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16. Abstract
This report documents research conducted in the evaluation of flashing arrowboards when located in advance of lane closure work zones. The effects of advance arrowboard placement were compared to the effectiveness of the arrowboard placement normally used by District 14 of the SDHPT.

The research indicates that arrowboard placement in advance of the beginning of a taper can be extremely effective if the sight distance to the arrowboard improves the effective sight distance to the work zone. This improvement is dependent on the horizontal and vertical alinement of each work zone. From the distances evaluated, 2000 ft. in advance of the taper appears to be the maximum advance placement. Distances greater than 2000 ft. may result in drivers moving back into the blocked lane.

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SUMMARY

Background

Flashing arrowboards have become an important traffic control device in work zone traffic management over the past several years. Because of this, arrowboards have been the subject of many research reports which cover a wide range of topics including design, human factors considerations and application guidelines. The results have been very positive indicating that arrowboards do have a very high target value and that motorists respond positively to the arrowboards' indications.

Two reports, however, differ concerning the placement of a flashing arrowboard for the most effective use. One report (1) recommended the placement of the arrowboard at the beginning of the taper; another (2) recommended that the most effective arrowboard placement is 100 ft. to 500 ft. in advance of the beginning of the taper. A study was therefore conducted on I-35 in Austin, Texas to further evaluate arrowboard placement.

Recommendation

The research documented in this report indicates that the placement of an arrowboard in advance of the beginning of a taper is beneficial only when the sight distance to the work zone is improved. For the maximum benefit in arrowboard usage, a minimum sight distance must be maintained. The minimum allowable sight distance for urban freeway operations, as developed in a related study (4), is 1000 ft. [as supported in related studies (3,4)]. The desired sight distance is 1500 ft.

Locating an arrowboard in advance of the beginning of the taper does not necessarily increase the sight distance. The vertical and/or horizontal geometrics at each work site would control the sight distance and the resulting placement of a flashing arrowboard. Figure 1 represents an example of when sight distance is not improved. Figure 2 represents a situation where moving the arrowboard in advance of the taper can be of great benefit.

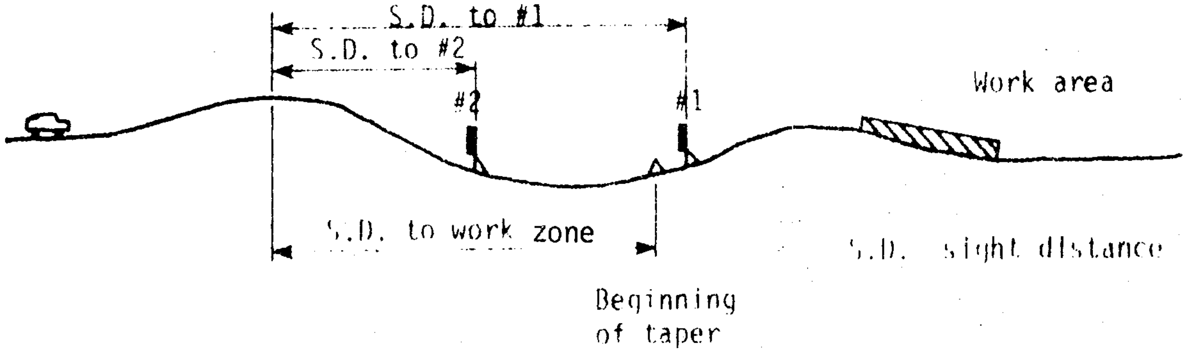


Figure 1. Typical Work Zone Where Critical Arrowboard Sight Distance is not Improved (Controlled by Geometrics)

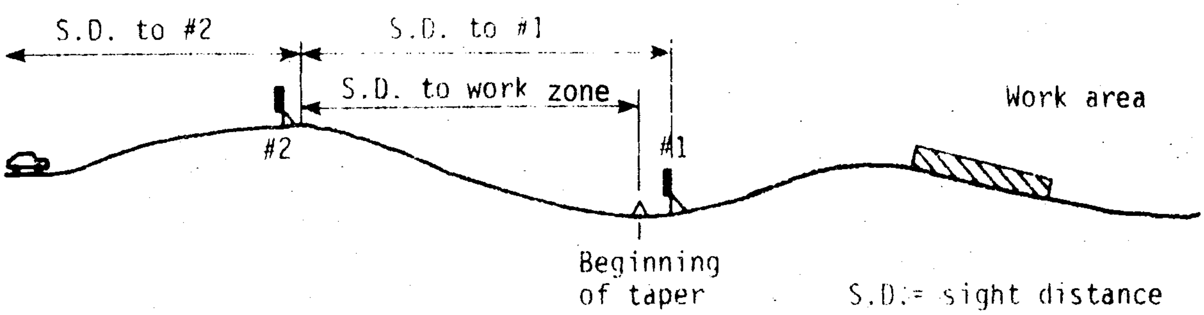


Figure 2. Typical Work Zone Where Critical Arrowboard Sight Distance is Improved

Work zones on a tangent section of roadway would not require advance arrowboard placement because, again, sight distance to the work zone is not critical (less than 1500 ft.). Figure 3 represents this situation.

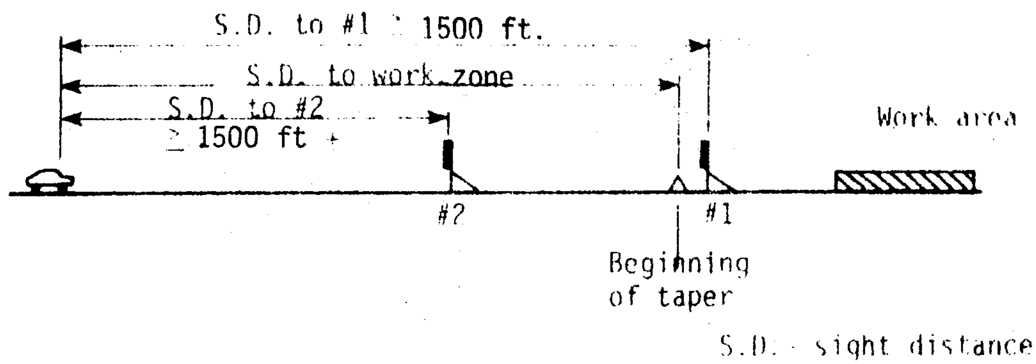


Figure 3. Typical Work Zone Where Critical Sight Distance is not Improved (Not Controlled by Geometrics)

The limitations of the study prohibited the determination of the distance in advance of the beginning of the taper at which the arrowboard becomes ineffective. From the two sites studied, the arrowboard when placed 2000 ft. in advance of the beginning of the taper was most effective in shifting traffic from the blocked lane. Little improvement in shifting traffic was observed after locating an arrowboard 2500 ft. in advance of the beginning of the taper at one of the sites. However, it appears that positioning an arrowboard too far in advance of the beginning of the taper does not imporve the effectiveness of the advance arrowboard. Shifted traffic was observed returning to the closed lane when an arrowboard was placed 4000 ft. in advance of the beginning of the cone taper.

In conclusion, when the sight distance to the work zone is less than 1500 ft., an arrowboard should be placed on the shoulder in advance of the beginning of the taper. When the sight distance to the work zone is between 1500 and 2500 ft., the use of a flashing arrowboard may be used to increase the advance warning (effective sight distance) to motorists. However, if the sight distance to the work zone is greater than 2500 ft., a flashing arrowboard in advance of the beginning of the cone taper is not needed.

STUDY APPROACH

Controlled field studies were conducted by TTI on I-35 in Austin, Texas. These studies were conducted in order to evaluate the effectiveness of flashing arrowboards when used in advance of work zones requiring a lane closure. The Texas State Department of Highways and Public Tranpsortation (SDHPT), Austin District, used flashing arrowboards to supplement the standard traffic control devices as suggested in the Texas MUTCD (5). Figures 4 and 5 are schematics of the two worksites and show the relative location of all traffic control devices used at each work zone. Thirteen controlled field studies were conducted at the two worksites. Seven arrowboard arrangements were studied at Site I and six at Site II.

The SDHPT required one arrowboard to be located and operating in each of the closed lanes at the end of the taper. This requirement restricted the capability of the study to isolate the effects of only the arrowboard in advance of the beginning of the taper. Data collected at each site while the arrowboards were in this required arrangement represented the base data or the normal driver response to the arrowboards. These data included the effects of the advance signing and permitted a comparison to be made of arrowboards when positioned in advance of the beginning of the taper to the base (or normal) placement.

The data collected during each of the studies consisted of freeway volume counts, lane distributions, and sight distances to the arrowboards. The volume counts and the lane distribution data were collected at count stations located upstream from the first taper. Stations were also located at all freeway access points in order to record entering and exiting vehicles, thus providing a closed system for data analysis. The lane distribution data

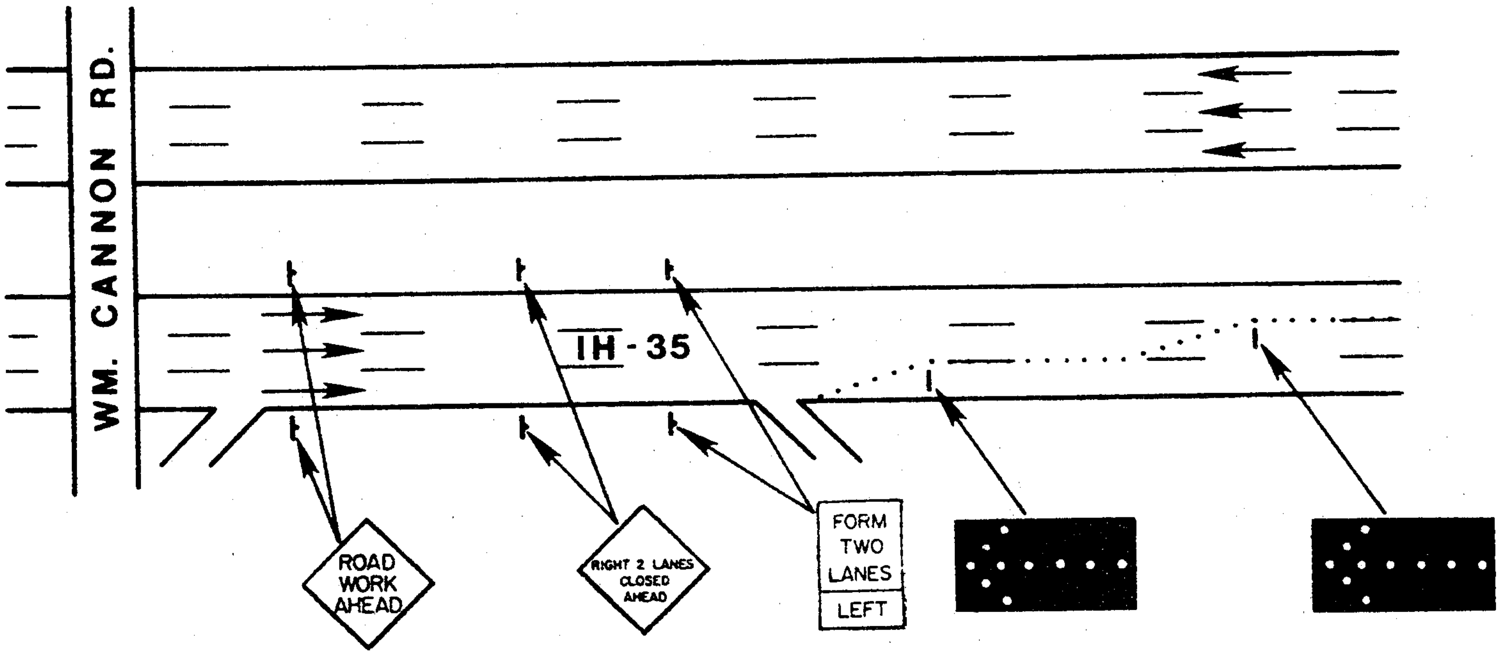


Figure 4. Site I Schematic (Base Condition)

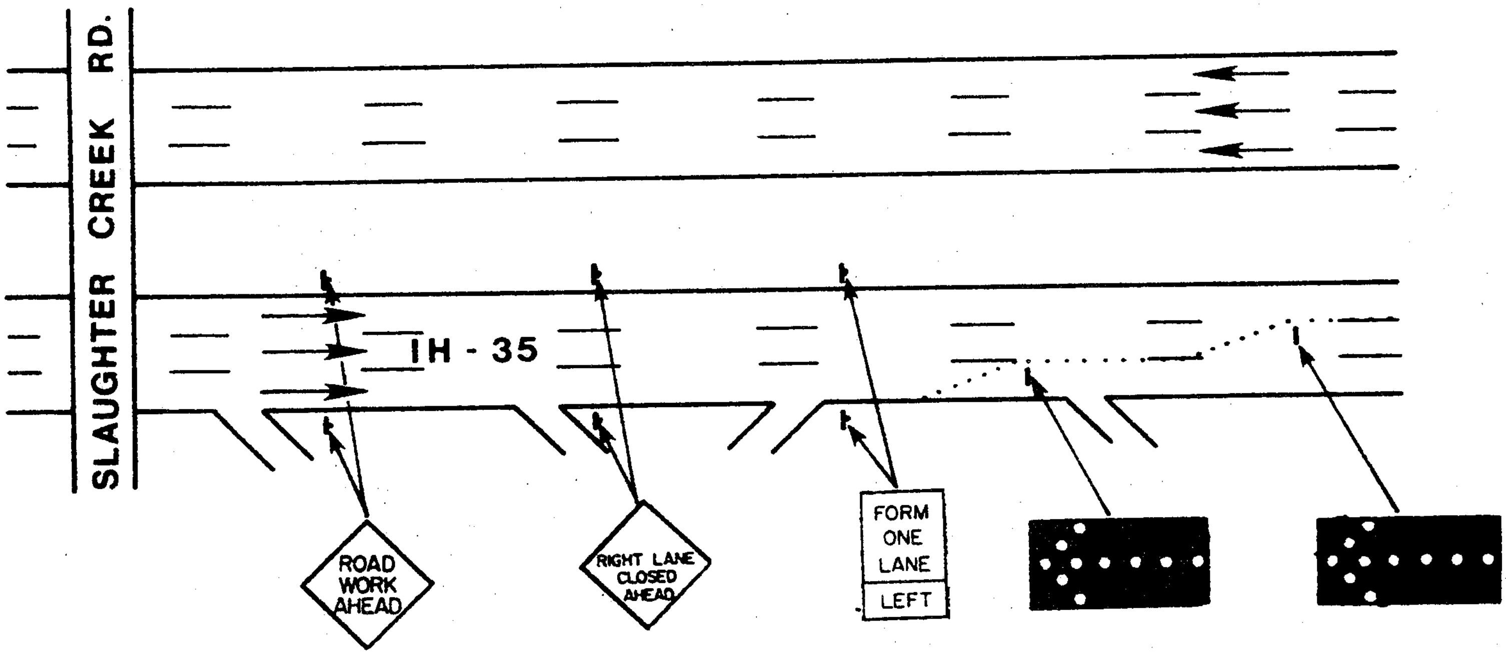


Figure 5. Site II Schematic (Base Condition)

provided information concerning the lane occupancy at each station so that the effects of the arrowboards could be determined. The sight distances to the arrowboards were determined by an observer traveling in a vehicle equipped with a distance measuring instrument (DMI). These data, when compared to each arrowboard arrangement studied, reflected the relationships of lane distribution with the arrowboard locations and relative sight distances in advance of the work zone.

The data for each arrowboard arrangement were collected during sixty minute periods. After each set of data was collected, a new arrowboard arrangement was positioned. A fifteen minute gap between arrowboard positioning and data collection was provided in order for the data to represent normal traffic flow.

The data representing the effectiveness of an advanced arrowboard placement were collected when an arrowboard was positioned at distances ranging from 250 ft. to 4000 ft. in advance of the beginning of the taper. An additional study was conducted to evaluate the positioning of an arrowboard at the beginning of the taper versus the normal placement at the end of the taper.

STUDY RESULTS

Vertical and/or horizontal alinement control the sight distance to the arrowboard or the work zone. The results from both sites indicated that the sight distance to an arrowboard and thus the driver's perception of a lane closure influence the lane changing behavior of approaching motorists.

Both worksites were located downstream from varying geometric alinements. The actual work at Site I was located downstream from a vertical crest and on a downgrade. Site II was downstream from a short crest and a long, relatively flat section. The work area, however, began in a sag and the closure extended along an upgrade. The results of all the data collected during the different arrowboard arrangements are shown on Figures 6 and 7.

From these Figures, it can be seen that the advance signing and arrowboard placement normally used by the Austin District reduced the traffic in the closed lane 40% at Site I (Figure 6) and approximately 30% at Site II (Figure 7). With these percentages representing the base signing effectiveness measured at 2000 ft. in advance of the beginning of the taper, a comparison on the effects of advance arrowboard placement was made for each site. One such comparison is shown on each figure. At Site I, when placing an arrowboard 2000 ft. in advance of the beginning of the taper, a 60% reduction in traffic (20% fewer from normal) was evidenced. At Site II, a 65% reduction (35% fewer than normal) was experienced when placing an arrowboard 2000 ft. in advance of the beginning of the taper. This reduction of traffic in the blocked lane was caused by the advanced arrowboard placement and the increased effective sight distance. The effective sight distance in this case is that sight distance to the arrowboard which communicates an oncoming hazard to the motorist.

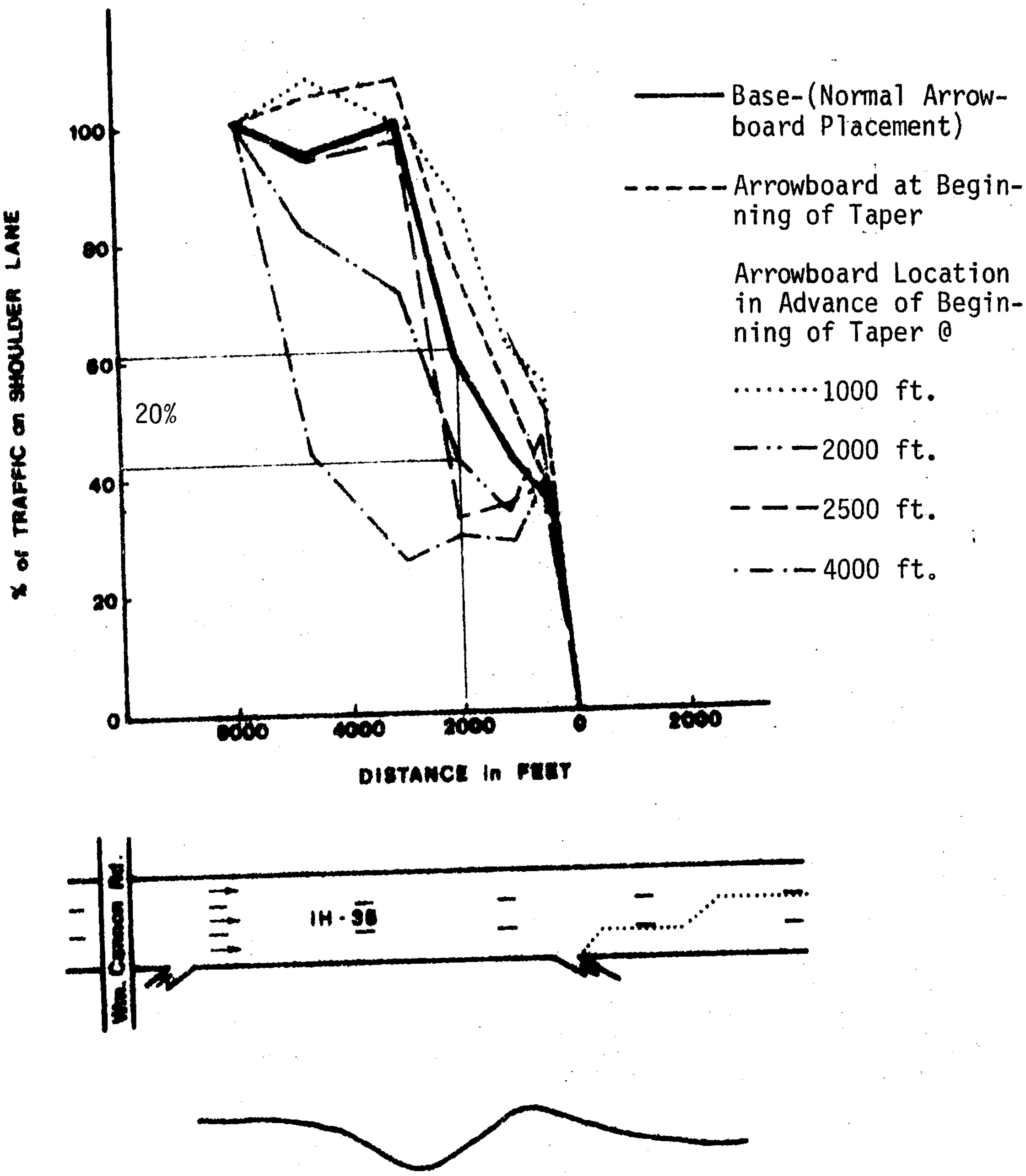


Figure 6. Arrowboard Placement Effectiveness at Site I

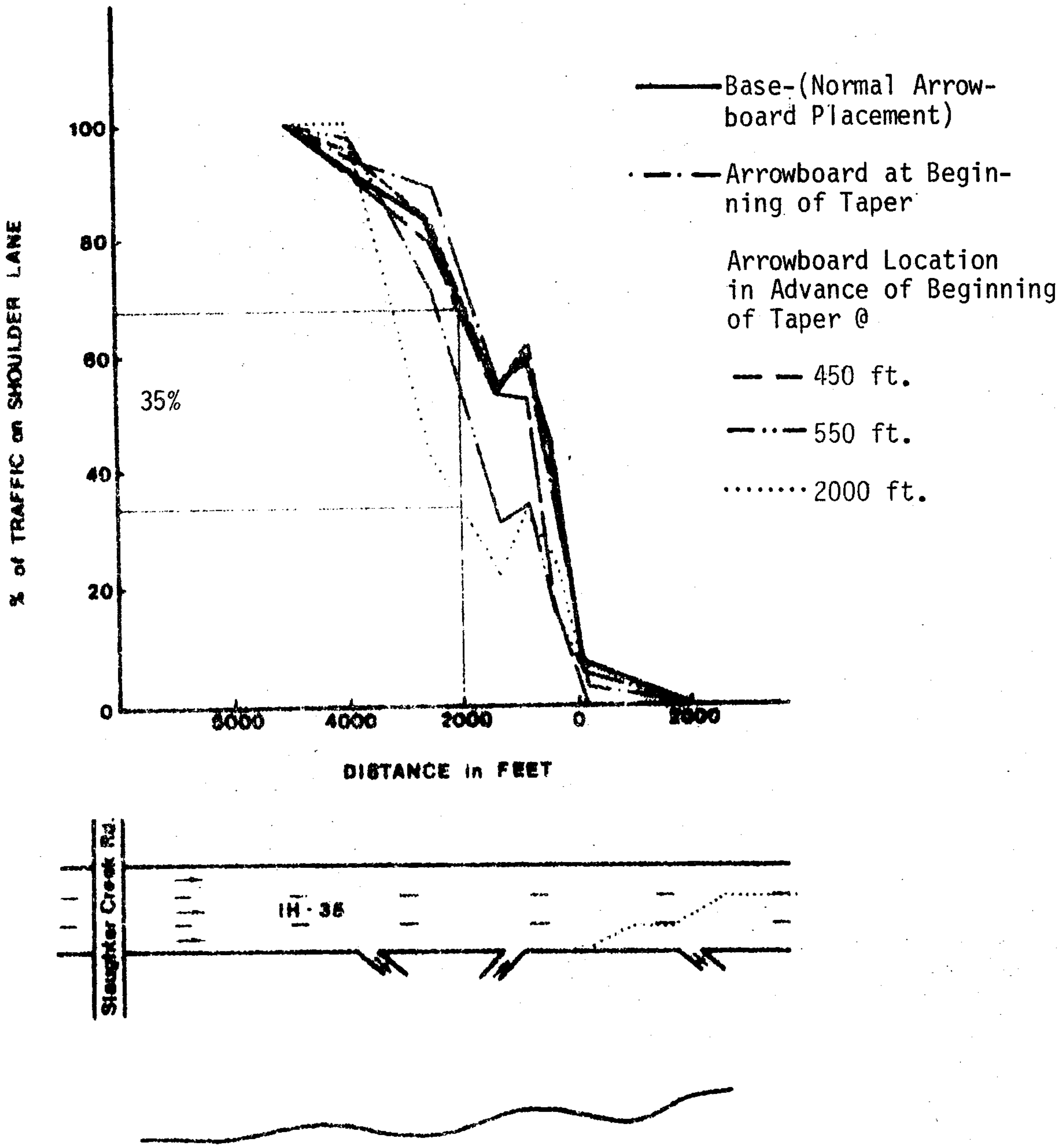


Figure 7. Arrowboard Placement Effectiveness at Site II

Figures 8 and 9 represent the comparison of traffic remaining in the blocked lane with effective sight distances to the arrowboard at 2000 ft. upstream from the beginning taper for the advance arrowboard placements studied. From these figures, it can be observed that the improved effective sight distance reduced the amount of traffic in the closed lane. Conversely, as the advance arrowboard's sight distance approached that of the normal arrowboard placement (base sight distance) the amount of traffic in the blocked lane increased.

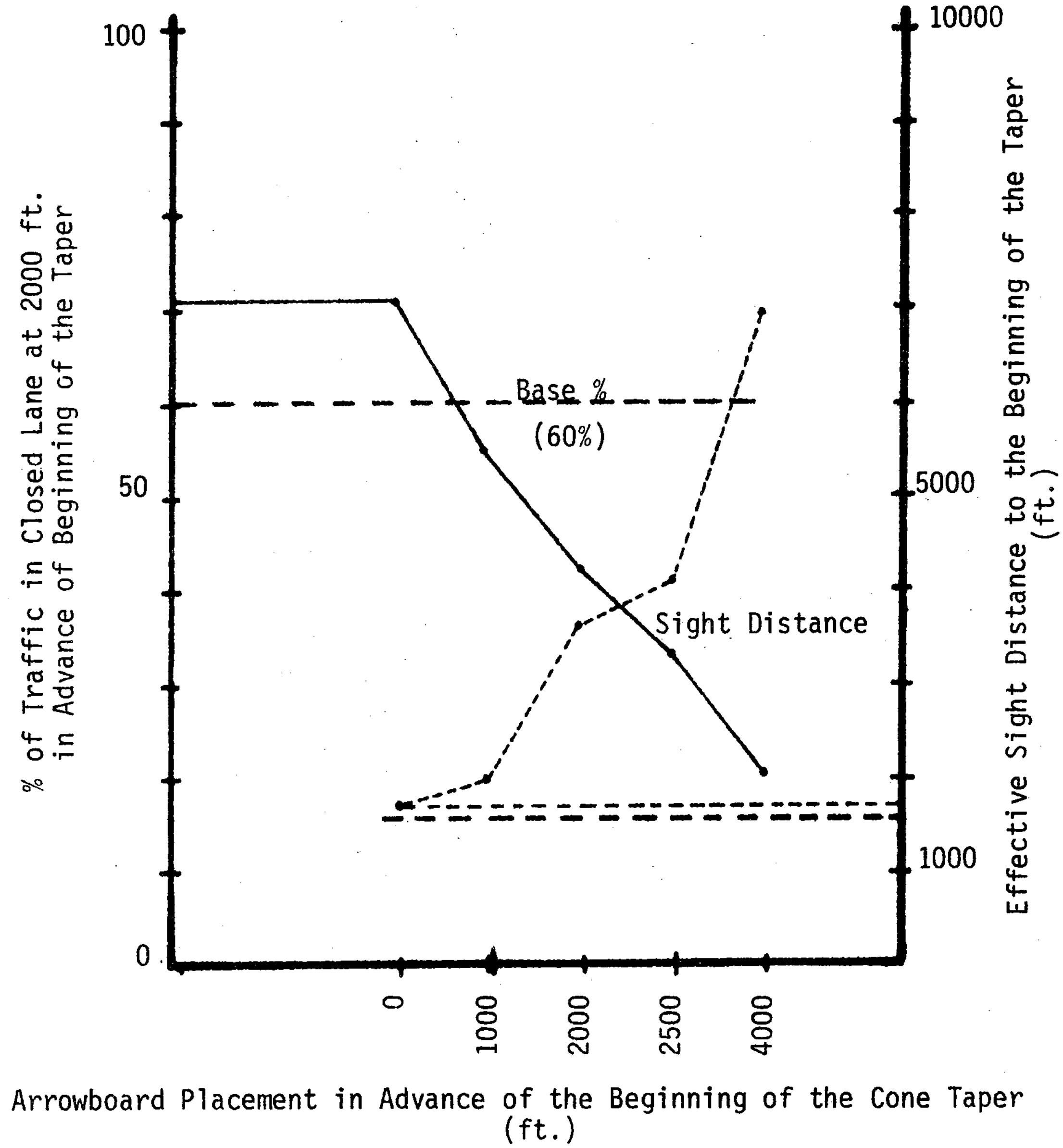
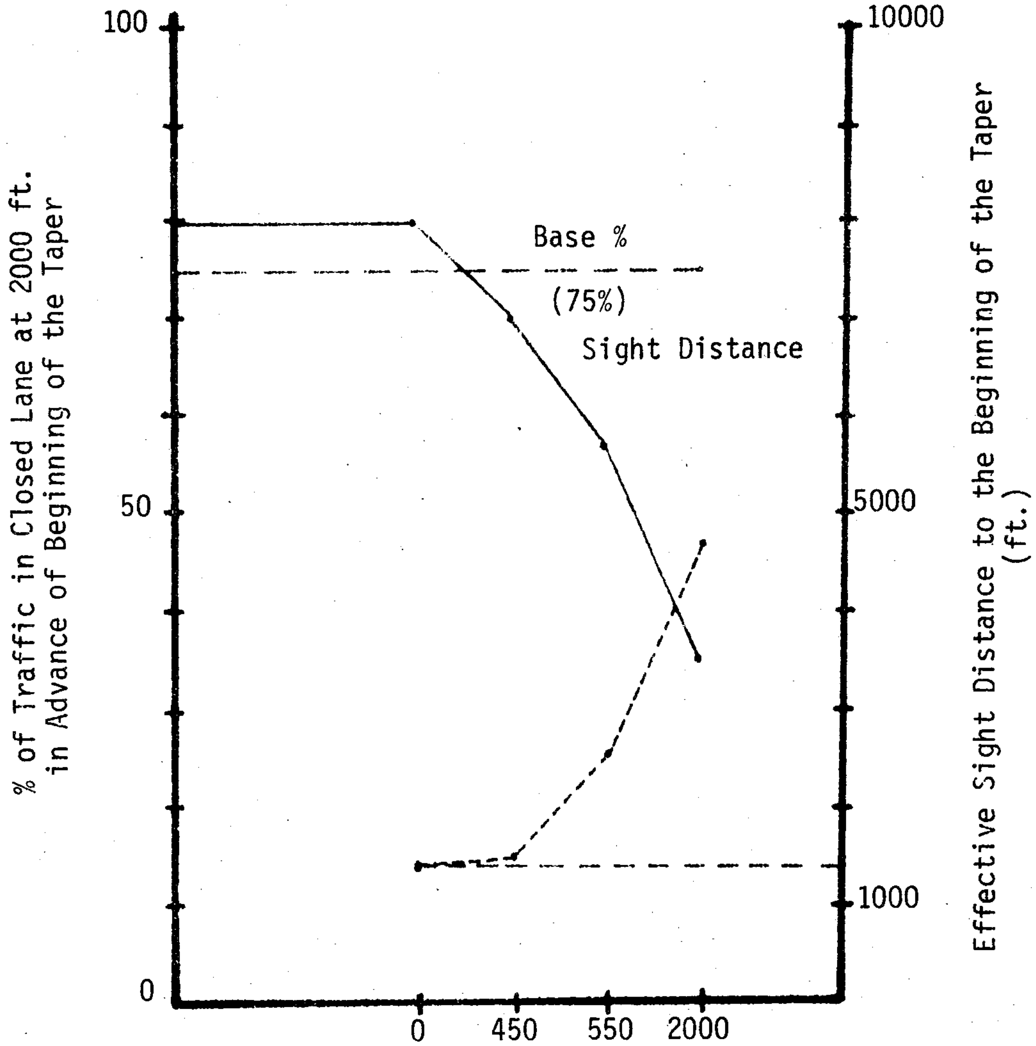


Figure 8. Site I Arrowboard Placement and the Effect of Lane Distribution and Sight Distances



Arrowboard Placement in Advance of the Beginning of the Cone Taper
(ft.)

Figure 9. Site II Arrowboard Placement and the Effect on Lane Distribution and Sight Distance

FINDINGS

The Texas and National MUTCDs (6,7) each contain a section on flashing arrowboards. These sections, however, deal primarily with minimum design standards. The need for and the location of an arrowboard are optional. The need of an arrowboard upstream from the beginning of a cone taper should be dependent primarily on the horizontal and vertical alinement upstream from a work zone and should be determined during the preparation of the Traffic Control Plan (TCP).

The results from the sites studied indicate that the use of a flashing arrowboard in advance of the beginning of a cone taper can be effective in shifting approaching traffic out of a blocked lane. This improved effectiveness is, however, based on an increased effective sight distance to the work zone.

An arrowboard should be located in advance of the beginning of the cone taper when the sight distance to the work zone or arrowboard is less than 1500 ft. However, since the sight distance to each work zone varies with vertical and/or horizontal alinement, a standard location for an arrowboard in advance of the beginning of the cone taper for all work zones is impractical.

In one study when an arrowboard was positioned at 4000 ft. in advance of the beginning of the taper, traffic which had vacated the blocked lane returned to the blocked lane. Therefore, whenever an arrowboard is placed in advance of the beginning of the taper, a field evaluation should be conducted to ensure that a minimum sight distance (1500 ft.) is maintained and to determine if traffic is moving back into the blocked lane. If vehicles are returning to the blocked lane, the distance from the beginning of the taper to the arrowboard is excessive and the arrowboard should be relocated closer to the beginning of taper. If the vertical and/or horizontal alinement is such that the advance location is needed, an additional arrowboard may be required to confirm the closure ahead.

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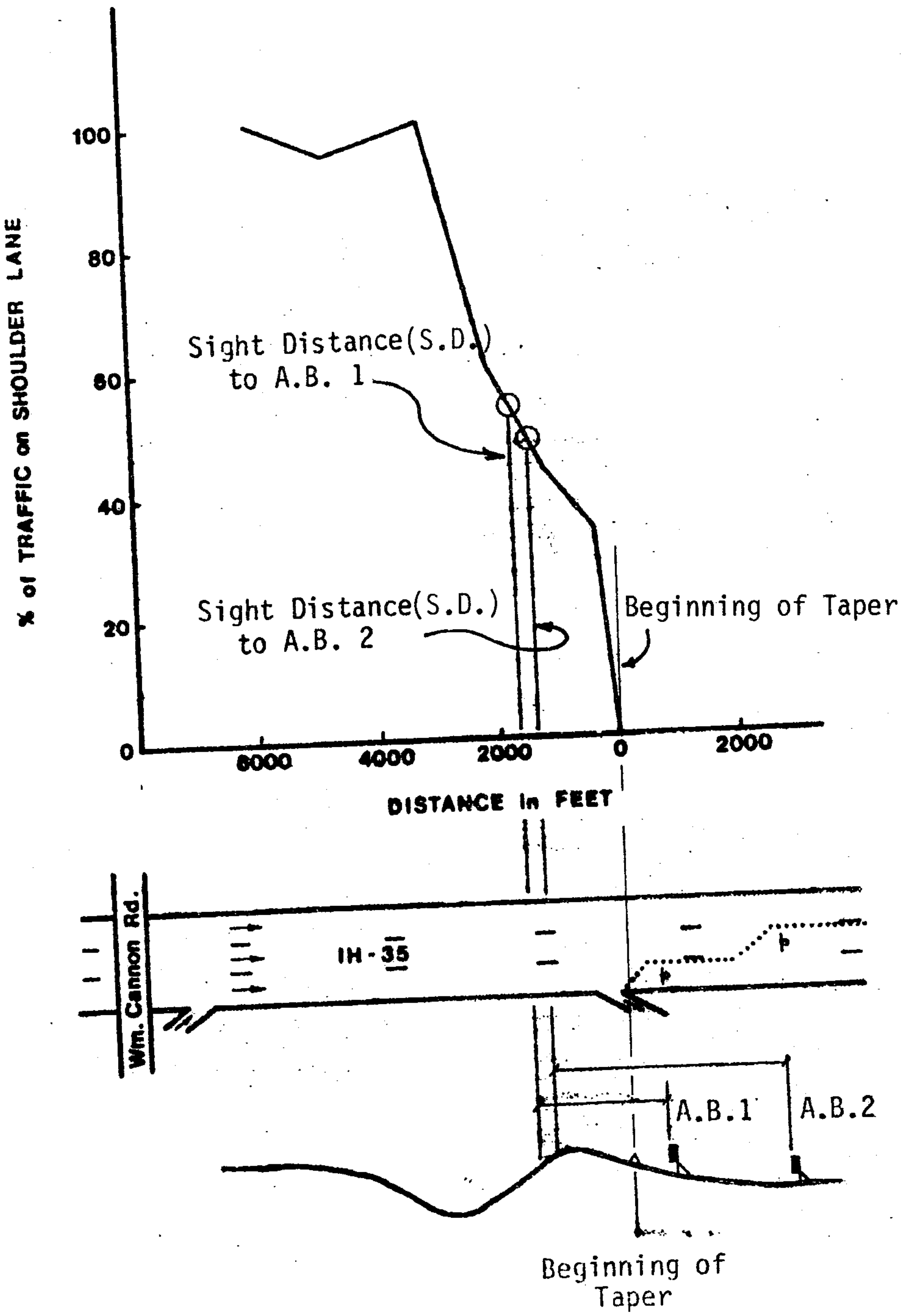
APPENDIX A

ARROWBOARD CASE STUDIES -

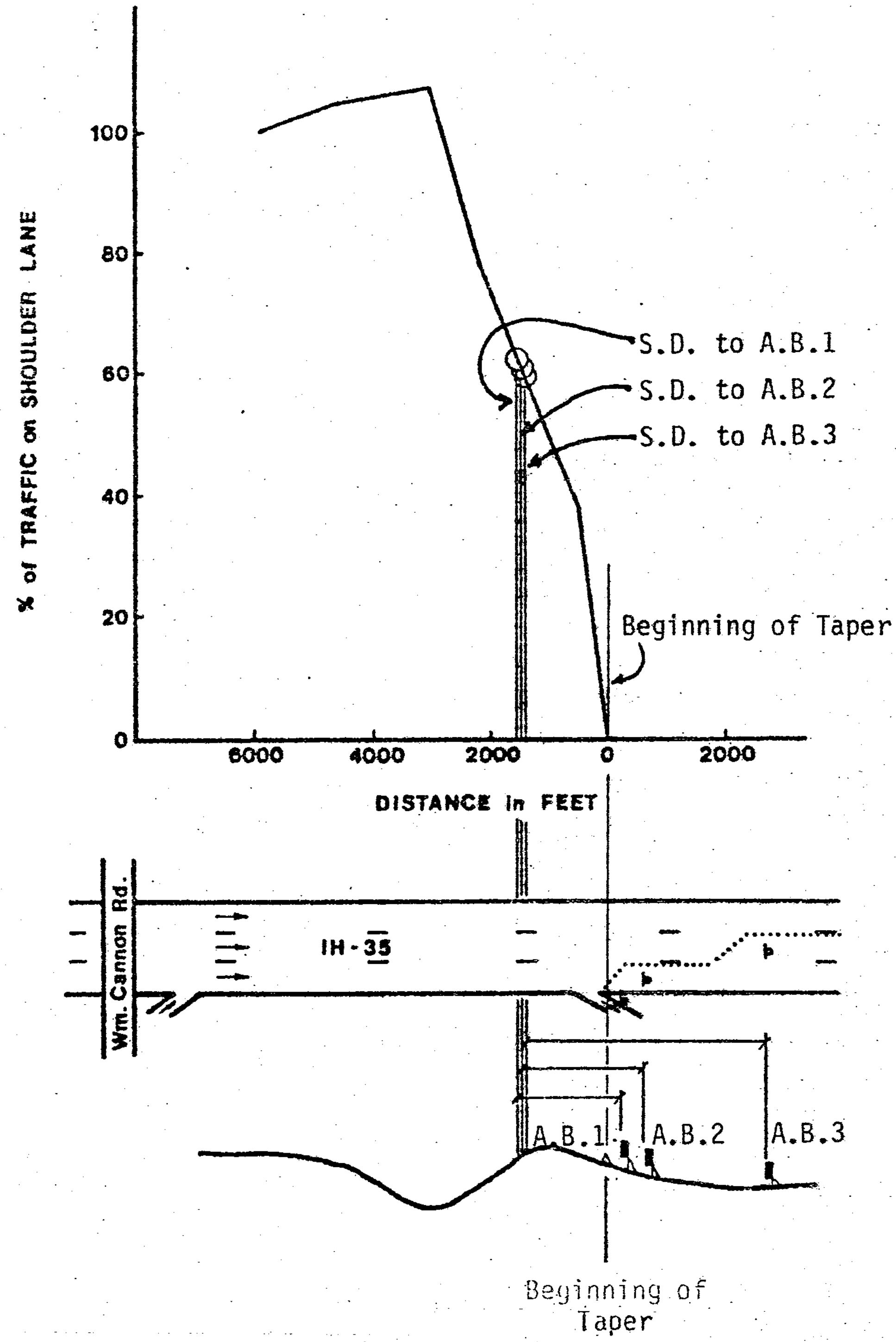
Placement in Advance of Taper

The results of each of the advance placement arrowboard studies for both Sites I and II are contained in the following pages. The graphs illustrate the percentage of traffic in the blocked lane upstream of the beginning of the taper and the relative sight distances to each arrowboard used.

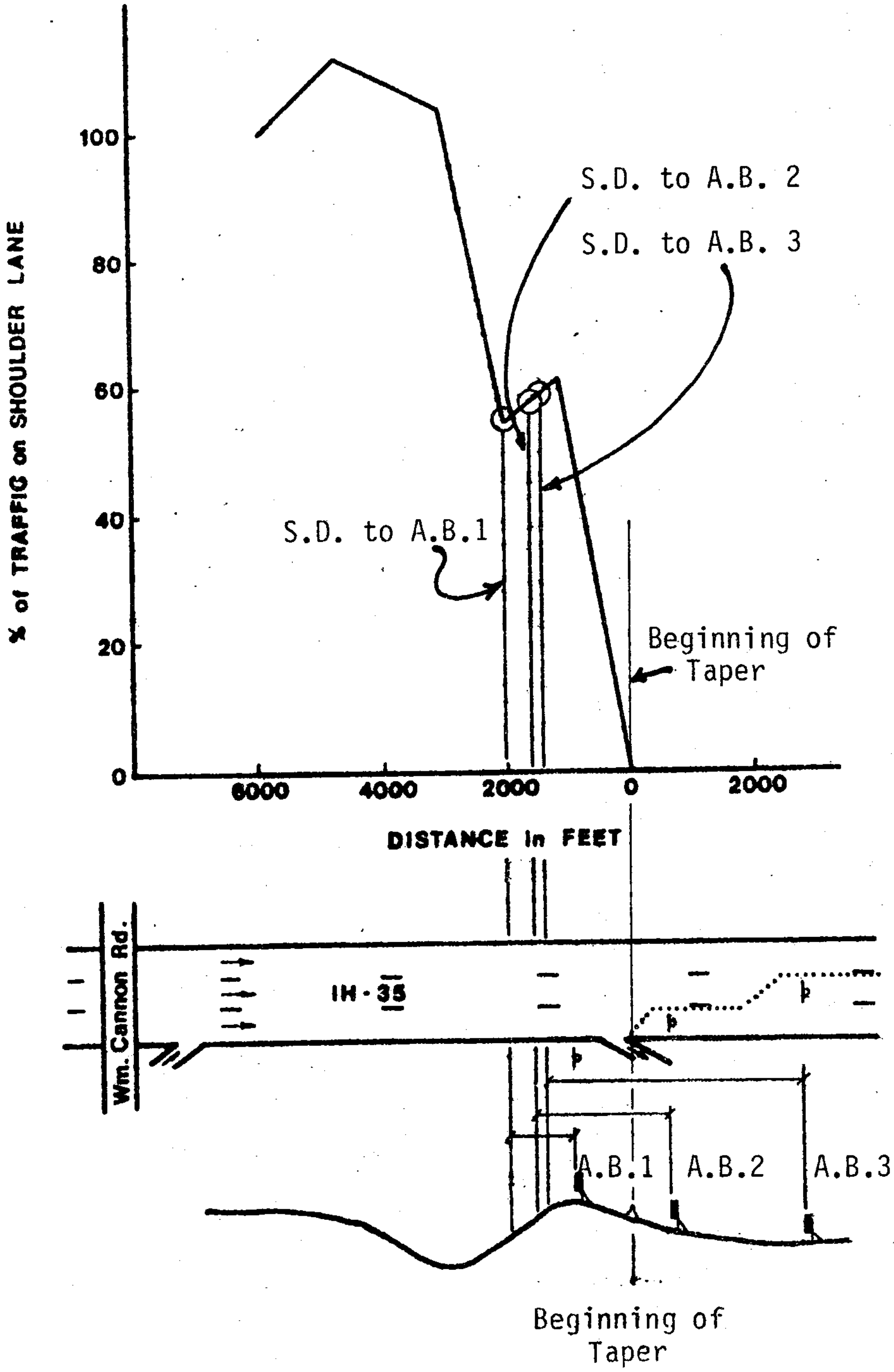
The plan and profile views below each graph illustrates the location of each arrowboard in relation to the cone tapers and the relative vertical alinement at each site.



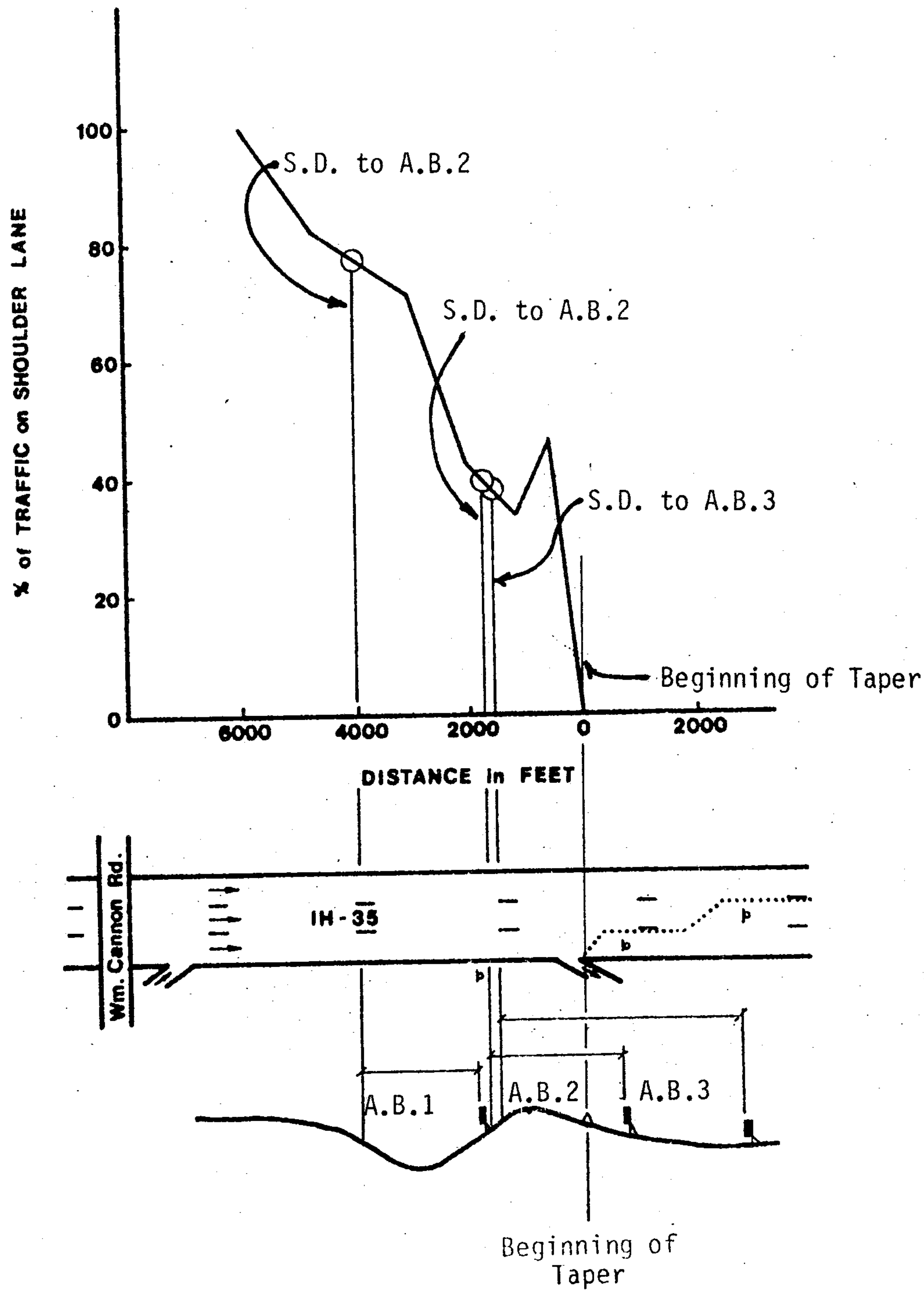
Site I - Base Condition



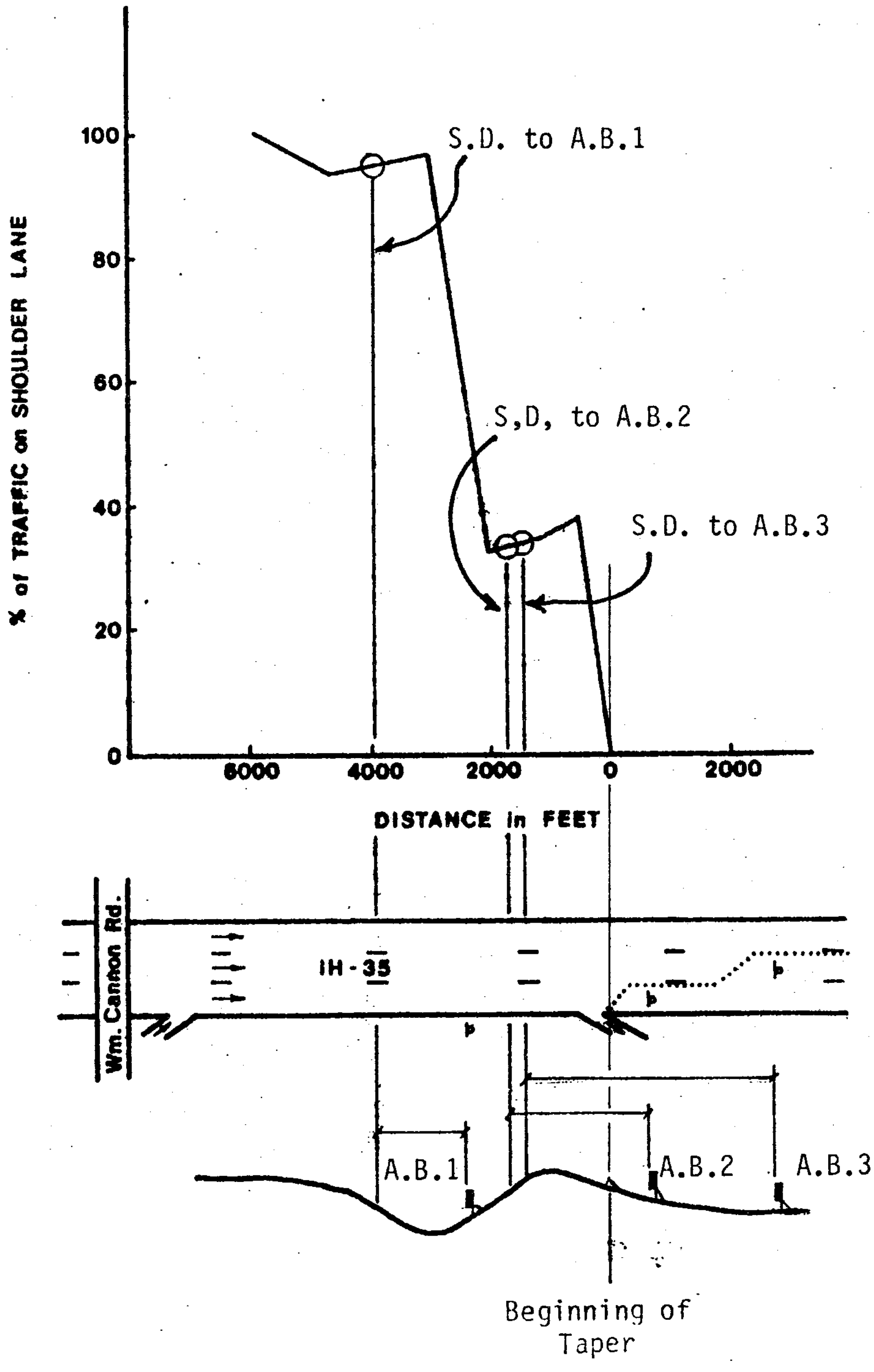
Site 1 - Arrowboard at the Beginning of the 1st Cone Taper and Base



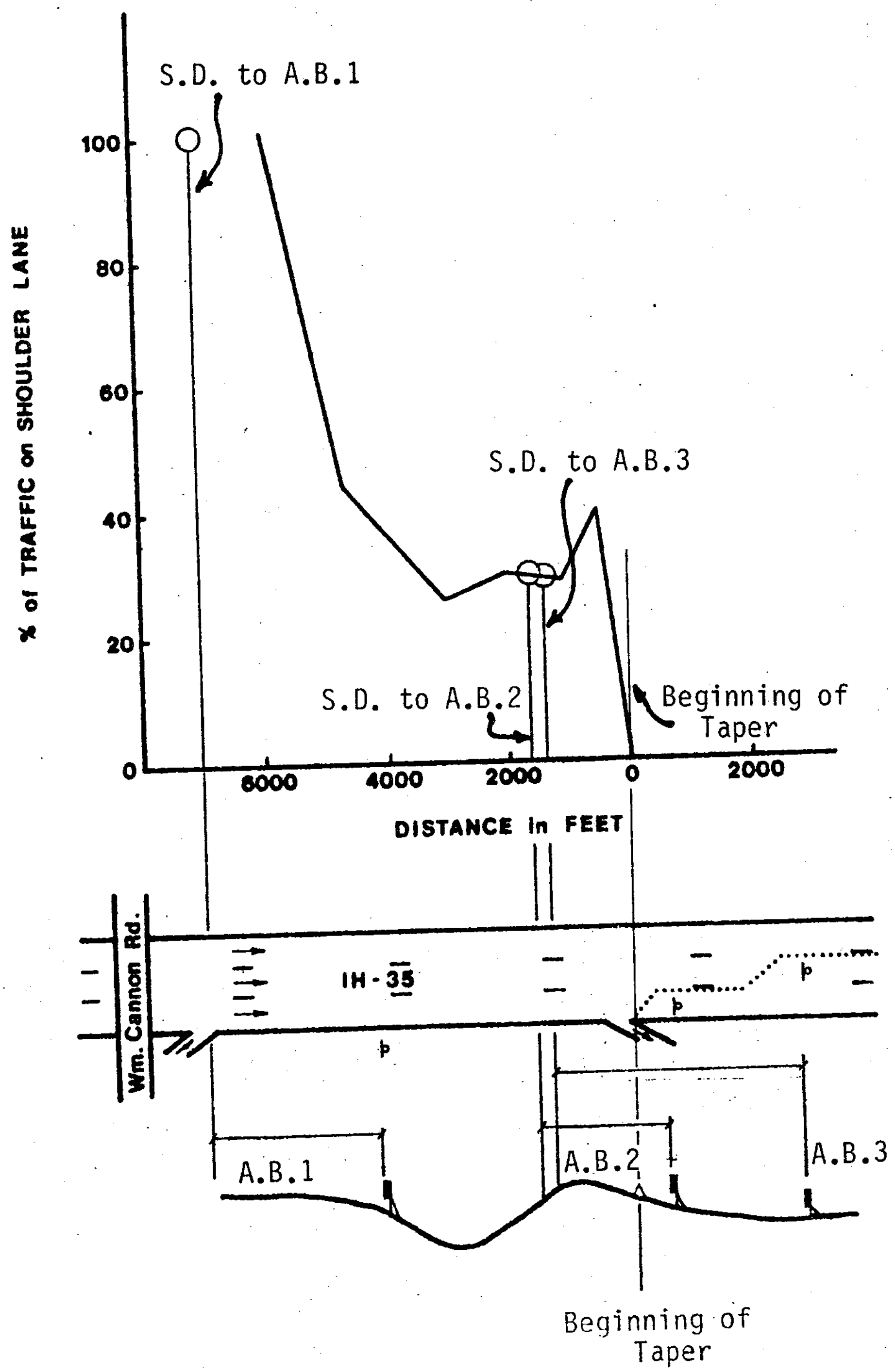
Site I - Arrowboard 1000 ft. in Advance of the 1st Cone Taper and Base



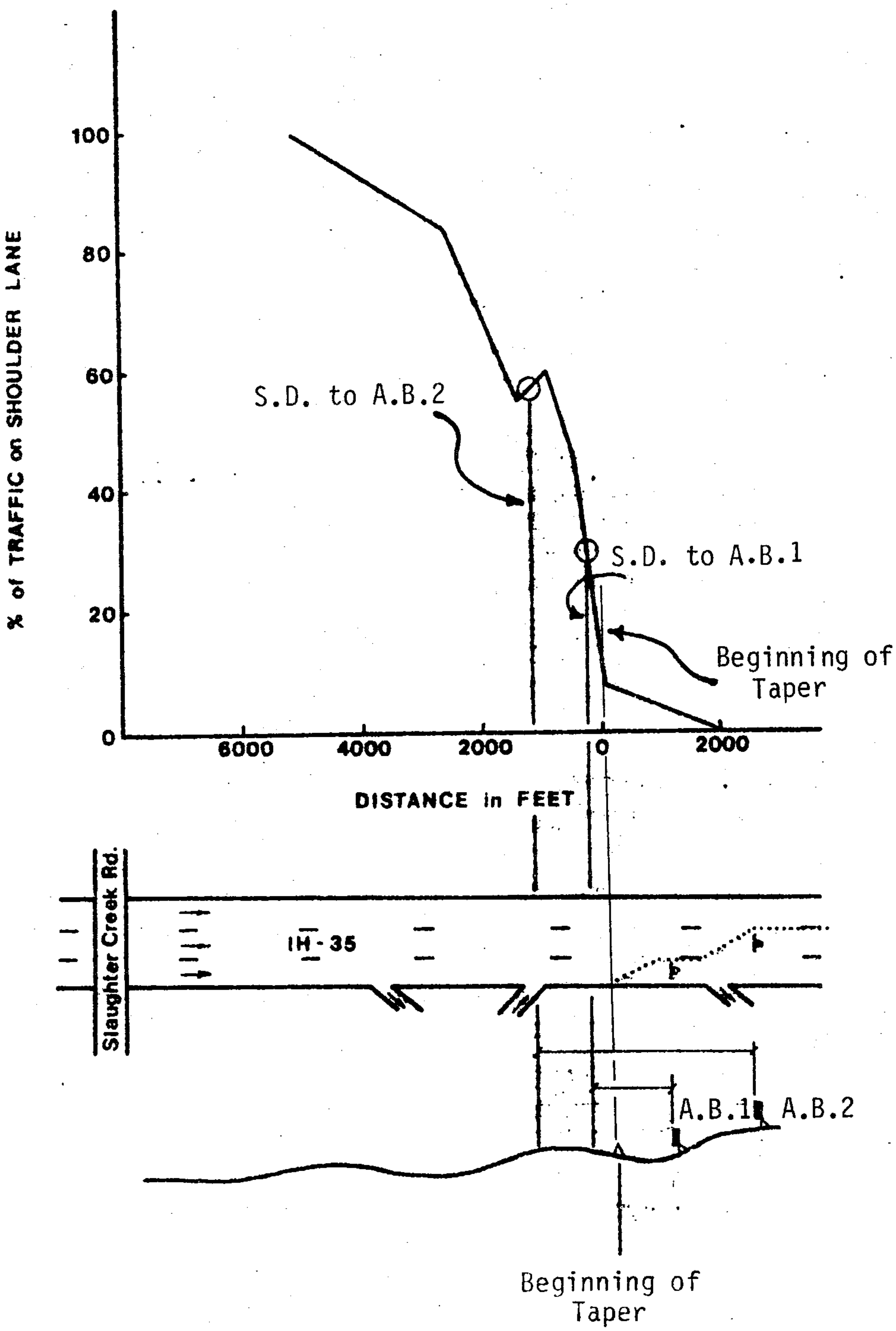
Site I - Arrowboard 2000 ft. in Advance of the 1st Cone Taper and Base



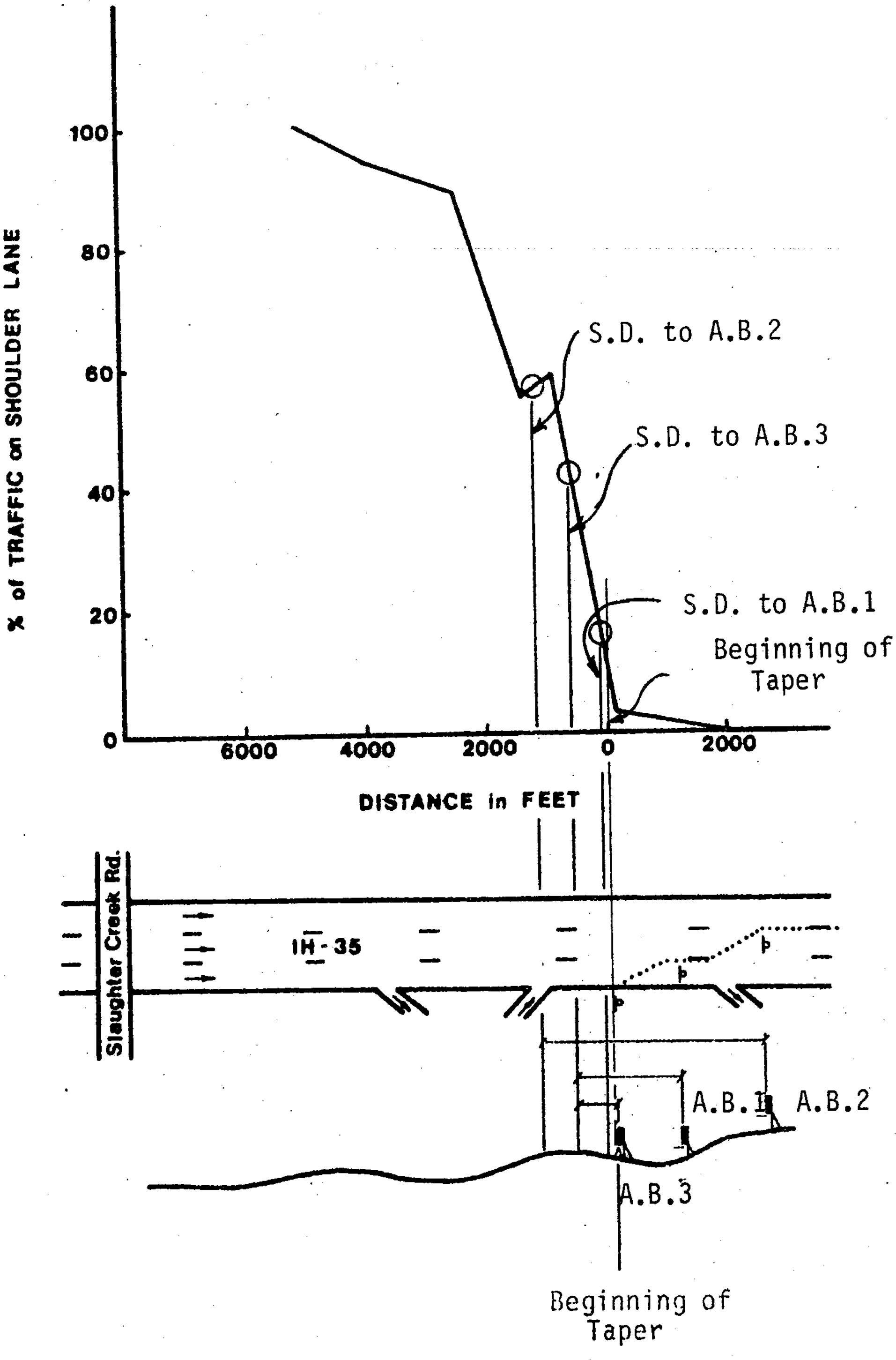
Site I - Arrowboard 2500 ft. in Advance of the 1st Cone Taper and Base



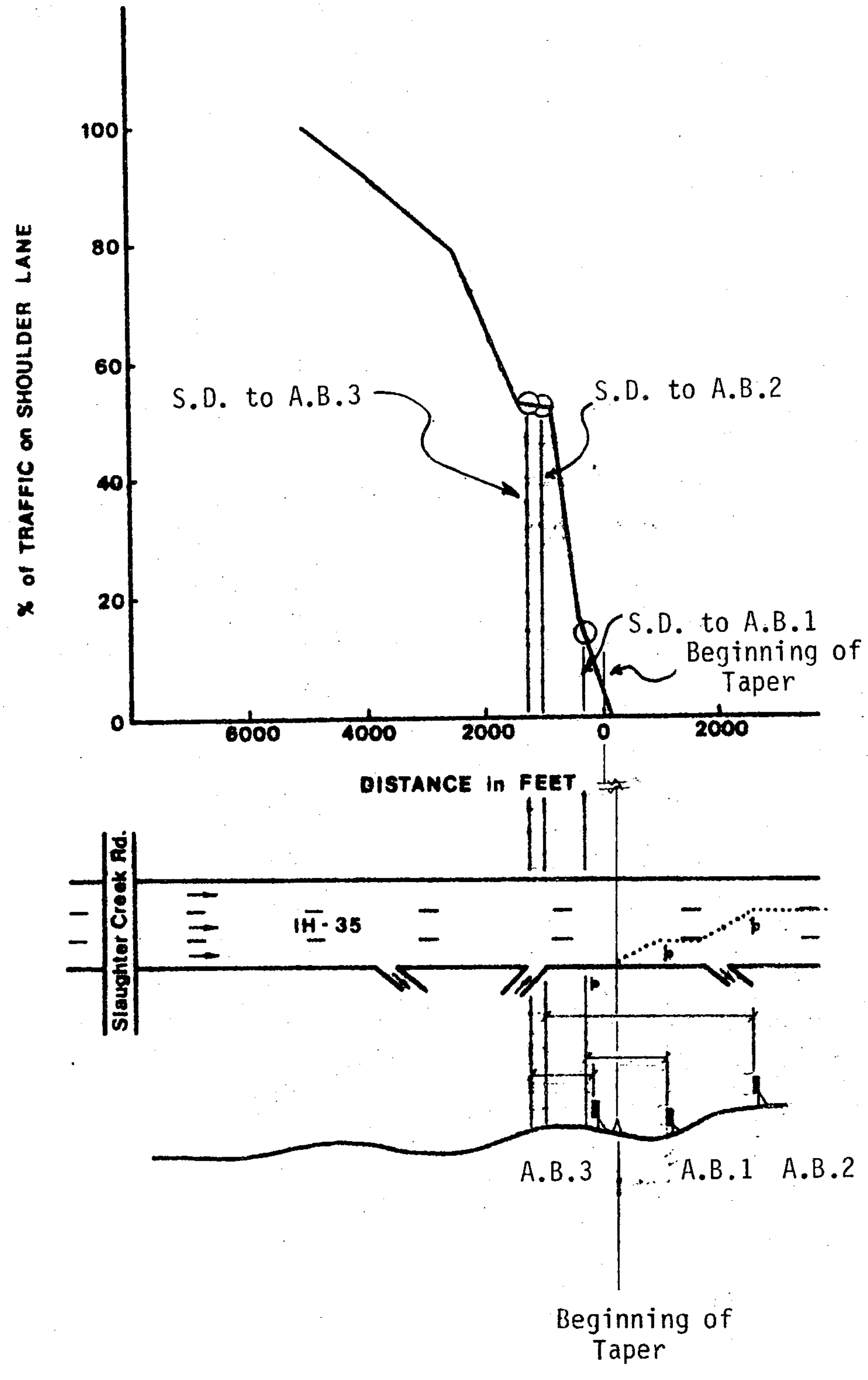
Site I - Arrowboard 4000 ft. in Advance of the 1st Cone Taper and Base



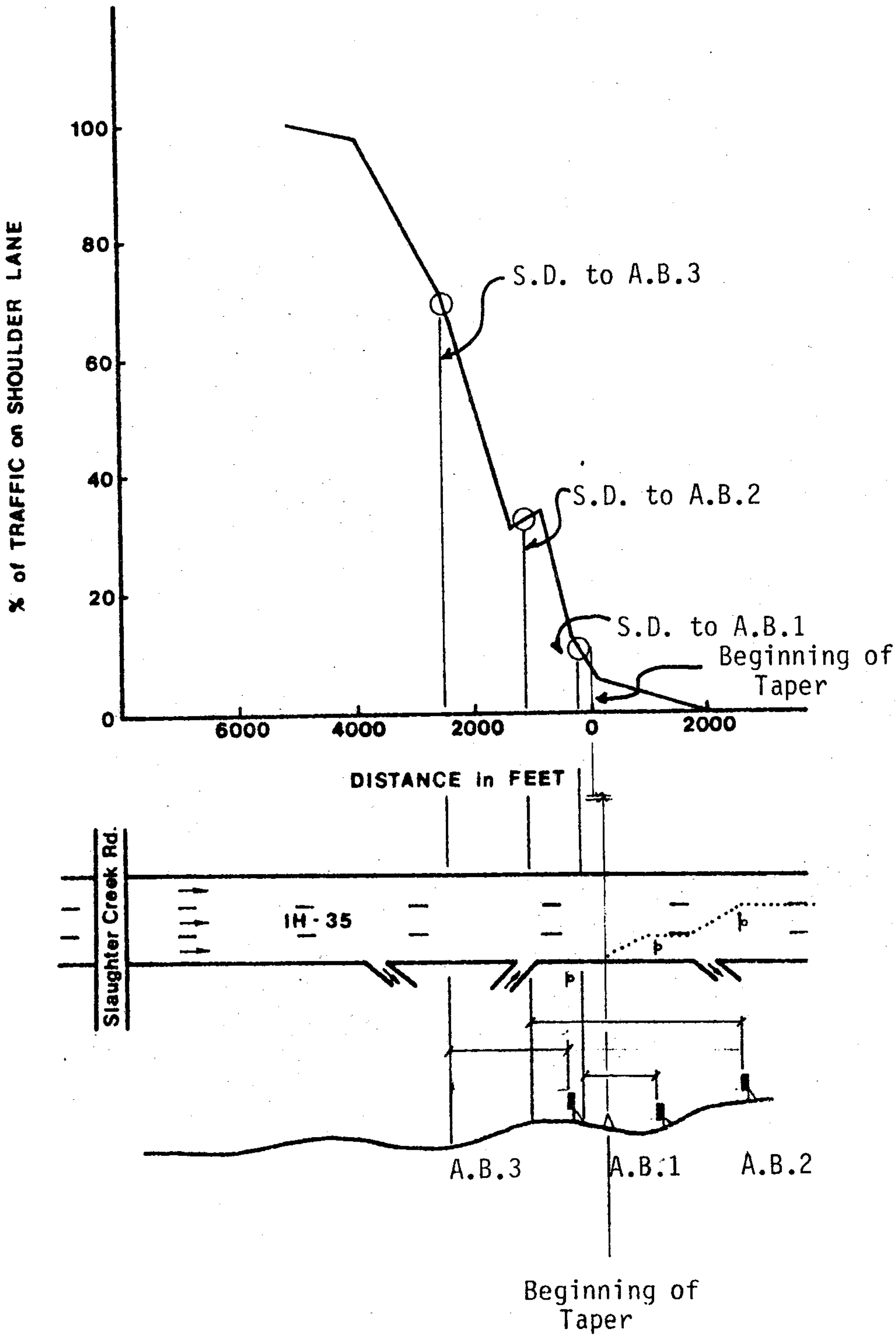
Site II - Base Condition



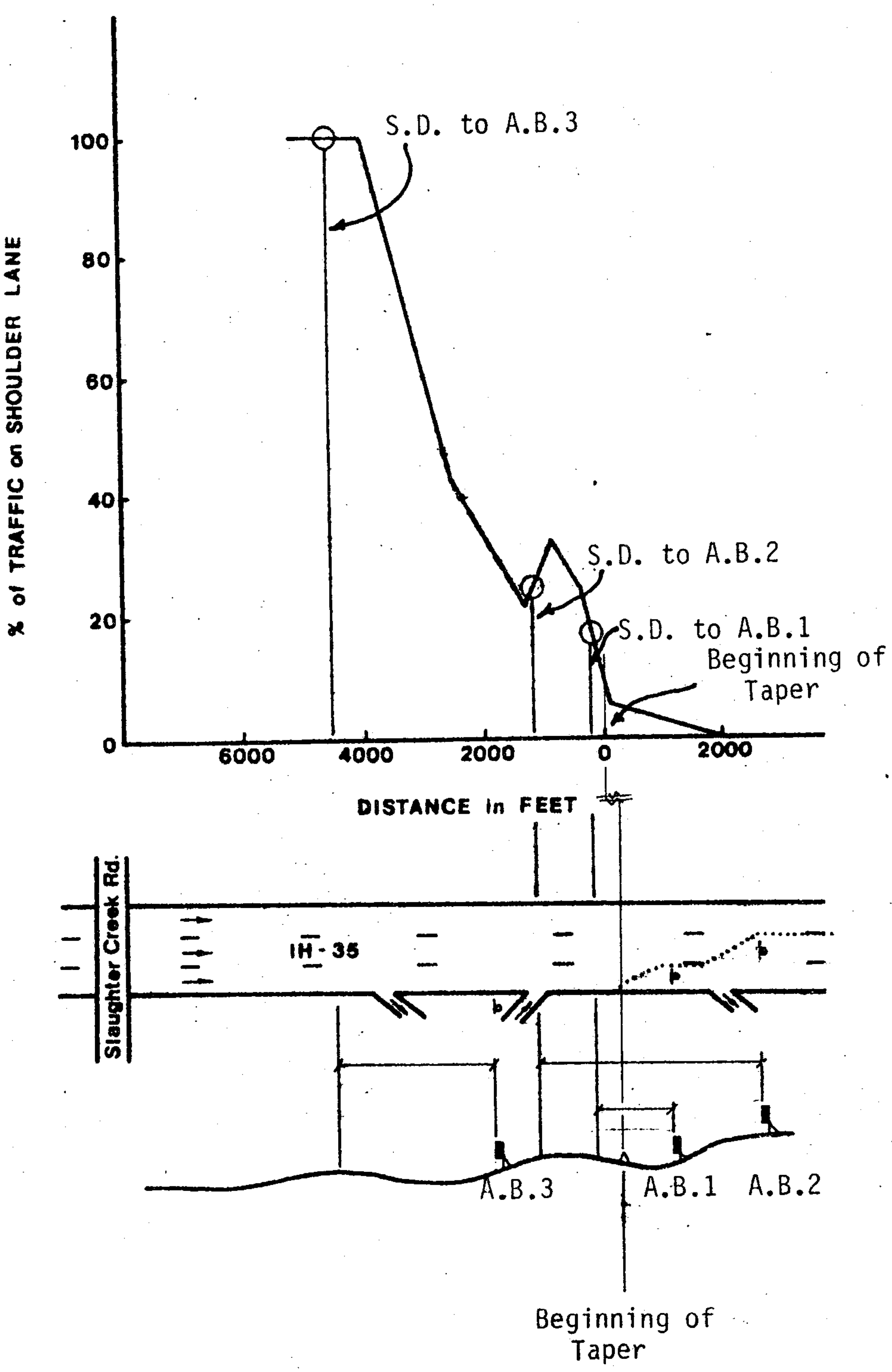
Site II - Arrowboard at the Beginning of the 1st Cone Taper and Base



Site II - Arrowboard 450 ft. in Advance of the 1st Cone Taper and Base



Site II - Arrowboard 550 ft. in Advance of the 1st Cone Taper and Base



Site II - Arrowboard 2000 ft. in Advance of the 1st Cone Taper and Base

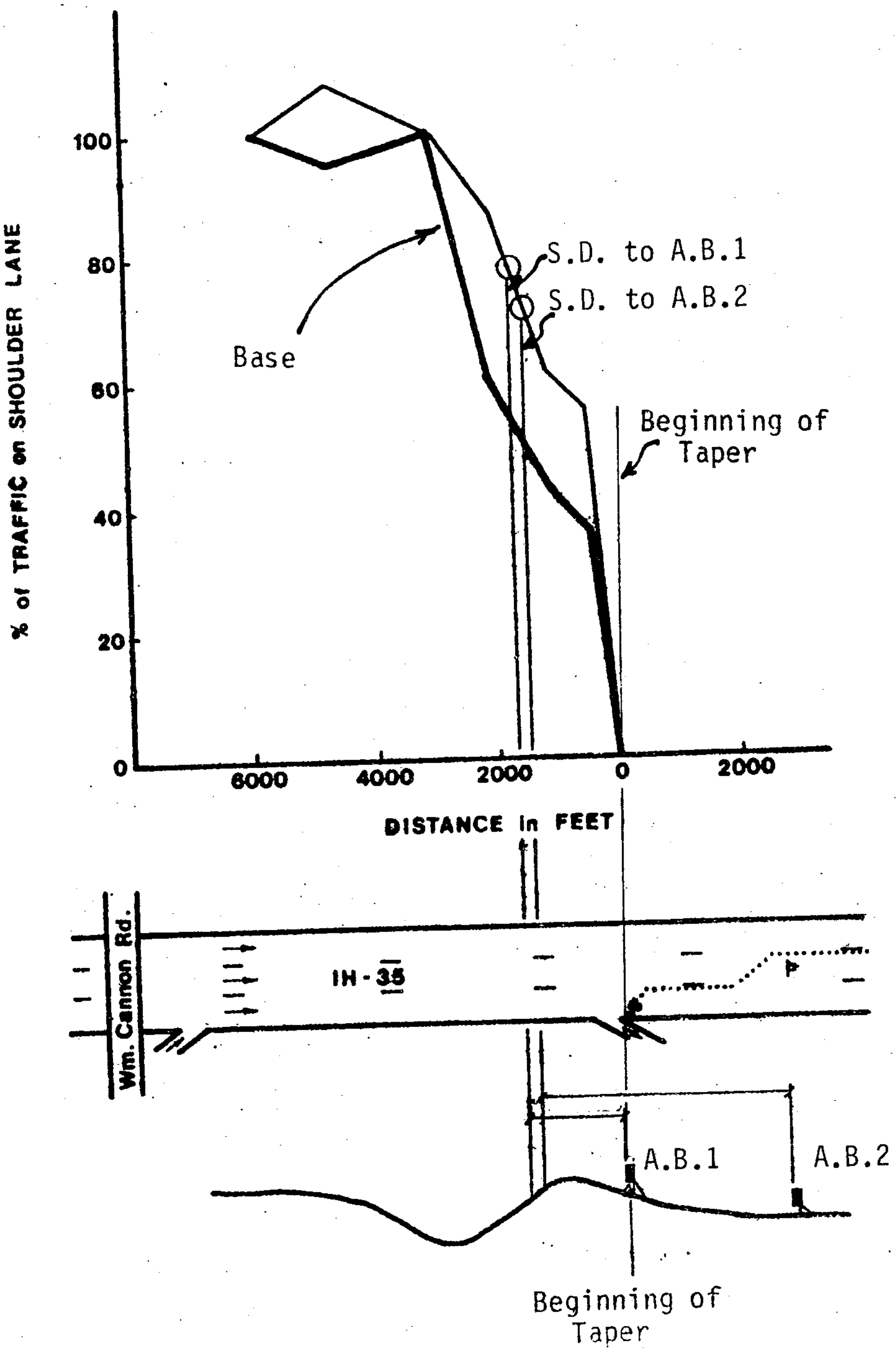
APPENDIX B

ARROWBOARD CASE STUDY -

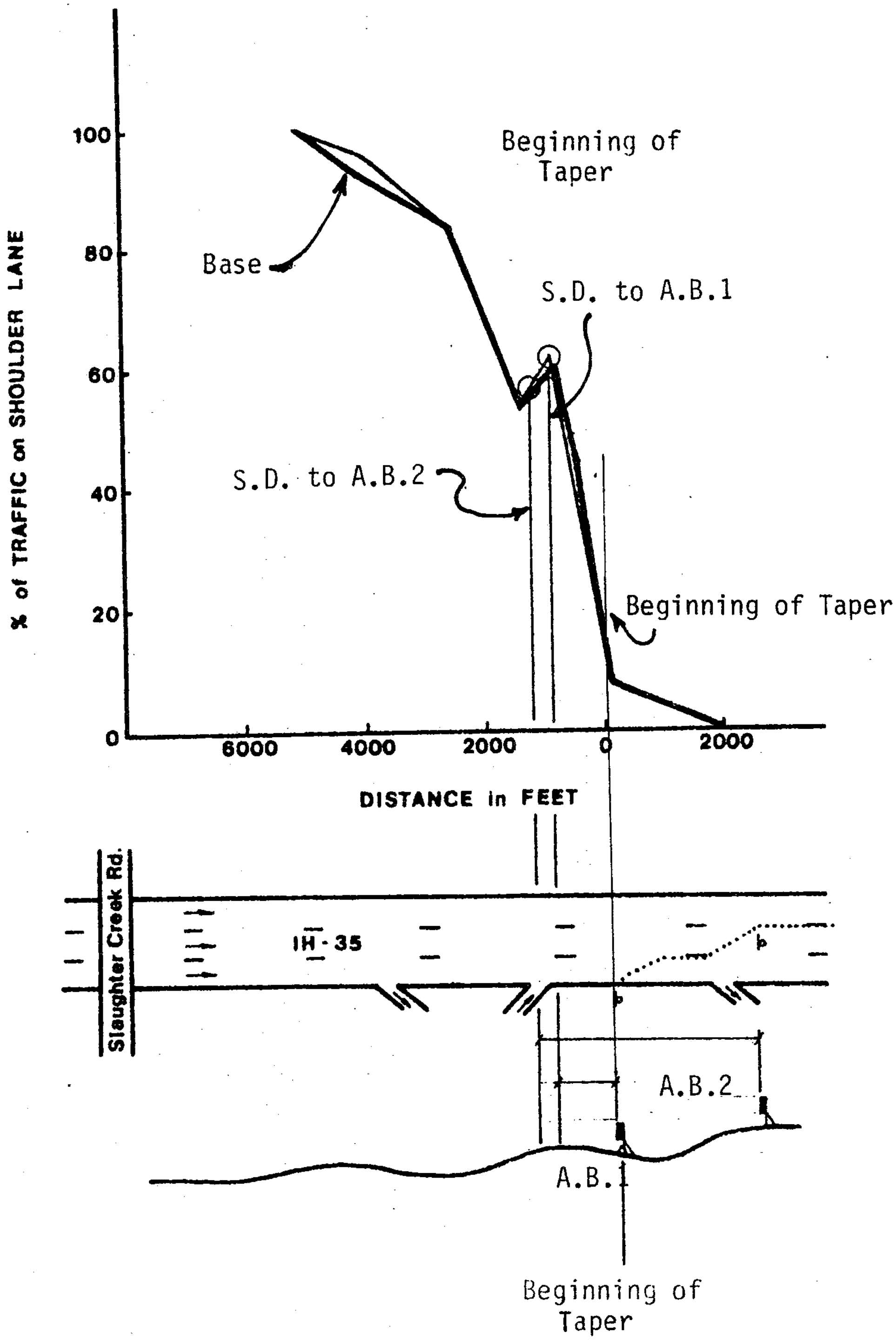
Placement at End of Taper vs. Placement at Beginning of Taper

The effect of arrowboard placement within the closure, either at the beginning or end of taper, is documented in this appendix. The base arrowboard position is at the end of the taper or at the closure.

The plan and profile view illustrate the relative arrowboard placement and the vertical alinement of each work zone.



Site I - Base Condition vs. Arrowboard Placement at the Beginning of the 1st Taper and at the End of the 2nd Taper



Site II - Base Condition vs. Arrowboard Placement at the Beginning of the 1st Taper and at the End of the 2nd Taper

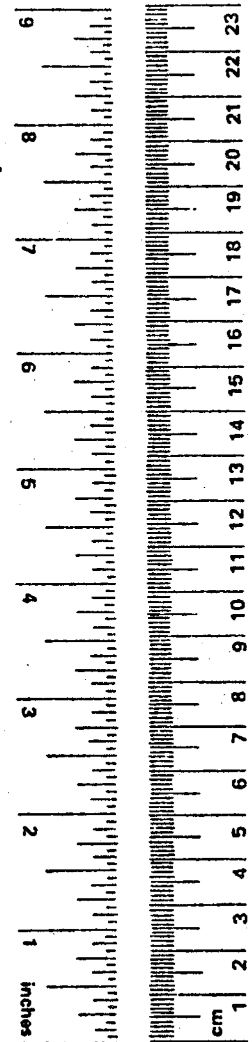
APPENDIX C

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

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

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



Approximate Conversions from Metric Measures

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