1310.01 General

Intersections are a critical part of Washington State Department of Transportation (WSDOT) 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 provide 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
1320	Roundabouts
1330	Traffic signals
1340	Road approaches
1360	Interchanges
1510	Pedestrian design considerations

For assistance with intersection design, contact the Headquarters (HQ) Design Office.

1310.02 References

(1) Federal/State Laws and Codes

Americans with Disabilities Act of 1990 (ADA) (28 CFR Part 36, Appendix A)

Revised Code of Washington (RCW) 35.68.075, Curb ramps for persons with disabilities – Required – Standards and requirements
http://apps.leg.wa.gov/rcw/default.aspx?cite=35.68.075

Washington Administrative Code (WAC) 468-18-040, Design standards for rearranged county roads, frontage roads, access roads, intersections, ramps and crossings
http://apps.leg.wa.gov/wac/default.aspx?cite=468-18-040

WAC 468-52, Highway access management – Access control classification system and standards
http://apps.leg.wa.gov/wac/default.aspx?cite=468-52

(2) Design Guidance

Local Agency Guidelines (LAG), M 36-63, WSDOT
www.wsdot.wa.gov/publications/manuals/m36-63.htm

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)
www.wsdot.wa.gov/publications/manuals/mutcd.htm

Standard Plans for Road, Bridge, and Municipal Construction (Standard Plans), M 21-01, WSDOT
www.wsdot.wa.gov/publications/manuals/m21-01.htm

(3) Supporting Information

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

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

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

Intersection Channelization Design Guide, NCHRP 279

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

1310.03 Definitions

Note: 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 1140; for ***lane***, ***median***, and ***shoulder***, see Chapter 1230; and for ***decision sight distance***, ***sight distance***, and ***stopping sight distance***, see Chapter 1260.

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.

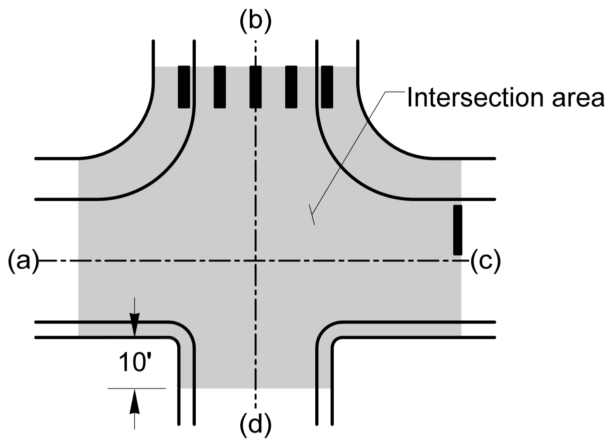
curb extensions A curb and sidewalk bulge or extension into the parking lane or shoulder to decrease the length of a pedestrian crossing (see Chapter 1510).

curb section A roadway cross section with curb and sidewalk.

design vehicle A vehicle used to establish the intersection geometry.

intersection angle The angle between any two intersecting legs at the point 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 to the farthest point: (a) the end of the corner radii, (b) through any marked crosswalks adjacent to the intersection, (c) to the stop bar, or (d) 10 feet from the edge of shoulder of the intersecting roadway (see Exhibit 1310-1).



Intersection Area
Exhibit 1310-1

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.

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

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

wye (Y) intersection An intersection formed by three legs in the general form of a “Y” where 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 length of roadway visible to the driver 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.

roundabout A circular intersection at grade (see Chapter 1320).

rural intersection An intersection in a rural design area (see Chapter 1140).

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. These are often separated by an island.

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 1140).

1310.04 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. Intersection configurations 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. When well designed, they are an efficient form of intersection control. They have fewer conflict points, lower speeds, easier decision making, and need less maintenance.

When properly designed and located, roundabouts have been found to reduce injury collisions, traffic delays, fuel consumption, and air pollution. They 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 collisions 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.

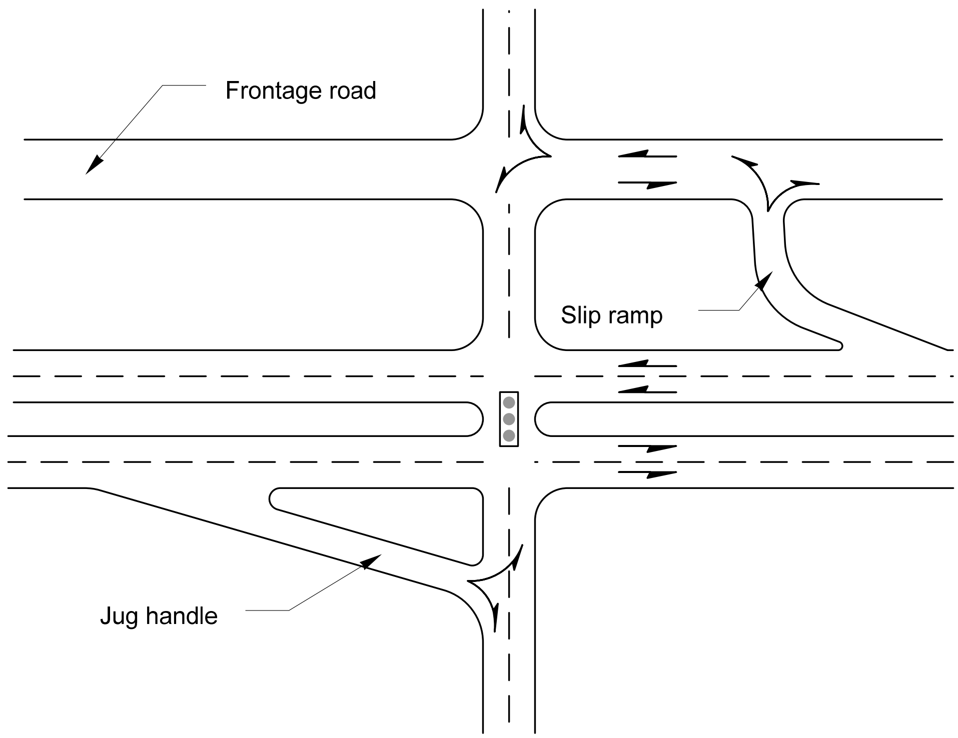
Other tradeoffs with roundabouts include:

- Roundabouts give equal priority to all legs.
- The design forces the entering traffic to reduce speed.

Refer to Chapter 1320 for information and criteria for the design and documentation of roundabouts.

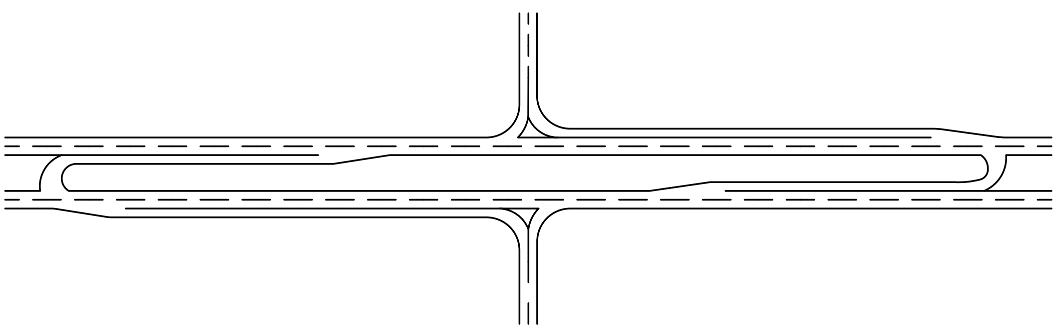
(2) Indirect Left Turns

At signalized intersections, indirect left-turn intersections reduce conflict points and delays to the major route by eliminating the left-turn phase (see Exhibit 1310-2a for an example).



Indirect Left Turns: Signalized Intersections
Exhibit 1310-2a

At unsignalized intersections, indirect left-turn intersections help mitigate entering-at-angle collisions. Left-turning and through traffic on the crossroad must turn right and then make a U-turn at a median crossover or a nearby intersection (see Exhibit 1310-2b 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 1310.08 for guidance on the design of U-turn locations.)

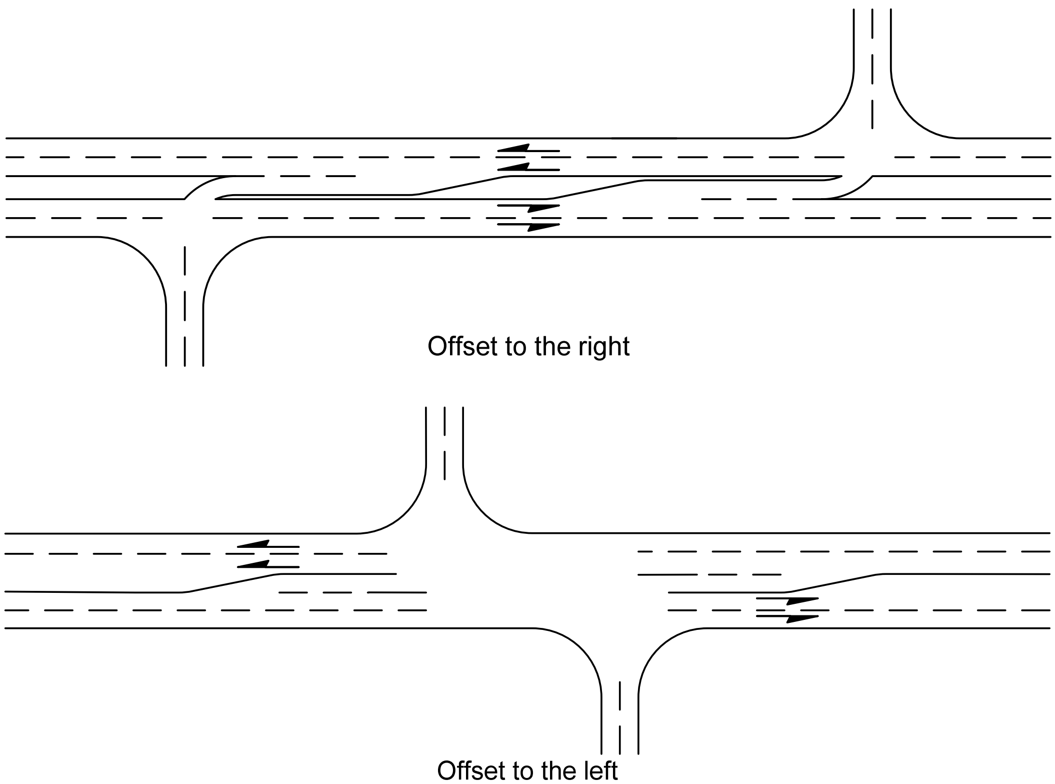


Indirect Left Turns: Unsignalized Intersections
Exhibit 1310-2b

(3) Split Tee

Avoid split tee intersections where there is less than the design intersection spacing (see 1310.05(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.

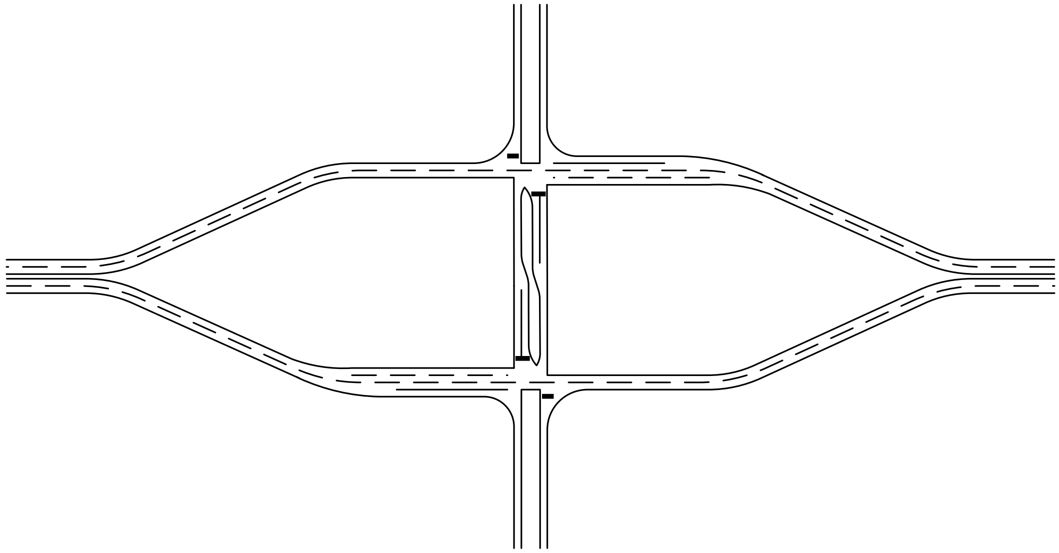
Split tee intersections with the offset to the right (see Exhibit 1310-3) have the additional disadvantages of overlapping main line left-turn lanes, the increased possibility of wrong-way movements, and a more complicated traffic signal design. Do not design a split tee intersection with an offset to the right less than the design intersection spacing (see 1310.05(4)) unless traffic is restricted to right-in/right-out only.



Split Tee Intersections
Exhibit 1310-3

(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 Exhibit 1310-4). Traffic on the crossroad makes the through and left-turn movements in two stages, reducing the needed sight distance and the probability of the driver misjudging the gap. To avoid potential conflicts with through traffic, provide a median width sufficient to store the anticipated queue for crossing and left-turning vehicles. The minimum median width is 100 feet, with 200 to 300 feet being desirable.



Split Intersections
Exhibit 1310-4

(5) Nonstandard Configurations

Low average daily traffic (ADT) can hide operational problems. Do not design intersections with the following configurations:

- Intersections with offset legs, except for split tee intersections (see 1310.04(3)).
- 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 configurations (see 1310.04(1) and Chapter 1320).

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.

1310.05 Design Considerations

Consider all potential users of the facility in the design of an intersection. 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 results in 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 design vehicle (see 1310.06). This is done to control the speed of turning vehicles and reduce the area of exposure for vehicles, bicycles, and pedestrians. For additional information on pedestrian needs, see Chapter 1510. For intersections with shared-use paths, see Chapter 1515. For bicycle considerations at intersections, see Chapter 1520.

(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, the function depends on the driver's ability to perceive what is happening with respect to the surroundings and other vehicles. When choosing an acceptable gap, the driver first identifies the approaching vehicle and then determines its 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 drivers to discern one object from another.

(2) Intersection Angle

An important intersection design characteristic is the intersection angle. The desirable intersection angle is 90°, with 75° to 105° allowed.

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 so that the entering through traffic is 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 Exhibit 1310-5).

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 250 feet or more 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

Provide intersection spacing for efficient operation of the highway. The minimum design intersection spacing for highways with limited access control is covered in Chapter 530. For other highways, the minimum design intersection spacing is dependent on the managed access highway class. (See Chapter 540 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 530 and 540. Evaluate closing or restricting movements at intersections with operational issues.

Document the spacing of existing intersections that will remain in place and the effects of the spacing on operation, capacity, and circulation.

(5) Design Vehicle

There are competing design objectives when considering the turning needs of larger vehicles and the crossing needs 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 needed, the pavement areas, pedestrian crossing distances, and traffic signal arms will also be larger than needed. (See 1310.06 for information on selecting a design vehicle and acceptable encroachments.)

(6) Sight Distance

For traffic to move 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, with justification, stopping sight distance may be provided. (See Chapter 1260 for guidance.)

Drivers approaching an intersection on the through roadway need to be able to see the intersection far enough in advance 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 the area 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 1510 for additional guidance on crosswalks and Chapter 1260 for guidance on on decision and stopping sight distances.)

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 complete all legal maneuvers before an approaching vehicle on the through roadway can reach the intersection. (See 1310.09 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 1140.

When the crossroad is a state facility, design the crossroad according to the applicable design level and functional class (see Chapters 100, 1130, and 1140). 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. The crown slope of the main line might need to be adjusted in the intersection area to improve the profile for the cross traffic.

Design the grade at the crosswalk to meet the requirements for accessibility. (See Chapter 1510 for additional crosswalk information.)

In areas that experience accumulations of snow and ice for all legs that 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

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 Exhibit 1310-5. Higher-volume intersections with multiple ramp lanes are designed individually.

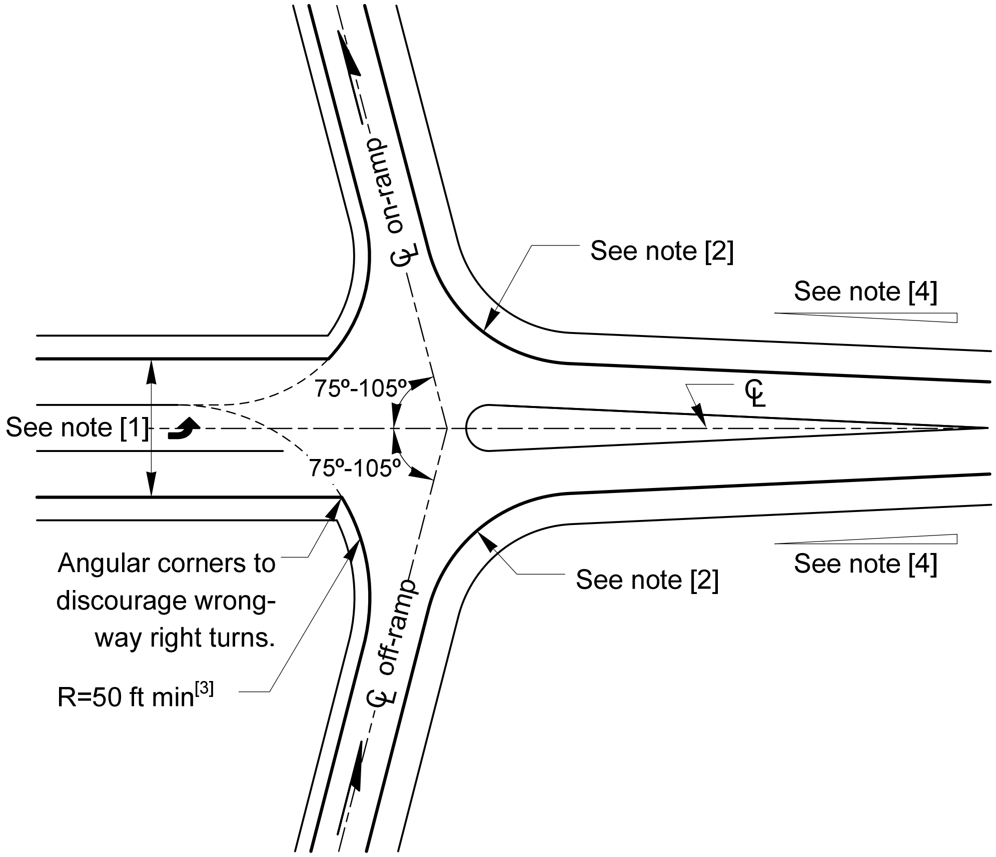
Provide ramp terminal designs consistent with the speed of the crossroad. (See 1310.06 for selection of the design vehicle.)

Where stop control or signal control is implemented, the intersection configuration criteria for ramp terminals are normally the same as for other intersections. One exception 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 getting 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 expected. 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°105° to avoid broken back or reverse curves in the ramp alignment.



Notes:

[1] 12-ft through lanes and 13-ft left-turn lane desirable.
[2] For right-turn corner design, see Exhibit 1310-14.
[3] Use templates to verify that the design vehicle can make the turn.
[4] For taper rates, see Exhibit 1310-18a, Table 1.

General:
Ramp terminal intersection design may vary depending on traffic volume, other users, and local conditions.

Interchange Ramp Terminal Details
Exhibit 1310-5

(10) Wrong-Way Movement Countermeasures

Wrong-way collisions, though infrequent, have the potential to be more serious than other types of collisions, especially on high-speed facilities. Collision data show that impaired and older drivers are overrepresented and that a high percentage of these occurrences are at night. Washington State data show approximately equal numbers of collisions on the Interstate and multilane urban principal arterial highways. Give consideration to discouraging wrong-way maneuvers at all stages of design.

(a) Wrong-Way Driving Countermeasure Categories

There are three categories of countermeasures to discourage wrong-way driving:

- Signing and delineation

- Intelligent transportation systems
- Geometric design

1. Signing and Delineation

Signing and delineation countermeasures include:

- DO NOT ENTER and WRONG WAY signs.
- ONE WAY signs.
- Turn restriction signs.
- Red-backed raised pavement markers (RPMs).
- Directional pavement arrows.
- Yellow edge line on left and white edge line on right side of exit ramps.
- Pavement marking extension lines to direct drivers to the correct ramp.

Signing can be a more effective countermeasure when the signs are lowered. At night, lowered signs are better illuminated by low-beam headlights. Other improvements may include a second set of signs, supplemental sign placards, oversized signs, flashing beacons, internal illumination, overhead-mounted signs, red reflective tape on the back of signs, extra overhead lighting, and red-backed guideposts on each side of the ramp up to the WRONG WAY sign.

2. Intelligent Transportation Systems (ITS)

Wrong-way ITS countermeasures are wrong-way detection and warning systems. Contact the region Traffic Office for assistance when considering an ITS wrong-way warning system.

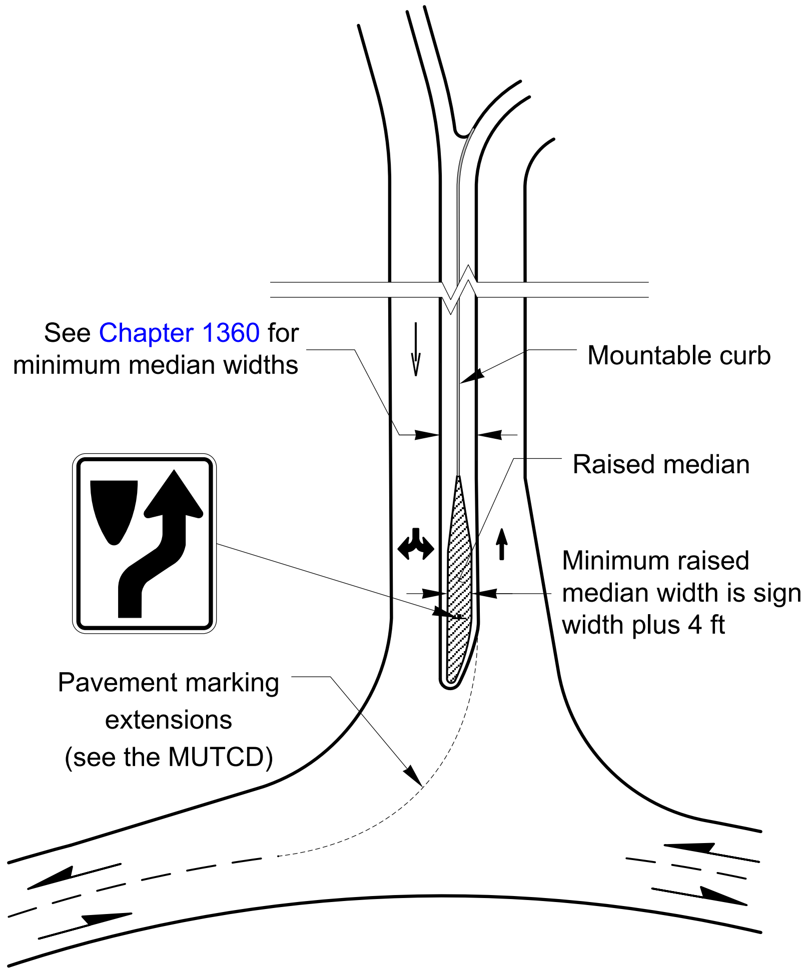
3. Geometric Design

Geometric countermeasures include separating wrong-way movements from other movements, discouraging wrong-way movements, encouraging right-way movements, and improving the visibility of the right-way movement.

a. Separate On- and Off-Ramp Terminals

Consider the separation of on- and off-ramp terminals, particularly at interchanges where the ramp terminals are closely spaced (for example, partial cloverleaf ramps). Wider medians between off- and on-ramp terminals provide room for signing and allow the median end to be shaped to help direct vehicles onto the correct roadway. The minimum width of the raised median is 7 feet, face of curb to face of curb, to accommodate a 36-inch sign.

Extend the raised median on a two-way ramp from the ramp terminal intersection to the split of the on- and off-ramps. The median outside of the intersection area may be reduced to the width of a dual-faced mountable curb. (See Exhibit 1310-6 for an example of the minimum median at the terminal of a two-way ramp.)



Median at Two-Way Ramp Terminal
Exhibit 1310-6

b. Reduced Off-Ramp Terminal Throat Width

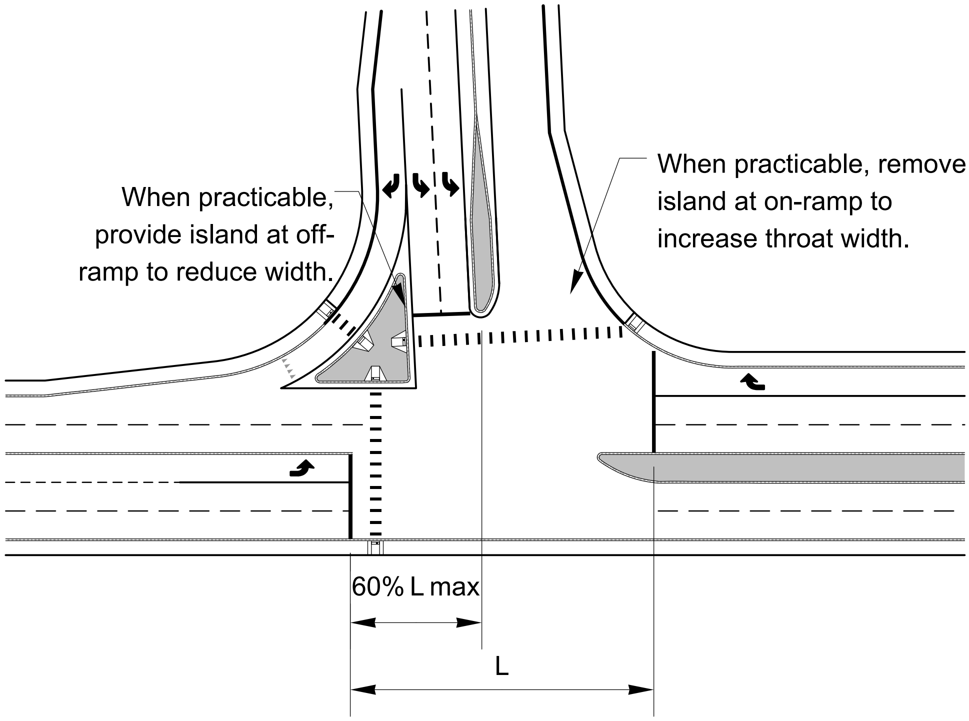
Reducing the width of the off-ramp throat has been a successful method of discouraging wrong-way movements. A smaller opening makes the wrong-way entry less inviting, particularly for closely spaced ramps. When off-ramp terminals have right-turn lanes, a raised island will reduce the potential for a wrong-way movement.

c. Increased On-Ramp Terminal Throat Width

Increasing the width of the on-ramp throat can encourage right-way movements. A larger opening for the on-ramp makes it easier to turn into. To increase the throat width of on-ramps, use flat radii for left- and right-turning traffic and remove islands.

d. Intersection Balance

When drivers make a left turn, they are required to leave the intersection in the extreme left-hand lane lawfully available. As a result, left-turning drivers tend to head for a point between 50% and 60% of the way through the intersection. At a two-way ramp terminal, the desirable throat width for the on-ramp roadway is not less than the off-ramp roadway width to accommodate this behavior (see Exhibit 1310-7). Much of this can be achieved by adjusting the stop bar position on the interchange cross street.



Intersection Balance Example
Exhibit 1310-7

e. Visibility

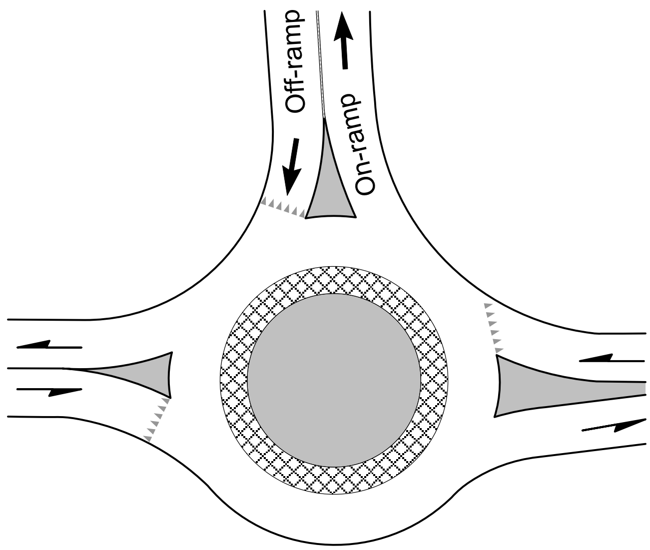
When drivers can see and recognize the roadway they want to turn onto, they are less likely to make a mistake and turn onto the wrong roadway. For two-way ramps and divided multilane roadways with barrier in the median, end the barrier far enough from the intersection that a left-turning driver can see and recognize the roadway going the correct direction. Drivers need to see the delineation pavement markings, curbs, or other elements to locate the correct roadway.

f. Angular Corners on the Left of Off-Ramp Terminals

Angular corners on the left side of off-ramp terminals will discourage wrong-way right turns. Provide a corner design as angular as feasible that will provide for the left turn from the off-ramp. Circular curves can look inviting for a wrong-way right turn onto the off-ramp (see Exhibit 1310-5).

g. Roundabouts

The design of roundabouts makes wrong-way movement less likely. Where wrong-way driving is a concern, evaluate a roundabout as an alternative. (See Exhibit 1310-8 for an example of a roundabout at a two-way ramp terminal.)



Roundabout at a Two-Way Ramp Terminal
Exhibit 1310-8

(b) Countermeasure Applications

Following are applications of wrong-way countermeasures for some common locations. For assistance with signing and delineation, contact the region Traffic Office.

1. All Ramps

Countermeasures that can be used on almost any ramp or intersection with potential wrong-way concerns include:

- Enlarged warning signs.
- Directional pavement arrows at ramp terminals.
- Redundant signing and pavement arrows.
- Roundabout ramp terminal intersections, where room is available.
- Red-backed RPMs

2. One-Way Diamond Off-Ramp

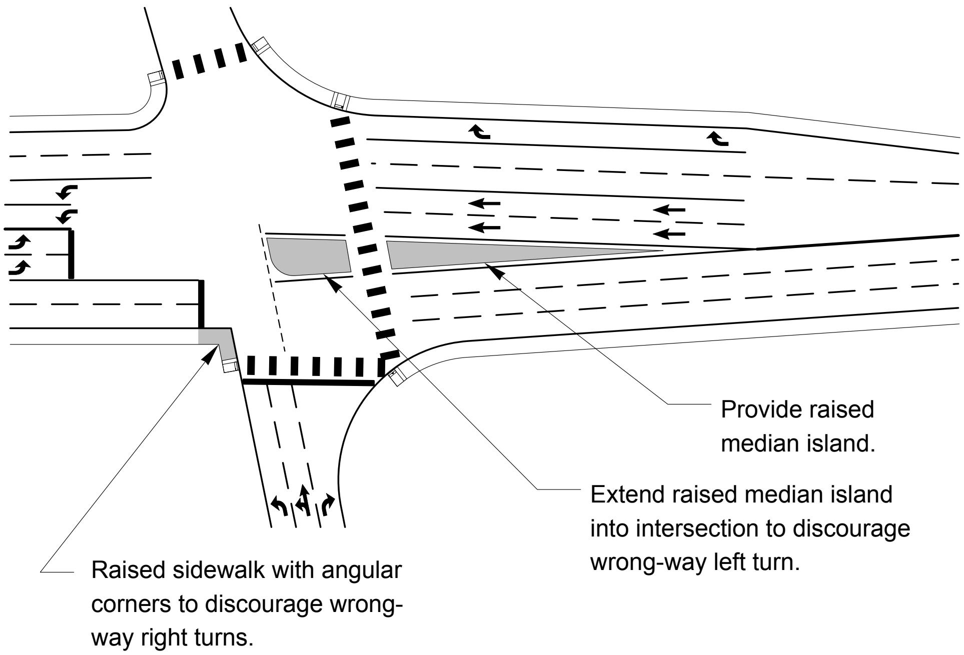
Diamond interchanges are common, and although drivers are familiar with them, they can still get confused and go the wrong way. In addition to signing and pavement markings for these interchanges, provide:

- Angular corners to discourage wrong-way right turns.

3. Diamond Interchange With Advance Storage

Diamond interchanges with advance storage have left-turn storage lanes that extend from the on-ramp past the off-ramp (see Exhibit 1310-9). This allows for a potential early left turn onto the off-ramp. Following are additional countermeasures for interchanges with advanced left-turn storage:

- Provide a raised median to discourage the wrong-way left turn.
- Provide signing and directional arrows to direct traffic to the correct left-turn point.



Diamond Interchange With Advance Storage
Exhibit 1310-9

4. Two-Way Ramps

Two-way ramps have the on- and off-ramp adjacent to each other. They are used at partial cloverleaf, trumpet, and button hook interchanges. Because the on and off roadways are close to each other, they are more vulnerable to wrong-way driving. Also, when the separation between on and off traffic is striping only, the ramps are susceptible to drivers entering the correct roadway and inadvertently crossing to the wrong ramp. In addition to signing and delineation, the following are countermeasures for two-way ramps:

- Separate the on- and off-ramp terminals.
- Reduce off-ramp terminal throat width.
- Increase on-ramp terminal throat width.
- Maintain intersection balance.
- Improve on-ramp visibility.
- Provide a raised median or dual-faced curb from the ramp terminal intersection to the gore nose.

5. HOV Direct Access Ramps

HOV direct access ramps are two-way ramps in the median; therefore, the ability to provide separation between the on and off traffic is limited by the width of the median. An additional concern is that HOV direct access ramps are left-side ramps. Drivers normally enter the freeway using a right-side ramp and they may mistakenly travel the wrong way on a left-side ramp. Review existing and proposed signing for inadvertent misdirection.

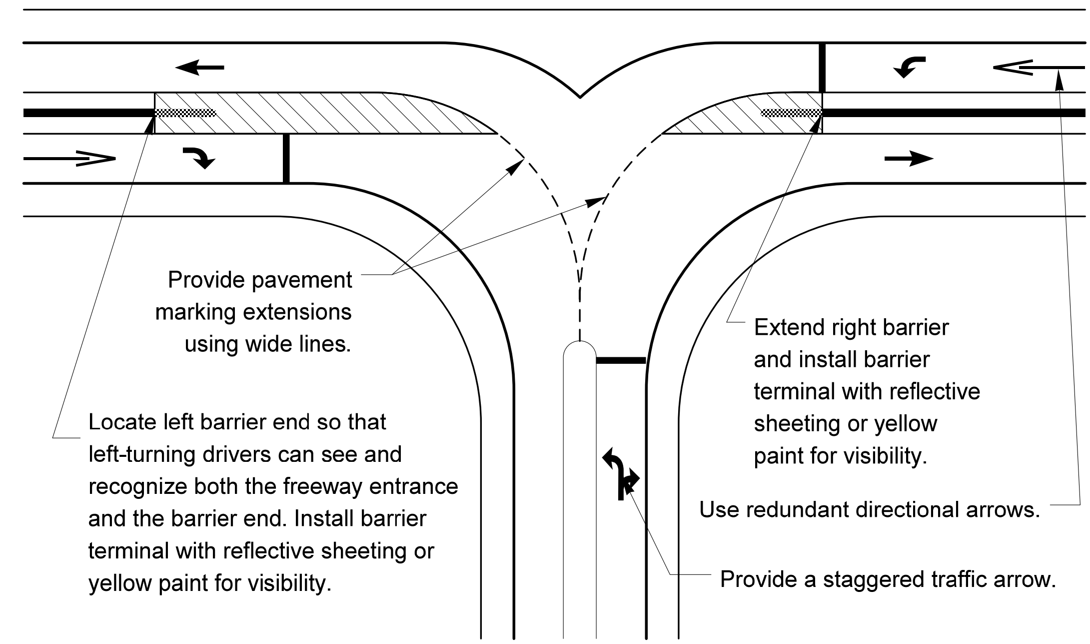
Following are countermeasures for wrong-way driving at HOV direct access ramps:

- Provide a staggered traffic arrow to better describe the left and right turns (see Exhibit 1310-10a).
- Provide pavement marking extensions, using wide lines, through intersections (see Exhibit 1310-10a).
- Use redundant directional pavement arrows at ramp terminals.
- Paint or use reflective sheeting to highlight barrier terminals (see Exhibit 1310-10a).
- Locate the left barrier end to provide good visibility for left-turning traffic for both the barrier terminal and the on-ramp roadway.
- Extend right barrier as far as feasible while providing a 4-foot clearance for the left-turning exiting design vehicle.
- Provide redundant signing (see Exhibit 1310-10b).
- Provide enlarged warning signs.

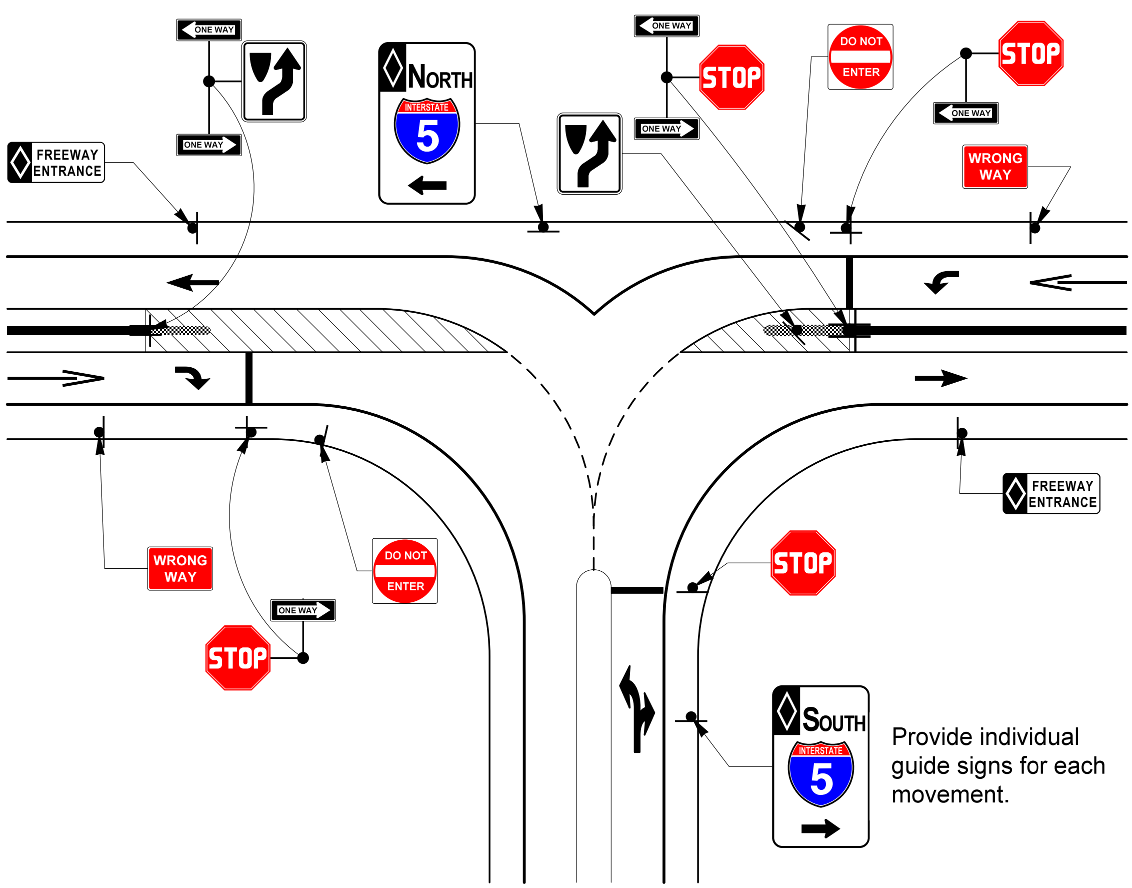
6. Multilane Divided Roadways

Wrong-way driving can also occur on multilane divided nonfreeway facilities. Wrong-way drivers may enter multilane divided facilities at driveways and at-grade intersections. Countermeasures for wrong-way driving on nonfreeway multilane divided highways include:

- Wrong-way signing and delineation at the intersections.
- Right-in/right-out road approaches.



HOV Direct Access: Pavement Markings
Exhibit 1310-10a



HOV Direct Access: Signing
Exhibit 1310-10b

1310.06 Design Vehicle Selection

When selecting a design vehicle for an intersection, consider the needs of all users and the costs. The primary use of the design vehicle is to determine radii for each leg of the intersection. It is possible for each leg to have a different design vehicle. Exhibit 1310-11 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. Exhibit 1310-12 shows the minimum design vehicles. Justify the decision 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 (Exhibits 1310-13a through 13c, other published templates, 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. Justify the operational tradeoffs associated with this encroachment. When encroachment on the shoulder is required, increase the pavement structure to support the anticipated traffic.

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

Design Vehicle Types
Exhibit 1310-11

Intersection Type	Minimum Design Vehicle
Junction of Major Truck Routes	WB-67
Junction of State Routes	WB-50[1]
Ramp Terminals	WB-50[1]
Other Rural	WB-50
Industrial	WB-40
Commercial	SU[2][3]
Residential	SU[2][3]

Notes:
[1] WB-67 is desirable.
[2] To accommodate pedestrians, the P vehicle may be used as the design vehicle when justified in a traffic analysis.
[3] When the intersection is on a transit or school bus route, use the BUS design vehicle as a minimum. (See Chapter 1430 for additional guidance on transit facilities.)

Minimum Intersection Design Vehicle
Exhibit 1310-12

In addition to the design vehicle, design intersections to accommodate the occasional larger vehicle. When vehicles larger than the design vehicle are allowed and are anticipated to occasionally use the intersection, make certain 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 vehicle usage and the resulting disruption to other traffic. Use the WB-67 as the largest vehicle at state route-to-state route junctions. Consider oversized vehicles for intersections that are commonly used to route oversized loads. Justify any required encroachment into other lanes and any degradation of intersection operation in an evaluate upgrade.

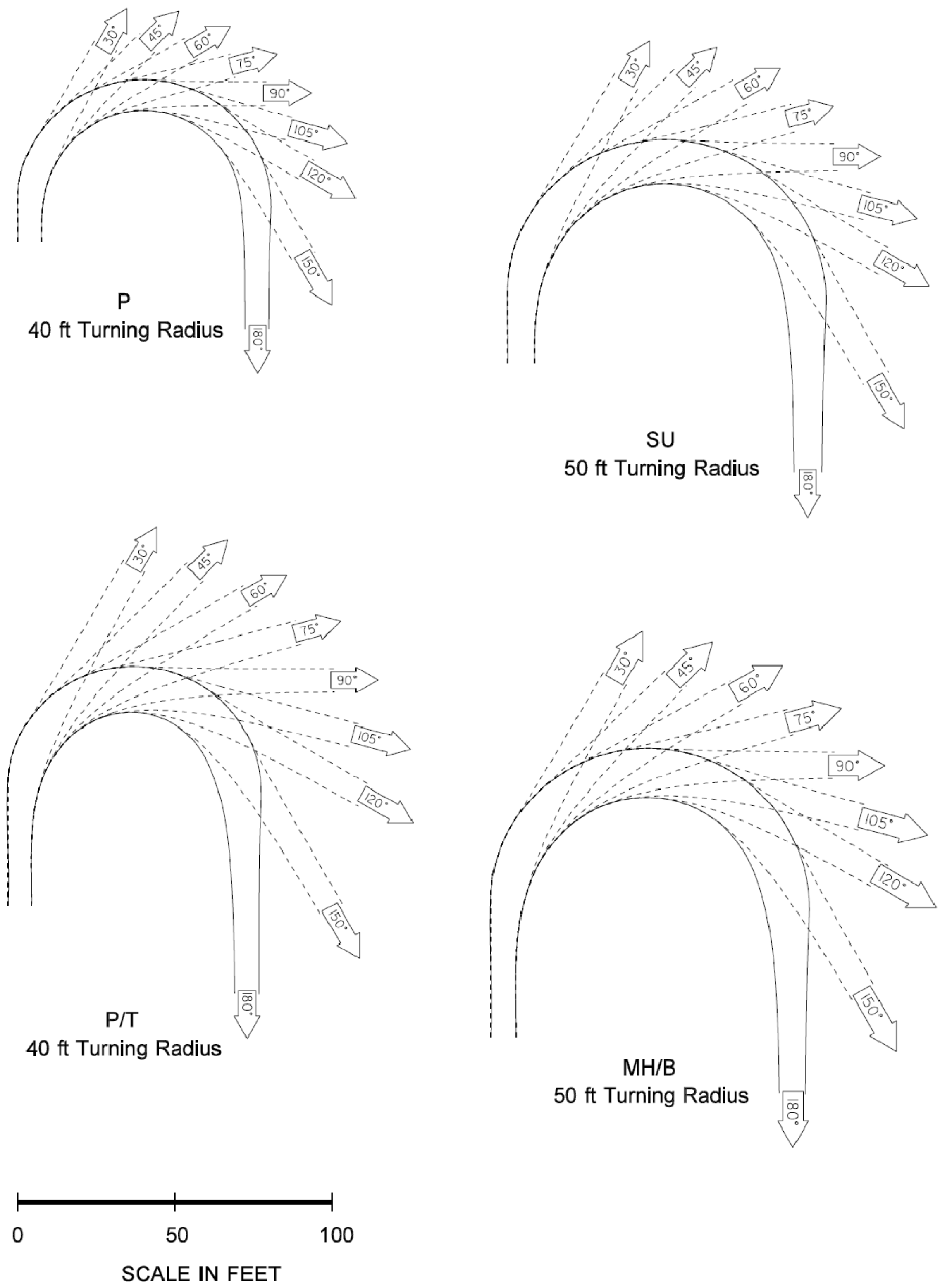
1310.07 Design Elements

When designing an intersection, identify and address the needs of all intersection users.

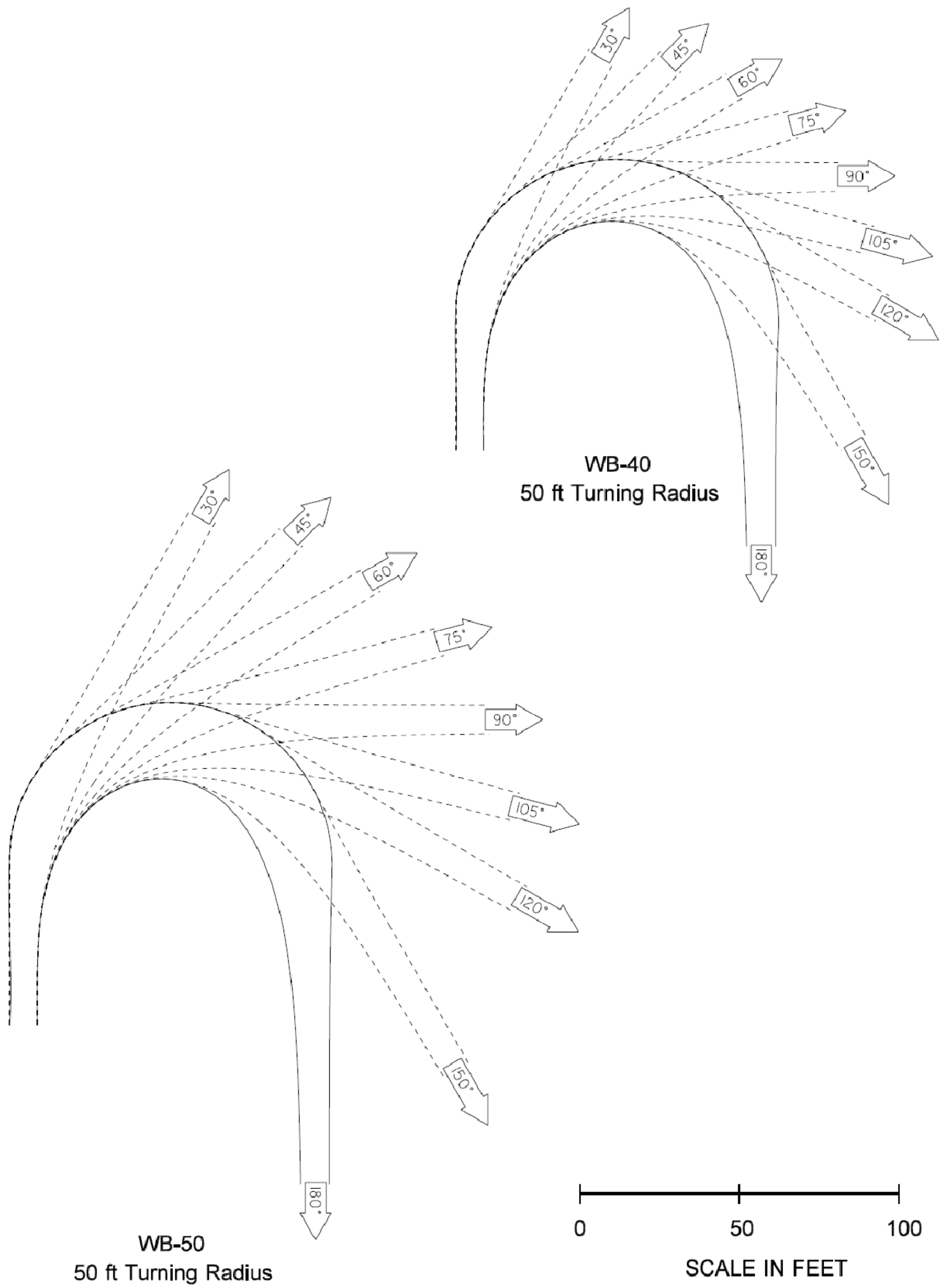
When pedestrian issues are a primary concern, the design objective becomes one of reducing the potential for vehicle/pedestrian conflicts. This is done by minimizing pedestrian crossing distances and controlling the speeds of turning vehicles. This normally leads to right-corner designs with smaller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

Pedestrian refuge islands can be beneficial. They minimize the pedestrian 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.

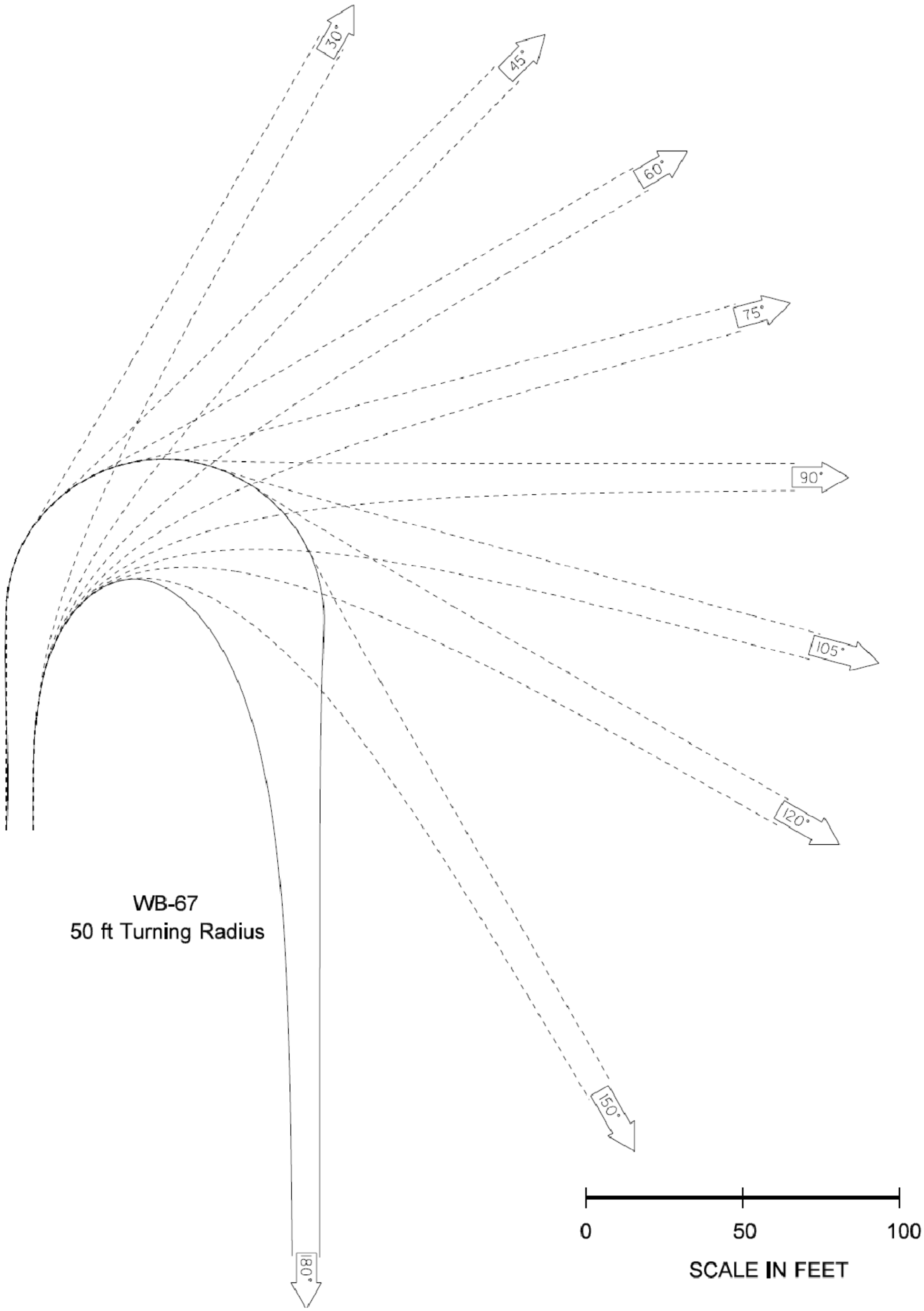
Channelization, the separation or regulation of traffic movements into delineated paths of travel, can facilitate the orderly movement of vehicles, bicycles, and pedestrians. Channelization includes left-turn lanes, right-turn lanes, speed change lanes (both acceleration and deceleration lanes), and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



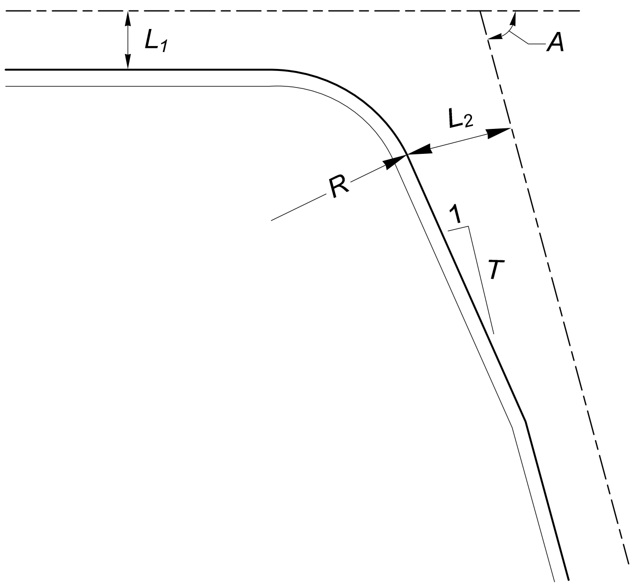
Turning Path Template
Exhibit 1310-13a



Turning Path Template
Exhibit 1310-13b



Turning Path Template
Exhibit 1310-13c



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*	L_1[1]	L_2[2]	*T*	Vehicle	*A*	*R*	L_1[1]	L_2[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.

General:

All distances given in feet and angles in degrees.

Right-Turn Corner

Exhibit 1310-14

(1) Right-Turn Corners

Exhibit 1310-14 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, the right-turn corner designs given in Exhibit 1310-14 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 1310.07(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

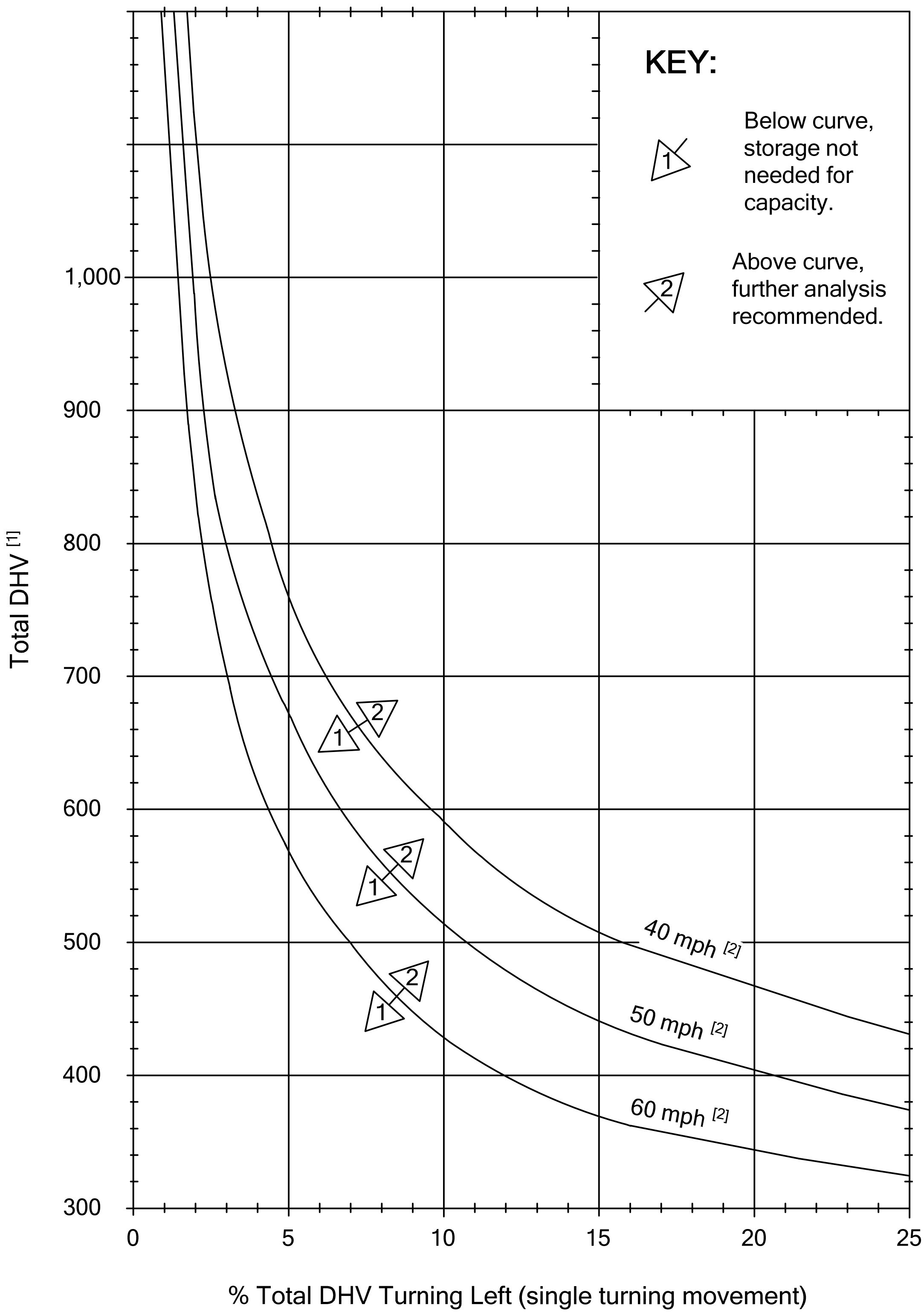
One-way left-turn lanes are separate storage lanes for vehicles turning left from one roadway onto another. One-way left-turn lanes may be an economical way to lessen delays and crash potential involving left-turning vehicles. In addition, they can allow deceleration clear of the through traffic lanes. Provide a minimum storage length of 100 feet for one-way left-turn 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 the storage length. If the length determined is less than the 100-foot minimum, make it 100 feet (see Chapter 1330).

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 congestion reduction with a left-turn lane. On two-lane highways, use Exhibit 1310-15a, 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 Exhibit 1310-15b to determine whether a left-turn lane is recommended.
- A study indicates crash reduction with a left-turn lane.
- Restrictive geometrics require left-turning vehicles to slow greatly below the speed of the through traffic.
- There is less than decision sight distance for traffic approaching a vehicle stopped at the intersection to make a left-turn.

A traffic analysis based on the *Highway Capacity Manual* (HCM) may also be used to determine whether left-turn lanes are needed to maintain the desired level of service.



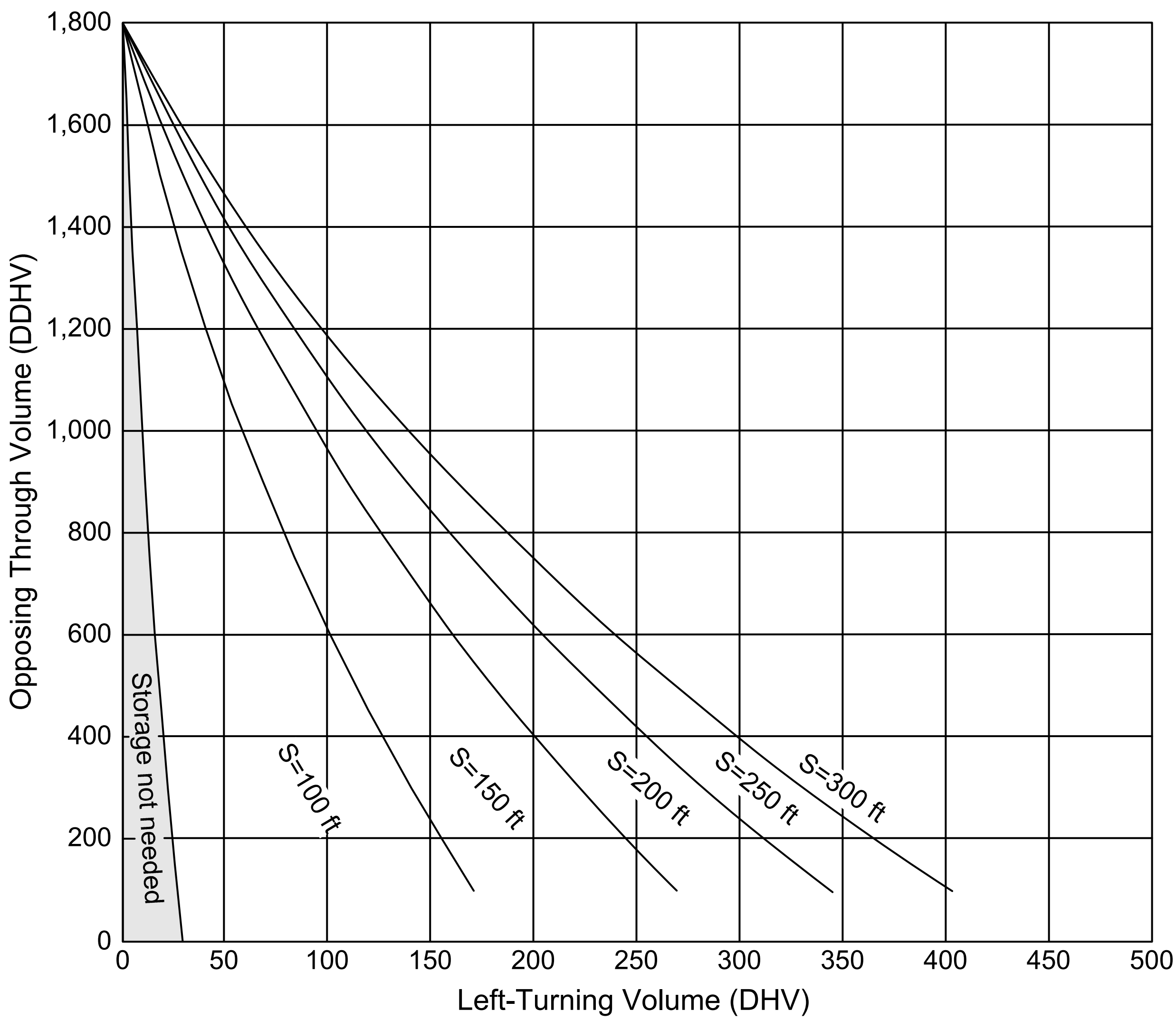
Notes:

[1] DHV is total volume from both directions.

[2] Speeds are posted speeds.

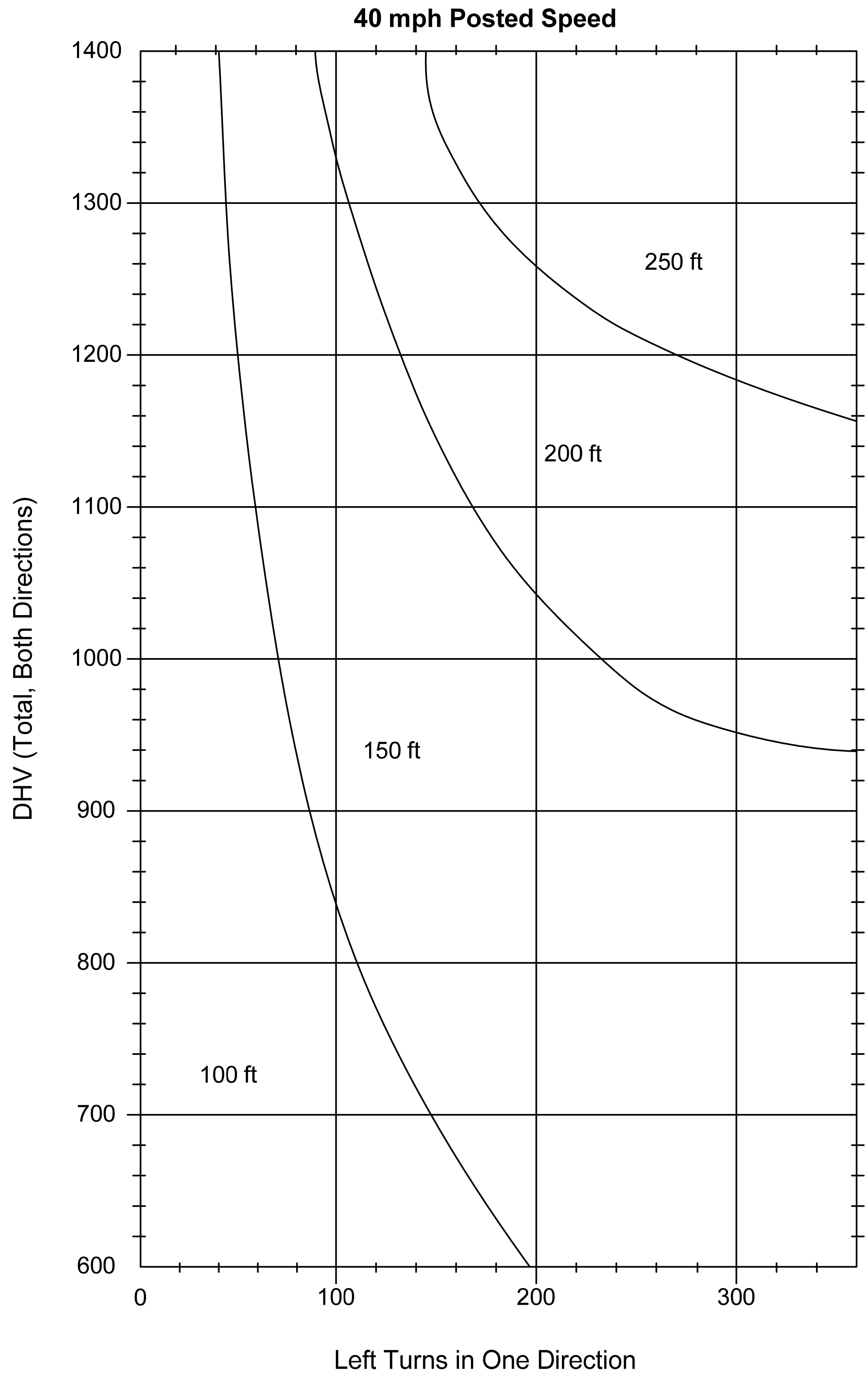
Left-Turn Storage Guidelines: Two-Lane, Unsignalized

Exhibit 1310-15a

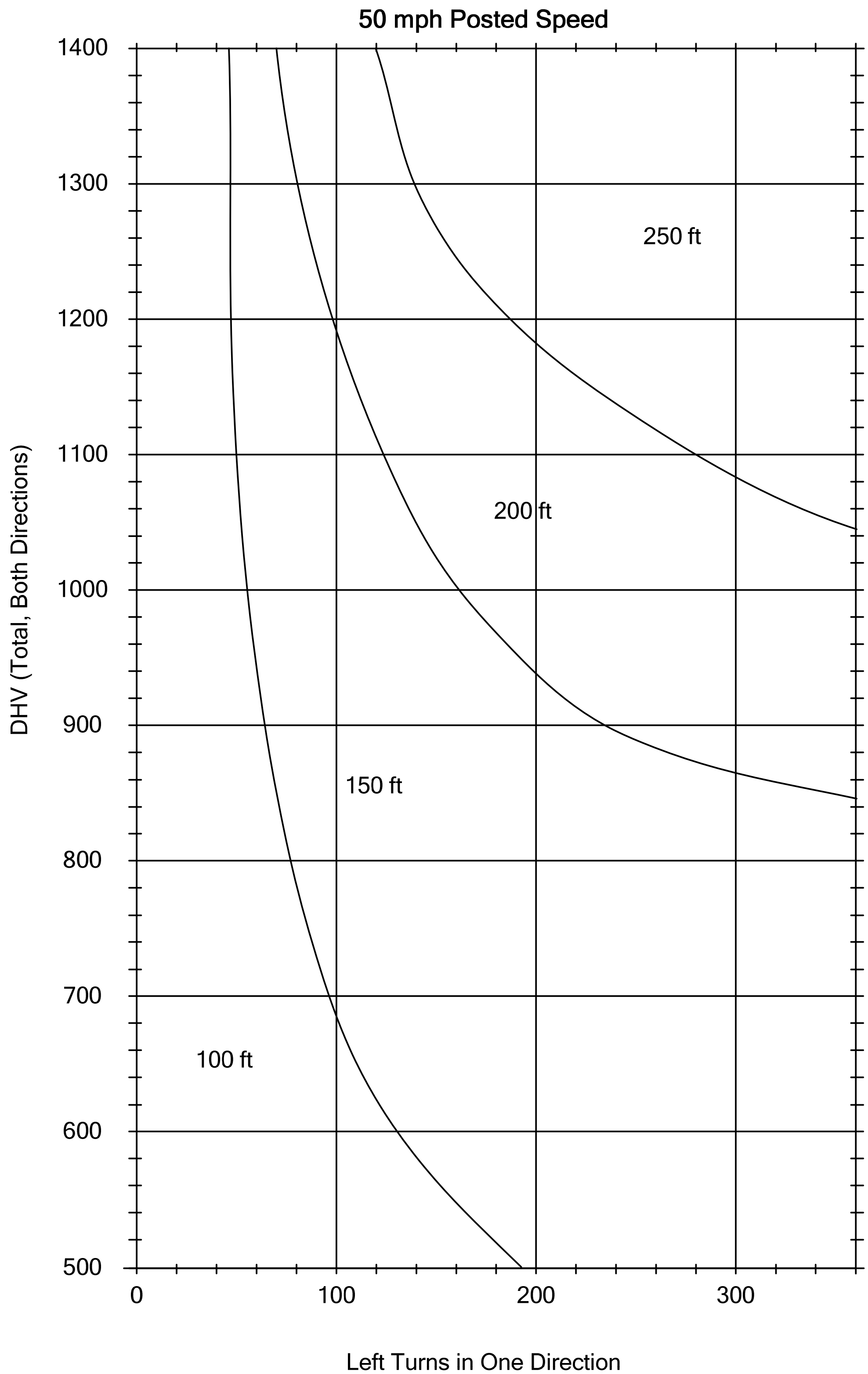


S = Left-turn storage length

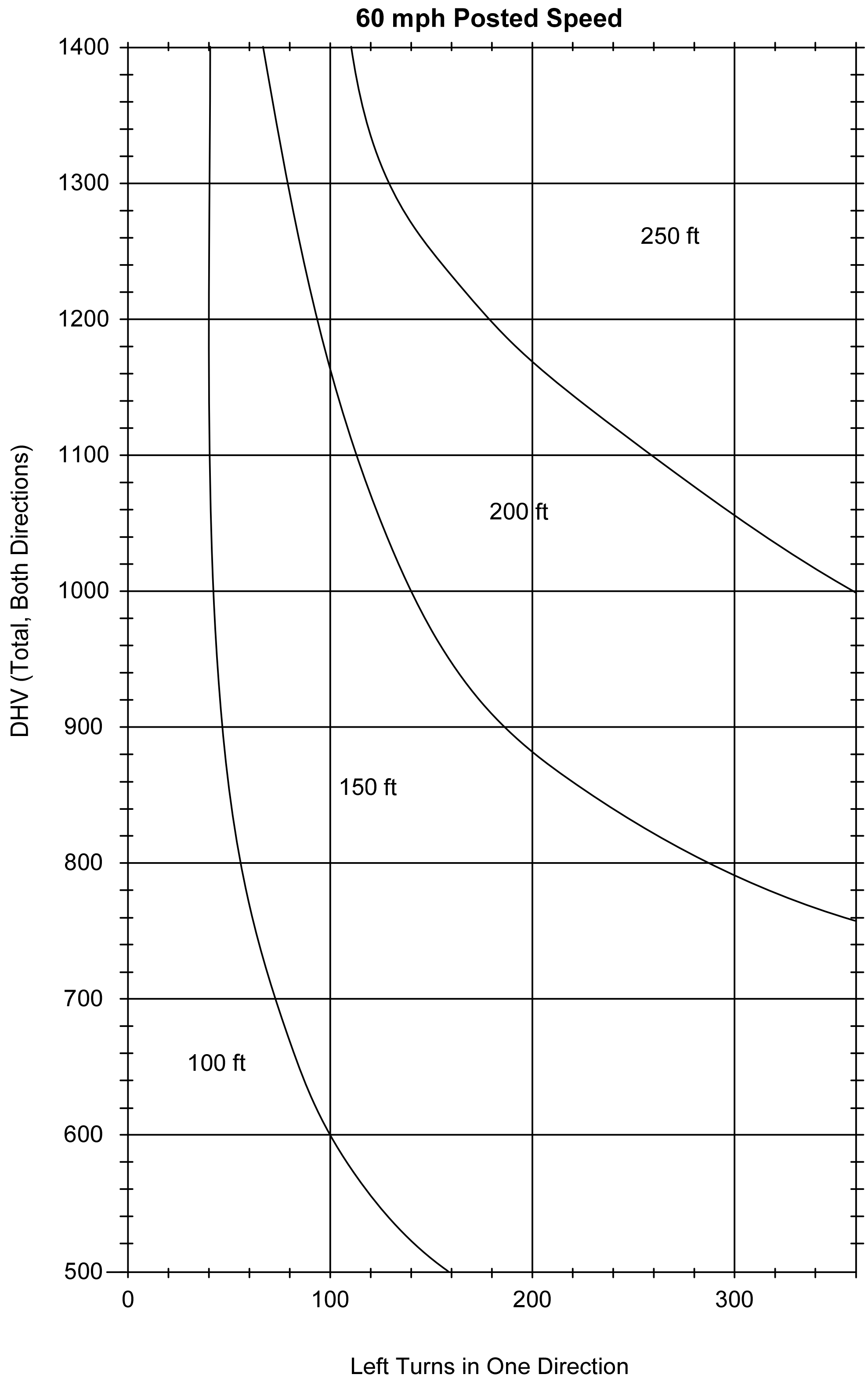
Left-Turn Storage Guidelines: Four-Lane, Unsignalized
Exhibit 1310-15b



Left-Turn Storage Length: Two-Lane, Unsignalized
Exhibit 1310-16a



Left-Turn Storage Length: Two-Lane, Unsignalized
Exhibit 1310-16b



Left-Turn Storage Length: Two-Lane, Unsignalized
Exhibit 1310-16c

Determine the storage length on two-lane highways by using Exhibits 1310-16a through 16c. On four-lane highways, use Exhibit 1310-15b. These lengths do not consider trucks. Use Exhibit 1310-17 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 Exhibits 1310-15b and 1310-16a, 16b, or 16c.					

Left-Turn Storage With Trucks (ft)
Exhibit 1310-17

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.

Where one-way left-turn channelization with curbing is to be provided, evaluate surface water runoff and design additional drainage facilities if needed to control the runoff.

Provide illumination at left-turn lanes in accordance with the guidelines in Chapter 1040.

At signalized intersections with high left-turn volumes, double (or triple) left-turn lanes may be needed to maintain the desired level of service. For a double left-turn, 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 desirable to provide for the design vehicle in the outside lane and an SU vehicle turning abreast rather than two design vehicles turning abreast.

Exhibits 1310-18a through 18f show left-turn lane geometrics, which are described as follows:

1. Widening

It is desirable that offsets and pavement widening (see Exhibit 1310-18a) 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

Widening is not needed for left-turn lane channelization where medians are 11 feet wide or wider (see Exhibits 1310-18b through 18d). 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 (see Exhibit 1310-18b) to improve sight distance and increase opposing left-turn clearances.

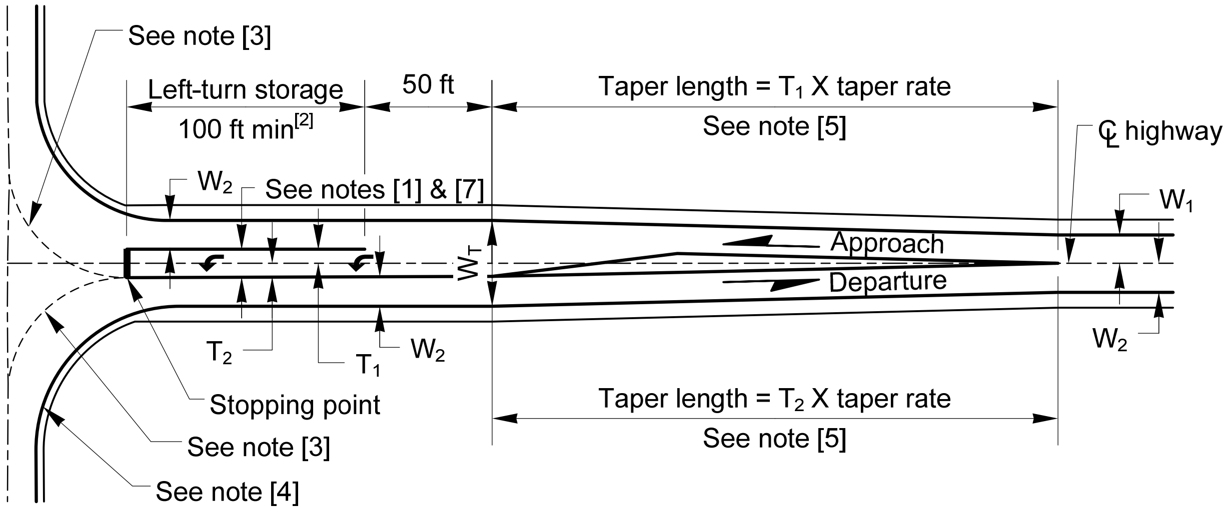
A median acceleration lane (see Exhibits 1310-18c and 18d) may be provided where the median is 23 feet or wider. The median acceleration lane might not be needed at a signalized intersection. When a median acceleration lane is to be used, design it in accordance with 1310.07(4), Speed Change Lanes. Where medians have sufficient width, provide a 2-foot shoulder adjacent to a left-turn lane.

3. Minimum Protected Left Turn With a Median

At intersections on divided highways where channelized left-turn lanes are not provided, provide the minimum protected storage area (see Exhibit 1310-18e).

4. Modifications to Left-Turn Designs

With an evaluate upgrade, the left-turn lane designs discussed above and given in Exhibits 1310-18a through 18e 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. Provide a modified design that is able to accommodate the design vehicle, and provide for the striping (see 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.



Notes:

[1] The minimum width of the left-turn storage lane (T_1+T_2) is 11 ft. The desirable width is 12 ft.

[2] For left-turn storage length, see Exhibits 1310-15b for 4-lane roadways or 1310-16a through 16c 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 Exhibit 1310-14.

[5] For desirable taper rates, see Table 1. With justification, taper rates from Table 2, Exhibit 1310-18c, 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 shoulders to the left-turn lane width. For shoulder widths at curbs, see 1310.07(6) and Chapter 1240.

W_1 = Approaching through lane width

W_2 = Departing lane width

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 = Total width of left-turn lane

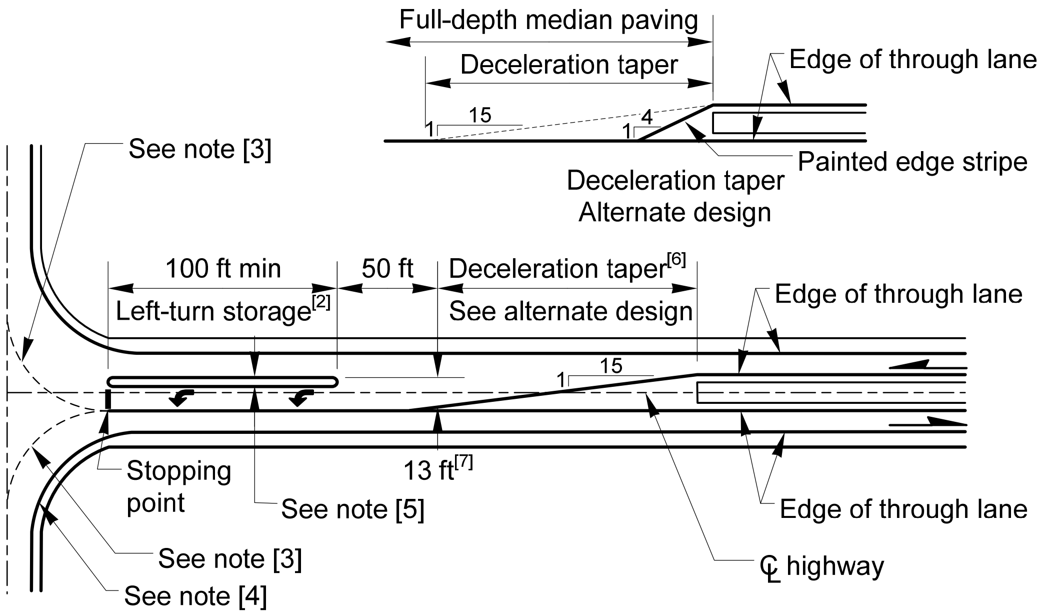
W = Total width of channelization ($W_1+W_2+T_1+T_2$)

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

Exhibit 1310-18a



Notes:

[1] Lane width of 13 ft is desirable. When curb is provided, add the width of the curb and the shoulders. For shoulder widths at curbs, see 1310.07(6) and Chapter 1240.

[2] For left-turn storage length, see Exhibits 1310-15b for 4-lane roadways or 1310-16a through 16c 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 Exhibit 1310-14.

[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.

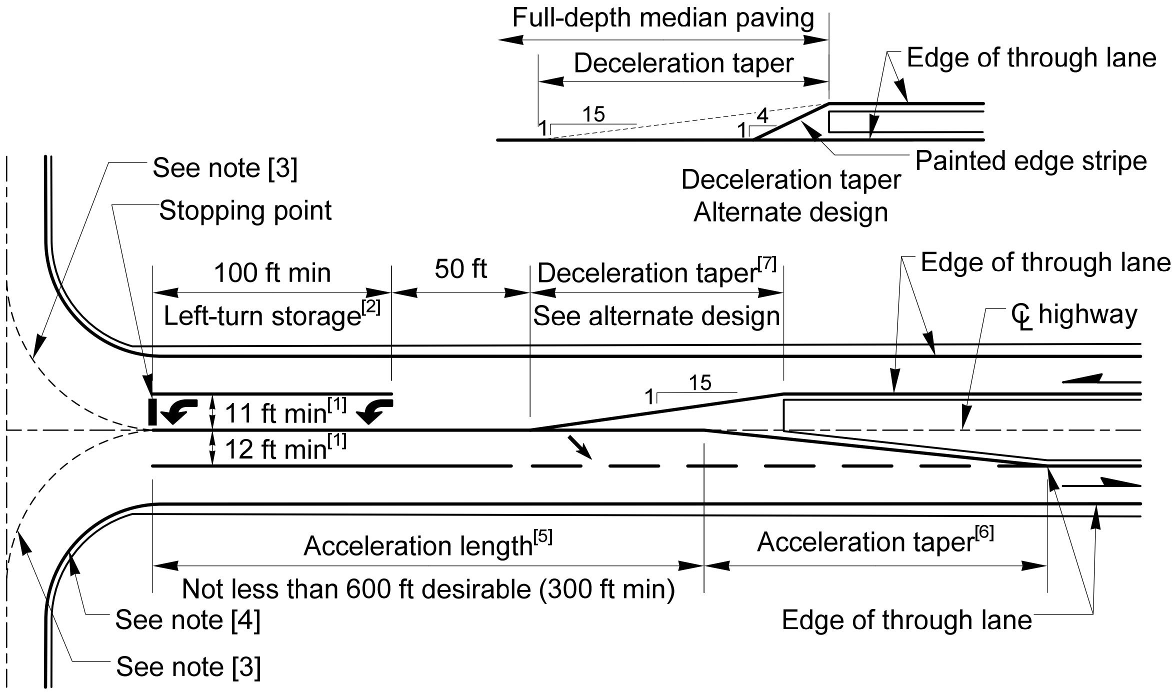
[6] For increased storage capacity, the left-turn deceleration taper alternate design may be used.

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

General:

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

Median Channelization: Median Width 11 ft or More
Exhibit 1310-18b



Notes:

[1] Lane widths of 13 ft are desirable for both the left-turn storage lane and the median acceleration lane. When curb is provided, add the width of the curb.

[2] For left-turn storage length, see Exhibits 1310-15b for 4-lane roadways or 1310-16a through 16c 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 Exhibit 1310-14.

[5] The minimum total length of the median acceleration lane is shown in Exhibit 1310-22.

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

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

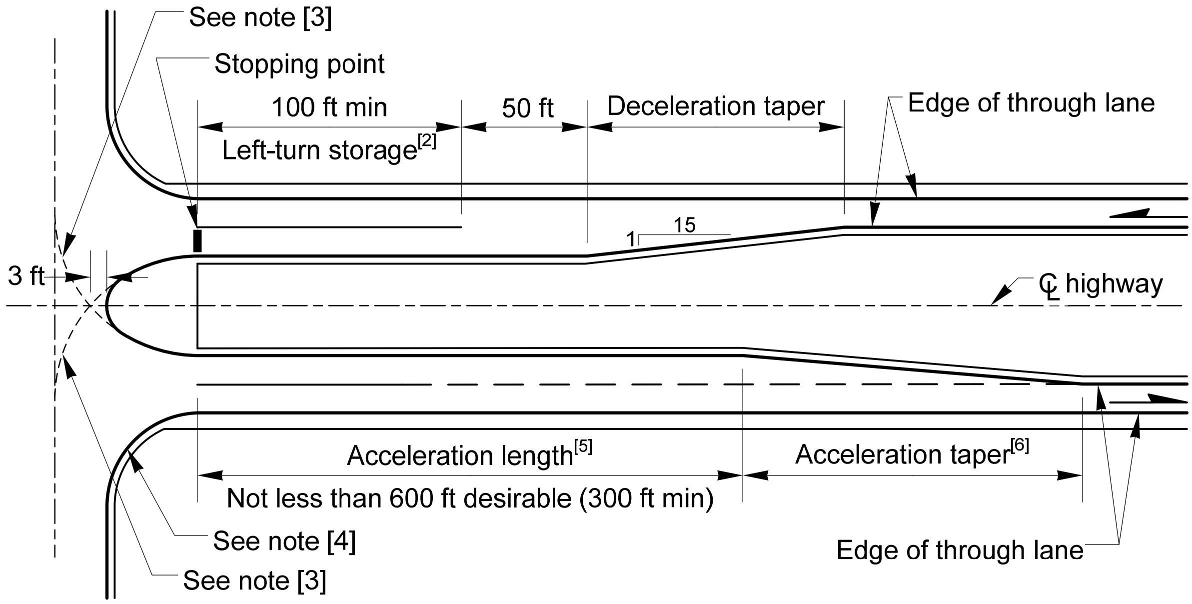
Posted Speed	Taper Rate
55 mph	55:1
50 mph	50:1
45 mph	45:1
40 mph	27:1
35 mph	21:1
30 mph	15:1
25 mph	11:1

Table 2

General:

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

Median Channelization: Median Width 23 ft to 26 ft
Exhibit 1310-18c



Notes:

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

[2] For left-turn storage length, see Exhibits 1310-15b for 4-lane roadways or 1310-16a through 16c 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 Exhibit 1310-14.

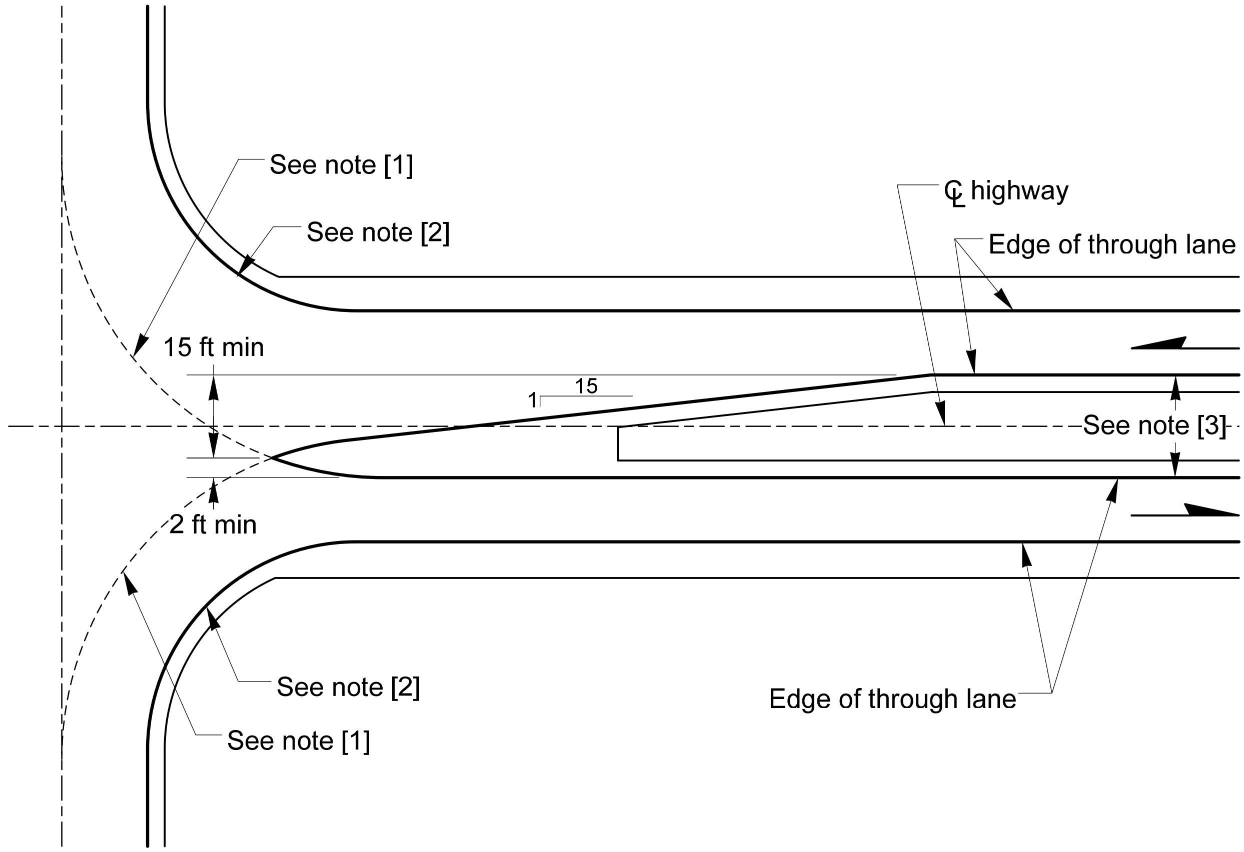
[5] The minimum length of the median acceleration lane is shown in Exhibit 1310-22.

[6] For acceleration taper rate, see Exhibit 1310-18c, Table 2.

General:

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

Median Channelization: Median Width of More Than 26 ft
Exhibit 1310-18d



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 Exhibit 1310-14.

[3] For median width 17 ft or more. For median width less than 17 ft, widen to 17 ft or use Exhibit 1310-18b.

General:

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

Median Channelization: Minimum Protected Storage

Exhibit 1310-18e

(b) Two-Way Left-Turn Lanes (TWLTL)

Two-way left-turn lanes 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:

- A collision study indicates reduced crashes with a TWLTL.
- 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.

TWLTLs can reduce delays to through traffic, reduce rear-end collisions, and provide separation between opposing lanes of traffic. However, they do not provide 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 1140 and 540 for additional restrictions on the use of TWLTLs.)

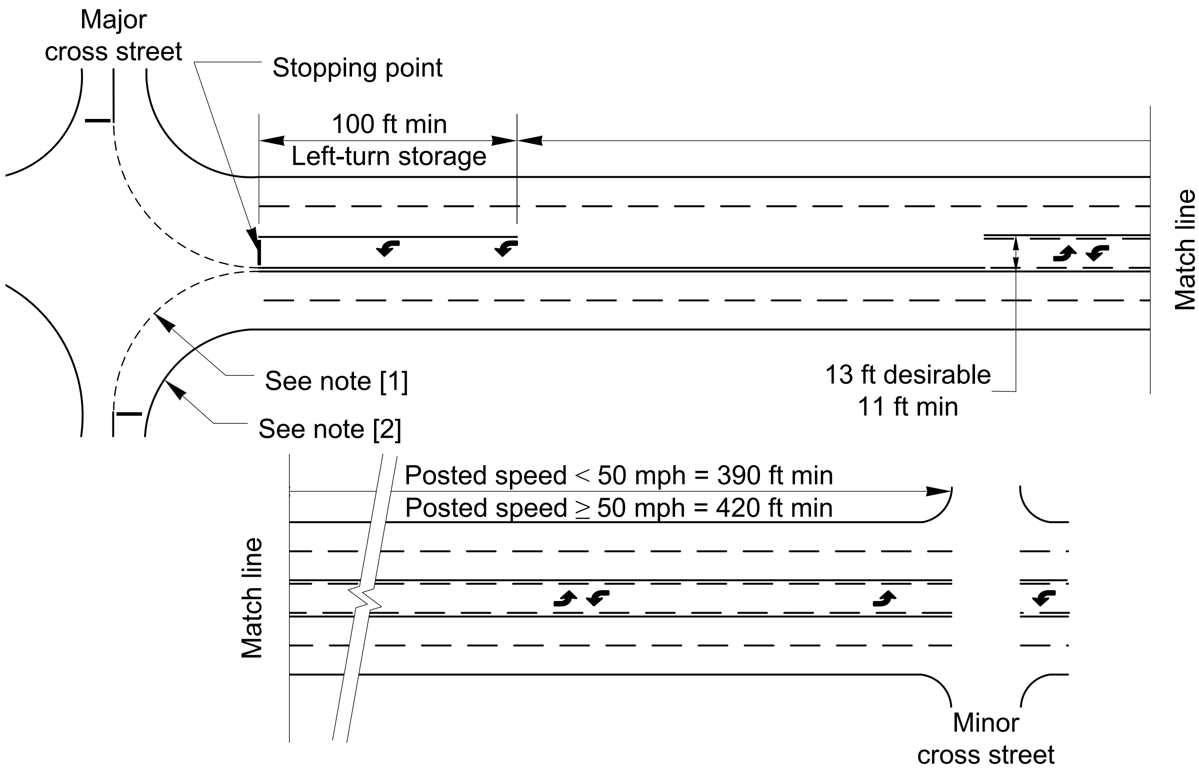
The basic design for a TWLTL is illustrated in Exhibit 1310-18f. Additional criteria are as follows:

- The desirable length of a TWLTL is not less than 250 feet.
- Provide illumination in accordance with the guidelines in Chapter 1040.
- 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 to determine when to provide right-turn lanes at unsignalized intersections:

- For two-lane roadways and for multilane roadways with a posted speed of 45 mph or above, when recommended by Exhibit 1310-19.
- A collision study indicates an overall crash reduction with a right-turn lane.
- The presence of pedestrians requires right-turning vehicles to stop.
- Restrictive geometrics require right-turning vehicles to slow greatly below the speed of the through traffic.
- There is less than decision sight distance for traffic approaching the intersection.



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 Exhibit 1310-14.

General:

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

Median Channelization: Two-Way Left-Turn Lane

Exhibit 1310-18f

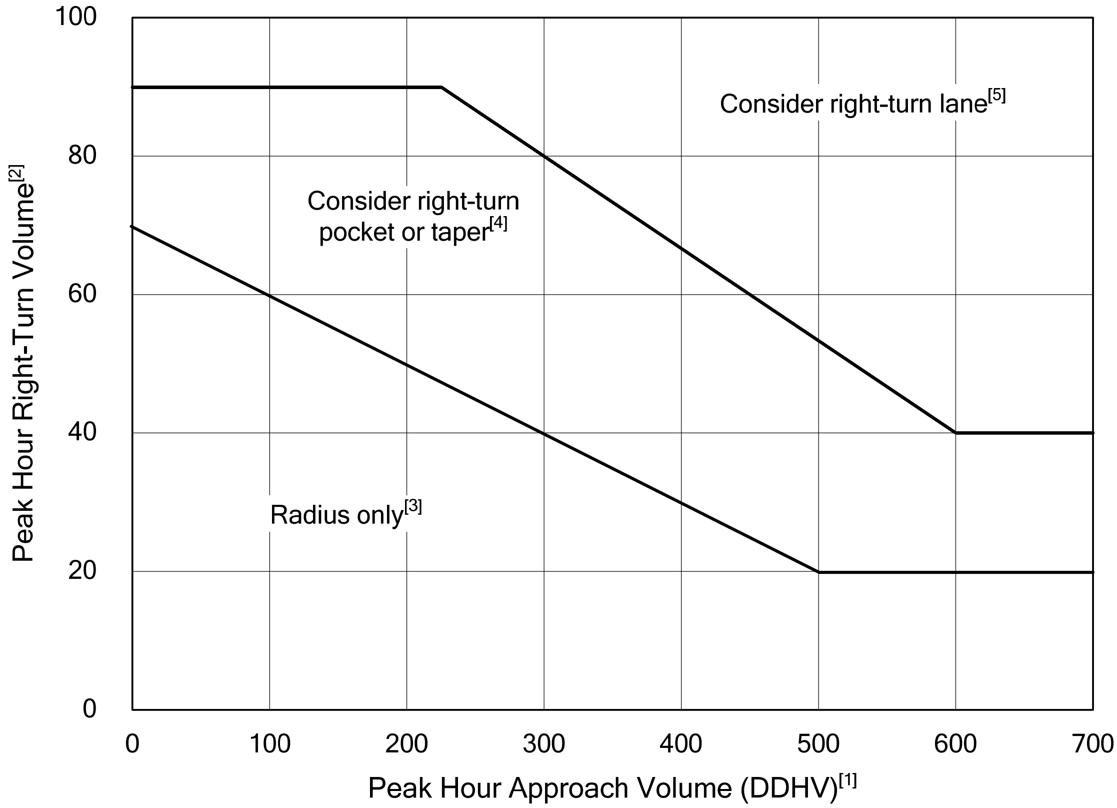
For unsignalized intersections, see 1310.07(4) for guidance on right-turn lane lengths. For signalized intersections, use a traffic signal analysis to determine whether a right-turn lane is needed and what the length is (see Chapter 1330).

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

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

The right-turn pocket or the right-turn taper (see Exhibit 1310-20) may be used at any minor intersection where a right-turn lane is not provided. These designs reduce interference and delay to the through movement by offering an earlier exit to right-turning vehicles.

If the right-turn pocket is used, Exhibit 1310-20 shows taper lengths for various posted speeds.



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 below
- 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 Exhibit 1310-14.

[4] For right-turn pocket or taper design, see Exhibit 1310-20.

[5] For right-turn lane design, see Exhibit 1310-21.

General:

For additional guidance, see 1310.07(3).

Right-Turn Lane Guidelines[6]
Exhibit 1310-19

(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; design and frequency of intersections; and collision history.

A dedicated deceleration lane (see Exhibit 1310-21) is advantageous because it removes slowing vehicles from the through lane.

An acceleration lane (see Exhibit 1310-22) 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 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 Exhibits 1310-21 and 1310-22. 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 1360. 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 1210 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 1,500 feet. For facilities with a posted speed lower than 45 mph, provide a lane of sufficient length that the advanced lane reduction warning sign can 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 Exhibit 1310-22.

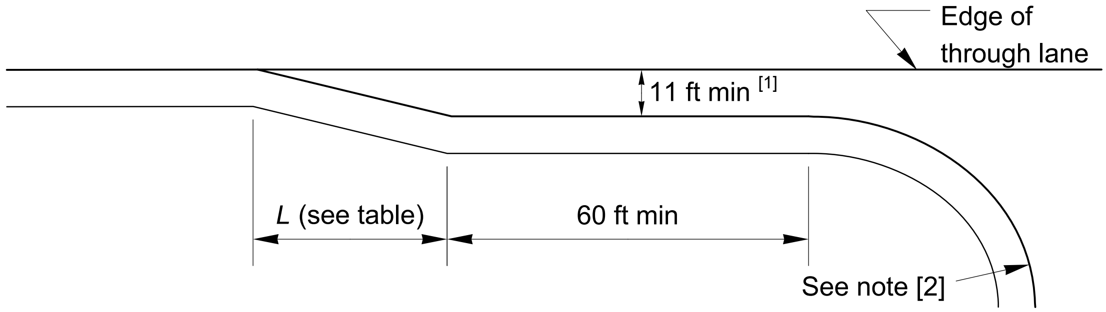
(6) Shoulders

With justification, shoulder widths 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.

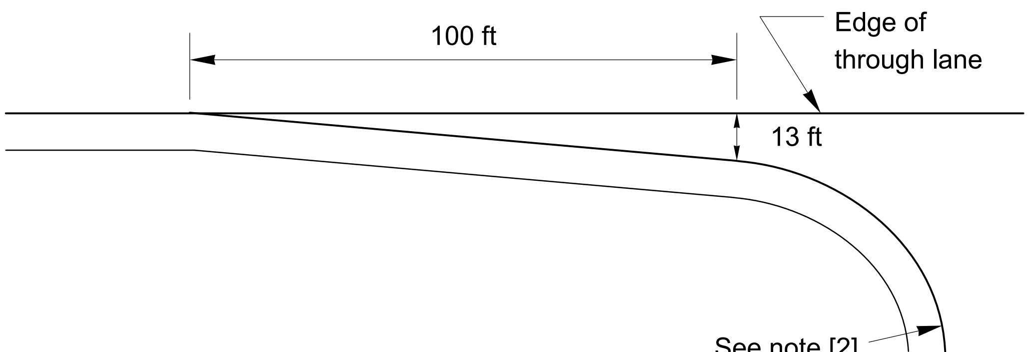
For roadways without curb sections, the shoulder adjacent to turn lanes and speed change lanes may be reduced to 2 feet on the left and 4 feet on the right. When a curb and sidewalk section is used with a turn lane or speed change lane 400 feet or less in length, the shoulder abutting the turn lane may 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 needed 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 1520 for information on bicycle facilities.)



Right-Turn Pocket



Right-Turn Taper

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

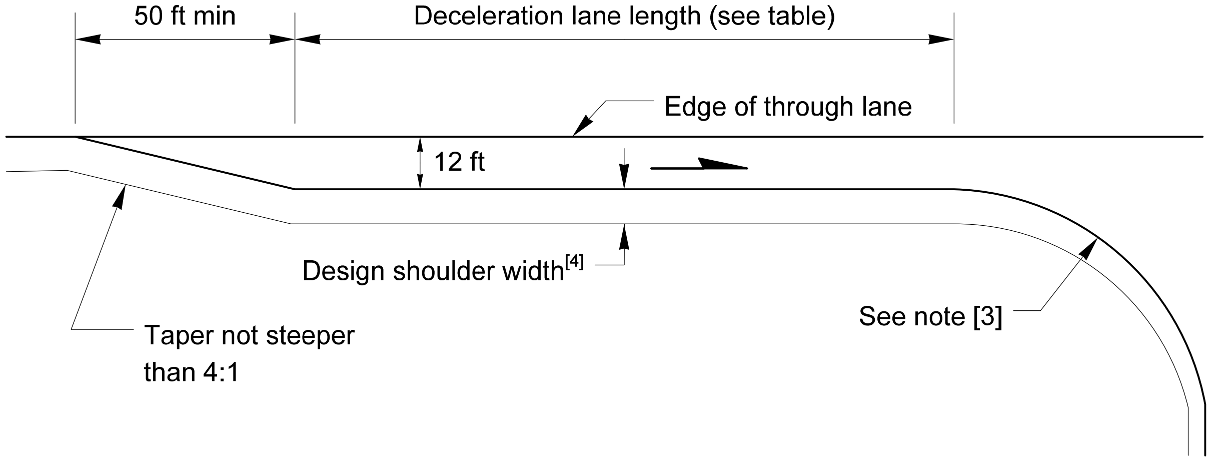
Notes:

[1] 12 ft desirable.

[2] For right-turn corner design, see Exhibit 1310-14.

Right-Turn Pocket and Right-Turn Taper

Exhibit 1310-20



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 Exhibit 1310-14.

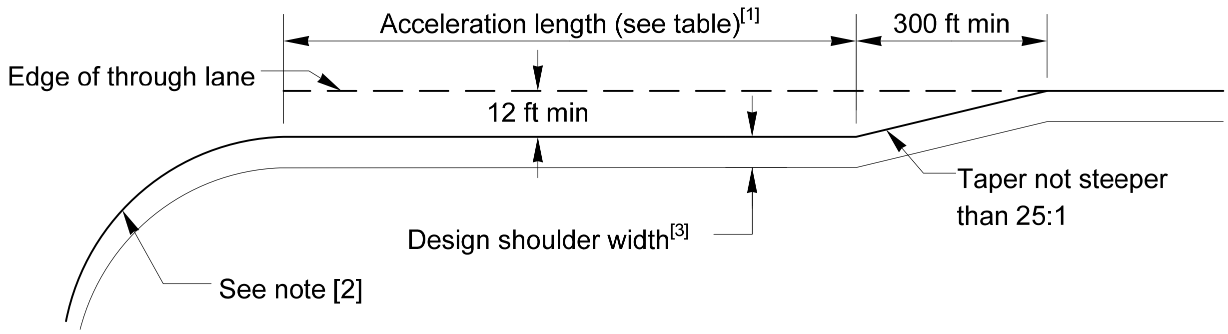
[4] May be reduced (see 1310.07(6)).

General:

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

Right-Turn Lane

Exhibit 1310-21



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	1,200	1,140	1,100
65	1,410	1,350	1,310
70	1,620	1,560	1,520

Minimum Acceleration Lane Length (ft)[1]

Highway Design Speed (mph)	% Grade	Upgrade	Downgrade
40	3% to less than 5%	1.3	0.7
50	3% to less than 5%	1.3	0.65
60	3% to less than 5%	1.4	0.6
70	3% to less than 5%	1.5	0.6
40	5% or more	1.5	0.6
50	5% or more	1.5	0.55
60	5% or more	1.7	0.5
70	5% or more	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 Exhibit 1310-14.

[3] May be reduced (see 1310.07(6)).

General:

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

Acceleration Lane

Exhibit 1310-22

(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 and bicyclists crossing the roadway.
- 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 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 below, 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 Exhibits 1310-23a through 23c. 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 1240 for desirable turning roadway widths.)

Island markings may be supplemented with reflective raised pavement markers.

Provide barrier-free access at crosswalk locations where raised islands are used. For pedestrian refuge islands and barrier-free access requirements, see Chapter 1510.

(b) Location

Design the approach ends of islands so they are visible to motorists. 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 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 Exhibit 1310-23b). 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.

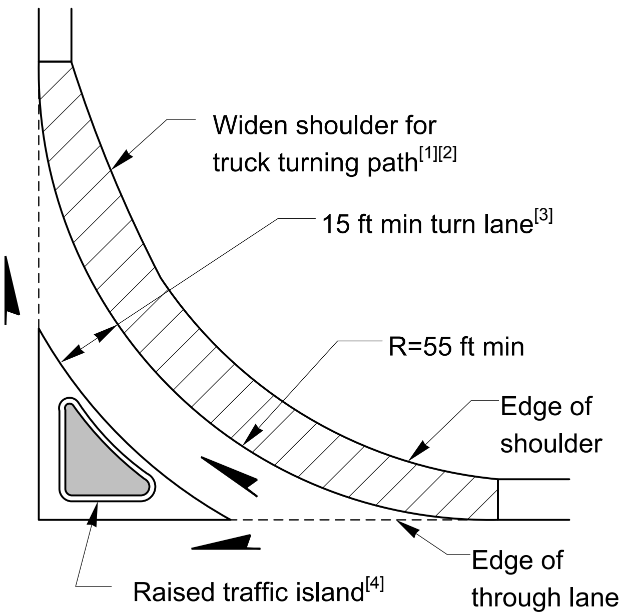
Also consider curbing for:

- Divisional and channelizing islands.
- Landscaped islands.

In general, except to meet one of the uses listed above, it is desirable not to use curbs on facilities with a posted speed of 45 mph or above.

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

Refer to Chapter 1140 for additional information and design criteria on the use of curbs.



Small Traffic Island Design[5]

Notes:

[1] Widen shoulders when 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 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 1240.

[4] For additional details on island placement, see Exhibit 1310-23c.

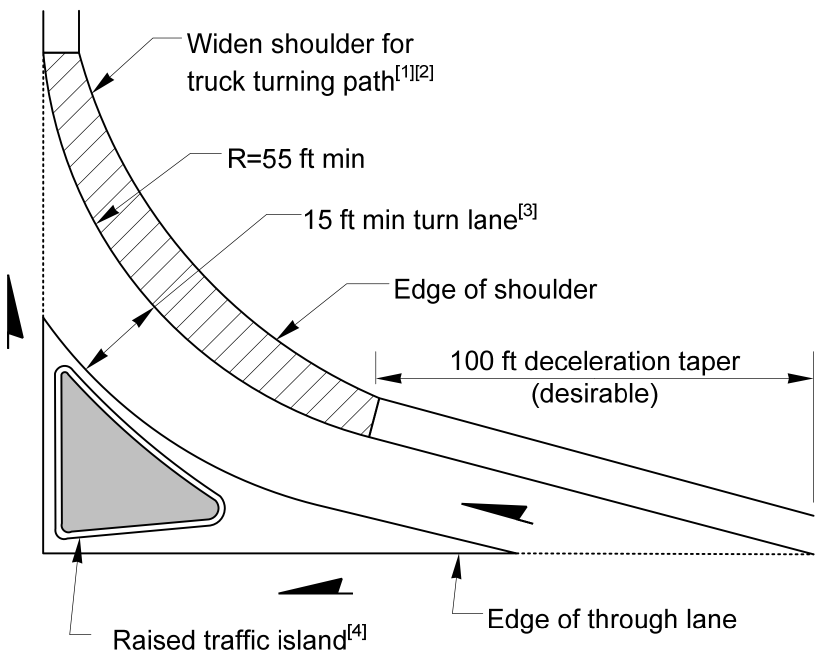
[5] Small traffic islands have an area of 100 ft^2 or less; large traffic islands have an area greater than 100 ft^2.

General:

Provide an accessible route for pedestrians (see Chapter 1510).

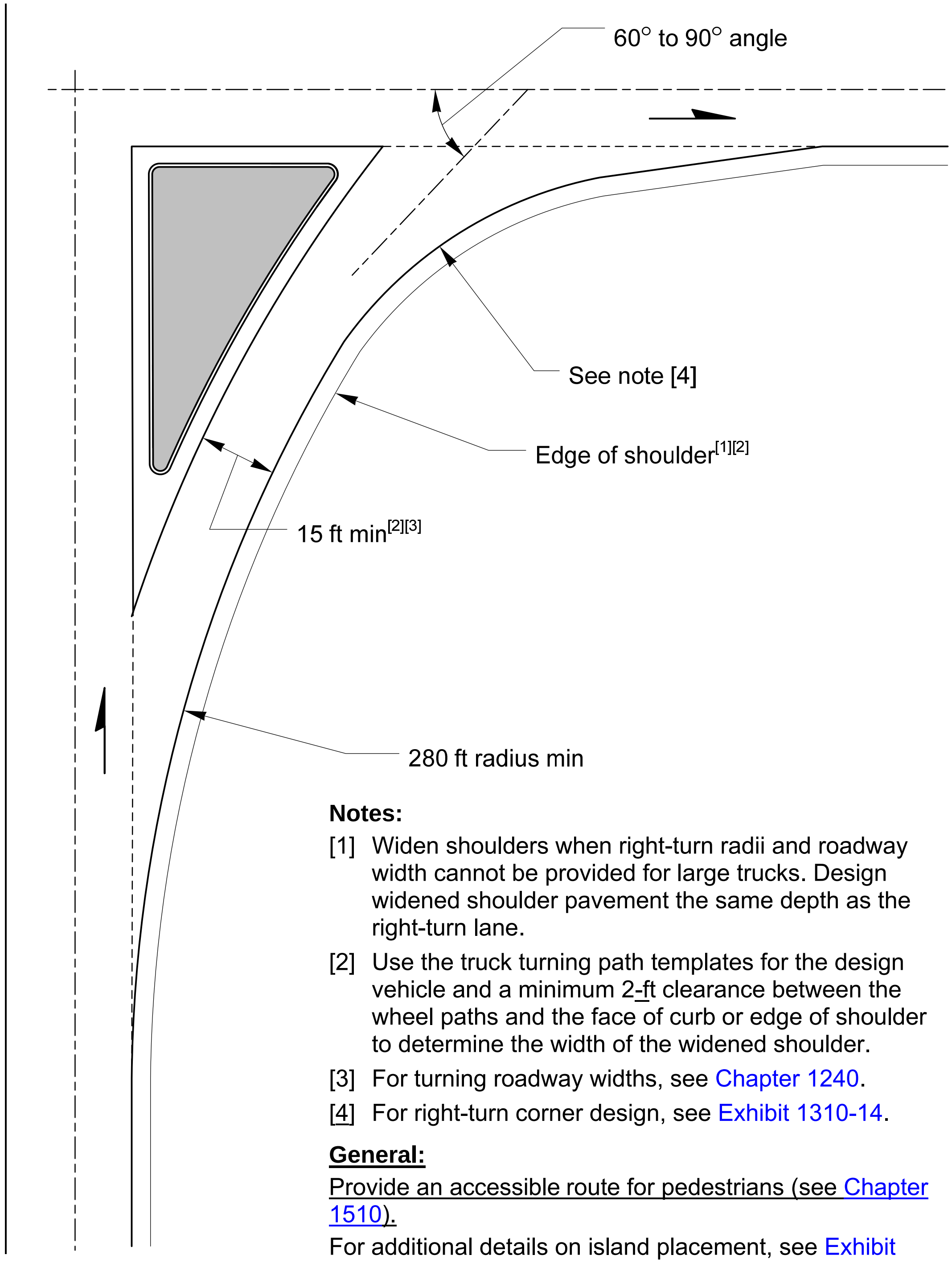
60° to 90° angle at stop or yield control.

For right-turn corner design, see Exhibit 1310-14.



Large Traffic Island Design[5]

Traffic Island Designs
Exhibit 1310-23a



Notes:

[1] Widen shoulders when 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 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 1240.

[4] For right-turn corner design, see Exhibit 1310-14.

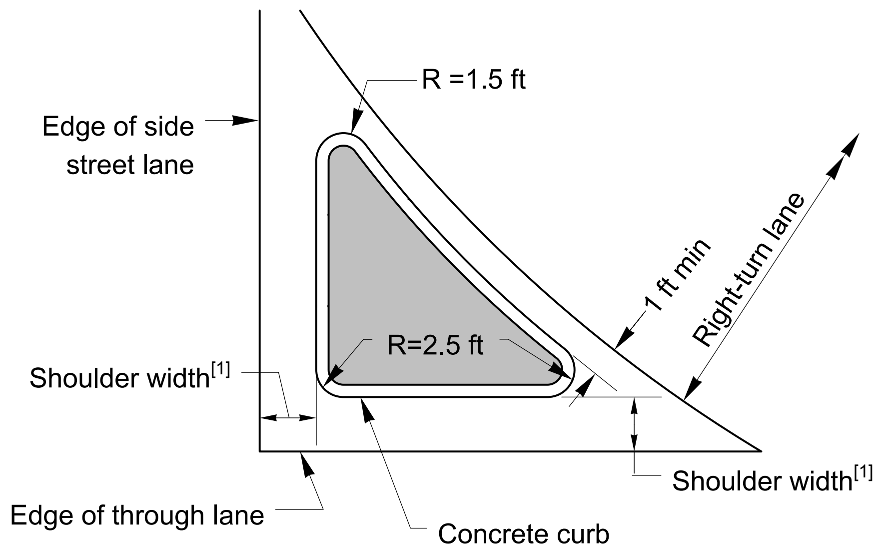
General:

Provide an accessible route for pedestrians (see Chapter 1510).

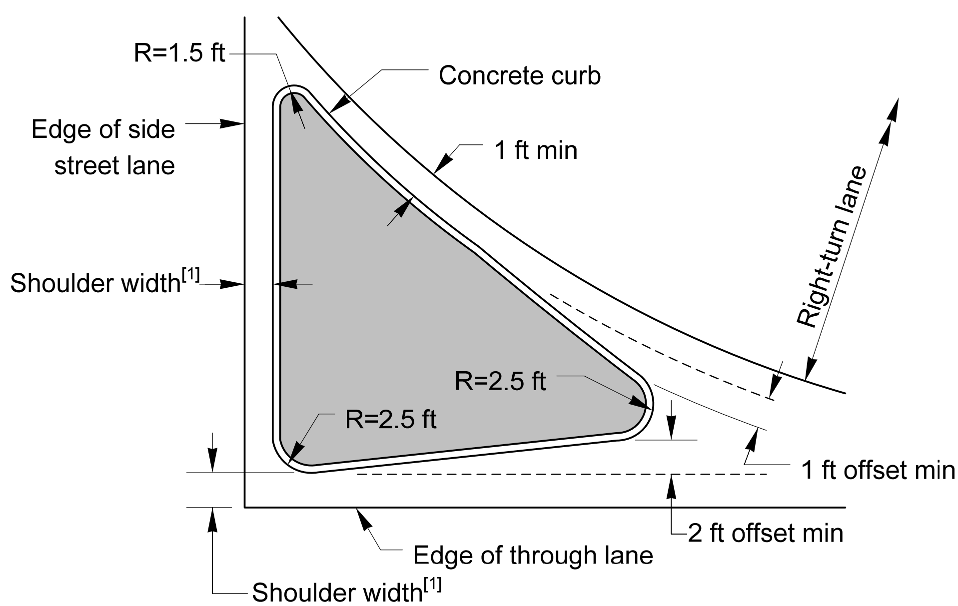
For additional details on island placement, see Exhibit 1310-23c.

Traffic Island Designs: Compound Curve

Exhibit 1310-23b



Small Raised Traffic Island[2]



Large Raised Traffic Island

Notes:

[1] For minimum shoulder width at curbs, see Chapter 1140. For additional information on shoulders at turn lanes, see 1310.07(6).

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

General:

Provide an accessible route for pedestrians (see Chapter 1510).

Traffic Island Designs
Exhibit 1310-23c

1310.08 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 provided between intersections to accommodate U-turns. Use the desirable U-turn spacing (see Exhibit 1310-24) as a guide to determine when to provide U-turn median openings between intersections. Where the U-turning volumes are low, longer spacing may be used.

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

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

Notes:

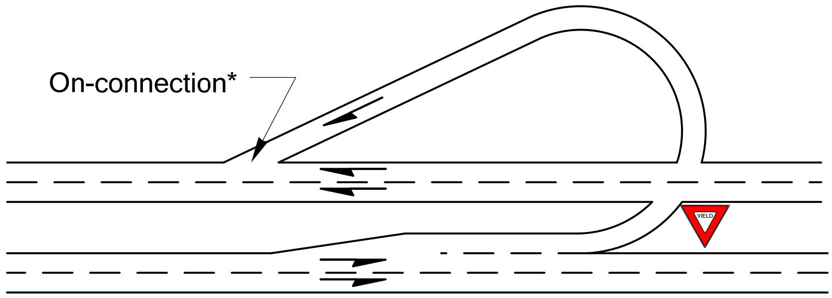
[1] For design speeds higher than 45 mph, use suburban spacing.

[2] The minimum spacing is the acceleration lane length from a stop (see Exhibit 1310-22) plus 300 ft.

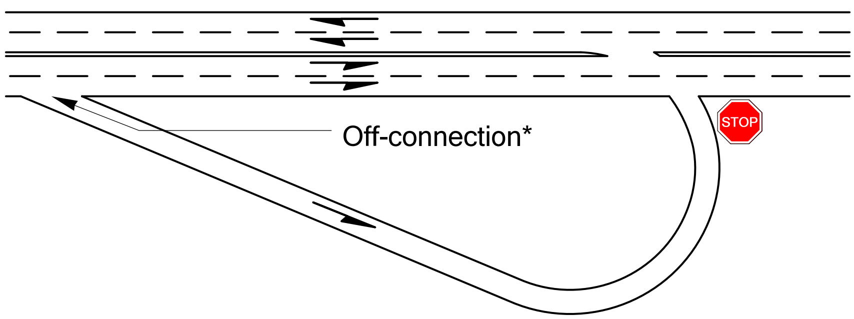
[3] For design speeds 60 mph or higher, the minimum spacing is the acceleration lane length from a stop (see Exhibit 1310-22) plus 300 ft.

U-Turn Spacing
Exhibit 1310-24

When designing U-turn median openings, use Exhibit 1310-26 as a guide. Where the median is less than 40 feet wide with a large design vehicle, provide a U-turn roadway (see Exhibit 1310-25). Design A, with the U-turn roadway after the left-turn, is desirable. Use Design A when the median can accommodate a left-turn lane. Use Design B only where left-turn channelization cannot be built in the median.



Design A



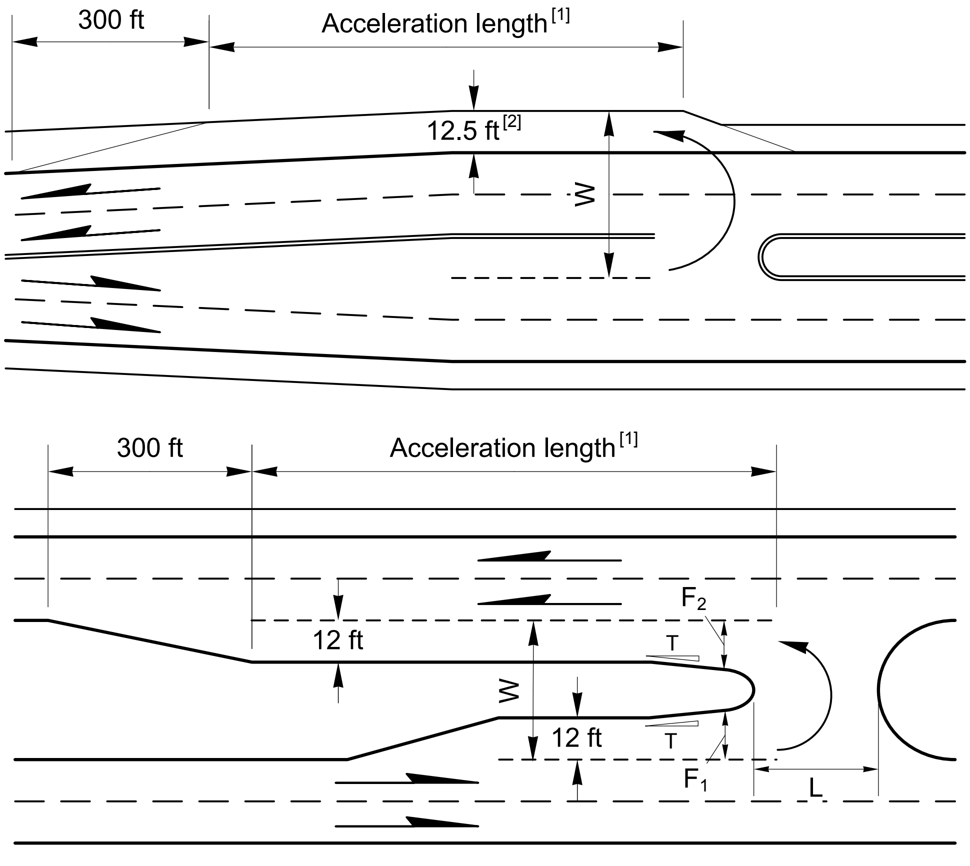
Design B

*Design on- and off-connections in accordance with Chapter 1360.

U-Turn Roadway
Exhibit 1310-25

Document the need for U-turn locations, the spacing used, and 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 need the acceleration lanes shown in Exhibit 1310-26. For new U-turn locations at signal-controlled intersections, evaluate conflicts between right-turning vehicles from side streets and U-turning vehicles. Warning signs on the cross street might be appropriate.



Vehicle	W	R	L	F_1	F_2	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 Exhibit 1310-22. Acceleration lane may be eliminated at signal-controlled intersections.

[2] 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.

General:

All dimensions are in feet.

U-Turn Median Openings

Exhibit 1310-26

1310.09 Intersection Sight Distance

Providing drivers the ability to see stop signs, traffic signals, and oncoming traffic in time to react accordingly will reduce the probability of conflicts occurring at an intersection. Actually avoiding conflicts is dependent on the judgment, abilities, and actions of all drivers using the intersection.

Provide decision sight distance, where feasible, in advance of stop signs, traffic signals, and roundabouts. (See Chapter 1260 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 complete all legal maneuvers before an approaching vehicle on the through roadway can reach the intersection. Use Exhibit 1310-27a to determine minimum sight distance along the through roadway.

The sight triangle is determined as shown in Exhibit 1310-27b. 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. Eliminate parking to 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 510).

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 limit 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. Drivers who do not have the desired sight distance creep out until the sight distance is available; therefore, the setback may be reduced 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 no identified collision trend at the intersection. Document the intersection location and the available sight distance in the Design Variance Inventory (see Chapter 300) 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 for the major roadway, with an evaluate upgrade and HQ Design Office review and concurrence. (See Chapter 1260 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 no identified collision trend at the intersection. Document the intersection location and the available sight distance in the Design Variance Inventory (see Chapter 300) as an evaluate upgrade.

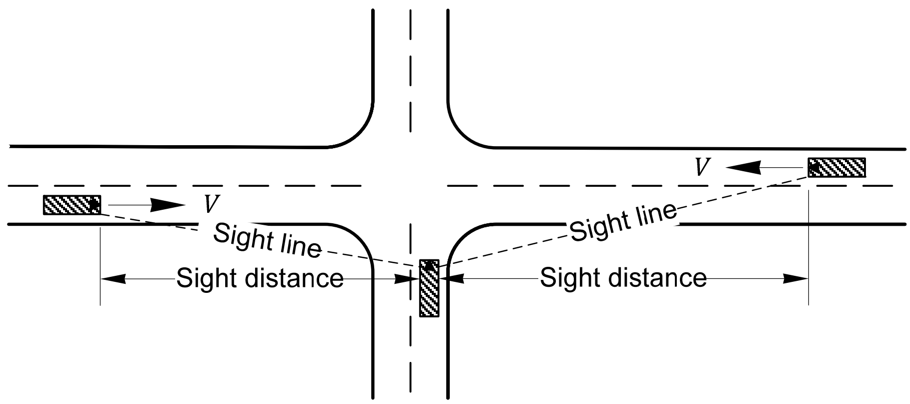
In some instances, intersection sight distance is provided at the time of construction, but subsequent vegetative growth has degraded the sight distance available. The growth may be seasonal or occur over time. In these instances, intersection sight distance can be restored through the periodically scheduled 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. Exhibit 1310-27b 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.



$S_i = 1.47Vt_g$
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

Adjust the t_g values listed in Table 2 as follows:

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

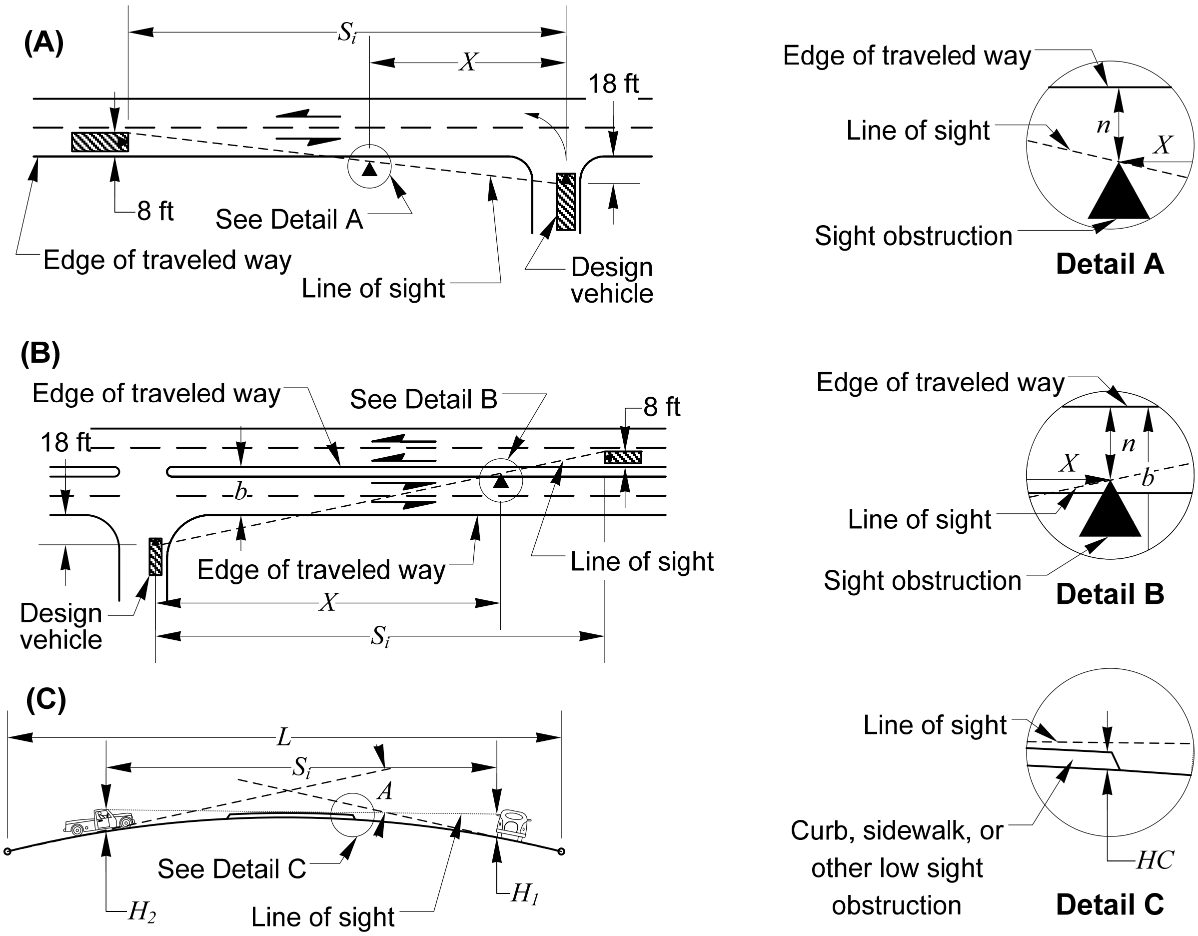
Note: Where medians are wide enough to store the design vehicle, determine the sight distance as two maneuvers.

Crossroad grade greater than 3%:

All movements upgrade for each percent that exceeds 3%:

All vehicles	add 0.2 sec

Sight Distance at Intersections
Exhibit 1310-27a



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 when S<L:

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

$$L = \frac{AS_i^2}{100\left[\sqrt{2(H_1 - HC)} + \sqrt{2(h_2 - HC)}\right]^2}$$

Where:

- S_i = 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
Exhibit 1310-27b

1310.10 Traffic Control at Intersections

Intersection traffic control is the process of moving traffic 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.

(1) Intersection Traffic Control Objectives

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

(a) 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.

(b) Reduce Conflict Points

The crossing, converging, and diverging of traffic creates conflicts that increase the potential for collisions. Establishing appropriate controls can reduce the possibility of two cars attempting to occupy the same space at the same time. Pedestrian collision potential can also be reduced by appropriate controls.

(c) 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, provide a preliminary signal plan (see Chapter 1330). If a new signal permit is required, obtain approval before the design is approved.

(2) Analysis of Alternatives

Prior to proceeding with the design, provide an analysis of alternatives for 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, approved by the region Traffic Engineer, with review and comment by the HQ Design Office. Include the following alternatives in the analysis:

- Channelization: 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.

1310.11 Signing and Delineation

Use the MUTCD and the *Standard Plans* for signing and delineation criteria. Provide a route confirmation sign on all state routes shortly after major intersections. (See Chapter 1020 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 1030, and the *Standard Plans*.

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

1310.12 Procedures

Document design decisions and conclusions in accordance with Chapter 300. For highways with limited access control, see Chapter 530.

(1) Approval

An intersection is approved in accordance with Chapter 300. Complete the following items, as needed, before intersection approval:

- Traffic analysis
- Deviations approved in accordance with Chapter 300
- Approved Traffic Signal Permit (DOT Form 242-014 EF) (see Chapter 1330)

(2) Intersection Plans

Provide intersection plans 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 website:
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 300 prior to approval of the plan. After the plan approval, the region prepares a construction agreement with the project initiator (see the *Utilities Manual*).

1310.13 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/