



**Handbook of  
Traffic Control Practices for**

# **Low-Volume Roads in Indiana**

**Highway Extension & Research  
Project for Indiana Counties & Cities  
Purdue University  
West Lafayette, Indiana**

Publication No.: H-84-3

## DISCLAIMER

The contents of this handbook are adapted from various manuals, research findings, technical reports, and experiment-based studies. The Highway Extension and Research Project for Indiana Counties and Cities (HERPICC) is not responsible for the facts and accuracy of the data cited in this manual. The material presented does not necessarily reflect the views and policies of the Federal Highway Administration. The handbook is to be used as a guide to traffic control on low volume roads, and is not intended to represent a standard, specification, or regulation. It does not relieve the user of the responsibilities to adhere to the MUTCD and to apply sound engineering judgment.

## ACKNOWLEDGMENTS

Much of this handbook is adapted from the **Kansas Handbook of Traffic Control Practices for Low Volume Rural Roads**. Special appreciation is extended to its authors, Dr. Bob L. Smith and Susan L. Gerth, for providing the basis for this Indiana handbook and for allowing us to use excerpts of their handbook. The effort of James Poturalski in preparing early drafts of this handbook is also gratefully acknowledged. HERPICC's Marian Sipes typed the various drafts of this handbook, using the word processor. The author extends his appreciation for her contributions to the preparation of this handbook.

Jon D. Fricker  
HERPICC  
February 1984

## LIST OF TABLES AND FIGURES

	<b>Page</b>
<b>Table 3.1: Summary of Suggested Control Criteria.</b>	<b>14</b>
<b>Figure 3.1: Height and Lateral Location of Signs</b>	<b>23</b>
<b>Figure 3.2: Typical Locations for STOP and YIELD Signs.</b>	<b>24</b>
<b>Figure 3.3: Typical Locations of Signs on a Wide Throated Intersection.</b>	<b>25</b>
<b>Figure 3.4: Typical Locations of Signs on T and Y Intersections.</b>	<b>26</b>
<b>Figure 4.1: Typical Signing and Pavement Marking on a Turn with a Safe Driving Speed 30 mph or Less.</b>	<b>33</b>
<b>Figure 4.2: Typical Signing and Pavement Marking on a Curve with Safe Driving Speed Between 30 and 50 mph.</b>	<b>34</b>
<b>Figure 5.1: Typical Signing and Marking for a Narrow Structure and a One-Lane Structure. Alternate A - Type 3 object markers on all four corners.</b>	<b>39</b>
<b>Figure 5.2: Typical Signing and Marking for a Narrow Structure and a One-Lane Structure. Alternate B - Type 3 object markers on both sides of single position on right side of each approach.</b>	<b>40</b>

<b>Figure 5.3: Typical Marking of Roadway Culverts (Box Culvert or Cross Road Pipe Culvert) with or without Hubguard, Curb, and Handrail.</b>	<b>41</b>
<b>Figure 5.4: Typical Mounting of Object Marker.</b>	<b>42</b>
<b>Figure 6.1: Typical Two-Lane, Two-Way Marking Application.</b>	<b>44</b>
<b>Figure 6.2: Standard Pavement Markings.</b>	<b>45</b>
<b>Figure 8.1: Typical Signing and Pavement Markings at a Railroad-Highway Grade Crossing.</b>	<b>51</b>
<b>Figure 8.2: Advance Stop and Warning for Parallel Railroad Grade Crossing.</b>	<b>52</b>
<b>Figure 8.3: Typical R Symbol Pavement Marking Details for Railroad-Highway Grade Crossing.</b>	<b>53</b>
<b>Figure 9.1: Typical Signing for Road Work Duration of One-Half Day or More.</b>	<b>56</b>
<b>Figure 10.1: Record of Field Inspections.</b>	<b>58</b>
<b>Figure A.1: No Stop or Signal Control at Intersection. Cases I and II.</b>	<b>62</b>
<b>Figure A.2: Required Sight Distance Triangle for No Intersection Control.</b>	<b>65</b>
<b>Table B.1: Classification of Low Volume Roads.</b>	<b>68</b>
<b>Table B.2: Determination of Road Type.</b>	<b>68</b>
<b>Table C.1: Minimum Taper Lengths (L, feet).</b>	<b>69</b>
<b>Figure C.1: Taper Details.</b>	<b>70</b>

## TABLE OF CONTENTS

	Page
Preface	1
1. Introduction	3
2. Important Terms and Concepts	5
3. Intersections	11
4. Curves and Turns	27
5. Narrow Bridges, Culverts, & Roadside Obstacles	35
6. Centerline Markings	43
7. No-Passing Zones	47
8. Railroad Grade Crossings	49
9. Miscellaneous Signing	55
10. Sign Inventory and Maintenance	57
Appendix A: Approach Speed and Sight Distance	61
Appendix B: Road Classification	67
Appendix C: Tapering Technique	69
Appendix D: Selected Indiana State Statutes	71
Bibliography	73



## PREFACE

The purpose of the **Handbook on Traffic Control Practices for Low Volume Roads in Indiana** is to provide a guide to supplement the existing Manuals on Uniform Traffic Control Devices (MUTCD). Both the National and the Indiana MUTCDs provide general guidelines for the design, installation, and use of traffic control devices (signs, signals, and markings) on all roads and streets, but their main concern is with higher-volume highways. Neither specifically addresses the operational and guidance problems associated with roads that carry fewer than 400 vehicles per day. This handbook's intent is to make these low volume roads safer by fostering greater consistency in traffic control practices in Indiana. It also promotes the more economical use of the limited funds available to local government agencies that are responsible for providing traffic control, and should lead to reduced costs to users of these low volume roads. Use of this guide should help a traffic engineer determine the amount of signing that, based on available research and experience, will provide adequate safety without excessive costs.

This handbook does not supercede any information contained in the two MUTCDs, but attempts to assist the traffic engineer in extending or supplementing their contents when applying them to low volume roads. This handbook should be used as a guide to the installation of traffic control devices, not as a legal basis for their use. No manual of this sort can foresee all possible situations that can occur. There is no substitute for the sound judgment of the traffic engineer. While it would be advantageous for users of this handbook to have access to a copy of the Indiana MUTCD (available from the Indiana Department of Highways), this handbook provides sufficient information and a uniform starting point on which to base that judgment.

This handbook is a compilation of generally accepted practice. Chapters 3 through 9 are designed to provide the most direct, yet flexible, guidelines possible for the major topics in traffic control on low volume roads. Chapter 2 is included to aid the user in understanding his responsibility with respect to several terms mentioned in the guidelines chapters. These terms -- "engineering study", "field investigation", and "engineering judgment" -- refer to the user's need to verify that a specific situation is covered adequately by the guidelines and, if not, to modify those guidelines for the individual case. The National MUTCD [13] addresses this topic. Qualified engineers are needed to exercise the engineering judgment inherent in the selection of traffic control devices, just as they are needed to locate and design the roads and streets that the devices complement. Jurisdictions with responsibility for traffic control, that do not have qualified engineers on their staffs, should seek assistance from the State highway department, their county, a nearby large city, or a traffic consultant. Properly used, this handbook can form the basis for a systematic program of traffic control that protects the traveling public and government officials alike.



## CHAPTER 1

# INTRODUCTION

Many roads within the State of Indiana can be classified as low volume rural roads. These are roads that carry fewer than 400 vehicles per day. Although the total traffic on these roads is very small compared with the traffic on other roads, the combined mileage of low volume roads make up a very high percentage of the state's total road mileage.

For roads to be safe, drivers must know what the roadway has in store for them. They should always be made aware of upcoming hazards and, given enough time and roadway space, to avoid dangerous situations. Traffic control devices should be used to improve these situations. But, with limited funds available to state and local agencies, this is not always an easy task. An awareness of safety hazards and their most economical remedies is essential to the welfare of both the driving public and the public treasury.

Due to the small amount of traffic on the low volume roads, the Indiana MUTCD sometimes is not directly applicable or does not address specifically the types of situations encountered. Many of the hazardous situations occurring on more highly traveled roads may rarely be encountered on the low volume roads. In some cases, then, traffic control may not be needed. Also, because the Indiana MUTCD does not specifically address low volume roads, different government agencies within the state may interpret the manual differently and, thus, there can be a lack of consistency within the state. This situation can lead to a decrease in the overall safety of roadways. This manual attempts to make the signing and marking along low volume roads within the State of Indiana more uniform, for the benefit of all concerned.



## CHAPTER 2

# IMPORTANT TERMS AND CONCEPTS

### Principles of Traffic Control Measures

For a user of this manual to effectively apply its contents, he must understand the principles that allow drivers on any roadway to travel with a minimum of hazard. If one is more aware of what goes through a driver's mind, he can better control roadway situations. The principles that are pertinent here are driver expectancy, positive guidance, and consistency.

#### Driver Expectancy

If a driver has some idea about the conditions that are about to arise, then his reaction time to the events will be increased. He will have more time to react appropriately if he can anticipate situations and formulate appropriate responses. For example, if a driver knows that a hazardous curve or intersection is ahead, he can reduce his speed in preparation for the potential hazard. In many locations, a driver can usually see for himself that a problem situation is arising. However, due to poor weather conditions or darkness, these same situations may become unseen, unexpected, and therefore, much more hazardous. Appropriate traffic control is warranted.

A driver's past experiences also play an important role in "expectancy". After years of driving, most people learn that certain upcoming conditions will be announced in advance by signs and markings that are properly placed. They assume that all railroad crossings will be signed and marked and that severe turns and curves will have advance warning signs. Also, they know (at least subconsciously) what standard signs and markings are supposed to represent. These past experiences become part of a driver's reaction to the placement of traffic control devices on all roads. The devices should be used to reinforce the driver's expectancy, not confuse it.

Finally, signs and markings should represent the situations at hand and not mislead the drivers. Many times the geometry of curves on a section of road is difficult to represent on a sign. One should then make the most effective use of the available types of signs. They should, at least, make the drivers realize that an unusual stretch of roadway is ahead, and represent the geometry in the best possible way. This will give drivers a better expectation, or advance warning, of the situation.

### **Positive Guidance**

Positive guidance is the concept that a driver can be given sufficient information where he needs it and in a form he can best use to safely avoid a hazard [1]. Positive guidance can be in the form of signs and markings, or it can be through the use of the geometry of the roadway itself. For example, widening or tapering of the roadway where needed is a form of positive guidance, even though drivers may not be conscious of it. Tapering can be used effectively on approaches to narrow bridges or culverts (with appropriate signs, as necessary) to safely guide vehicles over them. Widening of roads around sharp curves also gives drivers more space to handle their vehicles. Positive guidance is needed most where drivers cannot judge hazardous situations by themselves and require help in driving their vehicles safely.

### **Consistency**

This third principle relates mainly to the expectations of the driver. Most drivers do not expect a stretch of roadway to be highly variable, that is, to frequently change its characteristics such as design speed, width, surface type, or geometrics. If there are many changes, consistency is lost and the expectations of drivers can become unclear. When this happens the safety of the roadway is reduced unless positive traffic control is used. Proper signs and markings should be used to let drivers know that inconsistencies exist and to give them advice on how to safely proceed. For example, on roadways that are relatively straight for long distances, a curve warning sign would be needed to allow drivers to change their expectations of the roadway ahead. Inconsistencies cannot always be avoided, but with proper control they can be anticipated by drivers.

The three principles discussed here -- driver expectancy, positive guidance, and consistency -- are related in many ways. Drivers should be given as much help as is practical to make their jobs easier, especially under conditions that are not naturally conducive to safe automobile travel. These three principles form the basis for effective traffic control practices.

## **Traffic Control Devices**

Placement and design of traffic control devices must follow basic principles and guidelines in order to be effective. Standardization helps to inform drivers and to give them an idea of what to expect. Therefore, this handbook, along with the Indiana MUTCD, sets forth the recommended design and suggested usage of traffic control devices. The following sections are to be used as a guide in deciding what traffic control devices are appropriate on low volume roads

### **Requirements of Traffic Control Devices**

To be effective, a traffic control device should meet five basic requirements. They are [13]:

- Fulfill a need.
- Command attention.
- Convey a clear, simple meaning.
- Command respect of road users.
- Give adequate time for proper response.

### **Considerations to Ensure Requirements Are Met**

Five basic considerations are employed to ensure that these requirements are met. They are: design, placement, operation, maintenance, and uniformity.[13]

DESIGN of the device is intended to assure that such features as size, contrast, colors, shape, composition, and lighting or reflectorization are combined to draw attention to the device; that shape, size, colors, and simplicity of message combine to produce a clear meaning; that legibility and size combine with placement to permit adequate time for response; and that uniformity, reasonableness of the regulation, size and legibility combine to command respect. In the design of a device, minor modifications of the specified design elements may be necessary under certain conditions, provided that the essential appearance characteristics are met.

PLACEMENT of the device is intended to assure that it is within the "cone of vision" of the user so that it will command attention; that it is positioned with respect to the point, object, or situation to which it applies to aid in conveying the proper meaning; and that its location, combined with suitable legibility, is such that a driver traveling at normal speed has adequate time to make the proper response.

OPERATION (or application) is intended to assure that appropriate devices and related equipment are installed to meet the traffic requirements at a given location. Furthermore, the device must be operated and placed in a uniform and consistent manner to assure, to the extent possible, that the motorist can be expected to properly respond to the device, based on his previous exposure to similar traffic control situations.

MAINTENANCE of devices includes ensuring that visibility and legibility are acceptable for existing devices and that any device that is unnecessary or no longer needed is removed. It is good maintenance practice to keep devices in as clean and as good a working condition as economically feasible. In addition to physical maintenance, the functional maintenance of the traffic control device should help assure proper operation.

UNIFORMITY of traffic control devices simplifies the task of the road user because it aids in recognition and understanding. It aids road users, police officers, and traffic courts by giving everyone the same interpretation. It aids public highway and traffic officials through economy in manufacturing, installation, maintenance, and administration.

These five basic considerations are not intended to lead to the overuse or misuse of traffic control devices. The overuse of any traffic device tends to make the device itself ineffective since the public can begin to underestimate the significance of its originally intended message.

## Classification of Signs

Signs are classified according to their functions as follows:

- Regulatory signs give notice of traffic laws or regulations.
- Warning signs call attention to conditions on, or adjacent to, a highway or street that are potentially hazardous to traffic operations.
- Guide signs show route designations, destinations, directions, distances, services, points of interest, and other geographical or cultural information.

## Meanings of "Shall," "Should," and "May"

The various sections of this handbook, as well as the Indiana MUTCD, occasionally use the words "shall," "should," and "may" to describe specific conditions concerning traffic control devices. To clarify the meaning of these words when used in this handbook, the following definitions shall apply:

"SHALL" normally indicates a mandatory condition; however, the "SHALL" stipulation indicates that when the device is used, the requirements stated therewith shall be met.

"SHOULD" normally indicates an advisory or recommended position. It is not a mandatory condition and does suggest that when a device is used, the practices as described would generally be appropriate.

"MAY" is meant to be a permissive and not mandatory condition. No specific requirements are intended in the design or use of the device.





## CHAPTER 3

# INTERSECTIONS

Approximately 95 percent of nonsignalized low volume intersections are stop controlled, rather than uncontrolled or yield controlled [10, 11, 12]. It is difficult to believe that such a large percentage of low volume intersections are unduly hazardous or that motorists approaching such intersections do not know who has the right-of-way. In fact, studies [8, 10] have demonstrated that the mere presence of stop signs at low volume intersections does not reduce accident frequency. Other research work [4] has outlined conditions in which removal of certain intersection controls can be justified. This is not to say that most stop signs at low volume intersections should be removed. There are legal, political, and practical reasons for leaving them in place that must be weighed against any traffic engineering arguments for their removal.

Sound engineering practice dictates that installation of stop signs be based on a number of important criteria. The national MUTCD [13] gives as one condition a combination of high speed, restricted view, and a serious accident history. Many stop-controlled intersections have none of these elements. The result has been increased travel time and driving costs [15], an increasing disregard for the stop sign as a traffic control device [8,14], and a proliferation of unwarranted signs that must be installed, inventoried, and maintained. The answer is to compare the conditions at each intersection where traffic control is considered with guidelines or warrants for use of such controls, then make a brief record of the decision and its justification. This chapter provides guidelines for use of traffic controls at low volume intersections. The user must make the observations, exercise sound judgment, and create an adequate record of the basis for the decision that resulted.

## Suggested Control Criteria for Low-Volume Intersections

Although the studies on this subject have used a variety of approaches and produced results that are difficult to compare, certain guidelines have almost universal acceptance.

1. If control is to be used, do so only on the minor approach. Dale [15] concluded that there was almost no justification for four-way stop control, except for unusual situations above medium volume conditions. The minor approach is that direction of traffic, E-W or N-S, etc., that has the lower two-way Average Daily Traffic (ADT) volumes. If ADT values are the same, consider other reasonable criteria, such as lower approach speed, narrower pavement, or poorer surface, to designate the minor approach.
  2. Uses of signs, other than STOP and YIELD:
    - Cross Road or Side Road signs may be used on all approaches to intersections where no other control is used.
    - T Symbol, Y Symbol, and Large Arrow signs should be used according to the descriptions of their usage presented later in this chapter.
    - STOP AHEAD and YIELD AHEAD signs should be used, usually placed 750 feet before the intersection, where Stop or Yield signs are not visible from the following distances:
      - Type A road: 450 feet
      - Type B road: 300 feet
      - Type C road: 225 feet
- See Appendix B for definitions of road types.
3. Basic criteria to be used in placement of traffic control signs:
    - In rural areas, signs should not be located closer together than 200 feet along the highway.
    - Whenever possible, all signs should be located so as to be viewed by motorists without obstruction from a distance of at least 400 feet.
    - Placing signs in dips or beyond the crest of hills, and placing informational signs on curves should be avoided.

Typical locations and positions of Stop and Yield signs can be found at the end of this chapter.

Stockton, Brackett, and Mounce [8] have summarized and supplemented previous research to develop warrants for traffic control devices at low volume intersections. Their attempts at identifying what factors influence driver behavior, accident experience, and travel time at such crossroads produced results that form the basis for the following criteria:

1. STOP signs should be installed on the minor approach(es) of intersections, where one or more of the following conditions exist:
  - a. Sight distance on any quadrant (see Appendix A) produces a safe approach speed on the minor approach of less than 10 mph [13].
  - b. Accidents involving minor roadway vehicles have occurred with either of the following frequencies:
    - Four or more within the last three years, or
    - Three or more within the last three years, provided that minor roadway volumes are less than 300 vehicles per day.
2. YIELD sign(s) should be installed on the minor approach(es) of intersections where available sight distance exists on *all* quadrants to permit a safe approach speed of at least 10 mph *and* one or more of the following conditions exist:
  - a. No more than two accidents involving minor roadway vehicles have occurred within the last three years, or
  - b. At intersections with minor roadway volumes greater than 300 vehicles per day, no more than three such accidents have occurred within the last three years.
3. No Control need be used at intersections where the sight distances specified for YIELD signs exist *and* there have been no accidents in the last three years, *and* the major roadway volume is less than 2000 vehicles per day.

Table 3.1 summarizes these guidelines. Notice that the criteria do not involve *combined* ADT, but rather *major* roadway ADT. Although most earlier studies sought to tie combined volumes to the traffic control decision, Stockton et al. [8] found no connection between these volumes and their three major factors. This is convenient for the users of this manual for at least two reasons: (1) the user does not need to determine ADT counts for each low volume road and (2) roads with ADTs in excess of 2000 are typically important enough to have volume counts already available.

**Table 3.1: Summary of Suggested Control Criteria. (1)**

Minimum Sight Distance (2)	Accident History (3)	Major Roadway Volume	
		Up to 2000 vpd	> 2000 vpd
Satisfied	0	No Control	
	1,2	YIELD	
	3	STOP(4)	
	4+	STOP	
Violated			

**NOTES**

- (1) Adapted from [8].
- (2) See Appendix A.
- (3) The number of accidents involving minor roadway vehicles in the last three years.
- (4) If minor roadway has greater than 300 vehicles per day and has had fewer than 4 accidents in last three years, YIELD control is appropriate.

## **An Implementation Plan [8]**

Implementation of low volume intersection control criteria should be considered in a priority order for two categories: new intersections and existing intersections. This section details the order in which control changes should be considered and the analyses necessary to identify appropriate control for each location.

### **New Intersections**

New intersections are those created by the opening of new streets, either singly or in subdivisions. For new intersections involving low volume streets entering collector streets, YIELD control should be installed at the time of the intersection's opening. The only analysis required will be an estimate of the adequacy of sight distance for proper YIELD operation. Details on this measurement are provided in Appendix A. Intersections of new local/local streets in a subdivision should be left uncontrolled, provided there is adequate sight distance and no other circumstances require control.

### **Existing Intersections**

Control changes at locations where conditions are known to be within the recommended criteria (Table 3.1) should be implemented immediately. At other locations, estimates of traffic volumes, sight distance and a determination of accident history must be made prior to the implementation of control changes. For situations where a city-wide or county-wide assessment of all intersections is impractical due to funding or personnel constraints, existing STOP-controlled intersections should be considered first, because the changeover from STOP to YIELD control produces the maximum benefit in traffic flow. The remaining intersections should be considered as time and funding permit. The following paragraphs identify the procedures necessary to determine the feasibility of a control change.

## **Identification of Low Volume Intersections**

A determination of which of the candidate intersections fit the low volume criterion should be made first. If traffic volumes are not known, a one-hour count should be conducted and converted to vehicle-per-day (vpd) estimates. Intersections that do not meet the minimum criteria for changing control (Table 3.1) should be discarded.

## **Identification of Control Type**

This activity occurs as part of a study of *all* low volume intersections in a jurisdiction, not just those with STOP control. On-site inspection of each intersection is needed to insure that type of device is in place. This seemingly unnecessary task is included here because significant error is often present in control device inventories.

## **Determination of Accident History**

Intersections with YIELD control can be eliminated from further study.

The accident history should be determined for each of the remaining intersections. Only accidents involving minor roadway vehicles should be considered. Intersections with four or more accidents in the last three years should be STOP-controlled. Those with two or fewer accidents can be further considered for a control type change. (See Table 3.1.)

## **Determine Adequacy of Sight Distance**

Before either YIELD or No Control can be implemented, sight distance adequate for a safe approach speed of 10 mph must be verified. Safe approach speed can be determined from Appendix A. Speeds should be measured if possible. If speed measurement is not possible, the posted speed limit for the approach should be used.

## Priorities of Control Changes

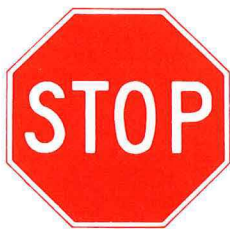
First priority among those intersections that meet the criteria for YIELD control should go to those STOP-controlled intersections with major volumes less than 2000 vehicles per day. This is the category where the need for change can be most readily demonstrated. Implementation in this category will enhance future implementation at higher volume ranges. Implementation in this range should be undertaken immediately.

Next priority should be given to changing STOP-controlled intersections in the >2000 vpd range to YIELD, followed by No Control to YIELD at local/local intersections as funding permits. Although YIELD produces lower operating costs than No Control, care should be exercised not to apply control at every local/local intersection, lest the effectiveness eventually be diminished through overuse.

## Signs for Intersections

The following is a list of signs that may be used at or before intersections. Included are descriptions and warrants for their use. Illustrations of and size specifications for the various signs appear in the margins. The standard size for each sign and its location in the national MUTCD are also provided. Where conditions of speed, volume, or special hazard require greater visibility or emphasis, larger signs are suggested.

### Regulatory Signs



R1-1

*Standard Size*

*30"x30"*

*Minimum Size*

*24"x24"*

*See MUTCD*

*page 2B-2*

**Stop Sign (R1-1):** Because the STOP sign causes a substantial inconvenience motorists, it should be used only where warranted. A STOP sign may be warranted at an intersection where one or more of the following conditions exist:

1. Intersection of a less important road with a main road where application of the normal right-of-way rule is not recommended by field investigation.

2. Street entering a through highway or street.
3. Unsignalized intersection in a signalized area.
4. Other intersections where a combination of high speed, restricted view, and accident records may indicate a need for control by the STOP sign.



R1 - 2

*Standard Size*  
36"x36"x36"  
*See MUTCD*  
page 2B-4

**Yield Sign (R1-2):** The YIELD sign assigns right-of-way to traffic on certain approaches to an intersection. Vehicles controlled by a YIELD sign need stop only when necessary to avoid interference with other traffic that is given the right-of-way. The YIELD sign may be considered for use:

1. On a minor road at the entrance to an intersection where it is necessary to assign right-of-way to the major road, but where a stop is not necessary at all times, and where the safe approach speed on the minor road exceeds 10 mph. (See Appendix A).
2. Where there is a separate or channelized right-turn lane, without an adequate acceleration lane.
3. At any intersection where a special problem exists and where an engineering study indicates the problem to be susceptible to correction by the use of the YIELD sign.



## Warning Signs



W2 - 1

*Standard Size*  
30"x30"  
*See MUTCD*  
page 2C-6

**Cross Road Sign (W2-1):** The Cross Road sign should be limited in usage, and is intended for use on a through highway to indicate the presence of an obscured public crossroad intersection. It is not ordinarily used where Junction signs or other warning signs are present.

W2 - 2R



W2 - 3L

*Standard Size*  
30"x30"  
*See MUTCD*  
page 2C-6

**Side Road Sign (W2-2, W2-3):** The Side Road sign, showing a side-road symbol either left or right, and at an angle of either 90 or 45 degrees, is intended for use in advance of a side-road intersection according to the same warrants as set forth for the Cross Road sign. The relative importance of the intersecting roads may be shown by different widths of line in the diagram. If the side road occurs in the vicinity of a curve, the symbol may be modified appropriately. The sign should not be used in conjunction with a STOP or YIELD sign.



W2-4

*Standard Size*  
30"x30"  
See MUTCD  
page 2C-7

**T Symbol Sign (W2-4):** The T Symbol sign is intended to warn traffic approaching a T intersection on the road that forms the stem of the T, i.e., the traffic that must make a turn either to the right or to the left. The sign should not generally be used on an approach where traffic is required to stop before entering the intersection. The relative importance of the intersecting roads may be shown by different widths of line in the symbol. It may be desirable to place a double-headed Large Arrow sign at the head of the T directly in line with approaching traffic.



W2-5

*Standard Size*  
30"x30"  
See MUTCD  
page 2C-7

**Y Symbol Sign (W2-5):** The Y Symbol sign is intended to warn motorists approaching a Y intersection on the road that forms the stem of the Y. It is not generally used at a Y intersection that is channelized by traffic islands. The relative importance of the intersecting roads may be shown by different widths of line in the symbol. It may be desirable to erect a double-headed Large Arrow sign at the fork of the Y directly in line with approaching traffic.

W3 - 1



**Stop Ahead Sign (W3-1):** A STOP AHEAD sign is intended for use on an approach to a STOP sign that is not visible for the sufficient distance to permit the driver to bring his vehicle to a stop at the STOP sign (Table A.1). The obstruction causing the limited visibility may be permanent or intermittent.



W3 - 1a

*Standard Size*

*36"x36"*

*Minimum Size*

*30"x30"*

*See MUTCD*

*page 2C-8*

W3 - 2



**Yield Ahead Sign (W3-2):** The YIELD AHEAD sign is for use in advance of a YIELD sign that is not visible for a sufficient distance to permit the driver to bring his vehicle to a stop at the YIELD sign (Table A.1). Other considerations for the use of the YIELD AHEAD sign are the same as those given for the STOP AHEAD sign, as determined by a field investigation.



W3 - 2a

*Standard Size*

*36"x36"*

*Minimum Size*

*30"x30"*

*See MUTCD*

*page 2C-8*



W1 - 6R



W1 - 7

*Standard Size*  
*48"x24"*  
*See MUTCD*  
*page 2C-4*

**Large Arrow Sign (W1-6, W1-7):** The Large Arrow sign is intended to give notice of a sharp change in the direction of travel. It is not to be used where there is no such direction change, such as at center piers, ends of medians, etc. When used, the Large Arrow sign shall be erected on the outside of a curve or on the far side of an intersection, in line with and at right angles to approaching traffic. It should be mounted high enough to be visible for approximately 500 feet in advance of the sign. (See also T Symbol Sign in this chapter and Turn sign in the next chapter). No exact specifications can be given for the placement of this sign. Its location must be checked by trial runs over the road by day and by night as determined in the field.

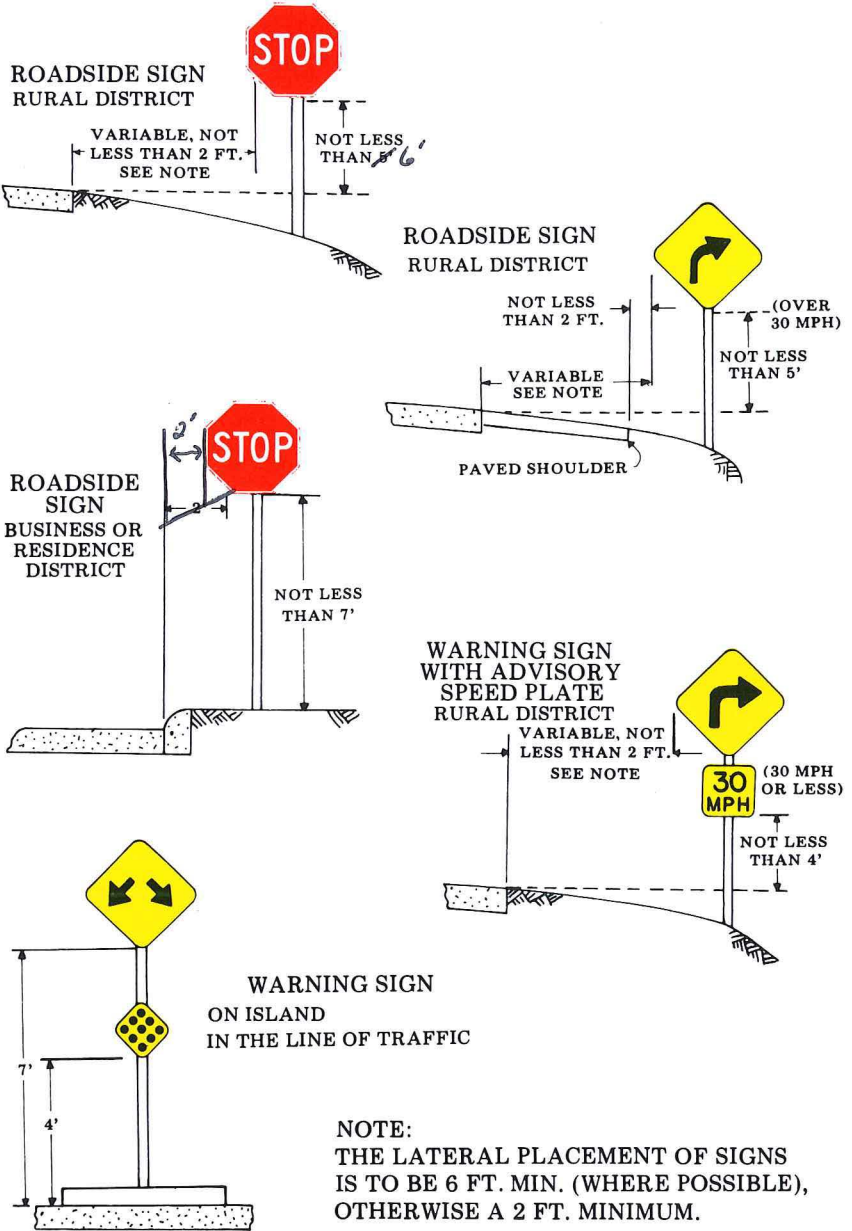
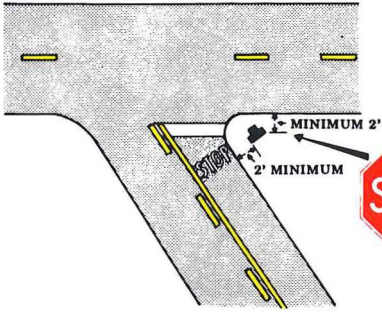
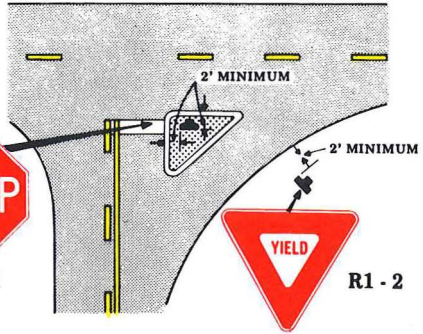


Figure 3.1: Height and Lateral Location of Signs. [5]



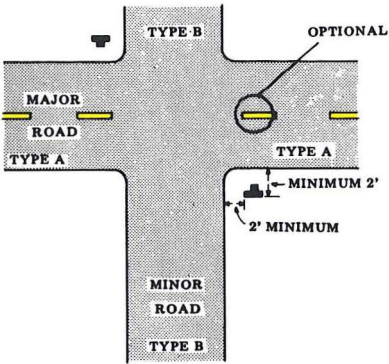
R1 - 1



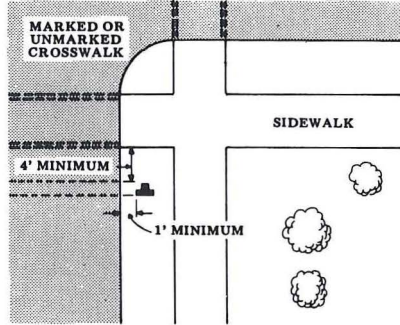
R1 - 2

ACUTE ANGLE INTERSECTION

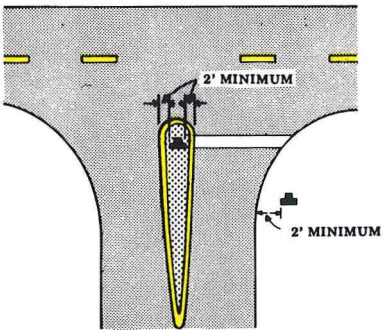
CHANNELIZED INTERSECTION



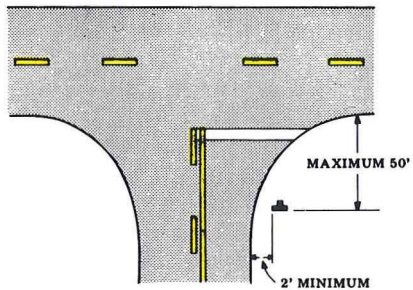
MINOR CROSSROAD



URBAN INTERSECTION



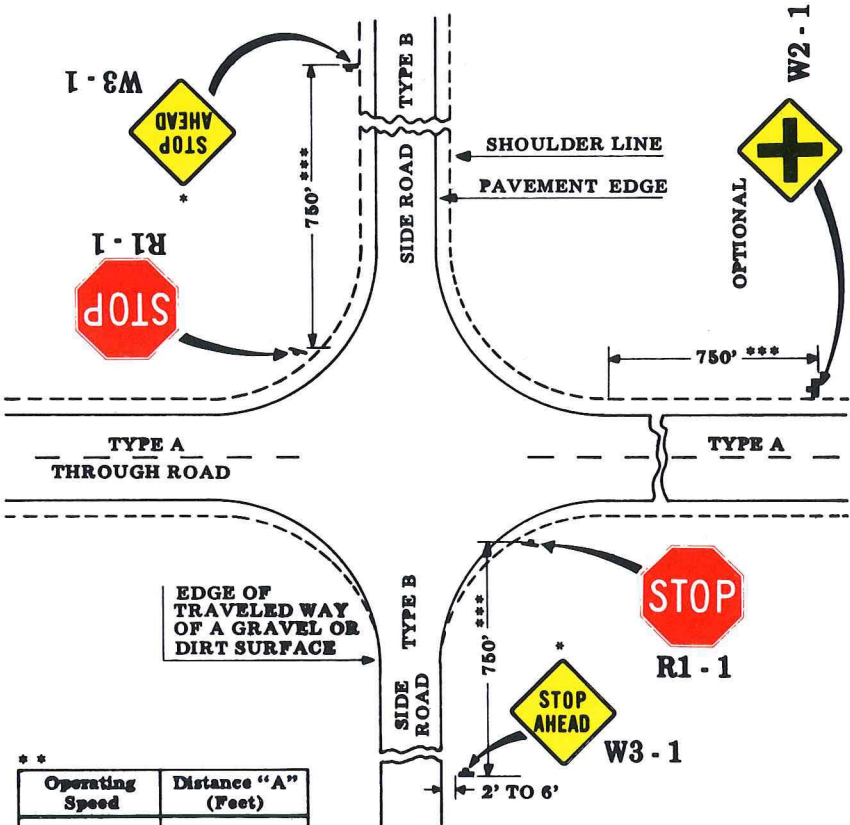
DIVISIONAL ISLAND



WIDE THROAT INTERSECTION

Figure 3.2: Typical Locations for STOP and YIELD Signs. [5]

TYPE B ROAD INTERSECTING TYPE A ROAD



\*\*

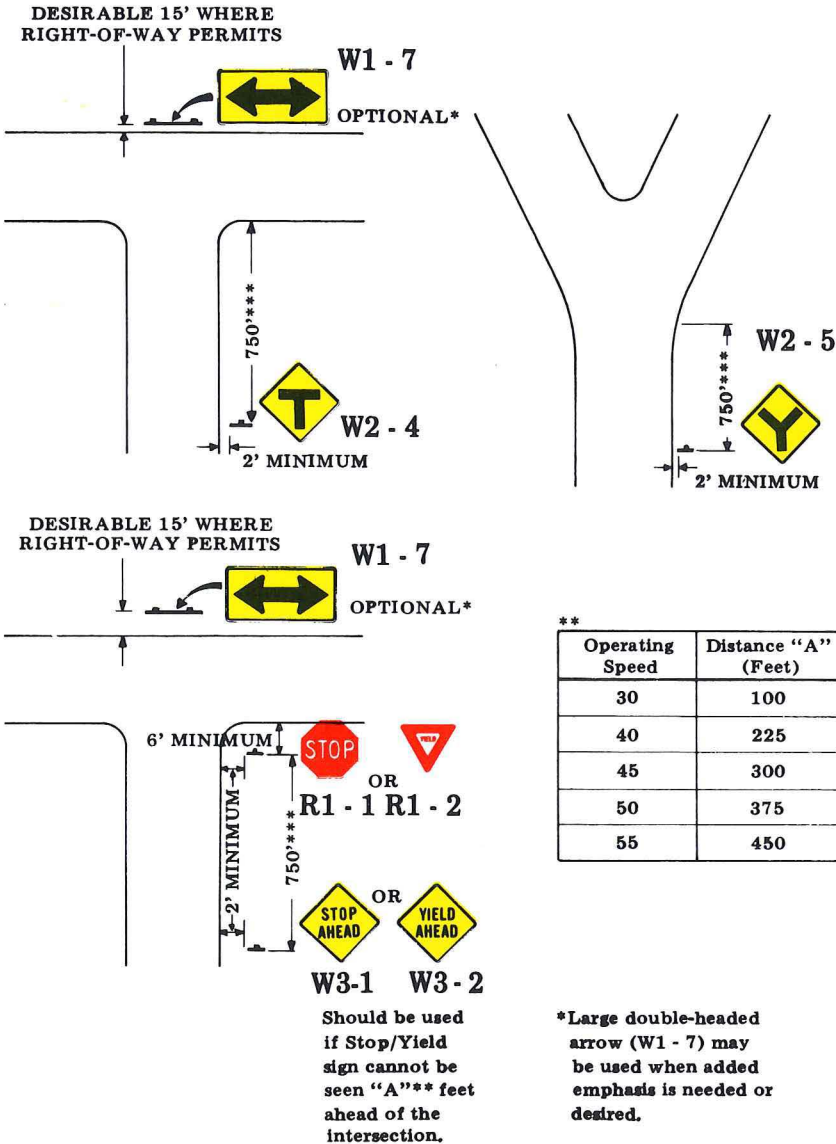
Operating Speed	Distance "A" (Feet)
30	100
40	225
45	300
50	375
55	450

\*Erected when Stop/Yield sign cannot be seen "A"\*\*\* feet ahead of the intersection (optional).

\*\*\*Nominal Distance; other distance may be used if engineering study indicates.

NOTE: Intended for use on Type A and B roads. May be used on Type C roads.

Figure 3.3: Typical Locations of Signs on a Wide Throated Intersection. [5]



\*\*\* Nominal Distance; other distance may be used if engineering study indicates.

NOTE: Intended for use on Type A and B roads, May be used on Type C

Figure 3.4: Typical Locations of Signs on T and Y Intersections. [5]



## CHAPTER 4

# CURVES AND TURNS

The decision whether to use signs when a road changes horizontal direction is a prime example of the application of the three principles of traffic control practice -- driver expectancy, positive guidance, and consistency. If this change of direction is unexpected and severe enough, with respect to visibility and approach speed, appropriate traffic control measures are called for. Like intersection controls, signs at curves and turns can be excessively and improperly used. This chapter outlines the conditions that warrant use of the various signs that may be employed at or before curves and turns.

### Criteria for Placement

The following is a compilation of the type of signing to be used at or before turns and curves. The ideas presented here are results of work done by Walton, et al. [2, 3], and Smith and Gerth [5].

### Recommended Placement of Warning Signs

1. **The Curve Sign** (or Reverse Curve or Winding Road sign) should be used on sections that have recommended safe speeds, as determined by field investigation, between 30 and 55 mph and a posted speed limit for adjoining straight sections that is at least 10 mph greater than the safe speed on the curve.

2. **The Turn Sign** (or Reverse Turn or Winding Road sign) should be used on sections that have recommended safe speeds, as determined by field investigation, of 30 mph or slower, and a posted speed limit for straight sections that is at least 10 mph greater than the safe speed on the turn.
3. In addition to the Turn and Curve signs, **Advisory Speed Plates** should be used when the posted speed limit for straight sections is at least 15 mph greater than the safe speed of the curve or turn.
4. These signs, as described below, are intended for use on Type A and Type B roads. (See Appendix B.)
5. The warning signs are normally placed 750 feet before the beginning of the section in question.

### **Additional Considerations**

1. Advisory Speed Plates may also be used on Reverse Curve and Turn and Winding Road signs, if needed as recommended above.
2. Warning signs may also be placed on Type C roads if an engineering study indicates the need for their use.
3. Large Arrow or Chevron signs may be used in conjunction with the other warning signs at more hazardous areas as judged necessary by an engineering study.

Typical locations and positions of turn and curve signs can be found at the end of this chapter.

### **Signs for Curves and Turns**

The following is a list of signs that may be used at or near areas of curves or turns. Included are descriptions and warrants for their use. Illustrations of the various signs appear in the margin.



W1 - 1R

**Turn Sign (W1-1):** The TURN sign (right or left) is intended for use where field investigations or roadway, geometric, and operating conditions show the recommended speed on a turn to be 30 mph or less, and this recommended speed is equal to or less than the speed limit established by law or by regulation for that section of highway. Where a TURN sign is warranted, a LARGE ARROW sign (see previous chapter) may be used on the outside of the turn. Additional guidance may be provided by use of the ADVISORY SPEED plate.



W1 - 1L

*Standard Size*  
*30"x30"*  
*See MUTCD*  
*page 2C-2*



W1 - 2R

**Curve Sign (W1-2):** The CURVE sign (right or left) is intended for use where field investigations of roadway, geometric, and operating conditions show the recommended speed on the curve to be in the range between 30 and 55 mph and equal to or less than the speed limit established by law or regulation for that section of highway. Additional guidance may be provided by use of the ADVISORY SPEED plate.



W1 - 2L

*Standard Size*  
*30"x30"*  
*See MUTCD*  
*page 2C-3*

W1 - 3R



**Reverse Turn Sign (W1-3):** The REVERSE TURN sign is intended to mark two turns or a curve and a turn in opposite directions, as defined in the warrants for TURN and CURVE signs, that are separated by a tangent of less than 600 feet. If the first turn is to the right, a RIGHT REVERSE TURN Sign (W1-3R) shall be used. If the first turn is to the left, a LEFT REVERSE TURN Sign (W1-3L) shall be used.



W1 - 3L

For additional protection, the ADVISORY SPEED Plate may be used.

Standard Size  
30"x30"  
See MUTCD  
page 2C-3

W1 - 4R



**Reverse Curve Sign (W1-4):** The REVERSE CURVE sign is intended to mark two curves in opposite directions, as defined in the warrants for CURVE signs, that are separated by a tangent of less than 600 feet. If the first curve is to the right, a RIGHT REVERSE CURVE Sign (W1-4R) shall be used. If the first curve is to the left, a LEFT REVERSE CURVE Sign (W1-4L) shall be used.



W1 - 4L

For additional protection, the ADVISORY SPEED Plate may be used.

Standard Size  
30"x30"  
See MUTCD  
page 2C-4

W1 - 5R



**Winding Road Sign (W1-5):** The WINDING ROAD sign is intended for use where there is a series of turns or curves, as defined in the warrants for TURN and CURVE signs, separated by tangent distances of less than 600 feet. If the first turn or curve is to the right, a RIGHT WINDING ROAD Sign (W1-5R) shall be used. If the first turn or curve is to the left, a LEFT WINDING ROAD Sign (W1-5L) shall be used.

W1 - 5L



When the WINDING ROAD sign is used, it shall be erected in advance of the first turn or curve.

Additional guidance may be provided by the installation of road delineation markers and by use of the ADVISORY SPEED Plate.

*Standard Size  
30"x30"  
See MUTCD  
page 2C-4*

**Large Arrow Sign (W1-6):** See Chapter 3.



W1-8

*Standard Size*  
18"x24"  
*See MUTCD*  
page 2C-5

**Chevron Alignment Sign (W1-8):** A group of CHEVRON ALIGNMENT signs may be used to supplement standard delineation treatments and as an alternate or supplement to the LARGE ARROW sign. CHEVRON ALIGNMENT signs, when used, are normally erected on the outside of a curve, sharp turn, an interchange ramp, in line with and at right angles to approaching traffic. Spacing of the signs should be such that the motorists always have two in view, until the change in alignment eliminates the need for the signs. To be effective, the signs should be visible for approximately 500 feet; trial runs by day and night may be desirable to determine final positioning.



W13-1

*Standard Size*  
24"x24"  
*Minimum Size*  
18"x18"  
*See MUTCD*  
page 2C-18

**Advisory Speed Plate (W13-1):** The ADVISORY SPEED PLATE may be considered for use in conjunction with a standard yellow warning sign to indicate the recommended safe speed around a curve or through a possible conflict location. The discretionary use of this sign is determined by a field investigation [9].

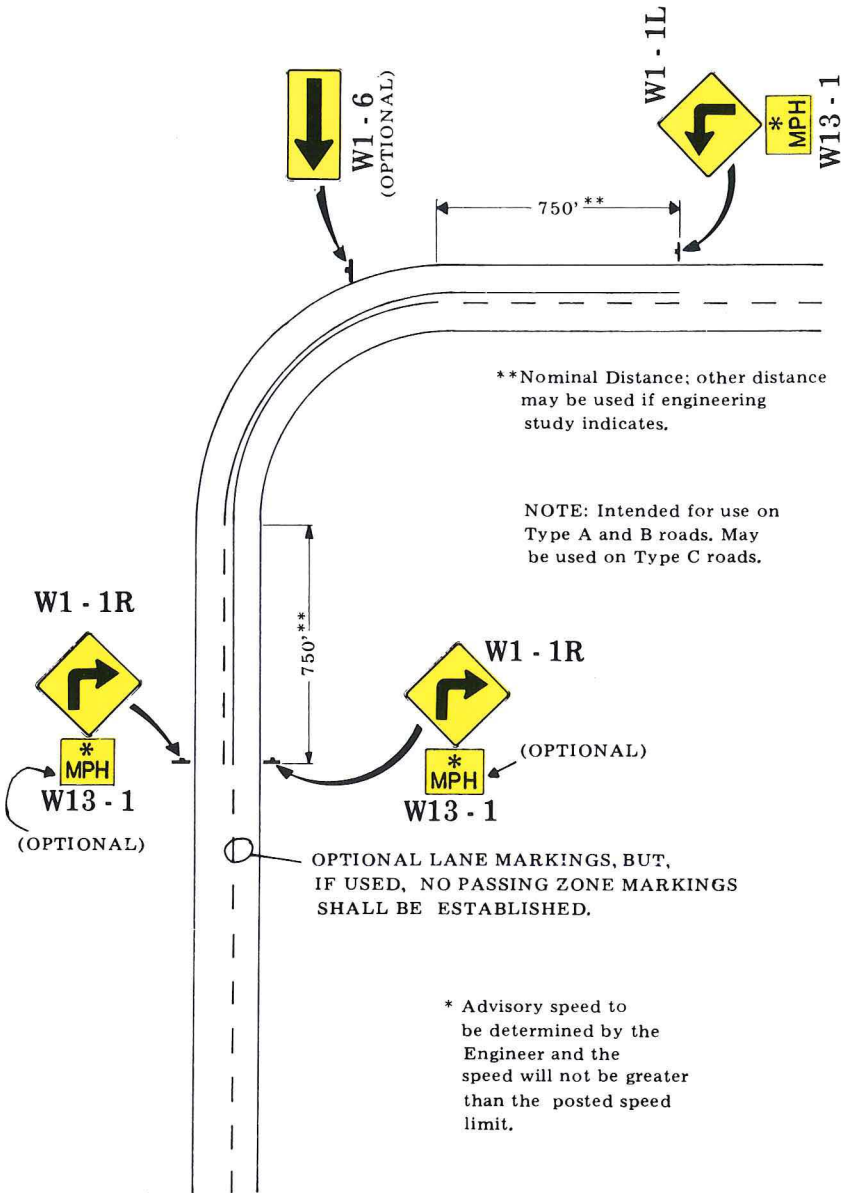
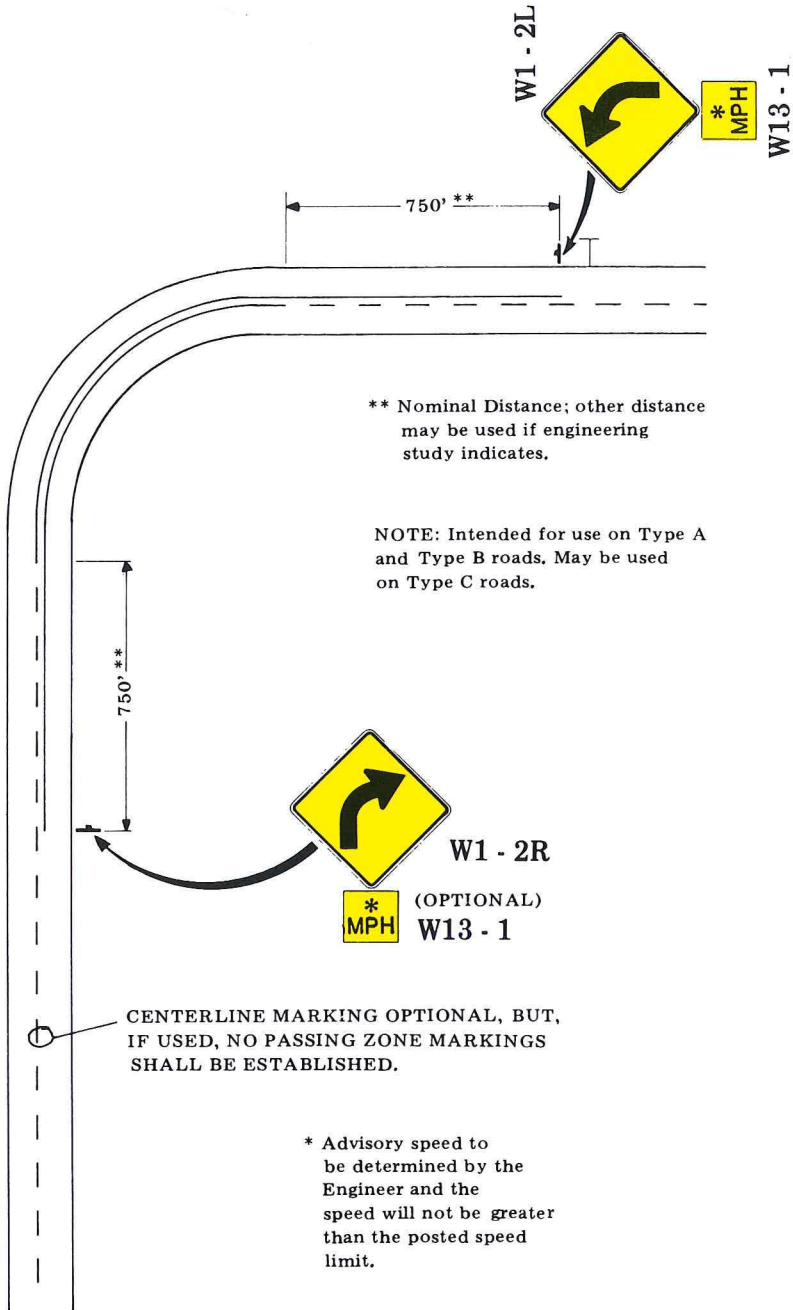


Figure 4.1: Typical Signing and Pavement Marking on a Turn with Safe Driving Speed 30 mph or Less. [5]



**Figure 4.2: Typical Signing and Pavement Marking on a Curve with Safe Driving Speed Between 30 and 50 mph. [5]**



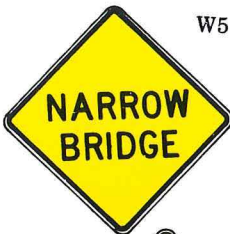
## CHAPTER 5

# NARROW BRIDGES, CULVERTS, AND ROADSIDE OBSTACLES

Bridges and culverts are often narrower than the approaching roadway, resulting in an inconsistency and a possible hazard to drivers. Obstacles placed or located near roadways also create hazardous situations that cause inconsistencies. Therefore, it may be necessary to provide some kind of guidance and warning so that drivers can safely make it through these sections of roadway. Signs, object markers, and pavement markings can be used alone or in combination, as will be shown, to provide this guidance. See also section 3C of the Indiana MUTCD.

### Description of Applicable Devices

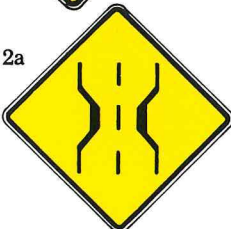
The following is a list of traffic control devices that may be used at or near narrow bridges, culverts, and roadside obstacles. Included are the conditions for their use. Illustrations of the various devices appear in the margin.



W5 - 2

**Narrow Bridge Sign (W5-2):** The NARROW BRIDGE sign is intended to indicate a bridge or culvert having a clear two-way roadway width of approximately 16 to 18 feet inclusive, or any bridge having a roadway clearance less than the width of the approaching roadway. Field investigation will determine the posting of structures having a clear roadway of 16 to 18 feet as either a one lane bridge or a narrow bridge.

W5 - 2a



*Standard Size*  
30"x30"  
See MUTCD  
page 2C-11



W5-3

Standard Size

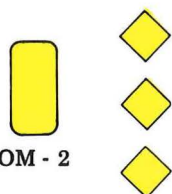
36"x36"

Minimum Size

30"x30"

See MUTCD

page 2C-11



OM-2

Standard Size

3-5" Diamonds

Minimum Size

3-3" Diamonds



OM-3L

OM-3R

Standard Size

12"x36"

See MUTCD

page 3C-2

**One Lane Bridge Sign (W5-3):** The ONE LANE BRIDGE sign is intended to mark all bridges having a clear roadway width of 16 feet or less, or 18 feet or less when a high proportion of traffic is commercial vehicles. The ONE LANE BRIDGE sign is also intended for use when there exists a poor alignment on the approach to a structure having a clear roadway width of 18 feet or less. Additional protection may be provided by the erection of reflector markers.

**Type 1 Object Marker (OM-1):** Either a marker consisting of nine yellow reflectors, each with a minimum dimension of approximately 3", mounted symmetrically on an 18" yellow or black diamond panel; or an all yellow reflective diamond panel of the same size. Type 1 markers may be larger if conditions warrant.

**Type 2 Object Marker (OM-2):** Either a marker consisting of three yellow reflectors, each with a minimum dimension of approximately 3", arranged either horizontally or vertically; or an all-yellow reflective panel, 6" by 12". Type 2 markers may be larger if conditions warrant.

**Type 3 Object Marker (OM-3):** Striped marker consisting of a vertical rectangle approximately 1 foot by 3 feet in size with alternating black and reflectorized yellow or white stripes sloping downward at an angle of 45 degrees toward the side of the obstruction on which traffic is to pass. The minimum width of the yellow or white stripe shall be 3 inches. A better appearance can be achieved if the black stripes are wider than the yellow or white stripes.

Pavement Markings may be used to indicate pavement edges and lane reduction transitions. See Sections 3B-6 and 3B-8 of the Indiana MUTCD.

Delineators may be used. See Section 3D of the Indiana MUTCD.

## Recommendations

The following are recommendations for the type of devices to be used at or near narrow or one lane bridges, culverts, and roadside obstacles, as suggested by Smith and Gerth [5] and the Indiana MUTCD [7], section 3C.

### **Type A roads.** (See Appendix B.)

1. A NARROW BRIDGE sign or a ONE LANE BRIDGE sign should be used on each approach.
2. Type 3 object markers shall be used on each approach.
3. The approaches to the structure should be tapered. (See tapering procedures in Appendix C.)
4. Guardrail may be used.
5. Delineators may be used.
6. Pavement markings may be used.

### **Type B and Type C roads** (See Appendix B)

1. A NARROW BRIDGE sign or a ONE LANE BRIDGE sign may be used.
2. Type 3 object markers shall be used on each approach, unless the approaches to the structure are tapered such that the structure is no longer narrower than the roadway. If tapering is used, Type 3 object markers may be used to warn of additional hazard.

## Objects in the Roadway.

1. Obstructions *within* the roadway are marked with a Type 1 or Type 3 object marker. For additional emphasis, a large surface such as a bridge pier may be painted with diagonal stripes, 12 inches or greater in width, similar in design to the Type 3 object marker. The alternating black and reflectorized yellow or white stripes shall be sloped down at an angle of 45 degrees toward the side of the obstruction which traffic is to pass. The minimum mounting height is normally 4 feet.
2. Objects not actually in the roadway may be so close to the edge of the road that they need a marker. These include underpass piers, bridge abutments, handrails, and culvert headwalls. In some cases, other roadside conditions such as narrow shoulder drop-offs, gores, small islands, and abrupt changes in the roadway alignment may make it dangerous for a driver to leave the roadway. Type 2 or 3 object markers are intended for use at such locations. The inside edge of the marker shall be in line with the inner edge of the obstruction. Where the vertical clearance of an overhead structure exceeds the maximum legal height of vehicles by less than one foot, the clearance in feet and inches should normally be clearly marked on the structure.

\* If horizontal or vertical alignment warrants, an additional sign may be erected at the closer distance shown.

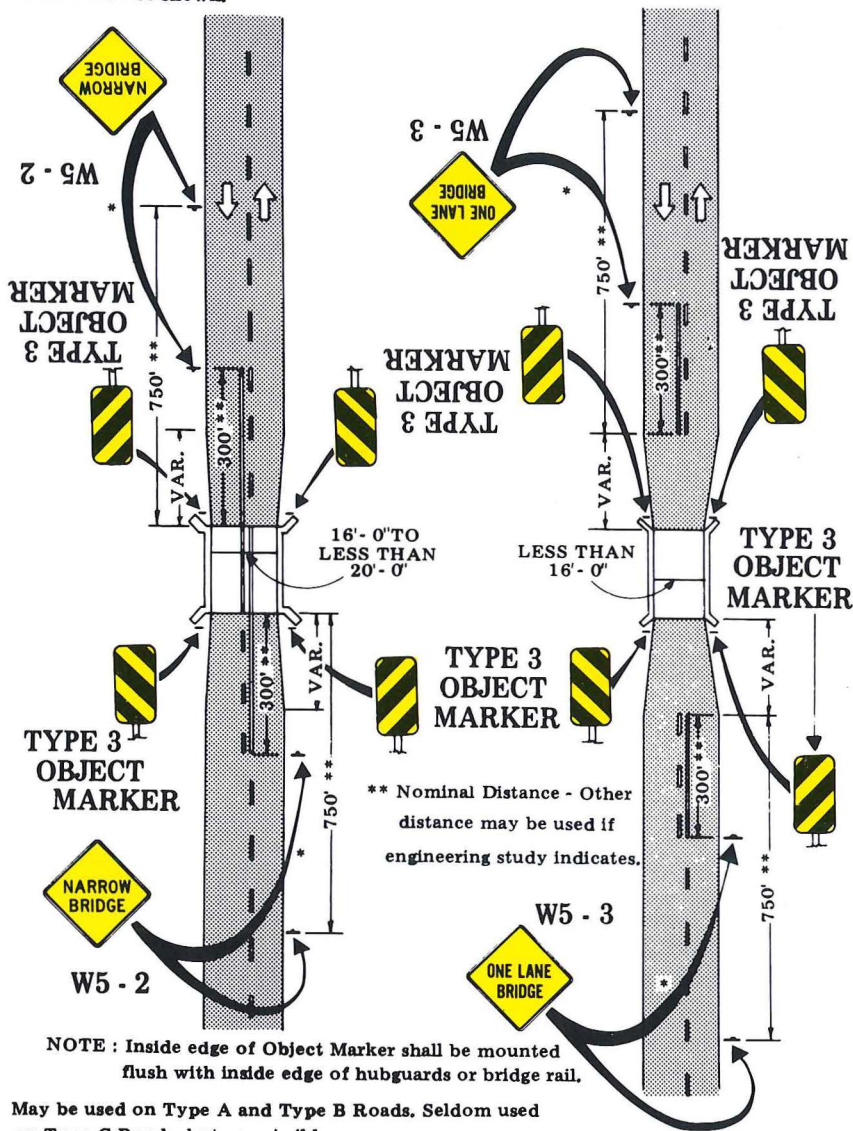


Figure 5.1: Typical Signing and Marking for a Narrow Structure and a One-Lane Structure. Alternate A - Type 3 object markers on all four corners. [5]

\* If horizontal or vertical alignment warrants, an additional sign may be erected at the closer distance shown.

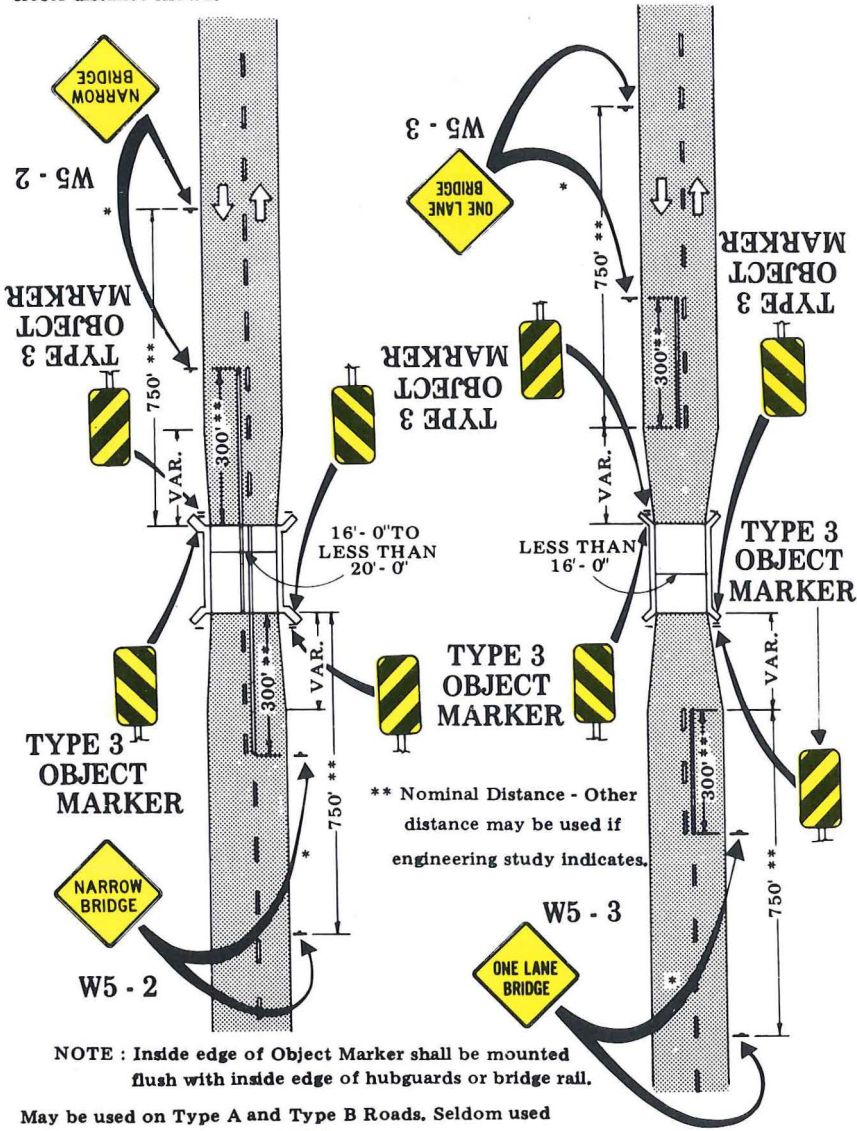
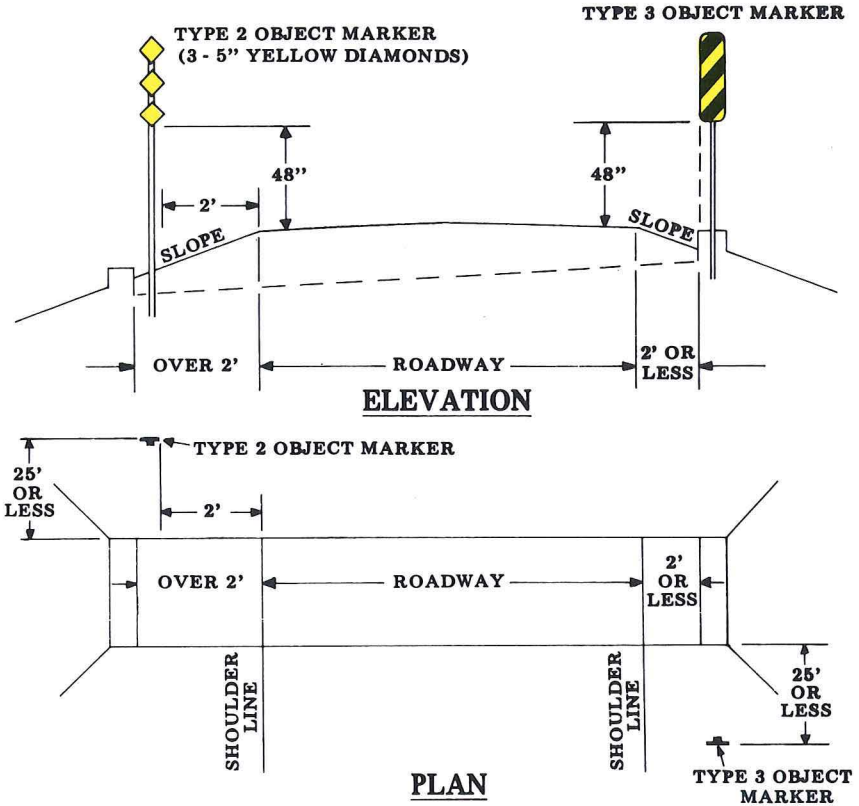


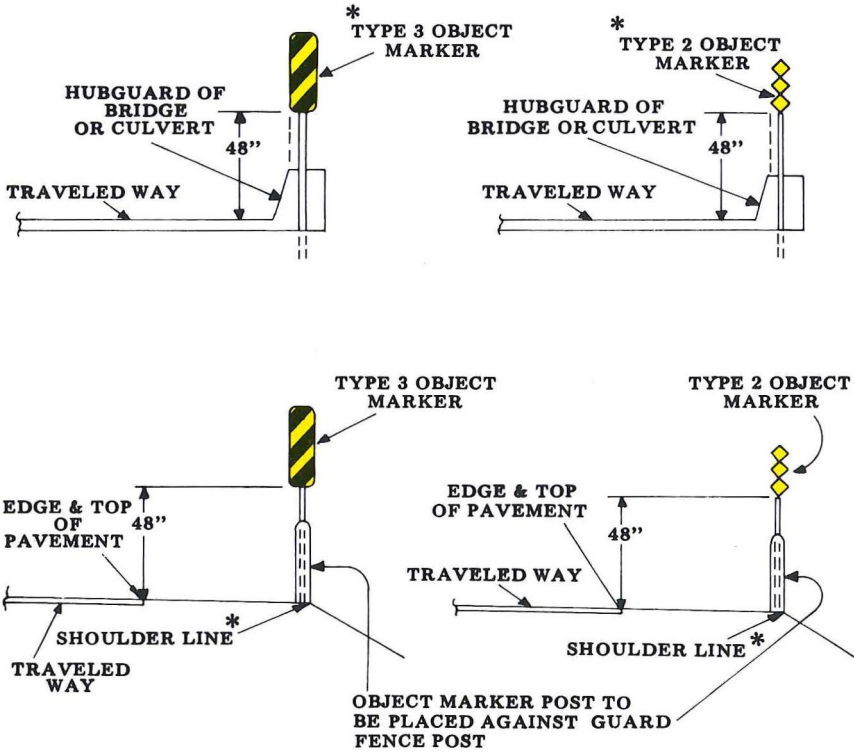
Figure 5.2: Typical Signing and Marking for a Narrow Structure and a One-Lane Structure. Alternate B - Type 3 object markers on both sides of single post position on right side of each approach. Alternate B may be used if structure is not longer than 15 feet. [5]



Signing as shown may be used on Type A and Type B Roads; and is seldom used on Type C Roads.

**NOTE:** Do not mix Type 2 and Type 3 Object Markers at same structure.  
For shoulder widths greater than 2 ft. may use either Type 2 or Type 3 Object Markers.  
For shoulder widths 2 ft. or less use Type 3 Object Markers.

**Figure 5.3: Typical Marking of Roadway Culverts (Box Culvert or Cross Road Pipe Culvert) with or without Hubguard, Curb, and Handrail. [5]**



\* For shoulder widths greater than 2 ft. may use either Type 2 or Type 3 Object Markers. For shoulder widths 2 ft. or less use Type 3 Object Markers.

NOTE: Signing as shown may be used on Type A Type B Roads; and is seldom used on Type C Roads.

Figure 5.4: Typical Mounting of Object Marker. [5]



## CHAPTER 6

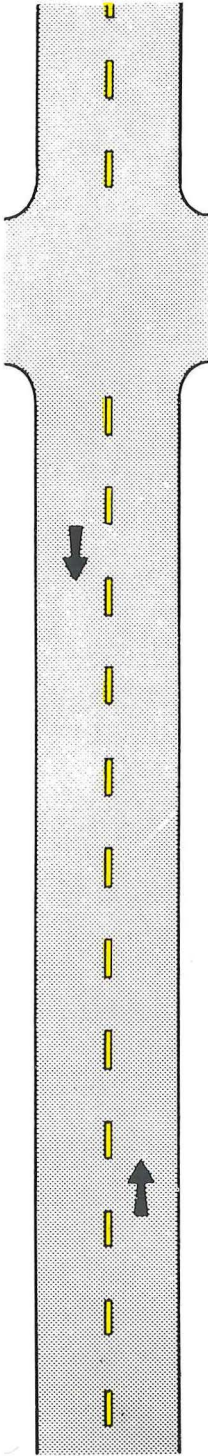
# CENTERLINE MARKINGS

Centerline markings are used to guide drivers along a roadway and to make it easier for them to judge their clearance distance from opposing vehicles. Of course, these markings can only be placed on paved roadways. The painting of these lines is not permanent and thus requires additional painting when the lines become worn and less visible. A study was done by Glennon [6] to determine whether the painting of centerlines was cost effective for low volume roads. His results showed that, comparing expected accident costs and painting costs, centerline painting was not cost effective for ADT values less than 300.

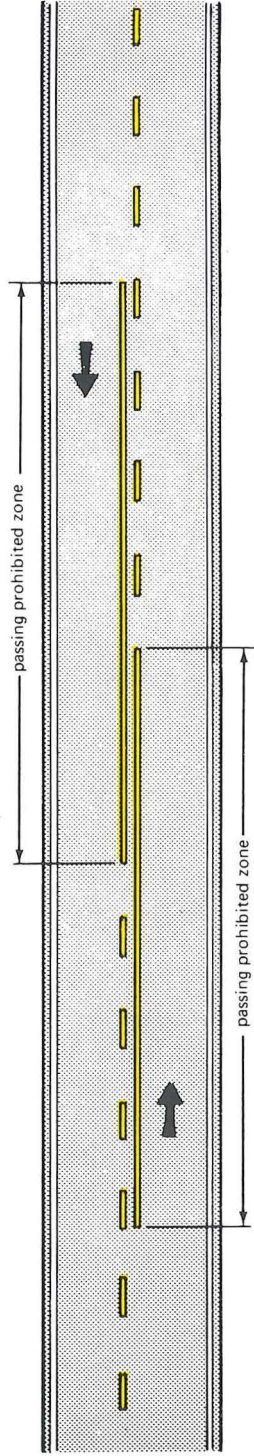
According to the Indiana MUTCD [5], section 3B-1, centerlines are recommended in rural districts on two-lane pavements 16 feet or more in width with prevailing speeds of greater than 35 mph. The type of markings that can be used are the standard ones shown in the Indiana MUTCD.

the standard ones shown in the Indiana MUTCD.

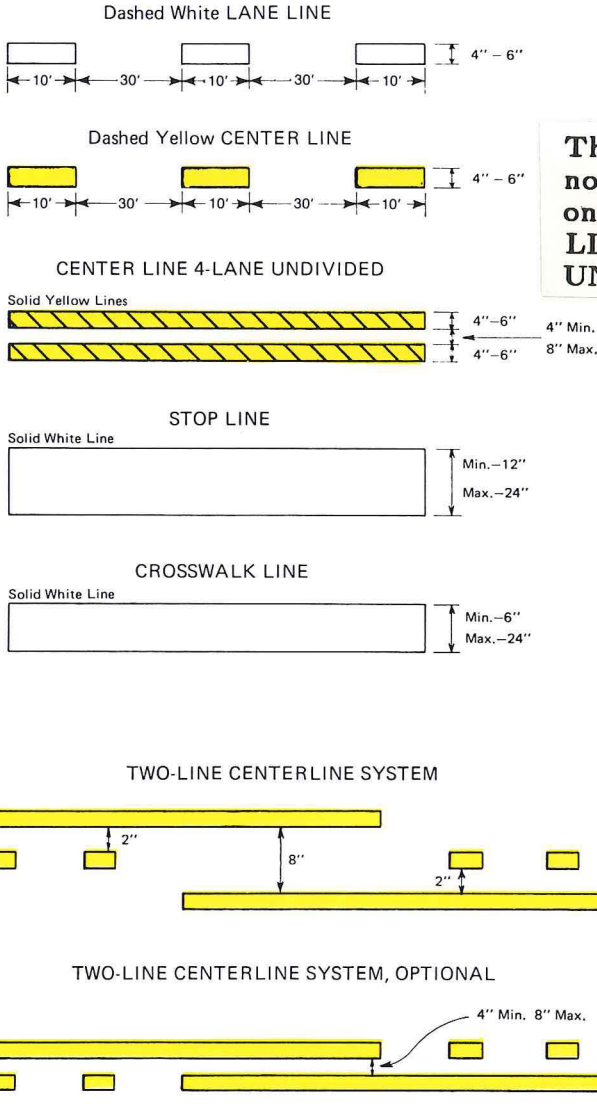
a - Typical two-lane, two-way marking with passing permitted.



b - Typical two-lane, two-way marking with passing prohibited zones.



**Figure 6.1: Typical Two-Lane, Two-Way Marking Application. [7]**



**There should be no crosshatching on CENTER LINE 4-LANE UNDIVIDED.**

Schematic Not To Scale

**Figure 6.2: Standard Pavement Markings. [7]**



## CHAPTER 7

# NO-PASSING ZONES

The use of no-passing stripes is the principal means of warning motorists that they are at a section of inadequate passing sight distance. The regulatory sign, "DO NOT PASS" (MUTCD R4-1) can be used to supplement the no-passing stripes. Also, the warning sign, "NO PASSING ZONE" (MUTCD W14-3) can be used to supplement the pavement markings and/or the "DO NOT PASS" sign. Like centerlines, no-passing stripes are only used on paved roadways, and no-passing stripes are only used where there are centerlines.

Glennon [6] studied the benefits and costs of using no-passing stripes. As with centerlines, no-passing stripes wear out and must be repainted regularly. Glennon concluded that, due to the small likelihood of three vehicles simultaneously being at the same point of the roadway on low volume roads, and the prudent nature of most drivers, painting no-passing stripes was not cost effective. This was found to be the case for all low volume roads, that is, roads with ADT values up to 400.

Since no-passing stripes are not normally to be used, the supplemental use of the before-mentioned signs (DO NOT PASS and NO PASSING ZONE) would not apply. Without the stripes, drivers would have to rely on their own judgment as to where the no-passing zones should be. If engineering judgment indicates that some guidance is called for, two options are available:



W14 - 3

*Standard Size*  
*36"x48"x48"*  
*See MUTCD*  
*page 2C-20*

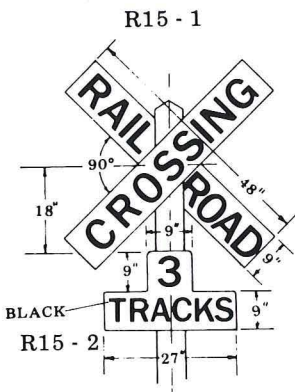
1. For extended sections of no-passing zones, a PASSING HAZARDOUS sign may be used, supplemented by a NEXT XX MILES sign as suggested by Walton, et al. [2]. These signs must conform to MUTCD standards for warning signs.
2. For individual sections of restricted passing sight distance, DO NOT PASS (R4-1) signs may be used to mark the beginning of no-passing zones. These signs may be supplemented by NO PASSING ZONE (W14-3) signs, which, when used shall be erected on the left side of the roadway, opposite the DO NOT PASS sign.

## CHAPTER 8

# RAILROAD GRADE CROSSINGS

The use of traffic control devices at railroad grade crossings is as important to the safety of the drivers on low volume roads as on other roads. There is little difference in the placement of signs and markings on these roads compared to the higher volume roads. As stated in the Indiana MUTCD, the determination of need and selection of devices at a grade crossing is made by the public agency having jurisdictional authority.

The following traffic control devices are those that are normally used on low volume roads. Each of the signs shall be reflectorized to show the same shape and color to an approaching motorist both by day and by night.



**Railroad Crossing (Crossbuck) Sign (R15-1):** As a minimum, one crossbuck sign shall be used on each roadway approach to every grade crossing, along or in combination with other traffic control devices. If there are two or more tracks between the signs, the number of tracks shall be indicated on an auxiliary sign of an inverted "T" shape mounted below the crossbuck. (Use of the auxiliary sign is optional at crossings with automatic gates.) Installation and maintenance of the crossbuck sign and the number of tracks sign shall normally be the responsibility of the railroad.

See MUTCD  
page 8B-1



W10 - 1

*Standard Size  
36" Diameter  
See MUTCD  
page 8B-3*

**Railroad Advance Warning Sign (W10-1):** A Railroad Advance Warning sign shall be used on each roadway in advance of every grade crossing, except on low volume, low speed roadways crossing minor spurs or other tracks that are infrequently used and that are always flagged by train crews. *All* of these exceptions must be satisfied for a Railroad Advance warning sign *not* to be required. The county engineer or road supervisor must carefully follow the MUTCD guidelines in the area of railroad grade crossings.

These signs should normally be placed 750 feet or more in advance of the crossing in rural areas. Installation and maintenance of the Railroad Advance Warning signs shall normally be the responsibility of the state, local, or private agency having jurisdiction over the roadway in question.

**Pavement Markings:** Pavement markings in advance of a grade crossing shall consist of an X, the letters RR, a no-passing marking (for 2 lane roads), and certain transverse lines. (See the figures at the end of this chapter.) Identical markings shall be placed in each approach lane on all paved approaches to grade crossings where grade crossing signals or automatic gates are located, at all other grade crossings where the prevailing speed of traffic is 40 mph or greater, and at crossings where an engineering study indicates that there is a significant potential conflict between vehicles and trains. Of course, these markings are only to be used on paved roadways. Installation and maintenance of the pavement markings shall be the responsibility of the state, local, or private agency having jurisdiction over the roadway in question.



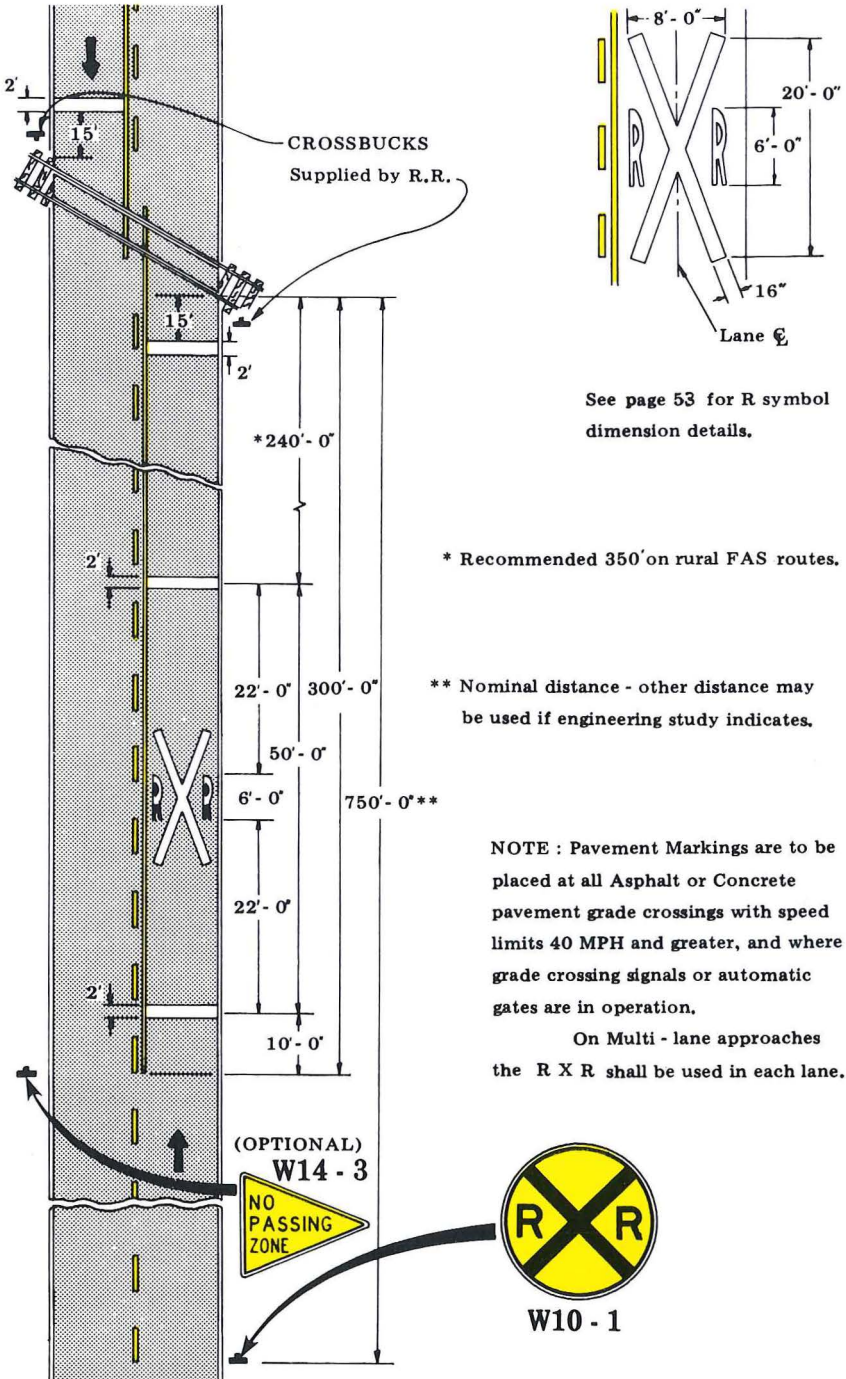
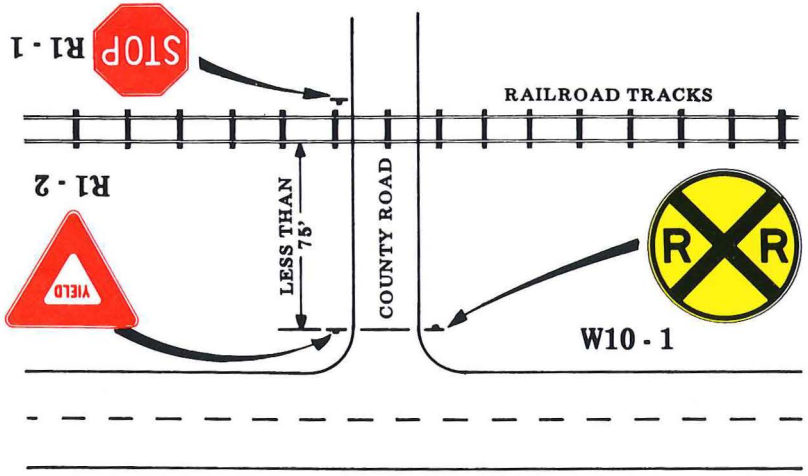


Figure 8.1: Typical Signing and Pavement Markings at a Railroad-Highway Grade Crossing. [5]



Intended for use where road sight distance is restricted.

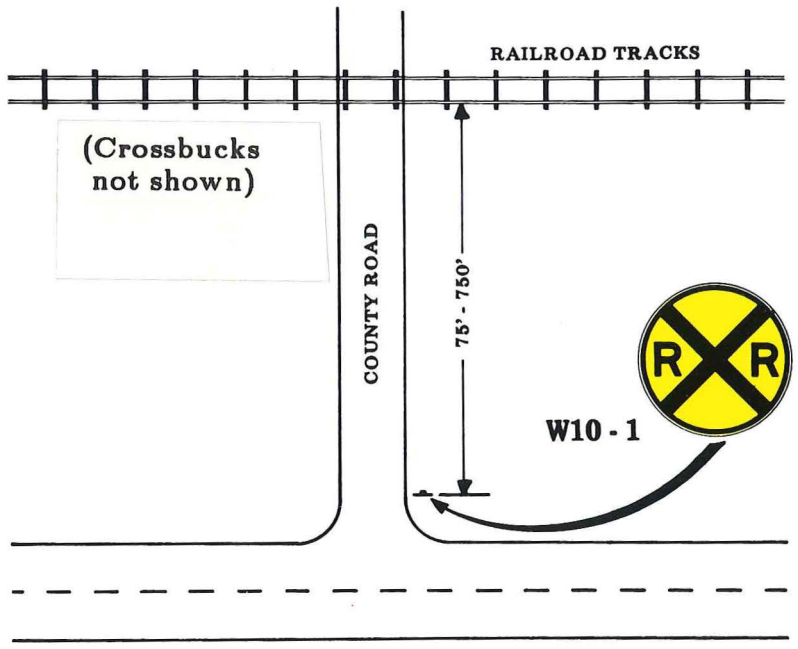


Figure 8.2: Advance Stop and Warning for Parallel Railroad Grade Crossing. [5]

## CHAPTER 9

# TRAFFIC CONTROL IN CONSTRUCTION & MAINTENANCE AREAS ON TWO-LANE TWO-WAY ROADWAYS

The purpose of this chapter is to provide information and guidelines to those persons involved in providing traffic control devices to warn and guide motorists and pedestrians in construction and maintenance areas on two-lane two-way roadways. This booklet is to serve as a supplement to the *Indiana Manual on Uniform Traffic Control Devices for Streets and Highways*.

The following is taken from State of Indiana Statute 9-4-2-1 section 1: "*The Indiana Manual on Uniform Traffic Control Devices for Streets and Highways* shall be adhered to by all governmental agencies within the state responsible for the signing, marking, and erection of all traffic control devices on all streets and highways within the state." Copies of the Manual can be obtained from the Indiana Department of Highways, Room 1313, Indianapolis, Indiana 46204: Attention - Contracts Engineer. A copy of the Manual is on file in each county courthouse in the state.

Another publication that can be very useful is *Work Zone Traffic Control Standards and Guidelines - 1985 Edition*. The booklet is Part VI, Traffic Controls for Street and Highway Construction and Maintenance Operations of the *Manual on Uniform Traffic Control Devices* and Part VI, Work Zone Traffic Control, of the *Traffic Control Devices Handbook*. Copies of the booklet can be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, D. C. 20402. The stock number is 050-001-00290-6. The price is \$2.75. Copies can also be obtained by calling the GPO Chicago Store at 312-353-5133.

## Responsibility for Safety on Highways

The responsibility for the safety of the public using a public roadway as well as the safety of workers rests with the unit of government which has operational control over the street or highway. This means that regardless of whether work is performed by governmental agency personnel, by a private contractor, or by a public utility company, the governmental unit having jurisdiction (i.e., city, town, county, special authority, or state) is ultimately responsible for the safety of the public. This does not mean that the supervisor of the construction or maintenance activity or the workers involved with the job are relieved of responsibility for the safety of the public. They are also responsible. The control of traffic in a construction or maintenance area is called a ministerial task. Highway departments, employees, and others involved in construction or maintenance who do not follow the provisions in the MUTCD are very likely to be held liable for negligence in the instance of accidents occurring in construction or maintenance areas.

Highway personnel should anticipate the likelihood of lawsuits in the event of an accident. To prevent or minimize such litigation and to help defend lawsuits, the following is recommended:

- Know and comply with the traffic control for street and highway construction and maintenance operations set forth in the State MUTCD and nationally accepted engineering standards and practices.
- Provide properly working devices at the site particularly when unattended (nights, weekends, etc.).
- Document all actions taken on or related to traffic controls that are placed in effect at the worksite.
- Inspect the worksite at frequent intervals with a view to detecting and immediately correcting deficiencies in traffic control.
- Remove all material and equipment not needed at the site as soon as possible (this applies also to traffic control devices that cease to be needed).
- Provide warning and protection to motorists, pedestrians, and workers for potential conflicts and hazards that may result from work being done at the site.

## Goals and Principles of Traffic Control in C/M Areas

Goals common to all traffic control zones in construction and maintenance areas are to minimize accidents and accident severity and to minimize inconvenience to and conflicts with motorists and pedestrians as a result of construction and maintenance work within the roadway.

Construction and maintenance areas can present motorists with unexpected or unusual operational situations. It is necessary to take special care in applying traffic control techniques in these areas. Do not surprise the motorist. Do not assume that motorists and pedestrians will see or recognize workers or hazards in work areas.

Traffic should be inhibited as little as possible. It should be guided in a clear and positive manner while approaching and passing around or through construction and maintenance areas. Positive guidance means telling the motorist in clear unmistakable terms what path to follow and what speed to drive. This guidance is provided by using standard traffic control devices such as signs, markings, and channelizing devices which are effective under varying conditions of light and weather to alert motorists to impending conditions, warn them of the hazards and direct them through the proper path. The standard traffic control devices are specified in the *Manual of Uniform Traffic Control Devices*.

Traffic safety in construction zones should be an integral and high priority element of every project from planning through design and construction. Also maintenance work should be planned and conducted with the safety of the motorist, pedestrian and worker kept in mind at all times.

Traffic control should permit the safe and efficient movement of traffic through the construction or maintenance zones and at the same time provide a safe area where construction or maintenance activity can be conducted efficiently.

## Procedure for Controlling Traffic in Construction and Maintenance Areas

The procedure for controlling traffic in construction and maintenance areas includes the following:

- planning and design
- installation
- inspection and maintenance
- removal

### Planning and Design

A traffic control plan, in detail appropriate to the complexity of the work project, construction or maintenance, should be prepared. Before going to the work site, a plan should be prepared to determine the type and number of traffic control devices (signs, barricades, cones, etc.) that will be needed to safely control the traffic.

No one standard sequence of signs and/or other traffic control devices can be set up as an inflexible arrangement for all situations due to the variety of conditions that can be encountered in the field. The unique conditions of each site must be evaluated. Typical layouts as illustrated in the included examples provide a good starting point but often require modification if they are to function properly. Examples provided are minimum desirable standards for normal situations. Additional protection must be provided when special conditions and hazards exist.

The system of traffic control devices, signs, markings, channelizing devices (barricades, cones, etc.) warn the motorist of presence of workers and equipment, warn of changes in road alignment and cross section, road surface condition or roadside features due to construction or maintenance activities, warn of nature or extent of special hazards, and safely guide the road user through the work area.

A typical traffic control device plan will include an advance warning area where the motorist is told there is construction or maintenance activity ahead, an approach area where the motorist is informed as to a safe speed and travel path to follow, the actual work area where the proper path for traffic around or through the construction or maintenance activity is delineated, and the downstream area where the motorist is told that the construction or maintenance area has ended. See Figure 9.1.

When selecting traffic control devices (signs, markings, channelizing devices) it is very important to use standard devices as to shape, size, color, message, as illustrated in the *Indiana Manual on Uniform Traffic Control Devices*. Typical examples are given in Figures 9.2 through 9.9. Warning signs in construction and maintenance areas shall be diamond shaped (square with one diagonal vertical), having a black symbol or message on an orange background. Any traffic control devices that are to be used at night must be reflectorized. Since most traffic control devices may be used at one time or another at night it is best to have all signs, markings, and channelizing devices reflectorized.

In Indiana there are several suppliers who are familiar with the standards for traffic control devices and can provide signs, marking materials and channelizing devices that comply with the *Indiana Manual on Uniform Traffic Control Devices*. Contact the Indiana Department of Highways for names of these suppliers. Do not use "nonconforming" home made signs.

Channelizing devices are traffic control devices used as part of a traffic control system to warn and alert motorists of hazards created by construction or maintenance activities in or near the traveled way, and to guide and direct the motorist along a path safely past the hazards. Channelizing devices includes cones, vertical panels, drums, barricades, and barriers. See Figure 9.9. Cones shall be a minimum of 18" in height. On high speed roadways and on all facilities during hours of darkness or whenever more conspicuous guidance is needed, a minimum cone height of 28" is preferable. Drums shall be approximately 36" in height and a minimum of 18" in diameter. Type I and II barricades are a minimum of 3 feet high. Markings for barricade rails shall be alternate orange and white stripes (sloping downward at an angle of 45 degrees in the direction traffic is to pass). All channelizing devices should be constructed so as not to inflict any undue damage to a vehicle that inadvertently strikes them. Where barricades may be susceptible to overturning in the wind, sandbags should be used for ballasting. Sandbags may be placed on lower parts of the frame or stays to provide the required ballast but shall not be placed on top of any striped rail. Drums should not be weighted with sand, water, or any material to the extent that would make them hazardous to motorists. When used in the winter, they should have drain holes in the bottom so water will not accumulate and freeze.

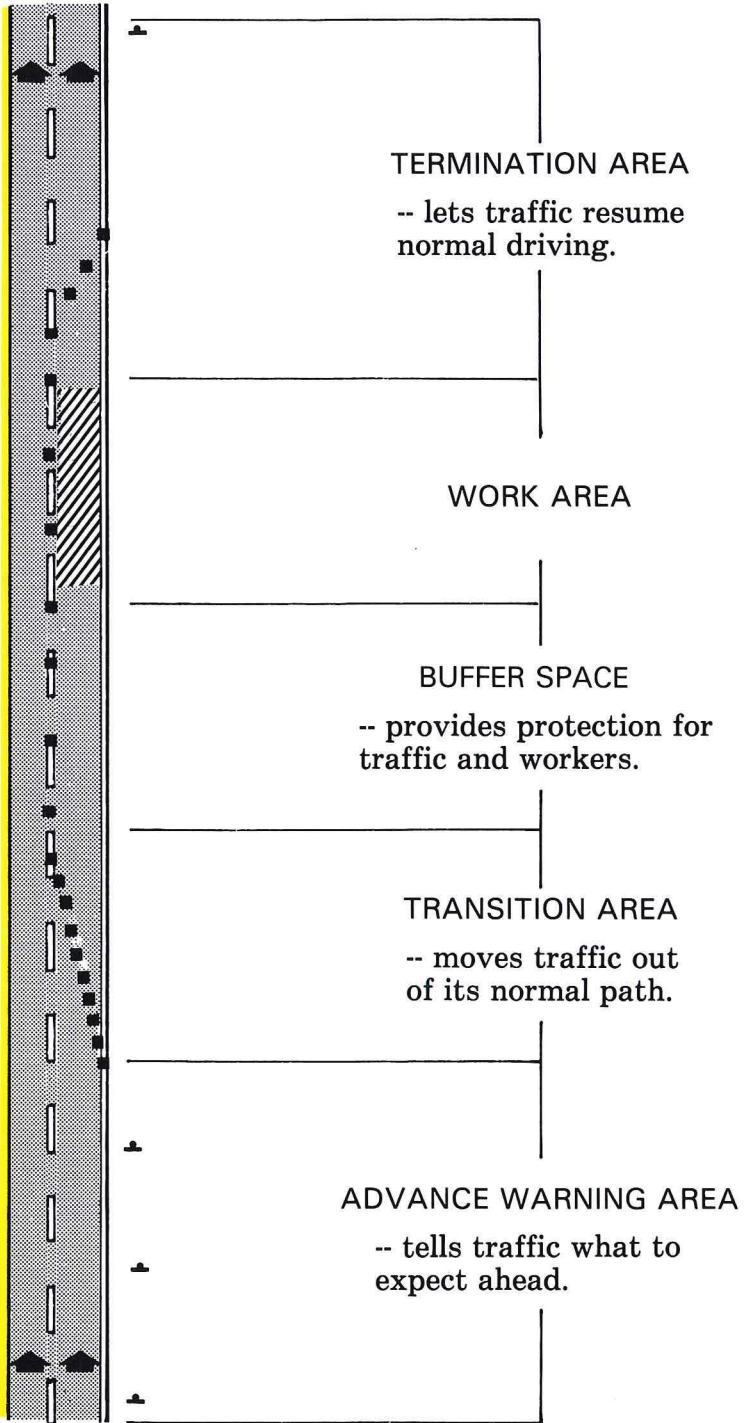


Figure 9.1: Areas in a Traffic Control Zone. [9-2]





XW20-1  
48" x 48"

**Advance Road (Street) Construction Sign (XW20-1):** The Advance Road (Street) Construction sign is to be located in advance of the initial activity or detour a driver may encounter, and is intended for use as a general warning of obstructions or restrictions. It carries the legend ROAD (STREET) CONSTRUCTION (1500) FT or ROAD (STREET) CONSTRUCTION (1/2) MILE, or ROAD CONSTRUCTION AHEAD. It may be used in repetition with appropriate legends, or in conjunction with other construction signs.



XW20-1a  
48" x 48"  
Line 1--8"-C  
Line 2--8"-C  
Line 3--6"-C  
Line 4--6"-C



XW20-2  
48" x 48"

**Advance Detour Sign (XW20-2):** The Advance Detour sign is intended for use in advance of a point at which traffic is diverted over a temporary roadway or route. It carries the legend DETOUR (1500) FT or DETOUR (1/2) MILE, or DETOUR AHEAD. It may be used with repetition with appropriate legends or in conjunction with other construction signs.



XW20-2a  
48" x 48"  
Letters 8"-D

**Advance Road (Street) Closed Sign (XW20-3):** The Advance Road (Street) Closed sign is intended for use in advance of a point at which a roadway is closed to all traffic or to all but local traffic. It carries the legend ROAD (STREET) CLOSED (1000) FT or ROAD (STREET) CLOSED (1/4) MILE, or ROAD (STREET) CLOSED AHEAD. It may be used in repetition with appropriate legends or in conjunction with other construction signs.



XW20-3  
48" x 48"

**Figure 9.2: Warning Signs Used in Construction or Maintenance Areas. [9-1]**



XW20-4  
48" x 48"

**Advance One Lane Road Sign (XW20-4):** The Advance One Lane Road sign is intended for use only in advance of a point where traffic both directions must use a single lane. It carries the legend ONE LANE ROAD (1000) FT or ONE LANE ROAD (1/4) MILE. It may be used in repetition with appropriate legends or in conjunction with other construction signs.

If the one-lane stretch is of such length as not to be visible throughout from either end, or if the traffic is of such volume that simultaneous arrivals at both ends occur frequently, provision should be made to permit traffic to move alternately under control.



XW20-7  
48" x 48"

**Advance Flagman Sign (XW20-7):** The Advance Flagman sign is intended for use in advance of any point at which a flagger has been stationed to control traffic through a construction or maintenance project. It carries the flagger symbol. When needed, an appropriate distance message may be displayed on a supplemental plate below the symbol sign. It may be used in repetition with appropriate revisions in the supplemental distances plate or in conjunction with other construction signs.

The word message sign XW20-7 with appropriate distances may be used as an alternate to the XW20-7a flagger symbol sign.

The sign shall be promptly removed, covered, or turned to face away from the roadway whenever the flagger is not at the station.



XW20-7a  
36" x 36"

**Figure 9.3: Warning Signs Used in Construction or Maintenance Areas. [9-1]**



XW6-3  
48" x 48"

**TWO-WAY TRAFFIC Sign (XW6-3):** TWO-WAY TRAFFIC sign should be used as needed at intervals to periodically remind drivers that they are on a two-way highway which contains opposing traffic. The word message TWO WAY TRAFFIC may be used as an alternate to the symbol sign.



XW6-3a  
48" x 48"  
Letters 8"-C

**Worker Sign (XW21-1):** A Worker sign is intended for use in conjunction with minor maintenance and public utility operations for the protection of workers in or near the roadway. On low-speed urban roads a worker sign is intended for use at limited obstruction sites which are adequately marked and clearly visible, such as an open manhole with a fence around it. The XW21-1 word message sign may be used as an alternate to the XW21-1a Worker Symbol sign.



XW21-1  
36" x 36"



XW21-1a  
36" x 36"

**FRESH OIL Sign (XW21-2):** The FRESH OIL (TAR) sign is intended for use to warn motorists that resurfacing operations have rendered the surface of the pavement temporarily hazardous, and that objectionable splashing on vehicles may occur.



XW21-2  
30" x 30"

**Figure 9.4: Warning Signs Used in Construction or Maintenance Areas. [9-1]**

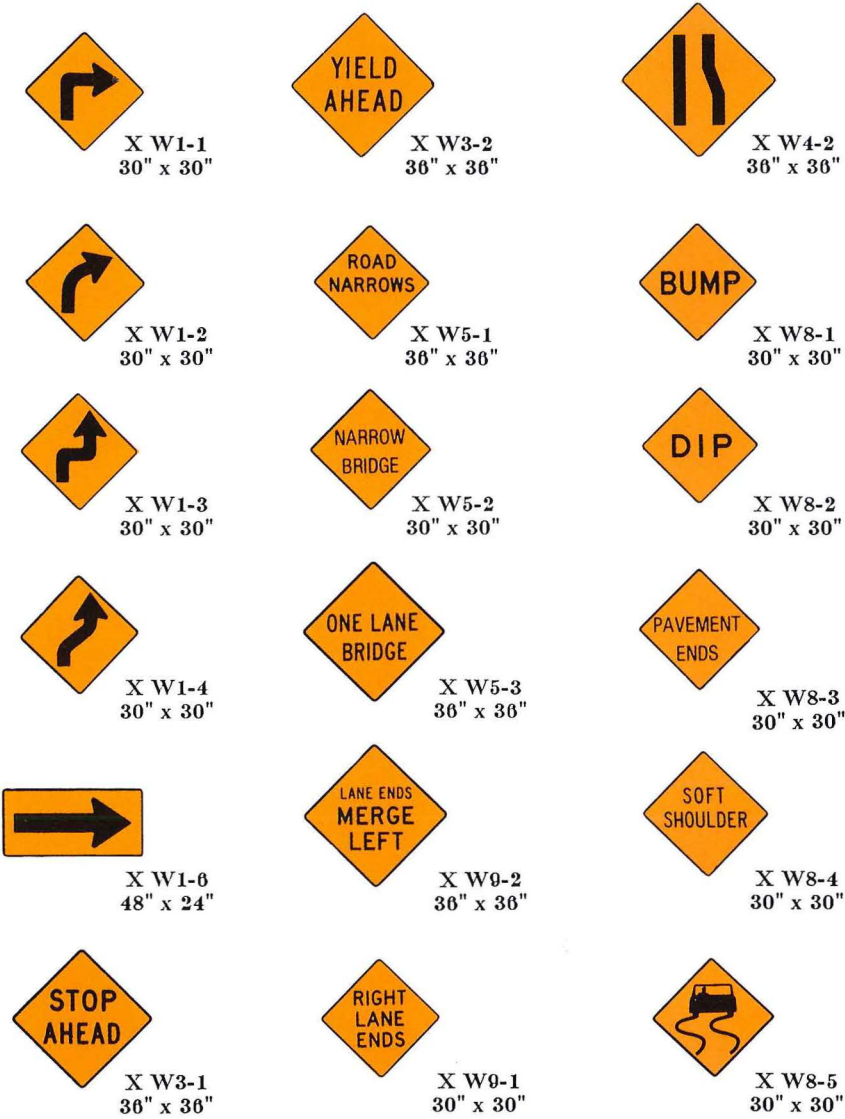


Figure 9.5: Warning Signs Used in Construction or Maintenance Areas. [9-1]



XW21-3  
36" x 36"

**ROAD MACHINERY Sign (XW21-3):** The ROAD MACHINERY sign is intended for use in areas where heavy equipment is operating in or adjacent to the roadway.



XW21-4  
36" x 36"

**ROAD WORK Sign (XW21-4):** The ROAD WORK sign is intended for use in advance of maintenance or minor reconstruction operations in the roadway.



XW21-5  
30" x 30"

**SHOULDER WORK Sign (XW21-5):** The SHOULDER WORK sign is intended for use in advance of maintenance or minor reconstruction operations involving the shoulder, where the traveled way remains unobstructed.



XW21-6  
30" x 30"

**SURVEY CREW Sign (XW21-6):** The SURVEY CREW sign is intended for use in advance of a point where a surveying crew is working in or adjacent to the roadway.

**Figure 9.6: Warning Signs Used in Construction or Maintenance Areas. [9-1]**

**Length of Construction Sign (XG20-1):**

The Length of Construction sign is for use at the limits of any road construction or maintenance job of more than 2 miles in extent, where Traffic is maintained through the job. It carries the legend ROAD CONSTRUCTION NEXT (5) MILES. It can be effectively mounted on a wing barricade. This sign may be used where required, for jobs of lesser length or on urban streets with appropriate distances shown.

XG20-1  
60" x 36"



**END CONSTRUCTION (ROAD WORK) Sign (XG20-2):** The END CONSTRUCTION (ROAD WORK) sign should be erected approximately 500 feet beyond the end of a construction or maintenance job. It may be erected on the back of a warning sign set up facing the opposite direction of traffic or on the back of a wing barricade. Where appropriate, the legend END ROAD WORK may be used.

XG20-2  
60" x 24"



XG20-2a  
60" x 24"



Figure 9.7: Warning Signs Used in Construction or Maintenance Areas. [9-1]



XM4-10 (R or L)  
48" x 18"

**Detour Signs and Markers (XM4-8, 9 and 10):** The Detour Arrow sign (XM4-10) is used at a point where a detour roadway or route has been established due to the closure of a street or highway to through traffic. It should normally be mounted just below the ROAD CLOSED sign or the Local Traffic Only sign.

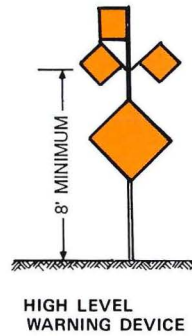
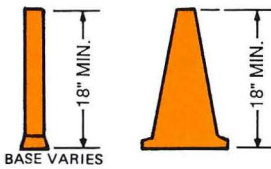
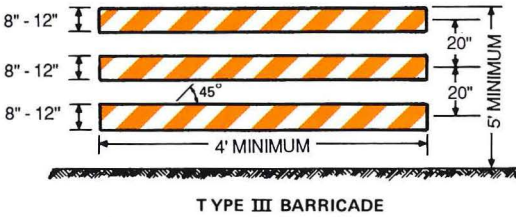
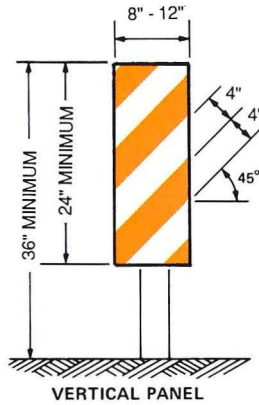
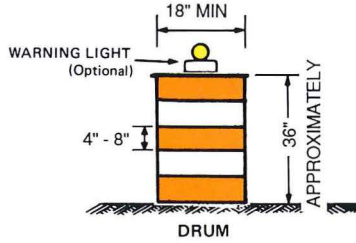
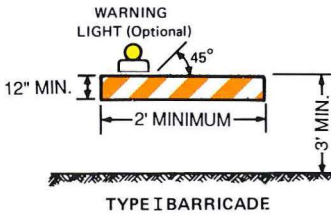


XM4-9 (R or L)  
30" x 24"

The Detour Arrow sign uses a horizontal arrow pointed to the right or left as required at each location.

Each detour shall be adequately marked with standard temporary route markers and destination signs as a responsibility of the highway agency. The Detour marker (XM4-8) mounted at the top of a route marker assembly is to be used to mark a temporary route that branches from a regular numbered route, bypasses a section of a route which is closed or blocked by construction, major maintenance, roadway damage or traffic emergency and rejoins the regularly numbered route beyond that section. The Detour sign (XM4-9) is to be used for unnumbered routes; for use in emergency situations; for periods of short durations; or where, over relatively short distances, it is not necessary to show route markers to guide traffic along the detour and back to its desired route.

Figure 9.8 Warning Signs Used in Construction or Maintenance Areas. [9-1]



**NOTE:**

Flashing or steady burn warning lights should be used on barricades, panels and drums as needed.

**Figure 9.9: Channelizing Devices and High Level Warning Devices. [9-1]**



Barriers are devices designed to prevent vehicular penetration from the traveled way into construction or maintenance areas behind the barrier. A precast concrete safety shape barrier is often used in construction and maintenance work areas.

High level warning devices as shown in Figure 9.9 are used to supplement other controls and devices necessary to alert motorists of construction and maintenance activities or obstructions in the roadway and are designed to be seen over the top of preceding vehicles.

A taper is a series of channeling devices (barricades, cones, drums) and pavement markings placed at an angle to move traffic out of its normal path. The length of the taper used to close a lane is determined by the speed of traffic and the width of the lane to be closed. The formulas for taper length are given in the following table.

#### FORMULAS FOR TAPER LENGTH

Posted Speed	Formula
40 mph or under	$L = WS^2/60$
45 mph and over	$L = WS$

where

L = taper length in feet

W = width of lane or offset in feet

S = posted speed or off peak 85 percentile speed in mph

Speed Limit mph	Taper Length L in feet			Number of Channelizing Devices for Taper*	Spacing of Devices Along Taper in Feet
	Lane Width in Feet				
	10	11	12		
20	70	75	80	5	20
25	105	115	125	6	25
30	150	165	180	7	30
35	205	225	245	8	35
40	270	295	320	9	40
45	450	495	540	13	45
50	500	550	600	13	50
55	550	605	660	13	55

\*Based on 12 foot wide lane.

If restricted sight distance is a problem (e.g. a sharp vertical curve or horizontal curve) the taper should begin well in advance of the view obstruction. Generally, tapers should be lengthened, not shortened, to increase their effectiveness.

The two-way traffic taper is used in advance of a work area that occupies part of a two-way road in such a way that the remainder of the road is used alternately by traffic in either direction. A short taper is used to cause traffic to slow down by giving the appearance of restricted alignment. One or more flaggers are usually employed to assign right-of-way in such situations. Two-way traffic tapers should be 50 to 100 feet long, with channelizing devices spaced a maximum of 10 to 20 feet, respectively, to provide clear delineation of the taper.

For a shoulder closure taper, one half the length given in the preceding table is suggested as a maximum provided the shoulder is not used as a travel lane due to construction.

The selection and placement of traffic control devices for control of traffic is dependent on the length of time that the road will be occupied by the construction or maintenance activity. The work zone activities can be either moving, mobile or intermittent moving, short term stationary or long term stationary.

A moving work zone is a construction, maintenance or utility work site that is continuously being moved during the period when work is actively in progress. For such activities fixed signing and channelization are not practical. The traffic control devices used will be service vehicle mounted and possibly supplemented by trailer mounted or portable advanced warning signs.

The vehicles used in the work zone should be painted either orange or yellow, and have appropriate warning signs and an operating amber light visible to all approaching traffic for a distance of 1000 feet. The light shall be an amber strobe light or an amber flashing, oscillating or rotating incandescent, directed beam light. Red flags at least 10 feet high may also be mounted on the vehicle. If the vehicle is moving less than 25 mph a slow moving vehicle sign should be displayed. If the vehicle is traveling over 25 mph the sign should be removed or covered.

For moving operations, a separate sign truck (shadow vehicle) with warning signs, flashing lights, and flags follows the work vehicle to warn approaching traffic and to shield the work

vehicle. On two-lane two-way roads, a lead vehicle with signs and lights may also be used. On low volume roads with flat grades and straight alignment, moving operations may be performed without a shadow vehicle however the work vehicle must be equipped with adequate traffic control devices.

Crash attenuators or pads may be mounted on the rear of the shadow vehicle or the work vehicle if no shadow vehicle is used.

For the mobile or intermittent moving operations (15 minutes or less), the traffic control devices would be the same as for moving operations, however, channelizing devices such as cones may be used to guide traffic around the work area. High level warning devices which have excellent visibility and are easily transportable could also be used at these sites.

For short term stationary operations (those work activities that require more than 15 minutes and less than one period of daylight to complete and are not performed during hours of darkness) advanced warning signs would be placed on portable or trailer mounts. Cones would be used for channelizing devices to guide traffic around the work area. High level warning devices could also be used to increase the visibility of the work site.

For long term stationary work zones (those work activities that take longer than one period of daylight to complete or are performed during hours of darkness) more permanent mountings are used for signs and type I or II barricades or drums would be used for channelizing traffic around the work area. Steady burning lights would be placed on the barricades and drums for channelizing traffic at night. Flashing lights are used to warn motorists of obstructions in or adjacent to the roadway.

## **Installation**

Signs shall be placed in positions where they will convey their messages most effectively. Signs shall be so placed that the motorist will have adequate time for response.

As a general rule signs shall be located on the right-hand side of the street or roadway. Where special emphasis is needed, dual installations may be made which consist of duplicate signs opposite each other on the left and right sides of the roadway.

Within a construction or maintenance zone it is often necessary and/or desirable to erect signs on portable supports placed within the roadway itself. It is also permissible to mount appropriate signs on barricades or on work vehicles. See Figure 9.10.

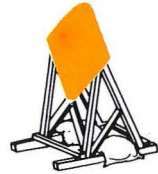
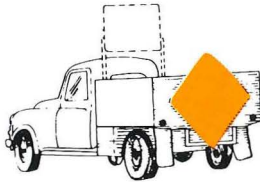
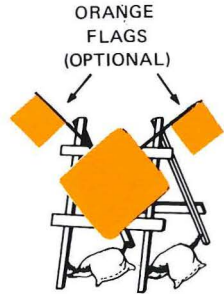
Standards for height and lateral clearance of roadside signs are shown in Figure 9.11.

Single sign supports are usually adequate for signs up to 36" x 36". Larger signs normally require two supports to prevent twisting and turning of the sign assembly. Signs mounted on barricades or temporary supports may be at lower heights, but the bottom of the sign shall not be less than one foot above the pavement elevation.

Advance warning signs should be far enough from the work site to give time for the motorist to react to the message on the sign yet close enough to the work site to constantly remind.

Where open highway conditions prevail on the approach to the work site, advance warning signs should be placed approximately 1500 feet in advance of the condition to which they are calling attention. Where a series of advance warning signs are used, the warning sign nearest the work site should be placed approximately 500 feet from the point of restriction with the additional signs at 500 to 1000 foot intervals. On limited access facilities, the advance warning distance should be increased to one-half mile or more. On city streets, where more restrictive conditions prevail on the approach to the work area, signs in the immediate vicinity of the work may be placed at closer spacings.

PORTABLE AND TEMPORARY MOUNTINGS



WING BARRICADES

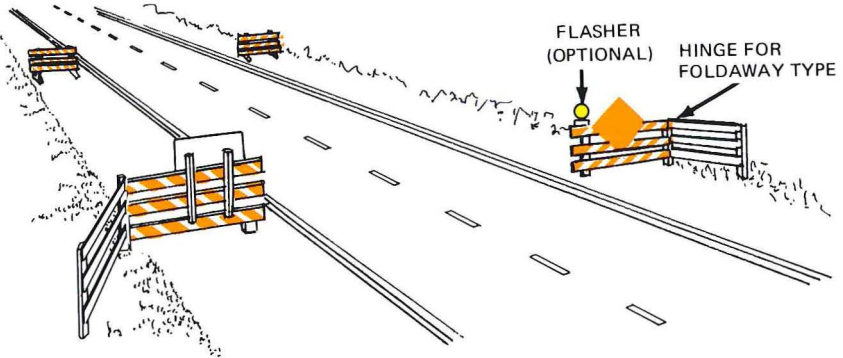
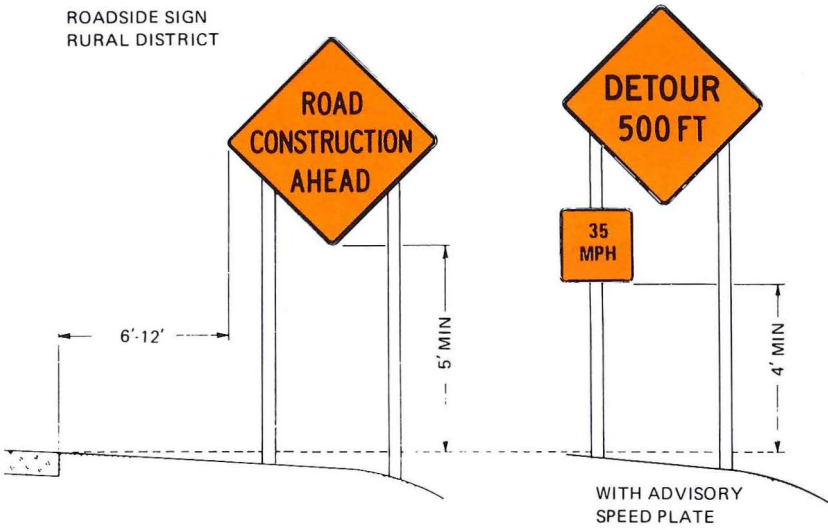


Figure 9.10: Methods of Mounting Signs other than on Posts.  
[9-1]

ROADSIDE SIGN  
RURAL DISTRICT



ROADSIDE SIGN  
URBAN DISTRICT

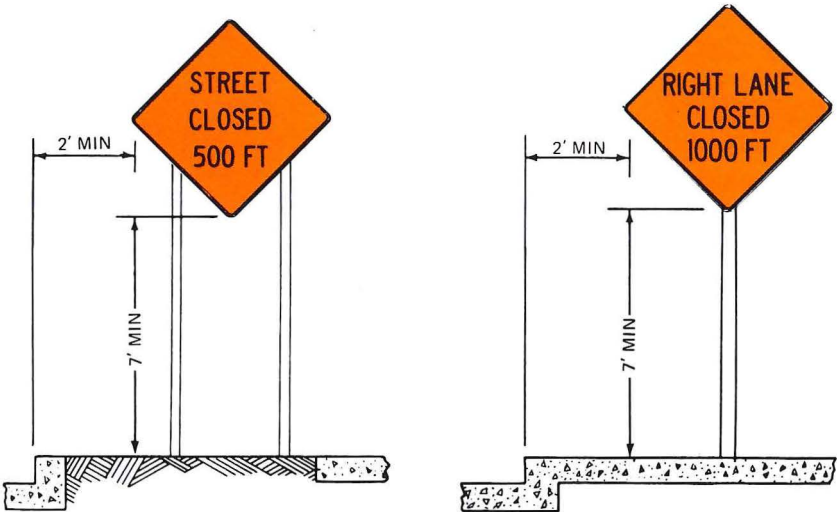


Figure 9.11: Height and Lateral Locations of Signs -- Typical Installation [9-1]

A rule-of-thumb for the spacing between signs in a series is:

250 feet for urban, residential or business districts or with speeds under 40 mph;

500 feet for urban arterials and rural roads or with speeds over 40 mph; and

1000 feet for expressways and freeways.

Traffic control devices should be placed in the order that motorists will see them, starting with the sign or device that is farthest from the work area. The first traffic control device to be installed is an advance warning sign placed upstream of the work area. From this starting point other signs, cones, barricades and devices are set up with the flow of traffic until the work site is reached. Next the work site is barricaded. The end construction sign beyond the work site, is the last sign to be placed.

When one direction of traffic will be directed into opposing traffic lanes, the signs, devices and pavement markings for the opposing traffic should be placed first. When the signs and devices are across from or at the work area, the devices for the oncoming direction can then be set up. It is essential to channelize opposing traffic out of its lane before moving the oncoming traffic into the lane.

The signs and devices would be removed in reverse order in which they were placed.

When signs or channelizing devices are to be installed and removed several times during the work operation, a spot should be painted where the devices are located, so that the installation can be repeated quickly and so that proper placement is assured.

## Inspection and Maintenance

Once the traffic control devices have been placed, it is important to make sure they are going to function as planned. Before work begins a drive through the construction or maintenance area during daylight and at night should be made to check that all traffic control devices are in the proper place, are visible to the motorist and convey the information that is needed by the motorist to safely pass through the work area.

After the work has begun the traffic control layout should be checked from time to time. Checks can be made in the morning before work starts, at noon, in the afternoon following work, and once after dark.

Proper maintenance of the traffic control devices is very important. Dirty signs and channelizing devices must be cleaned. Damaged or missing signs and channelizing devices must be replaced. Channelizing devices that have been displaced by vehicular contact, slip stream from trucks, workers or wind must be replaced in their original position.

## Removal

Traffic control devices (signs, channelizing devices, pavement markings) that are not applicable because either work has not started yet or work has been finished or a change has been made in the traffic control pattern must be either removed, securely covered or turned so that they do not face traffic. Signs that are no longer applicable and are covered must be covered with an opaque material. Burlap or other materials that are not opaque are not acceptable. At night, non-opaque materials let the messages be seen because headlights reflect the message through the material.

Methods for pavement marking removal include grinding, burning, chemical treatment, sandblasting, hydroblastic, and high pressure water jetting. Overpainting no longer appropriate markings with black paint or bituminous solutions is not allowed by the *Manual on Uniform Traffic Control Devices*.



## Documentation

Traffic control actions taken in the field should be recorded. Documentation should include:

- starting and ending time of work
- location of work
- type, condition and position of traffic control devices
- names of personnel
- types of equipment used and
- any change in temporary or permanent regulatory devices.

Several methods of recording traffic control can be used. These include:

- photologging
- photographs either keyed to a diary or containing a brief description of time, location, direction, and photographer's name
- special notes on construction plans
- daily diary entries of times, locations, and names of individuals involved in the installation, change, and removal of traffic control devices

Change orders or work orders should be keyed to the diary when used. Routine inspections should be performed and documented. When inspections reveal a condition that requires correction, documentation should include:

- description of correction needed, when it was noted and by whom
- corrections made or deferred and why
- replacements made or deferred and why
- any other needed actions

Instructions to contractors and subcontractors should be recorded.

In case of an accident, the circumstances and relevant factors should be promptly recorded and documented. Photographs of the site are recommended.

## Flagging

Flaggers should only be used when required to control traffic or when all other methods of traffic control are inadequate to warn and direct motorists. Flaggers are responsible for the safety of traffic and workers. They should be alert, have good eyesight, quick reflexes, and a thorough understanding of their job. For short work areas where both ends can be seen at the same time one flagger may be adequate. Both directions of traffic must be able to see the flagger and to recognize the person as a flagger. On longer work areas, two or more flaggers are often needed.

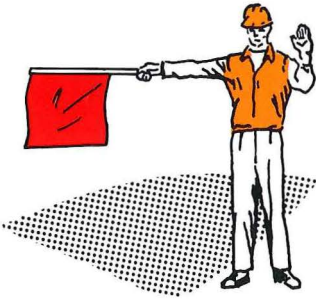
Flaggers are required to wear orange or fluorescent orange clothing such as a vest, shirt or jacket. The wearing of an orange hard hat is recommended. For night time conditions, similar garments shall be reflectorized and a floodlighted flagger's station is recommended. Flaggers may use either a red 24" flag or a reflectorized 18" STOP-SLOW paddle. The paddle is recommended over the flag. The standard signals to be used by flaggers are shown in Figure 9.12. Flaggers should be visible, should always face traffic and should be prepared to warn workers to get out of the way if necessary.

Flaggers stations shall be located far enough in advance of work site so that approaching traffic will have sufficient distance to reduce speed before entering the project, usually 200 to 300 feet is desirable. In urban areas when speeds are low and streets closely spaced, the distance necessarily must be decreased.

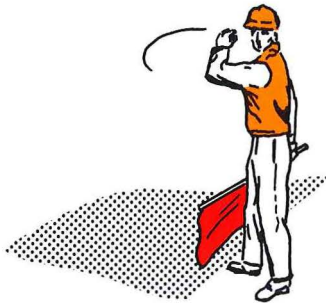
The flagger should stand either on the shoulder adjacent to the traffic being controlled or in a barricaded lane. At a spot obstruction a position may have to be taken on the shoulder opposite the barricaded section. Under no circumstances should a flagger stand in a lane being used by moving traffic.

Whenever a flagger is on duty, the advance flagger sign should be displayed to traffic. When a flagger is not on duty, the sign should be removed or covered.

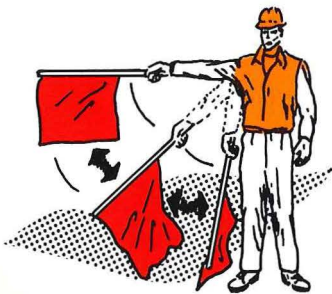
FLAG



TO STOP  
TRAFFIC



TRAFFIC  
PROCEED



TO ALERT  
AND SLOW  
TRAFFIC

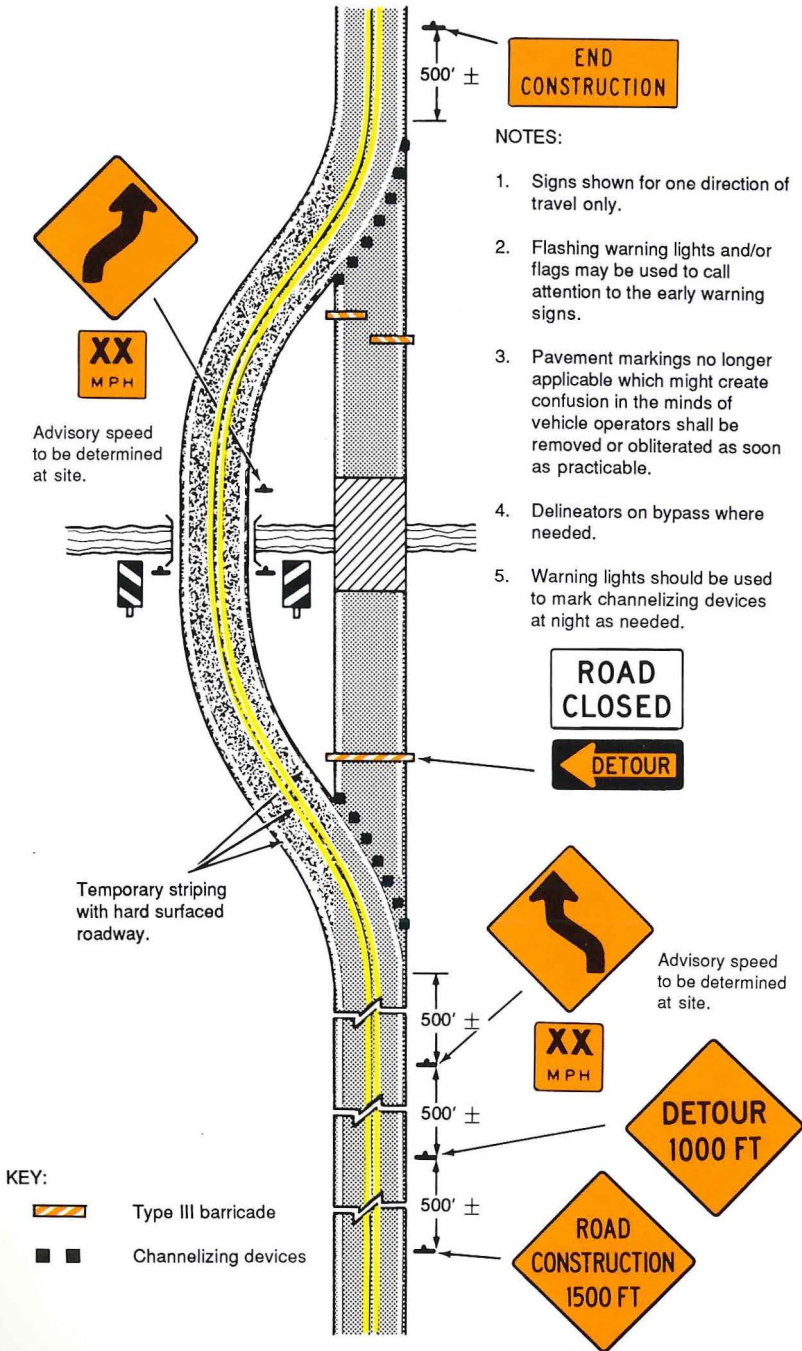
PADDLE



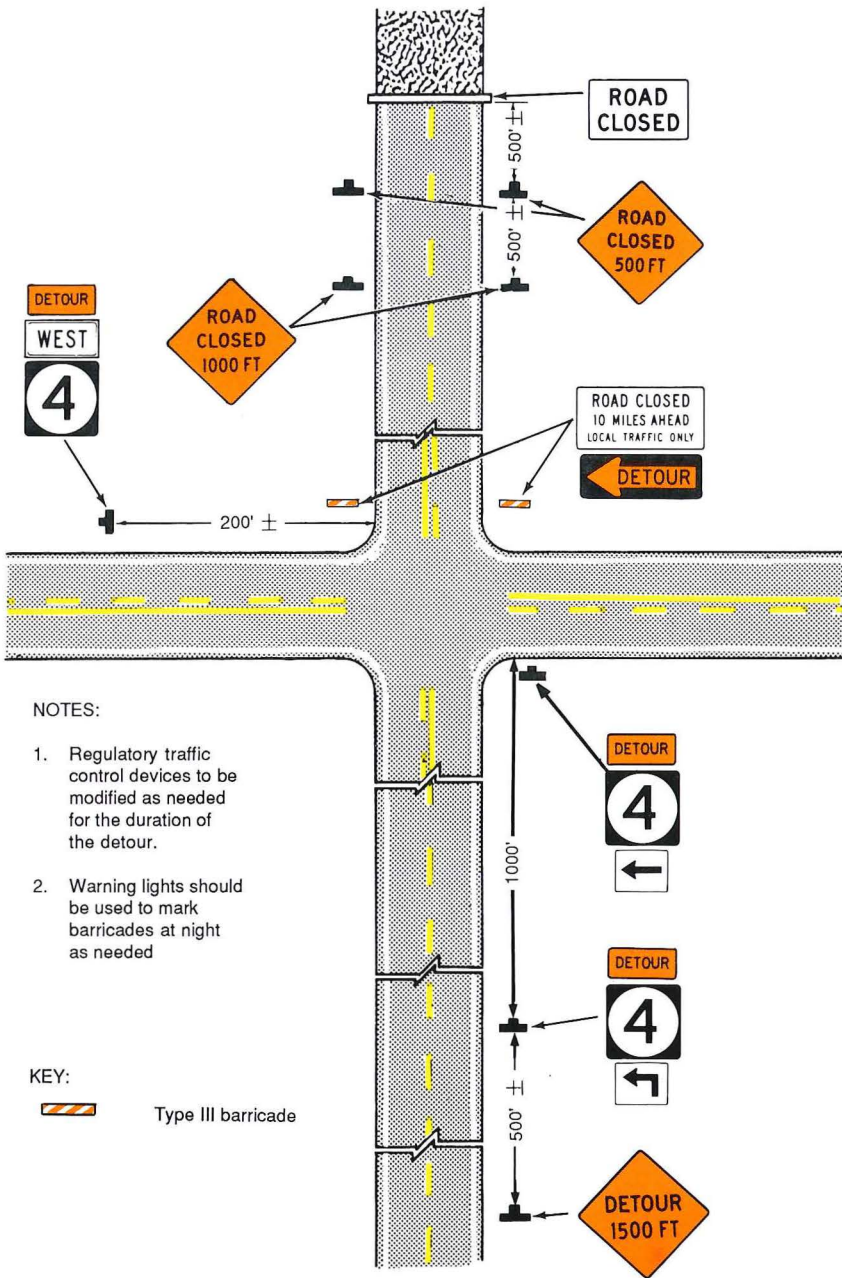
Figure 9.12: Use of Hand Signaling Devices by Flagger. [9-1]

## Examples

The following illustrations (Figures 9.13 through 9.29) are examples of layouts for two-lane two-way roadways. The *Manual on Uniform Traffic Control Devices* states "No one standard sequence of signs or other control devices can be set up as an inflexible arrangement for all situations due to the variety of conditions encountered." These examples taken from the MUTCD and other publications are the minimum desirable layouts for normal situations. Additional protection must be provided when special complexities and hazards are present. There is a need to recognize the physical and traffic operational characteristics of each individual construction or maintenance work area when developing the traffic control plan for use of the various traffic control devices (signs, pavement markings, channelizing devices) at the work site.



**Figure 9.13: Typical Applications of Traffic Control Devices on a Two-lane Highway Where the Entire Roadway is Closed and a Bypass Detour is Provided. [9-1]**



NOTES:

1. Regulatory traffic control devices to be modified as needed for the duration of the detour.
2. Warning lights should be used to mark barricades at night as needed

KEY:


 Type III barricade

Figure 9.14: Typical Application -- Roadway Closed Beyond Detour Point. [9-1]

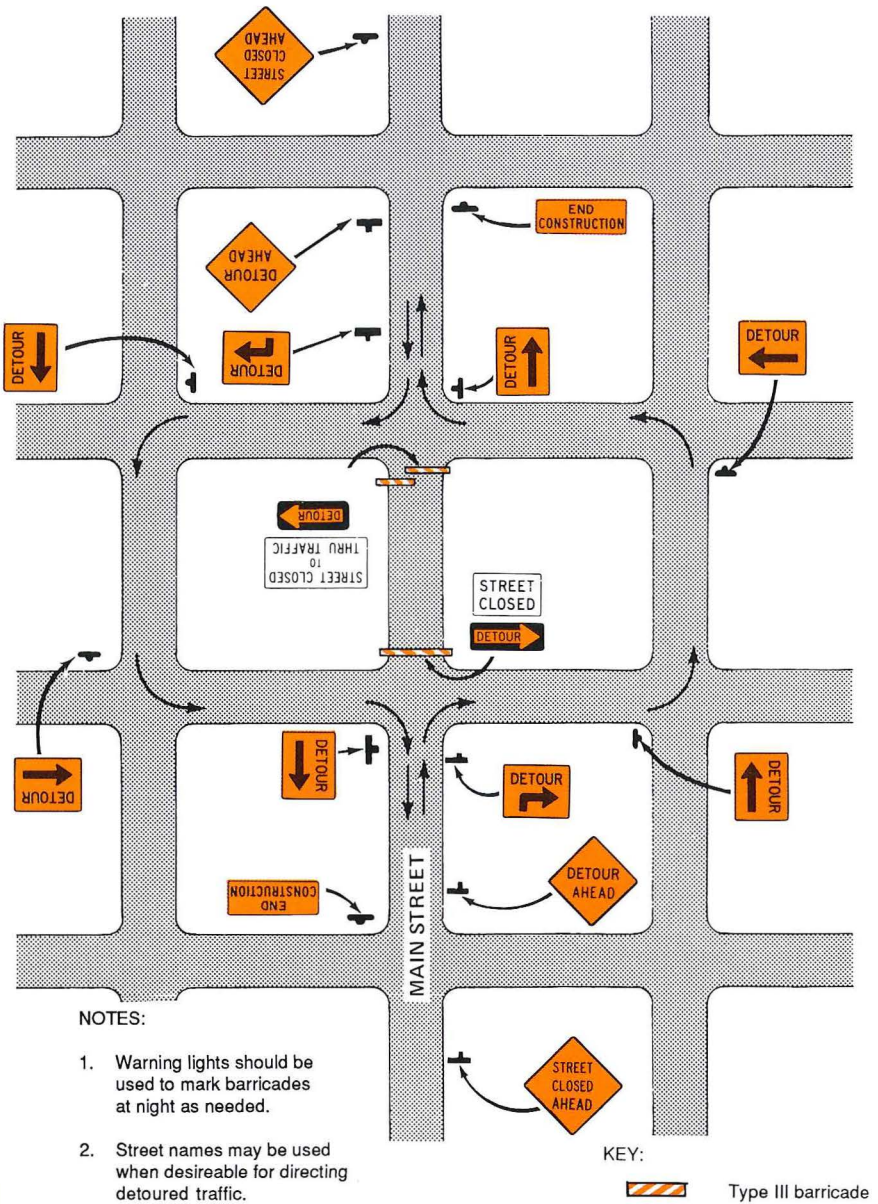


Figure 9.15: Typical Application -- Detour Signing for Street Construction Project in a Street Grid. [9-1]









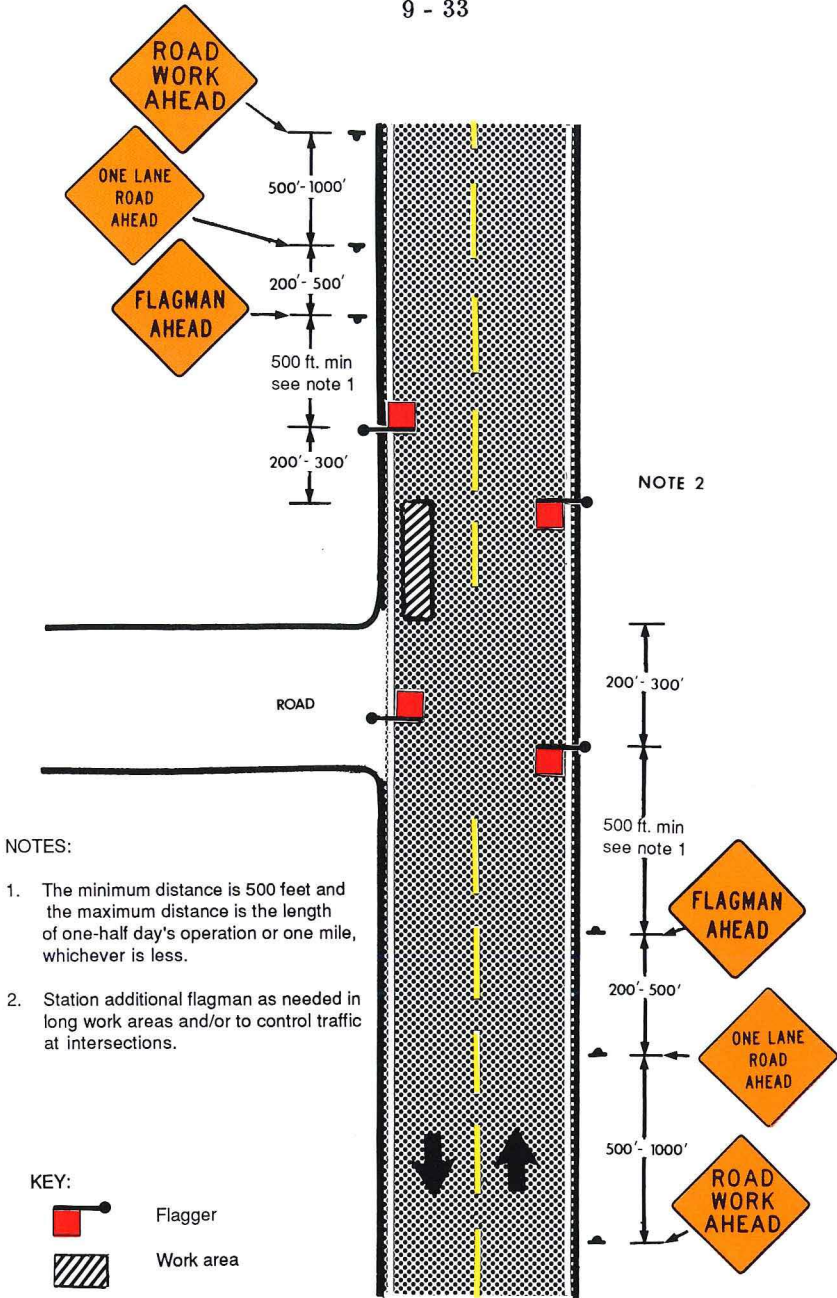


Figure 9.19: Two Lane Highway -- One Lane Obstructed -- Extended Work Zone. [9-5]

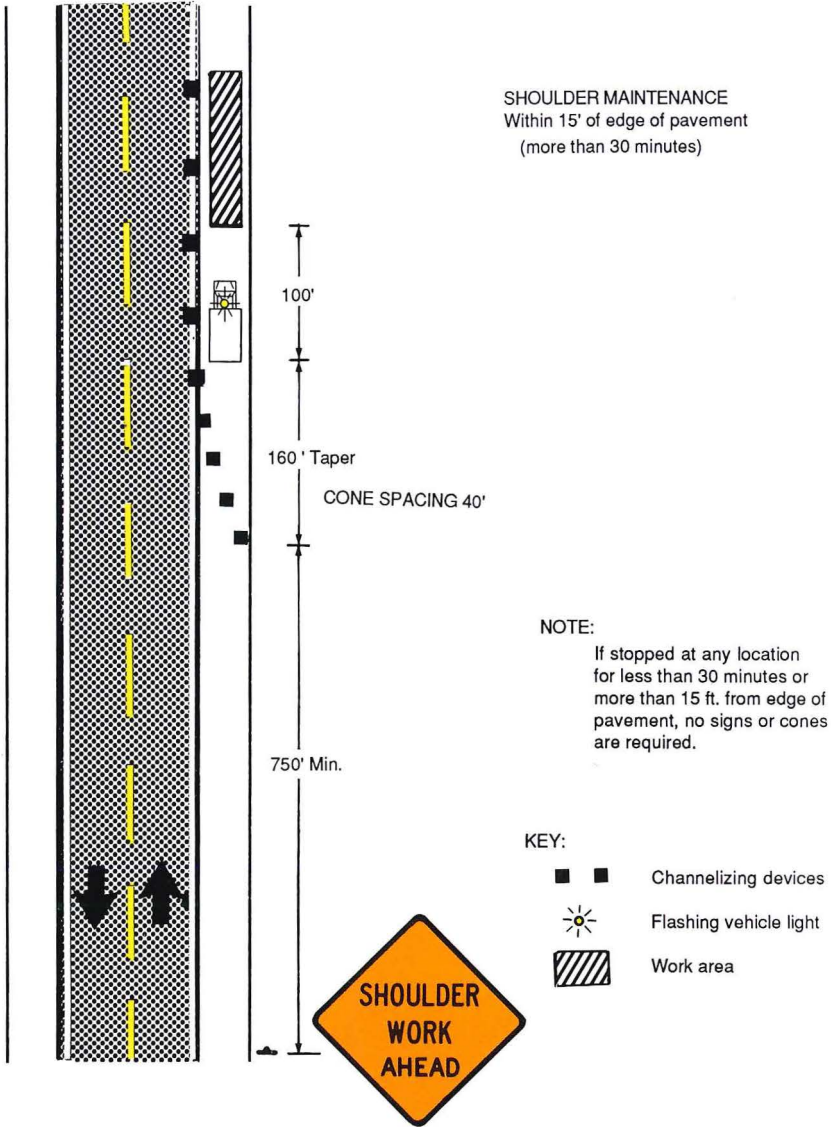


Figure 9.20: Two Lane Highway -- Shoulder Maintenance.  
[9.5]

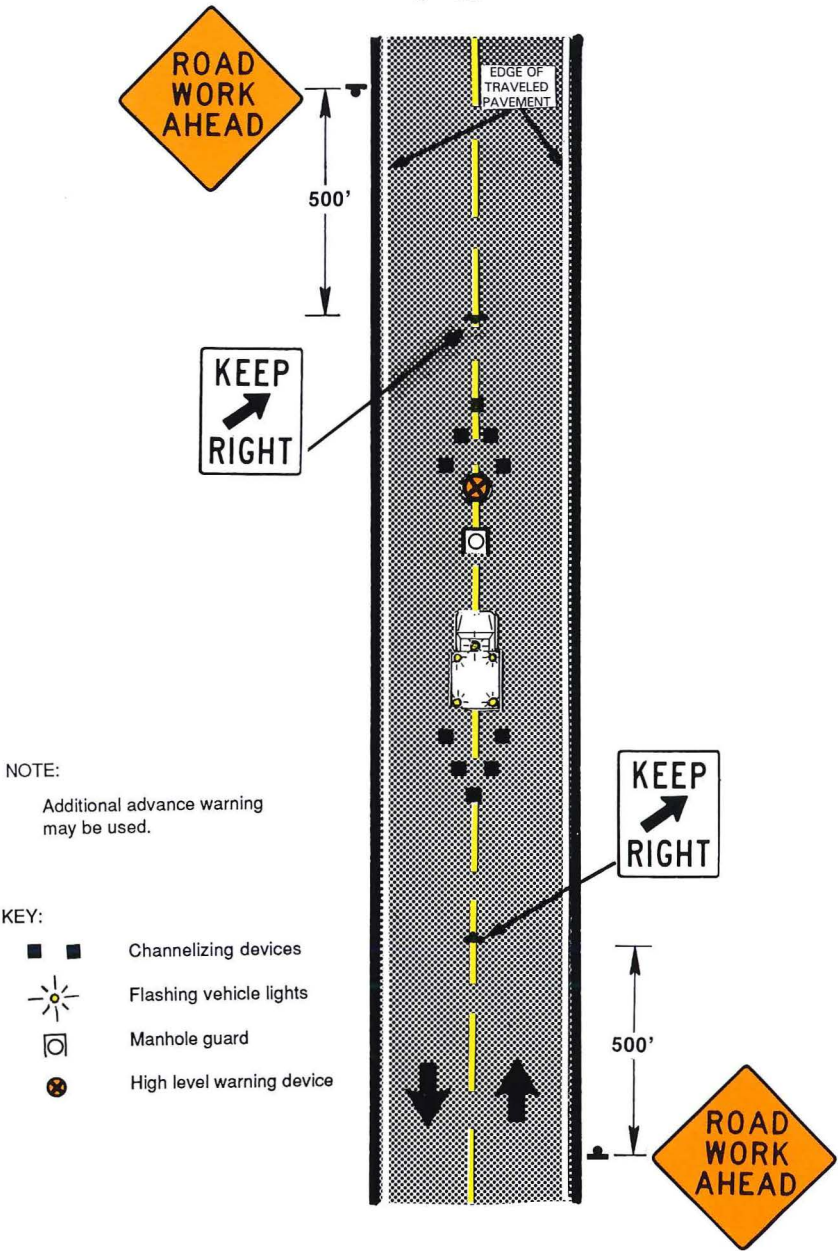


Figure 9.21: Typical Application of Traffic Control Devices on a Short-term Utility Operation in an Urban Location. [9-2]

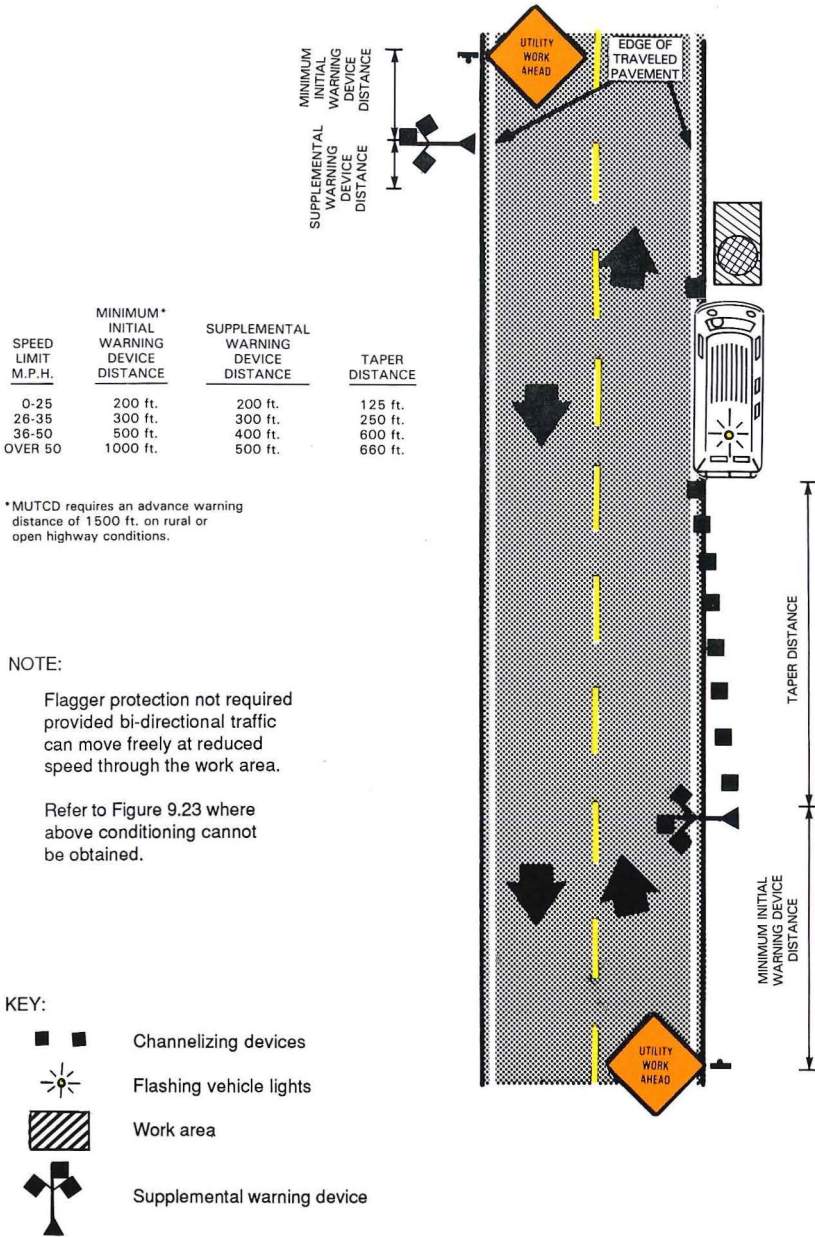


Figure 9.22: Typical Application for a Utility Work Zone on a Two-lane Roadway with Low Traffic Volume. [9-2]

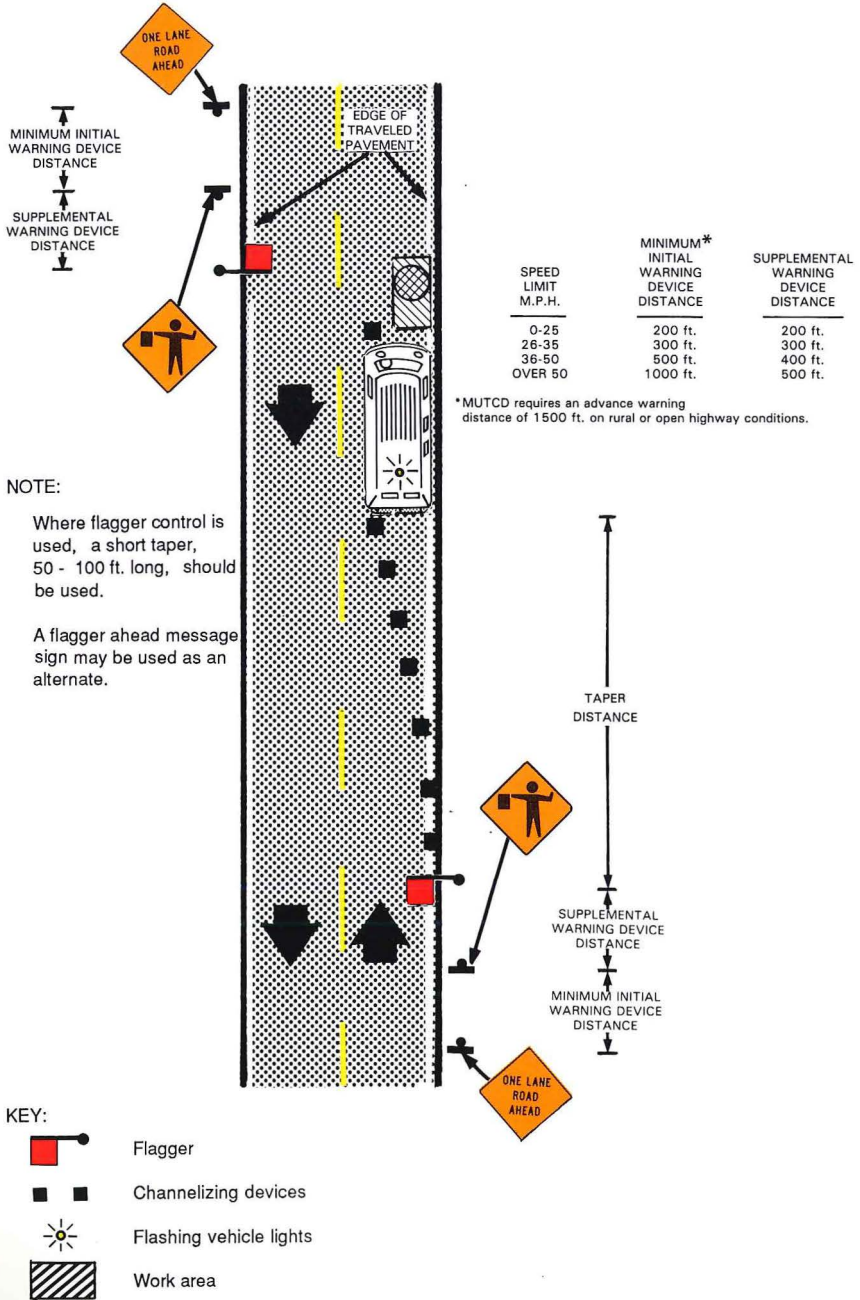
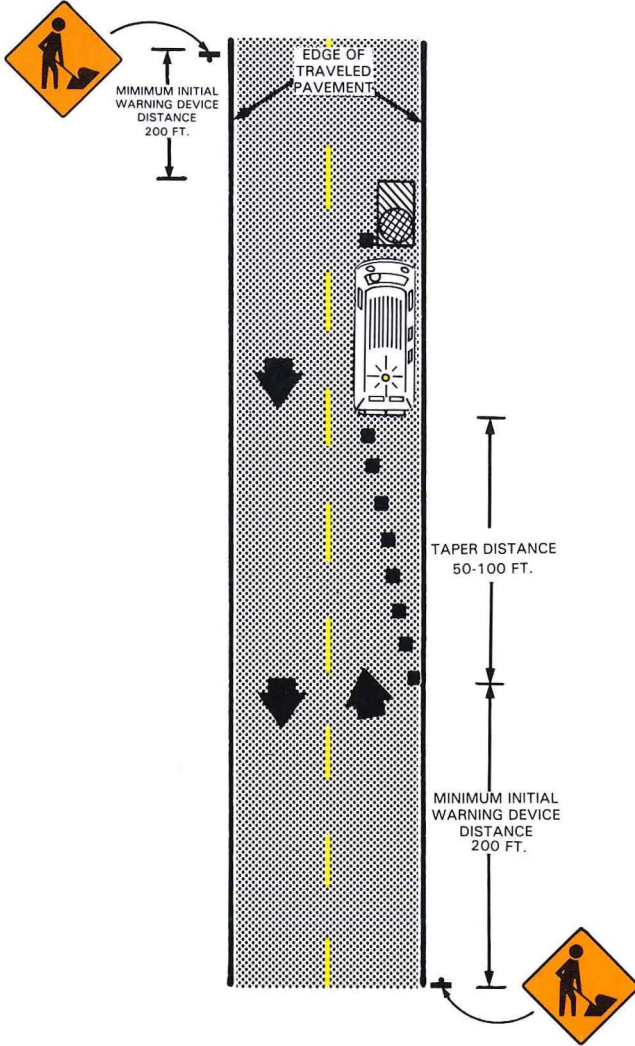


Figure 9.23: Typical Application for a Utility Work Zone on a Two-lane Roadway. [9-2]



NOTES:

Where a flagger is required because of traffic volume or visibility, refer to Figure 9.23 for set-up.

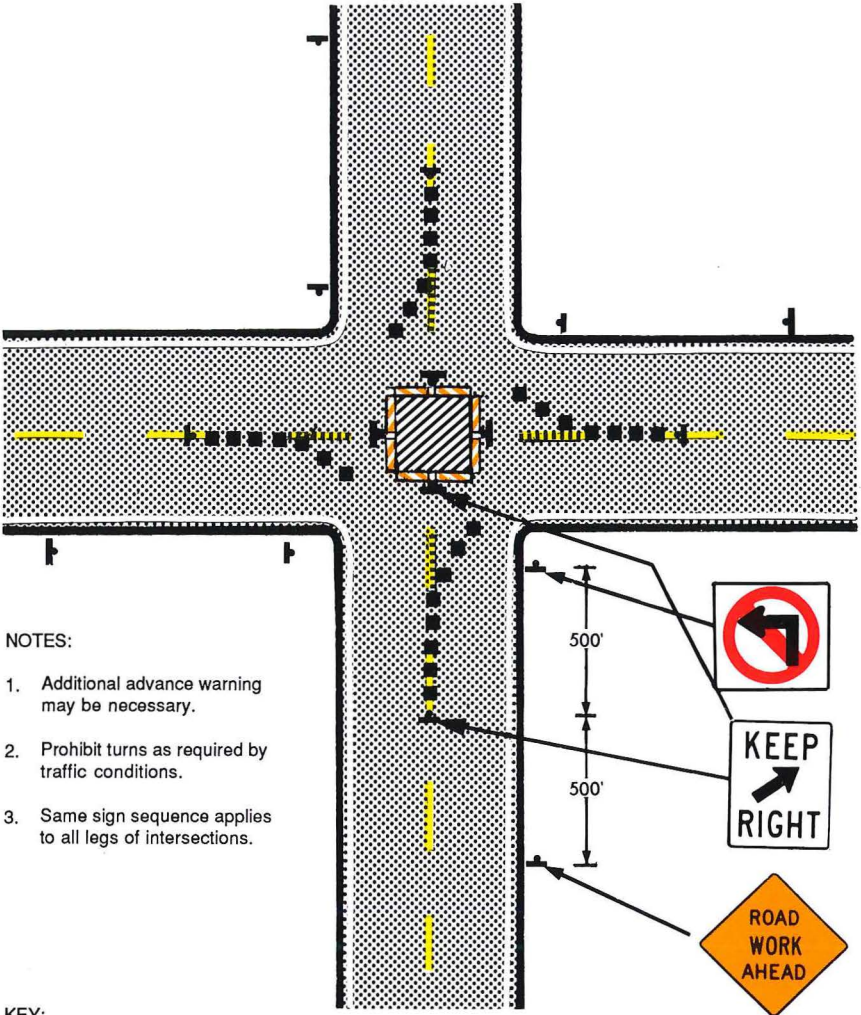
With very few exceptions, this control device set-up is not to be used in rural areas. Typical applications of traffic control devices on other roadways are shown on figures 9.22 and 9.23

KEY:

- ■ Channelizing devices
- ☀ Flashing vehicle light
- ▨ Work Area

**Figure 9.24: Typical Application for a Utility Work Zone on a Two-lane Residential Street (Low Traffic Volume). [9-2]**





NOTES:

1. Additional advance warning may be necessary.
2. Prohibit turns as required by traffic conditions.
3. Same sign sequence applies to all legs of intersections.

KEY:



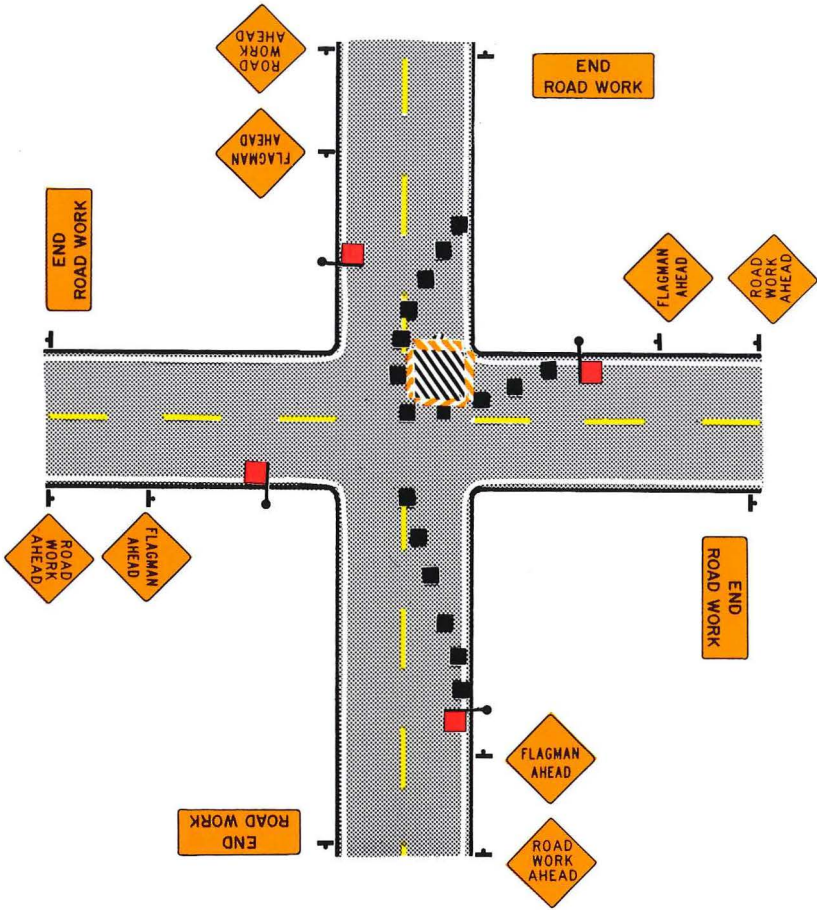
- ■ Channelizing devices
-  Work Area
-  Type III barricades
- ..... Pavement markings that should be removed for a long term project. Temporary markings to be placed as needed.

Figure 9.25: Typical Application of Traffic Control Devices when the Work Area is in the Center of an Intersection. [9-2]



NOTES:

Low volumes (2 lanes), use one flagger at center of intersection.

High volumes (4 lanes), use four flaggers on intersection legs as shown.

"ONE LANE ROAD AHEAD" sign may also be necessary to provide adequate advanced warning.

NOTE FOR NIGHT CLOSURE:

1. Flashing lights on signs
2. Steady burn lights for delineation and channelization

KEY:





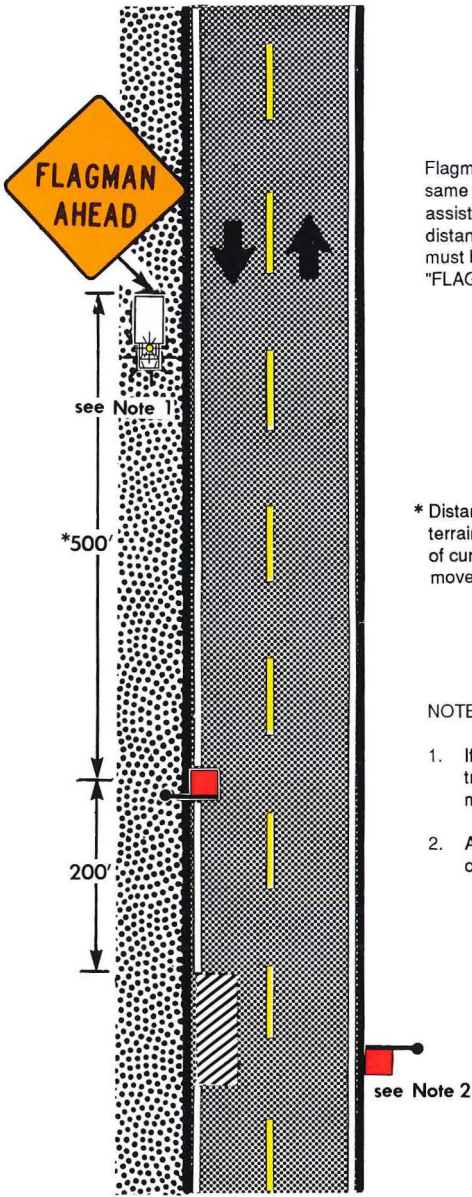
-  Flagger
-  Channelizing devices
-  Work Area
-  Type III barricades

Figure 9.26: Flagger Control for Intersection Lane Closure.  
[9-4]



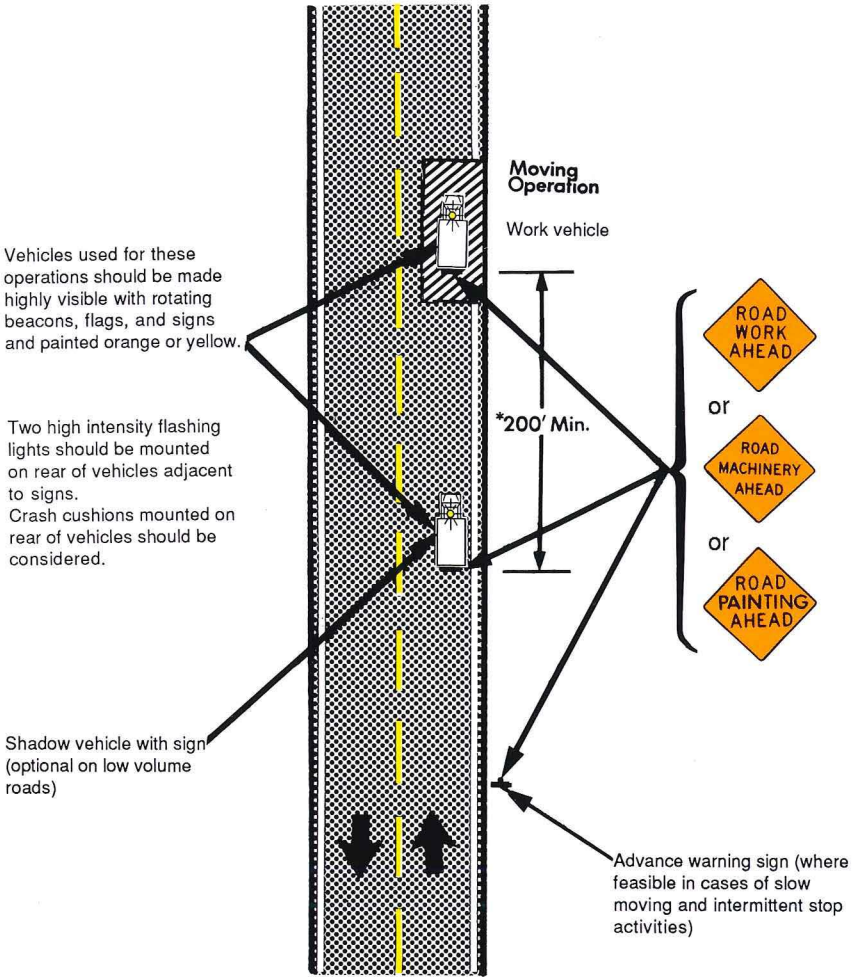
Flagman to control only traffic moving in the same direction as work vehicle. Flagman to assist driver in choosing gaps when sight distance is limited. When traffic is heavy, and must be controlled for both directions, use a "FLAGMAN AHEAD" sign for both directions.

\* Distance requirement dependent on terrain. Sign truck to stay at beginning of curve or top of hill until work has moved 1500' from beginning or top.



NOTES:

1. If shoulder restricts getting truck off pavement, use tripod standard. Distance to standard should be minimum 500', maximum 1 mile.
2. Alternate location of flagman on low volume roads or if work area on curve.

Figure 9.27: Two Lane Highway -- One Lane Obstructed (less than 30 minutes). [9-5]

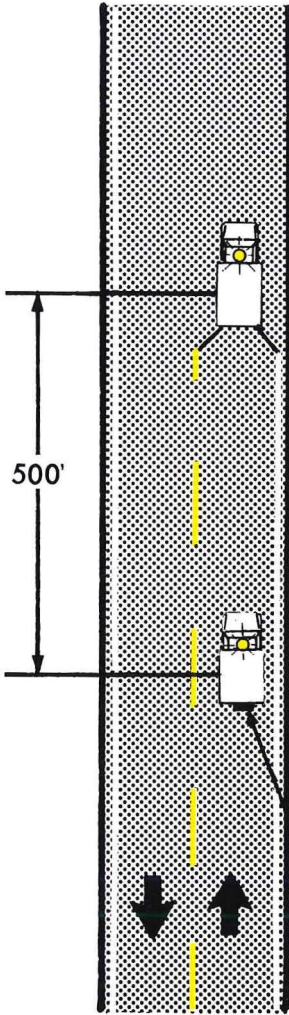


KEY:

-  Flashing vehicle light
-  Work Area

\*Distance requirement depends on terrain. Shadow truck with sign to stay at beginning of curve or top of hill until work has moved 1000 ft. to 1500 ft. from beginning or top.

Figure 9.28: Two Lane Highway -- One Lane Obstructed -- Moving Operation. [9-5]



NOTES:

1. With this type of control, the work and shadow vehicles should pull over frequently to allow traffic to pass.
2. The distance between the work and shadow vehicles may vary according to terrain, paint drying time and other factors.
3. Additional shadow vehicles to warn and reduce speed of oncoming traffic may be used.
4. Another method for traffic control is to perform edge striping from the shoulders and to place the center line with the work and shadow vehicles directly over the centerline.
5. Crash cushions mounted on the rear of the vehicles should be considered.
6. Two high-intensity flashing lights should be mounted on rear of vehicles adjacent to sign.

KEY:



Flashing vehicle light



or



Figure 9.29: Typical Application -- Using a Shadow Vehicle for Advance Warning. [9-2]

## Bibliography

- [9-1]. Indiana Department of Highways, *Indiana Manual on Uniform Traffic Control Devices for Streets and Highways*, 1981.
- [9-2]. Federal Highway Administration, U.S. Department of Transportation, *Work Zone Traffic Control, Standards and Guidelines*, 1985 Edition (Part VI, Traffic Controls for Street and Highway Construction and Maintenance Operations of the Manual on Uniform Traffic Control Devices and Part VI, Work Zone Traffic Control of the Traffic Control Devices Handbook).
- [9-3]. Federal Highway Administration, U.S. Department of Transportation, Franklin, J. D. et. al, *Traffic Controls in Construction and Maintenance Work Zones*, Volume 1, Office Function, FHWA-TS-77-204, May 1977.
- [9-4]. Federal Highway Administration, U.S. Department of Transportation, Franklin, J. D. et. al, *Traffic Controls in Construction and Maintenance Work Zones*, Volume II, Field Function, FHWA-TS-77-203, May 1977.
- [9-5]. Indiana Department of Highways, Division of Maintenance, *Worksite Traffic Control Manual for Daylight Maintenance and Traffic Operations*, June 1981.
- [9-6]. J. W. Hall and J. D. Brogan, Construction and Maintenance Area Traffic Control Short Course Notes, University of New Mexico, June 1984.







## CHAPTER 10

# SIGN INVENTORY AND MAINTENANCE

There are two important reasons for seeing that traffic control devices remain in their original location and in good condition:

1. The continued safety of the traveling public.
2. The minimization of tort liability arising from missing or damaged signs.

“Low volume roads appear particularly susceptible to lawsuits since they are typically constructed to lower standards than high volume routes and because funding levels are not adequate to deal with problem locations” [16]. While the physical condition of roadways and bridges is the primary cause of claims on low volume roads, the condition of traffic control devices can also become a legal issue. Fortunately, a number of low-cost, routine procedures can be adopted to greatly reduce the liability of those responsible for traffic control devices. These procedures are all elements of a sign inventory.

### Recommended Elements of a Sign Inventory

#### List of Signs by Location

Each time a traffic control sign is installed or replaced, its number and location should be recorded. Some of the information which may be included in a sign inventory list includes a record of:

1. type and size of sign,
2. time, date, and by whom the sign was installed or inventoried,
3. location of the sign,
4. condition of the sign, to include a note as to whether or not the sign is reflectorized; and
5. time, date, and by whom any maintenance was performed on the sign.



TRAFFIC CONTROL DEVICES INSPECTION SHEET

Sheet No.

County/ Township Jones Road identification: Rd. No. 6 Location, direction Co. Rd "x" to Co. Rd 2" - length 6.0 M

Beginning point Begin of Co. Rd. 6 and "x" east

Odometer Reading	Side of Road	Sign No.	Sign I.D.	Sign Type	Inspection Date ( Note Condition)			
					Date	Action taken	Date	Action taken
0.00	Rt	1	R1-1	Stop	✓			
0.82	Rt.	2	W2-1	Int.	✓			
		2	W13-1	Adv. Speed Pl.	✓			
1.00	L+R	3	R1-1	stop	✓			
1.18	L	4	W2-1	Int	✓			
		4	W13-1	Adv. Speed Pl.	✓			
1.25	L+R	5	OM-2	Obj. Marker	1-OM-2 missing	OM2 Replaced 1-4-80		
2.00	L+R	6	R1-1	stop	✓			
2.3	R	7	W10-1	RR Adv. Warn.	✓			
2.5	L	8	W10-1	" " "	✓			
3.0	L+R	9	R1-1	Stop	bullet holes			
3.2	R	10	W5-2	Narrow Bridge	✓			
3.3	L+R	11	OM-3	Obj. Markers	✓			
3.31	L+R	12	OM-3	" "	✓			
3.41	L	14	R1-2	Yield	✓			
4.0	R	15	R1-1	stop	✓			
4.2	R	16	W1-2	Curve	Poor reflectivity			
4.7	L	17	W1-2	"	✓			
6.0	L+R	18	R1-1	stop	too low	sign raised 1-3-80		
Inspector					ADM	ADM		

- ✓ - sign is OK
- - needs attention

Figure 10.1: Record of Field Inspections. [5]

## **Marked signs**

It is a distinct advantage in identifying and recovering signs that have been removed by vandals if each has a special number stamped, engraved, etched, or painted on it. The numbering may be quite simple -- merely having the abbreviation or number of the county, for example. A much more complete and useful marking system would include the number of the sign used in the original inventory list. Thus, "IN-79-113" would indicate sign #113 installed by Tippecanoe County in Indiana. Further codes as to location and date of installation could be added, but these are more easily kept in the Sign Inventory Files for each sign.

## **Periodic Field Inspection**

As often as experience dictates, each sign in the inventory should be inspected to see if it is still in place, is clean and visible, and is undamaged. (See Figure 10.1 on previous page.) The findings should be used to update the sign inventory, and corrective action taken within a reasonable time.

## **A Formal Complaint System**

Local citizens can be a valuable source of information to supplement periodic inspections and detect particularly hazardous developments. The actions taken in response to a citizen's call or complaint should be organized along these lines:

1. Record date and time of complaint,
2. Record name, address and telephone number of complainant,
3. Record location and description of problem,
4. Rank the problem according to an established priority system based upon potential criticality of having an accident (see Priority System below),
5. Investigate, if necessary, in order to determine necessary corrective action,
6. Contact maintenance personnel and instruct them to take appropriate action, immediately in case of a high priority ranking,

7. Record time, date and to whom the corrective action instructions were assigned,
8. Ask for local law enforcement support at location, if necessary, until action can be taken,
9. Record date and time that corrective action was completed,
10. Upon completion of action, notify complainant about corrective action taken, and express appreciation for assistance,
11. Maintain a record system of all complaints, and file according to location, and
12. Provide for periodic review of records, noting recurring problems that may need special attention.

### **A Priority System**

The highway department budget may not permit an immediate response to every citizen's complaint. The following list contains several factors that may be included in developing a priority system for selecting the order of responding to citizen complaints:

1. The number of accidents in a given area,
2. The severity of accidents in a given area,
3. The volume of traffic in a given area,
4. The amount of work to be done by the Highway Department as a total,
5. The availability of manpower,
6. The availability of equipment,
7. The availability of materials, and
8. The finances available to the Highway Department.

### **General Comments**

It is a common argument that highway budgets do not always allow replacement of missing or damaged signs within a reasonable time, but the propensity of accident victims -- even those who apparently contributed to the accident -- to file lawsuits against every conceivable party makes the replacement effort an important one. The best defense against unsafe roadways and legal action is a systematic procedure for using available resources most efficiently. The information and records systems described in this chapter have these considerations in mind.

## APPENDIX A

# APPROACH SPEED AND SIGHT DISTANCE

### Speeds and Speed Signs

The use of speed limit signs should normally follow the guidelines outlined in the Indiana MUTCD. Additional recommended guidelines taken from Walton, et al. [2], for use on low volume roads are as follows. If the normal operating speed (defined as the 85th percentile speed) is 50 mph or greater, placement shall be (a) at all points where dissimilar speed limits or speed reduction areas terminate or begin and (b) beyond all intersections. Also, speed limit signs may not be necessary on roadways with normal operating speeds less than 50 mph, since road surface, sight distance (described later), or geometric conditions will establish the safe speed and the roadway itself will serve as reinforcement. It is also not advised to place speed limit signs on any unpaved roadways unless required by law [2].

Procedures for establishing speed limits or estimating actual approach speeds should follow the guidelines set forth in the Indiana MUTCD, section 2B-10.I2. The speeds so found can be used in the tables in the text below.

### Sight Distance at Intersections [5]

It is desirable that the driver have an unobstructed view of the intersection and a length of the intersecting road sufficient to permit control of the vehicle to avoid collisions. When traffic at the intersection is controlled by signs, the unobstructed view may be limited to the area of control. The minimum sight distance considered safe under various assumptions of physical conditions and driver behavior is related directly to vehicle speeds and to the resultant distances traversed during perceptions and reaction time and during braking.

## Minimum Sight Triangle

There should be unobstructed sight along both roads at an intersection and across their included corner for distances sufficient to allow the operators of vehicles approaching simultaneously to see each other in time to prevent collision at the intersection. (See Figure A.1.)

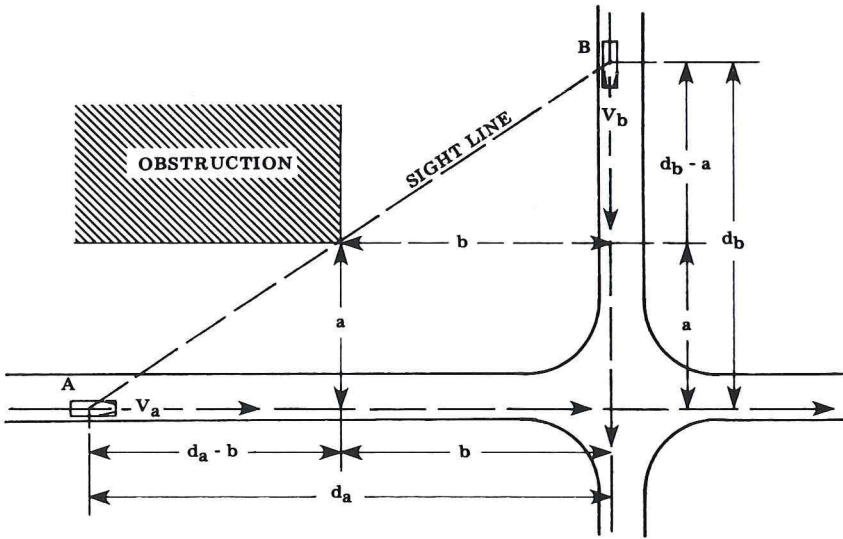


Figure A.1: No Stop or Signal Control at Intersection. Cases I and II. [5]

Two general cases at intersections are considered. In each case assumptions are made of a physical layout and of the actions of vehicle operators on both intersecting roads. For each, the space-time-velocity relations indicate the minimum sight triangle required to be free of obstructions or, if a sight triangle below the desirable minimum must be used, they fix the necessary modifications in approach speeds.

Any object within the sight triangle high enough above the elevation of the adjacent roadways to constitute a sight obstruction should be removed or lowered. Such objects include cut slopes, hedges, bushes, or tall crops. This requires the elimination of parking within the sight triangle. This applies whether the intersecting roads are level or on grades.

## No Stop or Signal Control at Intersection

### Case I--Enabling Vehicles to Adjust Speed

Where a crossing is not controlled by YIELD signs, STOP signs, or traffic signals, the operator of a vehicle approaching an intersection should be able to perceive a hazard in sufficient time to alter the speed of his vehicle as necessary before reaching the intersection. The minimum time in which deceleration can be started is the driver perception and reaction time which, for intersection design, can be assumed to be 2 seconds. In addition, the driver should begin actual braking some distance from the intersection to accomplish deceleration to avoid collision. An arbitrary minimum for the distance from an intersection, where a driver can first see a vehicle approaching the intersection on the intersecting road, is that traversed during 2 seconds for perception and reaction plus 1 additional second to actuate braking or accelerating to regulate speed. The distances traveled by a vehicle in 3 seconds are:

Speed (mph)	10	20	25	30	40	45	50	55
Distance (feet)	45	90	110	130	180	200	220	240

Under case I for given speeds the minimum sight triangle is determined by these minimum distances along the road. Referring to Figure A.1, highway A with 50 mph speed and highway B with 30 mph speed would require an unobstructed sight triangle between points on highways A and B with legs extending at least 220 feet and 130 feet, respectively, from the intersection. These or greater distances would permit a vehicle on either road to change speed, before reaching the intersection.

Intersections with sight triangles having road distances no greater than those indicated above are not necessarily safe since there is possible confusion between vehicle operators and the possibility of a driver on one highway being confronted with a succession of vehicles on the intersecting highway when the time and distance are sufficient only to avoid one vehicle. Even where only one vehicle on each of adjacent legs approaches an intersection, both vehicles may begin to slow down and reach

the intersection at the same time. The use of the above distances, which are only one-half to two-thirds of the safe stopping distances, to determine the unobstructed sight triangle is a minimum and not a desirable practice. They should be used only in the design of rural intersections on lightly traveled highways and where the removal of corner sight obstructions would be costly. Where the triangle described is not open to view, signs may be erected to effect a slowing down or stopping of vehicles on one road even if both roads are lightly traveled.

### Case II--Enabling Vehicles to Stop

In this set of conditions for crossings not controlled by YIELD signs, STOP signs or traffic signals, it is assumed that the operator of a vehicle on either highway should be able to see the intersection and the intersecting highway in sufficient time to stop his vehicle, if necessary, before reaching the intersection. The safe stopping distances for intersection design are the same as those for design at any other section of highway. The minimum stopping sight distances are:

Speed (mph)	10	20	25	30	40	50	60
Safe Stopping Distance (feet)	50	120	160	200	275	350	475

For two highways of known design speeds, the minimum sight triangle determined by these case II minimum distances is a much safer design than that with the limited case I distances. An operator sighting a vehicle on the intersecting road may stop, if necessary, or otherwise change speed to avoid hazard. There is some danger of confusion between drivers because both may slow down and reach the intersection at the same time, but this danger is slight due to the great number of speed-change possibilities, the time available, and the normal decrease in speed as an intersection is approached under such conditions.

### Description of Sight Distance

Adequate sight distance makes a lower level of signing possible. Using the tables in the text above, the following example will enable the user of this manual to determine whether there is adequate sight distance on all directions of approach.



### Example 1

Road A has an approach speed of 50 mph and road B has an approach speed of 40 mph. A triangle of clear visibility is developed using the approach speeds of the two legs of the triangle (Figure A.2). A driver on road A must have clear visibility of road B for 180 feet in each direction from the intersection when he/she is at a point 220 feet from the intersection. The reverse, of course, must also hold. A driver on road B, traveling at the 40 mph approach speed 180 feet from the crossroads, must be able to see 220 feet along road A in both directions from the crossing. These values will allow drivers on both roadways to have enough time to adjust their speeds to avoid a conflict. Any obstruction of the field of view over 3 feet in height within the Clear Visibility Triangle of Figure A.2 makes some traffic control at the intersection necessary.

The sight distance available on the lesser volume (the minor) road should permit a safe approach speed greater than 10 mph in order to consider a control less positive than a stop.

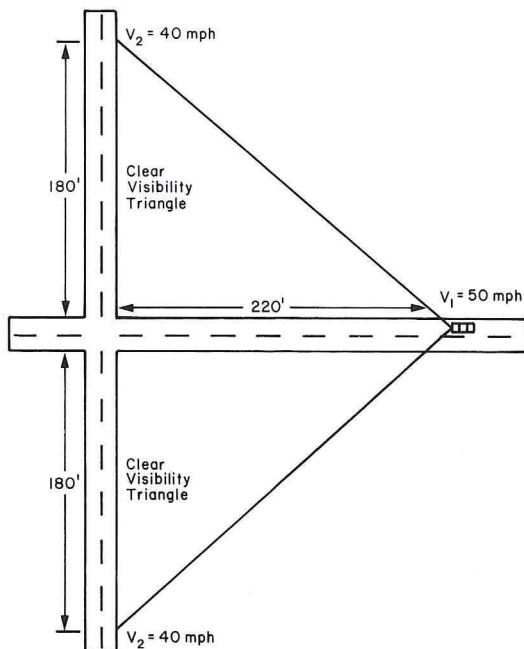


Figure A.2: Required Sight Distance Triangle for No Intersection Control. [2]

## Obstructions to Sight [5]

Where an obstruction, which cannot be removed except at prohibitive cost, fixes the vertices of the sight triangle at points that are less than the safe stopping distances from the intersection, vehicles may be brought to a stop (after sighting other vehicles on the intersecting road) only if they are traveling at a speed appropriate to the available sight distance. If vehicles on one of the roads are permitted to travel at the design speed, the critical corresponding speed on the other road can be evaluated in terms of the design speed and the dimensions to the known obstruction.

### Example 2

Referring to Figure A.1 in the typical case where speed  $V_a$  is known,  $a$  and  $b$  are the known distances to the sight obstruction from the respective paths of vehicles A and B. The critical speed ( $V_b$ ) of vehicle B can then be evaluated in terms of these known factors. Distance  $d_a$  is the minimum stopping distance for vehicle A. When vehicle A is at a distance  $d_a$  from the intersection and the drivers of vehicles A and B first sight each other, vehicle B is at a distance  $d_b$  from the intersection. By the proportions of similar triangles

$$d_b = \frac{ad_a}{d_a - b}$$

and the critical speed  $V_b$  is that for which the stopping distance is  $d_b$ . The signs on road B, showing the safe speed with which to approach the intersection, should be so located that a driver can reduce his speed to  $V_b$  by the time he reaches the point that is the distance  $d_b$  from the intersection. Similar calculations may be used to determine how far back an obstruction need be moved to provide sufficient sight for safe driving at desired vehicle speeds on the respective roads.

## APPENDIX B

# ROAD CLASSIFICATION

The low volume roads within the state have a wide variability of type and condition. Some are well designed and well maintained, while others are nothing more than dirt roads that become difficult to ride on when there are poor weather conditions. For this reason, not all low volume roads should be classified similarly and have traffic control devices placed in the same manner. For example, gravel roads can never have pavement markings, the same type of passing maneuvers cannot be undertaken on all types of low volume roads, and there are general conditions of the road and roadside that can be vastly different in their effect upon driving behavior. Design speeds and available sight distances also can be very different, with each road having its own set of characteristics. Although it would be very difficult for this handbook to anticipate and prescribe traffic control devices for every conceivable set of circumstances, it is possible to classify roads into three major types. This will make it easier to provide guidance on how to consistently sign and mark most roads. However, use of engineering judgment is always important where special situations occur or where direct use of this handbook is difficult.

The three types of roadways addressed in this handbook are called Type A, Type B, and Type C. Table B.1 is to be used as an aid in classifying road types. Various characteristics are listed and are assigned a value of 1, 2, or 3, according to whether they correspond to a Type A, B, or C road, respectively. The total of all of the characteristics' values are then compared to the values listed in Table B.2, where a road is assigned a classification of A, B, or C.

Again, this is only an aid toward the more uniform placement of signs and markings. There may be some roads with special circumstances that would make the use of Tables B.1 and B.2 inappropriate, but this procedure systematizes the process of evaluating a particular road's need for traffic control devices.

**Table B.1: Classification of Low Volume Roads.**

Road Type:	A(1 pt.)	B(2 pts.)	C(3 pts.)
Approach Speed	50 + mph	35-45 mph	< 35 mph
Surface Type	Paved	Stable Gravel or Sand	Natural Surface; Loose Gravel or Sand
Sight Distances at Intersections	At or Above Desired	Between Minimum and Desired	At or Below Minimum
Geometrics	Good	Fair	Poor
Consistency of Roadway	Very Much	Moderate	Little

**Table B.2: Determination of Road Type.**

Total Points:	5-7	8-12	13-15
Road Type:	A	B	C

## APPENDIX C

### TAPERING TECHNIQUE

A tapered roadway edge may be used to guide the driver away from hazardous obstacles such as bridge abutments, dropoffs, culverts or other objects which narrow the roadway.

Recommended minimum taper lengths are shown in Table C.1 below. The taper lengths in Table C.1 were adapted from Figure 3-10 of the National MUTCD. [13] See Figure C.1 for the meanings of L and W.

**Table C.1: Minimum Taper Lengths (L, feet).**

Prevailing Speed	Less than 30 mph	30-40 mph	Over 40 mph
W (feet)			
2 or less	30	50	100
3	45	75	150
4	60	100	200
6	90	150	300

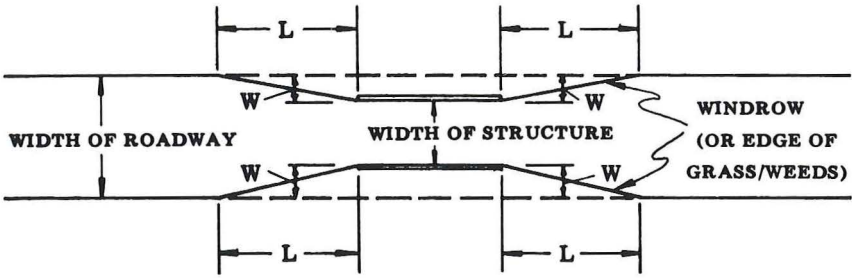


Figure C.1: Taper Details.

## APPENDIX D

# SELECTED INDIANA STATE STATUTES

The contents of this handbook as well as the Indiana MUTCD are formulated to meet the requirements of the statutes of the State of Indiana. The following statutes are those that allow for the use of this handbook and the MUTCD (since this handbook is within the guidelines of the Indiana MUTCD): Indiana Code 4-22-2, 9-4-1, 9-4-2, and 9-4-3. Sections that may be of special interest to users of this handbook are:

- |           |  |
|-----------|--|
| 9-4-1-30  | Manual and specifications                      |
| 9-4-1-31  | Manual and specifications; state highways      |
| 9-4-1-32  | Local authorities; highways under jurisdiction |
| 9-4-2-1   | Manual; scope                                  |
| 9-4-2-2   | Manual; statewide application                  |
| 9-4-2-3   | Manual; repeal of conflicting laws             |
| 9-4-3.1-1 | Standards                                      |
| 9-4-3.1-4 | Permission to install traffic control devices  |





## BIBLIOGRAPHY

1. Alexander, G.J. and Lunenfeld, H. *Positive Guidance in Traffic Control*. Washington, D.C.: U.S. Department of Transportation, Federal Highway Administration, 1975.
2. Walton, N.E., Mounce, J.M., Stockton, W.R. "Signs and Markings for Low Volume Roads." *Report No. FHWA-RD-77-39*. U.S. Department of Transportation, Federal Highway Administration, Washington, D.C., May 1977.
3. Walton, N.E., Mounce, J.M., Stockton, W.R. *Guidelines for Signing and Marking of Low-Volume Rural Roads*. Texas Transportation Institute, Texas A&M University, College Station, Texas, March 1976.
4. Hall, D.L. "Energy, Air Pollution, Delay, and Safety Evaluation of Non-Signalized Control at Low Volume Intersections." *Report No. CE-TRA-77-1*. Purdue University, School of Civil Engineering, West Lafayette, Indiana, August 1977.
5. Smith, B.L. and Gerth, S.L. *Handbook of Traffic Control Practices for Low Volume Rural Roads*. Through Kansas Department of Transportation and Kansas County Engineers Association, Kansas State University, 1981.
6. Glennon, J.C. "Design and Traffic Control Guidelines for Low Volume Rural Roads." *NCHRP Report 214*, Transportation Research Board, Washington D.C., October 1979.
7. Indiana Department of Highways. *Indiana Manual on Uniform Traffic Control Devices for Streets and Highways*. 1981.

8. Stockton, W.R., Brackett, R.Q., Mounce, J.M. "Stop, Yield, and No Control at Intersections." *Report No. FHWA-RD-81-084*. U.S. Department of Transportation, Federal Highway Administration, Washington, D.C., May 1977.
9. Lyles, Richard W. "Advisory and Regulatory Speed Signs for Curves: Effective or Overused?" *ITE Journal*, Vol. 52, No. 8, August 1982, p. 20-22.
10. Lum, Harry S. and Parker, Martin R., Jr. "Intersection Control and Accident Experience in Rural Michigan." *Public Roads*, Vol. 46, No. 3, December 1982, p. 102-105. Same article also published in *ITE Journal*, Vol. 53, No. 5, May 1983, p. 27.
11. Stockton, W. R. "Toward More Efficient Low Volume Intersection Control." *Proceedings, International Symposium on Traffic Control Systems*, Volume 2C, University of California at Berkeley, December 1979. Cited in reference 10.
12. *Uniform Vehicle Code and Model Traffic Ordinance, Supplement II*. National Committee on Uniform Traffic Laws and Ordinances, Washington, D. C., 1976. As cited in [10].
13. *Manual on Uniform Traffic Control Devices*. U.S. Department of Transportation, Federal Highway Administration, Washington, D. C., 1978.
14. Dyar, Robert D. "An Analysis of Driver Observance of Stop Signs." *Masters Thesis*, Clemson University, 1977. As cited in [8].
15. Dale, C. W. "Cost Analysis of Intersection Traffic Controls." *Traffic Engineering*, Vol. 36, No. 8, May 1966.
16. Eck, Ronald W. and Hisham H. Malaeb "Reducing Tort Liability on Low Volume Roads Through Analysis of Case Law." *Transportation Research Record* 898, p. 115f.