FURTHER REDUCTION IN INCIDENCES OF WRONG-WAY DRIVING

by

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(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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ABSTRACT

Over a four-year period beginning in 1970, wrong-way incidents and accidents on Virginia's interstate highways were reduced by 50% and those on non-interstate 4-lane divided highways by 70%. However, since 1975 an upward trend has been observed on interstate roads while the downward trend has continued on non-interstate roads.

The report discusses engineering measures taken to reduce wrong-way driving; namely, the use of reflectorized pavement arrows on ramps, the elimination of pavement flares, the provision of stop lines across exit ramps near their junction with crossroads, continuation of the pavement edge line across exit ramps, continuation of double yellow lines on 2-lane divided crossroads opposite exit ramps, reduction of the width of crossovers across exit ramps, additional guidance to local drivers on new interchanges, informing the driver of the geometry of the intersection before he enters it, and providing guidance for drivers at T-intersections without a crossover.

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INTRODUCTION

Since 1970, Virginia highway engineers have been engaged in an intensive effort to reduce wrong-way driving. This effort was brought to the attention of the Research Council, and an investigation was initiated to determine the probable common causes of most wrong-way entries onto interstate and other divided highways. Since 1972 almost every interchange on the interstate system and many intersections on the other 4-lane divided highways have been inspected to determine the varied geometrics, signs, and other aspects of these facilities. Based on these surveys, techniques for alleviating the problem of wrong-way driving have been recommended.(1,2,3)

PURPOSE AND SCOPE

The purpose of this report is to review the progress made in reducing wrong-way incidents and accidents on Virginia highways since 1970 and to describe the engineering techniques employed in the state's efforts.

The data presented include the trends in wrong-way incidents and accidents since 1970. The engineering measures described are limited to pavement markings, pavement geometrics, proper location of signs for night visibility, and raised pavement markers. In some instances the reasoning underlying employment of the measures is given.

ACCIDENT EXPERIENCE SINCE 1970

A survey of wrong-way incidents by the Virginia Department of Highways & Transportation and Virginia State Police was initiated in June 1970 and has been continued since then, except for a period from December 1970 to June 1971. The data collected show that up to June 30, 1976, a total of 114 wrong-way accidents occurred on interstate highways. In these 54 persons were killed and 120 were injured. In 167 accidents reported on other 4-lane divided highways during the same period, 33 persons were killed and 173 injured.

The numbers of fatalities and injuries due to wrong-way driving accidents on interstate highways and 4-lane divided highways in Virginia were compared with the numbers of fatalities and injuries caused by total accidents on interstate highways and 4-lane divided highways in the state during the period 1970-1976. This comparison showed that though wrong-way accidents were relatively few compared to the total number of accidents, they were exceptionally severe. The data showed that the fatality rate per wrong-way accident was 31 times greater than that for other types of accidents on interstate highways and 10 times greater than that for other types on 4-lane divided highways. The data also showed that the injury rate was 2.9 times greater than that for other types of accidents on interstate highways, and 2.3 times greater than the rate for other types of accidents on 4-lane divided highways.

However, the wrong-way incidents and accidents could not be related to the total accidents on a statewide basis for interstate and other 4-lane divided highways. Table 1* gives the vehicle miles, total accidents, wrong-way incidents, and wrong-way accidents for each calendar year since 1970 for interstate, arterial, and primary highways. These data show that on interstate highways the total number of accidents during 1972 was 1,515 for every billion vehicle miles of travel. In 1973 the total dropped to 1,389, a decrease of 8.3% as compared to the 1972 data. This reduction was possibly due to legislation effective as of June 1972 that reduced the blood alcohol content(BAC) level for a presumption of drunken driving from 0.15% to 0.10% and stipulated a mandatory revocation of the driver's license for a period of 6 months for persons convicted of driving while intoxicated. Later, in December 1972, breath tests were introduced to make conviction for driving while intoxicated easier. Thus on interstate roads in 1973 the total anticipated accident rate was curtailed sharply due to enforcement of these regulations. In 1974, on the interstate highways the total number of accidents decreased to 1,022 for every billion vehicle miles, a reduction of 26.4% as compared to 1973. This shift in 1974 was possibly due in large part to the energy crisis of 1973-74 with the accompanying reduction in the speed limit to 88.5 km/hr (55 mph). As shown in Figure 1, there was a considerable dip in wrong-way incidents and accidents at the beginning of 1973— possibly because of the reduction in the BAC level and fear of conviction. Later in 1973 wrong-way incidents and accidents increased and did not seem to be affected by the new legislation and reduced speed limit. The 26.4% reduction in total accidents during 1974 does not seem to have been reflected in the figures for wrong-way incidents and accidents (see Figure 1 and Table 1). From 1970 to 1973, when the vehicle miles of travel and total accidents were increasing, the wrong-way incidents and accidents on interstate highways either remained constant or decreased. Since 1974, when the

*All tables and figures are appended.

vehicle miles of travel and total accidents again increased, the wrong-way incidents and the accidents also tended to increase, causing a reversal of the relationship between total accidents and wrong-way incidents and accidents. It is therefore concluded that on interstate highways there is no apparent relationship between vehicle miles of travel or total accidents and wrong-way incidents or accidents.

On arterial and primary highways vehicle miles of travel increased till 1973. In 1974 they decreased, probably because of the energy crunch, and began a continuing increase in 1975. The total accident rate on the arterial and primary highways increased from 1970 through 1972 (as shown in Table 1), and since then have decreased (see Figure 2). This reduction could be attributed to the change in legislation relating to driving while intoxicated in 1972. Hence for 4-lane divided non-interstate highways, no statistical relationship seems to exist between the vehicle miles of travel or total accidents and wrong-way incidents or accidents.

Trends in Wrong-Way Incidents and Accidents Since 1970

Figure 1 shows the wrong-way incident and accident data for interstate highways in Virginia from June 1970 through June 1976. The wrong-way incidents decreased from 1970 through 1974, from 38 during the first 7-month period of study in 1970 to 18 during the second 6-month period of 1974. For the same periods, wrong-way accidents on the interstate system were reduced from 12 to 6. These figures show an approximate reduction of 50% in wrong-way incidents and in the accident rate on interstate highways during the 4-year period.

Figure 2 shows the wrong-way incident and accident data for 4-lane divided non-interstate highways from June 1970 through June 1976. The wrong-way incidents decreased from 1970 to 1976, from 83 during the first 7-month period of June to December 1970 to 22 during the last 6-month period of January to June 1976. For the same periods, wrong-way accidents on the 4-lane divided non-interstate highways were reduced from 18 to 9. These figures reflect a reduction of more than 70% in wrong-way incidents and approximately 50% in the accident rate during the 4-year period. Figures 1 and 2 also show the proportionate decrease in day and night accidents from wrong-way entries.

The data from the period 1974-1976 in Figures 1 and 2 show a very low rate of increase in wrong-way incidents and the accident rate on interstate highways, and a very low rate of reduction in wrong-way incidents and the accident rate on the 4-lane divided non-interstate highways.

The data collected from 1970 to 1976 in Virginia have shown that about 50% of the wrong-way entries originate from the interchanges; about 15% originate at crossovers and rest stops, or are associated with U-turns and median crossings. The origin of the remaining 35% is unknown.

On non-interstate 4-lane divided highways, about 40% of the drivers making wrong-way entries emerge from intersections with crossroads or exit ramps connecting with interstate roads; about 25% come from business establishments like gas stations and motels; and about 20% come from residential areas, crossovers, beginnings of divided sections, and construction sites, or are associated with U-turns and median crossings. The origin of the remaining 15% is unknown.

In order, therefore, to reduce wrong-way driving, improvements in Virginia have been focused on interchanges, intersections, and exits from business areas. In addition, some crossovers on interstate highways have been closed. U-turns, which are more common on interstates than on non-interstate 4-lane divided highways, do cause wrong-way driving, but no preventive measures for them have yet been determined.

Compounding the problem of wrong-way driving is the considerable contribution of the drunken driver. The survey showed that out of the 287 wrong-way drivers spotted on interstate highways, 152 were drunk, 85 were not drunk, and the condition of the others was not stated. On the non-interstate 4-lane divided highways 188 out of 569 wrong-way drivers were drunk, 302 were not drunk, and the condition of the remainder was not stated. Among the 302 non-drunk drivers on non-interstate highways, many could have made intentional wrong-way maneuvers to cut short the driving distance. An example of such an intentional wrong-way maneuver is given in Figure 3. Among the non-drunken wrong-way drivers were quite a few people whose responses to stimuli were impaired because of age, sickness, medication, or other factors.

The 1972 Virginia legislation on drunk driving does not seem to have reduced wrong-way driving by drunken drivers. Figure 4 shows that on interstate highways, though the total number of wrong-way incidents decreased after June 1972, the reduction was mostly due to the elimination of faulty maneuvering by non-drunken drivers rather than to improvement by drunken drivers. Figure 5 shows that on non-interstate highways the decrease in the number of wrong-way incidents was attributable to improvements by both drunken and non-drunken drivers. The data do not, therefore, confirm that the change in the law has contributed to the reduction of wrong-way incidents. The reduction probably has resulted from other factors such as the engineering measures taken from time to time and increased public awareness of the problem of wrong-way driving.

ENGINEERING MEASURES INITIATED TO REDUCE WRONG-WAY DRIVING

The most significant of the many engineering measures instituted in Virginia during the continuing program to reduce wrong-way driving are discussed in the following subsections.

Reflectorized Pavement Arrows on Ramp

All interstate exit and entry ramps in Virginia have been provided with 5.6 m (18.8 ft.) long reflectorized direction arrow indicators. Two arrows are placed on the exit ramp and one on the entrance ramp, and site investigations have shown that the distance from the tip of the arrow to the stop line on the exit ramp varies from 1.5 m (5 ft.) to more than 7.5 m (25 ft.).

Observations have shown that arrows placed close to the intersection of the crossroad and the exit ramp are visible to the potential wrong-way driver making either a right-hand or left-hand turn into the exit ramp as shown in Figure 6, and that those placed beyond 4 to 5 m (13 to 16.5 ft.) from the intersection are not visible. Therefore, the first arrow on the exit ramp should be very close, say within 1.5 m (5 ft.), to the junction of the exit ramp and the crossroad. This arrow will then be visible to the potential wrong-way driver during the day and at night under low beam headlights. The second arrow on the exit ramp should be placed approximately 30 m (100 ft.) from the stop line as recommended,[4] so as to provide a second warning to the wrong-way driver.

Similarly, the arrow on the entrance ramp can guide the driver from the crossroad into the correct direction only if the driver can see it from the crossroad. The arrow far removed from the junction of the crossroad and entrance ramp will not be visible to the driver from the crossroad and thus will fail to perform its function. It will only reassure the driver after he has gotten onto the entrance ramp.

Elimination of Flares

It has been found that on almost all interchanges on which wrong-way entries have been made, either into an exit ramp or from an exit ramp into a crossroad, the left edge of the left lane of the exit ramp has been flared into the right pavement edge of the crossroad. An example of such a flare is shown in Figure 7. Such flares probably mislead the driver into the wrong lane.

The results of removing such flares have been very encouraging. The following example shows how the wrong-way entries have been completely eliminated by their removal. Figure 7 shows the flare at the intersection of an interstate exit ramp and a primary highway. This intersection had experienced six wrong-way entries (the highest in Virginia), all by non-drunken drivers during the first 2 years of the survey period. In 1974 the author suggested that the flare be eliminated by installing two right angled lines.(5) This suggestion was implemented as shown in Figure 8, and as of October 1976, no wrong-way incidents had been reported. The marking apparently discourages drivers from quickly turning left onto the wrong side of the median, and also increases the visibility distance on the primary highway.

Previously, in approaching the crossroad from the exit ramp all drivers would stop on the stop line. With the introduction of the flare marking, a driver who needs an increased visibility distance crosses the stop line and comes to a stop at the corner of the flare marking as shown in Figure 8. Other examples of the removal of flares are given in a report by the author.(1) Scrifes also has recommended the removal of flares to reduce wrong-way driving.(6)

Stop Line

The traffic on the one-way exit ramp of all partial interchanges must stop at the ramp's junction with the crossroad. During field investigations it was observed that many of the exit ramps which had been involved in wrong-way entries onto the crossroad or onto the interstate highway did not have stop lines at the junction.

The stop line probably has the following two advantages:

1. More drivers tend to stop for a stop line than for a stop sign only; and

2. the stop line probably discourages the driver on the crossroad from entering the exit ramp.

During the investigations it was found that at a few locations the stop line was very close to the intersection of the crossroad and the exit ramp. Such lines were found to be very clearly visible from considerable distances ahead of the intersection while driving along the crossroad during the day and at night under low beam headlights. An example is shown in Figure 9. A stop line placed very close, say within 1.5 m (5 ft.)

of the junction of the crossroad and the exit ramp, will be visible to the driver on the crossroad at day and night, and hence will be of immense help in preventing wrong-way entries into the exit ramp. Figure 10 shows the placement of the stop line at the intersection.

Continuation of Pavement Edge Line

Drivers are now so much accustomed to the pavement edge line that they subconsciously use it as a guide. Drunken drivers or drivers with low responses would probably depend on this line bacause their range of vision is restricted. If this pavement edge line was continued across the exit ramp it would make the exit ramp inconspicuous to such drivers on the crossroad, especially at night. An example of the continuation of the pavement edge line across the exit ramp is shown in Figure 10.

In fact, there is a great danger in not continuing the pavement edge line across the exit ramp, because in Virginia it has been observed that in most cases the line has been continued into the exit ramp as shown in Figure 11. This figure is a night photograph of an intersection which had a wrong-way entry into the exit ramp at night. As shown in this figure continuation of the line into the exit ramp does not discourage driver from entering the exit ramp. Such discouragement is even less when the driver sees no stop line across the exit ramp.

Double Yellow Lines on 2-Lane Undivided Crossroads

Undivided crossroads at interchanges are provided with double yellow lines (along the center of the road) with very wide gaps opposite exit ramps. (In one case a wrong-way drunken driver entered this gap, causing an accident in which six persons were killed.) This has been discussed in detail in a previous report.[5] There is a strong possibility that a gap in the lines opposite the exit ramp encourages a wrong-way entry through the gap into the exit ramp. It is therefore recommended that no gap be provided in the double yellow lines, and that double yellow lines be continued opposite the exit ramp as shown in Figure 10. Some undivided crossroads at interchanges have been provided with continuous solid double yellow lines and no wrong-way entry has been reported at these interchanges. It has also been observed that the provision of continuous double yellow lines does not cause any inconvenience to the drivers who cross these lines to negotiate an interchange. There is no economic loss in providing continuous double yellow lines, and the author is of the opinion that they may prevent some of the wrong-way entries without interfering with normal traffic.

Added Guidance at Unfamiliar Interchanges

Wrong-way incidents are more common at interchanges during the first year or two after their construction than in later years. It has been found that local drivers are involved in such wrong-way incidents, a probable reason being that such drivers have had no previous experience with interchanges. More facilities for the guidance of drivers therefore need to be provided during the first two years after construction. The most economical measure would be pavement markings (on crossroads) that would fade away after a year or two. Instructions by pavement markings such as "North Route 95" and an arrow, as shown in Figure 10, are likely to be helpful to a driver who is confused by the introduction of a new interchange.

Reduced Width of Crossover Opposite the Exit Ramp at Interchanges

The width of the crossover opposite the exit ramps is often much more than is needed by a vehicle from the exit ramp making a left turn around the nose of the crossroad median. This excess has contributed to a number of wrong-way maneuvers onto and from the exit ramps. Virginia's traffic engineers realize the need for channelizing the crossovers and the state is encouraging such programs to provide the needed improvements.

Locations where the widths of the crossovers were reduced were investigated, and many times it was found that even after extension of the nose of the median there was an ample gap between the nose and the biggest trailer truck. A photograph showing this gap at one of the interchanges is given in Figure 12. The left-hand median in this photograph was recently extended to reduce the width of the crossover. To assist a traffic technician locate the nose for a channelized crossover, a simple ordinate method has been developed.[2] By this method the shape and location of the two noses on either side of the crossover can be determined and the crossover can be properly channelized.

Optical Illusion at Night

Wrong-way entries can be caused by drivers suffering optical illusions. The author has observed two such wrong-way entries, one of which is described below.

Figure 13 is a photograph of the lighted intersection at which one of the wrong-way entries was observed. On inquiry, the driver (local, non-drunken) said that he did not see the lane on the far side of the median. This is a level intersection, and unless a person is very observant he is unable to see the lanes on the far side of the median. A "divided highway" sign visible on the left of the driver before he negotiates the intersection and makes a left turn will inform him of the geometry of the intersection. An additional turn sign at the left nose of the median would provide further guidance. The locations of both such signs are shown in Figure 14. These signs have been installed on an experimental basis at 72 intersections over a 92-km (57-mile) stretch of a primary highway in Virginia. Figure 14 is a photograph showing both these signs and their locations at one of these intersections.

The "divided highway" sign is the same as that used in Delaware (7) to reduce wrong-way entries. This sign has been used in Delaware for several years, and Delaware engineers state that it has been very effective in reducing wrong-way entries. They claim that in 1967 the rate of wrong-way incidents was reduced to 0.006 accident per million motor vehicle miles, which amounted to 5 accidents. This number was much below the national average.

T-Intersections Without a Crossover

Small businesses like gas stations, clubs, restaurants, and motels, and small residential areas are not provided with an exit through the median of a divided highway. At such locations the driver, while making an exit, assumes the road to be a 2-lane highway and sometimes makes a wrong-way entry. In most cases, one-way arrow signs are provided opposite these exits. A survey of these locations has shown that there is no definite pattern in the location of the signs, and in many cases such signs are not visible to the driver under low beam headlights at night when he is coming out into the divided highway. The optimum use of this sign could be obtained by placing it opposite the vehicle coming out of a business or residential area as shown in Figure 15.

Raised Pavement Markers

In addition to the investigations leading to the above cited improvements in signs and pavement markings to reduce wrong-way driving in Virginia, others have been conducted.

One of the noteworthy recommendations from these investigations has been one for the provision of raised pavement markers spread over the width of the pavement on a short section of the exit ramp. The feasibility of such use of the pavement markers has been determined[8], and they have now been placed at two exit ramps for further study.

CONCLUSIONS

1. Data show that in Virginia incidents of wrong-way driving on interstate highways decreased by more than 50% in the four years following 1970; on non-interstate 4-lane divided highways the reduction was more than 70%.

2. The reduction in wrong-way incidents was probably the result of engineering measures taken from time to time and to increased public awareness of the wrong-way driving problem.

RECOMMENDATION

To continuously reduce wrong-way incidents and accidents, the Department's district traffic engineers should expand the implementation of the engineering techniques described in this report.

ACKNOWLEDGEMENTS

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7. Division of Highways, Delaware— Correspondence from Director Ernest A. Davidson dated August 29, 1968, to Executive Director A. E. Johnson of the American Association of State Highway Officials, Washington, D. C.

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Table 1

Traffic and Wrong-Way Driving and Accident Summary

Year	Interstate				Arterial and Primary Highways			
	Annual Vehicle Miles of Travel (Millions)	Total Accidents	Wrong-Way Incidents	Wrong-Way Accidents	Annual Vehicle Miles of Travel (Millions)	Total Accidents	Wrong-Way Incidents	Wrong-Way Accidents
1970	4,682	6,729	38 (June-Dec.)	12 (June-Dec.)	10,061	35,617	83 (June-Dec.)	18 (June-Dec.)
1971	5,213	8,133	38 (June-Dec.)	13 (June-Dec.)	10,439	37,195	113 (June-Dec.)	26 (June-Dec.)
1972	5,943	9,005	64	25	11,052	40,366	135	39
1973	6,531	9,076	41	19	11,603	39,929	100	24
1974	6,333*	6,474*	37	19	11,358*	35,125*	60	18
1975	6,780	6,617**	42	17	11,741	30,747**	56	31
1976	–	–	28 (Jan.-June)	12	–	–	22	9

*Due to energy crisis during 1973-74 the vehicle miles of travel decreased. Total accidents alsc decreased due to a reduction of the speed limit to 88 km/hr. (55 mph).

**Effective January 1, 1975, the accident reporting threshold changed from $100 to $250.

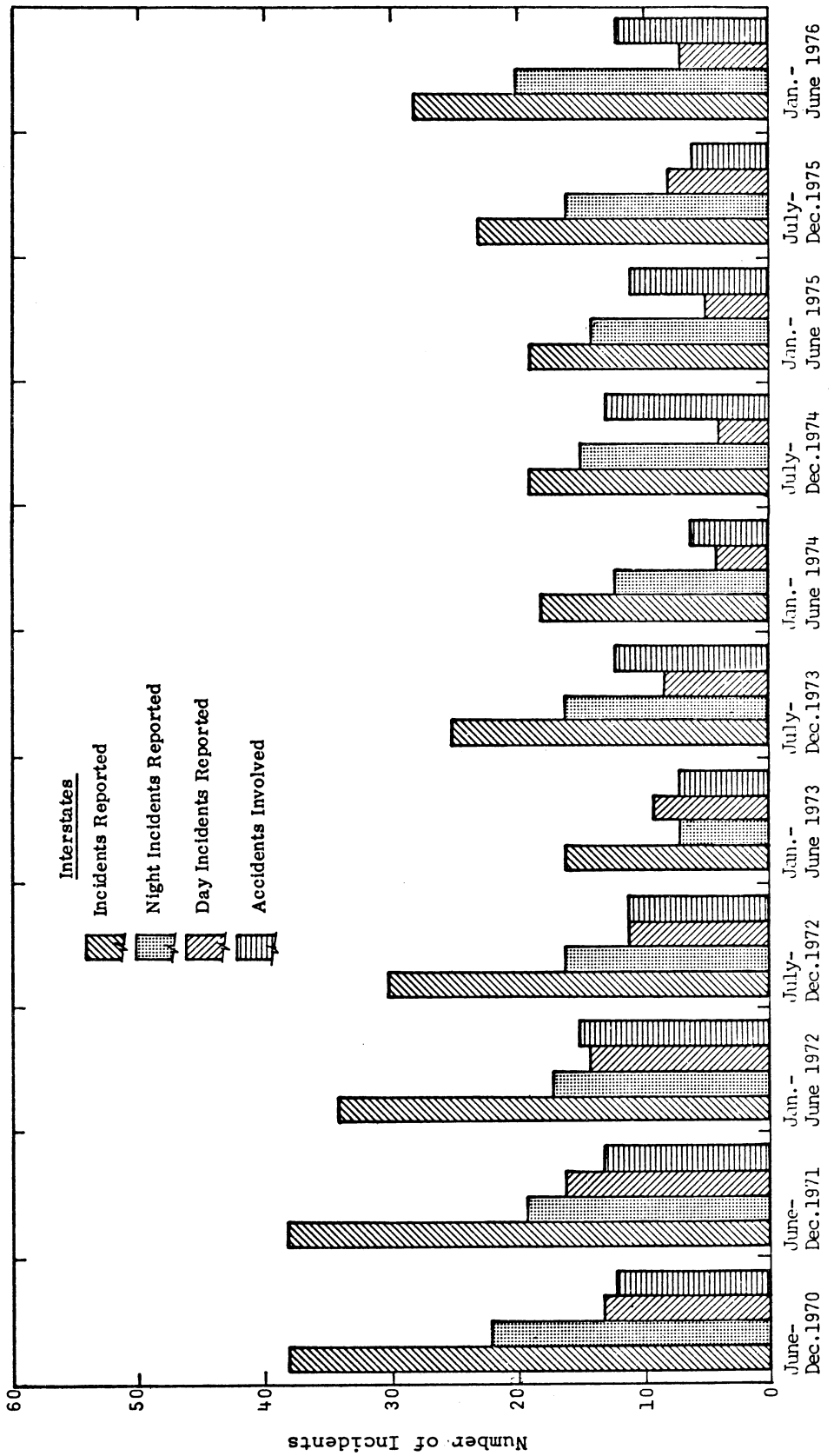

Figure 1. Summary of incident and accident data for interstate system.

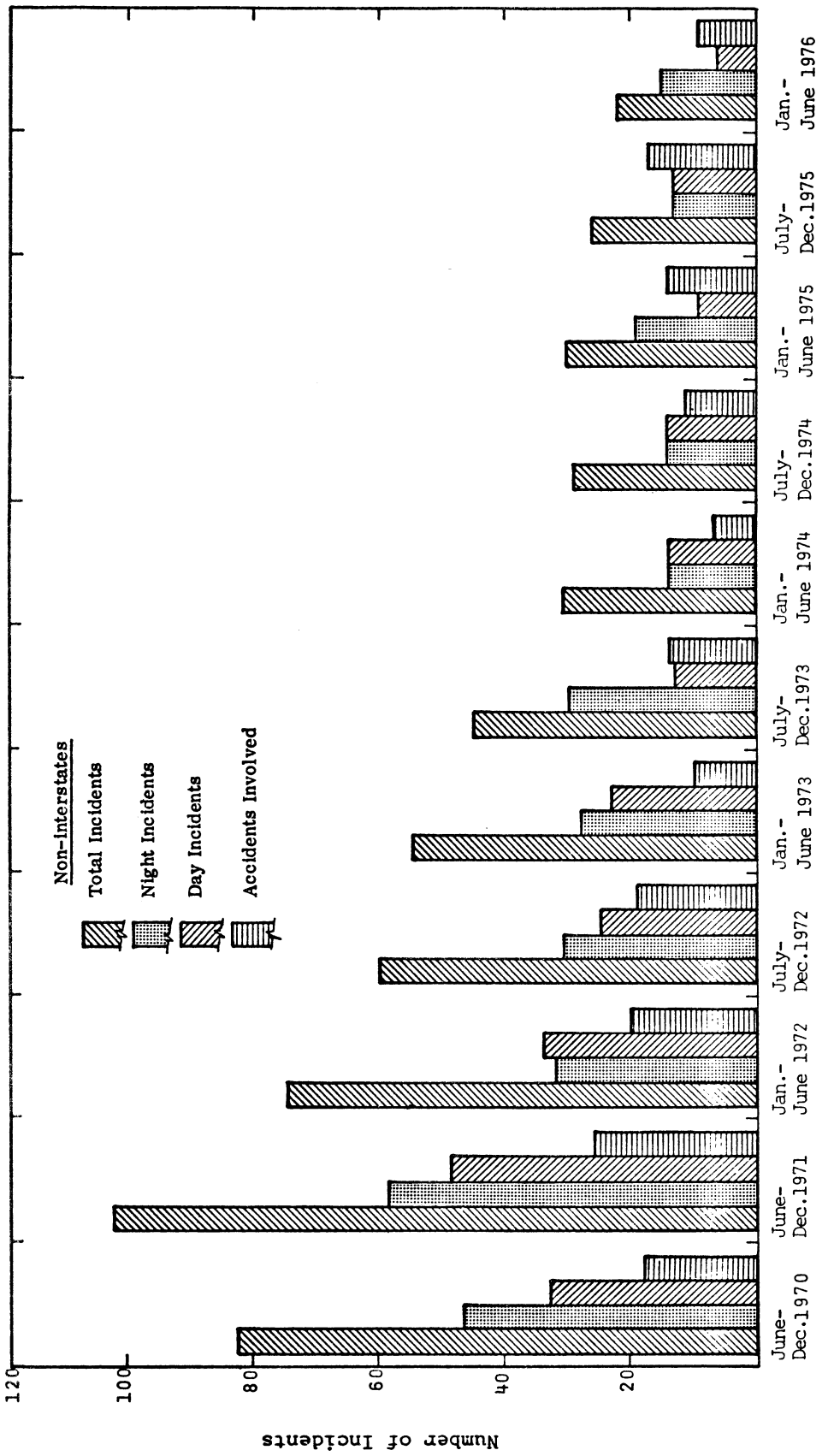

Figure 2. Summary of incident and accident data for non-interstate highways.

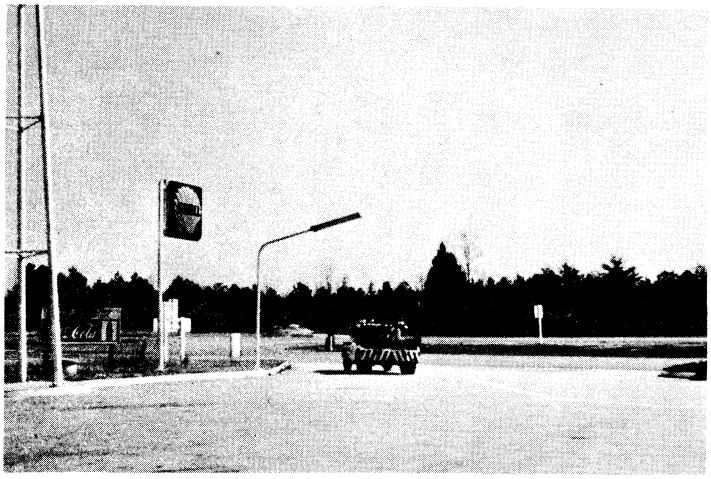

Figure 3. Example of an intentional wrong-way exit from a gas station.

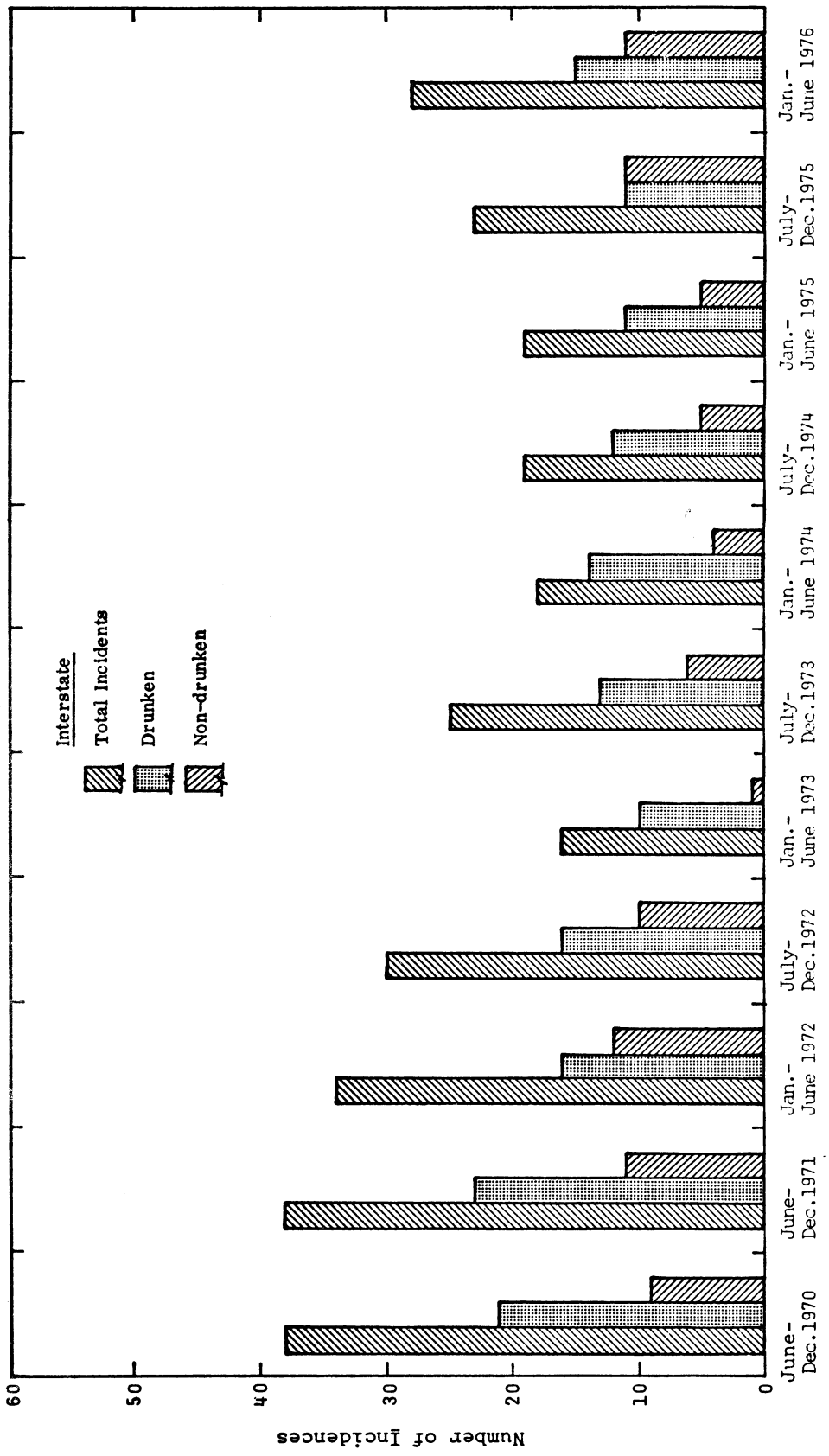

Figure 4. Number of wrong-way incidents and the numbers of drunken and non-drunken drivers for each 6-month period on interstate system.

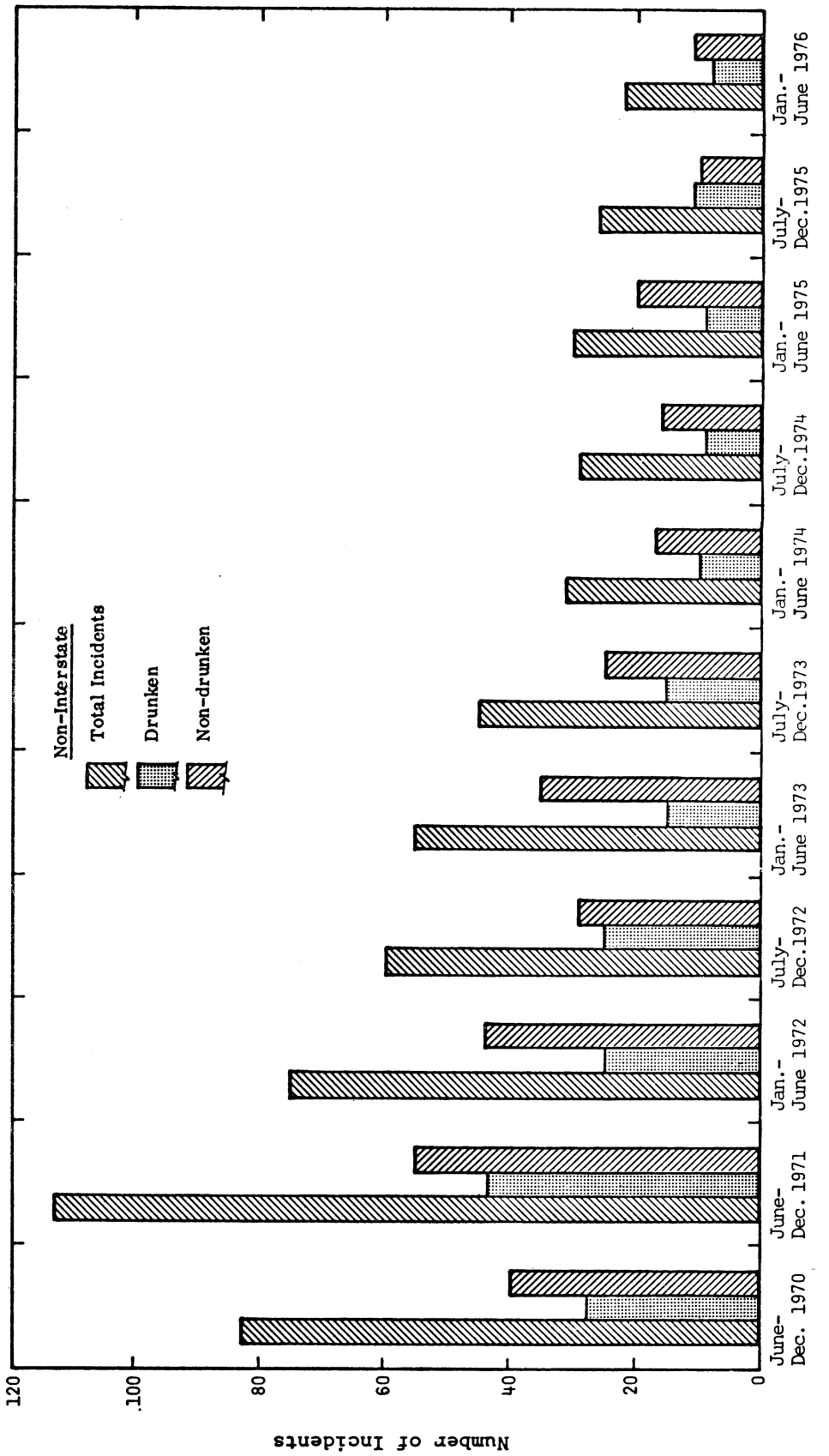

Figure 5. Number of total wrong-way incidents and the numbers of drunken and non-drunken drivers for each 6-month period on non-interstate, 4-lane divided highways.

Figure 6. Visibility of pavement arrow marking when placed near the stop line. No wrong-way incident reported.

Figure 7. Junction of exit ramp and primary highway before marking of the left flare. Site of six wrong-way incidents before improvement.

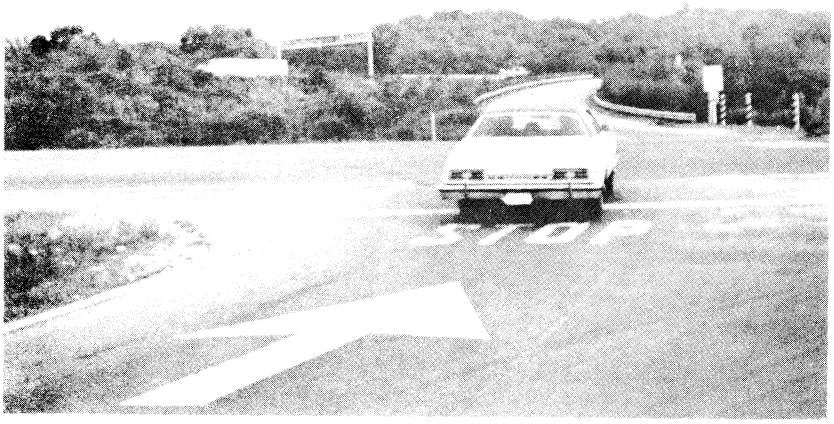

Figure 8. Junction of the exit ramp and primary highway after marking of the left flare. Note that the driver ignores the stop line to get a better view of the crossroad. No wrong-way incident after marking.

Figure 9. Clear visibility of the stop line from a considerable distance on the crossroad. No wrong-way incident after the marking of stop line.

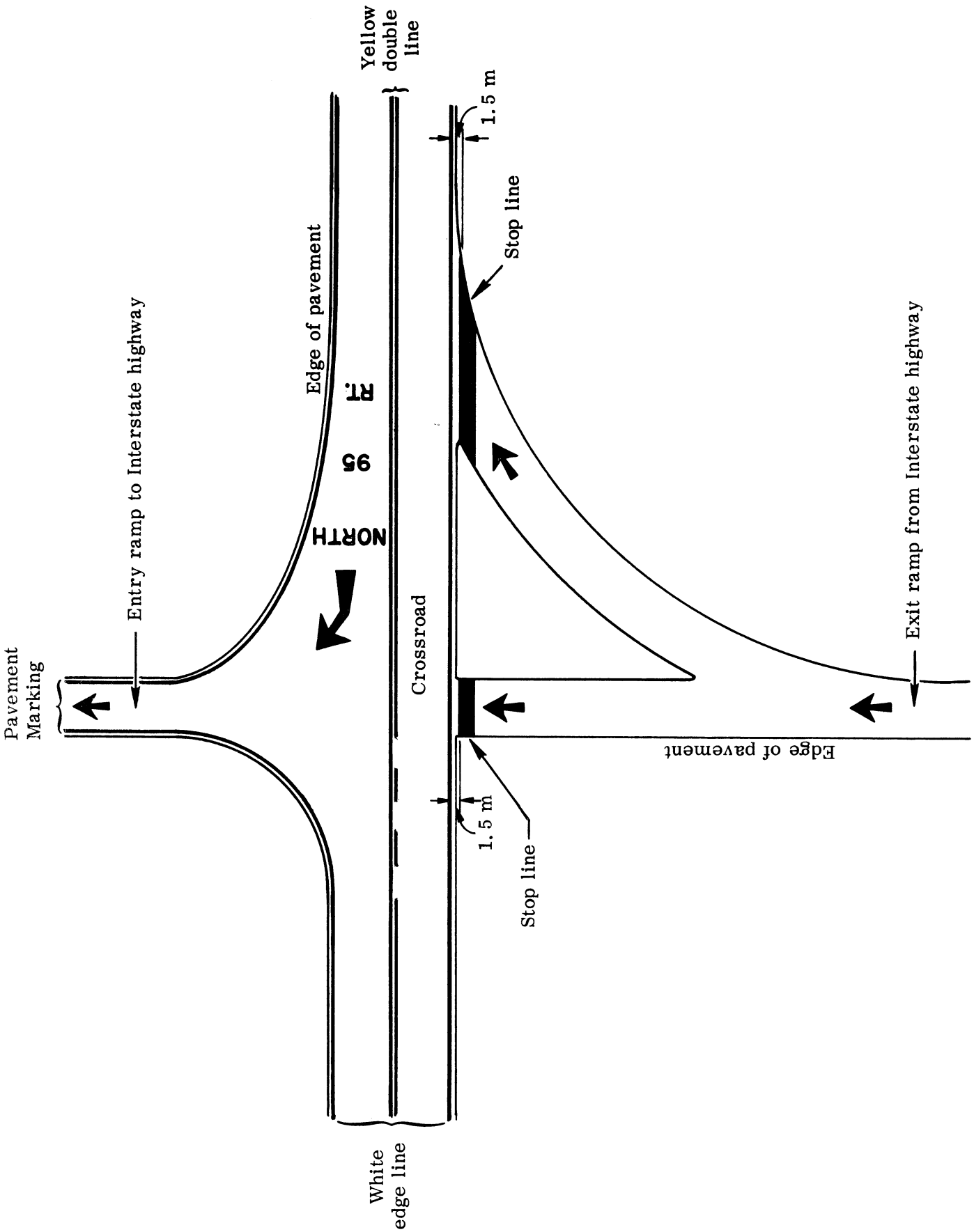

Figure 10. Recommended marking on undivided crossroad.

Figure 11. The pavement edge line flared into the exit ramp and may have encouraged the driver to make a wrong-way entry in the exit ramp.

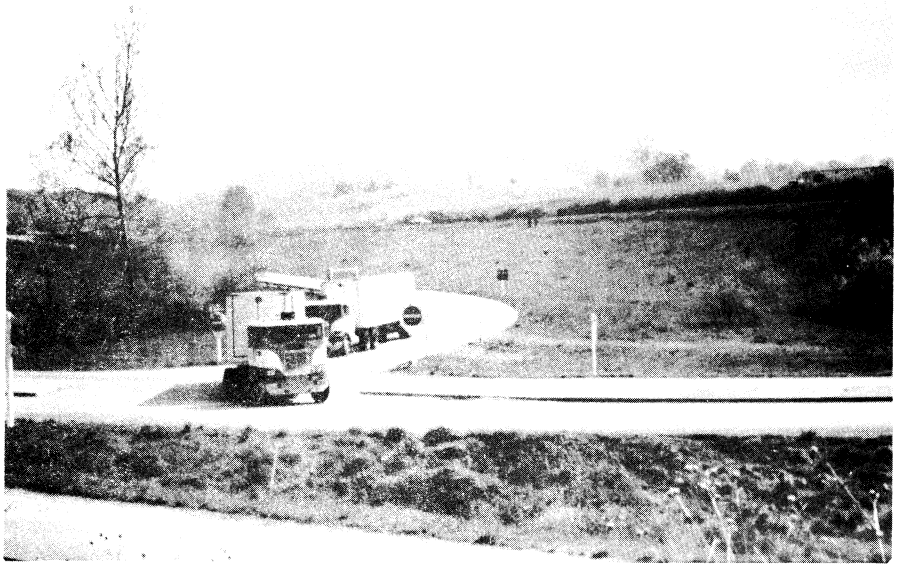

Figure 12. Even after extension of nose of median, there is ample gap between nose and biggest trailer truck. A site of wrong-way entries.

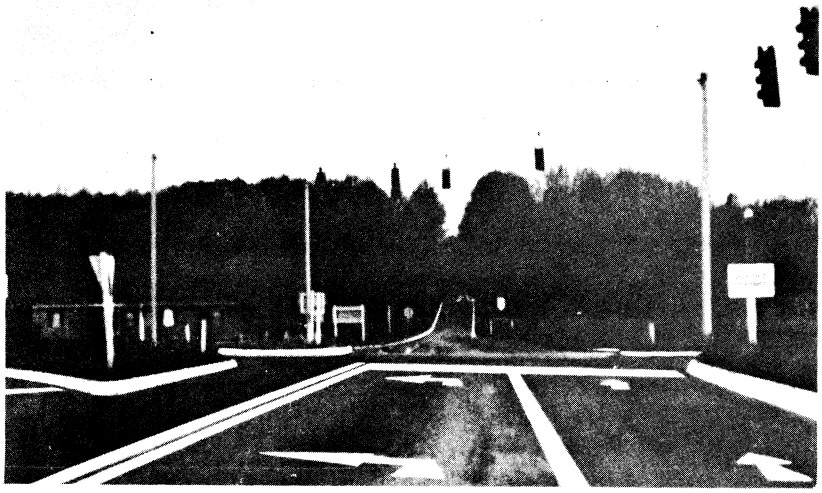

Figure 13. Intersection showing poor visibility of the lanes across the median. A site of wrong-way entry.

Figure 14. Location of "divided highway" and "turn" sign.

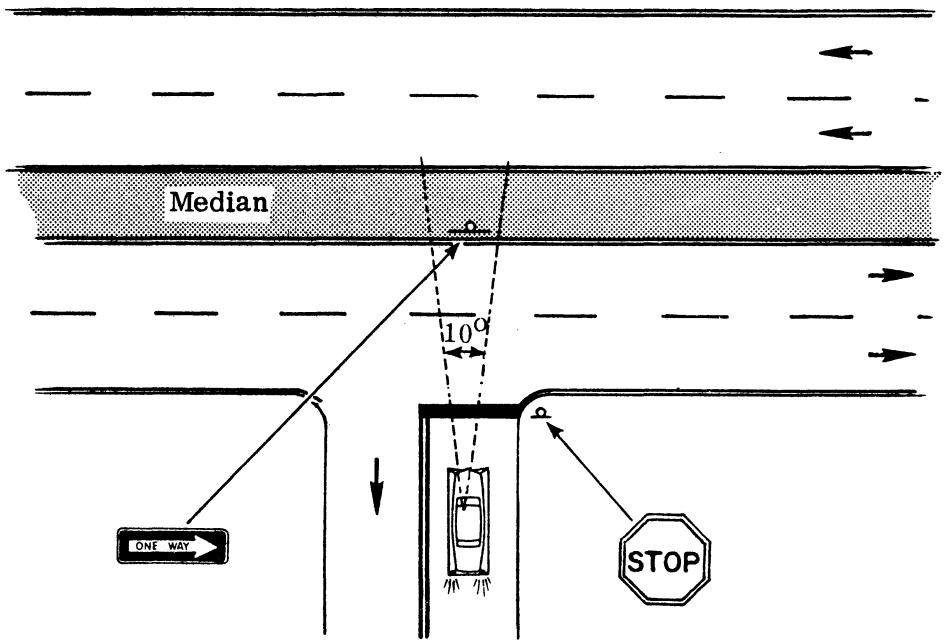

Figure 15. Diagram for sign placement in residential area or small business area, e.g., area with gas station, club, restaurant, or motel.