Chapter 910 Intersections At Grade

910.01 General

Intersections are a critical part of highway design because of increased conflict potential. Traffic and driver characteristics, bicycle and pedestrian needs, physical features, and economics are considered during the design stage to develop channelization and traffic control to enhance safe and efficient multimodal traffic flow through intersections.

This chapter provides guidance for designing intersections at grade, including at-grade ramp terminals. Refer to the following chapters for additional information:

Chapter	**Subject**
915	Roundabouts
920	Road approaches
940	Interchanges
1025	Pedestrian design considerations

If an intersection design situation is not covered in this chapter, contact the Headquarters (HQ) Design Office for assistance.

910.02 References

(1) Federal/State Laws and Codes

Americans with Disabilities Act of 1990 (ADA) (23 CFR Part 36, Appendix A)

RCW 35.68.075, Curb ramps for persons with disabilities – Required – Standards and requirements

WAC 468-18-040, Design standards for rearranged county roads, frontage roads, access roads, intersections, ramps and crossings

WAC 468-52, Highway access management – access control classification system and standards

(2) Design Guidance

Local Agency Guidelines (LAG), M 36-63, WSDOT

Manual on Uniform Traffic Control Devices for Streets and Highways, USDOT, FHWA; as adopted and modified by Chapter 468-95 WAC “Manual on uniform traffic control devices for streets and highways” (MUTCD)

Standard Plans for Road, Bridge, and Municipal Construction (Standard Plans), M 21-01, WSDOT

(3) Supporting Information

A Policy on Geometric Design of Highways and Streets (Green Book), AASHTO, 2004

Guidelines and Recommendations to Accommodate Older Drivers and Pedestrians, FHWA-RD-01-051, USDOT, FHWA, May 2001

Highway Capacity Manual (HCM), Special Report 209, Transportation Research Board, National Research Council

Highway Research Record No. 211, *Aspects of Traffic Control Devices*, pp 1-18, "Volume Warrants for Left-Turn Storage Lanes at Unsignalized Grade Intersections." Harmelink, M.D.

NCHRP 279, *Intersection Channelization Design Guide*

Roundabouts: An Informational Guide, FHWA-RD-00-067, USDOT, FHWA

910.03 Definitions

For definitions of ***design speed***, ***divided multilane***, ***expressway***, ***highway***, ***roadway***, ***rural design area***, ***suburban area***, ***traveled way***, ***undivided multilane***, and ***urban design area***, see Chapter 440; for ***lane***, ***median***, and ***shoulder***, see Chapter 640; and for ***decision sight distance***, ***sight distance***, and ***stopping sight distance***, see Chapter 650.

conflict An event involving two or more road users, in which the action of one user causes the other user to make an evasive maneuver to avoid a collision.

conflict point A point where traffic paths cross, merge, or diverge.

crossroad The minor roadway at an intersection. At a stop-controlled intersection, the crossroad has the stop.

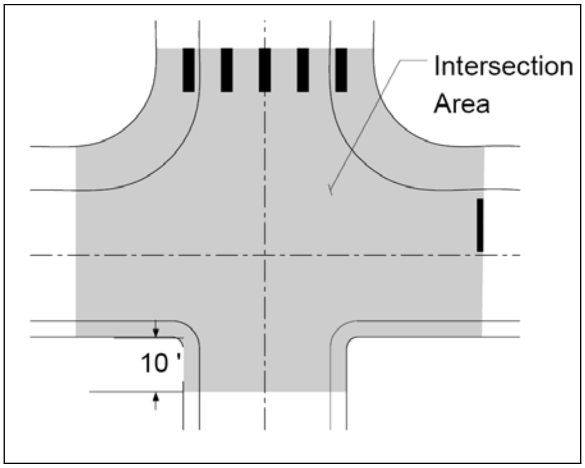
curb extensions A curb and sidewalk bulge or extension into the parking lane or shoulder to decrease the length of a pedestrian crossing (see Chapter 1025).

curb section A roadway cross section with curb and sidewalk.

design vehicle A vehicle, the dimensions and operating characteristics of which are used to establish the intersection geometry.

intersection angle The angle between any two intersecting legs at the point that the centerlines intersect.

intersection area The area of the intersecting roadways bounded by the edge of traveled ways and the area of the adjacent roadways for the farther distance (1) to the end of the corner radii, (2) through any marked crosswalks adjacent to the intersection, (3) to the stop bar, or (4) 10 feet from the edge of shoulder of the intersecting roadway (see Figure 910-1).



Intersection Area
Figure 910-1

intersection at grade The general area where a roadway or ramp terminal is met or crossed at a common grade or elevation by another roadway.

four-leg intersection An intersection formed by two crossing roadways.

tee (T) intersection An intersection formed by two roadways where one roadway terminates at the point it meets a through roadway.

split tee A four-leg intersection with the crossroad intersecting the through roadway at two tee intersections. The tee intersection must be offset at least the width of the roadway.

wye (Y) intersection An intersection formed by three legs in the general form of a "Y" and the angle between two legs is less than 60°.

intersection leg Any one of the roadways radiating from and forming part of an intersection.

entrance leg The lanes of an intersection leg for traffic entering the intersection.

exit leg The lanes of an intersection leg for traffic leaving the intersection.

Note: Whether an intersection leg is an entrance leg or an exit leg depends on which movement is being analyzed. For two-way roadways, each leg is an entrance leg for some movements and an exit leg for other movements.

intersection sight distance The required length of roadway visible to the driver for the safe operation of a vehicle entering an intersection.

island A defined area within an intersection, between traffic lanes, for the separation of vehicle movements or for pedestrian refuge.

channelization island An island that separates traffic movements into definite paths of travel and guides traffic into the intended route.

divisional island An island introduced at an intersection on an undivided roadway to warn drivers of the crossroad ahead and regulate traffic through the intersection.

refuge island An island at or near a crosswalk or bicycle path to aid and protect pedestrians and bicyclists crossing the roadway.

roundabout A circular intersection at grade (see Chapter 915).

rural intersection An intersection in a rural design area (see Chapter 440).

slip ramp A connection between legs of an intersection that allows right-turning vehicles to bypass the intersection or a connection between an expressway and a parallel frontage road.

two-way left-turn lane (TWLTL) A lane located between opposing lanes of traffic to be used by vehicles making left turns from either direction, from or onto the roadway.

urban intersection An intersection in an urban design area (see Chapter 440).

910.04 Intersection Configurations

At-grade intersection configurations in their simplest forms are three-leg, four-leg, and multileg. More complex designs are variations or combinations selected to accommodate the constraints and traffic presented by the location. The intersection configurations at any location are determined by the number of intersecting legs; the topography; the character of the intersecting roadways; the traffic volumes, patterns, and speeds; and the desired type of operation.

(1) Roundabouts

Modern roundabouts are circular intersections. They can be an effective intersection type.

When well designed, roundabouts are an efficient form of intersection control. They have fewer conflict points, lower speeds, and easier decision making, and they require less maintenance. When properly designed and located, they have been found to reduce injury accidents, traffic delays, fuel consumption, and air pollution. Roundabouts also permit U-turns.

Include roundabouts as an alternative at intersections where:

- Stop signs result in unacceptable delays for the crossroad traffic.
- There is a high left-turn percentage.
- There are more than four legs.
- A disproportionately high number of accidents involve crossing or turning traffic.
- The major traffic movement makes a turn.
- Traffic growth is expected to be high and future traffic patterns are uncertain.
- It is not desirable to give priority to either roadway.

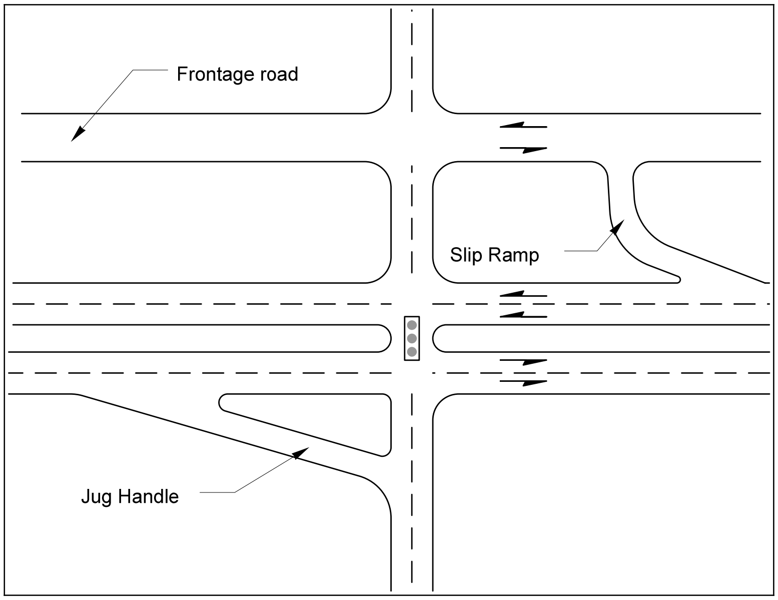
Other tradeoffs with roundabouts include:

- Roundabouts give equal priority to all legs.
- All traffic entering a roundabout is required to reduce speed.

Refer to Chapter 915 for information and requirements on the design and documentation of roundabouts.

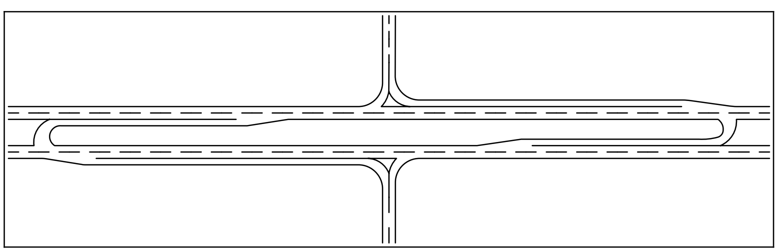
(2) Indirect Left Turns

At signalized intersections, indirect left-turn intersections reduce conflict points and delays to the major route by eliminating the left-turn phase (see Figure 910-2a for an example).



Indirect Left Turns (Signalized Intersections)
Figure 910-2a

At unsignalized intersections, indirect left-turn intersections help mitigate entering-at-angle collisions. Left-turning and through traffic on the crossroad mustturn right and then make a U-turn at a median crossover or a nearby intersection (see Figure 910-2b for an example). Provide for weaving movements when selecting the distance between right turns and U-turns on major routes and the storage (if needed) for U-turning vehicles. This treatment eliminates conflict points while minimizing delays to the major route. (See 910.08 for guidance on the design of U-turn locations.)

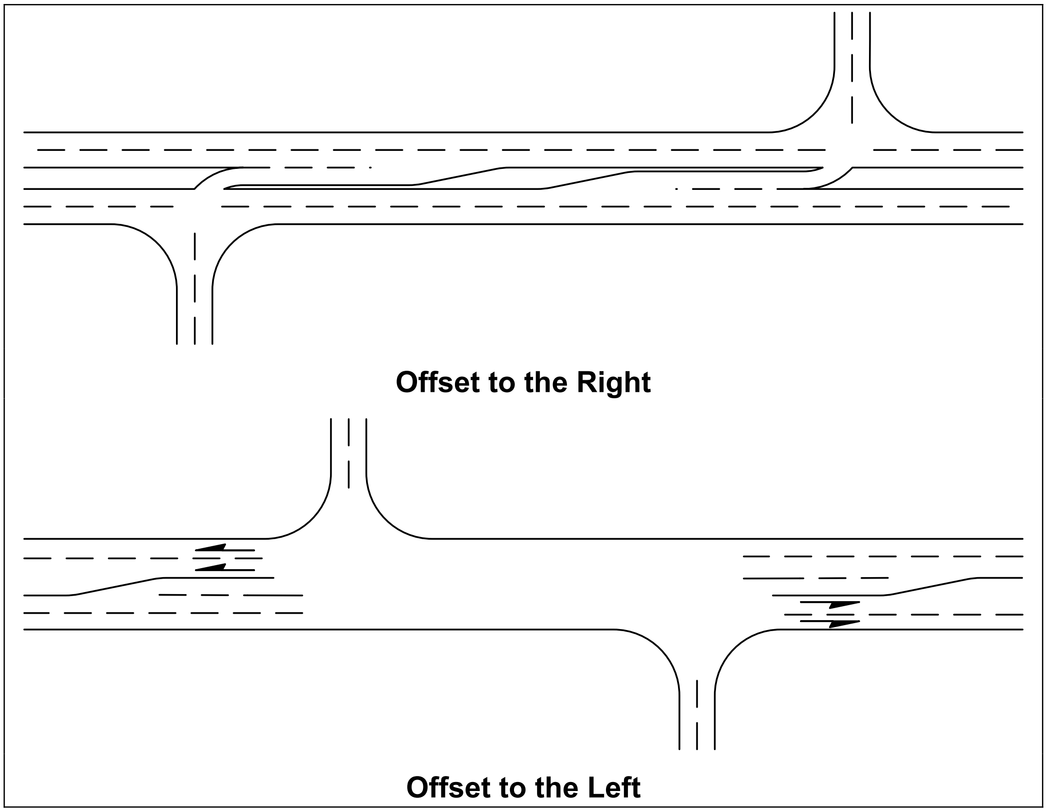


Indirect Left Turns (Unsignalized Intersections)
Figure 910-2b

(3) Split Tee

Avoid split tee intersections where there is less than the required intersection spacing (see 910.05(4)). Split tee intersections with an offset distance to the left greater than the width of the roadway, but less than the intersection spacing, may be designed, with justification. Evaluate the anticipated benefits against the increased difficulty for cross traffic in driving through the intersection and a more complicated traffic signal design.

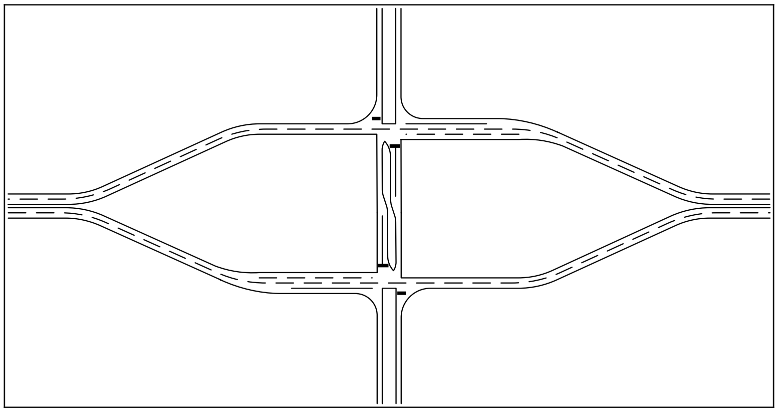
Split tee intersections with the offset to the right (see Figure 910-3) have the additional disadvantages of overlapping main line left-turn lanes, the increased possibility of wrong way movements, and a traffic signal design (if required) that will be even more complicated. Do not design a split tee intersection with an offset to the right less than the required intersection spacing (see 910.05(4)) unless traffic is restricted to right-in/right-out only.



Split Tee Intersections
Figure 910-3

(4) Split Intersections

Split intersections provide wide medians on divided multilane highways, which separate the traveled ways of the through roadway to allow storage of left-turning and crossing traffic (see Figure 910-4). Traffic on the crossroad makes the through and left-turn movements in two stages, reducing the required sight distance and the probability of the driver misjudging the required gap. The median width must be sufficient to store all crossing and left-turning vehicles to avoid potential conflicts with through traffic. The minimum median width is 100 feet, with 200 to 300 feet being desirable.



Split Intersections
Figure 910-4

(5) Nonstandard Configurations

Low average daily traffic (ADT) can hide operational problems. Do not design intersections with nonstandard configurations such as:

- Intersections with offset legs, except for split tee intersections (see 910.04(3)).
- Intersections with more than four legs.
- Tee intersections with the major traffic movement making a turn.
- Wye intersections that are not a one-way merge or diverge.

A roundabout might be an alternative to these nonstandard configurations (see 910.04(1) and Chapter 915).

With justification and approval from the Region Traffic Engineer, existing intersections with nonstandard configurations may remain in place when an analysis shows no collision history related to the configuration.

910.05 Design Considerations

Intersection design requires consideration of all potential users of the facility. This involves addressing the needs of a diverse mix of user groups, including passenger cars, heavy vehicles of varying classifications, bicycles, and pedestrians. Often, meeting the needs of one user group requires a compromise in service to others. Intersection design balances these competing needs, resulting in appropriate levels of operation for all users.

In addition to reducing the number of conflicts, minimize the conflict area as much as possible while still providing for the required design vehicle (see 910.06). This is done to control the speed of turning vehicles and reduce vehicle, bicyclist, and pedestrian exposure.

(1) Nongeometric Considerations

Geometric design considerations, such as sight distance and intersection angle, are important. Equally important are perception, contrast, and a driver's age. Perception is a factor in the majority of collisions. Regardless of the type of intersection control, the safe function of any intersection depends on the driver's ability to perceive what is happening with respect to the surroundings and other vehicles, whether it is the speed of the vehicles in front when approaching an intersection or the speed of approaching vehicles when selecting an acceptable gap in traffic to enter an intersection. In order to choose an acceptable gap, the driver must first clearly identify the approaching vehicle(s) and then determine the speed. The driver uses visual clues provided by the immediate surroundings in making these decisions. Thus, given equal sight distance, it may be easier for the driver to judge a vehicle's oncoming speed when there are more objects to pass by in the driver's line of sight. Contrast allows us to discern one object from another. Contrast sensitivity is affected by available light and the weather.

(2) Intersection Angle

An important intersection design characteristic is the intersection angle. The desirable intersection angle is 90°, with 75° to 105° allowed for new, reconstructed, or realigned intersections.

Existing intersections with an intersection angle between 60° and 120° may remain. Intersection angles outside this range tend to restrict visibility; increase the area required for turning; increase the difficulty of making a turn; increase the crossing distance and time for vehicles and pedestrians; and make traffic signal arms difficult or impossible to design.

(3) Lane Alignment

Design intersections with entrance lanes aligned with the exit lanes. Do not put angle points on the roadway alignments within intersection areas or on the through roadway alignment within 100 feet of the edge of traveled way of a crossroad. This includes short radius curves where both the PC and PT are within the intersection area. However, angle points within the intersection are allowed at intersections with a minor through movement, such as at a ramp terminal (see Figure 910-10).

When feasible, locate intersections such that curves do not begin or end within the intersection area. It is desirable to locate the PC and PT at least 250 feet from the intersection so that a driver can settle into the curve before the gap in the striping for the intersection area.

(4) Intersection Spacing

Adequate intersection spacing is required to provide for safety and the desired operational characteristics for the highway. The minimum spacing for highways with limited access control is covered in Chapters 1430. For other highways, the minimum spacing is dependent on the Highway Access Management Class. (See Chapter 1435 for minimum intersection spacing on managed access highways.)

As a minimum, provide enough space between intersections for left-turn lanes and storage length. Space signalized intersections and intersections expected to be signalized to maintain efficient signal operation. Space intersections so that queues will not block an adjacent intersection.

Evaluate existing intersections that are spaced less than shown in Chapters 1430 and 1435. Evaluate closing or restricting movements at intersections with operational problems. Document the spacing of existing intersections to remain in place and their effects on operation, capacity, and circulation.

(5) Design Vehicle

The geometric design of an intersection requires identifying and addressing the needs of all intersection users. There are competing design objectives when considering the turning requirements of larger vehicles and the crossing requirements of pedestrians. To reduce the operational impacts of large design vehicles, larger turn radii are used. This results in increased pavement areas, longer pedestrian crossing distances, and longer traffic signal arms.

To reduce the intersection area, a smaller design vehicle is used or encroachment is allowed. This reduces the potential for vehicle/pedestrian conflicts, decreases pedestrian crossing distance, and controls the speeds of turning vehicles.

If the selected design vehicle is too small, a capacity reduction and greater speed differences between turning vehicles and through vehicles might result. If the vehicle is larger than necessary, the pavement areas, pedestrian crossing distances, and traffic signal arms will also be larger than needed. (See 910.06 for information on selecting a design vehicle and acceptable encroachments.)

(6) Sight Distance

For traffic to move safely through intersections, drivers need to be able to see stop signs, traffic signals, and oncoming traffic in time to react accordingly.

Provide decision sight distance in advance of stop signs, traffic signals, and roundabouts. Where decision sight distance is not feasible, stopping sight distance may be provided. (See Chapter 650 for guidance.)

Drivers approaching an intersection on the through roadway need to be able to see the intersection far enough ahead to assess developing situations and take appropriate action. Locate new intersections where decision sight distance is available for through traffic. At crosswalks, provide decision sight distance to an area the width of the crosswalk and 6 feet from the edge of traveled way. Where decision sight distance is not feasible, stopping sight distance may be provided. (See Chapter 650 for guidance on decision and stopping sight distances.)

The driver of a vehicle that is stopped, waiting to cross or enter a through roadway, needs obstruction-free sight triangles in order to see enough of the through roadway to safely complete all legal maneuvers before an approaching vehicle on the through roadway can reach the intersection. (See 910.09 for guidance on intersection sight distance sight triangles.)

(7) Crossroads

When the crossroad is a city street or county road, design the crossroad beyond the intersection area according to the applicable design criteria given in Chapter 440.

When the crossroad is a state facility, design the crossroad according to the applicable design level and functional class (see Chapters 325, 430, and 440). Continue the cross slope of the through roadway shoulder as the grade for the crossroad. Use a vertical curve that is at least 60 feet long to connect to the grade of the crossroad.

Evaluate the profile of the crossroad in the intersection area. To prevent operational problems, the crown slope of the main line might need to be adjusted in the intersection area.

Design the grade for stop-controlled legs so that the cross slope for the crosswalk is not greater than 2%. For all other legs, adjust the grade so that the maximum crosswalk cross slope is 5%. (See Chapter 1025 for additional crosswalk information.)

In areas that experience accumulations of snow and ice and for all legs that will require traffic to stop, design a maximum grade of ±4% for a length equal to the anticipated queue length for stopped vehicles.

(8) Rural Expressway At-Grade Intersections

At-grade intersections on high-speed rural expressways can result in safety problems. The main problem is right-angle, far-side collisions for crossroad traffic making a left-turn or crossing maneuver. Evaluate grade separations at all intersections on rural expressways.

Design high-speed at-grade intersections on rural expressways as indirect left turns, split intersections, or roundabouts.

The State Traffic Engineer's approval is required for any new intersection or signal on a rural expressway.

(9) Interchange Ramp Terminals

When stop control or traffic signal control is selected, the design to be used or modified is shown in Figure 910-10. Higher-volume intersections with multiple ramp lanes are designed individually.

In urban and suburban areas, match the design speed at the ramp terminal to the speed of the crossroad.

Where stop control or signal control is implemented, the intersection configuration requirements for ramp terminals are normally the same as for other intersections. One exception to this is that an angle point is allowed between an off-ramp and an on-ramp. This is because the through movement of traffic getting off the freeway, going through the intersection, and back on the freeway is minor.

Another exception is at ramp terminals where the through movement is eliminated (for example at a single point interchange). For ramp terminals that have two wye connections, one for right turns and the other for left turns and no through movement, the intersection angle has little meaning and does not need to be considered.

Due to the probable development of large traffic generators adjacent to an interchange, width for a median on the local road is desirable whenever such development is believed to be imminent. This allows for future left-turn channelization. Use median channelization when justified by capacity determination and analysis or by the need to provide a smooth traffic flow.

Adjust the alignment of the intersection legs to fit the traffic movements and to discourage wrong-way movements. Use the allowed intersecting angles of 75° to 105° (60° to 120° for modified design level) to avoid broken back or reverse curves in the ramp alignment.

910.06 Design Vehicle Selection

When selecting a design vehicle for an intersection, the needs of all users and the costs must be considered. The primary use of the design vehicle is to determine radii requirements for each leg of the intersection. It is possible for each leg to have a different design vehicle. Figure 910-5 shows commonly used design vehicle types.

Evaluate the existing and anticipated future traffic to select a design vehicle that is the largest vehicle that normally uses the intersection. Figure 910-6 shows the minimum design vehicles. Provide justification to use a smaller vehicle; include a traffic analysis showing that the proposed vehicle is appropriate.

To minimize the disruption to other traffic, design the intersection to allow the design vehicles to make each turning movement without encroaching on curbs, opposing lanes, or same-direction lanes at the entrance leg. Use turning path templates (see Figures 910-20a through 20c, templates from another published source, or computer-generated templates) to verify that the design vehicle can make the turning movements.

Encroachment on the same-direction lanes of the exit leg and the shoulder might be necessary to minimize crosswalk distances; however, this might negatively impact vehicular operations. Document and justify the operational tradeoffs associated with this encroachment. When encroachment on the shoulder is required, increase the pavement structure to support the anticipated traffic.

Design Symbol	Vehicle Type
P	Passenger car, including light delivery trucks.
BUS	Single-unit bus
A-BUS	Articulated bus
SU	Single-unit truck
WB-40	Semitrailer truck, overall wheelbase of 40 ft
WB-50	Semitrailer truck, overall wheelbase of 50 ft
WB-67	Semitrailer truck, overall wheelbase of 67 ft
MH	Motor home
P/T	Passenger car pulling a camper trailer
MH/B	Motor home pulling a boat trailer

Design Vehicle Types
Figure 910-5

Intersection Type	Design Vehicle
Junction of Major Truck Routes	WB-67
Junction of State Routes	WB-50
Ramp Terminals	WB-50
Other Rural	WB-50
Industrial	WB-40
Commercial	SU[1][2]
Residential	SU[1][2]

Notes:

[1] To accommodate pedestrians, the P vehicle may be used as the design vehicle if justification, with a traffic analysis, is documented.

[2] When the intersection is on a transit or school bus route, use the BUS design vehicle as a minimum. (See Chapter 1060 for additional guidance on transit facilities.)

Minimum Intersection Design Vehicle
Figure 910-6

In addition to the design vehicle, intersections must often be designed to accommodate a larger vehicle. When vehicles larger than the design vehicle are allowed and are anticipated to occasionally use the intersection, make certain that they can make the turn without leaving the paved shoulders or encroaching on a sidewalk. The amount of encroachment allowed is dependent on the frequency of the vehicle and the resulting disruption to other traffic. Use the WB-67 as the largest vehicle at all state route-to-state route junctions. Document and justify any required encroachment into other lanes and any degradation of intersection operation.

910.07 Design Elements

The geometric design of an intersection requires identifying and addressing the needs of all intersection users. There can be competing design objectives when considering the turning requirements of the design vehicle and the crossing requirements of pedestrians. To reduce the operational impacts of large trucks, right-turn radii are designed so that the truck can complete its turn without encroaching on the adjacent lanes. This results in larger corner radii; increased pavement area and pedestrian crossing distances; a larger conflict area; and higher turning speeds for smaller vehicles.

When pedestrian issues are a primary concern, the design objective becomes one of reducing the potential for vehicle/pedestrian conflicts. This is done by minimizing pedestrian crossing distances and controlling the speeds of turning vehicles. This normally leads to right-corner designs with smaller turning radii. The negative impacts include possible capacity reductions and greater speed differences between turning vehicles and through vehicles.

Pedestrian refuge islands can also improve pedestrian safety. Pedestrian refuge islands minimize the crossing distance, reduce the conflict area, and minimize the impacts on vehicular traffic. When designing islands, speeds can be reduced by designing the turning roadway with a taper or large radius curve at the beginning of the turn and a small radius curve at the end. This allows larger islands while forcing the turning traffic to slow down.

Channelization, the separation or regulation of traffic movements into delineated paths of travel, can facilitate the safe and orderly movement of vehicles, bicycles, and pedestrians. Channelization includes left-turn lanes, right-turn lanes, speed change lanes (both acceleration and deceleration lanes), and islands.

(1) Right-Turn Corners

Figure 910-11 shows right-turn corner designs for the design vehicles. These are considered the minimum pavement area to accommodate the design vehicles without encroachment on the adjacent lane at either leg of the curve.

With an evaluate upgrade, right-turn corner designs given in Figure 910-11 may be modified. Document the benefits and impacts of the modified design, including changes to vehicle-pedestrian conflicts; vehicle encroachment on the shoulder or adjacent same direction lane at the exit leg; capacity restrictions for right-turning vehicles or other degradation of intersection operations; and the effects on other traffic movements. To verify that the design vehicle can make the turn, include a plot of the design showing the design vehicle turning path template.

(2) Left-Turn Lanes and Turn Radii

Left-turn lanes provide storage, separate from the through lanes, for left-turning vehicles waiting for a signal to change or for a gap in opposing traffic. (See 910.07(4) for a discussion on speed change lanes.)

Design left-turn channelization to provide sufficient operational flexibility to function under peak loads and adverse conditions.

(a) **One-Way Left-Turn Lanes** are separate storage lanes for vehicles turning left from one roadway onto another. When recommended, one-way left-turn lanes may be an economical way to lessen delays and accident potential involving left-turning vehicles. In addition, they can allow deceleration clear of the through traffic lanes. When evaluating left-turn lanes, include impacts to all intersection movements and users.

At signalized intersections, use a traffic signal analysis to determine whether a left-turn lane is needed and what the storage requirements are (see Chapter 850).

At unsignalized intersections, use the following as a guide to determine whether or not to provide one-way left-turn lanes:

- A traffic analysis indicates that a left-turn lane will reduce congestion. On two-lane highways, use Figure 910-12a, based on total traffic volume (DHV) for both directions and percent left-turn traffic, to determine whether further investigation is needed. On four-lane highways, use Figure 910-12b to determine whether a left-turn lane is recommended.
- An accident study indicates that a left-turn lane will reduce accidents.
- Restrictive geometrics require left-turning vehicles to slow greatly below the speed of the through traffic.
- There is less than decision sight distance at the approach to the intersection.

An HCM analysis may also be used to determine whether left-turn lanes are necessary to maintain the desired level of service.

Determine the storage length required on two-lane highways by using Figures 910-13a through 13c. On four-lane highways, use Figure 910-12b. These lengths do not consider trucks. Use Figure 910-7 for storage length when trucks are present.

Storage* Length (ft)	% Trucks in Left-Turn Movement				
	10	20	30	40	50
100	125	125	150	150	150
150	175	200	200	200	200
200	225	250	275	300	300
250	275	300	325	350	375
300	350	375	400	400	400
*Length from Figures 910-12b, 13a, 13b, or 13c.					

Left-Turn Storage With Trucks (ft)
Figure 910-7

Use turning templates to verify that left-turn movements for the design vehicle(s) do not have conflicts. Design opposing left-turn design vehicle paths with a minimum 4-foot (12-foot desirable) clearance between opposing turning paths. Existing signalized intersections that do not meet the 4-foot clearance may remain with split signal phasing, an evaluate upgrade, and concurrence from the Region Traffic Office.

Where one-way left-turn channelization with curbing is to be provided, ensure that surface water will drain.

Provide illumination at left-turn lanes in accordance with the guidelines in Chapter 840.

At signalized intersections with high left-turn volumes, double left-turn lanes may be needed to maintain the desired level of service. A throat width of 30 to 36 feet is desirable on the exit leg of the turn to offset vehicle offtracking and the difficulty of two vehicles turning abreast. Use turning path templates to verify that the design vehicle can complete the turn. Where the design vehicle is a WB-40 or larger, it is preferred to provide for the design vehicle in the outside lane and an SU vehicle turning abreast rather than two design vehicles turning abreast.

Figures 910-14a through 14e show one-way left-turn lane geometrics. Figure 910-14a shows widening to accommodate the new lane. Figures 910-14b, 14c, and 14d show the use of a median. Figure 910-14e shows the minimum protected left turn with a median.

1. **Widening** (see Figure 910-14a). It is desirable that offsets and pavement widening be symmetrical about the centerline or baseline. Where right of way or topographic restrictions, crossroad alignments, or other circumstances preclude symmetrical widening, pavement widening may be on one side only.
2. **Divided Highways** (see Figures 910-14b through 14d). Widening is not required for left-turn lane channelization where medians are 11 feet wide or wider. For medians between 13 feet and 23 feet or where the acceleration

lane is not provided, it is desirable to design the left-turn lane adjacent to the opposing lane (shown in Figure 910-14b) to improve sight distance and increase opposing left-turn clearances.

A median acceleration lane (shown in Figures 910-14c and 14d) may be provided where the median is 23 feet or wider. The median acceleration lane might not be necessary at a signalized intersection. When a median acceleration lane is to be used, design it in accordance with 910.07(4), Speed Change Lanes. Where medians have sufficient width, provide a 2-foot shoulder adjacent to a left-turn lane.

3. **Minimum Protected Left Turn With a Median** (see Figure 910-14e). At intersections on divided highways where channelized left-turn lanes are not provided, provide the minimum protected storage area.

   With an evaluate upgrade, the left-turn lane designs given in Figures 910-14a through 14e may be modified. Document the benefits and impacts of the modified design, including changes to vehicle-pedestrian conflicts; vehicle encroachment; deceleration length; capacity restrictions for turning vehicles or other degradation of intersection operations; and the effects on other traffic movements. The modified design must be able to accommodate the design vehicle and provide for the striping requirements of the *Standard Plans* and the MUTCD. To verify that the design vehicle can make the turn, include a plot of the design showing the design vehicle turning path template.

(b) **Two Way Left-Turn Lanes** (TWLTL) are located between opposing lanes of traffic. They are used by vehicles making left turns from either direction, from or onto the roadway.

Use TWLTLs only on managed access highways where there are no more than two through lanes in each direction. Evaluate installation of TWLTLs where:

- An accident study indicates that a TWLTL will reduce accidents.
- There are existing closely spaced access points or minor street intersections.
- There are unacceptable through traffic delays or capacity reductions because of left-turning vehicles.

A TWLTL can reduce delays to through traffic, reduce rear-end accidents, and provide separation between opposing lanes of traffic. However, they do not provide a safe refuge for pedestrians and can encourage strip development with additional closely spaced access points. Evaluate other alternatives (such as prohibiting midblock left turns and providing for U-turns) before using a TWLTL. (See Chapters 440 and 1435 for additional restrictions on the use of TWLTLs.)

The basic design for a TWLTL is illustrated in Figure 910-14f. Additional criteria are:

- The desirable length of a TWLTL is not less than 250 feet.
- Provide illumination in accordance with the guidelines in Chapter 840.
- Pavement markings, signs, and other traffic control devices must be in accordance with the MUTCD and the *Standard Plans*.
- Provide clear channelization when changing from TWLTLs to one-way left-turn lanes at an intersection.

(3) Right-Turn Lanes

Right-turn movements influence intersection capacity even though there is no conflict between right-turning vehicles and opposing traffic. Right-turn lanes might be needed to maintain efficient intersection operation. Use the following guidelines to determine when to provide right-turn lanes at unsignalized intersections.

- Recommendation from Figure 910-15 based on same-direction approach and right-turn traffic volumes for multilane roadways with a posted speed 45 mph or above and for all two-lane roadways.
- An accident study indicates that a right-turn lane will result in an overall accident reduction.
- The presence of pedestrians who require right-turning vehicles to stop.
- Restrictive geometrics that require right-turning vehicles to slow greatly below the speed of the through traffic.
- Less than decision sight distance at the approach to the intersection.

For unsignalized intersections, see 910.07(4), Speed Change Lanes, for guidance on right-turn lane lengths. For signalized intersections, use a traffic signal analysis to determine whether a right-turn lane is needed and the length requirement (see Chapter 850).

A capacity analysis may be used to determine whether right-turn lanes are necessary to maintain the desired level of service.

Where adequate right of way exists, providing right-turn lanes is relatively inexpensive and can provide increased safety and operational efficiency.

The right-turn pocket or the right-turn taper (see Figure 910-16) may be used at any minor intersection where a right-turn lane is not required. These designs will cause less interference and delay to the through movement by offering an earlier exit to right-turning vehicles.

If the right-turn pocket is used, Figure 910-16 shows taper lengths for various posted speeds.

(4) Speed Change Lanes

A speed change lane is an auxiliary lane primarily for the acceleration or deceleration of vehicles entering or leaving the through traveled way. Speed change lanes are normally provided for at-grade intersections on multilane divided highways with access control. Where roadside conditions and right of way allow, speed change lanes may be provided on other through roadways. Justification for a speed change lane depends on many factors, including speed, traffic volumes, capacity, type of highway, the design and frequency of intersections, and accident history.

A deceleration lane (Figure 910-17) is advantageous because, if a deceleration lane is not provided, the driver leaving the highway must slow down in the through lane regardless of following traffic.

An acceleration lane (Figure 910-18) is not as advantageous because entering drivers can wait for an opportunity to merge without disrupting through traffic. However, acceleration lanes for left-turning vehicles provide a safe benefit by allowing the turn to be made in two movements.

When either deceleration or acceleration lanes are to be used, design them in accordance with Figures 910-17 and 18. When the design speed of the turning traffic is greater than 20 mph, design the speed change lane as a ramp in accordance with Chapter 940. When a deceleration lane is used with a left-turn lane, add the deceleration length to the storage length.

(5) Drop Lanes

A lane may be dropped at an intersection with a turn-only lane or beyond the intersection. Do not allow a lane-reduction taper to cross an intersection or end less than 100 feet before an intersection. (See Chapter 620 for lane reduction pavement transitions.)

When a lane is dropped beyond signalized intersections, provide a lane of sufficient length to allow smooth merging. For facilities with a posted speed of 45 mph or higher, use a minimum length of 1500 feet. For facilities with a posted speed less than 45 mph, provide a lane of sufficient length so that the advanced lane reduction warning sign will be placed not less than 100 feet beyond the intersection area.

When a lane is dropped beyond unsignalized intersections, provide a lane beyond the intersection not less than the acceleration lane length from Figure 910-18.

(6) Shoulders

With justification, shoulder width requirements may be reduced within areas channelized for intersection turning lanes or speed change lanes. Apply left shoulder width criteria to the median shoulder of divided highways. On one-way couplets, apply the width criteria for the right shoulder to both the right and left shoulders.

For roadways without curb sections, the shoulder adjacent to turn lanes and speed change lanes may be reduced to 2 feet on the left and 4 feet on the right. When a curb and sidewalk section is used with a turn lane or speed change lane, 400 feet or less in length, the shoulder abutting the turn lane may be eliminated. In instances where curb is used without sidewalk, provide a minimum of 4-foot-wide shoulders on the right. Where curbing is used adjacent to left-turn lanes, the shoulder may be eliminated. Adjust the design of the intersection as necessary to allow for vehicle tracking.

Reducing the shoulder width at intersections facilitates the installation of turn lanes without unduly affecting the overall width of the roadway. A narrower roadway also reduces pedestrian exposure in crosswalks and discourages motorists from using the shoulder to bypass other turning traffic.

On routes where provisions are made for bicycles, continue the bicycle facility between the turn lane and the through lane. (See Chapter 1020 for information on bicycle facilities.)

(7) Islands

An island is a defined area within an intersection between traffic lanes for the separation of vehicle movements or for pedestrian refuge. Within an intersection, a median is considered an island. Design islands to clearly delineate the traffic channels to drivers and pedestrians.

Traffic islands perform the following functions:

- Channelization islands control and direct traffic movements
- Divisional islands separate traffic movements
- Refuge islands provide refuge for pedestrians
- Islands can provide for the placement of traffic control devices and luminaires
- Islands can provide areas within the roadway for landscaping

(a) **Size and Shape**. Divisional and refuge islands are normally elongated and at least 4 feet wide and 20 feet long.

Channelization islands are normally triangular. In rural areas, 75 ft^2 is the minimum island area and 100 ft^2 is desirable. In urban areas where posted speeds are 25 mph or less, smaller islands are acceptable. Use islands with at least 200 ft^2 if pedestrians will be crossing or traffic control devices or luminaires will be installed.

Design triangular-shaped islands as shown in Figures 910-19a through 19c. The shoulder and offset widths illustrated are for islands with vertical curbs 6 inches or higher. Where painted islands are used, such as in rural areas, these widths are desirable but may be omitted. (See Chapter 641 for desirable turning roadway widths.)

Island markings may be supplemented with reflective raised pavement markers.

Barrier-free access must be provided at crosswalk locations where raised islands are used (see Chapter 1025).

(b) **Location**. Design the approach ends of islands to provide adequate visibility to alert motorists to their presence. Position the island so that a smooth transition in vehicle speed and direction is attained. Begin transverse lane shifts far enough in advance of the intersection to allow gradual transitions. Avoid introducing islands on a horizontal or vertical curve. If the use of an island on a curve cannot be avoided, provide adequate sight distance, illumination, or extension of the island.

(c) **Compound Right-Turn Lane**. To design large islands, the common method is to use a large radius curve for the turning traffic. While this does provide a larger island, it also encourages higher turning speeds. Where pedestrians are a concern, higher turning speeds are undesirable. An alternative is a compound curve with a large radius followed by a small radius (see Figure 910-19b). This design forces the turning traffic to slow down.

(d) **Curbing**. Provide vertical curb 6 inches or higher for:

- Islands with luminaires, signals, or other traffic control devices.
- Pedestrian refuge islands.

Also consider curbing for:

- Divisional and channelizing islands.
- Landscaped islands.

In general, unless required for the uses listed above, it is preferred not to use curbs on facilities with a posted speed of 45 mph or greater.

Avoid using curbs if the same objective can be attained with pavement markings.

Refer to Chapter 440 for additional information and requirements on the use of curbs.

910.08 U-Turns

For divided multilane highways without full access control that have access points where the median prevents left turns, evaluate the demand for locations that allow U-turns. Normally, U-turn opportunities are provided at intersections. However, where intersections are spaced far apart, U-turn median openings may be required between intersections to accommodate U-turns. Use the desirable U-turn spacing (see Figure 910-8) as a guide to determine when to provide U-turn median openings between intersections. When the U-turning volumes are low, longer spacing may be used.

Locate U-turn median openings where intersection sight distance can be provided.

	Desirable	Minimum
Urban[1]	1,000 ft	[2]
Suburban	½ mi	¼ mi[3]
Rural	1 mi	½ mi

Notes:

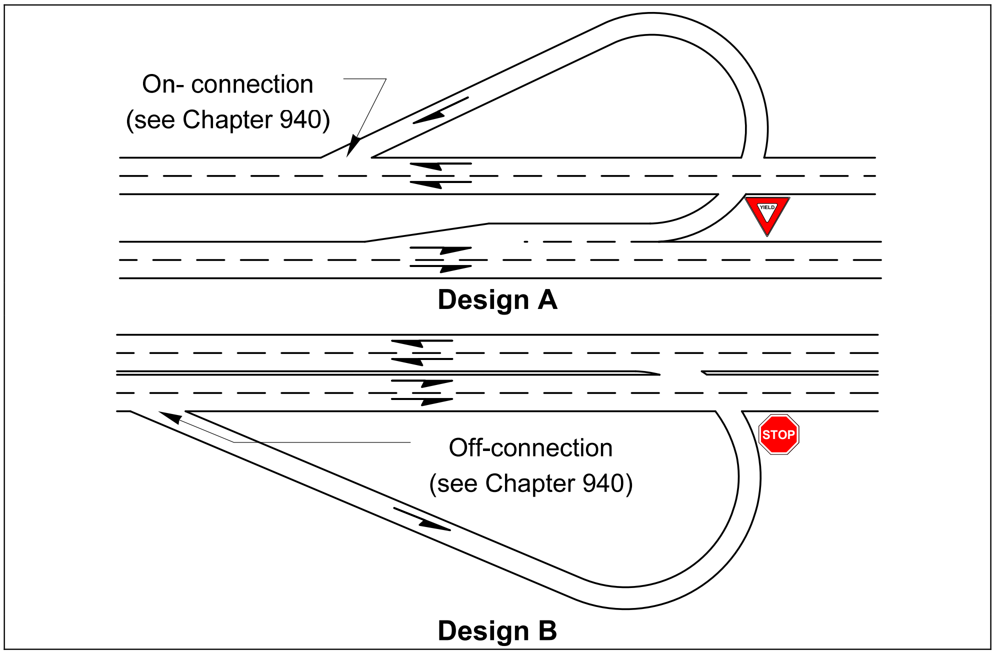
[1] For design speeds greater than 45 mph, use suburban spacing.

[2] The minimum spacing is the acceleration lane length from a stop (Figure 910-18) plus 300 ft.

[3] For design speeds 60 mph or greater, the minimum spacing is the acceleration lane length from a stop (Figure 910-18) plus 300 ft.

U-Turn Spacing
Figure 910-8

When designing U-turn median openings, use Figure 910-21 as a guide. Where the median is less than 40 feet wide and a large design vehicle is required, provide a U-turn roadway (see Figure 910-9). Design A, with the U-turn roadway after the left-turn, is preferred. Use Design A when the median can accommodate a left-turn lane. Use Design B only with narrow medians where left-turn channelization cannot be built in the median.



U-Turn Roadway
Figure 910-9

Document the need for U-turn locations and the spacing used, and justify the selected design vehicle. If the design vehicle is smaller than the largest vehicle using the facility, provide an alternate route.

U-turns at signal-controlled intersections do not require the acceleration lanes shown in Figure 910-21. For new U-turn locations at signal-controlled intersections, ensure that right-turning vehicles from side streets will not conflict with U-turning vehicles. Warning signs on the cross street might be appropriate.

910.09 Intersection Sight Distance

For traffic to move safely through intersections, drivers need to be able to see stop signs, traffic signals, and oncoming traffic in time to react accordingly.

Provide decision sight distance, where feasible, in advance of stop signs, traffic signals, and roundabouts. (See Chapter 650 for guidance.)

The driver of a vehicle that is stopped and waiting to cross or enter a through roadway needs obstruction-free sight triangles in order to see enough of the through roadway to safely complete all legal maneuvers before an approaching vehicle on the through roadway can reach the intersection. Use Figure 910-22a to determine minimum sight distance along the through roadway.

The sight triangle is determined as shown in Figure 910-22b. Within the sight triangle, lay back the cut slopes and remove, lower, or move hedges, trees, signs, utility poles, signal poles and anything else large enough to be a sight obstruction. Eliminating parking will remove obstructions to sight distance. In order to maintain the sight distance, the sight triangle must be within the right of way or a state maintenance easement (see Chapter 1410).

The minimum setback distance for the sight triangle is 18 feet from the edge of traveled way. This is for a vehicle stopped 10 feet from the edge of traveled way. The driver is almost always 8 feet or less from the front of the vehicle; therefore, 8 feet are added to the setback. When the stop bar is placed more than 10 feet from the edge of traveled way, providing the sight triangle to a point 8 feet back of the stop bar is desirable.

Provide a clear sight triangle for a P vehicle at all intersections. In addition, provide a clear sight triangle for the SU vehicle for rural highway conditions. If there is significant combination truck traffic, use the WB-50 or WB-67 rather than the SU. In areas where SU or WB vehicles are minimal and right of way restrictions prohibit adequate sight triangle clearing, only the P vehicle sight distance needs to be provided.

At existing intersections, when sight obstructions within the sight triangle cannot be removed due to limited right of way, the intersection sight distance may be modified. A driver who does not have the desired sight distance will creep out until the sight distance is available; therefore, the 10-foot stopping distance from the edge of traveled way may be reduced to 2 feet, reducing the setback to 10 feet. Document the right of way width and provide a brief analysis of the intersection sight distance clarifying the reasons for reduction. Verify and document that there is not an accident problem at the intersection. Document the intersection location and the available sight distance in the Design Variance Inventory (see Chapter 330) as a design exception.

If the intersection sight distance cannot be provided using the reductions in the preceding paragraph, where stopping sight distance is provided for the major roadway, the intersection sight distance, at the 10-foot setback point, may be reduced to the stopping sight distance required for the major roadway, with an evaluate upgrade and HQ Design Office review and concurrence. (See Chapter 650 for required stopping sight distance.) Document the right of way width and provide a brief analysis of the intersection sight distance clarifying the reasons for reduction. Verify and document that there is not an accident problem at the intersection. Document the intersection location and the available sight distance in the Design Variance Inventory (see Chapter 330) as an evaluate upgrade.

In some instances, intersection sight distance is provided at the time of construction, but subsequent vegetative growth has degraded the sight distance available. The growth may be seasonal or occur over time. In these instances, intersection sight distance will be restored through the periodically scheduled maintenance of vegetation in the sight triangle within the WSDOT right of way or state maintenance easement.

At intersections controlled by traffic signals, provide sight distance for right-turning vehicles.

Designs for movements that cross divided highways are influenced by median widths. If the median is wide enough to store the design vehicle, with a 3-foot clearance at both ends of the vehicle, sight distances are determined in two steps. The first step is for crossing from a stopped position to the median storage; the second step is for the movement, either across or left into the through roadway.

Design sight distance for ramp terminals as at-grade intersections with only left- and right-turning movements. An added element at ramp terminals is the grade separation structure. Figure 910-22b gives the sight distance guidance in the vicinity of a structure. In addition, when the crossroad is an undercrossing, check the sight distance under the structure graphically using a truck eye height of 6 feet and an object height of 1.5 feet.

Document a brief description of the intersection area, sight distance restrictions, and traffic characteristics to support the design vehicle and sight distances chosen.

910.10 Traffic Control at Intersections

Intersection traffic control is the process of moving traffic safely through areas of potential conflict where two or more roadways meet. Signs, signals, channelization, and physical layout are the major tools used to establish intersection control.

There are three objectives to intersection traffic control that can greatly improve intersection operations.

- **Maximize Intersection Capacity**. Since two or more traffic streams cross, converge, or diverge at intersections, the capacity of an intersection is normally less than the roadway between intersections. It is usually necessary to assign right of way through the use of traffic control devices to maximize capacity for all users of the intersection. Turn prohibitions may be used to increase intersection capacity.
- **Reduce Conflict Points**. The crossing, converging, and diverging of traffic creates conflicts that increase the potential for accidents. Establishing appropriate controls can reduce the possibility of two cars attempting to occupy the same space at the same time. Pedestrian accident potential can also be reduced by appropriate controls.
- **Prioritize Major Street Traffic**. Traffic on major routes is normally given the right of way over traffic on minor streets to increase intersection operational efficiency.

If a signal is being considered or exists at an intersection that is to be modified, a preliminary signal plan is required (see Chapter 850). If a new signal permit is required, it must be approved before the design is approved.

A proposal to install a traffic signal or a roundabout on a state route, either NHS or Non-NHS, with a posted speed limit of 45 mph or higher requires an analysis of alternatives, approved by the Region Traffic Engineer, with review and comment by the HQ Design Office, prior to proceeding with the design. Include the following alternatives in the analysis:

- Channelization, providing deceleration lanes, storage, and acceleration lanes for left- and right-turning traffic
- Right-off/right-on with U-turn opportunities
- Grade separation
- Roundabouts
- Traffic control signals

Include a copy of the analysis with the preliminary signal plan or roundabout justification.

910.11 Signing and Pavement Marking

Use the MUTCD and the *Standard Plans* for signing and pavement marking criteria. Provide a route confirmation sign on all state routes shortly after major intersections. (See Chapter 820 for additional information on signing.)

Painted or plastic pavement markings are normally used to delineate travel paths. For pavement marking details, see the MUTCD, Chapter 830, and the *Standard Plans*.

Contact the Region or HQ Traffic Office for additional information when designing signing and pavement markings.

910.12 Procedures

Document design considerations and conclusions in accordance with Chapter 330. For highways with limited access control, see Chapter 1430 for requirements.

(1) Approval

An intersection is approved in accordance with Chapter 330. When required, the following items must be completed before an intersection may be approved:

- Traffic analysis
- Deviations approved in accordance with Chapter 330
- Approved Traffic Signal Permit (DOT Form 242-014 EF) (see Chapter 850)
- HQ Design Office approval for intersections with roundabouts (see Chapter 915 for approval procedures)

(2) Intersection Plans

Intersection plans are required for any increases in capacity (turn lanes) at an intersection, modification of channelization, or change of intersection geometrics. Support the need for intersection or channelization modifications with history; school bus and mail route studies; hazardous materials route studies; pedestrian use; public meeting comments; and so forth.

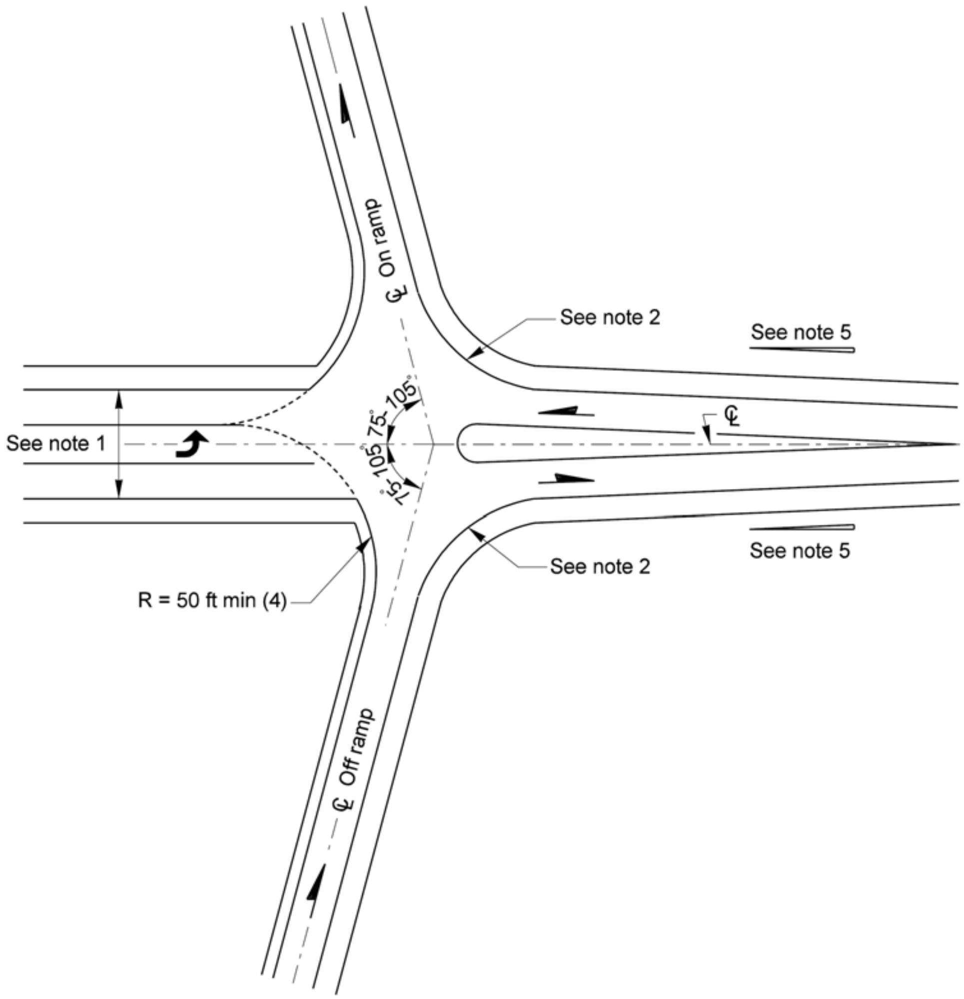
For information to be included on the Intersection Plan for Approval, see the Intersection/Channelization Plan for Approval Checklist on the following web site:
www.wsdot.wa.gov/design/projectdev/

(3) Local Agency or Developer-Initiated Intersections

There is a separate procedure for local agency or developer-initiated projects at intersections with state routes. The project initiator submits an intersection plan and the documentation of design decisions that led to the plan to the Region for approval. For those plans requiring a design variance, the deviation or evaluate upgrade must be approved in accordance with Chapter 330 prior to approval of the plan. After the plan approval, the Region prepares a construction agreement with the project initiator (see the *Utilities Manual*).

910.13 Documentation

For the list of documents required to be preserved in the Design Documentation Package and the Project File, see the Design Documentation Checklist:
www.wsdot.wa.gov/design/projectdev/



Notes:

[1] 12-ft through lanes and 13-ft left-turn lane desirable.

[2] For right-turn corner design, see Figure 910-11.

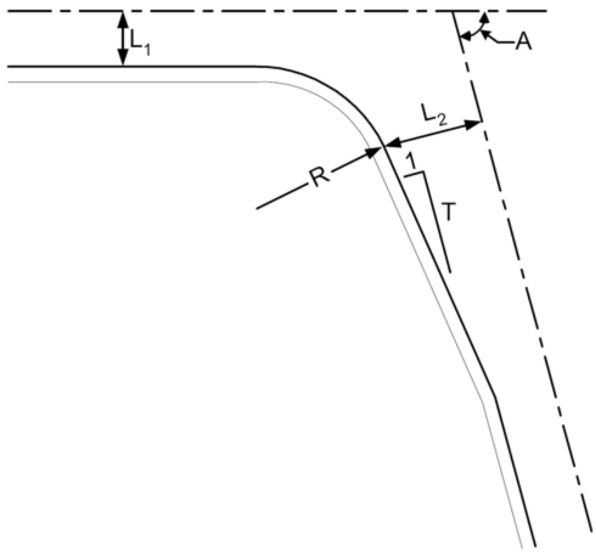
[3] Intersections may be designed individually.

[4] Use templates to verify that the design vehicle can make the turn.

[5] For taper rates, see Figure 910-14a, Table 1.

Interchange Ramp Terminal Details

Figure 910-10



L_1 = Minimum available roadway width[2] that the vehicle is turning from

L_2 = Available roadway width[2] for the vehicle leaving the intersection

R = Radius to the edge of traveled way

T = Taper rate (length per unit of width of widening)

A = Delta angle of the turning vehicle

Vehicle	A	R	L1[1]	L2[2]	T	Vehicle	A	R	L1[1]	L2[2]	T
WB-67	60	85	11	22	7	WB-40	60	55	11	15	7.5
	75	75	11	21	8		75	55	11	15	7.5
	90	70	11	21	8		90	55	11	14	7.5
	105	55	11	24	7		105	45	11	16	7.5
	120	50	11	24	7		120	45	11	15	7.5
WB-50	60	55	11	19	6	SU & BUS	All	50	11	11	25
	75	55	11	18	6	P	All	35	11	11	25
	90	55	11	17	6						
	105	50	11	17	6						
	120	45	11	18	6						

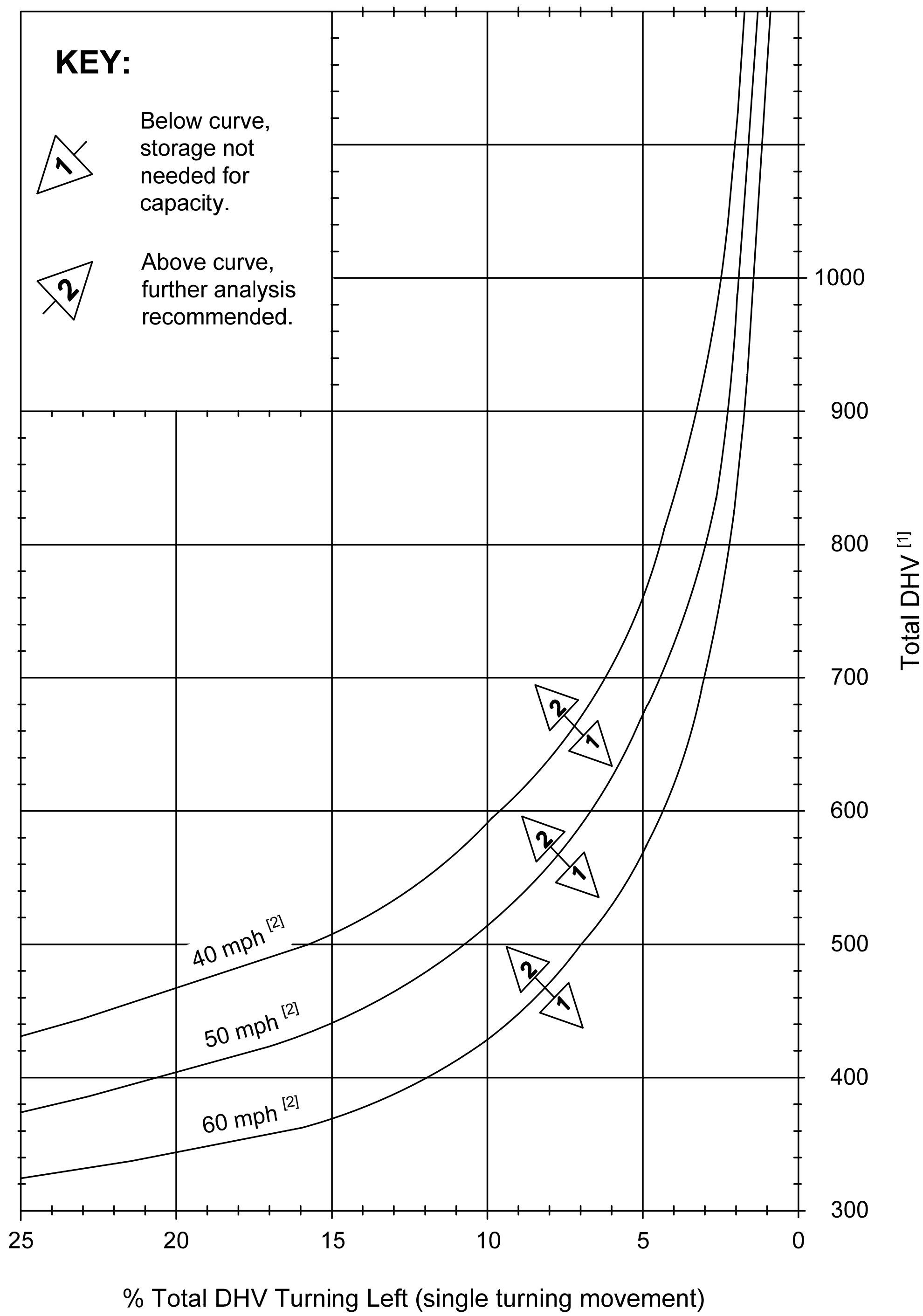
Notes:

[1] When available roadway width is less than 11 ft, widen at 25:1.

[2] Available roadway width includes the shoulder, less a 2-ft clearance to a curb, and all the same-direction lanes of the exit leg at signalized intersections.

[3] All distances given in feet and angles in degrees.

Right-Turn Corner
Figure 910-11

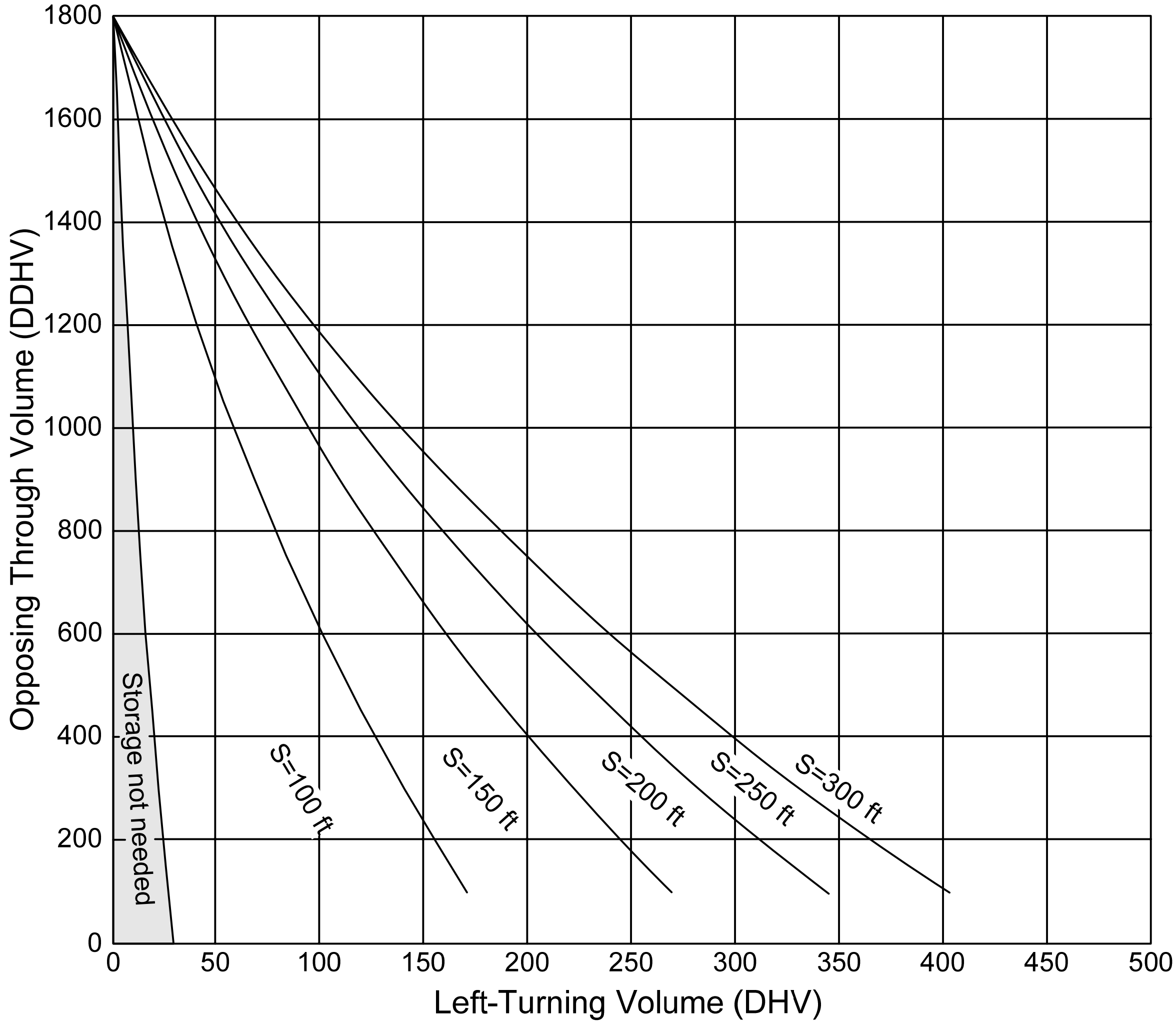


Notes:

[1] DHV is total volume from both directions.

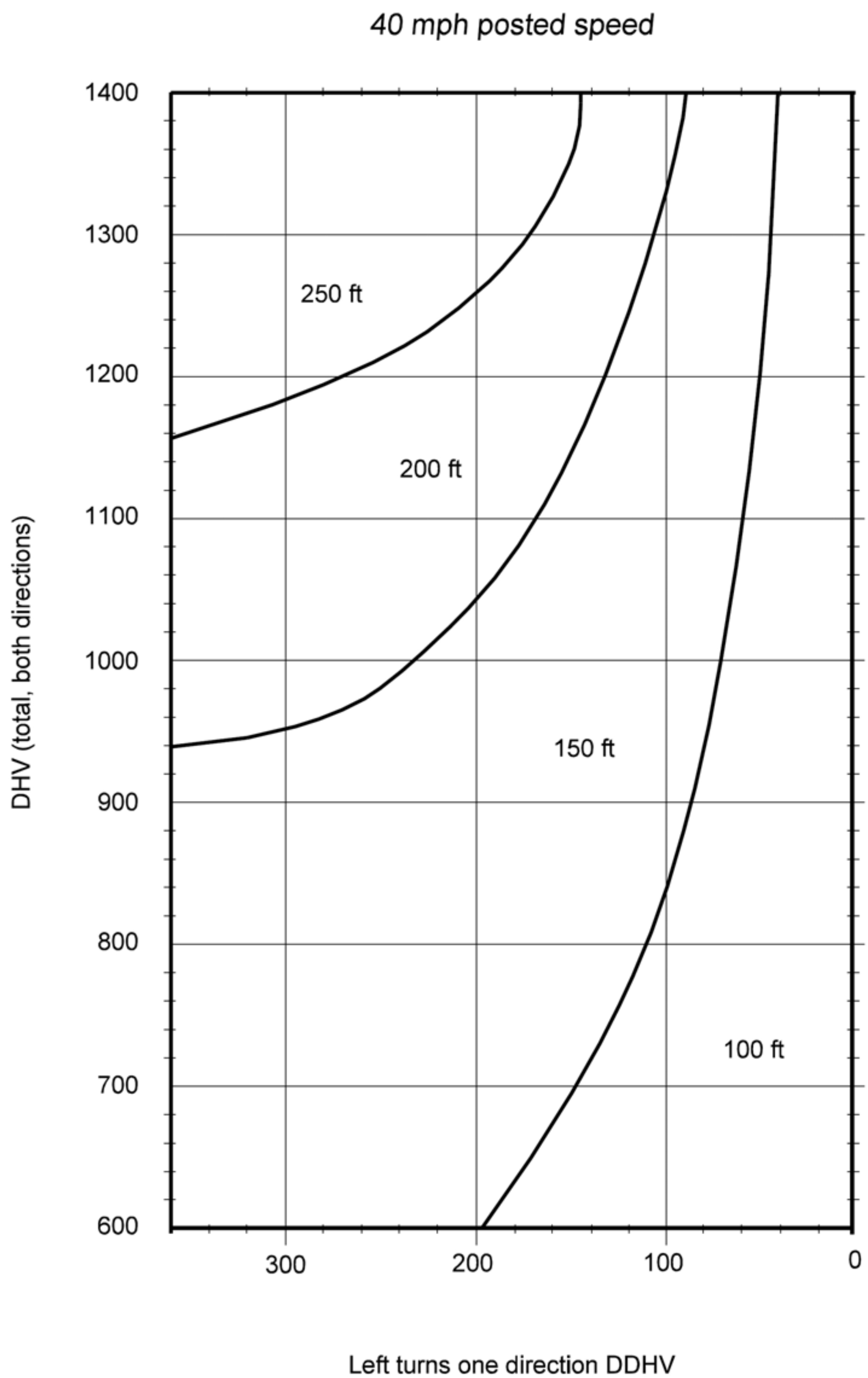
[2] Speeds are posted speeds.

Left-Turn Storage Guidelines (Two-Lane, Unsignalized)
Figure 910-12a

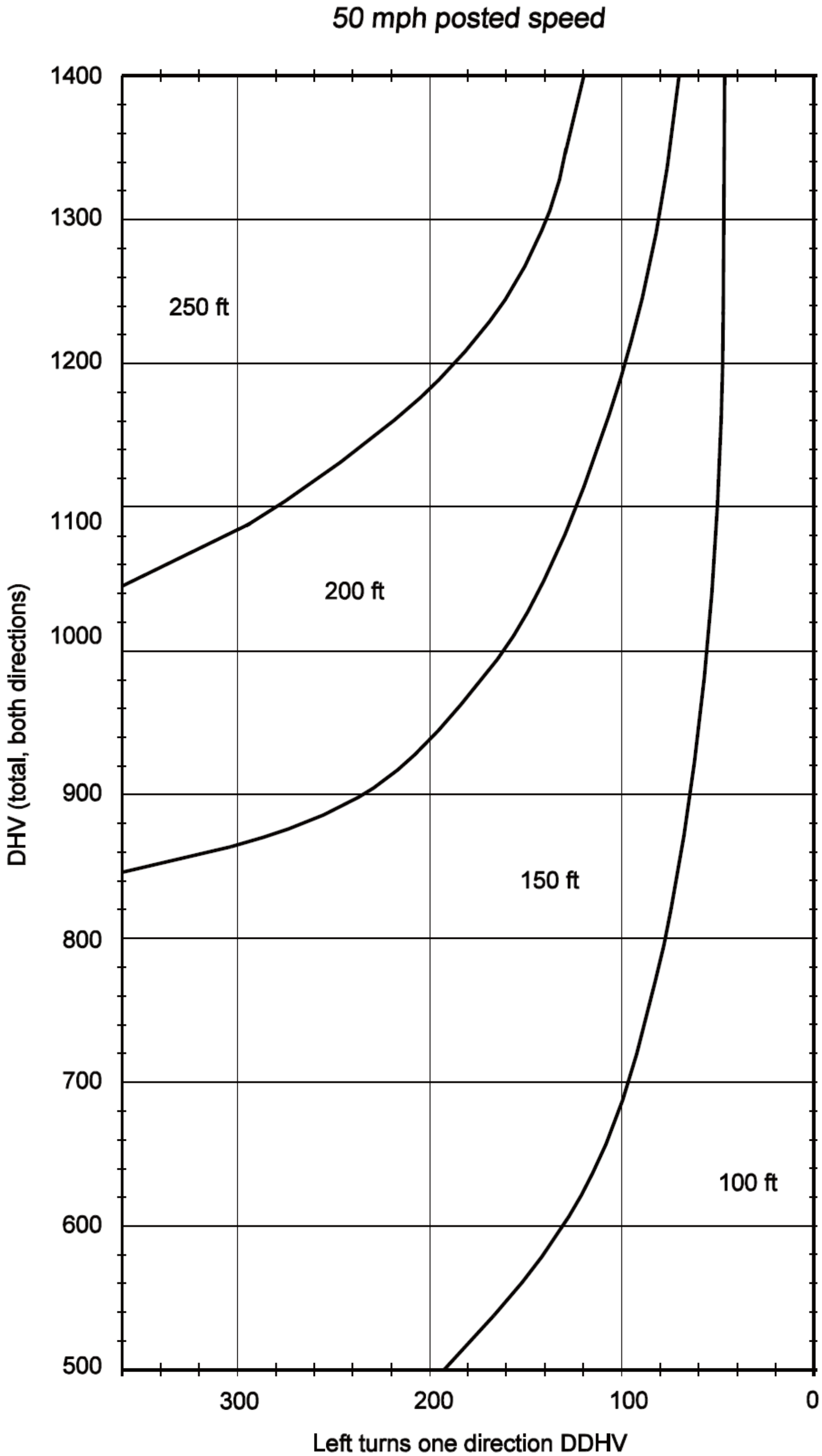


Note:
S = Left-turn storage length

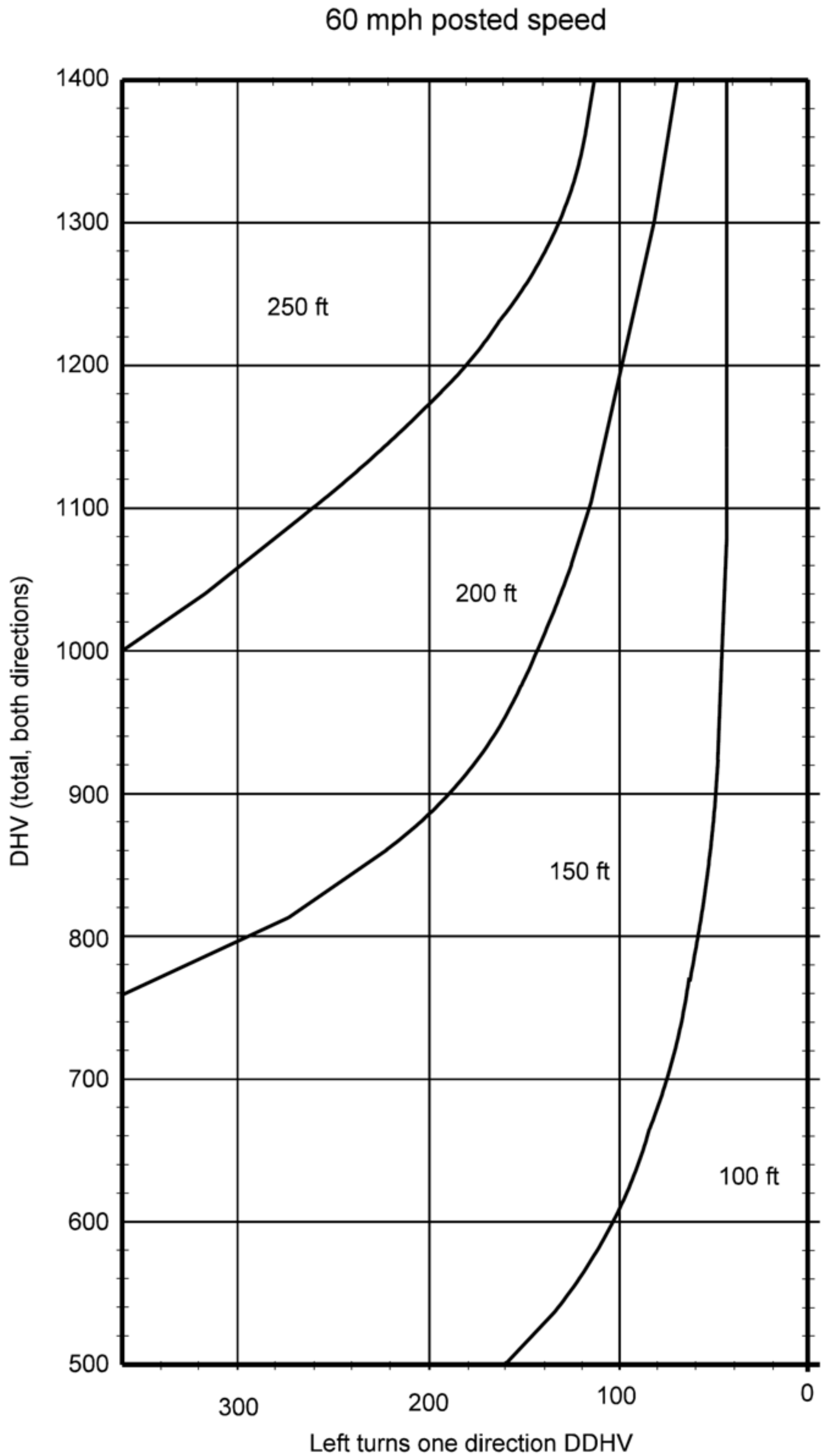
Left-Turn Storage Guidelines (Four-Lane, Unsignalized)
Figure 910-12b



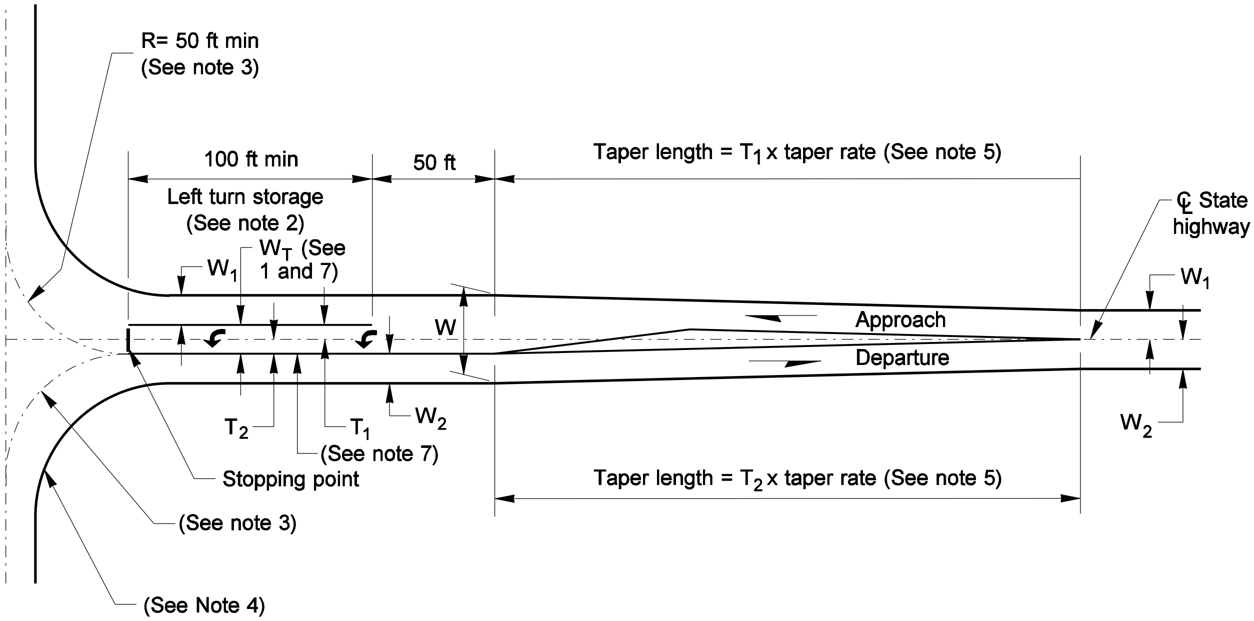
Left-Turn Storage Length (Two-Lane, Unsignalized)
Figure 910-13a



Left-Turn Storage Length (Two-Lane, Unsignalized)
Figure 910-13b



Left-Turn Storage Length (Two-Lane, Unsignalized)
Figure 910-13c



Notes:

[1] The minimum width of the left-turn storage lane (T1+T2) is 11 ft. The desirable width is 12 ft.

[2] For left-turn storage length, see Figures 910-12b for 4-lane roadways or 13a through 13c for 2-lane roadways.

[3] Desirable radius not less than 50 ft. Use templates to verify that the design vehicle can make the turn.

[4] For right-turn corner design, see Figure 910-11.

[5] For desirable taper rates, see Table 1. With justification, taper rates from Table 2, Figure 910-14c, may be used.

[6] For pavement marking details, see the *Standard Plans* and the MUTCD.

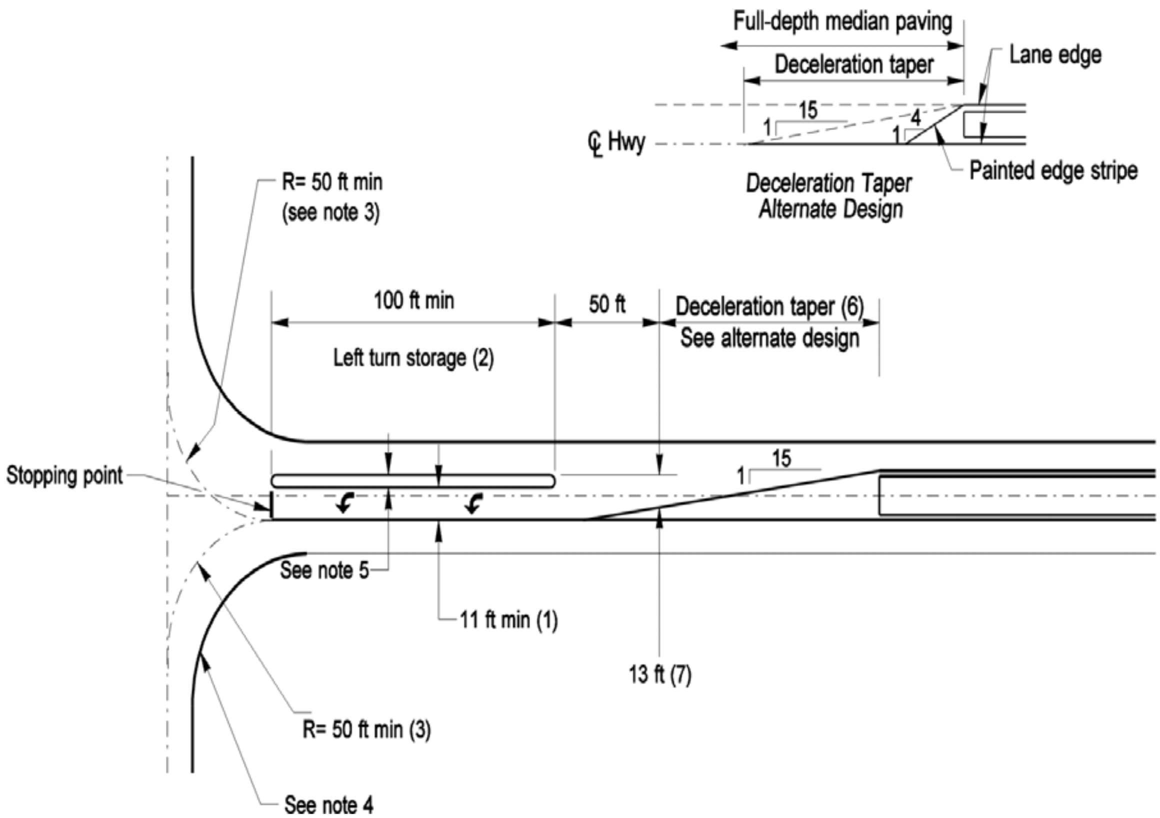
[7] When curb is provided, add the width of the curb and the required shoulders to the left-turn lane width. For required shoulder widths at curbs, see 910.07(6) and Chapter 440.

W_1 = Approaching through lane
W_2 = Departing lane
T_1 = Width of left-turn lane on approach side of centerline
T_2 = Width of left-turn lane on departure side of centerline
W_T <u>Total width of left-turn lane</u>
W = Total width of channelization ($W_1+W_2+T_1+T_2$)

Posted Speed	Desirable Taper Rate[6]
55 mph	55:1
50 mph	50:1
45 mph	45:1
40 mph	40:1
35 mph	35:1
30 mph	30:1
25 mph	25:1

Table 1

Median Channelization (Widening)
Figure 910-14a



Notes:

[1] Lane width of 13 ft is desirable.

[2] For left-turn storage length, see Figures 910-12b for 4-lane roadways or 13a through 13c for 2-lane roadways.

[3] Desirable radius not less than 50 ft. Use templates to verify that the design vehicle can make the turn.

[4] For right-turn corner design, see Figure 910-11.

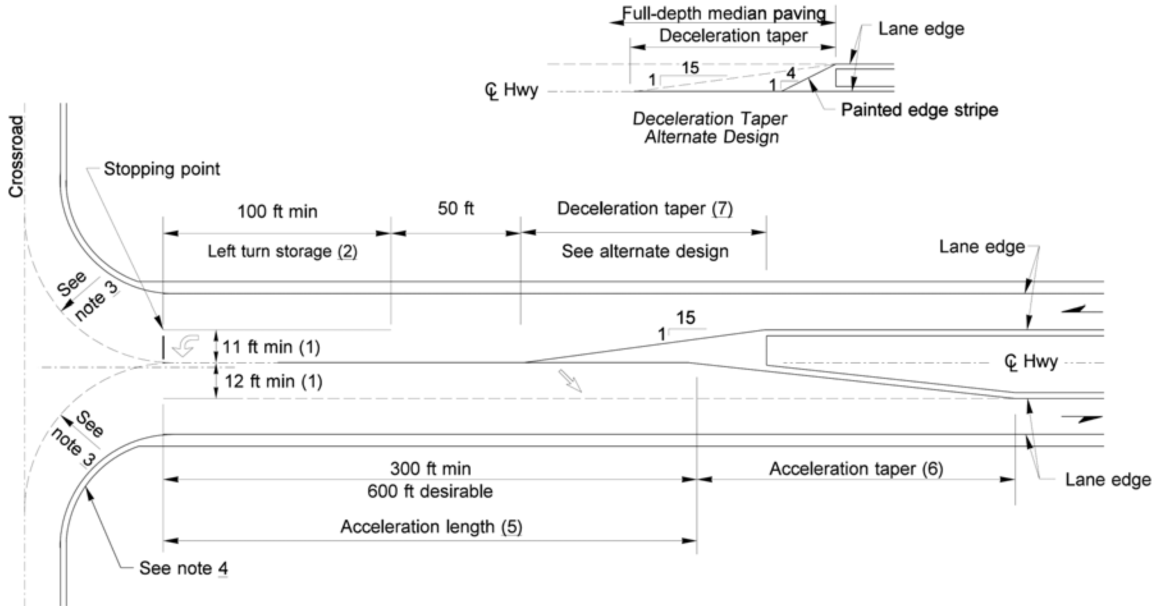
[5] For median widths greater than 13 ft, it is desirable to locate the left-turn lane adjacent to the opposing through lane with excess median width between the same direction through lane and the turn lane.

[6] For increased storage capacity, the left-turn deceleration taper alternate design may be used.

[7] Reduce to lane width for medians less than 13 ft wide.

[8] For pavement marking details, see the *Standard Plans* and the MUTCD.

Median Channelization (Median Width 11 ft or More)
Figure 910-14b



Notes:

[1] Lane widths of 13 ft are desirable for both the left-turn storage lane and the median acceleration lane.

[2] For left-turn storage length, see Figures 910-12b for 4-lane roadways or 13a through 13c for 2-lane roadways.

[3] Desirable radius not less than 50 ft. Use templates to verify that the design vehicle can make the turn.

[4] For right-turn corner design, see Figure 910-11.

[5] The minimum total length of the median acceleration lane is shown in Figure 910-18.

[6] For acceleration taper rate, see Table 2.

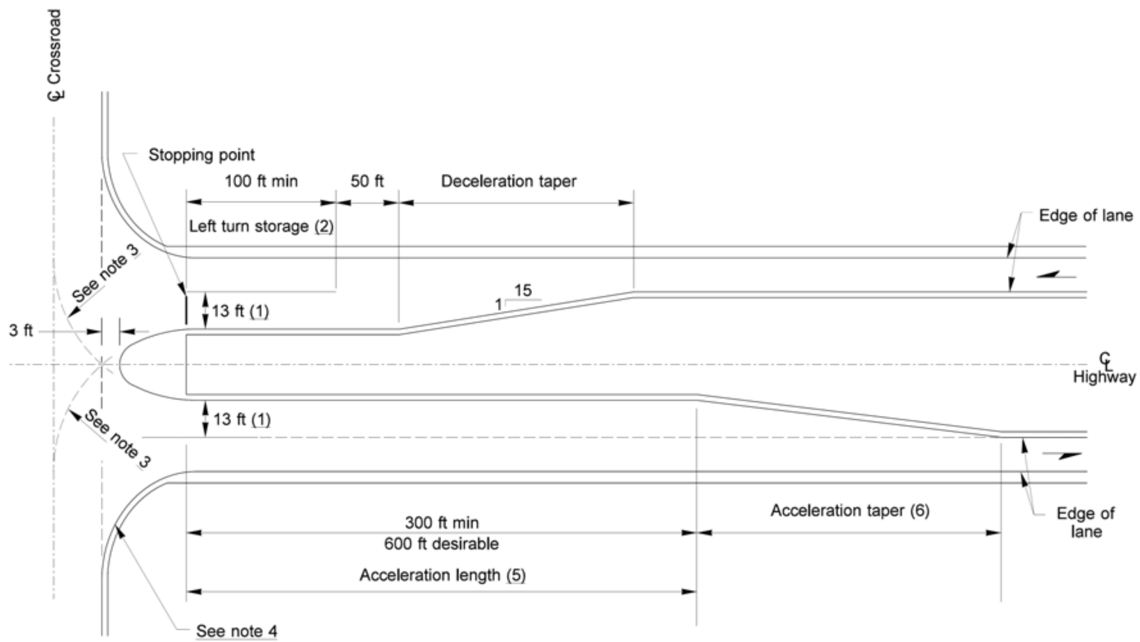
[7] For increased storage capacity, the left-turn deceleration taper alternate design may be used.

[8] For pavement marking details, see the *Standard Plans* and the MUTCD.

Posted Speed	Taper Rate
55 mph	55:1
50 mph	50:1
45 mph	45:1
40 mph	27:1
35 mph	21:1
30 mph	15:1
25 mph	11:1

Table 2

Median Channelization (Median Width 23 ft to 26 ft)
Figure 910-14c



Notes:

[1] May be reduced to 11 ft, with justification.

[2] For left-turn storage length, see Figures 910-12b for 4-lane roadways or 13a through 13c for 2-lane roadways.

[3] Desirable radius not less than 50 ft. Use templates to verify that the design vehicle can make the turn.

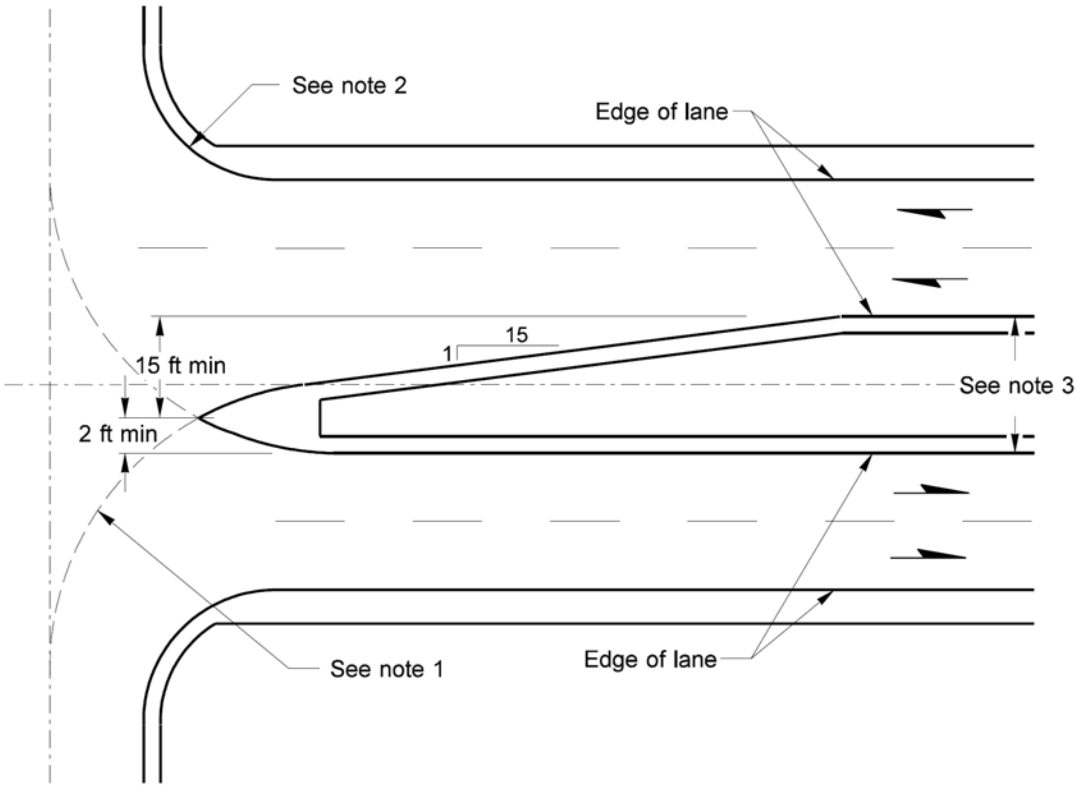
[4] For right-turn corner design, see Figure 910-11.

[5] The minimum length of the median acceleration lane is shown in Figure 910-18.

[6] For acceleration taper rate, see Figure 910-14c, Table 2.

[7] For pavement marking details, see the *Standard Plans* and the MUTCD.

Median Channelization (Median Width of More Than 26 ft)
Figure 910-14d



Notes:

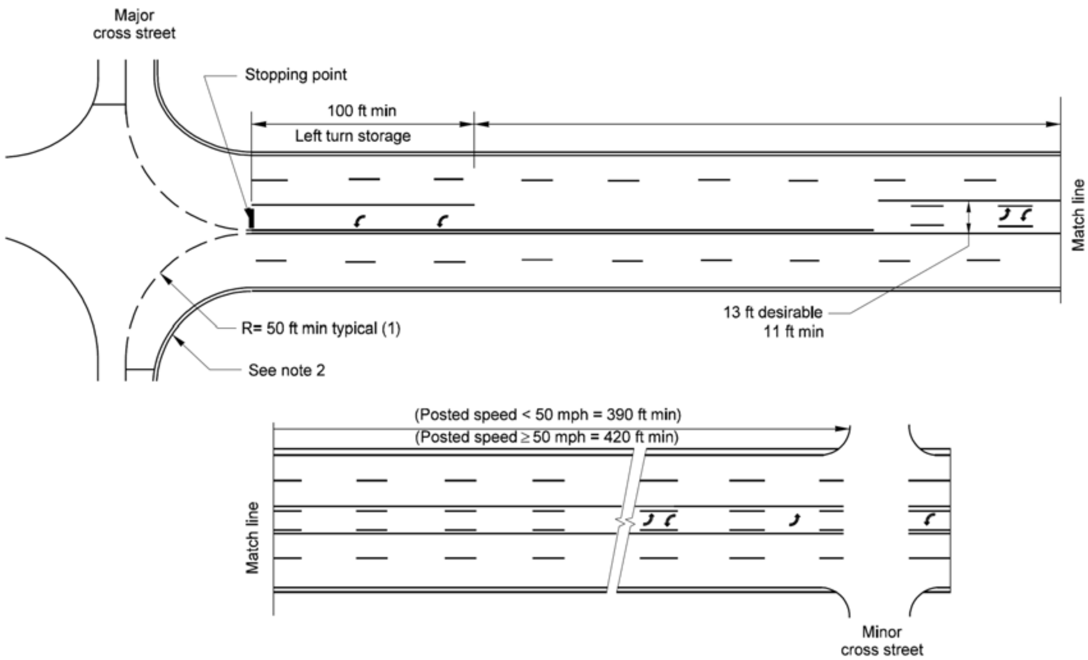
[1] Desirable radius not less than 50 ft. Use templates to verify that the design vehicle can make the turn.

[2] For right-turn corner design, see Figure 910-11.

[3] For median width 17 ft or more. For median width less than 17 ft, widen to 17 ft or use Figure 910-14b.

[4] For pavement marking details, see the *Standard Plans* and the MUTCD.

Median Channelization (Minimum Protected Storage)
Figure 910-14e



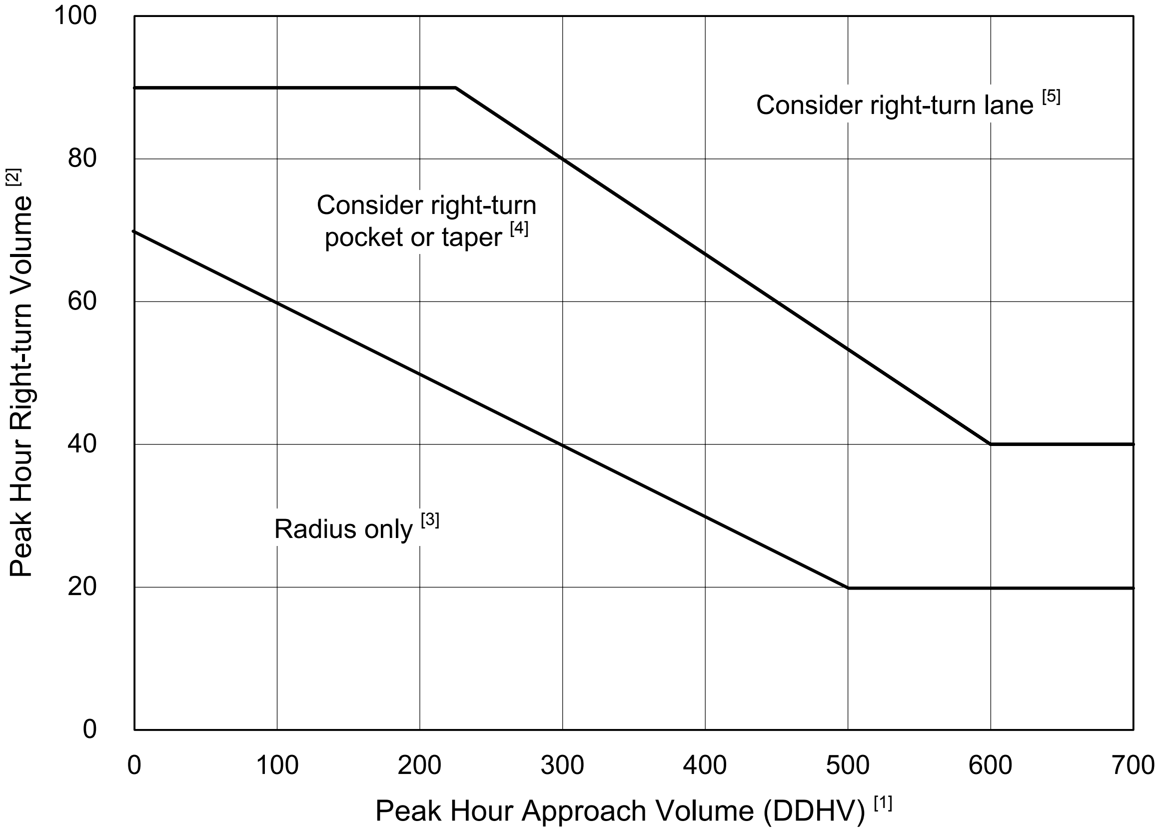
Notes:

[1] Desirable radius not less than 50 ft. Use templates to verify that the design vehicle can make the turn.

[2] For right-turn corner design, see Figure 910-11.

[3] For pavement marking details and signing criteria, see the *Standard Plans* and the MUTCD.

Median Channelization (Two-way Left-Turn Lane)
Figure 910-14f



Notes:

[1] For two-lane highways, use the peak hour DDHV (through + right-turn).

For multilane, high-speed highways (posted speed 45 mph or above), use the right-lane peak hour approach volume (through + right-turn).

[2] When all three of the following conditions are met, reduce the right-turn DDHV by 20.

- The posted speed is 45 mph or less
- The right-turn volume is greater than 40 VPH
- The peak hour approach volume (DDHV) is less than 300 VPH

[3] For right-turn corner design, see Figure 910-11.

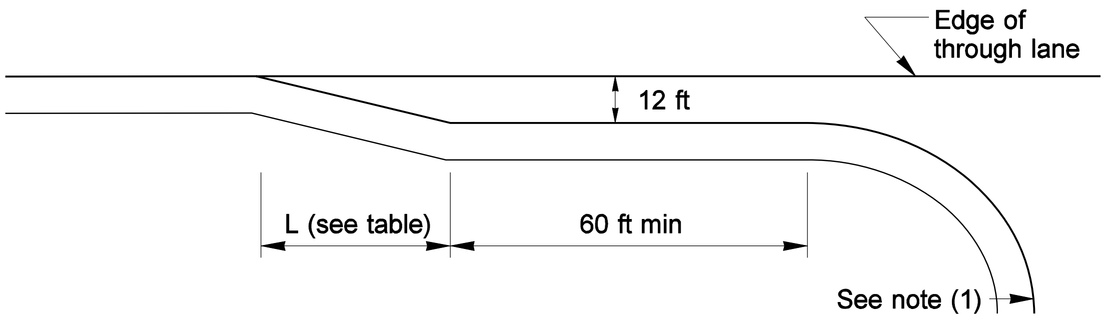
[4] For right-turn pocket or taper design, see Figure 910-16.

[5] For right-turn lane design, see Figure 910-17.

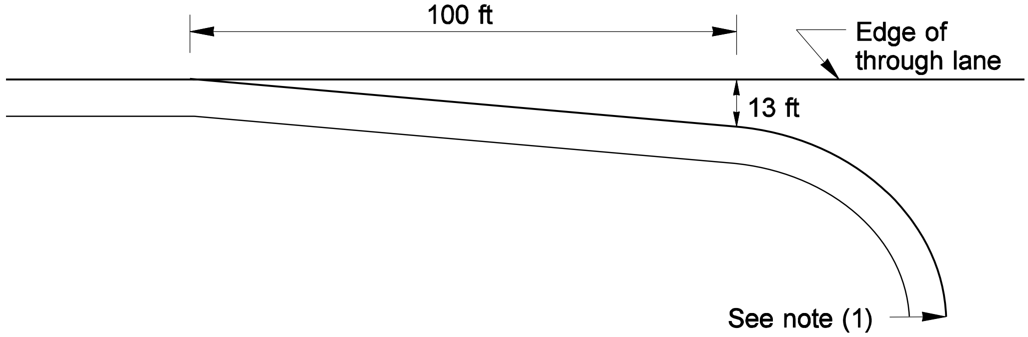
[6] For additional guidance, see 910.07(3).

Right-Turn Lane Guidelines[6]

Figure 910-15



Right-Turn Pocket



Right-Turn Taper

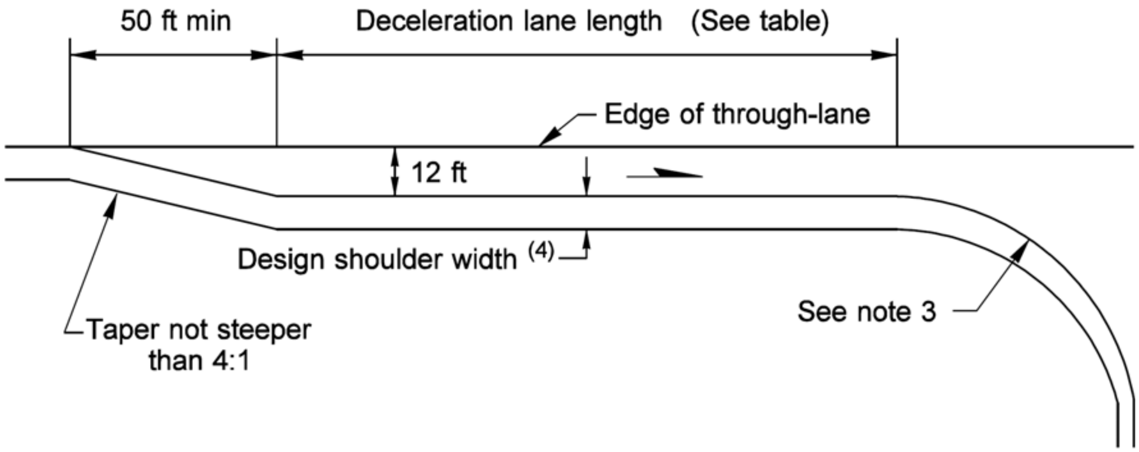
Posted Speed Limit	L
Below 40 mph	40 ft
40 mph or above	100 ft

Notes:

[1] 12 ft desirable.

[2] For right-turn corner design, see Figure 910-11.

Right-Turn Pocket and Right-Turn Taper
Figure 910-16



Highway Design Speed (mph)	Turning Roadway Design Speed (mph)		
	Stop[1]	15	20
30	235	200[2]	170[2]
35	280	250	210
40	320	295	265
45	385	350	325
50	435	405	385
55	480	455	440
60	530	500	480
65	570	540	520
70	615	590	570

Minimum Deceleration Lane Length (ft)

Grade	Upgrade	Downgrade
3% to less than 5%	0.9	1.2
5% or more	0.8	1.35

Adjustment Multiplier for Grades 3% or Greater

Notes:

[1] For use when the turning traffic is likely to stop before completing the turn (for example, where pedestrians are present).

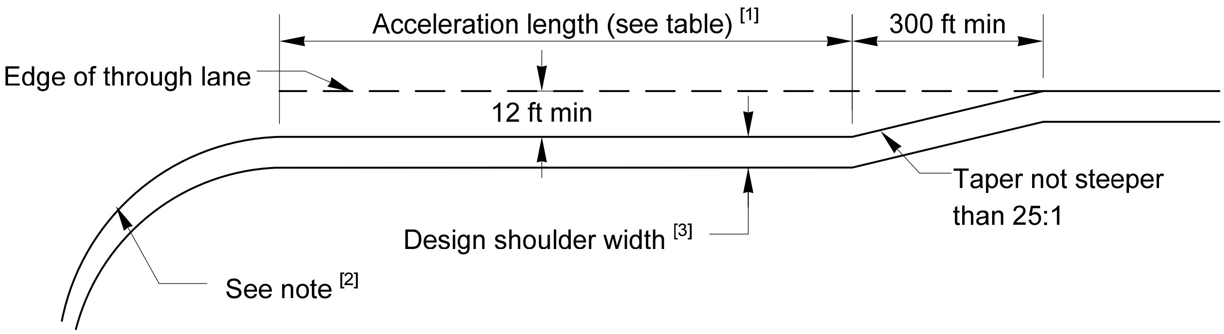
[2] When adjusting for grade, do not reduce the deceleration lane to less than 150 ft.

[3] For right-turn corner design, see Figure 910-11.

[4] May be reduced (see 910.07).

[5] For pavement marking details, see the *Standard Plans* and the MUTCD.

Right-Turn Lane
Figure 910-17



Highway Design Speed (mph)	Turning Roadway Design Speed (mph)		
	Stop	15	20
30	180	140	
35	280	220	160
40	360	300	270
45	560	490	440
50	720	660	610
55	960	900	810
60	1200	1140	1100
65	1410	1350	1310
70	1620	1560	1520

Minimum Acceleration Lane Length (ft)[1]

Highway Design Speed (mph)	% Grade	Upgrade	Downgrade
40	3% to less than 5%	1.3	0.7
50		1.3	0.65
60		1.4	0.6
70		1.5	0.6
40	5% or more	1.5	0.6
50		1.5	0.55
60		1.7	0.5
70		2.0	0.5

Adjustment Multiplier for Grades 3% or Greater

Notes:

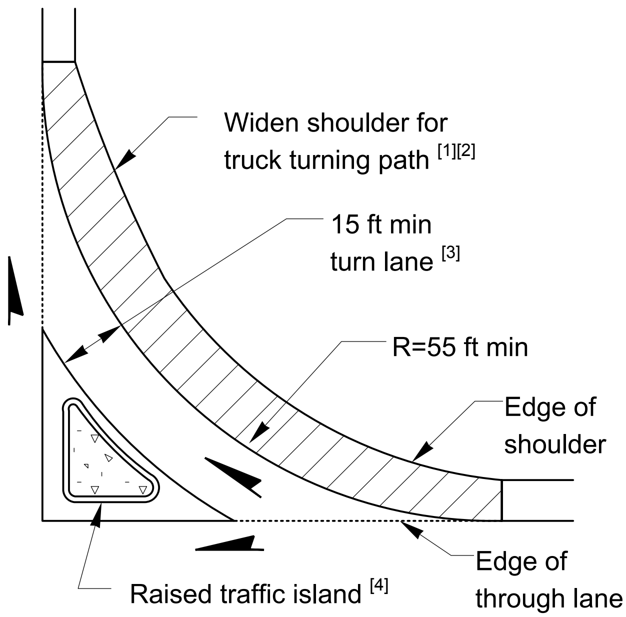
[1] At free-right turns (no stop required) and all left turns, the minimum acceleration lane length is not less than 300 ft.

[2] For right-turn corner design, see Figure 910-11.

[3] May be reduced (see 910.07(6)).

[4] For pavement-marking details, see the *Standard Plans* and the MUTCD.

Acceleration Lane
Figure 910-18



Small Traffic Island Design [5]

Notes:

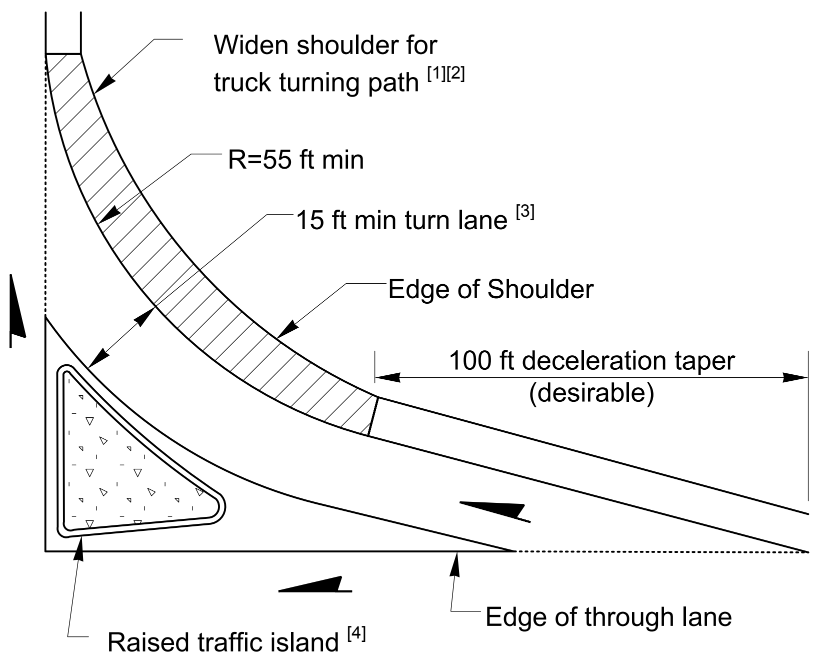
[1] Widen shoulders when adequate right-turn radii or roadway width cannot be provided for large trucks. Design widened shoulder pavement the same depth as the right-turn lane.

[2] Use the truck turning path templates for the design vehicle and a minimum of 2 ft clearance between the wheel paths and the face of curb or edge of shoulder to determine the width of the widened shoulder.

[3] For desirable turning roadway widths, see Chapter 641.

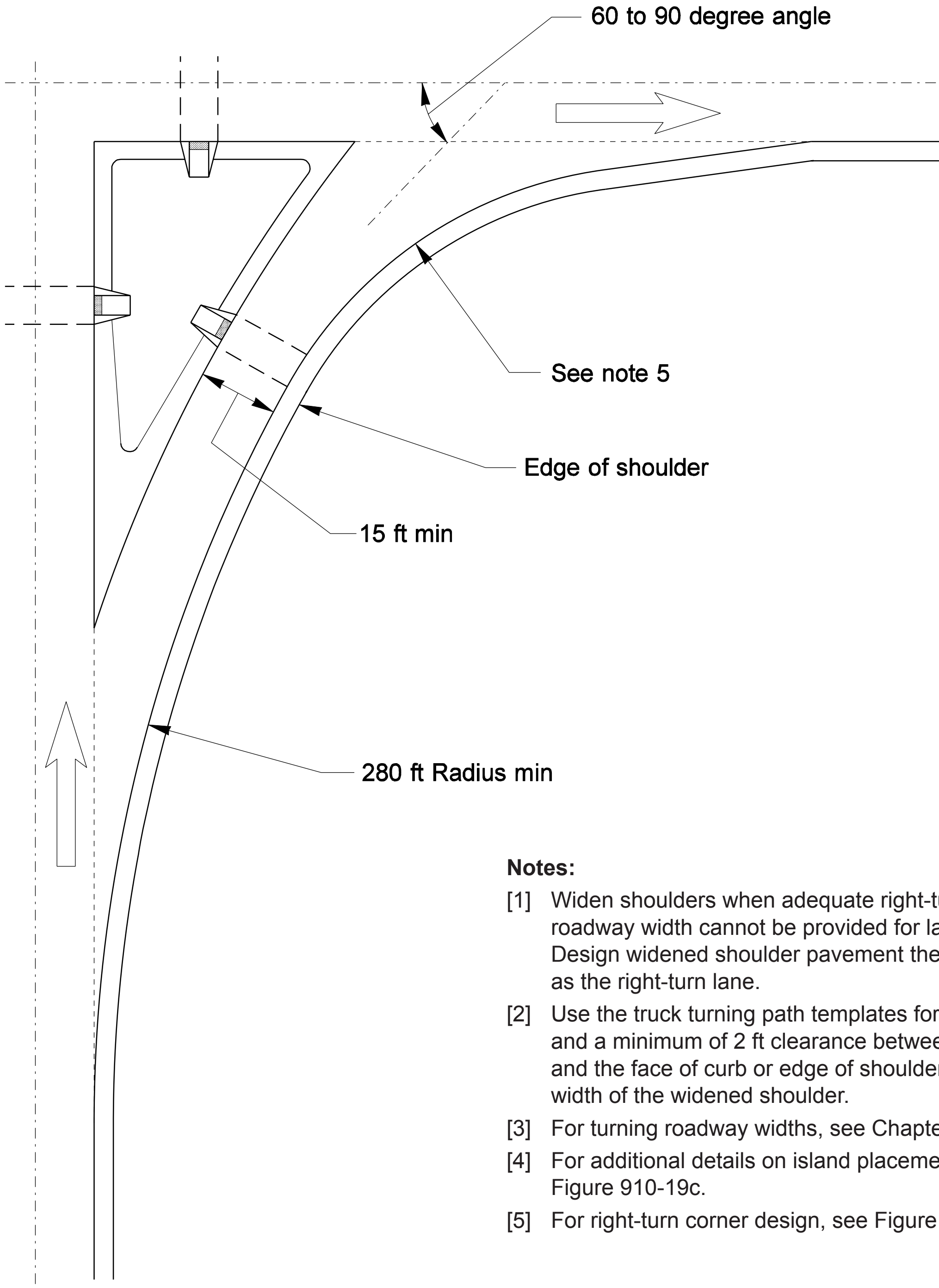
[4] For additional details on island placement, see Figure 910-19c.

[5] Small traffic islands have an area of 100 ft^2 or less; large traffic islands have an area greater than 100 ft^2.



Large Traffic Island Design [5]

Traffic Island Designs
Figure 910-19a



Notes:

[1] Widen shoulders when adequate right-turn radii and roadway width cannot be provided for large trucks. Design widened shoulder pavement the same depth as the right-turn lane.

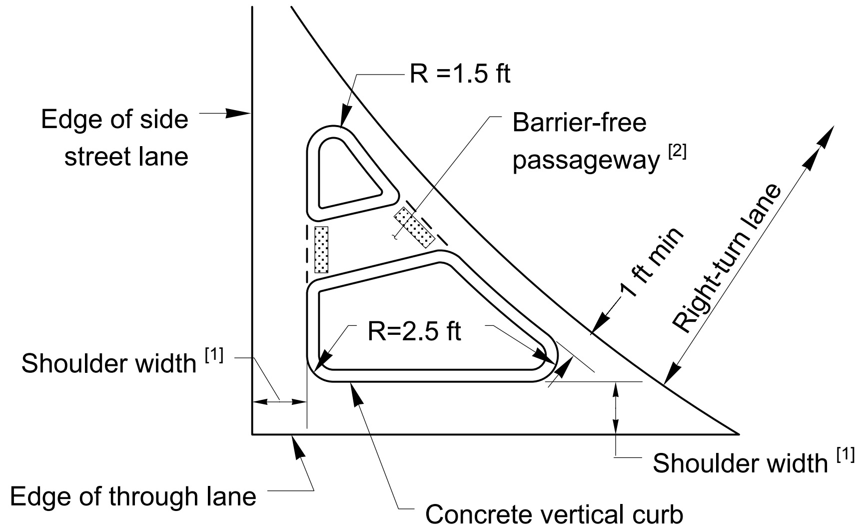
[2] Use the truck turning path templates for the design vehicle and a minimum of 2 ft clearance between the wheel paths and the face of curb or edge of shoulder to determine the width of the widened shoulder.

[3] For turning roadway widths, see Chapter 641.

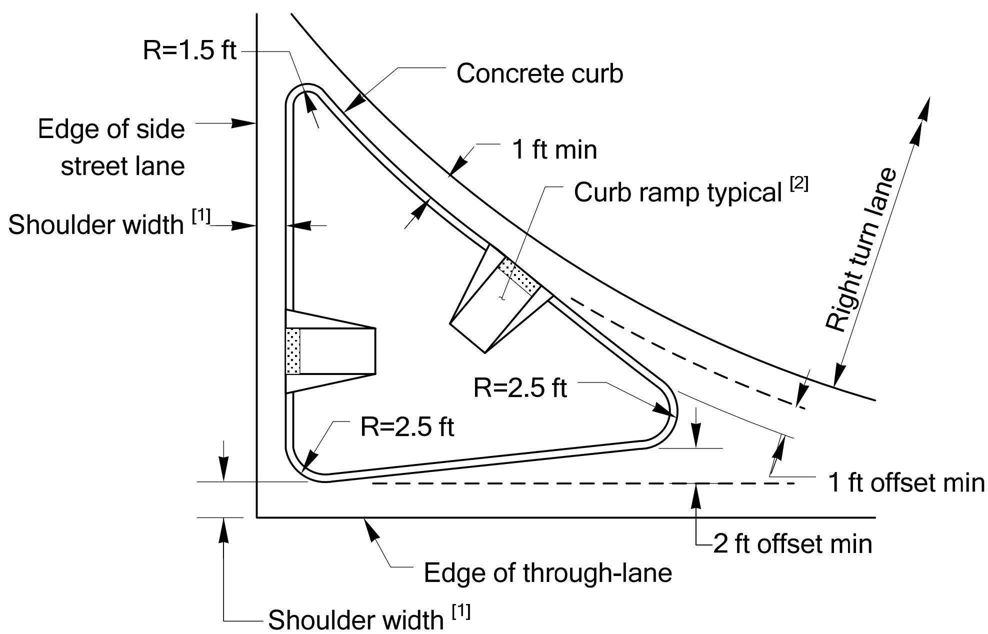
[4] For additional details on island placement, see Figure 910-19c.

[5] For right-turn corner design, see Figure 910-11.

Traffic Island Designs (Compound Curve)
Figure 910-19b



Small Raised Traffic Island [3]



Large Raised Traffic Island

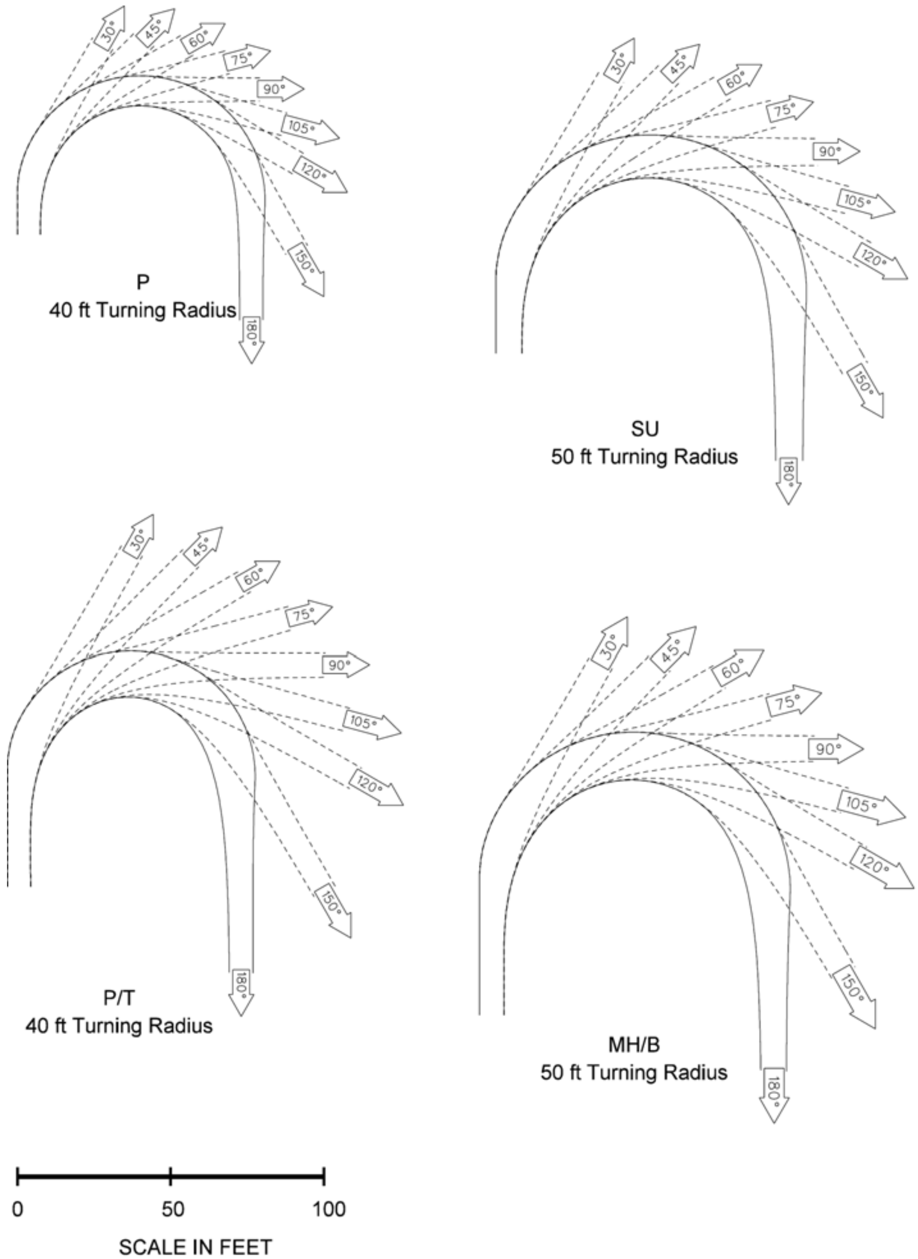
Notes:

[1] For minimum shoulder width at curbs, see Chapter 440. For additional information on shoulders at turn lanes, see 910.07(6).

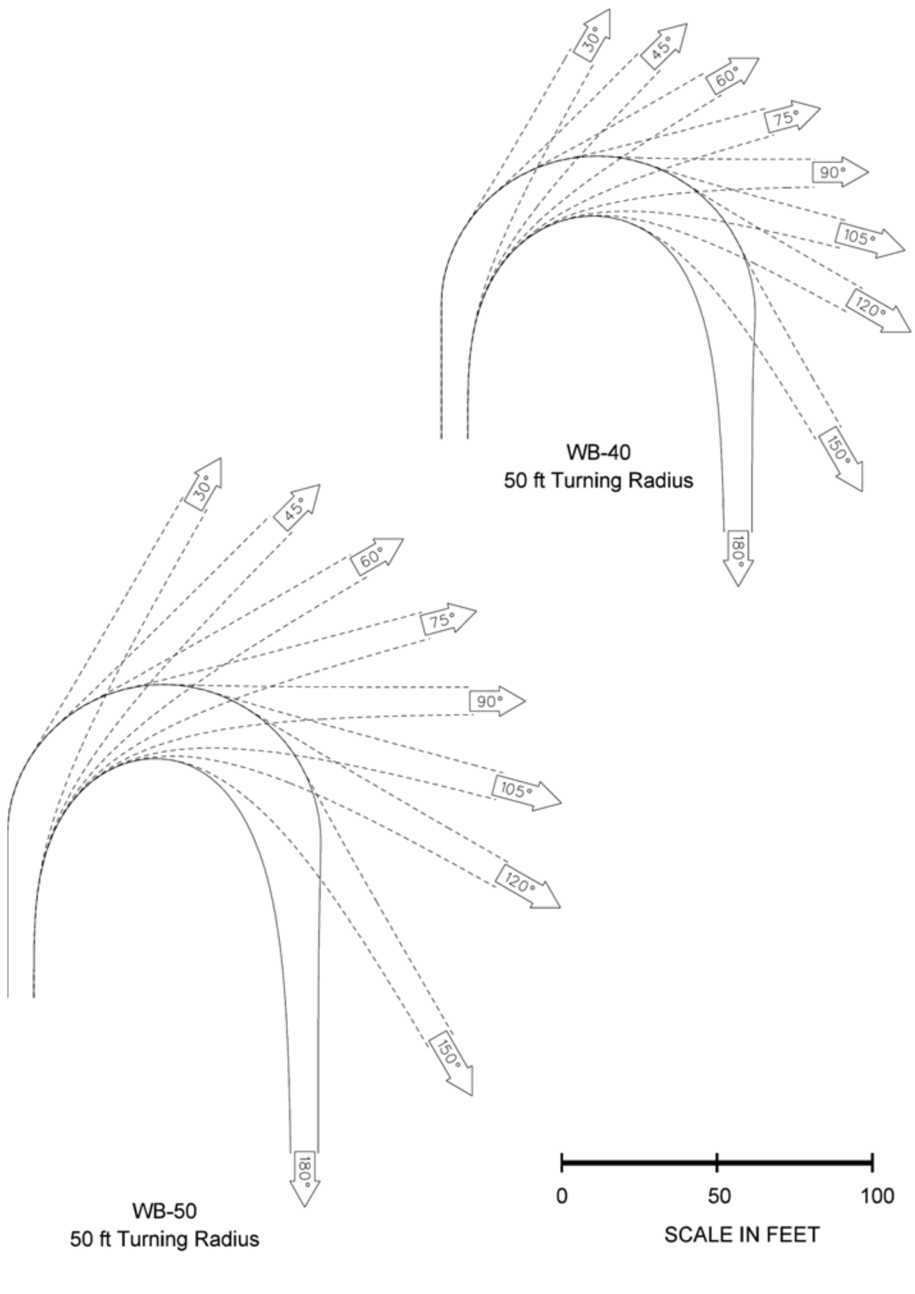
[2] Provide barrier-free passageways or curb ramps when required (see Chapter 1025).

[3] Small traffic islands have an area of 100 ft^2 or less; large traffic islands have an area greater than 100 ft^2.

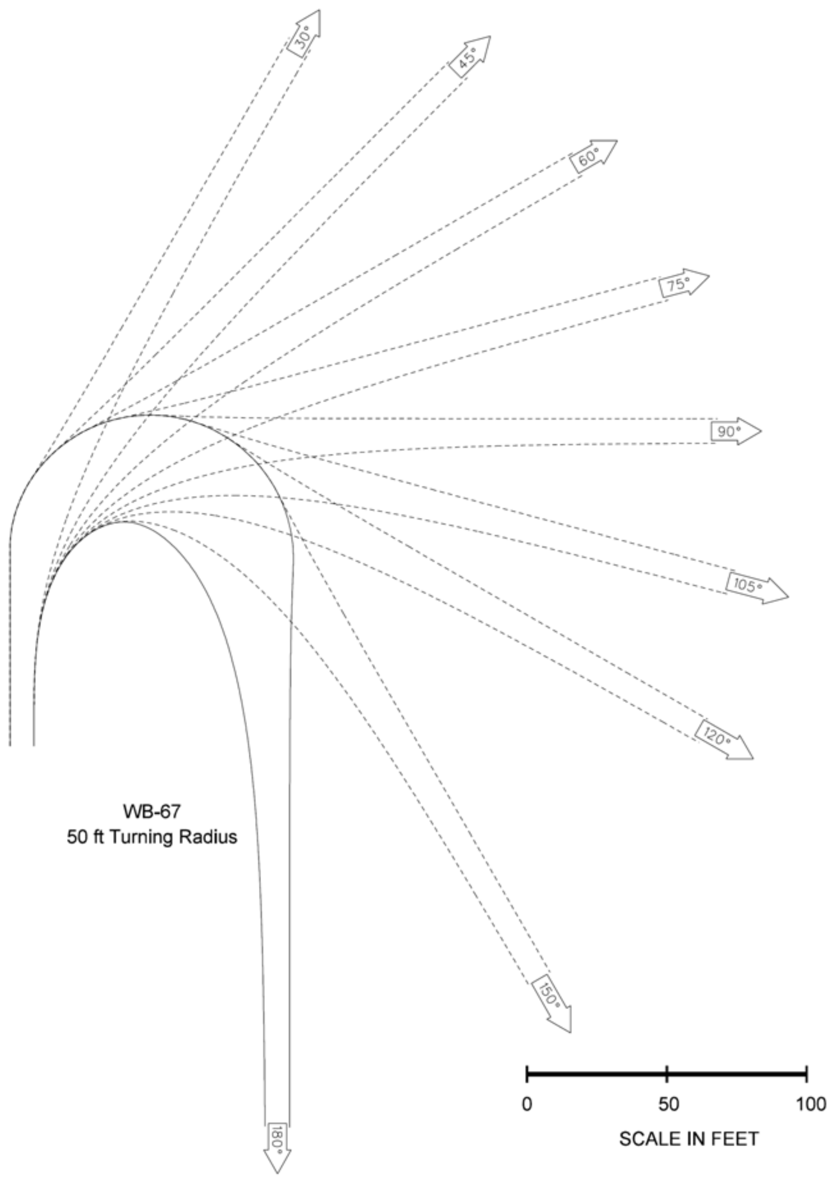
Traffic Island Designs
Figure 910-19c



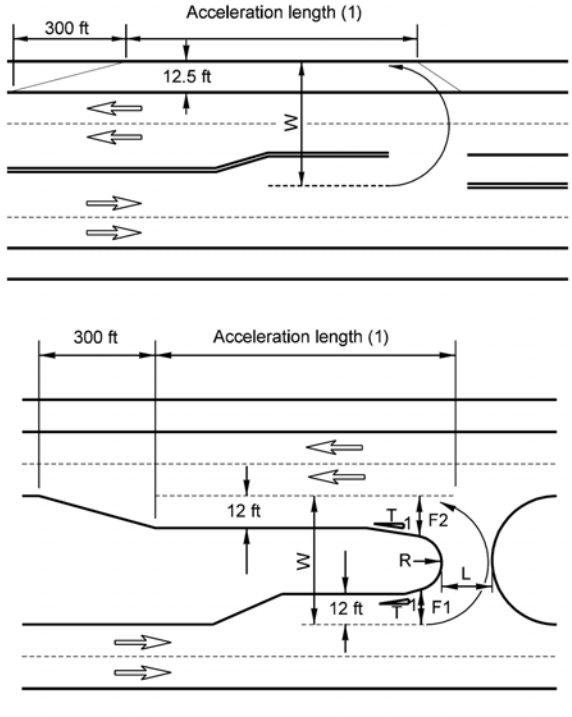
Turning Path Template
Figure 910-20a



Turning Path Template
Figure 910-20b



Turning Path Template
Figure 910-20c



Vehicle	W	R	L	F1	F2	T
P	52	14	14	12	12	—
SU	87	30	20	13	15	10:1
BUS	87	28	23	14	18	10:1
WB-40	84	25	27	15	20	6:1
WB-50	94	26	31	16	25	6:1
WB-67	94	22	49	15	35	6:1
MH	84	27	20	15	16	10:1
P/T	52	11	13	12	18	6:1
MH/B	103	36	22	15	16	10:1

U-Turn Design Dimensions

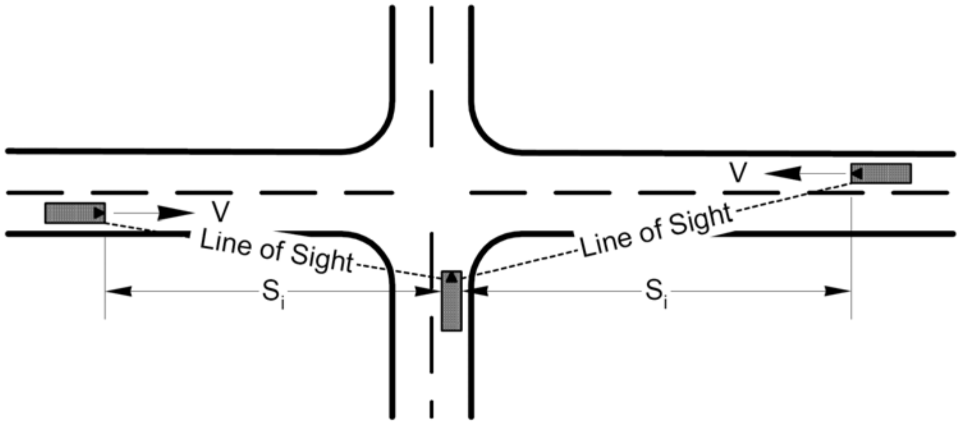
Notes:

[1] The minimum length of the acceleration lane is shown in Figure 910-18. Acceleration lane may be eliminated at signal-controlled intersections.

[1] All dimensions in feet.

[1] When U-turn uses the shoulder, provide 12.5-ft shoulder width and shoulder pavement designed to the same depth as the through lanes for the acceleration length and taper.

U-Turn Median Openings
Figure 910-21



$S_i = 1.47Vtg$
Where: S_i = Intersection Sight Distance (ft) V = Design speed of the through roadway (mph) t_g = Time gap for the minor roadway traffic to enter or cross the through roadway (sec)

Intersection Sight Distance Equation
Table 1

Design Vehicle	Time Gap (t_g) in Sec
Passenger car (P)	7.5
Single-unit trucks and buses (SU & BUS)	9.5
Combination trucks (WB-40, WB-50, & WB-67)	11.5
Note: Values are for a stopped vehicle to turn left onto a two-lane two-way roadway with no median and grades 3% or less.	

Intersection Sight Distance Gap Times (t_g)
Table 2

The t_g values listed in Table 2 require the following adjustments:

Crossing or right-turn maneuvers:

All vehicles subtract 1.0 sec

Multilane roadways:

Left turns, for each lane in excess of one, to be crossed and for medians wider than 4 ft:

Passenger cars add 0.5 sec
All trucks and buses add 0.7 sec

Crossing maneuvers, for each lane in excess of two, to be crossed and for medians wider than 4 ft:

Passenger cars add 0.5 sec
All trucks and buses add 0.7 sec

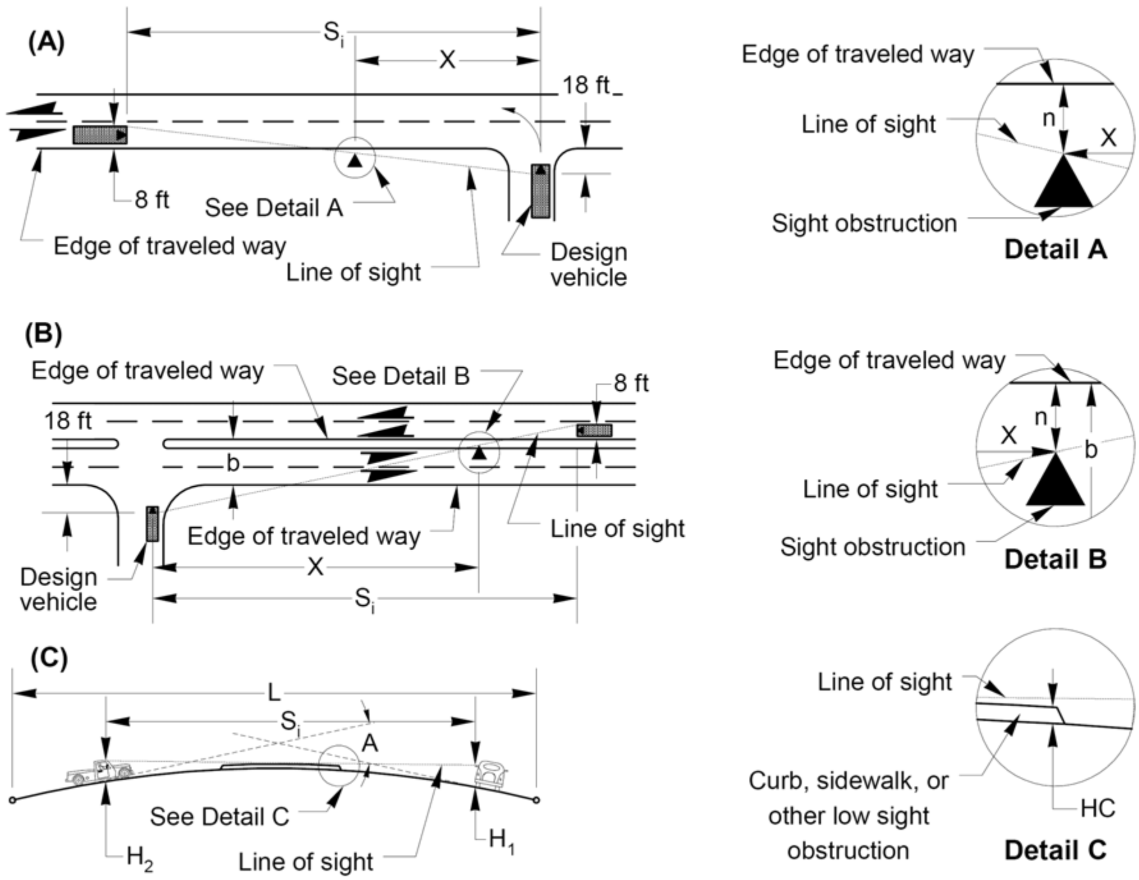
Note: Where medians are wide enough to store the design vehicle, determine the sight distance as two maneuvers.

Crossroad grade greater than 3%:

All movements upgrade, for each percent that exceeds 3%:

All vehicles add 0.2 sec

Sight Distance at Intersections
Figure 910-22a



For sight obstruction driver cannot see over:

$$S_i = \frac{(26+b)(x)}{(18+b-n)}$$

Where:

S_i = Available intersection sight distance (ft)

n = Offset from sight obstruction to edge of lane (ft)

b = Distance from near edge of traveled way to near edge of lane approaching from right (ft) (b=0 for sight distance to the left)

X = Distance from centerline of lane to sight obstruction (ft)

For crest vertical curve over a low sight obstruction where S<L:

$$S = \sqrt{\frac{100L\left[\sqrt{2(H_1-HC)}+\sqrt{2(H_2-HC)}\right]^2}{A}}$$

$$L = \frac{AS^2}{100\left[\sqrt{2(H_1-HC)}+\sqrt{2(H_2-HC)}\right]^2}$$

Where:

S = Available sight distance (ft)

H_1 = Eye height (3.5 ft for passenger cars; 6 ft for all trucks)

H_2 = Object height (3.5 ft)

HC = Sight obstruction height (ft)

L = Vertical curve length (ft).

A = Algebraic difference in grades (%)

Sight Distance at Intersections
Figure 910-22b