Chapter 1310 Intersections

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1310.01 General

Intersections are a critical part of Washington State Department of Transportation (WSDOT) highway design because of increased conflict potential. Design intersections for the needs of motor vehicles, bicycles, and pedestrians. Channelization, which is the separation or regulation of traffic movements into delineated paths of travel, can facilitate the orderly movement of pedestrians, bicycles, and vehicles. Channelization includes left-turn lanes, right-turn lanes, speed change lanes (both acceleration and deceleration lanes), and islands. If pedestrian facilities are present, 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. Pedestrian refuge islands can be beneficial.

See chapters in the 1100 series for instruction on multimodal practical design, including identifying project needs, context, design controls, modal performance, alternatives analysis, and design element dimensioning.

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

- Chapter 1103 Design controls
- Chapter 1106 Design element dimensions
- Chapter 1230 Geometric cross section
- Chapter 1300 Intersection control type
- Chapter 1320 Roundabouts
- Chapter 1330 Traffic signals
- Chapter 1340 Driveways
- Chapter 1360 Interchanges
- Chapter 1510 Pedestrian facilities
- Chapter 1520 Roadway bicycle facilities

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

1310.02 Designing for Motor Vehicles

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 Chapter 1103). 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.

1310.02(1) Non-Geometric 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 crashes. 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.

1310.02(2) Intersection Angle and Roadway Alignment

An important intersection design characteristic is the intersection angle. The desirable intersection angle is 90°, with 60° to 120° allowed. 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. However, angle points within the intersection are allowed at intersections with a minor through movement, such as at a ramp terminal (see Exhibit 1310-2).

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. Do not locate short curves where both the PC and PT are within the intersection area.

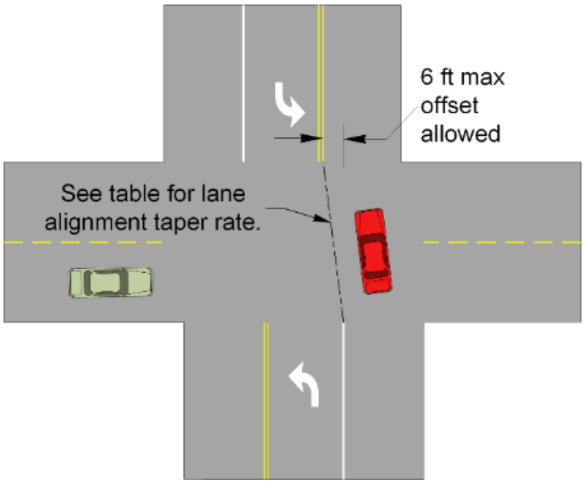
1310.02(3) Lane Alignment

It is desirable that entering through traffic is aligned with the exit lanes. However, the entering and exit lanes may be offset up to 6 feet when the following conditions are met:

- Illumination is provided.
- The intersection is not within a horizontal curve, nor is it within a crest vertical curve.
- The taper rates provided in Exhibit 1310-1 are used.
- There is a posted speed of 55 mph or less.

Consider dotted extension lines that continue through the intersection.

Exhibit 1310-1 Lane Alignment Taper Rate



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

1310.02(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 Chapter 530 and Chapter 540. Also, 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.

1310.02(5) Accommodating vs. Designing for Vehicles

Accommodating for a vehicle allows encroachment of other lanes, shoulders, or other elements to complete the required maneuver. Designing for a vehicle does not require encroachment on those elements.

There are competing design objectives when considering the crossing needs of pedestrians and the turning needs of larger vehicles. To design for large design vehicles, larger turn radii are used. This results in increased pavement areas, longer pedestrian crossing distances, and longer traffic signal arms. (See Chapter 1103 for design vehicle selection criteria.)

When appropriate, to reduce the intersection area, consider accommodating for large vehicles instead of designing for them. This reduces the potential for vehicle/pedestrian conflicts, decreases pedestrian crossing distance, and controls the speeds of turning vehicles. Use turn simulation software (such as AutoTURN®) to verify the design.

1310.02(6) Sight Distance

For stopping and decision sight distance criteria, see Chapter 1260. Intersection sight distance criteria are discussed in Section 1310.02(10).

1310.02(7) Crossroads

When the crossroad is a city street or county road, design the crossroad beyond the intersection area in cooperation with the local agency.

When the crossroad is a state facility, design the crossroad according to the *Design Manual*. 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.

1310.02(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 Transportation Operations Engineer's approval is required for any new intersection or signal on a rural expressway.

1310.02(9) Interchange Ramp Terminals

When stop control or traffic signal control is selected, the design to be used or modified is shown in Exhibit 1310-2. Higher-volume intersections with multiple ramp lanes are designed individually. Provide ramp terminal designs consistent with the speed of the crossroad.

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.

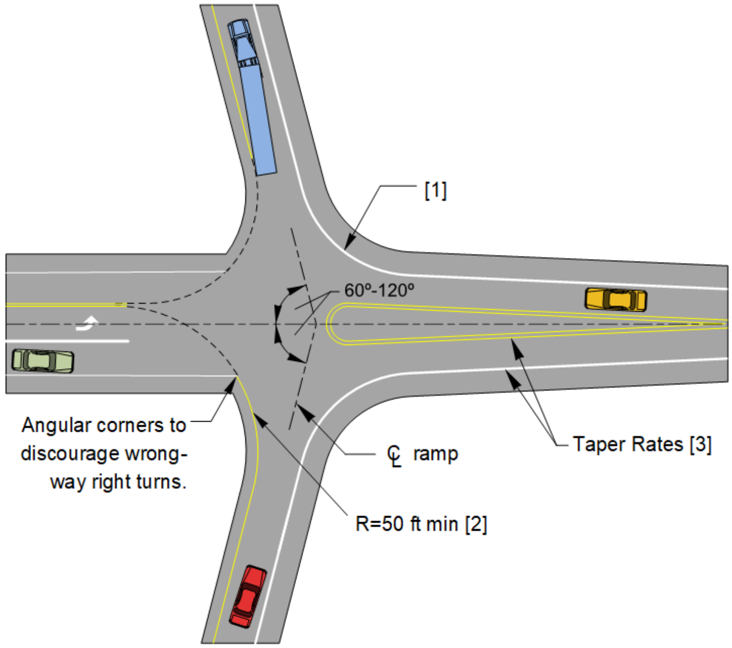
Another exception is at ramp terminals where the through movement is eliminated (for example, at a single-point interchange). For ramp terminals that have two wye connections, one for right turns and the other for left turns, and no through movement, the intersection angle has little meaning and does 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 60° to 120° in designing the best alignment for efficiency and intersection operations.

Exhibit 1310-2 Ramp Terminal Intersection Details



Notes:

[1] For right-turn corner design, see Exhibit 1310-8.
[2] Use turn simulation software to verify that the design vehicle can make the turn.

For taper rates, see Exhibit 1310-15, Table 1.

1310.02(10) Intersection Sight Distance (Eye Height – 3.5 ft, Object Height – 3.5 ft)

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. Avoiding conflicts is dependent on the judgment, abilities, and actions of all drivers using the intersection.

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 1310-3 to determine minimum intersection sight distance along the through roadway.

The sight triangle is determined as shown in Exhibit 1310-3 with an eye height of 3.5 feet for passenger cars and pickups and 6 feet for trucks.

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 vehicles that would be 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 Section 510.05(5)(a)).

1310.02(10)(a) New Intersections on Existing Highways

New intersections on existing highways require a setback distance of 18 feet from the edge of traveled way for the sight triangle. This represents the position of the driver's eye when the vehicle is stopped 10 feet from the edge of traveled way. The driver is typically 8 feet or less from the front of the vehicle; therefore, 8 feet are added to the 10-foot setback. When the stop bar is placed more than 10 feet from the edge of traveled way, provide the sight triangle to a point 8 feet back of the stop bar.

Provide a clear sight triangle for the SU-30 vehicle. If there is significant combination truck traffic, use the common WB vehicle rather than the SU-30. In areas where SU-30 or WB vehicles are minimal and right of way restrictions limit sight triangle clearing, only the P vehicle sight distance needs to be provided.

1310.02(10)(b) Existing Intersections

At existing intersections, where sight obstructions within the sight triangle cannot be removed due to limited right of way, the setback distance may be reduced. 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 intersection location, available sight distance, and 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 crash trend at the intersection.

1310.02(10)(c) All Intersections

For all intersections, if the intersection sight distance cannot be provided, use the stopping sight distance of the vehicles travelling on the major roadway and document with a Design Analysis. (See Chapter 1260 for required stopping sight distance.) This will require a Deign Analysis with a brief analysis of the intersection sight distance clarifying the reasons for having to rely on mainline vehicle stopping sight distance. Verify and record that there is no identified crash trend involving intersection sight distance.

1310.02(10)(d) Other Sight Distance Situations

At intersections controlled by traffic signals, provide sight distance for right-turning vehicles. For intersections controlled by the geometry of roundabouts, see Chapter 1320.

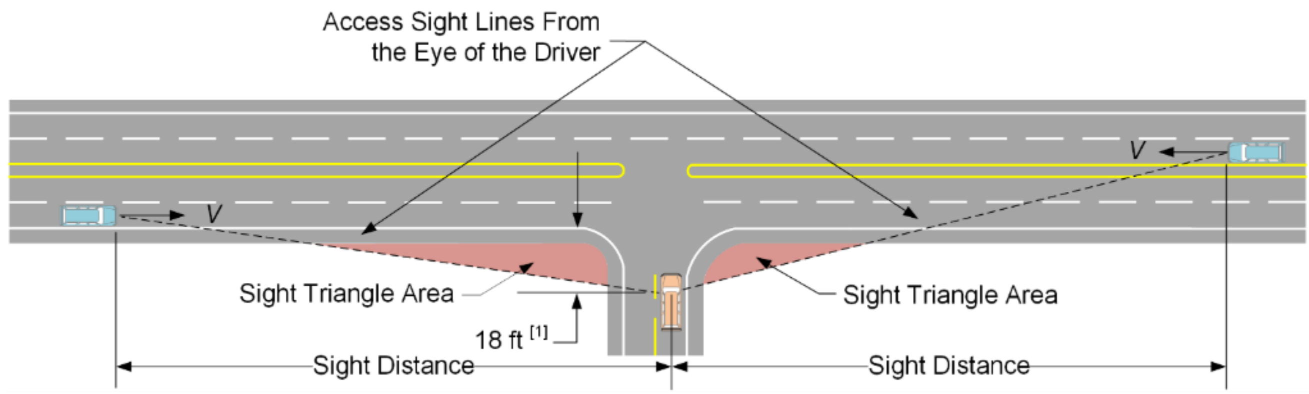
Designs for movements that cross divided highways are influenced by median widths. If the median is wide enough to store the design vehicle, with a 3-foot clearance at both ends of the vehicle, sight distances are determined in two steps. The first step is for crossing from a stopped position to the 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 1310-4 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.

Exhibit 1310-3 Sight Distance at Intersections



Notes:

[1] 18-foot setback measured from the edge of traveled way to the drive's eye. (See Section 1310.02(10)).

Intersection Sight Distance Equation

$$Si = 1.47Vtg$$

Where:

Si = Intersection sight distance (ft)

V = Design speed of the through roadway (mph)

tg = Time gap for the minor roadway traffic to enter or cross the through roadway (sec)

Intersection Sight Distance Time Gaps (tg)	
Design Vehicle	**Time Gap (tg) in Sec**
Passenger car (P)	7.5
Single-unit trucks and buses (SU-30 & CITY-BUS)	9.5
Combination trucks (WB-40 & 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.	

Adjust the tg values 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

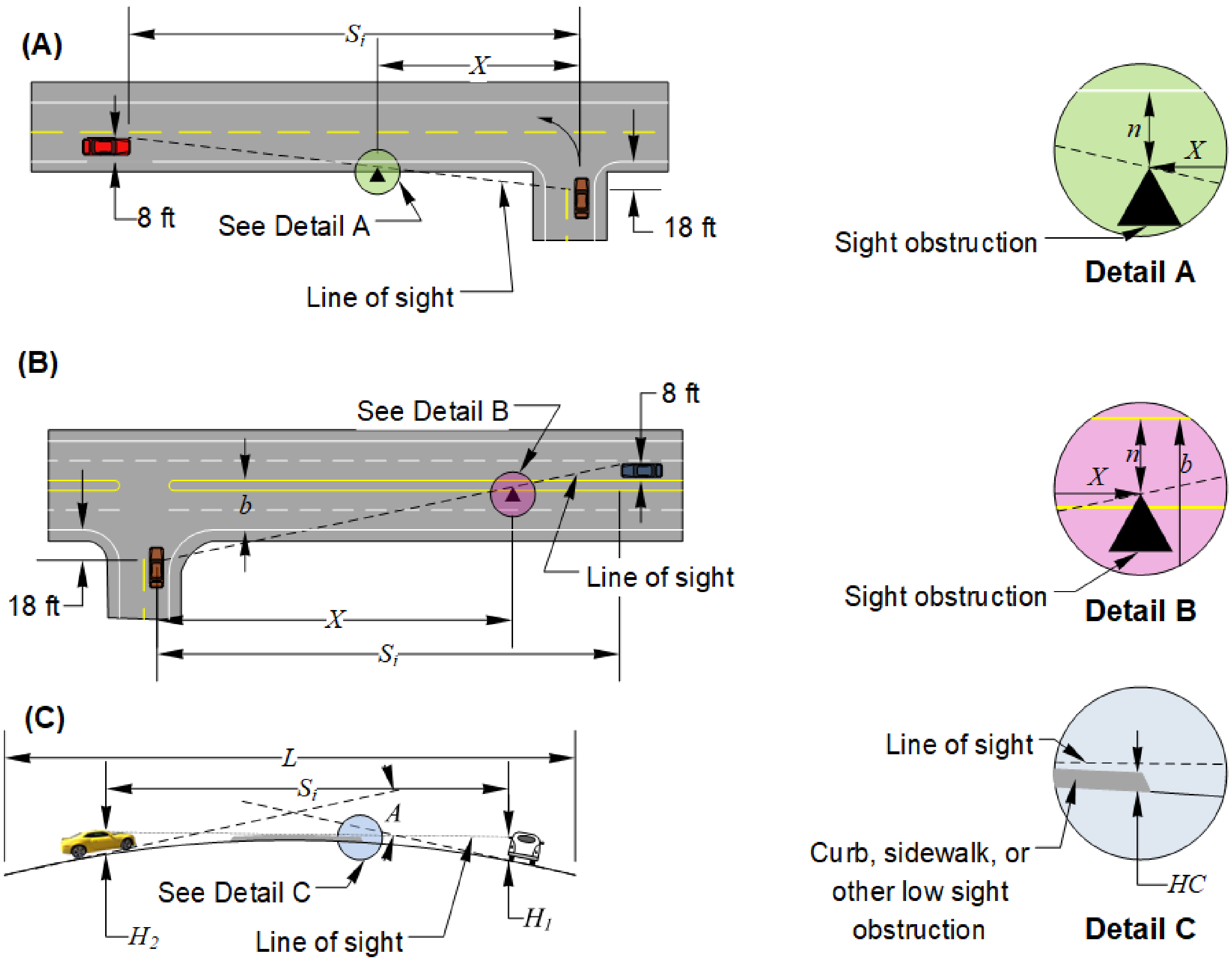
Where medians are wide enough to store the design vehicle, determine the sight distance as two maneuvers.

Crossroad grade greater than 3%:

All movements upgrade for each percent that exceeds 3%:

All vehicles add 0.2 sec

Exhibit 1310-4 Sight Distance at Intersections



For sight obstruction driver cannot see over:

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

Where:

Si = 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:

Si = Available sight distance (ft)

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

H_2 = Approaching vehicle height (3.5 ft)

HC = Sight obstruction height (ft)

L = Vertical curve length (ft)

A = Algebraic difference in grades (%)

1310.02(11) Wrong-Way Movement Countermeasures

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

1310.02(11)(a) Wrong-Way Driving Countermeasure Categories

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

- Signing and delineation
- Intelligent transportation systems
- Geometric design

1310.02(11)(a)(i) Signing and Delineation

Signing and delineation countermeasures include:

- DO NOT ENTER and WRONG WAY signs.
- ONE WAY signs.
- Turn restriction signs.
- Guideposts with red delineation.
- 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.

DO NOT ENTER and WRONG WAY signs may be more effective when they are lowered to 4 feet above the edge of traveled way as they are better illuminated by low-beam headlights. Do not lower these signs when the height obscures intersection sight distance, interferes with pedestrian or bicyclists' movements, or where snow or vegetation will block viewing of the sign.

1310.02(11)(a)(ii) Intelligent Transportation Systems

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

1310.02(11)(a)(iii) Geometric Design

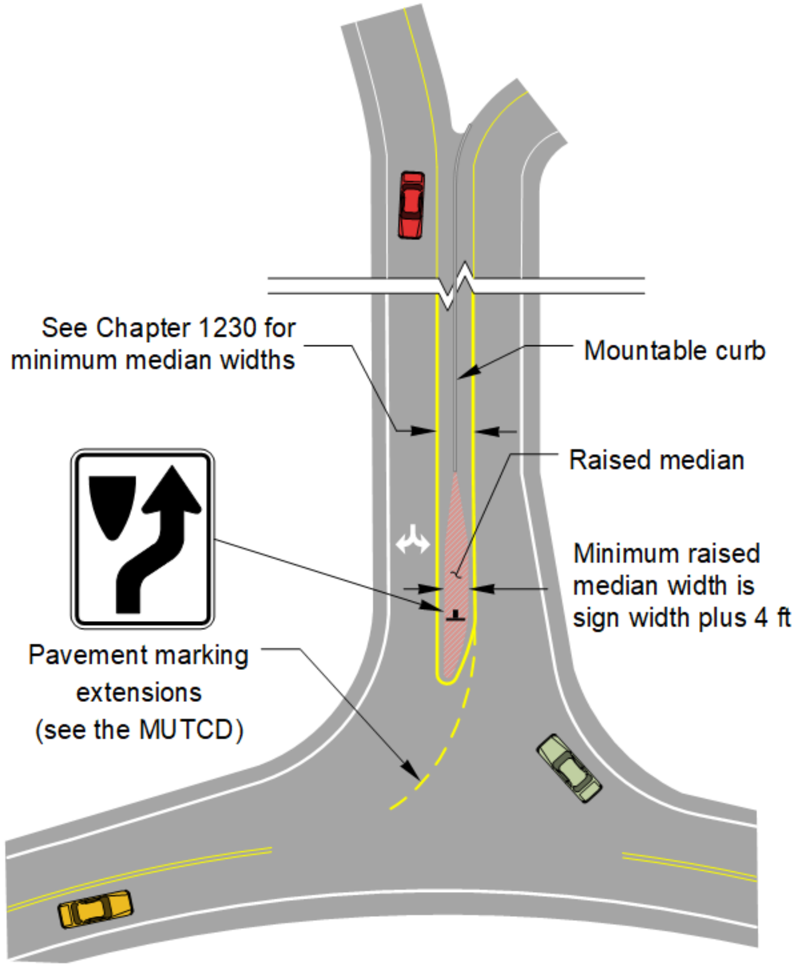
Geometric countermeasures include separating wrong-way movements from other movements, discouraging wrong-way movements, encouraging right-way movements, and improving the visibility of the right-way movement.

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 combined with other 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 1310-5 for an example of the minimum median at the terminal of a two-way ramp.)

Exhibit 1310-5 Median at Two-Way Ramp Terminal



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

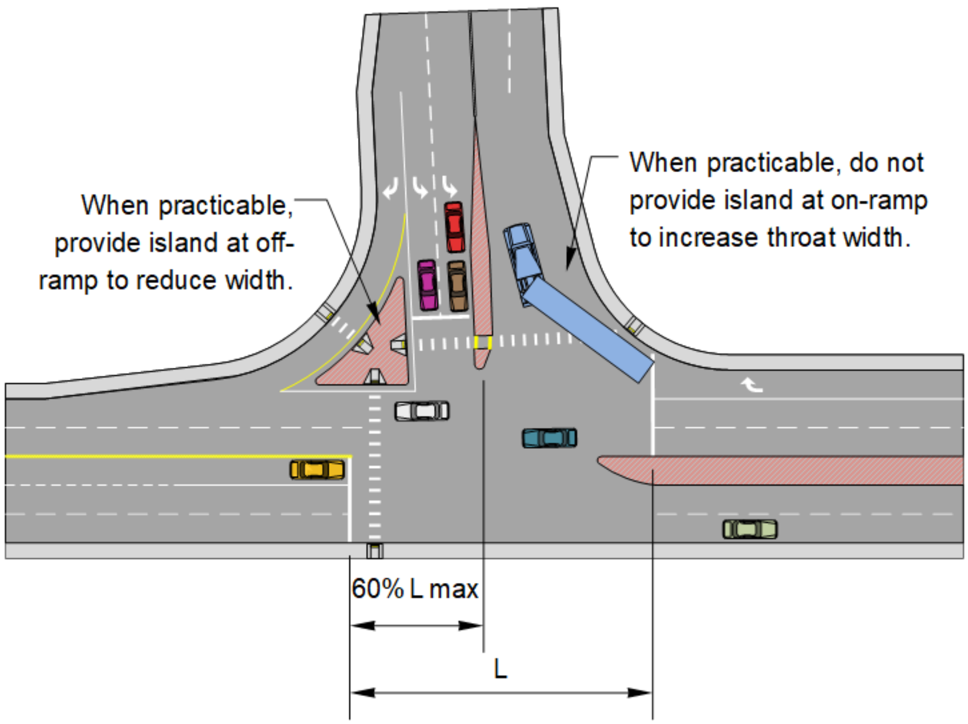
Increasing the width of the on-ramp throat can encourage right-way movements. A larger opening for the on-ramp makes it easier to turn into. To increase the throat width of on-ramps, use flat radii for left- and right-turning traffic and remove islands.

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 1310-6). Much of this can be achieved by adjusting the stop bar position on the interchange cross street.

Exhibit 1310-6 Intersection Balance Example



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 1310-2).

1310.02(11)(b) Countermeasure Applications

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

1310.02(11)(b)(i) 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.

1310.02(11)(b)(ii) 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:

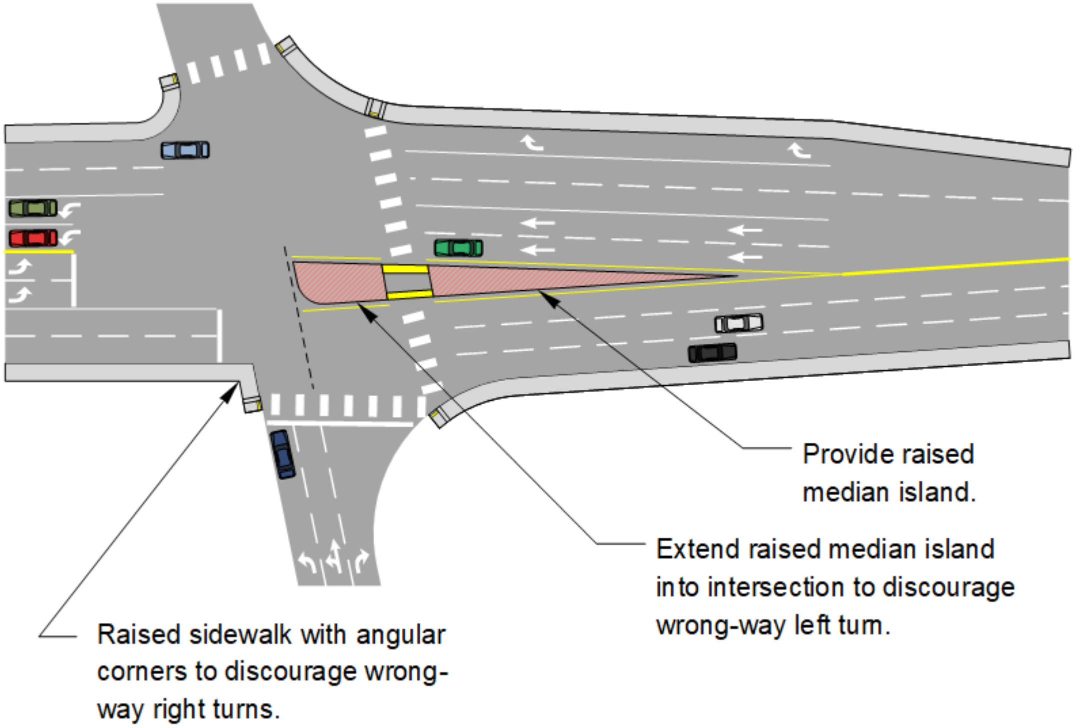
- Angular corners to discourage wrong-way right turns.

1310.02(11)(b)(iii) 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 1310-7). 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.

Exhibit 1310-7 Diamond Interchange with Advance Storage



1310.02(11)(b)(iv) 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.

1310.02(11)(b)(v) 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. (See Chapter 1420 for HOV direct access and countermeasures for wrong-way driving at HOV direct access ramps.)

1310.02(11)(b)(vi) 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.

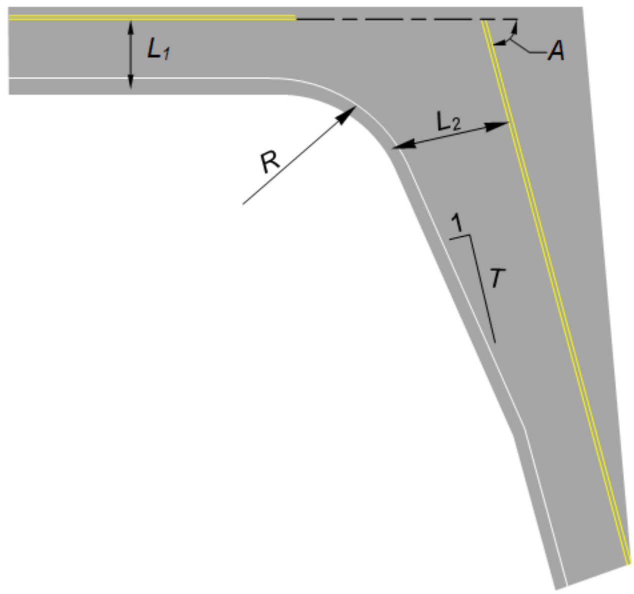
1310.02(12) Right-Turn Corners

Exhibit 1310-8 shows initial ranges for right-turn corner designs using a simple curve with a taper. These are considered approximate pavement areas to ensure the design vehicles do not encroach into the adjacent lane at either leg of the curve.

Other design considerations may include a combination of simple or compound curves, tapers at the beginning or end of the turn, and so on. Verify the design vehicle can make the turn using turn simulation software (such as AutoTURN®).

Depending on the context of the roadway and right-turn corner (which vehicles will be designed for, and which vehicles will be accommodated), there may be several design considerations. Consider 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.

Exhibit 1310-8 Initial Ranges for Right-Turn Corner (Simple Curve-Taper)



L1 = Available roadway width [2] that the vehicle is turning from

L2 = 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
P	All	30	11	11	25
SU-30 & CITY-BUS	All	50	11	11	25
WB-40	All	55	11	15	7.5
WB-67	All	50-85	11	22-24	7

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

1310.02(13) 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 Section 1310.02(16) for a discussion on speed change lanes.)

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

1310.02(13)(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 1310-9, 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 1310-10 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.

Exhibit 1310-9 Left-Turn Storage Guidelines: Two-Lane, Unsignalized

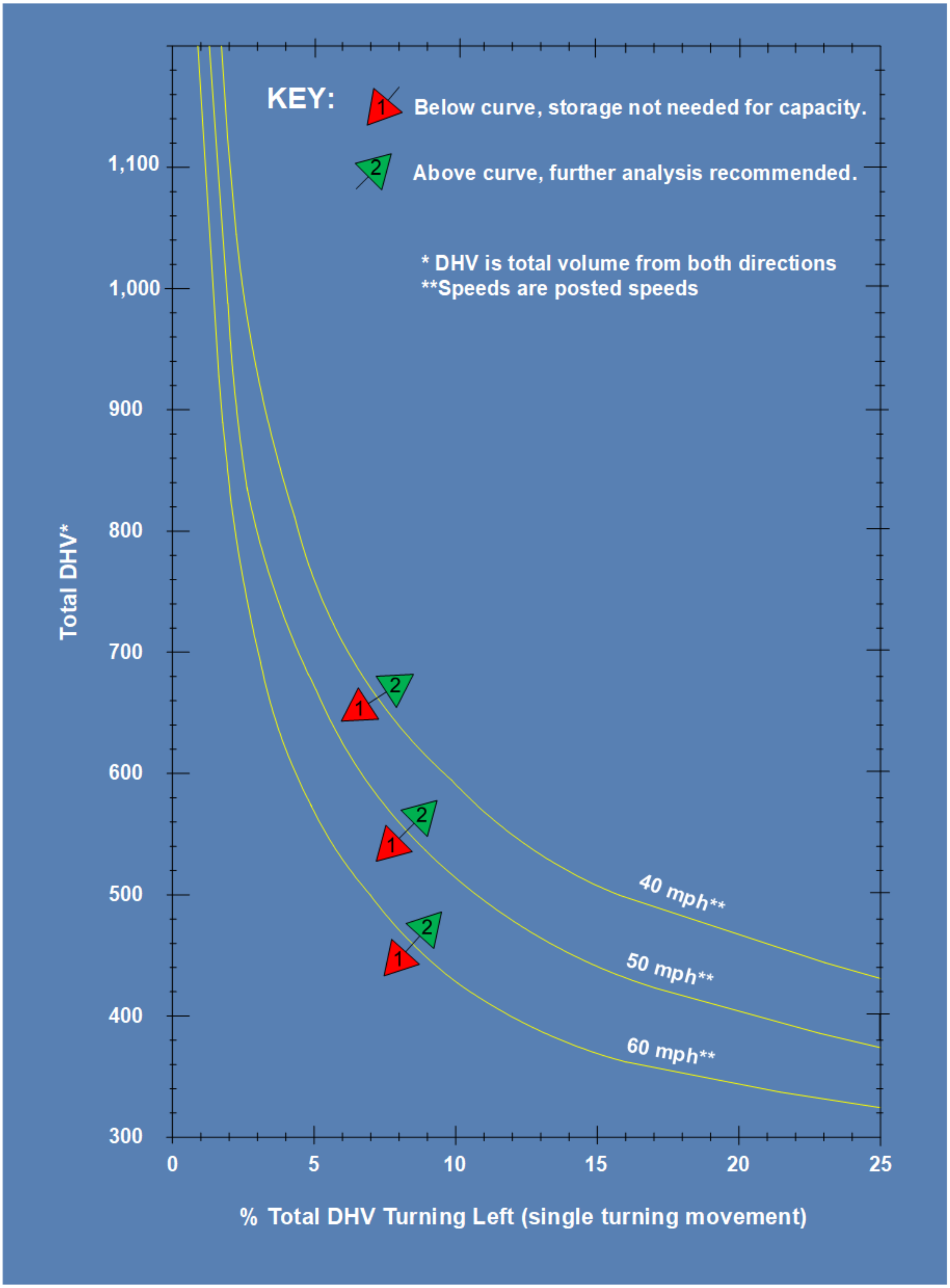
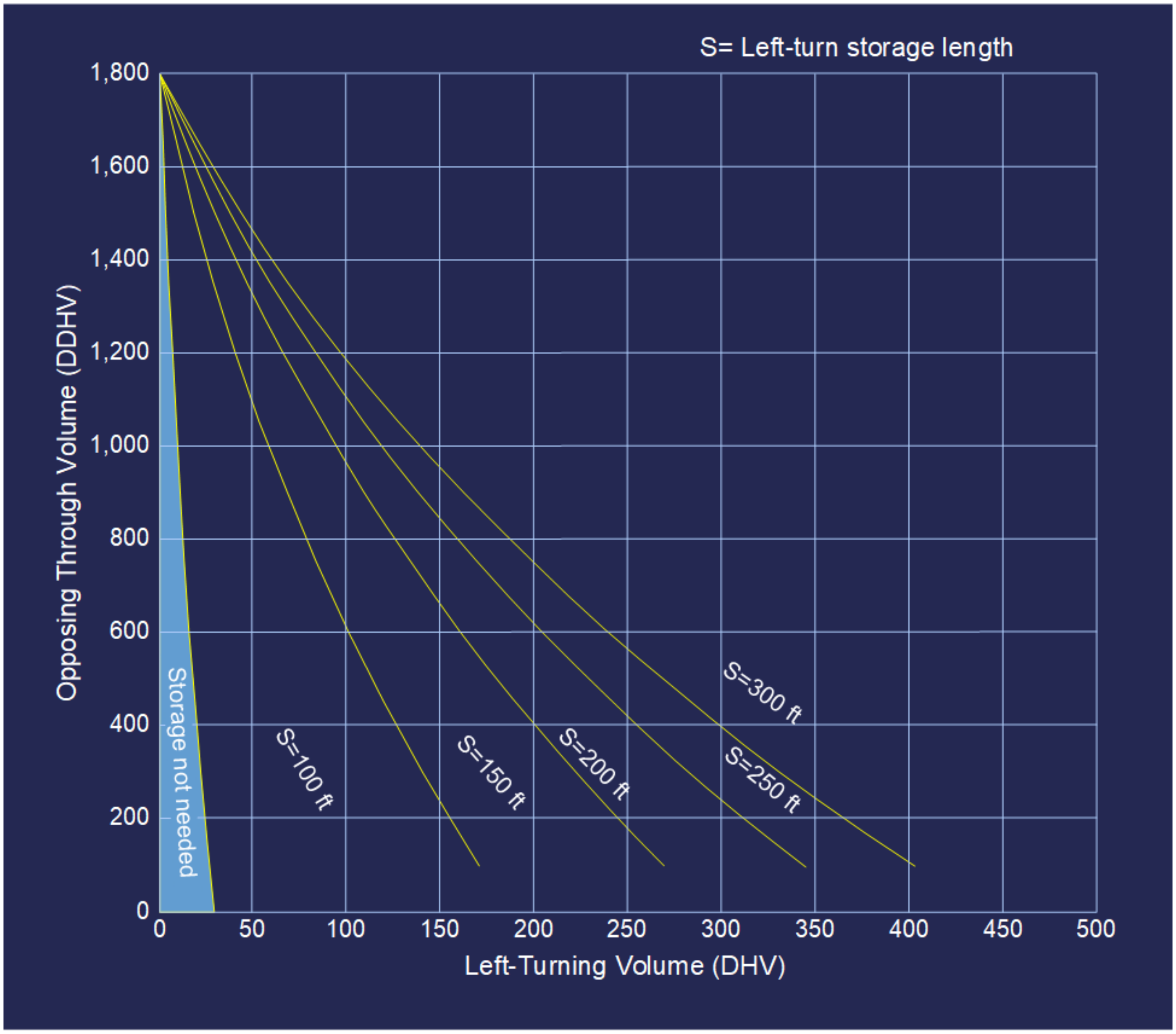


Exhibit 1310-10 Left-Turn Storage Guidelines: Four-Lane, Unsignalized



Determine the storage length on two-lane highways by using Exhibit 1310-11 through Exhibit 1310-13. On four-lane highways, use Exhibit 1310-10. These lengths do not consider trucks. Use Exhibit 1310-14 for storage length when trucks are present.

Use turn simulation software (such as AutoTURN®) 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.

Exhibit 1310-11 Left-Turn Storage Length: Two-Lane, Unsignalized (40 mph)

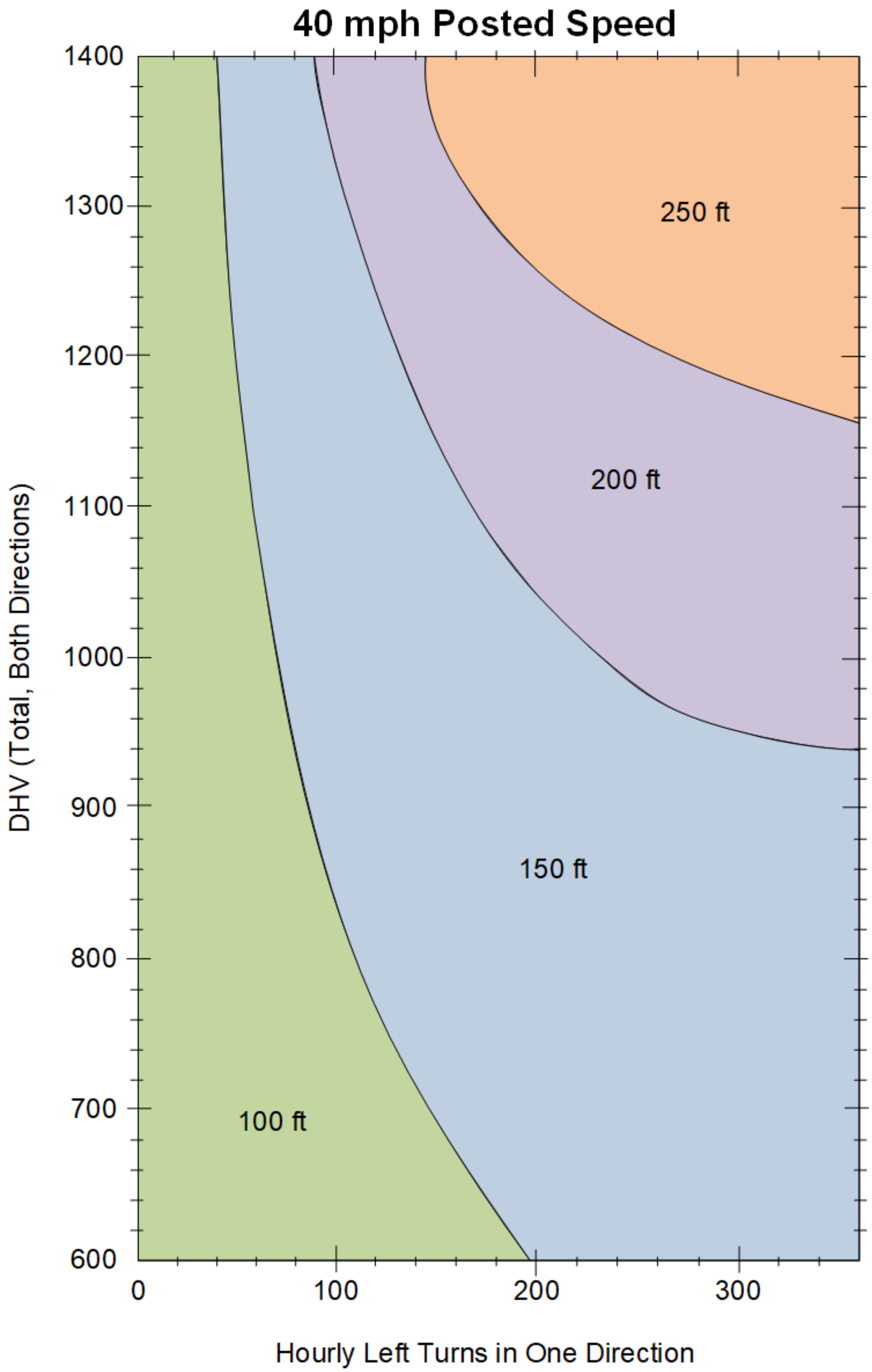


Exhibit 1310-12 Left-Turn Storage Length: Two-Lane, Unsignalized (50 mph)

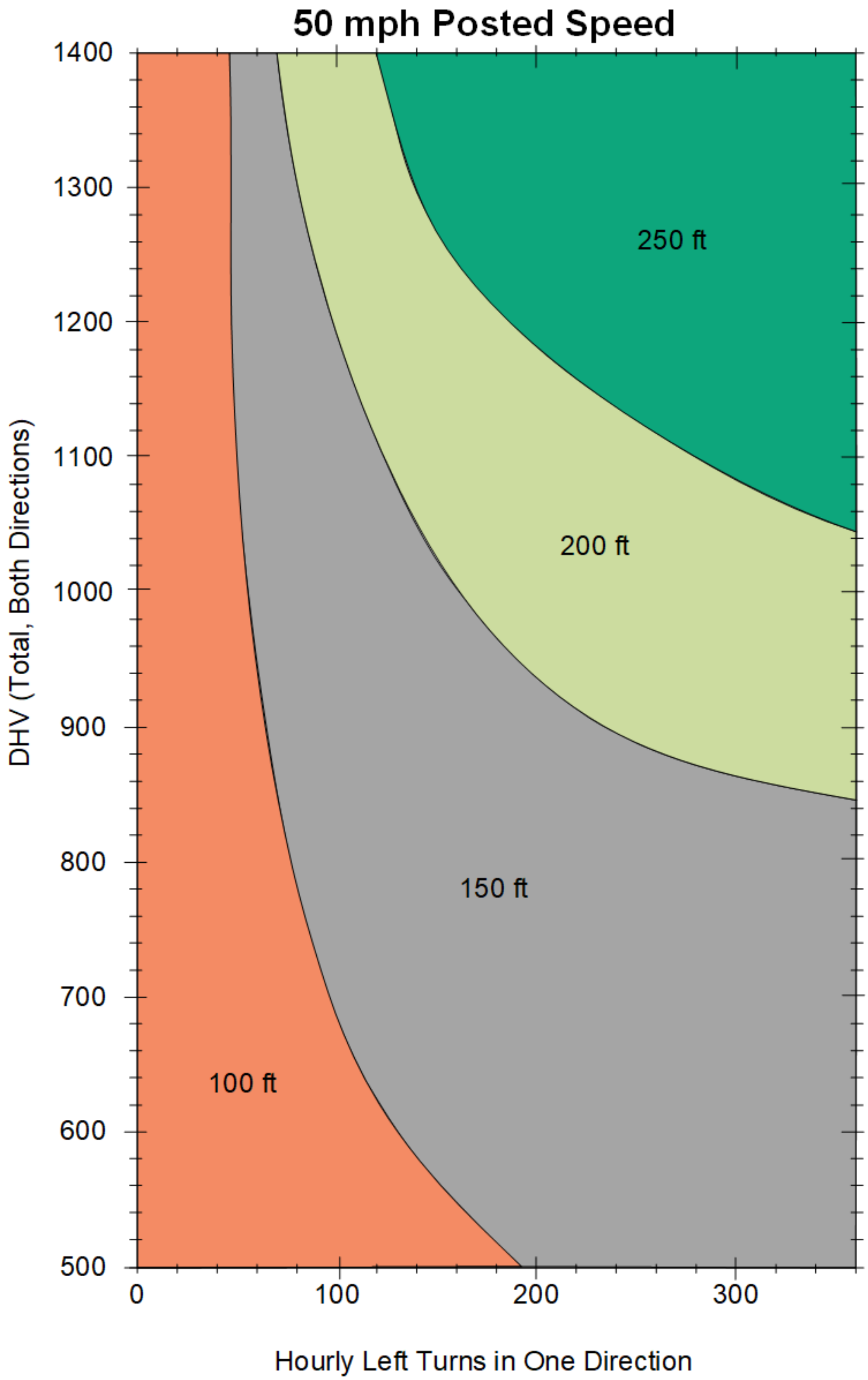


Exhibit 1310-13 Left-Turn Storage Length: Two-Lane, Unsignalized (60 mph)

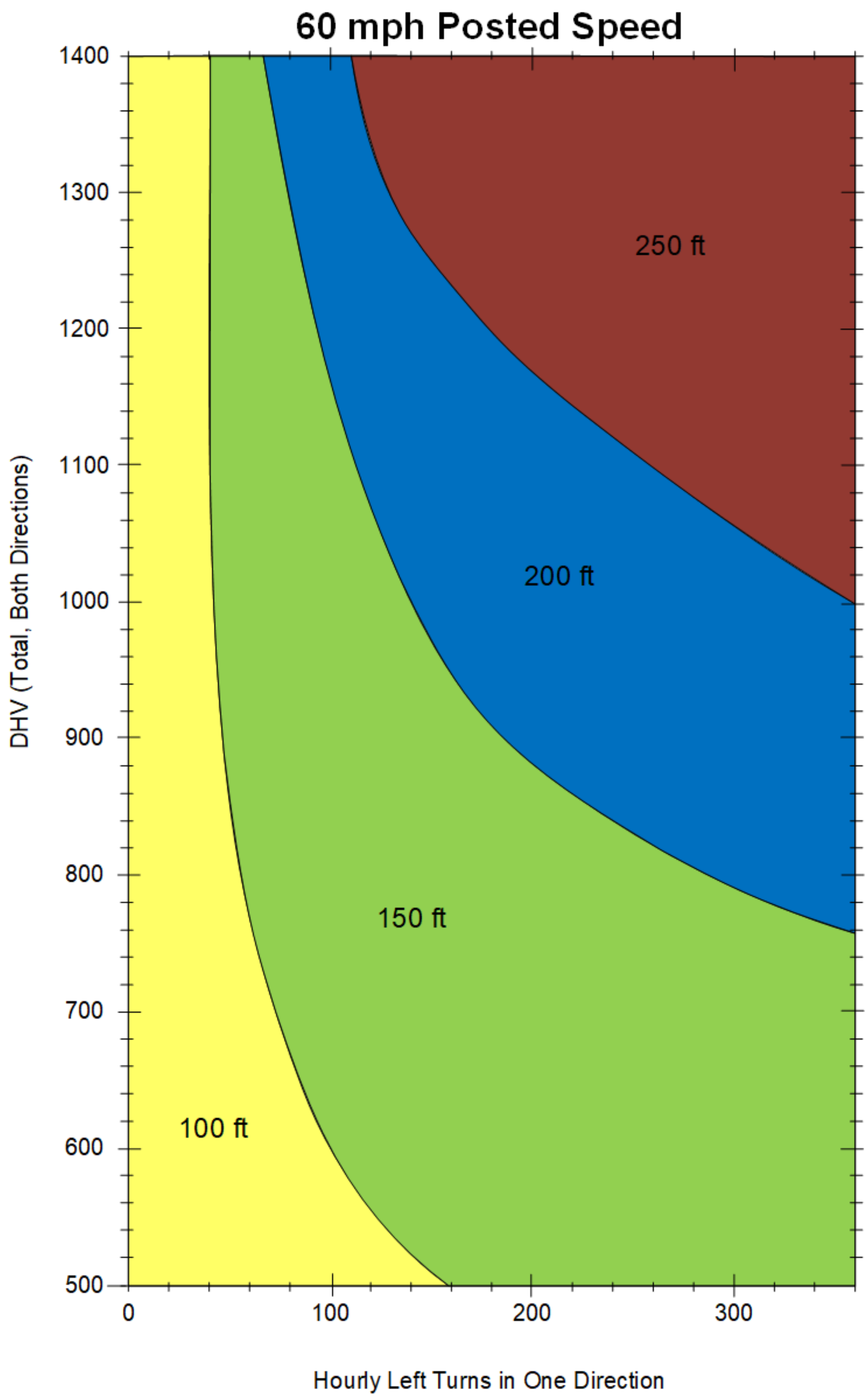


Exhibit 1310-14 Left-Turn Storage with Trucks (ft)

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 Exhibit 1310-10 and Exhibit 1310-11, Exhibit 1310-12, or Exhibit 1310-13.

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 turn simulation software (such as AutoTURN®) 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-30 vehicle turning abreast rather than two design vehicles turning abreast.

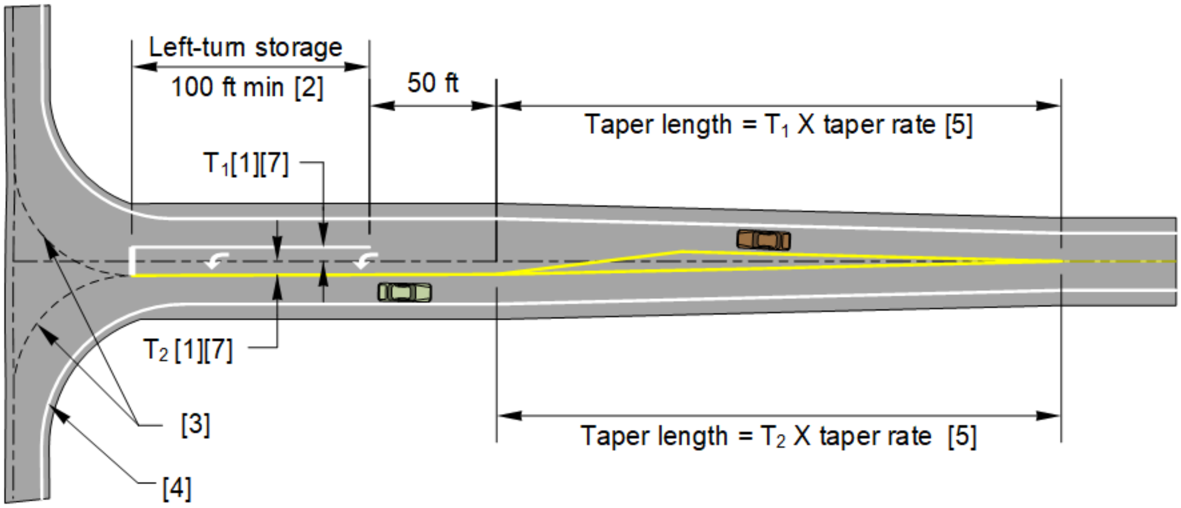
Exhibit 1310-15 through Exhibit 1310-20 show left-turn lane geometrics, which are described as follows:

1310.02(13)(a)(i) Modifications to Left-Turn Designs

The left-turn lane designs discussed above and given in Exhibit 1310-15 through Exhibit 1310-19 may be modified when determined by design element dimensioning (see Chapter 1106.) 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 supports the design vehicle, and provide for the striping (see the Standard Plans and the MUTCD). Verify the design vehicle can make the turn using turn simulation software (such as AutoTURN®); include a plot of the design and verification.

Exhibit 1310-15 Median Channelization: Widening



Notes:

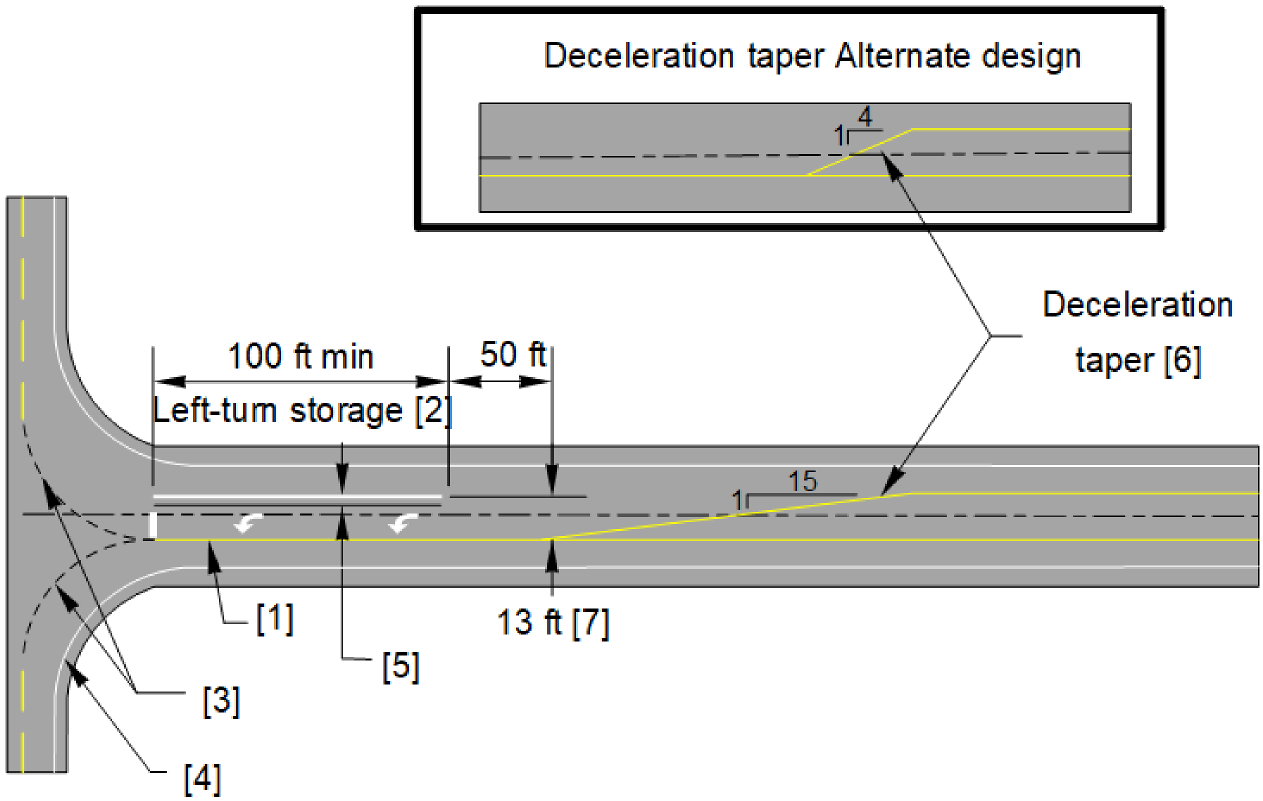
- [1] The minimum width of the left-turn storage lane (T1+T2) is 10 ft.
- [2] For left-turn storage length, see Exhibit 1310-10 for 4-lane roadways or Exhibit 1310-11 through Exhibit 1310-13 for 2-lane roadways.
- [3] Use turn simulation software (such as AutoTURN®) to verify the design vehicle can make the turn.
- [4] For right-turn corner design, see Exhibit 1310-8.
- [5] For desirable taper rates, see Table on this Exhibit. With justification, taper rates from the Table in Exhibit 1310-17 may be used.
- [6] For pavement marking details, see the Standard Plans and the MUTCD.
- [7] Where curb is provided, add the width of the curb and the shoulders to the left-turn lane width. For shoulder widths at curbs, see Section 1310.02(18) and Chapter 1230.

T1 = Width of left-turn lane on approach side of centerline

T2 = Width of left-turn lane on departure side of centerline

Design 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

Exhibit 1310-16 Median Channelization: Median Width 10 ft or More



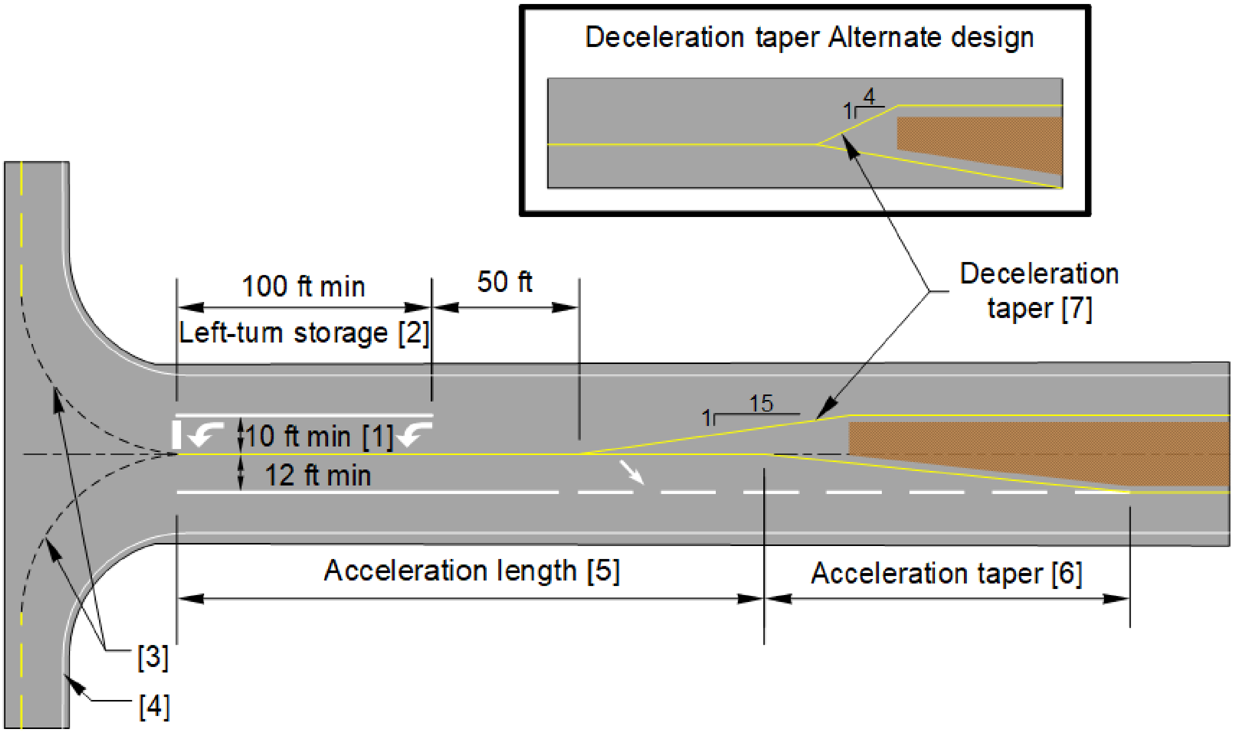
Notes:

- [1] Where curb is provided, add the width of the curb and the shoulders. For shoulder widths at curbs, see Section 1310.02(18) and Chapter 1230.
- [2] For left-turn storage length, see Exhibit 1310-10 for 4-lane roadways or Exhibit 1310-11 through Exhibit 1310-13 for 2-lane roadways.
- [3] Verify the design vehicle can make the turn using turn simulation software (such as AutoTURN®).
- [4] For right-turn corner design, see Exhibit 1310-8.
- [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. 10 ft Minimum.

General:

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

Exhibit 1310-17 Median Channelization: Median Width 23 ft to 26 ft



Notes:

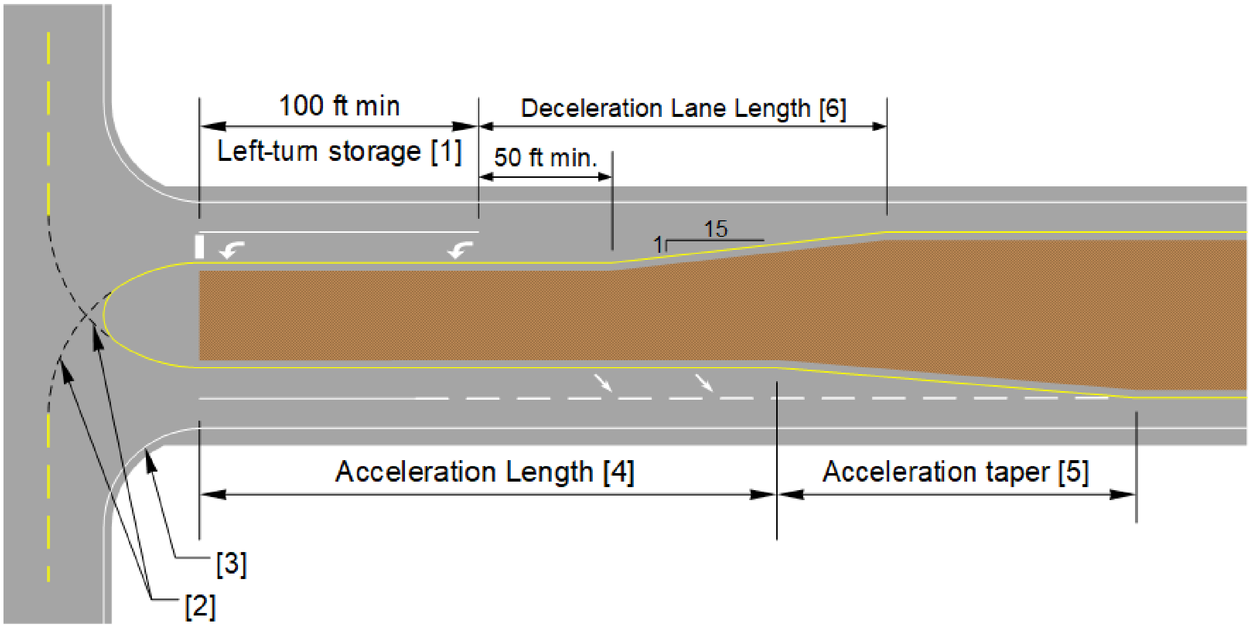
- [1] When curb is provided, add the width of the curb.
- [2] For left-turn storage length, see Exhibit 1310-10 for 4-lane roadways or Exhibit 1310-11 through Exhibit 1310-13 for 2-lane roadways.
- [3] Verify the design vehicle can make the turn using turn simulation software (such as AutoTURN®).
- [4] For right-turn corner design, see Exhibit 1310-8.
- [5] The minimum total length of the median acceleration lane is shown in Exhibit 1310-27.
- [6] For acceleration taper rate, see Table on this exhibit.
- [7] For increased storage capacity, the left-turn deceleration taper alternate design may be used.
- [8] The desirable length of the left-turn deceleration lane including taper is shown in Exhibit 1310-26.

Design 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

General:

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

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



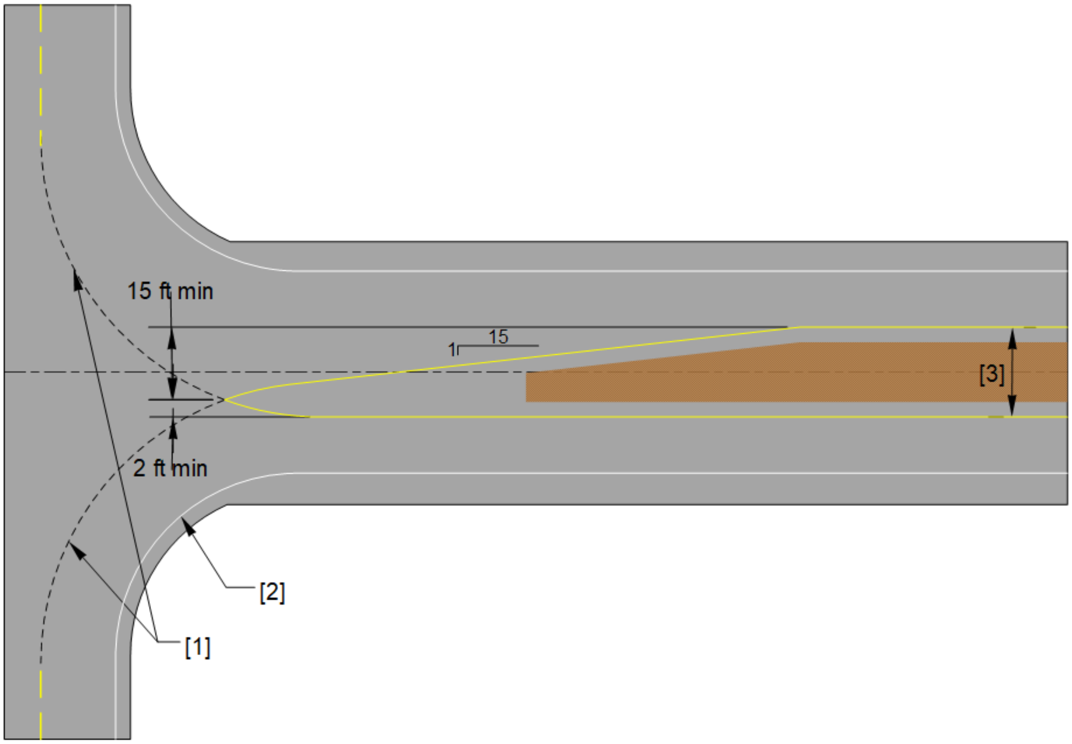
Notes:

- [1] For left-turn storage length, see Exhibit 1310-10 for 4-lane roadways or Exhibit 1310-11 through Exhibit 1310-13 for 2 lane roadways.
- [2] Verify the design vehicle can make the turn using turn simulation software (such as AutoTURN®).
- [3] For right-turn corner design, see Exhibit 1310-8.
- [4] The minimum length of the median acceleration lane is shown in Exhibit 1310-27.
- [5] For acceleration taper rate, see the Table on Exhibit 1310-17.
- [6] The desirable length of the left-turn deceleration lane including taper is shown in Exhibit 1310-26.

General:

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

Exhibit 1310-19 Median Channelization: Minimum Protected Storage



Notes:

- [1] Verify the design vehicle can make the turn using turn simulation software (such as AutoTURN®).
- [2] For right-turn corner design, see Exhibit 1310-8.
- [3] For median width 17 ft or more. For median width less than 17 ft, widen to 17 ft. or use Exhibit 1310-16.

General:

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

1310.02(13)(a)(ii) Widening

It is desirable that offsets and pavement widening (see Exhibit 1310-15) 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.

1310.02(13)(a)(iii) Divided Highways

Widening is not needed for left-turn lane channelization where medians are 11 feet wide or wider (see Exhibit 1310-16 through Exhibit 1310-18). 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 1310-16) to improve sight distance and increase opposing left-turn clearances.

A median acceleration lane (see Exhibit 1310-17 and Exhibit 1310-18) 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 Section 1310.02(16), Speed Change Lanes. Where medians have sufficient width, provide a 2-foot shoulder adjacent to a left-turn lane.

1310.02(13)(a)(iv) 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 1310-19).

1310.02(13)(b) Two-Way Left-Turn Lanes

Two-way left-turn lanes (TWLTLs) 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:

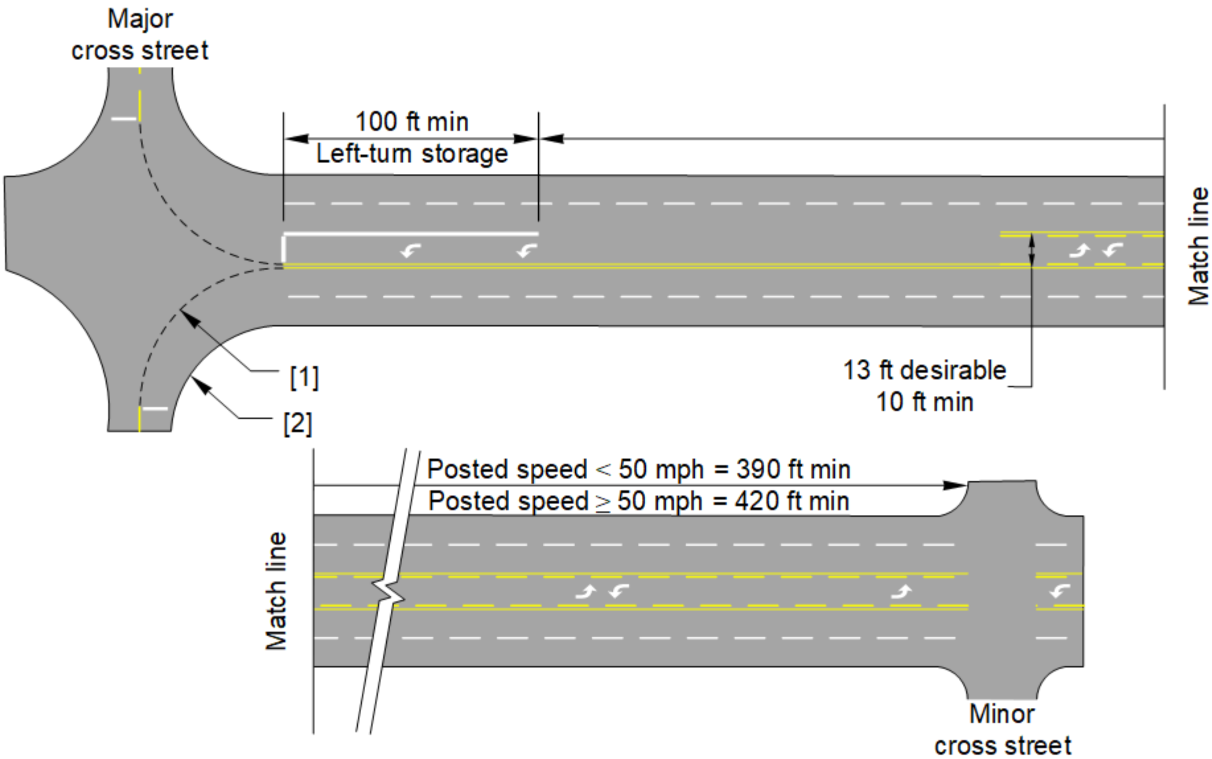
- A crash study indicates reduced crashes with a TWLTL.
- There are existing closely spaced access points or minor street intersections.
- There are unacceptable through traffic delays or capacity reductions because of left-turning vehicles.

TWLTLs can reduce delays to through traffic, reduce rear-end crashes, 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 Chapter 540 for additional restrictions on the use of TWLTLs, and Chapter 1230 for discussion of Roadway Cross Section Reallocation, which commonly employ a center turn lane.

The basic design for a TWLTL is illustrated in Exhibit 1310-20. 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.

Exhibit 1310-20 Median Channelization: Two-Way Left-Turn Lane



Notes:

[1] Verify the design vehicle can make the turn using turn simulation software (such as AutoTURN®).
[2] For right-turn corner design, see Exhibit 1310-8.

General:

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

1310.02(14) Islands

An island is a defined area within an intersection between traffic lanes for the separation of vehicle movements or for pedestrian refuge. Pedestrian refuge islands can be beneficial because they minimize the pedestrian crossing distance, reduce the conflict area, and minimize the impacts on vehicular traffic. Within an intersection, a median is considered an island. Design islands to clearly delineate the traffic channels to drivers, pedestrians, and bicyclists. 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. Use turn simulation software (such as AutoTURN®) to verify the design.

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.

Traffic islands can create a right turn slip lane where traffic control can differ from the traffic control used for other vehicular movements through the intersection. Slip lanes introduce an additional area where pedestrians and bicyclists are exposed to motor vehicle traffic. Designing intersections without traffic islands, removing existing slip lanes, or enhancing the design of slip lanes can provide benefits for pedestrians and bicyclists.

Where traffic islands and associated slip lanes are deemed necessary, active transportation design elements may be available to manage speed (see Section 1510.09(7)), reduce exposure, and increase the conspicuity of vulnerable users crossing these features. Consult with HQ Active Transportation Division for design recommendations when evaluating traffic islands and slip lanes.

1310.02(14)(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 slower, 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 Exhibit 1310-21 through Exhibit 1310-23. 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.)

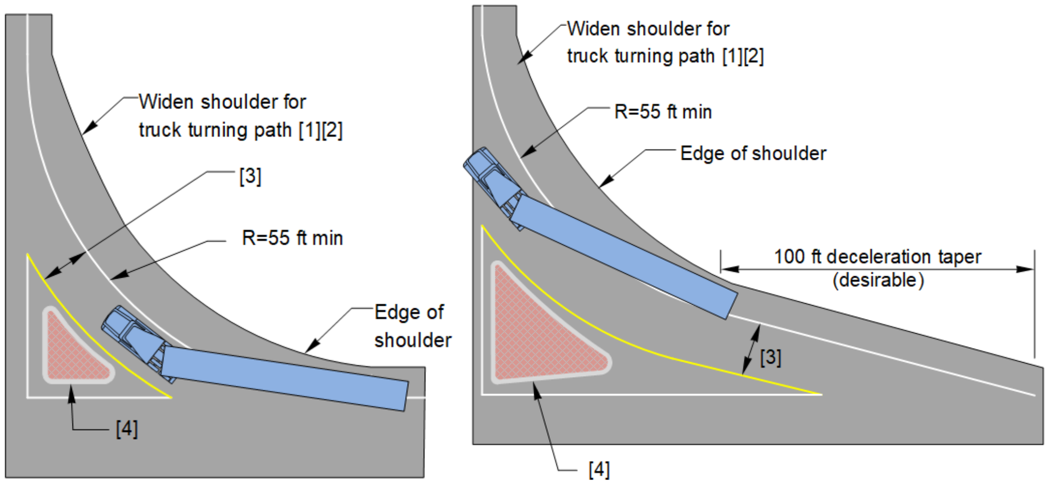
Island markings may be supplemented with reflective raised pavement markers.

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

1310.02(14)(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.

Exhibit 1310-21 Traffic Island Designs



Small Traffic Island Design [5]   **Large 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 turn simulation software (such as AutoTURN®) for the intersection design vehicle.
[3] For turning roadway widths, see Chapter 1240.
[4] For additional details on island placement, see Exhibit 1310-23.
[5] Small traffic islands have an area of 100 ft^2 or less; large traffic islands have an area greater than 100 ft^2.

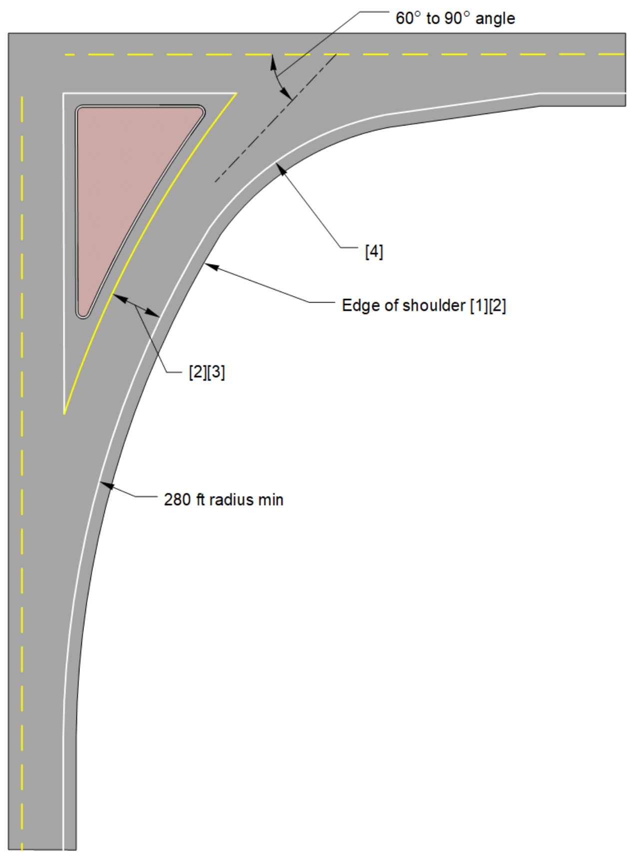
General:

- 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 1310-8.

1310.02(14)(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 1310-22). This design forces the turning traffic to slow down.

Exhibit 1310-22 Traffic Island Designs: Compound Curve



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 turn simulation software (such as AutoTURN®) for the intersection design vehicle.
[3] For turning roadway widths, see Chapter 1240.
[4] For right-turn corner design, see Exhibit 1310-8.

General:

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

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

1310.02(14)(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:

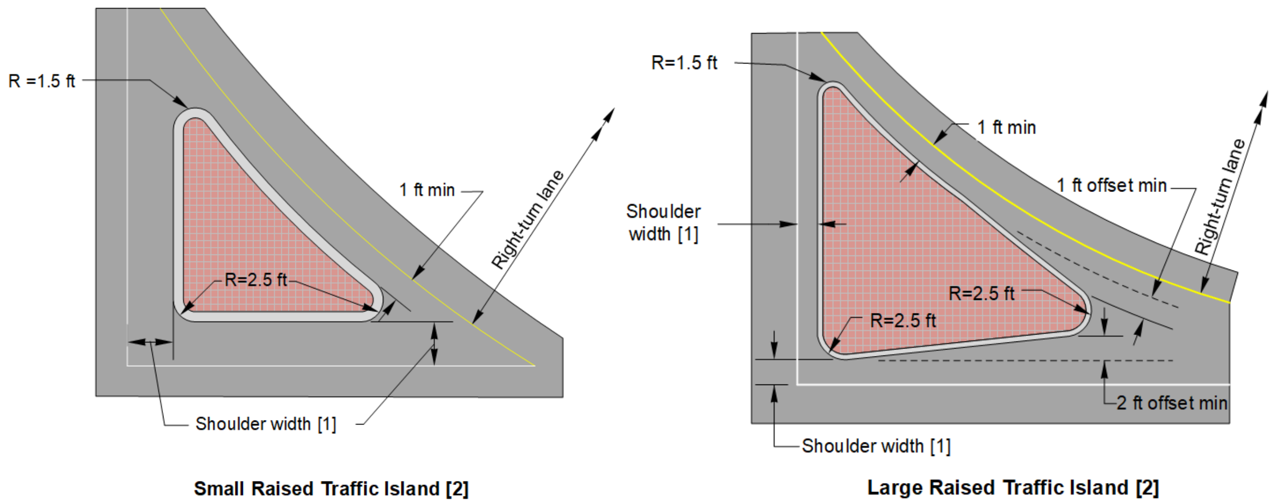
- Divisional and channelizing islands.
- Landscaped islands.
- Stormwater conveyance.

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 1230 for additional information and design criteria on the use of curbs.

Exhibit 1310-23 Traffic Island Designs



Notes:

[1] For shoulder width at curbs, see Chapter 1230. For additional information on shoulders at turn lanes, see Section 1310.02(18).

[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).

1310.02(15) 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 consider right-turn lanes at unsignalized intersections (see Section 1310.02(16) for guidance on right-turn lane lengths):

- For two-lane roadways and for multilane roadways with a posted speed of 45 mph or above, when recommended by Exhibit 1310-24.
- A crash 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.

For signalized intersections, use a traffic signal analysis to determine whether a right-turn lane is needed and what the length should be.

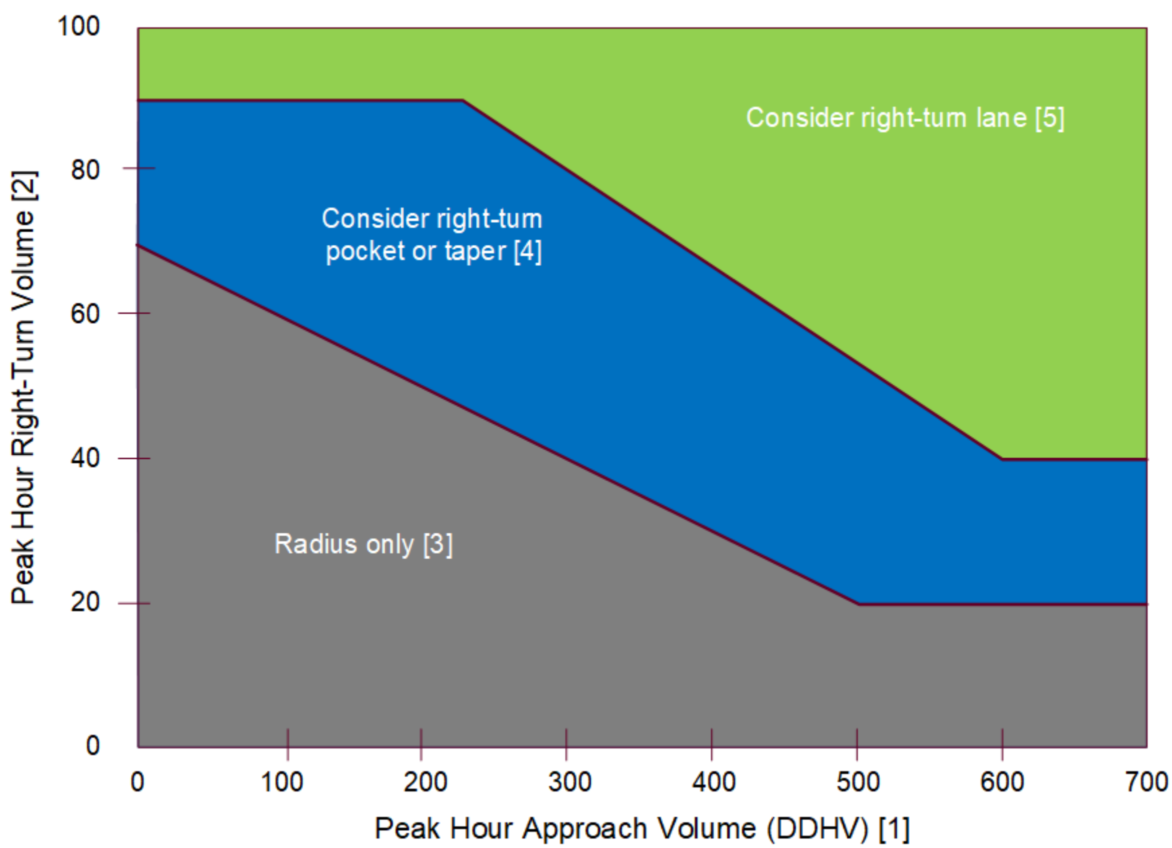
A capacity analysis may be used to determine whether right-turn lanes are needed to maintain the desired level of service.

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 1310-25) 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 1310-25 shows taper lengths for various posted speeds.

Exhibit 1310-24 Right-Turn Lane Guidelines



Notes:

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

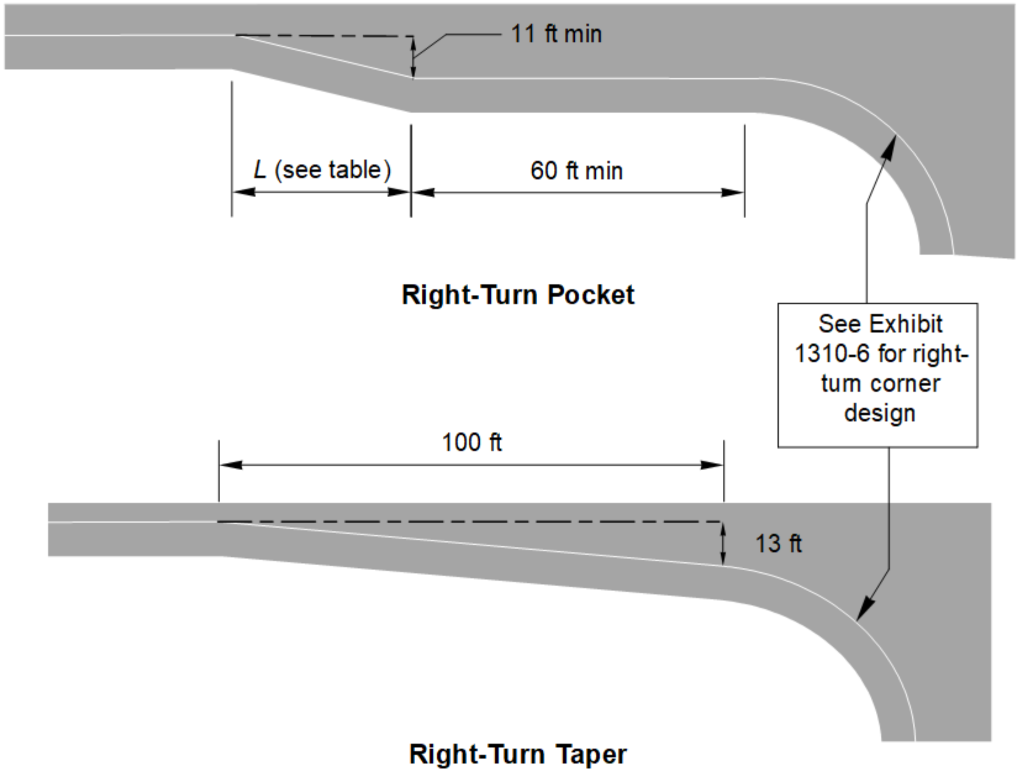
[2] When all three of the following conditions are met, reduce the right-turn DDHV by 20:
- The posted speed is 45 mph or below
- The right-turn volume is greater than 40 VPH
- The peak hour approach volume (DDHV) is less than 300 VPH

[3] For right-turn corner design, see Exhibit 1310-8.

[4] For right-turn pocket or taper design, see Exhibit 1310-25.

[5] For right-turn lane design, see Exhibit 1310-26.

Exhibit 1310-25 Right-Turn Pocket and Right-Turn Taper



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

1310.02(16) Speed Change Lanes

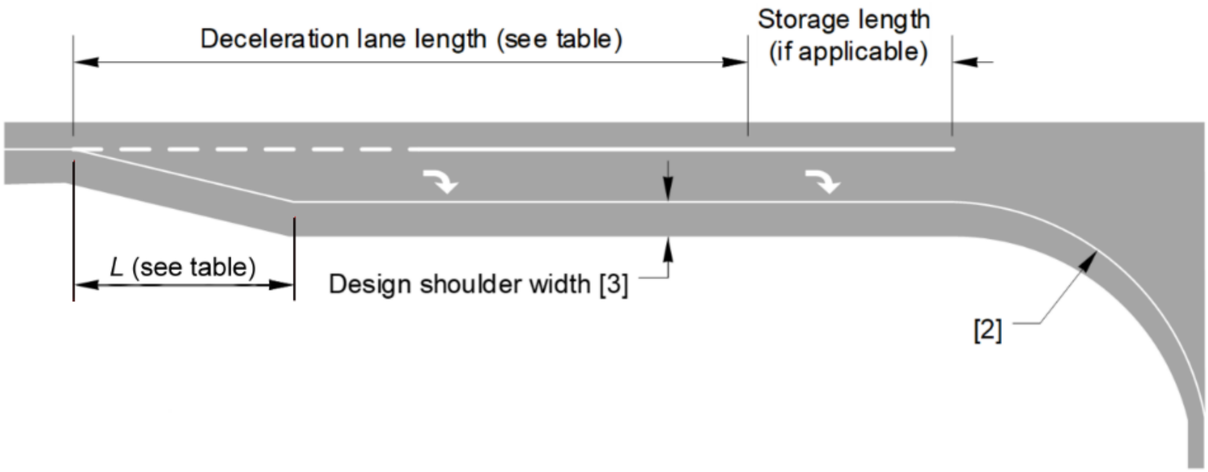
A speed change lane is an auxiliary lane primarily for the acceleration or deceleration of vehicles entering or leaving the through traveled way. Speed change lanes are normally provided for at-grade intersections on multilane divided highways with access control. Where roadside conditions and right 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 crash history.

When either deceleration or acceleration lanes are to be used, design them in accordance with Exhibit 1310-26 and Exhibit 1310-27. 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.

A dedicated deceleration lane (see Exhibit 1310-26) is advantageous because it removes slowing vehicles from the through lane.

An acceleration lane (see Exhibit 1310-27) 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.

Exhibit 1310-26 Right-Turn Lane



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

Highway Design Speed (mph)	Deceleration Lane Length (ft)
30	160 [1]
35	220
40	275
45	350
50	425
55	515
60	605
65	715
70	820

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		

Minimum Deceleration Lane Length (ft)

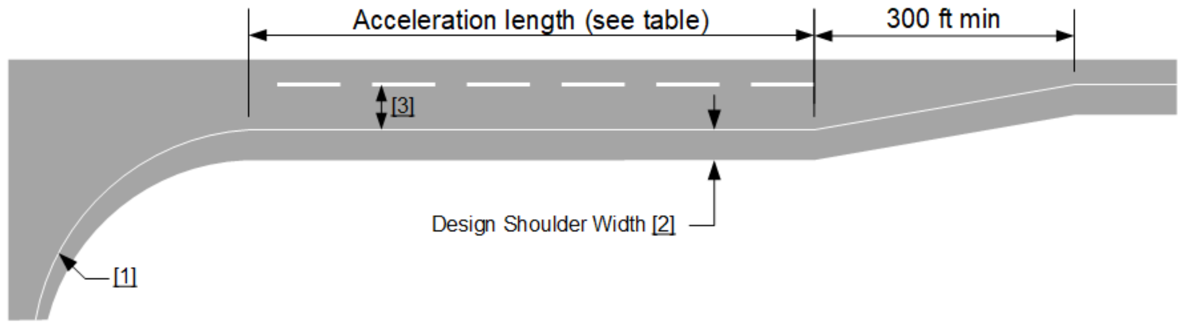
Notes:

[1] When adjusting for grade, do not reduce the deceleration lane to less than 150 ft.
[2] For right-turn corner design, see Exhibit 1310-8.
[3] See Section 1310.02(18) and Chapter 1230.

General:

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

Exhibit 1310-27 Acceleration Lane



Minimum Acceleration Length (ft)			
Highway Design Speed (mph)	Turning Roadway Design Speed (mph)		
	Stop	15	20
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

Adjustment Multiplier for Grades 3% or Greater			
Highway Design Speed (mph)	% Grade	Upgrade	Downgrade
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		1.5	0.55
60		1.7	0.5
70		2.0	0.5

Notes:

[1] For right-turn corner design, see Exhibit 1310-8.
[2] See Section 1310.02(18) and Chapter 1230.
[3] Lane width as determined by Chapter 1106 and Chapter 1230.

General:

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

1310.02(17) 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 1310-27.

1310.02(18) Shoulders

Shoulder width is controlled by its intended functional use and its contribution to achieving the desired safety performance when balanced with other design elements. See Exhibit 1239-2 for functional uses and recommended shoulder widths.

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.

1310.02(19) 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 U-turn spacing (see Exhibit 1310-28) 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.

Exhibit 1310-28 U-Turn Spacing

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

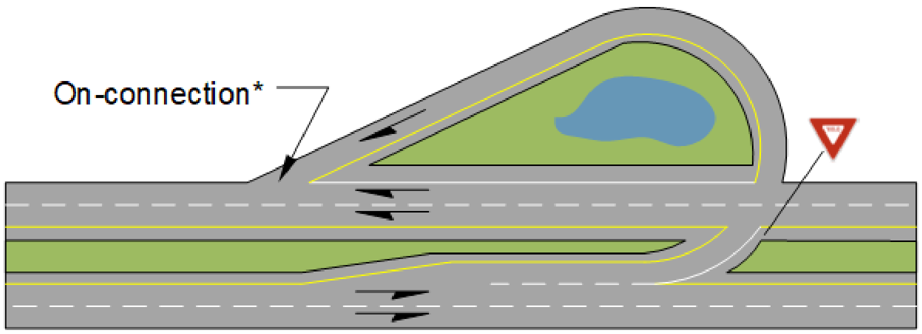
Notes:

[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 1310-27) plus 300 ft.
[3] For design speeds 60 mph or higher, the minimum spacing is the acceleration lane length from a stop (see Exhibit 1310-27) plus 300 ft.

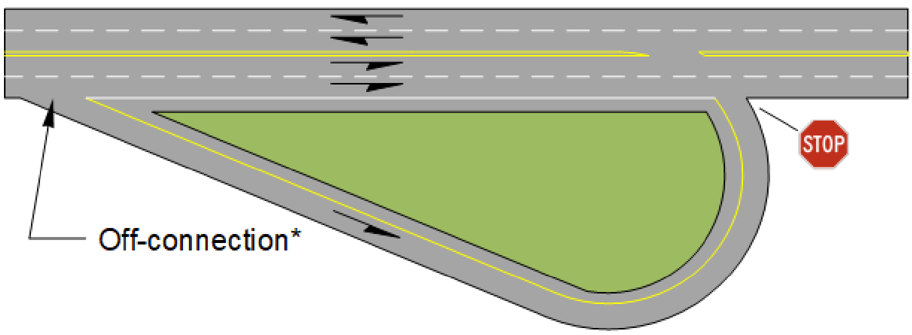
When designing U-turn median openings, use Exhibit 1310-30 as a guide. Where the median is less than 40 feet wide, with a large design vehicle, provide a U-turn roadway (see Exhibit 1310-29). Design A, with the U-turn roadway after the left-turn, is desirable. Use Design A when the median can accommodate a left-turn lane. Use Design B only where left-turn channelization cannot be built in the median.

Exhibit 1310-29 U-Turn Roadway

Design A



Design B

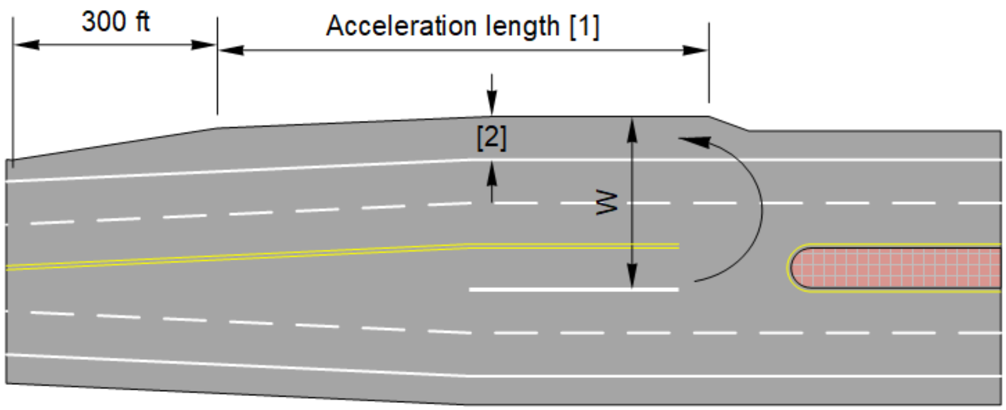


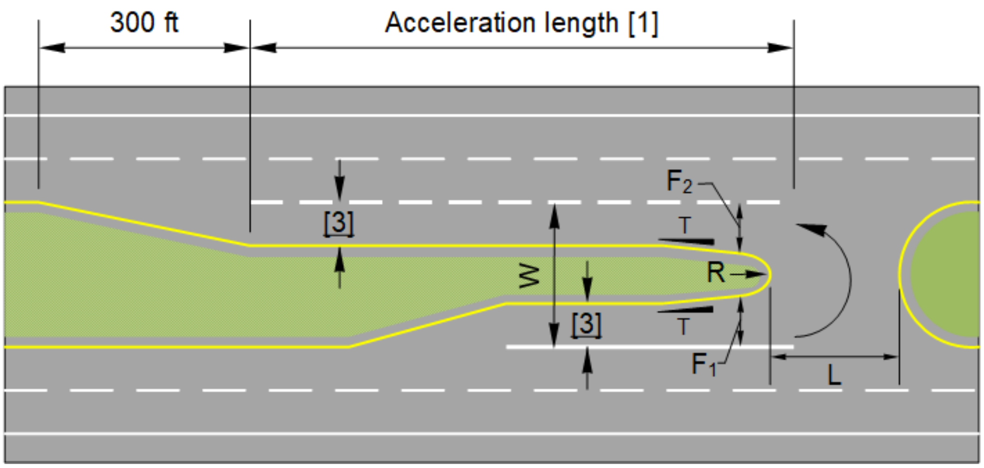
*Design on- and off-connections in accordance with Chapter 1360.

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 1310-30. 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.

Exhibit 1310-30 U-Turn Median Openings





U-Turn Design Dimensions						
Vehicle	**W**	**R**	**L**	**F_1**	**F_2**	**T**
P	52	14	14	12	12	—
SU-30	87	30	20	13	15	10:1
CITY-BUS	87	28	23	14	18	10:1
WB-40	84	25	27	15	20	6:1
WB-67	94	22	49	15	35	6:1

Notes:

- [1] The minimum length of the acceleration lane is shown in Exhibit 1310-27. Acceleration lane may be eliminated at signal-controlled intersections.
- [2] When U-turn uses the shoulder, provide shoulder width sufficient for the intersection design vehicle to make the turn and shoulder pavement designed to the same depth as the through lanes for the acceleration length and taper.
- [3] Lane width as determined by Chapter 1106 and Chapter 1230.

General: All dimensions are in feet.

1310.03 Designing for Active Transportation

Design intersections to provide accommodation for pedestrian and bicycle movement at and through intersections on facilities where they are legally allowed. This includes new or reconstructed intersections at locations where completes streets does not apply.

Accommodation of pedestrian and bicycle movements at intersections is achieved through incorporation of various design strategies that benefit one or more of the six functional characteristics that affect active transportation user's comfort and safety. These functional characteristics include exposure, speed, delay, conspicuity, predictability, separation in space, and separation in time. Improve the safety and comfort of active transportation users by:

- Decreasing pedestrian/bicyclist **exposure** to points of conflict with motor vehicle traffic;
- Decreasing motor vehicle **operating speed**;
- Increasing pedestrian/bicyclist user **conspicuity**;
- Increasing the **predictability** of movements of different user groups through the intersection;
- Increasing **separation in space** between motorists and pedestrians/bicyclists; and/or
- Increasing **separation in time** between motorists and pedestrians/bicyclists.

Intersection designs may not be able to incorporate design strategies that benefit all functional characteristics. Review the project for possible improvements to individual functional characteristics and apply engineering judgment as to which bullets are appropriate and to what extent they will be addressed (see Section 1310.03(1)).

For more complex or innovative intersection layouts such as Diverging Diamond Interchanges, Displaced Left Turns, Single Point Urban Interchanges, etc., contact the HQ Transportation Operations Division for support. For additional information for roundabouts see Chapter 1320.

1310.03(1) Design Process

The identification of appropriate bicycle and pedestrian design features for all intersections along a corridor or at an individual intersection is informed by the corridor's existing or planned bicycle and pedestrian facilities and other design elements (e.g., parking). The appropriateness of various design feature may be limited by geometric constraints (e.g., sufficient width). Moreover, the effectiveness of specific design features may be diminished if they are not supported by complementary corridor infrastructure and/or violate driver expectancy. Some features may not be conducive to a given corridor, while others may not be conducive to an individual intersection application.

When designing for pedestrian and bicycle movements under a complete streets (CS) project, although a minimum Level of Traffic Stress (LTS) value of 2 or better is the standard for bicyclists and pedestrians, interpretation of that standard at intersections is still in development. In the interim, the CS requirements for intersections will be met if you follow the design table and implement appropriate strategies as outlined below. Design decisions made relative to the corridor will be reflected in the intersection and will therefore meet CS requirements. See Section 1510.02(5)(a) for Pedestrian Level of Traffic Stress (PLTS) and Section 1520.03(3)(a) for Bicycle Level of Traffic Stress (BLTS).

The approach to determining the appropriate intersection treatments for bicycle and pedestrian facilities focuses on matching selected intersection treatments to the corridor's linear bike/pedestrian facilities and providing treatments that support local agency plans and WSDOT project goals.

When used in conjunction with the table in Exhibit 1310-31, intersection treatments selected under this approach will support the LTS goals of the corridor. The table is designed to result in lower-stress intersection treatments that match lower-stress corridor facility types.

The approach follows a five-step process:

Step 1: Gather and review all pertinent active transportation goals and plans from local agency active transportation plans and/or comprehensive plans, the WSDOT Active Transportation Plan, and the project summary. Additional information may be provided in the Basis of Design and any design recommendations from the Region Complete Streets Team, where applicable.

Step 2: Determine whether the project will include bicycle and pedestrian facility improvements. Most projects will include some form of bicycle and pedestrian facility improvements. A small selection of preservation projects in which complete streets does not apply might not include any bicycle or pedestrian facility improvements. If your project does not include any bicycle or pedestrian improvements, Step 2 is the last step in the process. For all other projects proceed to Step 3.

Step 3: Determine the linear bicycle and pedestrian facility types that will be applied along your project corridor between intersections. For some projects the linear bicycle and pedestrian facilities will match existing facilities, and for others the project may propose new facility types to replace existing facilities (or to establish new facilities where none exist today). For intersection projects determine the linear bicycle and pedestrian facility types that exist leading up to the intersection. For all complete streets projects, the linear bicycle and pedestrian facility types will meet LTS 2.

Step 4: Consult the table in Exhibit 1310-31. Find the columns under "Corridor Linear Bike/Ped Facility Types" that match the bicycle and pedestrian facilities determined in Step 3. Note that you will be tracking columns for both the bicycle and pedestrian facilities. Review and select any treatments from the "Intersection Treatments Applied at All Intersections Throughout Corridor" (orange group) that will support the corridor bicycle and pedestrian treatments determined in Step 3, local agency plans, and WSDOT project goals. Note that multiple treatments might be selected from this group in order to achieve a project's goals. For corridor projects, the treatments selected from the orange group should be applied to all intersections in the corridor.

Step 5: Next, review and select any treatments from the "Intersection Treatments Applied at Individual Intersections" (blue group) that will likewise support the corridor bicycle and pedestrian treatments determined in Step 3, local agency plans, and WSDOT project goals. As with the orange group, multiple treatments from the blue group might be selected in order to achieve a project's goals. Repeat Step 5 for each individual intersection in the project.

When reviewing potential treatments in the table, the cells marked "Yes" indicate that the treatment in the row is an appropriate treatment for the facility type in the column and should be considered for inclusion in the project. For the cells marked "No", that treatment type should not be combined with the facility type in that column and therefore should not be used in the project.

For the cells marked “N/A”, the treatment type in that row does not have any relationship with the facility type in the column and is therefore not applicable to the decision about whether to use that treatment. Note that other facility types that might apply to your project could still indicate use of that treatment. An example of this is the “Bikecross Markings” treatment. For that treatment, the pedestrian facility type has no bearing on the decision about whether to use bikecross markings, since these markings are not connected to the pedestrian facilities and do not serve any function for pedestrians. Therefore, the cells under the pedestrian facility types are all marked “N/A” for this treatment; however, the bicycle facility type does drive the decision about whether or not to use bikecross markings, and for certain bicycle facility types bikecross markings cannot be used, so some bicycle facility types are marked “Yes” for this treatment and some are marked “No”.

For the cells marked “Not Typical”, the treatment in the row is not usually used in conjunction with the facility type in the column; however, under certain limited circumstances there may be a reason to consider the treatment. These combinations are normally not used unless there is a specific contextual reason to do so.

After completing all five steps, document your determinations and results in the DDP.

Exhibit 1310-31 Pedestrian and Bicycle Intersection Treatments

Intersection Treatments	Reference	Corridor Linear bike/Ped Facility Types[3] (Evaluate Bicycle and Pedestrian Needs Together Based on Facility Types)									Performance Characteristics										
		Bicycle Facility Type						Pedestrian Facility Type			Reduce SPEED	Increase CONSPICUITY		Increase SPACE SEPARATION		Increase TIME SEPARATION		Decrease EXPOSURE		Increase PREDICTABILITY	
		Separated Bike Lane	Buffered Bike Lane	Striped Bike Lane	Neighborhood Greenway	None[4]	Shared-Use Path	Buffered Sidewalk	Sidewalk (No Buffer)	At-Grade Shoulder		Bike	Ped	Bike	Ped	Bike	Ped	Bike	Ped	Bike	Ped
Intersection Treatments Applied at All Intersections Throughout Corridor[1]																					
Pavement Marking/Geometric Treatments																					
Green pavement Markings[5]	1520.05(1)(a)	Yes	Yes	Yes	Yes (see specific treatments)	No	Not Typical	N/A	N/A	N/A		X								X	
Bikecross Markings (Bike Lane Extension Through Intersection)	1520.04(1)	Yes	Yes	Yes	Yes (requires bike lanes at intersection)	No	Not Typical	N/A	N/A	N/A		X		X						X	
Two-Stage Bicycle Turn Box (at signalized intersections only)	1520.04(3)	Yes	Yes	Yes	Not Typical	No	Not Typical	N/A	N/A	N/A		X		X				X		X	
Physical Parking Restriction Near Pedestrian Crossings	Chapter 1510	N/A	N/A	N/A	N/A	N/A	Yes	Yes	Yes	Yes			X		X						
Reduced Turn Radii	1310.03(1) and 1310.03(2)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	X		X		X				X		
Signalized/Beacon Treatments																					
Signal Phase Separation		Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes	Yes						X	X	X	X	X	X
Pedestrian Signal Heads	1330.07(5)	N/A	N/A	N/A	N/A	N/A	Yes	Yes	Yes	Yes						X	X	X	X		X
Intersection Treatments Applied at Individual Intersections[2]																					
Pavement Marking/Geometric Treatments																					
Curb Extensions	1510.09(5)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes (Constructed sidewalk at intersection)	X		X		X				X		X
Corner Island for Bike Lane	See Protected Intersection, Chapter 1520	Yes	Yes	Yes	No	No	N/A	N/A	N/A	N/A	X	X		X	X			X	X		
Pedestrian/Bicycle Refuge Island	TM 4-6.6, H and I	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	X				X			X	X	X	X
Mountable Truck Aprons	1510.09(6)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Not Typical	X				X				X		
Raised Intersection	Chapter 1510	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	X		X								
Raised Crosswalk	TM 4-6.6, N	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	X		X								
Marked Crosswalks	1510.09(2)(b)	[7]	[7]	[7]	[7]	N/A	Yes	Yes	Yes	Yes			X								
Leading Bike Box (at signalized intersections only)	1520.04(2)	Yes	Yes	Yes	Yes (requires bike lanes at intersection)	N/A	N/A	N/A	N/A	N/A		X		X	X					X	
"Turning Vehicles Stop for Peds" sign	Chapter 1510	Yes (bike version)	Yes (bike version)	Yes (bike version)	No	N/A	Yes	Yes	Yes	Yes			X							X	X
In-Street Pedestrian Crossing Sign	TM Exhibit 4-2.3, 4-6.6	N/A	N/A	N/A	N/A	N/A	Yes	Yes	Yes	Yes			X								X
Prohibit Turns on Red Light	TM 2-7.14	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes								X	X	X	X
Hardened Centerline (use with Marked Crosswalks)	Chapter 1510, Ohio DOT Guide 7.2.7[8]	N/A	N/A	N/A	N/A	N/A	Yes	Yes	Yes	Yes	X										X
Median Diverter[6]	Exhibit 1520-10	Not Typical	Not Typical	Yes	Yes	Yes	N/A	Yes	Yes	Yes	X							X	X	X	X
Slip Lane Elimination	Chapter 1310	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	X		X						X	X	X
Signalized/Beacon Treatments																					
Pedestrian Signal	TM 4-6.5, 4-6.6	[7]	[7]	[7]	Yes	N/A	Yes	Yes	Yes	Yes		X	X			X	X	X	X		X
Pedestrian Hybrid Beacon	TM 4-6.5, 4-6.6	[7]	[7]	[7]	Yes	N/A	Yes	Yes	Yes	Yes		X	X			X	X	X	X		X
Leading Pedestrian Interval (LPI)	TM 4-6.5	[7]	[7]	[7]	Yes	N/A	Yes	Yes	Yes	Yes		X	X			X	X		X		
Rectangular Rapid Flashing Beacon ((RRFB), use with Marked Crosswalks)	TM 4-6.3, A	N/A	N/A	N/A	Yes	N/A	Yes	Yes	Yes	Yes			X								X

Key: "Yes" = treatment is appropriate for this facility type; "No" = treatment is not appropriate for this facility type; "N/A" = treatment is not applicable in the evaluation for this facility type—use other determinants for evaluation of potential use of treatment; "Not Typical" = not a typical treatment for this facility type but can be considered if circumstances warrant use.

Notes:

[1] If a treatment is selected for use from this group, apply at all intersections; however, individual intersections within a project may not require certain treatments.
[2] Treatments in this group are evaluated on an intersection-by-intersection basis; can be used at any or all intersections in a project.
[3] To evaluate appropriate intersection treatments, typically select one column from the bicycle facility type group and one column from the pedestrian facility type group and review potential treatments with consideration for both.
[4] "None" means there are no facilities dedicated to bicycle use in the right of way (i.e., no bike lanes, no Neighborhood Greenway, no shared-use path). This type includes locations with only sharrows in traffic lanes, as sharrows do not establish dedicated space for cyclists.
[5] Green-colored pavement markings can be applied as a conspicuity enhancement to bike lanes, bikecross markings, two-stage turn boxes, and leading bike boxes.
[6] The use of median diverters is evaluated at the corridor-wide network level but applied at individual intersections.
[7] Marked crosswalks and pedestrian signal features are primarily intended for pedestrian use; however, at some high-conflict intersections, bicyclists may be directed to use pedestrian crossing facilities.
[8] "Ohio DOT Guide" is the 2022 Ohio DOT Multimodal Design Guide. Discuss this treatment with your ASDE when considering this guidance.

1310.03(2) Protected Intersection

A protected intersection is a comprehensive design approach that incorporates a suite of design features to address all of the functional characteristics listed in Section 1310.03. This suite of design features can be applied to one or more corners of an intersection.

A protected intersection is a geometric treatment that keeps bicyclists physically separated from drivers up to the intersection, including the corners. As such, they are typically implemented as a continuation of a separated bike lane facility, including two-way separated bike lanes. Protected intersections also provide benefits for pedestrians. The term protected in this context refers to the separation provided between vehicle lanes and pedestrians and bicyclists. Protected intersections include the following standard set of treatment countermeasures:

- Corner island
- Bike queue area
- Bikeway setback and driver yield zone
- Pedestrian refuge island
- Pedestrian crossing of the bike lane
- Pedestrian curb ramp
- Bicyclist crossing of travel lanes
- Pedestrian crossing of travel lanes

Protected intersection features are applied at signalized and unsignalized intersections. When used at a signalized location, they sometimes include specialized signal phasing. Protected intersection features can be applied to one or more intersection legs.

In a protected intersection, the separated nature of roadway bike lane and a pedestrian walkway at the intersection is created or preserved. In addition, a standard set of treatments is provided that are intended to improve the crossing for pedestrians and bicyclists. The design seeks to minimize shared space between bicyclists and vehicles, ideally to a single point where the motor vehicle turns across the bike lane and pedestrian crossing. The speed of each mode at this conflict point is controlled using geometric design techniques. Crossings are also offset from the physical corner to improve sight distance and decision time.

Where feasible, transition the bike lane buffer to a minimum of 6 feet wide as it approaches and departs the intersection. This allows space for a motorist to stop for bicyclists and pedestrians without blocking traffic, improves a motorist's view of approaching bicyclists by creating a crossing that is more perpendicular, and can potentially provide more time for all users to identify the point of conflict and react as needed (Exhibit 1310-32, #9).

Use corner islands to influence the speed of right-turning motor vehicles and reduce crossing distances for bicyclists and pedestrians, minimizing exposure to turning traffic (Exhibit 1310-32, #1). (See Section 1510.09(6)) Corner islands provide positive separation between motor vehicles and bicycles up to the point of crossing. Restricting right turn on red can also reduce inadvertent encounters between travel modes.

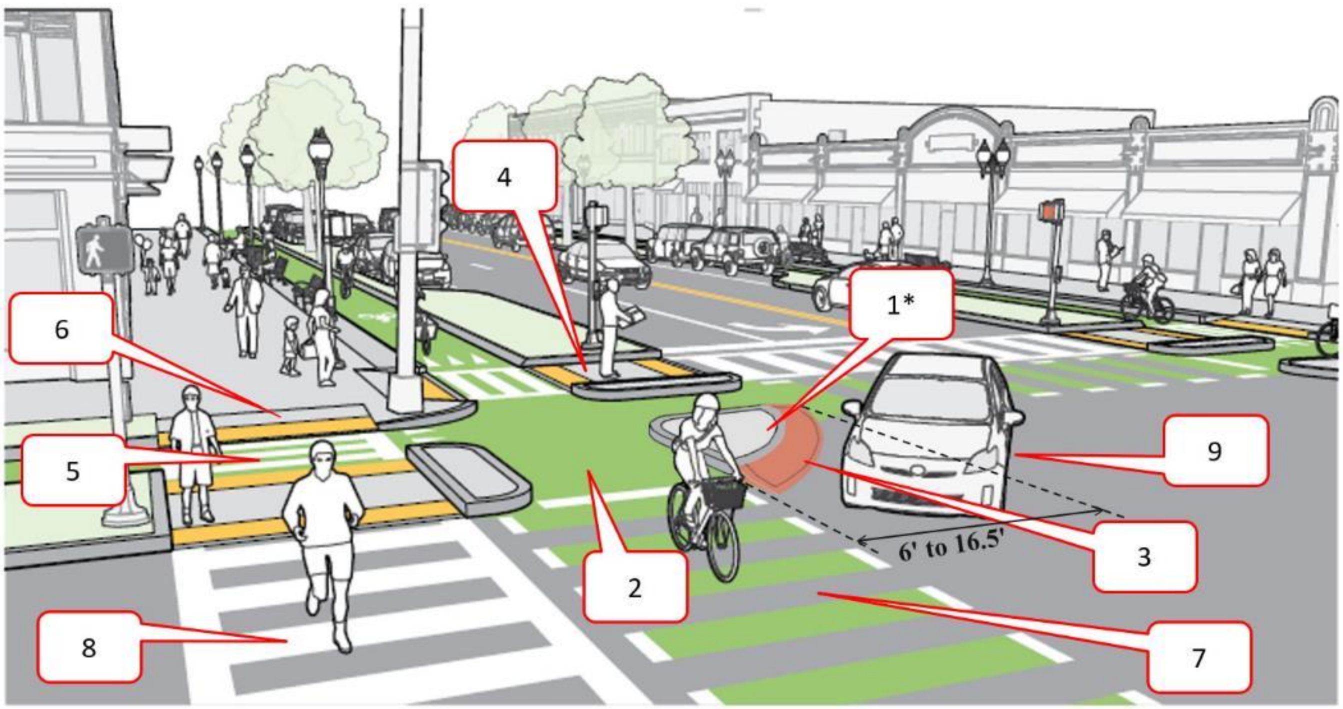
At locations where a small radius corner is desirable to control speeds of passenger vehicle traffic, but needs to accommodate occasional use by larger vehicles, mountable aprons may be used in conjunction with corner islands (Exhibit 1310-32, #3; see also Section 1510.09(6)).

At locations where there are sufficient buffer widths, such as streets with parking lanes, provide advance bicycle queuing areas (Exhibit 1310-32, #2) to improve visibility of cyclists and allow them to enter the intersection before turning motorists. These queue areas should be at least 6 feet long to fit a typical bicycle. At locations where advance queuing areas cannot be provided the bike lane stop bar should be placed ahead of the crosswalk on the approach.

Use delineator islands to separate bicycle and pedestrian crossings and help guide pedestrians to the crosswalk and curb ramps.

Design elements include:

Exhibit 1310-32 Protected Intersection Design Elements (from the AASHTO Bike Guide 2021 Draft)



1. Corner island minimizes the right-turn radius - this defines a path that encourages a lower vehicle turning speed (see Section 1510.09(6))
2. Bike queue area – to improve visibility and exclusive area for waiting to reduce conflict
3. Corner island truck apron (optional) – to accommodate a vehicle larger than the design vehicle
4. Pedestrian refuge island– to improve gap acceptance and comfort for pedestrians, shortens exposed crossing distance, and decreases conflict with bicyclists
5. Pedestrian crossing of the bike lane – to improve conspicuity and comfort for pedestrians
6. Pedestrian curb ramp – to meet ADA standards (see Chapter 1510)
7. Bicycle crossing of travel lanes – to indicate joint usage with motor vehicles and priority for bicycles
8. Pedestrian crossing of travel lanes - to indicate joint usage with motor vehicles and priority for pedestrians
9. Car in motorist yield zone – to provide a space for waiting to reduce conflicts with crossing pedestrians/bicyclists and through motorists

1310.04 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 Transportation Operations Division for additional information when designing signing and pavement markings.

1310.05 Intersection Plan for Approval

Provide Intersection Plans for Approval for any changes in capacity (such as 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; transit routes and stops; public meeting comments; etc. For information to be included on the intersection plan for approval, consult your region PFA checklist, or if your region does not have one, see the Plan for Approval Checklist on the following website: Design - Support | WSDOT (wa.gov)

1310.06 References

1310.06(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

Washington Administrative Code (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

1310.06(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

1310.06(3) Supporting Information

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

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