers shall be located as closely as practicable to the centre of median with a minimum acceptable offset of 1·5m from edge of pavement to closest obstruction.

OTTAWA - CARLETON *Transportation Department*	TRANSITWAY DESIGN MANUAL	TRANSITWAY BRIDGE CLEARANCES (AT HIGHWAYS - CLASS A)
Director Design & Construction		80 06 15 Rev. TD-C-01

Figure 3-16

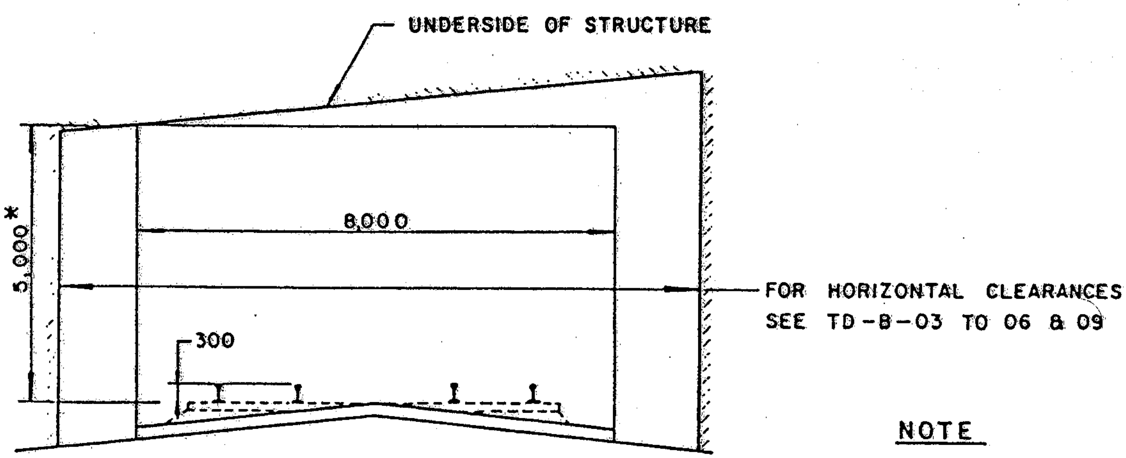


NOTES

'S' - Minimum 1·5m but may be reduced to 500 mm at median piers, subject to approval.

OTTAWA - CARLETON *Transportation Department*	TRANSITWAY DESIGN MANUAL	TRANSITWAY BRIDGE CLEARANCES (AT HIGHWAYS - CLASS B, C_1 & C_2)
Director Design & Construction		80 06 15 Rev. TD-C-02

Figure 3-17



NOTE

* In specific locations where buses only will operate, the underpass clearance may be reduced with the permission of Director, Design & Construction.

OTTAWA - CARLETON *Transportation Department*	TRANSITWAY DESIGN MANUAL	TRANSITWAY UNDERPASS CLEARANCES	
Director Design & Construction		80 06 15 Rev.	TD-C-03

Figure 3-18

At the downtown end they will bridge over the west bound lanes to gain the space needed to divide into their three terminals.

Interstate 394 will be aligned on the route of existing US Highway 12. Traffic will be maintained on US-12 during construction, and preferential treatment of HOV's will be initiated during the construction phase.

3.4.1.3 Cross Section

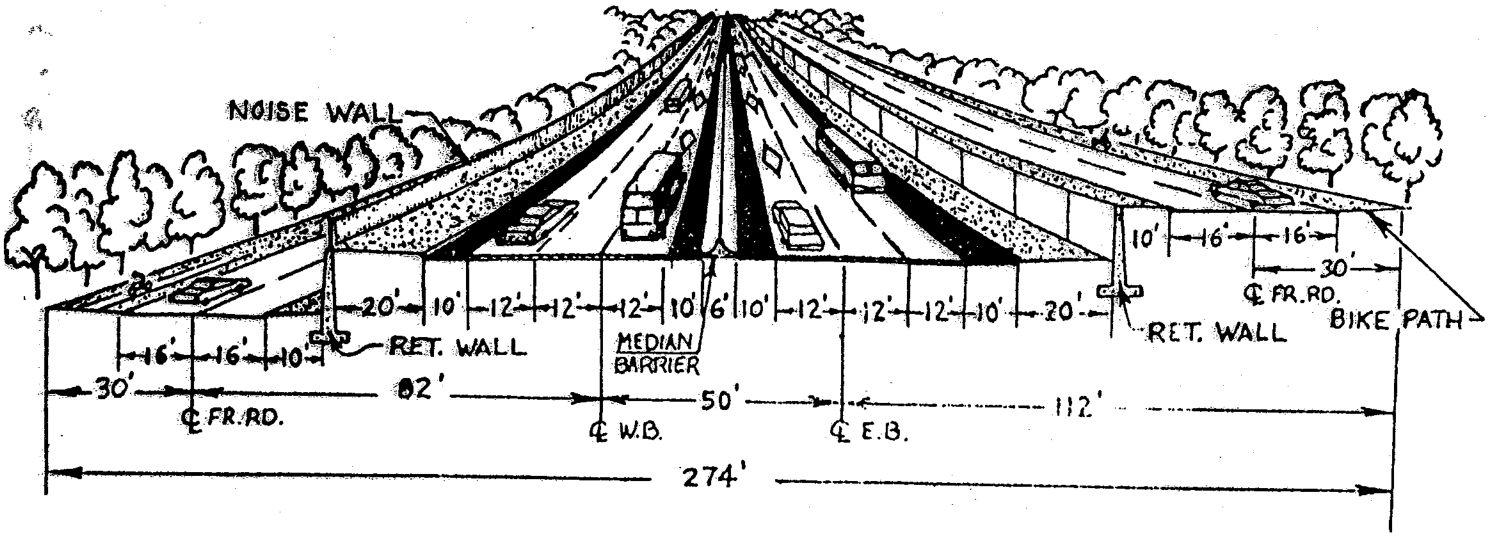
The transitway will consist of two twelve-foot travelled lanes with five- to ten-foot shoulders on each side (see Figure 3-19). The shoulders will accommodate emergency vehicles, permit traffic to pass around any stalled vehicles, and provide room for winter snow storage.

3.4.1.4 Design Speeds

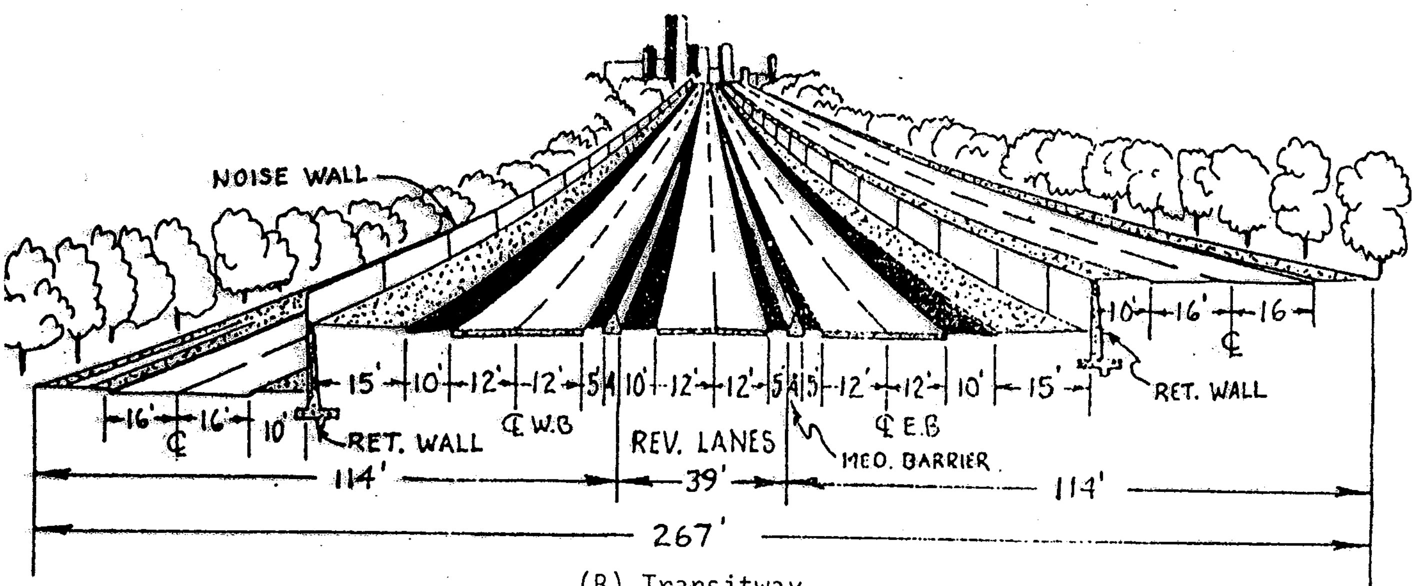
The design speed of I-394, including the HOV lanes, will generally be 70 miles per hour, based on the stopping sight distance. One curve in the HOV lane segment will have only a 60 mile per hour design speed. The speed limit will be 55 MPH.

3.4.1.5 Capacity and Level of Service

The intent is to keep the traffic flowing freely on the HOV lanes, moving markedly better than the traffic on the normal directional lanes, to promote ride sharing. The level of service can be adjusted by redefining the number of persons that constitute a carpool. The number may be either two or three persons. This number seems reasonable in this area which has a very low rate of ridesharing. The HOV Lanes should provide a high level of service under either definition.



(A) "Diamond Lanes"



(B) Transitway

Figure 3-19

3.4.1.6 Access and Terminals

Vehicles on the reversible lanes will have to transverse its entire two and one-half mile length. All access points will be at its east and west ends; there will be no intermediate points from which to enter or leave these lanes. At each end, however, there will be several access routes.

3.5 PENNSYLVANIA GUIDELINES

3.5.1 Source [6]: Correspondence with H. Cusack, Port Authority of Allegheny County, Pittsburg, PA. June 1984.

3.5.1.1 General

The Port Authority of Allegheny County currently operates two busways. The South Busway is a 4.3 mile Class B busway which was opened December 1977. The East Busway is a 6.8 mile Class A busway which opened for service in February 1983.

3.5.1.2 Design Criteria

Both the South and East Busways were constructed in accordance with the design criteria presented in Table 3-3 As suggested in NCHRP Report 155 2. Typical sections for the East Busway are shown in Figures 3 - 20 through 3 - 24. As can be seen, the busway cross section includes two lanes with 8 foot shoulders on each side in most sections. The total width of travel way varies from 34-40 feet within exclusive grade separated ROW. Ramp connections are provided to major arterial streets and several transit facility stations are located on-line.

3.6 TEXAS GUIDELINES

3.6.1 Source [7]: Bovay Engineers Inc./Parsons Brinckerhoff. Metropolitan Transit Authority of Harris County TX, Uniform Design Standards Manual, July 1981.

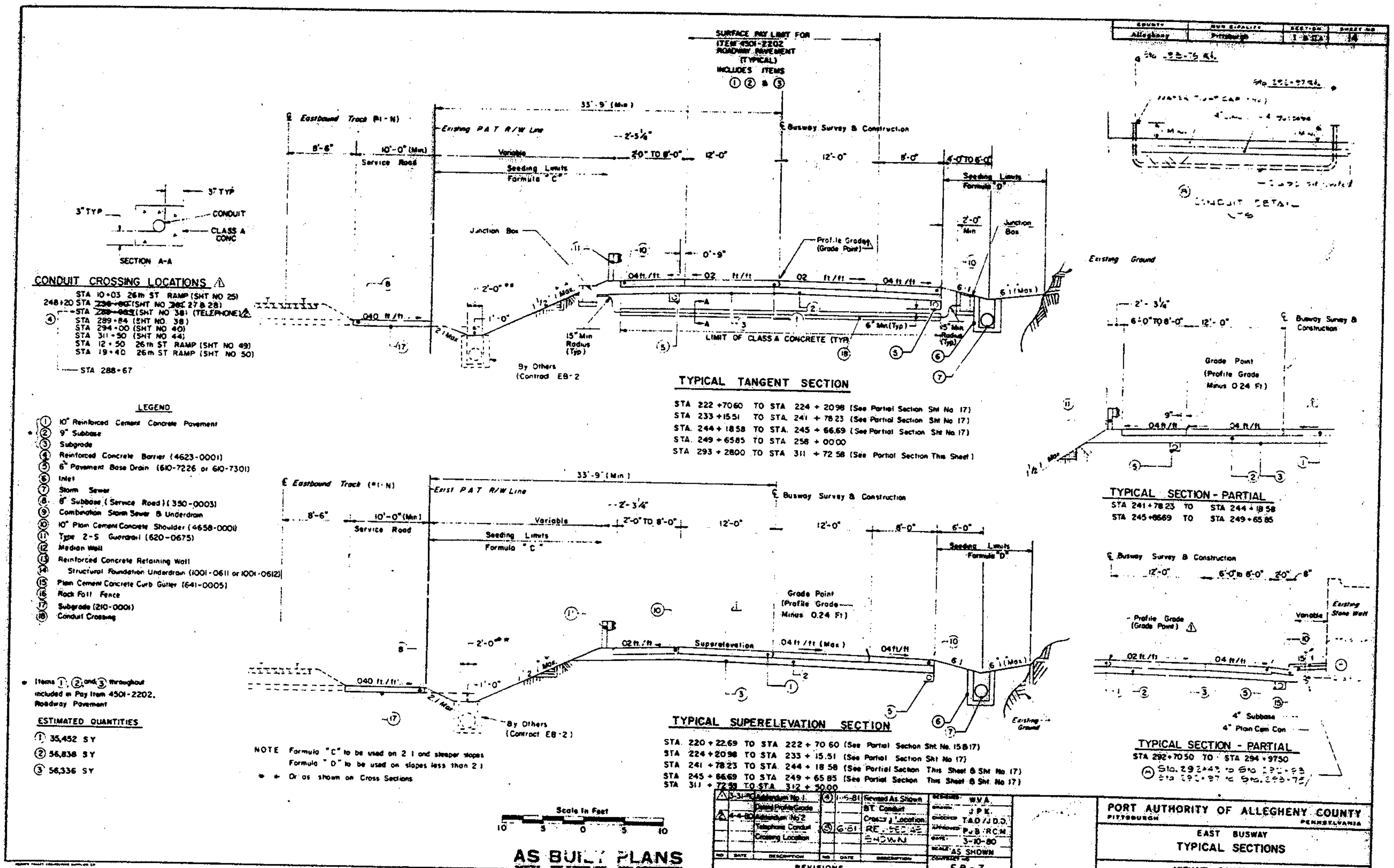
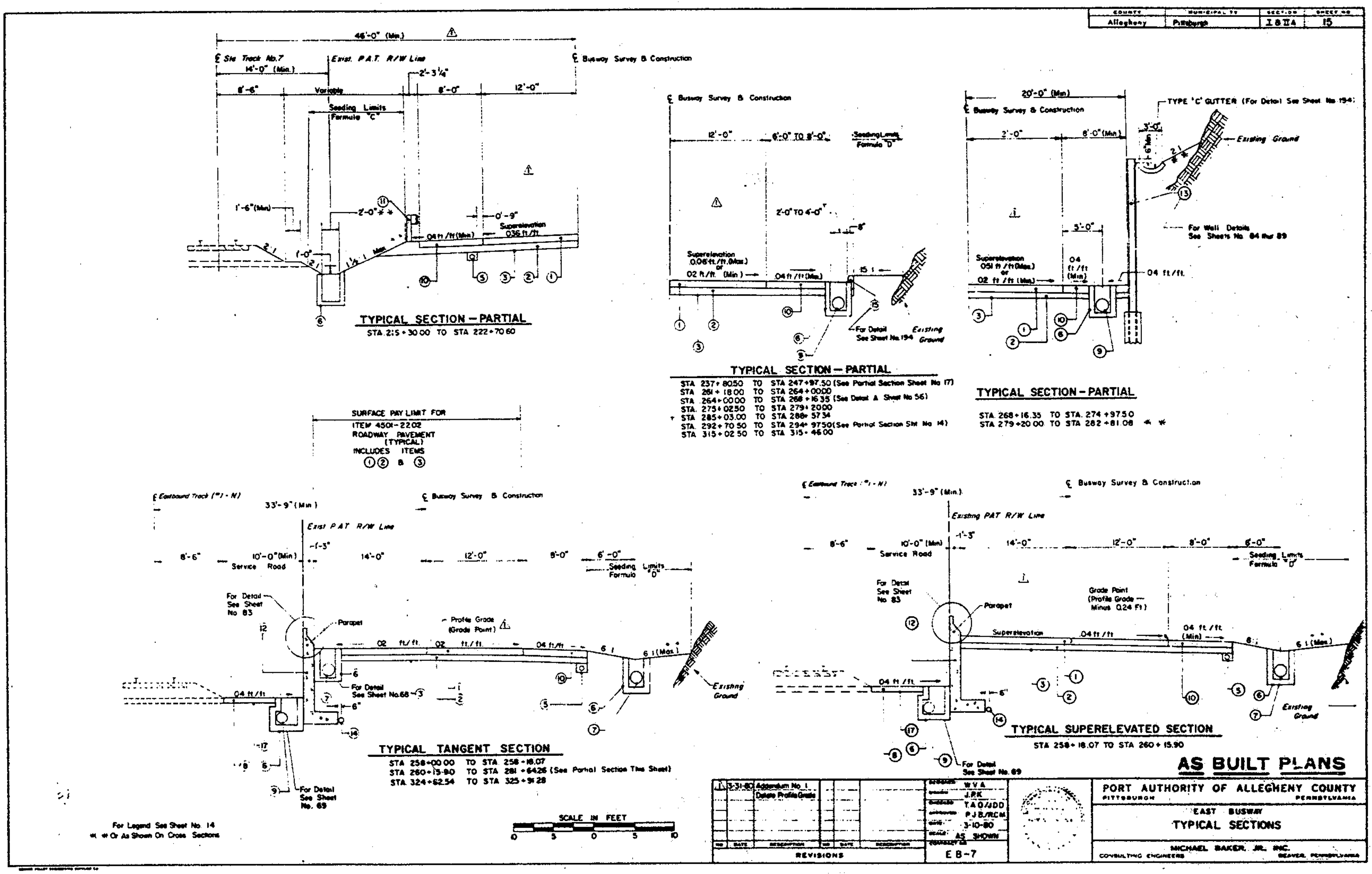
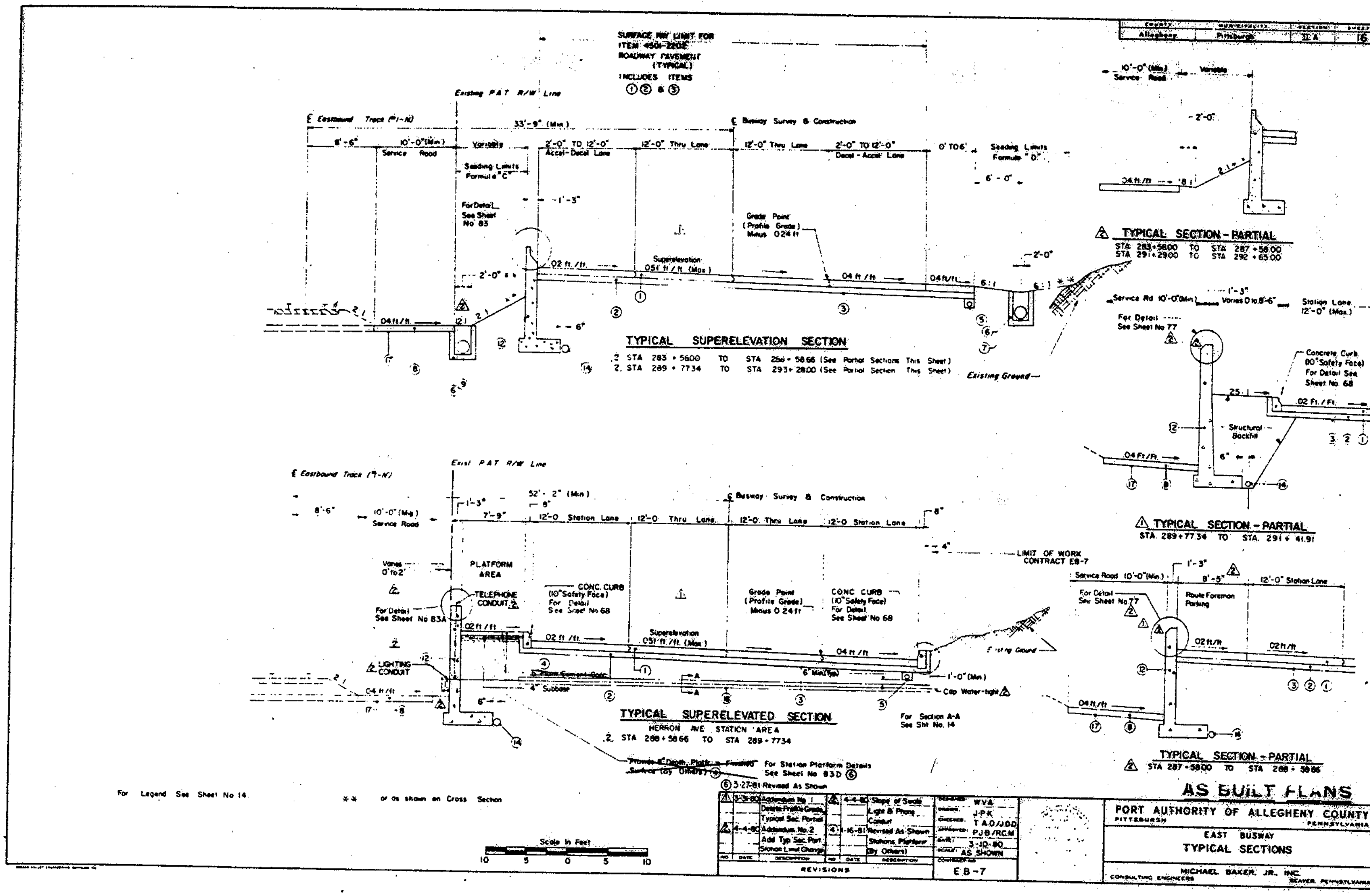

CONDUIT CROSSING LOCATIONS
SECTION A-A
LEGEND
10" Reinforced Cement Concrete Pavement
9" Subbase
Subgrade
Reinforced Concrete Barrier (4623-0001)
6" Pavement Base Drain (610-7226 or 610-7301)
Inlet
Storm Sewer
8" Subbase (Service Road) (350-0003)
Combination Storm Sewer & Underdrain
10" Plain Cement Concrete Shoulder (4658-0001)
Type 2-S Guardrail (620-0675)
Median Wall
Reinforced Concrete Retaining Wall
Structural Foundation Underdrain (1001-0611 or 1001-0612)
Plain Cement Concrete Curb Gutter (641-0005)
Rock Fall Fence
Subgrade (210-0001)
Conduit Crossing
ESTIMATED QUANTITIES
35,452 SY
56,838 SY
56,336 SY
TYPICAL TANGENT SECTION
TYPICAL SUPERELEVATION SECTION
TYPICAL SECTION - PARTIAL
TYPICAL SECTION - PARTIAL
Busway Survey & Construction
Service Road
Seeding Limits
Scale in Feet
AS BUILT PLANS
PORT AUTHORITY OF ALLEGHENY COUNTY
PITTSBURGH PENNSYLVANIA
EAST BUSWAY
TYPICAL SECTIONS
MICHAEL BAKER, JR., INC.
EB-7
REVISIONS

Figure 3-20



TYPICAL SECTION – PARTIAL
STA 215+30.00 TO STA 222+70.60
TYPICAL SECTION – PARTIAL
TYPICAL SECTION – PARTIAL
STA 268+16.35 TO STA 274+97.50
STA 279+20.00 TO STA 282+81.08
SURFACE PAY LIMIT FOR
ITEM 4501-2202
ROADWAY PAVEMENT
(TYPICAL)
INCLUDES ITEMS
TYPICAL TANGENT SECTION
TYPICAL SUPERELEVATED SECTION
STA 258+16.07 TO STA 260+15.90
AS BUILT PLANS
PORT AUTHORITY OF ALLEGHENY COUNTY
EAST BUSWAY
TYPICAL SECTIONS
MICHAEL BAKER, JR., INC.
SCALE IN FEET
REVISIONS
E B-7

Figure 3-21



TYPICAL SUPERELEVATION SECTION
TYPICAL SUPERELEVATED SECTION
HERRON AVE. STATION AREA
TYPICAL SECTION - PARTIAL
TYPICAL SECTION - PARTIAL
TYPICAL SECTION - PARTIAL
For Legend See Sheet No 14
Scale In Feet
REVISIONS
AS BUILT PLANS
PORT AUTHORITY OF ALLEGHENY COUNTY
PITTSBURGH
PENNSYLVANIA
EAST BUSWAY
TYPICAL SECTIONS
MICHAEL BAKER, JR., INC.
CONSULTING ENGINEERS
EB-7

Figure 3-22

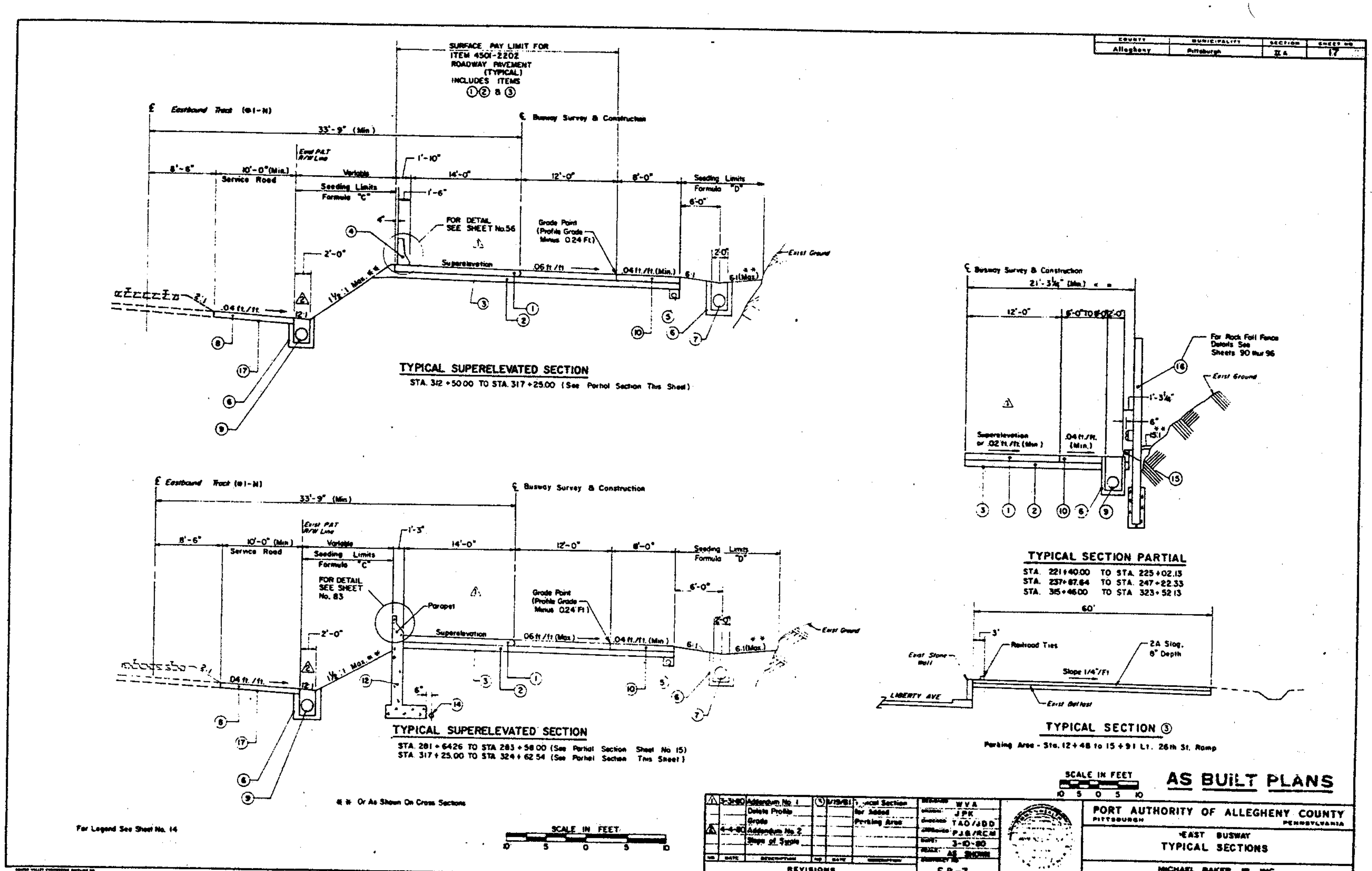

SURFACE PAY LIMIT FOR ITEM 4501-2202 ROADWAY PAVEMENT (TYPICAL) INCLUDES ITEMS ① ② & ③
Busway Survey & Construction
FOR DETAIL SEE SHEET No. 56
Superelevation
Seeding Limits Formula "C"
Seeding Limits Formula "D"
Service Road
Exist Ground
TYPICAL SUPERELEVATED SECTION
STA. 312 + 50.00 TO STA. 317 + 25.00 (See Partial Section This Sheet)
Eastbound Track
Busway Survey & Construction
FOR DETAIL SEE SHEET No. 83
Parapet
Superelevation
TYPICAL SUPERELEVATED SECTION
STA. 281 + 64.26 TO STA 283 + 58.00 (See Partial Section Sheet No 15)
STA. 317 + 25.00 TO STA 324 + 62.54 (See Partial Section This Sheet)
** Or As Shown On Cross Sections
For Legend See Sheet No. 14
SCALE IN FEET
For Rock Fall Fence Details See Sheets 90 thru 96
TYPICAL SECTION PARTIAL
STA. 221+40.00 TO STA. 225+02.15
STA. 237+87.64 TO STA. 247+22.33
STA. 315+46.00 TO STA. 323+52.13
Railroad Ties
2A Slag, 6" Depth
Slope 1/4"/Ft
LIBERTY AVE
TYPICAL SECTION ③
AS BUILT PLANS
PORT AUTHORITY OF ALLEGHENY COUNTY
PITTSBURGH PENNSYLVANIA
EAST BUSWAY
TYPICAL SECTIONS
MICHAEL BAKER, JR., INC.
CONSULTING ENGINEERS
BEAVER, PENNSYLVANIA
REVISIONS
EB-7

Figure 3-23

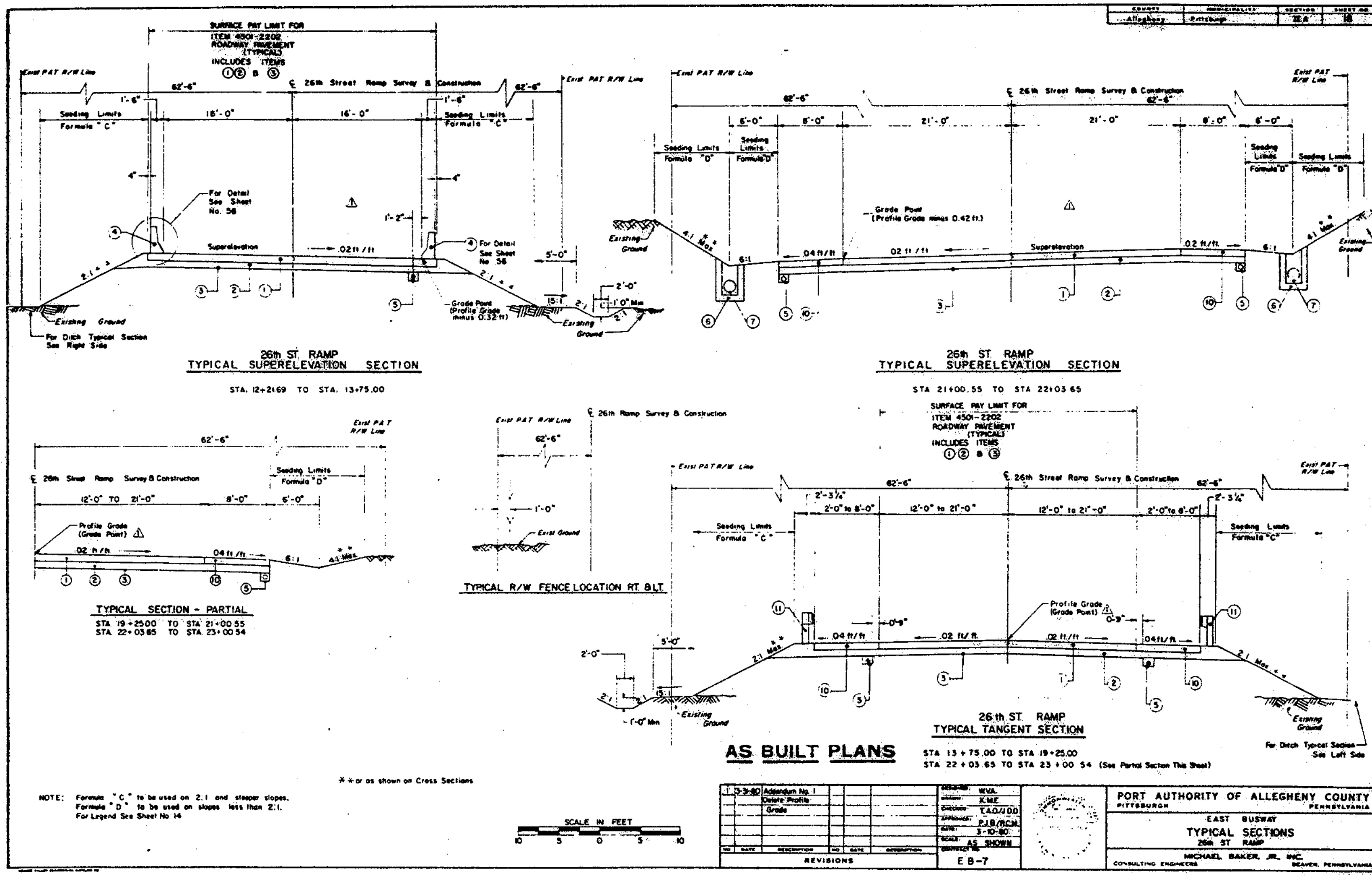

26th ST. RAMP
TYPICAL SUPERELEVATION SECTION
STA. 12+21.69 TO STA. 13+75.00
26th ST. RAMP
TYPICAL SUPERELEVATION SECTION
STA. 21+00.55 TO STA. 22+03.65
TYPICAL SECTION - PARTIAL
STA. 19+25.00 TO STA. 21+00.55
STA. 22+03.65 TO STA. 23+00.54
TYPICAL R/W FENCE LOCATION RT. & LT.
26th ST. RAMP
TYPICAL TANGENT SECTION
STA. 13+75.00 TO STA. 19+25.00
STA. 22+03.65 TO STA. 23+00.54 (See Partial Section This Sheet)
AS BUILT PLANS
NOTE: Formula "C" to be used on 2:1 and steeper slopes.
Formula "D" to be used on slopes less than 2:1.
For Legend See Sheet No. 14
SCALE IN FEET
PORT AUTHORITY OF ALLEGHENY COUNTY
PITTSBURGH PENNSYLVANIA
EAST BUSWAY
TYPICAL SECTIONS
26th ST. RAMP
MICHAEL BAKER, JR., INC.
CONSULTING ENGINEERS BEAVER, PENNSYLVANIA
REVISIONS
EB-7

Figure 3-24

3.6.1.1 Busway Classifications

The Metropolitan Transit Authority of Harris County/Houston (MTA) has anticipated the need to consider four potential uses of busways, each of which has its own set of facility definitions and standard designs. These are:

Narrow Busway - A single lane, exclusive, bus roadway designed for single direction reversible operation, with the reverse peak movement of buses accommodated in the mixed traffic of freeway lanes. The siting of the standard designs presented here include only freeway medians - probably existing freeway medians reconstructed to add the narrow busway.

Wide Busway - A two-lane, exclusive, bus roadway designed for two-direction operation or alternatively for single direction reversible operation. The siting of the standard designs presented here includes development on an independent MTA right-of-way and development in a freeway median.

Wide Busway With Carpools - A two-lane roadway designed for two-direction operation by buses and other high occupancy passenger vehicles. The siting of the standard designs presented here include development on an independent MTA right-of-way and development in a freeway median.

Convertible Busway - A wide busway designed for future conversion to a rail transit facility.

3.6.1.2 Design Vehicle

Development of uniform design standards for busways includes a review of the modern bus vehicle and its basic characteristics. The MTA operates, or will operate, several models of coaches which are of recent design. Consideration has been given to the physical characteristics of such vehicles and to other types of buses which MTA busways should accommodate. All such vehicles are assumed to be street type in that they conform to width and length restrictions of the area of service. Figure 3-25 summarizes the modern bus vehicles examined.

3.6.1.3 Busway Operations

There are three general concepts of busway operations and variations of each. Any of these concepts may be evaluated in planning MTA's long range transit needs. Each has its own requirements for the fixed facilities of busways and for the interface accommodations with feeder modes. The alternative concepts are:

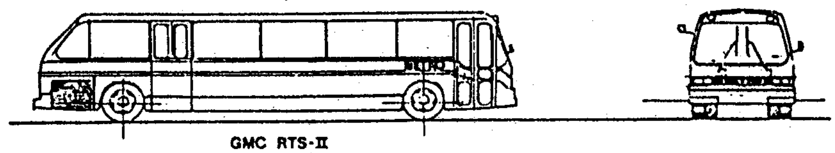
Express Busway - A busway which serves as an exclusive high-speed roadway link between suburban communities and neighborhoods and the central business district (CBD). All bus loading and unloading is accomplished in city CBD streets or suburban neighborhoods prior to entering the busway or after leaving it. No stations along the busway are provided.

Busway with Stations - A busway similar to the express busway but provided with on-line stations where all buses or selected buses may stop to load and unload patrons. By-pass lanes are provided.

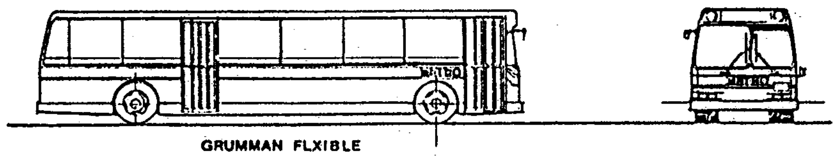
Closed-Loop Busway - A busway with on-line stations operating as a bus rapid transit system, in that the busway buses never operate on city streets. All patrons load or unload at busway stations including one or more central urban area or CBD stations. In this option the buses may be oversized and otherwise designed for exclusive high-speed operation. The concept anticipates separate feeder transit.

3.6.1.4 General Design Criteria

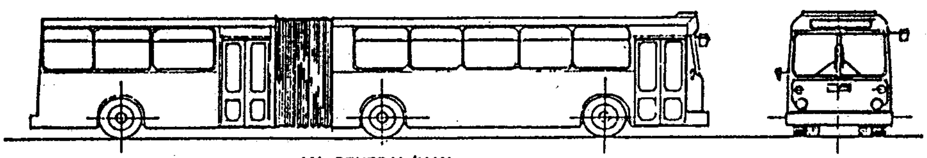
Table 3-5 summarizes general design criteria for the MTA busways. Where exclusive busways are listed, the vertical curve and stopping sight distance



GMC RTS-II



GRUMMAN FLXIBLE

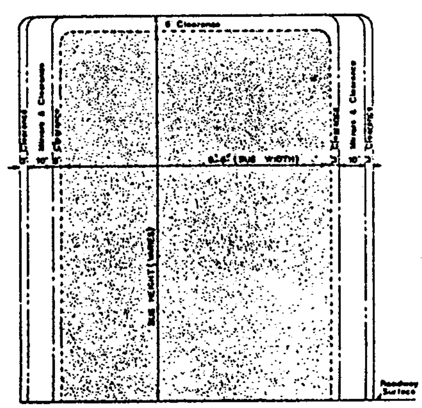


AM GENERAL/MAN

	URBAN BUS		ARTICULATED	INTERCITY BUS
	GRUMMAN FLXIBLE	GMC RTS-II	AM GENERAL/MAN	EAGLE 0-5
LENGTH	40'-0"	40'-0"	55'0"/59'-8"*	40'-0"
WIDTH	8'-6"	8'-6"	8'-6"	8'-0
HEIGHT	9'-11"	9'-9.5"	10'-2"	[illegible]
WHEEL BASE	24'-11"	24'-11"	21'0"/23'-11"*	285.5"
FRONT TRACK	7'-1"	7'-2"	5'-11"	[illegible]
TURNING RADIUS	42'-7.5"	42'-0"	39'-6"	44'-3"
SEATING CAPACITY	48	45	65/69	46

*MODEL SG-220-16.5-2A/SG-220-18-2A

VEHICLE DIMENSIONS



CLEARANCE ENVELOPE

ABSOLUTE MINIMUM CLEARANCE ENVELOPE = 9'-0" wide x 10'-8" high (excludes intercity bus)

DESIRED MINIMUM CLEARANCE ENVELOPE = 10'-8" wide x 12'-6" high (includes intercity bus)

DESIRED CLEARANCE ENVELOPE = 11'-2" wide x 12'-6" high (includes intercity bus)

LEGEND

— - — ABSOLUTE MINIMUM CLEARANCE = Bus dimensions + 3" clearance with mirrors folded to side of bus. Passing speed less than 5 mph.

— - - — DESIRED MINIMUM CLEARANCE = Bus dimensions + 3" clearance with mirrors in normal position protruding 10" from each side of bus. Passing speed up to 10 mph.

——— DESIRABLE CLEARANCE = Bus dimensions + 6" clearance with mirrors in normal position protruding 10" from each side of bus. Passing speed up to 30 mph.

UNIFORM DESIGN STANDARDS MANUAL METROPOLITAN TRANSIT AUTHORITY OF HARRIS COUNTY		BUS DIMENSIONS & CLEARANCE ENVELOPE
Bovay Engineers, Inc. / Parsons Brinckerhoff Engineers and Planners Houston, Texas	Moseley Associates, Architects Houston, Texas	PLATE 1

Figure 3-25

TABLE 3-5. General Design Criteria for MTA Busways

ITEM / TYPE	NARROW BUSWAY	WIDE BUSWAY	WIDE BUSWAY WITH CARPOOLS	WIDE BUSWAY CONVERTIBLE TO: LIGHT RAIL TRANSIT	WIDE BUSWAY CONVERTIBLE TO: RAIL RAPID TRANSIT	REMARKS
Design Vehicle	Bus	Bus	Bus & Carpool	Bus-- Light Rail Transit	Bus-- Rail Rapid Transit	
Driver's Eye Height	7'	7'	7' 3.75'	7'	7'	
Operating Speed (MPH)	50 - 55	50 - 55	50 - 55	50 - 60	50 - 60	
Design Speed (MPH)	60	60	60	60	60	
Minimum Design Speed (MPH)	40	40	40	40	50	Through Restricted Areas
Horizontal Curvature Minimum Desirable Min. Rad.	750' 1600'	750' 1600'	750' 1600'	750' 1600'	1000' 1950'	For Reduced Speed Operation For Full Speed Operation
Absolute min. Rad.	42' - 7.5" at entrances or exits			82' At Turnout or Stops	300' At Turnout or Stops	For Less Than 5 MPH Operation
Transition Curve	Spiraled or Compounded Transition curves are not required for curves with radius greater than 1910' (3^{0}) See State Highway Design Manual			Required for R<16000' Length $\geq$ 1.17 VE or 1.0 VU or 50E	Required for all curves Length $\geq$ 1.4 VE or 1.0VU or 60E	V = Design Speed E=Superelev. U = Unbalanced Superelev. For Future Track E (max.) = 6" U (max.) = 4"
Superelevation	0.08 ft. per ft. max.					
Minimum Pavement Cross Slope	1/8 in./ft.					
Vertical Grade: Maximum (Main Line) Maximum (Ramps) Minimum	4% 6% 0.3%				3.0% (1% at stations) 6.0% 0.3%	
Vertical (Parabolic) Curve: Min. Length L Crest: L = KA Sag: L = KA	100' K = 150 (K = 40 for ramp) K = 100 (K = 30 for ramp)	100' K = 150' (K = 40 for ramp) K = 100' (K = 30 for ramp)	100' K =180 K=(50 for ramp) K =110 K=(35 for ramp)	100' K = 150 (K=40 for ramp) k = 100 (k=30 for ramp)	100' K=210 (K=40 for ramp) K=110 (K=30 for ramp)	A=Algebraic Diff. in Grades K may be reduced for lower speed
Design Load on Structures: Live load Impact Other Forces	HS20-44 I (Impact Fraction) = 50/(Span Length in feet + 125) $\leq 30\%$ See Standard Specifications for Highway Bridges by AASHO			Light Rail Train Use A.R.E.A Manual " " "	Heavy Rail Train Use A.R.E.A. Manual " " "	
Stopping Sight Distance	(See Texas State Highway Design Manual) 200'min.					
Acceleration Lane (Interm. Entrance)	350'(min.) 400' (desirable)	350' (min.) 400' (desirable)	350'(min) 900'(desirable)	350' (min.)	400' (desirable)	
Deceleration Lane (Interm. Exit)	150' (min.) 400' (desirable)	150' (min.) 400' (desirable)	300'(min) 600'(desirable)	150' (min.)	400' (desirable)	

minimums, except for wide busway with carpools, reflect the height of driver's eye for bus operations.

Variances from these maxima and minima may be warranted for specific facilities or operations. The MTA will consider recommendations for variances in such specific cases. The highway design practices of Texas SDHPT and those offered as "desirable" by AASHTO shall govern in design matters not set forth here.

3.6.1.5 Standard Designs

Narrow Busway

As used by the MTA, a Narrow Busway is a single-lane, exclusive, bus roadway, designed for single-direction, reversible operation. The facility is designed for use in the median of an existing freeway, with the reverse peak movement of buses accommodated in the mixed traffic of the freeway.

Figures 3-26 and 3-27 depict four typical sections of the narrow busway in four conditions of siting in a freeway median.

(a) At-Grade (Figure 3-26)

(b) Elevated (Figure 3-26)

(c) Depressed (Figure 3-27)

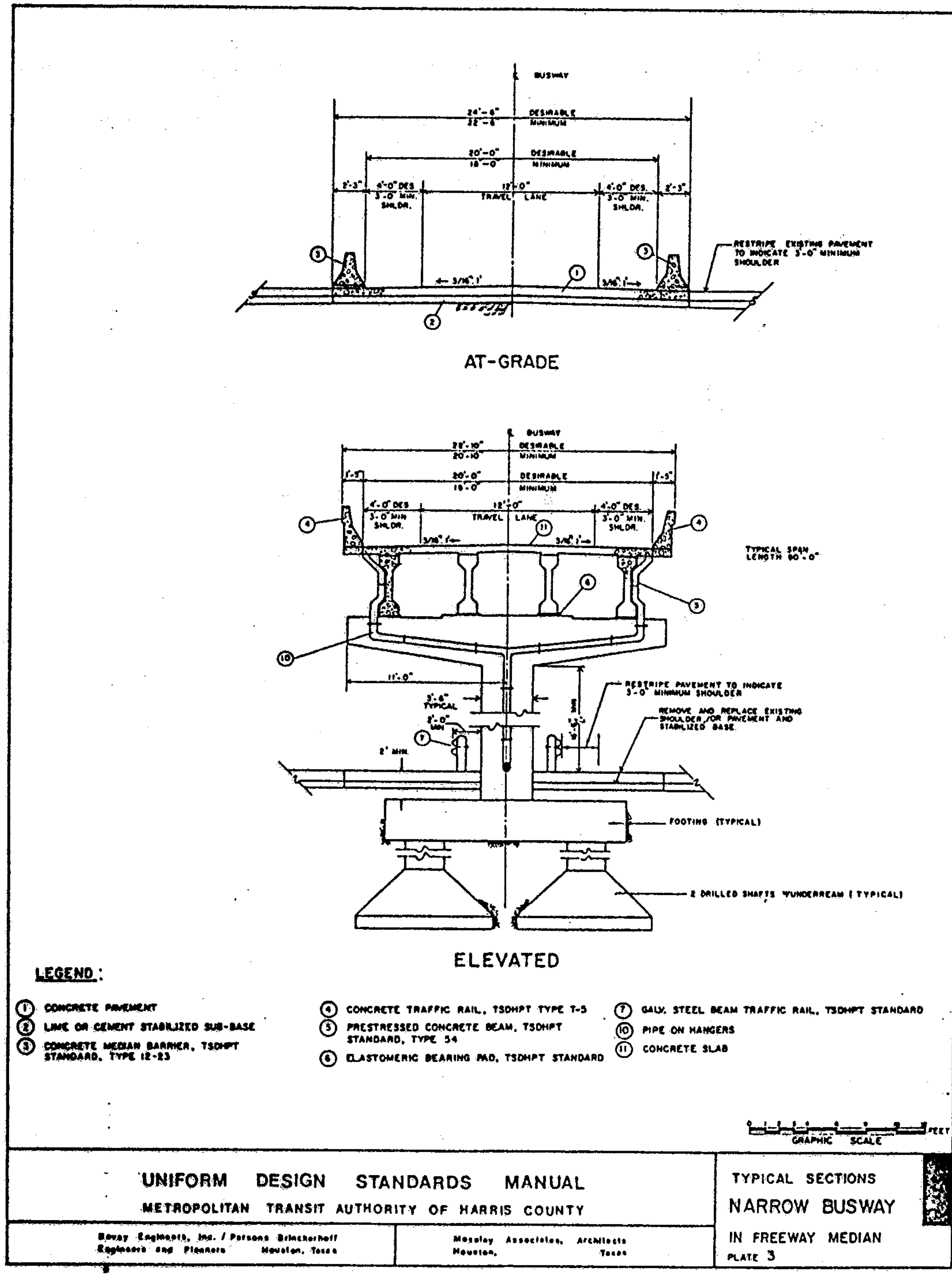
(d) Transition (Figure 3-27)

Wide Busway

As used by the MTA, a wide busway is a two-lane, exclusive, bus roadway, designed for two-way or single-direction, reversible operation. It may be sited in a freeway median or developed on an independent MTA right-of-way.

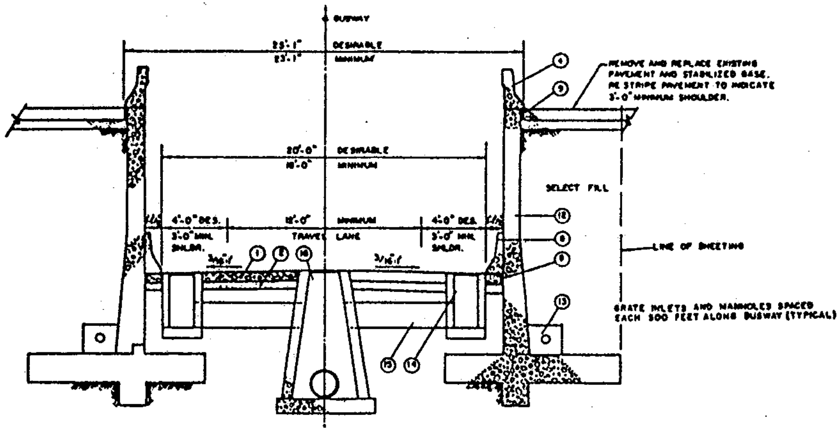
Figures 3-28 through 3-32 depict ten typical sections of the Wide Busway in various conditions of siting, as follows:

(a) At-Grade (Figure 3-28)
(b) Elevated (Figure 3-28)
(c) Depressed (Figure 3-29)
(d) Cut-and-Cover (subway) (Figure 3-29)

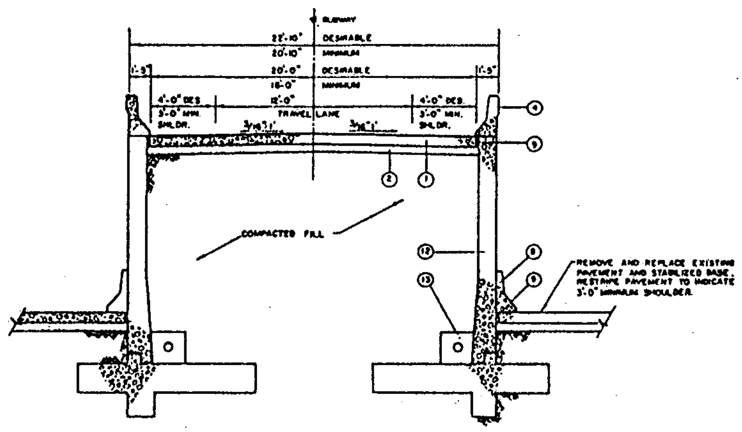


AT-GRADE
RESTRIPE EXISTING PAVEMENT TO INDICATE 3'-0" MINIMUM SHOULDER
ELEVATED
TYPICAL SPAN LENGTH 80'-0"
RESTRIPE PAVEMENT TO INDICATE 3'-0" MINIMUM SHOULDER
REMOVE AND REPLACE EXISTING SHOULDER FOR PAVEMENT AND STABILIZED BASE.
FOOTING (TYPICAL)
2 DRILLED SHAFTS W/UNDERREAM (TYPICAL)
LEGEND:
1 CONCRETE PAVEMENT
2 LIME OR CEMENT STABILIZED SUB-BASE
3 CONCRETE MEDIAN BARRIER, TSDHPT STANDARD, TYPE 12-23
4 CONCRETE TRAFFIC RAIL, TSDHPT TYPE T-5
5 PRESTRESSED CONCRETE BEAM, TSDHPT STANDARD, TYPE 54
6 ELASTOMERIC BEARING PAD, TSDHPT STANDARD
7 GALV. STEEL BEAM TRAFFIC RAIL, TSDHPT STANDARD
10 PIPE ON HANGERS
11 CONCRETE SLAB
GRAPHIC SCALE
FEET
UNIFORM DESIGN STANDARDS MANUAL
METROPOLITAN TRANSIT AUTHORITY OF HARRIS COUNTY
TYPICAL SECTIONS
NARROW BUSWAY
IN FREEWAY MEDIAN
PLATE 3

Figure 3-26



DEPRESSED



TRANSITION

LEGEND:

- (1) CONCRETE PAVEMENT
- (2) LIME OR CEMENT STABILIZED SUB-BASE
- (4) CONCRETE TRAFFIC RAIL, TSDHPT TYPE T-5
- (8) 1/2 CONCRETE MEDIAN BARRIER, TSDHPT STANDARD, TYPE 3
- (9) EXPANSION JOINT MATERIAL
- (12) RETAINING WALL, TSDHPT STANDARD
- (13) FILTER MATERIAL (TYPE "F") W/UNDERDRAIN PIPE (TYPE 5, 9, 10 OR 11), TSDHPT STANDARD
- (14) GRATE INLET
- (15) REINFORCED CONCRETE PIPE (SLOPE TO DRAIN)
- (16) MANHOLE

0 1 2 3 4 6 8 10 12 FEET
GRAPHIC SCALE

UNIFORM DESIGN STANDARDS MANUAL
METROPOLITAN TRANSIT AUTHORITY OF HARRIS COUNTY

Bovay Engineers, Inc. /Parsons Brinckerhoff
Engineers and Planners Houston, Texas

Moseley Associates, Architects
Houston, Texas

TYPICAL SECTIONS
NARROW BUSWAY
IN FREEWAY MEDIAN
PLATE 4

Figure 3-27

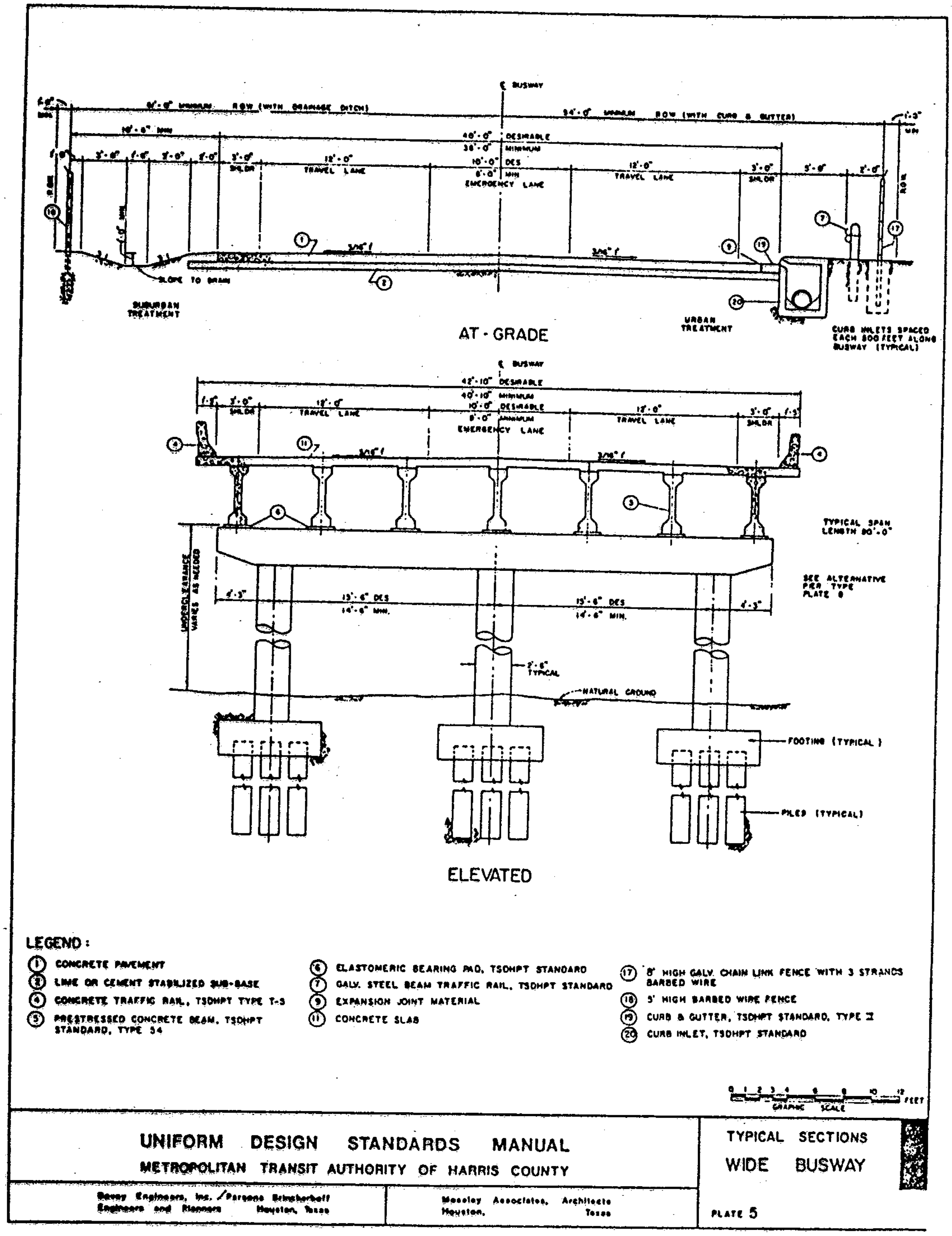

AT - GRADE
ELEVATED
LEGEND:
1 CONCRETE PAVEMENT
2 LIME OR CEMENT STABILIZED SUB-BASE
4 CONCRETE TRAFFIC RAIL, TSDHPT TYPE T-5
5 PRESTRESSED CONCRETE BEAM, TSDHPT STANDARD, TYPE 54
6 ELASTOMERIC BEARING PAD, TSDHPT STANDARD
7 GALV. STEEL BEAM TRAFFIC RAIL, TSDHPT STANDARD
9 EXPANSION JOINT MATERIAL
11 CONCRETE SLAB
17 8' HIGH GALV. CHAIN LINK FENCE WITH 3 STRANDS BARBED WIRE
18 5' HIGH BARBED WIRE FENCE
19 CURB & GUTTER, TSDHPT STANDARD, TYPE II
20 CURB INLET, TSDHPT STANDARD
GRAPHIC SCALE
FEET
UNIFORM DESIGN STANDARDS MANUAL
METROPOLITAN TRANSIT AUTHORITY OF HARRIS COUNTY
TYPICAL SECTIONS
WIDE BUSWAY
PLATE 5
Moseley Associates, Architects
Houston, Texas

Figure 3-28

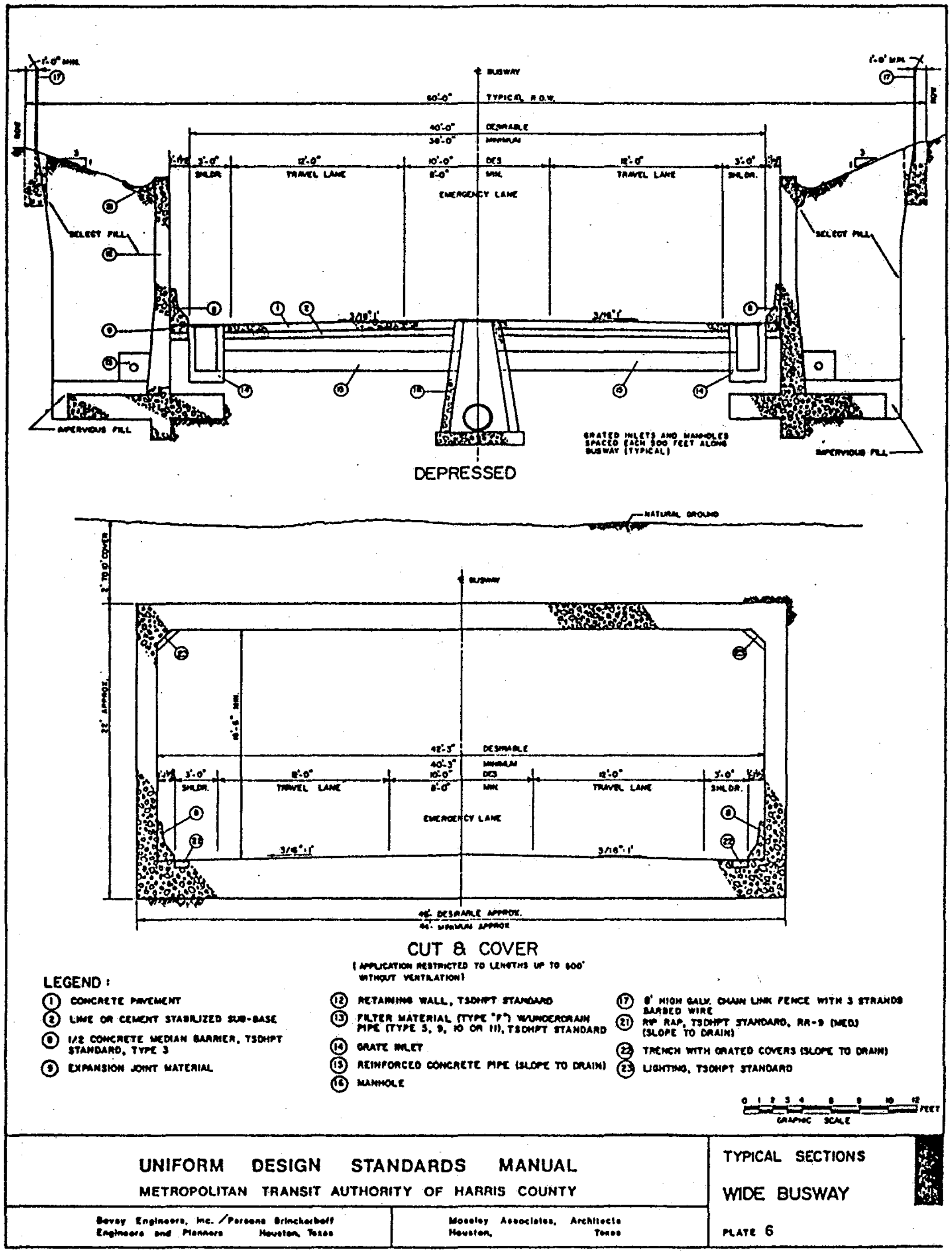

DEPRESSED
CUT & COVER
(APPLICATION RESTRICTED TO LENGTHS UP TO 600' WITHOUT VENTILATION)
LEGEND:
1 CONCRETE PAVEMENT
2 LIME OR CEMENT STABILIZED SUB-BASE
8 1/2 CONCRETE MEDIAN BARRIER, TSDHPT STANDARD, TYPE 3
9 EXPANSION JOINT MATERIAL
12 RETAINING WALL, TSDHPT STANDARD
13 FILTER MATERIAL (TYPE "F") W/UNDERDRAIN PIPE (TYPE 5, 9, 10 OR 11), TSDHPT STANDARD
14 GRATE INLET
15 REINFORCED CONCRETE PIPE (SLOPE TO DRAIN)
16 MANHOLE
17 8' HIGH GALV. CHAIN LINK FENCE WITH 3 STRANDS BARBED WIRE
21 RIP RAP, TSDHPT STANDARD, RR-9 (MED) (SLOPE TO DRAIN)
22 TRENCH WITH GRATED COVERS (SLOPE TO DRAIN)
23 LIGHTING, TSDHPT STANDARD
GRAPHIC SCALE
FEET
UNIFORM DESIGN STANDARDS MANUAL
METROPOLITAN TRANSIT AUTHORITY OF HARRIS COUNTY
TYPICAL SECTIONS
WIDE BUSWAY
PLATE 6

Figure 3-29

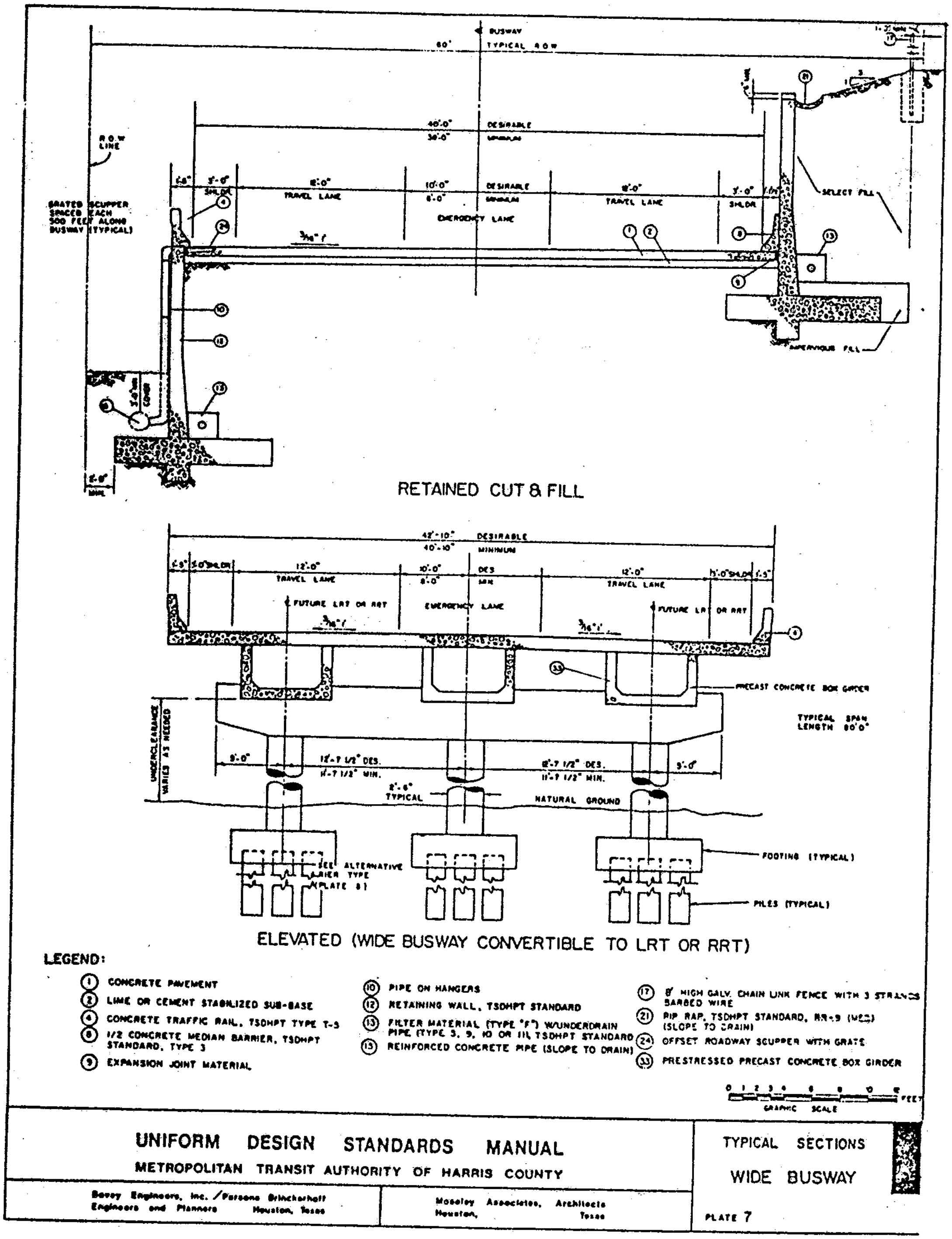
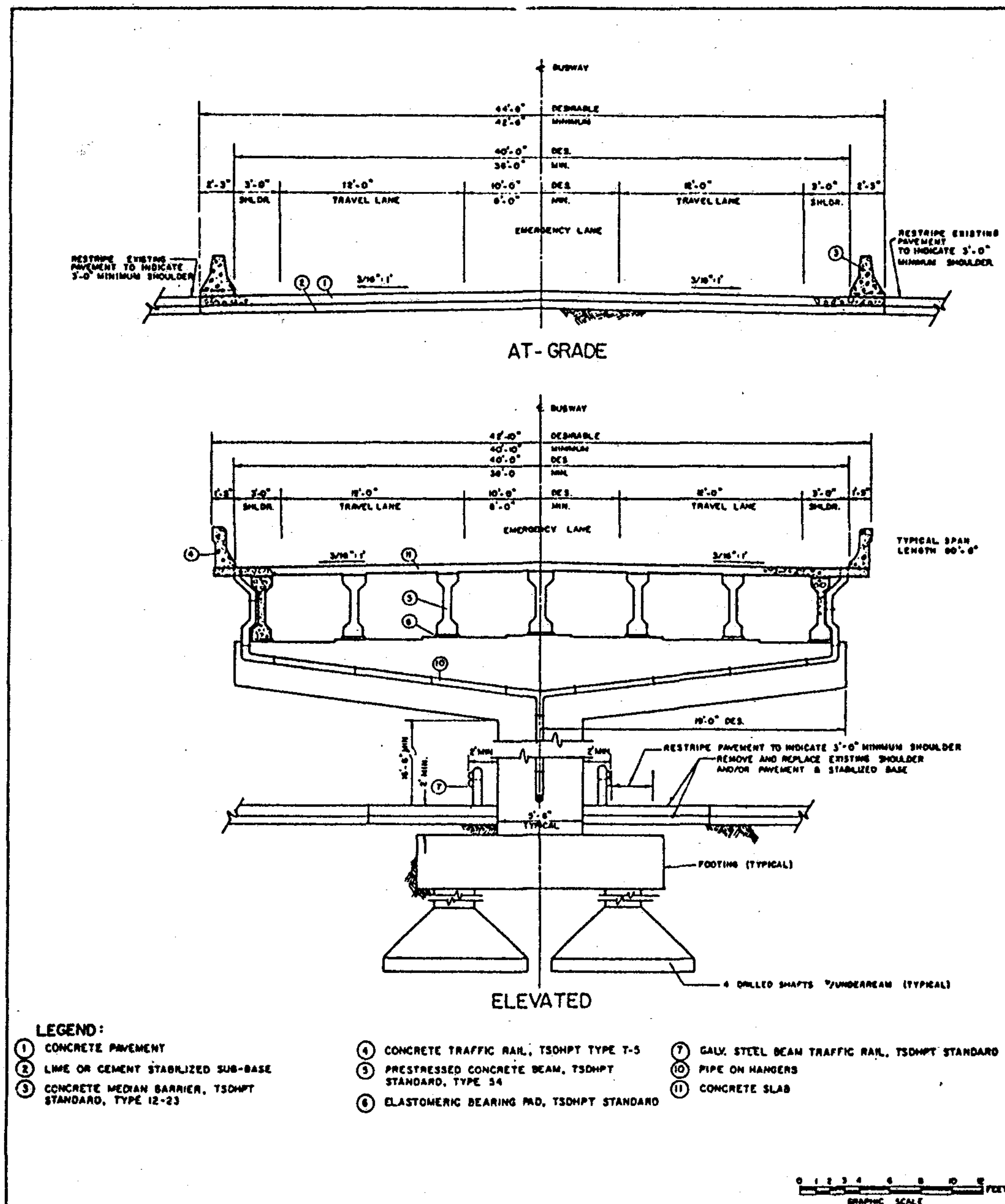

RETAINED CUT & FILL
SELECT FILL
PRECAST CONCRETE BOX GIRDER
NATURAL GROUND
FOOTING (TYPICAL)
PILES (TYPICAL)
ELEVATED (WIDE BUSWAY CONVERTIBLE TO LRT OR RRT)
LEGEND:
1 CONCRETE PAVEMENT
2 LIME OR CEMENT STABILIZED SUB-BASE
4 CONCRETE TRAFFIC RAIL, TSDHPT TYPE T-5
8 1/2 CONCRETE MEDIAN BARRIER, TSDHPT STANDARD, TYPE 3
9 EXPANSION JOINT MATERIAL
10 PIPE ON HANGERS
12 RETAINING WALL, TSDHPT STANDARD
13 FILTER MATERIAL (TYPE "F") W/UNDERDRAIN PIPE (TYPE 5, 9, 10 OR 11), TSDHPT STANDARD
15 REINFORCED CONCRETE PIPE (SLOPE TO DRAIN)
17 8' HIGH GALV. CHAIN LINK FENCE WITH 3 STRANDS BARBED WIRE
21 RIP RAP, TSDHPT STANDARD, RR-9 (MOD) (SLOPE TO DRAIN)
24 OFFSET ROADWAY SCUPPER WITH GRATE
33 PRESTRESSED PRECAST CONCRETE BOX GIRDER
GRAPHIC SCALE
UNIFORM DESIGN STANDARDS MANUAL
METROPOLITAN TRANSIT AUTHORITY OF HARRIS COUNTY
TYPICAL SECTIONS
WIDE BUSWAY
PLATE 7

Figure 3-30



UNIFORM DESIGN STANDARDS MANUAL METROPOLITAN TRANSIT AUTHORITY OF HARRIS COUNTY		TYPICAL SECTIONS WIDE BUSWAY IN FREEWAY MEDIAN PLATE 8
Bovay Engineers, Inc. /Parsons Brinckerhoff Engineers and Planners Houston, Texas	Moseley Associates, Architects Houston, Texas	

Figure 3-31

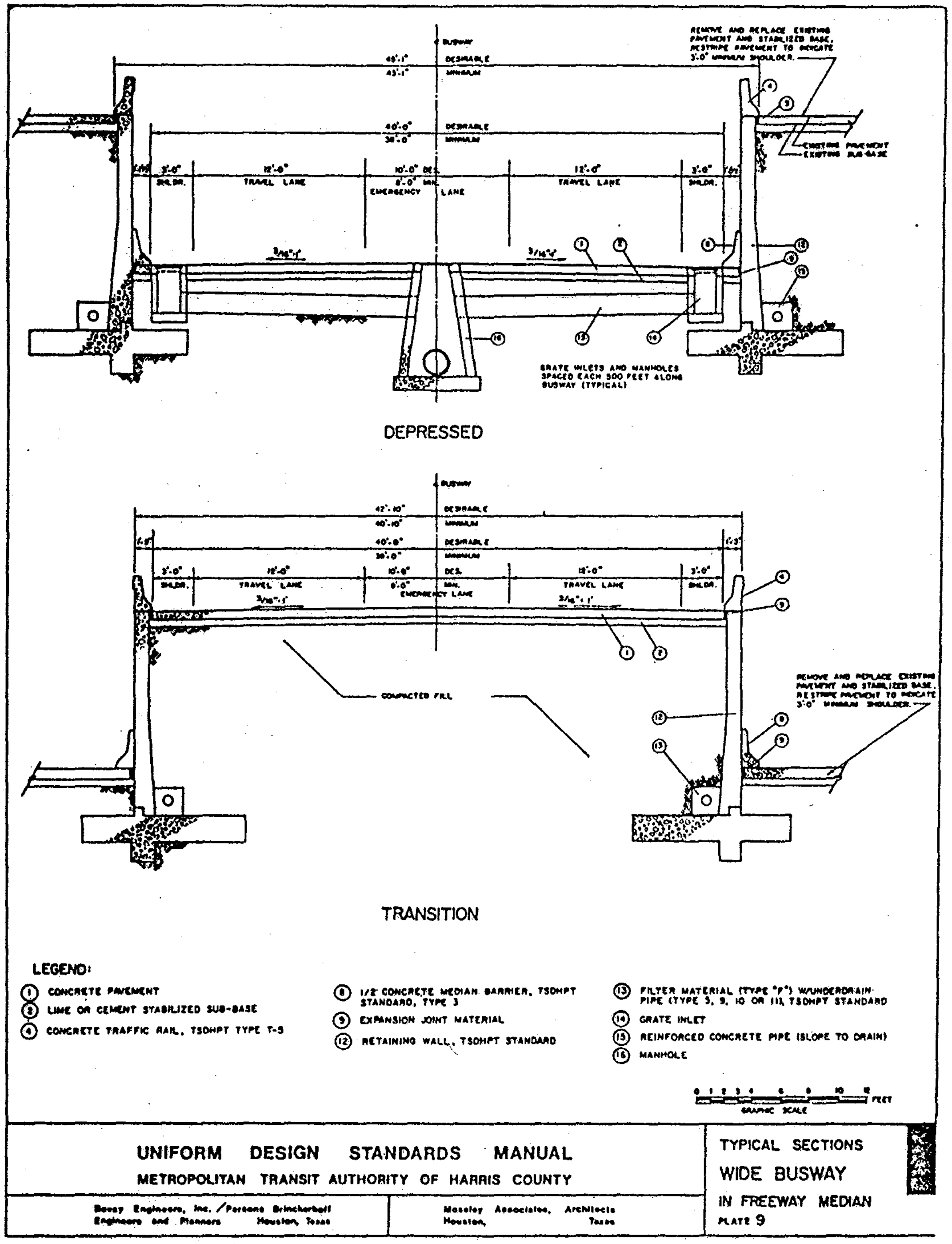

DEPRESSED
TRANSITION
LEGEND:
1 CONCRETE PAVEMENT
2 LIME OR CEMENT STABILIZED SUB-BASE
4 CONCRETE TRAFFIC RAIL, TSDHPT TYPE T-5
8 1/2 CONCRETE MEDIAN BARRIER, TSDHPT STANDARD, TYPE 3
9 EXPANSION JOINT MATERIAL
12 RETAINING WALL, TSDHPT STANDARD
13 FILTER MATERIAL (TYPE "F") W/UNDERDRAIN PIPE (TYPE 5, 9, 10 OR 11), TSDHPT STANDARD
14 GRATE INLET
15 REINFORCED CONCRETE PIPE (SLOPE TO DRAIN)
16 MANHOLE
GRAPHIC SCALE
FEET
UNIFORM DESIGN STANDARDS MANUAL
METROPOLITAN TRANSIT AUTHORITY OF HARRIS COUNTY
TYPICAL SECTIONS
WIDE BUSWAY
IN FREEWAY MEDIAN
PLATE 9

Figure 3-32

(e) Retained Cut/Fill (Figure 3-30)
(f) Elevated-Convertible to Rail (Figure 3-30)
(g) At-Grade in Freeway (Figure 3-31)
(h) Elevated in Freeway (Figure 3-31)
(i) Depressed in Freeway (Figure 3-32)
(j) Transition in Freeway (Figure 3-32)

Wide Busway With Carpools

As used by the MTA, a wide busway with carpools is a two-lane, two-direction roadway, designed for use by the same public transportation buses and emergency vehicles as in the case of the exclusive wide busway, but with additional use by other high occupancy vehicles - "carpools" in the terminology of the MTA. The addition of carpools to the users of the busway profoundly changes the wide busway design for considerations of safety. The wide busway with carpools may be sited in a freeway median or developed on an independent MTA right-of-way.

Figures 3-33 through 3-37 depict nine typical sections of the wide busway with carpools in various conditions of siting, as follows:

(a) At-Grade (Figure 3-33)
(b) Elevated (Figure 3-33)
(c) Depressed (Figure 3-34)
(d) Cut-and-Cover (Subway) (Figure 3-34)
(e) Retained Cut/Fill (Figure 3-35)
(f) At-Grade in Freeway (Figure 3-36)
(g) Elevated in Freeway (Figure 3-36)
(h) Depressed in Freeway (Figure 3-37)
(i) Transition in Freeway (Figure 3-37)

3.6.1.6 Busway Intersections and Junctions

Through the route location and preliminary engineering phases, many different needs for busway intersections, junctions, access ramps, and terminations may occur. Each of these special design situations will have its own geometric and functional requirements and restrictions. Figures 3-38 and 3-39 present a few schematic layouts for the treatment of several types of busway special features. For the design of each, or any others, the use of this Manual will need to relate the projected traffic flows along each path

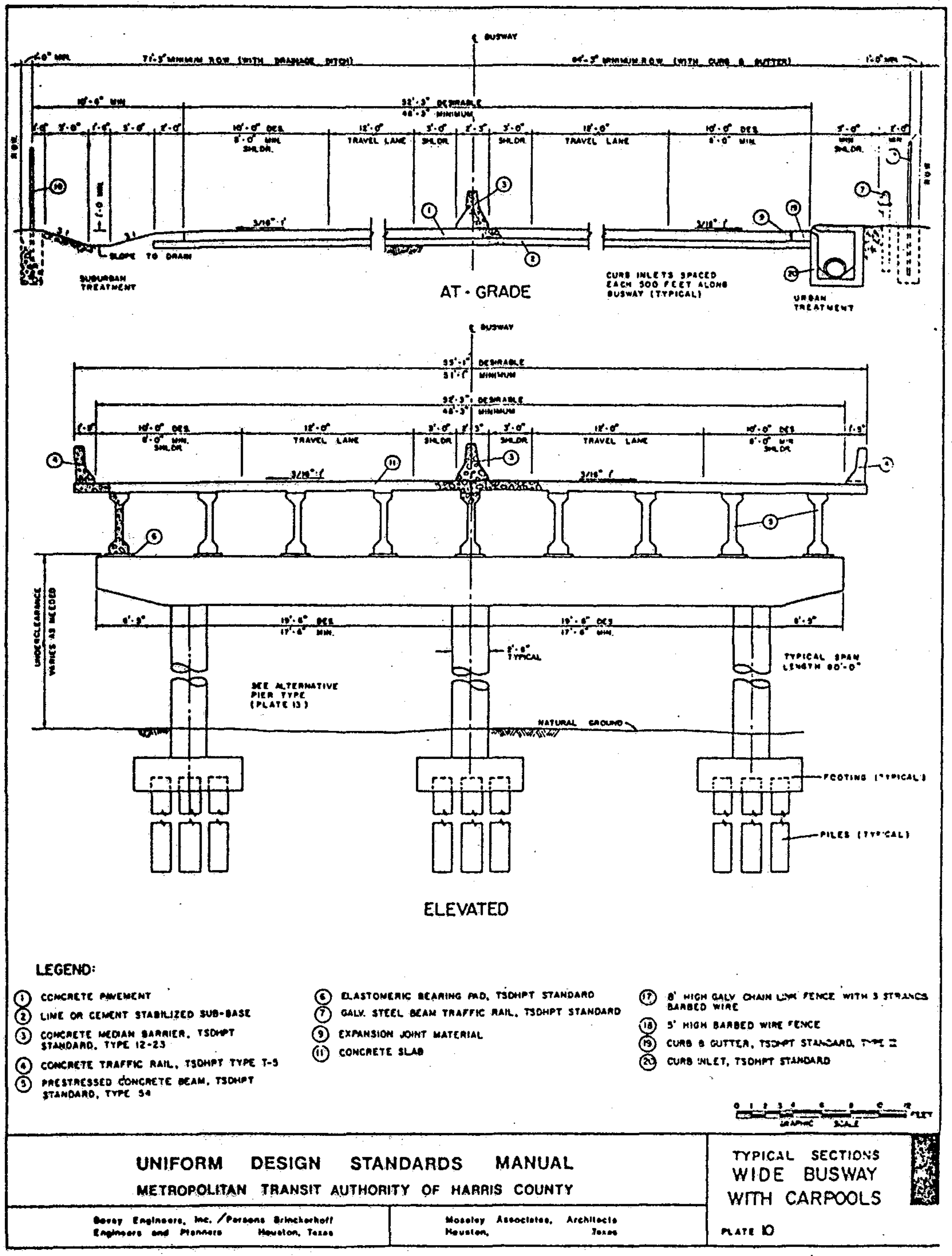

AT - GRADE
ELEVATED
LEGEND:
1 CONCRETE PAVEMENT
2 LIME OR CEMENT STABILIZED SUB-BASE
3 CONCRETE MEDIAN BARRIER, TSDHPT STANDARD, TYPE 12-23
4 CONCRETE TRAFFIC RAIL, TSDHPT TYPE T-5
5 PRESTRESSED CONCRETE BEAM, TSDHPT STANDARD, TYPE 54
6 ELASTOMERIC BEARING PAD, TSDHPT STANDARD
7 GALV. STEEL BEAM TRAFFIC RAIL, TSDHPT STANDARD
9 EXPANSION JOINT MATERIAL
11 CONCRETE SLAB
17 8' HIGH GALV CHAIN LINK FENCE WITH 3 STRANDS BARBED WIRE
18 5' HIGH BARBED WIRE FENCE
19 CURB & GUTTER, TSDHPT STANDARD
20 CURB INLET, TSDHPT STANDARD
UNIFORM DESIGN STANDARDS MANUAL
METROPOLITAN TRANSIT AUTHORITY OF HARRIS COUNTY
TYPICAL SECTIONS
WIDE BUSWAY
WITH CARPOOLS
PLATE 10

Figure 3-33

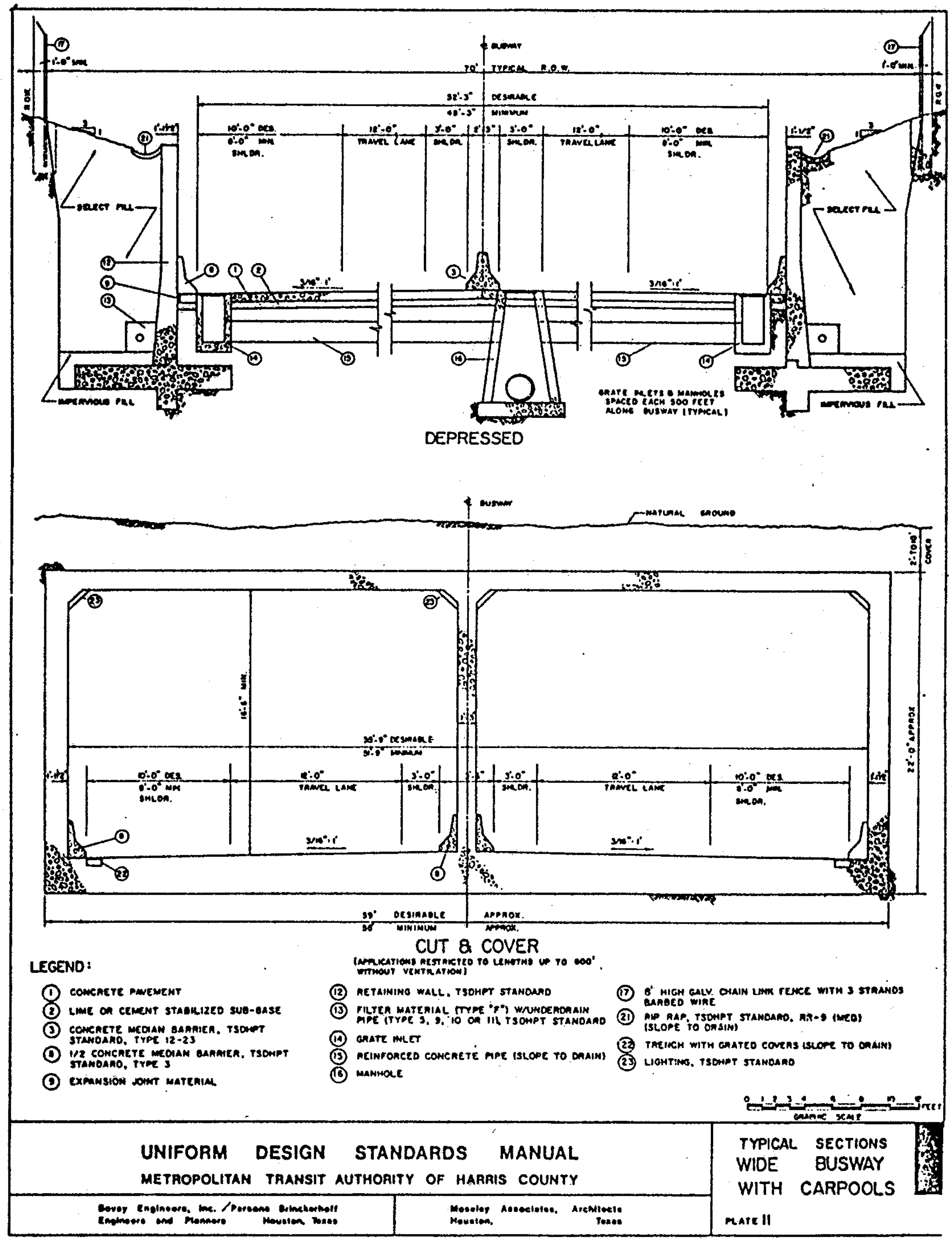
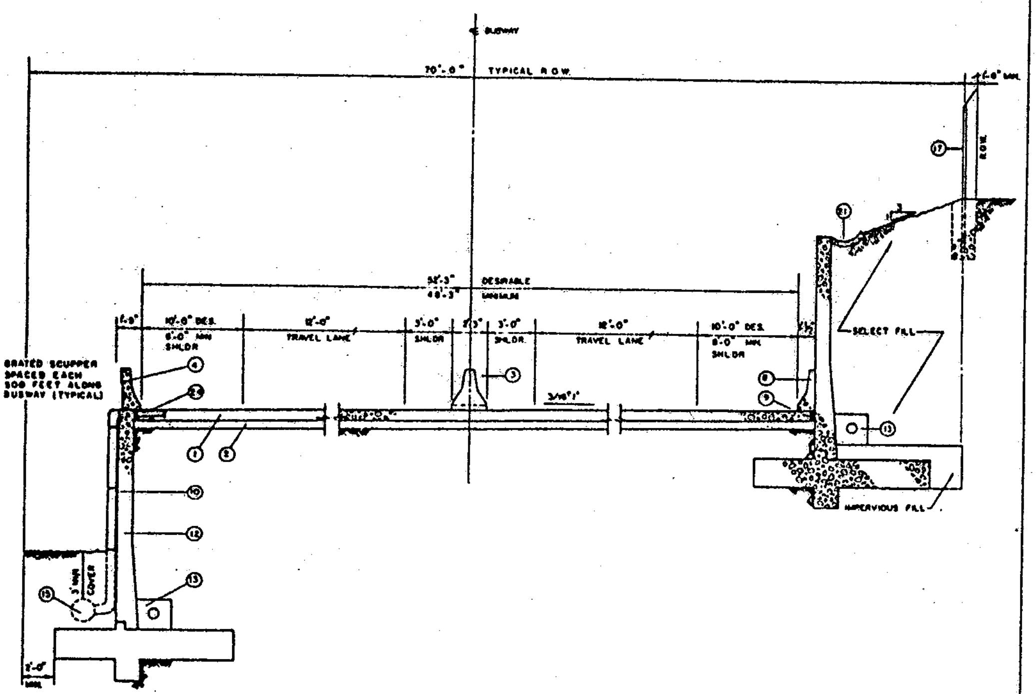

DEPRESSED
SELECT FILL
IMPERVIOUS FILL
GRATE INLETS & MANHOLES SPACED EACH 500 FEET ALONG BUSWAY (TYPICAL)
NATURAL GROUND
CUT & COVER
(APPLICATIONS RESTRICTED TO LENGTHS UP TO 800' WITHOUT VENTILATION)
LEGEND:
1 CONCRETE PAVEMENT
2 LIME OR CEMENT STABILIZED SUB-BASE
3 CONCRETE MEDIAN BARRIER, TSDHPT STANDARD, TYPE 12-23
8 1/2 CONCRETE MEDIAN BARRIER, TSDHPT STANDARD, TYPE 3
9 EXPANSION JOINT MATERIAL
12 RETAINING WALL, TSDHPT STANDARD
13 FILTER MATERIAL (TYPE "F") W/UNDERDRAIN PIPE (TYPE 5, 9, 10 OR 11) TSDHPT STANDARD
14 GRATE INLET
15 REINFORCED CONCRETE PIPE (SLOPE TO DRAIN)
16 MANHOLE
17 6' HIGH GALV. CHAIN LINK FENCE WITH 3 STRANDS BARBED WIRE
21 RIP RAP, TSDHPT STANDARD, RR-9 (MOD) (SLOPE TO DRAIN)
22 TRENCH WITH GRATED COVERS (SLOPE TO DRAIN)
23 LIGHTING, TSDHPT STANDARD
UNIFORM DESIGN STANDARDS MANUAL
METROPOLITAN TRANSIT AUTHORITY OF HARRIS COUNTY
TYPICAL SECTIONS WIDE BUSWAY WITH CARPOOLS
PLATE II

Figure 3-34



RETAINED CUT & FILL

LEGEND :

- (1) CONCRETE PAVEMENT
- (2) LIME OR CEMENT STABILIZED SUB-BASE
- (3) CONCRETE MEDIAN BARRIER, TSDHPT STANDARD, TYPE 12-23
- (4) CONCRETE TRAFFIC RAIL, TSDHPT TYPE T-5
- (8) 1/2 CONCRETE MEDIAN BARRIER, TSDHPT STANDARD, TYPE 3
- (9) EXPANSION JOINT MATERIAL
- (10) PIPE ON HANGERS
- (12) RETAINING WALL, TSDHPT STANDARD
- (13) FILTER MATERIAL (TYPE "F") W/UNDERDRAIN PIPE (TYPE 5, 9, 10 OR 11), TSDHPT STANDARD
- (15) REINFORCED CONCRETE PIPE (SLOPE TO DRAIN)
- (17) 8' HIGH GALV. CHAIN LINK FENCE WITH 3 STRANDS BARBED WIRE
- (21) RIP RAP, TSDHPT STANDARD, RR-9 (MED.) (SLOPE TO DRAIN)
- (24) OFFSET ROADWAY SCUPPER WITH GRATE

0 1 2 3 4 6 8 10 12 FEET
GRAPHIC SCALE

UNIFORM DESIGN STANDARDS MANUAL METROPOLITAN TRANSIT AUTHORITY OF HARRIS COUNTY		TYPICAL SECTIONS WIDE BUSWAY WITH CARPOOLS
Bovay Engineers, Inc. / Parsons Brinckerhoff Engineers and Planners Houston, Texas	Moseley Associates, Architects Houston, Texas	PLATE 12

Figure 3-35

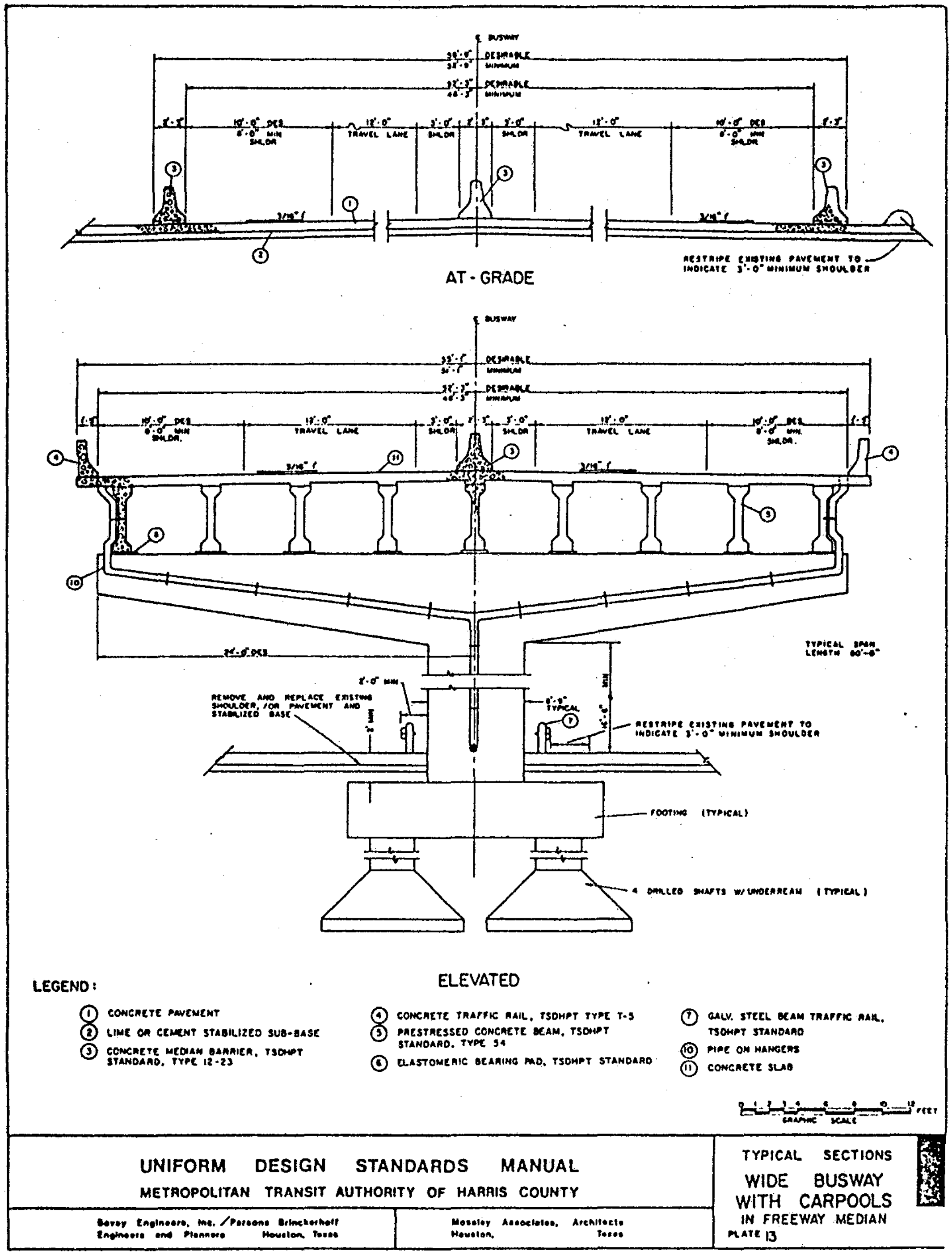

AT - GRADE
ELEVATED
LEGEND:
1 CONCRETE PAVEMENT
2 LIME OR CEMENT STABILIZED SUB-BASE
3 CONCRETE MEDIAN BARRIER, TSDHPT STANDARD, TYPE 12-23
4 CONCRETE TRAFFIC RAIL, TSDHPT TYPE T-5
5 PRESTRESSED CONCRETE BEAM, TSDHPT STANDARD, TYPE 54
6 ELASTOMERIC BEARING PAD, TSDHPT STANDARD
7 GALV. STEEL BEAM TRAFFIC RAIL, TSDHPT STANDARD
10 PIPE ON HANGERS
11 CONCRETE SLAB
FOOTING (TYPICAL)
4 DRILLED SHAFTS W/ UNDERREAM (TYPICAL)
RESTRIPE EXISTING PAVEMENT TO INDICATE 3'-0" MINIMUM SHOULDER
UNIFORM DESIGN STANDARDS MANUAL
METROPOLITAN TRANSIT AUTHORITY OF HARRIS COUNTY
TYPICAL SECTIONS
WIDE BUSWAY WITH CARPOOLS IN FREEWAY MEDIAN
PLATE 13

Figure 3-36

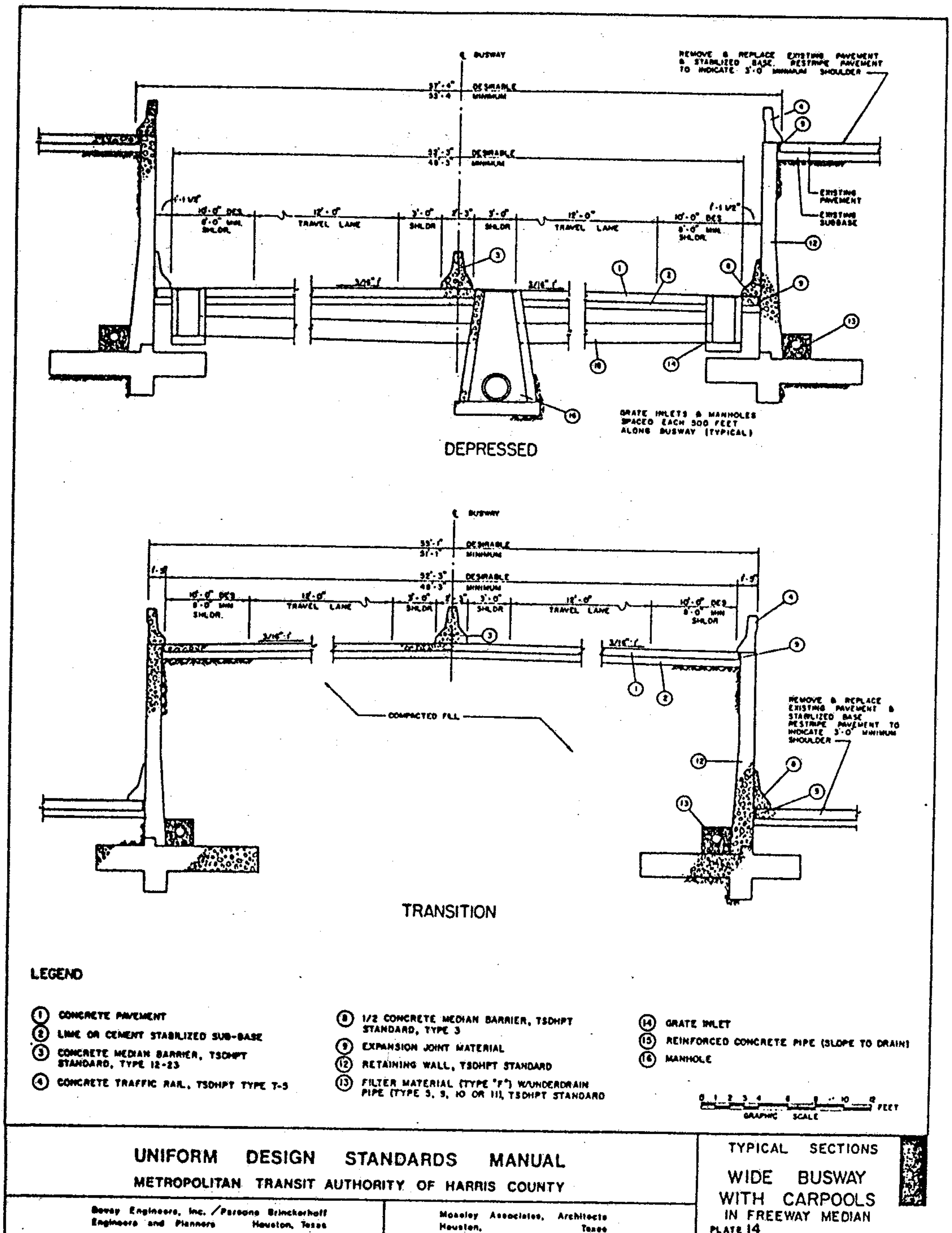
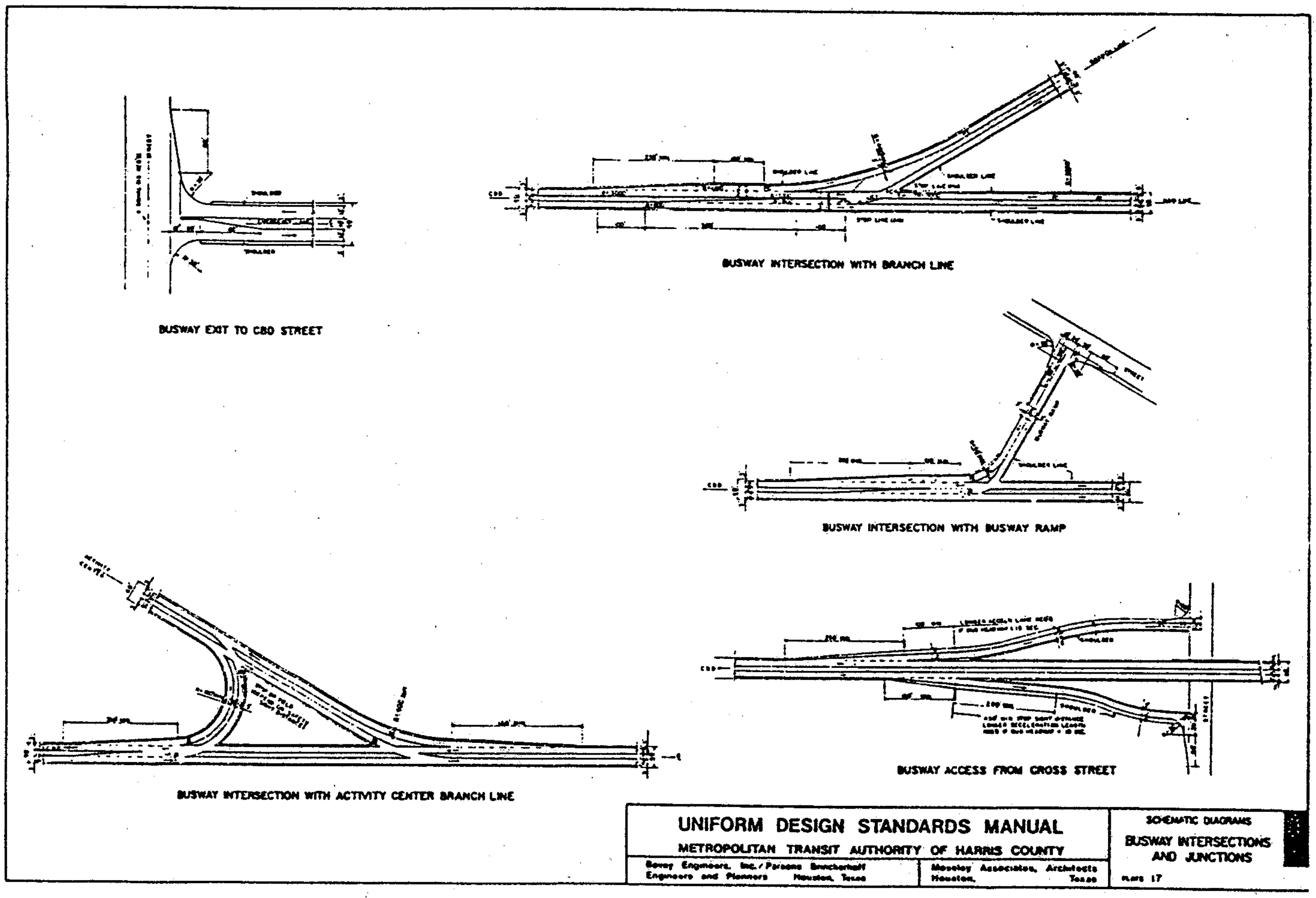

DEPRESSED
TRANSITION
COMPACTED FILL
LEGEND
1 CONCRETE PAVEMENT
2 LIME OR CEMENT STABILIZED SUB-BASE
3 CONCRETE MEDIAN BARRIER, TSDHPT STANDARD, TYPE 12-23
4 CONCRETE TRAFFIC RAIL, TSDHPT TYPE T-5
8 1/2 CONCRETE MEDIAN BARRIER, TSDHPT STANDARD, TYPE 3
9 EXPANSION JOINT MATERIAL
12 RETAINING WALL, TSDHPT STANDARD
13 FILTER MATERIAL (TYPE "F") W/UNDERDRAIN PIPE (TYPE 5, 9, 10 OR 11), TSDHPT STANDARD
14 GRATE INLET
15 REINFORCED CONCRETE PIPE (SLOPE TO DRAIN)
16 MANHOLE
GRAPHIC SCALE
FEET
UNIFORM DESIGN STANDARDS MANUAL
METROPOLITAN TRANSIT AUTHORITY OF HARRIS COUNTY
TYPICAL SECTIONS
WIDE BUSWAY WITH CARPOOLS
IN FREEWAY MEDIAN
PLATE 14

Figure 3-37



BUSWAY EXIT TO CBD STREET
BUSWAY INTERSECTION WITH BRANCH LINE
BUSWAY INTERSECTION WITH BUSWAY RAMP
BUSWAY INTERSECTION WITH ACTIVITY CENTER BRANCH LINE
BUSWAY ACCESS FROM CROSS STREET
UNIFORM DESIGN STANDARDS MANUAL
METROPOLITAN TRANSIT AUTHORITY OF HARRIS COUNTY
Bovay Engineers, Inc./Parsons Brinckerhoff Engineers and Planners Houston, Texas
Moseley Associates, Architects Houston, Texas
SCHEMATIC DIAGRAMS
BUSWAY INTERSECTIONS AND JUNCTIONS
PLATE 17

Figure 3-38

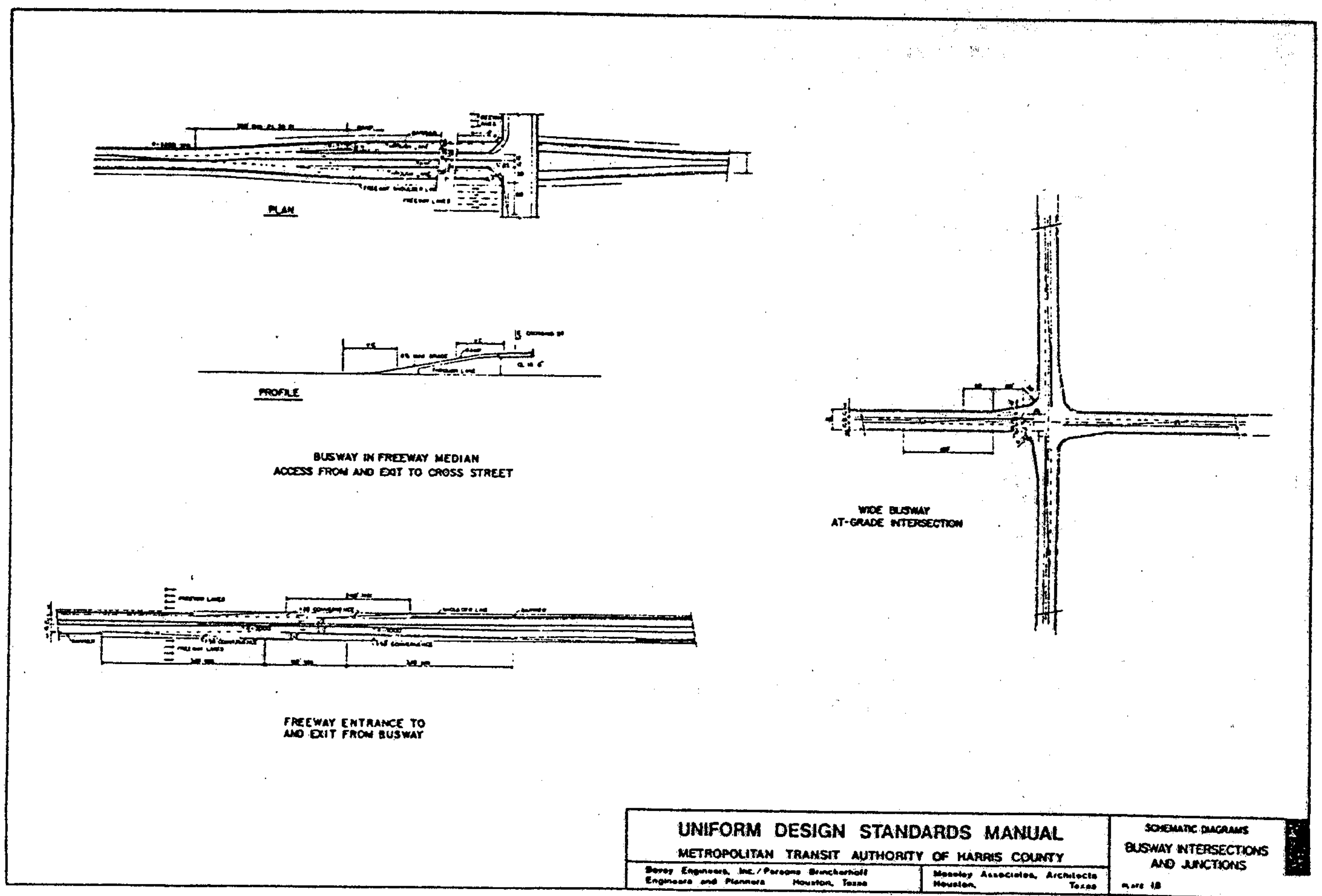

PLAN
PROFILE
BUSWAY IN FREEWAY MEDIAN
ACCESS FROM AND EXIT TO CROSS STREET
WIDE BUSWAY
AT-GRADE INTERSECTION
FREEWAY ENTRANCE TO
AND EXIT FROM BUSWAY
UNIFORM DESIGN STANDARDS MANUAL
METROPOLITAN TRANSIT AUTHORITY OF HARRIS COUNTY
SCHEMATIC DIAGRAMS
BUSWAY INTERSECTIONS
AND JUNCTIONS

Figure 3-39

and the speeds which should be provided for. Reference to published geometric design criteria such as the policy handbooks of AASHTO should be consulted for design guidance.

The schematic drawings on Figures 3-38 and 3-39 are based on a wide busway as the main line basis of design. Where the narrow busway or the wide busway with carpools is the adopted mainline, appropriate variations in these layouts for the functional differences must be made.

3.6.2 Source [8]: Texas State Dept. of Highways and Public Transportation. Highway Design Division Operations and Procedures Manual June 1981.

3.6.2.1 General

Buses operate rapidly and efficiently on uncongested urban freeways. Many freeways, particularly radial routes leading to downtown areas, become routinely congested during peak hours, delaying buses as well, as other freeway users. To improve bus travel, several general techniques may be considered, including busways on separate rights-of-way, busways on freeway rights-of-way, ramp metering and special bus ramps.

Busways on Separate Rights-of-Way

Exclusive busways on their own rights-of-way with complete access control provide the highest type of service. Abandonded or little used railroad rights-of-ways are potential locations for these exclusive busways.

Busways on Freeway-Rights-of-Way: Use of Median Area

Lengthy, flush medians may provide space for exclusive bus lanes on freeways. Most existing freeways with flush medians are deficient in width, or include only a few miles of length with adequate median characteristics. These areas may be used, however, for short exclusive bus lanes to give buses priority treatment through bottleneck areas. In the design of new urban freeways, it may be desirable to reserve a portion the median area for exclusive use by buses or other transit modes. Thirty to fifty feet of width should normally be provided with wider areas at pickup and discharge points.

Reserved Freeway Lanes, Normal Flow

Reservation of a freeway lane in the peak direction for exclusive use by buses (and possibly carpools) generally is not given serious consideration. There are weaving problems associated with this type of operation, regardless of which lane is selected for estricted use, and enforcement is difficult.

Reserved Freeway Lanes, Contraflow

Application of the contraflow concept has greater possibilities on existing freeways. Candidate sites should have a minimum of six freeway main lanes, and the contraflow lane should have a logical beginning and ending point. Left-hand ramps or connections introduce traffic conflicts with the contraflow lane. However, when located at the beginning or ending point of the contraflow lane, conversion of left-hand ramps to two-way operation may be a convenient way to initiate or terminate the contraflow lane. Directional split of traffic should be considered. Volume on the remaining off-peak direction traffic lanes should not exceed 1500 vehicles per hour per lane to insure that congestion will not be caused in the off-peak direction. Also, traffic in the peak direction should be near capacity (congested), say over 1800 vehicles per hour per lane, so that the advantages in using transit are evident. Special markings, cones, and overhead signals are required for contraflow operation.

3.6.2.2 General Design Criteria

Table 3-6 summarizes general busway design criteria and Figure 3-40 presents typical busway sections. Basically, these design criteria reflect standards of high-type freeway design. The typical sections shown represent two-lane facilities ranging from narrow (28 feet, no shoulders) to wide (44 feet, full shoulders). No single lane, reversible designs as presently under construction in Houston, Texas are given.

Designation is also made between carpool and professional drivers. However, the HOV user authorization procedure currently being utilized in Houston requires special driver training for all individuals on the facility. Therefore, this categorization may not necessarily apply to justify a difference in design criteria.

3.6.3 Source [9]: Long-Range Metro Transit Plan for Houston/Harris County Advisory Committee, 1984.

3.6.3.1 General

A multiagency task force was formed to assist Metro in formulating a long-range transit plan for the Houston area. Houston is already constructing and desgning transitways and the long-range plan will call for additional transitway construction.

As a result, in formulating Metro's plan, considerable attention was given to transitways. The combined expertise of the group was used to develop design standards for us in cost estimation and comparison of alternatives.

Table 3-6. Summary of Busway Geometric Design Standards

Traveled Way:	Desirable	Minimum
Design Speed (mph)	50-70	30-50
Lane Widths (ft.)[a]	13	12
Shoulder Widths (ft.)		
a. Carpool Users	8-10	6-8
b. Professional Drivers Only	8-10	2-4
Total Pavement Width (ft.)b	44	28[3]
Vertical Clearance (ft.)	14.5	12.5
Maximum Gradients (%)	3	6
Lateral Distance to Fixed Obstruction (ft.)[d]		
Left	3.5	2
Right	6	3

Pavement cross slope, vertical curvature, horizontal curvature, and superelevation should conform to Departmental highway design practice.

Busway Ramps:		
Design Speed (mph)	30-35	15-25
Lane Width (ft.)		
With paved shoulders	12	12
Without paved shoulders	14	13
Paved shoulder width (ft.)	8	8
Total paved width (ft.)	14-20	13-20

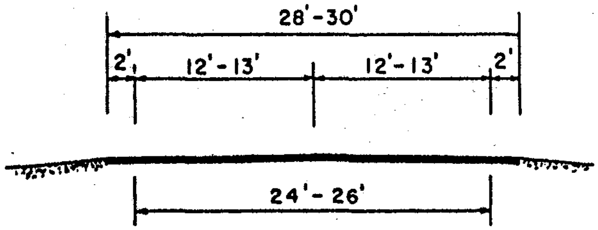
[a]Increase lane widths one (1) foot when longitudinal barriers are used adjacent to busway travel lane.

[b]Total pavement width between stations. At stations, single parallel platforms should be at least 6 feet and preferably 10 feet or more in width.

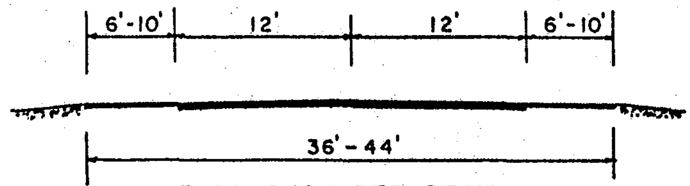
[c]Elevated sections also 28 feet in width; tunnel widths minimally 31 feet.

[d]Distance from edge of busway travel lane to face of noncontinuous obstruction such as a bridge pier.

Source: [8]

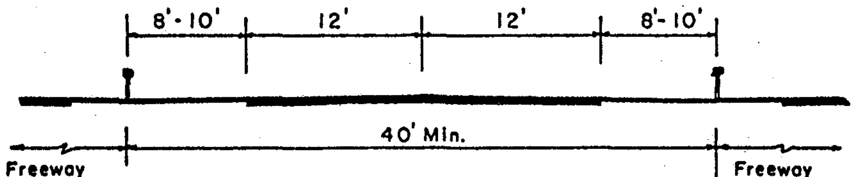


MINIMUM DESIGN

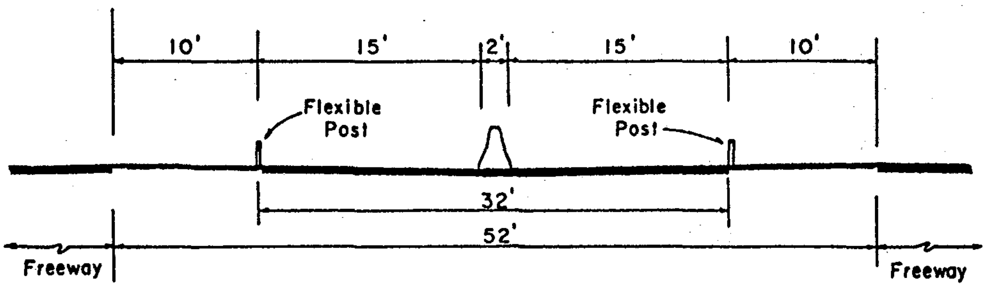


FULL SHOULDER DESIGN

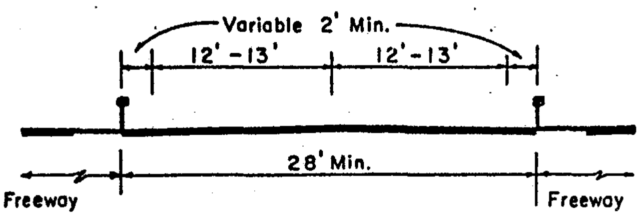
EXCLUSIVE BUSWAY ON SEPARATE RIGHT-OF-WAY



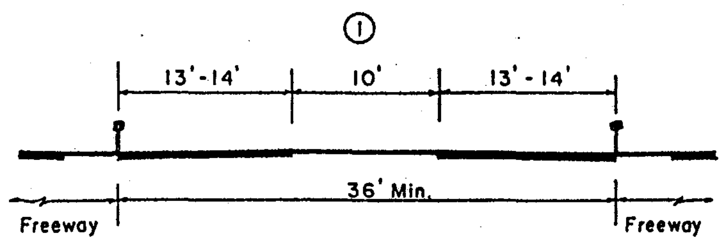
FULL OUTSIDE SHOULDER DESIGN



COMMON FREEWAY-BUSWAY SHOULDER



MINIMUM OUTSIDE SHOULDER DESIGN



FULL INTERIOR SHOULDER DESIGN

BUSWAYS IN FREEWAY MEDIANS

(1) May operate as normal or contra flow, interior lane for breakdown or passing

Figure 3-40

Included in the task force were the following individuals.

- Paul Bay, Assistant General Manager, Metro
- Bill Ward, Engineer-Manager, Houston Urban Office, State Department of Highways and Public Transportation.
- Omer Poorman, District Engineer, District 12, State Department of Highways and Public Transportation
- Dick Conley, Director of Traffic and Transportation, City of Houston
- Mike Weaver, Transportation Manager, Houston-Galveston Area Council
- Richy Rivera, Engineer, Harris County

3.6.3.2 Design Cross Sections

Figures 3-41 to 4-44 represent proposed desirable design cross-sections for both one lane, reversible, and two lane two way transitways placed either at grade or in an aerial configuration.

3.7 VIRGINIA GUIDELINES

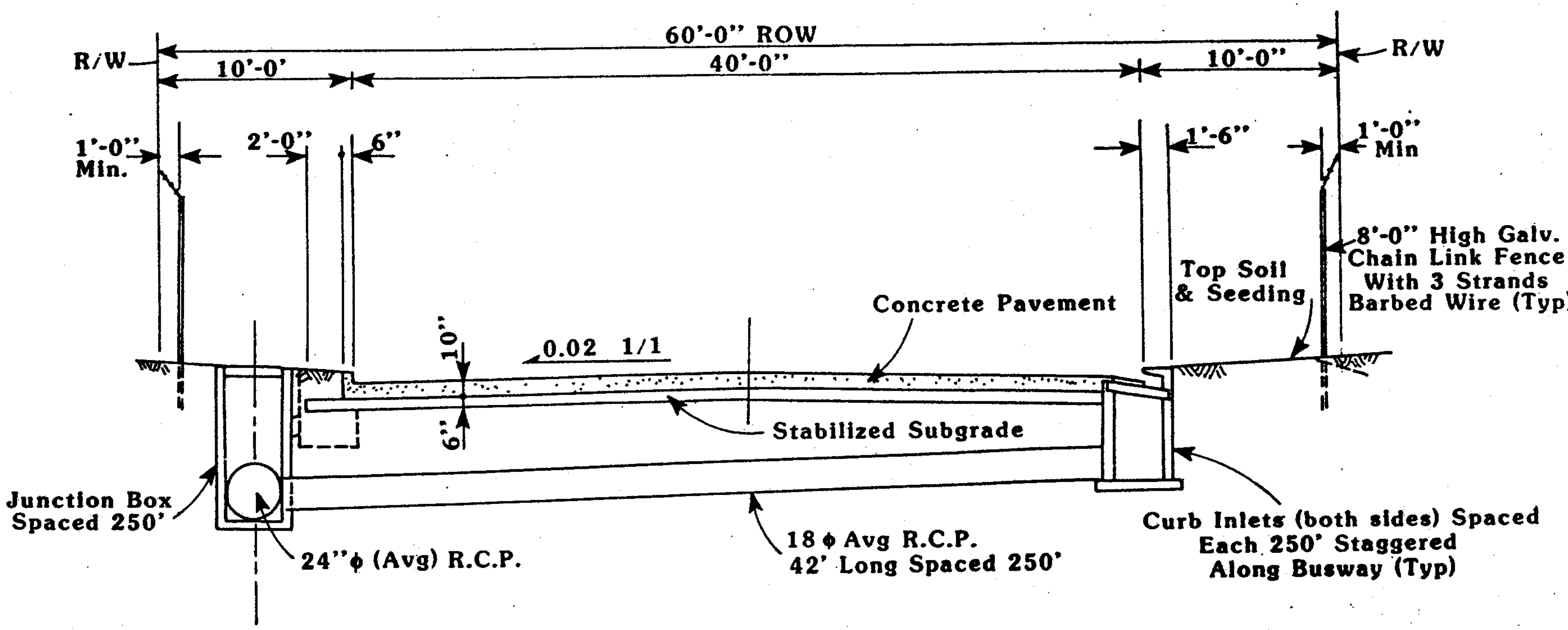
3.7.1 Source [10]: JHK and Associates. Extending the Shirley Highway HOV Lanes, A Planning and Feasibility Study. March 1982.

3.7.1.1 Background

With the volume on the Shirley Highway beginning to approach the capacity of the existing six lane cross section, the Virginia Department of Highways and Transportation (VDH&T) is considering increasing the capacity of the Shirley Corridor south of Springfield by extending the existing HOV lanes. This proposal would extend the HOV lanes 19 miles. The complete 30 mile HOV facility would be the longest facility in the world.

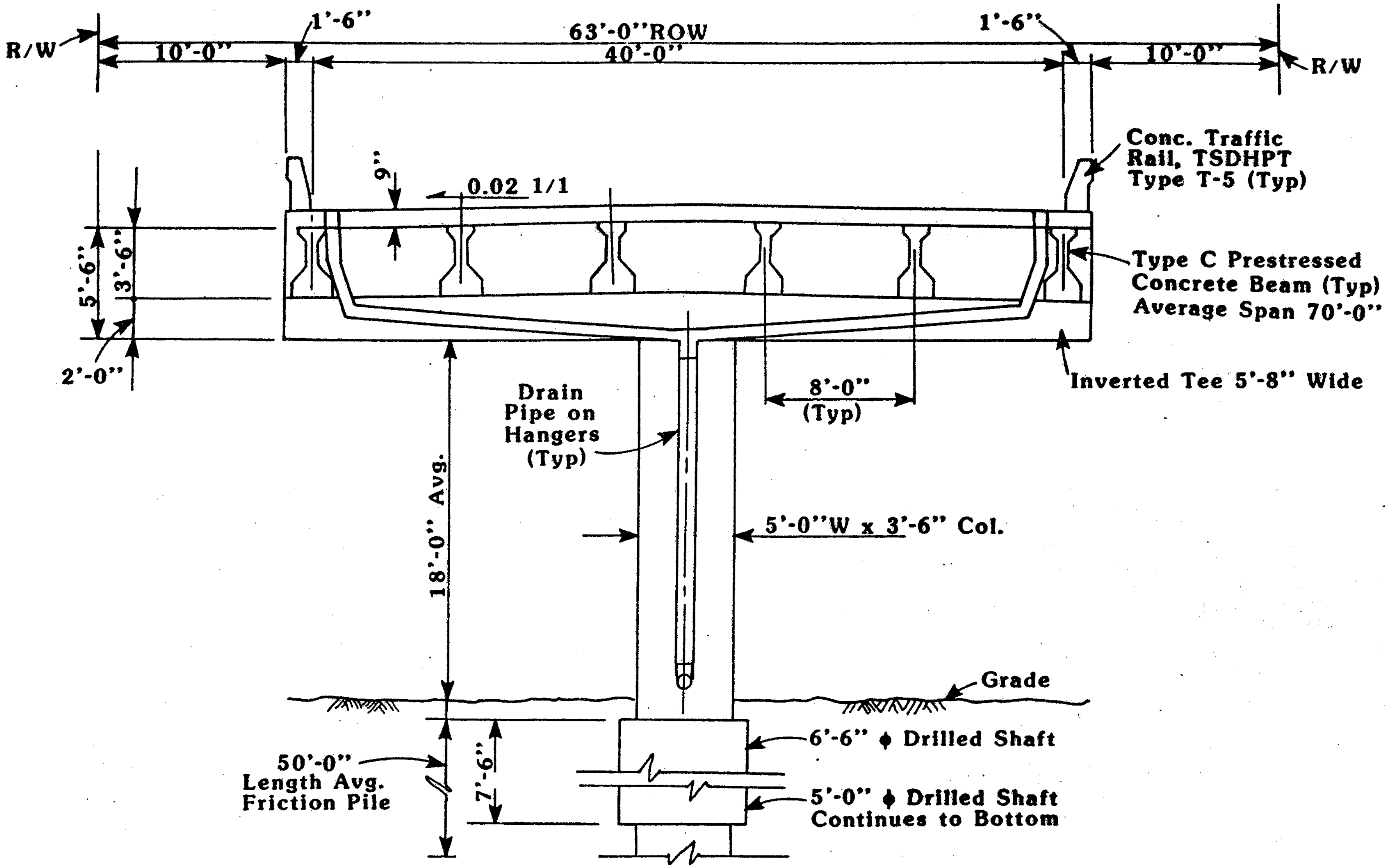
3.7.1.2 Typical Sections

Figures 3-45 through 3-49 shown typical sections for the proposed facility. As shown, the proposed project would extend the dual HOV lanes encompassed in a total width cross-section of 36 feet (2-12 foot mainlanes, 1-12 foot shoulder). Also shown are schematic details for slip ramp connections



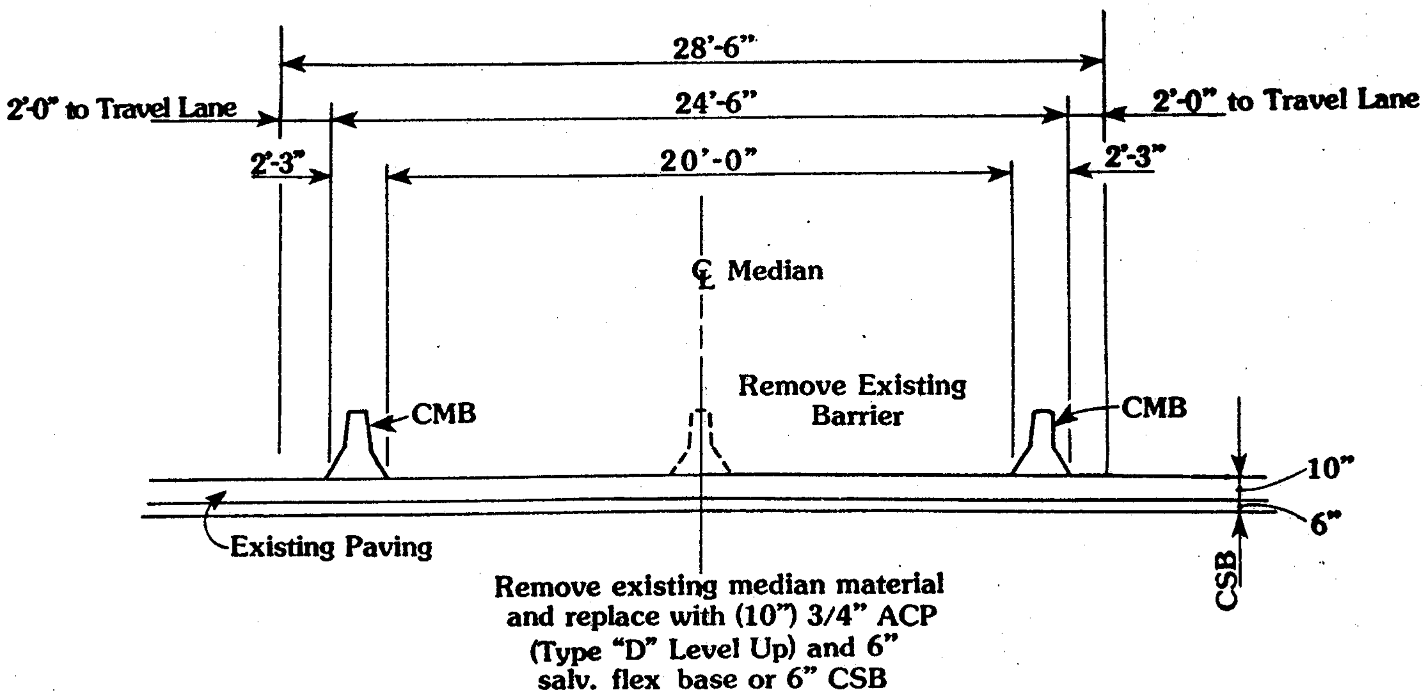
BUSWAY IN METRO R/W TWO-LANE (AT GRADE)

Figure 3-41



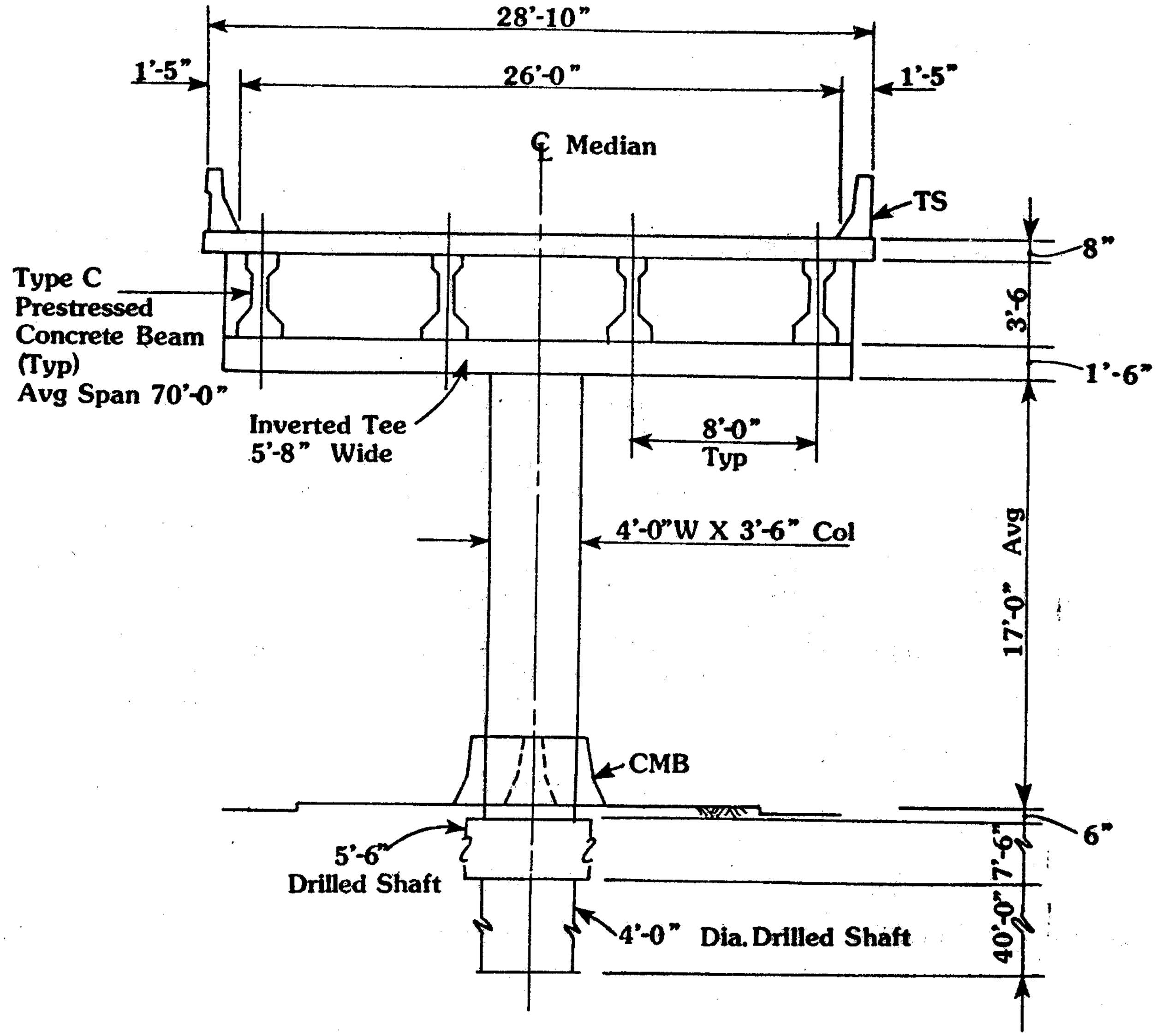
BUSWAY IN METRO R/W TWO-WAY TWO LANE (AERIAL)

Figure 3-42



BUSWAY IN FREEWAY R/W REVERSIBLE, ONE LANE - AT GRADE

Figure 3-43



BUSWAY IN FREEWAY R/W REVERSIBLE, ONE LANE - AERIAL

Figure 3-44

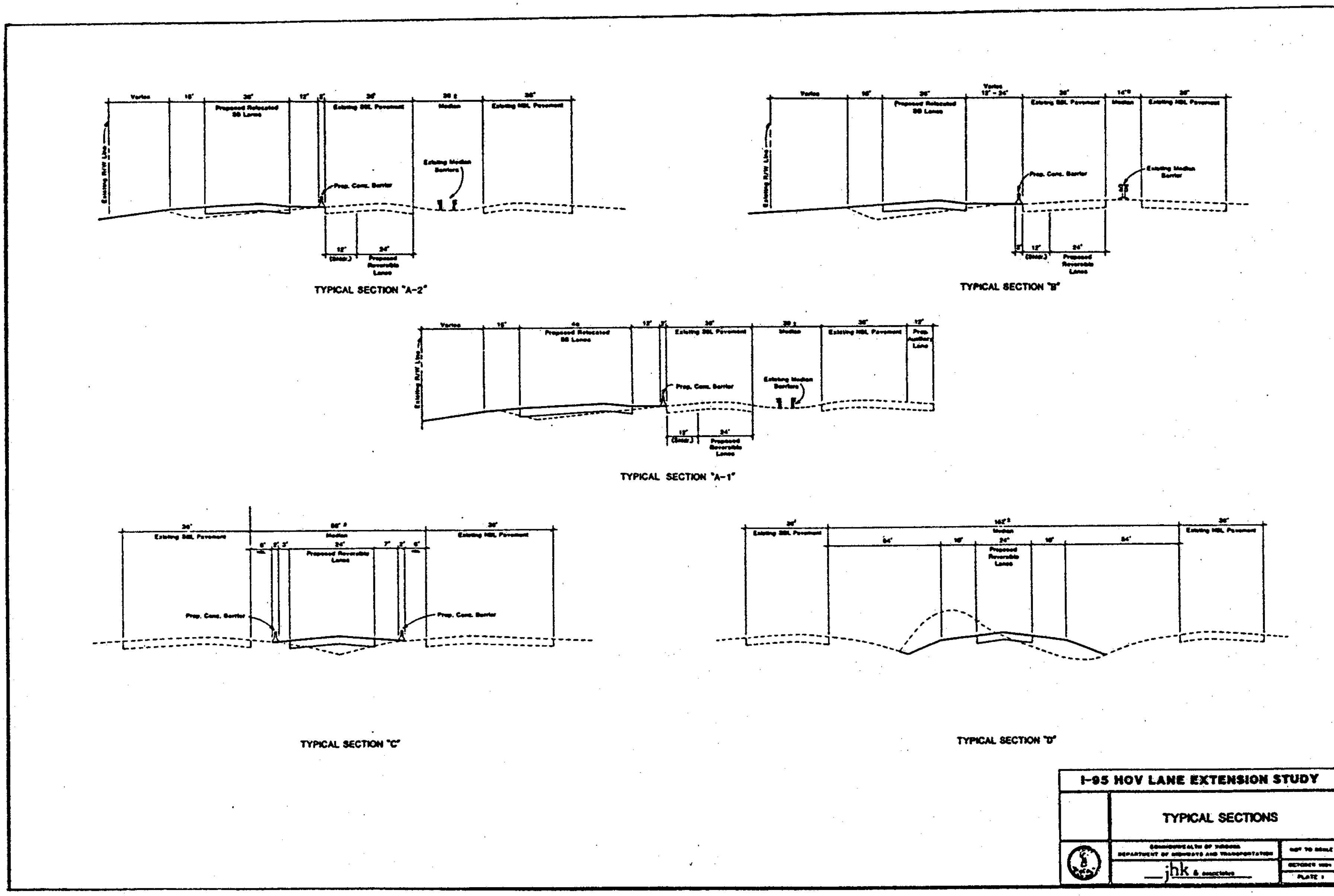

TYPICAL SECTION "A-2"
TYPICAL SECTION "B"
TYPICAL SECTION "A-1"
TYPICAL SECTION "C"
TYPICAL SECTION "D"
I-95 HOV LANE EXTENSION STUDY
TYPICAL SECTIONS
jhk

Figure 3-45

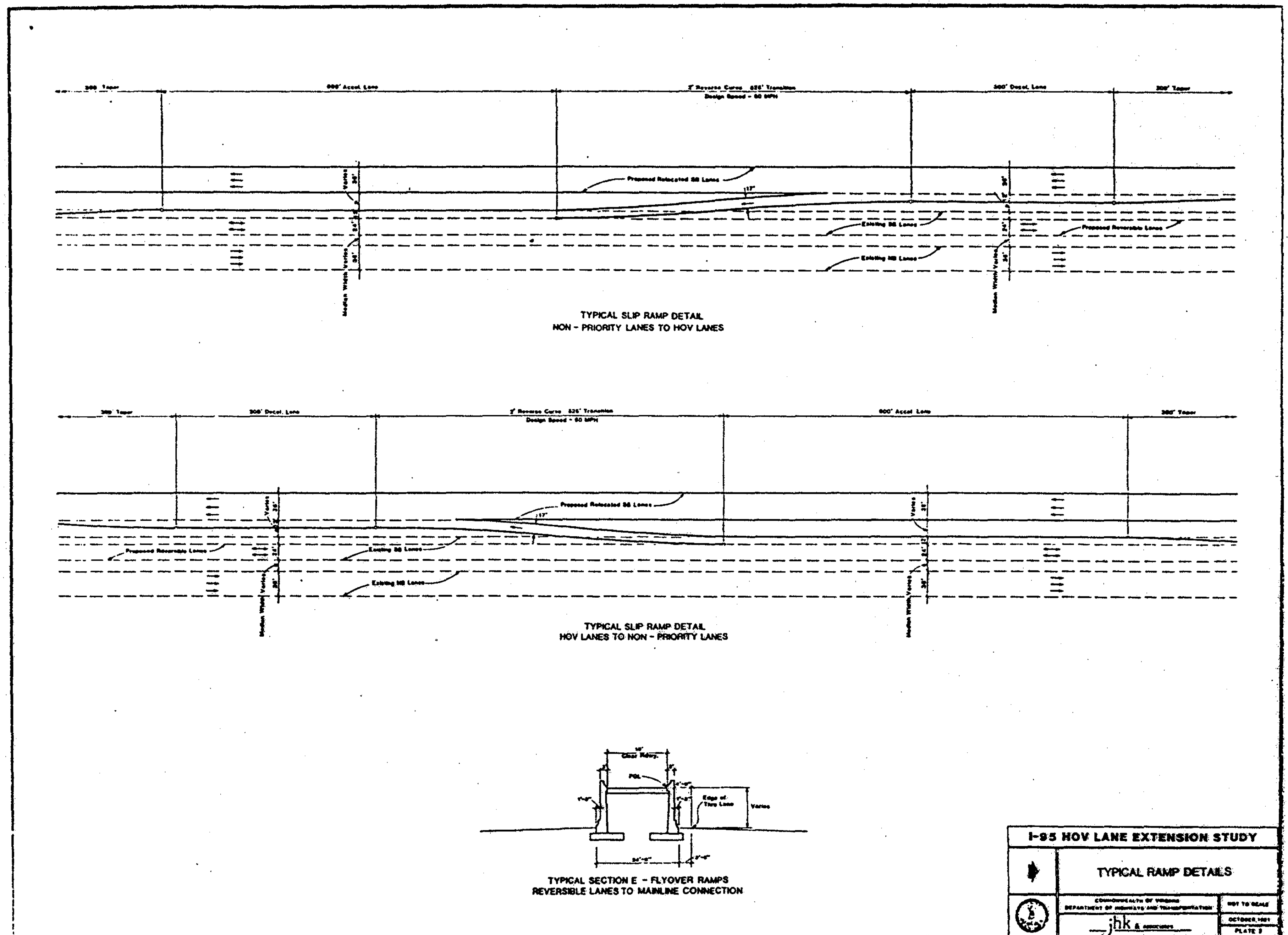
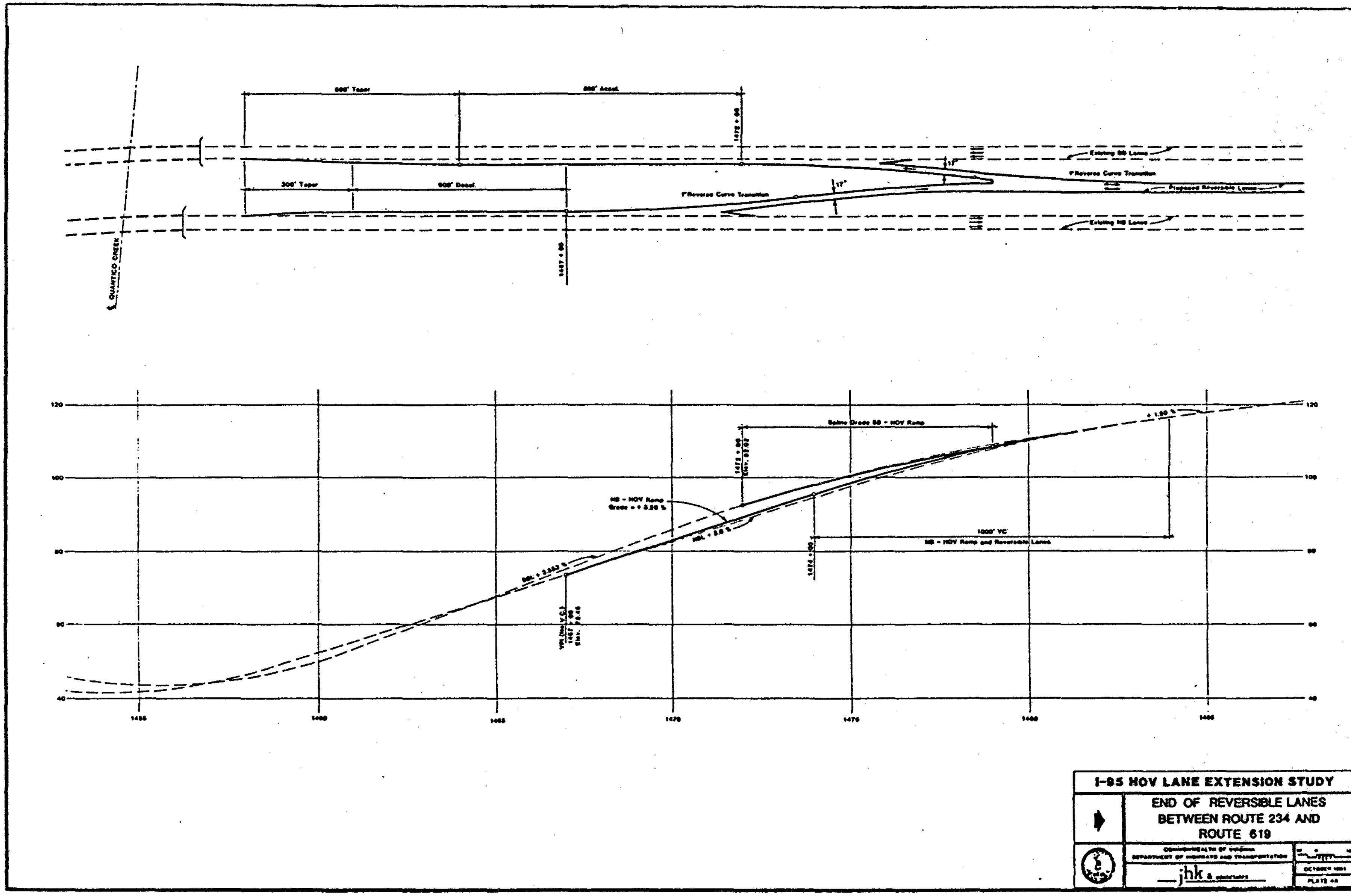

TYPICAL SLIP RAMP DETAIL
NON - PRIORITY LANES TO HOV LANES
TYPICAL SLIP RAMP DETAIL
HOV LANES TO NON - PRIORITY LANES
TYPICAL SECTION E - FLYOVER RAMPS
REVERSIBLE LANES TO MAINLINE CONNECTION
I-95 HOV LANE EXTENSION STUDY
TYPICAL RAMP DETAILS

Figure 3-46



I-95 HOV LANE EXTENSION STUDY
END OF REVERSIBLE LANES BETWEEN ROUTE 234 AND ROUTE 619
QUANTICO CREEK
300' Taper
Existing SB Lanes
Proposed Reversible Lanes
Existing NB Lanes
jhk

Figure 3-47

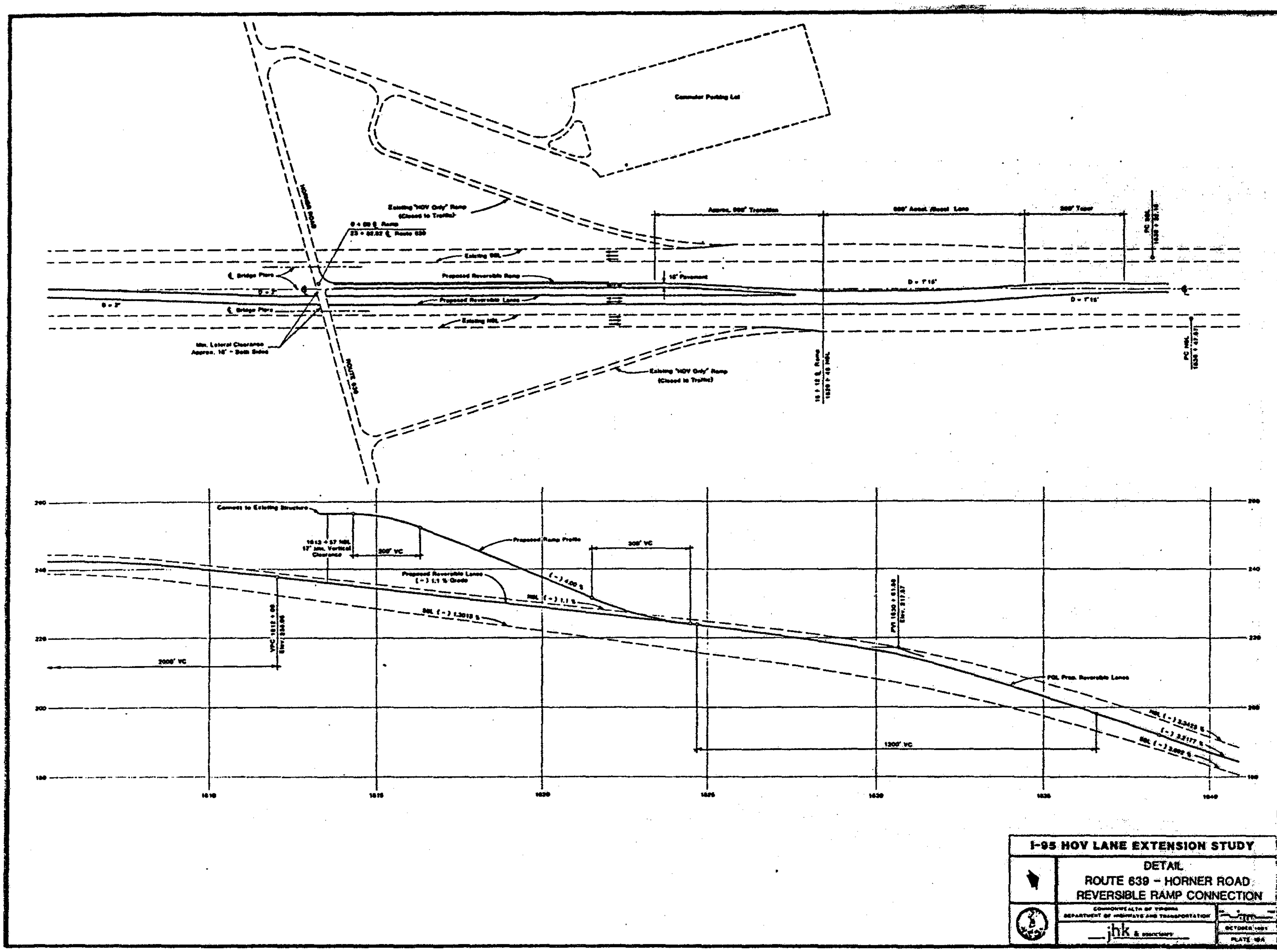

Commuter Parking Lot
Existing "HOV Only" Ramp (Closed to Traffic)
Proposed Reversible Ramp
Proposed Reversible Lanes
Existing SBL
Existing NBL
Connect to Existing Structure
Proposed Ramp Profile
I-95 HOV LANE EXTENSION STUDY
DETAIL
ROUTE 639 - HORNER ROAD
REVERSIBLE RAMP CONNECTION
jhk

Figure 3-48

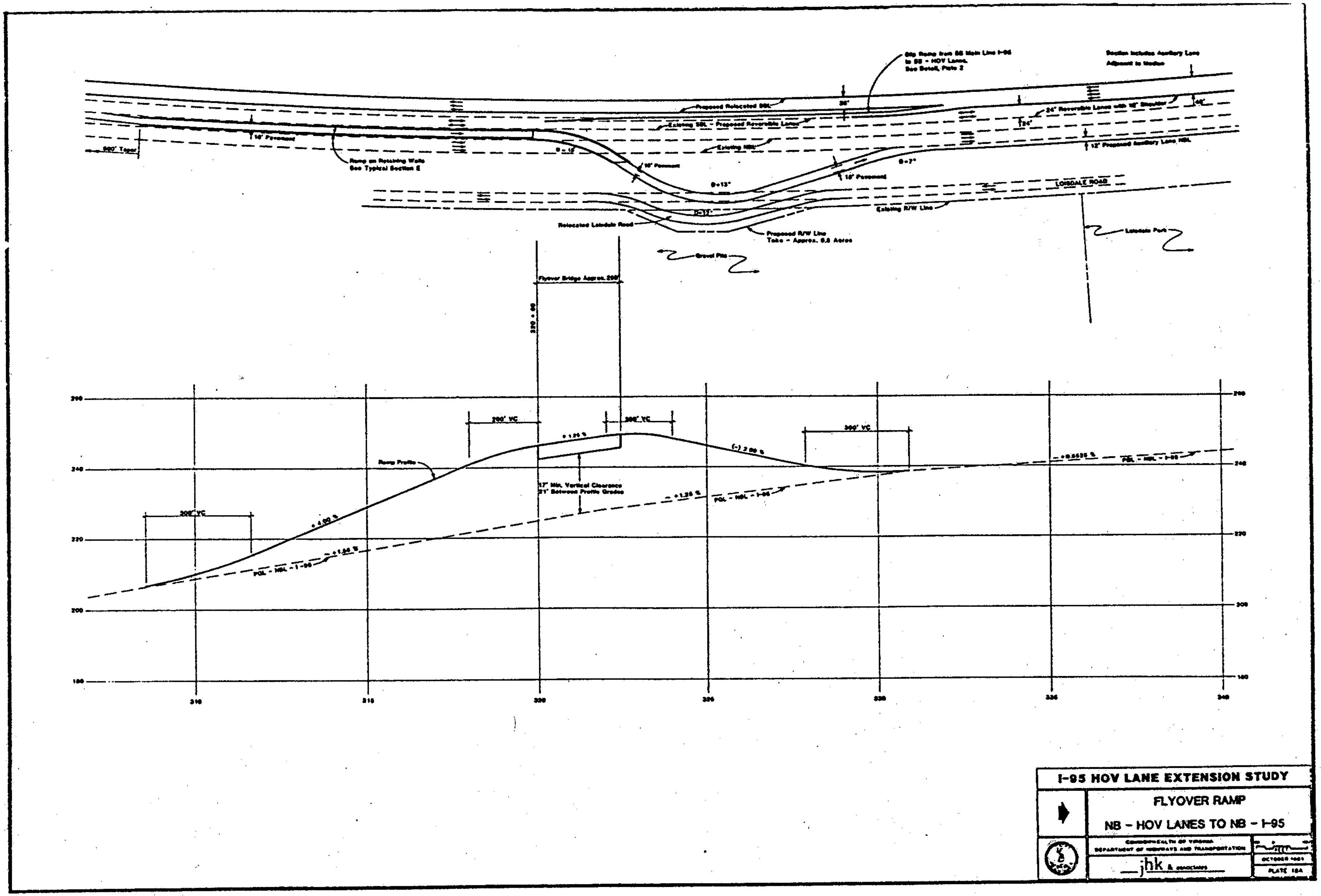

I-95 HOV LANE EXTENSION STUDY
FLYOVER RAMP
NB - HOV LANES TO NB - I-95
jhk

Figure 3-49

from the HOV lanes into and out of non-priority lanes. A schematic is also presented of the flyover ramp interchange with I-95 northbound traffic.

3.8 WISCONSIN GUIDELINES

3.8.1 Source [11]: Barton-Aschman Associates, Inc. General Criteria for Transitway Design, Milwaukee County Transitway, December 1968.

3.8.1.1 Design Vehicle

The dimensions of the design vehicle are those of the largest vehicles considered so that lesser dimensions may be proposed after a specific type of equipment is selected.

Conventional buses are normally 8'0" to 8'-6" wide. Trends and requests for permissive legislation indicate a 9'-0" width may become standard. The advantage of the extra width is that it permits wider aisles and seats. A width greater than 9'0" width is unlikely for standard buses, which have to use city streets or freeways now designed.

A height of eye of 5.0 feet is considerably lower than that of present buses. However, this dimension is one which may be changed significantly with the design of higher speed "new look" buses or other types of equipment. The five foot dimension should be adequate to cover potential new equipment. The proposed heights of eye and heights of object also retain the option of using the transitway for autos and trucks with a design speed of 60 mph plus, which is consistent with county highway design standards. In general, the assumed design vehicles performance capabilities are set as minimums so that any type of equipment ultimately selected would be capable of meeting them. The assumed operating speed of 55 to 65 miles per hour for the design vehicle is essential if transit line-haul travel times are to be competitive with auto travel on parallel facilities. During peak hours, when auto travel speeds drop, transit vehicles may not maintain the assumed operating speed. Nonetheless, the design criteria and standards used to plan the transitway should not preclude the higher speeds. A summary of basic design vehicle criteria is given in Table 3-7.

3.8.1.2 Design Speeds

The speed selected for design is an approximation of the highest operating speeds anticipated without automatic control or guidance. This standard or criteria, more than any other, will control design dimensions of the transitway and are as follows:

Transitway - 70 mph
Ramp - 35 mph minimum

3.8.1.3 Level of Service

The transitway is to be designed for a level of service B, thereby permitting (1) an operating speed at, or greater than, 55 mph, and (2) the permissible transit vehicle volume per lane should not exceed 50 percent of the lane's capacity, according to widely accepted procedures for calculating capacity limitations.

3.8.1.4 Pavement Width

The width of pavement, recommended as 13 feet, refers only to the width of the through traffic or high-speed travel lanes. Guidelines for ramp widths are given in Table 3-8. An extra foot of width has been added to the standard 12-foot lane. This additional width can contribute to safer operation by providing increased lateral spacing between the high-speed, wider design vehicles.

TABLE 3-7. Vehicle Characteristics Providing Restraint On Transitway Geometrics

	Conventional BUS	**RTX**	**Skybus**	**StaRRbus**	**Rail Rapid Transit (Typical)**
Vehicle Dimensions:					
Width	8'-0"-8'-6"	8'-6"	8'-6"	5'-4"	9'-4"-11'-4"
Height	10'-2"	9'-1"	-	7'-6"	11'-10"
Length	40'-0"	40'-0"	30'-6"	14'-0"	48'-0"-57'-2"
Front Overhang	-	-	-	N/A	N/A
Rear Overhang	-	-	-	N/A	N/A
Wheelbase	23'-8"	23'-8"	17'-8"	N/A	N/A
Driver Eye Height	7' +	6' +	N/A	N/A	N/A
Weight	28,700 empty	28,700 empty	19,000	4,800 loaded	117,300 loaded
Attainable Speed (Line-Haul)	70 mph	70 mph	50 mph	60 mph	50 mph
Acceleration	2 mph/sec.	2.5-3.0 mph/sec.	2.5-3.0 mph/sec.	3.0 mph/sec.	2.3.-3.0 mph/sec.
Deceleration	2.5 mph/sec.	2.5 mph/sec.	2.5 mph/sec.	(Comfort)	4.0 mph/sec.
Maximum Operating Grade	10%	10%	10%	7%	5% +
Turning Radius	42'-3"	42'-3" ±	150'-0"	-	-
Transitway Requirements:					
Type	Road	Road	Elevated, at-grade track/guide	Unrestricted + guideway	Track
Width	Variable	Variable	2 line/elevated 19'-6" 1 line/elevated 8'-6" at-grade/1 line 10'-0"	1 line/at-grade 8'-0" (ROW)	2 line 27'-34

Table 3-8: Design Width of Pavements for Ramps

Radius on Inner Edge of Pavement Feet	Degree of Curve (Approx.)	Case I 1-Lane, One-Way Operation--No Provision for Passing	Case II 1-Lane, One-Way Operation, With Provision for Passing a Stalled Vehicle	Case III 2-Lane Operation--Either One-Way or Two-Way
Design Traffic Condition		SU	SU/SU	SU/SU
50	-	18 ft.	29 ft.	35 ft.
75	-	17	27	33
100	-	16	25	31
150	38.2°	16	24	30
200	28.6°	16	23	29
300	19.1°	15	22	28
400	14.3°	15	22	28
500	11.5°	15	22	28
Tangent	-	15	21	26

Note: SU = single-unit trucks or buses.

The design width of pavement includes the total paved width of traveled roadway, plus the right shoulder.

3.8.1.5 Sight Distance

The minimum safe stopping sight distance controls the permissible horizontal and vertical curvature as well as lateral clearances in special cases. These are given as follows:

Design Speed	Minimum Safe Stopping Sight Distance (ft.)
70	600
60	475
50	350
45	315
35	240

3.8.1.6 Grades

The maximum grades permitted on the transitway and its ramps are controlled more by safety considerations and desirable operations in the winter months, rather than the performance characteristics of the transit equipment. These are:

Transitway - Maximum 5%
Ramp - Maximum 6%

The maximum length of grade is to be such that vehicle operations would not be hindered by more than a 15 mph speed reduction, taking into consideration the length and percent of grade. A minimum longitudinal grade of 0.50% is controlled by the need to provide adequate drainage and the prevention of ponding, or long periods during which water would be retained on the paved surface.

3.8.1.7 Vertical Curves

Table 3-9 indicates vertical curve criteria to be used. These criteria are based on the assumed height of eye of 5.0 feet, the height of object of 6 inches, and the properties of a parabolic curve. Headlight sight distance criteria will not apply where adequate lighting is provided.

Table 3-9: Vertical Curve Criteria (K Factors)

Design Speed	Minimum Length (feet)	Minimum K Factors (Feet/Percent Change in A)		
		Crest	Sag	
		Stopping Sight	Headlight Sight	Comfort
70	200	210	145	105
60	200	130	105	75
50	150	70	75	55
45	150	55	65	45
35	100	35	45	25

3.8.1.8 Clearances

Clearances are given as follows:

Minimum Vertical Clearances

Transitway under highway or railroad	15'-0"	(+3")
Transitway over freeway	15'-0"	(∓3")
Transitway over Interstate	16'-6"	(∓3")
Transitway over railroad	23'-0"	

Horizontal Clearances

Left edge of transitway pavement tovertical obstruction	30'-0" desirable 3'-6" minimum
Right edge of transitway pavement to vertical obstruction	30'-0" desirable 8'-0" minimum

3.8.1.9 Horizontal Curves

Transitway	Degree of Curve
Desirable Maximum	2 - 00'
Maximum	3 - 00'
Ramps	
Maximum	18 - 00'

3.8.1.10 Superelevation

Maximum superelevation shall be 0.080 ft./ft. with rate of change for transition not to exceed:

Transitway	1:200
Ramps	1:100

3.8.1.11 Typical Sections

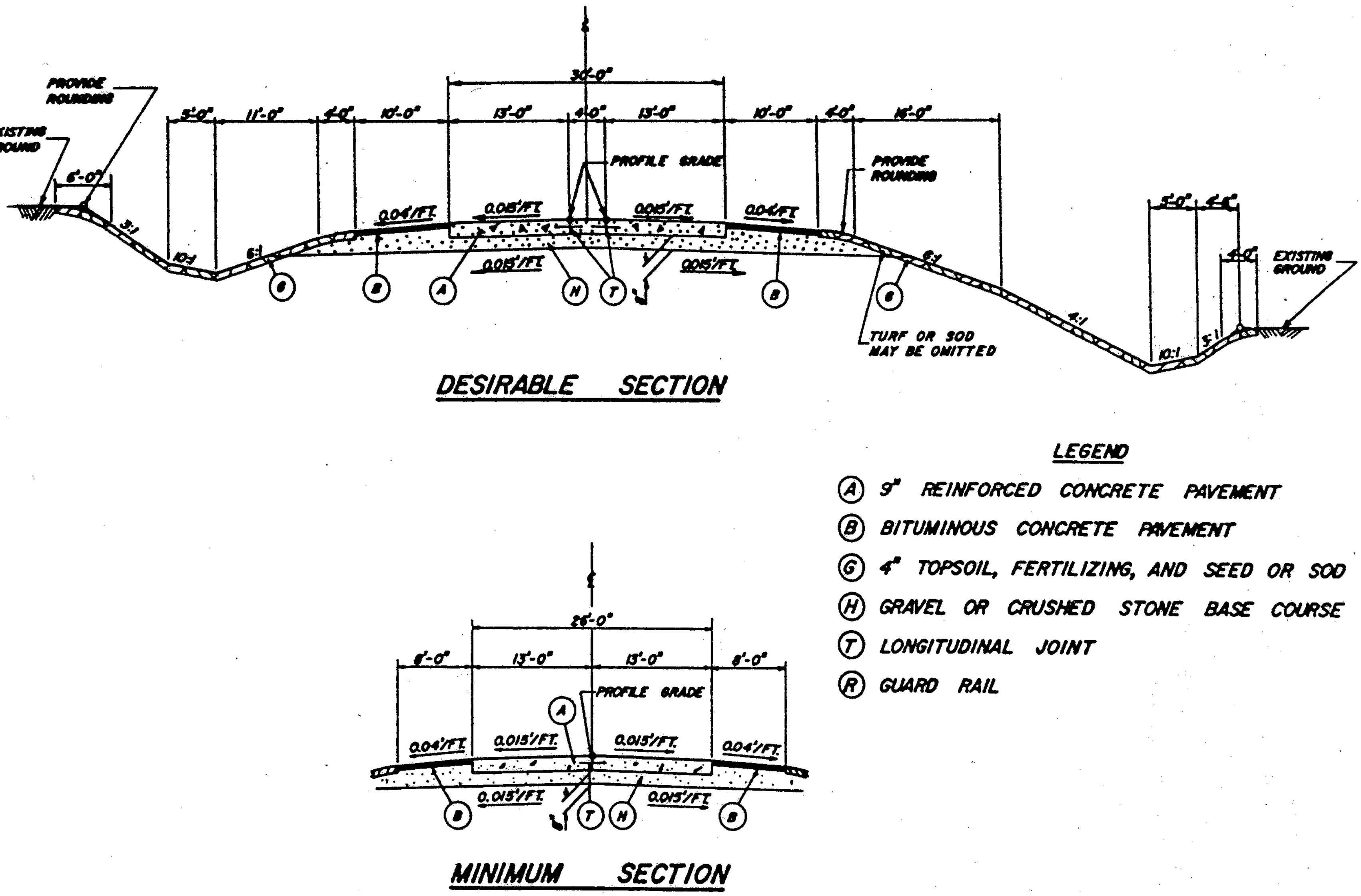
Drawings of the recommended typical cross sections are shown in Figures 3-50 through 3-53. A wide range of roadway widths was considered prior to recommending two, 13-foot lanes as the basic cross section. The requirements of the combined pavement and shoulder width include:

(1) Enough width must be available so that a stalled or stopped vehicle can be passed without encroaching on the opposing lanes.

(2) The total width must be adequate for future construction of a rail system.

(3) The total width must provide adequate acceleration lanes for entering vehicles. In most cases, the shoulder will be used as a combined acceleration lane as well as an emergency storage area.

All mainline pavement shall have a crown line and tangent cross slopes as follows:



TRANSITWAY SECTIONS

Figure 3-50

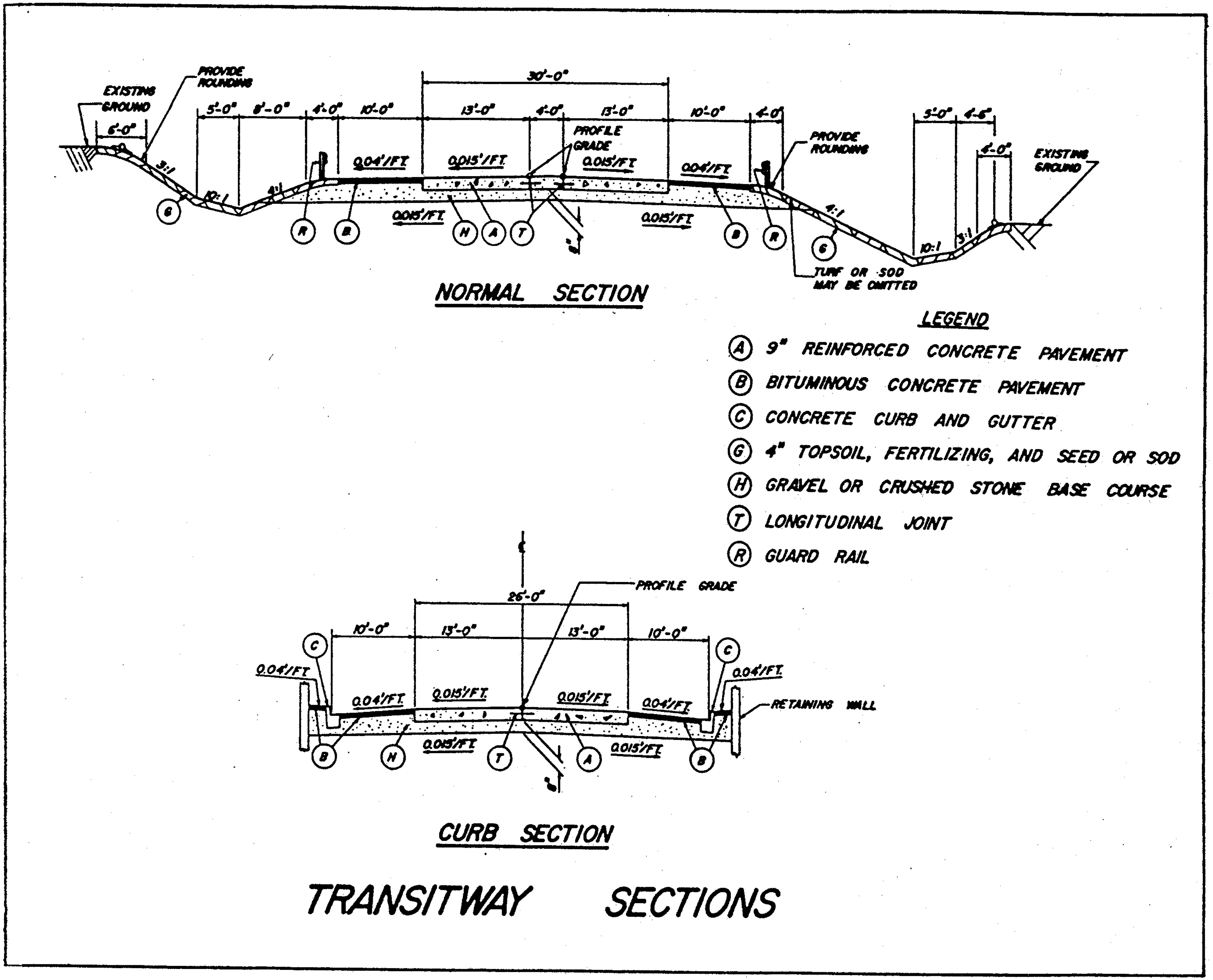

NORMAL SECTION
EXISTING GROUND
PROVIDE ROUNDING
6'-0"
5'-0"
8'-0"
4'-0"
10'-0"
30'-0"
13'-0"
4'-0"
13'-0"
10'-0"
4'-0"
PROFILE GRADE
0.04'/FT.
0.015'/FT.
0.015'/FT.
0.04'/FT.
0.015'/FT.
0.015'/FT.
3:1
10:1
4:1
4:1
10:1
3:1
PROVIDE ROUNDING
5'-0"
4'-6"
4'-0"
EXISTING GROUND
TURF OR SOD MAY BE OMITTED
LEGEND
(A) 9" REINFORCED CONCRETE PAVEMENT
(B) BITUMINOUS CONCRETE PAVEMENT
(C) CONCRETE CURB AND GUTTER
(G) 4" TOPSOIL, FERTILIZING, AND SEED OR SOD
(H) GRAVEL OR CRUSHED STONE BASE COURSE
(T) LONGITUDINAL JOINT
(R) GUARD RAIL
CURB SECTION
PROFILE GRADE
26'-0"
10'-0"
13'-0"
13'-0"
10'-0"
0.04'/FT.
0.04'/FT.
0.015'/FT.
0.015'/FT.
0.04'/FT.
0.04'/FT.
0.015'/FT.
0.015'/FT.
RETAINING WALL
TRANSITWAY SECTIONS

Figure 3-51

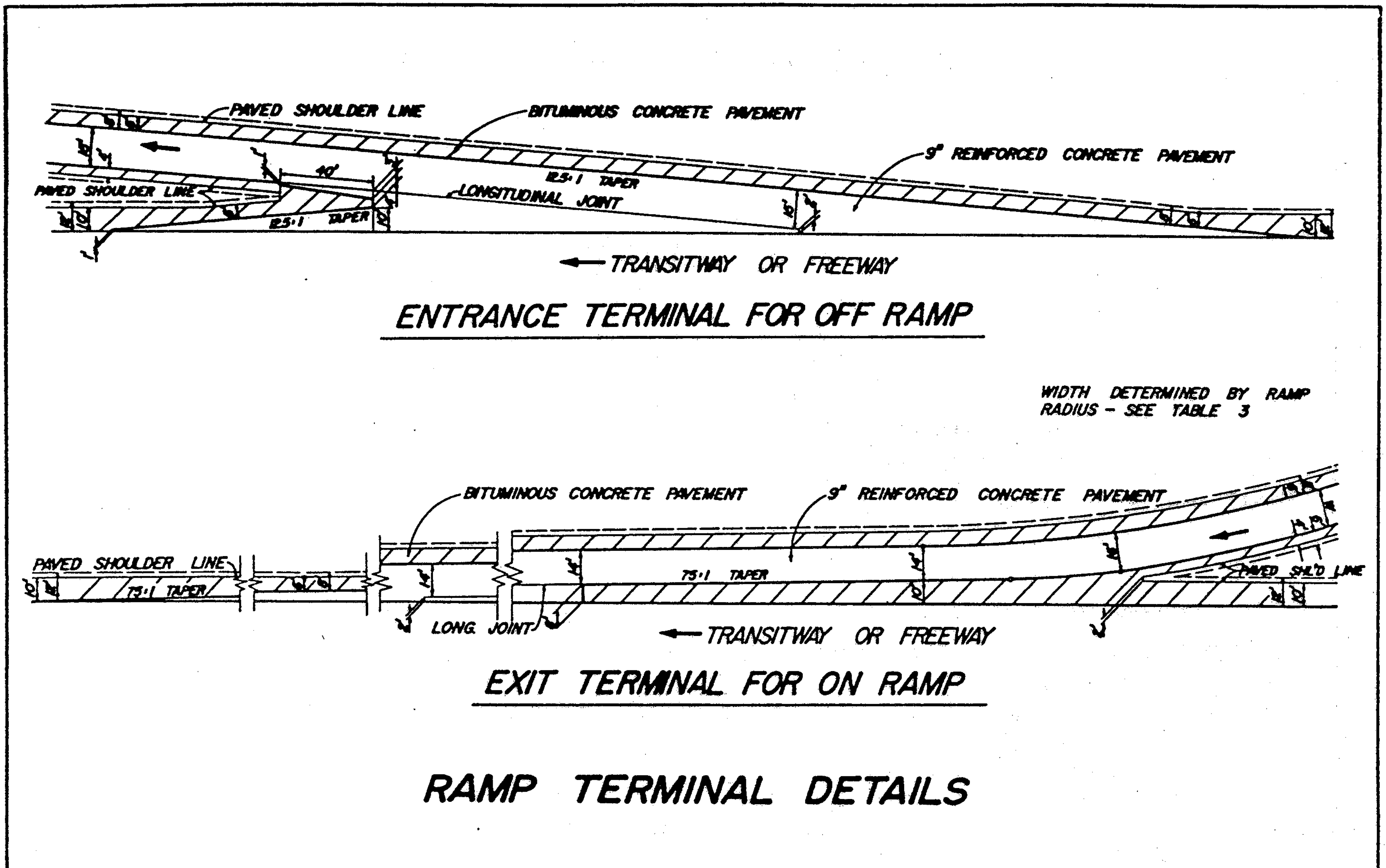

PAVED SHOULDER LINE
BITUMINOUS CONCRETE PAVEMENT
9" REINFORCED CONCRETE PAVEMENT
40'
12.5:1 TAPER
PAVED SHOULDER LINE
LONGITUDINAL JOINT
12.5:1 TAPER
TRANSITWAY OR FREEWAY
ENTRANCE TERMINAL FOR OFF RAMP
WIDTH DETERMINED BY RAMP RADIUS - SEE TABLE 3
BITUMINOUS CONCRETE PAVEMENT
9" REINFORCED CONCRETE PAVEMENT
PAVED SHOULDER LINE
75:1 TAPER
75:1 TAPER
PAVED SHL'D LINE
LONG. JOINT
TRANSITWAY OR FREEWAY
EXIT TERMINAL FOR ON RAMP
RAMP TERMINAL DETAILS

Figure 3-52

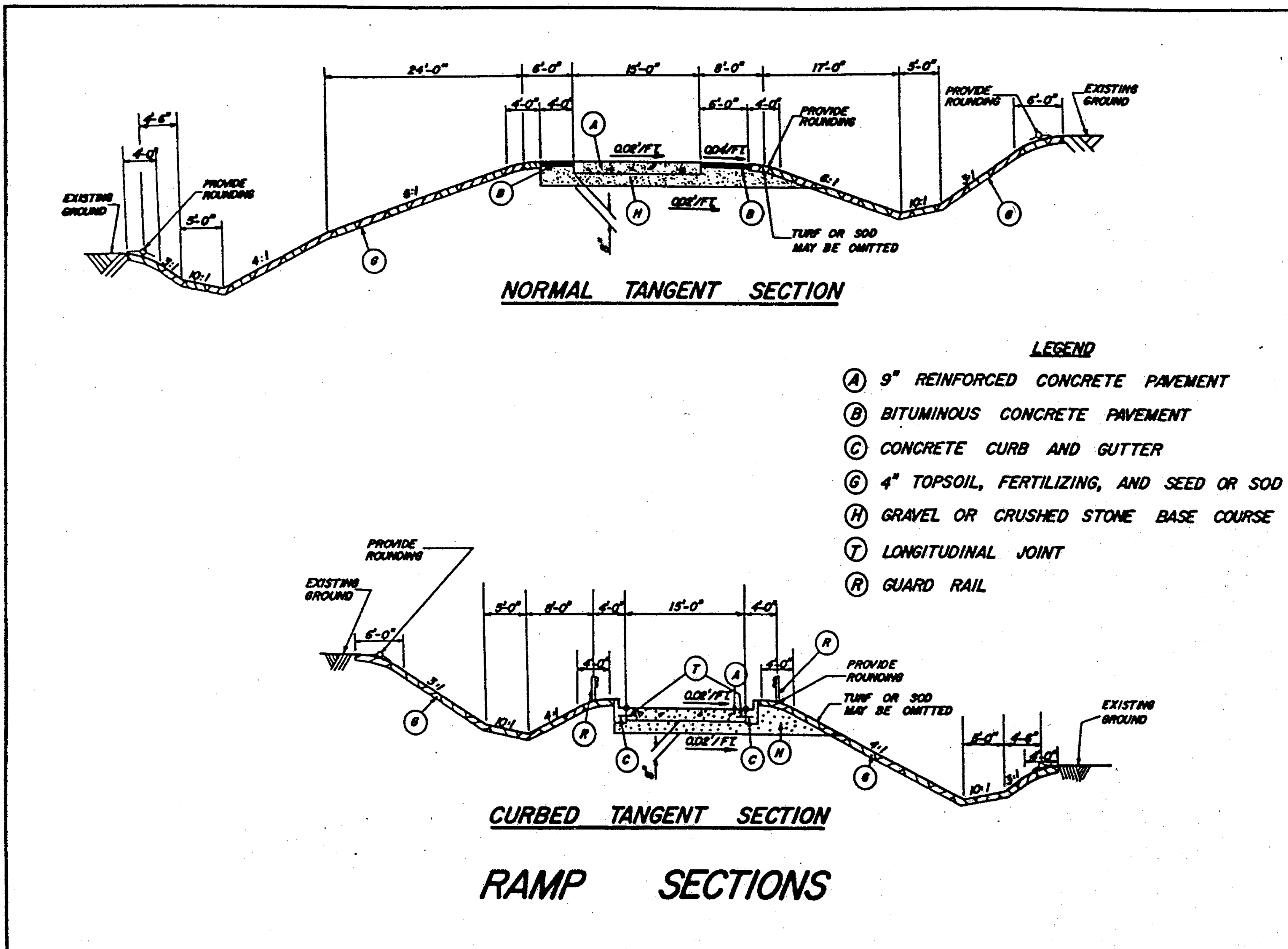

NORMAL TANGENT SECTION
24'-0"
6'-0"
15'-0"
8'-0"
17'-0"
5'-0"
4'-0"
6'-0"
4'-6"
5'-0"
0.02'/FT
0.04'/FT
PROVIDE ROUNDING
EXISTING GROUND
TURF OR SOD MAY BE OMITTED
6:1
4:1
3:1
10:1
CURBED TANGENT SECTION
15'-0"
8'-0"
PROVIDE ROUNDING
EXISTING GROUND
TURF OR SOD MAY BE OMITTED
LEGEND
(A) 9" REINFORCED CONCRETE PAVEMENT
(B) BITUMINOUS CONCRETE PAVEMENT
(C) CONCRETE CURB AND GUTTER
(G) 4" TOPSOIL, FERTILIZING, AND SEED OR SOD
(H) GRAVEL OR CRUSHED STONE BASE COURSE
(T) LONGITUDINAL JOINT
(R) GUARD RAIL
RAMP SECTIONS

Figure 3-53

Pavement cross slope - 0.015 ft./ft.

Ramp cross slope - 0.020 ft./ft.

The shoulders will be of adequate width to permit storage of disabled vehicles removed from the traveled way in order to insure passenger safety and prevent delays to other vehicles. Full width right shoulders will be provided on all structures, irrespective of the length of the structure. The following are recommended:

Desired paved width of shoulder - 10'-0"
Minimum paved width of shoulder - 8'-0"
Shoulder cross slopes - 1/2" per foot

The normal transitway cross section will include a four-foot wide strip between the transit lanes. This strip may be used for striping, special delineation, rumble strips, or special barriers. Medians will be located where judged apropriate on the transitway and shall be a barrier type.

The recommended length of acceleration lanes where transit vehicles rejoin freeway traffic will be roughly 50 percent greater than the normal freeway standards. This standard is warranted because of the limited acceleration capability of the assumed design vehicle. Other new transit vehicles being analyzed or developed probably will have relatively low acceleration capabilities so that a significant improvement in the near future cannot be assumed.

Standard freeway deceleration lane lengths will be used. Deceleration characteristics of the assumed design vehicles are similar, if not identical, to the design vehicles used in high-type, highway design.

4. LIST OF AGENCY CONTACTS

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