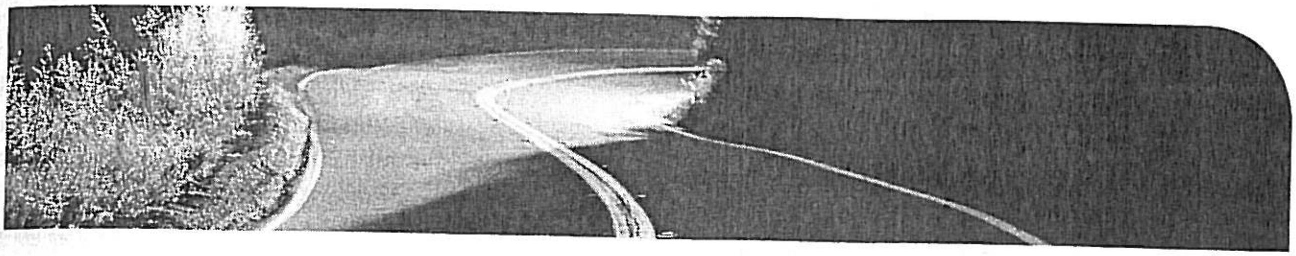


Chapter 3

Roadside Topography and Drainage Features

3.0 OVERVIEW

This chapter discusses the development and evaluation of the forgiving roadside concept and its application to roadside design and clear zones. It also discusses embankment slopes and ditches and how these features influence roadside features such as curbs, culverts, and drop inlets, whose purpose is to provide adequate roadway drainage. The designer is presented with several options that enhance safety without affecting the capabilities of these elements to drain the highway.

Most of the forgiving roadside design principles discussed in this chapter have been practiced to varying degrees for several years. This chapter attempts to reemphasize and collect the currently accepted design principles to provide guidance in the area of roadside design. However, to include every recommendation or design value in this chapter on every future highway project is neither feasible nor possible. Engineering judgment will have to play a part in determining the extent to which improvements reasonably can be made with the limited resources available.

As the designer studies the options available, some consideration should be given to the future maintenance of drainage facilities and roadside topography. Ongoing repair and upkeep will be necessary to ensure the continued function and safety of various roadside drainage features. Personnel, materials, equipment, and cost are some of the considerations in every maintenance program. The designer should take into account the exposure of crews to traffic conditions while completing repairs. Also, maintenance activities can cause various levels of disruption in the traffic flow, which may increase the potential for crashes.

3.1 THE CLEAR-ZONE CONCEPT

Beginning in the early 1960s, as more Interstate highways and other freeways were opened to traffic, the nature and characteristics of the typical rural highway crashes began to change. Instead of head-on crashes with other vehicles or crashes involving trees immediately adjacent to the roadway, many drivers were running off the new freeways and colliding with man-made objects, such as bridge piers, sign supports, culverts, ditches, and other design features of the roadside. In 1967, the American Association of State Highway Officials (AASHO) Traffic Safety Committee (currently the American Association of State Highway and Transportation Officials [AASHTO] Standing Committee on Highway Traffic Safety) issued a report entitled, *Highway Design and Operational Practices Related to Highway Safety (2)*. This document became known as the "Yellow Book," and its principles were widely applied to highway construction projects, particularly high-speed, controlled-access facilities. A second edition of the Yellow Book, published by AASHTO in 1974, stated that "for adequate safety, it is desirable to provide an unencumbered roadside recovery area that is as wide as practical on a specific highway section. Studies have indicated that on high-speed highways, a width of 9 m [30 ft] or more from the edge of the through traveled way permits about 80 percent of the errant vehicles leaving the roadway to recover"*(6)*.

Subsequently, most highway agencies began to try to provide a 9-m [30-ft] clear zone, particularly on high-volume, high-speed, rural roadways. A clear zone is the unobstructed, traversable area provided beyond the edge of the through traveled way for the recovery of errant vehicles. The clear zone includes shoulders, bike lanes, and auxiliary lanes, except those auxiliary lanes that function like through lanes. Many obstacles located within this clear-zone distance were removed, relocated, redesigned, or shielded by traffic barriers or crash cushions. It soon became apparent, however, that in some limited situations in which the embankment sloped significantly downward, a vehicle could encroach farther from the through traveled way and a 9-m [30-ft] clear zone might not be adequate. Conversely, on most low-volume, urban, or low-speed facilities, a 9-m [30-ft] clear-zone distance was considered excessive and seldom could be justified for engineering, environmental, or economic reasons.

The 1977 AASHTO *Guide for Selecting, Locating, and Designing Traffic Barriers (1)* modified the earlier clear-zone concept by introducing variable clear-zone distances based on traffic volumes, speeds, and roadside geometry. Table 3-1 can be used to determine the suggested clear-zone distance for selected traffic volumes and speeds. However, Table 3-1 provides only a general approximation of the needed clear-zone distance. These data are based on limited empirical data that were extrapolated to provide information for a wide range of conditions. The designer should keep in mind site-specific conditions, design speeds, rural versus urban locations, and practicality. The distances obtained from Table 3-1 should suggest only the approximate center of a range to be considered and not a precise distance to be held as absolute. For roadways with low traffic volumes, it may not be practical to apply even the minimum values found in Table 3-1. Refer to Chapter 12 for additional considerations for low-volume roadways and Chapter 10 for additional guidance for urban applications.

Table 3-1. Suggested Clear-Zone Distances in Meters (Feet) from Edge of Through Traveled Lane *(6)*

Metric Units

Design Speed (km/h)	Design ADT	Foreslopes			Backslopes		
		1V:6H or flatter	1V:5H to 1V:4H	1V:3H	1V:3H	1V:5H to 1V:4H	1V:6H or flatter
≤60	UNDER 750[c]	2.0–3.0	2.0–3.0	[b]	2.0–3.0	2.0–3.0	2.0–3.0
	750–1500	3.0–3.5	3.5–4.5	[b]	3.0–3.5	3.0–3.5	3.0–3.5
	1500–6000	3.5–4.5	4.5–5.0	[b]	3.5–4.5	3.5–4.5	3.5–4.5
	OVER 6000	4.5–5.0	5.0–5.5	[b]	4.5–5.0	4.5–5.0	4.5–5.0
70–80	UNDER 750[c]	3.0–3.5	3.5–4.5	[b]	2.5–3.0	2.5–3.0	3.0–3.5
	750–1500	4.5–5.0	5.0–6.0	[b]	3.0–3.5	3.5–4.5	4.5–5.0
	1500–6000	5.0–5.5	6.0–8.0	[b]	3.5–4.5	4.5–5.0	5.0–5.5
	OVER 6000	6.0–6.5	7.5–8.5	[b]	4.5–5.0	5.5–6.0	6.0–6.5
90	UNDER 750[c]	3.5–4.5	4.5–5.5	[b]	2.5–3.0	3.0–3.5	3.0–3.5
	750–1500	5.0–5.5	6.0–7.5	[b]	3.0–3.5	4.5–5.0	5.0–5.5
	1500–6000	6.0–6.5	7.5–9.0	[b]	4.5–5.0	5.0–5.5	6.0–6.5
	OVER 6000	6.5–7.5	8.0–10.0[a]	[b]	5.0–5.5	6.0–6.5	6.5–7.5
100	UNDER 750[c]	5.0–5.5	6.0–7.5	[b]	3.0–3.5	3.5–4.5	4.5–5.0
	750–1500	6.0–7.5	8.0–10.0[a]	[b]	3.5–4.5	5.0–5.5	6.0–6.5
	1500–6000	8.0–9.0	10.0–12.0[a]	[b]	4.5–5.5	5.5–6.5	7.5–8.0
	OVER 6000	9.0–10.0[a]	11.0–13.5[a]	[b]	6.0–6.5	7.5–8.0	8.0–8.5
110[d]	UNDER 750[c]	5.5–6.0	6.0–8.0	[b]	3.0–3.5	4.5–5.0	4.5–5.0
	750–1500	7.5–8.0	8.5–11.0[a]	[b]	3.5–5.0	5.5–6.0	6.0–6.5
	1500–6000	8.5–10.0[a]	10.5–13.0[a]	[b]	5.0–6.0	6.5–7.5	8.0–8.5
	OVER 6000	9.0–10.51	11.5–14.0[a]	[b]	6.5–7.5	8.0–9.0	8.5–9.0

Notes:

a) When a site-specific investigation indicates a high probability of continuing crashes or when such occurrences are indicated by crash history, the designer may provide clear-zone distances greater than the clear zone shown in Table 3-1. Clear zones may be limited to 9 m for practicality and to provide a consistent roadway template if previous experience with similar projects or designs indicates satisfactory performance.

b) Because recovery is less likely on the unshielded, traversable 1V:3H foreslope on a fill section, fixed objects should not be present in the vicinity of the toe of these slopes. Recovery of high-speed vehicles that encroach beyond the edge of the shoulder may be expected to occur beyond the toe of slope. Determination of the width of the recovery area at the toe of slope should consider right-of-way availability, environmental concerns, economic factors, safety needs, and crash histories. Also, the distance between the edge of the through traveled lane and the beginning of the 1V:3H slope should influence the recovery area provided at the toe of slope. While the application may be limited by several factors, the foreslope parameters that may enter into determining a maximum desirable recovery area are illustrated in Figure 3-2. A 3-m recovery area at the toe of slope should be provided for all traversable, non-recoverable fill slopes.

c) For roadways with low volumes, it may not be practical to apply even the minimum values found in Table 3-1. Refer to Chapter 12 for additional considerations for low-volume roadways and Chapter 10 for additional guidance for urban applications.

d) When design speeds are greater than the values provided, the designer may provide clear-zone distances greater than those shown in Table 3-1.

U.S. Customary Units

Design Speed (mph)	Design ADT	Foreslopes			Backslopes		
		1V:6H or flatter	1V:5H to 1V:4H	1V:3H	1V:3H	1V:5H to 1V:4H	1V:6H or flatter
≤40	UNDER 750[c]	7–10	7–10	[b]	7–10	7–10	7–10
	750–1500	10–12	12–14	[b]	12–14	12–14	12–14
	1500–6000	12–14	14–16	[b]	14–16	14–16	14–16
	OVER 6000	14–16	16–18	[b]	16–18	16–18	16–18
45–50	UNDER 750[c]	10–12	12–14	[b]	8–10	8–10	10–12
	750–1500	14–16	16–20	[b]	10–12	12–14	14–16
	1500–6000	16–18	20–26	[b]	12–14	14–16	16–18
	OVER 6000	20–22	24–28	[b]	14–16	18–20	20–22
55	UNDER 750[c]	12–14	14–18	[b]	8–10	10–12	10–12
	750–1500	16–18	20–24	[b]	10–12	14–16	16–18
	1500–6000	20–22	24–30	[b]	14–16	16–18	20–22
	OVER 6000	22–24	26–32[a]	[b]	16–18	20–22	22–24
60	UNDER 750[c]	16–18	20–24	[b]	10–12	12–14	14–16
	750–1500	20–24	26–32[a]	[b]	12–14	16–18	20–22
	1500–6000	26–30	32–40[a]	[b]	14–18	18–22	24–26
	OVER 6000	30–32[a]	36–44[a]	[b]	20–22	24–26	26–28
65–70[d]	UNDER 750[c]	18–20	20–26	[b]	10–12	14–16	14–16
	750–1500	24–26	28–36[a]	[b]	12–16	18–20	20–22
	1500–6000	28–32[a]	34–42[a]	[b]	16–20	22–24	26–28
	OVER 6000	30–34[a]	38–46[a]	[b]	22–24	26–30	28–30

Notes:

a) When a site-specific investigation indicates a high probability of continuing crashes or when such occurrences are indicated by crash history, the designer may provide clear-zone distances greater than the clear zone shown in Table 3-1. Clear zones may be limited to 30 ft for practicality and to provide a consistent roadway template if previous experience with similar projects or designs indicates satisfactory performance.

b) Because recovery is less likely on the unshielded, traversable 1V:3H fill slopes, fixed objects should not be present in the vicinity of the toe of these slopes. Recovery of high-speed vehicles that encroach beyond the edge of the shoulder may be expected to occur beyond the toe of slope. Determination of the width of the recovery area at the toe of slope should consider right-of-way availability, environmental concerns, economic factors, safety needs, and crash histories. Also, the distance between the edge of the through traveled lane and the beginning of the 1V:3H slope should influence the recovery area provided at the toe of slope. While the application may be limited by several factors, the foreslope parameters that may enter into determining a maximum desirable recovery area are illustrated in Figure 3-2. A 10-ft recovery area at the toe of slope should be provided for all traversable, non recoverable fill slopes.

c) For roadways with low volumes it may not be practical to apply even the minimum values found in Table 3-1. Refer to Chapter 12 for additional considerations for low-volume roadways and Chapter 10 for additional guidance for urban applications.

d) When design speeds are greater than the values provided, the designer may provide clear-zone distances greater than those shown in Table 3-1.

The designer may choose to modify the clear-zone distances in Table 3-1 with adjustment factors to account for horizontal curvature, as shown in Table 3-2. These modifications normally are considered only when crash histories indicate such a need, when a specific site investigation shows a definitive crash potential that could be significantly lessened by increasing the clear zone width, and when such increases are cost-effective. Horizontal curves, particularly for high-speed facilities, are usually superelevated to increase safety and provide a more comfortable ride. Increased banking on curves where the superelevation is inadequate is an alternate method of increasing roadway safety within a horizontal curve, except where snow and ice conditions limit the use of increased superelevation.

For relatively flat and level roadsides, the clear-zone concept is simple to apply. However, it is less clear when the roadway is in a fill or cut section where roadside slopes may be positive, negative, or variable, or where a drainage channel exists near the through traveled way. Consequently, these features should be discussed before a full understanding of the clear zone concept is possible.

Table 3-2. Horizontal Curve Adjustment Factor

Radius, m [ft]	Design Speed km/h [mph]					
	60 [40]	70 [45]	80 [50]	90 [55]	100 [65]	110 [70]
900 [2,950]	1.1	1.1	1.1	1.2	1.2	1.2
700 [2,300]	1.1	1.1	1.2	1.2	1.2	1.3
600 [1,970]	1.1	1.2	1.2	1.2	1.3	1.4
500 [1,640]	1.1	1.2	1.2	1.3	1.3	1.4
450 [1,475]	1.2	1.2	1.3	1.3	1.4	1.5
400 [1,315]	1.2	1.2	1.3	1.3	1.4	—
350 [1,150]	1.2	1.2	1.3	1.4	1.5	—
300 [985]	1.2	1.3	1.4	1.5	1.5	—
250 [820]	1.3	1.3	1.4	1.5	—	—
200 [660]	1.3	1.4	1.5	—	—	—
150 [495]	1.4	1.5	—	—	—	—
100 [330]	1.5	—	—	—	—	—

$CZ_c = (L_c)*(K_{cz})$

where:

CZ_c = Clear zone on outside of curvature, meters [feet]

L_c = Clear zone distance, meters [feet] (see Table 3-1)

K_{cz} = Curve correction factor

Note: The clear-zone correction factor is applied to the outside of curves only. Corrections are typically made only to curves less than 900-m [2,950-ft] radius.

3.2 ROADSIDE GEOMETRY

If a roadside is not flat, a motorist leaving the roadway will encounter a foreslope, a backslope, a transverse slope, or a drainage channel, as shown in Figure 3-1. Each of these features has an effect on a vehicle's lateral encroachment and trajectory as discussed in the following sections.

3.2.1 Foreslopes

Foreslopes parallel to the flow of traffic may be identified as recoverable, non-recoverable, or critical. Recoverable foreslopes are 1V:4H or flatter *(14)*. If such slopes are relatively smooth and traversable, the suggested clear-zone distance may be taken directly from Table 3-1. Motorists who encroach on recoverable foreslopes generally can stop their vehicles or slow them enough to return to the roadway safely. Fixed obstacles such as culvert headwalls normally will not extend above the foreslope within the clear-zone distance. Examples of suggested roadside design practices for recoverable foreslopes and the application of the clear-zone concept are in Section 3.3.

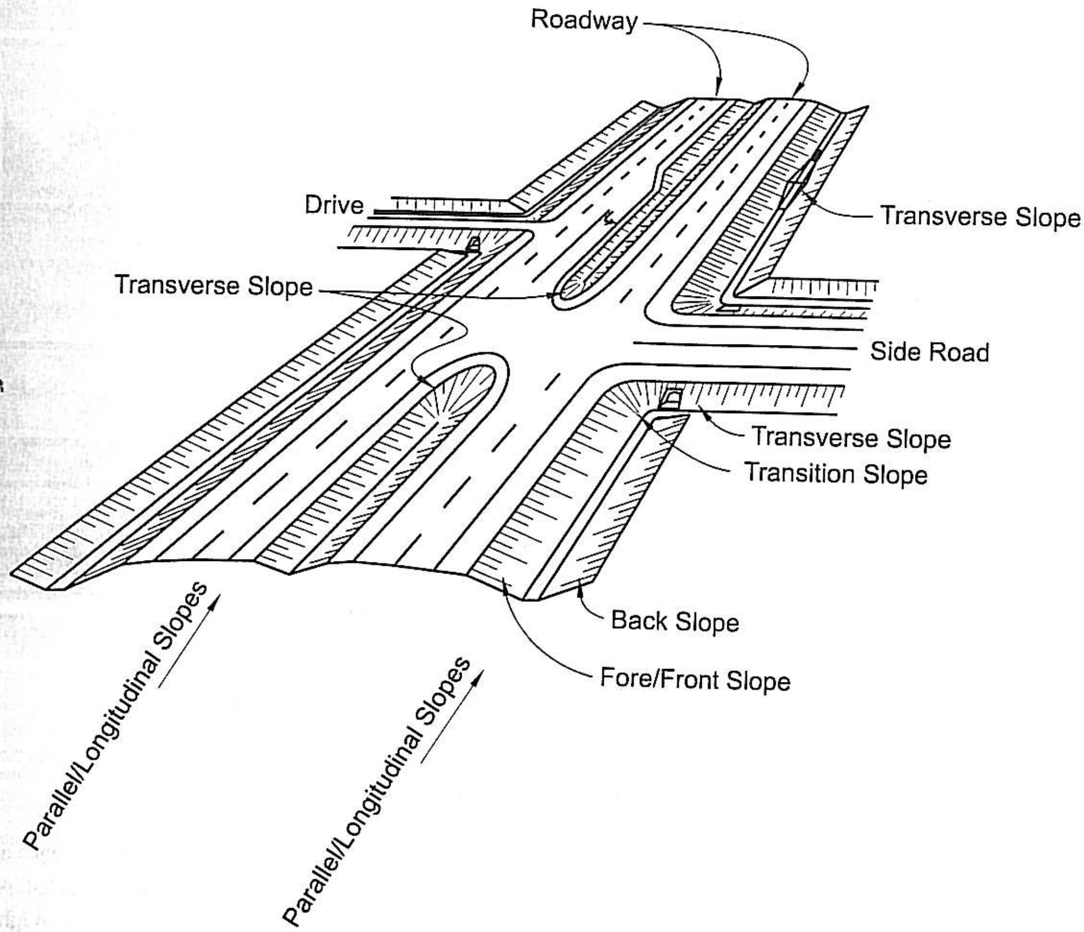


Figure 3-1. Roadway Geometry Features

A non-recoverable foreslope is defined as one that is traversable but from which most vehicles will not be able to stop or return to the roadway easily. Vehicles on such slopes typically can be expected to reach the bottom. Foreslopes between 1V:3H and 1V:4H generally fall into this category. Because a high percentage of encroaching vehicles will reach the toe of these slopes, the clear-zone distance cannot logically end on the slope. Fixed obstacles normally will not be constructed along such slopes and a clear runout area at the base is desirable. Section 3.3.2 discusses non-recoverable foreslopes. Example 3-C provides an example for a clear-zone computation.

A critical foreslope is one on which an errant vehicle has a higher propensity to overturn. Foreslopes steeper than 1V:3H generally fall into this category. If a foreslope steeper than 1V:3H begins closer to the edge of the traveled way than the suggested clear-zone distance for that specific roadway, a barrier might be recommended if the slope cannot readily be flattened. Barrier recommendations for critical foreslopes are discussed in Chapter 5.

Many states construct "barn roof" sections, providing a relatively flat recovery area adjacent to the roadway for some distance, followed by a steeper foreslope. Such a cross section is more economical than a continuous flat foreslope from the edge of the traveled way to the original ground line, and may be perceived as safer than constructing a continuous steeper foreslope from the edge of the shoulder. Figure 3-2 depicts the clear-zone distance reaching a non-recoverable parallel foreslope and the subsequent clear runout area that may be provided at the toe of the non-recoverable slope to provide a suggested adjusted clear-zone distance. This type of cross section is more fully discussed in Sections 3.3.2 and 3.3.4.

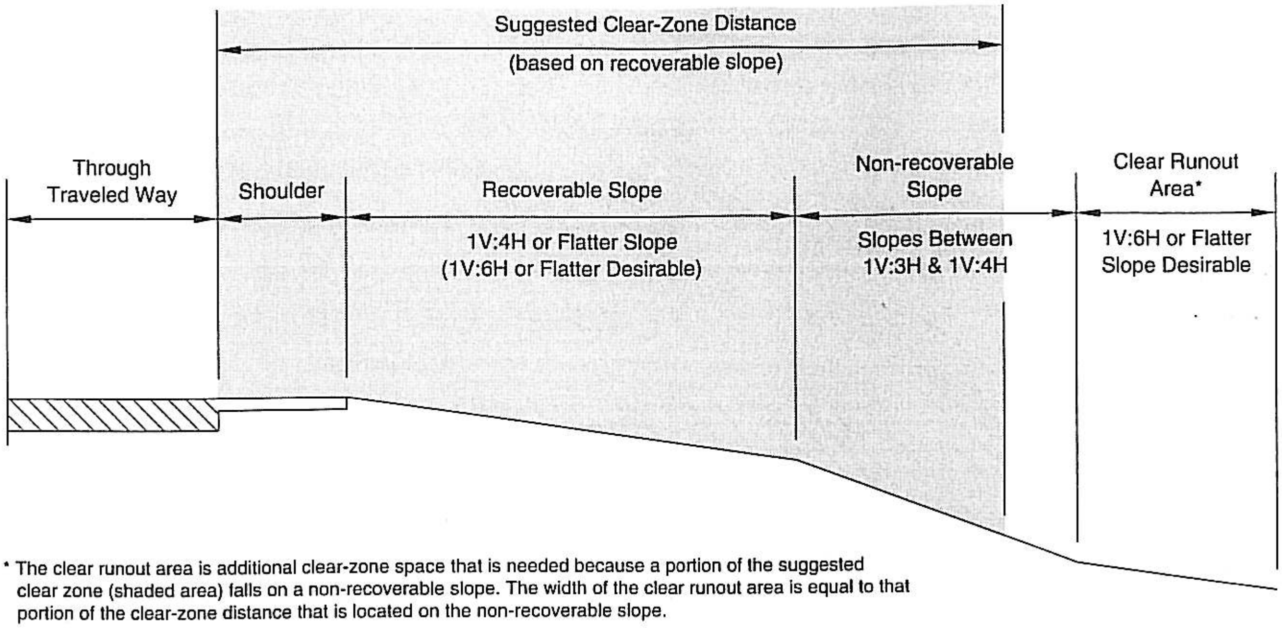


Figure 3-2. Clear Zone for Non-Recoverable Parallel Foreslope

3.2.2 Backslopes

When a highway is located in a cut section, the backslope may be traversable depending on its relative smoothness and the presence of fixed obstacles. If the foreslope between the roadway and the base of the backslope is traversable (1V:3H or flatter) and the backslope is obstacle-free, it may not be a significant obstacle, regardless of its distance from the roadway. On the other hand, a steep, rough-sided rock cut normally should begin outside the clear zone or be shielded. A rock cut normally is considered to be rough-sided when the face will cause excessive vehicle snagging rather than provide relatively smooth redirection.

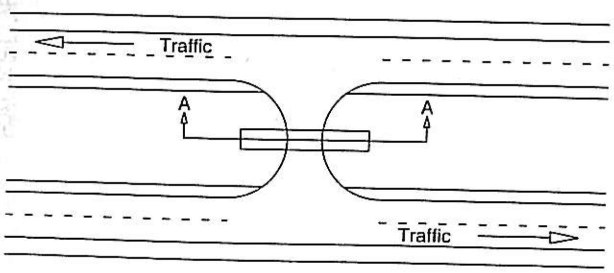
3.2.3 Transverse Slopes

A common obstacle on roadsides are transverse slopes created by median crossovers, berms, driveways, or intersecting side roads. Although the exposure for transverse slopes is less than that for foreslopes or backslopes, they generally are more critical to errant motorists because run-off-the-road vehicles typically strike them head-on.

Transverse slopes of 1V:10H are desirable *(7)*; however, their practicality may be limited by width restrictions and the maintenance problems associated with the long tapered ends of pipes or culverts. Transverse slopes of 1V:6H or flatter are suggested for high-speed roadways, particularly for the section of the transverse slope that is located immediately adjacent to traffic *(3)*. This slope then can be transitioned to a steeper slope as the distance from the edge of the through traveled way increases. Transverse slopes steeper than 1V:6H may be considered for urban areas or for low-speed facilities. Figures 3-3 and 3-4 show suggested designs for these slopes, while Section 3.4.3 discusses safety treatments for parallel drainage structures.

Figure 3-5 shows some alternative designs for drains at median openings. The water flows into a grated drop inlet in the median to a cross-drainage structure or directly underneath the travel lanes to an outside channel. This eliminates the two pipe ends that would be exposed to traffic in the median. The transverse slopes of the median opening then would be desirably sloped at 1V:10H or flatter.

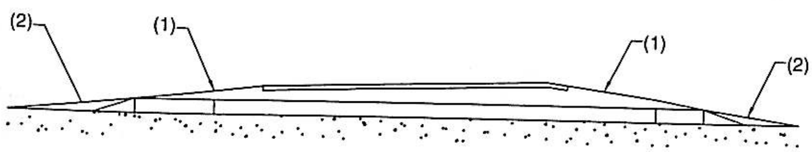
Figure 3-3. Suggested Design for Transverse Slopes



U-TURN MEDIAN OPENING

(1) Slope 1V:10H or flatter desirable. 1V:6H maximum on high-speed, high-volume facilities.

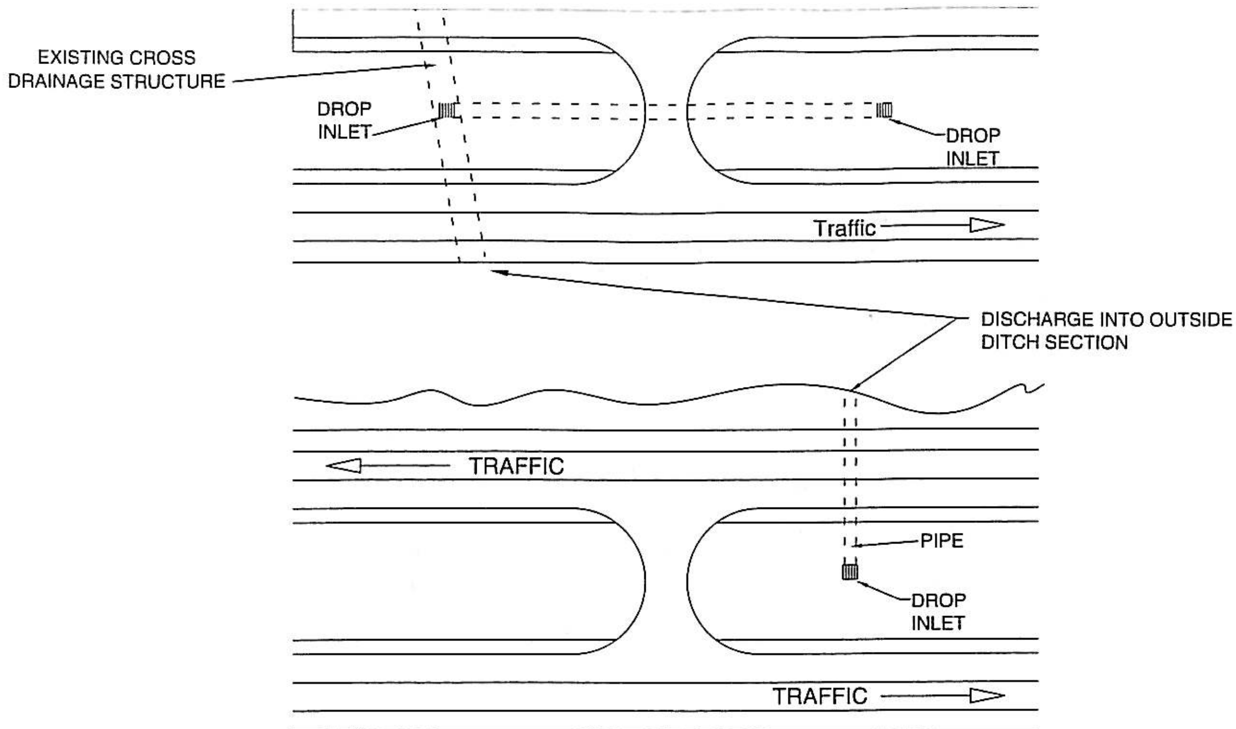
(2) End treatment as required to meet proposed slope.



Section A - A

*Use of the flattest possible median cross slopes on high-speed highways, particularly within the appropriate clear-zone area, can provide an improved roadside. Safety treatment of culverts as discussed in Section 3.4.3 may further enhance the improvement.

Figure 3-4. Median Transverse Slope Design

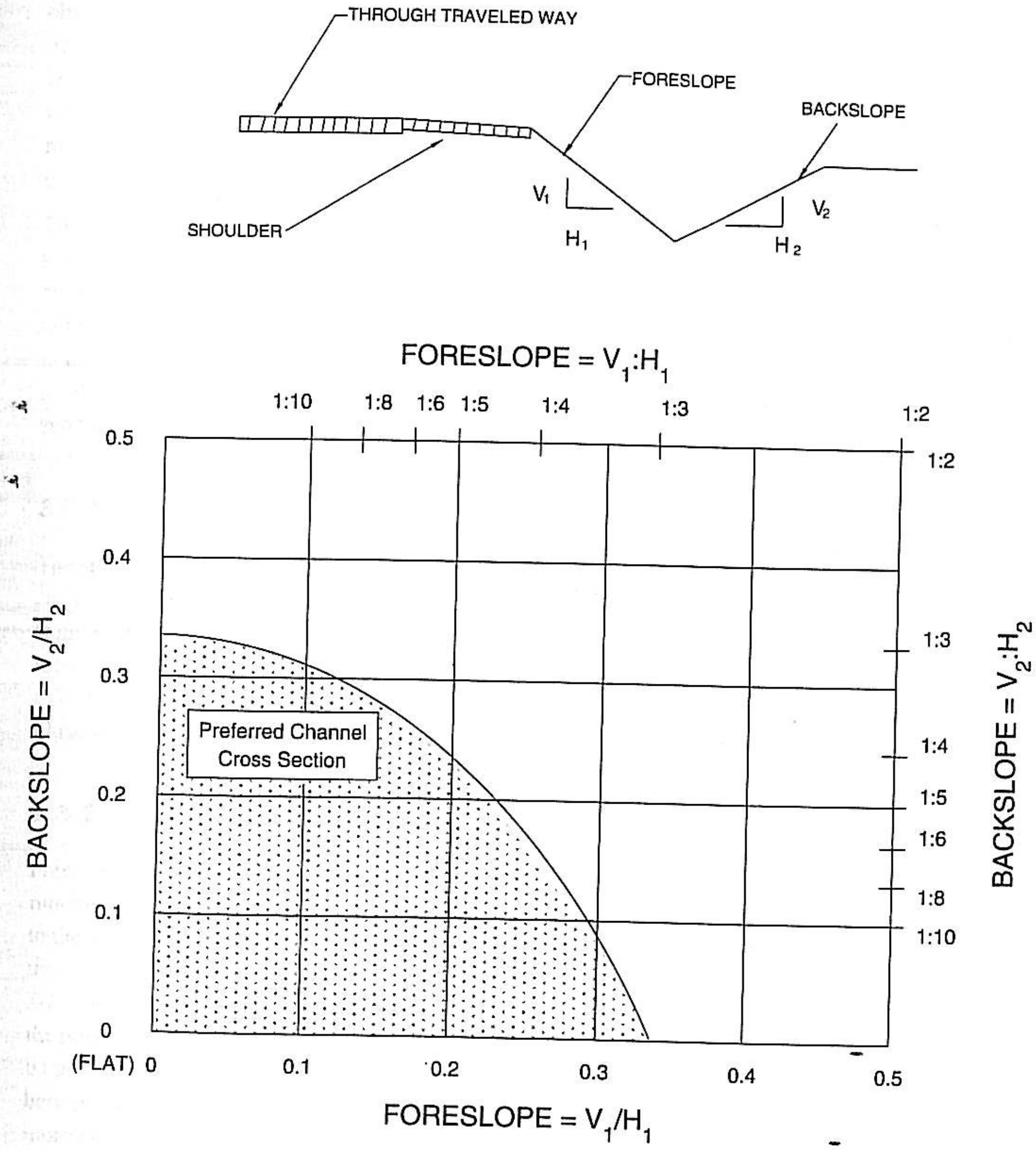


*These alternatives could be considered in lieu of a pipe underneath the median crossover.

Figure 3-5. Alternate Designs for Drains at Median Openings

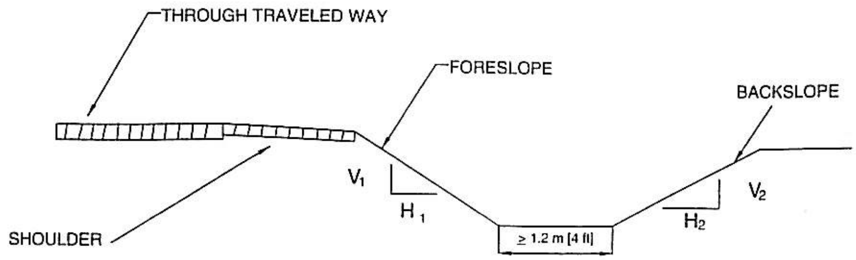
3.2.4 Drainage Channels

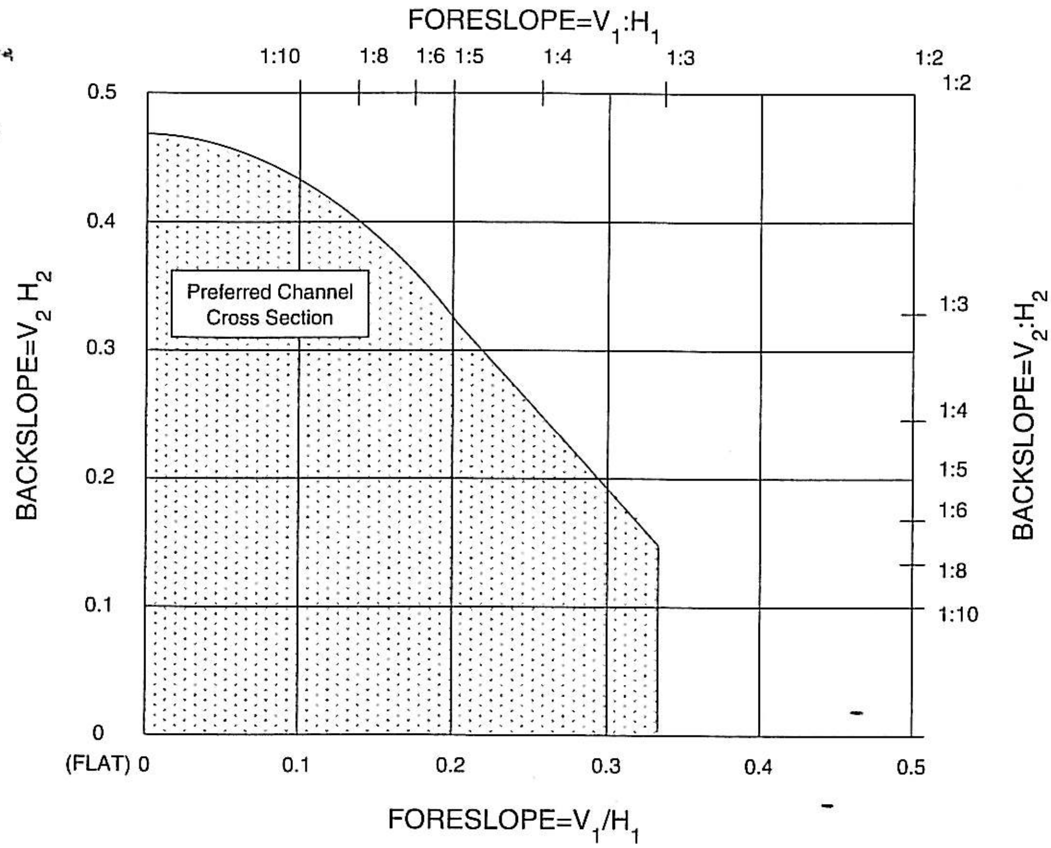
A drainage channel is an open channel usually paralleling the roadway. The primary function of drainage channels is to collect surface runoff from the roadway and areas that drain to the right-of-way and convey the accumulated runoff to acceptable outlet points. Channels should be designed to carry the design runoff and to accommodate excessive storm water with minimal highway flooding or damage. However, channels also should be designed, built, and maintained with consideration given to their effect on the roadside environment. Figures 3-6 and 3-7 present preferred foreslopes and backslopes for basic ditch configurations *(14)*. Cross sections shown in the shaded region of each figure are considered to have traversable cross sections. Channel sections that fall outside the shaded region are considered less desirable and their use should be limited where high-angle encroachments can be expected, such as the outside of relatively sharp curves. Channel sections outside the shaded region may be acceptable for projects having one or more of the following characteristics: restrictive right-of-way environmental constraints; rugged terrain; resurfacing, restoration, or rehabilitation (3R) projects; or low-volume or low-speed roads and streets, particularly if the channel bottom and backslopes are free of any fixed objects or located beyond suggested clear-zone distance.



*This chart is applicable to all Vee ditches, rounded channels with a bottom width less than 2.4 m [8 ft] and trapezoidal channels with bottom widths less than 1.2 m [4 ft].

Figure 3-6. Preferred Cross Sections for Channels with Abrupt Slope Changes





*This chart is applicable to rounded channels with bottom widths of 2.4 m [8 ft] or more and to trapezoidal channels with bottom widths equal to or greater than 1.2 m [4 ft].

Figure 3-7. Preferred Cross Sections for Channels with Gradual Slope Changes

If practical, drainage channels with cross sections outside the shaded regions and located in vulnerable areas may be reshaped and converted to a closed system (culvert or pipe) or, in some cases, shielded by a traffic barrier. Information from various jurisdictions for the use of roadside barrier to shield non-traversable channels within the clear zone is included in Chapter 5.

3.3 APPLICATION OF THE CLEAR-ZONE CONCEPT

A basic understanding of the clear-zone concept is critical to its proper application. The suggested clear-zone distances in Table 3-1 are based on limited empirical data that then were extrapolated to provide data for a wide range of conditions. Thus, the distances obtained from these tables represent a reasonable measure of the degree of safety suggested for a particular roadside, but they are neither absolute nor precise. In some cases, it is reasonable to leave a fixed object within the clear zone; in other instances, an object beyond the clear-zone distance may require removal or shielding. Use of an appropriate clear-zone distance amounts to a compromise between maximizing safety and minimizing construction costs. Appropriate application of the clear-zone concept often will result in more than one possible solution. The following sections intend to illustrate a process that may be used to determine if a fixed object or non-traversable terrain feature should be relocated, modified, removed, shielded, or remain in place.

The guidelines in this chapter may be most applicable to new construction or major reconstruction. On 3R projects, the primary emphasis is placed on the roadway itself. The actual performance of an existing facility may be evaluated through an analysis of crash records and on-site inspections as part of the design effort or in response to public input from road users and other stakeholders. It may not be cost-effective or practical to bring a 3R project into full compliance with all of the clear-zone width recommendations provided in this Guide because of environmental effects or limited right-of-way. Because of the scope of such projects and the limited funding available, emphasis should be placed on correcting or shielding areas in the project with identifiable safety problems related to clear-zone widths. Bodies of water and steep cliffs are the types of areas that may be considered for special emphasis.

3.3.1 Recoverable Foreslopes

The suggested clear-zone distance for recoverable foreslopes of 1V:4H or flatter may be obtained directly from Table 3-1. On new construction or major reconstruction, smooth slopes with no significant discontinuities and no protruding fixed objects are desirable from a safety standpoint. It also is desirable to have the top of the slope rounded so an encroaching vehicle remains in contact with the ground *(14)*. It also is desirable for the toe of the slope to be rounded to improve traversability by an errant vehicle. The flatter the selected slope, the easier it is to mow or otherwise maintain and the safer it becomes to negotiate. Examples at the end of this chapter illustrate the application of the clear-zone concept to recoverable foreslopes.

3.3.2 Non-Recoverable Foreslopes

Foreslopes from 1V:3H up to 1V:4H are considered traversable if they are smooth and free of fixed objects *(14)*. However, a clear runout area beyond the toe of the non-recoverable foreslope is desirable because many vehicles on slopes this steep will continue on to the bottom. The extent of this clear runout area could be determined by first finding the available distance between the edge of the through traveled way and the breakpoint of the recoverable foreslope to the non-recoverable foreslope, as previously shown in Figure 3-2. This distance then is subtracted from the suggested clear-zone distance based on the steepest recoverable foreslope before or after the non-recoverable foreslope and should be at least 3 m [10 ft] if practicable. The result is the desirable clear runout area that should be provided beyond the non-recoverable foreslope if practical. Such a variable sloped typical section often is used as a compromise between roadside safety and economics. By providing a relatively flat recovery area immediately adjacent to the roadway, most errant motorists can recover before reaching the steeper foreslope beyond. The foreslope break may be liberally rounded so that an encroaching vehicle does not become airborne. The steeper slope also may be made as smooth as practical and rounded at the bottom. Figure 3-2 illustrates a recoverable foreslope followed by a non-recoverable foreslope. Example 3-C demonstrates the method for calculating the desirable runout area.

3.3.3 Critical Foreslopes

Critical foreslopes are those steeper than 1V:3H *(5)*. These slopes create a higher propensity for an errant vehicle to overturn and should be treated if they begin within the clear-zone distance of a particular highway and meet the suggested barrier recommendations for shielding contained in Chapter 5. Examples 3-C, 3-D, and 3-E illustrate the application of the clear-zone concept to critical foreslopes.

3.3.4 Examples of Clear-Zone Application on Variable Slopes

A variable foreslope often is specified on new construction to provide a relatively flat recovery area immediately adjacent to the roadway followed by a steeper foreslope. This design requires less right-of-way and embankment material than a continuous, relatively flat foreslope and is commonly called a "barn-roof" section. If the suggested clear-zone distance (as determined from Table 3-1) exists on the flatter foreslope, the steeper slope then may be critical or non-traversable. Clear-zone distances for embankments with variable foreslopes ranging from essentially flat to 1V:4H may be averaged to produce a composite clear-zone distance. Slopes that change from a foreslope to a backslope cannot be averaged and should be treated as drainage channel sections and analyzed for traversability as shown previously in Figures 3-6 and 3-7.

Although a weighted average of the foreslopes may be used, it is preferable to use values in Table 3-1 that are associated with the steeper slope. If one foreslope is significantly wider, the clear-zone computation based on that slope alone may be used.

3.3.5 Clear-Zone Applications for Drainage Channels and Backslopes

Drainage channel cross sections that are considered preferable in Figures 3-6 and 3-7 are not obstacles and need not be constructed at or beyond the suggested clear-zone distance for a specific roadway. Roadside hardware should not be located in or near ditch bottoms or on the backslope near the drainage channel *(14)*. Any vehicle leaving the roadway may be funneled along the drainage channel bottom or encroach to some extent on the backslope, thus making an impact more likely. Breakaway hardware may not function as designed if the vehicle is airborne or sliding sideways when contact is made. Non-yielding fixed objects should be located beyond the suggested clear-zone distance for these cross sections as determined from Table 3-l.

3.3.6 Clear Zone for Auxiliary Lanes and Freeway Ramps

When auxiliary lanes function as a through lane (e.g., speed-change lanes on freeways), the clear zone for the highway may be determined using the larger of the clear zones calculated from the traveled way and adjacent auxiliary lane or lanes. The clear zone for the through travel lanes includes the width of the auxiliary lanes. The clear zone for auxiliary lanes should be based on its design speed, traffic volume, horizontal curvature (where appropriate, as discussed previously in Section 3.1), and adjacent side slopes. For speed-change lanes, the design speed should be determined using the speed reached (Va) as determined from the minimum acceleration and deceleration lengths for ramp terminals provided in Chapter 10 of AASHTO's *A Policy on Geometric Design for Highways and Streets (4)*. The speed from Chapter 10 should be rounded. A separate clear zone is not necessary for speed-change lanes on conventional highways and where the auxiliary lane does not function as a through lane (e.g., turning lanes for at-grade intersections). Refer to Example 3-J at the end of this chapter for an example of a freeway speed-change lane.

The suggested clear-zone distance along the ramp may be based on the speed, volume, horizontal curvature, and roadside geometry along the ramp. Because ramps are of limited length, often contain very sharp curves, and tend to be overdriven by motorists, designers should use a conservative approach to determining the clear-zone distance. For the purpose of determining this suggested clear-zone distance, the design speed along the ramp proper, which excludes a transition curve of 300 m [1000 ft] or greater, should be determined from the simplified curve formula in Chapter 3 of AASHTO's *A Policy on Geometric Design for Highways and Streets (4)*. Transition curves of 300 m [1000 ft] or more can act as extensions of the speed-change lane and should have speeds similar to the adjacent tangent or speed-change lane.

For simple ramps, such as loop and diagonal ramps, the design speed and volume of the ramp proper should be used to determine the suggested clear-zone distance. When compound and reverse curves are used, the clear-zone distance recommended for the higher-speed curve (excluding transition curves) may be used for the entire ramp. Refer to Example 3-K for more detailed information.

For complex ramps with multiple radii and variable operating speeds, a separate clear-zone distance may be determined for each unique segment of the ramp. Refer to Example 3-L for more detailed information.

Alternately, clear zones for ramps may be set at 9 m [30 ft] if previous experience with similar projects or designs indicates satisfactory experience. This method provides a consistent template that can be more practical to design and maintain.

3.4 DRAINAGE FEATURES

Effective drainage is one of the most critical elements in the design of a highway or street. However, drainage features should be designed and built while considering their consequences on the roadside environment. In addition to drainage channels, which were addressed in Section 3.2.4, curbs, parallel and transverse pipes and culverts, and drop inlets are common drainage system elements that should be designed, constructed, and maintained with both hydraulic efficiency and roadside safety in mind.

In general, the following options, listed in order of preference, are applicable to all drainage features:

- Eliminate non-essential drainage structures
- Design or modify drainage structures so they are traversable or present a minimal obstruction to an errant vehicle
- If a major drainage feature cannot be effectively redesigned or relocated, shield it by using a suitable traffic barrier if it is in a vulnerable location

The remaining sections of this chapter identify the safety problems associated with curbs, pipes and culverts, and drop inlets, and they offer recommendations about the location and design of these features to improve their safety characteristics without adversely affecting their hydraulic capabilities. The information presented applies to all roadway types and projects; however, as with many engineering applications, the specific actions taken at a given location often rely heavily on the exercise of good engineering judgment and on a case-by-case assessment of the costs and benefits associated with alternative designs.

3.4.1 Curbs

Curbs are commonly used for drainage control, pavement edge support and delineation, right-of-way reduction, aesthetics, sidewalk separation, and reduction of maintenance operations. Curb designs are classified as vertical or sloping. Refer to Figure 4-5 of AASHTO's *A Policy on Geometric Design of Highways and Streets (4)* for more details. Vertical curbs are those having a vertical or nearly vertical traffic face 150 mm [6 in.] or higher. They are intended to discourage motorists from deliberately leaving the roadway. Sloping curbs are those having a sloping traffic face 150 mm [6 in.] or less in height. Sloping curbs, especially those with heights of 100 mm [4 in.] or less, can be readily traversed by a motorist when necessary. Curbs higher than 100 mm [4 in.], whether sloping or vertical, may drag the underside of some vehicles. However, if higher curbs are used, they are not normally regarded as fixed objects that would require mitigation.

In general, curbs are not desirable along high-speed roadways *(9)*. If a vehicle is spinning or slipping sideways as it leaves the roadway, wheel contact with a curb could cause it to trip and overturn. In other impact conditions, a vehicle may become airborne, which may result in loss of control by the motorist. The distance over which a vehicle may be airborne and the height above or below normal bumper height attained after striking a curb may become critical if secondary crashes occur with traffic barriers or other roadside appurtenances. Refer to Section 5.6.2.1, for more details on the use of a curb in conjunction with a traffic barrier.

When obstructions exist behind curbs, a minimum lateral offset of 0.9 m [3 ft] should be provided beyond the face of curb to the obstruction at intersections and driveway openings. A minimum lateral offset of 0.5 m [1.5 ft] should be used elsewhere *(4)*. This lateral offset should not be construed as a clear-zone distance. Because curbs do not have a significant redirectional capability, obstructions behind a curb should be located at or beyond the suggested clear-zone distances shown in Table 3-1. In many instances, obtaining the suggested clear-zone distances on existing facilities will not be feasible. On new construction for which suggested clear-zone distances cannot be provided, fixed objects should be located as far from the traveled way as practical on a project-by-project basis, but in no case closer than 0.5 m [1.5 ft] from the face of the curb *(4)*.

3.4.2 Cross-Drainage Structures

Cross-drainage structures are designed to carry water underneath the roadway embankment and vary in size from 457 mm (18 in.) to 3 m (10 ft) or more for concrete, metal and plastic pipes. Typically, their inlets and outlets consist of concrete headwalls and wingwalls for the larger structures and beveled-end sections for the smaller pipes. Although these types of designs are hydraulically efficient and minimize erosion problems, they may represent an obstacle to motorists who run off the road. This type of design may result in either a fixed object protruding above an otherwise traversable embankment or an opening into which a vehicle can drop, causing an abrupt stop. The options available to a designer to minimize these obstacles are *(11)*:

- Using a traversable design,
- Extending the structure so that it is less likely to be hit, and

- Shielding the structure.

Each of these options is discussed in the following subsections.

3.4.2.1 Traversable Designs

To maintain a traversable foreslope, the preferred treatment for any cross-drainage structure is to extend or shorten it to intercept the roadway embankment and to match the inlet or outlet slope to the foreslope *(11)*. For small culverts, no other treatment is required. For cross-drainage structures, a small pipe culvert is a single round pipe with a 914-mm (36-in.) or less diameter or multiple round pipes each with a 762-mm (30-in.) or less diameter. Extending culverts to locate the inlets or outlets a fixed distance from the through traveled way is not recommended if such treatment introduces discontinuities in an otherwise traversable slope. Extending the pipe results in the warping of the foreslopes in or out to match the opening, which produces a significantly longer area that affects the motorist who has run off the road. Matching the inlet to the foreslope is desirable because it results in a much smaller target for the errant vehicle to hit, reduces erosion problems, and simplifies mowing operations.

Single structures and end treatments wider than 0.9 m [3 ft] can be made traversable for passenger-size vehicles by using bar grates or pipes to reduce the clear opening width *(11)*. Modifications to the culvert ends to make them traversable should not significantly decrease the hydraulic capacity of the culvert. Safety treatments should be hydraulically efficient. To maintain hydraulic efficiency, it may be necessary to apply bar grates to flared wingwalls, flared end sections, or culvert extensions that are larger than the main barrel. The designer should consider shielding the structure if significant hydraulic capacity or clogging problems could result.

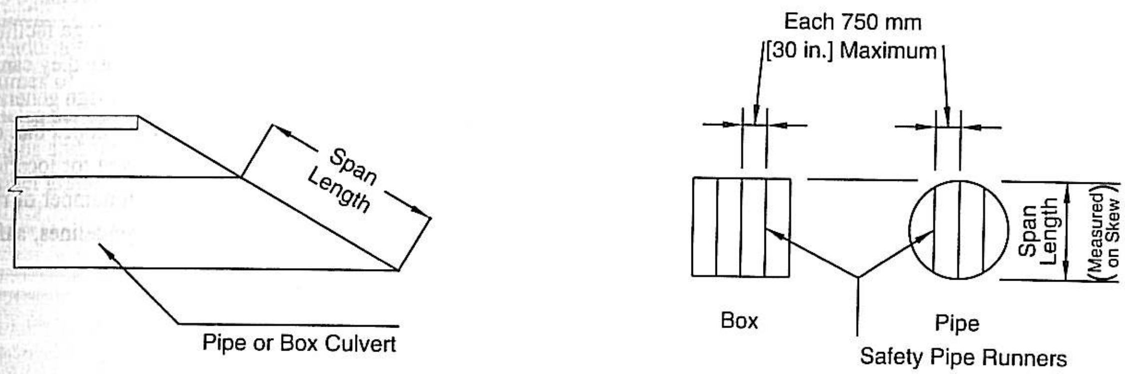
Full-scale crash tests have shown that automobiles can traverse cross-drainage structures with grated-culvert end sections constructed of steel pipes spaced on 760 mm [30 in.] centers on slopes as steep as 1V:3H and at speeds ranging from 30 km/h [20 mph] to 100 km/h [60 mph]. This spacing does not significantly change the flow capacity of the culvert pipe unless debris accumulates and causes partial clogging of the inlet. This underscores the importance of accurately assessing the clogging potential of a structure during design and the importance of keeping the inlets free of debris. Figure 3-8 shows recommended sizes to support a full-sized automobile and is based on a 760-mm [30-in.] bar spacing. More recently, two full-scale crash tests were conducted to examine the safety performance of a 6.4 m by 6.4 m [21 ft by 21 ft] culvert grate on a 1V:3H and designed in accordance with Figure 3-8. The first test involved a 2000P pick-up truck impacting the upstream portion of the grate. The second test involved an 820C small car striking the culvert grate with the left-side tires while the right-side tires encountered the slope above the grate. These scenarios were determined to be the worst testing conditions. This testing clearly demonstrated that the culvert safety grate recommended in Figure 3-8 meets the safety performance evaluation guidelines set forth in NCHRP Report 350 for a test level 3 (TL-3) device. Further, these findings clearly support historical studies that show culvert grates provide the most cost-beneficial safety treatment for cross-drainage culverts. More information is found in the report *Safety Grates for Cross-Drainage Culverts (12)*. It is important to note that the toe of the foreslope and the ditch or stream bed area immediately adjacent to the culvert should be more or less traversable if the use of a grate is to have any significant safety benefit.

For median drainage where flood debris is not a concern and where mowing operations are frequently required, much smaller openings between bars may be tolerated and grates similar to those commonly used for drop inlets may be appropriate. In addition, both the hydraulic efficiency and the roadside environment may be improved by making the culverts continuous and adding a median drainage inlet. This alternative eliminates two end treatments and is usually a practical design when neither the median width nor the height of fill is excessive. Figure 3-9 shows a traversable pipe grate on a concrete box culvert constructed to match the 1V:6H side slope.

3.4.2.2 Extension of Structure

For intermediate-sized pipes and culverts whose inlets and outlets cannot be readily made traversable, designers often extend the structure so the obstacle is located at or just beyond the suggested clear zone. While this practice reduces the likelihood of the pipe end being hit, it does not completely eliminate that possibility. If the extended culvert headwall remains the only significant fixed object immediately at the edge of the suggested clear zone along the section of roadway under design and the roadside is generally traversable to the right-of-way line elsewhere, simply extending the culvert to just beyond the suggested clear zone may not be the best alternative, particularly on freeways and other high-speed, access-controlled facilities. On the other hand, if the roadway has numerous fixed objects, both natural and man-made, at the edge of the suggested clear zone, extending individual structures to the same minimum distance from traffic may be appropriate. However, redesigning the inlet or outlet so that it is no longer an obstacle is usually the preferred safety treatment.

SPAN LENGTH		SAFETY PIPE RUNNER INSIDE DIAMETER	
up to 3.66 m	[12 ft]	75 mm	[3 in.]
3.66–4.88 m	[12–16 ft]	87 mm	[3.5 in.]
4.88–6.10 m	[16–20 ft]	100 mm	[4 in.]
6.10 m [20 ft] or less with center support		75 mm	[3 in.]



*The chart above shows recommended safety pipe runner sizes for various span lengths for cross-drainage structures. The safety pipe runners are Schedule 40 pipes spaced on centers of 750 mm [30 in.] or less.

Figure 3-8. Design Criteria for Safety Treatment of Pipes and Culverts

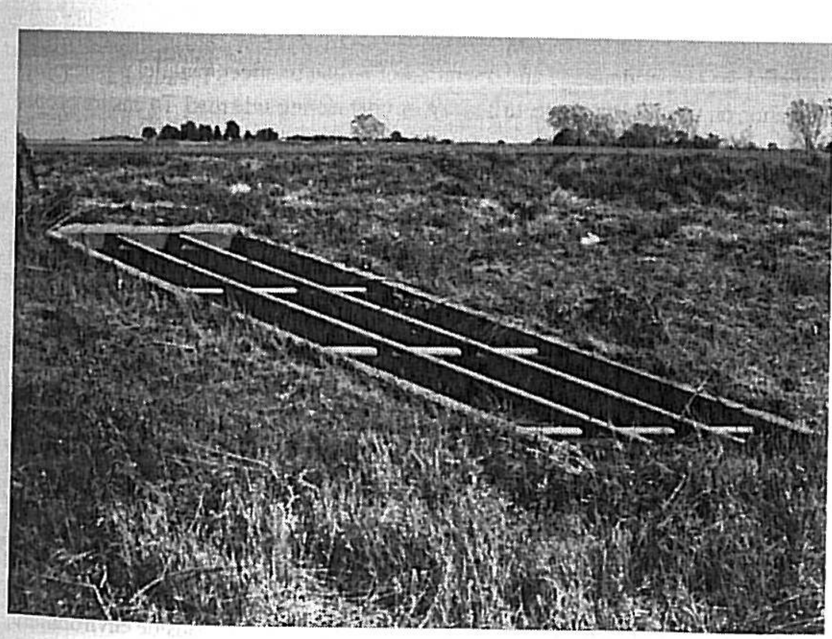


Figure 3-9. Safety Treatment for Cross-Drainage Culvert

3.4.2.3 Shielding

For major drainage structures that are costly to extend and whose end sections cannot be made traversable, shielding with an appropriate traffic barrier often is the most effective safety treatment. Although the traffic barrier is longer and closer to the roadway than the structure opening and is likely to be hit more often than an unshielded culvert located farther from the through traveled way, a properly designed, installed, and maintained barrier system may provide an increased level of safety for the errant motorist.

3.4.3 Parallel Drainage Features

Parallel drainage culverts are those that are oriented parallel to the main flow of traffic. They typically are used at transverse slopes under driveways, field entrances, access ramps, intersecting side roads, and median crossovers. Most of these parallel drainage culverts are designed to carry relatively small flows until the water can be discharged into outfall channels or other drainage facilities and carried away from the roadbed. However, these drainage features can present a significant roadside obstacle because they can be struck head-on by impacting vehicles. As with cross-drainage structures, the designer's primary concern should be to design generally traversable slopes and to match the culvert openings with adjacent slopes. Section 3.2.3 recommends that transverse slopes that can be struck at 90 degrees by run-off-the-road vehicles be constructed as flat as practical, with 1V:6H or flatter suggested for locations susceptible to high-speed impacts. On low-volume or low-speed roads, where crash history does not indicate a high number of run-off-the-road occurrences, steeper transverse slopes may be considered as a cost-effective approach. Using these guidelines, safety treatment options are similar to those for cross-drainage structures, in order of preference:

1. Eliminate the structure.
2. Use a traversable design.
3. Move the structure laterally to a less vulnerable location.
4. Shield the structure.
5. Delineate the structure if the above alternatives are not appropriate.

3.4.3.1 Eliminate the Structure

Unlike cross-drainage pipes and culverts that are essential for proper drainage and operation of a road or street, parallel pipes sometimes can be eliminated by constructing an overflow section on the field entrance, driveway, or intersecting side road. To ensure proper performance, care should be taken when allowing drainage to flow over highway access points, particularly if several access points are closely spaced or the water is subject to freezing. This treatment usually will be appropriate only at low-volume locations where this design does not decrease the sight distance available to drivers entering the main road. Care also should be exercised to avoid erosion of the entrance and the area downstream of the crossing. This usually can be accomplished by paving the overflow section (assuming the rest of the facility is not paved) and by adding an upstream and downstream apron at locations where water velocities and soil conditions make erosion likely.

Closely spaced driveways with culverts in drainage channels are relatively common as development occurs along highways approaching urban areas. Because traffic speeds and roadway design elements are usually characteristic of rural highways, these culverts may constitute a significant roadside obstacle. In some locations, such as along the outside of curves or where records indicate concentrations of run-off-the-road crashes, it may be desirable to convert the open channel into a storm drain and backfill the areas between adjacent driveways. This treatment will eliminate the ditch section as well as the transverse slopes with pipe inlets and outlets.

3.4.3.2 Traversable Designs

As emphasized earlier in this chapter, transverse slopes should be designed while considering their effect on the roadside environment. The designer should try to provide the flattest transverse slopes practical in each situation, particularly in areas where the slope has shown a high probability of being struck head-on by a vehicle. Once this effort has been made, parallel drainage structures should match the selected transverse slopes and, if possible, should be safety treated when they are located in a vulnerable position relative to main road traffic. Although many of these structures are small and present a minimal target, the addition of pipes and bars perpendicular to traffic can reduce wheel snagging in the culvert opening. Research has shown that for parallel drainage structures, a grate consisting of pipes set on 610 mm [24 in.] centers will significantly reduce wheel snagging. It also is recommended that the center of the bottom bar or pipe be set at 100 to 200 mm [4 to 8 in.] above the culvert invert.

Generally, single pipes with diameters of 610 mm [24 in.] or less will not require a grate *(11)*. When a multiple pipe installation is involved, however, a grate for smaller pipes may be appropriate. Reference may be made to the Texas Transportation Institute Research Study 2-8-79-280, *Safe End Treatment for Roadside Culverts (13)*, in which researchers concluded that a passenger vehicle should be able to traverse a pipe/slope combination at speeds up to 80 km/h [50 mph] without rollover. To achieve this result, the roadway (or ditch) foreslope and the driveway foreslope both should be 1V:6H or flatter and have a smooth transition between them. Ideally, the culvert should be cut to match the driveway slope and fitted with cross members perpendicular to the direction of traffic flow as described previously. This study suggests that it could be cost-effective to flatten the approach slopes to 1V:6H and match the pipe openings to these slopes for all sizes of pipes up to 910 mm [36 in.] in diameter for traffic volumes of more than 100 vehicles per day. The addition of grated inlets to these pipes was considered cost-effective for pipes 910 mm [36 in.] or greater in diameter with traffic volumes of more than 500 vehicles per day and for pipes over 610 mm [24 in.] in diameter for traffic volumes of more than 13,000 vehicles per day. Because these numbers were based in part on assumptions by the researchers, they should be interpreted as approximations and not as absolute numbers. Figure 3-10 illustrates a possible design for the inlet and outlet end of a parallel culvert. When channel grades permit, the inlet end may use a drop-inlet type design to reduce the length of grate required.

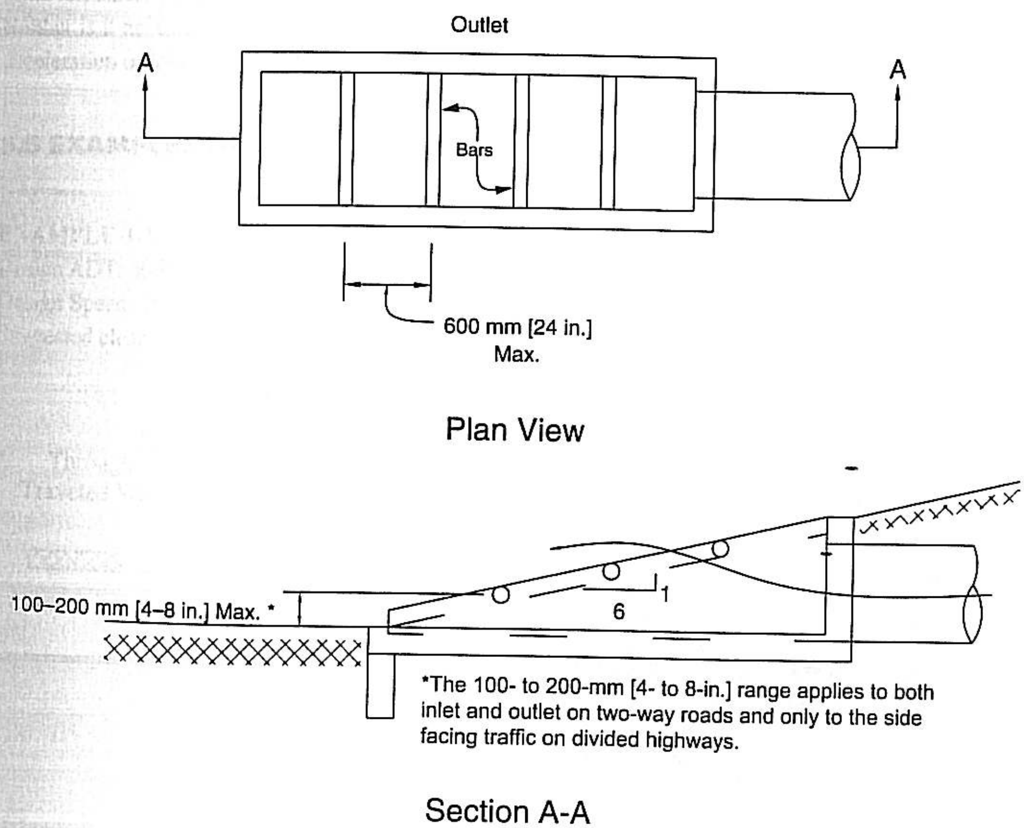


Figure 3-10. Inlet and Outlet Design Example for Parallel Drainage

The recommended grate design may affect culvert capacity if significant blockage by debris is likely; however, because capacity is not normally the governing design criteria for parallel structures, hydraulic efficiency may not be an overriding concern. A report issued by the University of Kansas suggests that a 25 percent debris blockage factor should be sufficiently conservative to use as a basis for culvert design in these cases *(8)*. This report also suggests that under some flow conditions, the capacity of a grated culvert may be equal to that of a standard headwall design as a result of decreased entrance turbulence. In those locations where headwater depth is critical, a larger pipe should be used or the parallel drainage structure may be positioned outside the clear zone, as discussed in the following section.

3.4.3.3 Relocate the Structure

Some parallel drainage structures can be moved laterally farther from the through traveled way. This treatment often affords the designer the opportunity to flatten the transverse slope within the selected clear-zone distance of the roadway under design. If the embankment at the new culvert locations is traversable and likely to be encroached upon by traffic from either the main road or side road, safety treatment should be considered. It is suggested that the inlet or outlet match the transverse slope regardless of whether additional safety treatment is deemed necessary. Figure 3-11 shows a suggested design treatment, while Figure 3-12 shows a recommended safety treatment for parallel drainage pipes.

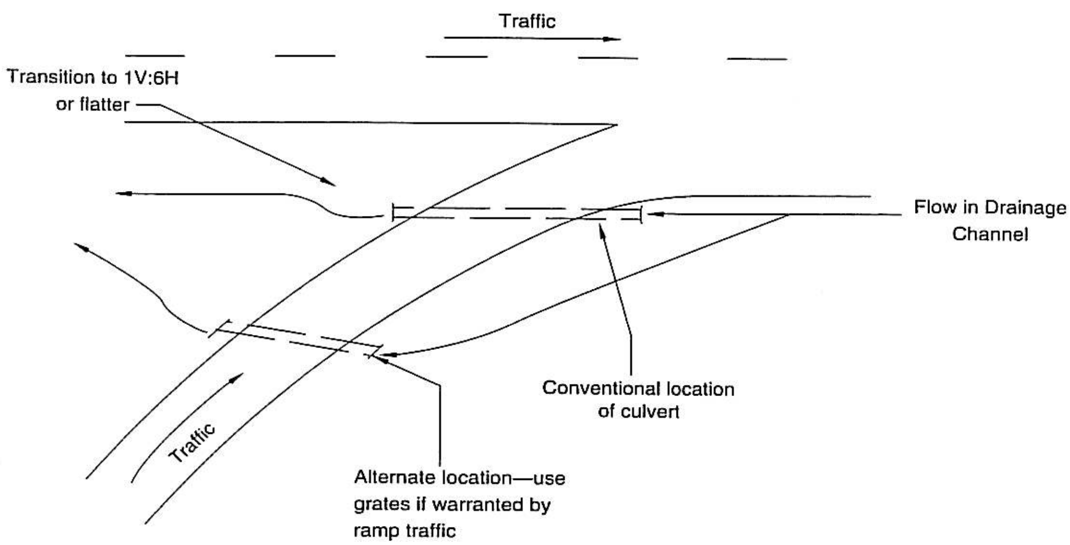


Figure 3-11. Alternate Location for a Parallel Drainage Culvert

Figure 3-12. Safety Treatment for Parallel Drainage Pipe

3.4.3.4 Shielding

In cases in which the transverse slope cannot be made traversable, the structure is too large to be safety treated effectively, and relocation is not feasible, shielding the obstacle with a traffic barrier may be necessary. Specific information on the selection, location, and design of an appropriate barrier system is in Chapter 5.

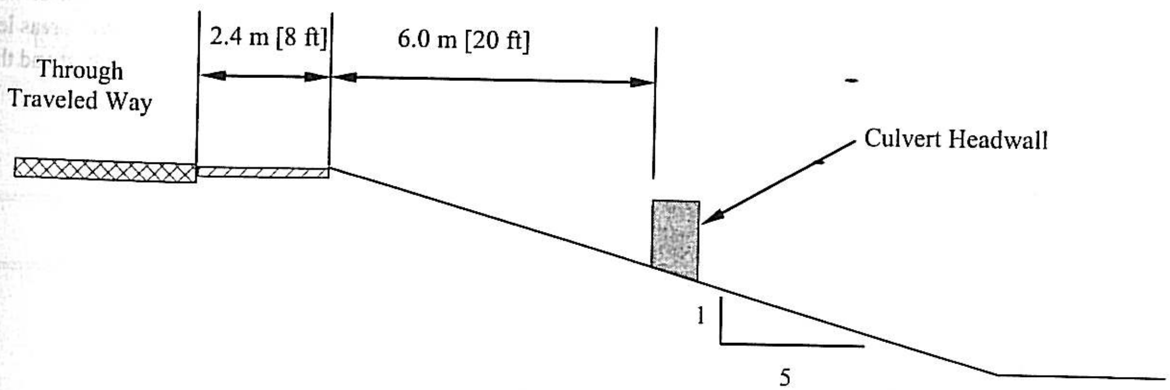
3.4.4 Drop Inlets

Drop inlets can be classified as on-roadway or off-roadway structures. On-roadway inlets are usually located on or alongside the shoulder of a street or highway and are designed to intercept runoff from the road surface. These include curb opening inlets, grated inlets, slotted drain inlets, or combinations of these three basic designs. Because they are installed flush with the pavement surface, they do not constitute a significant safety problem to errant motorists. However, they should be selected and sized to accommodate design water runoff. In addition, they should be capable of supporting vehicle wheel loads and should be pedestrian and bicycle compatible.

Off-roadway drop inlets are used in medians of divided roadways and sometimes in roadside ditches. Although their purpose is to collect runoff, they should be designed and located to present a minimal obstacle to errant motorists. This goal can be accomplished by building these features flush with the channel bottom or slope on which they are located. No portion of the drop inlet should project more than 100 mm [4 in.] above the ground line *(10)*. The opening should be treated to prevent a vehicle wheel from dropping into it; however, unless pedestrians are a consideration, grates with openings as small as those used for pavement drainage are not necessary. Neither is it necessary to design for a smooth ride over the inlet; it is sufficient to prevent wheel snagging and the resultant sudden deceleration or loss of control.

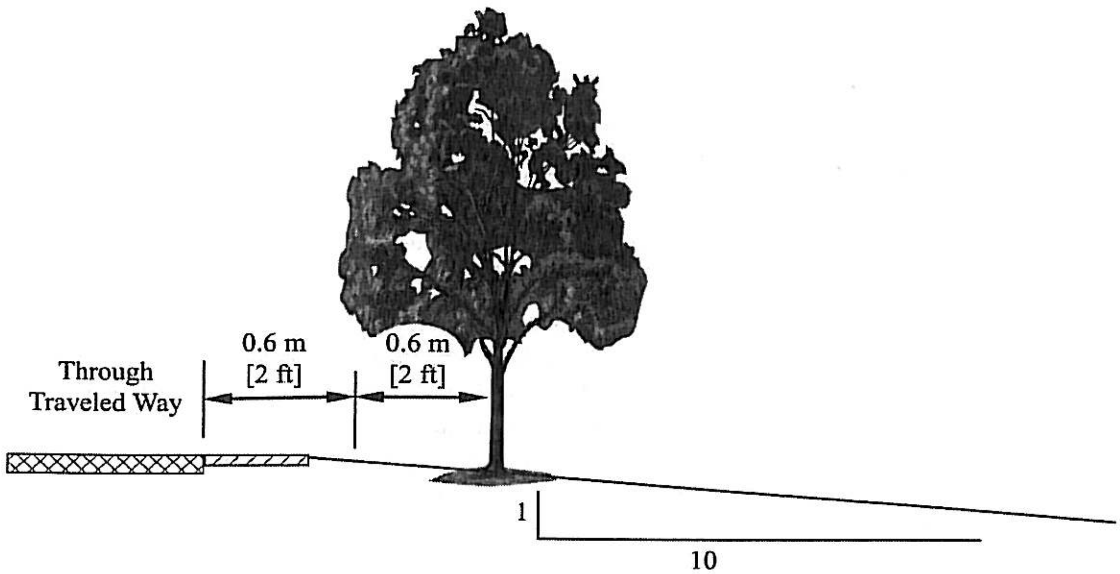
3.5 EXAMPLES OF THE CLEAR-ZONE CONCEPT TO RECOVERABLE FORESLOPES

EXAMPLE 3-A
Design ADT: 4000
Design Speed: 100 km/h [60 mph]
Suggested clear-zone distance for 1V:5H foreslope: 10 to 12 m [32 to 40 ft] (from Table 3-1)



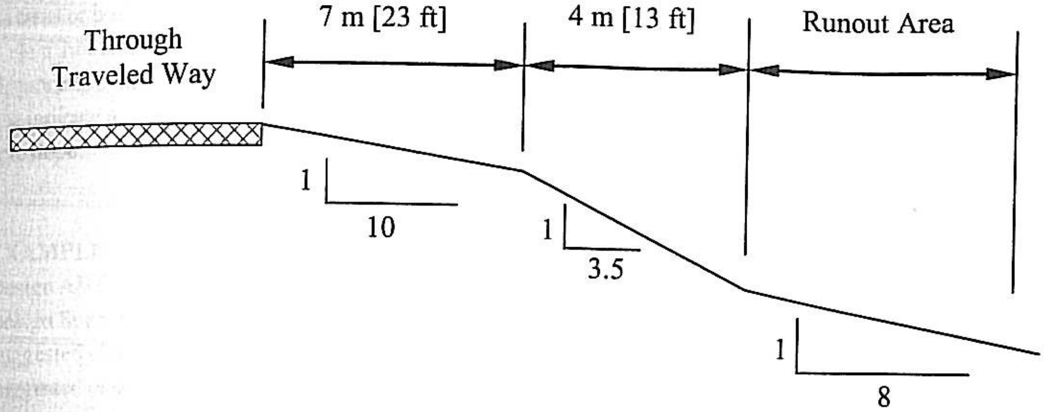
Discussion—The available recovery area of 8.4 m [28 ft] is 1.6 m to 3.6 m [4 to 12 ft] less than the suggested clear-zone distance. If the culvert headwall is greater than 100 mm [4 in.] in height and is the only obstruction on an otherwise traversable foreslope, it should be removed and the inlet modified to match the 1V:5H foreslope. If the foreslope contains rough outcroppings or boulders and the headwall does not significantly increase the obstruction to a motorist, the decision to do nothing may be appropriate. A review of the highway's crash history, if available, may be made to determine the nature and extent of vehicle encroachments and to identify any specific locations that may require special treatment.

EXAMPLE 3-B
Design ADT: 300
Design Speed: 60 km/h [40 mph]
Suggested clear-zone distance for 1V:10H slope: 2 to 3 m [7 to 10 ft] (from Table 3-1)



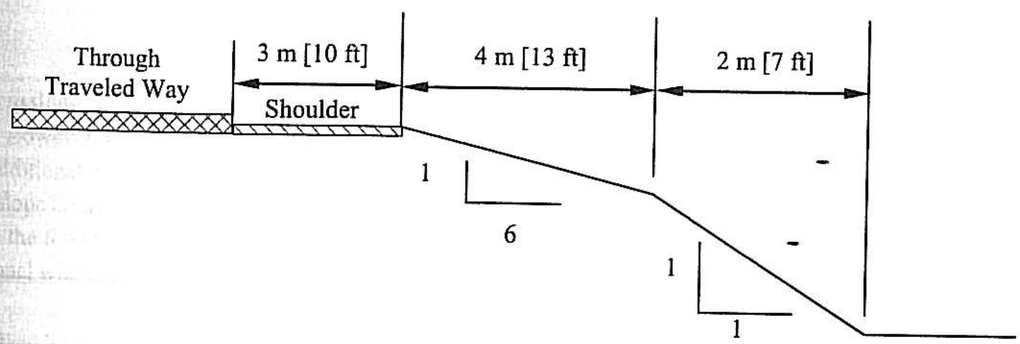
Discussion—The available recovery area of 1.2 m [4 ft] is 0.8 to 1.8 m [3 to 6 ft] less than the suggested clear-zone distance. If this section of road has a significant number of run-off-the-road crashes, it may be appropriate to consider shielding or removing the entire row of trees within the crash area. If this section of road has no significant history of crashes and is heavily forested with most of the other trees only slightly farther from the road, this tree would probably not require treatment. If, however, none of the other trees are closer to the roadway than, for example, 4.0 m [13 ft], this individual tree represents a more significant obstruction and should be considered for removal. If a tree were 3.0 m [10 ft] from the edge of through traveled way, and all or most of the other trees were 5 m [16 ft] or more, its removal may still be appropriate. Also, as this road is very low volume (ADT ≤400), and as suggested in Chapter 12 and the *AASHTO Guidelines for Geometric Design of Very Low-Volume Roads*, where constraints of cost, terrain, right-of-way, or potential socio/environmental impacts make the provision of a 2 m [6 ft] clear recovery area impractical, clear recovery areas less than 2 m [6 ft] in width may be used. This example emphasizes that the clear-zone distance is an approximate number at best and that individual objects should be analyzed in relation to other nearby obstacles.

EXAMPLE 3-C
Design ADT: 7000
Design Speed: 100 km/h [60 mph]
Suggested clear-zone distance for 1V:10H foreslope: 9 to 10 m [30 to 32 ft] (from Table 3-1)
Suggested clear-zone distance for 1V:8H foreslope: 9 to 10 m [30 to 32 ft] (from Table 3-1)
Available recovery distance before breakpoint of non-recoverable foreslope: 7 m [23 ft]
Clear runout area at toe of foreslope: 9 to 10 m [30 to 32 ft] minus 7 m [23 ft] or 2 to 3 m [7 to 10 ft]

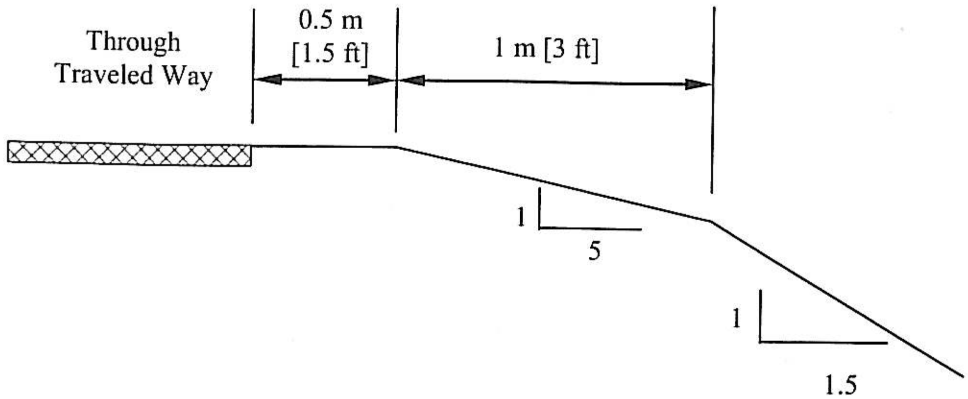


Discussion—Since the non-recoverable foreslope is within the recommended suggested clear-zone distance of the 1V:10H foreslope, a runout area beyond the toe of the non-recoverable foreslope is desirable. Using the steepest recoverable foreslope before or after the non-recoverable foreslope, a clear-zone distance is selected from Table 3-1. In this example, the 1V:8H foreslope beyond the base of the fill dictates a 9 to 10 m [30 to 32 ft] clear-zone distance. Since 7 m [23 ft] are available at the top, an additional 2 to 3 m [7 to 10 ft] could be provided at the bottom. Since this is less than the 3 m [10 ft] recovery area that should be provided at the toe of all the non-recoverable slopes the 3 m [10 ft] should be applied. All foreslope breaks may be rounded and no fixed objects would normally be built within the upper or lower portions of the clear-zone or on the intervening foreslope.

EXAMPLE 3-D
Design ADT: 12,000
Design Speed: 110 km/h [70 mph]
Suggested clear-zone distance for 1V:6H foreslope: 9 to 10.5 m [30 to 34 ft] (from Table 3-1)

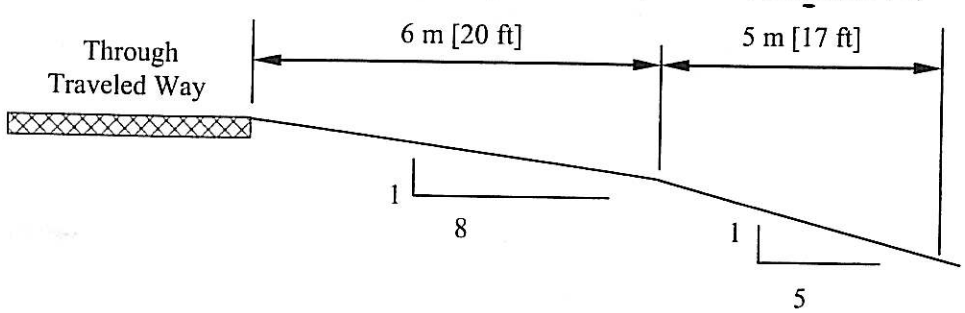


EXAMPLE 3-E
Design ADT: 350
Design Speed: 60 km/h [40 mph]
Suggested clear-zone distance for 1V:5H foreslope: 2 to 3 m [7 to 10 ft] (from Table 3-1)



Discussion—The available recovery area of 1.5 m [4.5 ft] is 0.5 to 1.5 m [2.5 to 5.5 ft] less than the suggested clear-zone distance. If much of this roadway has a similar cross section and no significant run-off-the-road crash history, neither foreslope flattening nor a traffic barrier would be recommended. On the other hand, even if the 1V:5H foreslope were 3 m [10 ft] wide and the clear-zone requirement were met, a traffic barrier might be appropriate if this location has noticeably less recovery area than the rest of the roadway and the embankment was unusually high. Also, as this road is very low volume (ADT ≤400), and as suggested in Chapter 12 and the AASHTO *Guidelines for Geometric Design of Very Low-Volume Roads*, where constraints of cost, terrain, right-of-way, or potential socio/environmental impacts make the provision of a 2 m [6 ft] clear recovery area impractical, clear recovery areas less than 2 m [6 ft] in width may be used. This example emphasizes that the clear-zone distance is an approximate number at best and that individual objects should be analyzed in relation to other nearby obstacles.

EXAMPLE 3-F
Design ADT: 5000
Design Speed: 100 km/h [60 mph]
Suggested clear-zone distance for 1V:8H foreslope: 8 to 9 m [26 to 30 ft] (from Table 3-1)
Suggested clear-zone distance for 1V:5H foreslope: 10 to 12 m [32 to 40 ft] (from Table 3-1)



Discussion—Since the range for the flatter slope of 26 to 30 ft extends past the slope break onto the steeper slope, the upper end of this range should be considered. However, the range for the steeper slope of 32' to 40' might be considered conservative since the majority of the clear zone area is on the flatter slope. Thus the lower range of this slope might be considered. An appropriate range for this combination slope could be 30 to 32 ft.

In this example, it would be desirable to have no fixed objects constructed on any part of the 1V:5H foreslope. Natural obstacles such as trees or boulders at the toe of the slope would not be shielded or removed. However, if the final foreslope were steeper than 1V:4H, a clear runout area of 3 m [10 ft] should be considered at the toe of the foreslope. The designer may choose to limit the clear-zone distance to 9 m [30 ft] if that distance is consistent with the rest of the roadway template, a crash analysis or site investigation does not indicate a potential run-off-the-road problem in this area, and the distance selected does not end at the toe of the non-recoverable foreslope.

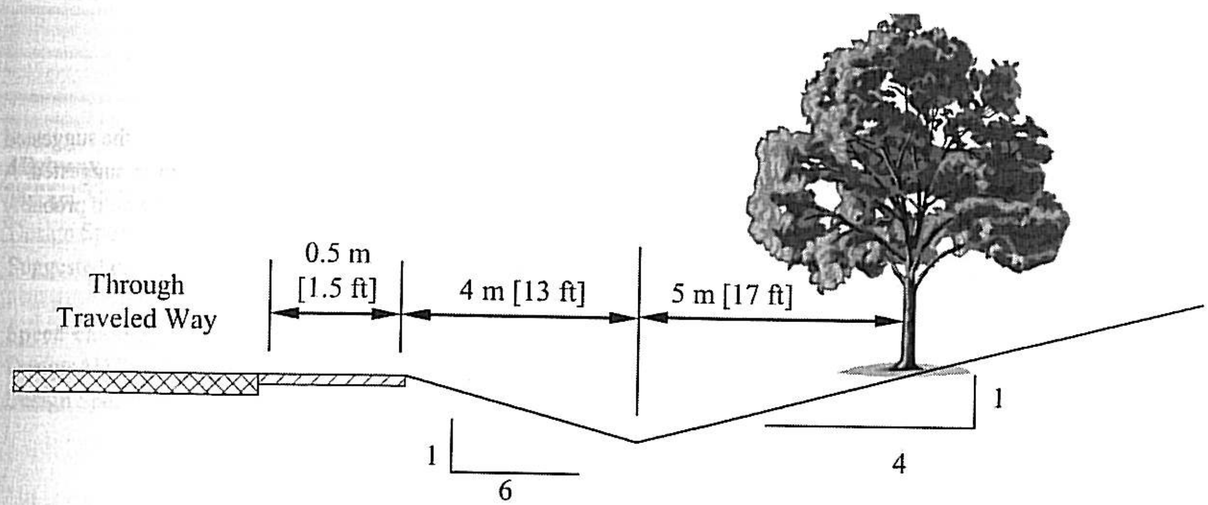
EXAMPLE 3-G

Design ADT: 1400

Design Speed: 100 km/h [60 mph]

Suggested clear-zone distance for 1V:6H foreslope (fill): 6 to 7.5 m [20 to 24 ft] (from Table 3-1)

Suggested clear-zone distance for 1V:4H backslope (cut): 5 to 5.5 m [16 to 18 ft] (from Table 3-1)

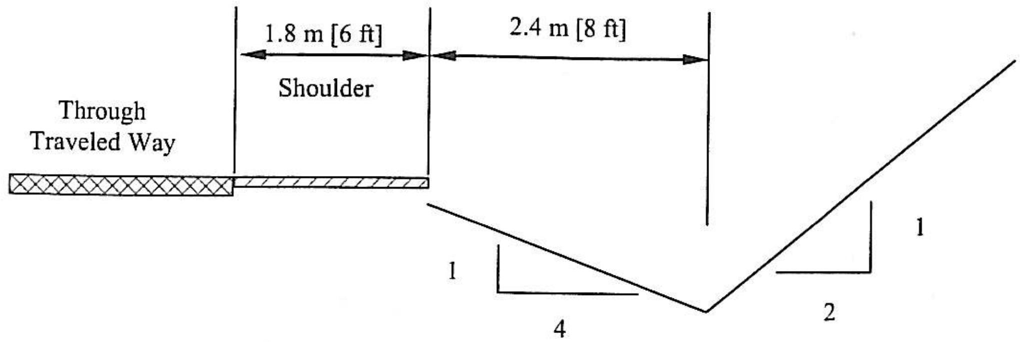


Discussion—For channels within the preferred cross-section area of Figures 3-6 or 3-7, the clear-zone may be determined from Table 3-1. However, when the suggested clear-zone exceeds the available recovery area for the foreslope, the backslope may be considered as additional available recovery area. The range for the suggested clear zone for the foreslope of 6 to 7.5 m [20 to 24 ft] extends past the slope break onto the backslope slope. Since the backslope (cut) has a suggested clear-zone of 5 to 5.5 m [16 to 18 ft] which is less than the foreslope the larger of the two values should be used. In addition, fixed objects should not be located near the center of the channel where the vehicle is likely to funnel. An appropriate range for this combination slope could be 20 to 24 ft.

Because the tree is located beyond the suggested clear zone, removal is not required. Removal should be considered if this one obstacle is the only fixed object this close to the through traveled way along a significant length.

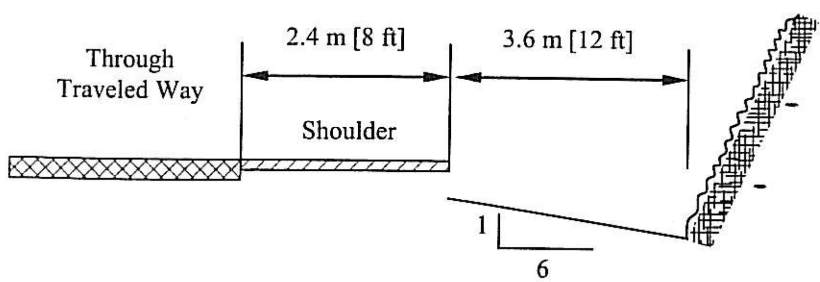
Drainage channels not having the preferred cross section (see Figure 3-6 or 3-7) should be located at or beyond the suggested clear zone. However, backslopes steeper than 1V:3H are typically located closer to the roadway. If these slopes are relatively smooth and unobstructed, they present little safety problem to an errant motorist. If the backslope consists of a rough rock cut or outcropping, shielding may be warranted as discussed in Chapter 5.

EXAMPLE 3-H
Design ADT: 800
Design Speed: 80 km/h [50 mph]
Suggested clear-zone distance for 1V:4H foreslope: 5 to 6 m [16 to 20 ft] (from Table 3-1)



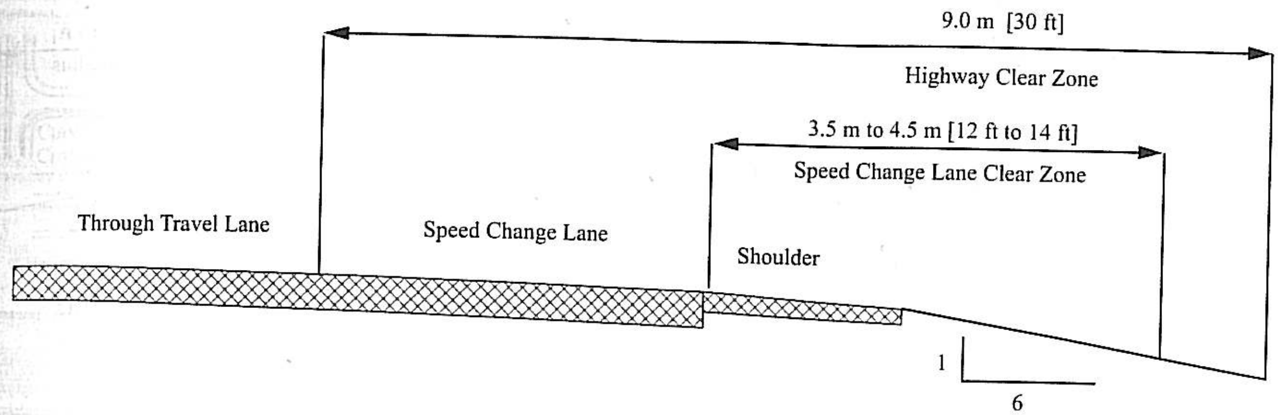
Discussion—The ditch is not within the preferred cross section area of Figure 3-6 and is 0.6 to 1.8 m [2 to 6 ft] less than the suggested clear-zone distance. However, if the ditch bottom and backslope are free of obstacles, no additional improvement is suggested. A similar cross section on the outside of a curve where encroachments are more likely and the angle of impact is sharper would probably be flattened if practical.

EXAMPLE 3-I
Design ADT: 3000
Design Speed: 100 km/h [60 mph]
Suggested clear-zone distance for 1V:6H foreslope: 8.0 to 9.0 m [26 to 30 ft] (from Table 3-1)



Discussion—The rock cut is within the given suggested clear-zone distance but would probably not warrant removal or shielding unless the potential for snagging, pocketing, or overturning a vehicle is high. Steep backslopes are clearly visible to motorists during the day, thus lessening the risk of encroachments. Roadside delineation of sharper than average curves through cut sections can be an effective countermeasure at locations having a significant crash history or potential.

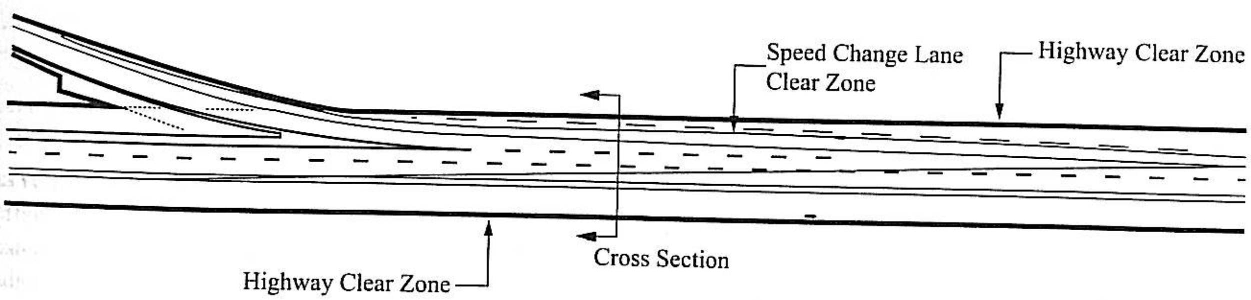
EXAMPLE 3-J



Clear Zone for Speed-Change Lane Cross Section

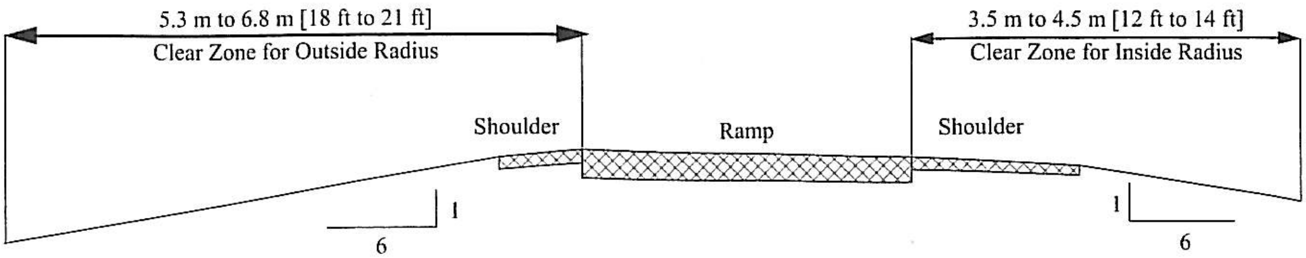
Highway
Design ADT: > 6000
Design Speed: 110 km/h [70 mph]
Suggested clear-zone distance for 6:1 foreslopes: 9.0 m [30 ft] (from Table 3-1)

Speed-change Lane
Design ADT: < 750
Design Speed: 90 km/h [55 mph] (from AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2011, Figure10-73)



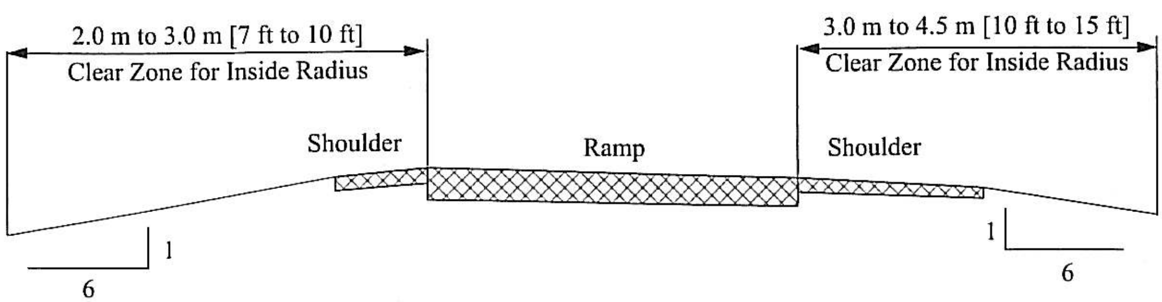
Discussion—The design speeds for the acceleration lane and deceleration lane are based on AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2011, Figures 3-8, 10-70, and 10-73, respectively. The suggested clear zone should be the greater of the two clear zones. Refer to the bold line in the above figure for the overall suggested clear zone. Refer to Examples K and L for the ramp clear zones.

EXAMPLE 3-K



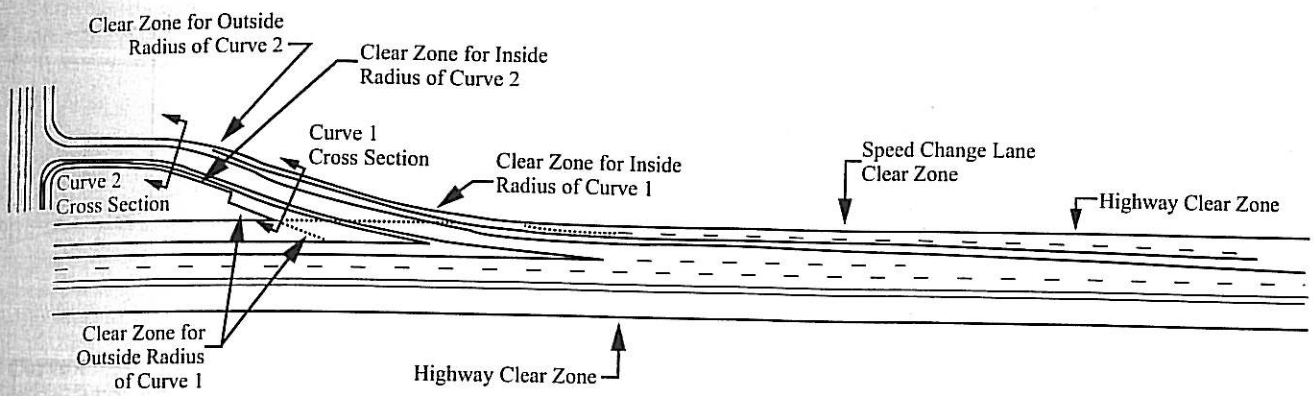
Clear Zone for Simple Ramps Cross Section Curve 1

Curve 1
Design ADT: < 750
Design Speed: 90 km/h [55 mph]
Radius: 300 m [1000 ft]
Suggested clear-zone distance for 6:1 foreslopes along the inside of curve: 3.5 to 4.5 m [12 to 14 ft] (from Table 3-1)
Suggested clear-zone distance for 6:1 foreslopes along the outside of curve: $CZ_c = (L_c)(K_{cz})$ = 3.5 to 4.5 m [12 to 14 ft] × 1.5 = 5.3 to 6.8 m [18 to 21 ft] (from Tables 3-1 and 3-2)



Clear Zone for Simple Ramps Cross Section Curve 2

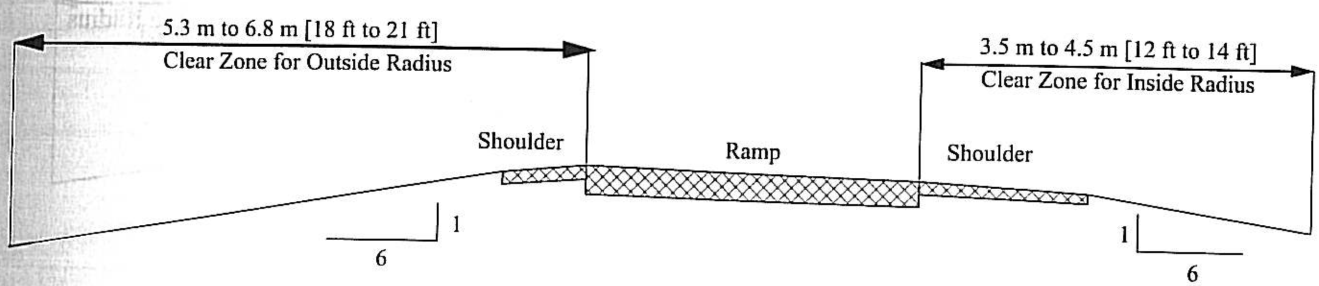
Curve 2
Design ADT: < 750
Design Speed: 50 km/h [30 mph]
Radius: 73 m [240 ft]
Suggested clear-zone distance for 6:1 foreslopes along the inside of curve: 2.0 to 3.0 m [7 to 10 ft] (from Table 3-1)
Suggested clear-zone distance for 6:1 foreslopes along the outside of curve: $CZ_c = (L_c)(K_{cz})$ = 2.0 to 3.0 m [7 to 10 ft] × 1.5 = 3.0 to 4.5 m [11 to 15 ft] (from Tables 3-1 and 3-2)



Clear Zone for Simple Ramps Plan View

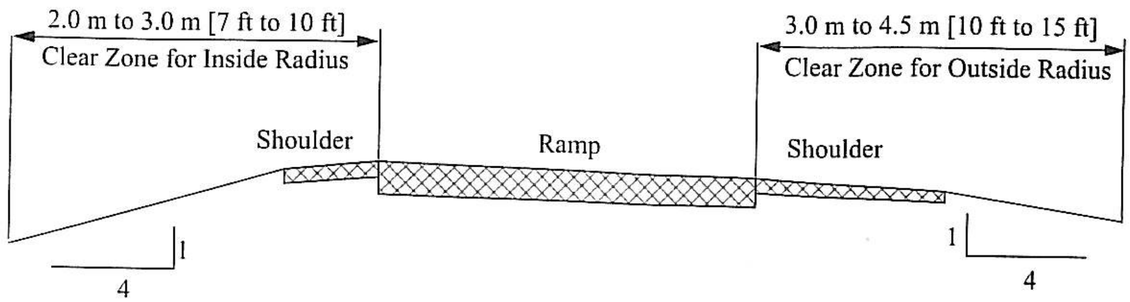
Discussion—Refer to the bold line in the above figure for the overall suggested clear zone. As an alternative, the clear zones for ramp may be set at 9 m [30 ft] if previous experience with similar projects or designs indicates satisfactory experience. See Example J for the speed-change lane clear zones.

EXAMPLE 3-L



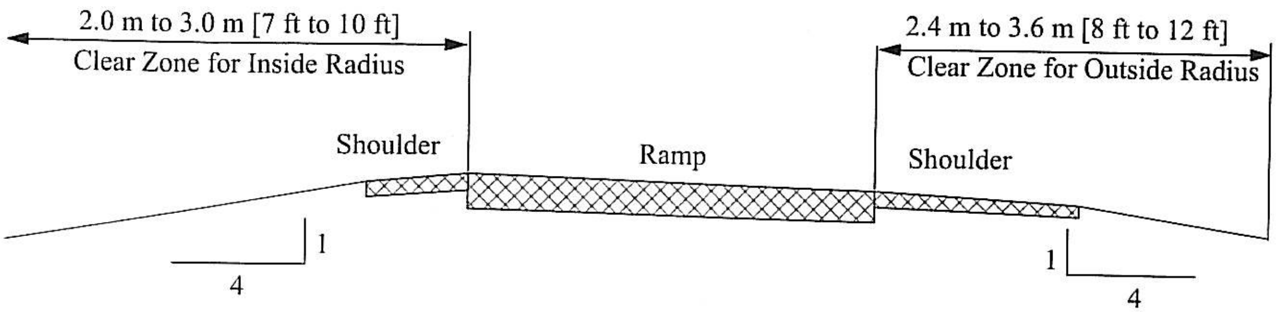
Clear Zone for Complex Ramps Cross Section-Curve 1

Curve 1
Design ADT: < 750
Design Speed: 90 km/h [55 mph]
Radius: 300 m [1,000 ft]
Suggested clear-zone distance for 6:1 foreslopes along the inside of curve: 3.5 to 4.5 m [12 to 14 ft] (from Table 3-1)
Suggested clear-zone distance for 6:1 foreslopes along the outside of curve: $CZ_c = (L_c)(K_{cz})$ = 3.5 to 4.5 m [12 to 14 ft] × 1.5 = 5.3 to 6.8 m [18 to 21 ft] (from Tables 3-1 and 3-2)



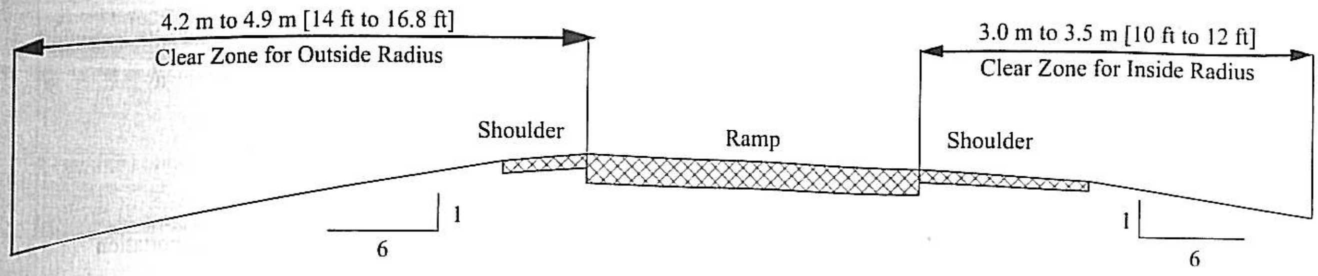
Clear Zone for Complex Ramps Cross Section Curve 2

Curve 2
Design ADT: < 750
Design Speed: 50 km/h [30 mph]
Radius: 73 m [240 ft]
Suggested clear-zone distance for 4:1 foreslopes along the inside of curve: 2.0 to 3.0 m [7 to 10 ft] (from Table 3-1)
Suggested clear-zone distance for 4:1 foreslopes along the outside of curve: $CZ_c = (L_c)(K_{cz}) =$ 2.0 to 3.0 m [7 to 10 ft] × 1.5 = 3.0 to 4.5 m [10.5 to 15 ft] (from Tables 3-1 and 3-2)



Clear Zone for Complex Ramps Cross Section Curve 3

Curve 3
Design ADT: < 750
Design Speed: 60 km/h [40 mph] assuming traffic is accelerating to enter freeway.
Radius: 300 m [1,000 ft]
Suggested clear-zone distance for 4:1 foreslopes along the inside of curve: 2.0 to 3.0 m [7 to 10 ft] (from Table 3-1)
Suggested clear-zone distance for 4:1 foreslopes along the outside of curve: $CZ_c = (L_c)(K_{cz}) =$ 2.0 to 3.0 m [7 to 10 ft] ×1.2 = 2.4 to 3.6 m [8.4 to 12 ft] (from Tables 3-1 and 3-2)



Clear Zone for Complex Ramps Cross Section Curve 4

Curve 4

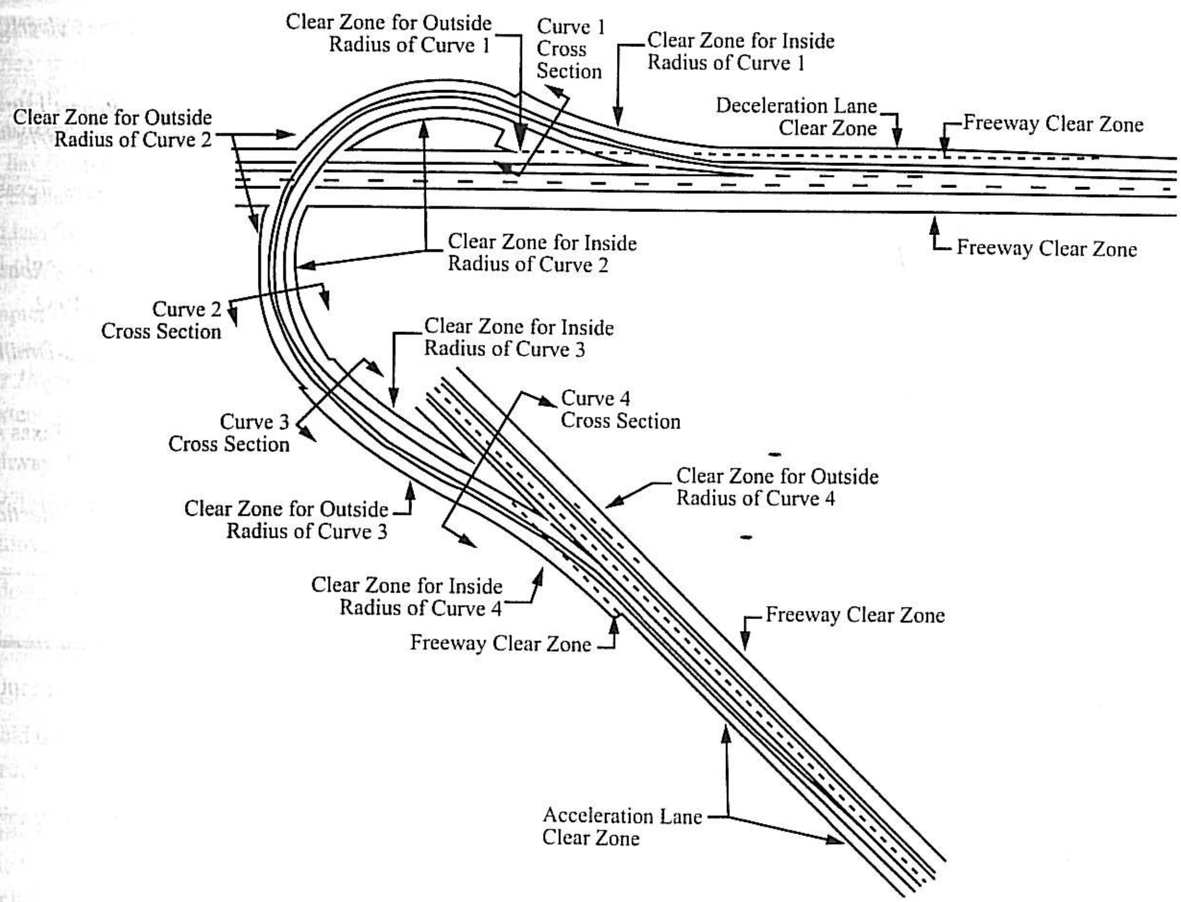
Design ADT: < 750

Design Speed: 80 km/h [50 mph] assuming traffic is accelerating to enter freeway.

Radius: 300 m [1,000 ft]

Suggested clear-zone distance for 6:1 foreslopes along the inside of curve: 3.0 to 3.5 m [10 to 12 ft] (from Table 3-1)

Suggested clear-zone distance for 6:1 foreslopes along the outside of curve: $CZ_c = (L_c)(K_{cz}) =$ 3.0 to 3.5 m [10 to 12 ft] ×1.4 = 4.2 to 4.9 m [14 to 16.8 ft] (from Tables 3-1 and 3-2)



Discussion—Refer to the bold line in the above figure for the overall suggested clear zone. As an alternative, the clear zones for ramp may be set at 9 m [30 ft] if previous experience with similar projects or designs indicates satisfactory experience. See Example J for the speed-change lane clear zones.