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POOR VISIBILITY, A COMMON CAUSE 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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SUMMARY

On-site investigations were made of interchanges in Virginia, some of which had been the site of wrong-way entries and some of which had not, and of intersections that had experienced wrong-way incidents. From the observations made on-site it has been concluded that poor visibility at intersections due to road geometrics and incomplete or improper guidance signs and pavement markings is a major cause of wrong-way entries at day and night.

This report discusses the causes of poor visibility and presents seven case studies of interchanges and intersections. Several recommendations for preventing wrong-way entries for a given set of conditions are given below.

1. The locations of road signs and pavement markings should be designed on the basis of night visibility rather than day visibility. The application of the theory of a "cone of vision" for placement of signs needs to be modified. The "keg of legibility" as developed in this investigation for night legibility of signs seems to be more applicable.

2. At intersections with poor geometrics, such as differences in elevation between the opposite lanes of 4-lane divided highways, the crossroads sloping downward from divided highways, or wide crossovers, could lead to wrong-way entries. A divided highway intersection diagrammatic sign placed at the junction of the crossroad and the divided highway will inform the driver of the geometry of the intersection during day and night. Also in some places a left turn diagrammatic sign placed at the nose of the median will inform the driver of the location of the nose of the left median and the need for turning around it.

3. There is a great need for pavement markings that will channelize vehicle movements at night. To discourage a driver from entering an exit ramp at night when his depth of vision is low, the pavement edge marking should be continued across the exit ramp or the stop line should be brought closer to the edge of the crossroad such that it is visible to the driver on the crossroad.

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INTRODUCTION

Wrong-way driving surveys carried out in Virginia since 1970 have shown that most of the wrong-way incidents originate at interchanges, intersections, or business areas. An interchange is a conglomerate of Tee-intersections with one-way traffic on the exit and entry ramps. The driver, in this case, has to be very careful to choose the correct ramp or left turn lane to avoid a wrong-way entry. In business areas and at intersections, however, the driver needs to be guided into correct left turn lanes around the nose of the median to prevent a wrong-way entry. To prevent wrong-way entries, traffic engineers provide visual type information devices, e. g. signs and pavement markings, and other features like curbs, all made conspicuous by a color scheme that hopefully will gain the attention of the driver.

Guidance by visual types of information devices at difficult locations is considerably reduced by the driver's limited visibility of the features of the intersection, during the day and night, and the poor visibility of the information devices themselves under low beam headlights at night. The former generally results from poor geometric designs, while the latter can be attributed to improper location of the devices.

PURPOSE

This study was an attempt to develop recommendations for improving upon the guidance provided motorists at interchanges where visibility is less than desirable because of the roadway geometrics or the location of devices furnishing guidance information.

PERCEPTION AND INFORMATION SUPPLIED

The prevention of wrong-way entries depends on the visibility and perception of the information supplied. The visible information, when recognized and interpreted, becomes perception. Perception therefore depends on visibility and the drivers' stimuli. Driver's stimuli are decreased by various factors including old age, sickness, drunkenness, and mental disturbances of a temporary or permanent nature; hence they vary in their abilities to properly negotiate intersections and interchanges with the aid of visual cues only.

As noted before, the information supplied the driver is of the visual type. Certain elements in the design of an intersection may tend to impair the driver's ability to see or understand the overall configuration from the information supplied or seen. To cite examples, such impairment occurs (1) when an exit or entrance ramp or an interchange or an undivided crossroad at an intersection slopes downward from the 4-lane divided highway; (2) when the opposite lanes of a 4-lane divided highway are at different elevations, and (3) when the crossover is very wide.

The visibility controls the amount of information received by the driver. Information supplied beyond the driver's visibility serves no useful purpose. Hence at night information beyond the zone lighted by low beam headlights remains invisible to the driver. Such information is therefore redundant at night. This is further discussed below.

NEED FOR DESIGN BASED ON NIGHT VISIBILITY

At night visibility is limited within the range of the low beam headlight of the vehicle and depends on the reflectance of the road element. This is not so during the daytime when the visibility is much better as regards the depth and side views. Thus drivers who could negotiate an interchange or an intersection at night with the information visible to them can easily negotiate the same interchange during the day. Hence the design and placement of appurtenances so that they will convey information at night will automatically help in the daytime.

VISIBILITY AND LEGIBILITY AT NIGHT

The present theory of a driver's vision is based on the cone of vision. Pignataro[1] states that the most acute vision is within a narrow cone of 3 to 5 degrees and that the limit of far clear sight is within a cone of 10 to 12 degrees. Figure 1 (all figures are attached) shows a 10 degree cone of vision and the vertical and horizontal distances from the pavement edge within which, according to the present theory, a sign would have to be placed for optimum visibility. This theory, however, is based on day vision and may not hold for a narrow range of low beam headlights and a low reflectance under such headlights.

In this investigation a study was carried out to determine the visibility of a used 2 ft. x 2 ft. (0.6 m x 0.6 m) reflectorized diagrammatic sign. The sign was positioned at distances of 0, 5, 10, and 15 ft. (0, 1.5, 3.0, and 4.5 m) from the pavement edge, with its center at heights of 5, 8, and 11 feet (1.5, 2.4, and 3.3 m) above the road level. Night and daytime photographs were taken of the signs at each combination of locations from distances of 50, 100, 150, 200, and 250 ft. (15, 30, 45, 60, 75 m). The lens of the camera was 4 ft. (1.2 m) above the road surface and 9 ft. (2.7 m) from the pavement edge. At night, low beam headlights were used. The sky was clear and there was average humidity during the day and night. Typical day and night photographs of the sign are shown in Figures 2 and 3. These photographs were projected in a darkened room before five persons who graded the legibility of the sign. The limits of good legibility in terms of depth, height, and distance from the pavement edge were thus determined. These limits are shown diagrammatically in Figure 4. This diagram shows that the zone of legibility at night is not conical (as shown in Figure 1) but is keg-shaped with the horizontal axis as the distance from the pavement edge, the vertical axis as the height of the sign, and the depth axis as the distance from the eye. Then, for example, at 100 ft. (30 m) from the eye a sign placed in a quadrant of an oval 15 ft. by 12 ft. (4.5 by 3.6 m) with its axis on the pavement edge should be legible to the driver. This keg of legibility is considered to provide good night visibility for a normal person viewing under low beam headlights during good weather conditions on a straight road. The night legibility will decrease under defective headlights and during humid weather. Other observations made in this sub-study were as follows:

1. The 8 ft. (2.4 m) height gave better visibility than did the 4 ft. (1.2 m) and 10 ft. (3 m) heights. At distances up to 125 ft. (37.5 m) the 4 ft. (1.2 m) height was better than the 10 ft. (3 m) height on a level road. Whereas for distances greater than 125 ft. (37.5 m), the 10 ft. (3 m) height was better than the 4 ft. (1.2 m) height.

2. As the depth viewing distance increased, the side viewing distance decreased.

Johansson and Rumar,[2] as a result of their investigation with dimmed headlights, found that for an object with 4% reflectance, the average visibility distance was 72.6 ft. (22 m), and that when the reflectance was increased by 25%, the visibility distance increased to 132 ft. (40 m). A 150 ft. (45 m) legibility distance for the reflectorized sign in this investigation therefore seems to be in line with the findings of Johnansson and Rumar. However, it is important to note that alcohol impaired drivers require significantly brighter signs.[3]

An example of the reflectance and visibility of road features other than signs which help the driver negotiate an intersection or an interchange is given in Figures 5 and 6. These figures are day and night photographs of a 4-lane divided intersection taken from the driver's position with the vehicle entering from the undivided crossroad. Both photographs were taken when the sky was clear. The night photograph was taken when the humidity was low and the road was dry, and hence at maximum visibility. A comparison of the two photographs shows that at night the luminosity and hence visibility decreases in the following order: (1) signs, (2) painted areas, (3) roadway and grass where the headlight makes a direct hit, and (4) unpainted concrete curb. It is, therefore, concluded that at night the driver is guided only by the high reflectance signs, painted curbs, guardrails, pavement markings, and other appurtenances, depending upon their reflecting power and the geometry of the road ahead. The comparison further shows that at night the informational devices visible to the driver are confined within a very narrow range of the low beams.

IMPROVEMENTS NEEDED AT INTERSECTIONS AND INTERCHANGES

During this investigation intersections and interchanges at which wrong-way entries had taken place at night were inspected at day and night. Also, for the purpose of comparison, intersections and interchanges at which wrong-way entries had not been reported were also inspected during day and night. This investigation showed that wrong-way incidents could be reduced by eliminating certain inherent defects, the most important of which are discussed in the following paragraphs.

Poor Geometrics at Intersections

The two most common problems involving the geometrics at the intersections were as follows:

1. The crossroad sloped downward from the divided crossroad. The slope would sometimes be so steep that a driver approaching the divided highway would have very little or no light from the headlights of the car falling on the road surface to illuminate the road features.

2. The opposite lanes of the divided highway were at different elevations. The driver coming from the crossroad would not be able to see both sets of the lanes under low beam headlights, and hence would consider the divided highway as a 2-lane road with the median being the opposite edge of the road.

The problem of poor geometrics is compounded when the situations above are combined at one intersection. The steeper the downward slopes of the crossroads or the greater the difference between the elevations of the two opposite lanes of the divided highway, the poorer is the visibility.

In addition to the two problems of geometric design stated above, another one encountered at the intersection was the provision of a very wide crossover. Wide crossovers are often associated with crossroads intersecting at angles less than 90 degrees. A few cases of intersections with poor geometrics are discussed below, and remedies for overcoming wrong-way incidents at these intersections are suggested.

Case Study No. 1 — Intersection of Routes 250 and 1426

Figure 7 is a photograph of an intersection of a 4-lane divided highway, Route 250, and a crossroad, Route 1426, taken from the north end of the crossroad. This intersection is a site of two wrong-way entries, both by non-drunken drivers; one during the day from the north end and the other during dark from the south end of Route 1426.

As is evident from the photograph, the north end of the crossroad slopes down from the divided highway. Also there is a considerable difference in elevation between the eastbound and the westbound lanes of the divided highway. The combination of these two factors is not a rare occurrence. The south end of the crossroad is, however, level with the eastbound lane of the divided highway. A cross section of the divided highway at the intersection is shown in Figure 8. This cross section also shows the slopes of the crossroads.

As was observed at the site and also as is evident from Figures 7 and 8, a driver approaching the intersection from the north end of the crossroad is not able to see any portion of the two eastbound lanes, including the crossover, even during the daytime. He therefore perceives the main highway as a 2-lane road on the north side of the median only. The situation is similar when the driver approaches from the south end of the crossroad at night and is not able to see any portion of the two westbound lanes. The intersection could be improved as described below.

1. The driver must be informed of the geometry of the roadways before he enters the intersection. This can best be achieved by a divided highway intersection, diagrammatic sign as shown in Figure 9. This sign is used in Virginia on the same principle as other intersection warning signs, i.e. by placing them about 350 to 500 ft. (105 to 150 m) in advance of the intersection. It should be placed in such a way that it is visible to the driver using low beam headlights at night and at the time when the driver needs to know the geometry the most. The best location is therefore below the stop sign on the same pole.

Delaware is using a similar sign with the addition of arrows as shown in Figure 10. They place this sign on all divided highway intersections, under the stop sign on the same pole. They have found it to be very effective in reducing wrong-way incidents.

In view of their experience and Virginia's need for guidance signs it is recommended that the divided highway intersection sign be provided at the junction of two roads as shown in Figure 11.

2. At some intersections the nose of the median which the driver has to negotiate to complete a left turn is not visible to the driver at night. In such cases it may be necessary to provide guidance for this maneuver. The needed information would be additional to the divided highway intersection sign that gives the driver the geometry of the intersection. At such complicated intersections, the driver must be made aware of two things: the location of the left nose of the median and the fact that he has to turn around it. Such information is especially important when the driver is not able to see the nose delineators before starting a left turn. Nose delineators, because of their low height, are some times not visible; for example, when the

crossroad is sloping downward from a divided highway and the driver's car is at such an inclination to the divided highway that no headlight falls on the delineators as shown in Figure 8. Nose delineators may have a negligible impact on the driver when the nose is quite far from the entry lane. A diagrammatic left turn guidance sign is shown in Figure 12, and its placement is shown in Figure 11.

Case Study No. 2 — Tee Intersection of Routes 250 and 640

Figures 13 and 14 are photographs of a Tee intersection with the same geometric drawbacks as in the previous case; i.e., the crossroad slopes down from the 4-lane divided highway and the opposite lanes of the divided highway are at different elevations. The two lanes of the divided highway adjacent to the crossroad are at higher elevations than the two lanes in the opposite direction. Figure 13 is a photograph taken from the approach to the intersection. It shows the steep slope of the crossroad and poor visibility of the details of the intersection. Figure 14 is a photograph taken at the intersection. At night the road surface, the one-way arrow marked A, and most of the other details are not visible to the driver. Such Tee intersections, therefore, badly need a divided highway Tee intersection sign and a left turn diagrammatic sign. These two signs could be placed as shown in Figure 15.

Case Study No. 3 — Tee Intersection of Routes 460 and 647

Figures 5 and 6, mentioned earlier to illustrate night visibility, are day and night photographs of a Tee intersection of Route 460, a 4-lane divided highway with a 2-lane crossroad, Route 647. It has the geometric drawbacks noted in the previous case, but the two westbound lanes of the divided highway adjacent to the crossroad are at lower elevations than the two eastbound lanes in the opposite direction on the other side of the median. This is the site of a wrong-way entry at night. As is evident from the night photographs, the two eastbound lanes are not at all visible when the driver enters the crossroad, but all signs are very clearly visible. The divided highway Tee intersection sign shown in Figure 16 will evidently inform the driver of the geometry of the intersection, which otherwise would be unknown to him. Since the crossover is not so wide, as not to be visible under low beam headlights while turning, left turn signs may not be necessary.

Case Study No. 4 — Intersection of Routes 460 and 24

Figure 17 is a photograph of the intersection of 4-lane divided Route 460 and 2-lane Route 24 taken from the crossroad on the north end. This intersection is the site of three wrong-way entries at night, one by a non-drunken driver and two by drunken drivers. Two wrong-way entries were from the crossroad on the north end. Contrary to the case studies discussed above, the elevations of the opposite lanes of the divided highway at the intersection are the same. The crossroad is also at the same elevation. In this case the roads intersect at an angle sharper than the right angle and the left nose of the median is quite far from the entering lane, which provides a very wide crossover. It is impossible to see any sign or delineator on the left nose of the median from the north end of the crossroad under low beam headlights at night. The immediate rectification for this crossover is to place a divided highway intersection sign at the north end of the crossroad as shown in Figure 18. The left nose of the crossing as seen from the north end needs to be extended as recommended in the report on "Engineering Measures for Reducing Wrong-way Driving" by the author. [4]

Poor Visibility of Road Features

As stated previously and as explained by Figures 5 and 6, good reflectance and visibility of road features by the use of reflectorized signs and pavement markings help in the maneuvering through an intersection or an interchange. If such guidance aids are not properly attended to, wrong-way entries are bound to increase. A few case studies of poor visibility leading to wrong-way entries are discussed below, and remedial measures are suggested.

Case Study No. 5 — Transition from an Undivided to a Divided Highway

The transition from an undivided highway to a divided highway sometimes leads to wrong-way entries. Eight such wrong-way entries have been reported in Virginia during the wrong-way driving survey period over the last 5 years. Except at one location, where there were two wrong-way entries by non-drunken drivers, the remaining were by drunken drivers. All of these wrong-way entries were made at night.

To mark the transition, yellow stripping is generally provided on the pavement in front of and around the nose of the median to create a pseudo-median effect which should be visible at night. Also the centerlines of the two traffic lanes are continued. If these measures are not taken there are increased chances of a wrong-way entry taking place. Many locations where such wrong-way incidents have been reported were inspected during this investigation. One case study is presented here.

The site for this wrong-way entry is on Route 58 at South Hill. Day and night photographs of this site are shown in Figures 19 and 20, respectively. The pattern of yellow stripping and continuation of the centerlines of the two traffic lanes that could be applicable in this case are shown in Figure 21. Since the stripping was not provided nor were the centerlines continued, the wrong-way driver traveled from A to B as shown in this figure.

The day photograph in Figure 19 shows that even though the transition pavement markings are not provided, a driver traveling in the passing lane towards the 4-lane divided highway has sufficient depth and side visibility so as not to be misguided into the wrong lane. However, this is not true at night as is evident from the night photograph in Figure 20. Figure 20 clearly shows a lack of depth visibility and a limited side visibility. Two things are therefore evident from the case study.

1. The need for a proper pavement marking to separate the two opposite lanes in the transition on Route 58 at South Hill.

2. At night, because of a lack of depth visibility and limited side transverse visibility under low beam headlights, the driver does not have complete knowledge of the road features and geometrics. The driver at night is therefore guided by pavement markings, signs, and other reflective road features which are very close to him, depending upon their degree of visibility. The degree of his visibility and perception decreases with a decrease in the stimuli available to him. It is therefore the author's contention that drunken drivers are completely guided by what they see very close to the road surface, e.g. pavement edge markings.

Case Study No. 6 — Intersection of I-81 Exit Ramp and Route 654, Exit 55A

In case study No. 5 it was concluded that at night, because of a lack of depth and side vision under low beam headlights, a driver with low stimuli is guided by the pavement markings, signs, and other reflective features which are very close to the him, depending upon their degree of reflectivity and hence visibility.

Figures 22 and 23 are day and night photographs of the exit ramp at the intersection of I-81 and Route 654. This is the site of a wrong-way entry. Two things are evident from this case study.

1. As seen in Figure 23, because of restricted depth and width of vision at night, a driver with low external stimuli is likely to be guided by the pavement edge line, which flares into the right lane. Continuation of the pavement edge line straight across the ramp pavement might discourage a wrong-way entry at night. Figure 23, a night photograph, shows that the stop line, which is visible in the day photograph, cannot be seen. An alternative to prevent wrong-way entries is to bring the stop line close enough to the crossroad such that it would be within the zone illuminated by low beam headlights. This suggestion has been discussed in detail by the author in previous reports.[4,5] Continuation of the pavement edge line across the exit ramp or the stop line might channelize the movement of drivers, especially those with low external stimuli. It may also provide a pseudo-pavement edge effect.

2. A comparison of Figures 22 and 23 shows that the one-way arrow sign, which is visible to the driver during daylight, is not visible at night. If drivers are able to find their path under poor visibility at night without the benefit of observing a particular sign, it is obvious that this particular sign has no utility during daytime when the visibility is much better. Hence the location of signs should be based more on night visibility than on day visibility.

Case Study No. 7 — I-64 West and Rt. 340 (Parclo Interchange)

Figure 24 is a day photograph of the I-64 — Rt. 340 intersection where a wrong-way driver entered the exit lane. As seen from the photograph, the nose of the median between the exit and entry ramps is set back from the junction of the ramps and the 4-lane divided crossroad. The night photograph at the same junction in Figure 25 shows that this nose is no longer visible. If this nose is made visible at night, it will show a separation between the exit and the entry ramps and hence will reduce the probability of the driver entering the exit ramp instead of the entry ramp, which are so close together. The following improvements could therefore be recommended for parclo (partial clover leaf) interchanges where the exit and entry ramps are very close to each other.

1. When the exit and entry ramps are very close together on parclo interchanges, the nose of the median should be extended up to the edge of the crossroad. The nose should be of concrete so that it could be made conspicuous at night by the use of reflective paint. This nose should be made even more conspicuous by the use of delineators. Figure 26 shows the suggested improvement. Such a nose would not only provide proper visibility and the separation between the exit and the entry ramps, but also would fully channelize the exit ramp and thus discourage drivers from getting into the exit ramp from the crossroad.

2. Provide a continuous pavement edge line across the exit ramp or bring the stop line very close to the edge of the crossroad such that it is visible at night under low beam headlights.

3. Flare the pavement edge line into the entry ramp to encourage drivers to maneuver properly into the entry ramp.

CONCLUSIONS AND RECOMMENDATIONS

1. The locations of road signs and pavement markings should be designed on the basis of night visibility rather than day visibility.

2. At intersections with poor geometrics such as differences in elevation between the opposite lanes of 4-lane divided highways, crossroads sloping down from divided highways, or wide crossovers that could lead to wrong-way entries, additional guidance in the form of diagrammatic signs are recommended as follows:

A. A divided highway intersection diagrammatic sign placed at the junction of the crossroad and the divided highway below the stop sign will inform the driver of the geometry of the intersection during day and night.

B. A left turn diagrammatic sign placed at the nose of the median will inform the driver about the location of the left median nose and the need for turning around it. This sign is recommended to improve night visibility. It may also help to attract a driver's attention during the day.

3. Because of low depth and side visibility under low beam headlights at night, it is not possible for drivers to know the overall geometry of an intersection or interchange as compared to the daytime. The driver is therefore guided by the road reflecting appurtenances like signs, pavement markings, painted curbs, and noses, depending upon the degree of reflectance of these appurtenance. Hence there is a need for pavement markings to channelize vehicle movements at night.

4. The application of the theory of "cone of vision" for the placement of signs need to be modified. The "keg of legibility" as developed in this investigation for night legibility of signs seems to be more applicable.

5. To discourage a driver from entering an exit ramp at night when his depth of vision is low, the pavement edge marking should be continued across the exit ramp or the stop line should be brought closer to the edge of the crossroad such that it is visible to the driver on the crossroad.

6. On parclo interchanges with the exit and entry ramps very close together, the median should extend up to the edge of the crossroad and its nose should be of concrete with reflective painting. This feature will make the nose conspicuous, and hence show the separation between the exit and entry ramps near the crossroad, and also channelize traffic from the exit ramp.

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d	h	w
50'	5'	2
100	13	4
150	17	8
200	21	12
250	25	16
300	29	20
and so on		

d = Depth of vision

w = Distance from right edge of the pavement

h = Height of the keg quadrant

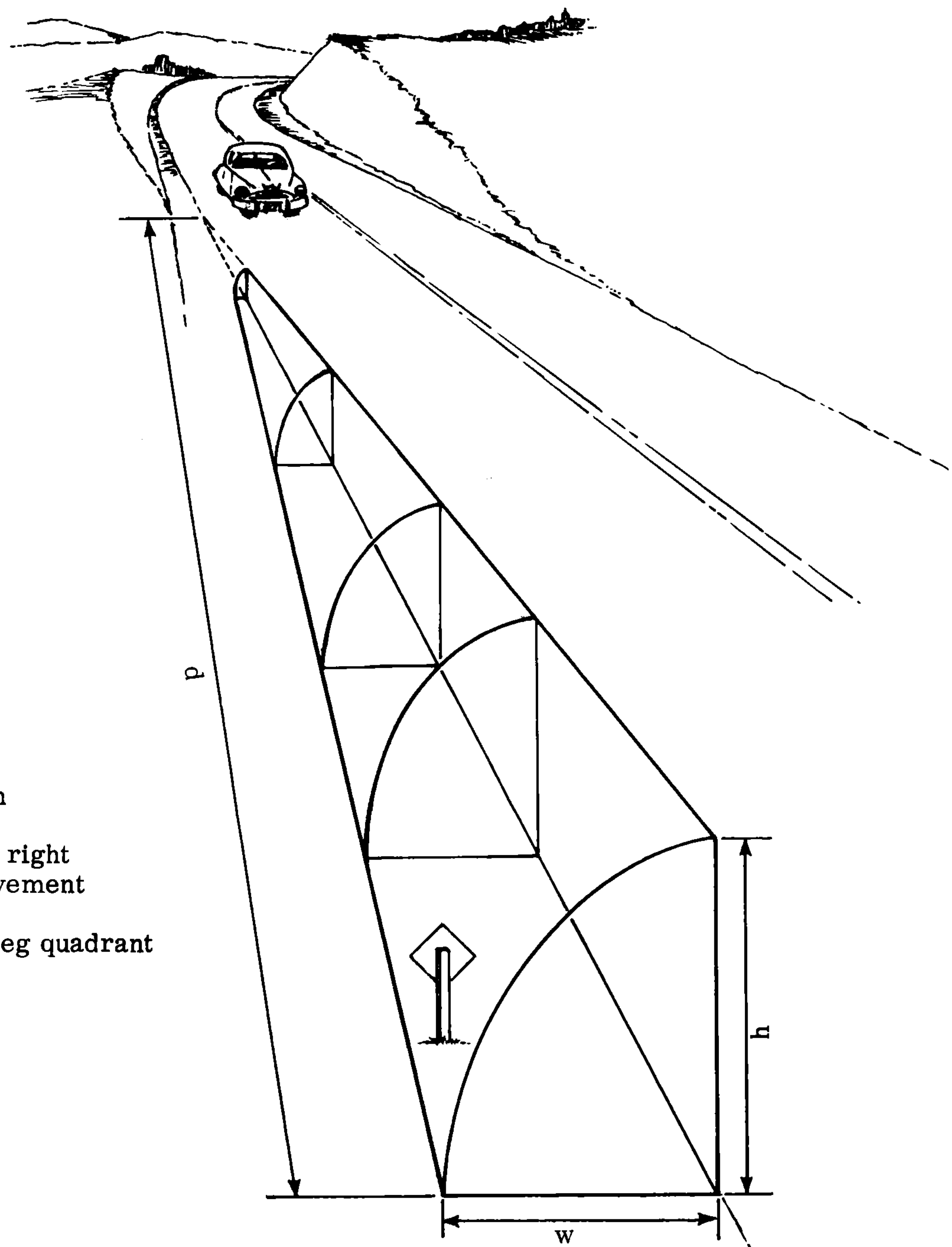


Figure 1. Ten degree cone of vision. No limit of legibility for 2 ft. x 2 ft. diagrammatic sign under low beam headlights.

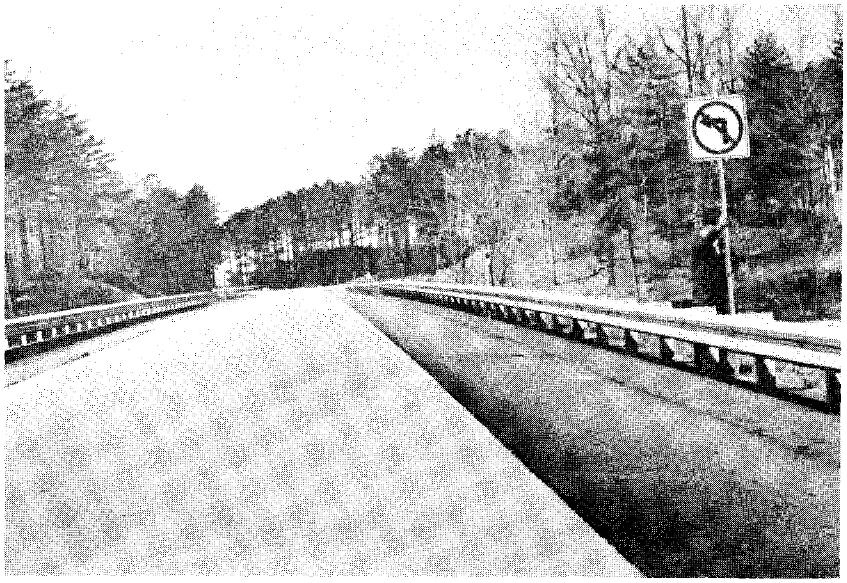


Figure 2. Day photograph of 8 ft. (2.4 m) high sign at 50 ft. (15 m) from the driver and 10 ft. (3 m) lateral distance.

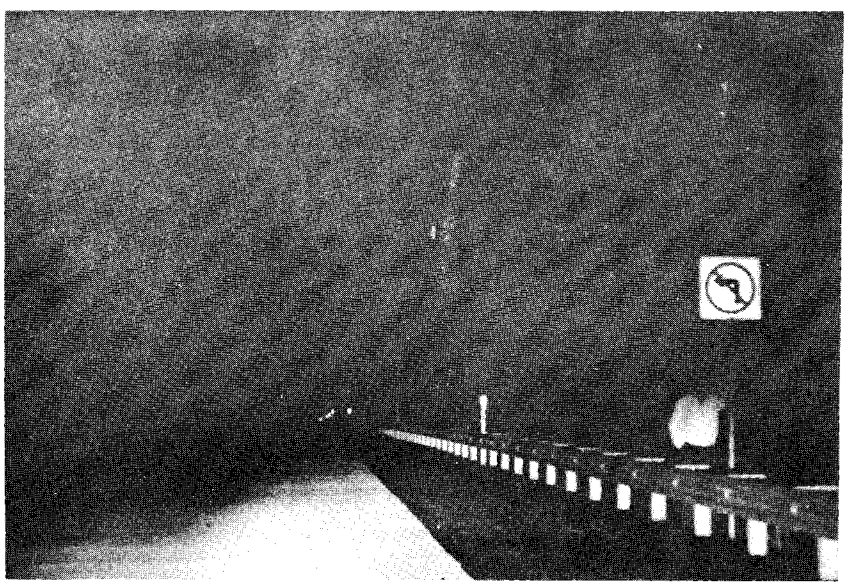


Figure 3. Night photograph of 8 ft. (2.4 m) high sign at 50 ft. (15 m) from the driver and 10 ft. (3 m) lateral distance.

d = depth of vision

w = Distance from right
edge of the pavement.

h = Height of the keg quadrant.

d	h	w
50'	13'	10'
100'	15'	12'
150'	8'	5'
200'	5'	4'

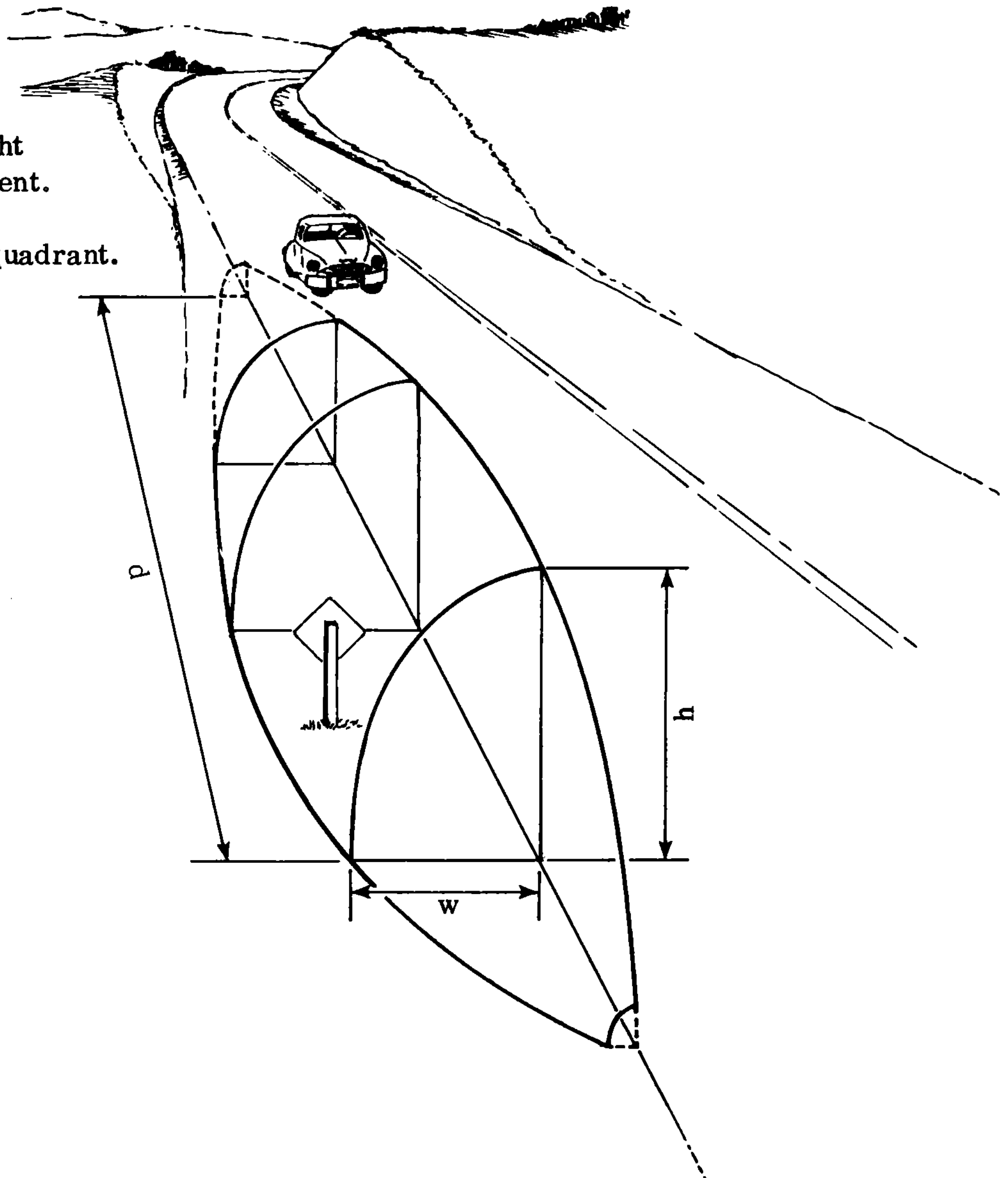


Figure 4. **Keg of good legibility of 2 ft. x 2 ft. diagrammatic reflective sign under low beam headlights.**

Figure 5. Daylight view from a crossroad of a 4-lane divided highway with the far lane higher than the near lane.

Figure 6. Night view from a crossroad of a 4-lane divided highway with the far lane higher than the near lane.

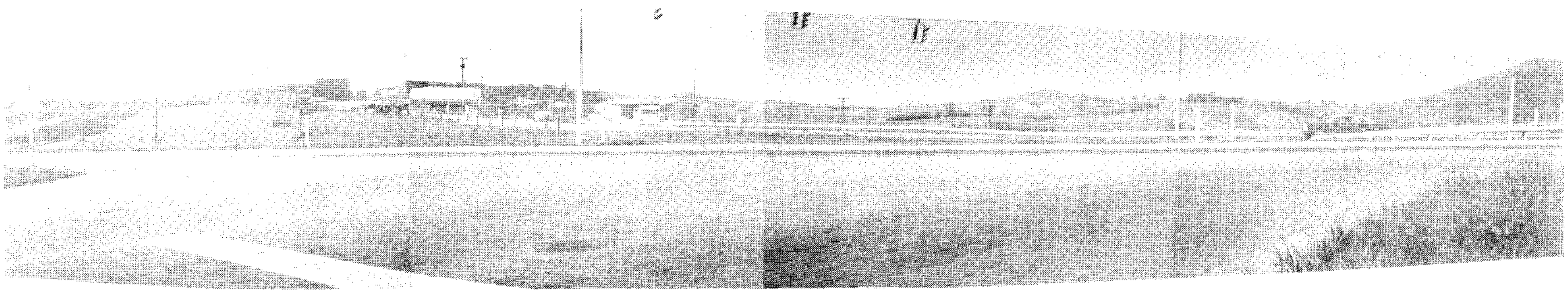


Figure 7. Intersection of 4-lane **divided** Rte. 250 and 2-lane Rte. 1426.

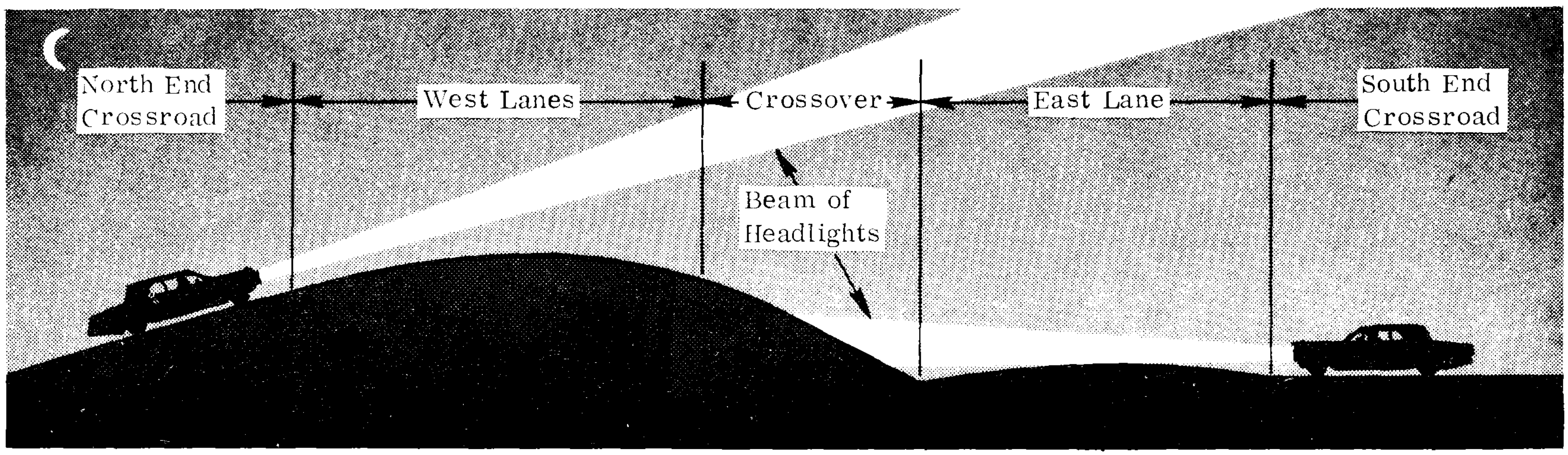


Figure 8. Intersection of 250 and 1426. Cross section across the 4-lane divided intersection extended into the crossroad.

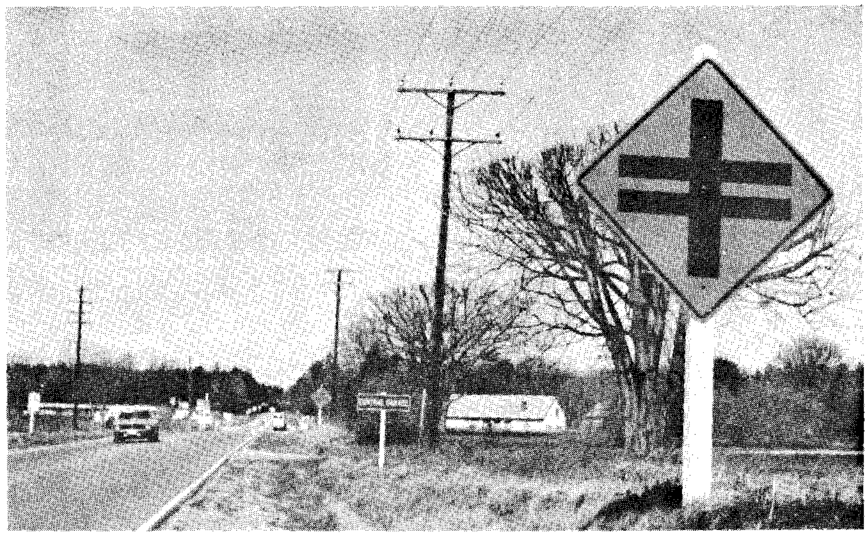
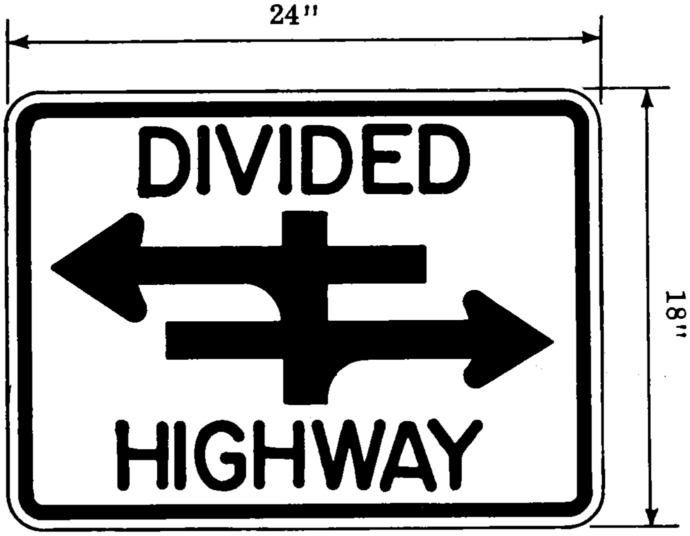
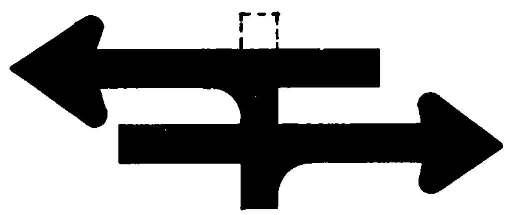


Figure 9. Divided highway crossroad sign as used in Virginia.



DIVIDED HIGHWAY
CROSSROAD



SAME AS LEFT WITHOUT
THROUGH ROAD — (DOTTED LINE)
DIVIDED HIGHWAY
SIDE ROAD

SCREENED BLACK LETTERS ON BEADED WHITE SCOTCHLITE

Figure 10. Divided highways crossroad signs used in Delaware.

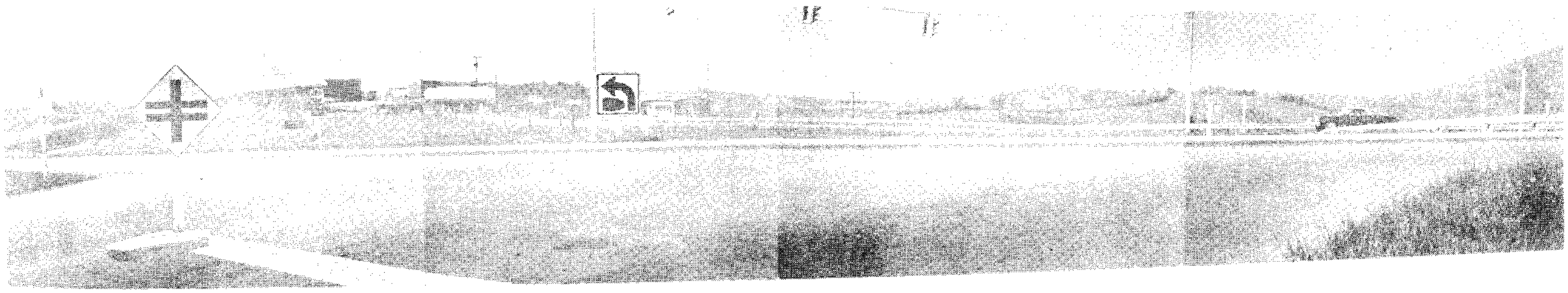
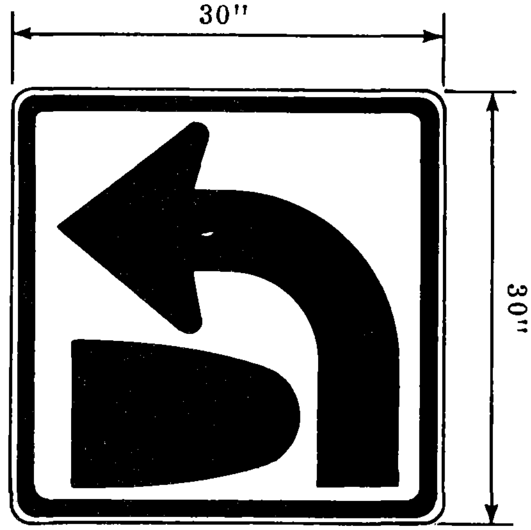


Figure 11. Suggested improvements on the intersection shown in Figure 7 by providing crossroad signs at the junction of the crossroad with the main road with a geometric sign at the nose of the median.



Reflectorized black on white.

Figure 12. A left turn geometric sign.

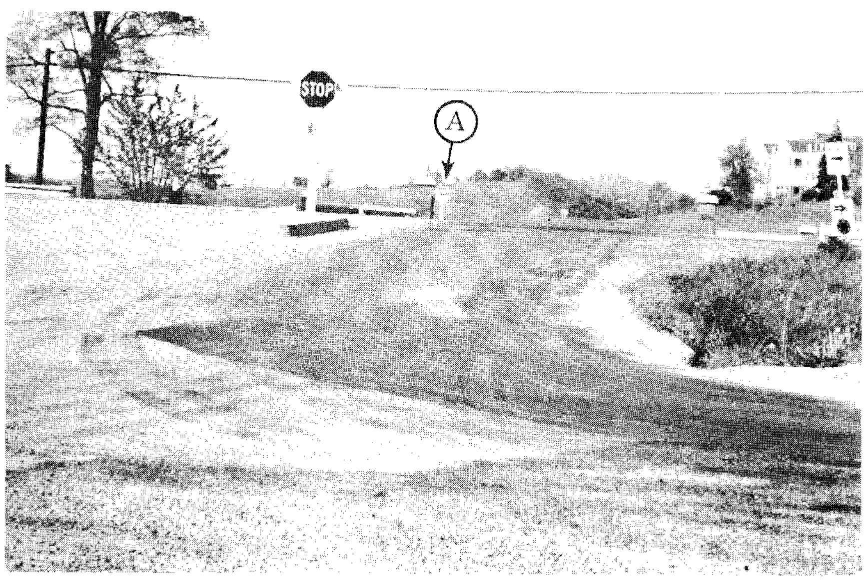


Figure 13. Day photograph from approach to intersection.

Figure 14. Day photograph from vehicle approaching the intersection.

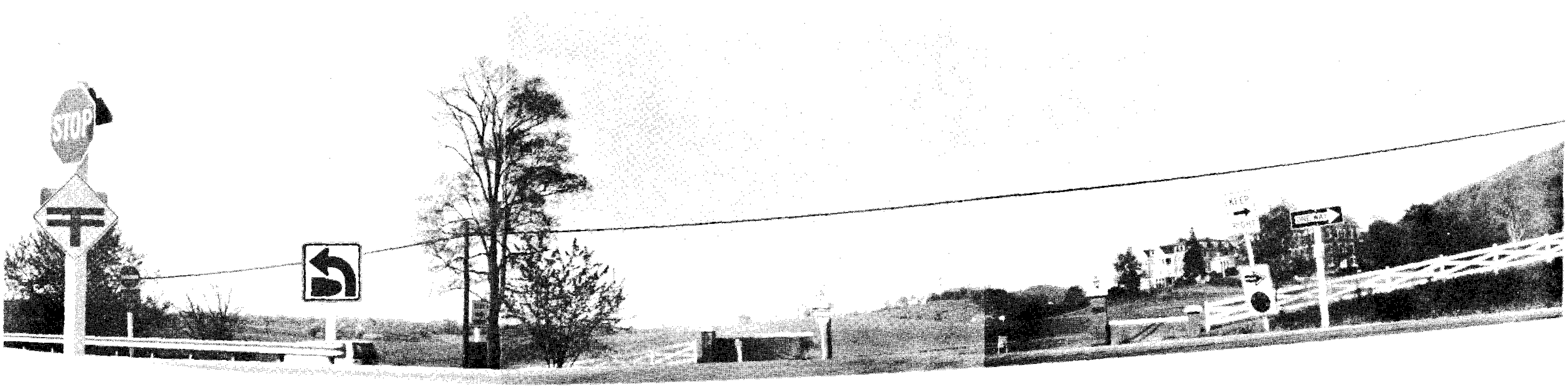


Figure 15. A divided crossroad sign and a left turn sign located at the position shown would guide the driver into a left turn without making a wrong-way entry.

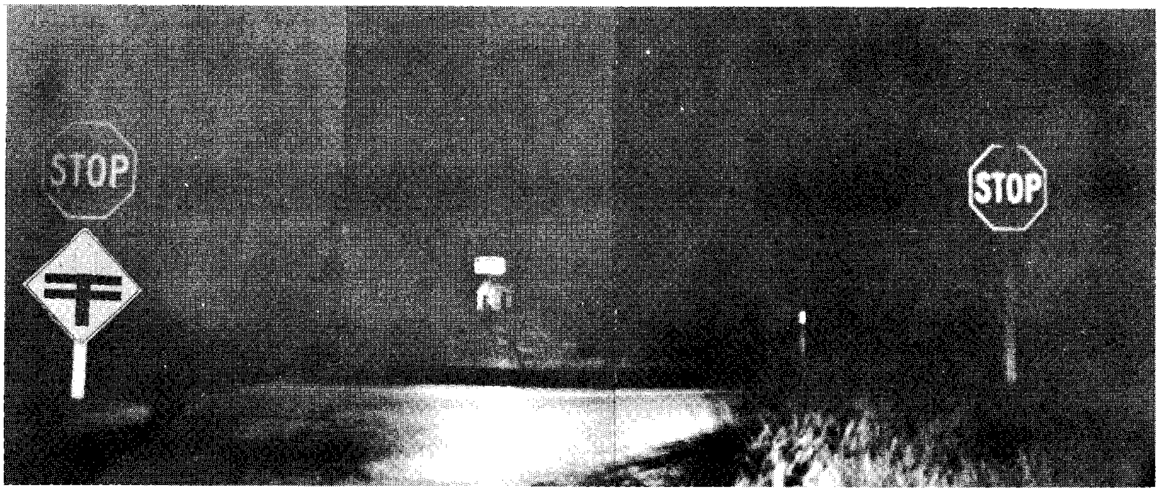


Figure 16. Divided highway crossroad sign placed below the stop sign would inform the driver of the geometry of the intersection under poor visibility conditions.

Figure 17. Intersection of Rte. 24 and Rte. 460, site of three wrong-way entries. A nontypical intersection with a wide crossover.

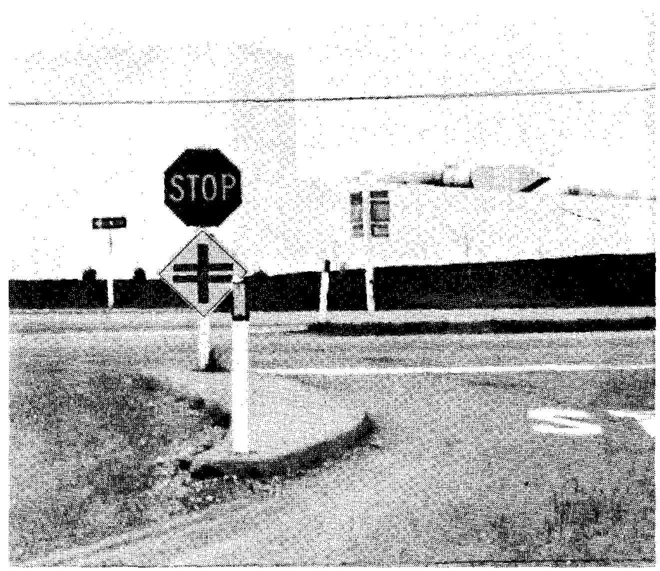


Figure 18. Suggested improvement to interchange shown in Figure 17 by addition of crossroad sign. If found desirable, left turn sign could be added.

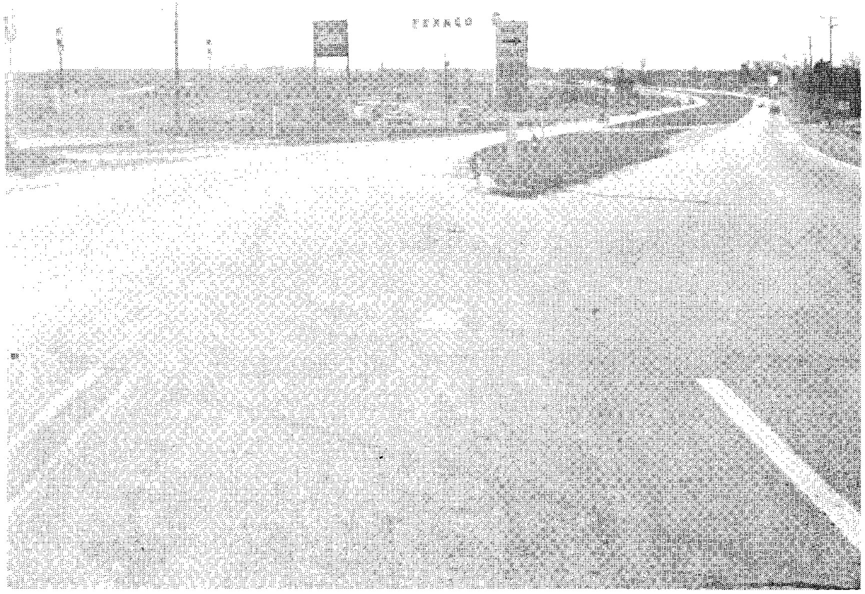


Figure 19. Route 58 at South Hill. Day photograph of transition from 3-lane undivided highway to a 4-lane divided highway with no transitional pavement marking.

Figure 20. Route 58 at South Hill. Night photograph of the transition from 3-lane undivided highway to a 4-lane divided highway with no transitional pavement marking. Site of wrong-way entry.

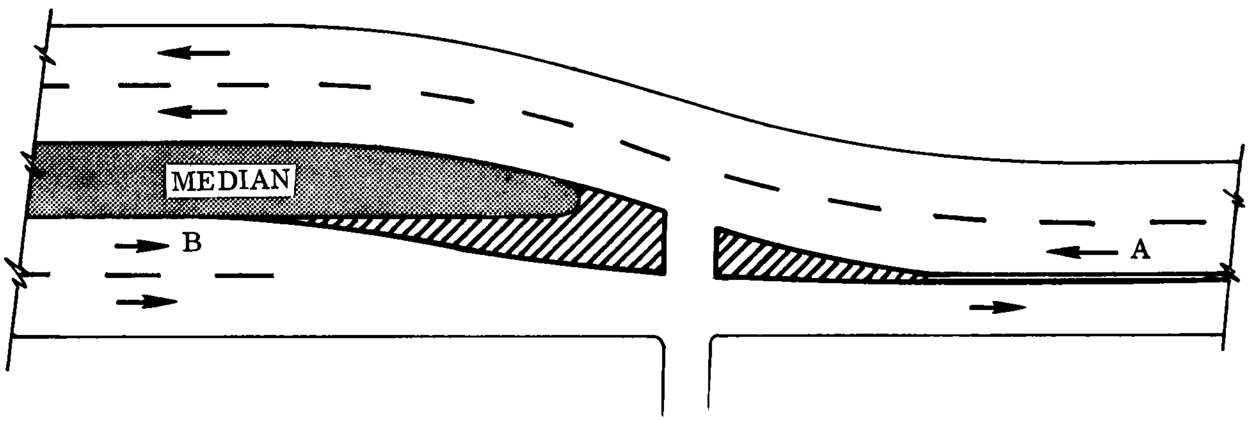


Figure 21. Stripping and its visibility at night is essential for preventing wrong-way entries from A to B at night.

Figure 22. Intersection of I-81 exit ramp and Route 654. Day photograph showing one-way arrow sign and stop line.

Figure 23. Night photograph of the same intersection as shown in Figure 22. The one-way arrow sign and stop line are not now visible.

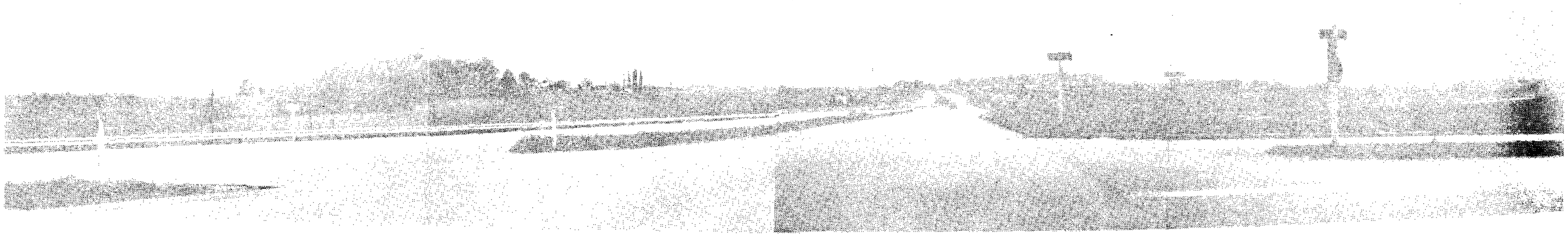


Figure 24. Partial cloverleaf intersection of I-64 and Rte. 340.

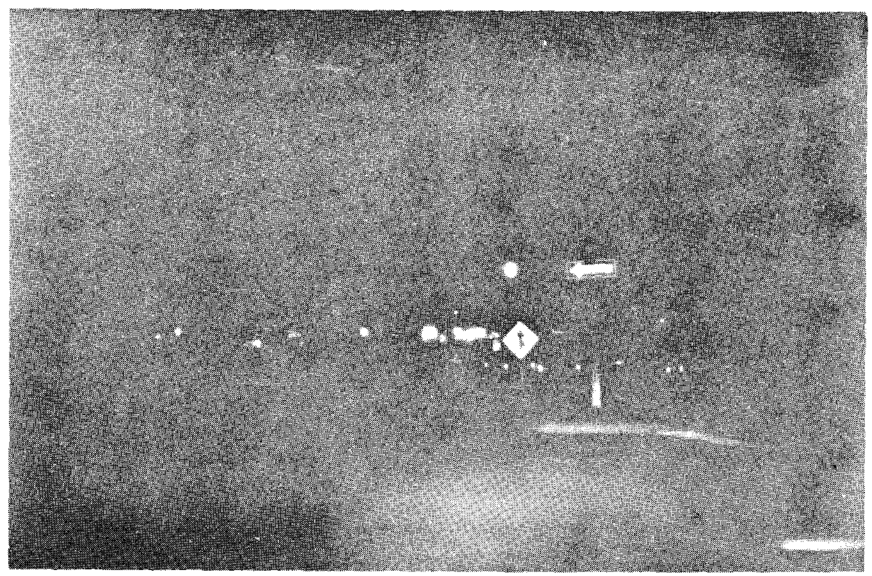


Figure 25. Visibility at night under low beam headlights of the site shown in Figure 24.

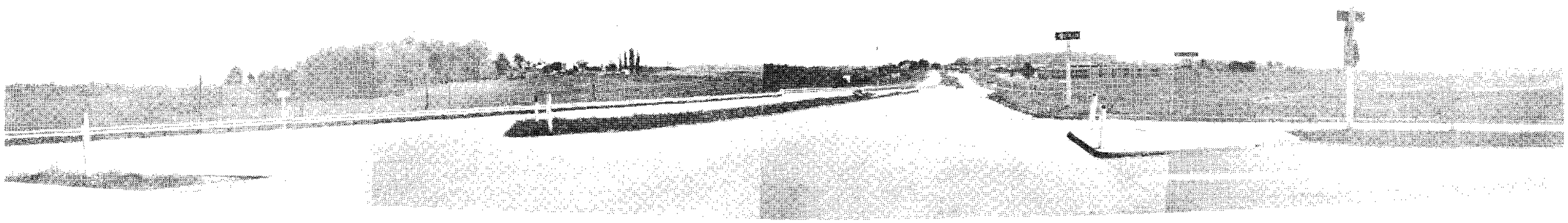


Figure 26. Recommended modifications of interchange shown in Figure 24 by providing a painted concrete nose to show separation between the exit and entry ramps, and also to channelize the exit ramp traffic.

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