EVALUATION OF DIAMOND BARRICADES IN CONSTRUCTION ZONES

FINAL REPORT

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Oregon Department of Transportation
Highway Division
Traffic Engineering Section

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SUMMARY

Experimental diamond barricades, developed by the Federal Highway Administration, were deployed and evaluated on two construction projects in Oregon. The diamond barricades, types II and III, were fabricated by the state sign shop and were installed in place of standard striped barricades at typical work zone lane closures, one on an interstate freeway, the other on an urban arterial highway. Observations and measurements of traffic flow characteristics were made in an effort to compare the two barricade designs and to identify any potential deficiences in the diamond barricades.

Data obtained from vehicle speed and lane change measurements did not conclusively prove either barricade type to be superior to the other. As a traffic control device, both panel designs were equally effective. Traffic conflict and erratic maneuver rates, on the other hand, were significantly lower for the diamond barricades at the urban site.

No particular problems were found in the barricade fabrication process. If the barricades were to be made a standard, production costs would not increase over the current cost of producing striped barricades, except for costs associated with larger panel sizes. In the field, the diamond barricades were found to be more visible than the striped barricades, due to an increased panel width (8" to 12"), as well as the tendency of the diamond pattern to stand out from the background better than the striped pattern. The overall performance of the diamond panel in these tests indicates that it is an acceptable alternative to the striped panel design for use on barricade rails.

INTRODUCTION

The orange-on-white diamond panel pattern was developed by the Federal Highway Administration as an alternative to the standard diagonally striped pattern for use on barricades and vertical panels (see Figures 6 and 11, Appendix B). Problems with misapplications and misinterpretations of the directional meaning of the striped panel led to the design of the non-directional diamond pattern. A controlled study was conducted by FHWA to optimize the design and to test the pattern for legibility and driver acceptance. The results of these tests were found to be satisfactory, and FHWA recommended that the barricades (and vertical panels) be deployed as an experimental feature on several construction projects nationwide. This report presents Oregon's evaluation of the diamond barricades based on their use on two construction projects in this state.

The objective of this study was to fabricate, install, and evaluate diamond barricades in typical construction zones in order to determine whether they are an acceptable alternative to standard striped barricades. The evaluation was limited to the use of the barricades as channelizing devices in work zone lane closures. The barricades evaluated were types II and III with 12-inch wide rails and engineer-grade reflective sheeting. Vertical panels were not made a part of this study, as they are infrequently used on construction projects in Oregon.

EXPERIMENTAL DESIGN

Two approaches were used to evaluate the diamond barricades. The first was for the project evaluator to observe the fabrication and use of the barricades and to record any problems associated with them. Interviews with sign shop personnel and field crews were conducted to help identify any difficulties. The barricades were observed in the work zones for visibility, legibility, and overall appearance. Observations were made both day and night, in dry as well as wet weather.

The second approach was to directly compare the diamond barricades to standard striped barricades based on measures of traffic flow characteristics. Data was collected at two right lane closure construction sites. The performance measures selected for the evaluation were speed, speed variance, location of vehicle lane changes, and traffic conflict rate. A low conflict rate, earlier lane changes, and a gradual speed decrease coupled with a low speed variance were the desired characteristics. Previous studies have found these parameters effective in comparisons of work zone traffic control devices. In order to make these comparisons valid, all devices in the work zone were left unchanged except for the type of barricade. It was also recognized at the outset that as much data as possible would have to be collected because of the presence of the many other traffic control devices in the work zone. The more signs, cones, drums, and arrow boards present, the more difficult it becomes to establish the relative effect of the type of barricade panel used.

SITE DESCRIPTIONS

Two federal-aid construction projects were selected for the evaluation. Both projects were located on four-lane facilities and both required right lane closures with barricades in the lane taper.

Site A was located on a four-lane divided urban interstate freeway (I-84, The Dalles - refer to Figures 1-6, Appendix B). The ADT at this site is approximately 10,100 vehicles, with 16% trucks and a posted speed of 55 mph. A concrete median barrier separates east- and west-bound traffic. The work involved joint repair and patching of the PCC concrete pavement in the right lane. The work zone was present both day and night. Four type III barricades (4-ft. wide by 5-ft. high) were placed in the lane taper at 100-ft. spacings. These were compared to standard striped barricades of the same dimensions (but with 8-inch rails). A comparison was also made with a lane taper having no barricades. Also in the taper were cones, plastic drums, and a sequencing arrow board. In advance of the lane taper were the following construction signs: "ROAD CONSTRUCTION AHEAD" (900 ft. from beginning of taper), "SPEED 40" (700 ft.), "RIGHT LANE CLOSED AHEAD" (500 ft.), and a Pavement Width Transition sign (300 ft.). The 40 mph speed was posted as a regulatory sign.

Site B was a rockfall protection project located on an undivided urban arterial highway (Oregon 99E, Oregon City - see Figures 7-11, Appendix B). At this location the roadway has an ADT of 13,200 vehicles, with about 2% trucks, and a posted speed of 45 mph. A 2-ft. painted median separates north- and south-bound traffic. The work involved the installation of a rockfall protection net on the cut slope above the right lane. Only daytime work was conducted. Four type II barricades were required, with tube-type cones, in the lane taper. The standard barricades were 4-ft. by 3-ft. with 8-inch rails, while the diamond barricades were 4-ft. by 4-ft. with 12-inch rails.

Two flaggers were present in the work zone approximately 1000 feet from the end of the lane taper. Traffic was, however, allowed to proceed through the zone without stopping (the presence of the flaggers was required as a safety precaution against falling rocks). Because the lane closure was located on a curve, drivers could not see either the flaggers or any construction activity until they were beyond the lane taper. The advance signs were "ROAD WORK AHEAD" (2000 ft. from taper), "ROAD CONSTRUCTION AHEAD" (800 ft.), "CONSTRUCTION SPEED 30" (700 ft.), "BE PREPARED TO STOP" (300 ft.), and "FLAGGER AHEAD" (at beginning of lane taper). The speed was posted as an advisory construction speed sign. It should be noted that the only warning of the lane closure in this case was provided by the barricades themselves - there were no advance signs warning of the lane closure. Therefore it was expected that this site would be more effective in identifying differences between the barricade designs.

DATA COLLECTION PROCEDURE

Vehicle speeds were measured at several selected sites along the work zone approaches using a vehicle-mounted radar unit. Only free-flowing passenger-type vehicles were included in the speed checks. At least one hundred speeds were measured at each location in order to obtain a statistically large sample size. The type of radar used records speeds to the nearest 1 mph.

Traffic conflicts and erratic maneuvers were tabulated at both construction sites. Counts were made by the same observer for all tests, who was positioned approximately 800 feet in advance of the lane taper. Counts were taken for an average of three hours for each experimental treatment. Total volumes were also tabulated so that conflict rates could be determined. Conflicts, secondary conflicts, and conflict opportunities were all recorded. The majority of the conflicts involved abrupt lane changes, slow merges, slow vehicles, and erratic maneuvers (vehicles braking or swerving with no other vehicles nearby).

Lane change data was collected at site B. The zonal system for determining vehicle lane changes on the approach to the right lane closure was used [1]. Pneumatic tubes and tape-punch counters were installed at 150- to 250-foot intervals in the right lane approach (see Figure 1, Appendix A). With this arrangement, the difference in count between any two successive counters yielded the number of vehicles that changed lanes in that zone.

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[1] Cottrell Jr., Benjamin H., "Use of Chevron Patterns on Traffic Control Devices in Work Zones" (Abridgement), Page 3, Transportation Research Record No. 833, 1981.

RESULTS

FINDINGS FROM FIELD OBSERVATIONS

No difficulties were encountered in the fabrication of the diamond barricades. The panels were made by cutting diamond shapes from rolls of engineer-grade reflective sheeting and applying them to panels over a reflective white background, then baking the panels in a pressurized heating device. If the barricades were to become standardized, production would be performed using a silkscreen device as our sign shop now uses to produce striped barricade rails. The cost of producing a diamond panel would then be no different than that of producing a striped panel, except for increased costs due to larger panel sizes.

Observations of the barricades in the field revealed no unusual driver confusion or misunderstanding. The diamond barricades tended to be more visible and to attract attention better than the standard barricades, due both to their larger panel size as well as their ability to stand out from background clutter. The diamond shapes were distinguishable at a distance of 700 to 800 feet. Nighttime observations found the barricades to be highly visible and to display more orange color than the striped barricades.

Field crews generally preferred the diamond barricades, citing their greater visibility and larger panel size. Transporting, handling, and storing the barricades was the same as for the standard barricades. Some susceptibility of the type III barricades to strong wind gusts from passing trucks was noted at site A, but the problem was solved by weighting the barricades with sandbags.

DATA REDUCTION

Site A

Traffic data at the freeway site was collected using three lane taper treatments : (1), standard striped barricades; (2), diamond barricades; and (3), no barricades (drums, cones and arrow board only).

1. Vehicle Speeds - A sample computer speed analysis printout is shown in Figure 2, Appendix A. Table 1 summarizes speed variances, mean speeds, and adjusted mean speeds at each location for each lane taper treatment. The mean speed adjustment was necessitated by the differences in mean speeds for each treatment found at the initial speed check location. At this distance from the taper (1200 ft.), the barricade type should have no influence on vehicle speeds The differences recorded are probably due to daily speed fluctuations. To account for these differences, initial mean speeds for the barricade treatments (1 and 2) were set equal to that of the no-barricade treatment (3), and subsequent speeds were adjusted proportionally.

The adjusted mean speed profile is shown in Figure 3. The no-barricade case produced the largest speed reduction and highest deceleration rate. Treatments 1 and 2 produced approximately the same speed profiles, except for an indication that drivers increased speed along the taper section for the standard barricade condition.

Figure 4 shows the speed variance profile. The general trend is for speed variance to increase as the lane taper is approached. Treatment 3 had the largest variances as well as the largest increase in speed variance, especially along the taper section. The diamond barricades showed the smallest speed variance increase.

2. Conflicts - Conflict count results, broken down by treatment number and conflict type, are shown in Table 2. Conflict rates were calculated as the number of conflicts recorded per 100 vehicles. Treatments 1 and 2 produced virtually identical total conflict rates of 15.0% and 15.1%, respectively, while treatment 3 produced a rate of 17.7%. This difference in conflict rate between treatment 3 and treatments 1 and 2 is significant at the 93% confidence level (based on z-test for proportions).

Table 1. Reduced Speed Data - Site A.

Lane Taper Treatment	Distance From Beg. of Taper (ft)	Speed Variance $(mph)^2$	Mean Speed (mph)	Adjusted Mean Speed (mph)
No Barricades	1150	28.5	55.36	55.36
	700	36.1	53.20	53.20
	300	34.2	49.80	49.80
	0	37.8	48.03	48.03
	-500	53.1	46.40	46.40
Standard Barricades	1300	21.1	55.03	55.36
	0	29.8	49.85	50.15
	-250	36.2	51.84	52.15
Diamond Barricades	1300	28.7	54.58	55.35
	700	27.9	51.36	52.08
	-250	32.9	49.81	50.51

Table 3. Reduced Speed Data - Site B.

Lane Taper Treatment	Distance From Beg. of Taper (ft)	Speed Variance $(mph)^2$	Mean Speed (mph)	Adjusted Mean Speed (mph)
Standard Barricades	1200	31.5	45.65	45.65
	800	23.9	42.61	42.61
	500	28.1	42.05	42.05
	300	30.4	41.42	41.42
	0	28.5	42.10	42.10
	-300	23.7	42.39	42.39
Diamond Barricades	1200	23.0	47.24	45.60
	800	18.2	44.12	42.58
	500	25.9	42.17	40.70
	300	17.1	43.20	41.70
	0	27.6	43.21	41.70
	-300	30.5	42.90	41.40

Table 2. Traffic Conflict Rates - Site A. [1]

Lane Taper Treatment	Total Vehicles #	Lane Change Conflicts #/Rate (2)	Slow to Merge Conflicts #/Rate (2,3)	Slow Vehicle Conflicts #/Rate (2)	Erratic Maneuver Opportunities #/Rate	Other Conflicts #/Rate (3,4)	All Conflicts #/Rate (2,3)
Standard Barricades	472	11 2.3	17 3.6	32 6.8	11 2.3	0 0.0	71 15.0
Diamond Barricades	1160	9 0.8	45 3.9	66 5.7	54 4.7	1 1.0	175 15.1
No Barricades	780	6 0.8	50 6.4	46 5.9	35 4.5	1 1.0	138 17.7

Table 4. Traffic Conflict Rates - Site B. [1]

Lane Taper Treatment	Total Vehicles #	Lane Change Conflicts #/Rate (2)	Slow to Merge Conflicts #/Rate (2,3)	Slow Vehicle Conflicts #/Rate (2)	Erratic Maneuver Opportunities #/Rate	Other Conflicts #/Rate (3,4)	All Conflicts #/Rate (2,3)
Standard Barricades	1313	20 1.5	49 3.7	50 3.8	12 0.9	11 0.8	142 10.8
Diamond Barricades	1530	10 0.7	28 1.8	26 1.7	10 0.7	6 0.4	80 5.2

NOTES:

1 Rate expressed as number of conflicts per 100 vehicles
2 Includes Secondary Conflicts
3 Includes Conflict Opportunities
4 Wrong Way Lane Changes, Lane Encroachments, and Stopped Vehicle Conflicts

Site B

Two experimental treatments were investigated at the urban arterial site : (1) standard barricades, and (2) diamond barricades.

1. Vehicle Speeds - The reduced speed data for site B is shown in Table 3. Again, because of initial speed differences, mean speeds were adjusted. The adjusted mean speed profile, Figure 5, indicates that vehicle speeds were not affected by barricade type beyond 800 feet from the beginning of the lane taper (which corresponds to the legibility distance of the diamond pattern). Within this distance, the mean speed for the diamond barricades decreases up to 500 feet from the taper, then increases and levels off. The speed reduction is less for the standard barricades, and occurs later than for the diamond barricades.

Few trends can be found in the speed variance profile (Figure 6), but the diamond barricades show a lower speed variance than for the standard barricades, up to the lane taper. Along the taper, speed variance increased for the diamond barricades while decreasing for the standard barricade lane taper.

2. Conflicts - Conflicts and erratic maneuvers recorded at site B are displayed in Table 4. The conflict rate computed for the diamond barricade treatment (5.2%) was significantly lower than that for the standard barricades (10.8%). This difference is significant at greater than the 99% confidence level (using the z-test for proportions). This reduction in conflict rate was similar for all types of conflicts. In addition to counting conflicts, a count was made of the number of vehicles that made a forced merge (vehicles which did not merge into the left lane until forced to do so by the lane taper). The rates calculated for this maneuver were about the same - 3.9 for the standard barricades, 4.1 for the diamond barricades.

3. Lane Change Behavior - Figure 7 shows the distribution of vehicle lane changes by zone. It is immediately apparent from this graph that the type of barricade present in the lane taper did not affect where vehicles made their lane changes.

DATA ANALYSIS

Site A

The data collected at the freeway construction site did not uncover any significant differences between the two types of barricades. The only conclusion that can be drawn from this data is that having some barricades present in the lane closure - of any type - is better than having no barricades. The lane taper without barricades resulted in a greater speed reduction, higher speed variance, and larger conflict rate (the large speed reduction might be desireable in some instances, but not when accompanied by a large speed variance). That the data for the two barricade treatments proved inconclusive is probably due primarily to the large number of other traffic control devices present in the work zone (especially the sequencing arrow). It appears that a much larger amount of data would have to be collected for this type of situation in order for significant differences in barricade performance to be found.

Site B

The results for the urban arterial site, which had fewer traffic control devices, were more conclusive. The speed data indicate that the diamond barricades reduced speeds earlier and slightly more than the standard barricades. They also showed a generally lower speed variance, except along the taper. The diamond barricades definitely reduced vehicle conflicts. The high visibility of the barricades apparently makes drivers more alert and cautious. The lane change data indicates that the barricade patterns had no effect on the position of vehicle lane changes. This is also borne out by the fact that the forced merge rates were the same for both barricade types. (It would appear that a certain small percentage of drivers, about 5%, pay little attention to advance warning signs and devices and do not change lanes until presented with a physical barrier that forces them to do so.)

CONCLUSIONS

The results of the analysis of vehicle speeds tended to be either inconclusive (ie., neither barricade type produced significantly better results than the other), or somewhat subject to interpretation. The question of which is more desireable, lower speeds or more uniform higher speeds, is debatable. However, a large speed reduction coupled to a large speed variance did indicate that the lane taper with barricades was more desireable than the one without.

Data on location of vehicle lane changes found that the type of barricade present in the lane taper had virtually no effect on where vehicles switched lanes. Therefore the effectiveness of the directional meaning of the striped barricades is questionable.

Although traffic flow characteristics were not affected to a significant degree by which barricade type was used, the diamond barricades did appear to be superior to the standard barricades in terms of reducing traffic conflicts in the lane closure approach area. The low conflict and erratic maneuver rate found at the urban arterial site for the diamond barricade condition was highly significant. This result, which was found for all conflict types, was probably due to the improved visibility of the diamond panel design. The larger panel size and the ability of the pattern to stand out from the background seemed to get the attention of drivers earlier, thus providing them with more time to respond.

Based on this study, the diamond barricade is an acceptable alternative to the standard striped barricade.

REFERENCES

Anderson, H. L., "Work Zone Safety", Page 1, Transportation Research Record No. 693, 1978

Cottrell , Benjamin H. Jr., "Use of Chevron Patterns on Traffic Control Devices in Work Zones" (Abridgement), Page 3, Transportation Research Record No. 833, 1981

Gordon, Dr. Donald A., "Evaluation of Diamond Pattern for Use on Barricade Rails", FHWA Report No. FHWA/RD-82/109, August, 1982

Graham, J. L.; Paulsen, R. J.; and Glennon, J. C., "Accident and Speed Studies in Construction Zones", FHWA Report No. FHWA/RD-77-80, June, 1977

Pain, R. F.; McGee, H. W.; and Knapp, B. G. (Biotechnology, Inc.), "Evaluation of Traffic Controls for Highway Work Zones", NCHRP Report No. 236, Transportation Research Board, National Research Council, October, 1981

APPENDIX A - ILLUSTRATIONS

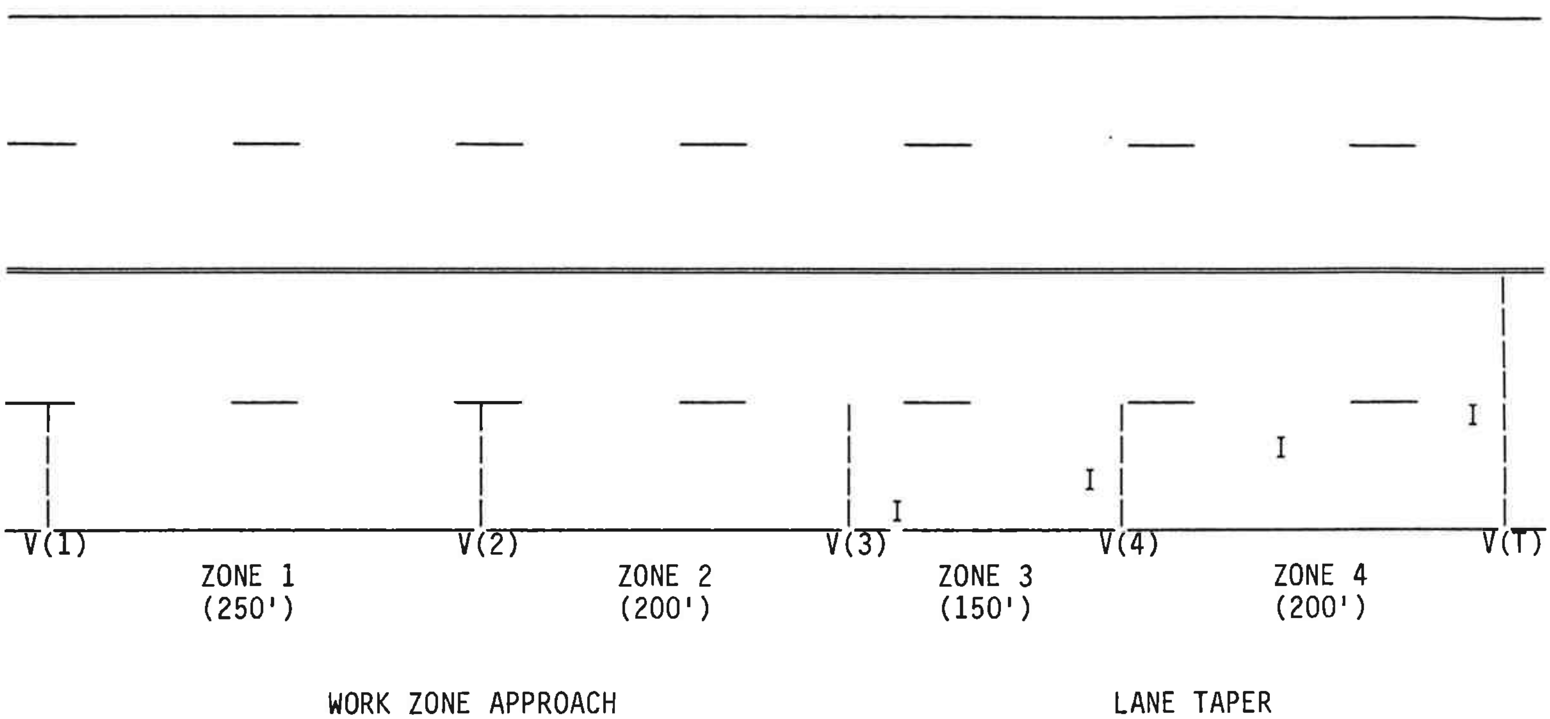


Figure 1
Lane Change Data Collection System - Site B

Figure 2. Sample Speed Analysis Printout

ROAD OR STREET: PACIFIC HWY EAST (99E)
HWY NO. 1E

DATE: FRIDAY, SEPTEMBER 2, 1983

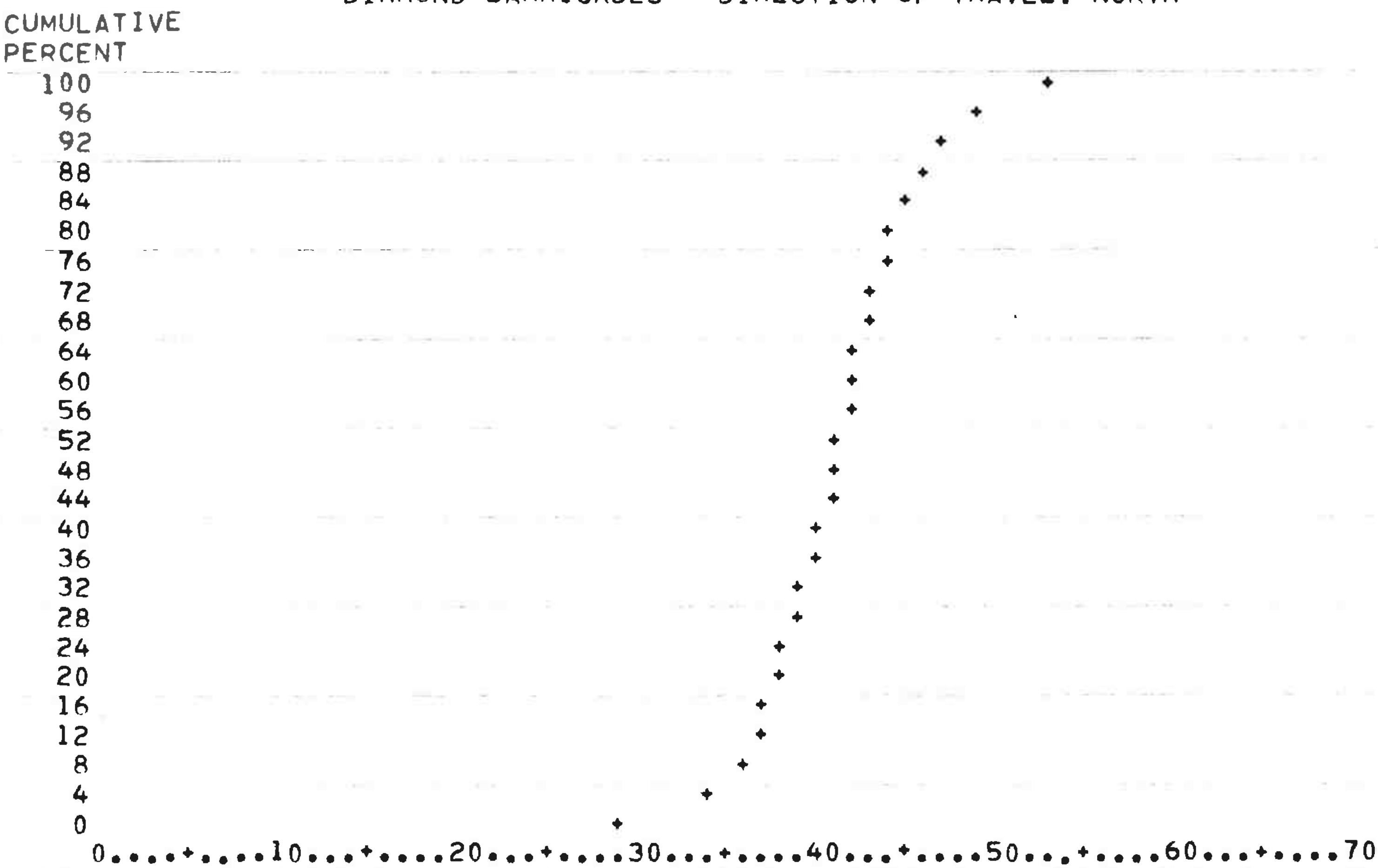
CITY OR COUNTY: OREGON CITY

TIME: 8:50 AM TO 9:30 AM

GENERAL LOCATION: 300 FEET FROM
BEGINNING OF TAPER
DIAMOND BARRICADES

WEATHER: OVERCAST, COOL, DAMP

DIRECTION OF TRAVEL: NORTH



% EXCEEDING 100 100 100 100 98 75 25 4 0 0 0 0

SPEED (MPH)

	NORTH ~~& SOUTH~~ BOUND
# OF VEHICLES	107
85% SPEED	47.19
PACE LIMITS	38-48
% IN PACE	77.57
MEAN SPEED	43.20
MEDIAN SPEED	43.50
STD. DEV.	4.13
MAX. SPEED	54
POSTED SPEED	45
% EXCEEDING POSTED SPEED	25.23

Figure 4. Speed Variance Profile, Site A

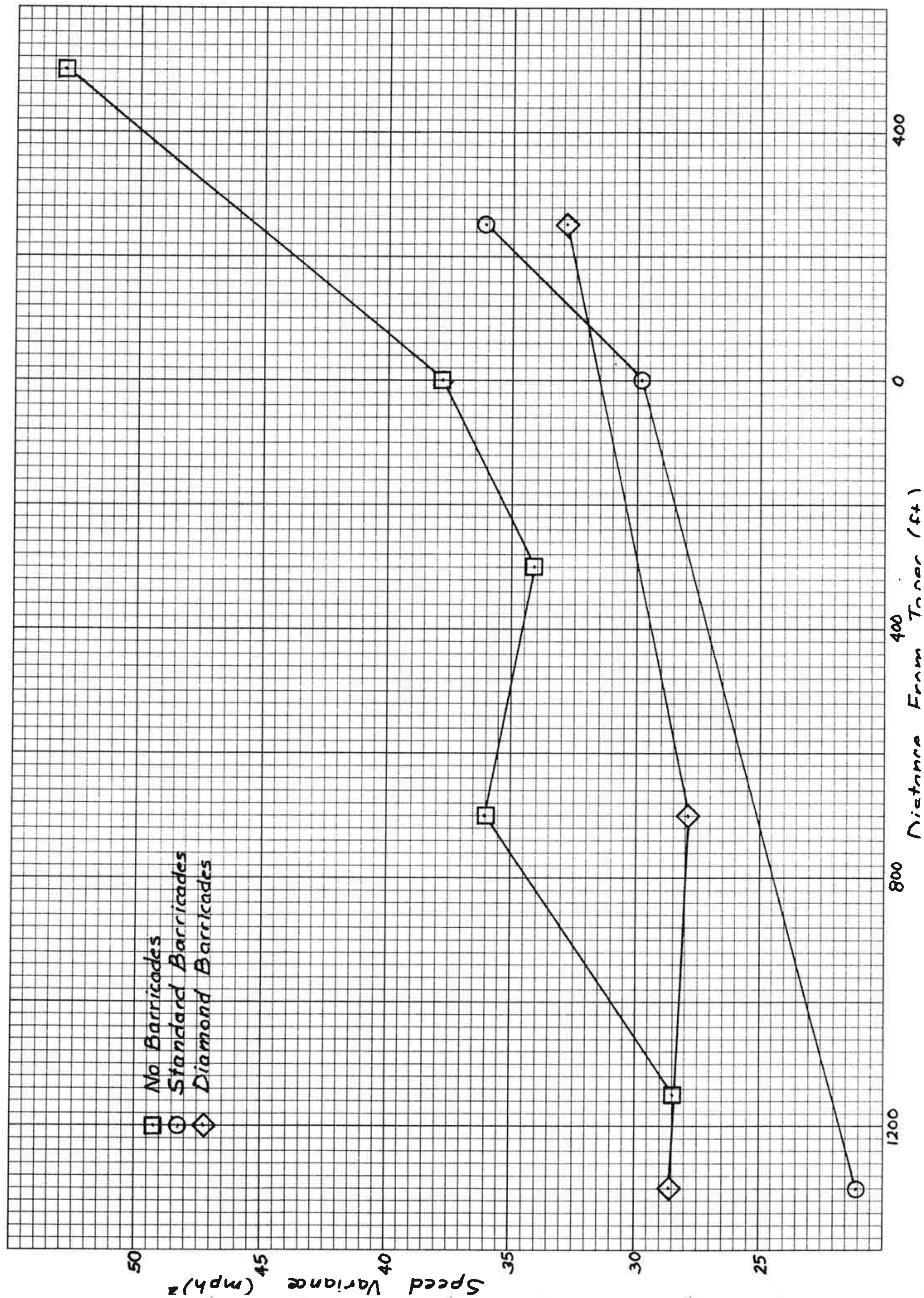


Figure 3. Adjusted Mean Speed Profile, Site A

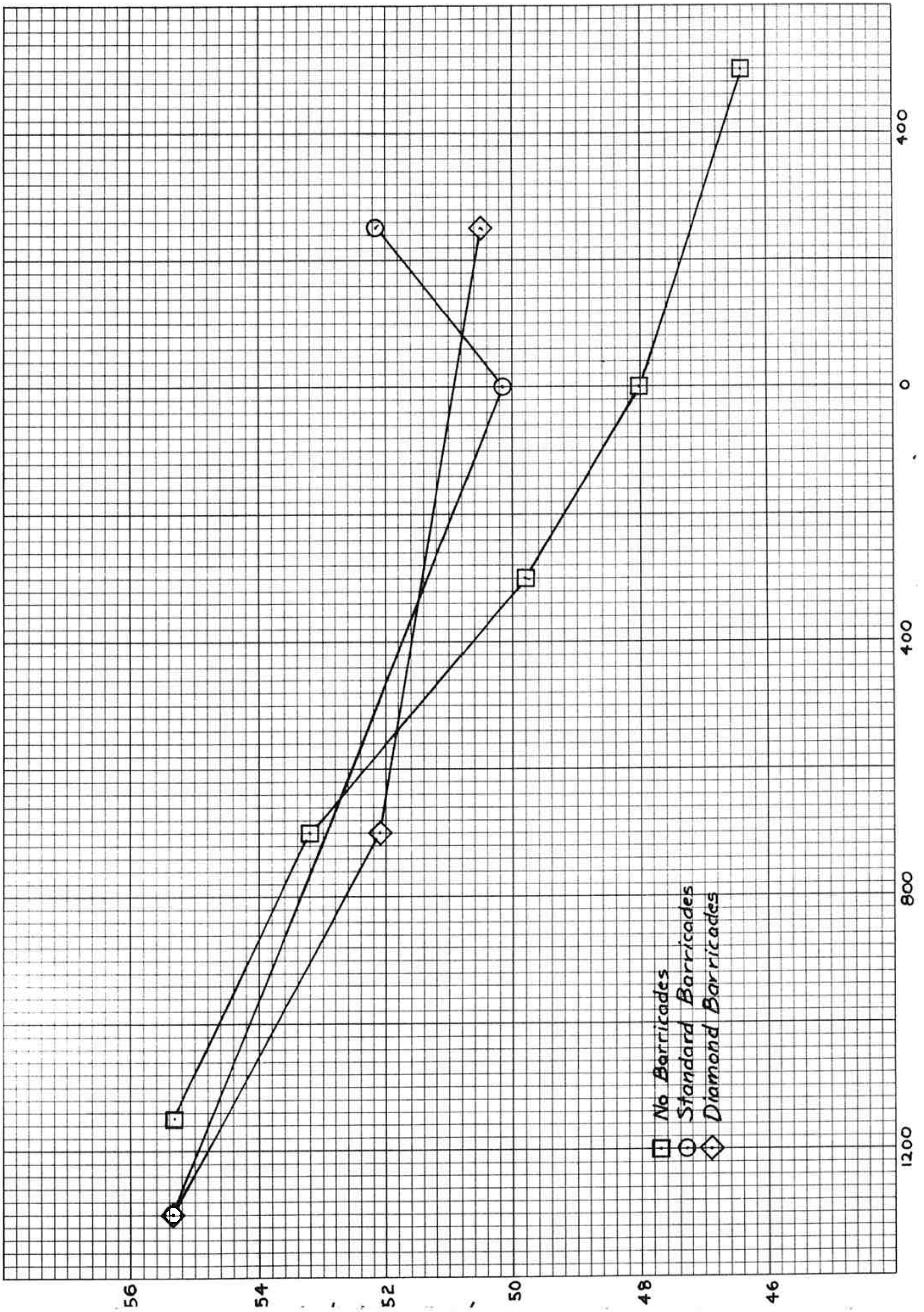


Figure 5. Adjusted Mean Speed Profile, Site B

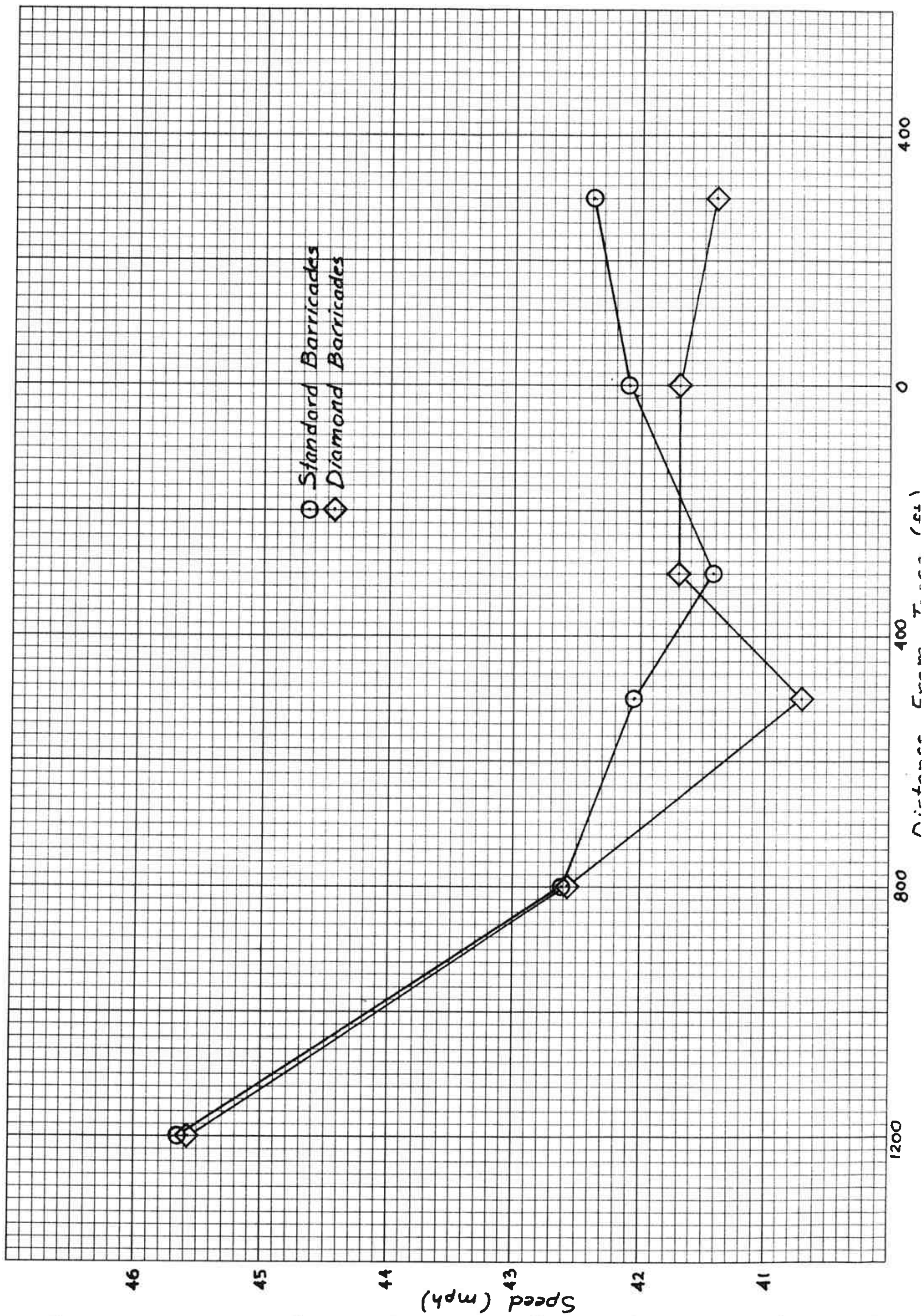
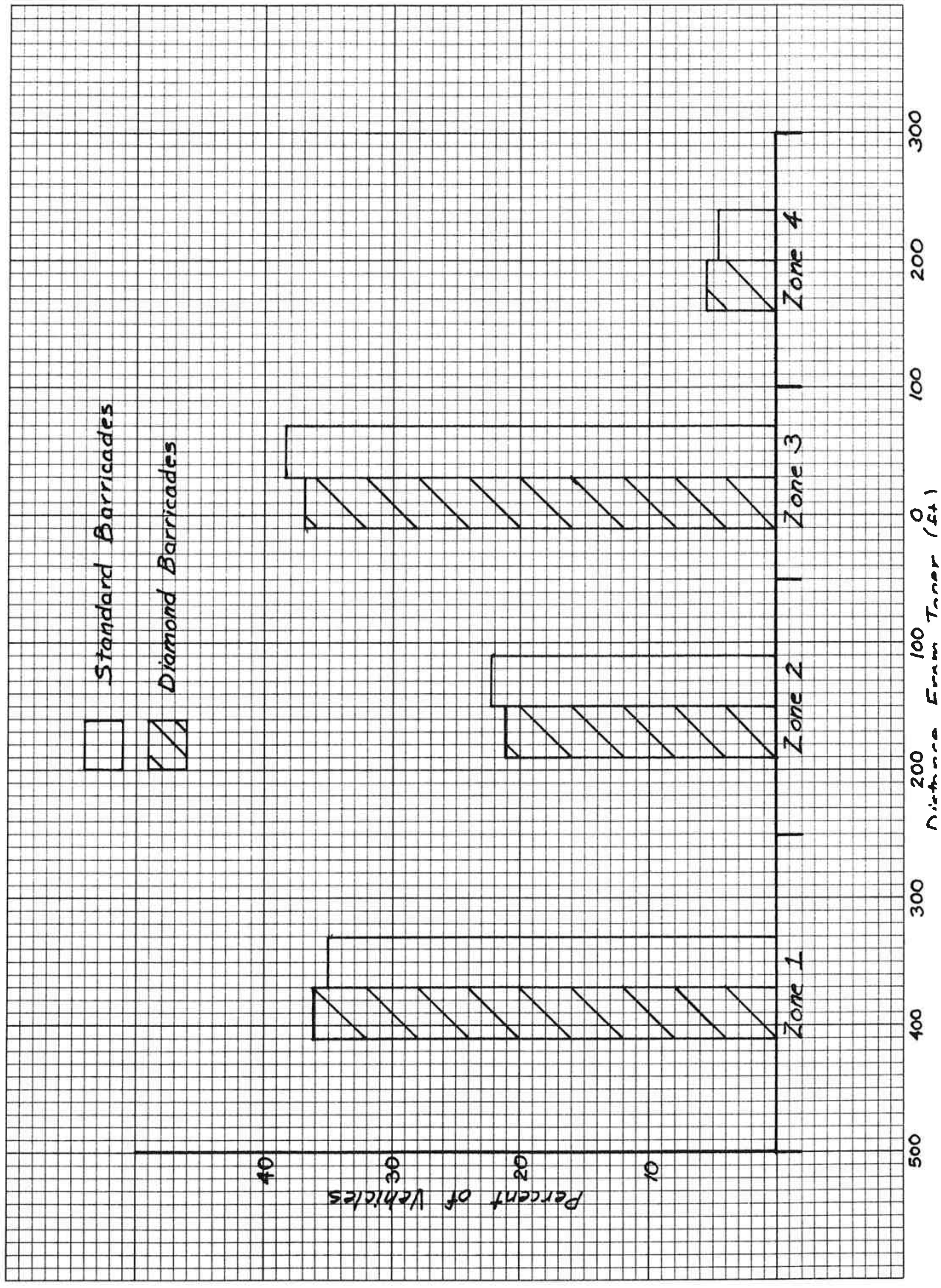


Figure 7. Lane Change Behavior, Site B



APPENDIX B - SITE PHOTOGRAPHS

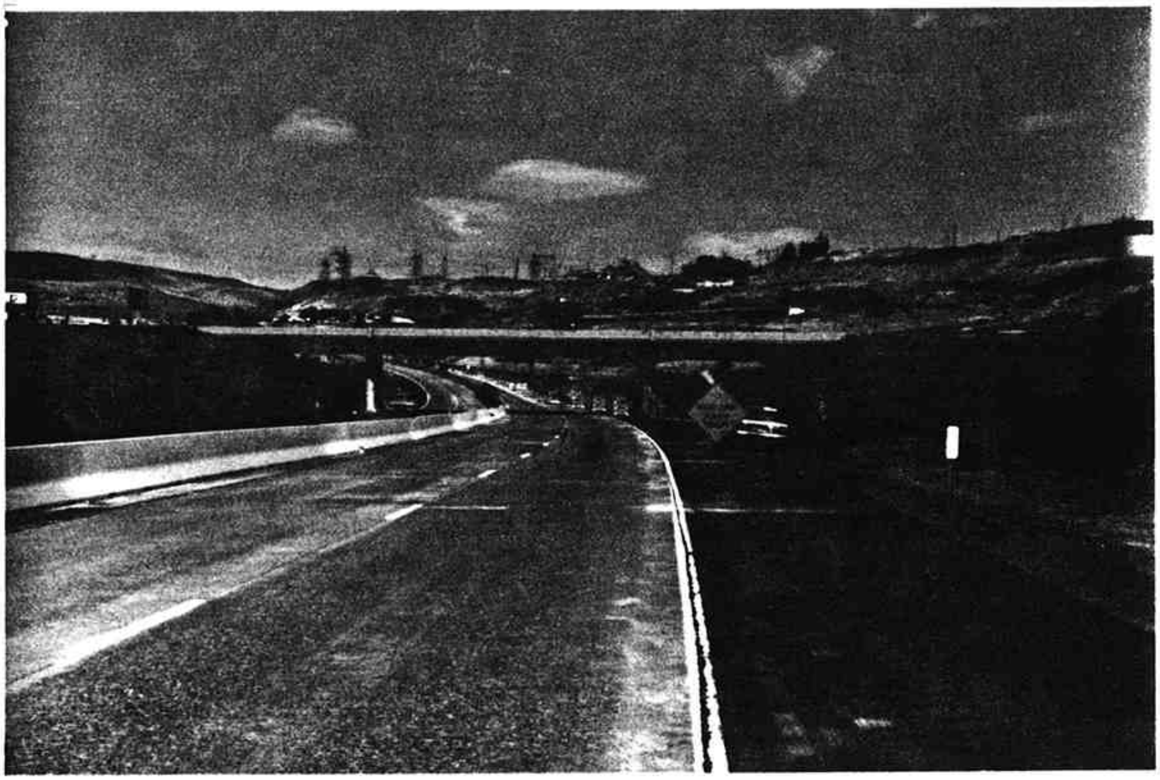


Figure 1. Site A - Diamond Barricades, 700 ft. from taper

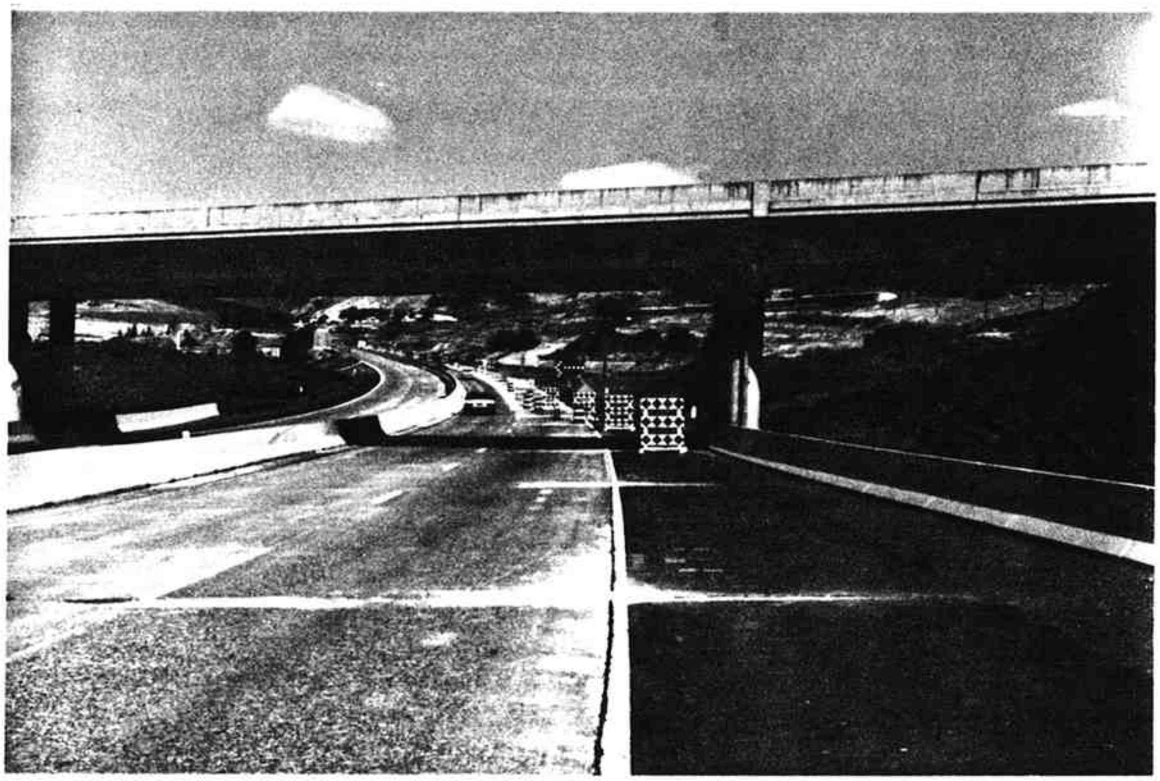


Figure 2. Site A - Diamond Barricades, 200 ft. from taper

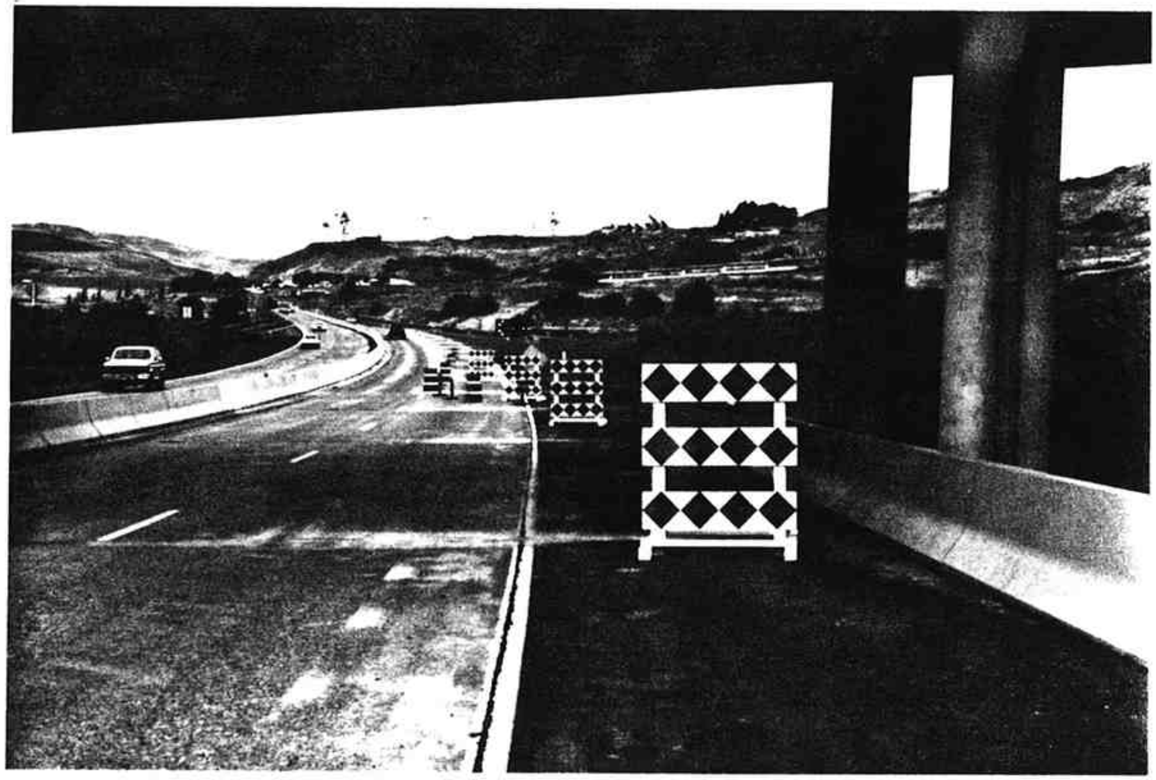


Figure 3. Site A - Diamond Barricades, at taper

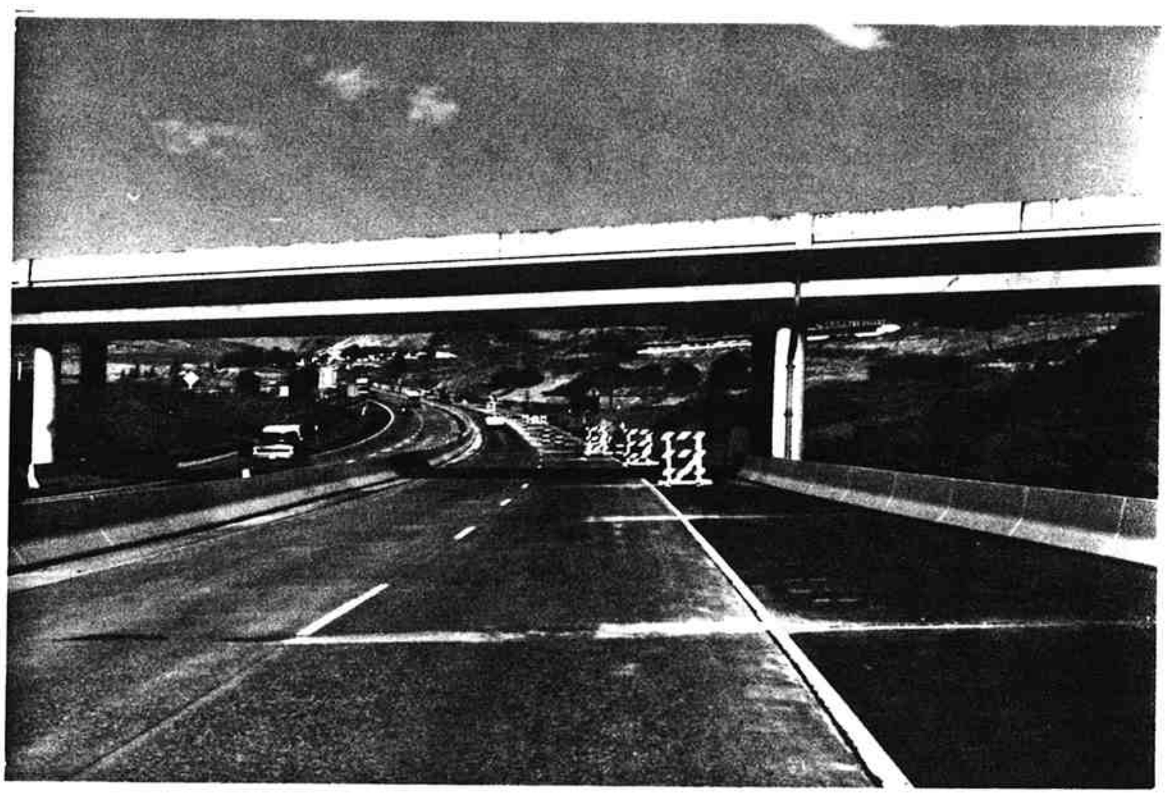


Figure 4. Site A - Standard Barricades, 200 ft. from taper

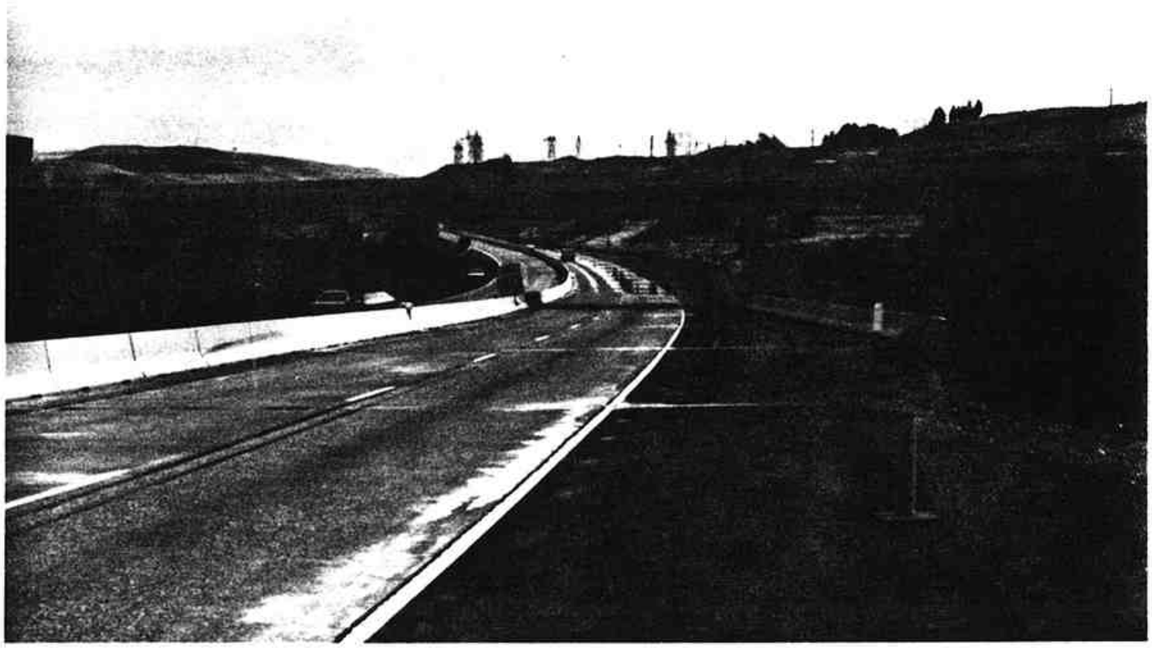


Figure 5. Site A - Lane taper without barricades

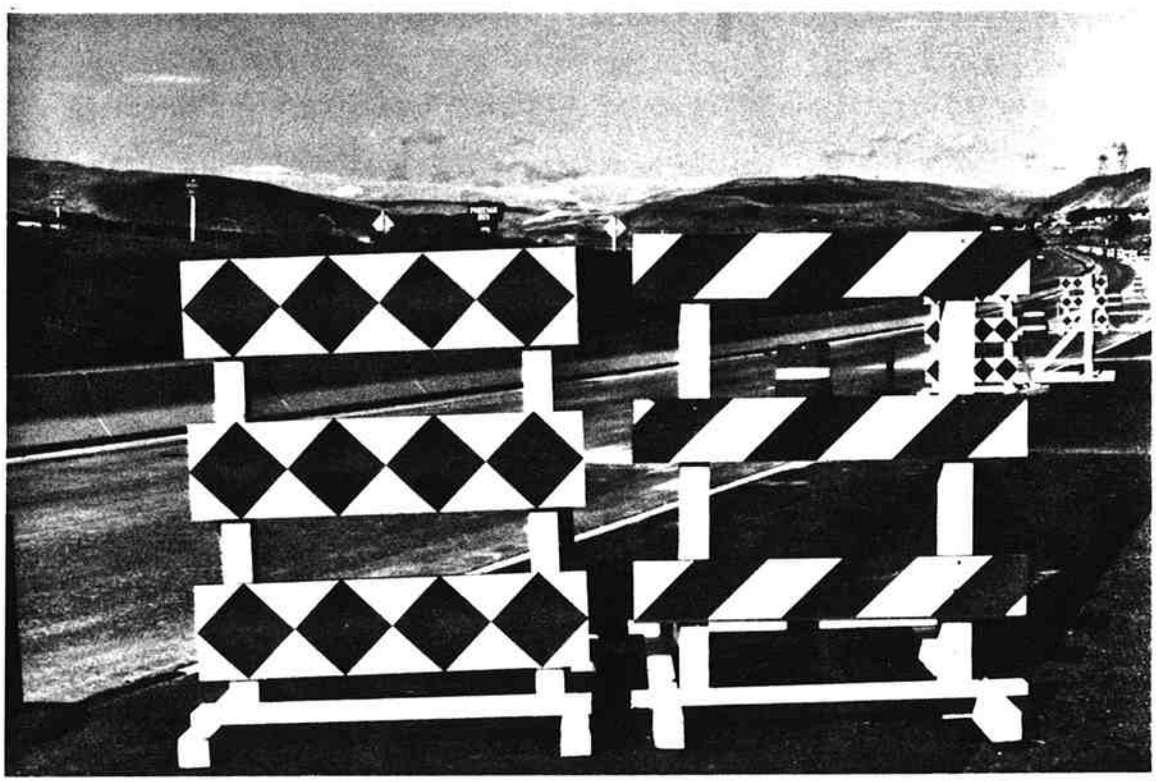


Figure 6. Site A - Comparison of Diamond and Standard Barricades

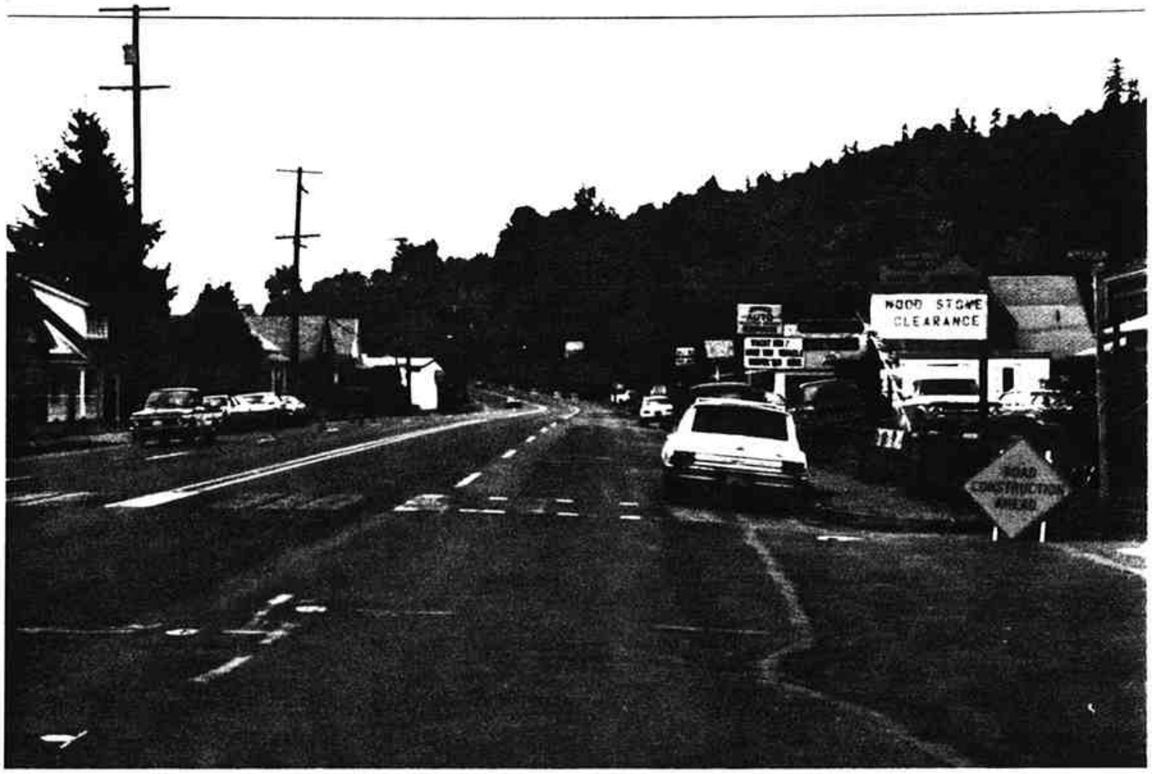


Figure 7. Site B - Diamond Barricades, 850 ft. from taper

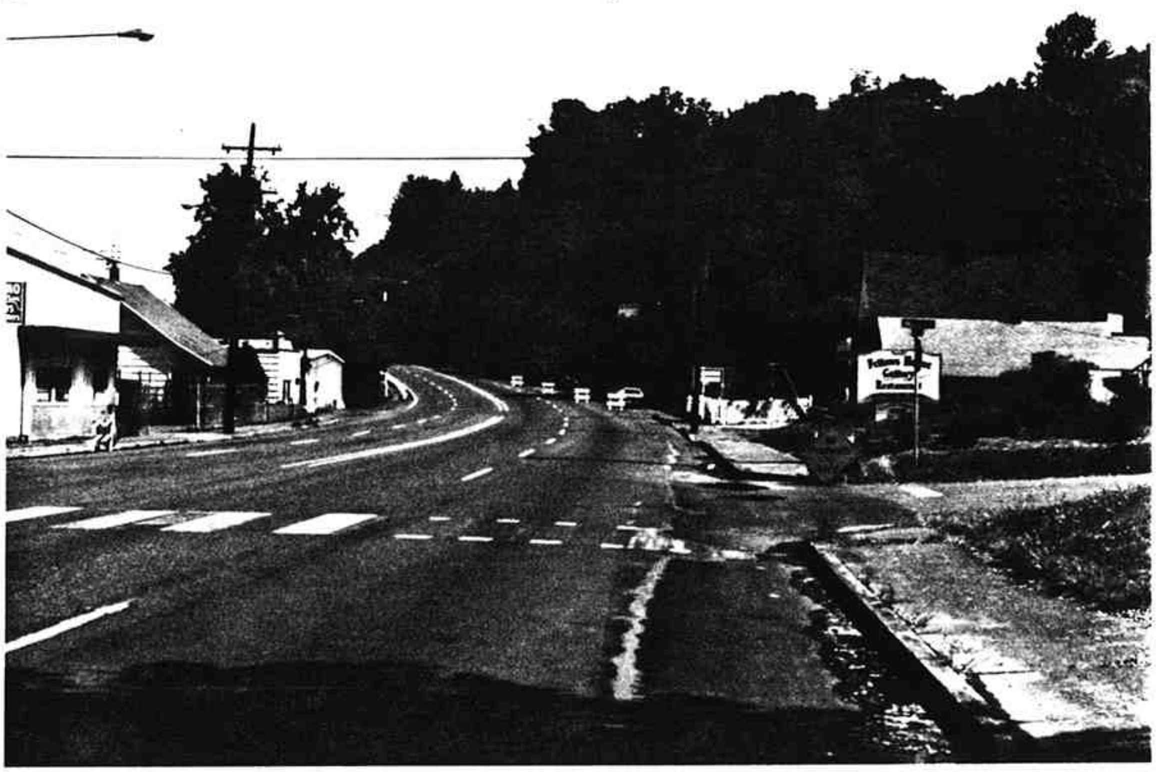


Figure 8. Site B - Diamond Barricades, 400 ft. from taper

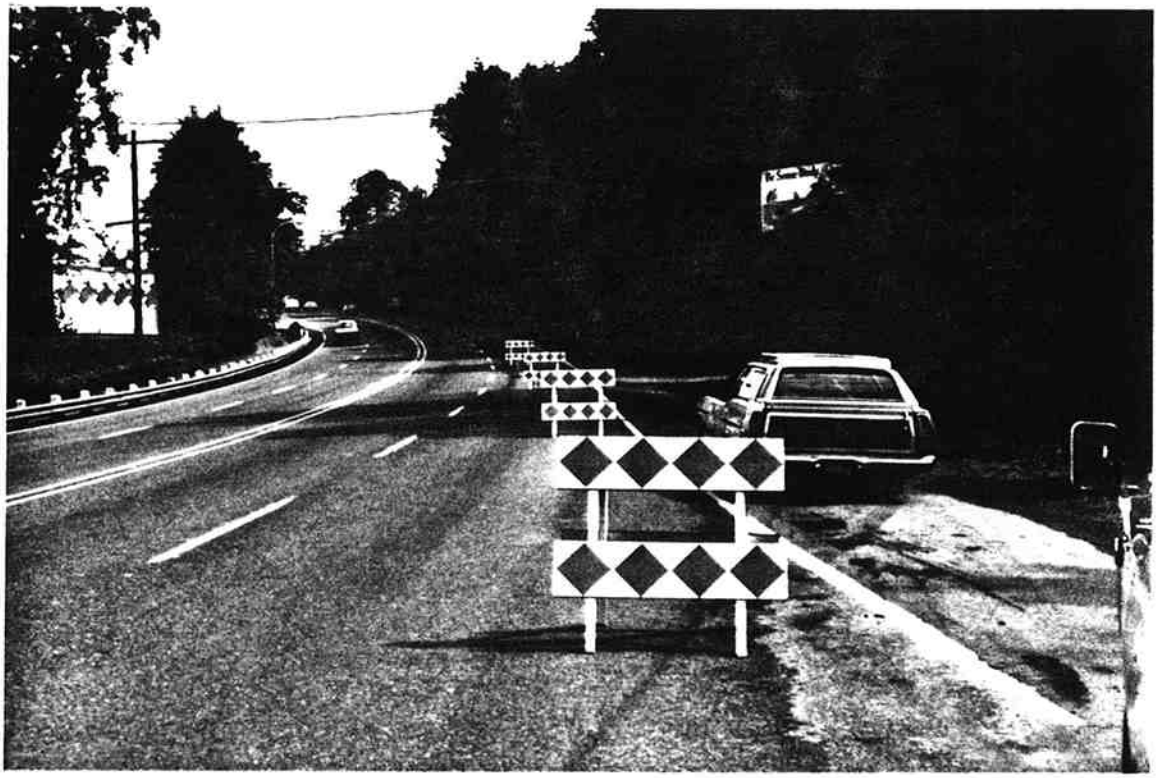


Figure 9. Site B - Diamond Barricades, at lane taper

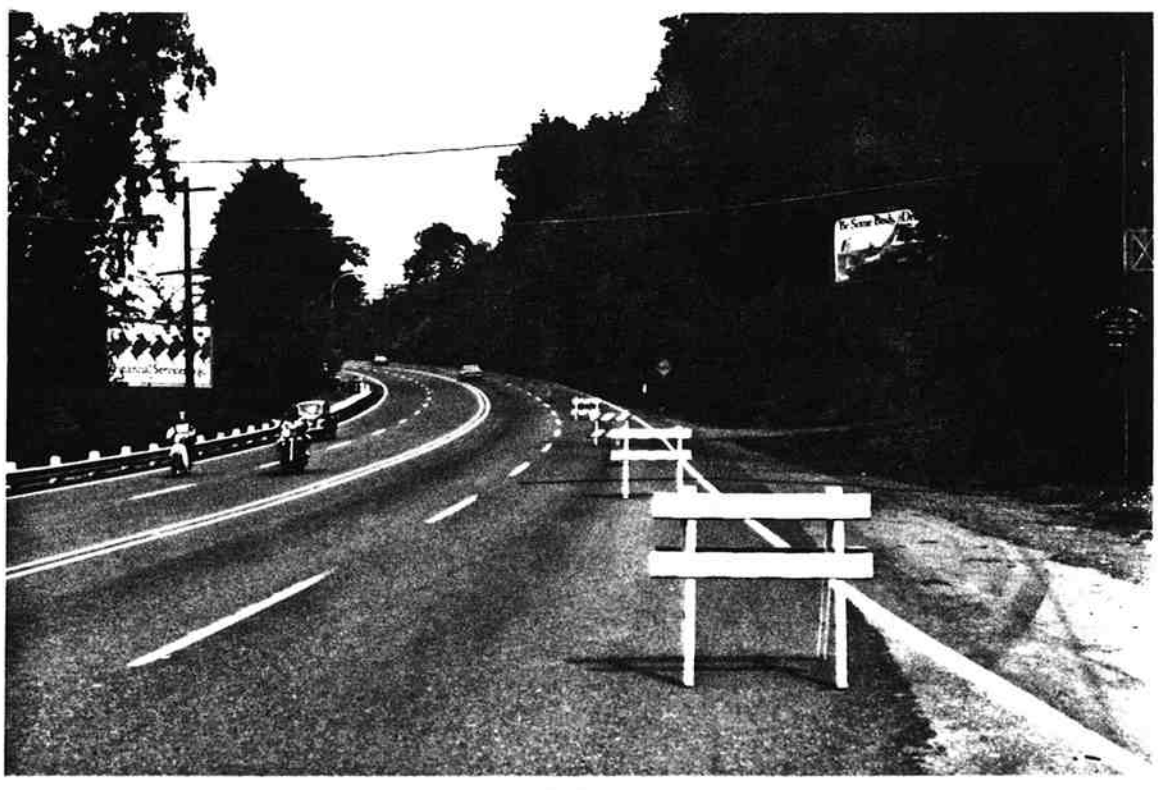


Figure 10. Site B - Striped Barricades, at lane taper

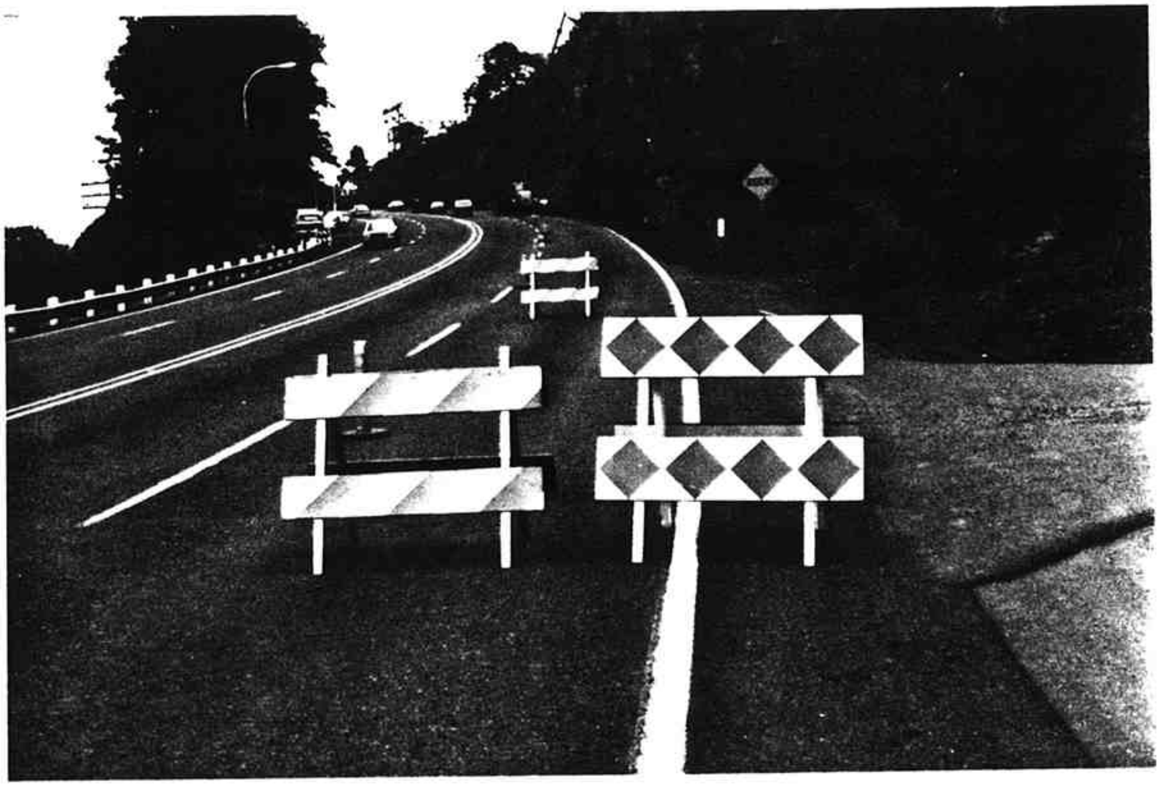


Figure 11. Site B - Comparison of Diamond and Striped Barricades