EVALUATION OF CHANNELIZING DEVICES FOR WORK ZONES: TYPE II BARRICADES AND CHEVRON PANELS

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ABSTRACT

The objectives of this research were (1) to evaluate the 4-in. (10.2-cm) and 6-in. (15.2-cm) wide alternating diagonal stripes on barricade rails less than 3 ft. (0.92-m) long, and (2) to select the most effective chevron panel. A secondary objective was to investigate minimum sight distance requirements for work zone lane closures.

These objectives were accomplished by (1) conducting field tests on the channelizing devices using the position of lane changing as the measure of performance and (2) conducting observer evaluations to obtain detection and legibility distances and preferences for various channelizing devices and taper arrays.

It was found that the 6-in. (15.2-cm) wide stripes on type II barricade rails less than 3 ft. (0.92 m) long were more effective than the 4-in. (10.2-cm) wide stripes. A chevron (18 in. x 24 in. [0.46 m x 0.61 m]) with a black arrow was more effective than a chevron with a white arrow. Overall, the large chevron (24 in. x 30 in. [0.61 m x 0.77m])with a black arrow and 80-ft. (24.2-m) taper spacing was the most effective chevron panel. The chevron with a black arrow and 40-ft. (12.2-m) taper spacing was rated second in overall effectiveness. A minimum desirable sight distance of 1,500 ft. (457.5 m) and a minimum allowable sight distance of 1,000 ft. (305 m) were suggested for work zone lane closures.

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INTRODUCTION AND PROBLEM

Channelizing devices are employed "to warn and alert drivers of hazards created by construction or maintenance activities in or near the traveled way, and to guide and direct drivers safely past the hazards."(1) Recent research efforts have investigated the design and application of channelizing devices, with special emphasis on the use of chevron patterns to provide a clear directional message.

In the report on the study entitled "Evaluation of Chevron Patterns for Use on Traffic Control Devices in Street and Highway Work Zones,"(2) it was concluded that based on the position of lane changes, driver response was not strongly dependent upon the pattern used on channelizing devices employed in a taper. Moreover, throughout that study several matters requiring further attention were identified. To ensure the safe and orderly flow of traffic through work sites, it was recommended that the following items be investigated in detail.

1. The effectiveness of 4-in. (10.2-cm) and 6-in. (15.2-cm) wide stripes on barricade rails less than 3 ft. (0.92-m) long

2. The detection and legibility distances for chevron channelizing devices

3. Drivers' perception, understanding, and preferences of chevron channelizing devices and their reactions to the devices

4. Tapers utilizing chevron devices at 40-ft. (12.2-m) versus 80-ft. (24.4-m) spacings

Consideration was given to the first item as a result of conflicting opinions on the effectiveness of 4-in. (10.2-cm) wide stripes used on barricades less than 3 ft. (0.92 m) long. Section 6C-8 of the most recent Manual on Uniform Traffic Control Devices (MUTCD) states that barricades with rails less than 3 ft. (0.92 m) long shall have 4-in. (10.2-cm) wide alternating diagonal orange and white stripes.(1) However, the previously cited research report indicated that the 4-in. (10.2-cm) stripe was the most ineffective pattern used on a barricade.[2] Also, the inferiority of the 4-in. (10.2-cm) stripe to the 6-in. (15.2-cm) stripe has been verified in research conducted by Bio Technology, Inc.[3]

Detection and legibility distances are important factors in the effectiveness of a channelizing device. While in the previously cited research by the author, detection and legibility distances were examined for single channelizing devices,[2] it was suggested that information on the detection and legibility distances of the devices in a taper should be helpful in evaluating their effectiveness.

Although drivers' reactions to different devices may not vary, their understanding of the directional messages and their preferences may. Thus, it was thought that a subjective evaluation of chevron channelizing devices should give valid evidence of the ones most preferred.

In regard to item 4 above, it appeared that a taper spacing of 80 ft. (24.4 m) was preferred over a 40-ft. (12.2-m) spacing because with the former the entire panel is visible to the motorist. However, it was believed that this should be confirmed.

Moreover, the MUTCD is unclear in its definition of the chevron panel as a channelizing device. It states: "the Chevron Alignment sign is intended to provide additional emphasis and guidance for vehicle operators as to changes in the horizontal alignment of the roadway. Chevron Alignment signs, when used, are erected on the outside of a curve, sharp turn, or on the far side of an intersection, in line with and at right angles to approaching traffic."[1] Some traffic engineers contend that a taper used for a lane closure represents a horizontal alignment change; therefore the chevron alignment warning sign for work zones is appropriate for use in a taper as a channelizing device. Consequently, a chevron panel with a black arrow and orange background, the chevron alignment warning sign, is frequently used in the field for channelization. However, the standard colors for channelizing devices are orange and white, but these present a problem with halation (the white reflectance appears too bright and distorts the orange). The earlier research, approved by the Federal Highway Administration, employed chevron panels with a 1-in. (2.54-cm) black stripe between the orange background and the white arrow as experimental channelizing devices to alleviate this problem.[2] Thus, there was a need to determine which color, black or white, is most effective for use on the arrow.

In a study conducted by the Texas Transportation Institute sight distance requirements at lane closure work zones on urban freeways were determined.[4] Since the Virginia Department of Highways and Transportation does not have similar requirements, there was a need to establish them.

OBJECTIVE AND SCOPE

The objectives of this research were (1) to evaluate the 4 in. (10.2 cm) and 6 in. (15.2 cm) wide alternating diagonal stripes on barricade rails less than 3 ft. (0.92 m) long, and (2) to select the most effective chevron panel. A secondary objective was to investigate minimum sight distances for work zone lane closures based on detection distances.

The research was limited to the use of type II barricades less than 3 ft. (0.92 m) long and chevron panels. A right-lane closure was the only work zone layout used.

To achieve these objectives, the study comprised four major tasks as listed below.

A. Review of the literature on completed and ongoing research on traffic control devices used in work zones.

B. Survey of the state's district traffic engineers and the Danville traffic engineer on their experiences with chevron panels.

C. Field tests of channelizing devices to obtain data on the average driver's response to these devices.

D. Subjective evaluations by observers to obtain detection and legibility distances and preferences for various channelizing devices.

LITERATURE REVIEW

A search of the available literature was conducted through the facilities of the Highway Research Information Service. Additional reports were identified by a less formal literature search. Information derived from the literature review is documented throughout the report.

SURVEY OF TRAFFIC ENGINEERS

In the survey of the district traffic engineers and the Danville traffic engineer, the respondents were requested to do the following:

1. Indicate how often chevron panels are used as channelizing devices.

2. a. Sketch the types of traffic control situations where chevrons are used (specify design and layout details).

   b. Address the problems encountered, accidents, public response, observations recorded, and your opinion relative to these traffic control situations.

3. List the different sizes of chevron panels that are used, and the reason for using each size.

4. List potential field test sites.

Table 1 displays the survey results. Of the five districts that employ chevron panels, two use the 18-in. x 24-in. (0.46-m x 0.61-m) size, and all five use the 24-in. x 30-in. (0.61-m x 0.76-m) panels. The panel with an orange background and black arrow is used by all five districts. The 18-in. x 24-in. (0.46-m x 0.61-m) panel is used only on primary and secondary roads in the Culpeper District and on secondary roads in the Suffolk District. The city of Danville, the only urban area surveyed, employed the 18-in. x 24-in. (0.46-m x 0.61-m) panel with a white arrow and with a 1-in. (2.54-cm) black stripe separating the orange and white.

In every case, chevrons were used in the transition taper only. All of the respondents indicated that no problems were encountered, and all stated that the chevron was effective and an improvement over the standard channelizing devices. The 24 in. x 30 in. (0.61 m x 0.76 m) was selected as the size for the large chevron panel for the evaluation.

FIELD TESTS

The objective of the field tests was to obtain information on motorists' responses to a given channelizing device in a taper arrangement under road conditions. The test procedure, field tests, and test results are discussed below.

Table 1

Information from Survey of District and Danville Engineers

District, City	Channelizing Device: Description and Usage	Comments
Culpeper	18 in. x 24 in. on primary and secondary roads 24 in. x 30 in. on interstate roads; taper spacing = 40 ft. for both sizes. Used for lane closures. Mounted on concrete base with 1-in. x 1-in. metal tubing.	No problems or accidents; public response is good; chevron effectiveness is excellent.
Fredericksburg	24 in. x 30 in. with a 50-ft. taper spacing. Taper is parallel to the New Jersey concrete barrier taper. Mounted on U posts.	No problems or accidents; chevron is very effective.
Richmond	24 in. x 30 in. with a 40-ft. taper spacing. Mounted on concrete base with 1-in. x 1-in. metal tubing. 36 in. x 48 in. (special) used to channel traffic from 4 lanes to 2 lanes. 96 in. x 48 in. (special, 3 arrows) used to channel traffic from 4 lanes to 2-lane collector road.	No problems; chevron serves a good purpose for work zone areas that exist for a long period of time.
Salem	24 in. x 30 in. with an 80-ft. taper spacing. Mounted on concrete base with 1-in. x 1-in. metal tubing. 36 in. x 48 in. used for abrupt turns on detours.	Chevrons are very effective; provide more guidance than other devices.
Suffolk	18 in. x 24 in. with 40-ft. taper spacing on secondary roads. 24 in. x 30 in. with 40-ft. taper spacing on primary and interstate roads. Taper spacing varies with location. Mounted on empty 55-gal. paint drums. Used for lane and road closures. 96 in. x 48 in. (special, 3 arrows) used on construction project detours.	No problems; chevrons channel traffic more smoothly than other devices.
Danville	18 in. x 24 in. with white arrow and 1-in. black stripe separating the orange and white. Used with 10 ft. taper spacing (and an 80-ft. long taper) and also alternated with lighted plastic barricades with a 15-ft. taper spacing. Used for lane closures. NOTE: A black arrow and orange background is used unless otherwise specified.	No problems; public response is good; chevrons are best device of this type; provide good directional guidance.

1 in. = 2.54 cm, 1 ft. = 0.305 m, 1 gal. = 3.79 l

Field Test Procedure

The test procedure employed was developed in a previous research effort.(2) The measure of effectiveness was the position of the motorists' lane changes. The basic premise for using the position of lane changes is that the earlier a driver changes lanes, the more effective the channelizing device is in providing guidance. A four-lane divided highway was specified to minimize the number of lane changes, and a right-lane closure was specified since most motorists drive in the right lane and would, therefore, have to make a lane change.

Three zones, each 350 ft. (10.77 m) long, were set up prior to the transition taper zone (Figure 1). The zone length was based on the estimated time required to change lanes, which is 4 to 5 seconds.(5)

Traffic counters were placed at the boundaries of the zones with the pneumatic tubes extending across about 75% of the right lane of traffic. By determining the differences in the volume counts on the traffic recorders bounding a zone, the number of vehicles changing lanes in that zone was obtained. Zone 4 was the critical zone because forced mergers were made there.

The transition taper is the single most important element in the system of traffic control devices in work zones where a reduction in pavement width is desired.(1) Much care was used in arranging the taper in accordance with MUTCD and Virginia Department of Highways and Transportation guidelines.

Field Tests

Five field tests were conducted to compare channelizing devices and taper arrangements. The features of the test are summarized in Table 2. Test 1 compared the type II barricade patterns, and test 2 examined the color of the chevron arrow. (The 18-in. x 24-in. [0.46-m x 0.61-m] chevron panel is referred to as the standard size panel; therefore, it is called the chevron.) Test 3 examined taper spacing, test 4 compared the standard size chevron and the large chevron, and test 5 examined effects of mounting the large chevron at different heights. Photographs of the tapers are shown in Appendix A.

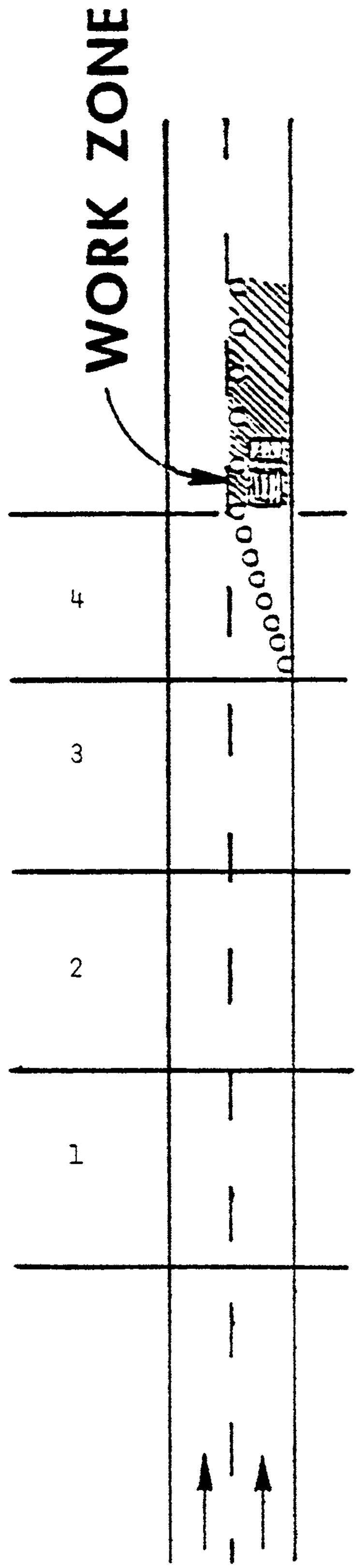

Figure 1. Zone system at the test site.

Table 2

Field Tests

Test	Channelizing Devices
1 a.	Type II barricade with 4-in. wide orange and white diagonal stripes on 2-ft. long and 12-in. high rails
b.	Type II barricade with 6-in. wide orange and white diagonal stripes on 2-ft. long and 12-in. high rails
2 c.	Chevron panel (18 in. x 24 in.) with a white arrow and 1-in. black stripe separating the arrow and orange background
d.	Chevron panel (18 in. x 24 in.) with a black arrow and orange background
3 c. and d.	Chevron panel at taper spacings of 40 ft. and 80 ft.
4 c. or d.	Chevron panel
e.	Large chevron panel (24 in. x 30 in.) standard mount
5 e.	Large chevron panel (24 in. x 30 in.) standard mount
f.	Large chevron panel (24 in. x 30 in.) low mount

NOTE: 1. The taper spacing was 40 ft. for tests 1 and 2.

2. The color of the arrow on the chevron panel selected in test #2 was used on all chevron panels in test 4 and test 5.

3. Test #3 determined the taper spacing for tests 4 and 5.

4. Standard mount = bottom of panel is 12 in. above the pavement; low mount = bottom of panel is on the concrete base.

1 in. = 2.54 cm.

1 ft. = 0.305 m.

Data were collected for an average of 21 hours for each channelizing device, except for the large chevron panel with the standard mount. Only 14 hours of data were collected for this array because a traffic counter malfunctioned.

The field tests were conducted on Interstate 81 North in Rockbridge County near Fancy Hill, where the average daily traffic volume is 12,935. A right-lane closure channeled traffic into the left lane and through the work area where a bridge deck was being repaired over U. S. Route 11 (at Exit #50). The transition taper began 3,600 ft. (1,098 m) before the bridge because of problems posed by a road curvature and an exit ramp 1,600 ft. (488 m) in advance of the bridge. The traffic control signing scheme for the work zone is shown in Figure 2 and the lane closure taper in Figure 3. The sight distance in advance of the taper was approximately 1,800 ft. (549 m).

Field Test Results

Results of the field tests are displayed in Tables 3, 4, and 5. The percentage of lane changes by zone and the weighted lane change (WLC) are given for day, night, and total data collection periods. The percentage of lane changes within a zone and weighted factors (based on the position of the zone in the zone system) were multiplied for each zone and then summed for all zones to obtain the WLC.(2) Thus,

$$WLC = 4 \times \text{zone } 1 + 3 \times \text{zone } 2 + 2 \times \text{zone } 3 + 1 \times \text{zone } 4,$$

where zone i = percentage of lane changes in zone i.

The higher the WLC, the more effective the test array. A comparative analysis based on the WLC is provided for each test below. Vehicle mergers in zone 4 and accidents that occurred during the field tests are discussed.

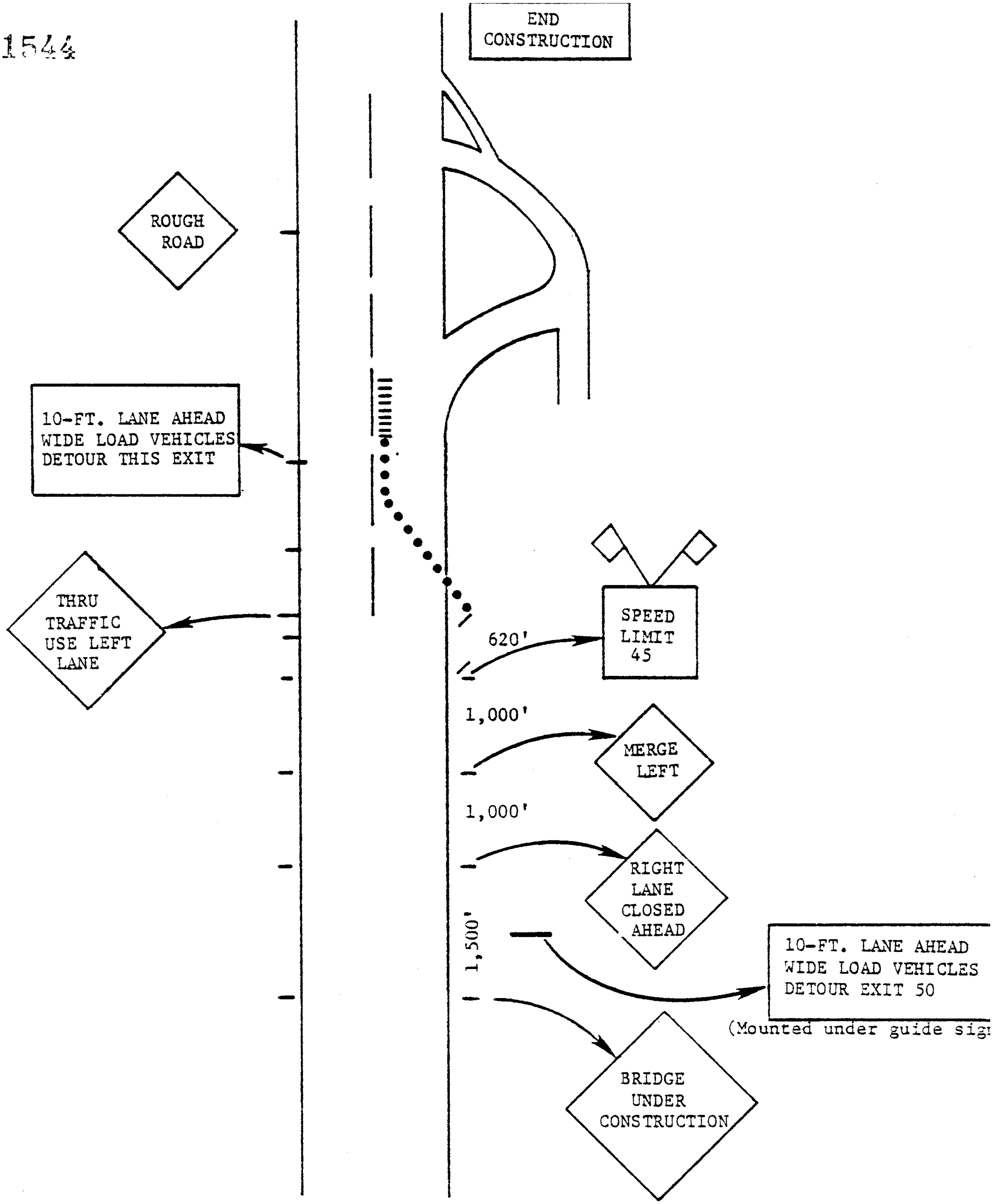

Figure 2. Traffic control layout for the field tests.
1 ft. = 0.305 m
1 mph = 1.6 km/h

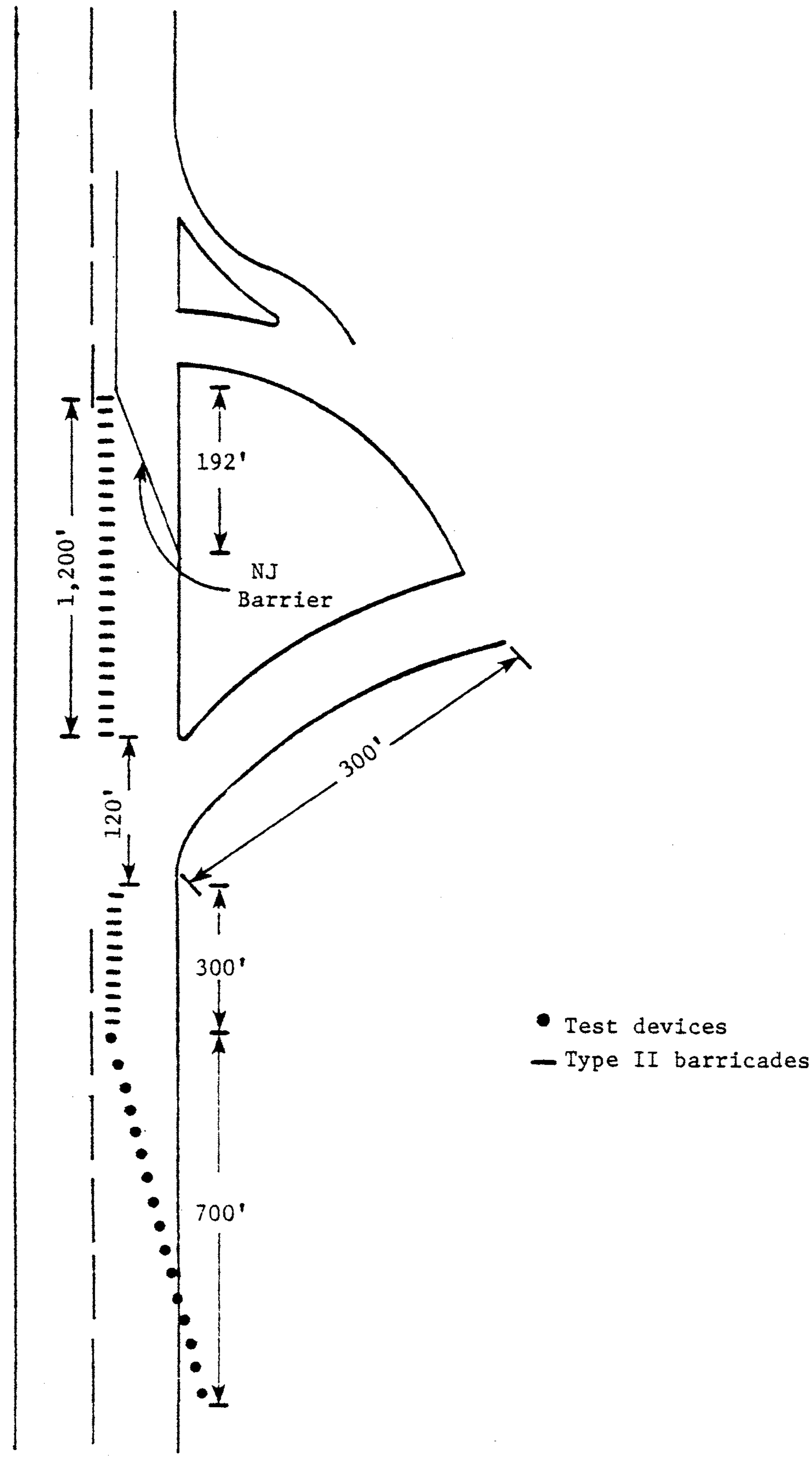

Figure 3. Lane closure for the field tests.
1 ft. = 0.305 m

Table 3

Field Test Results — Test 1

Type II barricades, 4-in. stripes vs. 6-in. stripes

Percentage of Lane Changes by Zone

Zone	Type II barricades, 4 in.-stripes	Type II barricades, 6 in.-stripes
Zone 1		
Day	32.4	32.7
Night	42.0	38.7
Total	35.9	34.8
Zone 2		
Day	30.8	31.1
Night	31.9	33.4
Total	31.2	31.9
Zone 3		
Day	22.6	22.6
Night	18.0	20.2
Total	20.9	21.8
Zone 4		
Day	14.3	13.6
Night	8.1	7.7
Total	12.0	11.6
Weighted Lane Changes		
Day	281.5	282.9
Night	307.8	303.1
Total	291.0	290.1

Taper Spacing = 40 ft., 1 in. = 2.54 cm, 1 ft. = 0.305 m.

Table 4

Field Test Results — Tests 2 and 3

Test 2. Chevron with white arrow versus chevron with black arrow, taper spacing of 40 ft.

Test 3. A) Chevron with white arrow, 40-ft. versus 80-ft. taper spacing
B) Chevron with black arrow, 40-ft. versus 80-ft. taper spacing

Percentage of Lane Changes by Zone

Zone	18-in. x 24-in. chevron with white arrow and 1-in. black stripe		18-in. x 24-in. chevron with black arrow	
	40 ft.	80 ft.	40 ft.	80 ft.
Zone 1				
Day	28.7	32.9	37.0	33.9
Night	40.8	36.6	38.0	37.7
Total	33.4	34.2	37.4	35.2
Zone 2				
Day	31.5	33.1	32.6	34.0
Night	32.4	34.7	35.9	35.1
Total	31.9	33.7	33.8	34.4
Zone 3				
Day	25.5	20.5	21.5	21.8
Night	20.4	19.7	14.1	19.7
Total	23.5	20.2	18.8	21.1
Zone 4				
Day	14.2	13.4	8.9	10.3
Night	6.4	9.1	12.0	7.5
Total	11.2	11.9	10.0	9.4

Weighted Lane Changes

Day	274.5	285.3	297.7	291.5
Night	307.6	299.0	299.9	303.0
Total	287.5	290.2	298.6	295.6

1 in. = 2.54 cm, 1 ft. = 0.305 m

Table 5

Field Test Results — Tests 4 and 5

Test 4. 18-in. x 24-in. chevron versus 24-in. x 30-in., chevron mounted high
Test 5. 24-in. x 30-in. chevron, standard mount versus low mount

Percentage of Lane Changes by Zone

Zone	18-in. x 24-in. chevron with black arrow, taper spacing = 40 ft.	24-in. x 30-in. chevron with black arrow, standard mount, taper spacing = 80 ft.	24-in. x 30-in. chevron with black arrow, low mount taper spacing = 80 ft.
Zone 1			
Day	36.9	41.6	38.9
Night	39.2	39.8	45.2
Total	37.9	40.8	41.4
Zone 2			
Day	34.3	33.7	37.4
Night	36.3	33.7	36.2
Total	35.0	33.7	36.9
Zone 3			
Day	20.2	16.4	18.1
Night	18.5	20.9	15.6
Total	19.5	18.3	17.1
Zone 4			
Day	8.6	8.3	5.5
Night	6.3	5.6	3.0
Total	7.6	7.1	4.5
Weighted Lane Changes			
Day	299.5	308.6	309.5
Night	309.0	307.7	323.6
Total	303.2	308.0	315.0

NOTE: Data represent 7-hour day and 7-hour night collection periods for all devices, since only 14 hours of data were available for the standard mounted large chevron. Standard mount = bottom of panel is 12 in. above the pavement; low mount = bottom of panel rests on concrete base.

1 in. = 2.54 cm, 1 ft. = 0.305 m

Test 1. Type II barricades, 4-in. (10.2-cm) versus 6-in. (15.2-cm) wide stripes

These 2 channelizing devices were ranked about the same by day, night, and total WLC (Table 3). The 4-in. (10.2-cm) stripe has a slightly higher night WLC. It was concluded that there was no difference between the two patterns based on the field tests.

Test 2. Chevron with white arrow versus chevron with black arrow, taper spacing of 40 ft. (12.2 m)

The field test results are given in columns 1 and 3 of Table 4. The chevron with a black arrow was rated higher during the day, whereas the chevron with a white arrow was rated slightly higher at night. This was expected because the white arrow has more reflective area. Since the total WLC was rated slightly higher for the black arrow, it was concluded that the black arrow was more effective. Subsequently, a black arrow was used for the large chevron panel in tests 4 and 5.

Test 3. (A) Chevron with white arrow, 40-ft. (12.2-m) versus 80-ft. (24.4-m) taper spacing; (B) chevron with black arrow, 40-ft. (12.2-m) versus 80-ft. (24.4-m) taper spacing

The results of tests 3A and 3B are given in Table 4, columns 1 and 2 and columns 3 and 4, respectively. Overall, there was little difference between the 40-ft. (12.2-m) and 80-ft. (24.4-m) taper spacings for the two chevron patterns. It is noted that the total WLCs were slightly higher for the chevron with a white arrow at an 80-ft.(24.4-m) taper spacing compared to the 40-ft. (12.2-m) spacing and the chevron with a black arrow at the 40-ft. (12.2-m) taper spacing compared to the 80-ft. (24.4-m) spacing. Since there was little difference in total WLC between the taper spacings for the chevron with a black arrow, an 80-ft. (24.4-m) taper spacing was used for the large chevron.

Test 4. Chevron with black arrow and 40-ft. (12.2-m) spacing versus large chevron with black arrow and 80-ft. (24.4-m) spacing on standard mount

Columns 1 and 2 of Table 5 display the field test results. The large chevron was rated slightly higher for the day and total WLCs and the night WLCs were rated nearly equal. Thus, the large chevron was slightly more effective.

Test 5. Large chevron, standard mount versus low mount

The results for test 5 are displayed in Table 5, columns 2 and 3. The low-mounted chevron was rated slightly higher at night, and there was no difference in the day WLCs. The low-mounted chevron was slightly more effective.

Vehicle Conflicts and Voluntary Mergers in Zone 4

As mentioned in the section on field test procedures, zone 4 is the critical zone because forced mergers are made there. To obtain data on forced mergers, observations were made for 1 hour (between 2:00 p.m. and 5:00 p.m., usually 2:00 p.m. - 3:00 p.m.) for each array. Although a 1-hour period is not statistically significant for traffic conflict observations, it does provide information on forced mergers and support for the WLC statistics. Data were collected on (1) the number of forced mergers due to vehicle conflicts (i.e., a vehicle was unable to merge left because another vehicle was in the left lane or a vehicle merged left in zone 4 and caused a vehicle in the left to brake), and (2) the number of voluntary mergers in zone 4 (i.e., the merging vehicle was unaffected by another vehicle). These are shown in Table 6. The conflict rate and percentage of vehicles making forced mergers were based on the total number of vehicles that merged left inside the zone system (i.e., vehicles that entered zone 1 in the right lane) and then merged.

The channelizing device arrays with the higher conflict rates, voluntary mergers, and percentage of vehicles merging in zone 4 also have the lower WLC values. This correlation was expected, since zone 4 had the lowest weighted lane change factor.

Accidents and Rain

Two accidents in which vehicles hit the transition taper occurred during the field tests. The first occurred when chevron panels with a black arrow were in the transition taper with an 80-ft. (24.4-m) spacing. This accident probably occurred at night during the rain and, based on tire marks, involved a trailer truck. The second accident occurred in the late afternoon in the rain when low-mounted large chevrons were in the transition taper. The automobile was driven by an elderly man, and an accident report was filed by the state police. In both cases, the first channelizing devices on the travel lane were hit. The implications are that rain was an important factor in both accidents.

Table 6

Vehicle Conflicts and Voluntary Mergers in Zone 4

	Vehicle Conflicts		Voluntary Merger (vehs.)	Percentage of Total Vehicles Making Mergers in Zone 4 (Conflicts and Voluntary)
	Number Conflicts	Conflict Rate		
Test 1				
a. Type II barricade with 4-in. stripes	2	6.6	25	9.0
b. Type II barricade with 6-in. stripes	2	8.0	18	8.0
Tests 2 and 3				
c. Chevron with white arrow				
1. taper spacing = 40 ft.	1	3.5	24	8.7
2. taper spacing = 80 ft.	2	6.9	37	13.5
d. Chevron with black arrow				
1. taper spacing = 40 ft.	1	3.4	22	7.9
2. taper spacing = 80 ft.	1	3.3	7	2.6
Tests 4 and 5				
d. Chevron with black arrow				
1. taper spacing = 40 ft.	1	3.4	22	7.9
e. Large chevron, standard mount	0	0	8	3.3
f. Large chevron, low mount	0	0	10	3.5

Conflict rate = conflicts/1,000 vehicles that merged left in zone system.

1 in. = 2.54 cm, 1 ft. = 0.305 m.

Conclusion

Although the differences in WLC values were small, the following conclusions were drawn from the tests.

1. There was no difference between the type II barricade patterns.

2. The black chevron arrow was more effective than the white arrow.

3. There was no difference between the 40-ft. (12.2-m) and 80-ft. (24.4-m) taper spacings for the standard size chevron panel.

4. The large chevron with a black arrow was more effective than the standard size chevron with a black arrow.

5. The low-mounted large chevron was more effective than the standard-mounted large chevron (both with a black arrow).

Overall, the large chevron with a black arrow performed best in the field tests, followed by the standard chevron with a black arrow, both of the type II barricades, and the chevron with a white arrow.

SUBJECTIVE EVALUATION OF CHANNELIZING DEVICES

The objectives of the subjective evaluation were to identify detection and legibility distances for channelizing devices and to examine observers' opinions of channelizing devices, especially chevron patterns. The procedure and results are discussed below.

Procedure

The subjective evaluation was conducted on a closed portion of Interstate 295 east of Richmond on August 10-11, 1982. Two right lane closure tapers were arranged about 1/2 mile (0.8 km) apart. The taper length was 560 ft. (170.8 m) and the tangent section was 120 ft. (36.6 m). Distance markers (8 in. x 3 in. [20.3 cm x 7.6 cm]) were placed on the right shoulder to indicate distances from the beginning of the taper to 2,600 ft. (0.79 km) in advance of the taper in 100-ft. (30.5-m) intervals. The site is illustrated in Figure 4.

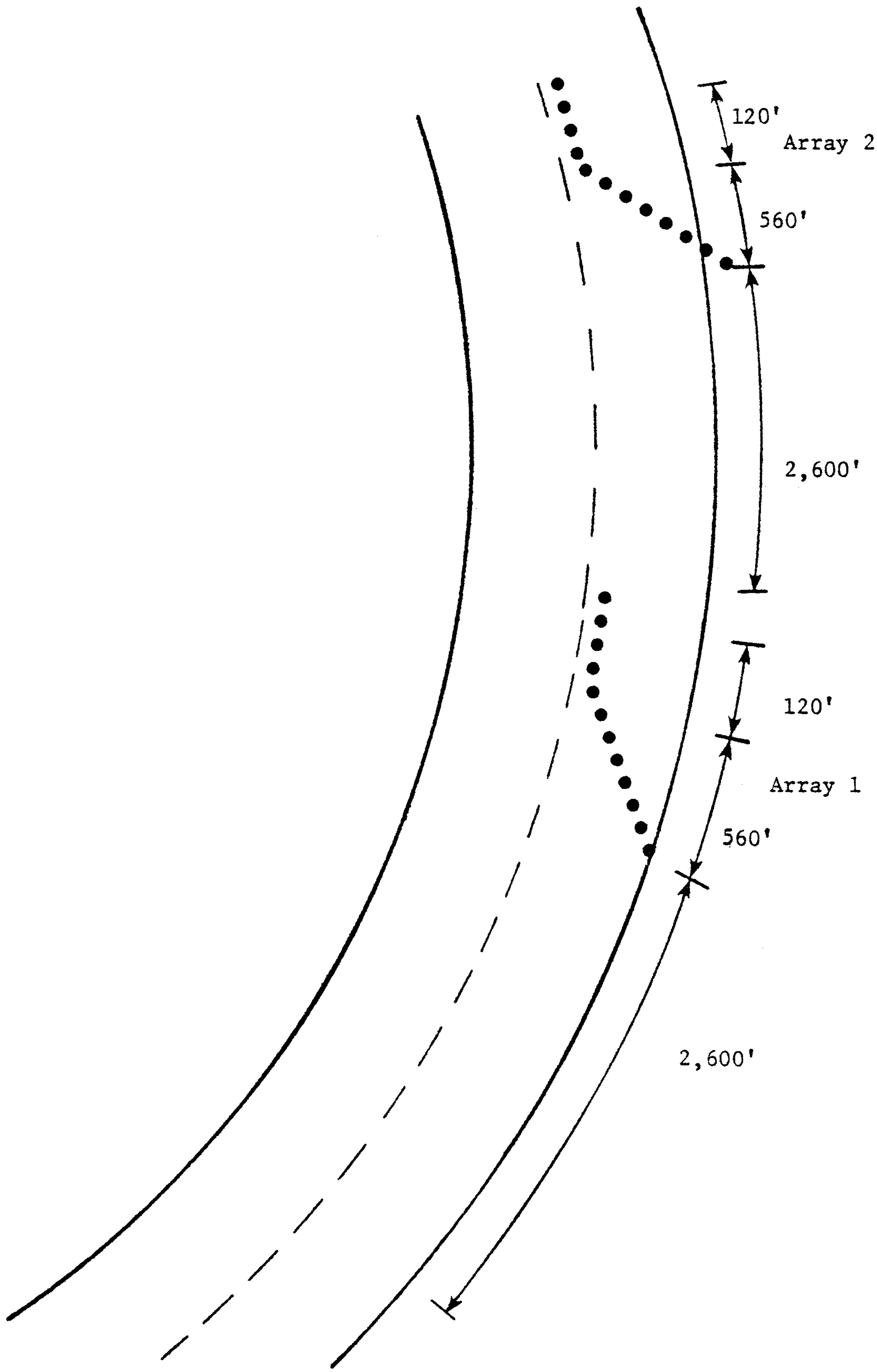

Figure 4. Layout of subjective evaluation site.
1 ft. = 0.305 m

There was a slight horizontal curve and upgrade prior to the first taper and a slight curve and downgrade prior to the second one. Some observers noted that the second taper was more visible than the first due to the geometrics and the background. However, the data did not indicate that the road geometrics were a significant influence.

The five tests conducted in the field were employed with the exception of Test 3a comparing the chevron with the white arrow at taper spacings of 40 ft. (12.2 m) and 80 ft. (24.4 m). Subjective evaluations were made by observers under both day and night conditions. No traffic control devices (such as warning signs and flashing arrow boards) other than the channelizing devices were employed. The observers were Virginia Department of Highways & Transportation Central Office employees in non-traffic-related positions. Three or four observers and a driver were seated in each vehicle. Two taper arrays of channelizing devices were observed during each test, with the observers being asked to indicate the detection and the legibility distance for each array and to indicate their preferences between the two arrays.

The detection distance was taken as the distance at which an observer first noticed that there was a lane closure ahead, and the legibility distance the distance at which he could clearly see the pattern of the channelizing devices. This information was recorded on the form shown in Appendix B. Four or five vehicles with 30-second headways proceeded through the test sections at a speed of 45 miles per hour (72.4 km per hour). Night observations were made on low beam headlights.

The following numbers of observations were made:

Session	Day	Night
#1, August 10	20	19
#2, August 11	19	15
Total	39	34

Each session required about 2 hours — 1 hour each for day and night observations. Although the evaluation tests were arranged in a different order than the field tests, the results are presented in the same order for consistency.

Results

The results are grouped into 2 areas: (1) detection and legibility distance, and (2) observer preferences.

Detection and Legibility Distances

The results for the detection and legibility distances are given in Tables 7 and 8, respectively.

From Table 7, the following observations are apparent.

1. The mean detection distances of all channelizing devices were lower at night than in the day except for the chevron with a white arrow.

2. The large chevron and type II barricade with a 4-in. (10.2-cm) stripe had the largest mean detection distances for day and night, respectively.

3. The chevron with a white arrow had the lowest mean detection distance for day (1,410 ft. [430 m]), and the chevron with a black arrow and 80-ft. (24.4-m) taper spacing had the lowest mean detection distance at night (1,300 ft. [396.5 m]).

4. The chevron with a white arrow had the largest variance and range for day and night.

5. The range of the mean detection distance was 1,410-1,750 ft. (430-533.9 m) for day observations and 1,300-1,570 ft. (396.5 - 478.9 m) for night.

Observations from Table 8 are as follows:

1. The large chevron with the standard mount and with the low mount had the longest mean legibility distance during the day and night, respectively.

2. The chevron with a white arrow had the lowest mean legibility distance for day (710 ft. [216.6 m]) and night (560 ft. [170.8 m]).

3. The type II barricade with 6-in. (15.2-cm) stripes had the largest variance overall.

4. The ranges of the mean legibility distances for day and night observations were 710-1,200 ft. (216.6-366 m) and 560-810 ft. (170.8-243.4 m), respectively.

Table 7

Detection Distances of Channelizing Devices, in feet

	Day			Night		
	Mean	Std. Dev.	Range	Mean	Std. Dev.	Range
Test 1. Taper spacing = 40 ft.						
a. Type II barricade with 4-in. stripes	1,680	260	900-2,000	1,570	270	1,200-1,900
b. Type II barricade with 6-in. stripes	1,730	230	1,200-2,000	1,510	430	500-1,900
Test 2. Taper spacing = 40 ft.						
a. Chevron with white arrow	1,410	330	800-2,000	1,420	440	500-1,900
b. Chevron with black arrow	1,650	220	1,100-2,000	1,400	380	600-1,900
Test 3.						
a. Chevron with black arrow taper spacing = 40 ft.	1,700	200	1,300-2,000	1,400	390	500-1,900
b. Chevron with black arrow, taper spacing = 80 ft.	1,640	230	1,100-2,000	1,300	400	500-1,800
Test 4.						
a. Chevron with black arrow taper spacing = 40 ft.	1,700	240	1,100-2,000	1,340	420	700-1,800
b. Large chevron with black arrow, standard mount, taper spacing = 80 ft.	1,730	200	1,200-2,000	1,430	370	700-2,000
Test 5. Taper spacing = 80 ft.						
a. Large chevron with black arrow, standard mount	1,750	210	1,200-2,000	1,430	360	700-2,000
b. Large chevron with black arrow, low mount	1,650	250	1,200-2,000	1,430	330	700-2,000
Range of the means for the 5 tests	1,410-1,750			1,300-1,570		

1 in. = 2.54 cm, 1 ft. = 0.305 m

Table 8

Legibility Distances of Channelizing Devices, in feet

	Day			Night		
	Mean	Std. Dev.	Range	Mean	Std. Dev.	Range
Test 1. Taper spacing = 40 ft.						
a. Type II barricade with 4-in. stripes	740	300	300-1,500	630	300	200-1,400
b. Type II barricade with 6-in. stripes	800	360	100-1,600	660	350	200-1,500
Test 2. Taper spacing = 40 ft.						
a. Chevron with white arrow	710	300	300-1,500	560	300	200-1,600
b. Chevron with black arrow	940	340	400-1,800	740	280	400-1,500
Test 3.						
a. Chevron with black arrow, taper spacing = 40 ft.	1,020	330	500-1,800	750	290	300-1,400
b. Chevron with black arrow, taper spacing = 80 ft.	1,020	320	400-1,800	680	270	300-1,200
Test 4.						
a. Chevron with black arrow, taper spacing = 40 ft.	1,010	370	400-1,800	720	250	300-1,200
b. Large chevron with black arrow, standard mount, taper spacing = 80 ft.	1,200	310	500-1,800	790	290	300-1,300
Test 5. Taper spacing = 80 ft.						
a. Large chevron with black arrow, standard mount	1,170	330	400-1,800	780	280	400-1,200
b. Large chevron with black arrow, low mount	1,030	350	400-1,800	810	310	300-1,400
Range of the means for the 5 tests	710-1,200			560-810		

1 in. = 2.54 cm, 1 ft. = 0.305 m

In general, the orange and white patterns were easier to detect but more difficult to see clearly at night. During the day, the orange and black combination provided better contrast than the orange and white. At night the orange and white was too bright (i.e., the effect of halation) compared to the legibility of the orange and black. Overall, the channelizing devices in Table 9 were selected based on the legibility and detection distances for each test.

It is noted that there were only small variations in the legibility and detection distances between tests for the chevron with a black arrow and 40-ft. (12.2-m) taper spacing, used in tests 2-4, and the large chevron with a standard mount, used in tests 4-5.

Table 9

Preferred Channelizing Devices Based on Detection and Legibility Distances

Test 1.	Type II barricade with 6-in. (15.2-cm) stripes
Test 2.	Chevron with black arrow
Test 3.	Chevron with black arrow and taper spacing of 40 ft. (12.2 m)
Test 4.	Large chevron with standard mount and a taper spacing of 80 ft. (24.4 m)
Test 5.	Large chevron with standard mount and a taper spacing of 80 ft. (24.4 m).

Preferences for Devices

Observer preferences for the channelizing devices by test are displayed in Table 10, where the percentages of observers preferring a particular taper of channelizing devices for day and night observations are given. For tests 1 and 4 there was no consistently preferred taper of channelizing devices. However, since nighttime preferences are more critical due to reduced visibility, the type II barricade with 6-in. (15.2-cm) stripes and the chevron with a black arrow were slightly preferred for tests 1 and 4, respectively. For tests 2 and 3 the chevron with a black arrow and 40-ft. (12.2-m) taper was preferred. For test 2, several observers indicated that the black arrow was more effective than the white one. The smaller spacing between devices was one reason for preferring the 40-ft. (12.2-m) taper spacing in test 3. For test 4, some observers preferred the smaller taper spacing, whereas other observers preferred the larger device and larger spacing. The large chevron with the

Table 10

Subjective Evaluation of Channelizing Devices — Observer Preferences

Channelizing Device	Preferences, % Day (39 observers)	Night (35 observers)
Test 1. 40-ft. taper spacing		
1. Type II barricade with 4-in. stripes	53.8	41.1
2. Type II barricade with 6-in. stripes	43.6	50.0
No preference	2.6	8.9
Test 2. 40-ft. taper spacing		
1. Chevron with black arrow*	94.9	76.5
2. Chevron with white arrow	0	23.5
No preference	5.1	0
Test 3.		
1. Chevron with black arrow at 40-ft. taper spacing*	51.3	67.6
2. Chevron with black arrow at 80-ft. taper spacing	38.5	26.5
No preference	10.2	5.9
Test 4.		
1. Chevron with black arrow at 40-ft. taper spacing	46.2	61.8
2. Large chevron with black arrow mounted high at 80-ft. taper spacing	53.8	38.2
Test 5. 80-ft. taper spacing		
1. Large chevron with black arrow, standard mount*	46.2	50.0
2. Large chevron with black arrow, low mount	38.5	32.4
No preference	15.3	17.6

*Denotes the preferred taper of channelizing devices for a given test. Tests 1 and 4 did not consistently indicate a preferred array.

1 in. = 2.54 cm, 1 ft. = 0.305 m

standard mount was preferred for test 5. In general, the primary reason for preferring a given taper was that it was more visible or easier to detect.

The final portion of the subjective evaluation determined preferences among all four types of channelizing devices that were observed, and the results are shown in Table 11. Based on the tests, the two preferred tapers of channelizing devices were the large chevron with a black arrow, standard mounting height, and taper spacing of 80 ft. (24.4 m), and the chevron with a black arrow and taper spacing of 40 ft. (12.2 m).

Table 11

Evaluation of Channelizing Devices — Overall Preferences

Channelizing Device	Overall Preferences, % Day	Overall Preferences, % Night
Large chevron with black arrow	66.7	57.6
Chevron with black arrow	23.1	20.6
Type II barricades	10.2	9.1
Chevron with white arrow	0.0	11.7

MINIMUM SIGHT DISTANCES FOR WORK ZONES

This section briefly describes the conclusions of studies on lane closures and the development of minimum sight distances for work zones.

McGee and Knapp proposed visibility requirements for reflective devices at work zones based on the time required for the 3 phases of the hazard avoidance process,(5) the three phases being (1) detection and recognition of the hazard, (2) driver's decision and initiation of response, and (3) completion of the maneuver (lane change). A suggested wording for a performance standard is "The (barricade, panel, drum, cone) should be installed and maintained so as to be visible at night under normal atmospheric conditions from a minimum distance of 900' (275 m) when illuminated by the low beams of standard automobile headlights."(5)

Richards and Dudek recommended a minimum desirable sight distance of 1,500 ft. (457.5 m) for lane closure work zones on urban freeways.[4] They studied sixteen maintenance work zones where one or two lanes of a three-lane section were closed and found that (1) more drivers were trapped in the closed lane at the taper area as sight distance to the lane closure decreased, and (2) the sight distance becomes more critical as the volume increases (from 1,000 vph to 3,000 vph or 150 vph/lane to 800 vph/lane). For sight distances less than 1,500 ft. (457.5 m), it was suggested that an arrow board be placed on the roadside upstream of the cone taper. The absolute minimum sight distance to a lane closure should be 1,000 ft. (305 m). It is implied that the study was conducted under daytime conditions only.

The present evaluation revealed that the lowest mean detection distance of the channelizing devices evaluated was 1,300 ft. (396.5 m). All of the devices were fairly new and in excellent condition. Although flashing arrow boards are included in typical work zone traffic control layouts for lane closures by the Virginia Department of Highways and Transportation, they were not used in the evaluation. The identification of the arrow on the flashing arrow board occurs between 1,500 and 2,500 ft. (457.5 m and 762.5 m).[6] Therefore, with the presence of a flashing arrow board, the minimum detection distance is about 1,500 ft. (457.5 m) for a typical lane closure. The age and maintenance of the reflective channelizing devices also affect the detection distances of the lane closure.

Based on the above discussions, it is suggested (1) that a minimum desirable sight distance of 1,500 ft. (457.5 m) be used for lane closure work zones (especially on urban freeways), and (2) that a minimum allowable sight distance and detection distance of 1,000 ft. (305 m) be used for lane closure work zones.

The two recommended distances provide adequate sight distance to ensure safe movements through the lane closure area.

CONCLUSION

The results of the field tests and subjective evaluation conducted in this research indicate the relative effectiveness of various channelizing devices. Conclusions on the five tests are discussed below based on the field tests and subjective evaluation.

Field Tests and Subjective Evaluation Results

The results of the five tests are presented in Table 12. Since evaluation preferences are dependent upon detection and legibility distances, these distances are discussed only when there is no clearly preferred channelizing device array.

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Table 12

Field Test and Subjective Evaluation Results — Recommended Channelizing Devices

Channelizing Device	Field Test	Evaluation	Combined
Test 1. 40 ft. taper spacing			
a. Type II barricade with 4-in. stripes			
b. Type II barricade with 6-in. stripes		X	X
c. No preference	X		
Test 2. 40 ft. taper spacing			
a. Chevron with black arrow	X	X	X
b. Chevron with white arrow			
c. No preference			
Test 3.			
a. Chevron with black arrow at 40 ft. taper spacing		X	X
b. Chevron with black arrow at 80 ft. taper spacing			
c. No preference	X		
Test 4.			
a. Chevron with black arrow at 40 ft. spacing		X	
b. Large chevron with black arrow mounted high at 80-ft. taper spacing	X		X
c. No preference			
Test 5.			
a. Large chevron with black arrow, standard mount		X	X
b. Large chevron with black arrow, low mount	X		
c. No preference			

1 in. = 2.54 cm, 1 ft. = 0.305 m

Test 1. Type II barricades, 4-in. (10.2-cm) versus 6-in. (15.2-cm) wide stripes

These two barricades were ranked equally by the WLC (Table 3), and were rated inconsistently in the subjective evaluation. However, since night preferences are critical due to the reduced visibility, the 6-in. (15.2-cm) wide stripe is recommended. Moreover, the 6-in. (15.2-cm) wide stripe is recommended based on the detection and legibility distances (Table 9). Overall, the 6-in. (15.2-cm) stripe pattern was recommended.

Test 2. Chevron with white arrow versus chevron with black arrow at a taper spacing of 40 ft. (12.2 m)

This is the only test where one channelizing device was clearly preferred in the field tests (Table 4), and subjective evaluation (Table 10). The chevron with a black arrow is recommended overall.

Test 3. Chevron with black arrow, 40-ft. (12.2-m) versus 80 ft. (24.4-m) taper spacing

These two taper arrays were ranked equally by the WLC (Table 4). The 40-ft. (12.2-m) taper spacing was preferred in the subjective evaluation (Table 10). Therefore, the 40-ft. (12.2-m) taper spacing is recommended for 18-in. x 24-in. (0.46-m x 0.61-m) panels.

Test 4. Chevron with black arrow and 40-ft. (12.2-m) taper spacing versus large chevron with black arrow and 80-ft. (24.4-m) taper spacing and standard mount

The large chevron was ranked slightly higher by the WLC (Table 5). The evaluation preferences were inconsistent, but the chevron was clearly preferred at night (Table 10) and was recommended. However, the large chevron is the preferred channelizing device overall in the subjective evaluation. Moreover, the large chevron is recommended based on the detection and legibility distances (Table 9). Overall, the large chevron is the recommended channelizing device.

Test 5. Large chevron with black arrow, standard mount versus low mount

The large chevron and low mount is ranked slightly higher by the WLC (Table 5). However, the standard mount is recommended based on the detection and legibility distances (Table 9) and the subjective evaluation (Table 10). Therefore, the large chevron with the standard mount is recommended.

Overall, it appears that the following two channelizing device arrays, ranked in order, are the most effective.

1. Large chevron with black arrow, standard mount, and 80-ft. (24.4-m) taper.

2. Chevron with black arrow and 40-ft. (12.2-m) taper.

The first channelizing device had the highest total WLC of detection and legibility distances and overall preference ranking. The second device generally had the second highest ratings in these three categories.

RECOMMENDATIONS

The results of this study provide support for the following three recommendations.

1. It is recommended that the Virginia Department of Highways and Transportation request the Federal Highway Administration to permit the use of 6-in. (15.2-cm) wide stripes on barricade rails less than 3 ft. (0.92 m) long.

2. It is recommended that the Department use as channelizing devices chevron panels with an orange background and black arrow on 24-in. x 30-in. (0.61-m x 0.76-m) panels at an 80-ft. (24.4-m) taper spacing, and the same pattern on 18-in. x 24-in. (0.46-m x 0.61-m) panels at a 40-ft. (12.2-m) taper spacing.

3. It is recommended that the Department adopt the following minimum sight distance requirements.

    a. A 1,500-ft. (457.5-m) minimum desirable sight distance for lane closure work zones, especially those on urban freeways, and

    b. a 1,000-ft. (305-m) minimum allowable sight distance and detection distance for lane closure work zones.

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REFERENCES

1. Manual on Uniform Traffic Control Devices, Federal Highway Administration, U. S. Department of Transportation, 1978.

2. Cottrell, B. H., Jr., "Evaluation of Chevron Patterns for Use on Traffic Control Devices in Street and Highway Work Zones," Virginia Highway and Transportation Research Council, VHTRC 80-R32 , Charlottesville, Virginia, February 1980.

3. McGee, H. W., R. F. Pain, and B. G. Knapp, Evaluation of Traffic Controls for Street and Highway Work Zones, National Cooperative Highway Research Program, Report 236, Transportation Research Board, Washington, D. C., October 1981.

4. Richards, S. H., and C. L. Dudek, "Sight Distance Requirements at Lane Closures for Work Zones on Urban Freeways," Texas Transportation Institute, Texas A & M University, Research Report 228-7, College Station, Texas, April 1981.

5. McGee, H. W., and B. G. Knapp, "Visibility Requirements of Work Zone Traffic Control Devices," Bio Technology, Inc., prepared for the FHWA, Washington, D. C., July 1978.

6. Pain, R. F., "Detection of Work Zone Traffic Control Devices," Transportation Research Circular No.229, Transportation Research Board, Washington, D. C., May 1981.

Figure A-1. Type II barricade with 4-in. (10.2-cm) stripes.

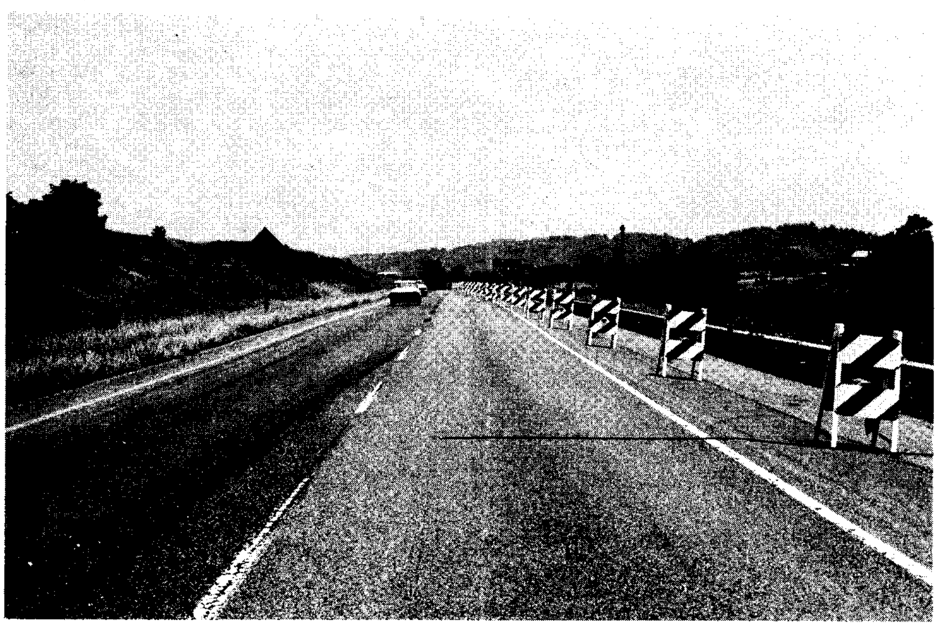

Figure A-2. Type II barricade with 6-in. (15.2-cm) stripes.

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Figure A-3. Chevron with a black arrow — 40-ft. (12.2-m) taper spacing.

Figure A-4. Chevron with a white arrow — 40-ft. (12.2-m) taper spacing.

Figure A-5. Chevron with a black arrow — 40-ft. (12.2-m) taper spacing.

Figure A-6. Chevron with a black arrow — 80-ft. (24.4-m) taper spacing.

Figure A-7. Chevron with black arrow — 40-ft. (12.2-m) taper spacing.

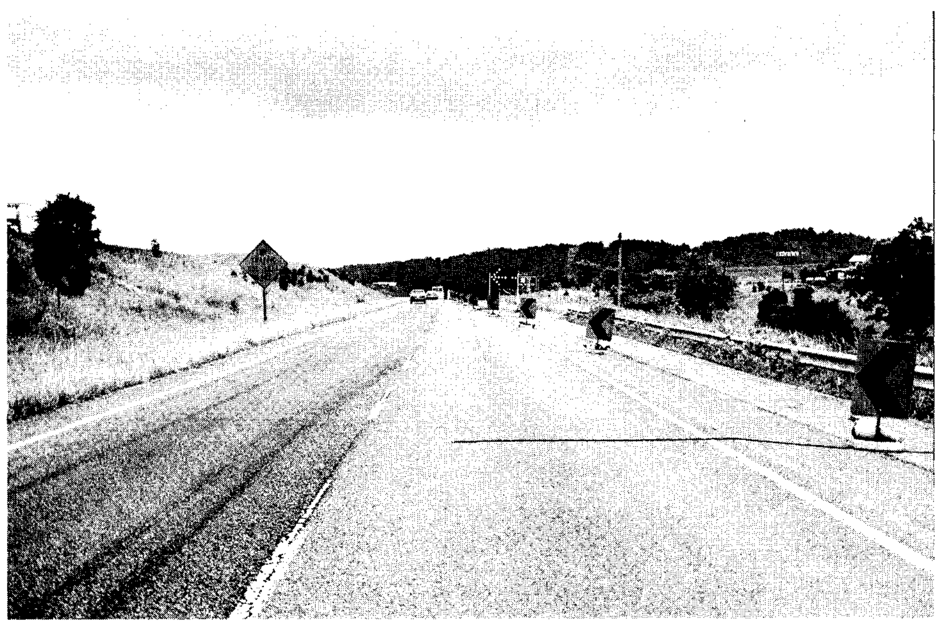

Figure A-8. Large chevron with black arrow — standard mount with 80-ft. (24.4-m) taper spacing.

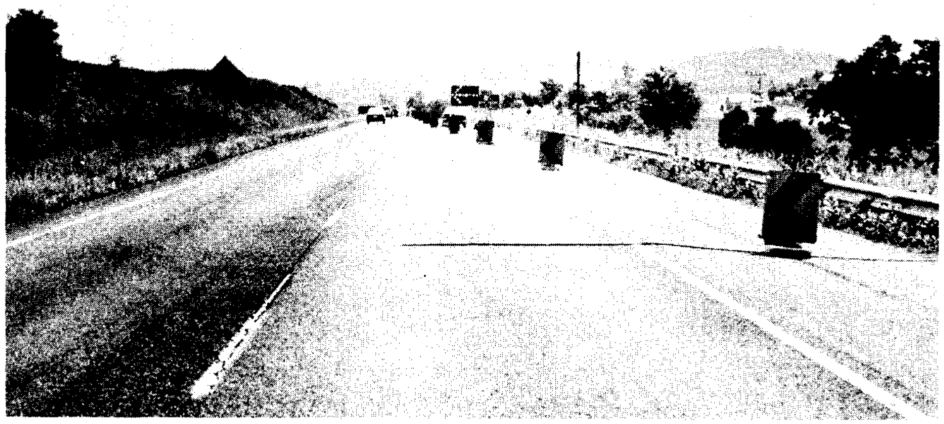

Figure A-9. Large chevron with black arrow — low mount.

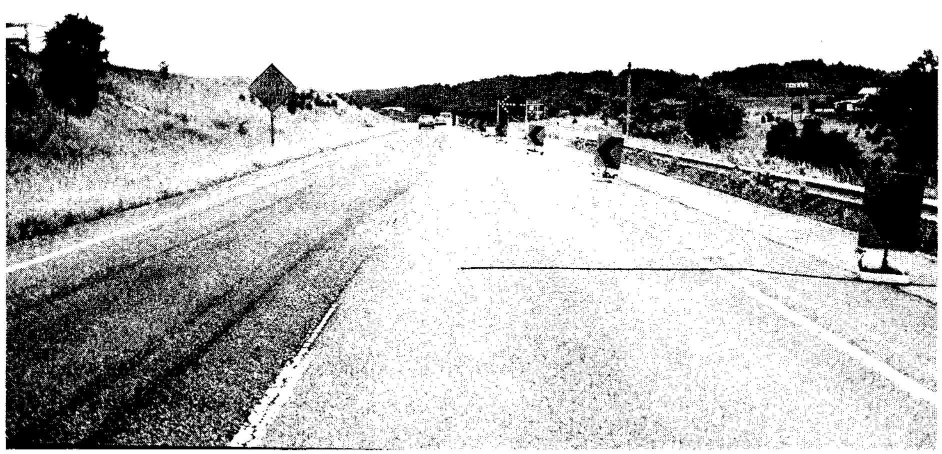

Figure A-10. Large chevron with black arrow — standard mount.

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APPENDIX B

FORM FOR EVALUATING CHANNELIZING DEVICES

Session # 2

____Day ____Night

Instructions

There will be one demonstration run and five runs through the study section for evaluation. Two arrays of channelizing devices will be observed during each evaluation run. Each array represents a right-lane closure. The two arrays are spaced about one-half mile (0.8 km) apart. You will answer questions concerning the detection and legibility distances and your preference for the channelizing devices.

I. DETECTION AND LEGIBILITY DISTANCES

Detection Distance is the distance at which you first notice that there is a right-lane closure ahead.

Legibility Distance is the distance from which you can clearly see the pattern on the channelizing devices.

You will identify these distances by writing down the number printed on the next distance marker that you pass. For example, after you notice that the right lane is closed ahead, the next distance marker bears the number 15. Then you will quickly write "15" in the space provided for the detection distance. After you can clearly see the pattern on the channelizing device, the next distance marker is 5. You will write "5" in the space provided for the legibility distance. Detection and legibility distances will be obtained for each of the two arrays.

II. PREFERENCES

After you have completed 1 run, you will have observed two lane closure arrays. The first array is labeled as array 1 and the second is array 2. The two questions on preferences ask: (1) What array do you prefer?, and (2) Why? When answering the second question, consider such factors as brightness, color contrast, device size, device spacing, and height.

TEST A

1576 I. Detection and Legibility Distances:

	Array 1	Array 2
Detection Distance	________	________
Legibility Distance	________	________

II. Preferences:

1. What array do you prefer? _____array 1 _____ array 2
2. Why do you prefer this array?______________________________

____

TEST B

I. Detection and Legibility Distances:

	Array 1	Array 2
Detection Distance	________	________
Legibility Distance	________	________

II. Preferences:

1. What array do you prefer? _____array 1 _____array 2
2. Why do you prefer this array?______________________________

____

TEST C

I. Detection and Legibility Distances:

	Array 1	Array 2
Detection Distance	________	________
Legibility Distance	________	________

II. Preferences:

1. What array do you prefer? _____array 1 _____array 2
2. Why do you prefer this array?______________________________

____

TEST D

I. Detection and Legibility Distances:

	Array 1	Array 2
Detection Distance	________	________
Legibility Distance	________	________

II. Preferences:

1. What array do you prefer? _____array 1 _____array 2
2. Why do you prefer this array?______________________________

____

TEST E

I. Detection and Legibility Distances:

	Array 1	Array 2
Detection Distance	________	________
Legibility Distance	________	________

II. Preferences:

1. What array do you prefer? _____array 1 _____array 2
2. Why do you prefer this array?______________________________

____

CONCLUSION

1. You have passed through 10 lane closures. Of the four types of channelizing devices observed, which one do you prefer? (check one)

    _____Type II barricade

    _____Chevron with a black arrow

    _____Chevron with a white arrow

    _____Large chevron with a black arrow

2. Why do you prefer it?____

    ____

* THANK YOU FOR PARTICIPATING IN THE EVALUATION *