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August 21, 1972

H.2.63

MEMORANDUM TO: J. R. Harbison
State Highway Engineer
Chairman, Research Committee

SUBJECT: Research Report No. 332 (Final); "Operational Characteristics of Lane Drops;" KYHPR-70-63; HPR-(8), Part II

Last October we submitted an interim report (No. 313) bearing the same title as the final report now completed. Three sites have now been analyzed. The purpose of the interim report was to bring information already at hand to bear directly on the problem concerning the I 64 - I 75 route junction and combined section westward and northward -- which at that time was under consideration for safety revisions. The plan under discussion then would have, involved one or more lane drops.

I shall not report here the comments offered in the transmittal for the interim report but shall merely invite attention to them.

It seems to me now that the most significant finding from the study concerns directional lane splits which are well signed and marked. The margin for improvement by innovative markings etc. is small. Mr. Cornette recognized the insensitivity of drivers to additional helpful devices. By far the greater influence seemed to be sight distance -- which was necessarily a subjective conclusion and afterthought.

Mr. Cornette plans to submit this work to the University of Kentucky as a thesis (MSCE). He transferred to the Madisonville District in May and is serving as Traffic Engineer there.

Respectfully submitted,

Jas. H. Havens
Director of Research

JHH:gd

Attachments
cc's: Research Committee

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16. Abstract

Traffic behavior studies were conducted at seven lane-drop locations, representing four lane-drop classes. These studies were composed of conflict observations (consisting of both erratic movement and brakelight applications), spot-speed observations, and lane volume counts. Such a study was made before and after each different traffic control device installation in an attempt to determine which device was the most effective in minimizing conflicts at existing lane drops. A study of conflict deviations indicates that no single type of traffic control device studied was significantly effective in reducing erratic movement and brakelight rates at all seven lane-drop locations. Rather, it appears that different traffic control devices are generally most effective at each of the locations. The single-lane exit without taper constituted the lane-drop classification with the lowest conflict rates of the four different lane-drop classifications studied. The lane-termination classification had the next lowest conflict rates. Those lane drops with poorer sight geometrics were observed to have higher conflict rates. No definitive relationship between traffic conflict rates and either traffic volumes or accident rates was found for the lane drops studied. Certain data limitations were discovered.

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Research Report
332

OPERATIONAL CHARACTERISTICS OF LANE DROPS

FINAL REPORT
KYHPR-70-63, HPR-1(8), Part II

by

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Division of Research
DEPARTMENT OF HIGHWAYS
Commonwealth of Kentucky

in cooperation with the
U.S. Department of Transportation
FEDERAL HIGHWAY ADMINISTRATION

August 1972

INTRODUCTION

A lane drop is defined as a location on a highway where the number of lanes provided for through traffic decreases. For purposes of this study, the broad category of lane drops has been further subdivided into three specific classes: lane exits, lane splits, and lane terminations. These subdivisions are illustrated schematically in Figure 1. A lane exit refers to a location where the number of through lanes decreases at an interchange on a multilane roadway. A lane split denotes a major bifurcation of a multilane highway where the level of traffic service provided at the terminus of either fork is approximately equal. Thus, the lane split does not have the same exit connotation which is associated with a lane exit. The third category is the lane termination which occurs where a lane ends. A lane termination leaves a driver with no choice, he must merge into the other available lane(s). A lane termination also has no connection with an exiting situation.

Associated with the first two categories, lane exits and lane splits, is the concept of driver decision. The driver who is confident of his destination and the proper path thereto generally presents no conflict with the flow of traffic. The problem arises largely from those drivers who are inattentive, intoxicated, uncertain of how to reach their destination and(or) have improper driving habits. Further compounding the problem are those drivers who are high-expressive self-testers, applying one of the terms coined by Roberts *(1)*, and who will knowingly remain in the "wrong" lane to take advantage of passing opportunities -- even at the possible cost of encountering higher risk when eventually merging into the correct lane *(2)*. It is each of these types of individuals, as shown in Figure 2, who conflict with the traffic stream. Therefore, it is imperative that the driver be made aware of the necessity for an early decision regarding his course of travel. The driver who makes an errant decision and abides by it is not as dangerous as the one who makes a delayed decision and attempts, often too late, to correct it. Thus, the driver who perchance takes the wrong branch is likely to resort to desperation tactics and back up or undertake some other maneuver that is illegal or contrary to safety.

The purpose of the study reported herein was to evaluate certain operational characteristics of lane-drop situations as they are influenced by various forewarning, decision-demanding messages. The operational characteristics evaluated were traffic conflicts (both erratic movements and brakelight applications), vehicle speeds (both automobiles and trucks), and lane volumes. More specifically, the immediate purpose was to discover types of signs, pavement markings, and lane delineations which minimize or reduce traffic conflicts at existing lane drops. Such "band-aid" type improvements were chosen for study because, insofar as existing lane-drop locations are concerned, some reduction in risk can be more quickly and cheaply accomplished than can the elimination of "causes" *(3)*. It was also hoped that an optimum design criteria for lane-drop situations might be determined.

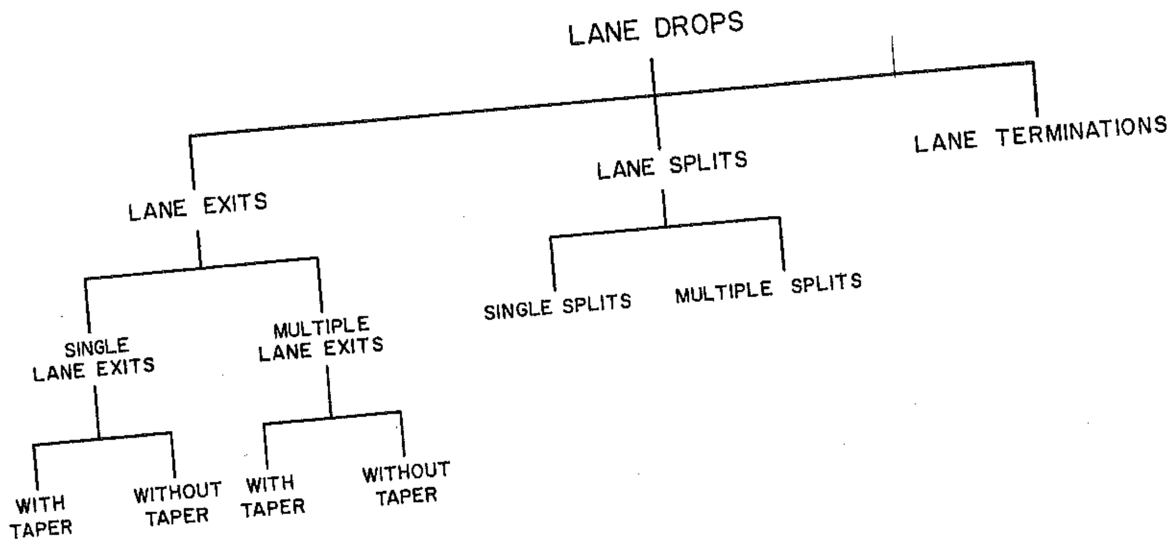


Figure 1. Lane Drop Types

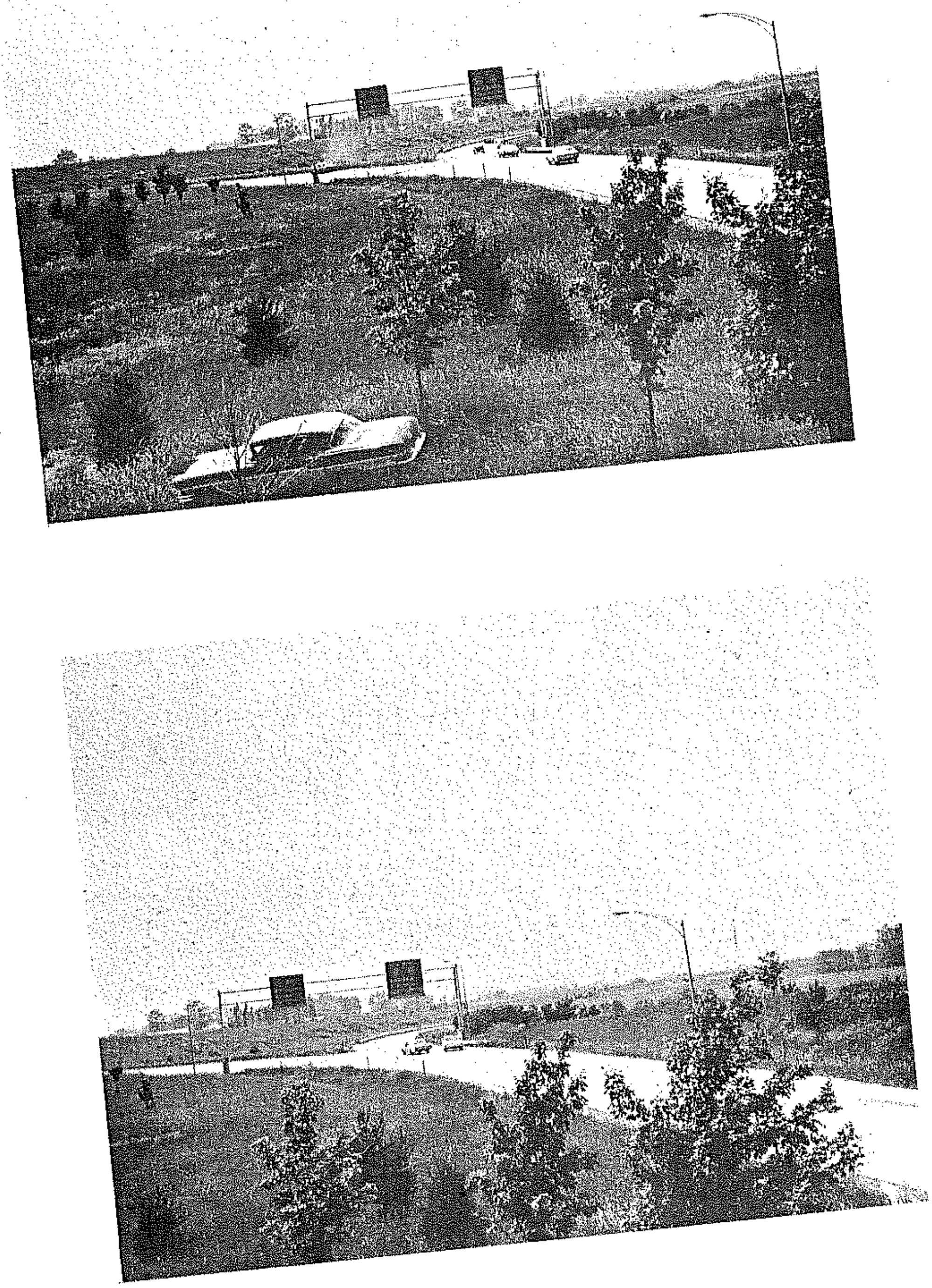


Figure 2. Typical Examples of Driver Confusion at Lane Drop Locations

Several standard and untried traffic control devices were selected for experimentation. A pilot study at a geographically advantageous location containing three lane splits was conducted, and data collection techniques were evaluated. Final studies were then conducted at four locations, each being a different lane-drop type.

LITERATURE REVIEW

The AASHO Special Traffic Safety Committee best described the undesirability of lane drops *(4)* when it said, "Lane drops should normally be avoided altogether by original design or later rebuilding, but where this is not practicable, fully adequate advance warning of lane-drop situations must always be provided to give drivers sufficient time to maneuver safely into the proper lanes." Others *(5, 6, 7, 8, 9)* are also critical of the potential hazards (vehicle entrapment, driver indecision, etc.) inherent in most lane-drop situations. Such hazards arise because lane drops are discontinuities in the highway system -- misfits in the driver's environment.

Although recognized by many as undesirable highway features, lane drops are a substantially unresearched area. One lane-drop study is currently being undertaken by the System Development Corporation of California *(10)*. It is essentially a study of traffic operations at several sites utilizing sequential aerial photographs to compute vehicle trajectories. At the present time, insufficient data have been accumulated to reach conclusions. Another study, by the California Division of Highways *(11)*, used accident data to evaluate lane drops. Four conclusions from this study were: 1) accident experiences were alike for all three-to-two lane terminations (three lanes transitioning to two lanes); 2) the single-lane exit without taper had the lowest overall accident rate; 3) in all two-to-one lane terminations, shoulder or right-hand through lanes had accident rates only half as great as the higher-speed median lanes continued through; and 4) there was only a slight increase in accident rates as the volume of traffic increased. A more recent study formulated, and validated by aerial photography, a mathematical model describing the density perturbation on a multilane freeway *(12)*.

No completely satisfactory manner of signing lane-drop situations has yet emerged *(4)*. Two studies concluded, insofar as nighttime conditions are concerned, that a carefully planned and executed delineator treatment is highly accepted by drivers, easily followed, and generally helpful *(13, 14)*. The **Manual on Uniform Traffic Control Devices** *(15)* also attests to the merits of a proper reflective treatment.

In a study of lane-termination signing in California, drivers' reactions to various signs viewed from film or slides were tested. The study indicated a rectangular four-foot by eight-foot sign bearing the message LANE ENDS -- MERGE LEFT was significantly better understood than four other signs or sign combinations used in the study *(16)*. A study in Michigan indicated some reduction in driver confusion with a "color coding" system, consisting of edgemarking, delineation and signing *(17)*. Another study by the Michigan Department of State Highways *(18)* disclosed that certain significant reductions in lane changes and erratic movements (70 and 78 percent decreases, respectively) could be attributed to a black-on-yellow EXIT ONLY panel and that the continued use of this panel for lane-drop situations would be advisable.

From two studies *(19, 20)* of the effectiveness of pavement edge markings, it was concluded that edge markings reduced both the number of fatalities and the number of accidents at intersections during both daytime and nighttime conditions. To explain these findings, it was suggested that edge markings encourage drivers to look farther ahead. Other studies describe the beneficial psychological effects on driver confidence provided by edge marking *(21, 22)*. Another study *(23)* related the usefulness of pavement markings in reducing hazardous lane changes where roadways diverge.

Two recent studies *(24, 25)* indicated it was possible to objectively measure the accident potential of a given area using the traffic conflict criterion, i.e., to evaluate the area dynamically -- not waiting for an accident history to evolve. The studies also indicated the traffic conflict technique provides a relatively quick test, in the form of "before and after" conflict counts, for determining the effectiveness of traffic engineering changes. Furthermore, the traffic conflict technique, according to these same studies, resulted in accurate measures of accident potentials, provided an understanding of basic causes of accidents and should ultimately lead to a reduction of traffic accidents. A later study employing the traffic conflict method at rural, dual highway intersections indicated that simple conflicts, defined as situations involving one or more vehicles taking evasive action, do not correlate closely with reported injury accidents. However, the same report states that serious conflicts, defined as situations involving a vehicle in at least a sudden rapid deceleration or lane change to avoid collision, correlate well with reported injury accidents both in location and time of day. Speed measurements were also made, but no evidence was found indicating that vehicles traveling faster than average were an important factor in generating accidents (26).

PROCEDURE

The pilot study was conducted at the I 64 - I 75 interchange in Fayette County. This is a standard three-leg interchange of directional design (with a three-level structure). At the time this interchange was designed, projected traffic volumes and existing safety design standards did not indicate an immediate need for constructing two-lane ramps on the legs. Therefore, this interchange provided three lane splits (Figures 3 through 5) which could be investigated as a pilot effort. The single-lane aspects of the legs provided an excellent example of the necessary decisions drivers must make.

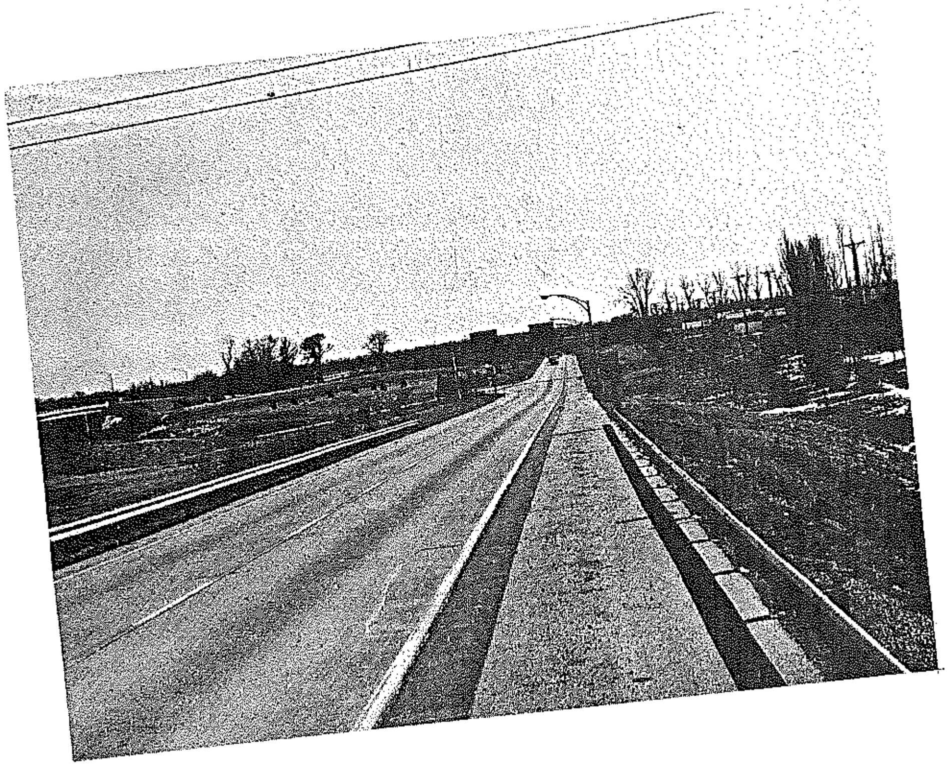
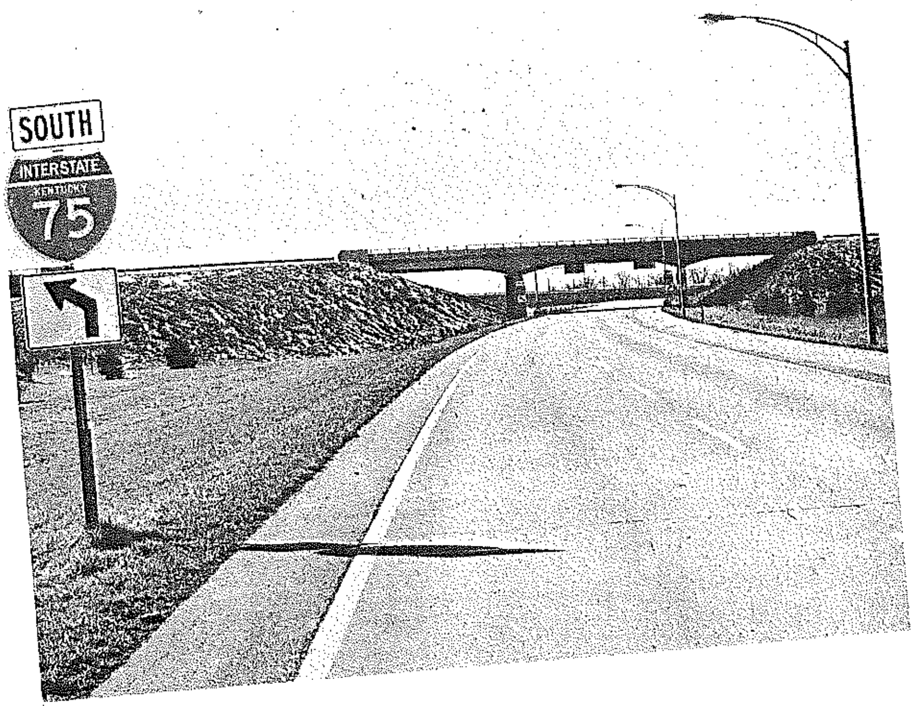


Figure 3. I 75 SB - I 64 EB Lane Split

Figure 4. I 75 NB - I 64 EB Lane Split



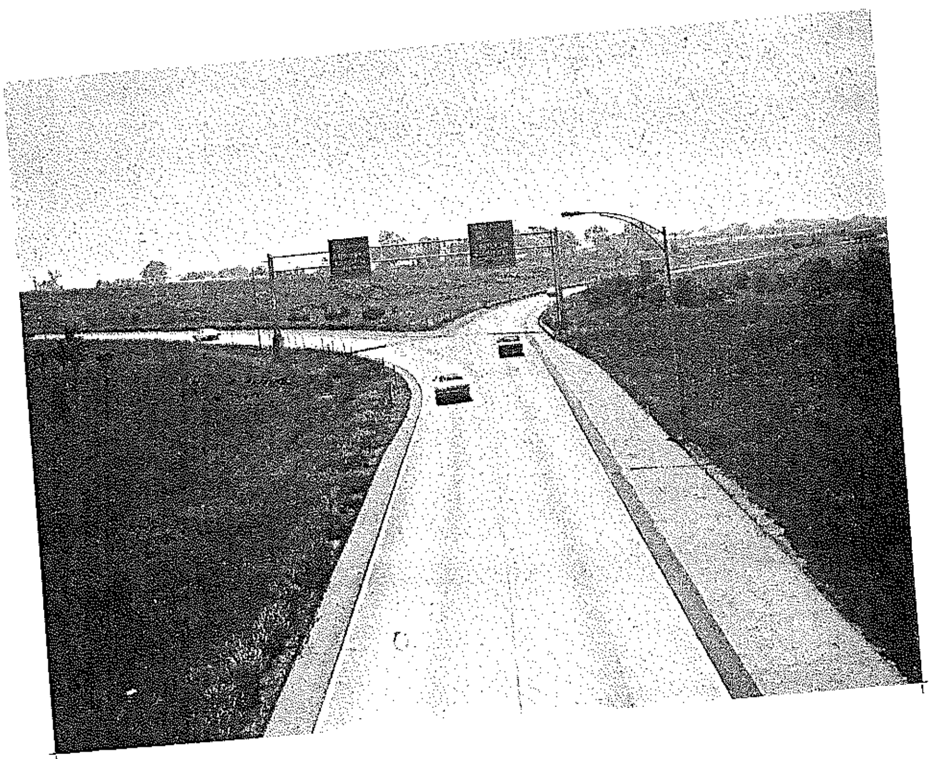


Figure 5. I 64 WB Lane Split

Conflict surveys (consisting of both erratic movement and brakelight application counts), spot-speed measurements and lane volume counts were made at each of the three approaches. Conflict studies were originally of 12-hour duration: nine hours in daytime and three hours in nighttime. Thus, at the I-75 northbound gore area, observations were made from noon to midnight on Sunday, the highest traffic-volume day in this direction. At the I-75 southbound gore area, the observation period was from noon to midnight on Friday. I-64 westbound lane-split observations were made on Tuesday because no exceptionally heavy traffic day existed there. Furthermore, the extremely light volume of traffic at this site under nighttime conditions made it unnecessary to record data after sunset. This schedule was abandoned because a linear multiple regression analysis failed to show any correlation between traffic volumes and erratic movement rates. The nine daytime hours were reduced to six, which were determined to be sufficient to obtain statistically significant results.

Erratic movements were grouped into six categories. These six categories -- cut across gore area, crowded weave, stopped or slowed drastically, swerved, backed at gore, and multiple error -- are defined in APPENDIX A. Brakelight actuations were also recorded.

Spot-speeds were recorded at each of the three approaches to the interchange. A minimum sample of 100 automobiles and 30 trucks was observed at four points in each two-lane approach: 1) the shoulder lane at the gore, 2) the median lane at the gore, 3) the shoulder lane a distance of 500 feet back from the gore, and 4) the median lane a distance of 500 feet back from the gore. Volume counts were made of both the median and shoulder lanes at each approach.

Finally, studies were conducted at the four lane drops shown in Figures 6 through 9. Each is typical of a different type of lane drop. The four sites were: 1) I-75 southbound at I-71 southbound, a single-lane exit with taper; 2) I-75 northbound at the 5th Street exit in Covington, single-lane exit without taper; 3) US 27-68 (Paris Pike) northbound, just north of New Circle Road in Fayette County, a lane termination; and 4) the western terminus of the Bluegrass Parkway at Elizabethtown, westbound, a single-lane split.

Conflicts, erratic movements and brakelight counts, were recorded for six daytime hours and three nighttime hours. Whereas in the pilot study, "stopped or slowed drastically" was one category, it seemed more definitive at this stage to separate them. "Backed at gore" was changed to "stopped and backed."

Only one set of observations was made at each site for each traffic control system utilized. Each set consisted of volume counts, conflicts, and spot-speed measurements. However, because random observers collected the conflict data for the pilot study sites, it was felt desirable to conduct "check" studies in an attempt to determine if any variability, due to observer bias, was being introduced. Three such check studies were made and the conflict results were not significantly different from the original surveys. There were a few significant (95 percent confidence level) mean speed differences, the reasons

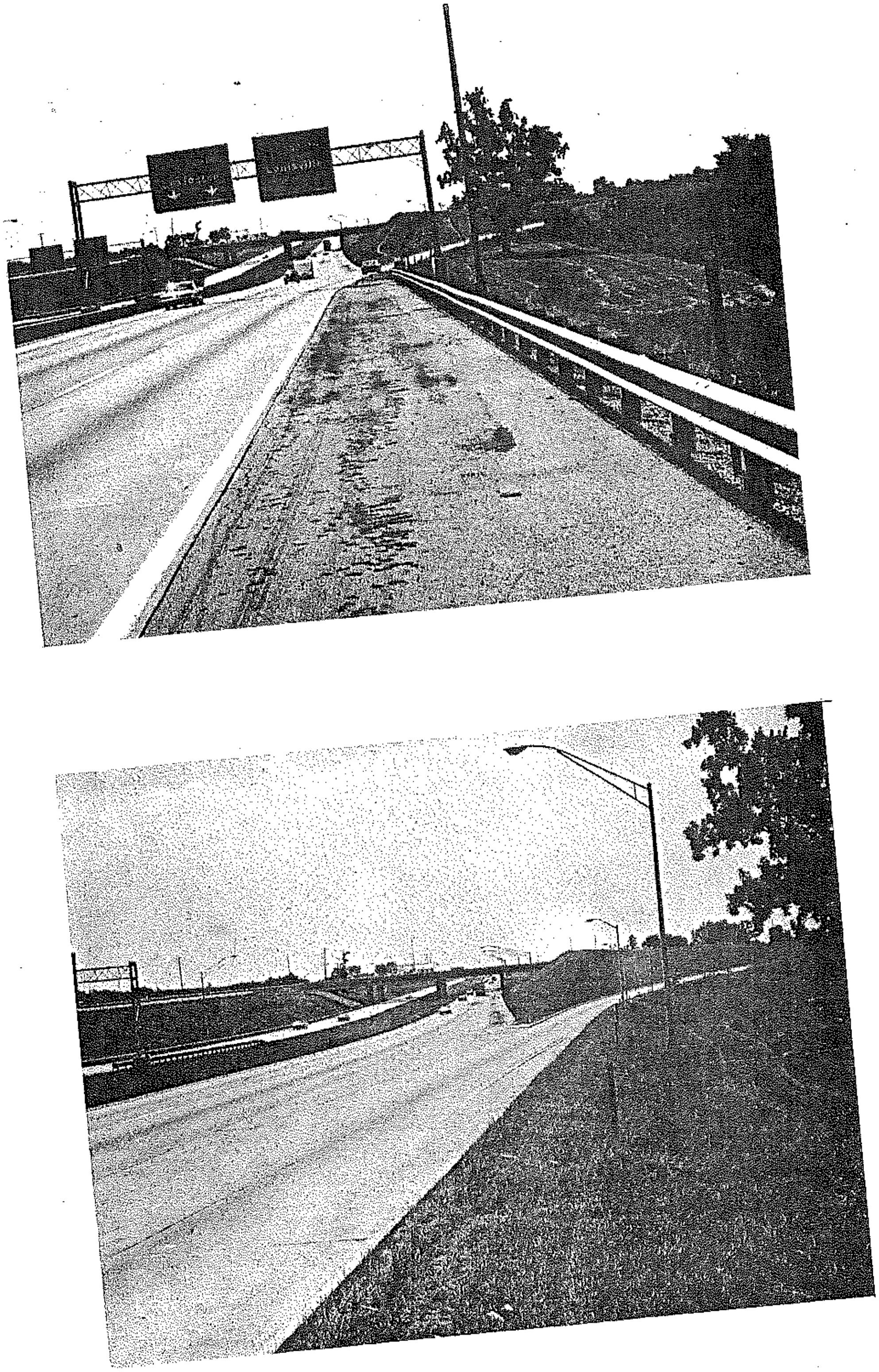


Figure 6. I 75 SB - I 71 SB Single Lane Exit with Taper

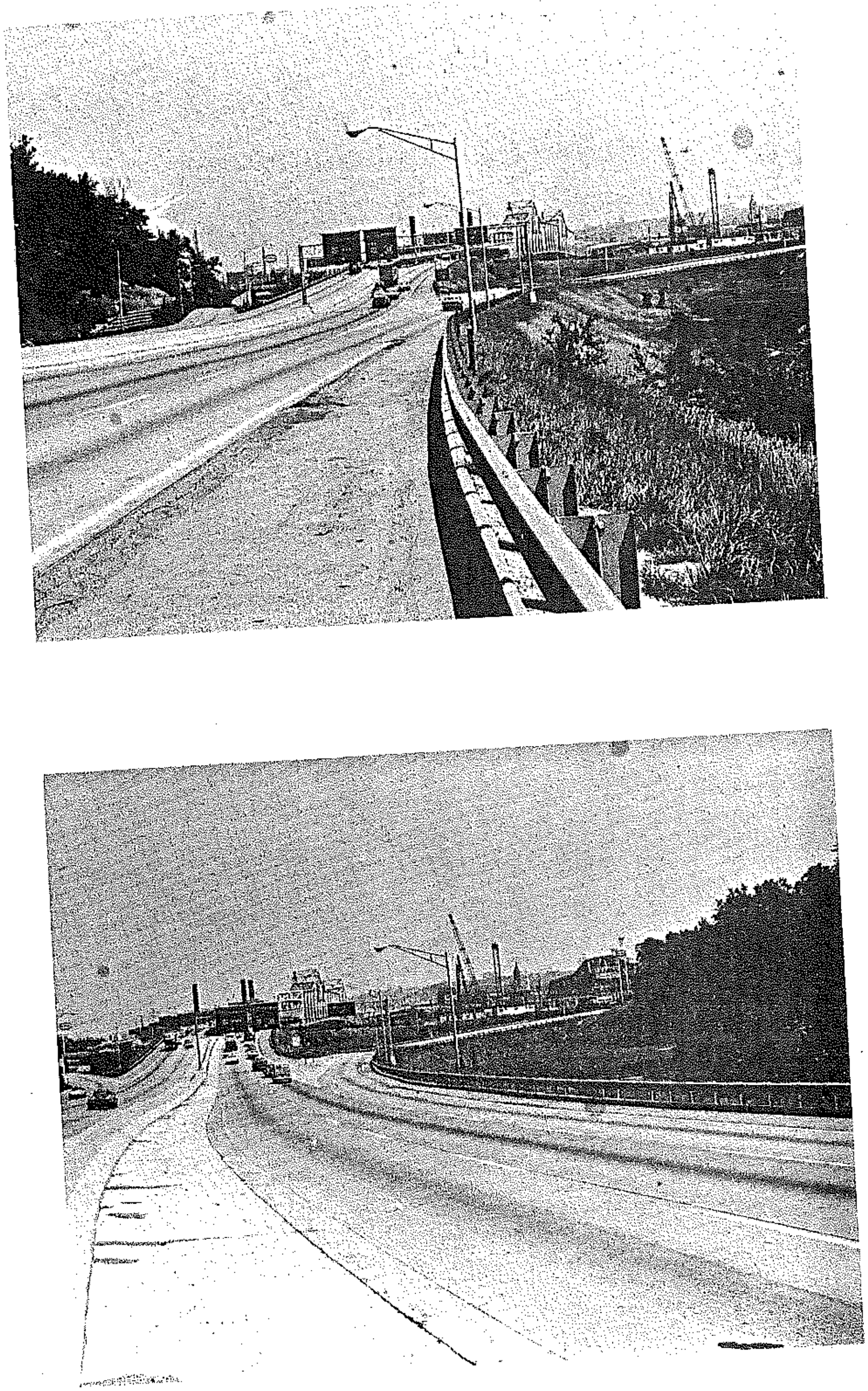


Figure 7. I 75 NB - 5th Street Single Lane Exit without Taper

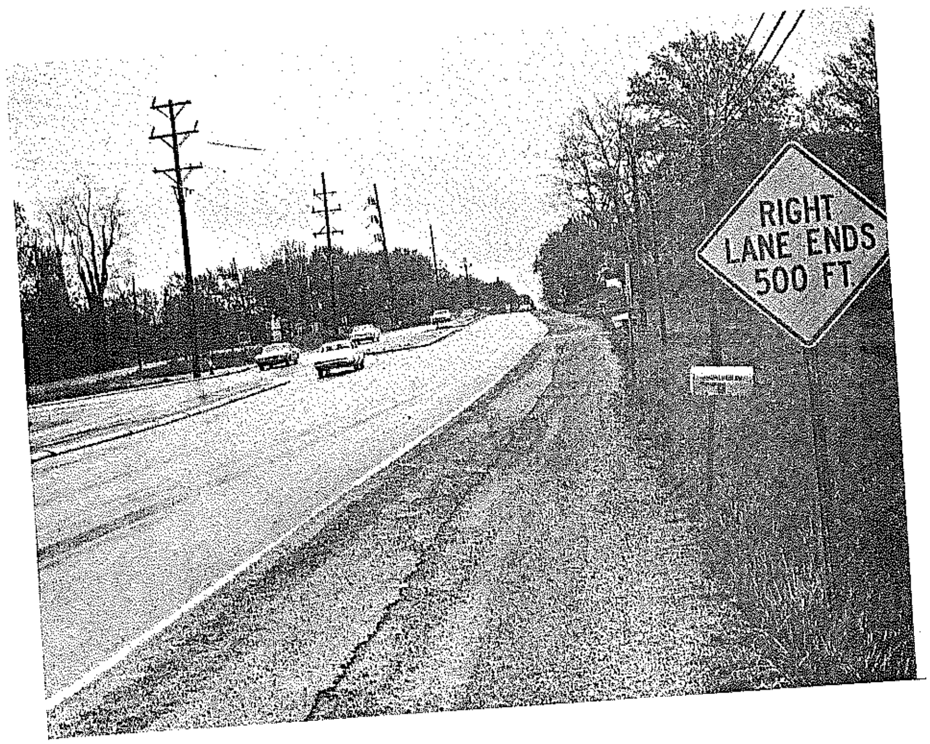
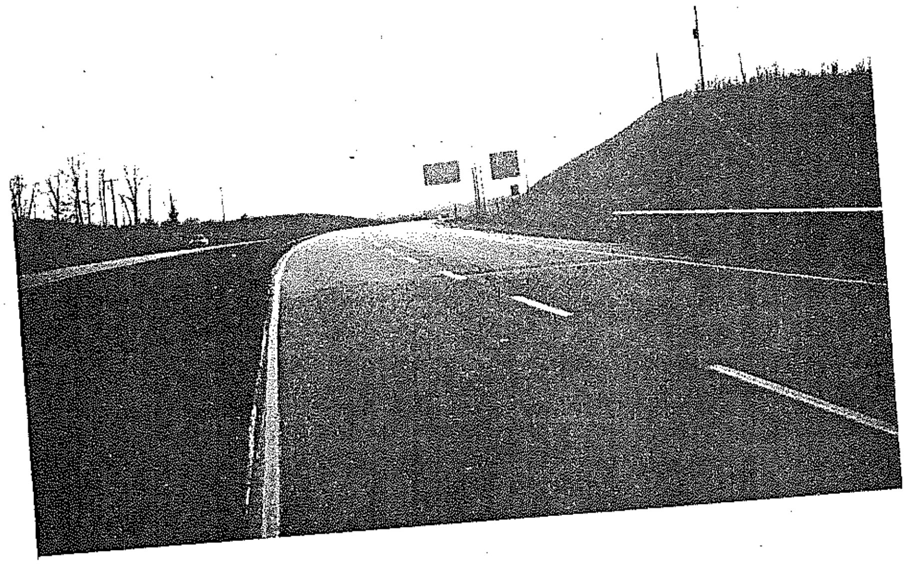


Figure 8. US 27 - 68 (Paris Pike) NB Lane Termination, North of New Circle Road, Fayette County



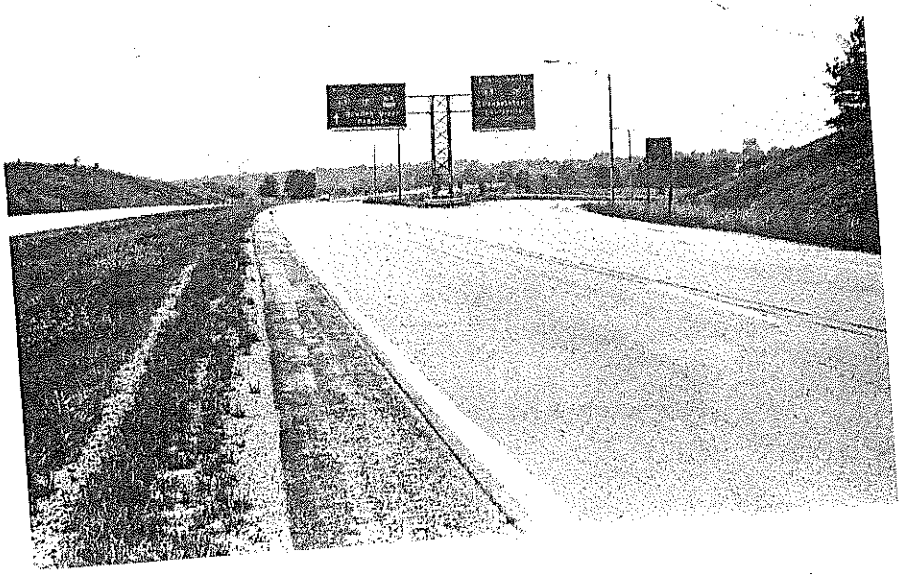


Figure 9. Bluegrass Parkway, WB Single Lane Split at Western Terminus

for which can only be speculated. Two possible explanations are offered here: 1) observers' bias in taking the radar meter readings and 2) actual speed difference due to the elapsed time (one year) between the original and check surveys. At any rate, the same observers were used whenever possible in the final surveys.

An inventory of existing traffic control devices was made. The pavement at all locations was marked with a four-inch wide, white centerline and equally wide, white edge lines. At six of the seven locations, approximately 750 feet of roadway leading to each lane drop was delineated by double amber reflectors spaced at 100- to 200-foot intervals. At greater distances from the lane drop, single white reflectors were used for delineation. There was no delineation at the Paris Pike lane termination. Original signing of the seven locations is shown schematically in Figures 10 through 16.

The intuitive but fundamental requirement for improving traffic flow is a fully adequate advance warning. Advance warning is necessary in order to give drivers sufficient time for decision making and subsequent maneuvering into the proper traffic lane. Three devices were used separately and in various combinations in this study: 1) five-inch wide, yellow edge lining and two-foot wide, yellow gore striping; 2) double amber reflectors on both sides of the roadway (where possible) with decreased spacing approaching the gore area; and 3) black-on-yellow exit ONLY signs. In addition, the Paris Pike lane termination was re-signed according to guidelines set forth in the new 1971 **Manual on Uniform Traffic Control Devices for Streets and Highways.** The new signing scheme is illustrated in Figure 17. Typical edge lining and delineator placement are illustrated in Figures 18 and 19. A black-on-yellow exit ONLY panel is shown in Figure 4.

Early in the pilot phase of this study, time-lapse still photography was utilized in an attempt to record two-dimensionally the traffic flow characteristics at a lane drop. It was felt that vehicle taillight tracings would give the reader some insight into the merging and erratic maneuvers that occur. However, difficulty was encountered in getting sufficient camera elevation for adequate viewing, and this portion of the study was terminated. Nonetheless, an overpass at the I-64 westbound lane split afforded the proper camera elevation for one location, albeit the overpass was located too close to the gore area to adequately record merging maneuvers. Figure 20 is the singular result of this phase of the study, and it does show with clarity the traffic flow at the I-64 westbound location, including one erratic movement at the gore area.

FINDINGS AND DISCUSSION

To enhance the clarity of findings, data analysis has been subdivided into six different comparisons: 1) conflicts with site geometrics, 2) conflicts with accidents, 3) erratic movement and brakelight rates

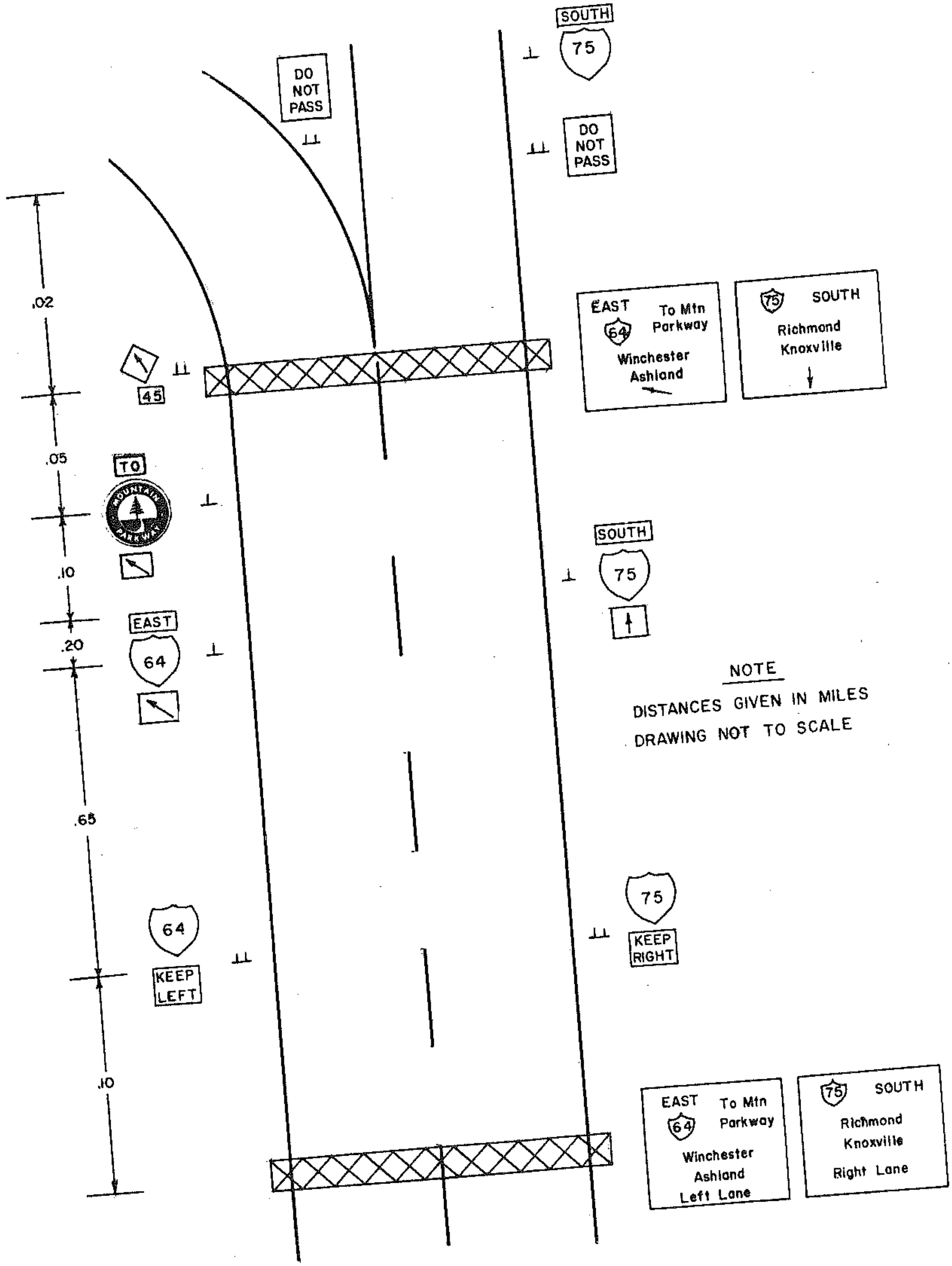


Figure 10. Original Signing Schematic of the I 75 SB - I 64 EB Lane Split

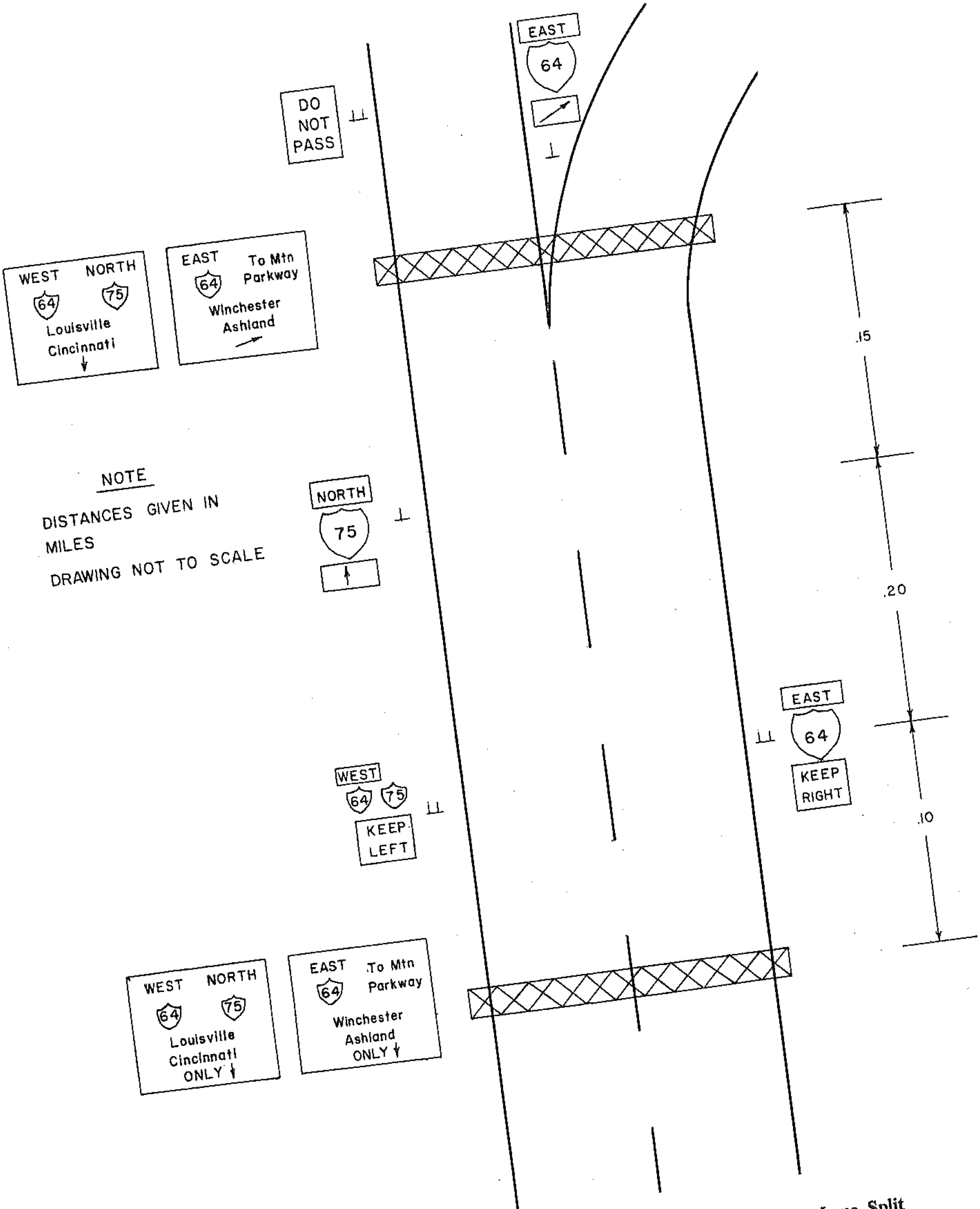


Figure 11. Original Signing Schematic of the I 75 NB - I 64 EB Lane Split

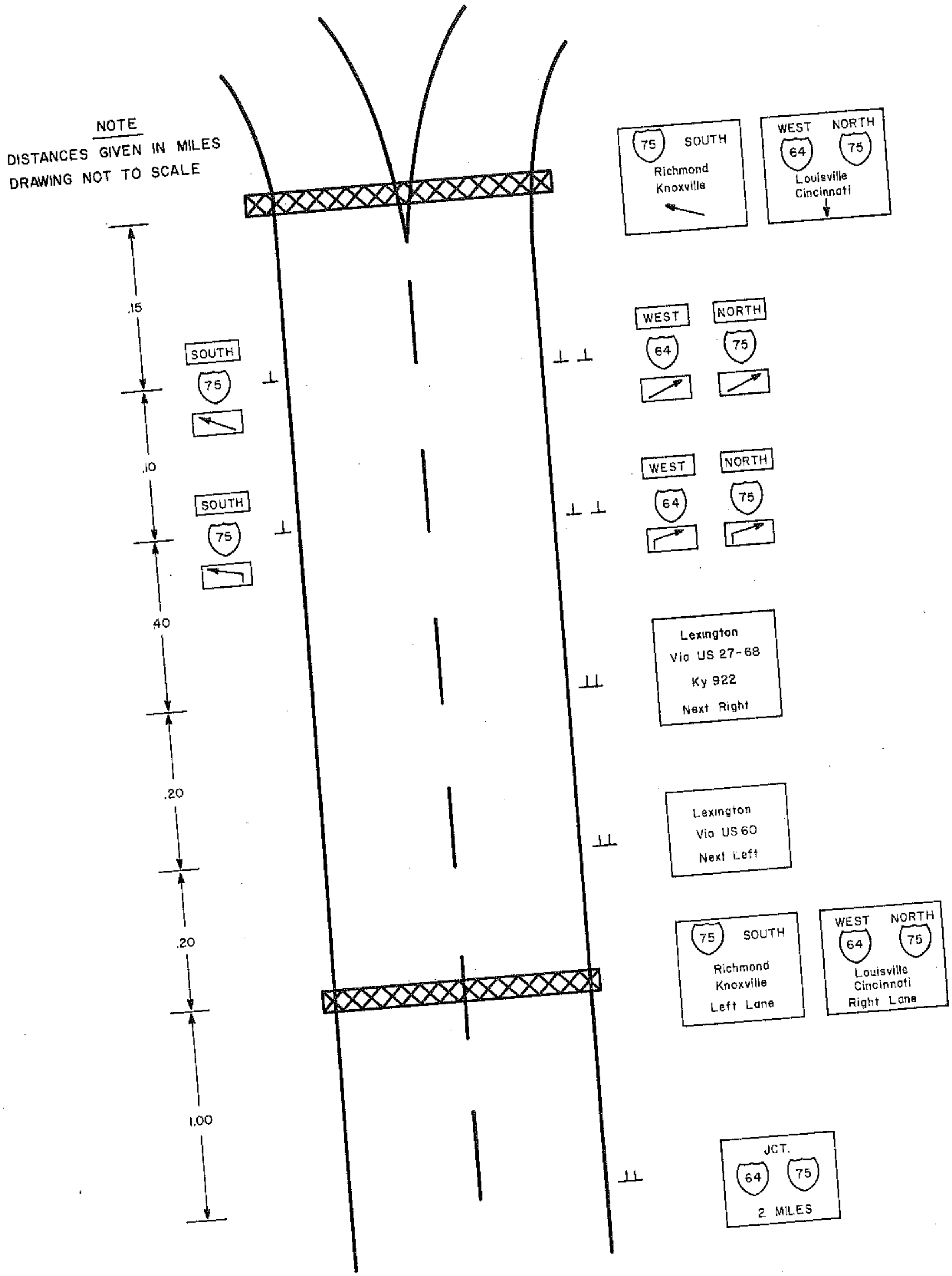


Figure 12. Original Signing Schematic of the I 64 WB Lane Split

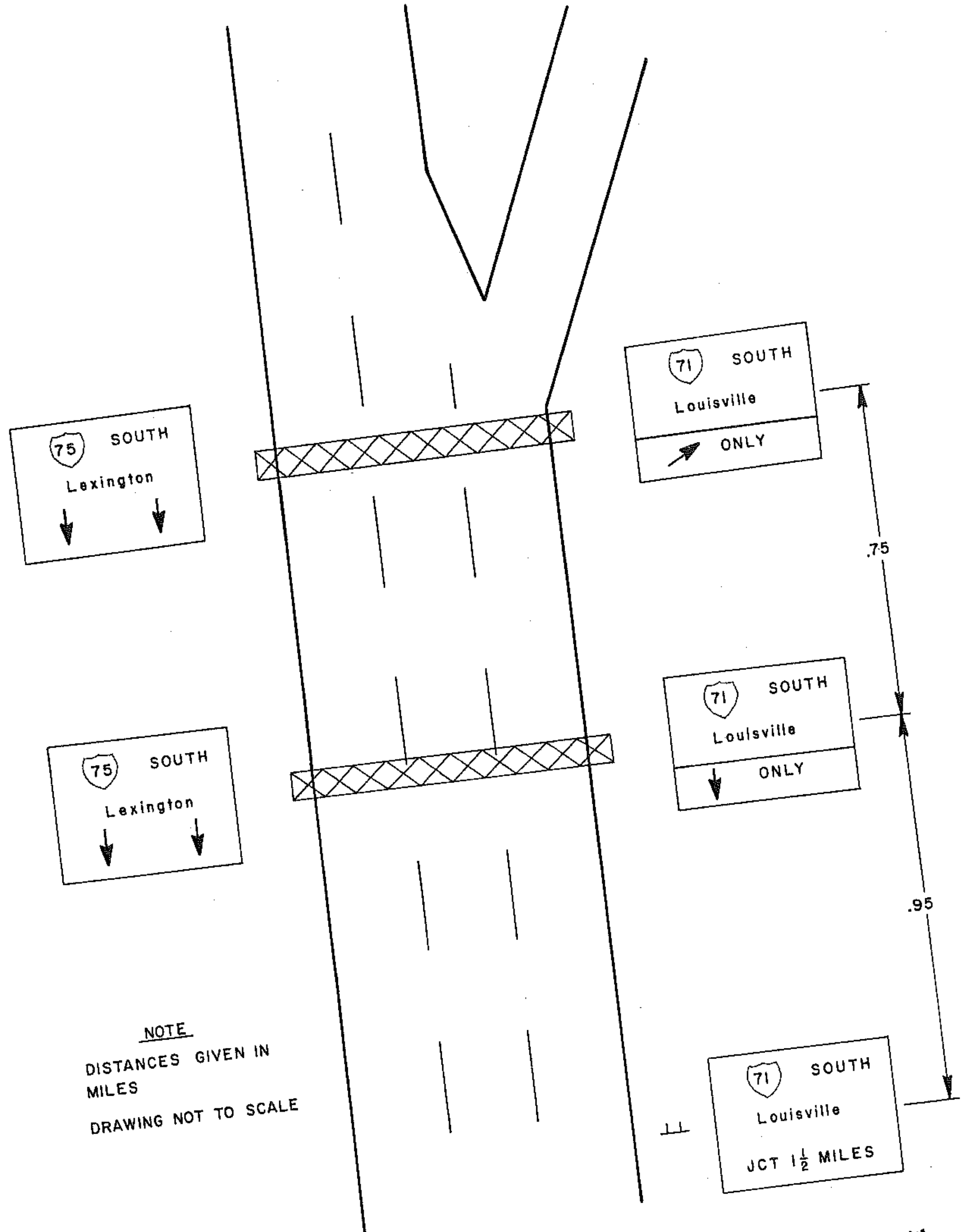


Figure 13. **Original Signing Schematic of the I 75 SB - I 71 SB Single Lane Exit with Taper**

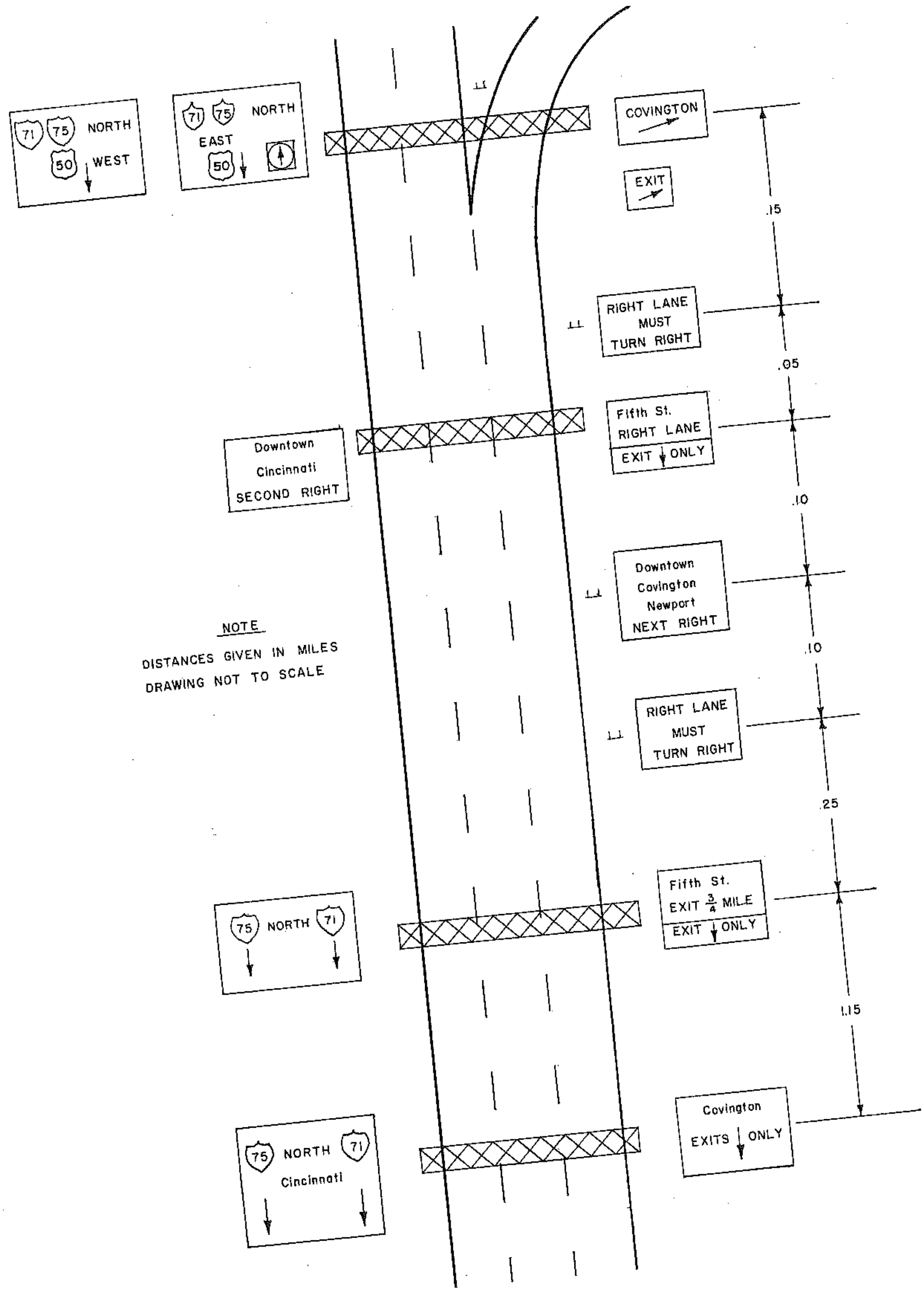


Figure 14. **Original Signing Schematic of the I 75 NB - 5th Street Single Lane Exit without Taper**

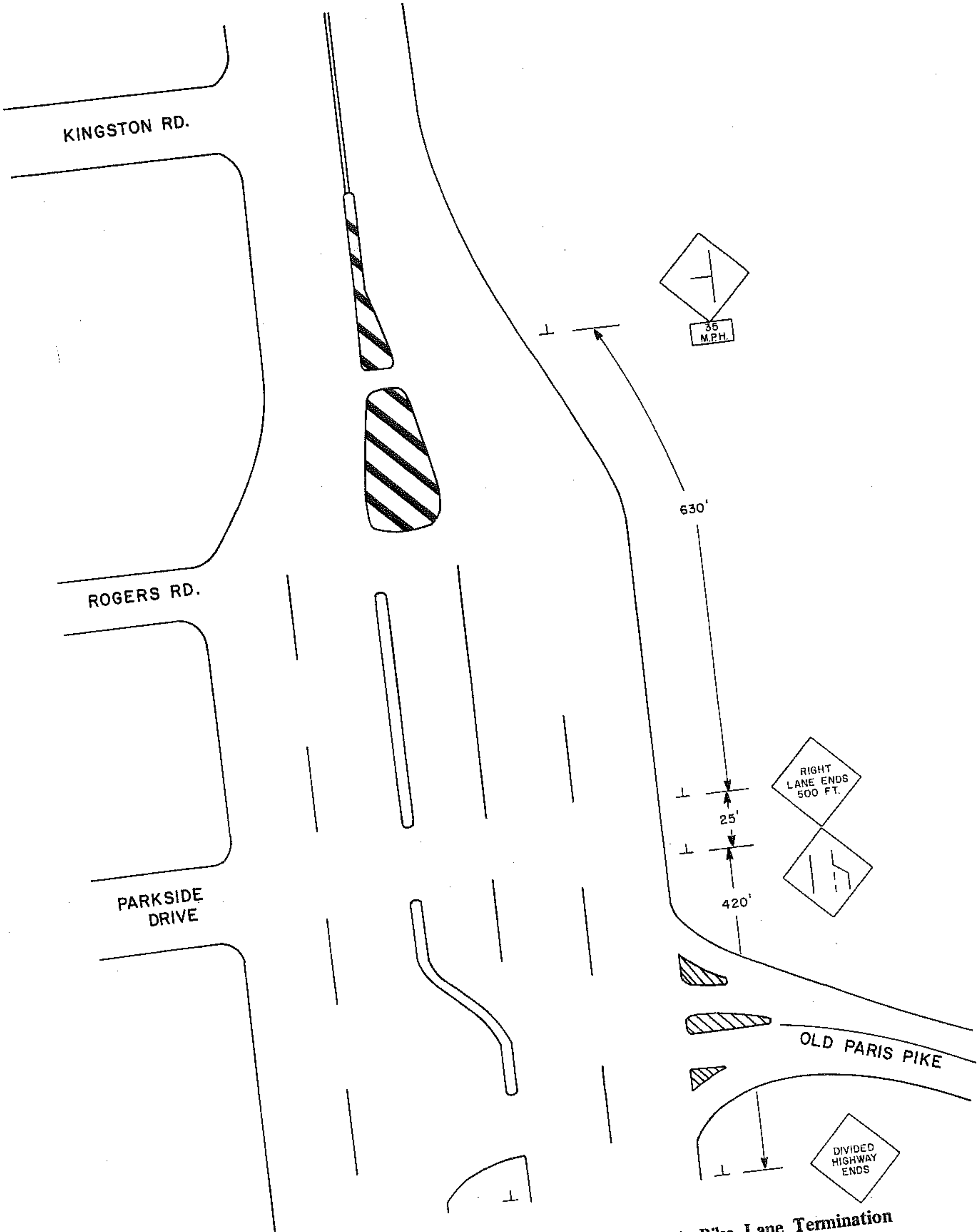


Figure 15. Original Signing Schematic of the Paris Pike Lane Termination

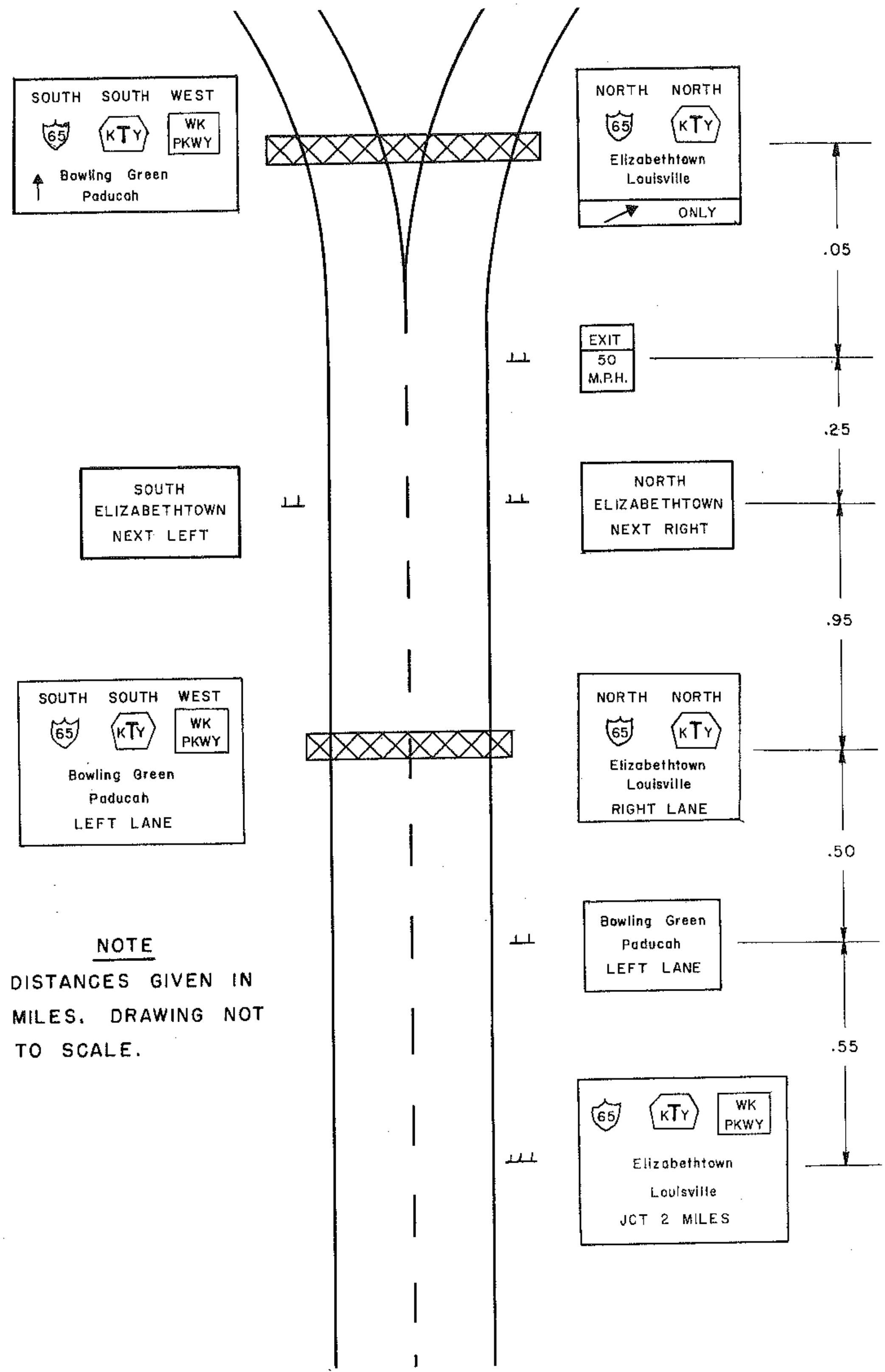


Figure 16. Original Signing Schematic of the Bluegrass Parkway Lane Split

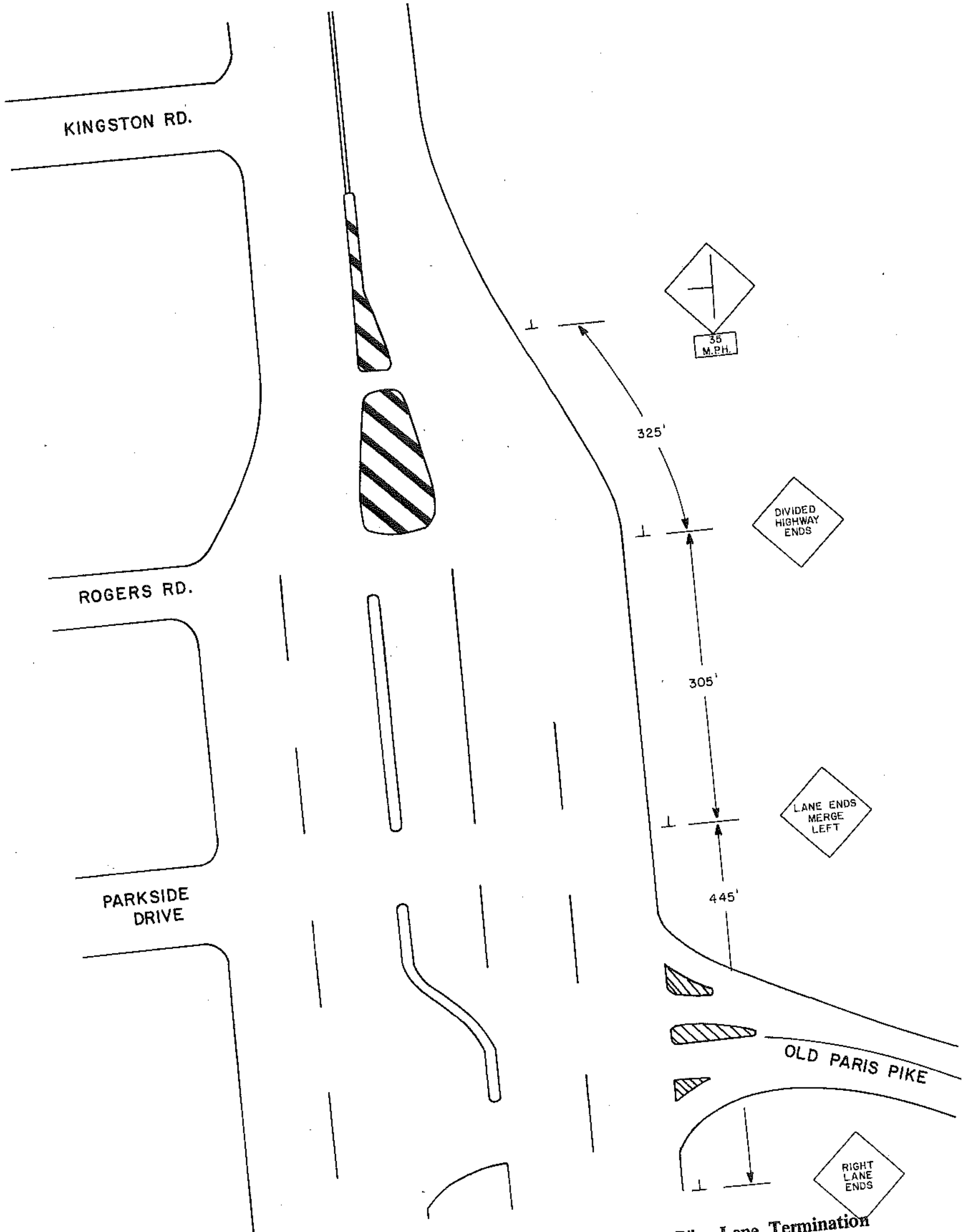


Figure 17. Revised Signing Schematic of the Paris Pike Lane Termination

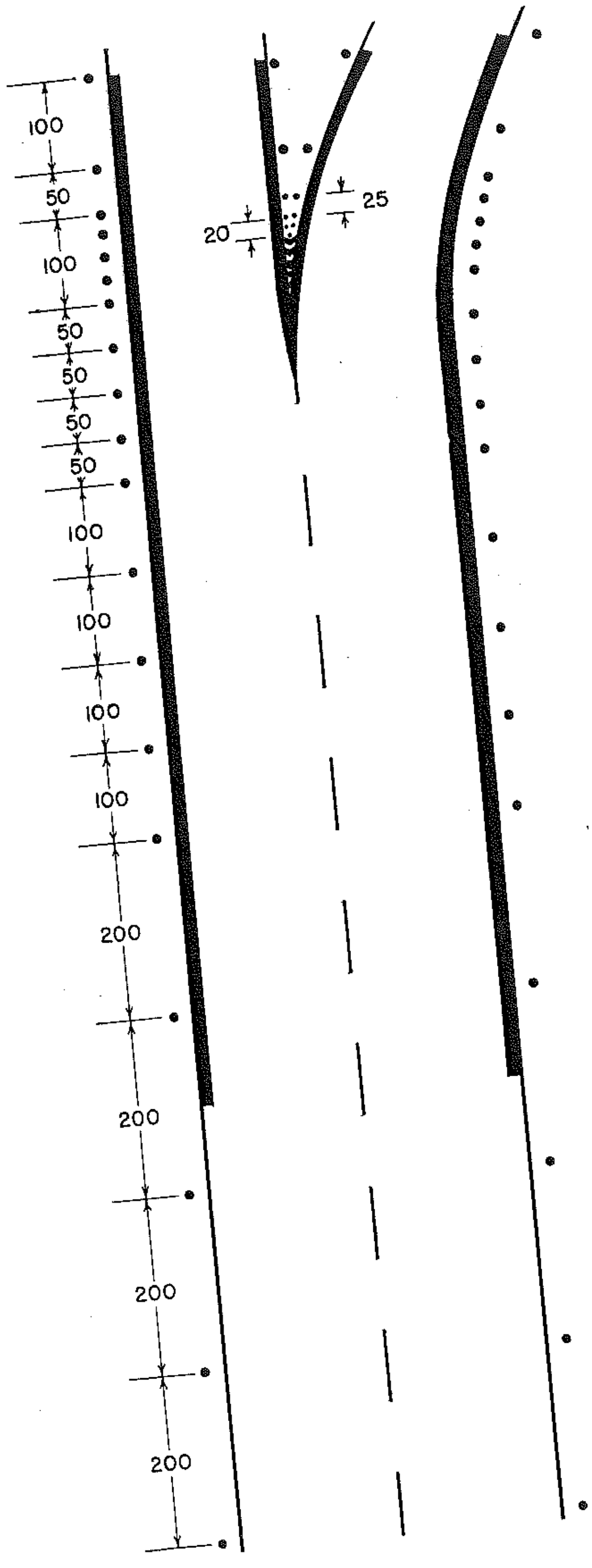


Figure 18. Typical Yellow Edgelining and Amber Delineator Placement (Schematic)

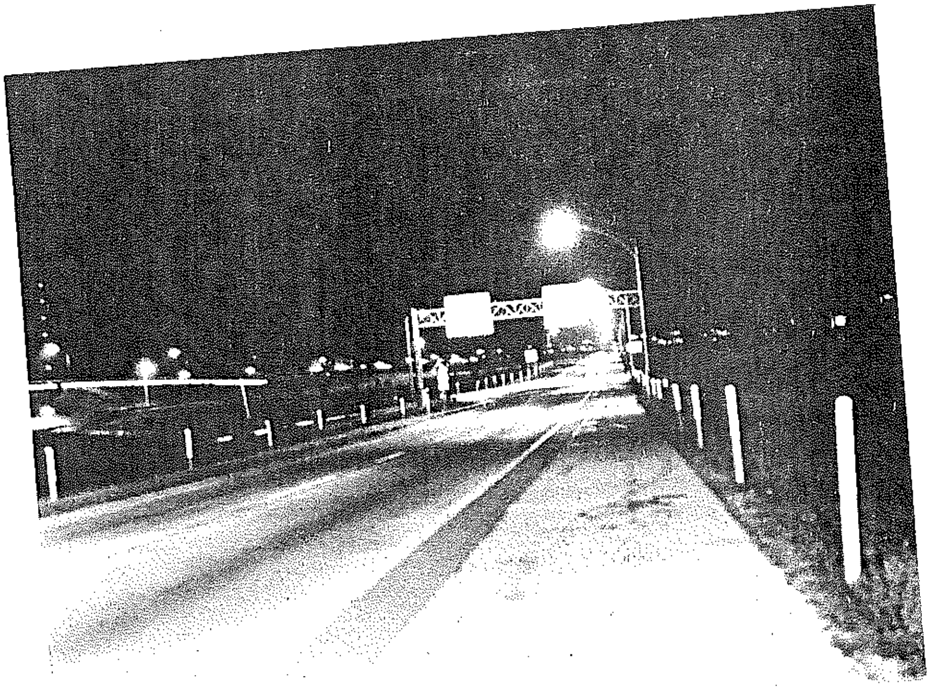


Figure 19. Typical Amber Delineator Placement

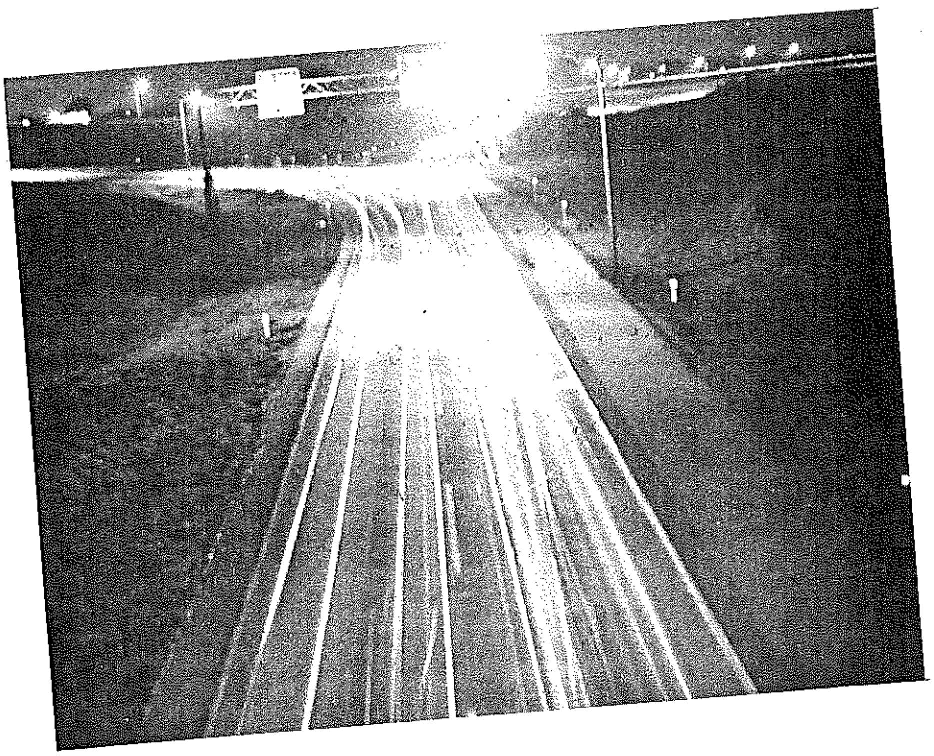


Figure 20. Traffic Flow at the I 64 WB Lane Split

before and after each traffic control device combination installation, 4) spot-speed means before and after each installation, 5) conflicts with spot-speed means, and 6) conflicts with spot-speed variance. A discussion of each of these comparisons and some comments on data restrictions follow.

CONFLICTS AND SITE GEOMETRICS

Erratic movement rates, brakelight rates, and average hourly volumes for all seven lane-drop locations are given in Tables 1 through 4. Site geometrics may be found in Figures 21 and 22. Although it has been argued that driving performance is largely dependent on inherent personal characteristics *(27)*, these figures clearly show the direct relationship between conflicts and site geometrics. Wherever horizontal curves had the least curvature and vertical curves where either nonexistent or negative, conflict rates were the lowest. Negative vertical grades provide optimum sight relationships, which are needed to indicate to the driver that he is approaching a discontinuity (a lane drop) in the route he is traveling *(28, 29)*. Positive vertical grades provide poor sight distances and are one reason for high conflict rates at such sites *(30)*. It has been stated that a high-speed exit is best provided by a flat angle of 4° or 5° *(28)*. However, of the six lane drops having exit-type ramps, only two (I-75 northbound at 5th Street and I-75 southbound at I-71 southbound) met this maximum curvature requirement. It is important to note that the two which met this requirement had the lowest conflict rates.

Operational characteristics of all the lane drops studied (except the Paris Pike lane termination) may be negatively affected by its non-conformance to certain rules of operational flexibility and expressway connection-system design. According to principles of operational flexibility, any change in the basic (minimum) number of lanes, in this case four, should occur at an intersection with another freeway; and then only if the exiting volume is sufficiently large to permit a change in the basic number of lanes beyond this point on the freeway route as a whole *(31)*. Two other deficiencies of the lane splits investigated may be enumerated: 1) "T" intersections between expressways should be avoided, particularly when the top of the "T" faces toward a region of higher average traffic density, and 2) two facilities should not reduce to one in areas of increasing traffic density; instead, they should merge as traffic loads become higher *(32)*.

Data in Tables 1 through 4 show no clear relationship between conflicts and volume. Indeed, the site with the lowest average hourly volume had the highest overall conflict rate, while the site with the highest average hourly volume had the lowest overall conflict rate. A detailed explanation of this phenonmena may be found in the literature *(33)*. It suffices to say that there are two primary reasons for this seemingly paradoxical observation. First, modern high-speed highways are designed to relieve

TABLE 1

PILOT STUDY
ERRATIC MOVEMENT AND BRAKELIGHT RATES* AND TRAFFIC VOLUMES
DAYTIME CONDITIONS

LOCATION	STUDY NUMBER	TRAFFIC CONTROL DEVICE(S) EMPLOYED	ERRATIC MOVEMENT RATES							BRAKELIGHT RATES			AVERAGE HOURLY TRAFFIC VOLUMES		
			CUT ACROSS GORE	CROWDED WEAVE	STOPPED	SWERVED	BACKED AT GORE	MULTIPLE ERRORS	TOTAL	MEDIAN LANE	SHOULDER LANE	TOTAL	MEDIAN LANE	SHOULDER LANE	TOTAL
I64 NB	1	ORIGINAL	1.38	.40	1.92	.34	.05	.33	4.40	27.86	24.60	25.10	137	219	356
	2	YELLOW STRIPING	1.37	.24	1.74	.66	.26	.36	4.51	26.57	18.01	20.69	157	274	431
	3	"↑ ONLY" SIGNS YELLOW STRIPING	.74	.02	.07	.75	.02	.17	1.80	22.83	14.38	17.83	151	207	358
	4	"↑ ONLY SIGNS YELLOW STRIPING AMBER DELINEATORS	.71	1.0	1.30	.60	.06	.40	3.18	35.62	18.59	25.30	167	246	413
I75 NB	1	ORIGINAL	2.69	.81	.55	.92	.04	1.23	6.11	8.91	34.97	14.12	832	202	1034
	2	YELLOW STRIPING	1.62	.81	.73	.30	.04	.73	4.10	6.90	29.32	12.61	666	220	886
	3	"↑ ONLY" SIGNS YELLOW STRIPING	2.32	1.19	.10	.16	.00	.91	4.69	6.68	29.27	11.80	848	253	1101
	4	"↑ ONLY" SIGNS YELLOW STRIPING AMBER DELINEATORS	2.27	.66	.39	.91	.20	.79	5.19	3.60	37.70	15.12	319	172	491
I75 SB	1	ORIGINAL	.70	.55	.25	.42	.01	.43	2.38	56.93	7.92	27.11	179	295	474
	2	YELLOW STRIPING	.57	.46	.45	.22	.02	.29	2.19	64.00	8.40	28.95	392	689	1081
	3	YELLOW STRIPING AMBER DELINEATORS	.40	.25	.08	.03	.00	.14	.81	53.56	5.50	23.19	234	390	624
	4	"↑ ONLY" SIGNS YELLOW STRIPING AMBER DELINEATORS	.17	.09	.08	.14	.15	.16	.60	60.45	5.13	24.25	292	535	827
	5	"↑ ONLY" SIGNS YELLOW STRIPING	.25	.22	.19	.21	.00	.29	1.21	67.81	3.35	29.05	226	324	550

* RATES WERE OBTAINED BY DIVIDING THE NUMBER OF ERRATIC MOVEMENTS OR BRAKELIGHT APPLICATIONS BY THE APPLICABLE TRAFFIC VOLUMES AND EXPRESSING THIS QUOTIENT AS A PERCENTAGE.

TABLE 2

THE FINAL STUDY
ERRATIC MOVEMENT AND BRAKELIGHT RATES* AND AVERAGE HOURLY VOLUMES
DAYTIME CONDITIONS

LOCATION	STUDY NUMBER	TRAFFIC CONTROL DEVICE(S) EMPLOYED	ERRATIC MOVEMENT RATES								BRAKELIGHT RATES					AVERAGE HOURLY VOLUMES			
			CUT ACROSS GORE	CROWDED WEAVE	SWERVE	SLOWED DRASTICALLY	STOPPED	STOPPED AND BRAKED	MULTIPLE ERRORS	TOTAL	MEDIAN LANE	MIDDLE LANE	SHOULDER LANE	SINGLE LANE	TOTAL	MEDIAN LANE	MIDDLE LANE	SHOULDER LANE	TOTAL
I 75 NB AT 5TH STREET EXIT (COVINGTON)	1	ORIGINAL	.28	.14	.02	.07	0	.01	.20	.72	4.55	6.79	12.05		6.91	743	899	341	1983
	2	AMBER DELINEATORS	.26	.14	.02	.05	.02	0	.13	.61	5.03	8.78	12.52		7.93	807	934	353	2094
	3	YELLOW STRIPING	.22	.10	.03	0	0	0	.13	.49	3.71	4.99	10.67		5.42	842	910	346	2098
	4	AMBER DELINEATORS & YELLOW STRIPING	.17	.09	.02	.01			.14	.42	3.96	6.23	8.24		5.59	1016	1046	354	2416
I 75 SB AT I 71 SB	1	ORIGINAL	1.11	.26	.13	.18	.04	0	.23	2.06	.78	1.46	23.91		8.42	178	356	239	772
	2	AMBER DELINEATORS	.88	.05	.13	.17	.02	0	.29	1.53	1.06	1.84	20.42		7.67	223	394	289	905
	3	YELLOW STRIPING	1.00	.15	.05	.04	0	.05	.31	1.56	.57	2.06	24.80		9.65	219	392	316	927
	4	AMBER DELINEATORS & YELLOW STRIPING	.02	.02	.28	.06	.03	0	.09	.48	.27	.61	15.37		5.15	197	366	256	819
WESTERN TERMINUS OF BG PARKWAY	1	ORIGINAL	24.37	.18	.21	1.00	.38	0	3.20	30.33	10.85		63.22		30.88	51		31	82
	2	AMBER DELINEATORS	16.45	0	.14	.50	0	0	1.73	18.82	5.84		45.54		24.07	52		45	97
	3	YELLOW STRIPING	11.66	0	0	.67	.46	0	1.97	16.77	8.68		71.47		27.10	64		27	91
	4	AMBER DELINEATORS & YELLOW STRIPING	11.25	0	0	.59	0	0	1.20	13.55	14.44		72.97		31.93	64		26	90
US 27-68 NB (PARIS PIKE) NORTH OF NEW CIRCLE ROAD (LEXINGTON)	1	ORIGINAL		.90	.32	.20	.21	0	.49	2.63	4.30		3.50	3.45	7.17	102		286	389
	2	AMBER DELINEATORS		1.09	0	.11	0	0	.26	1.43	2.80		3.47	5.33	7.67	114		288	402
	3	"NEW" SIGNS		.46	.06	.12	0	0	.14	.62	3.39		1.64	2.36	4.33	108		275	383
	4	"NEW" SIGNS & AMBER DELINEATORS		.82	.18	.08	.03	0	0	1.11	2.87		2.16	2.37	4.32	104		281	386
	5	"NEW" SIGNS & YELLOW STRIPING		.49	.07	0	.03	0	0	.39	2.55		1.68	1.84	3.79	131		289	420
	6	"NEW" SIGNS, YELLOW STRIPING AND AMBER DELINEATORS		.47	.03	.03	.06	0	0	.38	1.91		1.87	1.61	3.49	138		297	434

*Rates were obtained by dividing the number of erratic movements of brakelight applications by the applicable traffic volumes and expressing this quotient as a percentage.

TABLE 3

PILOT STUDY
ERRATIC MOVEMENT AND BRAKELIGHT RATES* AND TRAFFIC VOLUMES
NIGHTTIME CONDITIONS

LOCATION	STUDY NUMBER	TRAFFIC CONTROL DEVICE(S) EMPLOYED	ERRATIC MOVEMENT RATES: CUT ACROSS GORE	CROWDED WEAVE	STOPPED	SWERVED	BACKED AT GORE	MULTIPLE ERRORS	TOTAL	BRAKELIGHT RATES: MEDIAN LANE	SHOULDER LANE	TOTAL	AVERAGE HOURLY TRAFFIC VOLUMES: MEDIAN LANE	SHOULDER LANE	TOTAL
I75 NB	1	ORIGINAL	4.21	.45	.59	.73	.00	1.33	7.38	11.80	48.13	18.53	378	84	462
	2	YELLOW STRIPING	3.28	1.10	.41	.68	.00	1.42	7.90	6.48	39.65	15.70	256	134	390
	3	"↕ ONLY" SIGNS YELLOW STRIPING	4.17	1.86	.22	.38	.08	1.83	8.52	13.67	34.40	17.03	649	134	783
	4	"↕ ONLY SIGNS YELLOW STRIPING AMBER DELINEATORS	3.70	.68	1.21	1.14	.12	1.30	8.10	3.27	50.80	15.59	176	59	235
I75 SB	1	ORIGINAL	.97	.18	.31	.56	.05	.26	2.33	78.13	16.27	36.10	126	263	389
	2	YELLOW STRIPING	1.12	.23	.32	.06	.00	.64	2.50	75.88	12.17	31.07	297	719	1016
	3	YELLOW STRIPING AMBER DELINEATORS	.36	.00	.00	.13	.00	.00	.62	74.88	2.60	30.77	97	163	260
	4	"↕ ONLY" SIGNS YELLOW STRIPING AMBER DELINEATORS	.47	.15	.18	.09	.00	.00	1.21	68.77	3.90	27.10	172	300	472
	5	"↕ ONLY" SIGNS YELLOW STRIPING	.41	.22	.31	.26	.15	.41	1.81	77.20	3.23	29.31	90	160	250

* RATES WERE OBTAINED BY DIVIDING THE NUMBER OF ERRATIC MOVEMENTS OR BRAKELIGHT APPLICATIONS BY THE APPLICABLE TRAFFIC VOLUMES AND EXPRESSING THIS QUOTIENT AS A PERCENTAGE.

TABLE 4

THE FINAL STUDY
ERRATIC MOVEMENT AND BRAKELIGHT RATES* AND AVERAGE HOURLY VOLUMES
NIGHTTIME CONDITIONS

LOCATION	STUDY NUMBER	TRAFFIC CONTROL DEVICE(S) EMPLOYED	ERRATIC MOVEMENT RATES: CUT ACROSS GORE	CROWDED WEAVE	SWERVE	SLOWED DRASTICALLY	STOPPED	STOPPED AND BRAKED	MULTIPLE ERRORS	TOTAL	BRAKELIGHT RATES: MEDIAN LANE	MIDDLE LANE	SHOULDER LANE	SINGLE LANE	TOTAL	AVERAGE HOURLY VOLUMES: MEDIAN LANE	MIDDLE LANE	SHOULDER LANE	TOTAL
I 75 NB AT 5TH STREET EXIT (COVINGTON)	1	ORIGINAL	.19	.23	.02	.09	0	0	.14	.67	1.26	2.44	8.34		2.99	556	665	239	1453
	2	AMBER DELINEATORS	.37	.05	0	.02	.02	0	.02	.48	4.36	10.45	15.33		8.84	558	690	221	1469
	3	YELLOW STRIPING	.35	.08	.02	.02	.02	0	.26	.99	1.99	3.38	9.21		3.72	468	601	251	1319
	4	AMBER DELINEATORS & YELLOW STRIPING	.29	.04	.02	0	0	0	.09	.43	3.38	4.32	9.94		4.85	542	694	235	1471
I 75 SB AT I 71 SB	1	ORIGINAL	.91	.08	0	0	0	0	.16	1.14	0	1.75	20.82		8.65	62	209	163	434
	2	AMBER DELINEATORS	.80	.05	.07	.07	.07	0	.19	1.25	.25	3.35	22.22		9.57	98	244	193	535
	3	YELLOW STRIPING	.91	.14	.03	.06	0	0	.20	1.39	0	.30	23.73		8.64	81	227	170	478
	4	AMBER DELINEATORS & YELLOW STRIPING	0	0	.14	.07	0	0	.13	.33	0	.17	16.91		5.78	79	226	156	461
WESTERN TERMINUS OF BG PARKWAY	1	ORIGINAL	38.84	.48	.48	.48	0	0	0	40.79	11.32		44.76		31.40	19		27	46
	2	AMBER DELINEATORS	22.35	0	0	0	0	0	1.12	23.47	9.82		49.59		32.06	24		31	55
	3	YELLOW STRIPING	21.19	0	0	0	0	0	3.54	23.65	1.39		77.36		33.51	18		13	31
	4	AMBER DELINEATORS & YELLOW STRIPING	11.95	0	0	0	0	0	1.73	13.68	10.09		65.40		27.86	22		11	33
US 27-68 NB (PARIS PIKE) NORTH OF NEW CIRCLE ROAD (LEXINGTON)	1	ORIGINAL		.55	0	.30	0	0	0	.85	1.54		2.32	2.21	4.24	50		105	154
	2	AMBER DELINEATORS		0	0	0	0	0	.16	.16	.51		.87	2.15	2.87	79		158	238
	3	"NEW" SIGNS		.22	.50	0	0	0	0	.71	4.00		1.38	1.90	4.21	56		127	183
	4	"NEW" SIGNS & AMBER DELINEATORS		0	.27	0	.13	0	0	.40	.96		3.14	2.38	4.83	68		164	226
	5	"NEW" SIGNS & YELLOW STRIPING		.13	0	.13	.43	0	.30	.98	1.65		1.34	1.83	3.28	63		132	195
	6	"NEW" SIGNS, YELLOW STRIPING AND AMBER DELINEATORS		0	.45	0	0	0	.21	.69	.46		.76	.84	1.53	48		125	172

*Rates were obtained by dividing the number of erratic movements of brakelight applications by the applicable traffic volumes and expressing this quotient as a percentage.

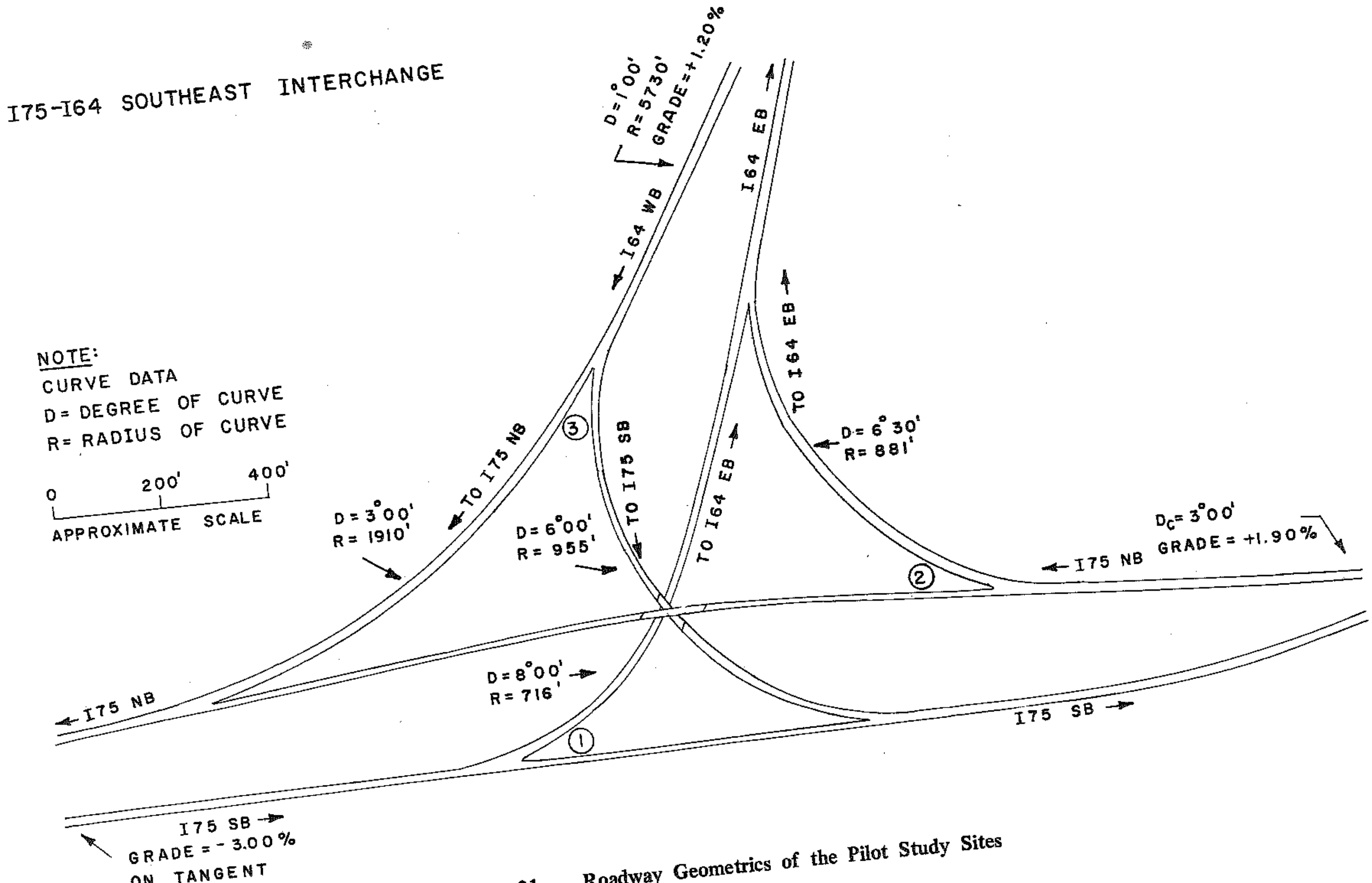


Figure 21. Roadway Geometrics of the Pilot Study Sites

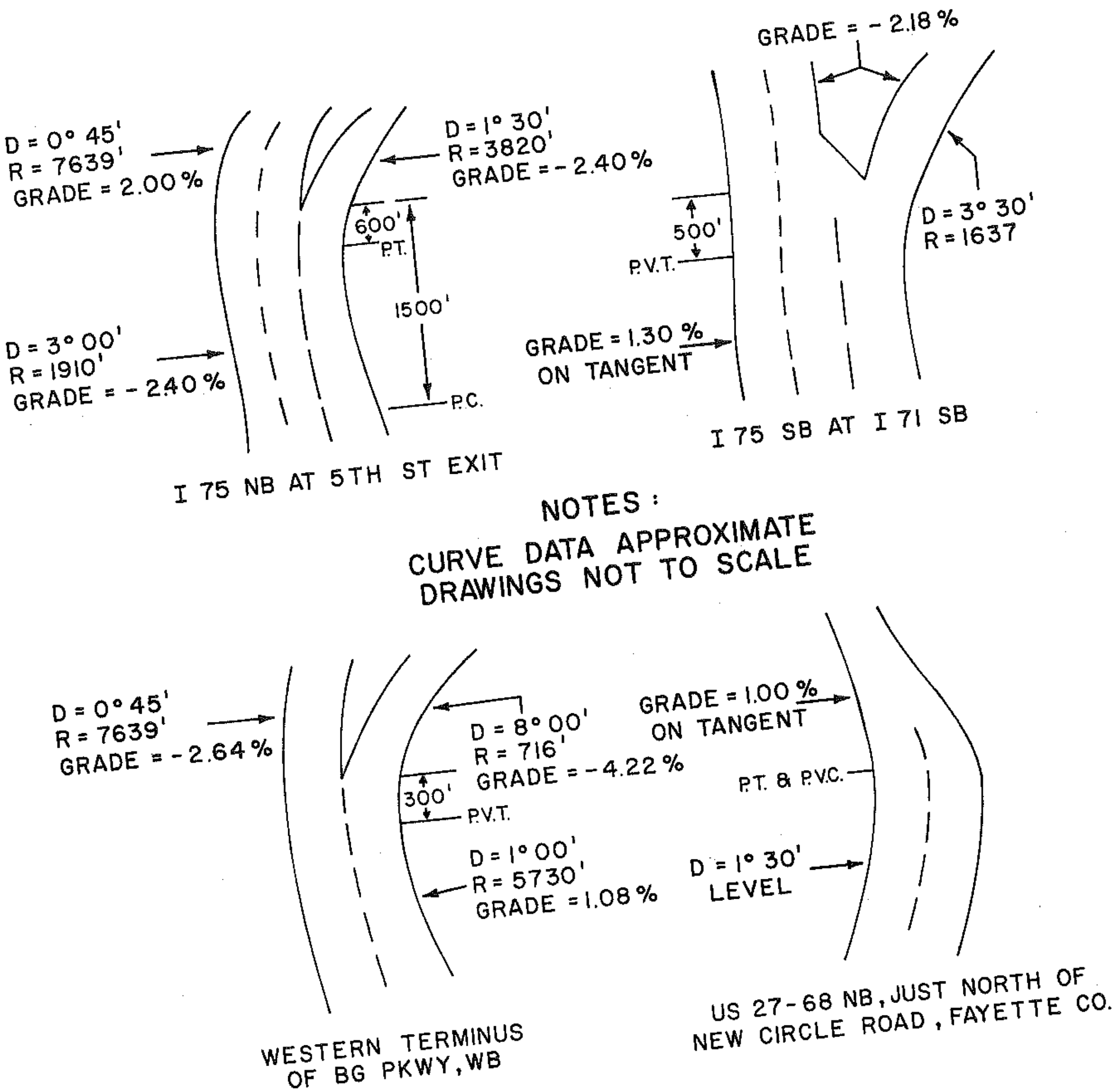


Figure 22. Roadway Geometrics of the Final Study Sites

the driver of many operational judgements and decisions associated with the older type highways. This environment leads to inattentiveness and reduced alertness, particularly at low traffic volumes, which increase the probability of a conflict-producing situation. Secondly, at low volumes there is reduced "caravaning", wherein each driver consciously or subconsciously follows the vehicle(s) ahead. At high volumes, the opposite of these two explanations is true.

There was also no clear trend in conflict rates at sites with intermediate volumes. A partial explanation of this observation is that it is these intermediate volume conditions, particularly between approximately 2,000 and 5,000 vehicles per day, which produce inconsistent conflict rates *(33)*.

CONFLICTS AND ACCIDENT RATES

Accident summaries of all seven lane-drop locations, as well as collision diagrams for the five locations with the highest accident frequencies, may be found in APPENDIX B *(34)*. Also included in APPENDIX B are 1971 adjusted average daily traffic volumes used in calculating accident rates.

Overall conflict rates and accident rates per million vehicles may be found in Table 5. Careful study of this table reveals no definitive relationship between conflict and accident rates at the lane drops investigated.

ERRATIC MOVEMENT AND BRAKELIGHT RATES BEFORE AND AFTER INSTALLATION OF EACH TRAFFIC CONTROL DEVICE COMBINATION

A statistical analysis of all erratic movement and brakelight rate deviations was made using the Smith-Satterthwaite test *(35)*. Significant erratic movement and brakelight rate deviations are given in Tables 6 through 18. A summary of statistical theory and tests utilized in the analysis of data is presented in APPENDIX C.

Environmental, goemetric and traffic conditions were different at each lane drop. This is perhaps the primary reason that a study of conflict deviations indicates no single type of traffic control device was significantly effective in reducing erratic movement and brakelight rates at the seven locations. Rather, it appears that different devices were generally most effective at each of the locations, i.e., amber delineators at the I-75 southbound lane split during both day and night conditions, exit ONLY signs at the I-64 westbound lane split during day conditions, yellow striping at the I-75 northbound lane split during day conditions, and amber delineators and yellow striping at the Bluegrass Parkway location under both day and night conditions. No device was particularly effective at the I-75 northbound lane split during night conditions.

At the Paris Pike lane termination, the signing scheme recommended by the 1971 **Manual on Uniform**

TABLE 5

OVERALL ERRATIC MOVEMENT, BRAKELIGHT, AND ACCIDENT RATES (PER MILLION VEHICLES)

LOCATION	OVERALL ERRATIC MOVEMENT RATE	OVERALL BRAKELIGHT RATE	ACCIDENT RATE
I 64 WB	34,700	222,300	1.58
I 75 NB	65,000	150,600	1.33
I 75 SB	15,700	286,900	1.45
BG PARKWAY	223,200	299,100	3.56
PARIS PIKE	9,000	43,500	4.72
I 75 NB @ 5th St	6,100	57,800	1.12
I 75 SB @ I 71 SB	12,200	79,400	.77

TABLE 6

I 75 SB - I 64 EB LANE SPLIT (DAYTIME) SIGNIFICANT ERRATIC MOVEMENT & BRAKELIGHT RATE DEVIATIONS*

STUDY NUMBER	TRAFFIC CONTROL DEVICE(S) EMPLOYED
1	ORIGINAL
2	YELLOW STRIPING
3	YELLOW STRIPING & AMBER DELINEATORS
4	"↑ ONLY" SIGNS, YELLOW STRIPING, & AMBER DELINEATORS
5	"↑ ONLY" SIGNS & YELLOW STRIPING

COMPARISON		TYPE OF ERRATIC MOVEMENT RATE							TYPE OF BRAKELIGHT RATE		
FROM STUDY #	TO STUDY #	CUT ACROSS GORE	CROWDED WEAVE	STOPPED	SWERVED	BACKED AT GORE	MULTIPLE ERRORS	TOTAL	MEDIAN LANE	SHOULDER LANE	TOTAL
1	2	—	—	—	DECREASE	—	—	—	INCREASE	—	—
1	3	—	DECREASE	DECREASE	DECREASE	—	DECREASE	DECREASE	—	—	DECREASE
1	4	DECREASE	DECREASE	DECREASE	DECREASE	INCREASE	DECREASE	DECREASE	—	—	—
1	5	DECREASE	DECREASE	—	—	—	—	DECREASE	INCREASE	DECREASE	—
2	3	—	DECREASE	DECREASE	DECREASE	—	DECREASE	DECREASE	DECREASE	DECREASE	DECREASE
2	4	DECREASE	DECREASE	DECREASE	—	INCREASE	—	DECREASE	—	DECREASE	DECREASE
2	5	DECREASE	DECREASE	DECREASE	—	—	—	DECREASE	—	DECREASE	—
3	4	—	DECREASE	—	INCREASE	INCREASE	INCREASE	—	INCREASE	—	—
3	5	—	—	—	—	—	INCREASE	INCREASE	INCREASE	DECREASE	INCREASE
4	5	—	—	INCREASE	—	DECREASE	INCREASE	INCREASE	INCREASE	DECREASE	INCREASE

* The words "INCREASE" & "DECREASE" refer to certain erratic movement or brakelight rate deviations that were found to be statistically significant at the 95% confidence level.

TABLE 7

I 75 SB - I 64 EB LANE SPLIT (NIGHTTIME)
SIGNIFICANT ERRATIC MOVEMENT & BRAKELIGHT RATE DEVIATIONS*

STUDY NUMBER	TRAFFIC CONTROL DEVICE(S) EMPLOYED
1	ORIGINAL
2	YELLOW STRIPING
3	YELLOW STRIPING & AMBER DELINEATORS
4	"↑ ONLY" SIGNS, YELLOW STRIPING, & AMBER DELINEATORS
5	"↑ ONLY" SIGNS & YELLOW STRIPING

COMPARISON		TYPE OF ERRATIC MOVEMENT RATE							TYPE OF BRAKELIGHT RATE		
FROM STUDY #	TO STUDY #	CUT ACROSS GORE	CROWDED WEAVE	STOPPED	SWERVED	BACKED AT GORE	MULTIPLE ERRORS	TOTAL	MEDIAN LANE	SHOULDER LANE	TOTAL
1	2	—	—	—	—	—	—	—	—	—	—
1	3	—	—	—	—	—	—	—	—	—	—
1	4	—	—	—	—	—	—	—	—	—	—
1	5	—	—	—	—	—	—	—	—	—	—
2	3	DECREASE	—	DECREASE	—	—	—	DECREASE	—	DECREASE	—
2	4	DECREASE	—	—	—	—	DECREASE	DECREASE	—	DECREASE	DECREASE
2	5	DECREASE	—	—	—	—	DECREASE	—	—	DECREASE	—
3	4	—	—	—	—	—	—	—	—	—	—
3	5	—	—	—	—	—	INCREASE	INCREASE	—	—	—
4	5	—	—	—	—	—	INCREASE	—	—	—	—

*The words "INCREASE" & "DECREASE" refer to certain erratic movement or brakelight rate deviations that were found to be statistically significant at the 95% confidence level.

TABLE 8

I 75 NB - I 64 EB LANE SPLIT (DAYTIME)
SIGNIFICANT ERRATIC MOVEMENT & BRAKELIGHT RATE DEVIATIONS*

STUDY NUMBER	TRAFFIC CONTROL DEVICE(S) EMPLOYED
1	ORIGINAL
2	YELLOW STRIPING
3	"↑ ONLY" SIGNS & YELLOW STRIPING
4	"↑ ONLY" SIGNS, YELLOW STRIPING, & AMBER DELINEATIONS

COMPARISON		TYPE OF ERRATIC MOVEMENT RATE							TYPE OF BRAKELIGHT RATE		
FROM STUDY #	TO STUDY #	CUT ACROSS GORE	CROWDED WEAVE	STOPPED	SWERVED	BACKED AT GORE	MULTIPLE ERRORS	TOTAL	MEDIAN LANE	SHOULDER LANE	TOTAL
1	2	DECREASE	—	—	DECREASE	—	DECREASE	DECREASE	—	DECREASE	—
1	3	—	—	DECREASE	DECREASE	—	—	—	—	—	—
1	4	—	—	—	—	—	—	—	DECREASE	—	—
2	3	INCREASE	—	DECREASE	—	—	—	—	—	—	—
2	4	INCREASE	—	DECREASE	INCREASE	—	—	—	DECREASE	INCREASE	—
3	4	—	—	INCREASE	INCREASE	INCREASE	—	—	—	INCREASE	—

*The words "INCREASE" & "DECREASE" refer to certain erratic movement or brakelight rate deviations that were found to be statistically significant at the 95% confidence level.

TABLE 9

I 75 NB - I 64 EB LANE SPLIT (NIGHTTIME)
SIGNIFICANT ERRATIC MOVEMENT & BRAKELIGHT RATE DEVIATIONS*

STUDY NUMBER	TRAFFIC CONTROL DEVICE (S) EMPLOYED
1	ORIGINAL
2	YELLOW STRIPING
3	"↑ ONLY" SIGNS & YELLOW STRIPING
4	"↑ ONLY" SIGNS YELLOW STRIPING, & AMBER DELINEATIONS

COMPARISON		TYPE OF ERRATIC MOVEMENT RATE							TYPE OF BRAKELIGHT RATE		
FROM STUDY #	TO STUDY #	CUT ACROSS GORE	CROWDED WEAVE	STOPPED	SWERVED	BACKED AT GORE	MULTIPLE ERRORS	TOTAL	MEDIAN LANE	SHOULDER LANE	TOTAL
1	2	———	INCREASE	———	———	———	———	———	DECREASE	———	———
1	3	———	———	———	———	———	———	———	———	DECREASE	———
1	4	———	———	———	———	———	———	———	DECREASE	———	———
2	3	———	———	———	———	———	———	———	———	———	———
2	4	———	———	———	———	———	———	———	DECREASE	———	———
3	4	———	———	INCREASE	———	———	———	———	DECREASE	———	———

*The words "INCREASE" & "DECREASE" refer to certain erratic movement or brakelight rate deviations that were found to be statistically significant at the 95% confidence level.

TABLE 10

I 64 WB LANE SPLIT (DAYTIME)
SIGNIFICANT ERRATIC MOVEMENT & BRAKELIGHT RATE DEVIATIONS*

STUDY NUMBER	TRAFFIC CONTROL DEVICE (S) EMPLOYED
1	ORIGINAL
2	YELLOW STRIPING
3	"↑ ONLY" SIGNS & YELLOW STRIPING
4	"↑ ONLY" SIGNS, YELLOW STRIPING, & AMBER DELINEATIONS

COMPARISON		TYPE OF ERRATIC MOVEMENT RATE							TYPE OF BRAKELIGHT RATE		
FROM STUDY #	TO STUDY #	CUT ACROSS GORE	CROWDED WEAVE	STOPPED	SWERVED	BACKED AT GORE	MULTIPLE ERRORS	TOTAL	MEDIAN LANE	SHOULDER LANE	TOTAL
1	2	———	———	———	———	INCREASE	———	———	———	DECREASE	DECREASE
1	3	DECREASE	DECREASE	DECREASE	———	———	———	DECREASE	———	DECREASE	DECREASE
1	4	DECREASE	———	DECREASE	———	———		DECREASE	———	DECREASE	———
2	3	DECREASE	———	DECREASE	———	DECREASE	———	DECREASE	———	DECREASE	———
2	4	DECREASE	———	———	———	DECREASE	———	DECREASE	———	———	———
3	4	———	———	INCREASE	———	———	———	INCREASE	INCREASE	———	INCREASE

*The words "INCREASE" & "DECREASE" refer to certain erratic movement or brakelight rate deviations that were found to be statistically significant at the 95% confidence level.

STUDY NUMBER	TRAFFIC CONTROL DEVICE(S) EMPLOYED
1	ORIGINAL
2	AMBER DELINEATORS
3	YELLOW STRIPING
4	AMBER DELINEATORS AND YELLOW STRIPING

TABLE 11

BLUEGRASS PARKWAY LANE SPLIT (DAYTIME)
SIGNIFICANT ERRATIC MOVEMENT AND BRAKELIGHT RATE DEVIATIONS*

COMPARISON		TYPE OF ERRATIC MOVEMENT RATE								TYPE OF BRAKELIGHT RATE		
FROM STUDY NO.	TO STUDY NO.	CUT ACROSS GORE	CROWDED WEAVE	SWERVE	SLOWED DRASTICALLY	STOPPED	STOPPED AND BACKED	MULTIPLE ERRORS	TOTAL	MEDIAN LANE	SHOULDER LANE	TOTAL
1	2	—	—	—	—	—	—	—	DECREASE	DECREASE	DECREASE	—
1	3	DECREASE	—	—	—	—	—	—	DECREASE	—	—	—
1	4	DECREASE	—	—	—	—	—	DECREASE	DECREASE	—	INCREASE	—
2	3	DECREASE	—	—	—	—	—	—	—	—	INCREASE	—
2	4	DECREASE	—	—	—	—	—	—	—	INCREASE	INCREASE	INCREASE
3	4	—	—	—	—	—	—	—	—	INCREASE	—	—

*The words "INCREASE" and "DECREASE" refer to certain erratic movement or brakelight rate deviations that were found to be statistically significant at the 95 percent confidence level.

STUDY NUMBER	TRAFFIC CONTROL DEVICE(S) EMPLOYED
1	ORIGINAL
2	AMBER DELINEATORS
3	YELLOW STRIPING
4	AMBER DELINEATORS AND YELLOW STRIPING

TABLE 12

BLUEGRASS PARKWAY LANE SPLIT (NIGHTTIME)
SIGNIFICANT ERRATIC MOVEMENT AND BRAKELIGHT RATE DEVIATIONS*

COMPARISON		TYPE OF ERRATIC MOVEMENT RATE								TYPE OF BRAKELIGHT RATE		
FROM STUDY NO.	TO STUDY NO.	CUT ACROSS GORE	CROWDED WEAVE	SWERVE	SLOWED DRASTICALLY	STOPPED	STOPPED AND BACKED	MULTIPLE ERRORS	TOTAL	MEDIAN LANE	SHOULDER LANE	TOTAL
1	2	DECREASE	—	—	—	—	—	—	DECREASE	—	—	—
1	3	DECREASE	—	—	—	—	—	—	DECREASE	DECREASE	INCREASE	—
1	4	DECREASE	—	—	—	—	—	—	DECREASE	—	—	—
2	3	—	—	—	—	—	—	—	—	DECREASE	INCREASE	—
2	4	—	—	—	—	—	—	—	—	—	—	DECREASE
3	4	—	—	—	—	—	—	—	—	—	—	—

*The words "INCREASE" and "DECREASE" refer to certain erratic movement or brakelight rate deviations that were found to be statistically significant at the 95 percent confidence level.

TABLE 13

PARIS PIKE LANE TERMINATION (DAYTIME)
SIGNIFICANT ERRATIC MOVEMENT AND BRAKELIGHT RATE DEVIATIONS*

STUDY NUMBER	TRAFFIC CONTROL DEVICE(S) EMPLOYED
1	ORIGINAL
2	AMBER DELINEATORS
3	"NEW" SIGNS
4	"NEW" SIGNS AND AMBER DELINEATORS
5	"NEW" SIGNS AND YELLOW STRIPING
6	"NEW" SIGNS, YELLOW STRIPING, AND AMBER DELINEATORS

COMPARISON		TYPE OF ERRATIC MOVEMENT RATE							TYPE OF BRAKELIGHT RATE			
FROM STUDY NO.	TO STUDY NO.	CROWDED WEAVE	SWERVE	SLOWED DRASTICALLY	STOPPED	STOPPED AND BACKED	MULTIPLE ERRORS	TOTAL	MEDIAN LANE	SHOULDER LANE	SINGLE LANE	TOTAL
1	2	—	DECREASE	DECREASE	DECREASE	—	—	DECREASE	—	—	—	—
1	3	—	—	DECREASE	DECREASE	—	DECREASE	DECREASE	—	DECREASE	DECREASE	DECREASE
1	4	—	—	DECREASE	DECREASE	—	DECREASE	DECREASE	—	—	—	DECREASE
1	5	—	—	DECREASE	DECREASE	—	—	DECREASE	—	DECREASE	DECREASE	DECREASE
1	6	—	—	DECREASE	—	—	—	DECREASE	DECREASE	DECREASE	DECREASE	DECREASE
2	3	DECREASE	—	—	—	—	—	DECREASE	—	—	DECREASE	—
2	4	—	INCREASE	—	—	—	DECREASE	—	—	—	DECREASE	—
2	5	—	—	—	—	—	—	DECREASE	—	—	DECREASE	DECREASE
2	6	DECREASE	—	—	—	—	—	DECREASE	—	—	DECREASE	DECREASE
3	4	—	—	—	—	—	—	INCREASE	—	—	—	—
3	5	—	—	—	—	—	—	—	—	—	—	—
3	6	—	—	—	—	—	—	—	—	—	—	—
4	5	—	—	—	—	—	—	DECREASE	—	—	—	—
4	6	DECREASE	—	—	—	—	—	DECREASE	DECREASE	—	—	—
5	6	—	—	—	—	—	—	—	—	—	—	—

* The words "INCREASE" and "DECREASE" refer to certain erratic movement or brakelight rate deviations that were found to be statistically significant at the 95 percent confidence level.

TABLE 14

PARIS PIKE LANE TERMINATION (NIGHTTIME)
SIGNIFICANT ERRATIC MOVEMENT AND BRAKELIGHT RATE DEVIATIONS*

STUDY NUMBER	TRAFFIC CONTROL DEVICE(S) EMPLOYED
1	ORIGINAL
2	AMBER DELINEATORS
3	"NEW" SIGNS
4	"NEW" SIGNS AND AMBER DELINEATORS
5	"NEW" SIGNS AND YELLOW STRIPING
6	"NEW" SIGNS, YELLOW STRIPING, AND AMBER DELINEATORS

COMPARISON		TYPE OF ERRATIC MOVEMENT RATE							TYPE OF BRAKELIGHT RATE			
FROM STUDY NO.	TO STUDY NO.	CROWDED WEAVE	SWERVE	SLOWED DRASTICALLY	STOPPED	STOPPED AND BACKED	MULTIPLE ERRORS	TOTAL	MEDIAN LANE	SHOULDER LANE	SINGLE LANE	TOTAL
1	2	—	—	—	—	—	—	DECREASE	—	—	—	—
1	3	—	—	—	—	—	—	—	—	—	—	—
1	4	—	—	—	—	—	—	DECREASE	—	—	—	—
1	5	—	—	—	—	—	—	—	—	—	—	—
1	6	—	—	—	—	—	—	—	—	—	—	—
2	3	—	—	—	—	—	—	INCREASE	INCREASE	—	—	—
2	4	—	—	—	—	—	—	—	—	INCREASE	—	—
2	5	—	—	—	—	—	—	INCREASE	—	—	—	—
2	6	—	—	—	—	—	—	—	—	—	—	—
3	4	—	—	—	—	—	—	—	—	—	—	—
3	5	—	—	—	—	—	—	—	—	—	—	—
3	6	—	—	—	—	—	—	—	DECREASE	—	—	—
4	5	—	—	—	—	—	—	INCREASE	—	—	—	—
4	6	—	—	—	—	—	—	—	—	DECREASE	—	DECREASE
5	6	—	—	—	—	—	—	—	—	—	—	—

* The words "INCREASE" and "DECREASE" refer to certain erratic movement or brakelight rate deviations that were found to be statistically significant at the 95 percent confidence level.

TABLE 15

I 75 SB AT I 71 SB (DAYTIME)
SINGLE LANE EXIT WITH TAPER
SIGNIFICANT ERRATIC MOVEMENT AND BRAKELIGHT RATE DEVIATIONS*

STUDY NUMBER	TRAFFIC CONTROL DEVICE(S) EMPLOYED
1	ORIGINAL
2	AMBER DELINEATORS
3	YELLOW STRIPING
4	AMBER DELINEATORS AND YELLOW STRIPING

COMPARISON		TYPE OF ERRATIC MOVEMENT RATE								TYPE OF BRAKELIGHT RATE			
FROM STUDY NO.	TO STUDY NO.	CUT ACROSS GORE	CROWDED WEAVE	SWERVE	SLOWED DRASTICALLY	STOPPED	STOPPED AND BACKED	MULTIPLE ERRORS	TOTAL	MEDIAN LANE	MIDDLE LANE	SHOULDER LANE	TOTAL
1	2	—	DECREASE	—	—	—	—	—	—	—	—	DECREASE	—
1	3	—	—	—	DECREASE	—	—	—	—	—	—	—	—
1	4	DECREASE	DECREASE	—	DECREASE	—	—	—	DECREASE	DECREASE	DECREASE	DECREASE	DECREASE
2	3	—	INCREASE	—	DECREASE	—	—	—	—	—	—	INCREASE	INCREASE
2	4	DECREASE	—	—	DECREASE	—	—	DECREASE	DECREASE	DECREASE	DECREASE	DECREASE	DECREASE
3	4	DECREASE	DECREASE	—	—	—	—	DECREASE	DECREASE	—	DECREASE	DECREASE	DECREASE

* The words "INCREASE" and "DECREASE" refer to certain erratic movement or brakelight rate deviations that were found to be statistically significant at the 95 percent confidence level.

TABLE 16

I 75 SB AT I 71 SB (NIGHTTIME)
SINGLE LANE EXIT WITH TAPER
SIGNIFICANT ERRATIC MOVEMENT AND BRAKELIGHT RATE DEVIATIONS*

STUDY NUMBER	TRAFFIC CONTROL DEVICE(S) EMPLOYED
1	ORIGINAL
2	AMBER DELINEATORS
3	YELLOW STRIPING
4	AMBER DELINEATORS AND YELLOW STRIPING

COMPARISON		TYPE OF ERRATIC MOVEMENT RATE								TYPE OF BRAKELIGHT RATE			
FROM STUDY NO.	TO STUDY NO.	CUT ACROSS GORE	CROWDED WEAVE	SWERVE	SLOWED DRASTICALLY	STOPPED	STOPPED AND BACKED	MULTIPLE ERRORS	TOTAL	MEDIAN LANE	MIDDLE LANE	SHOULDER LANE	TOTAL
1	2	—	—	—	—	—	—	—	—	—	—	—	—
1	3	—	—	—	—	—	—	—	—	—	—	—	—
1	4	DECREASE	—	—	—	—	—	—	—	—	—	—	DECREASE
2	3	—	—	—	—	—	—	—	—	—	DECREASE	—	—
2	4	DECREASE	—	—	—	—	—	—	DECREASE	—	DECREASE	—	DECREASE
3	4	DECREASE	—	—	—	—	—	—	DECREASE	—	—	DECREASE	DECREASE

* The words "INCREASE" and "DECREASE" refer to certain erratic movement or brakelight rate deviations that were found to be statistically significant at the 95 percent confidence level.

TABLE 17

I 75 NB AT 5TH STREET EXIT (DAYTIME)
SINGLE LANE EXIT WITHOUT TAPER
SIGNIFICANT ERRATIC MOVEMENT AND BRAKELIGHT RATE DEVIATIONS*

STUDY NUMBER	TRAFFIC CONTROL DEVICE(S) EMPLOYED
1	ORIGINAL
2	AMBER DELINEATORS
3	YELLOW STRIPING
4	AMBER DELINEATORS AND YELLOW STRIPING

COMPARISON		TYPE OF ERRATIC MOVEMENT RATE								TYPE OF BRAKELIGHT RATE			
FROM STUDY NO.	TO STUDY NO.	CUT ACROSS GORE	CROWDED WEAVE	SWERVE	SLOWED DRASTICALLY	STOPPED	STOPPED AND BACKED	MULTIPLE ERRORS	TOTAL	MEDIAN LANE	MIDDLE LANE	SHOULDER LANE	TOTAL
1	2	—	—	—	—	—	—	—	—	—	INCREASE	—	—
1	3	—	—	—	DECREASE	—	—	—	—	—	DECREASE	—	DECREASE
1	4	DECREASE	—	—	DECREASE	—	—	—	DECREASE	—	—	DECREASE	DECREASE
2	3	—	—	—	DECREASE	—	—	—	—	DECREASE	DECREASE	—	DECREASE
2	4	—	—	—	DECREASE	—	—	—	—	—	DECREASE	DECREASE	DECREASE
3	4	—	—	—	—	—	—	—	—	—	—	—	—

*The words "INCREASE" and "DECREASE" refer to certain erratic movement or brakelight rate deviations that were found to be statistically significant at the 95 percent confidence level.

TABLE 18

I 75 NB AT 5TH STREET EXIT (NIGHTTIME)
SINGLE LANE EXIT WITHOUT TAPER
SIGNIFICANT ERRATIC MOVEMENT AND BRAKELIGHT RATE DEVIATIONS*

STUDY NUMBER	TRAFFIC CONTROL DEVICE(S) EMPLOYED
1	ORIGINAL
2	AMBER DELINEATORS
3	YELLOW STRIPING
4	AMBER DELINEATORS AND YELLOW STRIPING

COMPARISON		TYPE OF ERRATIC MOVEMENT RATE								TYPE OF BRAKELIGHT RATE			
FROM STUDY NO.	TO STUDY NO.	CUT ACROSS GORE	CROWDED WEAVE	SWERVE	SLOWED DRASTICALLY	STOPPED	STOPPED AND BACKED	MULTIPLE ERRORS	TOTAL	MEDIAN LANE	MIDDLE LANE	SHOULDER LANE	TOTAL
1	2	—	DECREASE	—	DECREASE	—	—	DECREASE	—	INCREASE	INCREASE	INCREASE	INCREASE
1	3	—	DECREASE	—	—	—	—	—	—	INCREASE	—	—	—
1	4	—	DECREASE	—	DECREASE	—	—	—	—	—	INCREASE	—	—
2	3	—	—	—	—	—	—	—	—	—	DECREASE	DECREASE	DECREASE
2	4	—	—	—	—	—	—	—	—	—	—	DECREASE	—
3	4	—	—	—	—	—	—	—	—	—	—	—	—

* The words "INCREASE" and "DECREASE" refer to certain erratic movement or brakelight rate deviations that were found to be statistically significant at the 95 percent confidence level.

Traffic Control Devices for Streets and Highways was the most effective device used during daytime conditions, and the amber delineators were most effective during nighttime conditions.

At the I-75 southbound - I-71 southbound single-lane exit with taper, the combination of amber delineators and yellow striping was the most effective combination for both daytime and nighttime.

At the I 75-5th Street single-lane exit without taper, the combination of amber delineators and yellow striping was again the most effective combination tested under both daytime and nighttime conditions.

At these last two locations, nighttime effectiveness of the amber delineator and yellow striping combination was not statistically significant. However, the daytime effectiveness was statistically significant at the 95 percent confidence level.

SPOT SPEEDS BEFORE AND AFTER EACH INSTALLATION

The number of interacting factors involved in the generation of a conflict may be so large that the effect of any one variable is negligible. Therefore, it would seem reasonable to examine a feature of traffic behavior more directly sensitive to events occurring in traffic and which are under the conscious control of the driver. This is generally the case with vehicle speed, for this is one of the basic modes of vehicle control available to the driver and should be, therefore, one to which he is most responsive. It would seem reasonable that speed would be a primary control that a driver would employ to compensate for any potentially hazardous traffic situation, as when approaching lane drops *(36)*.

Spot-speeds, taken during daylight hours, were analyzed to determine significant mean-speed differences before and after each different traffic control device installation. The statistical method used may be found in APPENDIX C *(37)*. Mean speeds for each of the locations are given in Figures 23 through 29. Although these speeds may appear low upon initial inspection, it should be noted that two locations have speed limits of 50 mph and several of the other locations have posted advisory speeds of from 35 mph to 45 mph. It should be recognized that horizontal alignment is the principal roadway feature related to spot-speed characteristics *(38)*. Furthermore, it has been noted that, on the average, operating speeds through weaving sections for a given level of service will fall from 5 to 10 mph below those for the same level on adjacent roadway sections *(39)*.

At the beginning of this study, it was hypothesized that an effective traffic control device at a lane drop would result in higher spot speeds in the immediate vicinity of the gore and in slightly lower or unchanged spot speeds at a distance of approximately 500 feet back from the gore. It was felt that a driver recognizing the lane-drop situation ahead would either slow down slightly or keep a constant speed during the final few seconds of approach. This decision making was estimated to occur at a distance

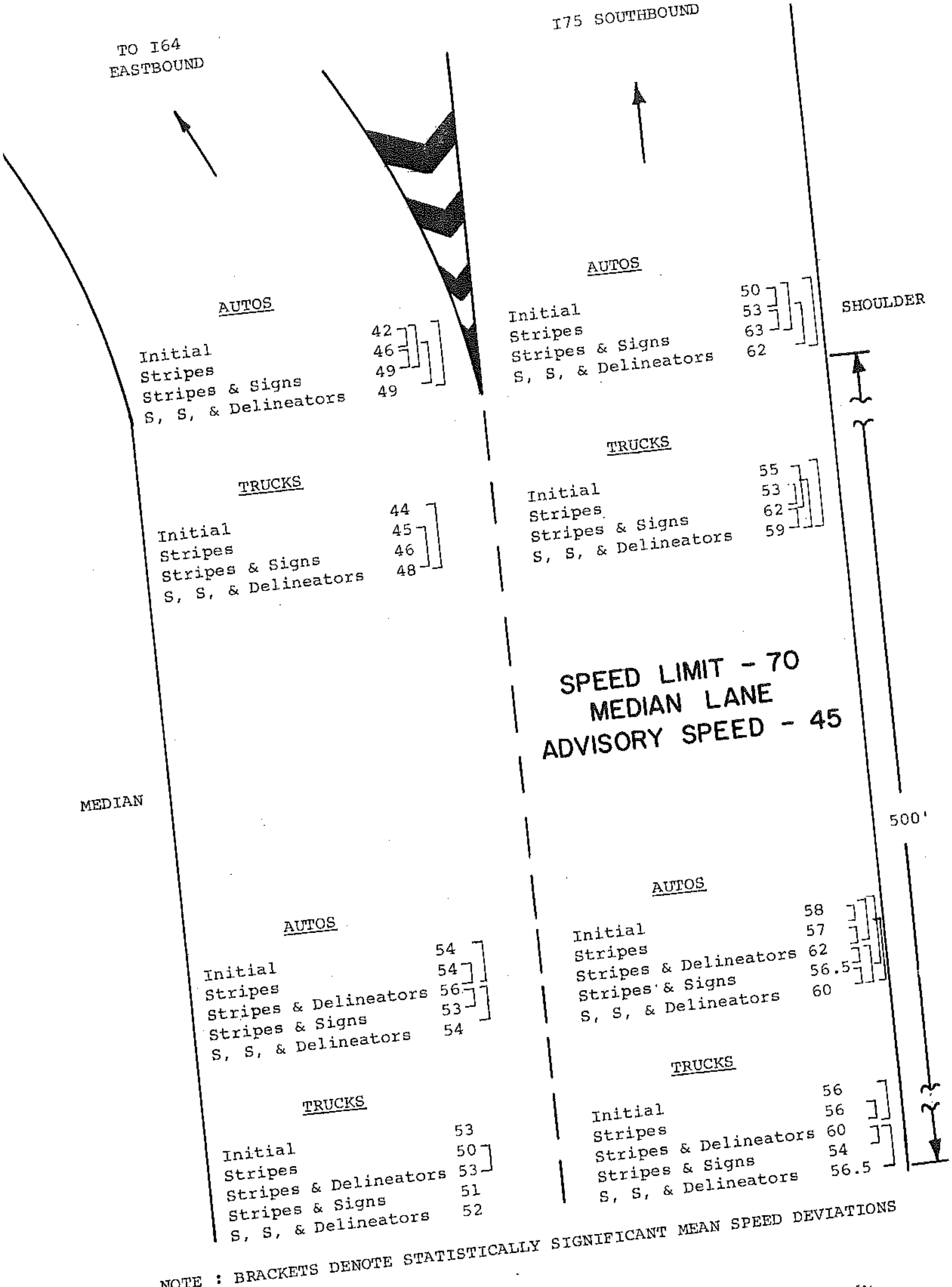


Figure 23. Mean Speeds at the I 75 SB - I 64 EB Lane Split

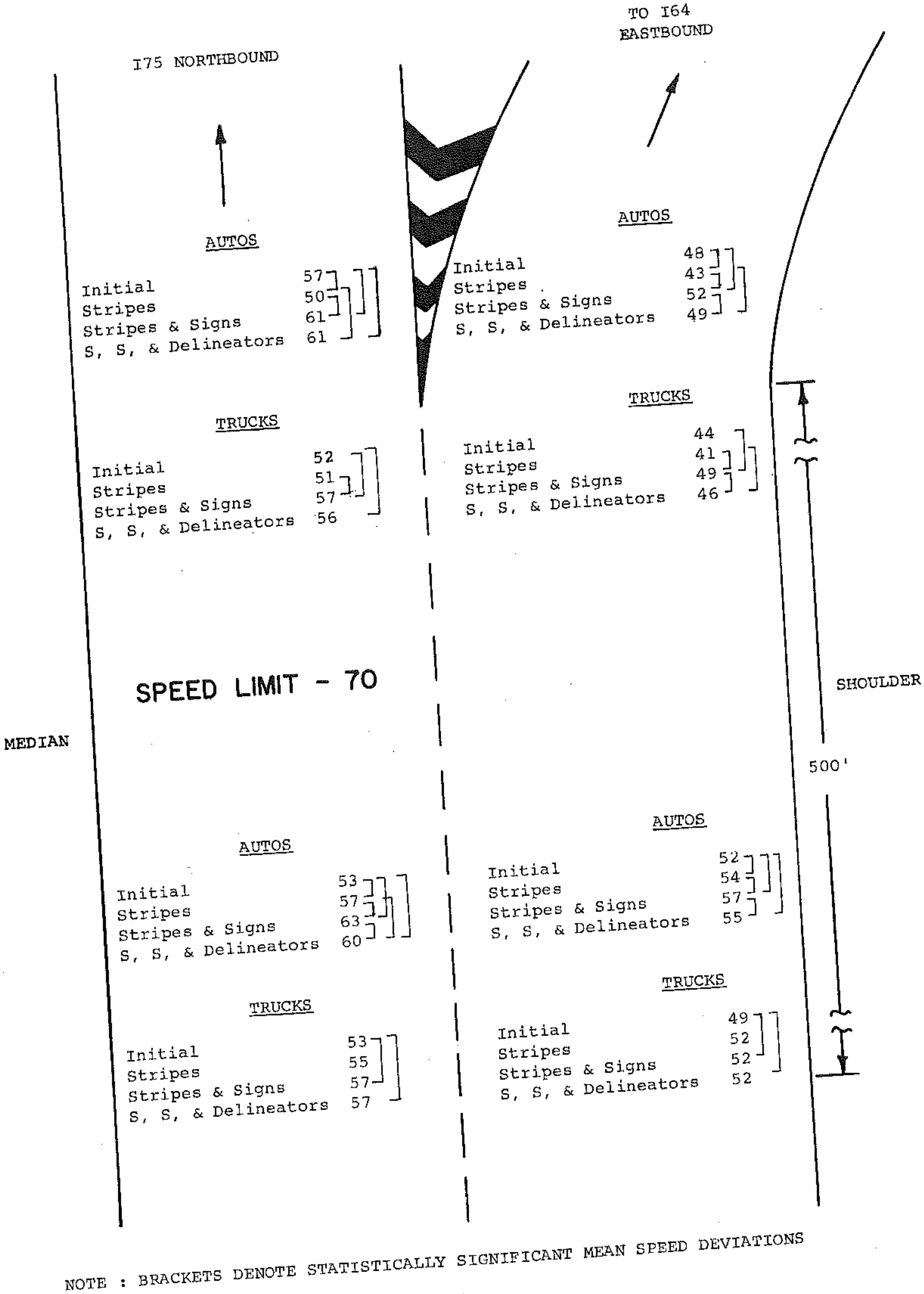
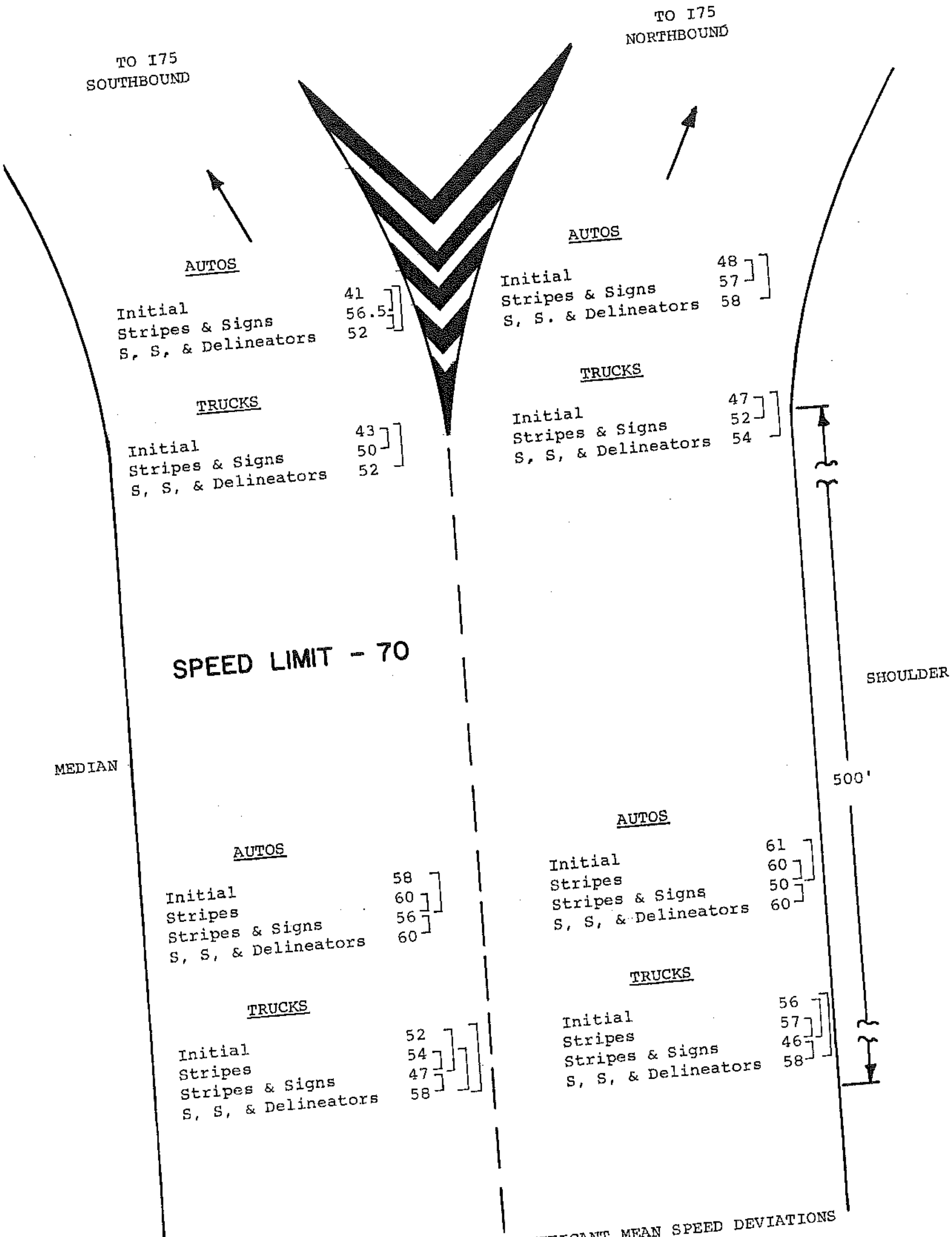


Figure 24. Mean Speeds at the I 75 NB - I 64 EB Lane Split



NOTE: BRACKETS DENOTE STATISTICALLY SIGNIFICANT MEAN SPEED DEVIATIONS

Figure 25. Mean Speeds at the I 64 WB Lane Split

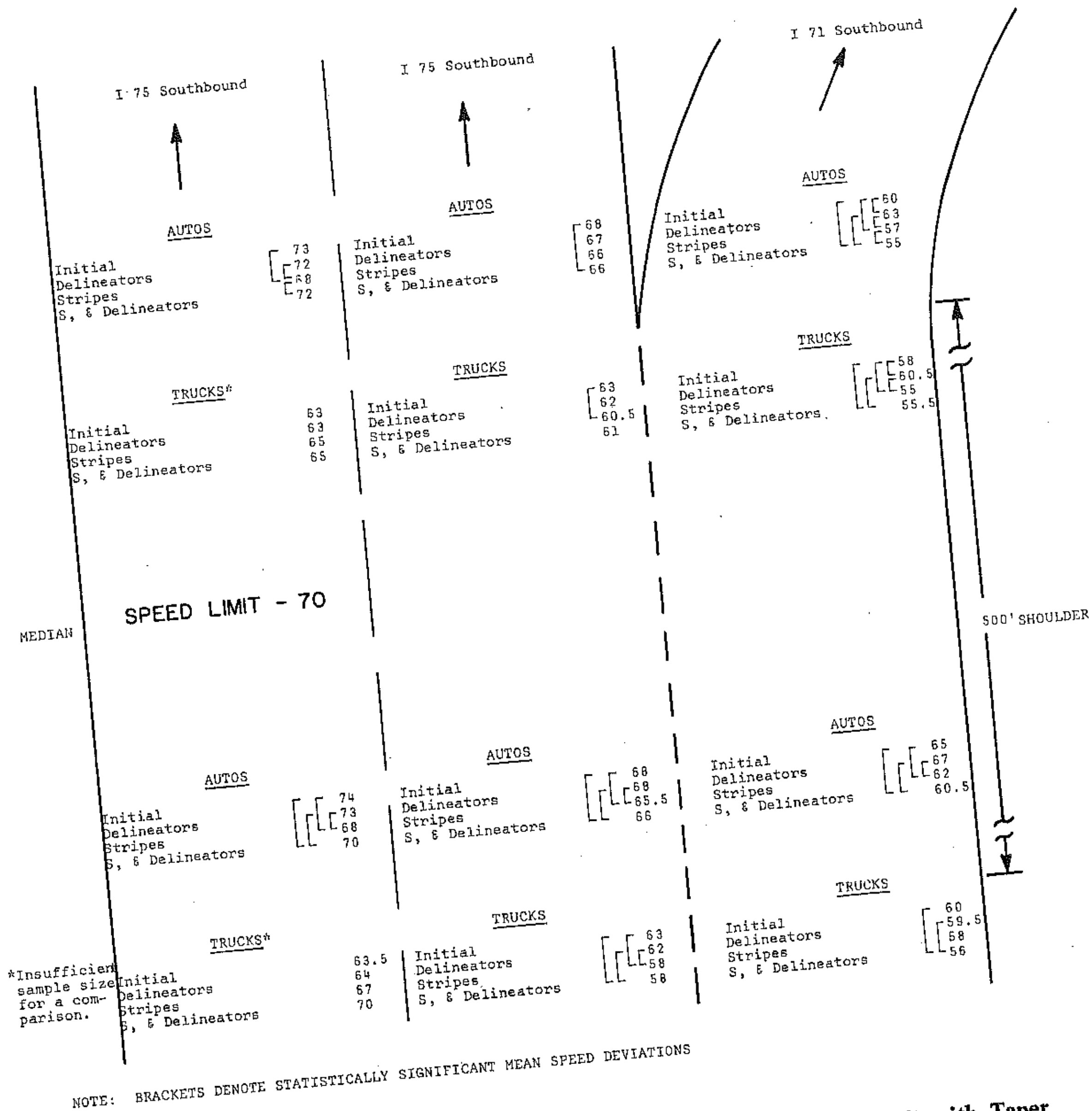


Figure 26. Mean Speeds at the I 75 SB - I 71 SB Single Lane Exit with Taper

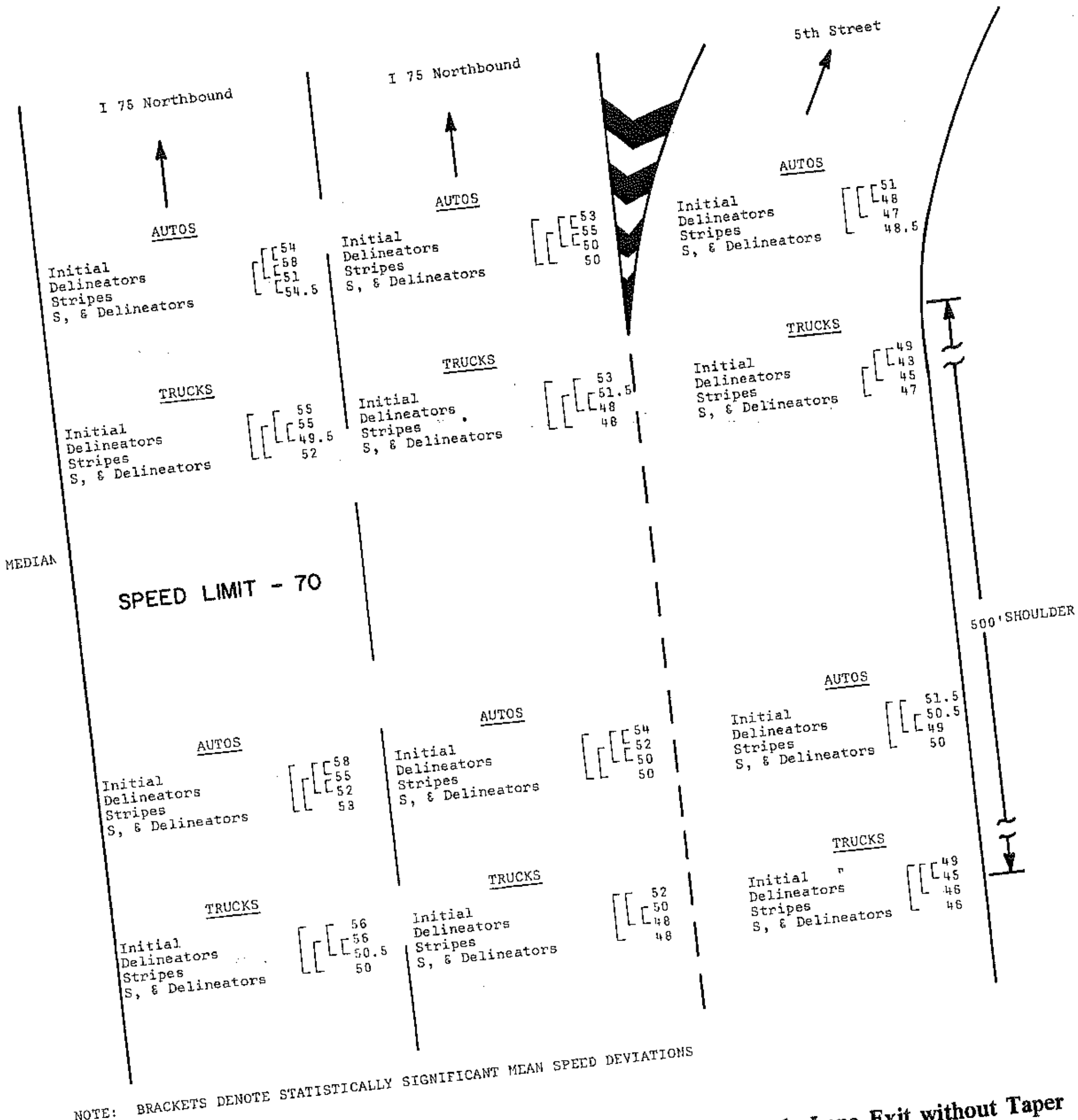


Figure 27. **Mean Speeds at the I 75 NB - 5th Street Single Lane Exit without Taper**

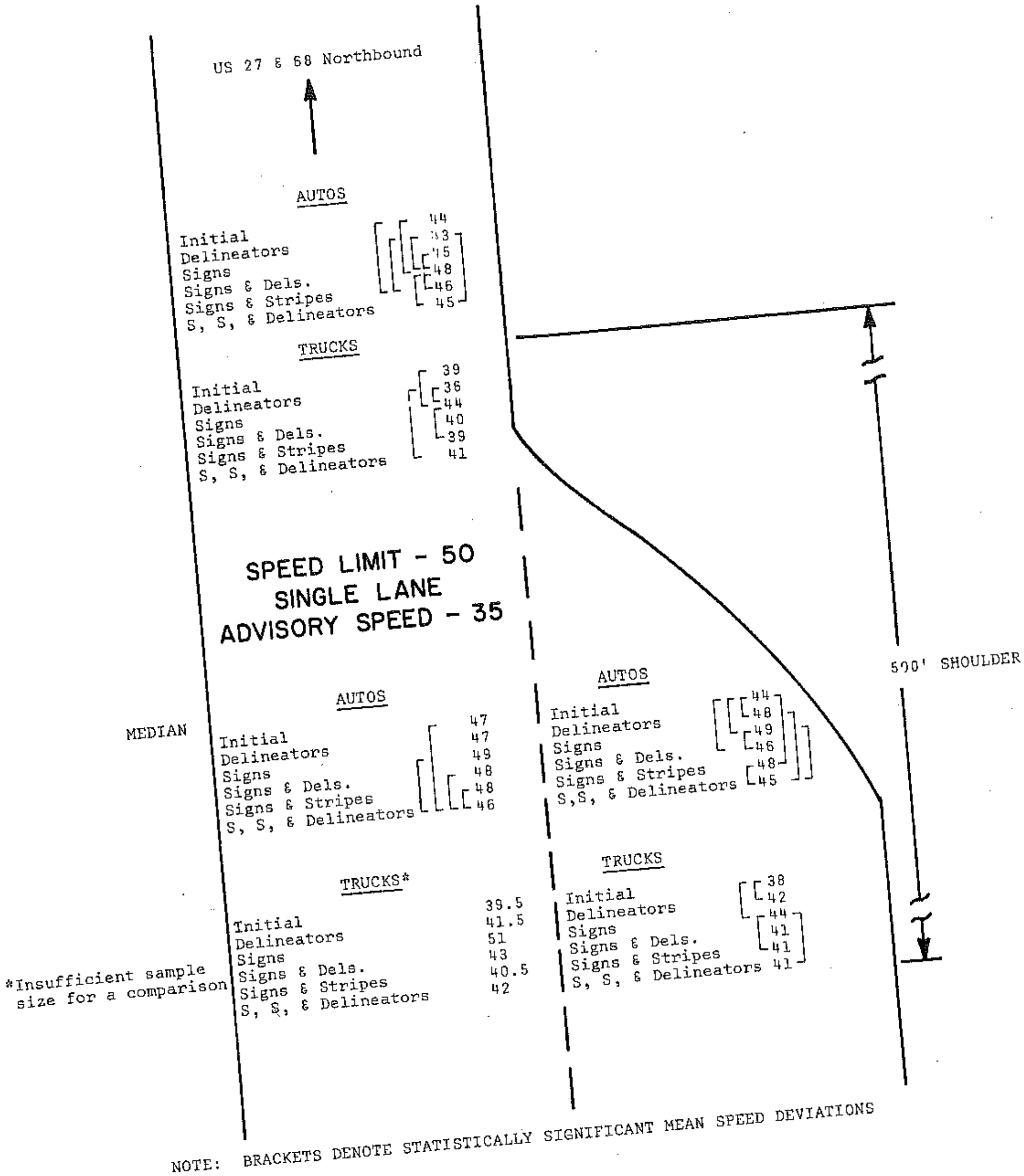


Figure 28. **Mean Speeds at the Paris Pike Lane Termination**

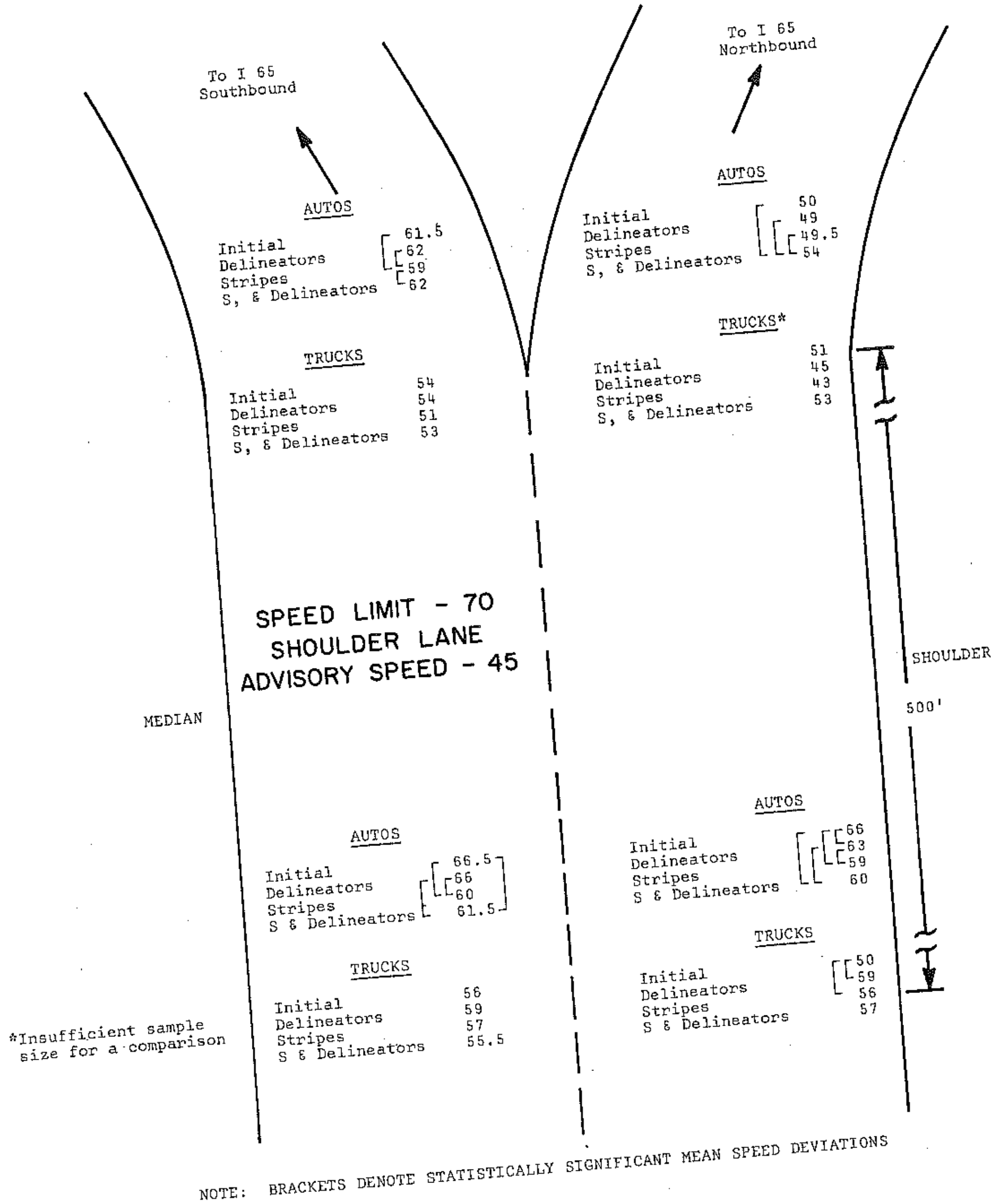


Figure 29. Mean Speeds at the Bluegrass Parkway Lane Split

of 500 feet from the lane split. At the gore, the driver becomes more certain of his path of travel and resumes speed. Generally, this trend was observed at each location for each of the traffic control device installations which were the most effective in reducing conflicts.

CONFLICTS AND SPOT-SPEED MEANS AND VARIANCES

Total erratic movement and brakelight rate deviations are compared with mean speed and sample variance deviations, for each lane-drop type studied, in Tables 19 through 22. Only daylight conflict rates were compared; speed studies were made for daylight conditions only. These comparisons were made in an attempt to determine if variations in conflict rates could be related to variations in mean speeds and/or sample variances. In the case of speed variance, it was felt that if, in fact, a traffic control device causes a reduction in the variance of speed, then it would also reduce the frequency of extreme responses and their attendent possibilities for driving errors, i.e., conflicts. However, a thorough study of Tables 19 through 22 reveals that there is no apparent relationship between conflict rates and mean speeds or sample variances. The sample from which this comparison was made consisted of all conflict rates, mean speeds, and speed variances, both initially and after installation of each experimental traffic control device.

DATA RESTRICTIONS

In summary, there are limitations on the interpretation of the data obtained in this study which are perhaps indicative of some basic restrictions inherent in all such field studies of this type. First, the freedom of response available to drivers is so great that the variability in operational characteristics may be random. Consequently, data taken from the roadside on a mass of motorists may be so unrealiable that definitive inferences are possible only in limited situations. Second, the time-varying characteristics, especially the "novelty effect" created by any new traffic control device within the highway system, prevent the establishment of any real experimental control in the field. There are too many uncontrolled variables. Third, observers, being human, are not capable of complete objectivity, regardless of how vigorously it is attempted. Finally, perhaps the greatest limitation was that traffic conflicts at several locations were observed under volume conditions which have been shown to produce inconsistent conflict rates, i.e., in the range from approximately 2,000 to 5,000 vehicles per day *(33)*. Such a limitation hindered the analysis of field data and the conclusions made therefrom.

CONCLUSIONS

Each of the three traffic control devices tested was effective, in varying degrees, in reducing traffic conflicts at lane drops. No single type of traffic control device tested was significantly effective in reducing

STUDY NUMBER	TRAFFIC CONTROL DEVICE(S) EMPLOYED
1	ORIGINAL
2	AMBER DELINEATORS
3	YELLOW STRIPING
4	AMBER DELINEATORS AND YELLOW STRIPING

TABLE 19

BLUEGRASS PARKWAY LANE SPLIT

COMPARISON OF TOTAL ERRATIC MOVEMENT AND TOTAL BRAKELIGHT RATES WITH MEAN SPEEDS AND SPOT-SPEED SAMPLE VARIANCES

COMPARISON		NET ERRATIC MOVEMENT RATE CHANGE	NET TOTAL BRAKELIGHT RATE CHANGE	AUTOS								TRUCKS							
				AT GORE AREA				500' BACK FROM GORE				AT GORE AREA				500' BACK FROM GORE			
				MEDIAN LANE		SHOULDER LANE		MEDIAN LANE		SHOULDER LANE		MEDIAN LANE		SHOULDER LANE		MEDIAN LANE		SHOULDER LANE	
FROM STUDY NO.	TO STUDY NO.			SAMPLE VARIANCE*	MEAN SPEED*	SAMPLE VARIANCE*	MEAN SPEED*	SAMPLE VARIANCE*	MEAN SPEED*	SAMPLE VARIANCE*	MEAN SPEED*	SAMPLE VARIANCE*	MEAN SPEED*	SAMPLE VARIANCE*	MEAN SPEED*	SAMPLE VARIANCE*	MEAN SPEED*	SAMPLE VARIANCE*	MEAN SPEED*
1	2	-11.51$^+$	-6.81	13.30	.78	-22.96	-.72	10.13	-.89	-7.56	-2.70$^+$	-19.02$^+$	.30	-108.26	-6.66	-4.79	2.51	-29.16$^+$	-8.42$^+$
1	3	-15.56$^+$	-3.38	.93	-2.47$^+$	-28.23$^+$	-.18	-5.37	-6.03	-5.87	-6.85$^+$	42.60$^+$	-3.10	-116.26	-8.66	-30.62$^+$	.45	-12.23	5.45$^+$
1	4	-16.78$^+$	1.05	-5.91	.74	24.02	4.67$^+$	29.30$^+$	-5.00$^+$	7.00	-6.00$^+$	5.47	-.77	-129.73$^+$	2.07	-9.09	-.85	-3.65	2.25
2	3	-4.05	3.43	-12.37	-3.25$^+$	-4.73	.54	-15.50	-5.14$^+$	1.69	-4.15$^+$	61.62$^+$	-3.40	-8.00	-2.00	-25.83$^+$	-2.06	16.93	-.03
2	4	-5.27	7.86$^+$	-19.21	-.04	47.52$^+$	5.39$^+$	19.17	-4.11$^+$	14.56	-3.30$^+$	13.55	-1.07	-21.47	8.73	-4.30	-2.36	15.51	-2.17
3	4	-1.22	4.43	-6.84	3.21$^+$	52.25$^+$	4.85$^+$	34.67$^+$	1.03	12.87	.85	-48.07$^+$	2.33	-13.47	10.73	21.53$^+$	-1.30	-1.42	.80

* Figures shown for sample variance and mean speed are net differences between the two studies being compared.
\+ Statistically significant difference at the 95% confidence level.

STUDY NUMBER	TRAFFIC CONTROL DEVICE(S) EMPLOYED
1	ORIGINAL
2	AMBER DELINEATORS
3	"NEW" SIGNS
4	"NEW" SIGNS AND AMBER DELINEATORS
5	"NEW" SIGNS AND YELLOW STRIPING
6	"NEW" SIGNS, YELLOW STRIPING, AND AMBER DELINEATORS

TABLE 20

PARIS PIKE LANE TERMINATION

COMPARISON OF TOTAL ERRATIC MOVEMENT AND TOTAL BRAKELIGHT RATES WITH MEAN SPEEDS AND SPOT-SPEED SAMPLE VARIANCES

COMPARISON		NET ERRATIC MOVEMENT RATE CHANGE	NET TOTAL BRAKELIGHT RATE CHANGE	AUTOS						TRUCKS					
				SINGLE LANE SECTION		500' BACK FROM SINGLE LANE				SINGLE LANE SECTION		500' BACK FROM SINGLE LANE			
						MEDIAN LANE		SHOULDER LANE				MEDIAN LANE		SHOULDER LANE	
FROM STUDY NO.	TO STUDY NO.			SAMPLE VARIANCE*	MEAN SPEED*	SAMPLE VARIANCE*	MEAN SPEED*	SAMPLE VARIANCE*	MEAN SPEED*	SAMPLE VARIANCE*	MEAN SPEED*	SAMPLE VARIANCE*	MEAN SPEED*	SAMPLE VARIANCE*	MEAN SPEED*
1	2	-1.20$^+$	.50	5.37	-.50	-.77	-.03	-26.51$^+$	3.58$^+$	-10.91	-2.68	-72.00$^+$	2.00	-6.41	4.04$^+$
1	3	-2.01$^+$	-2.84$^+$	-8.80	1.22	-5.92	1.48	-28.30$^+$	4.87$^+$	-22.52	4.96$^+$	-69.00	11.17	-.82	5.91$^+$
1	4	-1.52$^+$	-2.45$^+$	-9.21	4.38$^+$	-3.17	.24	-16.52$^+$	2.22$^+$	4.94	1.12	-21.13	3.70	36.77$^+$	2.51
1	5	-2.04$^+$	-3.38$^+$	-20.01$^+$	2.12$^+$	-11.00	.91	-28.62$^+$	3.88$^+$	-40.15$^+$	.52	-62.62$^+$	1.00	7.02	2.71
1	6	-2.05$^+$	-3.68$^+$	-15.54$^+$	1.41	.56	-1.60$^+$	-9.93	.98	-34.91$^+$	1.98	-39.53	2.10	-14.17	2.28
2	3	-.81$^+$	-3.34	-14.17	1.72	-5.15	1.51	-1.79	1.24	-11.61	7.64$^+$	3.00	9.17	5.59	1.87
2	4	-.32	-2.95	-14.58	4.88$^+$	-2.40	.27	9.99	-1.36	15.85	3.80	50.87	1.70	43.18$^+$	-1.53
2	5	-.84$^+$	-3.88$^+$	-25.38$^+$	2.62$^+$	-10.23	.94	-2.11	.30	-29.24$^+$	3.20	9.38	-1.00	13.43	-1.33
2	6	-.85$^+$	-4.18$^+$	-20.91$^+$	1.91$^+$	1.33	-1.57	16.58$^+$	-2.60$^+$	-24.00	4.66$^+$	32.47	.10	-7.76	-1.76
3	4	.49$^+$	.39	.41	3.16$^+$	2.75	-1.24	11.78	-2.60$^+$	27.46	-3.84	47.87	-7.47	37.59$^+$	-3.40
3	5	-.03	-.54	-11.21	.90	-5.08	-.57	-.32	-.94	-17.63	-4.44$^+$	6.38	-10.16	7.84	-3.20$^+$
3	6	-.04	-.84	-6.74	.19	6.48	-3.08$^+$	18.37$^+$	-3.84$^+$	-12.39	-2.98	29.47	-9.07	-13.35	-3.63$^+$
4	5	-.52$^+$	-.93	-10.80	-2.26$^+$	-7.83	.67	-12.10	1.66	-45.09$^+$	-.60	-41.49	-2.70	-29.75	.20
4	6	-.53$^+$	-1.23	-6.33	-2.97$^+$	3.73	-1.84$^+$	6.59	-1.24	-39.85$^+$	.86	-18.40	-1.60	-50.94$^+$	.23
5	6	-.01	-.30	4.47	-.71	11.56	-2.51$^+$	18.69$^+$	-2.90$^+$	5.24	1.46	23.09	1.10	-21.19	-.43

* Figures shown for sample variance and mean speed are net differences between the two studies being compared.
\+ Statistically significant difference at the 95% confidence level.

TABLE 21

I 75 SB AT I 71 SB
SINGLE LANE EXIT WITH TAPER

COMPARISON OF TOTAL ERRATIC MOVEMENT AND TOTAL BRAKELIGHT RATES
WITH MEAN SPEEDS AND SPOT-SPEED SAMPLE VARIANCES

STUDY NUMBER	TRAFFIC CONTROL DEVICE(S) EMPLOYED
1	ORIGINAL
2	AMBER DELINEATORS
3	YELLOW STRIPING
4	AMBER DELINEATORS AND YELLOW STRIPING

AUTOS

COMPARISON FROM STUDY NO.	COMPARISON TO STUDY NO.	NET ERRATIC MOVEMENT RATE CHANGE	NET TOTAL BRAKELIGHT RATE CHANGE	AT GORE AREA: MEDIAN LANE SAMPLE VARIANCE*	AT GORE AREA: MEDIAN LANE MEAN SPEED*	AT GORE AREA: MIDDLE LANE SAMPLE VARIANCE*	AT GORE AREA: MIDDLE LANE MEAN SPEED*	AT GORE AREA: SHOULDER LANE SAMPLE VARIANCE*	AT GORE AREA: SHOULDER LANE MEAN SPEED*	500' BACK FROM GORE: MEDIAN LANE SAMPLE VARIANCE*	500' BACK FROM GORE: MEDIAN LANE MEAN SPEED*	500' BACK FROM GORE: MIDDLE LANE SAMPLE VARIANCE*	500' BACK FROM GORE: MIDDLE LANE MEAN SPEED*	500' BACK FROM GORE: SHOULDER LANE SAMPLE VARIANCE*	500' BACK FROM GORE: SHOULDER LANE MEAN SPEED*
1	2	-.53	-.75	-11.23	-1.38	-5.84	-1.74	8.19	2.46†	6.68	-1.21	-.80	.09	7.49	1.40
1	3	-.50	1.23	-23.13†	-4.64†	-7.17	-1.94†	11.06	-3.36†	-8.80†	-5.71†	2.79	-2.39†	-9.41	-3.45†
1	4	-1.58†	-3.27†	-19.48†	-1.22	-3.21	-2.06†	-3.95	-5.50†	.19	-3.62†	-13.93†	-1.53†	-15.02	-4.66†
2	3	.03	1.98†	-11.90†	-3.15†	-1.33	-.20	2.87	-5.84†	-15.48†	-4.50†	3.59	-2.48†	-16.90†	-4.83†
2	4	-1.05†	-2.52†	-8.25	.26	2.63	-.32	-12.17	-7.96†	-6.49	-2.41†	-13.13†	-1.62†	-22.51†	-6.06†
3	4	-1.08†	-4.50†	3.65	3.42	3.96	-.12	-15.04†	-2.12†	8.99†	1.09	-16.72†	.96	-5.61	-1.23

TRUCKS

COMPARISON FROM STUDY NO.	COMPARISON TO STUDY NO.	NET ERRATIC MOVEMENT RATE CHANGE	NET TOTAL BRAKELIGHT RATE CHANGE	AT GORE AREA: MEDIAN LANE SAMPLE VARIANCE*	AT GORE AREA: MEDIAN LANE MEAN SPEED*	AT GORE AREA: MIDDLE LANE SAMPLE VARIANCE*	AT GORE AREA: MIDDLE LANE MEAN SPEED*	AT GORE AREA: SHOULDER LANE SAMPLE VARIANCE*	AT GORE AREA: SHOULDER LANE MEAN SPEED*	500' BACK FROM GORE: MEDIAN LANE SAMPLE VARIANCE*	500' BACK FROM GORE: MEDIAN LANE MEAN SPEED*	500' BACK FROM GORE: MIDDLE LANE SAMPLE VARIANCE*	500' BACK FROM GORE: MIDDLE LANE MEAN SPEED*	500' BACK FROM GORE: SHOULDER LANE SAMPLE VARIANCE*	500' BACK FROM GORE: SHOULDER LANE MEAN SPEED*
1	2	-.53	-.75	-33.09†	.23	14.36†	.77	2.03	2.87†	-3.10	.21	1.86	-1.12	11.10†	-.39
1	3	-.50	1.23	-20.29	2.43	27.90†	-2.23	4.15	-2.85†	-9.38	3.07	-.97	-4.88†	16.18†	-1.47
1	4	-1.58†	-3.27†	-28.29†	2.10	11.88	-1.63	-8.14	-2.16†	-17.00	6.50	1.12	-5.47†	9.56	-3.33†
2	3	.03	1.98†	12.80	2.20	13.54	-1.46	2.12	-5.72†	-6.28	2.86	.89	-3.76†	5.08	-1.28
2	4	-1.05†	-2.52†	4.80	1.87	-2.68	-.93	-10.17	-5.03†	-13.90	6.29	2.98	-4.35†	-1.54	-3.64†
3	4	-1.08†	-4.50†	-8.00	-.33	-16.22	.55	-12.29	.69	-7.62	3.43	2.09	-.59	-6.62	-2.36

*Figures shown for sample variance and mean speed are net differences between the two studies being compared.
†Statistically significant difference at the 95% confidence level.

TABLE 22

I 75 NB AT 5TH STREET EXIT
SINGLE LANE EXIT WITHOUT TAPER

COMPARISON OF TOTAL ERRATIC MOVEMENT AND TOTAL BRAKELIGHT RATES
WITH MEAN SPEEDS AND SPOT-SPEED SAMPLE VARIANCES

STUDY NUMBER	TRAFFIC CONTROL DEVICE(S) EMPLOYED
1	ORIGINAL
2	AMBER DELINEATORS
3	YELLOW STRIPING
4	AMBER DELINEATORS AND YELLOW STRIPING

AUTOS

COMPARISON FROM STUDY NO.	TO STUDY NO.	NET ERRATIC MOVEMENT RATE CHANGE	NET TOTAL BRAKELIGHT RATE CHANGE	At Gore Area: Median Lane Sample Variance*	At Gore Area: Median Lane Mean Speed*	At Gore Area: Middle Lane Sample Variance*	At Gore Area: Middle Lane Mean Speed*	At Gore Area: Shoulder Lane Sample Variance*	At Gore Area: Shoulder Lane Mean Speed*	500' Back from Gore: Median Lane Sample Variance*	500' Back from Gore: Median Lane Mean Speed*	500' Back from Gore: Middle Lane Sample Variance*	500' Back from Gore: Middle Lane Mean Speed*	500' Back from Gore: Shoulder Lane Sample Variance*	500' Back from Gore: Shoulder Lane Mean Speed*
1	2	-.11	1.02	2.00	4.92$^+$	-8.11$^+$	1.74$^+$	.23	-3.53$^+$	4.50	-2.86$^+$	.35	-1.96$^+$	-2.11	-1.08
1	3	-.23	-1.49$^+$	4.77$^+$	-2.22$^+$	-9.51$^+$	-3.52$^+$	4.30	-3.86$^+$	.07	-5.96$^+$	-5.29	-4.26$^+$	-7.22	-2.93$^+$
1	4	-.30$^+$	-1.32$^+$	2.02	.92	-10.75$^+$	-2.70$^+$	-6.25$^+$	-2.70$^+$	1.09	-5.02$^+$	-3.39	-3.90$^+$	-11.33$^+$	-1.86$^+$
2	3	-.12	-2.51$^+$	2.73	-6.44$^+$	-1.40	-5.06$^+$	4.53	-.28	-4.57	-3.10$^+$	-5.64	-2.30$^+$	-5.11	-1.85$^+$
2	4	-.19	-2.34$^+$	.02	-3.30	-2.64	-4.44$^+$	-6.02$^+$	.88	-3.41	-2.16$^+$	-7.94	-1.94$^+$	-9.25$^+$	-.78
3	4	-.07	.17	-2.71	3.14$^+$	-1.24	.62	-10.55$^+$	1.16	1.36	.94	1.70	.36	-4.11	1.07

TRUCKS

COMPARISON FROM STUDY NO.	TO STUDY NO.	At Gore Area: Median Lane Sample Variance*	At Gore Area: Median Lane Mean Speed*	At Gore Area: Middle Lane Sample Variance*	At Gore Area: Middle Lane Mean Speed*	At Gore Area: Shoulder Lane Sample Variance*	At Gore Area: Shoulder Lane Mean Speed*	500' Back from Gore: Median Lane Sample Variance*	500' Back from Gore: Median Lane Mean Speed*	500' Back from Gore: Middle Lane Sample Variance*	500' Back from Gore: Middle Lane Mean Speed*	500' Back from Gore: Shoulder Lane Sample Variance*	500' Back from Gore: Shoulder Lane Mean Speed*
1	2	5.91	.68	-.29	-1.40	-24.06	-6.06$^+$	16.12$^+$	.28	-8.89	-2.00	11.54	-3.82$^+$
1	3	15.12$^+$	-5.13$^+$	.08	-4.57$^+$	-33.03$^+$	-3.39$^+$	-2.06	-5.35$^+$	-6.67	-4.30$^+$	-1.54	-2.39$^+$
1	4	2.92	-2.87$^+$	3.86	-4.66$^+$	-12.60	-2.16	-6.03	-5.73$^+$	-9.84	-3.81$^+$	6.64	-2.45$^+$
2	3	10.11	-5.81$^+$	.37	-3.17$^+$	1.03	2.27	-18.17$^+$	-5.63$^+$	32.08	-2.30$^+$	-13.08	1.43
2	4	-2.09	-3.55$^+$	4.15	-3.26$^+$	11.46	3.90$^+$	-22.15$^+$	-6.01$^+$	-.95	-1.81	-4.90	1.37
3	4	-12.20	2.26	3.78	-.09	10.43	1.63	-3.98	-.38	-3.17	.49	5.18	-.06

* Figures shown for sample variance and mean speed are net differences between the two studies being compared.
$^+$ Statistically significant difference at the 95% confidence level.

conflicts at all seven lane drops. Rather, different devices were generally most effective at different locations.

The lane drop comprised of a single-lane exit without taper had the lowest conflict rates of the four different calssifications studied. The lane termination had the next lowest conflict rates.

Lane drops associated with poor site geometrics, i.e., high rates of curvature with attendant sight distance restrictions, were observed to have higher conflict rates than those associated with more optimal geometric features.

No distinct relationship between traffic volumes and conflict rates, as defined herein, was found at the lane drops studied. No definitive relationship between conflict and accident rates was found.

Lane drops must be designed properly from the outset, inasmuch as traffic control devices are not as effective in reducing conflicts as are proper site geometrics.

There are limitations on the interpretation of the data in this study which are perhaps indicative of some basic restrictions inherent in all such field studies of this type.

Although the traffic conflict criterion is well established *(24, 25)*, its usefulness in predicting accident potential at sites where the traffic volumes are in the range of approximately 2,000 - 5,000 vehicles per day is questionable.

RECOMMENDATIONS

Different environmental, geometric, and traffic conditions may explain why different traffic control devices were most effective in reducing conflict rates at different sites. Further study of the affecting conditions should be made to determine their relationship with the effectiveness of traffic control devices. The principal objective should be the preparation of guidelines for the installation of traffic control devices at lane-drop locations whenever the elimination of lane drops is not practicable.

In the words of the Special AASHO Traffic Safety Committee, "Lane drops should normally be avoided altogether by original design or later rebuilding...".

Whenever the elimination of lane drops is not practicable, optimum design criteria, i.e., those providing superior sight distance, should be followed even though such criteria may not be followed throughout the entire length of a particular route. Furthermore, the principles of operational flexibility, as expressed in the literature *(31)*, should be followed at all times.

Based on the findings of this study and one by the California Division of Highways *(11)*, it is recommended that the single-lane exit without taper type of lane drop be utilized at all single-lane exits

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APPENDIX A

ERRATIC MOVEMENT DEFINITIONS

ERRATIC MOVEMENT DEFINITIONS

Cut Across Gore Area -- Vehicle *crosses over* the *pavement markings* used to delineate the gore area.

Crowded Weave - Vehicle changes lanes *directly in front of* a following vehicle, causing the *following vehicle to apply its brakes.* This type of erratic movement *always directly involves* at least *two* vehicles.

Stopped - Vehicle comes to a *complete stop.*

Slowed Drastically -- Vehicle undergoes a *very rapid deceleration,* causing *"dipping"* of the front end or *tire squealing.*

Swerve -- Vehicle *abruptly veers* from its *straight ahead course.* A swerve *may* or *may not* consist of a change of lanes for the erratic vehicle. This type of erratic movement *always involves* only *one* vehicle.

Stopped and Backed - Vehicle comes to a *complete stop* and then *backs up.*

Multiple Error -- Occurs when a vehicle commits a combination of two or more of the above errors.

APPENDIX B

ACCIDENT ANALYSES

ACCIDENT SUMMARIES
COLLISION DIAGRAMS
1971 ADJUSTED AVERAGE DAILY TRAFFIC VOLUMES

ACCIDENT SUMMARIES

ACCIDENT SUMMARY

I 64 - I 75 TRI-LEVEL INTERCHANGE

STUDY PERIOD -- August 15, 1967, through December 31, 1970

ACCIDENT RATE -- 192 accidents per hundred million vehicle miles

INJURY RATE -- 101 accidents per hundred million vehicle miles

	NORTHBOUND	SOUTHBOUND	TOTAL	PERCENT
NUMBER OF ACCIDENTS	65	49	114	100
MULTIPLE VEHICLE ACCIDENTS	28	30	58	51
Sideswipe	10	12	22	
Rear-End	18	18	36	
SINGLE VEHICLE ACCIDENTS	37	19	56	49
Mechanical Failure	2	0	2	
Loss of Control*	35	19	54	
ACCIDENTS INVOLVING INJURY	17	17	34	30
TOTAL NUMBER INJURED	29	31	60	
TOTAL FATALITIES	0	0	0	
LIGHT CONDITION				
Daylight	49	27	76	67
Dark	16	22	38	33
PAVEMENT CONDITION				
Wet	27	12	39	34
Dry	38	37	75	66

*Loss of control includes falling asleep, adverse roadway conditions (wet, ice, snow, etc.), inattention, drinking, object in roadway, etc.

ACCIDENT SUMMARY

I-75 NORTHBOUND AT THE 5TH STREET EXIT IN COVINGTON

STUDY PERIOD - January 1, 1971 -- December 31, 1971

ACCIDENT RATE - 1.12 accidents per million vehicles

INJURY RATE - 0.40 injury accidents per million vehicles

	TOTAL	PERCENT
NUMBER OF ACCIDENTS	17	100
ACCIDENT TYPES		
Rear-End	9	53
Multiple Rear-End	5	29
Sideswipe	2	12
Fixed Object	1	6
ACCIDENTS INVOLVING INJURY	6	35
TOTAL NUMBER INJURED	12	
TOTAL FATALITIES	0	0
LIGHT CONDITION		
Daylight	14	82
Dark	2	12
Dawn or Dusk	1	6
PAVEMENT CONDITION		
Wet	5	29
Dry	12	71

ACCIDENT SUMMARY

US 27-68 (Paris Pike) NORTHBOUND, JUST NORTH OF NEW CIRCLE ROAD, FAYETTE COUNTY

STUDY PERIOD - January 1, 1971 -- December 31, 1971

ACCIDENT RATE - 4.72 accidents per million vehicles

INJURY RATE - 1.57 injury accidents per million vehicles

	TOTAL	PERCENT
NUMBER OF ACCIDENTS	9	100
ACCIDENT TYPES		
Rear-End	4	45
Multiple Rear-End	1	11
Oblique	2	22
Fixed Object	2	22
ACCIDENTS INVOLVING INJURY	3	33
TOTAL NUMBER INJURED	3	
TOTAL FATALITIES	0	0
LIGHT CONDITION		
Daylight	5	56
Dark	4	44
PAVEMENT CONDITION		
Wet	3	33
Dry	6	67

ACCIDENT SUMMARY

WESTERN TERMINUS OF THE BLUEGRASS PARKWAY, WESTBOUND

STUDY PERIOD - January 1, 1971 - December 31, 1971

ACCIDENT RATE - 3.56 accidents per million vehicles

INJURY RATE - 1.78 injury accidents per million vehicles

	TOTAL
NUMBER OF ACCIDENTS	2
ACCIDENT TYPES	
Fixed Object	1
Lost Control	1
ACCIDENTS INVOLVING INJURY	1
TOTAL NUMBER INJURED	1
TOTAL FATALITIES	0
LIGHT CONDITION	
Daylight	1
Dark	1
PAVEMENT CONDITION	
Dry	1
Icy	1

ACCIDENT SUMMARY

I-75 SOUTHBOUND AT I-71 SOUTHBOUND

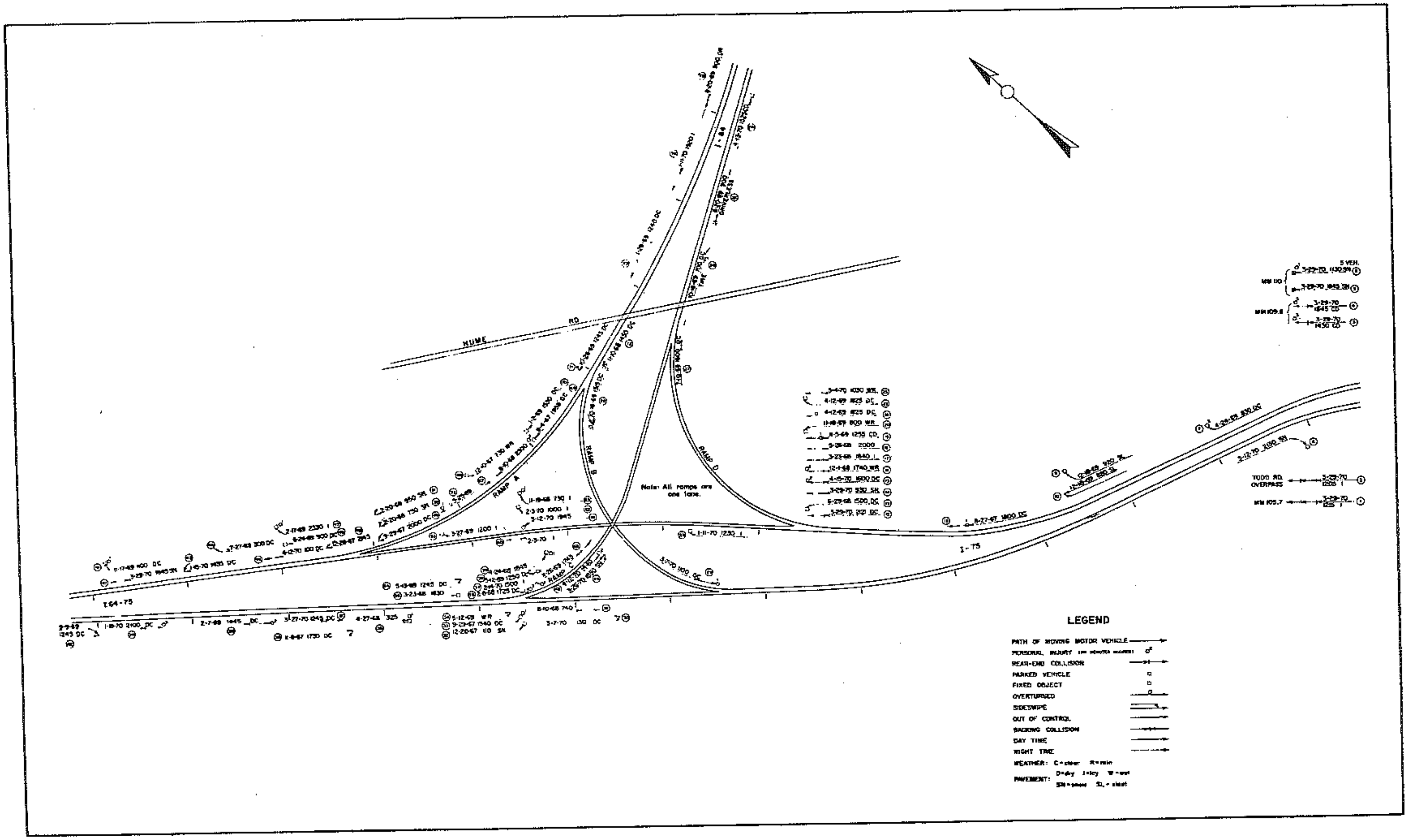
STUDY PERIOD - January 1, 1971 -- December 31, 1971

ACCIDENT RATE - 0.77 accidents per million vehicles

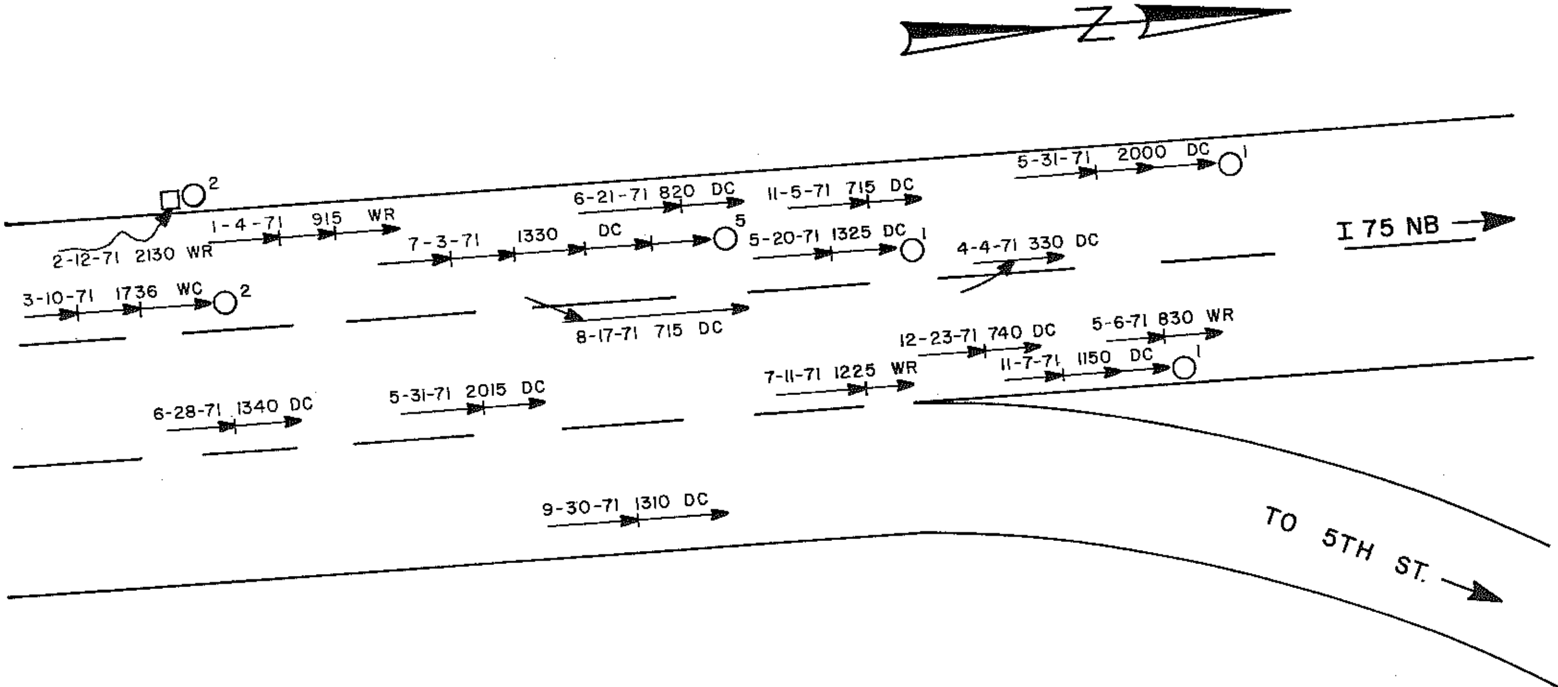
INJURY RATE - 0.46 injury accidents per million vehicles

	TOTAL	PERCENT
NUMBER OF ACCIDENTS	5	100
ACCIDENT TYPES		
Rear-End	2	40
Multiple Rear-End	1	20
Lost Control	1	20
Sideswipe	1	20
ACCIDENTS INVOLVING INJURY	3	60
TOTAL NUMBER INJURED	6	
TOTAL FATALITIES	0	0
LIGHT CONDITION		
Daylight	3	60
Dark	1	20
Dawn or Dusk	1	20
PAVEMENT CONDITION		
Wet	0	0
Dry	5	100

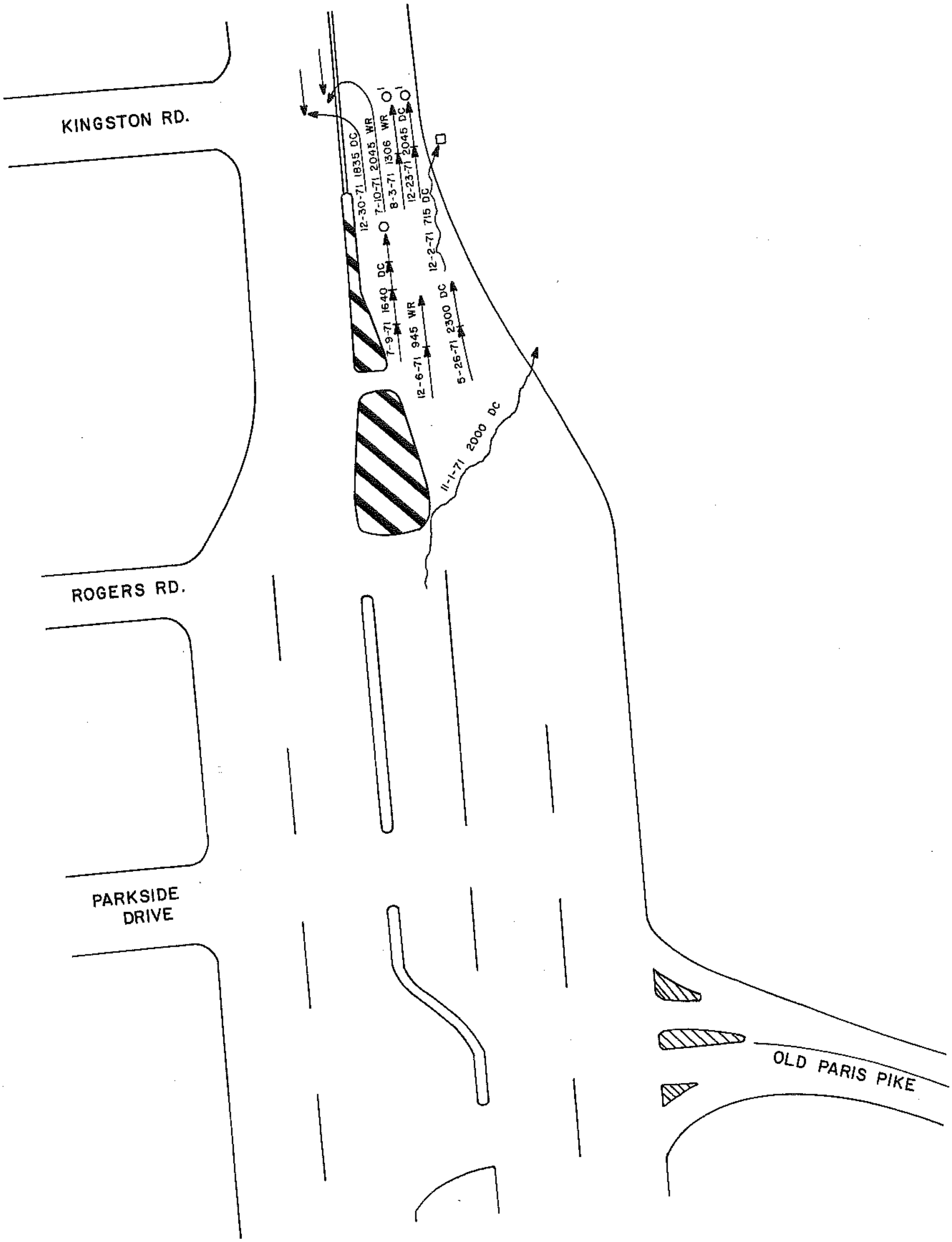
COLLISION DIAGRAMS



COLLISION DIAGRAM OF THE I 64
I 75 TRI-LEVEL INTERCHANGE



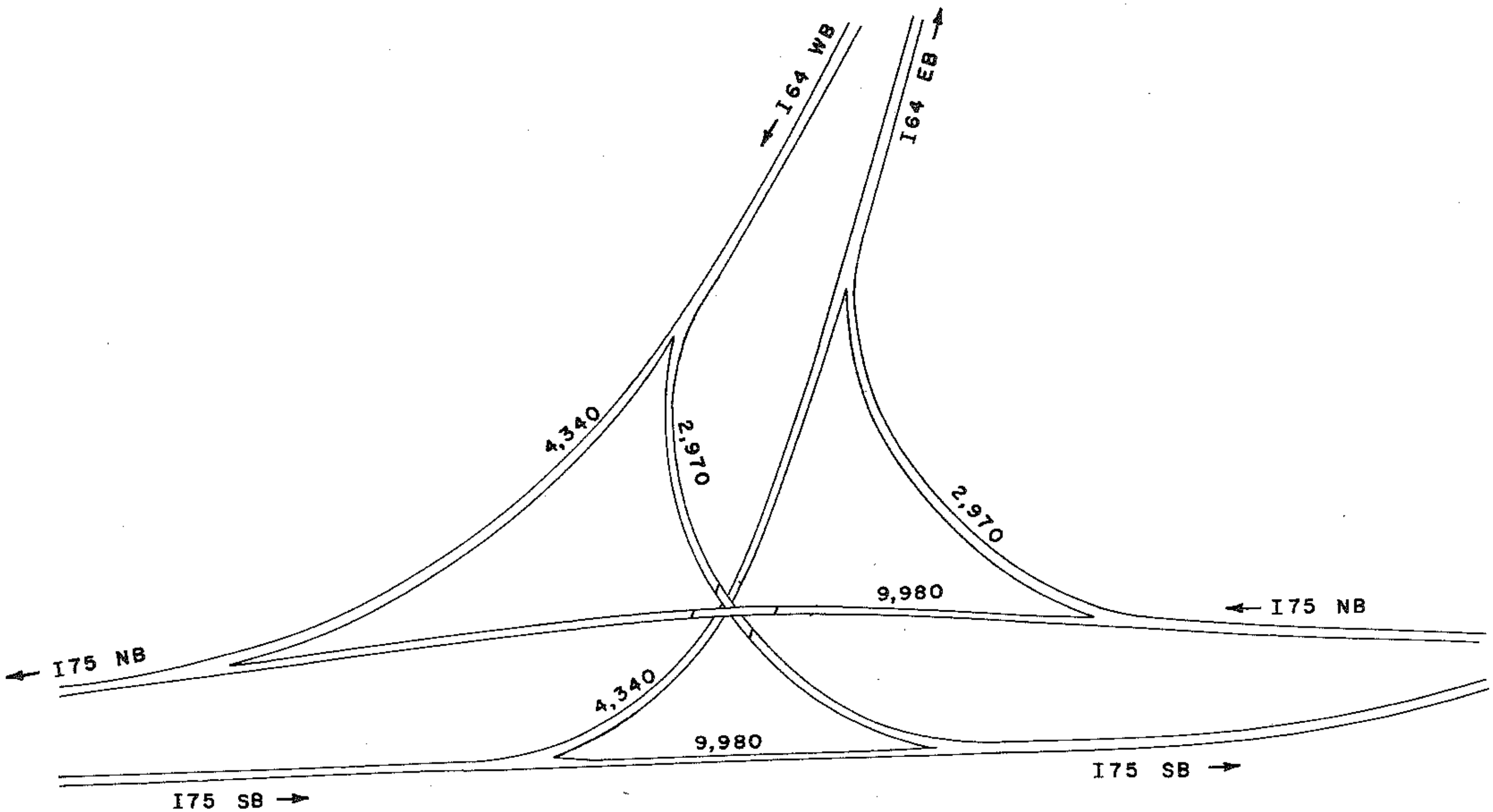
I 75 NB - 5th Street


KINGSTON RD.
12-30-71 1835 DC
7-10-71 2045 WR
8-3-71 1306 WR
12-23-71 2045 DC
12-2-71 715 DC
7-9-71 1640 DC
12-6-71 945 WR
5-26-71 2300 DC
11-1-71 2000 DC
ROGERS RD.
PARKSIDE DRIVE
OLD PARIS PIKE

1971 ADJUSTED AVERAGE DAILY TRAFFIC VOLUMES

1971 ADJUSTED AVERAGE DAILY TRAFFIC VOLUMES

LOCATION	1971 ADT (one way)
I-75 northbound at 5th Street	41,518
US 27-68 (Paris Pike) northbound	5,229
I-75 southbound at I-71 southbound	17,718
Bluegrass Parkway westbound terminus	1,540



1971 ADJUSTED AVERAGE DAILY TRAFFIC VOLUMES
FOR THE I 64 - I 75 TRI-LEVEL INTERCHANGE

APPENDIX C

STATISTICAL THEORY

STATISTICAL THEORY

INFERENCES CONCERNING MEANS

The following Smith-Satterthwaite test can be used to test for equality of means when concerned with two independent random samples with normal populations whose variances are not necessarily equal:

$$H_O : x = y \qquad H_1 : x \neq y$$

$$t = (x - y) \Big/ \left[\frac{s_x^2}{n_1} + \frac{s_y^2}{n_2} \right]^{1/2}$$

$$\upsilon = \left[\frac{s_x^2}{n_1} + \frac{s_y^2}{n_2} \right]^2 \div \left[\frac{(s_x^2/n_1)^2}{n_1 - 1} + \frac{(s_y^2/n_2)^2}{n_2 - 1} \right]$$

"BEFORE AND AFTER" SPOT-SPEED STUDIES

In order to determine significant differences between the mean speeds of "before and after" studies, it is necessary to estimate the standard deviation of the differences in means by use of the equation:

$$\hat{s} = \sqrt{s_{\bar{x}_b}^2 + s_{\bar{x}_a}^2}$$

where $\hat{s}$ = standard deviation of the difference in means,

$$s_{\bar{x}_b}^2 = \frac{\Sigma f_{b_i}(x_{b_i})^2 - \frac{1}{n_b}(\Sigma f_{b_i} x_{b_i})^2}{n_b(n_b - 1)}$$ = mean variance of "before" study, and

$$s_{\bar{x}_a}^2 = \frac{\Sigma f_{a_i}(x_{a_i})^2 - \frac{1}{n_a}(\Sigma f_{a_i} x_{a_i})^2}{n_a(n_a - 1)}$$ = mean variance of "after" study.

If the difference in mean speeds is greater than twice the standard deviation of the difference in means, i.e.

$$\bar{x}_b - \bar{x}_a > 2\hat{s},$$

it can be said with 95 percent confidence that the observed difference in mean speeds is significant (the change in conditions has significantly affected the mean speed).

DIFFERENCES IN SPOT-SPEED SAMPLE VARIANCES

The F test is a test of the differences between variances and is the ratio of the larger variance to the smaller.

If s_1^2 and s_2^2 are the variances of independent random samples of size n_1 and n_2, respectively, taken from two normal populations having the same variance, then

$$F = s_1^2/s_2^2$$

is a value of a random variable having the F distribution with parameters $\nu_1 = n_1 - 1$ and $\nu_2 = n_2 - 1$, where ν_1 = degrees of freedom for the sample variance in the numerator,
ν_2 = degrees of freedom for the sample variance in the denominator.