Washington State Department of Transportation

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Originating Organization

Environmental and Engineering Service Center, Design Office,
Design Policy, Standards, and Safety Research Unit through Engineering Publications

Remarks and Instructions

Remarks:

1. Division 1 chapters that are being deleted will be reorganized and rewritten for a future English revision.
2. Paper copies of this metric revision will not be distributed. They may be printed from the web.

Instructions:

Page numbers and corresponding sheet-counts are given in the table below to indicate portions of the *Design Manual* that are to be removed and inserted to accomplish this revision.

Chapter	Remove		Insert	
	Pages	Sheets	Pages	Sheets
Title Page	NA	1	NA	1
Foreword	i – ii	1	i – ii	1
Contents and Figures	1 – 23	12	1 – 23	12
100 “Manual Description”	1	1	0	0
110 “Nomenclature & References”	1 – 6	3	0	0
130 “Systems Data and Services”	1 – 2	1	0	0
140 “Program Development and Federal Aid Financing”	1 – 2	1	0	0
160 “General”	1 – 2	1	0	0
310 “Preliminary Studies”	1 – 8	4	0	0
325 “Design Matrix Procedures”	1 – 15	10	1 – 15	8
330 “Design Documentation, Approval, and Process Review”	1 – 17	9	1 – 14	7

Instructions continued on reverse >>

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Chapter	Remove		Insert	
	Pages	Sheets	Pages	Sheets
410 “Basic Design Level	1 – 2	1	1 – 2	1
430 “Modified Design Level”	1 – 11	6	1 – 11	6
440 “Full Design Level”	1 – 13	7	1 – 15	8
620 “Geometric Plan Elements”	1 – 2	1	1 – 2	1
630 “Geometric Profile Elements”	1 – 2	1	1 – 2	1
640 “Geometric Cross Section”	1 – 42	21	1 – 42	21
650 “Sight Distance”	9	1	9	1
700 “Roadside Safety”	1 – 6	3	1 – 6	3
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1130 “Retaining Walls and Steep Reinforced Slopes”	1 – 14	7	1 – 14	7
1210 “Hydraulic Design”	1 – 2	1	1 – 2	1
1440 “Surveying and Mapping”	1 – 2	1	1 – 2	1
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Washington State Department of Transportation

Design Manual Supplements and Instructional Letters

May 2001

In Effect	Chapter	Date	Type	Subject/Title
Yes	150	01/18/99	IL 4015.00	Right of Way Plan Development Process Improvements
No	330			(Chapter 330 revised June 1999)
No	1410			(Chapter 1410 revised June 1999)
Yes	1050 940 HOV*	9/28/99	DM Supplement	Left-Side HOV Direct Access Connections
Yes	1050 HOV*	05/03/00	DM Supplement	Left-Side HOV Parallel On-Connection
Yes	915	07/03/00	IL 4019.01	Roundabouts

* The *HOV Direct Access Design Guide*, Draft M 22-98

Notes:

- Changes since the last revision to the *Design Manual* are shown in bold print.
- Items with **No** in the **In Effect** column were superseded by the latest revision and will be dropped from the next printing of this list.
- The listed items marked *yes* have been posted to the web at the following location:

`http://www.wsdot.wa.gov/fasc/engineeringpublications/DesignLettersMemoInstruction.htm`

Design Manual

M 22-01

Metric

Washington State Department of Transportation
Environmental and Engineering Service Center
Design Office

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Foreword

This *Design Manual* is a guide for our engineering personnel. It provides policies, procedures, and methods for developing and documenting the design of improvements to the transportation network in Washington State.

The manual supplements the engineering analyses and judgment that must be applied to improvement and preservation projects. It provides uniform procedures for documenting and implementing design decisions.

The designer must understand that the design environment changes rapidly, and often without warning to the practitioner. To track every change, and to make improvements based upon each, is not feasible. The intent of this manual is to provide a range of recommended values for critical dimensions. Flexibility is permitted to encourage independent design that is tailored to particular situations.

The fact that new design guidelines are added to the *Design Manual* through the revision process does not imply that existing features are deficient or inherently dangerous. Nor does it suggest or mandate immediate engineering review or initiation of new projects.

Cost-effective and environmentally conscious design is emphasized, and consideration of the use of the highway corridor by transit, pedestrians, and bicyclists is included. Designers are encouraged to view the highway corridor beyond the vehicular movement context. To accommodate multimodal use, the guidance provided for one mode is to be appropriately adapted, as needed, at a specific location. The movement of people, distribution of goods, and provision of services are thereby emphasized.

The complexity of transportation design requires the designer to make fundamental tradeoff decisions that balance competing considerations. Although weighing these considerations adds to the complexity of design, it accounts for the needs of a particular project and the relative priorities of various projects and programs. Improvements must necessarily be designed and prioritized in light of finite transportation funding.

Updating the manual is a continuing process, and revisions are issued periodically. Questions, observations, and recommendations are invited. Page iii is provided to encourage comments and to assure their prompt delivery. For clarification of the content of the manual, contact the Design Office in the Olympia Service Center. The e-mail address is DesignManual@wsdot.wa.gov.

Clifford E. Mansfield, P.E.
State Design Engineer

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325.01 General

This highway *Design Manual* provides guidance for three levels of design for highway projects: the basic, modified, and full design levels. The design matrices in this chapter are used to identify the design level(s) for a project and the associated processes and approval authority for allowing design variances. The matrices address the majority of preservation and improvement projects and focus on those design elements that are of greatest concern in project development.

The design matrices are five tables that are identified by route type. Two of the matrices apply to Interstate highways. The other three matrices apply to preservation and improvement projects on non-Interstate highways.

325.02 Terminology

The **National Highway System (NHS)** consists of highways designated as a part of the Interstate System, other urban and rural principal arterials, and highways that provide motor vehicle access to facilities such as and a major port, airport, public transportation facility, or other intermodal transportation facility. The NHS includes a highway network that is important to the United States strategic defense policy and provides defense access, continuity, and emergency capabilities for the movement of personnel, materials, and equipment during times of war and peace. It also includes major network connectors that provide motor vehicle access between major military installations and other highways that are part of the strategic highway network.

The **Preventive Maintenance** mentioned under project type on Interstate Design Matrices 1 and 2 includes roadway work such as pavement patching; restoration of drainage system; panel replacement; joint and shoulder repair; and bridge work such as crack sealing, joint repair, seismic retrofit, scour countermeasures and painting. Preventive maintenance projects must not degrade any existing safety or geometric aspects of the facility.

In Design Matrices 1 and 2 and in Figure 330-1, the term ***New/Reconstruction*** includes the following types of work:

- Capacity changes: add a through lane, convert a general purpose (GP) lane to a special purpose lane (such as an HOV lane), or convert a high occupancy vehicle (HOV) lane to GP.
- Other lane changes: add or eliminate a collector-distributor or auxiliary lane. (A rural truck climbing lane that, for its entire length, meets the warrants in Chapter 1010 is not considered new/reconstruction.)
- Pavement reconstruction: full depth PCC or AC pavement replacement.
- New interchange
- Changes in interchange type such as diamond to directional
- New or replacement bridge (main line)

The **HAL, HAC, PAL, and Risk location** mentioned in the notes on Design Matrices 3, 4, and 5 are high accident locations (HAL), high accident corridors (HAC), pedestrian accident locations (PAL), and locations that have a high probability of run-off-the-road accidents based on existing geometrics (Risk).

The **Non-Interstate Freeway** mentioned on Design Matrices 3, 4, and 5 is multilane, divided highway with full access control.

The **Master Plan for Access Control** mentioned in the notes on Design Matrices 3, 4, and 5 is available from the Olympia Service Center, Design Office, Access and Hearings Unit.

The **corridor or project analysis** mentioned in notes 2 and 4 (on Design Matrices 3, 4, and 5) is the justification needed to support a change in design level from the indicated level. The analysis can be based on route continuity, and other existing features, as well as the recommendations for future improvements in an approved Route Development Plan.

(1) Project Types

Diamond Grinding is grinding a concrete pavement to remove surface wear or joint faulting.

Milling with AC Inlays is removal of a specified thickness of asphalt surfacing, typically from the traveled lanes, and then overlaying with asphalt concrete at the same specified thickness.

Nonstructural Overlay is an asphalt concrete pavement overlay that is placed to minimize the aging effects and minor surface irregularities of the existing asphalt concrete pavement structure. The existing pavement structure is not showing extensive signs of fatigue (longitudinal or alligator cracking in the wheel paths). Nonstructural overlays are typically less than 40 mm thick.

AC Structural Overlay is an asphalt concrete pavement overlay that is placed to increase the load carrying ability of the pavement structure. Structural overlay thickness is greater than or equal to 40 mm.

PCC Overlay is a Portland cement concrete pavement overlay of an existing PCC or AC pavement.

Dowel Bar Retrofit is re-establishing the load transfer efficiencies of the existing concrete joints and transverse cracks by the cutting of slots, placement of epoxy coated dowel bars, and placement of high-early strength, non-shrink concrete.

Bridge Deck Rehabilitation is repair of any delaminated concrete bridge deck and adding a protective overlay that will prevent further corrosion of the reinforcing steel.

Safety, All Others includes collision reduction, collision prevention, channelization, and signalization projects.

Safety, At Grade is a project on a multilane highway to build grade separation facilities that replace the existing intersection.

Bridge Restriction projects are listed under economic development because these bridges do not have any structural problems. However, if the vertical or load capacity restrictions are removed, then it will benefit the movement of commerce.

(2) Design Elements

The following elements are shown on the Design Matrices. If the full design level applies, see the chapters listed below. If basic design level applies, see Chapter 410. If the modified design level applies, see Chapter 430.

Horizontal Alignment is the horizontal attributes of the roadway including horizontal curvature, superelevation, and stopping sight distance; all based on design speed. (See Chapter 620 for horizontal alignment, Chapter 640 for superelevation, Chapter 650 for stopping sight distance, and Chapter 440 for design speed.)

Vertical Alignment is the vertical attributes of the roadway including vertical curvature, profile grades, and stopping sight distance; all based on design speed. (See Chapter 630 for vertical alignment, Chapters 440 and 630 for grades, Chapter 650 for stopping sight distance, and Chapter 440 for design speed.)

Lane Width is the distance between lane lines. (See Chapter 640.)

Shoulder Width is the distance between the outside or inside edge line and the edge of in-slope, or face of barrier. (See Chapter 640.)

Lane and Shoulder Taper (pavement transitions) are the rate and length of transition of changes in width of roadway surface. (See Chapters 440 and 620.)

Median Width is the distance between inside edge lines. (See Chapters 440 and 640.)

Cross Slope, Lane is the rate of elevation change across a lane. This element includes the algebraic difference in cross slope between adjacent lanes. (See Chapter 640.)

Cross Slope, Shoulder is the rate of elevation change across a shoulder. (See Chapter 640.)

On/Off Connection is the widened portion of the main line beyond the ramp terminal. (See Chapter 940.)

Fill/Ditch Slope is downward slope from edge of shoulder to bottom of ditch or catch. (See Chapter 640.)

Access is means of entering or leaving a public street or highway from an abutting private property or another public street or highway. (See Chapter 1420.)

Clear Zone is the total roadside border area, starting at the edge of the traveled way, available for use by errant vehicles. This area may consist of a shoulder, a recoverable slope, a nonrecoverable slope, and/or a clear run-out area. (See Chapter 700.)

Signing, Delineation, Illumination are signs, guide posts, pavement markings, and lighting. (See Chapter 820 for signing, Chapter 830 for delineation, and Chapter 840 for illumination.)

Basic Safety is the safety items listed in Chapter 410.

Bridge Lane Width is the distance between lane lines on a structure. (See Chapters 440, 640 and 1120.)

Bridge Shoulder Width is the distance between outside or inside edge line and face of curb or barrier, whichever is less. (See Chapters 440, 640 and 1120.)

Bridge Vertical Clearance is the minimum height between the roadway including shoulder and an overhead obstruction. (See Chapter 1120.)

Bridge Structural Capacity is the load bearing ability of a structure. (See Chapters 440 and 1120.)

Intersections Turning Radii See Chapter 910 for definition.

Intersections Angle See Chapter 910 for definition.

Intersections Sight Distance See Chapter 910 for definition.

Barriers Terminals and Transitions Section — **Terminals** are crashworthy end treatment for longitudinal barriers that is designed to reduce the potential for spearing, vaulting, rolling, or excessive deceleration of impacting vehicles from either direction of travel. Impact attenuators are considered terminals and beam guardrail terminals include anchorage. — **Transitions** are sections of barriers used to produce a gradual stiffening of a flexible or semi-rigid barrier as it connects to a more rigid barrier or fixed objects. (See Chapter 710 and 720.)

Barriers Standard Run are guardrail and other barriers excluding terminals, transitions, attenuators, and bridge rails. (See Chapter 710.)

Barriers Bridge Rail is barrier on a bridge excluding transitions. (See Chapter 710.)

325.03 Design Matrix Procedures

When scoping, or designing a project, the following steps are used to select and apply the design matrix. Each step is further explained in this chapter.

- *Select a design matrix* by identifying the route: Interstate, NHS, or non-NHS
- Within the design matrix: for Matrices 1 and 2 *select the row* by the type of work and for Matrices 3, 4 and 5 *select the row* by identifying the project type
- *Use the design matrix* to determine the design level for the design elements of the project. Apply the appropriate design levels and document the design decisions as required by this chapter and Chapter 330.

325.04 Selecting a Design Matrix

Selection of a design matrix is based on highway system (Interstate, non-NHS and other NHS) and location (main line, interchange). (See Figure 325-1.) Figures 325-2a and 2b provide a list of NHS highways in the state of Washington. The design matrices are shown in Figures 325-4 through 325-8. Follow *Design Manual* guidance for all projects except as noted in the design matrices and elsewhere as applicable.

Route	Project	
	Main Line	**Interchange Area**
Interstate	Matrix 1	Matrix 2
NHS	Matrix 3	Matrix 4
Non-NHS	Matrix 5	Matrix 4

Design Matrix Selection Guide
Figure 325-1

325.05 Project Type

In the design matrices, row selection is based on project type or type of work. The Project Summary defines and describes the project. (Project Summary is discussed in Chapter 330.) For non-NHS and NHS routes, the project's program/subprogram might be sufficient information for identifying project type.

For project types not listed in the design matrices, consult the OSC Design Office for guidance.

See Figures 325-3a through 3c for program and subprogram titles and definitions. The various sources of funds for these subprograms carry eligibility requirements that the designers and program managers must identify and monitor throughout project development — especially if the type of work changes — to ensure accuracy when writing agreements and to avoid delaying advertisement for bids.

Some projects involve work from several subprograms. In such cases, identify the various limits of the project that apply to each subprogram. Where the project limits overlap, apply the higher design level to the overlapping portion.

325.06 Using a Design Matrix

The column headings on a design matrix are **design elements.** They are based on the following thirteen FHWA controlling design criteria: design speed, lane width, shoulder width, bridge width, structural capacity, horizontal alignment, vertical alignment, grade, stopping sight distance, cross slope, superelevation, vertical clearance, and horizontal clearance. For the column headings, some of these controlling criteria have been combined (for example, design speed is part of horizontal and vertical alignment).

For Improvement type projects, full design level applies to all design elements except as noted in design matrices and in *Design Manual* chapters as applicable.

A **blank cell** on a design matrix signifies that the design element will not be addressed because it is beyond the scope of the project.

(1) Design Levels

In the Interstate matrices, full design level applies unless otherwise noted.

In the non-Interstate matrices, design levels are noted in the cells by B, M, F, and a number corresponding to a footnote on the matrix.

The design levels of basic, modified, and full (B, M, and F) were used to develop the design matrices. Each design level is based on the investment intended for the route type and type of work. (For example, the investment is higher for Interstate reconstruction than for an overlay on a non-NHS route.)

Basic design level (B) preserves pavement structures, extends pavement service life, and maintains safe operations of the highway. See Chapter 410.

Modified design level (M) preserves and improves existing roadway geometrics, safety, and operational elements. See Chapter 430.

Full design level (F) improves roadway geometrics, safety, and operational elements. See Chapter 440 and other applicable *Design Manual* chapters for design guidance.

(2) Design Variances

Types of design variances are design exceptions (DE), evaluate upgrades (EU), and deviations.

Design exception (DE) in a matrix cell indicates an existing condition that is not standard, relative to the current design level. The condition will not be corrected unless a need has been identified in the Highway System Plan and prioritized in accordance with the programming process. A design exception must be identified in the project documents but no further justification is required.

Evaluate upgrade (EU) in a matrix cell indicates that an existing nonstandard condition must be evaluated to determine the impacts and cost effectiveness of upgrading to the applicable design level. The decision whether or not to upgrade, and its analyses and justification, must be provided in the project documentation. See Chapter 330.

A **deviation** is required when an existing or proposed design element does not meet or exceed the applicable design level for the project and neither DE nor EU processing is indicated. Documentation of a deviation must contain justification and it must be approved at the appropriate approval level. The analyses and justification must be provided in the deviation request. See Chapter 330 for requirements.

P65:DP/DMM

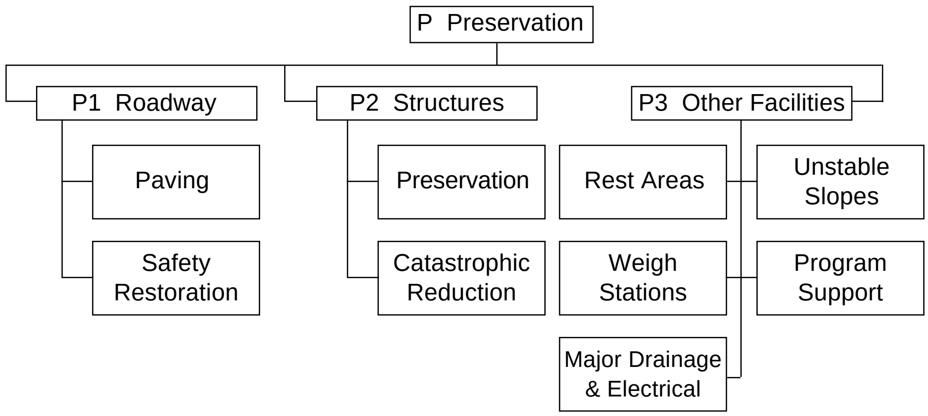
State Route	NHS Route Designation	Beginning SR MP	Begin ARM	Ending SR MP	End ARM
US 2	I-5 to Idaho State Line	0.00	0.00	334.51	326.64
US 2 Couplet	Everett Couplet	0.00	0.00	1.64	0.87
US 2 Couplet	Brown Street Couplet	287.45	0.00	288.08	0.63
US 2 Couplet	Division Street Couplet	289.19	0.00	290.72	1.53
SR 3	SR 101 to SR 104	0.00	0.00	60.02	59.81
SR 4	SR 101 to I-5	0.00	0.00	62.28	62.27
I-5	Oregon State Line to Canadian Border	0.00	0.00	276.56	276.62
SR 8	SR 12 to SR 101	0.00	0.00	20.67	20.67
SR 9	SR 539 to Canadian Border	93.61	93.52	98.17	98.08
SR 9 Spur	Sumas Spur	98.00	0.00	98.25	0.24
SR 11	I-5 to Alaskan Ferry Terminal	19.93	19.93	21.28	21.28
US 12	SR 101 to Idaho State Line	0.00	0.00	434.19	430.76
US 12 Couplet	Aberdeen Couplet	0.33	0.00	0.68	0.35
SR 14	I-5 to SR 97	0.00	0.00	101.02	100.93
SR 14 Spur	Maryhill Spur	100.66	0.00	101.05	0.39
SR 16	I-5 to SR 3	0.00	0.00	29.19	27.01
SR 16 Spur	SR 16 to SR 3	28.74	0.00	29.13	0.39
SR 17	SR 395 to I-90	7.43	0.00	50.89	43.40
SR 18	So. Federal Way Park & Ride to I-5	2.20B	0.00	0.00	0.53
SR 18	I-5 to I-90	0.00	0.53	27.91	28.41
SR 20	SR 101 to I-5	0.00	0.00	59.54	59.49
SR 20 Spur	SR 20 to San Juan Ferry	47.89	0.00	55.67	7.78
SR 22	SR 97 to I-82	0.70	0.00	4.00	3.31
SR 26	I-90 to US 195	0.00	0.00	133.53	133.61
SR 26 Spur	SR 26 to US 195	133.44	0.00	133.51	0.07
SR 28	SR 2 to SR 281	0.00B	0.00	29.77	33.91
I-82	I-90 to Oregon State Line	0.00	0.00	132.60	132.57
I-90	I-5 to Idaho State Line	1.94	0.00	299.82	297.52
I-90 Reverse Lane	Reversible lane	1.99	0.00	9.44	7.45
SR 96	McCollum Park and Ride to I-5	0.00	0.00	0.52	0.52
US 97	Oregon State Line to SR 22	0.00B	0.00	61.44	61.30
US 97	I-90 to Canadian Border	133.90	118.80	336.48	321.62
US 97 Couplet	Maryhill Couplet	2.59	0.00	2.68	0.09
US 97 Spur	SR 97 to SR 2 (Orondo)	213.36	0.00	213.62	0.26
US 97 Y	SR 970 to SR 97				
SR 99	188th to SeaTac Airport	18.35	14.70	18.77	15.12
SR 99	SR 509 to SR 104	26.04	22.40	43.60	39.84
US 101	Oregon State Line to SR 401	0.00	0.00	0.46	0.46
US 101	SR 4 to I-5	28.89	28.89	367.41	365.78
US 101 Couplet	Aberdeen Couplet	87.49	0.00	91.66	4.17
US 101 Couplet	Port Angeles Couplet	249.65	0.00	251.32	1.67
SR 104	SR 101 to I-5	0.20	0.00	29.67	29.14
SR 109	Pacific Beach Access	0.00	0.00	30.25	30.29
SR 125	Oregon State Line to SR 12	0.00	0.00	6.09	6.08
SR 125 Spur	SR 125 to SR 12	6.09	0.00	6.76	0.67
SR 127	SR 12 to SR 26	0.03	0.00	27.05	27.05
SR 128	SR 12 to Idaho State Line	0.00	0.00	2.30	2.30
This list provided by the OSC Planning Office					

NHS Highways in Washington
Figure 325-2a

State Route	NHS Route Designation	Beginning SR MP	Begin ARM	Ending SR MP	End ARM
SR 166	Naval Fuel Depot	0.02	0.00	3.40	3.38
SR 167	I-5 to I-405	0.00	0.00	27.28	28.60
I-182	I-82 to US 395	0.00	0.00	15.19	15.19
US 195	Idaho State Line to I-90	0.00B	0.00	95.99	93.37
US 195 Spur	US 195 to Idaho State Line	0.06	0.00	0.60	0.54
I-205	Oregon State Line to I-5	26.59	0.00	37.16	10.57
SR 240	Hanford Access	30.63	28.86	34.87	33.10
SR 270	SR 195 to Idaho	0.00	0.00	9.89	9.89
SR 270	Pullman Couplet	2.67	0.00	2.90	0.23
SR 270	SR 195 Y Connection	0.00	0.00	0.38	0.38
SR 281	SR 28 to I-90	0.00	0.00	10.55	10.55
SR 281 Spur	SR 281 to I-90	2.65	0.00	4.34	1.69
SR 303	SR 3 to SR 304	0.00B	0.00	8.73	8.89
SR 304	SR 16 to Bremerton Ferry	0.00	0.00	3.51	3.24
SR 305	SR 3 to Winslow Ferry	0.02	0.00	13.52	13.50
SR 307	SR 305 to SR 104	0.00	0.00	5.25	5.25
SR 310	SR 3 to SR 304	0.00	0.00	1.84	1.84
US 395	Congressional High Priority Route	13.05	13.05	270.26	275.09
SR 401	SR 101 to SR 4	0.00	0.00	12.13	12.13
I-405	I-5 to I-5	0.00	0.00	30.32	30.30
SR 432	SR 4 to I-5	0.00	0.00	10.33	10.32
SR 433	Oregon State Line to SR 432	0.00	0.00	0.94	0.94
SR 500	I-5 to SR 503	0.00	0.00	5.96	5.96
SR 501	I-5 to Port of Vancouver	0.00	0.00	3.83	3.42
SR 502	I-5 to SR 503	0.00B	0.00	7.56	7.58
SR 503	SR 500 to SR 502	0.00	0.00	8.09	8.09
SR 509	SR 99 to 12th Place S	24.35B	26.13	29.83	33.11
SR 509	Pacific Ave. to Marine View Drive	0.22	1.44	3.20	4.42
SR 512	I-5 to SR 167	0.00	0.00	12.06	12.06
SR 513	Sandpoint Naval Air Station	0.00	0.00	3.35	3.35
SR 516	I-5 to SR 167	2.03	2.02	4.72	4.99
SR 518	I-5 to SR 509	0.00	0.00	3.81	3.42
SR 519	I-5 to Seattle Ferry Terminal	0.00	0.00	1.14	1.14
SR 520	I-5 to SR 202	0.00	0.00	12.83	12.82
SR 522	I-5 to SR 2	0.00	0.00	24.68	24.68
SR 524	Lynnwood Park and Ride to I-5	4.64	4.76	5.20	5.32
SR 524 Spur	Cedar Way Spur - Lynnwood Park and Ride to I-5	4.64	0.00	5.14	0.50
SR 525	I-5 to SR 20	0.00	0.00	30.49	30.72
SR 526	SR 525 to I-5	0.00	0.00	4.52	4.52
SR 529	Everett Homeport	0.00	0.00	2.20	2.20
SR 539	I-5 to Canadian Border	0.00	0.00	15.16	15.16
SR 543	I-5 to Canadian Border	0.00	0.00	1.09	1.09
SR 546	SR 539 to Canadian Border	0.00	0.00	8.02	8.02
I-705	I-5 to Schuster Parkway	0.00	0.00	1.50	1.50
SR 970	I-90 to SR 97	0.00	0.00	10.31	10.31
SR 970 Y	Y connection to US 97	0.00	0.00	0.10	0.10
This list provided by the OSC Planning Office					

NHS Highways in Washington (continued)
Figure 325-2b

Highway Capital Preservation Program



P **Preservation** — Preserve the highway infrastructure cost effectively to protect the public investment.

P1 Roadway

1. Repave highways at regular intervals to minimize long-term costs.
2. Restore existing safety features.

P2 Structures

1. Rehabilitate or replace existing bridges and other structures to preserve operational and structural integrity.
2. Reduce the risk of naturally caused catastrophic bridge failures.

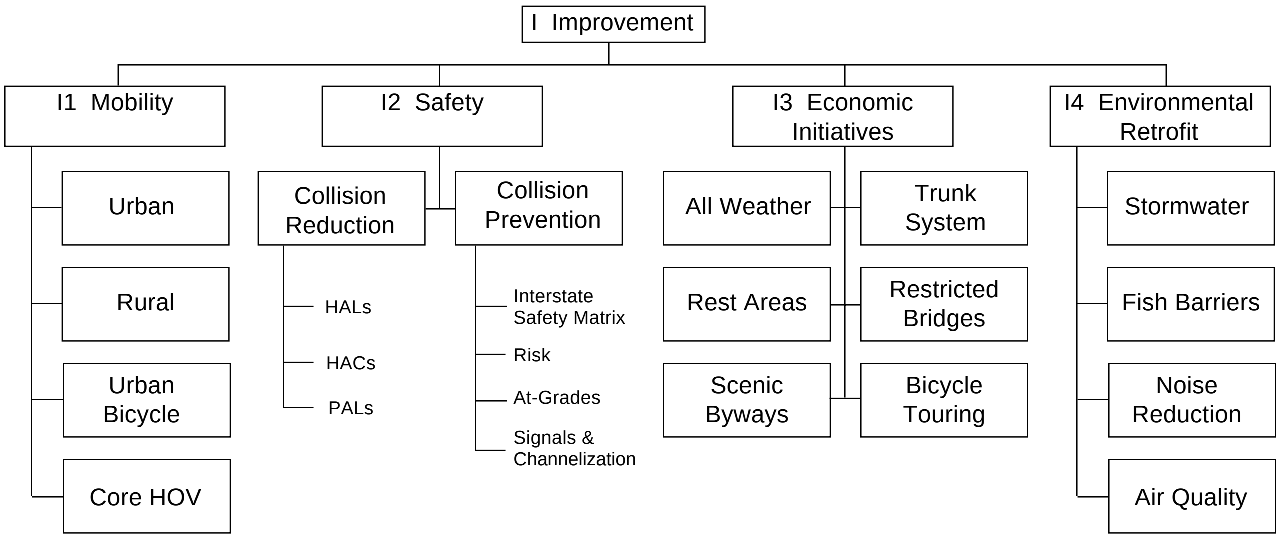
P3 Other Facilities

1. Refurbish rest areas to extend service life and improve safety.
2. Construct weigh facilities to ensure enforcement across the entire highway system.
3. Refurbish electrical systems, electronics, and mechanical systems to extend service life and improve safety. Rehabilitate or replace existing major drainage features to preserve operational and structural integrity.
4. Stabilize known unstable slopes.
5. The program support subcategory consists of critical construction support items that are required to maintain efficiency and ensure continued progress of the construction programs.

Paraphrased excerpt from the *State Highway System Plan*, State Highway System Plan Service Objectives and Action Strategies.

Preservation Program
Figure 325-3a

Highway Capital Improvement Program



I Improvement

I1 Mobility — Improve mobility within congested highway corridors.

1. Mitigate congestion on urban highways in cooperation with local and regional jurisdictions when the peak period level of service falls below Level of Service D.
2. Provide uncongested condition (Level of Service C) on rural highways.
3. Provide bicycle connections along or across state highways within urban growth areas to complete local bicycle networks.
4. Complete the Freeway Core HOV Lane System in the Puget Sound region.
5. Provide uncongested conditions (Level of Service C) on high occupying vehicle (HOV) lanes.

I2 Safety — Provide the safest possible highways within available resources.

1. Improve highway sections that have a high accident history.
2. Improve geometrics of the Interstate System per the Federal Highway Administration (FHWA)/WSDOT Stewardship Agreement.
3. Improve roadways where geometrics, traffic volumes, and speed limits indicate a high accident potential.
4. Eliminate major at-grade intersections on multilane highways with speed limits of 45 mph or higher.
5. Construct intersection channelization, signals, or both when traffic volume warrants (thresholds) are met.

Paraphrased excerpt from the *State Highway System Plan*, State Highway System Plan Service Objectives and Action Strategies.

Improvement Program
Figure 325-3b

I3 Economic Initiatives — Support efficient and reliable freight movement on state highways. Support tourism development and other Washington industries.

1. Upgrade state highways on the Freight and Goods Transportation System (FGTS) to have an all-weather surface capable of supporting legal loads year-round
2. Provide four-lane limited access facilities on a trunk system consisting of all FGTS highways with a T-1 classification (truck travel exceeding 10,000,000 tons per year).
3. Ensure public access to appropriately sized, rest room equipped facilities every 60 miles on the NHS and Scenic & Recreational (S & R) highways.
4. Where cost effective, replace or modify structures on the Interstate System with restricted vertical clearance.
5. Where cost effective, replace or modify structures that cannot carry legal overloads.
6. Cooperatively promote and interpret the heritage resources along S & R highways, including providing incentives for alternatives to outdoor advertising.
7. On rural bicycle touring routes, provide a minimum of 1.2 m shoulders (structures are not included).

I4 Environmental Retrofit — Retrofit state highway facilities as appropriate to reduce existing environmental impacts.

1. Reconstruct storm water discharge facilities as opportunities arise.
2. Remove identified fish passage barriers.
3. Reduce the public's exposure to noise from state highway facilities where local land use authorities have adopted development regulations which reduce future exposure to excessive noise levels near highway facilities.
4. Implement the WSDOT Transportation Control Measures required by the Statewide Implementation Plan for Air Quality.

Paraphrased excerpt from the *State Highway System Plan,* State Highway System Plan Service Objectives and Action Strategies

Improvement Program (continued)
Figure 325-3c

✍ Project Type														Bridges			Barriers		
Design Elements ✍	Horiz. Align.	Vert. Align.	Lane Width	Shldr Width (13)	On/Off Conn't.	Median Width	Cross Slope Lane	Cross Slope Shldr	Fill/Ditch Slopes	Clear Zone	Sign. (10)	Delini. (9)	Illumin.	Vert. Clear. (11)	Lane Width	Shldr Width	Structural Capacity	Term. & Trans. Section (12)	Std Run	Bridge Rail (14)
(1-1) Preventive Maintenance																				
Pavement Restoration																				
(1-2) Diamond Grinding										EU	EU	F		DE				F	EU	F
(1-3) Milling with ACP Inlays									EU	F	EU	F		DE				F	EU	F
(1-4) Nonstructural Overlay				DE			EU	EU	EU	F	EU	F		EU				F	F	F
Pavement Rehab./Resurf.																				
(1-5) ACP Structural Overlays	EU	DE	F	F	F	DE	F	EU	F	F	EU	F	F	F	F	DE		F	F	F
(1-6) PCCP Overlays	EU	DE	F	F	F	DE	F	EU	F	F	EU	F	F	F	F	DE		F	F	F
(1-7) Dowel Bar Retrofit	EU	DE	F	F	F	DE	DE		F	F	EU	F	F	DE		DE		F	F	F
Bridge Rehabilitation																				
(1-8) Bridge Deck Rehabilitation												F		F	F	DE	(11)	F (6)		F
Reconstruction (16)																				
(1-9) New/Reconstruction	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F

☐ Not Applicable
F Full design level
M Modified design level. See Chapter 430.
DE Design Exception to full design level.
EU Evaluate Upgrade to full design level.

(6) Applies only to bridge end terminals and transition sections.
(9) Continuous shoulder rumble strips required in rural areas. See Chapter 700.
(10) See Chapter 820.
(11) See Chapter 1120.
(12) Impact attenuators are considered as terminals.
(13) See Chapter 440 and 640.
(14) Includes crossroad bridge rail.
(16) For design elements not in the matrix headings, apply full design level as found in the applicable *Design Manual* chapters.

Design Matrix 1
Non-Interstate Interchange Areas
Figure 325-4

✍ Project Type	Ramps and Collector Distributors																			Cross Road										
														Ramp Terminals			Barriers											Barriers		
Design Elements ✍	Horiz. Align.	Vert. Align.	Lane Width	Shldr Width	Lane & Shldr. Taper	On/Off Conn't.	Cross Slope Lane	Cross Slope Shldr	Fill/ Ditch Slopes	Limited Access	Clear Zone	Vertical Clear. (11)	Sign., Del., Illumin.	Turn Radii	Angle	I/S Sight Dist.	Term. & Trans. Section (12)	Std Run	Bridge Rail	Lane Width	Shldr Width	Vert. Clear.	Ped. & Bike	Limited Access	Fill/ Ditch Slopes	Clear Zone	Sign., Del., Illumin.	Term. & Trans. Section (12)	Std . Run	Bridge Rail
(2-1) Preventive Maintenance																														
Pavement Restoration																														
(2-2) Diamond Grinding											EU		F (15)				F	EU	F							EU	F (15)	F	EU	F
(2-3) Milling with ACP Inlays									EU		F	F	F (15)				F	F	F						EU	F	F (15)	F	F	F
(2-4) Nonstructural Overlay							EU	EU	EU		F	F	F (15)				F	F	F						EU	F	F (15)	F	F	F
Pavement Rehab./Resurf.																														
(2-5) ACP Structural Overlays	EU	DE	F	F	F	F	F	EU	F	F	F	F	F (15)	F	F	F	F	F	F	DE	DE	F	DE	F	DE	F	F (15)	F	F	F
(2-6) PCCP Overlays	EU	DE	F	F	F	F	F	EU	F	F	F	F	F (15)	F	F	F	F	F	F	DE	DE	F	DE	F	DE	F	F (15)	F	F	F
(2-7) Dowel Bar Retrofit	DE		DE	DE	F	F	DE		F	F	F	DE	F (15)	F	F	F	F	F	F					F			F (15)	F	F	F
Bridge Rehabilitation																														
(2-8) Bridge Deck Rehabilitation												F					F (6)		F			F						F (6)		F
Reconstruction (16)																														
(2-9) New/Reconstruction	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F

☐ Not Applicable
F Full design level
M Modified design level. See Chapter 430.
DE Design Exception to full design level.
EU Evaluate Upgrade to full design level.

(6) Applies only to bridge end terminals and transition sections.
(10) See Chapter 820.
(11) See Chapter 1120.
(12) Impact attenuators are considered as terminals.
(15) EU for signing and illumination.
(16) For design elements not in the matrix headings, apply full design level as found in the applicable *Design Manual* chapters.

Design Matrix 2
Non-Interstate Interchange Areas
Figure 325-5

✍ Project Type															BRIDGES				INTERSECTIONS			BARRIERS		
Design Elements ✍	Horiz. Align.	Vert. Align.	Lane Width	Shldr Width	Lane & Shldr Taper	Median Width	Cross Slope Lane	Cross Slope Shldr	On/Off Conn.	Fill/ Ditch Slopes	Access (3)	Clear Zone	Sign., Del., Illumin.	Basic Safety	Lane Width	Shldr Width	Vertical Clear-ance	Structural Capacity	Turn Radii	Angle	Sight Dist.	Term. & Trans. Section (12)	Std Run	Bridge Rail
Preservation																								
Roadway																								
(3-1) Non-Interstate Freeway	DE/F	DE/F	DE/F	DE/F	DE/F	DE/F	DE/F	DE/F	DE/F	DE/F	DE/F		B	B	DE/F	DE/F	F					B	B	F
(3-2) ACP/PCCP/BST Overlays	DE/M	DE/M	DE/M	DE/M	DE/F	DE/M	DE/M	DE/M	DE/F	DE/M			B	B	DE/M	DE/M	F				B	B	B	F
(3-3) Repl. ACP w/ PCCP at I/S	DE/M	DE/M	EU/M	EU/M	DE/F	DE/M	EU/M	DE/M		DE/M			B	B	DE/M	DE/M	F				B	B	B	F
Structures																								
(3-4) Bridge Replacement	F (2)	F (2)	F (2)	F (2)	F	F (2)	F (2)	F (2)	F (2)	F (2)		F	F		F (2)	F (2)	F	F (11)	F (2)	F (2)	F	F	F	F
(3-5) Bridge Deck Rehab.													B	B			F					B (6)		F
Improvements (16)																								
Mobility																								
(3-6) Non-Interstate Freeway	F	F	F	F	F	F	F	F	F	F	F	F	F		F	F	F	F (11)	F	F	F	F	F	F
(3-7) Urban	F (2)	F (2)	F (2)	F (2)	F	F (2)	F (2)	F (2)	F (2)	F (2)	F	F	F		F (2)	F (2)	F	F (11)	F (2)	F (2)	F	F	F	F
(3-8) Rural	F (2)	F (2)	F (2)	F (2)	F	F (2)	F (2)	F (2)	F (2)	F (2)	F	F	F		F (2)	F (2)	F	F (11)	F (2)	F (2)	F	F	F	F
(3-9) HOV	F (2)	F (2)	F (2)	F (2)	F	F (2)	F (2)	F (2)	F (2)	F (2)	F	F	F		F (2)	F (2)	F	F (11)	F (2)	F (2)	F	F	F	F
(3-10) Bike/Ped. Connectivity	(5)	(5)	(5)	(5)	(5)		(5)	(5)		(5)	(5)	(5)	(5)		(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)
Safety																								
(3-11) Non-Interstate Freeway	F	F	F	F	F	F	F	F	F	F	F	F	F		F	F	F		F	F	F	F	F	F
(3-12) All Others (1)	M (4)	M (4)	M (4)	M (4)	F	M (4)	M (4)	M (4)	M (4)	M (4)	EU/F	F	F		M (4)	M (4)	F		M (4)	M (4)	F	F	F	F
Economic Development																								
(3-13) Freight & Goods (Frost Free) (8)	F (2)	F (2)	F (2)	F (2)	F	F (2)	F (2)	F (2)	F (2)	F (2)	EU/F	F	B		DE/F	DE/F	F	F (11)	EU/F	EU/F	EU/F	F	F	F
(3-14) 4-Lane Trunk System	F	F	F	F	F	F	F	F	F	F	F	F	F		F	F	F	F (11)	F	F	F	F	F	F
(3-15) Rest Areas (New)	F	F	F	F	F	F	F	F	F	F	F	F	F		F	F	F	F (11)	F	F	F	F	F	F
(3-16) Bridge Restrictions	F (2)	F (2)	F (2)	F (2)	F	F (2)	F (2)	F (2)	F (2)	F (2)		F	F		F (2)	F (2)	F	F (11)	F (2)	F (2)	F	F	F	F
(3-17) Bike Routes (Shldrs)			EU/M	(7)	EU/F			EU/M		EU/M			B	B	EU/M	EU/M	F				B	F	B	EU/F

☐ Not Applicable
F Full design level
M Modified design level. See Chapter 430.
B Basic design level. See Chapter 410.
DE Design Exception
EU Evaluate Upgrade

(1) Collision Reduction (HAL, HAC, PAL), or Collision Prevention (Risk, At Grade Removal, Signalization & Channelization). Specific deficiencies that created the project must be upgraded to design level as stated in the matrix.
(2) Modified design level may apply based on a corridor or project analysis. See 325.02.
(3) If designated in Limited Access Master Plan apply limited access standards, if not access management standards apply. See Chapter 920.
(4) Full design level may apply based on a corridor or project analysis. See 325.02.
(5) For bike/pedestrian design see Chapters 1020 and 1025.
(6) Applies only to bridge end terminal and transition sections.
(7) 1.2 m minimum shoulders.
(8) If all weather structure can be achieved with spot digouts and overlay, Modified Design Level Applies.
(11) See Chapter 1120.
(12) Impact attenuators are considered as terminals.
(16) For design elements not in the matrix headings, apply full design level as found in the applicable *Design Manual* chapters.

Design Matrix 3
Non-Interstate Interchange Areas
Figure 325-6

✍ Project Type / Design Elements ✍	Ramps and Collector Distributors: Horiz. Align.	Vert. Align.	Lane Width	Shldr Width	Lane & Shldr. Taper	On/Off Conn.	Cross Slope Lane	Cross Slope Shldr	Fill/ Ditch Slopes	Access (3)	Clear Zone	Sign, Del., Illumin.	Basic Safety	Ramp Terminals: Turn Radii	Ramp Terminals: Angle	Ramp Terminals: I/S Sight Dist.	Barriers: Term. & Trans. Section (12)	Barriers: Std Run	Barriers: Bridge Rail
Preservation																			
Roadway																			
(4-1) Non-Interstate Freeway	DE/F	DE/F	DE/F	DE/F	DE/F	DE/F	DE/F	DE/F	DE/F	DE/F		B	B	DE/F	DE/F	DE/F	B	B	F
(4-2) ACP/PCCP/BST Overlays Ramps												B	B			B	B	B	F
Structures																			
(4-3) Bridge Replacement	F (2)	F (2)	F (2)	F (2)	F	F (2)	F (2)	F (2)	F (2)	F	F	F		F	F	F	F	F	F
(4-4) Bridge Deck Rehab												B	B				B (6)		F
Improvements (16)																			
Mobility																			
(4-5) Non-Interstate Freeway	F	F	F	F	F	F	F	F	F	F	F	F		F	F	F	F	F	F
(4-6) Urban	F (2)	F (2)	F (2)	F (2)	F	F (2)	F (2)	F (2)	F (2)	F	F	F		F (2)	F (2)	F	F	F	F
(4-7) Rural	F (2)	F (2)	F (2)	F (2)	F	F (2)	F (2)	F (2)	F (2)	F	F	F		F (2)	F (2)	F	F	F	F
(4-8) HOV By Pass	F (2)	F (2)	F (2)	F (2)	F	F (2)	F (2)	F (2)	F (2)	F	F	F		F (2)	F (2)	F	F	F	F
(4-9) Bike/Ped. Connectivity	(5)	(5)	(5)	(5)	(5)		(5)	(5)	(5)	(5)	(5)	(5)		(5)	(5)	(5)	(5)	(5)	(5)
Safety																			
(4-10) Non-Interstate Freeway	F	F	F	F	F	F	F	F	F	F	F	F		F	F	F	F	F	F
(4-11) At Grade (1)	F (2)	F (2)	F (2)	F (2)	F	F (2)	F (2)	F (2)	F (2)	F	F	F		F (2)	F (2)	F	F	F	F
(4-12) All Others (1)	M (4)	M (4)	M (4)	M (4)	F	M (4)	M (4)	M (4)	M (4)	EU/F	F	F		M (4)	M (4)	F	F	F	F
Economic Development																			
(4-13) Four-Lane Trunk System	F	F	F	F	F	F	F	F	F	F	F	F		F	F	F	F	F	F

✍ Project Type / Design Elements ✍	Cross Road: Lane Width	Shldr Width	Vert. Clear.	Ped. & Bike	Access (3)	Sign., Del., Illumin.	Fill/ Ditch Slopes	Clear Zone	Basic Safety	Barriers: Term. & Trans. Section (12)	Barriers: Std . Run	Barriers: Bridge Rail
Preservation												
Roadway												
(4-1) Non-Interstate Freeway	DE/F	DE/F	F			B	DE/F		B	B	B	F
(4-2) ACP/PCCP/BST Overlays Ramps			F			B			B	B	B	F
Structures												
(4-3) Bridge Replacement	F (2)	F (2)	F	F	F	F	F (2)	F		F	F	F
(4-4) Bridge Deck Rehab			F			B			B	B (6)		F
Improvements (16)												
Mobility												
(4-5) Non-Interstate Freeway	F	F	F	F	F	F	F	F		F	F	F
(4-6) Urban	F (2)	F (2)	F	F	F	F	F (2)	F		F	F	F
(4-7) Rural	F (2)	F (2)	F	F	F	F	F (2)	F		F	F	F
(4-8) HOV By Pass	F (2)	F (2)	F	F	F	F	F (2)	F		F	F	F
(4-9) Bike/Ped. Connectivity	(5)	(5)	(5)	(5)		(5)	(5)			(5)	(5)	(5)
Safety												
(4-10) Non-Interstate Freeway	F	F	F		F	F	F	F		F	F	F
(4-11) At Grade (1)	F (2)	F (2)	F	F	F	F	F (2)	F		F	F	F
(4-12) All Others (1)	F (2)	F (2)	F		EU/F	F	M (4)	F		F	F	F
Economic Development												
(4-13) Four-Lane Trunk System	F	F	F		F	F	F	F		F	F	F

☐ Not Applicable
F Full design level
M Modified design level. See Chapter 430.
B Basic design level. See Chapter 410.
DE Design Exception
EU Evaluate Upgrade

(1) Collision Reduction (HAL, HAC, PAL), or Collision Prevention (Risk, Signalization & Channelization). Specific deficiencies that created the project must be upgraded to design level as stated in matrix.
(2) Modified design level may apply based on a corridor or project analysis. See 325.02.
(3) If designated in limited access master plan apply limited access standards, if not access management standards apply. See Chapter 920.
(4) Full design level may apply based on a corridor or project analysis. See 325.02.
(5) For bike/pedestrian design sees Chapter 1020 and 1025.
(6) Applies only to bridge end terminals and transition sections.
(7) 1.2 m minimum shoulders.
(12) Impact attenuators are considered as terminals.
(16) For design elements not in the matrix headings, apply full design level as found in the applicable Design

Design Matrix 4
Non-Interstate Interchange Areas
Figure 325-7

✍ Project Type													Bridges				Intersections			Barriers		
Design Elements ✍	Horiz. Align.	Vert. Align.	Lane Width	Shldr Width	Lane & Shldr Taper	Median Width	Cross Slope Lane	Cross Slope Shldr	Fill/ Ditch Slopes	Access (3)	Clear Zone	Sign, Del., Illumin.	Basic Safety	Lane Width	Shldr Width	Vertical Clear.	Structural Capacity	Turn Radii	Angle	Sight Dist.	Term. & Trans. Section (12)	Std Run	Bridge Rail
Preservation																							
Roadway																							
(5-1) ACP/PCCP												B	B			F				B	B	B	F
(5-2) BST																							
(5-3) BST Routes/Basic Safety												B	B							B	B	B	F
(5-4) Replace ACP with PCCP at I/S			EU/M	EU/M		EU/M	EU/M					B	B			F					B	B	F
Structures																							
(5-5) Bridge Replacement	M	F	M	M	F		M	M	M		F	F		F (2)	F (2)	F	F (11)	M	M	F	F	F	F
(5-6) Bridge Repl. (Multi-Lane)	F (2)	F (2)	F (2)	F (2)	F	F (2)	F (2)	F (2)	F (2)		F	F		F (2)	F (2)	F	F (11)	F (2)	F (2)	F	F	F	F
(5-7) Bridge Deck Rehab												B	B								B (6)	F	F
Improvements (16)																							
Mobility																							
(5-8) Urban (Multilane)	F (2)	F (2)	F (2)	F (2)	F	F (2)	F (2)	F (2)	F (2)	F	F	F		F (2)	F (2)	F	F (11)	EU/F	EU/F	F	F	F	F
(5-9) Urban	M	M	M	M	F		M	M	M	F	F	F		M	M	F	F (11)	EU/M	EU/M	F	F	F	F
(5-10) Rural	M	M	M	M	F	M	M	M	M	F	F	F		M	M	F	F (11)	EU/M	EU/M	F	F	F	F
(5-11) HOV	M	M	M	M	F	M	M	M	M	F	F	F		M	M	F	F (11)	EU/M	EU/M	F	F	F	F
(5-12) Bike/Ped. Connectivity	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)		(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)
Safety																							
(5-13) Non-Interstate Freeway	F(2)	F (2)	F (2)	F (2)	F (2)	F (2)	F (2)	F (2)	F (2)	F	F	F		F (2)	F (2)	F		F (2)	F (2)	F	F	F	F
(5-14) All Others (1)	EU/M	EU/M	EU/M	EU/M	EU/F	EU/M	EU/M	EU/M	EU/M	EU/F	F	EU/F		EU/M	EU/M	EU/F		EU/M	EU/M	EU/F	F	F	EU/F
Economic Development																							
(5-15) Freight & Goods(Frost Free)(8)	EU/M	EU/M	EU/M	EU/M	EU/F	EU/M	M	M	EU/M		F	B	B	EU/M	EU/M	F		EU/M	EU/M	EU/F	F	B	F
(5-16) Rest Areas(New)	F	F	F	F	F	F	F	F	F	F	F	F		F	F			F	F	F	F	F	F
(5-17) Bridge Restrictions	M	F	M	M	F	M	M	M	M		F	F		M	M	F	F (11)	M	M	F	F	F	F
(5-18) Bike Routes (Shldrs)			EU/M	(7)	EU/F			EU/M	EU/M			B	B	EU/M	EU/M					B	F	B	EU/F

☐ Not Applicable
F Full design level
M Modified design level. See Chapter 430
B Basic design level. See Chapter 410
EU Evaluate Upgrade

(1) Collision Reduction (HAL, HAC, PAL), or Collision Prevention (Risk, Signalization & Channelization). Specific deficiencies that created the project must be upgraded to design level as stated in matrix.
(2) Modified design level may apply based on a corridor or project analysis. See 325.02.
(3) If designated in Limited Access Master Plan, apply limited access standards. If not, access management standards apply. See Chapter 920.
(5) For bike/pedestrian design see Chapters 1020 and 1025.
(6) Applies only to bridge ends terminal and transition sections.
(7) 1.2 m minimum shoulders.
(8) If all weather structure can be achieved with spot digouts and overlay, basic design level applies. See Chapter 820.
(11) See Chapter 1120.
(12) Impact attenuators are considered as terminals.
(16) For design elements not in the matrix headings, apply full design level as found in the applicable *Design Manual* chapters.

Design Matrix 5
Non-Interstate Interchange Areas
Figure 325-8

330.01 General

The project file contains the documentation of planning, project definition, programming, design, approvals, contract assembly, utility relocation, needed right-of-way, advertisement, award, construction, and maintenance of a project. A project file is completed for all project and follows the project until a new project supersedes it.

Design documentation is a part of the project file. It documents design decisions and the design process followed. Design documentation is retained in a permanent retrievable file at a central location in each region. For operational changes and developer projects, design documentation is required and is retained by the region.

330.02 References

Construction Manual, M 41-01, WSDOT

Directional Documents Publication Index, D 00-00, WSDOT

Washington State Department of Transportation Certification Acceptance Approval from FHWA, December 4, 1978, and subsequent revisions

FHWA Washington Stewardship Plan, WSDOT 1993

Master Plan for Limited Access, WSDOT

Advertisement and Award Manual, M 27-02, WSDOT

Plans Preparation Manual, M 22-31, WSDOT

Route Development Plan, WSDOT

State Highway System Plan, WSDOT

Highway Runoff Manual, WSDOT

Executive Order E 1010.00, "Certification of Documents by Licensed Professionals," WSDOT

330.03 Purpose

Design documentation is prepared to record the evaluations by the various disciplines that result in design recommendations. Design assumptions and decisions made prior to and during the project definition phase are included. Changes that occur throughout the project development process are documented. Justification and approvals, if required, are also included.

The design documentation identifies:

- The condition or problem that generated the purpose and need for the project (as noted in the Project Summary)
- The design alternatives considered
- The project design selected
- The work required to satisfy the commitments made in the environmental documents
- The conformity of the selected design to departmental policies and standard practices
- The supporting information for any design variances
- The internal and external coordination

The design documentation is used to:

- Examine estimates of cost
- Prepare access and right of way plans
- Assure that all commitments are provided for in the recommended design
- Plan for maintenance responsibilities as a result of the project
- Provide supporting information for design variances
- Explain design decisions
- Document the project development process and design decisions

- Preserve a record of the project's development for future reference
- Prepare plans, specifications, and estimate (PS&E)

330.04 Project Development

The region initiates the project by preparing the Project Summary package. The project coordination with other disciplines (such as Real Estate Services, Utilities, and Surveying) is started in the project definition phase and continues throughout the project's development. The region coordinates with state and federal resource agencies and local governments to provide and obtain information to assist in developing the project.

The project is developed in accordance with all applicable Directives, Instructional Letters, and manuals as listed in D 00-00; the Master Plan for Limited Access Highways; *State Highway System Plan;* Level of Development Plan; *Route Development Plan;* FHWA Washington Stewardship Plan; and the Project Summary.

The region develops and maintains documentation for each project. This file includes documentation of all work on the project from before the project definition phase through public involvement, environmental action, design decisions, right of way acquisition, and PS&E development. Refer to the *Plans Preparation Manual* for PS&E documentation.

All projects involving FHWA action require NEPA clearance. Environmental action is determined through the Environmental Classification Summary (ECS) form. The environmental approval levels are shown in Figure 330-2.

Upon receipt of the ECS approval, the region proceeds with environmental documentation, including instituting public involvement methods that are appropriate to the magnitude and type of the project. (See Chapter 210.)

The Assistant State Design Engineer works with the regions on project development and conducts process reviews on projects as described in 330.08.

330.05 Project Definition Phase

Project definition is the initial phase of project development. The project definition effort is prompted by the *State Highway System Plan*. The project definition phase consists of determining a preliminary project description, schedule, and estimate. The intent is to make design decisions early in the project development process. During the project definition effort, the *Project Summary* documents are produced.

Project Summary provides information on the results of the project definition phase; links the project to the Highway System Plan; and documents the design decisions, the environmental classification, and agency coordination. The Project Summary is developed before the project is funded for construction. The Project Summary consists of the *Environmental Review Summary, Design Decisions Summary,* and *Project Definition.*

Environmental Review Summary (ERS) lists the environmental permits and approvals that will be required, environmental classifications, and environmental considerations. This form lists requirements by environmental and permitting agencies. If there is a change in project definition, the information in the ERS must be reviewed and changed to match the new project definition. The ERS is prepared during the project definition effort. The ERS is approved by the region.

Design Decisions Summary (DDS) states the roadway geometrics, design deviations, evaluate upgrades (EUs), other roadway features, and any design decisions made during the project definition phase of a project. The information contained in this form is compiled from various databases of departmental information, field data collection, and evaluations made in development of the *Project Definition* and the ERS. To sign the Design Decisions Summary, the region must be comfortable that there will be no significant change in the project definition or estimated cost. Design decisions may be revised throughout the project development process based on continuing evaluations.

The DDS is approved by the Assistant State Design Engineer for new construction and reconstruction projects on the Interstate System. The regional design authority approves the DDS for all other types of projects. (See Figure 330-1)

Project Definition (PD) identifies the various disciplines and design elements that will be encountered in project development. The Project Definition states the needs, the purpose of the project, program categories, and the design matrices that were used to develop the Project Definition. This information determines the level of documentation and evaluation that is needed for approval of the design. The Project Summary is completed in the project definition phase.

Once the project has been formally adopted into the WSDOT operating program, project development continues. Design of projects is further refined by a project manager through an interdisciplinary team process. Projects continue with the development of environmental and design documentation.

330.06 Design Documentation

(1) FHWA Requirements

For projects on the Interstate System, the level of FHWA oversight varies according to the type of project, the agency doing the work, and the funding source. See Figure 330-1 for details.

FHWA operational acceptance is required for any new or revised access point on the Interstate System, regardless of funding. (See Chapter 1425.)

Documentation for projects requiring FHWA review and approval is submitted through the Olympia Service Center (OSC) Design Office. Include the following items if applicable to the project:

- Project Definition (form) (PD)
- Environmental Review Summary (form) (ERS)
- Design Decisions Summary (form) (DDS)
- Design Variance Inventory (form) with support information for EUs and deviations
- Cost estimate
- NEPA documentation
- Design Clear Zone Inventory (form)
- Interchange plans, and profiles (and roadway sections if appropriate)
- Traffic projections and analysis
- Accident analysis
- The report requesting new or revised access points

The forms listed above (Project Definition, Environmental Review Summary, Design Decisions Summary) are generated by the Project Summary database. Specific on-line instructions for filling them out are contained in the database.

(2) Design Documents

The design portion of the project file preserves the decision documents generated during the design process. A summary (list) of these documents is recommended because projects vary in scope and the documents applicable to the project vary accordingly.

The design documents commonly included in the project file for all but the simplest projects are listed below. The ERS, PD, and DDS forms are in the Project Summary database which includes on-line instructions.

- Documentation of any design decision to do more, or less, than WSDOT guidance indicates and documentation of design decisions for components not addressed by WSDOT guidance. (These may be separate documents or portions of the documents listed below.)
- Environmental Review Summary (ERS form)
- Project Definition (PD form)
- Design Decisions Summary (DDS form)
- Corridor or project analysis. See Chapter 325 for definition and Figures 330-5a and 5b.
- Design Variance Inventory (form) with support information for EUs and deviations
- Cost Estimate
- Design Clear Zone Inventory (form)

- Copies of interchange plans, intersection plans, and profiles (and roadway sections if appropriate)
- Right of way plans
- Monumentation Map
- SEPA and NEPA documentation
- Work Zone Traffic Control Strategy
- Other project components: Provide documentation in the project file as detailed in the applicable *Design Manual* chapters. Documentation is not required for components not related to the project.

The Design Variance Inventory is required for NHS roadway preservation projects only. This form lists all design exceptions, evaluate upgrades not upgraded to the applicable design level, and deviations.

The Project Definition and Environmental Review Summary are required for all projects.

The Design Decisions Summary form is not required for the following project types unless they involve reconstructing the lanes, shoulders, or fill slopes. Since these project types are not included in the design matrices, evaluate them with respect to modified design level (M) for non-NHS routes and full design level (F) for all others.

- Bridge painting
- Crushing and stockpiling
- Pit site reclamation
- Lane marker replacement
- Guide post replacement
- Signal rephasing
- Signal upgrade
- Seismic retrofit
- Bridge joint repair
- Navigation light replacement
- Signing upgrade
- Illumination Upgrade
- Rumble Strips
- Electrical upgrades
- Major Drainage
- Slope Stability*
- Bridge scour
- Fish passage
- Other projects as approved by OSC Design

*Address rock scour within the project limits whenever feasible.

(3) Certification of Documents by Licensed Professionals

All original technical documents must bear the certification of the responsible licensee. See Executive Order E 1010.00.

(4) Deviation and Evaluate Upgrade Documentation

The *Design Variance Inventory* (a form), *DE*, *EU*, and *deviations* are introduced in Chapter 325.

To prepare a deviation request, or document an EU, use the list in Figure 330-6 as a general guide for the sequence of the content. The list is not all-inclusive of potential content and it might include suggested topics that do not apply to a particular project. Each deviation request will be unique. Sample deviations and EUs are on the Internet at www.wsdot.wa.gov/eesc/CAE/pse/

Documentation of a deviation must contain justification and must be approved at the appropriate administrative level as shown in Figure 330-1. When applying for deviation approval, it is necessary to provide two explanations. The first explains why the WSDOT guidance was not or cannot be used. The second provides the justification for the design that is proposed. Justification for a deviation must be supported by at least two of the following:

- Accident history or potential
- Benefit/cost analysis
- Engineering judgment
- Environmental issues
- Route continuity

An element of engineering judgment might be references to other publications.

Once a deviation is approved, it applies to that project only. When a new project is programmed at the same location, the subject design element must be reevaluated and either (1) the subject design element is rebuilt to meet or exceed the applicable design level, or (2) a new, approved deviation is preserved in the design file for the new project.

330.07 Design Approval

Design Approval is the approval of the design file. When the design file is complete, the region takes an action to make an approval that becomes part of the file. Figure 330-1 identifies the approval levels for design, evaluate upgrades (EUs), and deviations. The following items must be approved prior to design approval:

- Required environmental documentation (NEPA, SEPA)
- Project Summary (includes Project Definition, Design Decisions Summary, and Environmental Review Summary)
- Design Variance Inventory form (includes evaluate upgrades and deviations) for NHS, deviations and EUs for non-NHS
- Cost estimate

See Figures 330-1 through 4 for review and approval levels for project design and PS&E documents. Figures 330-2, 330-3, and 330-4 are summaries of information provided in other WSDOT documents.

330.08 Process Review

The process review is done to provide reasonable assurance that projects are prepared in compliance with established standards and procedures and that adequate records exist to show compliance with state and federal requirements.

The design and PS&E process review is performed in each region at least once each year by the OSC Project Development Branch. Four documents are used in the review process: the Design Review Check List, PS&E Review Check List, Design Review Summary, and PS&E Review Summary. These are generic forms used for all project reviews. Copies of these working documents are available for reference when assembling project documentation. OSC Design Office, Project Development maintains current copies on Exchange. For paper copies or a specific electronic address contact the OSC Project Development Branch.

Each project selected for review is examined completely and systematically beginning with the project definition and the project summary phase and continuing through contract plans and (when available) construction records and change orders. Projects are normally selected after contract award. For projects having major traffic design elements, the OSC Traffic Operations personnel are involved in the review. The WSDOT process reviews may be held in conjunction with FHWA process reviews.

The OSC Project Development Branch schedules the process review and coordinates it with the region. Notification of the scheduled process review is sent to FHWA for their information and for use in coordinating a joint process review.

A process review follows this general agenda:

1. Review team meets with regional personnel to discuss the object of the review.
2. Review team reviews the design and PS&E documents, and the construction documents and change orders if available, using the check lists.
3. Review team meets with regional personnel to ask questions and clarify issues that have arisen.
4. Review team meets with regional personnel to discuss findings.
5. Review team submits a draft report to the region for comments and input.
6. If the review of a project shows a serious discrepancy, the regional design authority is asked to report the steps that will be taken to correct the deficiency.
7. The process review summary forms are completed.

8. The summary forms and check lists are evaluated by the State Design Engineer.

9. The findings and recommendations of the State Design Engineer are forwarded to the regional design authority, for action and/or information, within 30 days of the review.

P65:DP/DMM

Project Design	FHWA Oversight Level	Deviation and Corridor/Project Approval[f]	EU Approval	Design Approval
Interstate				
New/Reconstruction[e] • Federal funds • No federal funds	 (a) (b)	FHWA	Region	FHWA
Intelligent Transportation System (ITS) over $1 million	(c)	OSC Design	Region	OSC Design
All Other[d] • Federal funds • State funds • Local agency funds	 (c) (c) (b)	OSC Design	Region	Region
NHS				
All	(c)	OSC Design	Region	Region
Non-NHS				
New/Reconstruction	N/A	OSC Design	Region	Region
All Other	N/A	Region	Region	Region

FHWA = Federal Highway Administration
OSC = Olympia Service Center

(a) Requires FHWA review and approval (full oversight) of design and PS&E submitted by OSC Design.

(b) To determine the appropriate oversight level, FHWA reviews the Project Summary (or other programming document) submitted by OSC Design or by TransAid through OSC Design.

(c) FHWA oversight is accomplished by process review. (See 330.08.)

(d) Reduction of through lane or shoulder widths (regardless of funding) requires FHWA review and approval of the proposal.

(e) See Chapter 325 for definition.

(f) These approval levels also apply to deviation processing for local agency work on a state highway.

Design Approval Level
Figure 330-1

Item	Region		OSC		FHWA	
	Review	Approval	Review	Approval	Review	Approval
Program Development						
Work Order Authorization				**X**		**X** [1]
Public Hearings						
Corridor Plan [13]				**X**		
Design Summary [14]				**X**		
Access Hearing Plan [14]				**X**		
Access Findings and Order [15]				**X**		
Environmental By Classification						
Summary (ECS) NEPA						**X**
Class I NEPA (EIS)			**X**			**X**
Class I SEPA (EIS)				**X**		
Class II NEPA *Programmatical Categorical Exclusion (CE)		**X**				
Class II NEPA — Documented Categorical Exclusion (CE)	**X**					**X**
Class II SEPA — Categorical Exemption (CE)		**X**				
Class III NEPA — Environmental Assessment (EA)			**X**			**X**
SEPA Check List		**X**				

*If on the preapproved list.

Notes:
X Normal procedure
[1] Federal aid projects only
[3] Applies to new/reconstruction projects on Interstate routes
[13] Assistant Secretary for Environmental and Engineering Service Center approval
[14] State Design Engineer approval
[15] Refer to Chapter 210 for approval requirements

Reviews and Approvals
Figure 330-2

Item	Region		OSC		FHWA	
	R	Approval	Review	Approval	Review	Approval
Design						
Design Deviations		[2]		[2]		[2]
Experimental Features				X		X [3]
Environmental Review Summary		X				
Final Design Decisions Summary		X		X [3]		
Final Project Definition				X [4]		
Access Point Decision Report			X			X
Non-Interstate Interchange Access Point Report				X		
Interchange Plans [12]		X		X [3]		
Intersection Plans [12]		X		X [3]		
Right of Way Plans		[13]		X		
Monumentation Map		X				
Materials Source Report				X [5]		
Pavement Determination Report				X [5]		
Project Design Approval		[2]		[2]		[2]
Resurfacing Report				X [5]		
Signal Permits		X [6]				
Geotechnical Report				X [5]		
Tied Bids		X				X [3]
Bridge Design Plans (Bridge Layout)		X		X		
Hydraulic Report		[7]	X [8]			
Preliminary Signalization Plans			X			
Rest Area Plans				X		
Roadside Restoration Plans		X [9]		X [10]		
Structures Requiring TS&L’s				X		X
Wetland Mitigation Plans		X		X		
Wetland Mitigation Planting Plans		X [9][11]		X [10]		
Grading Plans		X [9][11]		X [10]		

Reviews and Approvals, Design
Figure 330-3a

Notes:

X Normal procedure
[2] Refer to Figure 330-1 for design approval level
[3] Applies to new/reconstruction projects on Interstate routes
[4] OSC Program Management
[5] Submit to OSC Materials Branch for review and approval
[6] Approved by Regional Administrator
[7] See M 23-03, Hydraulics Manual for additional guidance
[8] Region to submit Hydraulic Report. Refer to Hydraulics Manual
[9] Applies only to regions with a Landscape Architect
[10] Applies only to regions without a Landscape Architect
[11] Approved by Regional Landscape Architect
[12] Include channelization details
[13] Certified by the responsible professional licensee

Reviews and Approvals, Design (continued)
Figure 330-3b

Item	Interstate New/ Reconstruction	NHS and Non-NHS
Minority/training goals* **	OSC(a)	OSC(a)
Right of way certification for federal aid projects	OSC(b)	OSC(b)
Right of way certification for state funded projects	Region(b)	Region(b)
Railroad agreements	OSC(c)	OSC(c)
Work performed for public or private entities*	OSC[1][5]	Region[1][5]
State force work*	FHWA[2](d)	OSC[2](c)(d)
Use of state furnished stockpiled materials*	FHWA[3]	Region[3]
Stockpiling materials for future projects*	FHWA[3]	Region[3]
Work order authorization	OSC[4](d)	OSC[4](d)
Ultimate reclamation plan approval through DNR	Region	Region
Proprietary item use*	FHWA[3]	OSC[5](c)
Mandatory material sources and/or waste sites*	FHWA[3]	Region[3]
Nonstandard bid item use*	Region	Region
Incentive provisions	FHWA	OSC(e)
Nonstandard time for completion liquidated damages*	FHWA(e)	OSC(e)
Interim liquidated damages*	OSC(f)	OSC(f)

Notes:
[1] This work requires a written agreement.
[2] Use of state forces is subject to $50,000 limitation as stipulated in RCWs 47.28.030 and 47.28.035.
[3] Applies only to federal aid projects. However, document for all projects.
[4] Prior FHWA funding approval required for federal aid projects.
[5] Region approval subject to $250,000 limitation.

Regional or Olympia Service Center approval authority:
(a) Office of Equal Opportunity
(b) Real Estate Services
(c) Design Office
(d) Program Management Office
(e) Construction Office
(f) Transportation Data Office

References:
**Plans Preparation Manual*
***Advertisement and Award Manual*

PS&E Process Approvals
Figure 330-4

Project Analysis

L-0000 SR A

Yodelin Hill Climbing Lane SR A MP B to MP C

Overview

High truck volumes and steep grades are adversely impacting traffic flows and safety on this section of highway. The purpose of this project is to increase traffic flows and safety by adding a climbing lane.

For this NHS rural mobility project, the Design Matrix calls for full design level with an option to use modified design level based on a corridor or project analysis. In *Design Manual* Chapter 440, the ADT of 6300, DHV of 730, and truck percentage of 18% in design year 2016 indicates design class P-2 multilane. Considering the following justification, the region proposes to design this project to the modified design level MDL-14 with a truck climbing lane.

A climbing lane warrant has been met.

Route Description

This section of SR A parallels a mountain stream and is located in steep mountainous terrain. Adjacent roadway sections consist of two 3.4 m lanes with 1.2 m shoulders. Fill slopes generally range between 1:3 and 1:4 as do ditch inslopes. The posted speed is 60 mph in both directions.

Comparison

	Existing Conditions	Modified Design Level (MDL-14)	Full Design Level (P-2)	Proposed (MDL-14)
Fill slopes	1:3 to 1:4	1:4	1:6	1:4
Lane Width	3.4	3.6	3.6	3.6
No. Thru. Lanes	2	2+1	4	2+1
Shoulder Width	1.2	1.2	3.0	1.2
Median Width	none	none	18	none

The use of full design level would require a wider roadway which would in turn require significant impacts to the stream, very high and lengthy rock cut, additional right of way including acquisition of numerous cabins, and utility impacts. The cost to construct this section to full design level is approximately $6 million more than to construct to modified design level with an additional climbing lane.

Adding a fourth lane throughout this narrow corridor would have minimal benefits to the traveling public. There is no proposed improvement in the 20 year System Plan to make either this section, or adjacent sections of highway, four lanes.

Sample Project Analysis
Figure 330-5a

Accidents

The accident history from April 1993 through March 1996 indicates 28 accidents resulting in 1 fatality, 16 injuries, and $392,100 in property damage.

14 of the 28 accidents, including the fatality, occurred while passing uphill traffic. Seven other accidents occurred during turning maneuvers at four different locations throughout the project.

Addition of the truck climbing lane should reduce the number and severity of accidents on this section of roadway. The additional fourth lane throughout would probably not significantly reduce the number or severity of accidents.

Summary

Considering route continuity, environmental constrains, additional cost, and minimal benefit, the region feels constructing to full design level is not justified. Therefore, the region proposes to construct this project to modified design level.

____________________	__________	____________________	__________
Regional Concurrence	Date	OSC Design Approval	Date

Sample Project Analysis
Figure 330-5b

1. Overview

   (a) The safety or improvement need that the project is to meet

   (b) Description of the project as a whole

   (c) Highway classification and applicable Design Matrix

   (d) Funding sources

   (e) Evidence of deviations approved for previous projects (same location)

2. Design Alternatives in Question

   (a) Existing Conditions and Design Data

      - Location in question
      - Rural, urban, or developing
      - Route development plan
      - Environmental issues
      - Right of way issues
      - Number of lanes and existing geometrics
      - Present and 20 year projected ADT
      - Speed limit and operating speed
      - Percentage of trucks

   (b) Accident Summary and Analysis

   (c) Design Using the *Design Manual* Guidance

      - Description
      - Cost estimate
      - B/C ratio
      - Advantages and disadvantages
      - Reasons for considering other designs

   (d) Other Alternatives

      - Description
      - Cost estimate
      - B/C ratio
      - Advantages and disadvantages
      - Reasons for rejection

   (e) Selected design requiring documentation as a deviation (or justification to file)

      - Description
      - Cost estimate
      - B/C ratio
      - Advantages and disadvantages
      - Justification - see 330.06(4)

3. Concurrences, Approvals, and Professional Seals

Deviation and Evaluate Upgrade Request/Documentation Content List
Figure 330-6

410.01 General

Basic design level (B) preserves pavement structures, extends pavement service life, and maintains safe operations of the highway. The basic design level includes restoring the roadway for safe operations and, where needed, may include safety enhancement. Flexibility is provided so that other conditions can be enhanced while remaining within the scope of pavement preservation work.

The required safety items of work listed below may be programmed under a separate project from the paving project as long as there is some benefit to the delay, the safety features remain functional, and the work is completed within two years after the completion of the paving project. If some of the required items are separated from the paving project, maintain a separate documentation file that addresses the separation of work during the two-year time period.

For bituminous surface treatment projects on non-NHS routes, the separation of required safety items is not limited to the two years stated above. The safety work can be accomplished separately using a corridor-by-corridor approach.

410.02 Required Basic Safety Items of Work

For basic design level (B), the following items of work are required:

- Install and replace delineation in accordance with Chapter 830
- Install and replace rumble strips in accordance with the matrices and Chapter 700
- Adjust existing features that are affected by resurfacing, such as monuments, catch basins, and access covers
- Adjust guardrail height in accordance with Chapter 710
- Replace deficient signing, as needed, using current standards. This does not include replacement of sign bridges or cantilever supports
- Relocate, protect, or provide breakaway features for sign supports, luminaires, and WSDOT electrical service poles inside the design clear zone
- Restore sight distance at public road intersections and the inside of curves through low cost measures if they are available such as removal or relocation of signs and other obstructions, and cutting of vegetative matter
- Upgrade nonstandard bridge rail in accordance with the matrices and Chapter 710
- Upgrade barrier terminals and bridge end protection, including transitions, in accordance with Chapter 710
- Restore the cross slope to 1.5 percent when the existing cross slope is flatter than 1.5 percent and, in the engineer's judgment, the steeper slope is needed to solve highway runoff problems in areas of intense rainfall

410.03 Minor Safety and Minor Preservation Work

Consider the following items, where appropriate, within the limits of a paving project:

- Spot safety enhancements. These are modifications to isolated roadway or roadside features that, in the engineer's judgment, reduce potential accident frequency or severity
- Striping changes that will provide additional or improved channelization for intersections where sufficient pavement width and structural adequacy exist
- Roadside safety hardware (such as guardrail, signposts, impact attenuators)

- Addressing Location 1 Utility Objects in accordance with the *Utilities Accommodation Policy*, M 22-86

Consider the following items when restoration, replacement, or completion is necessary to assure that an existing system can function as intended:

- Right of way fencing
- Drainage
- Illumination
- Electrical

Examples of the above include, but are not limited to, the following: installing short sections of fence needed to control access, replacing grates that are a hazard to bicycles, upgrading electrical system components that require excessive maintenance, and beveling culverts.

P65:DMM

430 Modified Design Level

430.01 General

Modified design level (M) preserves and improves existing roadway geometrics, safety, and operational elements. This chapter provides the design guidance that is unique to the modified design level.

Design elements that do not have modified design level guidance include:

- Access control, see Chapter 1420
- Access management, see Chapter 920
- Basic safety, see Chapter 410
- Clear zone, see Chapter 700
- Traffic barriers, see Chapter 710
- Gore area lighting, see Chapter 840
- Interchange areas, see Chapter 940

Design elements that have both modified and full design level components include:

- Horizontal alignment, see Chapter 620
- Superelevation and shoulder cross slope, see Chapter 640
- Vertical alignment, see Chapter 630

430.02 Design Speed

When applying modified design level to a project, select a design speed for use in the design process that reflects the character of the terrain and the type of highway. Select a speed that is not less than the posted speed, the proposed posted speed, or the operating speed, whichever is higher. Document which speed was used, include any supporting studies and data.

430.03 Roadway Widths

The design of a project must not decrease the existing roadway width.

Lane and shoulder widths are shown in Figures 430-3 and 4. Consider joint use with other modes of transportation in shoulder design.

Review route continuity and roadway widths. Select widths on the tangents to be consistent throughout a given section of the route. Make any changes where the route characteristics change.

(1) Turning Roadway Widths

It may be necessary to widen the roadway on curves to accommodate large vehicles. The total two-lane roadway width of a curve may not be less than that shown in Figure 430-5 or, if the internal angle (delta) is less than 90 degrees, Figure 430-6. The proposed roadway width for a curve may not be less than that of the adjacent tangent sections.

The total roadway width from Figure 430-5 or Figure 430-6 may include the shoulder. When the shoulder is included, full-depth pavement is required.

Widening of the total roadway width of a curve by less than 0.6 m is not required for existing two-lane roadways that are to remain in place.

(2) Median Width

See Figure 430-3.

430.04 Ramp Lane Widths

Ramp lane widths are shown in Figure 430-1 and in Figure 430-10. For ramps with radii less than 100 m apply full design level see Chapter 640.

Curve Radius	Lane Width
Tangent - 1200 m	3.9 m
900 m - 600 m	4.2 m
300 m - 100 m	4.5 m

Turning Ramp Lane Widths
Modified Design Level
Figure 430-1

430.05 Stopping Sight Distance

(1) Existing Stopping Sight Distance for Vertical Curves

For crest vertical curves use the existing algebraic difference in grades and the length of curve to compare the existing condition to Figure 430-7. If corrective action is required by Figure 430-7, apply full design level and see Chapter 650.

When modified design level is being applied, sag vertical curves are not normally addressed.

(2) Stopping Sight Distance for Horizontal Curves

For modified design level, use the existing lateral clearance to the sight obstruction and the curve radius to compare the existing condition to Figure 430-8. If corrective action is required by Figure 430-8, apply full design level and see Chapter 650.

For Figure 430-8, an obstruction is any object with a height of 0.6 m or more above the roadway surface on the inside of a curve. Examples of possible obstructions are median barrier, guardrail, bridges, walls, cut slopes, wooded areas, and buildings.

430.06 Profile Grades

When applying modified design level, profile grades generally are not flattened. However, corrective action may be justified for combinations of steep grades and restricted horizontal or vertical curvature. Identify major modifications to horizontal and vertical alignment in the Project Decisions Summary. Total removal of pavement and reconstruction of the subgrade are examples of major modifications.

430.07 Cross Slope

On all tangent sections, the normal cross slopes of the traveled way are 2 percent. Cross slopes up to 2 percent have a barely perceptible effect on vehicle steering, but cross slopes steeper than 2 percent can be noticeable.

The algebraic difference in cross slopes is an operational factor during a passing maneuver on a two-lane road. Its influence increases when increased traffic volumes decrease the number and size of available passing opportunities.

If a longitudinal contiguous section of pavement is to be removed or is on a reconstructed alignment, or if a top course is to be placed over existing pavement, design the restored pavement to a cross slope of 2 percent.

A somewhat steeper cross slope may be necessary to facilitate pavement drainage in areas of intense rainfall, even though this might be less desirable from the operational point of view. In such areas, the design cross slopes may be increased to 2.5 percent with an algebraic difference of 5 percent.

For existing pavements, cross slopes within a range of 1 to 3 percent may remain if there are no operational or drainage problems and— on a two-way, two-lane road — the following conditions are met:

- The algebraic difference is not greater than 4 percent where the ADT is greater than 2000.
- The algebraic difference is not greater than 5 percent where the ADT is 2000 or less.
- The algebraic difference is not greater than 6 percent and the road is striped or signed for no passing.

If the existing pavement does not meet the conditions above, correct the cross slope(s) to be within the range of 1.5 to 2.5 percent. For a two-way, two-lane road, provide an algebraic difference to meet the appropriate conditions stated above except when facilitating drainage in areas of intense rainfall. When applying modified design level to a road with bituminous surface treatment (BST), cross slope correction is not required on the basis of algebraic differences alone.

To maintain or restore curb height, consider lowering the existing pavement level and correcting cross slope by grinding before an asphalt overlay. On urban highways, the cross slope of the outside shoulder may be steepened to minimize curb height and other related impacts. The shoulder may be up to 6 percent with a rollover between the traveled way and the shoulder of no more than 8 percent.

430.08 Fill Slopes and Ditch Inslopes

Foreslopes (fill slopes and ditch inslopes) and cut slopes are designed as shown in Figure 430-9 for modified design level main line roadway sections. After the foreslope has been determined, use the guidance in Chapter 700 to determine the need for a traffic barrier.

When a crossroad or road approach has steep foreslopes, there is the possibility that an errant vehicle might become airborne. Therefore, flatten crossroad and road approach foreslopes to 1:6 where practical and at least to 1:4. Provide smooth transitions between the main line foreslopes and the crossroad or road approach foreslopes. Where possible, move the crossroad or road approach drainage away from the main line. This can locate the pipe outside the design clear zone and reduce the length of pipe required.

430.09 Intersections

(1) General

Except as given below, design intersections to meet the requirements in Chapter 910.

(2) Design Vehicle

Figure 430-2 is a guide for determining the design vehicle. Perform a field review to determine intersection type, type of vehicle that use the intersection, and adequacy of the existing geometrics.

Intersection Type	Design Vehicle
Junction of Major Truck Routes	WB-20
Junction of State Routes	WB-12
Ramp Terminals	WB-12
Other Rural	SU[1]
Urban Industrial	SU[1]
Urban Commercial	P[1]
Residential	P[1]

[1]When the intersection is on a transit or school bus route, use the BUS design vehicle. See Chapter 1060 for additional guidance for transit facilities and for the BUS turning path templates.

Design Vehicles
Modified Design Level
Figure 430-2

(3) Angle

The allowable angle between any two respective legs is between 60° and 120°. When realignment is required to meet this angle requirement, consider realigning to an angle between 75° and 105°.

430.10 Bridges

Design all new and replacement bridges to full desing level (Chapter 440) unless a corridor or project anlaysis justifies the use of modified design level lane and shoulder widths. Evaluate bridges to remain in place using Figures 430-3 and 4. Whenever possible, continue the roadway lane widths across the bridge and adjust the shoulder widths.

Consider joint use with other modes of transportation in lane and shoulder design. See Chapters 1020, 1050, and 1060.

430.11 Documentation

The following documents are to be preserved in the project file. See Chapter 330.

- ☐ Design speed selection
- ☐ Existing roadway widths
- ☐ Stopping sight distance evaluation
- ☐ Justification for profile grade modification
- ☐ Existing crown and superelevation
- ☐ Intersection field review

	Multilane Divided				Multilane Undivided			
	Trucks Under 10%		Trucks 10% and Over		Trucks Under 10%		Trucks 10% and Over	
Design Class	MDL-1	MDL-2	MDL-3	MDL-4	MDL-5	MDL-6	MDL-7	MDL-8
Current ADT(1)	Under 4000	Over 4000	Under 4000	Over 4000	Under 4000	Over 4000	Under 4000	Over 4000
Design Speed	The posted speed, the proposed posted speed, or the operating speed, whichever is higher.							
Traffic Lanes Number Width	4 or more 3.3 m	4 or more 3.3 m	4 or more 3.3 m	4 or more 3.6 m	4 or more 3.3 m	4 or more 3.3 m	4 or more 3.3 m	4 or more 3.6 m
Parking Lanes Urban	None	None	None	None	2.4 m	2.4 m (2)	2.4 m	2.4 m (2)
Median Width Rural Urban	Existing Existing	Existing Existing	Existing Existing	Existing Existing	0.6 m 0.6 m	1.2 m 0.6 m	1.2 m 0.6 m	1.2 m 0.6 m
Shoulder Width Right (3) Left (4)	1.2 m 0.6 m	1.8 m 0.6 m	1.2 m 0.6 m	1.8 m 0.6 m	1.2 m	1.8 m (5)	1.2 m	1.8 m (5)
Minimum Width for Bridges to Remain in Place (6)(7)(8)	7.3 m (9)	7.9 m (9)	7.3 m (9)	7.9 m (10)	14.6 m (9)	15.2 m (9)(11)	15.2 m (9)(11)	16.5 m (10)(11)
Minimum Width for Rehabilitation of Bridges to Remain in Place (6)(12)(8)	8.4 m (9)	9.0 m (9)	8.4 m (9)	9.6 m (10)	16.2 m (9)	18.0 m (9)(11)(13)	16.8 m (9)(11)	19.2 m (10)(11)(13)
Minimum Width for Replacement	Full Design Level Applies (14)							
Access Control	See Chapter 1420 and the Master Plan for Limited Access Highways, or WAC 468-52 and the region's Highway Access Management Classification Report							

(1) If current ADT is approaching a borderline condition, consider designing for the higher classification.
(2) Parking restricted when ADT is over 15,000.
(3) When curb section is used, the minimum shoulder width from the edge of traveled way to the face of curb is 1.2 m. On designated bicycle routes the minimum shoulder width is 1.2 m (See Chapter 1020).
(4) For lanes 3.3 m or more in width, the minimum shoulder width to the face of the curb is 0.3 m on the left.
(5) May be reduced by 0.6 m under urban conditions.
(6) Width is the clear distance between curbs or rails, whichever is less.
(7) Use these widths when a bridge within the project limits requires deck treatment or thrie beam retrofit only.
(8) For median widths 7.5 m or less, see Chapter 1120.
(9) Add 3.3 m for each additional lane.
(10) Add 3.6 m for each additional lane.
(11) Includes a 1.2 m median which may be reduced by 0.6 m under urban conditions.
(12) Use these widths when a bridge within the project limits requires any work beyond the treatment of the deck such as bridge rail replacement, deck replacement, or widening.
(13) Includes 1.8 m shoulders — may be reduced by 0.6 m on each side under urban conditions.
(14) Modified design level lane and shoulder widths may be used when justified with a corridor or project analysis.

Modified Design Level for Multilane Highways and Bridges
Figure 430-3

	Two-Lane Highways					
	Trucks Under 10%			Trucks 10% and Over		
Design Class	MDL-9	MDL-10	MDL-11	MDL-12	MDL-13	MDL-14
Current ADT(1)	Under 1000	1000-4000	Over 4000	Under 1000	1000-4000	Over 4000
Design Speed	The posted speed, the proposed posted speed, or the operating speed, whichever is higher.					
Traffic Lane(2) Width	3.3 m	3.3 m	3.3 m	3.3 m	3.6 m	3.6 m
Parking Lanes Urban	2.4 m	2.4 m	2.4 m(3)	2.4 m	2.4 m	2.4 m(3)
Shoulder Width(4)	0.6 m	0.9 m(5)	1.2 m	0.6 m	0.9 m(5)	1.2 m
Minimum Width for Bridges to Remain in Place (6)(7)	6.6 m(8)	7.2 m	8.5 m	6.6 m(8)	7.2 m	8.5 m
Minimum Width for Rehabilitation of Bridges to Remain in Place (7)(9)	8.4 m(10)	9.6 m	9.6 m	8.4 m(10)	9.6 m	9.6 m
Minimum Width for Replacement	Full Design Level Applies(11)					
Access Control	See Chapter 1420 and the Master Plan for Limited Access Highways, or WAC 468-52 and the region’s Highway Management Classification Report.					

(1) If current ADT is approaching a borderline condition, consider designing for the higher classification.

(2) See Figures 430-5 and 430-6 for turning roadways.

(3) Parking restriction recommended when ADT exceeds 7,500.

(4) When curb section is used, the minimum shoulder width from the edge of traveled way to the face of curb is 1.2 m. On designated bicycle routes the minimum shoulder width is 1.2 m (See Chapter 1020).

(5) For design speeds of 50 mph or less on roads of 2,000 ADT or less, width may be reduced by 0.3 m, with justification.

(6) Use these widths when a bridge within the project limits requires deck treatment or thrie beam retrofit only.

(7) Width is the clear distance between curbs or rails, whichever is less.

(8) 6.0 m when ADT 250 or less.

(9) Use these widths when a bridge within the project limits requires any work beyond the treatment of the deck such as bridge rail replacement, deck replacement, or widening.

(10) 7.8 m when ADT 250 or less.

(11) Modified design level lane and shoulder widths may be used when justified with a corridor or project analysis.

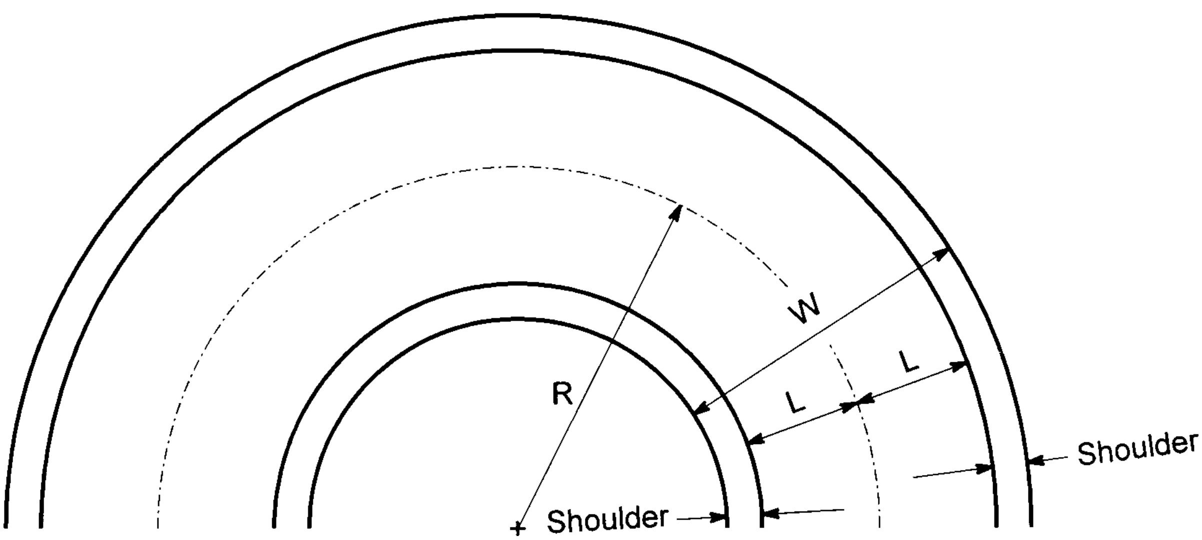
Modified Design Level for Two-Lane Highways and Bridges

Figure 430-4

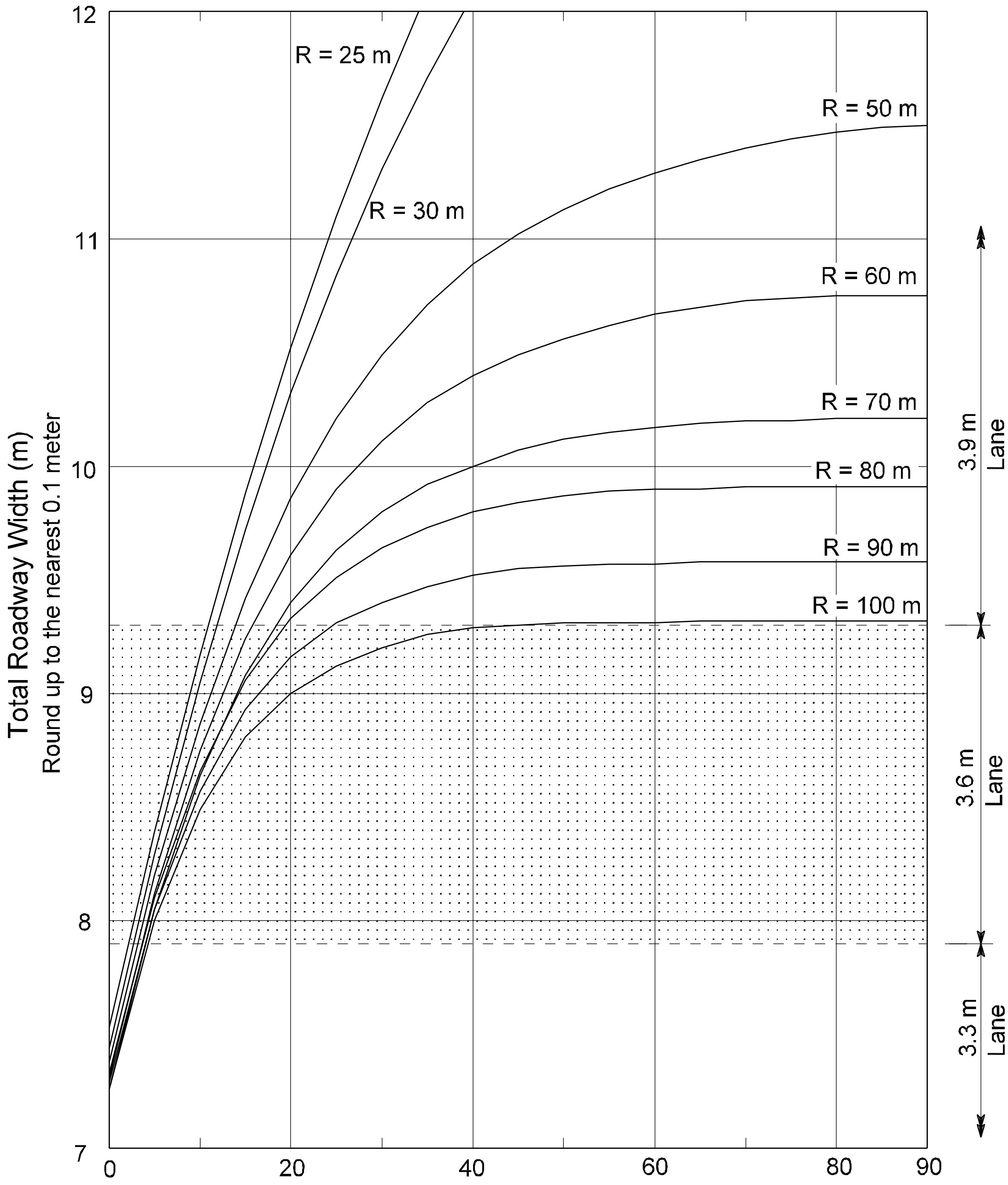
Radius of Center Line R (m)	Minimum Total Roadway Width W (m)	Minimum Lane Width L (m)
Tangent	7.8	3.3
300	7.8	3.3
200	8.3	3.6
150	8.6	3.6
120	9.0	3.6
100	9.3	3.6
90	9.6	3.9
80	9.9	3.9
70	10.2	3.9
60	10.8	3.9
50	11.5	3.9

Notes: Also see minimums from Figure 430-4.

If the minimum total roadway width is greater than the sum of the shoulders and lane widths, apply the extra width to the inside of the curve.

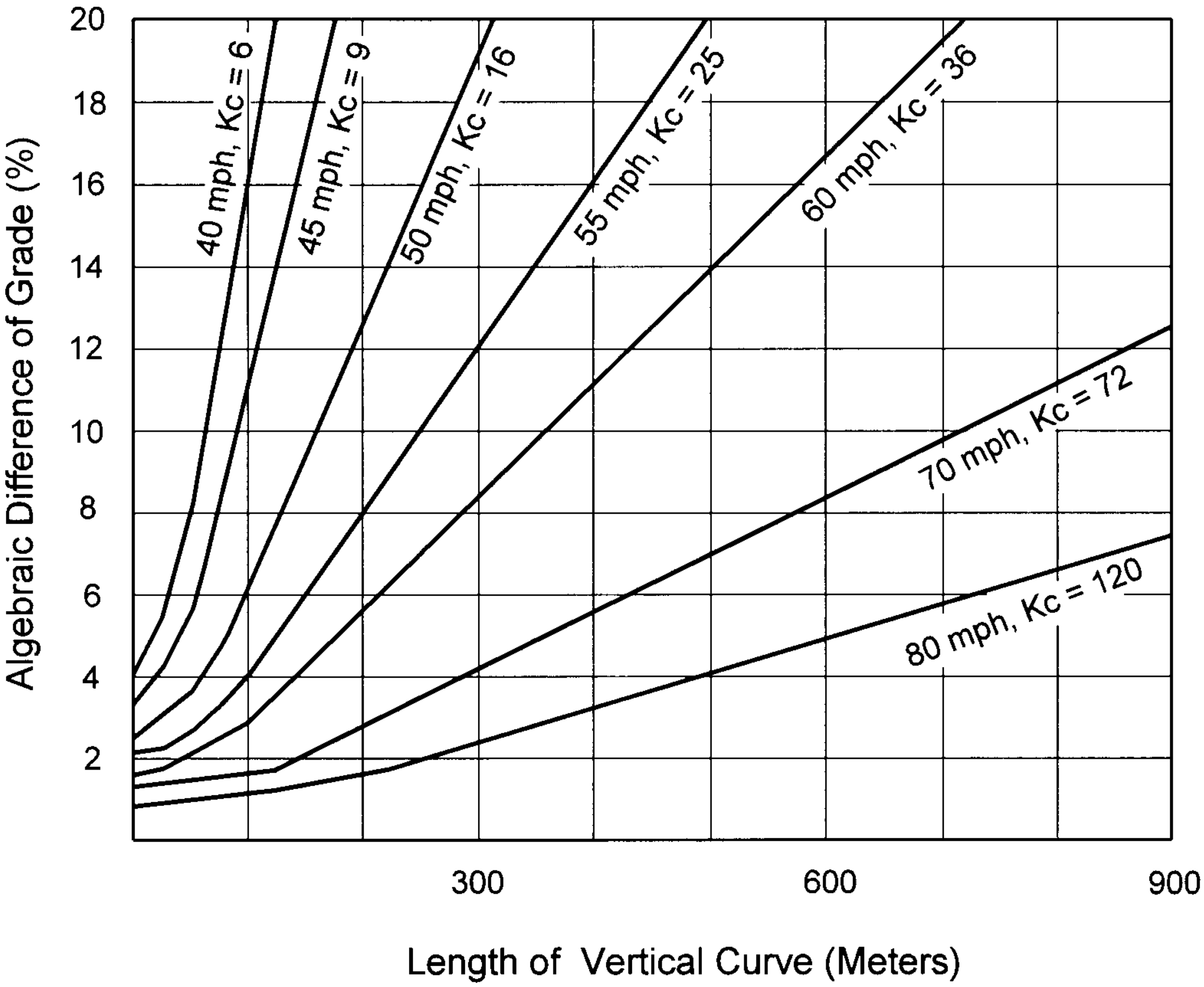


Minimum Total Roadway Widths for Two-Lane Highway Curves
Modified Design Level
Figure 430-5



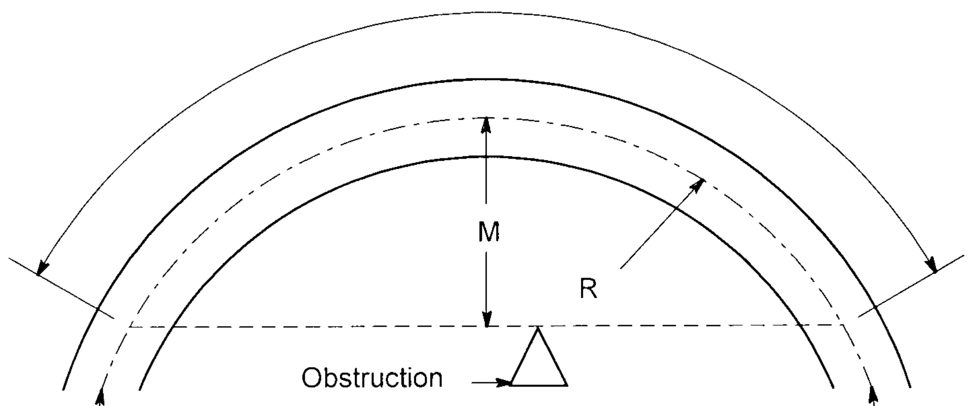
If result is less than the total roadway width
from Figure 430-4 use the greater.

Minimum Total Roadway Widths for Two-Lane Highway Curves, D<90°
Modified Design Level
Figure 430-6

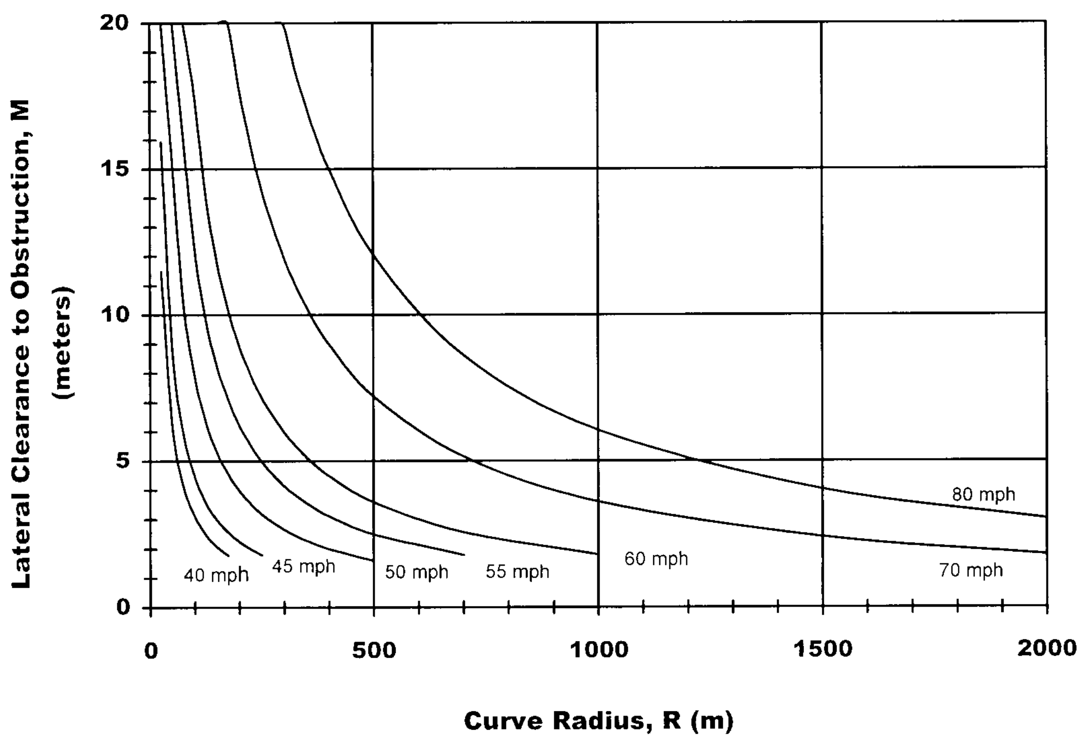


When the intersection of the algebraic difference of grade with the length of vertical curve is above the selected design speed line, corrective action must be considered.
Kc see Chapter 650.

Evaluation for Stopping Sight Distancefor Crest Vertical Curves
Modified Design Level
Figure 430-7

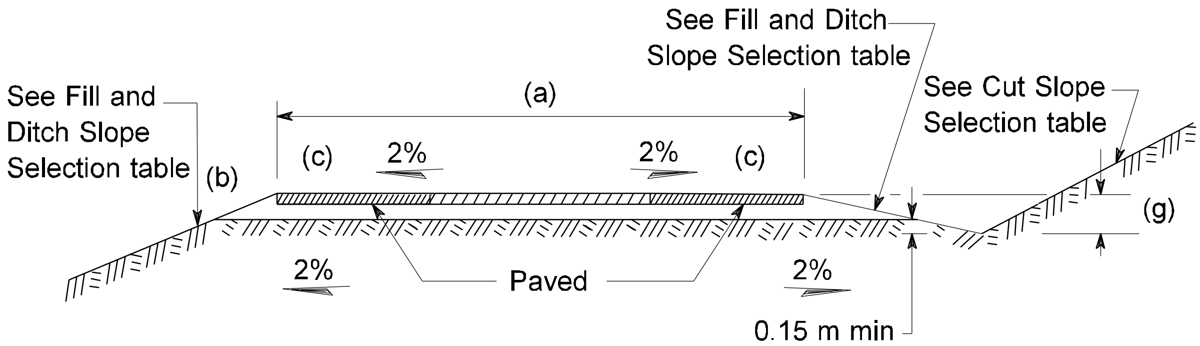


M is the distance in meters from the center line
of the inside lane to the obstruction.
Obstruction is a cut slope or other object
0.6 m or more above the inside lane.



When the intersection of the lateral clearance (M) with the curve radius (R) falls below the curve for the selected design speed, corrective action must be considered.

Evaluation for Stopping Sight Distance for Horizontal Curves
Modified Design Level
Figure 430-8



Height of Cut (m)	Slope not Steeper than (d)
0 - 1.5	1:4
1.5 - 6	1:3
over 6	1:2

Cut Slope Selection

Height of Fill/Depth of Ditch (m)	Slope not Steeper than
0 - 6	1:4
6 - 9	1:3
over 9	1:2 (e) (f)

Fill and Ditch Slope Selection

Notes:

(a) See Figures 430-3 and 4 for minimum roadway widths and Figures 430-5 and 6 for turning roadway widths.

(b) Widen and round embankments steeper than 1:4.

(c) See Chapter 640 for shoulder slope requirements.

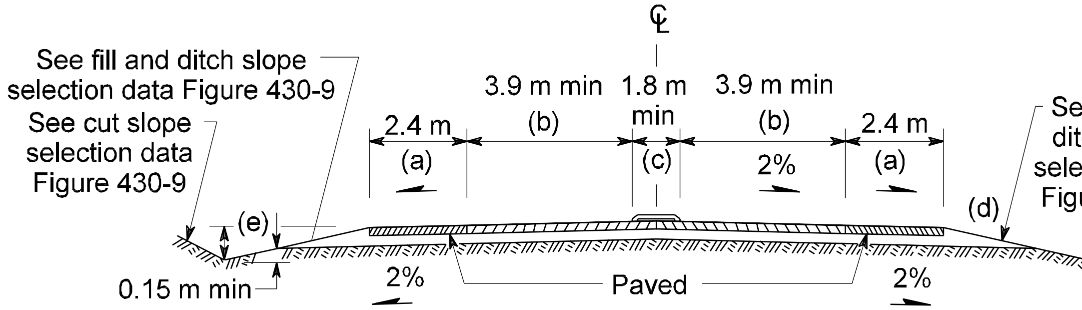
(d) Or as recommended by the soils or geotechnical report. Refer to Chapter 700 and 710 for clear zone and barrier requirements.

(e) Consider flatter slopes for the greater fill heights and ditch depths where practical.

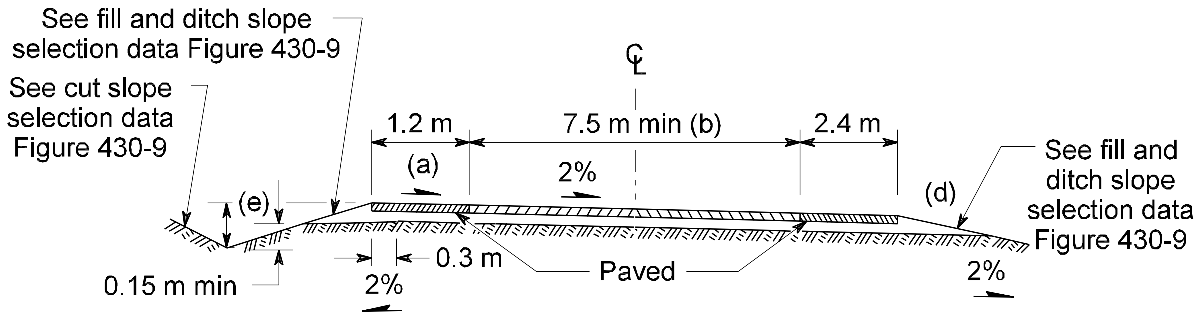
(f) Fill slopes up to 1:1½ may be used where favorable soil conditions exist. Refer to Chapter 640 for additional details and Chapter 700 and 710 for clear zone and barrier requirements.

(g) Minimum ditch depth is 0.6 m for design speeds over 40 mph or 0.45 m for design speeds 40 mph or less.

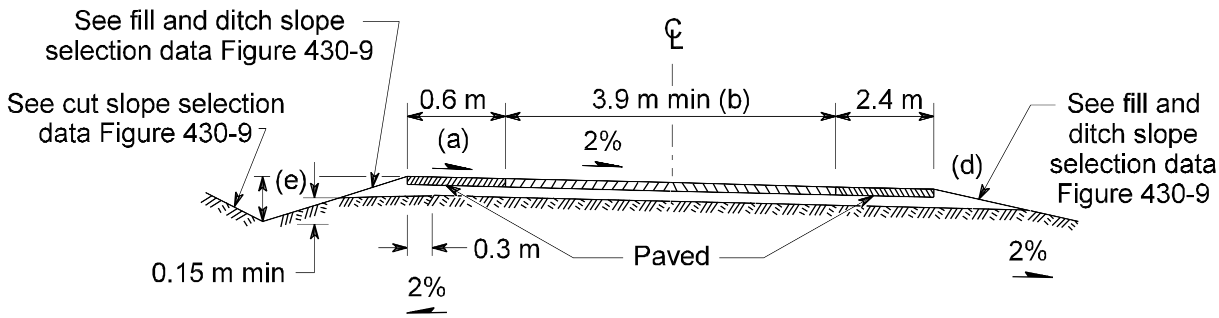
Main Line Roadway Sections
Modified Design Level
Figure 430-9



Two-Lane Two-Way Ramp



Two-Lane One-Way Ramp



One-Lane Ramp

(a) See Chapter 640 for shoulder slope requirements.

(b) See text 430.04 for minimum ramp width.

(c) The median width of a two-lane, two-way ramp shall not be less than that required for traffic control devices and their required shy distances.

(d) Widen and round embankments steeper than 1:4.

(e) Minimum ditch depth is 0.6 m for design speeds over 40 mph and 0.45 m for design speeds at and under 40 mph.

Ramp Roadway Sections
Modified Design Level
Figure 430-10

440.01 General

Full design level is the highest level of design and is used on new and reconstructed highways. These projects are designed to provide optimum mobility, safety, and efficiency of traffic movement. The overall objective is to move the greatest number of vehicles, at the highest allowable speed, and at optimum safety. Major design controls are functional classification, terrain classification, urban or rural surroundings, traffic volume, traffic character and composition, design speed, and access control.

440.02 References

Revised Code of Washington (RCW) 47.05.021, Functional classification of highways.

RCW 47.24, City Streets as Part of State Highways

Washington Administrative Code (WAC) 468-18-040, “Design standards for rearranged county roads, frontage roads, access roads, intersections, ramps and crossings”

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

Standard Specifications for Road, Bridge, and Municipal Construction (Standard Specifications), M 41-10, WSDOT.

Plans Preparation Manual, WSDOT, M 22-31

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

A Policy on Geometric Design of Highways and Streets (Green Book), 1994, AASHTO

A Policy on Design Standards - Interstate System, 1991, AASHTO

440.03 Definitions

auxiliary lane The portion of the roadway adjoining the through lanes for parking, speed change, turning, storage for turning, weaving, truck climbing, and other purposes supplementary to through-traffic movement.

bikeway Any trail, path, part of a highway or shoulder, sidewalk, or any other traveled way specifically signed and/or marked for bicycle travel.

collector system Routes that primarily serve the more important intercounty, intracounty, and intraurban travel corridors, collect traffic from the system of local access roads and convey it to the arterial system, and on which, regardless of traffic volume, the predominant travel distances are shorter than on arterial routes (RCW 47.05.021).

design speed The speed used to determine the various geometric design features of the roadway.

frontage road An auxiliary road that is a local road or street located on the side of a highway for service to abutting property and adjacent areas and for control of access.

functional classification The grouping of streets and highways according to the character of the service they are intended to provide.

high pavement type Portland cement concrete pavement or asphalt cement concrete pavement on treated base.

intermediate pavement type Asphalt cement concrete pavement on an untreated base.

Interstate System A network of routes selected by the state and the FHWA under terms of the federal aid acts as being the most important to the development of a national system. The Interstate System is part of the principal arterial system.

lane A strip of roadway used for a single line of vehicles.

lane width The lateral design width for a single lane, striped as shown in the Standard Plans and Standard Specifications. The width of an existing lane is measured from the edge of traveled way to the center of the lane line or between the centers of adjacent lane lines.

low pavement type Bituminous surface treatment.

median The portion of a divided highway separating the traveled ways for traffic in opposite directions.

minor arterial system A rural network of arterial routes linking cities and other activity centers that generate long distance travel and, with appropriate extensions into and through urban areas, form an integrated network providing interstate and interregional service (RCW 47.05.021).

***National Highway System* (NHS)** An interconnected system of principal arterial routes that serves interstate and interregional travel; meets national defense requirements; and serves major population centers, international border crossings, ports, airports, public transportation facilities, other intermodal transportation facilities, and other major travel destinations. The Interstate System is a part of the NHS.

operating speed The speed at which drivers are observed operating their vehicles during free-flow conditions. The 85th percentile of the distribution of observed speeds is most frequently used.

outer separation The area between the outside edge of traveled way for through traffic and the nearest edge of traveled way of a frontage road.

posted speed The maximum legal speed as posted on a section of highway using regulatory signs.

principal arterial system A connected network of rural arterial routes with appropriate extensions into and through urban areas, including all routes designated as part of the Interstate System, that serve corridor movements having travel characteristics indicative of substantial statewide and interstate travel (RCW 47.05.021).

roadway The portion of a highway, including shoulders, for vehicular use. A divided highway has two or more roadways.

shoulder The portion of the roadway contiguous with the traveled way, primarily for accommodation of stopped vehicles, emergency use, lateral support of the traveled way, and use by pedestrians and bicycles.

shoulder width The lateral width of the shoulder, measured from the outside edge of the outside lane to the edge of the roadway.

traveled way The portion of the roadway intended for the movement of vehicles, exclusive of shoulders and lanes for parking, turning, and storage for turning.

usable shoulder The width of the shoulder that can be used by a vehicle for stopping.

440.04 Functional Classification

As provided in RCW 47.05.021, the state highway system is divided and classified according to the character and volume of traffic carried by the routes and distinguished by specific geometric design standards. The functional classifications used on highways, from highest to lowest classification, are Interstate, principal arterial, minor arterial, and collector. The higher functional classes give more priority to through traffic and less to local access.

The criteria used in making the functional classification consider the following:

- Urban population centers within and without the state stratified and ranked according to size.
- Important traffic generating economic activities, including but not limited to recreation, agriculture, government, business, and industry.

- Feasibility of the route, including availability of alternate routes within and without the state.
- Directness of travel and distance between points of economic importance.
- Length of trips.
- Character and volume of traffic.
- Preferential consideration for multiple service which shall include public transportation.
- Reasonable spacing depending upon population density.
- System continuity.

440.05 Terrain Classification

To provide a general basis of reference between terrain and geometric design, three classifications of terrain have been established.

Level. Level to moderately rolling. This terrain offers few or no obstacles to the construction of a highway having continuously unrestricted horizontal and vertical alignment.

Rolling. Hills and foothills. Slopes rise and fall gently but occasional steep slopes might offer some restriction to horizontal and vertical alignment.

Mountainous. Rugged foothills, high steep drainage divides, and mountain ranges.

Terrain classification pertains to the general character of the specific route corridor. Roads in valleys or passes of mountainous areas might have all the characteristics of roads traversing level or rolling terrain and are usually classified as level or rolling rather than mountainous.

440.06 Geometric Design Data

(1) State Highway System

For all projects designed to full design level, use the geometric design data in Figures 440-4 through 7b.

(2) State Highways as City Streets

When a state highway within an urban area is coincident with and is a portion of a local agency roadway, develop the design features in cooperation with the local agency. For facilities on the NHS, use the design criteria in this manual as the minimum for the functional class of the route. For facilities not on the NHS, the *Local Agency Guidelines* may be used as minimum design criteria; however, the use of WSDOT standards is encouraged where feasible.

(3) City Streets and County Roads

Plan and design facilities that cities or counties will be requested to accept as city streets or county roads according to the applicable design criteria shown in:

- WAC 468-18-040.
- *Local Agency Guidelines*.
- The standards of the local agency that will be requested to accept the facility.

440.07 Design Speed

Vertical and horizontal alignment, sight distance, and superelevation will vary appreciably with design speed. Such features as traveled way width, shoulder width, and lateral clearances are usually not affected. See Chapters 620, 630, 640, and 650 for the relationships between design speed, geometric plan elements, geometric profile elements, superelevation, and sight distance.

The choice of a design speed is influenced principally by functional classification, posted speed, operating speed, terrain classification, traffic volumes, accident history, access control, and economic factors. However, a geometric design that adequately allows for future improvement is the major criterion, rather than strictly economics. Categorizing a highway by a terrain classification often results in arbitrary reductions of the design speed when, in fact, the terrain would allow a higher design speed without materially affecting the cost of construction. Savings in vehicle operation and other costs alone might be sufficient to offset the increased cost of right of way and construction.

It is important to consider the geometric conditions of adjacent sections. Maintain a uniform design speed for a significant segment of highway.

Design speeds for each functional class are given in Figures 4, 5a, 6a, and 7a. It is desirable that the design speed and the posted speed correlate as shown in Figure 440-1 and that the design speed be not less than the operating speed.

Posted Speed	Desirable Design Speed
35 mph or less	Not less than the posted speed.
40 mph to 50 mph	5 mph over the posted speed
55 mph or higher	10 mph over the posted speed

Desirable Design Speed
Figure 440-1

Select a design speed for urban arterial streets and highways with some access control and fairly long distances between intersections as discussed above. However, highway arterials that have obvious "street-like" characteristics, operationally and physically, do not require a design speed determination. In such instances, closely spaced intersections and other operational constraints usually limit vehicular speeds, negating the design speed factor.

440.08 Traffic Lanes

Lane width and condition has a great influence on safety and comfort. The added cost for wider lanes is offset, to some extent, by the reduction in shoulder maintenance cost due to the lessening of wheel load concentrations at the edge of the lane.

Lanes 3.6 m wide provide desirable clearance between large vehicles where traffic volumes are high and a high number of large vehicles are expected.

Highway capacity is also affected by the width of the lanes. With narrow lanes, drivers must operate their vehicles closer (laterally) to each other than they normally desire. To compensate for this, drivers reduce their speed and increase the headway, resulting in reduced capacity.

Figures 440-4 through 440-7b give the minimum lane width for the various design classes. See Chapter 640 for guidance on width requirements on turning roadways.

440.09 Shoulders

The shoulder width is controlled by the functional classification of the roadway, the traffic volume, and the function the shoulder is to serve.

The more important shoulder functions are to:

(1) Provide space for:

- Stopping out of the traffic lanes.
- Escaping potential accidents or to reduce their severity.
- Lateral clearance to roadside objects, such as guardrail (see Chapters 700 and 710).
- Pedestrian and bicycle use.
- Large vehicle off tracking on curves (see Chapter 640 and 910).
- Maintenance operations.
- Law enforcement.
- Bus stops (see Chapter 1060).
- Slow vehicles turnouts and shoulder driving (see Chapter 1010).
- Ferry holding lanes.
- A sense of openness contributing to driver ease and freedom from strain.
- For use as a lane during reconstruction of the through lanes.

(2) Provide structural support for the traveled way.

(3) Improve sight distance in cut sections (see Chapter 650).

(4) Improve capacity.

(5) Reduce seepage adjacent to the traveled way by discharging storm water farther away.

For minimum overall shoulder widths based on functional classification and traffic volume, see Figures 440-4 through 7b.

Guidance and width requirements for the shoulder functions with chapter references is in the referenced chapters. Figure 440-2 gives minimum overall and usable shoulder widths for other functions. For the remaining functions listed, the benefits vary with the width of the shoulder.

The width of shoulder required for maintenance operations depends on the operation performed and the equipment needed. To be able to park a maintenance truck out of the through lane, 3.0 m usable width is needed. For equipment with outriggers, such as used to service luminaires and repair guardrail, a width of 3.6 m is required or a lane will need to be closed while the equipment is working. Contact the region maintenance office to determine the shoulder width for maintenance operations. When shoulder widths wider than called for in Figures 440-4 through 7b are requested, compare the added cost of the wider shoulders to the added benefits to maintenance operations and other benefits that may be derived. When the maintenance office requests a shoulder width different than for the design class, justify the width selected.

Shoulder Function	Minimum Shoulder Width
Minimum lateral clearance and structural support	0.6 m
Pedestrian or bicycle use	1.2 m(1)
Stopping out of the traffic lanes	1.8 m(2)
Law enforcement and Ferry holding	1.8 m(2)

(1) Minimum usable shoulder width for bicycles. For additional information, see Chapter 1020 for bicycle and Chapter 1025 for pedestrians.
(2) Minimum usable shoulder width, 3.0 m preferred. See Chapters 1040 and 1050 for additional information on enforcement areas.

Minimum Shoulder Width
Figure 440-2

The usable shoulder width is less than the constructed shoulder width when vertical features (such as traffic barrier or walls) are at the edge of the shoulder. This is because drivers tend to shy away from the perceived hazard of the vertical feature. See Chapter 710 for the required widening.

Provide a minimum clearance to roadside objects so that the shoulders do not require narrowing. At existing bridge piers and abutments, shoulders less than full width to a minimum of 0.6 m may be used with design exception documentation. See Chapter 700 for design clear zone and safety treatment requirements.

Shoulder widths greater than 3.0 m may encourage use as a travel lane. Therefore, use shoulders wider than this only where required to meet one of the listed functions.

When curb section is used, the minimum shoulder width from the edge of traveled way to the face of curb is given in Figure 440- 3.

440.10 Medians

The primary functions of a median are to:

- Separate opposing traffic.
- Provide for recovery of out-of-control vehicles.
- Reduce head-on accidents.
- Provide an area for emergency parking.
- Allow space for left turn lanes.
- Minimize headlight glare.
- Allow for future widening.

For maximum efficiency, make medians highly visible both night and day. Medians may be depressed, raised, or flush with the through lanes.

The width of a median is measured from edge of traveled way to edge of traveled way and includes the shoulders. The minimum median width for each design class is given in Figures 440-4 through 440-7b. When selecting a median width, consider future needs such as wider left shoulders when widening from four to six lanes.

At locations where the median will be used to allow vehicles to make a u-turn, consider increasing the width to meet the needs of the vehicles making the u-turn. See Chapter 910 for information on u-turn locations.

See Chapter 700 for barrier requirements and Chapter 910 for left-turn lane design.

440.11 Curbs

Curbing is used for the following purposes:

- Drainage control.
- Delineation of the roadway edge.
- Delineation of pedestrian walkways.
- Delineation of islands.
- Right of way reduction.
- Assist in access control.
- Prevention of mid-block left turns.

The two general classes of curbs are barrier curbs and mountable curbs (see the Standard Plans for designs). Precast traffic curb, precast block curb, and all extruded curbs are considered mountable curbs.

Barrier curbs are 150 mm or more high with a face batter not flatter than 1H:3V. They are used:

- To inhibit or at least discourage vehicles from leaving the roadway.
- For walkway and pedestrian refuge separations.
- For raised islands on which a traffic signal, or traffic signal hardware, is located.

When an overlay will reduce the height of a barrier curb to less than 150 mm, evaluate grinding to maintain curb height, or replacing the curb, verses the need to maintain a barrier curb. Do not reduce the height of a curb needed for one of the three uses above to less than 100 mm.

Mountable curbs have a height of 150 mm or less, preferably 100 mm or less, with a sloping face that is more readily traversed. When the face slope is steeper than 1H:1V, the height of a mountable curb is limited to 100 mm or less. They are used where a curb is needed but barrier curb is not justified.

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

Where curbing is to be provided, ensure that surface water will drain.

Curbs can hamper snow removal operations. Contact the regional Operations Engineer when considering curbing in areas of heavy snowfall.

In general, neither mountable nor barrier curbs are used on facilities with a posted speed greater than 40 mph. The exceptions are for predominantly urban or rapidly developing areas where sidewalks are provided or where traffic movements are to be restricted.

When curbing is used, provide the minimum shoulder widths shown in Figure 440-3. (For traffic islands, also see Chapter 910.)

Lane Width	Design Speed		
	≥50 mph	<50 mph	All
	On Left		On Right
3.6 m or wider	1.2 m min(1)	0.3 m(2)	(3)
3.3 m	1.2 m min(1)	0.6 m(2)	(3)
3.0 m	1.2 m min(1)	0.9 m(2)	(3)

(1) Use the wider width when required for the functional class (Figures 440-5a through 7b).
(2) When mountable curb is used on routes with a posted speed of 35 mph or less, shoulder width is desirable but, with justification, curb may be placed at the edge of traveled way.
(3) Use the width required for the functional class (Figures 440-5a through 7b).
(4) Measured from the edge of traveled way to the face of the curb.

Shoulder Width for Curb(4)
Figure 440-3

440.12 Parking

In urban areas and rural communities, land use might require parking along the highway. In general, on-street parking decreases capacity, increases accidents, and impedes traffic flow. Therefore, it is desirable to prohibit parking.

Although design data for parking lanes are included on Figures 440-5a through 7b, consider them only in cooperation with the municipality involved. The lane widths given are the minimum for parking.

440.13 Pavement Type

The pavement types given in Figures 440-4 through 7a are the recommended for each design class. Submit Form 223-528, Pavement Type Determination to the OSC Materials Laboratory for a final determination of the pavement type to use. When a roadway is to be widened and the existing pavement will remain, the new pavement type may be the same as the existing without a pavement type determination.

440.14 Structure Width

Provide a clear width between curbs on a bridge equal to the approach roadway width (lanes plus shoulders). The structure widths given in Figures 440-4 through 7a are the minimum bridge width for each design class.

Shy distance is not normally added to the roadway width for the bridge width. When a bridge is in a run of roadside barrier, consider adding the shy distance on shorter bridges to prevent narrowing the roadway.

440.15 Grades

Grades can have a pronounced effect on the operating characteristics of the vehicles negotiating them. Generally, passenger cars can readily negotiate grades as steep as 5% without appreciable loss of speed from that maintained on level highways. Trucks, however, travel at the average speed of passenger cars on the level but display up to a 5% increase in speed on downgrades and a 7% or more decrease in speed on upgrades (depending on length and steepness of the grade as well as weight to horsepower ratio).

The maximum grades for the various functional classes and terrain conditions are shown in Figures 440-4 through 7a. For the effects of these grades on the design of a roadway see Chapters 630 and 1010.

P65:DP/DMM

Design Class	Divided Multilane I-1	
Design Year	(1)	
Access Control(2)	Full	
Separate Cross Traffic		
Highways	All	
Railroads	All	
Design Speed (mph)		
Rural	80(3)	
Urban	70	
Traffic Lanes		
Number	4 or more divided	
Width (m)	3.6	
Median Width (m)	4 lane	6 lanes or more
Rural —Minimum(4)	12	15
Urban —Minimum	4.8	6.6
Shoulder Width (m)		
Right of Traffic	3.0	3.0
Left of Traffic	1.2	3.0(5)
Pavement Type(6)	High	
Right of Way(7)		
Rural — Minimum Width (m)	19 from edge of traveled way	
Urban — Minimum Width (m)	As required (8)	
Structures Width(9) (m)	Full roadway width each direction(10)	

Grades (%)(11)

Type of Terrain	Design Speed (mph) 50	60	70	80
Level	4	3	3	3
Rolling	5	4	4	4
Mountainous	6	6	5	5

Interstate Notes:

1 The design year is 20 years after the year the construction is scheduled to begin.
2 See Chapter 1420 for access control requirements.
3 80 mph is the desirable design speed, with justification the design speed may be reduced to 60 mph in mountainous terrain and 70 mph in rolling terrain.
4 Independent alignment and grade is desirable in all rural areas and where terrain and development permits in urban areas.
5 For existing 6-lane roadways, existing 1.8 m left shoulders may remain when no other widening is required.
6 Submit Form 223-528, Pavement Type Determination.
7 Provide right of way width 3.0 m desirable, 1.5 m minimum, wider than the slope stake for fill and slope treatment for cut. See Chapter 640 and the Standard Plans for slope treatment information.
8 In urban areas, make right of way widths not less than those required for necessary cross section elements.
9 See Chapter 1120 for minimum vertical clearance.
10 For median widths 7.8 m or less, address bridge(s) in accordance with Chapter 1120.
11 Grades 1% steeper may be used in urban areas where development precludes the use of flatter grades and for one-way down grades except in mountainous terrain.

Geometric Design Data, Interstate

Figure 440-4

Design Class	Divided Multilane				Two-Lane						Undivided Multilane	
	P-1		P-2		P-3		P-4		P-5		P-6 (1)	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
DHV in Design Year (2) NHS / Non NHS	Over 1,500		Over 700		Over 201 (3) / Over 301		61-200 (4) / 101-300		60 and under / 100 and Under		Over 700	
Access Control	Full (5)		Partial (5)		(5)		(5)		(5)		(5)	
Separate Cross Traffic												
Highways	All		Where Justified		Where Justified		Where Justified		Where Justified		Where Justified	
Railroads	All		All		All (6)		Where Justified (7)		Where Justified (7)		Where Justified (7)	
Design Speed (mph) (8)	70		70		70	60	70	60	60	60	70	60
Mountainous Terrain (9)	50		50		50	40	50	40	40	30	40	30
Traffic Lanes												
Number	4 or more divided		4 or 6 divided		2		2		2		4	4 or 6
Width (m)	3.6		3.6		3.6		3.6		3.6		3.6	3.3 (10)
Shoulder Width (m)												
Right of Traffic	3.0		3.0		2.4		1.8		1.2		2.4	2.4 (11)
Left of Traffic	Variable (12)		Variable (12)									
Median Width (m)												
4 lane	12 (13)	4.8	18	4.8							1.2	0.6 (14)
6 or more lanes	14.4 (13)	6.6	18	6.6							1.2	0.6 (14)
Parking Lanes Width (m) — Minimum	None		None		None		None	3.0	None	3.0	None	3.0 (15)
Pavement Type (16)	High				High or intermediate							
Right of Way (17) — Min Width (m)	(18)	(19)	(18)	(19)	36	24	36	24	30	24	65	24
Structures Width (m) (20)	Full roadway width (21)				12.0		10.8		9.6		Full roadway width	
Other Design Considerations-Urban					(22)		(22)		(22)		(22)	

Grades (%) (23)

Type of Terrain	Rural — Design Speed (mph)					Urban — Design Speed (mph)			
	40	50	60	70	80	30	40	50	60
Level	5	4	3	3	3	8	7	6	5
Rolling	6	5	4	4	4	9	8	7	6
Mountainous	8	7	6	5	5	11	10	9	8

Geometric Design Data, Principal Arterial
Figure 440-5a

Principal Arterial Notes:

1. Justify the selection of a P-6 standard.
2. The design year is 20 years after the year the construction is scheduled to begin.
3. Where DHV exceeds 700, consider four lanes. When the volume/capacity ratio is equal to or exceeds 0.75, consider the needs for a future four-lane facility. When considering truck climbing lanes on a P-3 design class highway, perform an investigation to determine if a P-2 design class highway is justified.
4. When considering a multilane highway, perform an investigation to determine if a truck climbing lane or passing lane will satisfy the need. See Chapter 1010.
5. See Chapter 1420 and the Master Plan for Limited Access Highways for access control requirements. Contact the OSC Design Office Access & Hearings Unit for additional information.
6. All main line and major-spur railroad tracks will be separated. Consider allowing at-grade crossings at minor-spur railroad tracks.
7. Criteria for railroad grade separations are not clearly definable. Evaluate each site regarding the hazard potential. Provide justification for railroad grade separations.
8. These are the design speeds for level and rolling terrain and the preferred for mountainous terrain. Higher design speeds may be selected, with justification.
9. These design speeds may be selected in mountainous terrain, with justification.
10. 3.6 m lanes are required when the truck DHV is 6% or greater.
11. When curb section is used, the minimum shoulder width from the edge of traveled way to the face of curb is 1.2 m.
12. Minimum left shoulder width is to be as follows: four lanes — 1.2 m: six or more lanes — 3.0 m. For 6-lane roadways, existing 1.8 m left shoulders may remain when no other widening is required.
13. On freeways or expressways requiring less than eight lanes within the 20-year design period, provide sufficient median or lateral clearance and right of way to permit addition of a lane in each direction if required by traffic increase after the 20-year period.
14. When signing is required in the median of a six-lane section, the minimum width is 1.8 m. If barrier is to be installed at a future date, a 2.4 m minimum median is required.
15. Restrict parking when ADT is over 15,000.
16. Submit Form 223-528, Pavement Type Determination.
17. Provide right of way width 3.0 m desirable, 1.5 m minimum, wider than the slope stake for fill and slope treatment for cut. See Chapter 640 and the Standard Plans for slope treatment information.
18. 19 m from edge of traveled way.
19. Make right of way widths not less than those required for necessary cross section elements.
20. See Chapter 1120 for the minimum vertical clearance.
21. For median widths 7.8 m or less, address bridges in accordance with Chapter 1120.
22. For bicycle requirements see Chapter 1020. For pedestrian and sidewalk requirements see Chapter 1025. Curb requirements are in 440.11. Lateral clearances from the face of curb to obstruction are in Chapter 700.
23. Except in mountainous terrain, grades 1% steeper may be used in urban areas where development precludes the use of flatter grades or for one-way downgrades.

Geometric Design Data, Principal Arterial
Figure 440-5b

Design Class	Divided Multilane		Two-Lane						Undivided Multilane	
	M-1		M-2		M-3		M-4		M-5[1]	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
DHV in Design Year[2] NHS Non NHS	Over 700		Over 201[3] Over 401		61-200[4] 201-400		60 and Under 200 and Under		Over 700	
Access Control	(5)		(5)		(5)		(5)		(5)	
Separate Cross Traffic Highways Railroads	Where Warranted All		Where Warranted All[6]		Where Warranted Where Warranted[7]		Where Warranted Where Warranted[7]		Where Warranted Where Warranted[7]	
Design Speed (mph)[8] Mountainous Terrain[9]	70 50		70 50	60 40	70 50	60 40	60 40	60 30	70 40	60 30
Traffic Lanes Number Width (m)	4 or 6 divided 3.6		2 3.6		2 3.6		2 3.6		4 3.6	4 or 6 3.3[10]
Shoulder Width (m) Right of Traffic Left of Traffic	3.0 Variable[12]		2.4		1.8		1.2		2.4	2.4[11]
Median Width (m) 4 lane 6 lane	18 18	4.8 6.6							1.2	0.6[13]
Parking Lanes Width (m) — Minimum	None		None		None	3.0	None	3.0	None	3.0[14]
Pavement Type[15]	High		As required						High or Intermediate	
Right of Way[16] — Min Width (m)	(17)	(18)	36	24	36	24	30	24	45	24
Structures (m)[19]	Full Roadway Width[20]		12		10.8		9.6		Full Roadway Width	
Other Design Considerations-Urban			(21)		(21)		(21)		(21)	

Grades (%)[22]									
	Rural — Design Speed (mph)					Urban — Design Speed (mph)			
Type of Terrain	40	50	60	70	80	30	40	50	60
Level	5	4	3	3	3	8	7	6	5
Rolling	6	5	4	4	4	9	8	7	6
Mountainous	8	7	6	5	5	11	10	9	8

Geometric Design Data, Minor Arterial
Figure 440-6a

Minor Arterial Notes:

1 Justify the selection of an M-5 standard.
2 The design year is 20 years after the year the construction is scheduled to begin.
3 Where DHV exceeds 700, consider four lanes. When the volume/capacity ratio is equal to or exceeds 0.75, consider the needs for a future four-lane facility. When considering truck climbing lanes an M-2 design class highway, perform an investigation to determine if an M-1 design class highway is justified.
4 When considering a multilane highway, perform an investigation to determine if a truck climbing lane or passing lane will satisfy the need. See Chapter 1010.
5 See Chapter 1420 and the Master Plan for Limited Access Highways for access control requirements. Contact the OSC Design Office Access & Hearings Unit for additional information.
6 All main line and major-spur railroad tracks will be separated. Consider allowing at-grade crossings at minor-spur railroad tracks.
7 Criteria for railroad grade separations are not clearly definable. Evaluate each site regarding the hazard potential. Provide justification for railroad grade separations.
8 These are the design speeds for level and rolling terrain and the preferred for mountainous terrain. Higher design speeds may be selected, with justification.
9 These design speeds may be selected in mountainous terrain, with justification.
10 When the truck DHV is 6% or greater, consider 3.6 m lanes.
11 When curb section is used, the minimum shoulder width from the edge of traveled way to the face of curb is 1.2 m.
12 The minimum left shoulder width is 1.2 m for four lanes and 3.0 m for six or more lanes. For 6-lane roadways, existing 1.8 m left shoulders may remain when no other widening is required.
13 When signing is required in the median of a six-lane section, the minimum width is 1.8 m. If barrier is to be installed at a future date, a 2.4 m minimum median is required.
14 Restrict parking when ADT is over 15,000.
15 Submit Form 223-528, Pavement Type Determination.
16 Provide right of way width 3.0 m desirable, 1.5 m minimum, wider than the slope stake for fill and slope treatment for cut. See Chapter 640 and the Standard Plans for slope treatment information.
17 19 m from edge of traveled way
18 Make right of way widths not less than those required for necessary cross section elements.
19 See Chapter 1120 for the minimum vertical clearance.
20 For median widths 7.8 m or less, address bridges in accordance with Chapter 1120.
21 For bicycle requirements see Chapter 1020. For pedestrian and sidewalk requirements see Chapter 1025. Curb requirements are in 440.11. Lateral clearances from the face of curb to obstruction are in Chapter 700.
22 Except in mountainous terrain, grades 1% steeper may be used in urban areas where development precludes the use of flatter grades or for one-way downgrades.

Geometric Design Data, Minor Arterial
Figure 440-6b

Design Class	Undivided Multilane		Two-Lane					
	C-1		C-2		C-3		C-4	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
DHV in Design Year[1] NHS	Over 900		Over 301[2]		201-300[3]		200 and under	
Non NHS			Over 501		301-500		300 and Under	
Access Control	(4)		(4)		(4)		(4)	
Separate Cross Traffic								
Highways	Where Warranted		Where Warranted		Where Warranted		Where Warranted	
Railroads	Where Warranted[5]		All[5]		Where Warranted[5]		Where Warranted[5]	
Design Speed (mph)[6]	70	60	70	60	70	60	60	60
Mountainous Terrain[7]	40	30	50	40	50	40	40	30
Traffic Lanes								
Number	4	4 or 6	2		2		2	
Width (m)	3.6	3.3[8]	3.6		3.6		3.6	
Shoulder Width (m)	2.4	2.4[9]	2.4		1.8		1.2	
Median Width — Minimum (m)	1.2	0.6[10]						
Parking Lanes Width (m) — Minimum	None	3.0	None		None	3.0	None	3.0
Pavement Type[11]	High or Intermediate		As required					
Right of Way[12] (m)	45	24	36	24	36	24	30	24
Structures Width (m)[13]	Full Roadway Width		12.0		10.8		9.6	
Other Design Considerations-Urban	(14)		(14)		(14)		(14)	

Grades (%)[15]

	Rural — Design Speed (mph)					Urban — Design Speed (mph)			
Type of Terrain	30	40	50	60	70	30	40	50	60
Level	7	7	6	5	4	9	9	7	6
Rolling	9	8	7	6	5	11	10	8	7
Mountainous	10	10	9	8	6	12	12	10	9

Geometric Design Data, Collector
Figure 440-7a

Collector Notes:

1 The design year is 20 years after the year the construction is scheduled to begin.
2 Where DHV exceeds 900, consider four lanes. When the volume/capacity ratio is equal to or exceeds 0.85, consider the needs for a future four-lane facility. When considering truck climbing lanes on a C-2 design class highway, perform an investigation to determine if a C-1 design class highway is justified.
3 When considering a multilane highway, perform an investigation to determine if a truck climbing lane or passing lane will satisfy the need. See Chapter 1010.
4 See Chapter 1420 and the Master Plan for Limited Access Highways for access control requirements. Contact the OSC Design Office Access & Hearings Unit for additional information.
5 Criteria for railroad grade separations are not clearly definable. Evaluate each site regarding the hazard potential. Provide justification for railroad grade separations.
6 These are the design speeds for level and rolling terrain and the preferred for mountainous terrain. Higher design speeds may be selected, with justification.
7 These design speeds may be selected in mountainous terrain, with justification.
8 Consider 3.6 m lanes when the truck DHV is 6% or greater.
9 When curb section is used, the minimum shoulder width from the edge of traveled way to the face of curb is 1.2 m.
10 When signing is required in the median of a six-lane section, the minimum width is 1.8 m median. If barrier is to be installed at a future date, a 2.4 m minimum median is required.
11 Submit Form 223-528, Pavement Type Determination.
12 Provide right of way width 3.0 m desirable, 1.5 m minimum, wider than the slope stake for fill and slope treatment for cut. See Chapter 640 and the Standard Plans for slope treatment information.
13 See Chapter 1120 for the minimum vertical clearance.
14 For bicycle requirements, see Chapter 1020. For pedestrian and sidewalk requirements see Chapter 1025. Curb requirements are in 440.11. Lateral clearances from the face of curb to obstruction are in with Chapter 700.
15 Except in mountainous terrain, grades 1% steeper may be used in urban areas where development precludes the use of flatter grades or for one-way downgrades.

Geometric Design Data, Collector
Figure 440-7b

620.01 General

This chapter provides guidance on the design of horizontal alignment, frontage roads, number of lanes, the arrangement of the lanes, and pavement transitions. See the following chapters for additional information:

Chapter	Subject
430	All roadway width requirements for modified design level
440	Lane and shoulder width requirements for full design level
440	Shoulder width requirements at curbs
640	Open highway and ramp lane widths on turning roadways for full design level
640	Superelevation rate and transitions
650	Sight distance
910	Requirements for islands

620.02 References

Washington Administrative Code (WAC) 468-18-040, "Design standards for rearranged county roads, frontage roads, access roads, intersections, ramps and crossings"

Utilities Manual, M 22-87, WSDOT

Plans Preparation Manual, M 22-31, WSDOT

Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD), USDOT, FHWA; including the *Washington State Modifications to the MUTCD*, M 24-01, WSDOT

Right of Way Manual, M 26-01, WSDOT

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

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620.03 Definitions

auxiliary lane The portion of the roadway adjoining the traveled way for parking, speed change, turning, storage for turning, weaving, truck climbing, passing, and other purposes supplementary to through-traffic movement

basic number of lanes The minimum number of general purpose lanes designated and maintained over a significant length of highway

frontage road An auxiliary road that is a local road or street located on the side of a highway for service to abutting property and adjacent areas and for control of access

outer separation The area between the outside edge of the through highway lanes and the inside edge of a frontage road

turning roadway A curve on an open highway, a curve on a ramp, or a connecting roadway between two intersecting legs of an intersection

620.04 Horizontal Alignment

(1) General

Horizontal and vertical alignments (Chapter 630) are the primary controlling elements for highway design. It is important to coordinate these two elements with design speed, drainage, intersection design, and aesthetic principles in the early stages of design.

Figures 620-1a and 1c show both desirable and undesirable alignment examples for use with the following considerations:

(a) Make the highway alignment as direct as possible and still blend with the topography while considering developed and undeveloped properties, community boundaries, and environmental concerns.

(b) Make highway alignment consistent by:

- Using gentle curves at the end of long tangents.
- Using a transition area of moderate curvature between the large radius curves of rural areas and the small radius curves of populated areas.
- Making horizontal curves visible to approaching traffic.

(c) Avoid minimum radii and short curves unless:

- Restrictive conditions are present and are not readily or economically avoidable.
- On two-lane highways, minimum radii will result in tangent sections long enough for needed passing.

(d) Avoid any abrupt change in alignment. Design reverse curves with an intervening tangent long enough for complete superelevation transition for both curves. See Chapter 640 for more information on superelevation transitions.

(e) Avoid the use of curves in the same direction connected by short tangents (broken back curves); substitute a single larger curve.

(f) Avoid compound curves on open highway alignment if a simple curve can be obtained. When compound curves are used, make the shorter radius at least two-thirds the longer radius. Make the total arc length of a compound curve not less than 150 m.

(g) On divided multilane highways, take advantage of independent alignment to produce a flowing alignment along natural terrain.

(h) The preferred locations for bridges, interchanges, intersections, and temporary connections are on tangent sections in clear view of the driver.

(i) On two-lane, two-way highways, strive for as much passing sight distance as possible. (See Chapter 650.)

(2) Horizontal Curve Radii

Design speed is the governing element of horizontal curves. For guidance regarding design speed selection see Chapter 440 for full design level, Chapter 430 for modified design level, and Chapter 940 for ramps.

Use the following factors to determine the radius for a curve:

- Stopping sight distance where sight obstructions are on the inside of a curve. The following are examples of sight obstructions: median barrier, bridges, walls, cut slopes, wooded areas, buildings, and guardrail. See Chapter 650 to check for adequate stopping sight distance for the selected design speed.
- Superelevation is the rotation or banking of the roadway cross section to overcome part of the centrifugal force that acts on a vehicle traversing a curve. Design information on the relationship between design speed, radius of curve, and superelevation is in Chapter 640.
- Coordinate vertical and horizontal alignment (see Chapter 630).
- For aesthetic reasons, on open highways, the desirable minimum curve length is 450 m and the maximum is around 1500 m. See Figures 620-1a through 1c.

Spiral curves, although no longer used on new highway construction or major realignment, still exist on Washington highways. Spirals were used to transition between tangents and circular curves with the curvature rate increasing from tangent to curve and decreasing from curve to tangent. Spirals do not pose an operational concern and may remain in place.

620.05 Distribution Facilities

(1) General

In addition to the highway under consideration, other facilities can be provided to distribute traffic to and from the highway and to fulfill access requirements. Highway flexibility can be augmented by:

- Frontage roads
- Collector distributor roads

630.01 General

Vertical alignment (roadway profile) consists of a series of gradients connected by vertical curves. It is mainly controlled by:

- Topography
- Class of highway
- Horizontal alignment
- Safety
- Sight distance
- Construction costs
- Drainage
- Adjacent land use
- Vehicular characteristics
- Aesthetics

This chapter provides guidance for the design of vertical alignment. See the following chapters for additional information:

Chapter	Subject
440	Maximum grade for each functional class
620	Horizontal alignment
650	Sight distance

630.02 References

Washington Administrative Code (WAC) 468-18-040, "Design standards for rearranged county roads, frontage roads, access roads, intersections, ramps and crossings"

Plans Preparation Manual, M 22-31, WSDOT

Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD), USDOT, FHWA; including the *Washington State Modifications to the MUTCD*, M 24-01, WSDOT

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

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630.03 Vertical Alignment

(1) Design Controls

The following are general controls for developing vertical alignment (also see Figures 630-1a and 1c):

- Use a smooth grade line with gradual changes, consistent with the class of highway and character of terrain. Avoid numerous breaks and short grades.
- Avoid "roller coaster" or "hidden dip" profiles by use of gradual grades made possible by heavier cuts and fills or by introducing some horizontal curvature in conjunction with the vertical curvature.
- Avoid grades that will affect truck speeds and, therefore, traffic operations.
- Avoid broken back grade lines with short tangents between two vertical curves.
- Use long vertical curves to flatten grades near the top of long steep grades.
- Where at-grade intersections occur on roadways with moderate to steep grades, it is desirable to flatten or reduce the grade through the intersection.
- Establish the subgrade at least 0.3 m above the high water table (real or potential) or as recommended by the region Materials Engineer. Consider the low side of superelevated roadways.

- When a vertical curve takes place partly or wholly in a horizontal curve, coordinate the two as discussed in 630.04.

(2) Minimum Length of Vertical Curves

The minimum length of a vertical curve is controlled by design speed, the requirements for stopping sight distance, and the change in grade. See Chapter 650 to design vertical curves to meet stopping sight distance requirements.

In addition to stopping sight distance requirements, the minimum length of a vertical curve, in meters, is equal to the design speed, in miles per hour. For aesthetics, the desirable length of a vertical curve is two to three times the length required for stopping sight distance.

(3) Maximum Grades

Analyze grades for their effect on traffic operation because they may result in undesirable truck speeds. Maximum grades are controlled by functional class of the highway, terrain type, and design speed (Chapter 440).

(4) Minimum Grades

Minimum grades are used to meet drainage requirements. Avoid selecting a "roller coaster" or "hidden dip" profile merely to accommodate drainage.

Minimum ditch gradients of 0.3% on paved materials and 0.5% on earth can be obtained independently of roadway grade. Medians, long sag vertical curves, and relatively flat terrain are examples of areas where independent ditch design may be justified. A closed drainage system may be needed as part of an independent ditch design.

(5) Length of Grade

The desirable maximum length of grade is the maximum length on an upgrade at which a loaded truck will operate without a 15 mph reduction. Figure 630-2 gives the desirable maximum length for a given percent of grade. For grades that are not at a constant percent, use the average. For grades longer than the desirable maximum, consider an auxiliary climbing lane (Chapter 1010).

When long steep downgrades are unavoidable, consider an emergency escape ramp (Chapter 1010).

(6) Alignment on Structures

Avoid high skew, vertical curvature, horizontal curvature, and superelevation on structures, but do not sacrifice safe roadway alignment to achieve this.

630.04 Coordination of Vertical and Horizontal Alignments

Do not design horizontal and vertical alignment independently. Coordinate them to obtain safety, uniform speed, pleasing appearance, and efficient traffic operation. Coordination can be achieved by plotting the location of the horizontal curves on the working profile to help visualize the highway in three dimensions. Perspective plots will also give a view of the proposed alignment. Figures 630-1a and 1b show sketches of desirable and undesirable coordination of horizontal and vertical alignment.

Guides for the coordination of the vertical and horizontal alignment are as follows:

- Balance curvature and grades. Using steep grades to achieve long tangents and flat curves, or excessive curvature to achieve flat grades, are both poor design.
- Vertical curvature superimposed on horizontal curvature generally results in a more pleasing facility. Successive changes in profile not in combination with horizontal curvature may result in a series of dips not visible to the driver.
- Do not begin or end a horizontal curve at or near the top of a crest vertical curve. This condition can be unsafe, especially at night, if the driver does not recognize the beginning or ending of the horizontal curve. Safety is improved if the horizontal curve leads the vertical curve, that is, the horizontal curve is made longer than the vertical curve in both directions.

640.01 General

Geometric cross sections for state highways are governed by functional classification criteria, traffic volume, and whether the highway is in a rural or urban area. See Chapter 440 for guidance on selecting a design class.

High Occupancy Vehicle (HOV) lanes must be considered when continuous through lanes are to be added within the limits of an urban area over 200,000 population (Chapter 1050).

When a state highway within an incorporated city or town is a portion of a city street, the design features must be developed in cooperation with the local agency. For city streets and county roads that are not part of the state highway system, use Chapter 468-18 WAC and the Local Agency Guidelines.

See the following chapters for additional information:

Chapter	Subject
430	all roadway widths for modified design level
440	lane and shoulder widths for full design level
440	shoulder widths at curbs
910	requirements for islands
940	lane and shoulder widths for ramps

640.02 References

Washington Administrative Code (WAC 468-18-040), "Design standards for rearranged county roads, frontage roads, access roads, intersections, ramps and crossings"

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

Plans Preparation Manual, WSDOT, M 22-31

Highway Runoff Manual, M 31-16, WSDOT

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

Standard Specifications for Road, Bridge, and Municipal Construction (Standard Specifications), M 41-10,WSDOT.

WSDOT Pavement Guide for Design, Evaluation and Rehabilitation (Pavement Guide), WA-RD 335.1, WSDOT

A Policy on Geometric Design of Highways and Streets (Green Book), 1994, AASHTO

640.03 Definitions

auxiliary lane The portion of the roadway adjoining the through lanes for parking, speed change, turning, storage for turning, weaving, truck climbing, and other purposes supplementary to through-traffic movement.

high pavement type Portland cement concrete pavement or asphalt cement concrete on a treated base.

intermediate pavement type Asphalt cement concrete pavement on an untreated base.

lane A strip of roadway used for a single line of vehicles.

lane width The lateral design width for a single lane, striped as shown in the Standard Plans and the Standard Specifications. The width of an existing lane is measured from the edge of traveled way to the center of the lane line or between the centers of successive lane lines.

low pavement type Bituminous surface treatment.

median The portion of a divided highway separating the traveled ways for traffic in opposite directions.

outer separation The area between the outside edge of traveled way for through traffic and the nearest edge of traveled way of a frontage road.

roadway The portion of a highway, including shoulders, for vehicular use. A divided highway has two or more roadways.

shoulder The portion of the roadway contiguous with the traveled way, primarily for accommodation of stopped vehicles, emergency use, lateral support of the traveled way, and use by pedestrians.

shoulder width The lateral width of the shoulder, measured from the outside edge of the outside lane to the edge of the roadway.

superelevation The rotation of the roadway cross section in such a manner as to overcome part of the centrifugal force that acts on a vehicle traversing a curve.

superelevation runoff The length of highway needed to accomplish the change in cross slope from a level section to a fully superelevated section, or vice versa.

superelevation transition length The length of highway needed to change the cross slope from normal crown or normal pavement slope to full superelevation.

tangent runout The length of highway needed to change the cross slope from normal crown to a section with adverse crown removed (level).

traveled way The portion of the roadway intended for the movement of vehicles, exclusive of shoulders and lanes for parking, turning, and storage for turning.

turning roadway A curve on an open highway, a ramp, or the connecting portion of roadway between two intersecting legs of an intersection.

640.04 Roadways

The cross sections shown in Figures 640-3, 4, 5, 6a, and 6b represent minimum standards for full design level.

For the specific type of roadway section see Chapter 440 and for pavement type details see the Pavement Guide.

(1) Traveled Way Cross Slope

The cross slope on tangents and curves is a main element in cross section design. The cross slope or crown on tangent sections and large radius curves is complicated by two contradicting controls. Reasonably steep cross slopes are desirable to aid in water runoff and to minimize ponding as a result of pavement imperfections and unequal settlement. However, steep cross slopes are undesirable on tangents because of the tendency for vehicles to drift to the low side of the roadway. Cross slopes greater than 2% are noticeable in steering and increase susceptibility to sliding to the side on icy or wet pavements.

A 2% cross slope is normally used for tangents and large radius curves on high and intermediate pavement types.

In some areas, a somewhat steeper cross slope may be desirable to improve roadway runoff, although it is undesirable operationally. For these areas, with justification, a 2.5% cross slope may be used.

On low pavement types, such as bituminous surface treatment, the cross slope may be increased to 3% to allow for reduced construction control and greater settlement.

Superelevation on curves is determined by the design speed and the radius of the curve. See 640.05 for guidance on superelevation design.

(2) Turning Roadway Widths

The roadway on a curve may need to be widened to make the operating conditions comparable to those on tangents. There are two main reasons to do this. One is the offtracking of vehicles, such as trucks and buses. The other is the increased difficulty drivers have in keeping their vehicles in the center of the lane.

(a) **Two-lane two-way roadways.** Figure 640-7a shows the traveled way width W for two-lane two-way roadways. For values of R between those given, interpolate W and round up to the next tenth of a meter.

Minimum traveled way width W based on the delta angle of the curve is shown in Figure 640-7b. Round W to the nearest tenth of a meter.

(b) **Two-lane one-way roadways.** Figure 640-8a shows the traveled way width for two-lane one-way turning roadways, including two lane ramps and four lane divided highways. For values of R between those given, interpolate W and round up to the next tenth of a meter. Treat each direction of travel of multilane divided facilities as a one-way roadway.

Minimum width W based on the delta angle of the curve is shown in Figure 640-8b. Round W to the nearest tenth of a meter.

To keep widths to a minimum, traveled way widths for Figures 640-8a and 8b were calculated using the WB-12 design vehicle. When volumes are high for both trucks larger than the WB-12 and other traffic, consider using the widths from Figures 640-7a and 7b.

(c) **One-lane one-way roadways.** Figure 640-9a shows the traveled way width for one-lane one-way turning roadways, including one lane ramps. For values of R between those given, interpolate W and round up to the next tenth of a meter.

For minimum widths based on the delta angle of the curve, use Figure 640-9b for one-lane roadways using the radius to the outer edge of the traveled way and Figure 640-9c for one-lane roadways using the radius on the inner edge of the traveled way. Round W to the nearest tenth of a meter.

Build shoulder pavements at full depth for one-lane one-way roadways because, to keep widths to a minimum, traveled way widths were calculated using the WB-12 design vehicle which may force larger vehicles to encroach on the shoulders.

(d) **Other roadways.**

- For multilane two-way undivided roadways use the following:

$$W = \frac{W_a \times N}{2}$$

Where:

W = The multilane roadway width.

W_a = The width from 640.04(2)(a) for a two-lane two-way roadway.

N = The total number of lanes.

- For one-way roadways with more than two lanes, for each lane in addition to two, add the standard lane width for the highway functional class from Chapter 440 to the width from 640.04(2)(b).
- For three-lane ramps with HOV lanes, see Chapter 1050.

(e) **All roadways.** Full design shoulder widths for the highway functional class or ramp are added to the traveled way width to determine the total roadway width.

If the total roadway width deficiency is less than 0.6 m on existing roadways that are to remain in place, correction is not required.

When widening

- Traveled way widening may be constructed on the inside of the traveled way or divided equally between the inside and outside.
- Place final marked center line, and any central longitudinal joint, midway between the edges of the widened traveled way.
- Provide widening throughout the curve length.
- For widening on the inside, make transitions on a tangent, where possible.
- For widening on the outside, develop the widening by extending the tangent. This avoids the appearance of a reverse curve that a taper would create.
- For widening of 1.8 m or less, use a 1:25 taper, for widths greater than 1.8 m use a 1:15 taper.

(3) Shoulders

Pave the shoulders of all highways where high or intermediate pavement types are used. Where low pavement type is used, treat the roadway full width.

Shoulder cross slopes are normally the same as the cross slopes for adjacent lanes. With justification, shoulder slopes may be increased to 6%. The maximum difference in slopes between the lane and the shoulder is 8%. Examples of locations where it may be desirable to have a shoulder grade different than the adjacent lane are:

- Where curbing is used.
- Where shoulder surface is bituminous, gravel, or crushed rock.
- Where overlays are planned and it is desirable to maintain the grade at the edge of the shoulder.
- On divided highways with depressed medians where it is desirable to drain the runoff into the median.
- On the high side of the superelevation on curves where it is desirable to drain storm water or melt water away from the roadway.

When asphalt concrete curb is used, see the Standard Plans for required widening. Widening is normally required when traffic barrier is installed (see Chapter 710).

It is preferred that curb not be used on high speed facilities. In some areas, curb may be needed to control runoff water until ground cover is attained to prevent erosion. Plan for the removal of the curb when the ground cover becomes adequate. Arrange for curb removal with regional maintenance as part of the future maintenance plans. When curb is used in conjunction with guardrail, see Chapter 710 for guidance.

Figures 640-10a and 10b represent shoulder details and requirements.

640.05 Superelevation

To maintain the desired design speed, highway and ramp curves are usually superelevated to overcome part of the centrifugal force that acts on a vehicle.

(1) Superelevation Rates for Open Highways and Ramps

The maximum superelevation rate allowed for open highways or ramps is 10%. (See Figure 640-11a.)

Base superelevation rate and its corresponding radius for open highways on Figure 640-11a, Superelevation Rate (10% Max), with the following exceptions:

- Figure 640-11b, Superelevation Rate (6% Max), may be used under the following conditions:

  1. Urban conditions without limited access
  2. Mountainous areas or locations that normally experience regular accumulations of snow and ice
  3. Short-term detours (generally implemented and removed in one construction season). For long-term detours, consider a higher rate up to 10%, especially when associated with a main line detour.

- Figure 640-11c, Superelevation Rate (8% Max), may be used for existing roadways and for the urban, mountainous, and snow and ice conditions that are less severe or where the 6% rate will not work; for example, where a curve with a radius less than the minimum for the design speed from Figure 640-11b is required.

Design the superelevation for ramps the same as for open highways. With justification, ramps in urban areas with a design speed of 35 mph or less, Figure 640-12 may be use to determine the superelevation.

Round the selected superelevation rate to the nearest full percent.

Document which set of curves is being used and, when a curve other than the 10% maximum rate is used, document why the curve was selected.

Depending on design speed, construct large radius curves with a normal crown section and superelevate curves with smaller radii in accordance with the appropriate superelevation from Figures 640-11a through 11c. The minimum radii for normal crown sections are shown in Figure 640-1.

Design Speed (mph)	Minimum Radius for Normal Crown Section (m)
25	750
30	1020
35	1335
40	1695
45	2095
50	2540
55	3030
60	3565
70	4480
80	5510

Minimum Radius for Normal Crown Section
Figure 640-1

(2) Existing Curves

Evaluate the superelevation on an existing curve to determine its adequacy. Use the following equation:

$$R = \frac{2.04V^2}{e + f}$$

Where:

R = The minimum allowable radius of the curve in meters.

V = Design speed in mph

e = Superelevation rate in percent

f = Side friction factor from Figure 640-2

Superelevation is deficient when the radius is less that the minimum from the equation.

For preservation projects, where the existing pavement is to remain in place, the superelevation on existing curves may be evaluated with a ball banking analysis.

Address deficient superelevation as provided in 640.05 (1).

Design Speed (mph)	Side Friction Factor *f*
20	17
25	16
30	16
35	15
40	15
45	14
50	14
60	12
70	10
80	8

Side Friction Factor
Figure 640-2

(3) Turning Movements at Intersections

Curves associated with the turning movements at intersections are superelevated assuming greater friction factors than open highway curves. Since speeds of turning vehicles are not constant and curve lengths are not excessive, higher friction factors can be tolerated. Use superelevation rates as high as practical, consistent with curve length and climatic conditions. Figure 640-12 shows acceptable ranges of superelevation for given design speed and radius. It is desirable to use the values in the upper half or third of the specified range whenever possible. Use judgment in considering local conditions such as snow and ice. When using high superelevation rates on short curves, provide smooth transitions with merging ramps or roadways.

(4) Superelevation Runoff for Highway Curves

For added comfort and safety, provide uniform superelevation runoff over a length adequate for the likely operating speeds.

Provide transitions for all superelevated highway curves as specified in Figures 640-13a through 13e. Which transition to use depends on the location of the pivot point, the direction of the curve, and the roadway cross slope.

Consider the profile of the edge of traveled way. To be pleasing in appearance, do not let it appear distorted. The combination of superelevation transition and grade may result in a hump or dip in the profile of the edge of traveled way. When this happens, the transition may be lengthened to eliminate the hump or dip. If the hump or dip cannot be eliminated this way, pay special attention to drainage in the low areas.

When reverse curves are necessary, provide sufficient tangent length for complete superelevation runoff for both curves (that is, from full superelevation of the first curve to level to full superelevation of the second curve). If tangent length is longer than this but not sufficient to provide standard super transitions (that is, from full superelevation of the first curve to normal crown to full superelevation of the second curve), increase the superelevation runoff lengths until they abut. This provides one continuous transition, without a normal crown section, similar to Designs C2 and D2 in Figures 640-13c and 3d except full super will be attained rather than the normal pavement slope as shown.

Superelevation runoff is permissible on structures but not desirable. Whenever practical, strive for full super or normal crown slopes on structures.

(5) Superelevation Runoff for Ramp Curves

Superelevation transition lengths for one-lane ramps are shown in Figure 640-14a and 14b. For multilane ramps, use the method for highway curves (Figures 640-13a through 13e).

Superelevation transition lengths (L_T) given in Figures 640-14a and 14b are for a single 4.5 m lane. They are based on maximum cross slope change between the pivot point and the edge of the traveled way over the length of the superelevation transition. Maximum relative slopes for specific design speeds are similar to those given for highway curves.

For a single 4.5 m lane, use the distances given in the L_T column for L_R wherever possible. The L_B distances will give the maximum allowable rate of cross slope change. Use the L_B distances only with justification where the L_T distance cannot be achieved.

For ramps wider than 4.5 m, adjust the L_B distance by the equation for L_R. If the result is larger than the L_T distance, round upward to the next whole meter; if it is smaller, use the L_T distance.

640.06 Medians and Outer Separations

(1) Purpose

The main function of a median is to separate opposing traffic lanes. The main function of an outer separation is to separate the main roadway from a frontage road. Medians and outer separations also provide space for:

- Drainage facilities
- Undercrossing bridge piers
- Vehicle storage space for crossing and left turn movements at intersections
- Headlight glare screens, including planted or natural foliage
- Visual buffer of opposing traffic
- Safety refuge areas for errant or disabled vehicles
- Storage space for snow and water from traffic lanes
- Increased safety, comfort, and ease of operations

(2) Design

In addition to Figures 640-15a through 15c, refer to other applicable sections for minimum design requirements. Median widths in excess of the minimums are highly desirable. No attempt has been made to cover all the various grading techniques that are possible on wide, variable-width medians. Considerable latitude in treatment is intended, provided the requirements of minimum geometrics, safety, and aesthetics are met or exceeded.

When the horizontal and vertical alignments of the two roadways of a divided highway are independent of each other, determine median slopes in conformance with Figure 640-3. Unnecessary clearing, grubbing, and grading within wide medians is undesirable. Give preference to selective thinning and limited reshaping of the natural ground. For slopes into the face of traffic barriers, see Chapter 710.

In areas where land is expensive, make an economic comparison of wide medians to narrow medians with their barrier requirements. Consider right of way, construction, maintenance, and accident costs. The widths of medians need not be uniform. Make the transition between median widths as long as feasible.

Independent horizontal and vertical alignment, rather than parallel alignment, is desirable.

When using concrete barriers in depressed medians or on curves, provide for surface drainage on both sides of the barrier. The transverse notches in the base of precast concrete barrier are not intended to be used as a drainage feature but rather as pick-up points when placing the sections.

640.07 Roadsides

(1) Side Slopes

The Cut Slope Selection tables on Figures 640-3, 4, 5, and 6b are for preliminary estimates or where no other information is available. Design the final slope as recommended in the soils or geotechnical report.

When designing side slopes, fit the slope selected for any cut or fill into the existing terrain to give a smooth transitional blend from the construction to the existing landscape. Slopes flatter than recommended are desirable, especially within the Design Clear Zone. Slopes not steeper than 1:4, with smooth transitions where the slope changes, will provide a reasonable opportunity to recover control of an errant vehicle. Where mowing is contemplated, slopes must not be steeper than 1:3. If there will be continuous traffic barrier on a fill slope, and mowing is not contemplated, the slope may be steeper than 1:3.

In cases of unusual geological features or soil conditions, treatment of the slopes will depend upon results of a review of the location by the region's Materials Engineer.

Do not disturb existing stable cut slopes just to meet the slopes given in the Cut Slope Selection tables on Figures 640-3, 4, 5, and 6b. When an existing slope is to be revised, document the reason for the change.

If borrow is required, consider obtaining it by flattening cut slopes uniformly on one or both sides of the highway. Where considering wasting excess material on an existing embankment slope, consult the region's Materials Engineer to verify that the foundation soil will support the additional material.

In all cases, provide for adequate drainage from the roadway surface and adequate drainage in ditches. See 640.07(4) for details on drainage ditches in embankment areas.

At locations where vegetated filter areas or detention facilities will be established to improve highway runoff water quality, provide appropriate slope, space, and soil conditions for that purpose. See the *Highway Runoff Manual* for design criteria and additional guidance.

Rounding, as shown in the Standard Plans, is required at the top of all roadway cut slopes, except for cuts in solid rock. Unless Class B slope treatment is called for, Class A slope treatment is used. Call for Class B slope treatment where space is limited, such as where right of way is restricted.

(2) Roadway Sections in Rock Cuts

Typical sections for rock cuts, illustrated in Figures 640-16a and 16b, are guides for the design and construction of roadways through rock cuts. Changes in slope or fallout area are recommended when justified. Base the selection of the appropriate sections on an engineering study and the recommendations of the region's Materials Engineer and Landscape Architect. Olympia Service Center Materials Lab concurrence is required.

There are two basic design treatments applicable to rock excavation (Figures 640-16a and 16b). Design A applies to most rock cuts. Design B is a talus slope treatment.

(a) **Design A.** This design is shown in stage development to aid the designer in selecting an appropriate section for site conditions in regard to backslope, probable rockfall, hardness of rock, and so forth.

The following guidelines apply to the various stages shown in Figure 640-16a.

- Stage 1 is used where the anticipated quantity of rockfall is small, adequate fallout width can be provided, and the rock slope is 1:1/2 or steeper. Controlled blasting is recommended in conjunction with Stage 1 construction.
- Stage 2 is used when a "rocks in the road" problem exists or is anticipated. Consider it on flat slopes where rocks are apt to roll rather than fall.
- Stage 3 represents full implementation of all protection and safety measures applicable to rock control. Use it only when extreme rockfall conditions exist.

  Show Stage 3 as ultimate stage for future construction on the PS&E plans if there is any possibility that it will be needed.

The use of Stage 2 or 3 alternatives (concrete barrier) is based on the designer's analysis of the particular site. Considerations include maintenance, size and amount of rockfall, probable velocities, availability of materials, ditch capacity, adjacent traffic volumes, distance from traveled lane, and impact severity. Incorporate removable sections in the barrier at approximately 60 m intervals. Appropriate terminal treatment is required (Chapter 710).

Occasionally, the existing ground above the top of the cut is on a slope approximating the design cut slope. The height (H) is to include the existing slope or that portion that can logically be considered part of the cut. The cut slope selected for a project must be that required to effect stability of the existing material.

Benches may be used to increase slope stability; however, the use of benches may alter the design requirements for the sections given in Figure 640-16a.

The necessity for benches, their width, and vertical spacing is established only after an evaluation of slope stability. Make benches at least 6 m wide. Provide access for maintenance equipment at the lowest bench, and to the higher benches if feasible. Greater traffic benefits in the form of added safety, increased horizontal sight distance on curves, and other desirable attributes may be realized from widening a cut rather than benching.

(b) **Design B.** A talus slope treatment is shown in Design B (Figure 640-16b). The rock protection fence is placed at any one of the three locations shown but not in more than one position at a particular location. The exact placement of the rock protection fence in talus slope areas requires considerable judgment and should be determined only after consultation with the region's Materials Engineer.

- Fence position a is used when the cliff generates boulders less than 0.2 m^3 in size, and the length of the slope is greater than 100 m.
- Fence position b is the preferred location for most applications.
- Fence position c is used when the cliff generates boulders greater than 0.2 m^3 in size, regardless of the length of the slope. On short slopes, this may require placing the fence less than 30 m from the base of the cliff.
- Use of gabions may be considered instead of the rock protection shown in fence position a. However, gabion treatment is considered similar to a wall and, therefore, requires appropriate face and end protection for safety (Chapter 710).

Use of the alternate shoulder barrier is based on the designer's analysis of the particular site. Considerations similar to those given for Design A alternatives apply.

Rock protection treatments other than those described above may be required for cut slopes that have relatively uniform spalling surfaces, consult with the region's Materials Engineer.

(3) Stepped Slopes

Stepped slopes are a construction method intended to promote early establishment of vegetative cover on the slopes. They consist of a series of small horizontal steps or terraces on the face of the cut slope. Soil conditions dictate the feasibility and necessity of stepped slopes. They are to be considered only on the recommendation of the region's Materials Engineer (Chapter 510). Consult region's landscape personnel for appropriate design and vegetative materials to be used. See Figure 640-17 for stepped slope design details.

(4) Drainage Ditches in Embankment Areas

Where it is necessary to locate a drainage ditch adjacent to the toe of a roadway embankment, consider the stability of the embankment. A drainage ditch placed immediately adjacent to the toe of an embankment slope has the effect of increasing the height of the embankment by the depth of the ditch. In cases where the foundation soil is weak, the extra height could result in an embankment failure. As a general rule, the weaker the foundation and the higher the embankment, the farther the ditch should be from the embankment. Consult the region's Materials Engineer for the proper ditch location.

When topographic restrictions exist, consider an enclosed drainage system with appropriate inlets and outlets. Do not steepen slopes to provide lateral clearance from toe of slope to ditch location, thereby necessitating traffic barriers or other protective devices.

Maintenance operations are also facilitated by adequate width between the toe of the slope and an adjacent drainage ditch. Where this type of facility is anticipated, provide sufficient right of way for access to the facility and place the drainage ditch near the right of way line.

Provide for disposition of the drainage collected by ditches in regard to siltation of adjacent property, embankment erosion, and other undesirable effects. This may also apply to cut slope top-of-slope ditches.

P65:DP/DMM

(5) Bridge End Slopes

Bridge end slopes are determined by several factors, including: location, fill height, depth of cut, soil stability, and horizontal and vertical alignment. Close coordination between the OSC Bridge and Structures Office and the region is necessary to ensure proper slope treatment (Chapter 1120).

Early in the preliminary bridge plan development, determine preliminary bridge geometrics, end slope rates, and toe of slope treatments. Figure 640-18a provides guidelines for use of slope rates and toe of slope treatments for overcrossings. Figure 640-18b shows toe of slope treatments to be used on the various toe conditions.

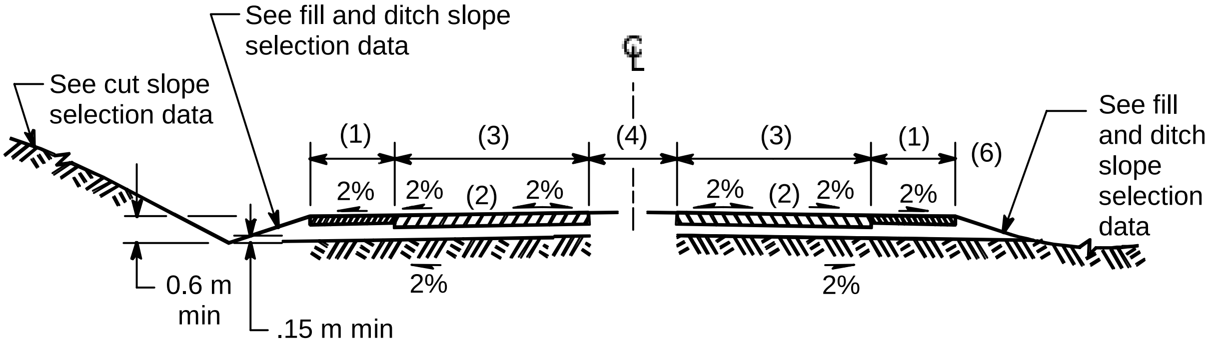
640.08 Roadway Sections

Provide a typical section for inclusion in the PS&E for each general type used on the main roadway, ramps, detours, and frontage or other roads. See the *Plans Preparation Manual* for requirements.

640.09 Documentation

The following documents are to be preserved in the project file. See Chapter 330.

- ☐ Justification for cross slopes other than 2% on tangents.
- ☐ Justification for shoulder cross slopes not the same as the cross slopes for the adjacent lane.
- ☐ Documentation of superelevation maximum rate being used and justification for a rate other than 10%maximum.
- ☐ Justification for the use of L_B on ramp curves when the minimum transition cannot be achieved.
- ☐ Documentation of the reasons for modifying an existing cut slope.
- ☐ Engineering study and recommendations for rock cuts.
- ☐ Materials Engineer recommendation for stepped slopes.
- ☐ Materials Engineer recommendation for ditch location at the toe of fill.



Class I, P-1, P-2, M-1

Height of fill/depth of ditch (m)	Slope not steeper than (5)
0 - 3	1 : 6
3 - 6	1 : 4
6 - 9	1 : 3 (6)
over 9	1 : 2 (6) (8)

Fill and Ditch Slope Selection

Height of cut (m)	Slope not steeper than
0 - 1.5	1 : 6
1.5 - 6	1 : 3
over 6	1 : 2 (7)

Cut Slope Selection (9)

(1) See Figures 640-10a and 10b for shoulder details. See Chapter 440 for minimum shoulder width.

(2) Generally, the crown slope will be as follows:

- Four-lane highway — slope all lanes away from the median.
- Six-lane highway — slope all lanes away from the median unless high rainfall intensities would indicate otherwise.
- Eight-lane highway — slope two of the four directional lanes to the right and two to the left unless low rainfall intensities indicate that all four lanes could be sloped away from the median.

(3) See Chapter 440 for minimum number and width of lanes. See Figures 640-8a and 8b and 640.04(2) for turning roadway width.

(4) See Figures 640-15a through 15c for median details. See Chapter 440 for minimum median width.

(5) Where practical, consider flatter slopes for the greater fill heights and ditch depths.

(6) Widen and round foreslopes steeper than 1:4 as shown on Figure 640-10b.

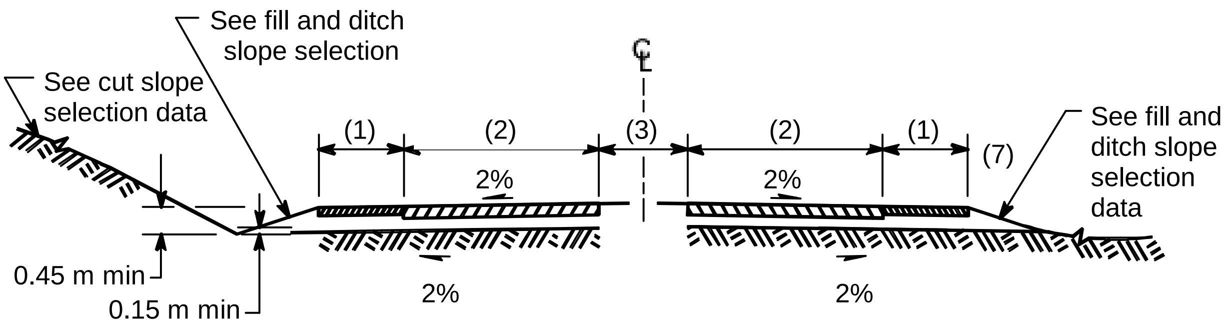
(7) Cut slopes steeper than 1:2 may be used where favorable soil conditions exist or stepped construction is used. See Chapter 700 for clear zone and barrier requirements.

(8) Fill slopes as steep as 1:1$^1/_2$ may be used where favorable soil conditions exist. See Chapter 700 for clear zone and barrier requirements.

(9) This table is for preliminary estimates or where no other information is available. Design the final slope as recommended in the soils or geotechnical report. Do not disturb existing stable slopes just to meet the slopes given in this table.

Divided Highway Roadway Sections

Figure 640-3



Class P-6,M-5,C-1

Height of fill/depth of ditch (m)	Slope not steeper than (4)
0 - 1.5	1 : 6
1.5 - 6	1 : 4
6 - 9	1 : 3 (7)
over 9	1 : 2 (6) (7)

Fill and Ditch Slope Selection

Height of cut (m)	Slope not steeper than
0 -1.5	1 : 4
over 1.5	1 : 2 (5)

Cut Slope Selection (8)

(1) See Figures 640-10a and 10b for shoulder details. See Chapter 440 for minimum shoulder width.

(2) See Chapter 440 for minimum number and width of lanes. See Figures 640-7a and 7b and 640.04(2) for turning roadway width.

(3) See Chapter 440 for minimum median width.

(4) Where practical, consider flatter slopes for the greater fill heights and ditch depths.

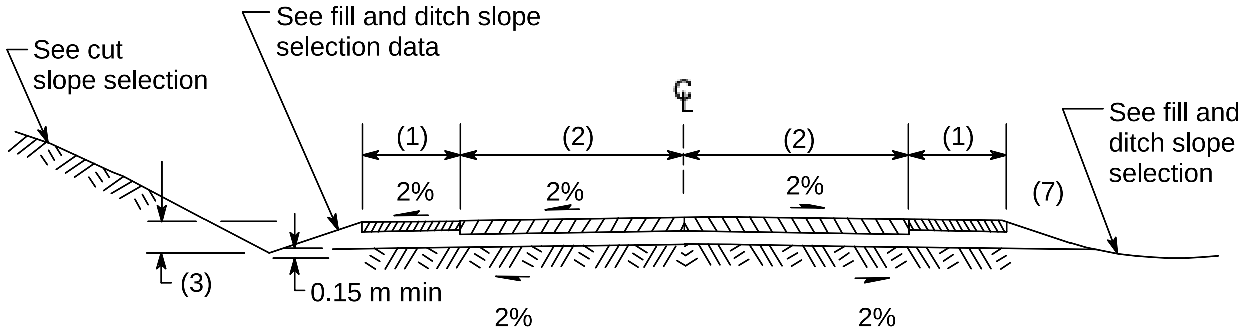
(5) Cut slopes steeper than 1:2 may be used where favorable soil conditions exist or stepped construction is used. See Chapter 700 for clear zone and barrier requirements.

(6) Fill slopes up to 1:1$^1/_2$ may be used where favorable soil conditions exist. See Chapter 700 for clear zone and barrier requirements.

(7) Widen and round foreslopes steeper than 1:4 as shown on Figure 640-10b.

(8) This table is for preliminary estimates or where no other information is available. Design the final slope as recommended in the soils or geotechnical report. Do not disturb existing stable slopes just to meet the slopes given in this table.

Undivided Multilane Highway Roadway Sections
Figure 640-4



Design Class P-3,P-4,P-5,M-2,M-3,M-4,C-2,C-3,C-4

Design class of highway	P-3, P-4, M-2, C-2 (4)	P-5, M-3, M-4, C-3, C-4
Height of fill/depth of ditch (m)	Slope not steeper than	
0 - 3	1 : 6	1 : 4
3 - 6	1 : 4	1 : 4
6 - 9	1 : 3 (7)	1 : 3 (7)
over 9	1 : 2 (5) (7)	1 : 2 (5) (7)

Fill and Ditch Slope Selection

Design class of highway	P-3, P-4, M-2, C-2	P-5, M-3, M-4, C-3, C-4
Height of cut (m)	Slope not steeper than	
0 - 1.5	1 : 6	1 : 4
1.5 - 6	1 : 3	1 : 2 (6)
over 6	1 : 2 (6)	1 : 2 (6)

Cut Slope Selection (8)

(1) See Figures 640-10a and 10b for shoulder details. See Chapter 440 for minimum shoulder width.

(2) See Chapter 440 for minimum width of lanes. See Figures 640-7a and 7b and 640.04(2) for turning roadway width.

(3) The minimum ditch depth is 0.60 m for Design Class P-3 and 0.45 m for Design Class P-4, P-5, M-2, M-3, M-4, C-2, C-3, and C-4.

(4) Where practical, consider flatter slopes for the greater fill heights.

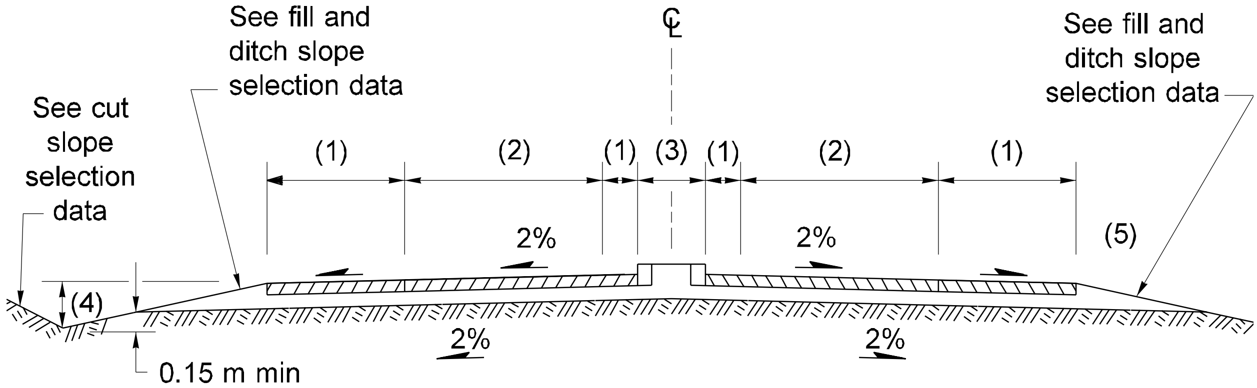
(5) Fill slopes up to $1{:}1^1/_2$ may be used where favorable soil conditions exist. See Chapter 700 for clear zone and barrier requirements.

(6) Cut slopes steeper than 1:2 may be used where favorable soil conditions exist or stepped construction is used. See Chapter 700 for clear zone and barrier requirements.

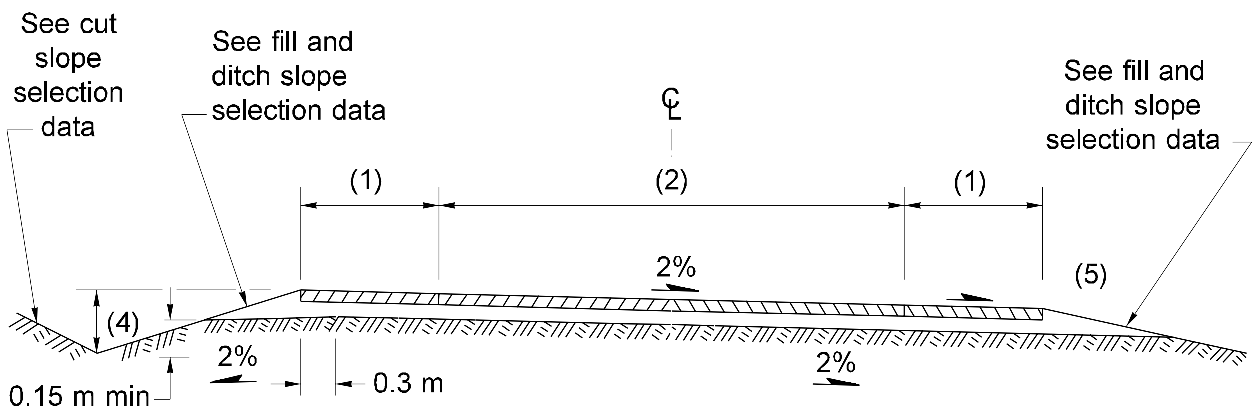
(7) Widen and round foreslopes steeper than 1:4, as shown on Figure 640-10b.

(8) This table is for preliminary estimates or where no other information is available. Design the final slope as recommended in the soils or geotechnical report. Do not disturb existing stable slopes just to meet the slopes given in this table.

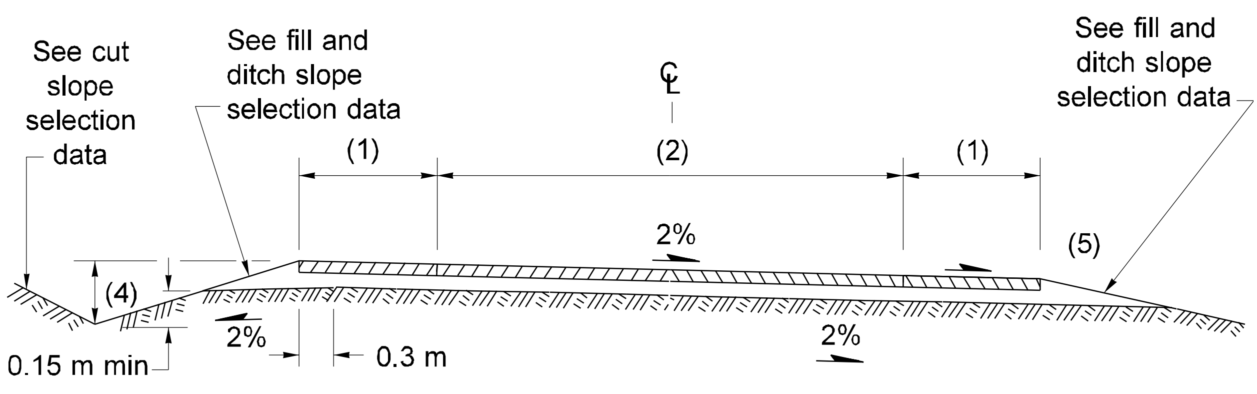
Two-Lane Highway Roadway Sections
Figure 640-5



Two-Lane Two-Way Ramp



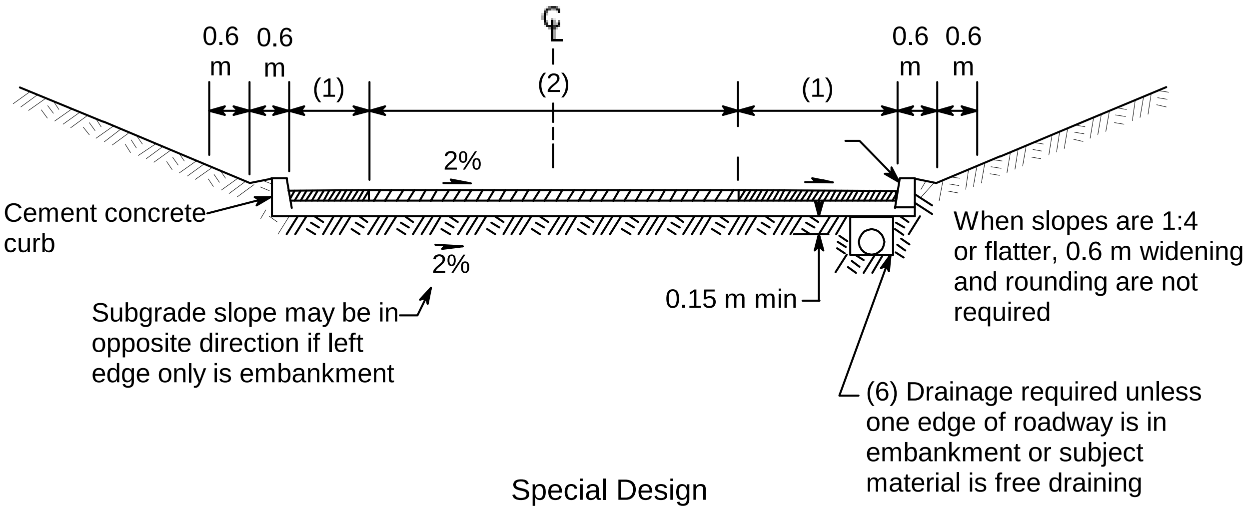
Two-Lane One-Way Ramp



One-Lane Ramp

For notes, dimensions, and slope selection tables see Figure 640-6b

Ramp Roadway Sections
Figure 640-6a



Special Design

This special design section is to be used only when restrictions (high right of way costs or physical features that are difficult or costly to correct) require its consideration.

Height of fill/depth of ditch (m)	Slope not steeper than (7)
0 - 3	1 : 6
3 - 6	1 : 4
6 - 9	1 : 3 (5)
over 9	1 : 2 (5) (9)

Fill and Ditch Slope Selection

Height of cut (m)	Slope not steeper than
0 - 1.5	1 : 6
1.5 - 6	1 : 3
over 6	1 : 2 (8)

Cut slope Selection (10)

(1) See Figures 640-10a and 10b for shoulder details. See Chapter 940 for minimum shoulder widths.

(2) See Chapter 940 for minimum ramp lane widths.

- For one-lane ramp turning roadways see Figures 640-9a thru 9c for traveled way width.
- For two-lane one-way ramp turning roadways, see Figures 640-8a & 8b for traveled way width.
- For two-way ramps treat each direction as a separate one-way roadway.

(3) The minimum median width of a two-lane, two-way ramp is not less than that required for traffic control devices and their respective clearances.

(4) Minimum ditch depth is 0.6 m for design speeds over 40 mph and 0.45 m for design speeds of 40 mph or less. Rounding may be varied to fit drainage requirements when minimum ditch depth is 0.6 m.

(5) Widen and round foreslopes steeper than 1:4 as shown on Figure 640-10b.

(6) Method of drainage pickup to be determined by the designer.

(7) Where practical, consider flatter slopes for the greater fill heights and ditch depths.

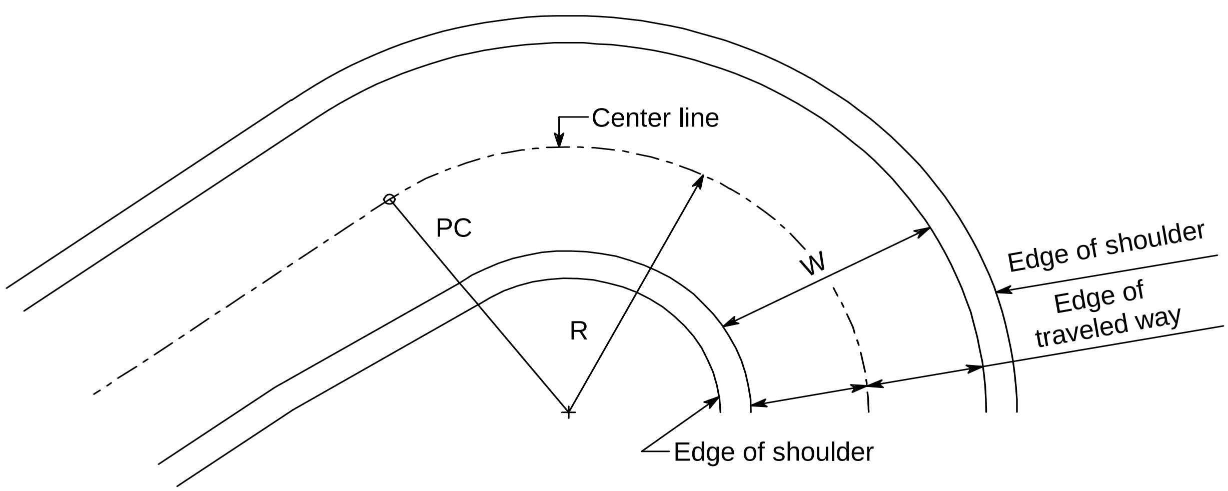
(8) Cut slopes steeper than 1:2 may be used where favorable soil conditions exist or stepped construction is used. See Chapter 700 for clear zone and barrier requirements.

(9) Fill slopes as steep as 1:1$^{1}/_{2}$ may be used where favorable soil conditions exist. See Chapter 700 for clear zone and barrier requirements.

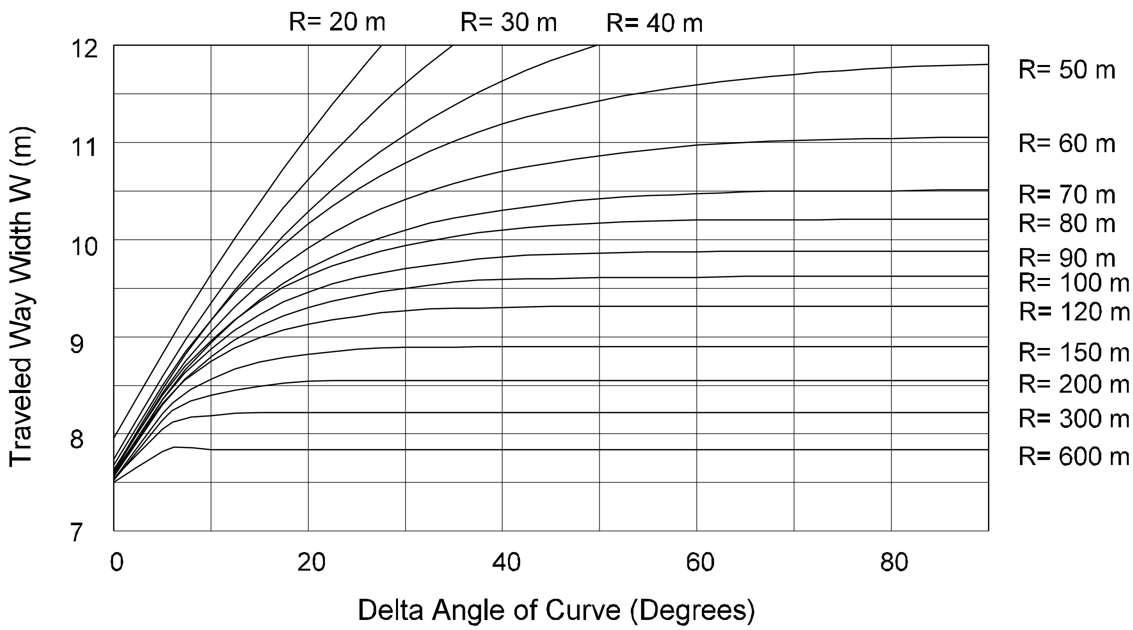
(10) This table is for preliminary estimates or where no other information is available. Design the final slope as recommended in the soils or geotechnical report. Do not disturb existing stable slopes just to meet the slopes given in this table.

Ramp Roadway Sections
Figure 640-6b

Radius on center line of traveled way (m)	Design traveled way width (W) (m)
900 to tangent	7.2
899	7.5
600	7.8
300	8.2
200	8.5
150	8.9
120	9.3
100	9.6
90	9.9
80	10.2
70	10.5
60	11.0
50	11.8



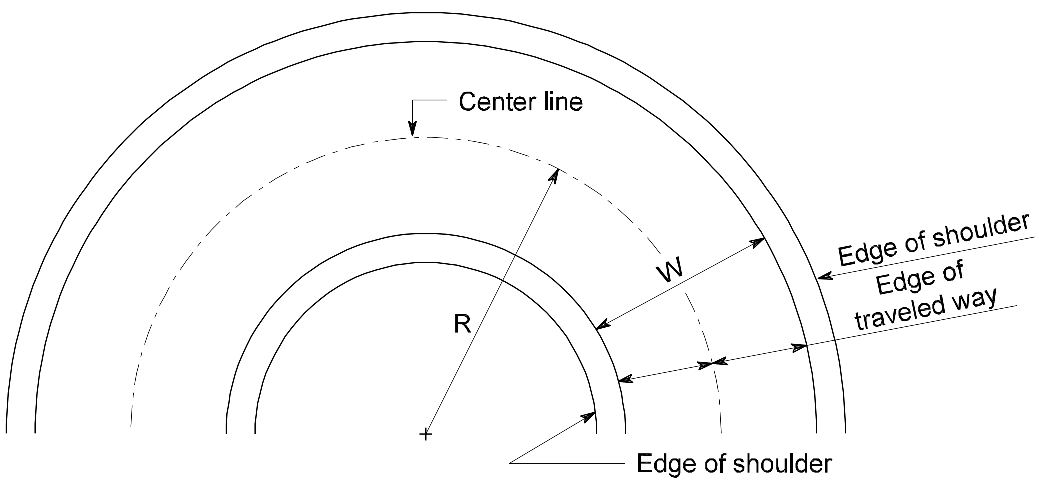
Traveled Way Width for Two-Way Two-Lane Turning Roadways
Figure 640-7a



Traveled Way Width for Two-Way Two-Lane Turning Roadways

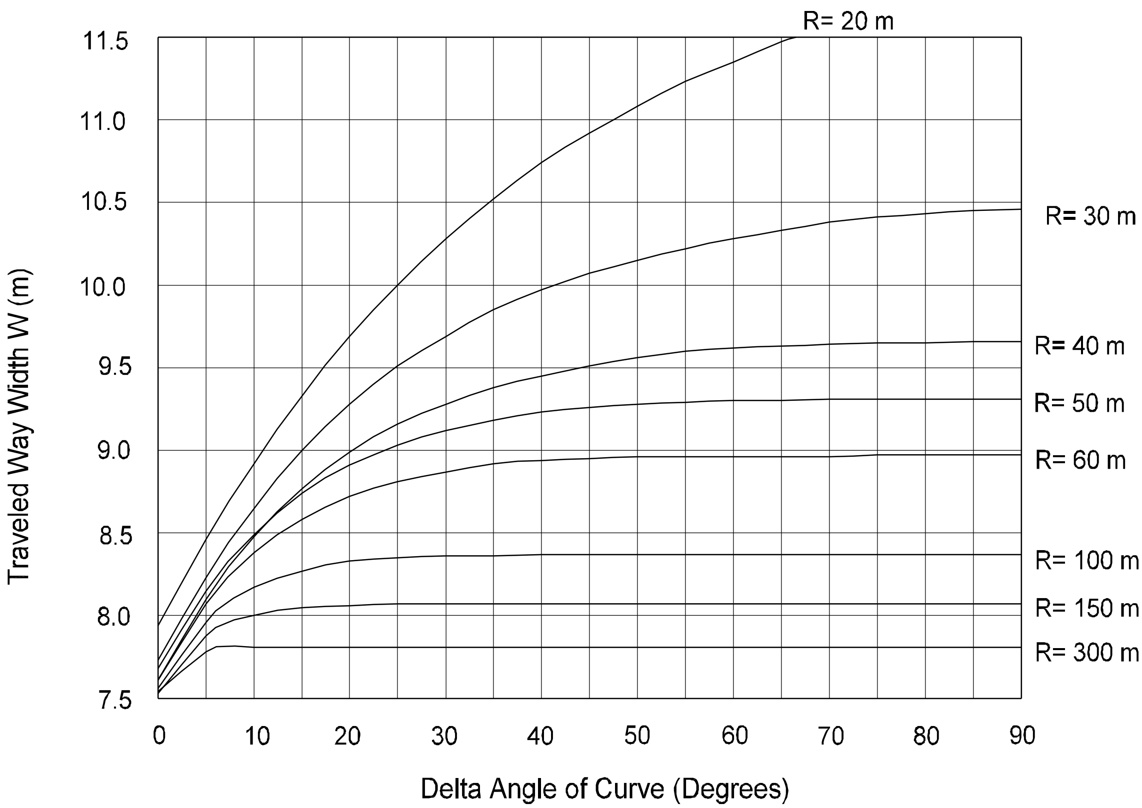
Figure 640-7b

Radius on center line of traveled way (m)	Design traveled way width (W) (m)
900 to tangent	7.2
300 to 899	7.5
299	7.8
150	8.1
100	8.4
60	9.0
50	9.3
40	9.7
30	10.5



Traveled Way Width for Two-Lane One-Way Turning Roadways

Figure 640-8a



Traveled Way Width for Two-Lane One-Way Turning Roadways
Figure 640-8b

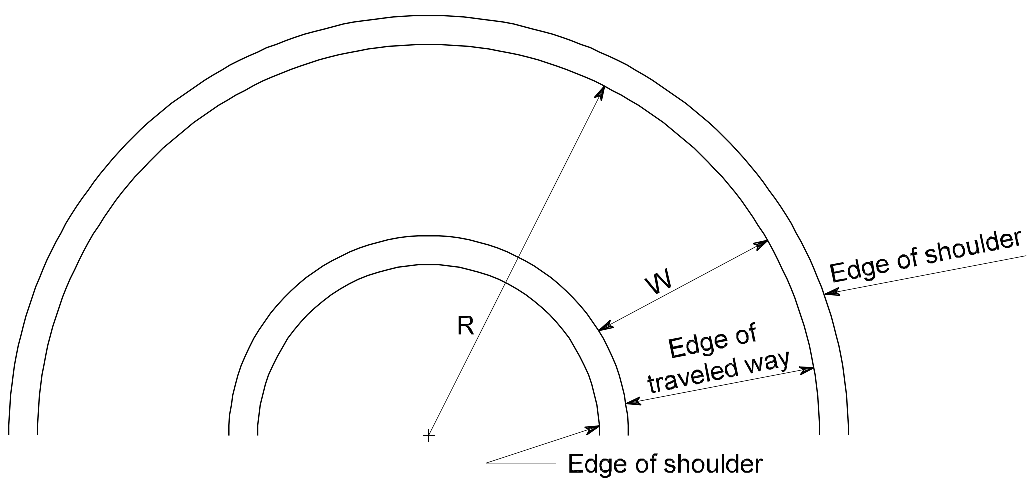
Radius (m)	Design traveled way width (W) (m)
100 to tangent	4.5(1)
99	4.8
80	4.9
60	5.1
50	5.3
40	5.5(2)
30	5.9(3)
20	6.8(4)

(1) On tangents, the minimum lane width may be reduced to 3.6 m

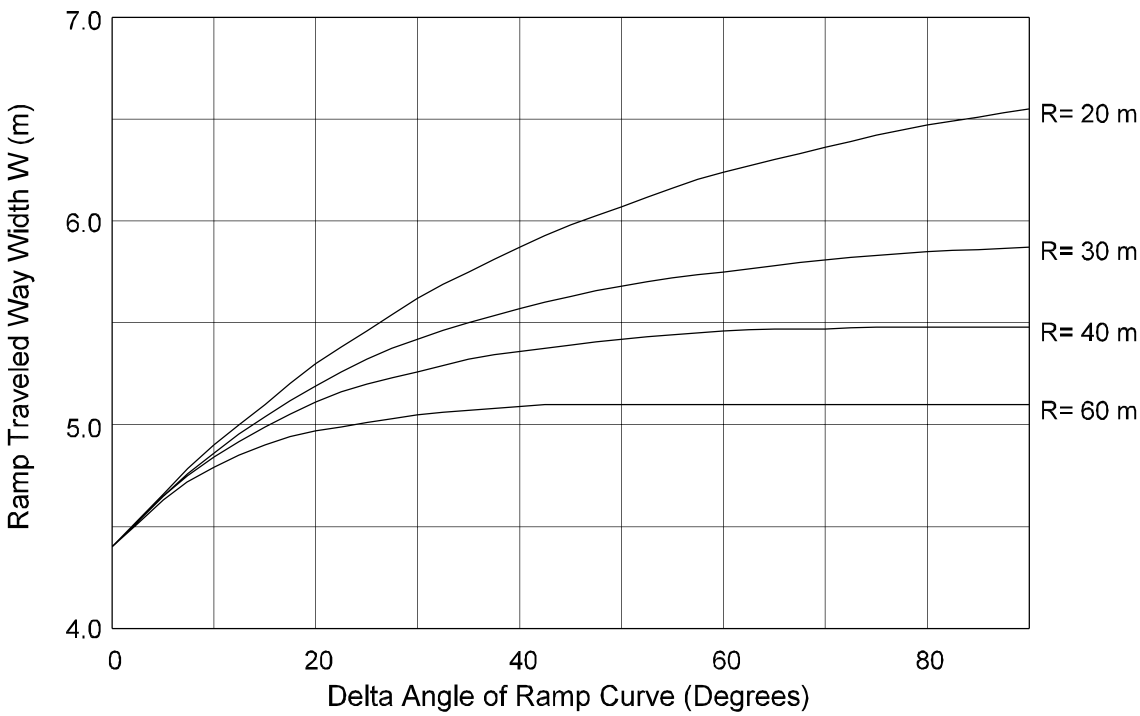
(2) The width given is for a radius on the outside edge of the traveled way. When the radius is on the inside edge of traveled way, the width may be 5.4 m.

(3) The width given is for a radius on the outside edge of the traveled way. When the radius is on the inside edge of traveled way, the width may be 5.6 m.

(4) The width given is for a radius on the outside edge of the traveled way. When the radius is on the inside edge of traveled way, the width may be 6.2 m.

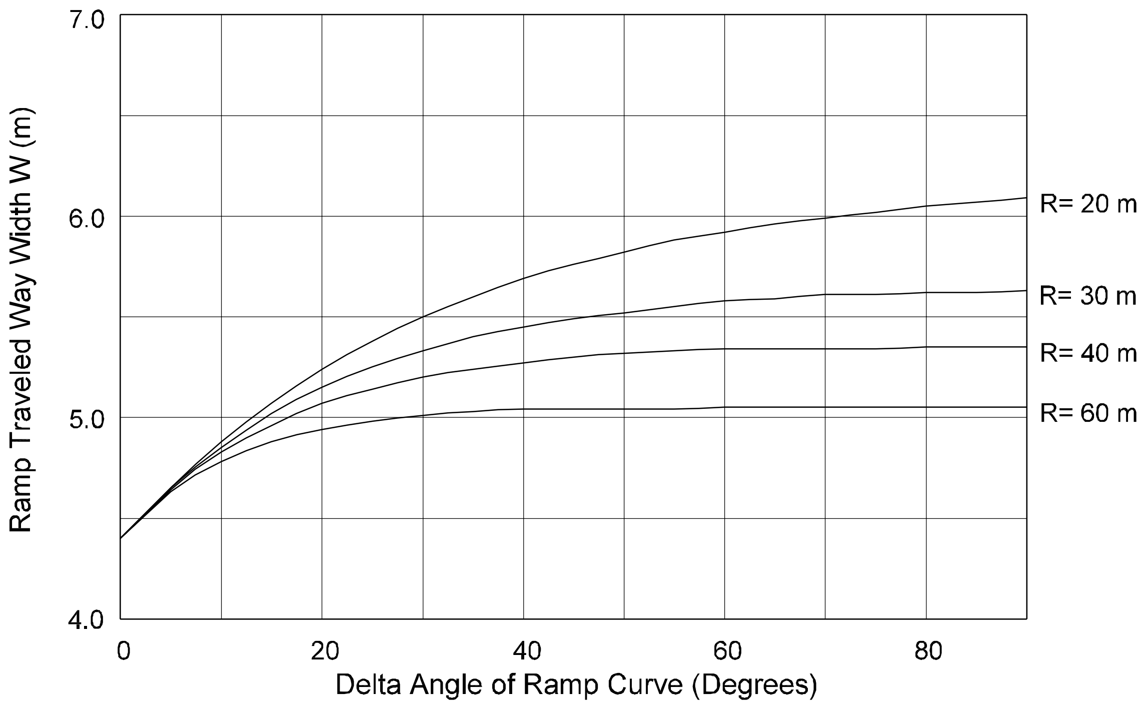


Traveled Way Width for One-Lane Turning Roadways
Figure 640-9a



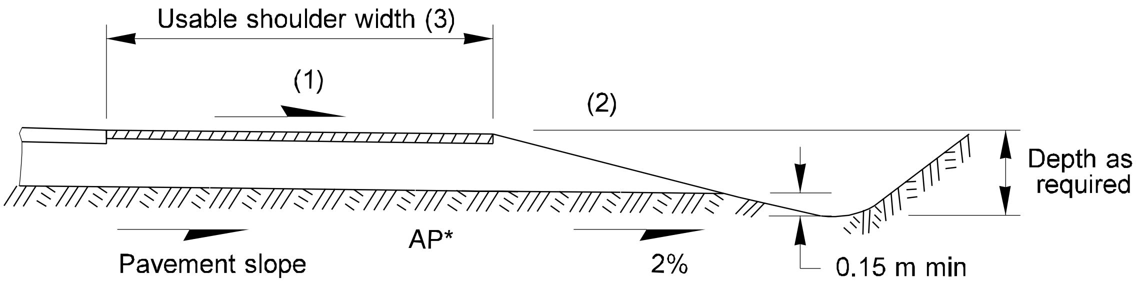
Note: All Radii are to the outside edge of traveled way.

Traveled Way Width for One-Lane Turning Roadways
Figure 640-9b

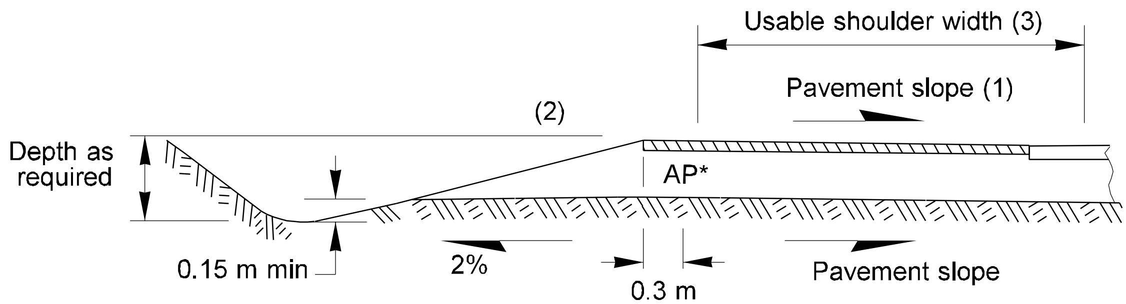


Note: All Radii are to the inside edge of traveled way.

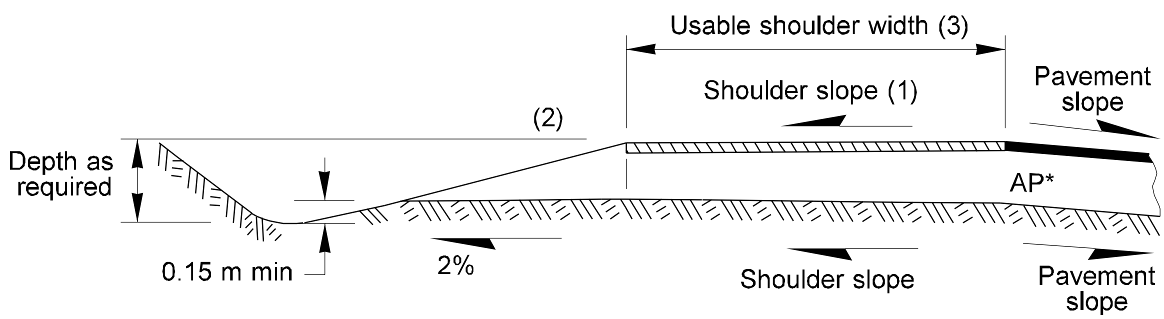
Traveled Way Width for One-Lane Turning Roadways
Figure 640-9c



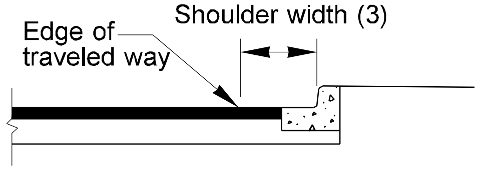
Shoulder Design on the Low Side of the Roadway for Cross Slopes Greater Than 2%



Shoulder Design on the High Side of the Roadway on Curves and Divided Roadways Shoulder Slopes with Roadway



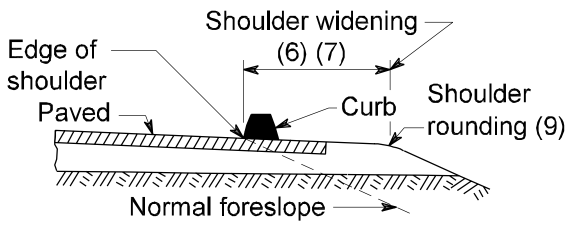
Shoulder Design on the High Side of the Roadway on Curves and Divided Roadways Away from Roadway



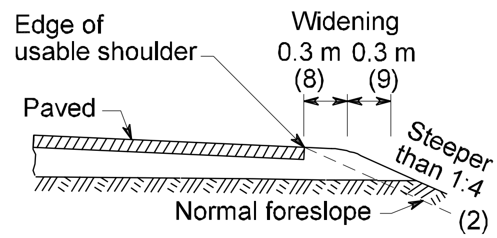
Shoulder Design with Curb(5)(6)

Shoulder Details

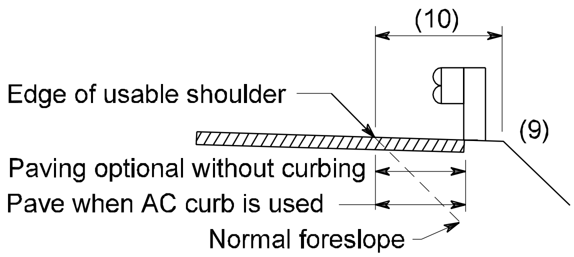
Figure 640-10a



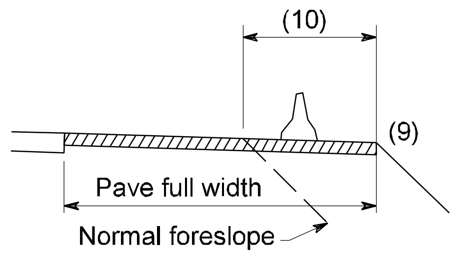
Asphalt Concrete Curb Placement



Shoulder Rounding



Shoulder Widening for Guardrail



Shoulder Widening for Guardrail

(1) Shoulder cross slopes are normally the same as the cross slopes for adjacent lanes. See 640.04(3) in the text for examples, additional information, and requirements of locations where it may be desirable to have a shoulder cross slope different than the adjacent lane.

(2) Widening and shoulder rounding outside the usable shoulder is required when foreslope is steeper than 1:4.

(3) See Chapter 440 for shoulder width.

(4) On divided multilane highways see Figures 640-15a through 15c for additional details and requirements for median shoulders.

(5) See Chapter 1025 for additional requirements for sidewalks.

(6) It is preferred that curb not be used on high speed facilities (posted speed >40 mph).

(7) Paved shoulders are required wherever asphalt concrete curb is placed. Use it only where necessary to control drainage from roadway runoff. See the Standard Plans for additional details and dimensions.

(8) When rounding is required, use it uniformly on all ramps and crossroads, as well as the main roadway.

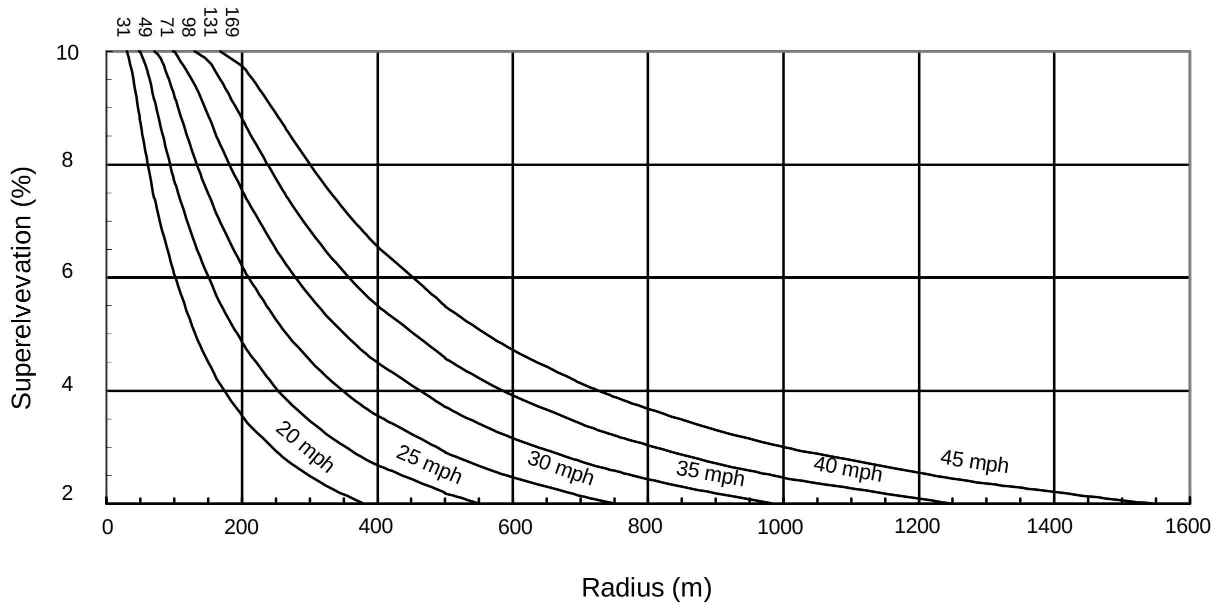
End rounding on the crossroad just beyond the ramp terminals and at a similar location where only a grade separation is involved.

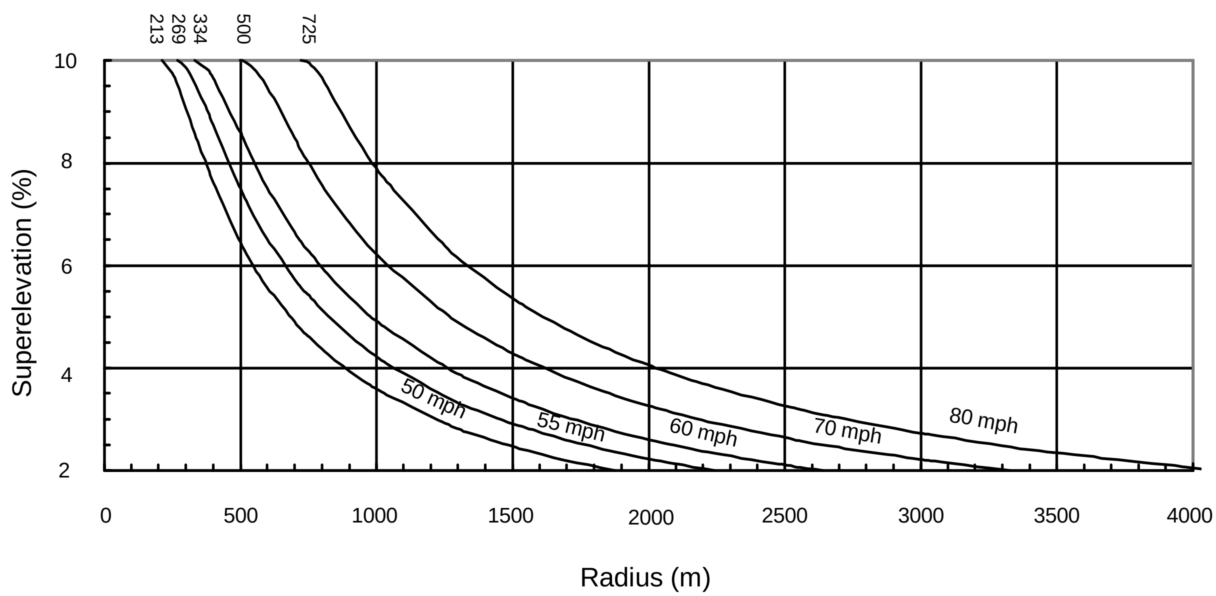
(9) When widening beyond the edge of usable shoulder is required for asphalt concrete curb, barrier, or other purposes, additional widening for shoulder rounding is not required.

(10) See Chapter 710 for required widening for guardrail and concrete barrier.

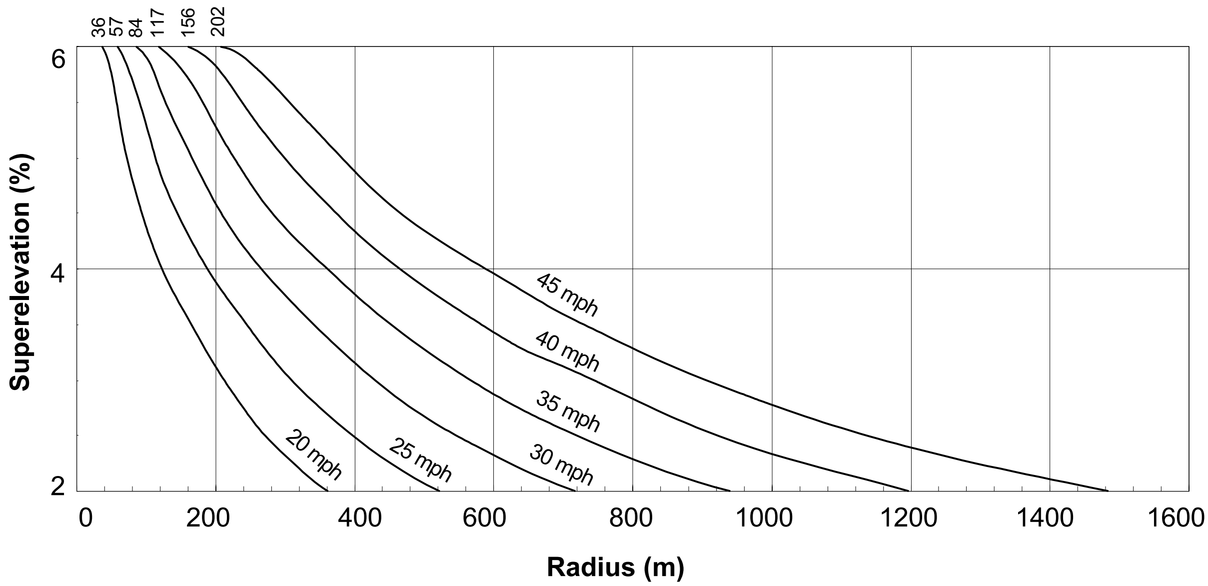
Shoulder Details

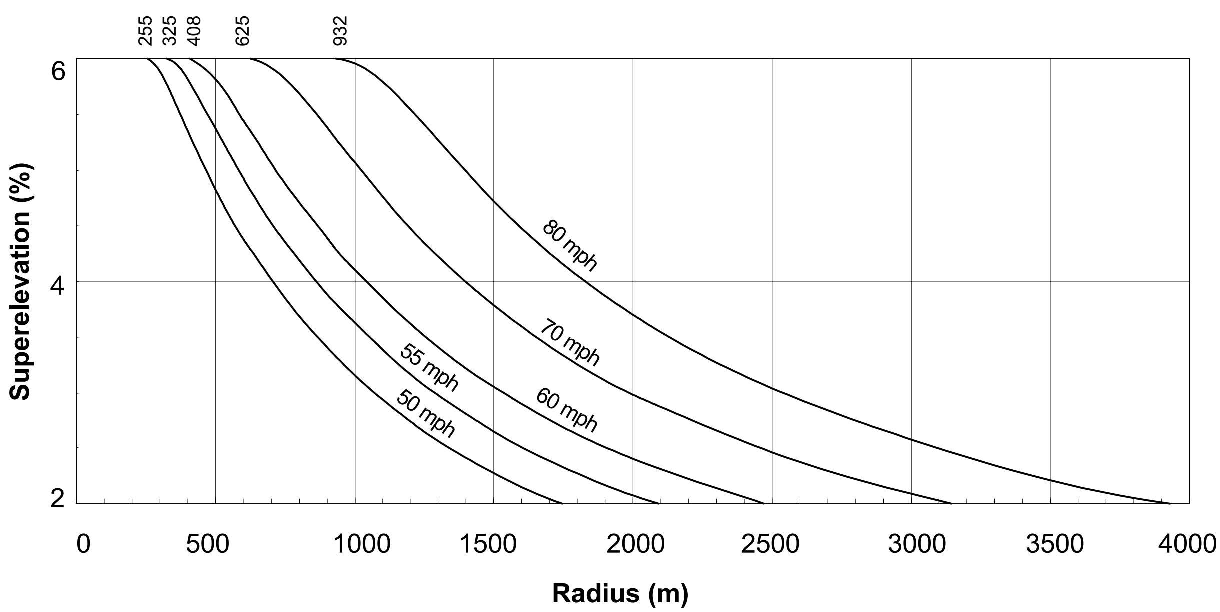
Figure 640-10b



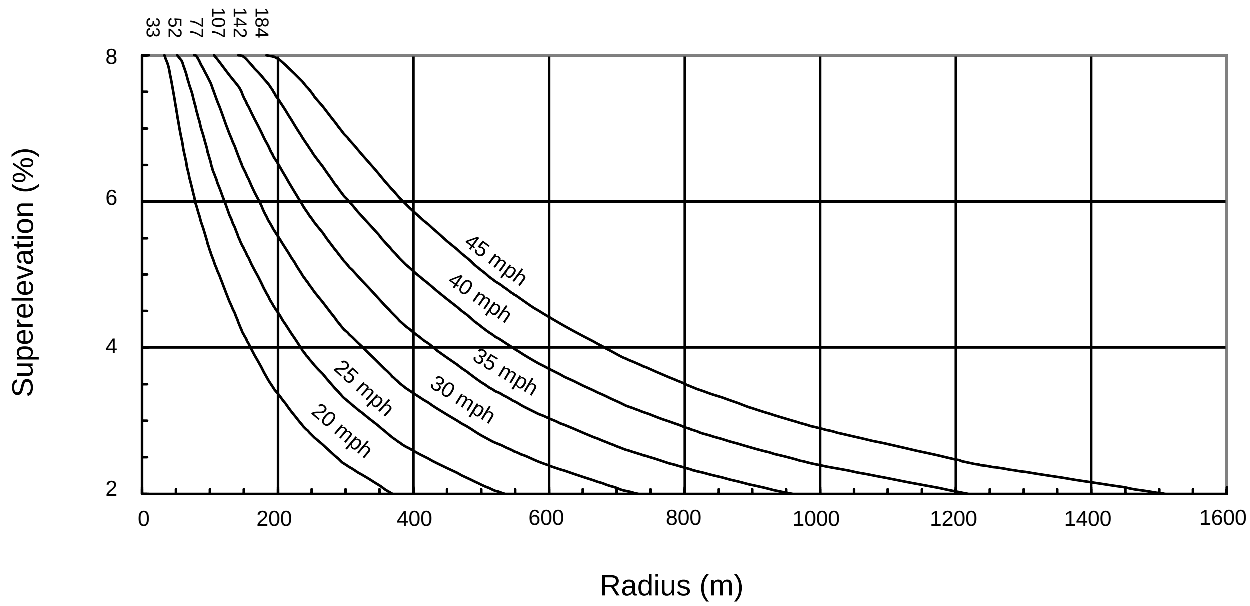


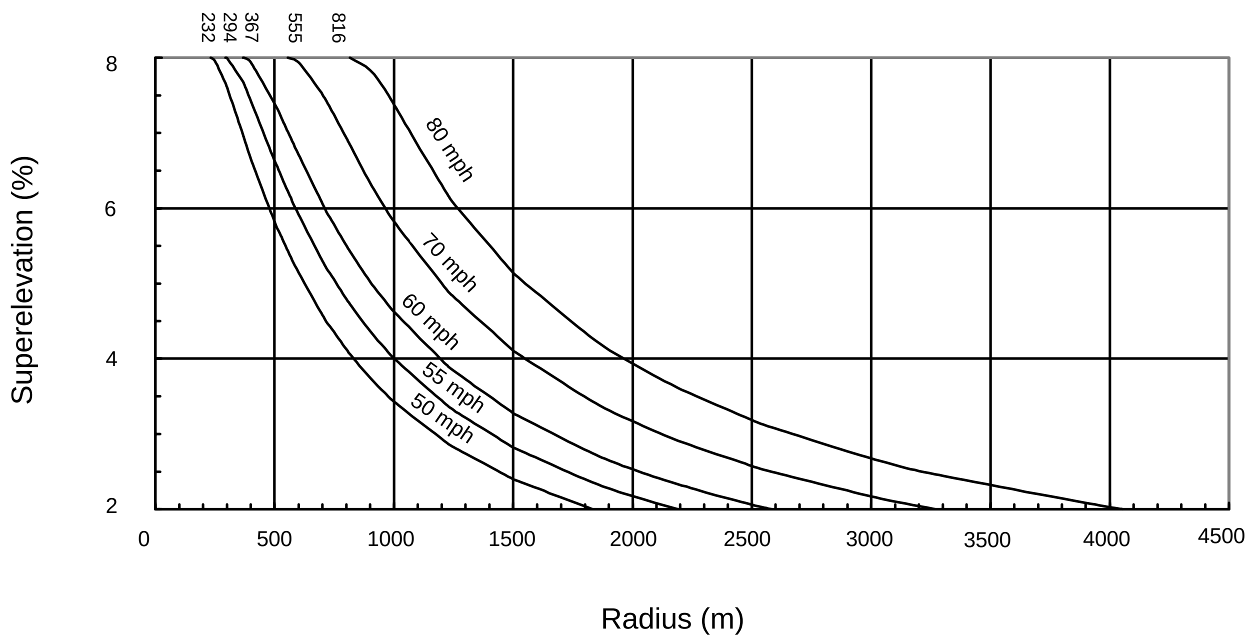
Superelevation Rates (10% max)
Figure 640-11a





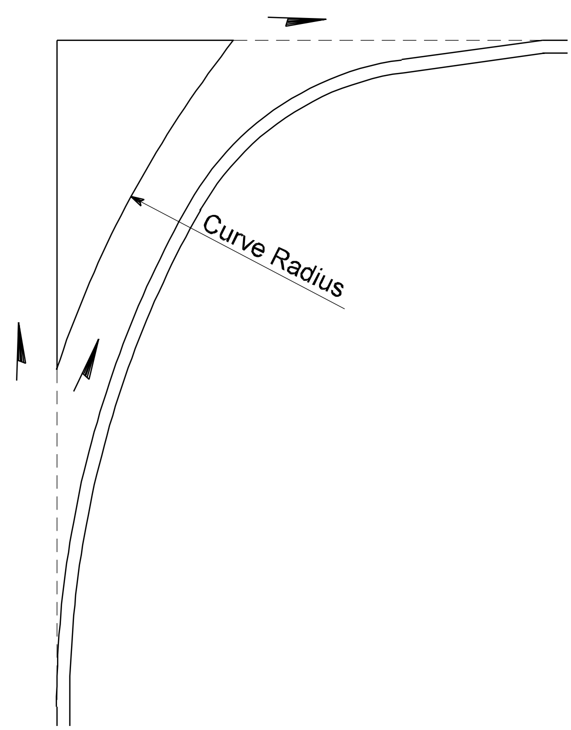
Superelevation Rates (6% max)
Figure 640-11b





Superelevation Rates (8% max)
Figure 640-11c

Curve Radius (m)	Range in Superelevation Rates (%) for Design Speed of:					
	15 mph	20 mph	25 mph	30 mph	35 mph	40 mph
15	2 - 10					
25	2 - 7	2 - 10				
50	2 - 5	2 - 8	4 - 10			
70	2 - 4	2 - 6	3 - 8	6 - 10		
100	2 - 3	2 - 4	3 - 6	5 - 9	8 - 10	
150	2 - 3	2 - 3	3 - 5	4 - 7	6 - 9	9 - 10
200	2	2 - 3	2 - 4	3 - 5	5 - 7	7 - 9
300	2	2 - 3	2 - 3	3 - 4	4 - 5	5 - 6
500	2	2	2	2 - 3	3 - 4	4 - 5
700	2	2	2	2	2 - 3	3 - 4
1000	2	2	2	2	2	2 - 3



Superelevation Rates for Turning Roadways at Intersections
Figure 640-12

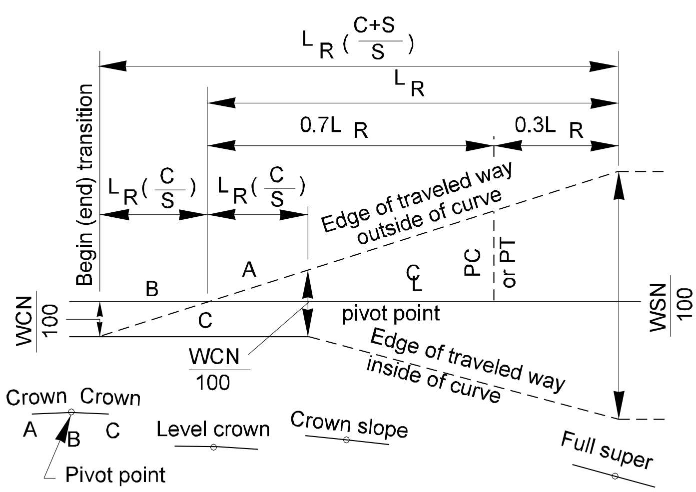
S	*L_B=Basic runoff in meters for Design Speed of:										
%	20 mph	25 mph	30 mph	35 mph	40 mph	45 mph	50 mph	55 mph	60 mph	70 mph	80 mph
2	10	10	11	12	13	14	14	15	16	18	20
3	14	15	16	18	19	20	22	23	24	27	30
4	19	20	22	23	25	27	29	31	32	36	40
5	24	25	27	29	32	34	36	38	40	45	50
6	29	31	32	35	38	41	43	46	48	54	60
7	34	36	38	41	44	47	50	54	56	63	70
8	38	41	43	47	50	54	58	61	64	72	80
9	43	46	49	53	57	61	65	69	72	81	90
10	48	51	54	59	63	68	72	77	80	90	100
Min L_R	20	25	35	35	40	45	50	50	55	65	70

*Based on one 3.6 m lane between the pivot point and the edge of traveled way. When the distance exceeds 3.6 m use the following equation to the obtain L_R:

$L_R=L_B(1+0.13889X)$

Where:

X = The distance in excess of 3.6 m between the pivot point and the furthest edge of traveled way, in meters

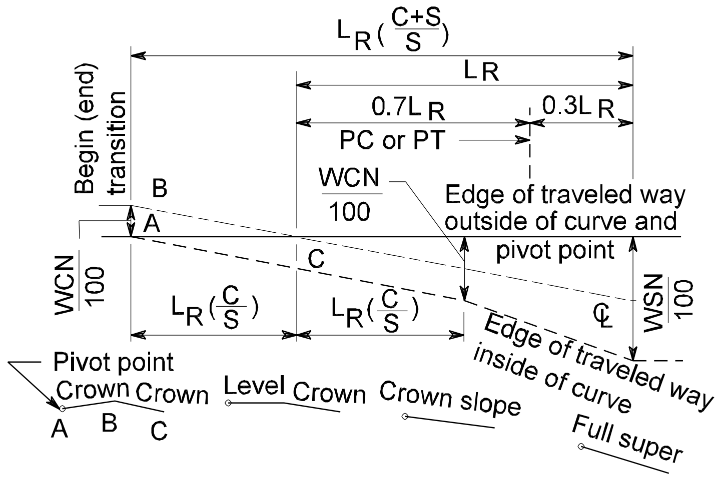


Design A Pivot Point on Center Line Crowned Section

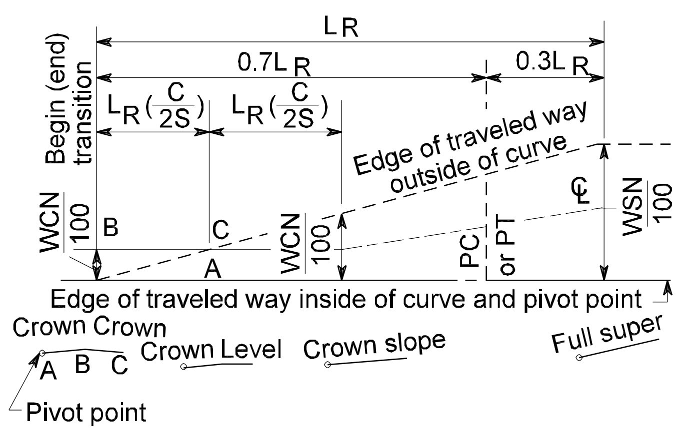
C = Normal crown (%)
S = Superelevation rate (%)
N = Number of lanes between points
W = Width of lane

Superelevation Transitions for Highway Curves

Figure 640-13a



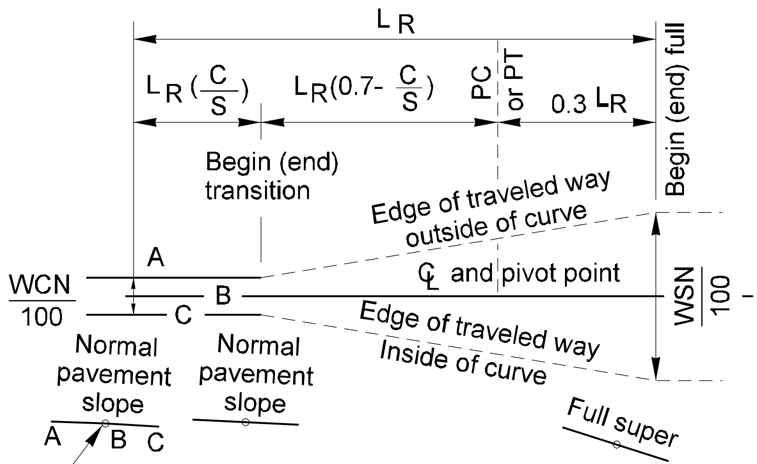
Design B[1] Pivot Point on Edge of Pavement Outside of Curve Crowned Section



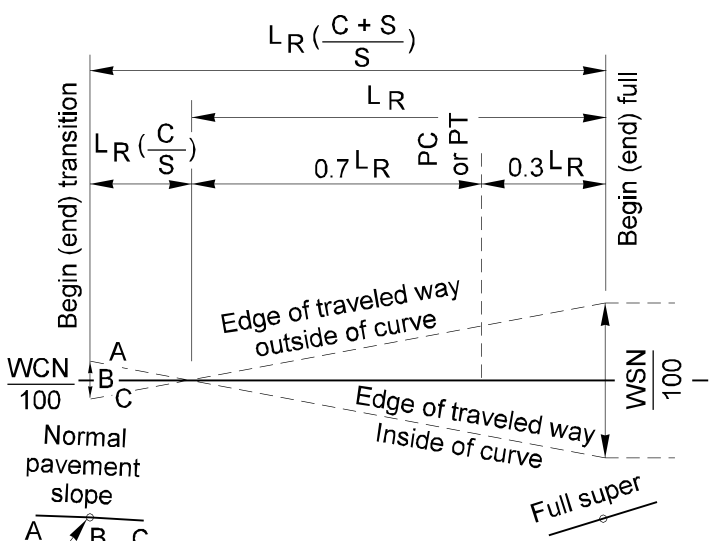
Design B[2] Pivot Point on Edge of Pavement Inside of Curve Crowned Section

C = Normal crown (%)
S = Superelevation rate (%)
N = Number of lanes between points
W = Width of lane

Superelevation Transitions for Highway Curves
Figure 640-13b



Design C[1]

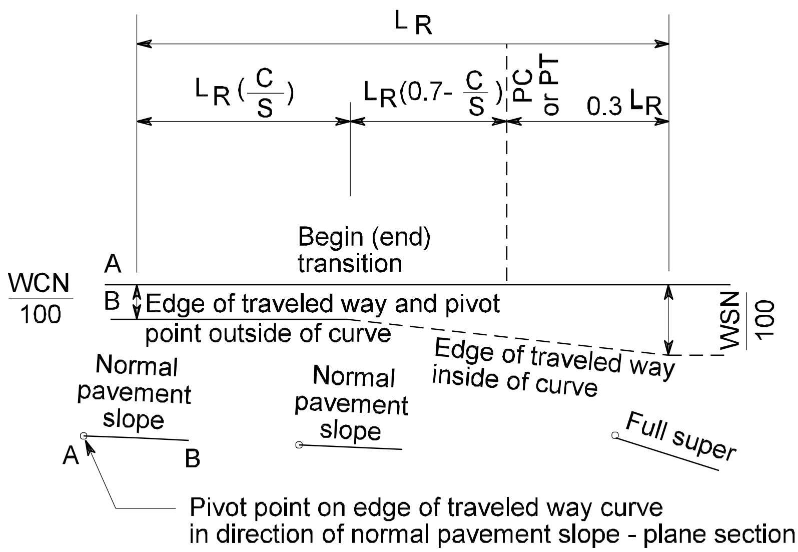


Design C[2]

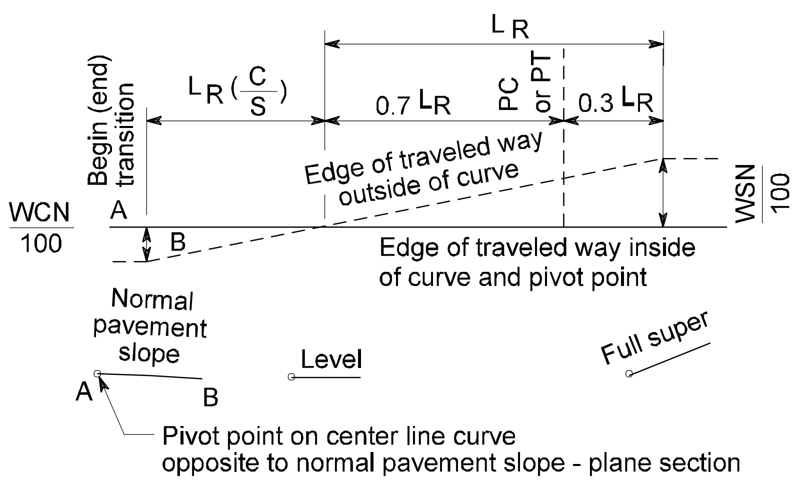
C = Normal crown (%)
S = Superelevation rate (%)
N = Number of lanes between points
W = Width of lane

Superelevation Transitions for Highway Curves

Figure 640-13c



Design D[1]

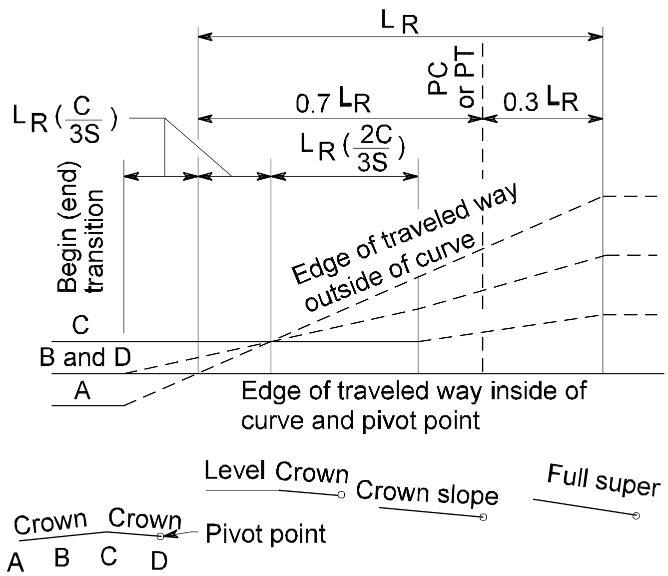


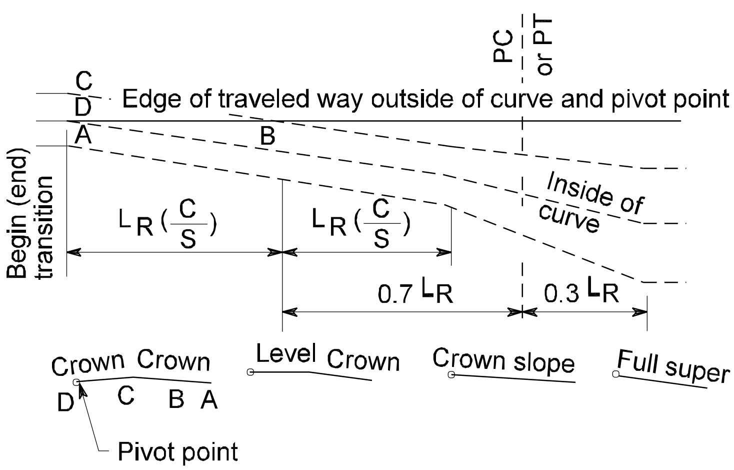
Design D[2]

C = Normal crown (%)
S = Superelevation rate (%)
N = Number of lanes between points
W = Width of lane

Superelevation Transitions for Highway Curves

Figure 640-13d



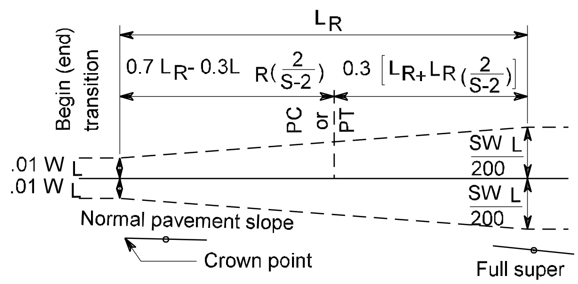


Transition profiles for typical six lanes with median

Design E

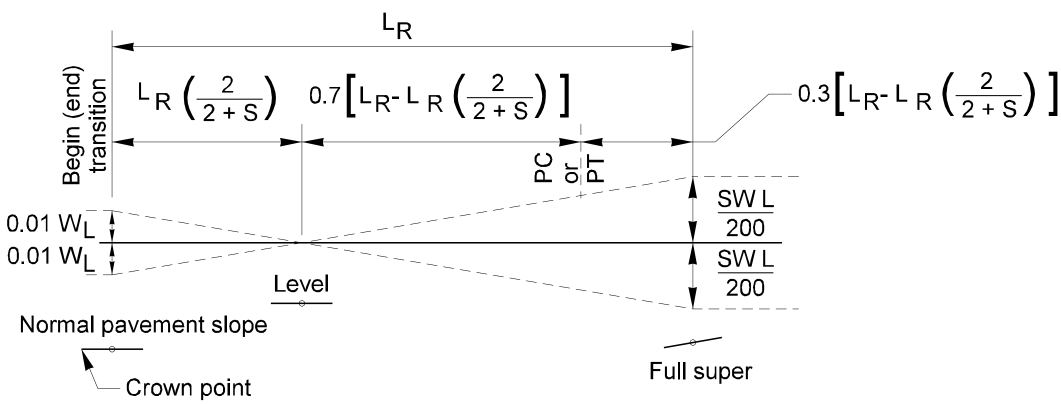
C = Normal crown (%)
S = Superelevation rate (%)
N = Number of lanes between points
W = Width of lane

Superelevation Transitions for Highway Curves
Figure 640-13e



S	Length of transition in meters for Design Speed of:															
	20 mph		25 mph		30 mph		35 mph		40 mph		45 mph		50 mph		≥ 55 mph	
(%)	L_B	L_T	L_B	L_T	L_B	L_T	L_B	L_T	L_B	L_T	L_B	L_T	L_B	L_T	L_B	L_T
3	3	20	4	25	4	35	4	35	4	40	5	45	5	50	5	50
4	6	20	7	25	7	35	8	35	8	40	9	45	9	50	10	50
5	9	20	10	25	11	35	11	35	12	40	13	45	14	50	15	50
6	12	20	13	25	14	35	15	35	16	40	17	45	18	50	20	50
7	15	20	16	25	17	35	19	35	20	40	22	45	23	50	24	50
8	18	20	20	25	21	35	22	35	24	40	26	45	27	50	29	50
9	21	21	23	25	24	35	26	35	28	40	30	45	32	50	34	50
10	24	24	26	26	27	35	30	35	32	40	34	45	36	50	39	50

Table 1 Pivot Point on Center Line — Curve in Direction of Normal Pavement Slope



S	Length of transition in meters for Design Speed of:															
	20 mph		25 mph		30 mph		35 mph		40 mph		45 mph		50 mph		≥ 55 mph	
(%)	L_B	L_T	L_B	L_T	L_B	L_T	L_B	L_T	L_B	L_T	L_B	L_T	L_B	L_T	L_B	L_T
2	12	20	13	25	14	35	15	35	16	40	17	45	18	50	20	50
3	15	20	16	25	17	35	19	35	20	40	22	45	23	50	24	50
4	18	20	20	25	21	35	22	35	24	40	26	45	27	50	29	50
5	21	21	23	25	24	35	26	35	28	40	30	45	32	50	34	50
6	24	24	26	26	27	35	30	35	32	40	34	45	36	50	39	50
7	27	27	29	29	31	35	33	35	36	40	38	45	41	50	44	50
8	30	30	32	32	34	35	37	37	40	40	43	45	45	50	48	50
9	33	33	36	36	38	38	41	41	44	44	47	47	50	50	53	53
10	36	36	39	39	41	41	44	44	48	48	51	51	54	54	58	58

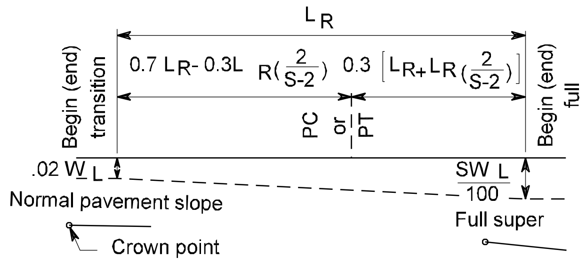
Table 2 Pivot Point on Center Line — Curve in Direction Opposite to Normal Pavement Slope

$L_R = L_B*(1+0.13889x)$ Where: x = width of lane greater than 4.5 m.

W_L = width of ramp lane

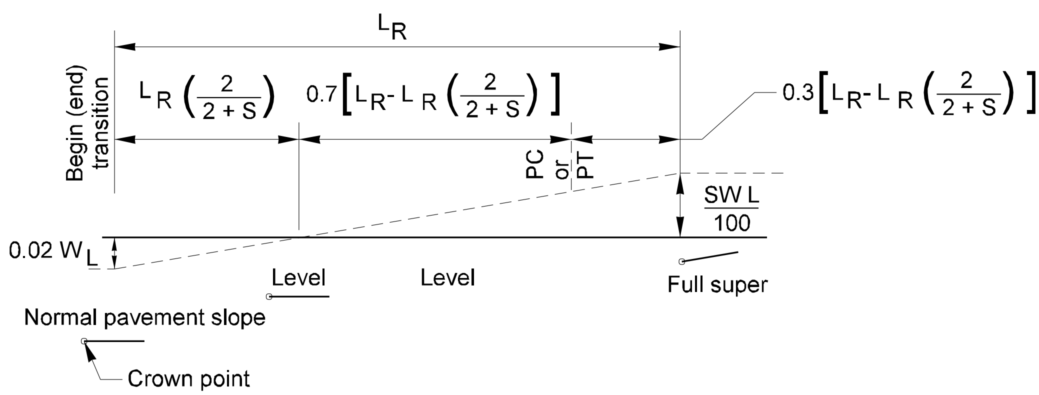
Superelevation Transitions for Ramp Curves

Figure 640-14a



S (%)	Length of transition in meters for Design Speed of: 20 mph L_B	20 mph L_T	25 mph L_B	25 mph L_T	30 mph L_B	30 mph L_T	35 mph L_B	35 mph L_T	40 mph L_B	40 mph L_T	45 mph L_B	45 mph L_T	50 mph L_B	50 mph L_T	≥ 55 mph L_B	≥ 55 mph L_T
3	6	20	7	25	7	35	8	35	8	40	9	45	9	50	10	50
4	12	20	13	25	14	35	15	35	16	40	17	45	18	50	20	50
5	18	20	20	25	21	35	22	35	24	40	26	45	27	50	29	50
6	24	24	26	26	27	35	30	35	32	40	34	45	36	50	39	50
7	30	30	32	32	34	35	37	37	40	40	43	45	45	50	48	50
8	36	36	39	39	41	41	44	44	48	48	51	51	54	54	58	58
9	42	42	45	45	48	48	52	52	56	56	60	60	63	63	68	68
10	48	48	51	51	54	54	59	59	63	63	68	68	72	72	77	77

Table 3 Pivot Point on Edge of Lane — Curve in Direction of Normal Pavement Slope



S (%)	Length of transition in meters for Design Speed of: 20 mph L_B	20 mph L_T	25 mph L_B	25 mph L_T	30 mph L_B	30 mph L_T	35 mph L_B	35 mph L_T	40 mph L_B	40 mph L_T	45 mph L_B	45 mph L_T	50 mph L_B	50 mph L_T	≥ 55 mph L_B	≥ 55 mph L_T
2	24	24	26	26	27	35	30	35	32	40	34	45	36	50	39	50
3	30	30	32	32	34	35	37	37	40	40	43	45	45	50	48	50
4	36	36	39	39	41	41	44	44	48	48	51	51	54	54	58	58
5	42	42	45	45	48	48	52	52	56	56	60	60	63	63	68	68
6	48	48	51	51	54	54	59	59	63	63	68	68	72	72	77	77
7	54	54	58	58	61	61	66	66	71	71	76	76	81	81	87	87
8	60	60	64	64	68	68	74	74	79	79	85	85	90	90	96	96
9	66	66	71	71	75	75	81	81	87	87	93	93	99	99	106	106
10	72	72	77	77	81	81	88	88	95	95	102	102	108	108	116	116

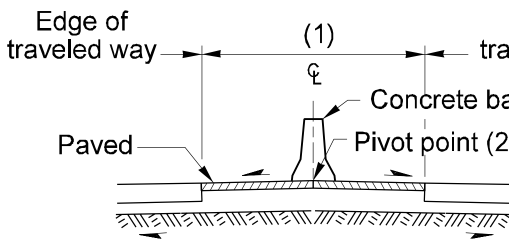
Table 4 Pivot Point on Edge of Lane — Curve in Direction Opposite to Normal Pavement Slope

$L_R = L_B*(1+0.13889x)$ Where: x = width of lane greater than 4.5 m.

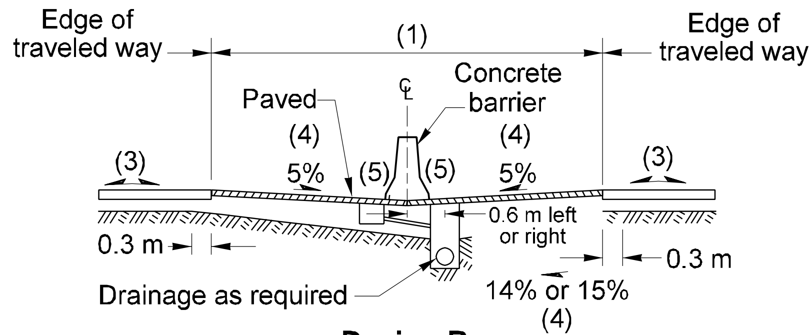
W_L = width of ramp lane

Superelevation Transitions for Ramp Curves

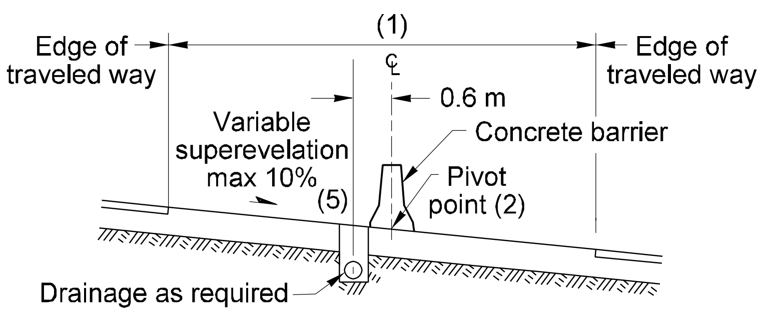
Figure 640-14b



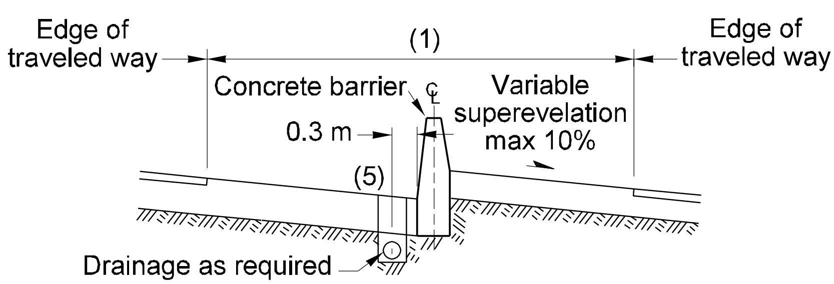
Design A
Crowned Median



Design B
Depressed Median (2)



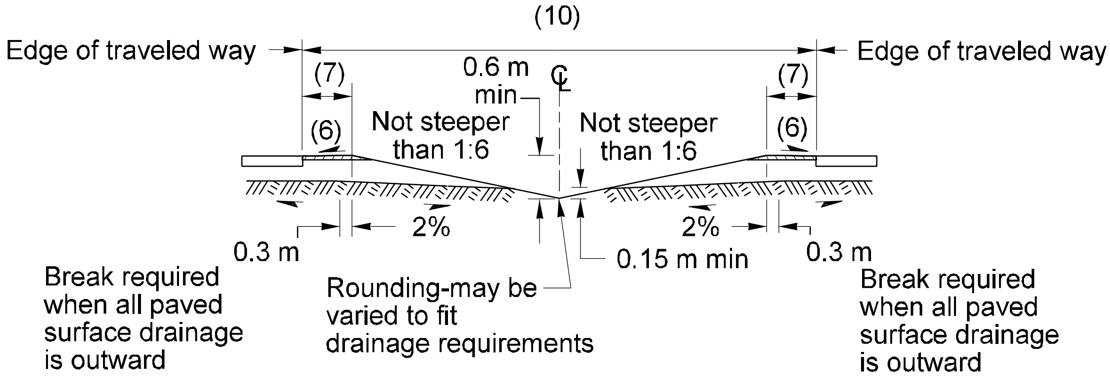
Alternate Design 1
Single Pivot Point



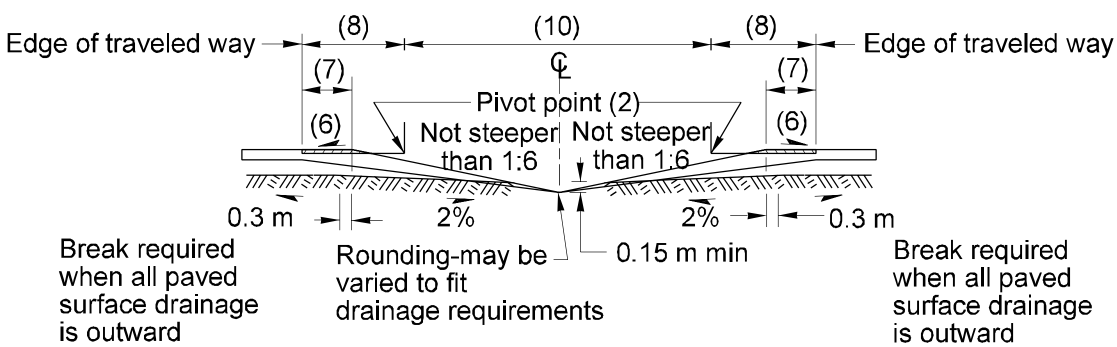
Alternate Design 2
Dual Pivot Points (2)

For notes, see Figure 640-15c

Divided Highway Median Sections
Figure 640-15a



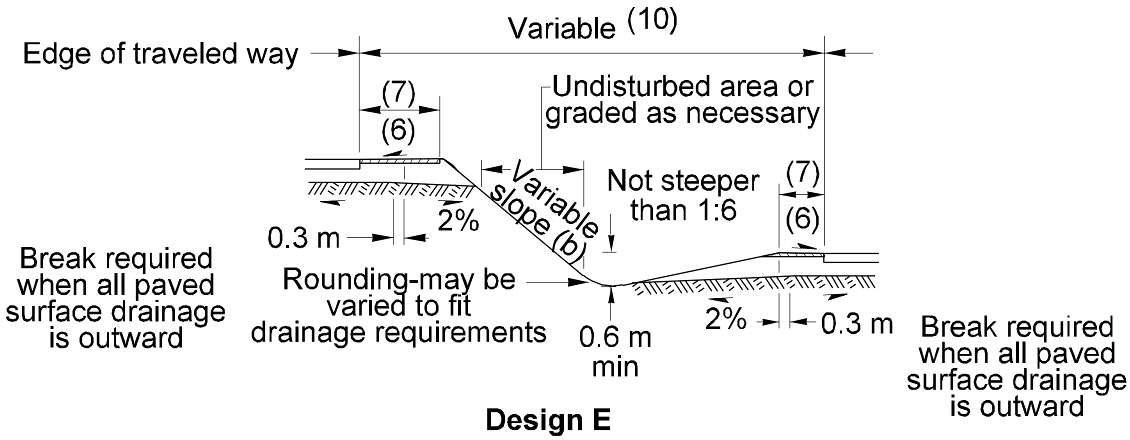
Design C Minimum Nonpaved Median for 4 or More Lanes (2)



Design D Minimum for 4 or More Lanes with Future Lanes in Median

For notes, see Figure 640-15c

Divided Highway Median Sections
Figure 640-15b



Design E

Minimum for 4 or more lanes with independent alignment

(1) Designs A and B including Alternate Designs 1 and 2 are urban median designs, see Chapter 440 for minimum urban median width.

(2) Locate the pivot point to best suit the requirements of vertical clearances, drainage, and aesthetics.

(3) Pavement slopes generally shall be in a direction away from the median. A crowned roadway section may be used in conjunction with the depressed median where conditions warrant. See Figure 640-3 for additional crown information.

(4) Design B may be used uniformly on both tangents and horizontal curves. Use alternate designs 1 or 2 when the "roll over" between the shoulder and the inside lane on the high side of a superelevated curve exceeds 8%. Provide suitable transitions at each end of the curve for the various conditions encountered in applying the alternate to the basic median design.

(5) Method of drainage pickup to be determined by the designer.

(6) Median shoulders normally slope in the same direction and rate as the adjacent through lane. When median shoulders are over 1.8 m wide or cement concrete pavement is used, median shoulders may slope toward the median. However, the "roll over" algebraic difference in rate of cross slope shall not exceed 8%. See figures 640-10a and 10b for additional shoulder details.

(7) See Chapter 440 for minimum shoulder width.

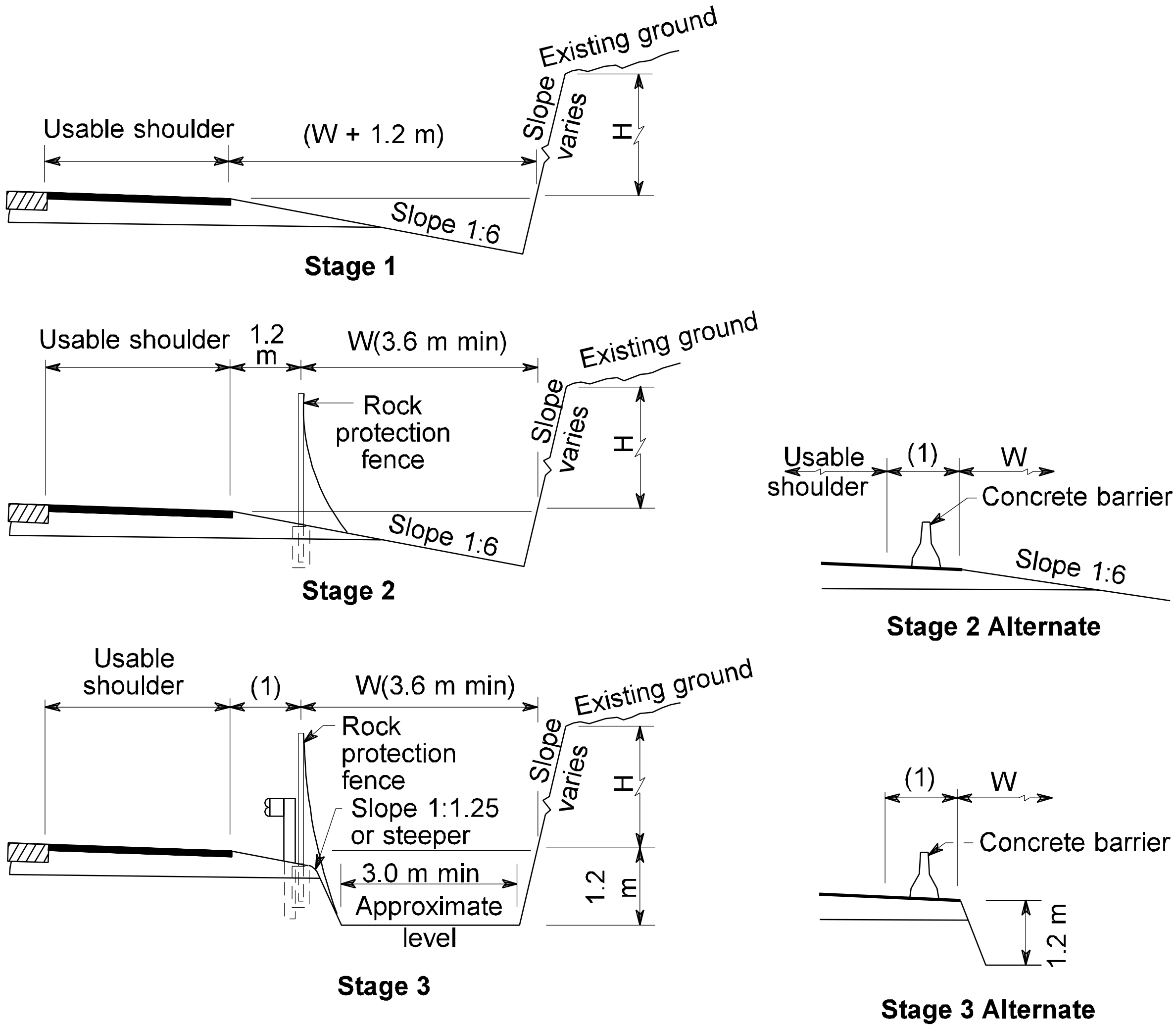
(8) Future lane, see Chapter 440 for minimum width.

(9) Widen and round foreslopes steeper than 1:4 as shown on Figure 640-10b.

(10) Designs C, D, and E are rural median desings, see Chapter 440 for minimum rural median widths. Rural median designs may be used in urban areas when minimum rural median widths can be achieved.

Divided Highway Median Sections

Figure 640-15c



Rock Slope	H(m)	W(m)
Near Vertical	6-9 9-18 >18	3.6 4.5 6.0
1:0.25 through 1:0.30	6-9 9-18 18-30 >30	3.6 4.5 6.0 7.5

Notes:

Cut heights less than 6.0 m shall be treated as a normal roadway unless otherwise determined by the Region Materials Engineer.

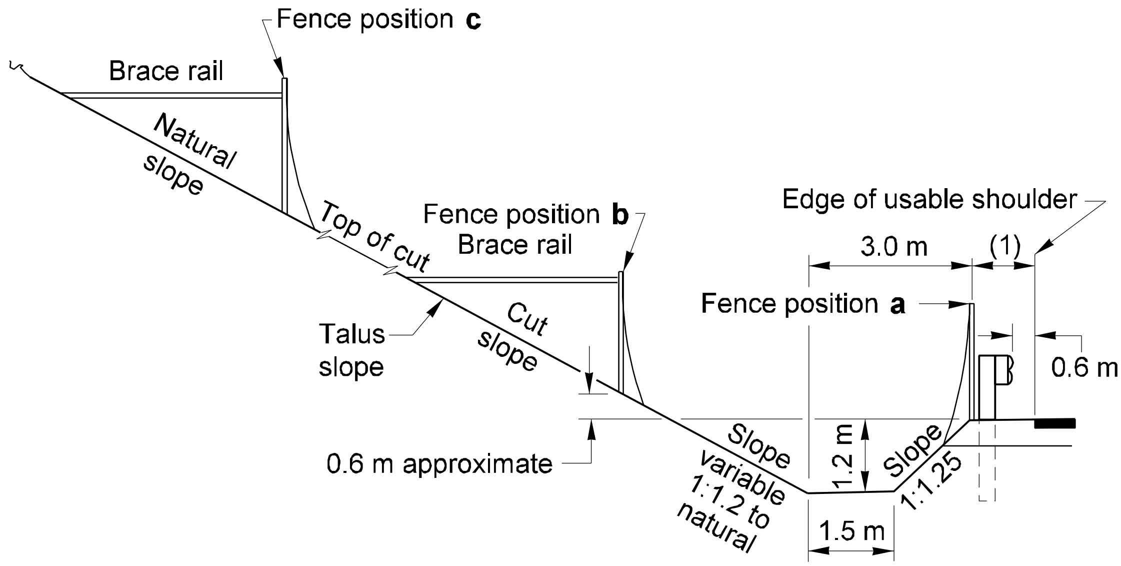
Stage 2 and 3 Alternates may be used when site conditions dictate.

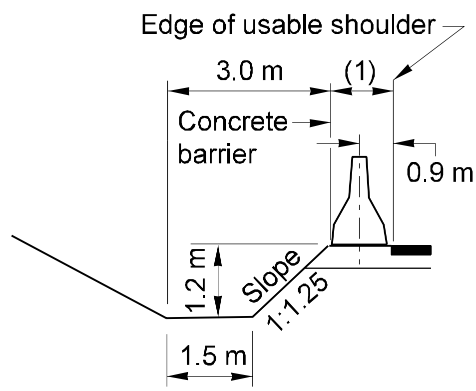
Fence may be used in conjunction with the Stage 3 Alternate. See Chapter 700 for clear zone requirements.

(1) See Chapter 710 for required widening for guardrail and concrete barrier.

Roadway Sections in Rock Cuts, Design A

Figure 640-16a





Shoulder Barrier Alternate

Notes

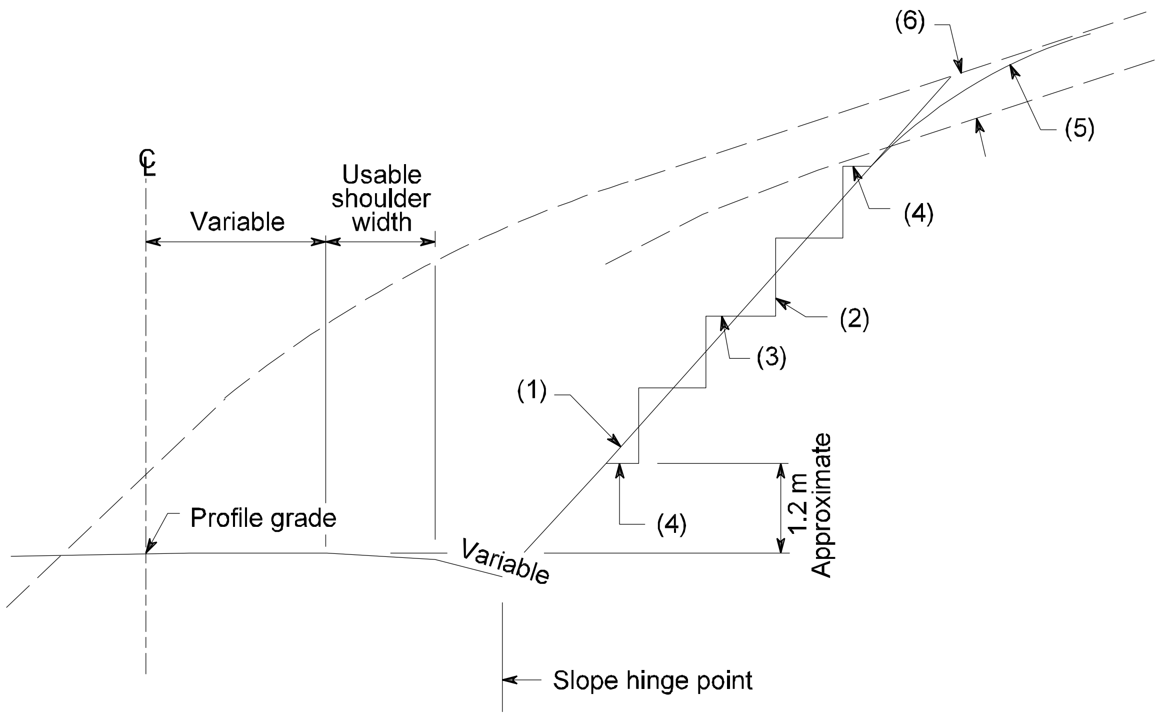
Ordinarily, place fence within a zone of 30 m to 60 m maximum from base of cliff measured along slope.

Rock protection fence may be used in conjunction with the Shoulder Barrier Alternate when site conditions dictate.

(1): See Chapter 710 for required widening for guardrail and concrete barrier.

Roadway Sections in Rock Cuts, Design B

Figure 640-16b



Notes:

(1) Staked slope line - Maximum slope 1:1.
(2) Step rise - height variable 0.3 to 0.6 m
(3) Step tread - width = staked slope ratio x step rise.
(4) Step termini - width = 1/2 step tread width.
(5) Slope rounding.
(6) Overburden area - variable slope ratio.

Roadway Sections With Stepped Slopes

Figure 640-17

Bridge End Condition	Toe of Slope End Slope Rate	Lower Roadway Treatment (1)	Slope Rate
End Piers on Fill	Height / Rate ≤ 10.5 m / $1:1^3/_4$ > 10.5 m / 1:2(2)	Posted speed of lower roadway. / Treatment > 50 mph / Rounding ≤ 50 mph / No rounding	
End Piers in Cut	Match lower roadway slope.(3)	No rounding, toe at center line of the lower roadway ditch.	(4)
Lower Roadway in Cut	Match lower roadway slope.(3)	No rounding, toe at center line of the lower roadway ditch.	(4)
Ends in Partial Cut and Fill	When the cut depth is > 2.5 m and length is > 30 m, match cut slope of the lower roadway.	When the cut depth is > 2.5 m and length is > 30 m, no rounding, toe at center line of the lower roadway ditch.	(4)
	When the cut depth is ≤1.5 m or the length is ≤30 m, it is designers choice.	When the cut depth is ≤1.5 m or the length is ≤30 m, it is designers choice.	(4)

Notes:

(1) See Figure 640-18b

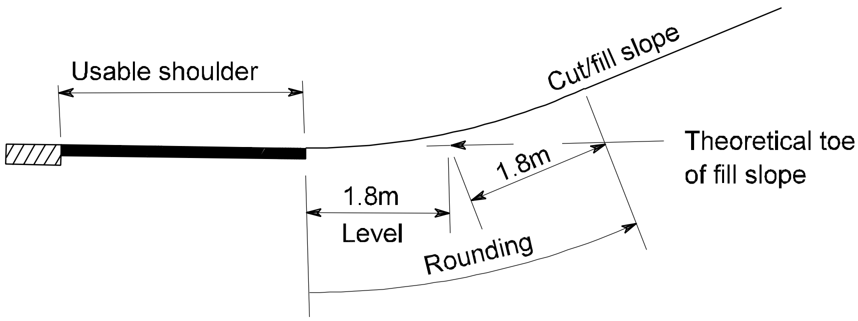
(2) Slope may be $1:1^3/_4$ in special cases.

(3) In interchange areas, continuity may require variations.

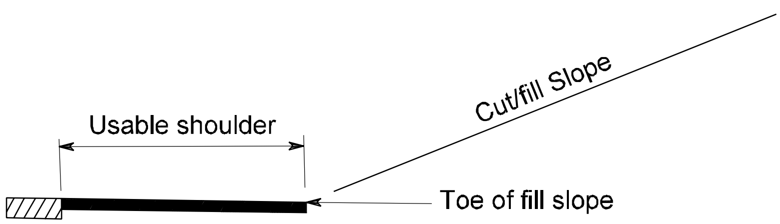
See 640.07.

Bridge End Slopes

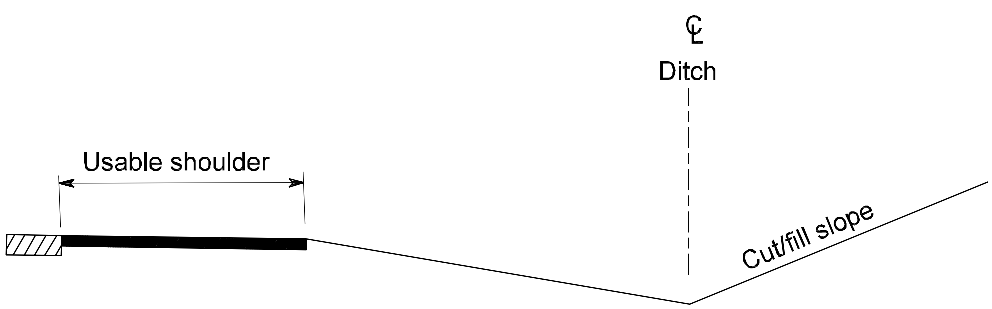
Figure 640-18a



Rounding



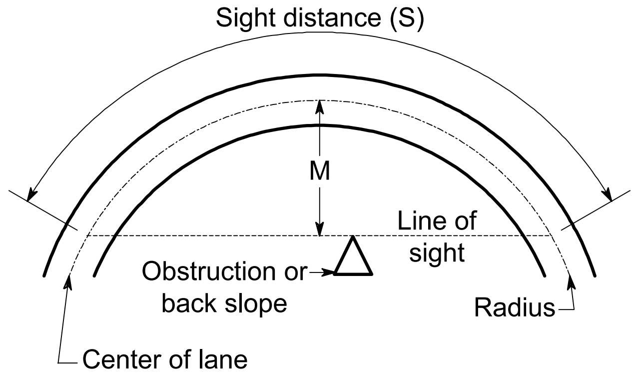
No Rounding



Toe at ℄ of Roadway Ditch

Bridge End Slopes
Figure 640-18b

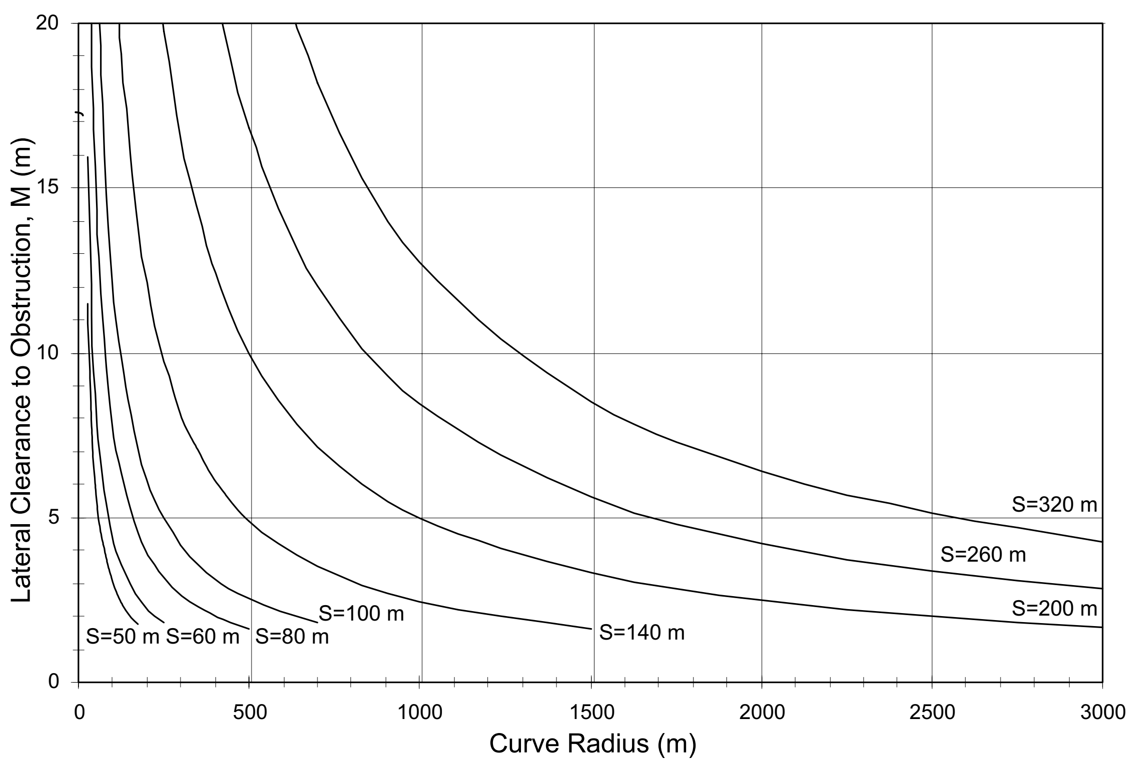
Height of eye: 1070 mm
Height of object: 150 mm
Line of sight is normally 610 mm above center line of inside lane at point of obstruction provided no vertical curve is present in horizontal curve.



$$M = R\left(1 - \cos\frac{28.65\,S}{R}\right)$$

$$S = \frac{R}{28.65}\left[\cos^{-1}\left(\frac{R - M}{R}\right)\right]$$

S ≤ Length of curve
Angle is expressed in degrees



Horizontal Stopping Sight Distance
Figure 650-9

700 Roadside Safety

700.01 General

Roadside safety addresses the area outside of the roadway and is an important component of total highway design. The roadside environment is significant to safety as illustrated by the fact that nearly one third of the fatal accidents are single vehicle run-off-the-road accidents. There are numerous reasons why a vehicle leaves the roadway. Regardless of the reason, a forgiving roadside can reduce the seriousness of the consequences of a roadside encroachment. The ideal highway has roadsides and median areas that are flat and unobstructed by hazards.

Elements such as side slopes, fixed objects, and water are potential hazards that a vehicle might encounter when it leaves the roadway. These hazards present varying degrees of danger to the vehicle and its occupants. Unfortunately, geography and economics do not always allow ideal highway conditions. The mitigative measures to be taken depend on the probability of an accident occurring, the likely severity, and the available resources.

In order of preference, mitigative measures are: removal, relocation, reduction of the impact severity (using breakaway features or making it traversable), and shielding with a traffic barrier. Consider cost (initial and life cycle costs) and maintenance requirements in addition to accident severity when selecting a mitigative measure. Use traffic barriers or earth berms only when other measures cannot reasonably be accomplished. See Chapter 710 for additional information on traffic barriers.

700.02 References

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

Roadside Manual, M 25-30, WSDOT

Roadside Design Guide, AASHTO

700.03 Definitions

ADT The average daily traffic for the design year under consideration.

clear run-out area The area at the toe of a nonrecoverable slope available for safe use by an errant vehicle.

clear zone The total roadside border area, starting at the edge of the traveled way, available for use by errant vehicles. This area may consist of a shoulder, a recoverable slope, a nonrecoverable slope, and/or a clear run-out area. The clear zone cannot contain a critical slope. ***Design Clear Zone*** is the minimum target value used in highway design.

critical slope A slope on which a vehicle is likely to overturn. Slopes steeper than 1:3 are considered critical slopes.

hazard A side slope, a fixed object, or water that, when struck, would result in unacceptable impact forces on the vehicle occupants or place the occupants in a hazardous position. It can be either natural or manmade.

nonrecoverable slope A slope on which an errant vehicle will continue until it reaches the bottom, without having the ability to recover control. Fill slopes steeper than 1:4, but no steeper than 1:3, are considered nonrecoverable.

recoverable slope A slope on which a the driver of an errant vehicle can regain control of the vehicle. Slopes of 1:4 or flatter are considered recoverable.

recovery area The minimum target value used in highway design when a fill slope between 1:4 and 1:3 starts within the Design Clear Zone

traffic barrier A longitudinal barrier, including bridge rail or an impact attenuator, used to redirect vehicles from hazards located within an established Design Clear Zone, to prevent median crossovers, to prevent errant vehicles from going over the side of a bridge structure, or (occasionally), to protect workers, pedestrians, or bicyclists from vehicular traffic.

traveled way The portion of the roadway intended for the movement of vehicles, exclusive of shoulders and lanes for parking, turning, and storage for turning.

700.04 Clear Zone

The clear zone is a primary consideration when analyzing hazards. The intent is to provide as much clear, traversable recovery area as practical. The Design Clear Zone values shown in Figure 700-1 are used to judge the adequacy of the existing clear zone and to provide a minimum target value for highway design. These values are not to be used as justification to compromise or take away from the existing clear zone.

A Design Clear Zone inventory is required for all projects indicating evaluate upgrade (EU) or Full Design Level (F) for the clear zone columns on the design matrices. (See Chapter 325.) Use the Design Clear Zone Inventory form (Figure 700-2) to inventory the roadside for potential hazards. Identify the hazards and propose corrective actions. Eliminating the hazard is the preferred action. Analyze a roadside hazard to determine if further mitigation is necessary even when it is beyond the values in Figure 700-1.

The Design Clear Zone is a function of the posted speed, side slope, and traffic volume. There are no distances in the table for IV:3H fill slopes. Although fill slopes between IV:4H and IV:3H are considered traversable if free of fixed objects, these slopes are defined as nonrecoverable slopes. A vehicle may be able to begin recovery on the shoulder, but will be unable to further this recovery until reaching a flatter area (1:4 or flatter) at the toe of the slope. Under these conditions, the Design Clear Zone distance is called a recovery area. The method used to calculate the recovery area and an example are shown in Figure 700-3.

For ditch sections, the following criteria determine the Design Clear Zone:

(a) For ditch sections with foreslopes IV:4H or flatter (see Figure 700-4, Case 1, for an example) the Design Clear Zone distance is the greater of:

1. The Design Clear Zone distance for a IV:10H cut section based on speed and ADT, or

2. A horizontal distance of 1.5 m beyond the beginning of the back slope.

When a back slope steeper than IV:3H continues for 1.5 m beyond the beginning of the back slope (as is the case with a redirectional land form), it is not necessary to use the IV:10H cut slope criteria.

(b) For ditch sections with foreslopes steeper than IV:4H, and back slopes steeper than IV:3H the Design Clear Zone distance is 3 m horizontal beyond the beginning of the back slope. (See Figure 700-4, Case 2, for an example.)

(c) For ditch sections with foreslopes steeper than IV:4H and back slopes IV:3H or flatter, the Design Clear Zone distance is the distance established using the recovery area formula (Figure 700-3). (See Figure 700-4, Case 3, for an example.)

700.05 Hazards to be Considered for Mitigation

There are three general categories of hazards: side slopes, fixed objects, and water. The following sections provide guidance for determining when these obstacles present a significant hazard to an errant motorist. In addition, several conditions require special consideration:

- Locations with high accident histories.
- Locations with pedestrian and bicycle usage. See Chapters 1020, “Bicycle Facilities,” and 1025, “Pedestrian Design Considerations.”

- Playgrounds, monuments, and other locations with high social or economic value may require mitigation such as a barrier.

Use of a traffic barrier for obstacles other than those described below requires justification in the design file.

(1) Side Slopes

(a) ***Fill Slopes.*** Fill slopes can present a hazard to an errant vehicle with the degree of severity dependant upon the slope and height of the fill. Providing fill slopes that are 1:4 or flatter can mitigate this hazard. If flattening the slope is not feasible or cost effective, the installation of a barrier may be appropriate. Figure 700-5 represents a selection procedure used to determine whether a fill side slope constitutes a hazard for which a barrier is a cost-effective mitigation. The curves are based on the severity indexes and represent the points where total costs associated with a traffic barrier are equal to the predicted accident cost associated with selected slope heights without traffic barrier. If the ADT and height of fill intersect on the "Barrier Recommended" side of the embankment slope curve, then provide a barrier if flattening the slope is not feasible or cost effective. Do not use Figure 700-5 for slope design. Design guidance for slopes is in Chapters 430 and 640. Also, if the figure indicates that barrier is not recommended at an existing nonstandard slope, that result is not justification for a deviation.

For example, if the ADT is 4000 and the embankment height is 3 m, barrier would be cost effective for a 1:2 slope, but not for a 1:2.5 slope.

This process only addresses the potential hazard of the slope. Obstacles on the slope may compound the hazard. Where barrier is not cost effective, use the recovery area formula to evaluate fixed objects on critical slopes less than 3 m high.

(b) ***Cut Slopes.*** A cut slope is usually less of a hazard than a traffic barrier. The exception is a rock cut with a rough face that could cause vehicle snagging rather than providing relatively smooth redirection.

Analyze the potential motorist risk and the benefits of treatment of rough rock cuts located within the Design Clear Zone. A cost-effectiveness analysis that considers the consequences of doing nothing, removal or smoothing of the cut slope, and all other viable options to reduce the severity of the hazard can be used to determine the appropriate treatment. Some potential options are:

- Redirectional land form.
- Flexible barrier.
- More rigid barrier.
- Rumble strips.

Conduct an individual investigation for each rock cut or group of rock cuts. Select the most cost-effective treatment.

(2) Fixed Objects

Consider the following objects for mitigation:

- Wooden poles or posts with cross sectional area greater than 10 000 square millimeters that do not have breakaway features.
- Nonbreakaway steel sign supports.
- Nonbreakaway luminaire supports.
- Trees having a diameter of 100 mm or more measured at 150 mm above the ground surface.
- Fixed objects extending above the ground surface by more than 100 mm; for example, boulders, concrete bridge rails, piers, and retaining walls.
- Existing nonstandard guardrail (see Chapter 710).
- Drainage items, such as culvert and pipe ends.

Remove objects that are hazards when feasible. Focus on the area within the Design Clear Zone but do not exclude consideration of objects outside this area. The possible mitigative measures are listed below in order of preference.

- Remove.
- Relocate.

- Reduce impact severity (using a breakaway feature).
- Shield the object by using redirectional landform, longitudinal barrier, or impact attenuator.

(a) ***Trees.*** When evaluating new plantings or existing trees, consider the maximum allowable diameter of 100 mm measured at 150 mm above the ground when the tree has matured. When removing trees within the Design Clear Zone, complete removal of stumps is preferred. However, to avoid significant disturbance of the roadside vegetation, larger stumps may be mitigated by grinding or cutting them flush to the ground and grading around them. See the *Roadside Management Manual* for further guidance on the treatment of the disturbed roadside.

(b) ***Mailboxes.*** Ensure that all mailboxes located within the Design Clear Zone have supports and connections as shown in the Standard Plans. The standard height of mailboxes from the ground to the bottom of the mailbox is 1.0 m. This height may vary from 1.0 m to 1.2 m if requested by the mail carrier. Include a note in the contract plans that gives the height desired if it is to be different from the standard height. See Figure 700-6 for installation guidelines.

In urban areas where sidewalks are prevalent, contact the postal service to determine the most appropriate mailbox location. Locate mailboxes on access controlled highways in accordance with Chapter 1420. A turnout, as shown on Figure 700-6, is not required on access controlled facilities with shoulders of 1.8 m or more where only one mailbox is to be installed. On highways without access control, mailboxes must be on the right-hand side of the road in the direction of travel of the postal carrier. Avoid placing mailboxes along high-speed, high-volume highways. Locate Neighborhood Delivery and Collection Box Units (NDCBU) outside the Design Clear Zone.

(c) Culvert Ends. Provide a traversable end treatment when the culvert end section or opening is on the roadway side slope and within the Design Clear Zone. This can be accomplished for small culverts by beveling the end to match the side slope, with a maximum of 100 mm extending out of the side slope.

Bars may be necessary to provide a traversable opening for larger culverts. Place bars in the plane of the culvert opening in accordance with the Standard Plans when:

1. Single cross culvert opening exceeds 1000 mm measured parallel to the direction of travel.
2. Multiple cross culvert openings that exceed 750 mm each, measured parallel to the direction of travel.
3. Culvert approximately parallel to the roadway has an opening that exceeds 600 mm measured perpendicular to the direction of travel.

Bars are permitted where they will not significantly affect the stream hydraulics and where debris drift is minor. Consult the regional Maintenance Office to verify these conditions. If debris drift is a concern, consider options to reduce the amount of debris that can enter the pipe (see the *Hydraulics Manual*). Other treatments are extending the culvert to move the end outside the Design Clear Zone or installing a traffic barrier.

(d) ***Sign Posts.*** Whenever possible, locate sign supports behind existing or planned traffic barrier installations to eliminate the need for breakaway supports. Place them at least 7.5 m from the end of the barrier terminal and with the sign face behind the barrier. When barrier is not present use terrain features to reduce the likelihood of an errant vehicle striking the sign supports. Whenever possible, depending on the type of sign and the sign message, adjust the sign location to take advantage of barrier or terrain features. This will reduce accident potential and, possibly, future maintenance costs. See Chapter 820 for additional information regarding the placement of signs.

Sign posts with cross sectional areas greater than 10 000 square millimeters that are within the Design Clear Zone and not located behind a barrier must have breakaway features as shown in the Standard Plans.

(3) Water

Water with a depth of 0.6 m or more and located with a likelihood of encroachment by an errant vehicle must be considered for mitigation on a project-by-project basis. Consider the length of time traffic is exposed to this hazard and its location in relationship to other highway features such as curves.

Analyze the potential motorist risk and the benefits of treatment of bodies of water located within the Design Clear Zone. A cost-effectiveness analysis that considers the consequences of doing nothing versus installing a longitudinal barrier can be used to determine the appropriate treatment.

700.06 Median Considerations

Medians must be analyzed for the potential of an errant vehicle to cross the median and encounter on-coming traffic. Median barriers are normally used on access controlled, multilane, high-speed, high traffic volume facilities. These facilities generally have posted speeds of 50 mph or greater. Median barrier is not normally placed on collector highways or other facilities that do not have controlled access. Providing access through median barrier requires openings and, therefore, end-treatments.

In the absence of cross median accident data, on access controlled, high-speed, multilane, high traffic volume facilities that have relatively flat, unobstructed medians, use Figure 700-7 to determine if median barrier is warranted.

As indicated in Figure 700-7, the need for median barrier is based on a combination of ADT and median widths. At low ADTs, the probability of a vehicle crossing the median is relatively low. Thus, for ADTs less than 20,000, use of median barrier is optional. Likewise, for relatively wide medians, the probability of a vehicle crossing the median is also relatively low. Thus, for median widths greater than 10 m, use of median barrier is optional. Consider cable barrier in these wide medians. Median barrier is not recommended for medians wider than 15 m unless there is a history of across-the-median accidents.

When median barrier is warranted for a median of less than 1.8 m on an existing facility, median widening is required to provide median width of 2.4 m. An approved deviation is required for the use of a median barrier in a median of less than 1.8 m.

Consider a wider median when the barrier casts a shadow on the roadway and hinders the melting of ice. See Chapter 640 for additional criteria for placement of median barrier. See Chapter 710 for information on the types of barriers that can be used. See Chapter 620 for lateral clearance on the inside of a curve to provide the required stopping sight distance.

When median barrier is being placed in an existing median, identify the existing crossovers and enforcement observation points. Provide the necessary median crossovers in accordance with Chapter 960, considering enforcement needs.

700.07 Other Roadside Safety Features

(1) Rumble Strips

Rumble strips are grooves or rows of raised pavement markers placed perpendicular to the direction of travel to alert inattentive drivers.

There are two kinds of rumble strips:

(a) **Roadway rumble strips** are placed across the traveled way to alert drivers approaching a change of roadway condition or a hazard that requires substantial speed reduction or other maneuvering. Examples of locations where roadway rumble strips may be used are in advance of:

- Stop controlled intersections.
- Port of entry/customs stations.
- Lane reductions where accident history shows a pattern of driver inattention.

They may also be placed at locations where the character of the roadway changes, such as at the end of a freeway.

Contact the Olympia Service Center Design Office for additional guidance on the design and placement of roadway rumble strips.

Document justification for using roadway rumble strips in the project file.

(b) **Shoulder rumble strips** are placed on the shoulders just beyond the traveled way to warn drivers when they are entering a part of the roadway not intended for routine traffic use. A comparison of rolled-in rumble strips and milled-in Continuous Shoulder Rumble Strips (CSRS) has determined that CSRS, although more expensive, are more cost effective. CSRS are the standard design.

Rumble strips may be used when an analysis indicates a problem with run-off-the-road accidents due to inattentive or fatigued drivers. Consider them on both shoulders of rural divided highways. CSRS are required on both the right and left shoulders of rural Interstate highways.

Lack of required CSRS is a design exception (DE) under any one of the following conditions:

- When another project scheduled within two years of the proposed project will overlay or reconstruct the shoulders or will use the shoulders for detours.
- When a pavement analysis determines that installing CSRS will result in inadequate shoulder strength.
- When shoulders will be less than 1.2 m wide on the left and 1.8 m wide on the right.

When CSRS are used, discontinue them where no edge strip is present such as at intersections and where curb and gutter are present.

(2) Headlight Glare

Headlight glare from opposing traffic can cause safety problems. Glare can be reduced by the use of wide medians, separate alignments, earth mounds, plants, standard and tall barriers, and by devices known as glare screens specifically designed to reduce glare. Consider long term maintenance when selecting the treatment for glare. When considering earth mound and planting to reduce glare, see the *Roadside Management Manual* for additional guidance. When considering glare screens, see Chapter 620 for lateral clearance on the inside of a curve to provide the required stopping sight distance. In addition to reducing glare, taller concrete barriers also provide improved crash performance for larger vehicles such as trucks.

Glare screen is relatively expensive and its use must be justified and documented. It is difficult to justify the use of glare screen where the median width exceeds 6 m, the ADT is less than 20,000 vehicles per day, or the roadway has continuous lighting. Consider the following factors when assessing the need for glare screen:

- Higher rate of night accidents compared to similar locations or statewide experience.
- Higher than normal ratio of night to day accidents.
- Unusual distribution or concentration of nighttime accidents.
- Over representation of older drivers in night accidents.
- Combination of horizontal and vertical alignment, particularly where the roadway on the inside of a curve is higher than the roadway on the outside of the curve.
- Direct observation of glare.
- Public complaints concerning glare.

The most common glare problem is between opposing main line traffic. Other conditions for which glare screen might be appropriate are:

- Between a highway and an adjacent frontage road or parallel highway, especially where opposing headlights might seem to be on the wrong side of the driver.
- At an interchange where an on-ramp merges with a collector distributor and the ramp traffic might be unable to distinguish between collector and main line traffic. In this instance, consider other solutions, such as illumination.
- Where headlight glare is a distraction to adjacent property owners. Playgrounds, ball fields, and parks with frequent nighttime activities might benefit from screening if headlight glare interferes with these activities.

850.01 General

Traffic control signals are power-operated traffic control devices that warn or direct motorists to take some specific action. More specifically, signals are used to control the assignment of right of way at locations where conflicts exist or where passive devices, such as signs and markings, do not provide the necessary flexibility of control to move traffic in a safe and efficient manner.

850.02 References

The following references are used in the design, construction, and operation of traffic control signals installed on state highways. The Revised Codes of Washington (RCWs) noted below are specific state laws concerning traffic control signals and conformance to these statutes is required.

RCW 35.77, "Streets-Planning, establishment, construction, and maintenance."

RCW 46.61.085, "Traffic control signals or devices upon city streets forming part of state highways—Approval by department of transportation."

RCW 47.24.020 (6) and (13), "Jurisdiction, control."

RCW 47.36.020, "Traffic control signals."

RCW 47.36.060, "Traffic devices on county roads and city streets."

Washington Administrative Code (WAC) 468-18-040, "Design standards for rearranged county roads, frontage roads, access roads, intersections, ramps and crossings."

Directive D 55-03, "Responsibility for Traffic Control Devices, Pavement Widening, and Channelization at Existing Intersections and Two-Way Left Turn Lanes in Cities"

Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD), USDOT, Washington DC, 1988, including the *Washington State Modifications to the MUTCD*, M 24-01, WSDOT, 1996

Plans Preparation Manual, M 22-31, WSDOT

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

850.03 Definitions

The various types of traffic control signals are defined below. Hazard identification beacons and ramp meter signals are energized only at specific times. All other signals remain in operation at all times.

conventional traffic signal A permanent or temporary installation providing alternating right of way assignments for conflicting traffic movements. At least two identical displays are required for the predominant movement on each approach.

emergency vehicle signal A special adaptation of a conventional traffic signal installed to allow for the safe movement of authorized emergency vehicles. Usually this type of signal is installed on the highway at the entrance into a fire station or other emergency facility. The signal assures protected entrance onto the highway for the emergency vehicle. When not providing for this movement, the signal either operates continuously, consistent with the requirements for a conventional traffic signal, or displays continuous green (allowed at nonintersection locations only). At least two identical displays are required per approach.

hazard identification beacon A beacon that supplements a warning or regulatory sign or marking. The display is a flashing yellow indication. These beacons are not used with “stop”, “yield”, or “do not enter” signs. A hazard identification beacon is energized only during those hours when the hazard or regulation exists.

intersection control beacon (flashing beacon) A secondary control device, generally suspended over the center of an intersection, that supplements intersection warning signs and stop signs. One display per approach may be used but two displays per approach are desirable. Intersection control beacons are installed only at an intersection to control two or more directions of travel.

lane control signal (reversible lanes) A special overhead signal that permits, prohibits, or warns of impending prohibition of lane use.

moveable bridge signal (drawbridge signal) A signal installed to notify traffic to stop when the bridge is opened for waterborne traffic. Moveable bridge signals display continuous green when the roadway is open to vehicular traffic.

overlapped displays Overlapped displays allow a nonconflicting traffic movement to run with another phase. Most commonly, a minor street’s exclusive right-turn phase is overlapped with the nonconflicting major street’s left-turn phase. An overlapped display can be terminated after the parent phase terminates. An overlapped display programmed for two or more parent phases continues to display until all of the parent phases have terminated.

pedestrian signal An adaptation of a conventional traffic signal installed at established pedestrian crossings. It is used to create adequate gaps in the vehicular movement to allow for safe pedestrian crossings. When not operating as a pedestrian signal, the system operates consistent with the requirements for an emergency vehicle signal.

portable traffic signal A type of conventional traffic signal used in work zones to control traffic. It is typically used on two-way, two-lane highways where one lane has been closed for roadwork. The traffic signal provides alternating right of way assignments for conflicting traffic movements. The signal has an adjustable vertical support with two three-section signal displays and is mounted on a mobile trailer with its own power source.

ramp meter signal A signal used to control the flow rate of traffic entering a freeway or similar facility. A minimum of two displays is required. When not in use, ramp meter signals are not energized.

speed limit sign beacon A beacon installed with a fixed or variable speed limit sign. The display is a flashing yellow indication.

stop sign beacon A beacon installed above a stop sign. The display is a flashing red indication.

temporary traffic signal A conventional traffic signal used during construction to control traffic at an intersection while a permanent signal system is being constructed. A temporary traffic signal is typically an inexpensive span-wire installation using timber strain poles.

850.04 Procedures

(1) Permit

State statutes (RCWs) require Department of Transportation approval for the design and location of all conventional traffic signals and some types of beacons located on city streets forming parts of state highways. Approval by the Department of Transportation for the design, location, installation, and operation of all other traffic control signals installed on state highways is required by department policy.

The Traffic Signal Permit (DOT Form 242-014 EF) is the formal record of the department’s approval of the installation and type of signal. The permit is completed by the responsible agency and submitted to the Regional Administrator for approval. The region retains a record of the permit approval, complete with supporting data, and a copy is forwarded to the State Traffic Engineer at the Olympia Service Center (OSC). Permits are required for the following types of signal installations:

- Conventional traffic signals
- Emergency vehicle signals
- Hazard identification beacons, when installed overhead at an intersection

- Intersection control beacons
- Lane control signals
- Moveable bridge signals
- Portable signals
- Ramp meter signals
- Pedestrian signals
- Temporary signals

Emergency vehicle signals require annual permit renewal. The region's traffic office reviews the installation for compliance with standards. If satisfactory, the permit is renewed by the Regional Administrator by way of a letter to the operating agency. A copy of this letter is also sent to the State Traffic Engineer.

Permits are not required for hazard identification beacons that are not installed overhead at an intersection, speed limit sign beacons, stop sign beacons, and lane assignment signals at toll facilities.

When it is necessary to increase the level of control, such as changing from an intersection control beacon to a conventional traffic signal, a new permit application is required. If the change results in a reduction in the level of control, as in the case of converting a conventional signal to a flashing intersection beacon, or if the change is the removal of the signal, submit the "Report of Change" portion of the traffic signal permit to the Regional Administrator with a copy to the State Traffic Engineer.

(2) Responsibility for Funding, Construction, Maintenance, and Operation

Responsibility for the funding, construction, maintenance, and operation of traffic signals on state highways has been defined by legislative action and transportation commission resolutions. See Figure 850-3. Responsibilities vary depending on location, jurisdiction, and whether or not limited access control has been established. Limited access as used in this chapter refers to full, partial, or modified limited access control as identified in the "Master Plan for Limited Access Highways Route Listing".

(a) **Inside the corporate limits of cities with a population of less than 22,500.** The Department of Transportation is responsible for funding, construction, maintenance, and operation of traffic signals.

(b) **Inside the corporate limits of cities with a population of 22,500 or greater where there is no established limited access control.** The city is responsible for the funding, construction, maintenance, and operation of traffic signals.

(c) **Inside the corporate limits of cities with a population of 22,500 or greater where there is established limited access control.** The Department of Transportation is responsible for funding, construction, maintenance, and operation of traffic signals.

(d) **Outside the corporate limits of cities and outside established limited access control areas.** The Department of Transportation is responsible for funding, construction, maintenance, and operation of a signal when a new state highway crosses an existing county road. The Department of Transportation is responsible for only the maintenance and operation when a new county road intersects an existing state highway. The county is responsible for the construction costs of the signal and associated illumination. When it is necessary to construct a traffic signal at an existing county road and state highway intersection, the construction cost distribution is based on the volume of traffic entering the intersection from each jurisdiction's roadway. The county's share of the cost, however, is limited to a maximum of fifty percent. The state is responsible for maintenance and operation. See WAC 468-18-040 for details.

(e) **Outside the corporate limits of cities and inside established limited access control areas**. The Department of Transportation is responsible for funding, construction, maintenance, and operation of traffic signals.

(f) **Emergency Vehicle Signals**. The emergency service agency is responsible for all costs associated with emergency vehicle signals.

(g) **Third Party Agreement Signals**. At those locations where the Department of Transportation is responsible for signals and agrees that the proposed signal is justified but where funding schedules and priorities do not provide for the timely construction of the signal requested by others, the following rules apply:

- The third party agrees to design and construct the traffic signal in conformance with the Department of Transportation's standards.
- The third party agrees to submit the design and construction documents to the Department of Transportation for review and approval.
- The third party obtains a traffic signal permit.

850.05 Signal Warrants

The requirements for traffic signal warrants are in the MUTCD. A signal warrant is a minimum condition in which a signal may be installed. Satisfying a warrant does not mandate the installation of a traffic signal. The warranting condition indicates that an engineering study, including a comprehensive analysis of other traffic conditions or factors, is required to determine whether the signal or another improvement is justified. There are eleven warrants for conventional traffic signal installations. These warrants are as follows:

- Warrant 1 Minimum vehicular volume
- Warrant 2 Interruption of continuous traffic
- Warrant 3 Minimum pedestrian volume
- Warrant 4 School crossings
- Warrant 5 Progressive movement
- Warrant 6 Accident experience
- Warrant 7 Systems
- Warrant 8 Combination of warrants
- Warrant 9 Four Hour Volumes
- Warrant 10 Peak Hour Delay
- Warrant 11 Peak Hour Volume

Warrants 1, 2, 9, and 11 of the MUTCD allow a reduction in the major street vehicle volume requirements when the 85th percentile speed exceeds 40 mph. This provision only acknowledges a difference in driver behavior on higher speed roadways. It does not imply that traffic signals are always the most effective solution on these facilities. A proposal to install a traffic signal on any state route with a posted speed of 45 mph or higher requires an alternatives analysis. See Chapter 910. A proposal to install a traffic signal on a high speed highway requires Olympia Service Center Design Office review and concurrence.

Warrant 6, Accident experience, is used when the types of accidents are correctable by the installation of a traffic signal. Correctable accidents typically are angle and side impact collisions with turning or entering vehicles.

Rear-end, sideswipe, and single vehicle accidents are usually not correctable with the installation of a traffic signal and are only used in special circumstances to satisfy the requirements of the accident warrant. In the project file, include an explanation of the conditions justify using these types of accidents to satisfy the accident warrant.

850.06 Conventional Traffic Signal Design

(1) General

The goal of any signal design is to assign right of way in the most efficient manner possible and still be consistent with traffic volumes, intersection geometrics, and safety.

(2) Signal Phasing

As a general rule, although there are exceptions, the fewer signal phases the more efficient the operation of the traffic signal. The number of phases required for safe, efficient operation is related to the intersection geometrics, traffic volumes, the composition of the traffic flow, turning movement demands, and the level of driver comfort desired. The traffic movements at an intersection have been standardized to provide a consistent system for designing traffic signals. See Figure 850-4 for standard intersection movements, signal head numbering, and the standard phase operation. Figure 850-5 shows the phase diagrams for various signal operations.

(a) **Level of Service.** The efficiency of a traffic signal is measured differently than highways. While highways use the number and width of lanes and other factors to determine capacity and a level of service, traffic signals are measured or rated by the overall delay imposed on the motorists. Phase analysis is the tool used to find the anticipated delay for all movements. These delay values are then equated to a level of service. There are several computer-based programs for determining delay and level of service. Letter designations from “A” to “F” denote the level of service (LOS) with “F” being the worst condition.

In new construction or major reconstruction projects where geometric design can be addressed, a level of service of at least “D” in urban locations and “C” in rural areas is desirable on state highways. These levels of service are a projection of the conditions that will be present during the highest peak hour for average traffic volumes during the design year of the traffic signal’s operation. Special or seasonal events of short duration or holidays, which can generate abnormally high traffic volumes, are not considered in this determination. Provide an explanation in the project file when the desired level of service cannot be obtained.

Intersection level of service can be improved by either adding traffic lanes or eliminating conflicting traffic movements. Intersections can sometimes be redesigned to compress the interior of the intersection by eliminating medians, narrowing lanes, or reducing the design vehicle turning path requirements. This compression reduces the travel time for conflicting movements and can reduce overall delay.

(b) **Left-turn phasing.** Left-turn phasing can be either permissive, protected, or a combination of both that is referred to as protected/permissive.

1. **Permissive left-turn phasing** requires the left turning vehicle to yield to opposing through traffic. Permissive left-turn phasing is used when the turning volume is minor and adequate gaps occur in the opposing through movement. This phasing is more effective on minor streets where providing separate, protected turn phasing might cause significant delays to the higher traffic volume on the main street. On high speed approaches or where sight distance is limited, consider providing a separate left-turn storage lane for the permissive movement to reduce the frequency of rear end type accidents and to provide safe turning movements.

2. **Protected/permissive left-turn phasing** means that the left-turn movements have an exclusive nonconflicting phase followed by a secondary phase when the vehicles are required to yield to opposing traffic. Where left-turn phasing will be installed and conditions do not warrant protected-only operation, consider protected/permissive left-turn phasing. Protected/permissive left-turn phasing can result in increased efficiency at some types of intersections, particularly “Tee” intersections, ramp terminal intersections, and intersections of a two-way street with a one-way street where there are no opposing left movements. Due to the geometry of these types of intersections, neither the simultaneous display of a circular red indication with a green left-turn arrow nor the condition referred to as “yellow trap” occur.

“Yellow trap” occurs on a two-way roadway when the permissive left-turn display changes to protected-only mode on one approach, while the display remains in the permissive mode on the opposite approach where a left turning motorist sees a yellow indication on the adjacent through movement. The motorist believes the opposing through movement also has a yellow display, when, in fact, that movement’s display remains green. It is possible to prevent “yellow trap” by recalling the side street, however, this can lead to inefficient operation and is not desirable.

3. **Protected left-turn phasing** provides the left turning vehicle a separate phase and conflicting movements are required to stop.

Protected phasing is always required for multilane left-turn movements.

Use protected left-turn phasing when left turning type accidents on any approach equal 3 per year, or 5 in two consecutive years. This includes left turning accidents involving pedestrians.

Use protected left-turn phasing when the peak hour turning volume exceeds the storage capacity of the turn lane because of insufficient gaps in the opposing through traffic and one or more of the following conditions are present:

- The 85th percentile speed of the opposing traffic exceeds 45 mph.
- The sight distance of oncoming traffic is less than 76 m when the 85th percentile speed is 35 mph or below or less than 122 m if the 85th percentile speeds are above 35 mph.
- The left-turn movement crosses three or more lanes (including right-turn lanes) of opposing traffic.
- Geometry or channelization is confusing.

Typically, an intersection with protected left turns operates with leading left turns. This means that on the major street, the left-turn phases, phase 1 and phase 5, time before the through movement phases, phase 2 and phase 6. On the minor street, the left-turn phases, phase 3 and phase 7, time before phase 4 and phase 8. Lagging left-turn phasing means that the through phases time before the conflicting left-turn phases. In lead-lag left-turn phasing one of the left-turn phases times before the conflicting through phases and the other left-turn phase times after the conflicting through phases. In all of these cases, the intersection phasing is numbered in the same manner. Leading, lagging, and lead-lag left-turn phasing are accomplished by changing the order in which the phases time internally within the controller.

(c) **Multilane left-turn phasing.** Multilane left turns can be effective in reducing signal delay at locations with high left turning volumes or where the left-turn storage area is limited longitudinally. At locations with closely spaced intersections, a two-lane left-turn storage area might be the only solution to prevent the left-turn volume from backing up into the adjacent intersection. Consider the turning paths of the vehicles when proposing multilane left turns. At smaller intersections the opposing left turn might not be able to turn during the two-lane left-turn phase and it might be necessary to reposition this lane. If the opposing left turns cannot time together the reduction in delay from the two-lane left-turn phase might be nullified by the requirement for separate opposing left-turn phase. Figure 850-6 shows two examples of two-lane left with opposing single left arrangements.

A two-lane exit is required for the two-lane left-turn movements. In addition, this two-lane exit must extend well beyond the intersection. A lane reduction on this exit immediately beyond the intersection will cause delays and backups into the intersection because the left turning vehicles move in dense platoons and lane changes are difficult. See Chapter 910 for the restrictions on lane reductions on intersection exits.

(d) **Right-turn phasing.** Right-turn overlapped phasing can be considered at locations with a dedicated right-turn lane where the intersecting street has a complimentary protected left-turn movement and U-turns are prohibited. Several right-turn overlaps are shown in the Phase Diagrams in Figure 850-5. The display for this movement is dependent on whether a pedestrian movement is allowed to time concurrently with the through movement adjacent to the right-turn movement.

For locations with a concurrent pedestrian movement, use a five section signal head consisting of circular red, yellow, and green displays with yellow and green arrow displays. Connect the circular displays to the through phase adjacent to the right-turn movement and connect the arrow displays to the complimentary conflicting minor street left-turn phase.

For locations without a concurrent pedestrian movement, use a three section signal head with all arrow displays or visibility limiting displays (either optically programmed sections or louvered visors) with circular red, yellow arrow, and green arrow displays. This display is in addition to the adjacent through movement displays. Program this display as an overlap to both the left-turn phase and the adjacent through phase.

(e) **Two-lane right-turn phasing.** Two-lane right-turn phasing can be used for an extraordinarily heavy right-turn movement. They can cause operation problems when "right turn on red" is permitted at the intersection. Limited sight distance and incorrect exit lane selection are pronounced and can lead to an increase in accidents. In most cases, a single unrestricted "right turn only" lane approach with a separate exit lane will carry a higher traffic volume than the two-lane right-turn phasing.

(f) **Phasing at railroad crossings.** Railroad preemption phasing is required at all signalized intersections when the nearest rail of a railroad crossing is within 61 m of the stop bar of any leg of the intersection, unless the railroad crossing is rarely used or is about to be abandoned. Preemption for intersections with the railroad crossing beyond 61 m from the intersection stop line is only considered when the queue on that approach routinely occupies the crossing. Contact the railroad company to determine if this line still actively carries freight or passengers.

Railroad preemption has two distinct intervals; the clearance interval before the train arrives and the passage interval when the train is crossing the intersection leg. During the clearance interval, all phases are terminated and the movement on the railroad crossing leg is given priority. When this movement has cleared the crossing, it is then terminated. During the passage interval, the traffic signal cycles between the movements not affected by the train crossing. See Figure 850-7 for an example of railroad preemption phasing.

Arranging for railroad preemption requires a formal agreement with the railroad company. The region's Utilities Engineer's office handles this transaction. Contact this office early in the design stage as this process can be time consuming and the railroad company might require some modifications to the design.

(3) Intersection Design Considerations

Left turning traffic can be better accommodated when the opposing left-turn lanes are directly opposite each other. When a left-turn lane is offset into the path of the approaching through lane, the left turning driver might assume that the approaching vehicles are also in a left-turn lane and fail to yield. To prevent this occurrence, less efficient split phasing is necessary.

Consider providing an unrestricted through lane on the major street of a "T" intersection. This design allows for one traffic movement to flow without restriction.

Skewed intersections, because of their geometry, are difficult to signalize and delineate. When possible, modify the skew angle to provide more normal approaches and exits. The large paved areas for curb return radii at skewed intersections, in many cases, can be reduced when the skew angle is lessened. See Chapter 910 for requirements and design options.

If roadway approaches and driveways are located too close to an intersection, the traffic from these facilities can affect signal operation. Consider restricting their access to "Right In / Right Out" operation.

Transit stop and pull out locations can affect signal operation. See Chapter 1060 for transit stop and pull out designs. When possible, locate these stops and pull outs on the far side of the intersection for the following benefits:

- Minimizes overall intersection conflict, particularly the right-turn conflict.
- Minimizes impact to the signal operation when buses need preemption to pull out.
- Provides extra pavement area where U-turn maneuvers are allowed.
- Eliminates the sight distance obstruction for drivers attempting to turn right on red.
- Eliminate conflict with right-turn pockets.

Large right-turn curb radii at intersections sometimes have negative impacts on traffic signal operation. Larger radii allow faster turning speeds and might move the entrance point farther away from the intersection area. See Chapter 910 for guidance in determining these radii.

At intersections with large right-turn radii, consider locating signal standards on raised traffic islands to reduce mast arm lengths. These islands are primarily designed as pedestrian refuge areas. See Chapter 1025 for pedestrian refuge area and traffic island designs.

Stop bars define the point where vehicles must stop to not be in the path of the design vehicle's left turn. Check the geometric layout by using the turning path templates in Chapter 910 or a computerized vehicle turning path program to determine if the proposed phasing can accommodate the design vehicles. Also, check the turning paths of opposing left-turn movements. In many cases, the phase analysis might recommend allowing opposing left turns to run concurrently, but the intersection geometrics are such that this operation cannot occur.

(4) Crosswalks and Pedestrians

Provide pedestrian displays and push buttons at all signalized intersections unless the pedestrian movement is prohibited. Crosswalks, whether marked or not, exist at all intersections. See Chapter 1025 for additional information on marked crosswalks. If a pedestrian movement will be prohibited at an intersection, provide signing for this prohibition. This signing is positioned on both the near side and far side on the street to be visible to the pedestrians. When positioning these signs for visibility, consider the location of the stop bar where this crossing will be prohibited. Vehicles stopped at the stop bar might obstruct the view of the signing. There are normally three crosswalks at a "T" intersection and four crosswalks at "four legged" intersection. For pedestrian route continuity the minimum number of crosswalks is two at "T" intersections and three for "four legged" intersections.

If a crosswalk is installed across the leg where right or left turning traffic enters, the vehicle display cannot have a green turn arrow indication during the pedestrian "walk" phase. If this cannot be accomplished, provide a separate pedestrian or vehicle turn phase.

Locate crosswalks as close as possible to the intersection, this improves pedestrian visibility for the right-turning traffic. Locate the push buttons no more than 1.5 m from the normal travel path of the pedestrian. Locate the push button no more than 4.5 m from the center point at the end of the associated crosswalk. At curb and sidewalk areas, locate the pedestrian push buttons adjacent to the sidewalk ramps to make them accessible to people with disabilities. Figures 850-8a and 850-8b show examples of the push button locations at raised sidewalk locations. When the pedestrian push buttons are installed on the vehicle signal standard, provide a paved path, not less than 1.2 m in width, from the shoulder or sidewalk to the standard. If access to the signal standard is not possible, install the push buttons on Type PPB push button posts or on Type PS pedestrian display posts. When pedestrian push buttons are installed behind guardrail, use Type PPB posts. Position these posts so that the push button is not more than 0.50 m from the face of the guardrail.

(5) Control Equipment

Controller assemblies can be either Type 170 controllers or National Electrical Manufacturers Association (NEMA) controllers with dual ring; eight vehicle phase, four pedestrian phase, four overlap, operational capabilities. From a design perspective, identical operation can be obtained from either controller. Specify the Type 170 unless the region's policy is to use NEMA controllers.

In situations where it is necessary to coordinate the traffic movements with another agency, it is necessary for one of the agencies to be responsible for the operation of the traffic signal, regardless of which agency actually owns and maintains the signal. This is accomplished by negotiating an agreement with the other agency. At a new intersection, where the state owns the signal but another agency has agreed to operate the signal, the controller must be compatible with that agency's system.

When Type 170 controllers are used, but it is necessary to coordinate the state owned and operated signals with another jurisdiction’s system using NEMA controllers, use compatible NEMA controllers installed in Type 170/332 cabinets. Specify a C1 plug connected to a NEMA A, B, C, and D plug adapter for these installations. The Model 210 conflict monitor in the Type 170/332 cabinet can be used with a NEMA controller by changing a switch setting. The Type 12 NEMA conflict monitor is not used in this configuration. It does not fit in a Type 170/332 cabinet and the operation is not compatible. When a NEMA cabinet is used, specify rack-mountings for the loop detector amplifiers and the preemption discriminators.

Coordinate with the region’s electronics technician to determine the optimum controller cabinet location and the cabinet door orientation. The controller cabinet is positioned to provide maintenance personnel access. At this location, a clear view of the intersection is desirable. Avoid placing the controller at locations where it might block the view of approaching traffic for a motorist turning right on red. Avoid locating the controller where flooding might occur or where the cabinet might be hit by errant vehicles. If possible, position the controller where it will not be affected by future highway construction.

If a telephone line connection is desired for remote signal monitoring and timing adjustments by signal operations personnel, provide a modem in the controller cabinet and separate conduits and a junction box between the cabinet and the telephone line access point.

Vehicle and pedestrian movements are standardized to provide uniformity in signal phase numbering, signal display numbering, preemption channel identification, detection numbering, and circuit identification. The following are general guidelines for the numbering system:

- Assign phases 2 and 6 to the major street through movements, orienting phase 2 to the northbound or eastbound direction of the major street.
- Assign phases 1 and 5 to the major street protected left-turn movements.
- Assign phases 4 and 8 to the minor street through movements.
- Assign phases 3 and 7 to the minor street protected left-turn movements.
- At “Tee” intersections, assign the movement on the stem of the “Tee” to either phase 4 or phase 8.
- At intersections with four approaches and each minor street times separately, assign the minor streets as phase 4 and 8 and note on the phase diagram that these phases time exclusively.
- Signal displays are numbered with the first number indicating the signal phase. Signal displays for phase 2, for example, are numbered 21, 22, 23,and so on. If the display is an overlap, the designation is the letter assigned to that overlap. If the display is protected/permissive, the display is numbered with the phase number of the through display followed by the phase number of the left-turn phase. A protected/permissive signal display for phase 1 (the left-turn movement) and phase 6 (the compatible through movement), for example, is numbered 61/11. The circular red, yellow, green displays are connected to the phase 6 controller output and the yellow and green arrow displays are connected to the phase 1 controller output.
- Pedestrian displays and detectors are numbered with the first number indicating the signal phase and the second number as either an 8 or 9. Pedestrian displays and detectors 28 and 29, for example, are assigned to phase 2.
- Detection is numbered with the first number representing the phase. Detection loops for phase 2 detectors are numbered 21, 22, 23, and so on.
- Emergency vehicle detectors are designated by letters; phase 2 plus phase 5 operation uses the letter “A”, phase 4 plus phase 7 uses the letter “B”, phase 1 plus phase 6 uses the letter “C”, and phase 3 plus phase 8 uses the letter “D”.

(6) Detection Systems

The detection system at a traffic actuated signal installation provides the control unit with information regarding the presence or movement of vehicles, bicycles, and pedestrians. Vehicle detection systems perform two basic functions: queue clearance and the termination of phases. Depending on the specific intersection characteristics, either of these functions can take priority. The merits of each function are considered and a compromise might be necessary.

The vehicle detection requirements vary depending on the 85th percentile approach speed as follows:

- When the posted speed is below 35 mph, provide stop bar detection from the stop bar to a point 9.1 m to 10.7 m in advance of that location. Assign the stop bar loops to detection input "extension" channels. When counting loops are installed, calculate the distance traveled by a vehicle in two seconds at the 85th percentile speed and position the advance loops at this distance in advance of the stop bar.
- When the posted speed is at or above 35 mph, provide advance detection based on the "dilemma zone detection design". Where installed, stop bar detection extends from the stop bar to a point 9.1 m to 10.7 m in advance of that location. Stop bar detection is required on minor streets. Assign stop bar detection to "call" channels and assign advance detection-to-detection input "extension" channels.

A dilemma occurs when a person is forced to make a decision between two alternatives. As applied to vehicle detection design, this situation occurs when two vehicles are approaching a traffic signal and the signal indications turn yellow. The motorist in the lead vehicle must decide whether to accelerate and risk being hit in the intersection by opposing traffic or decelerate and risk being hit by the following vehicle. Dilemma zone detection design has been developed to address this problem. This design allows the 90th percentile speed vehicle and the 10th percentile speed vehicle to either clear the intersection safely or decelerate to a complete stop before reaching the intersection. The method of calculating the dilemma zone and the required detection loops is shown in Figure 850-9.

A study of the approach speeds at the intersection is necessary to design the dilemma zone detection. Speed study data is obtained at the approximate location at or just upstream of the dilemma zone. Only the speed of the lead vehicle in each platoon is considered. Speed study data is gathered during off-peak hours in free-flow conditions under favorable weather conditions. Prior speed study information obtained at this location can be used if it is less than one and a half years old and driving conditions have not changed in the area.

When permissive left-turn phasing is installed on the major street with left-turn channelization, include provisions for switching the detector input for future protected left-turn phasing. Assign the detector a left-turn detector number and connect to the appropriate left-turn detector amplifier. Then specify a jumper connector between that amplifier output and the extension input channel for the adjacent through movement detector. The jumper is removed when the left-turn phasing is changed to protected in the future.

In most cases, electromagnetic induction loops provide the most reliable method of vehicle detection. Details of the construction of these loops are shown in the Standard Plans. Consider video detection systems for projects that involve extensive stage construction with numerous alignment changes. Video detection functions best when the detectors (cameras) are positioned high above the intersection. In this position, the effective detection area can be about ten times the mounting height in advance of the camera. When video detection is proposed, consider using Type III signal standards in all quadrants and install the cameras on the luminaire mast arms. High wind can adversely affect the video equipment by inducing vibration in the luminaire mast arms. Areas that experience frequent high winds are not always suitable for video detection.

(7) Preemption Systems

(a) **Emergency vehicle preemption.** Emergency vehicle preemption is provided if the emergency service agency has an operating preemption system. WSDOT is responsible for the preemption equipment that is permanently installed at the intersection for new construction or rebuild projects. The emergency service agency is responsible for preemption emitters in all cases. If the emergency agency requests additional preemption equipment at an existing signal, that agency is responsible for all installation costs for equipment installed permanently at the intersection. These same guidelines apply for a transit agency requesting transit preemption. The standard emergency vehicle system is optically activated to be compatible with all area emergency service agency emitters. Approval by the State Traffic Engineer is required for the installation of any other type of emergency vehicle preemption system.

Optically activated preemption detectors are positioned for each approach to the intersection. These detectors function best when the approach is straight and relatively level. When the approach is in a curve, either horizontal or vertical, it might be necessary to install additional detectors in or in advance of the curve to provide adequate coverage of that approach. Consider the approximate speed of the approaching emergency vehicle and the amount of time necessary for phase termination and the beginning of the preemption phase when positioning these detectors.

(b) **Railroad preemption.** An approaching train is detected either by electrical contacts under the railroad tracks or by motion sensors. The railroad company installs these devices. The region provides the electrical connections between the railroad signal enclosure (called a bungalow) and the preemption phasing in the traffic signal controller. A two-conductor cable is used for the electrical connection. The electrical circuit is connected to a closed “dry” contact using a normally energized relay. When a train is detected, the relay opens the circuit to the traffic signal controller. Contact the railroad to determine the voltage they require for this relay. This will determine the requirements for the isolator at the traffic signal controller. The railroad company’s signal equipment usually operates at 24 volt DC storage batteries charged by a 120 volt AC electrical system. Conduit crossings under railroad tracks are normally jacked or pushed because open excavation is rarely allowed. The usual depth for these crossings is 1.2 m below the tracks but railroad company requirements can vary. Contact the company for their requirements. They, also, will need the average vehicle queue clearance time values in order to finalize the preemption agreement. These values are shown on Figure 850-10.

Flashing railroad signals are usually necessary when railroad preemption is installed at a signalized intersection. Automatic railroad gates are also necessary when train crossings are frequent and the exposure factor is high. Chapter 930 provides guidance on determining the railroad crossing exposure factor. Advance signals, signal supports with displays, are also only installed at locations with high exposure factors. See Figures 850-11a and 850-11b. When the nearest rail at a crossing is within 27 m of an intersection stop bar on any approach, provide additional traffic signal displays in advance of the railroad crossing. The 27-meter distance provides storage for the longest vehicle permitted by statute (23.0 m plus 1.0 m front overhang and 1.2 m rear overhang) plus a 1.8 m down stream clear storage distance.

Light rail transit crossings at signalized intersections also use a form of railroad preemption. Light rail transit makes numerous stops along its route, sometimes adjacent to a signalized intersection. Because of this, conventional railroad preemption detection, which uses constant speed as a factor, is not effective. Light rail transit uses a type of preemption similar to that used for emergency vehicle preemption.

(c) **Transit priority preemption.** Signal preemption is sometimes provided at intersections to give priority to transit vehicles. The most common form of preemption is the optically activated type normally used for emergency preemption. This can be included in mobility projects, but the transit company assumes all costs in providing, installing, and maintaining this preemption equipment. The department's role is limited to approving preemption phasing strategies and verifying the compatibility of the transit company's equipment with the traffic signal control equipment.

(8) Signal Displays

Signal displays are the devices used to convey right of way assignments and warnings from the control mechanism to the motorists and pedestrians. When selecting display configurations and locations, the most important objective is the need to present these assignments and warnings to the motorists and pedestrians in a clear and concise manner. Typical vehicle signal displays are shown in Figures 850-12a through 850-12e. In addition to the display requirements contained in the MUTCD, the following also apply:

- Always provide two identical indications for the through (primary) or predominate movement, spaced a minimum of 2.4 m apart when viewed from the center of the approach. At a tee intersection, select the higher volume movement as the primary movement and provide displays accordingly. A green left-turn arrow on a primary display and a green ball on the other primary display do not comply with this rule.
- Use arrow indications only when the associated movement is completely protected from conflict with other vehicular and pedestrian movements. This includes conflict with a permissive left-turn movement.
- Locate displays overhead whenever possible and in line with the path of the applicable vehicular traffic.
- Locate displays a minimum of 12.2 m (18.3 m desirable) ands a maximum of 45.7 m from the stop line.
- Consider installation of a near-side display when the visibility requirements of Table 4-1 of the MUTCD cannot be met.
- Use vertical vehicle-signal display configurations. Horizontal displays are not allowed unless clearance requirements cannot be achieved with vertical displays. Approval by the State Traffic Engineer is required for the installation of horizontal displays.
- Use 300-mm signal sections for all vehicle displays except the lower display for a post-mount ramp-meter signal.
- Use all arrow displays for protected left turns when the left turn operates independently from the adjacent through movement.
- When green and yellow arrows are used in combination with circular red for protected left turns operating independently from the adjacent through movement, use visibility-limiting displays (either optically programmed sections or louvered visors). Contact the local maintenance superintendent, signal operations office, or traffic engineer to ensure correct programming of the head.
- Use either a five section cluster arrangement (dog house) or a five section vertical arrangement.
- Use either Type M or Type N mountings for vehicle display mountings on mast arms. Provide only one type of mounting for each signal system. Mixing mounting types at an intersection is not acceptable except for supplemental displays mounted on the signal standard shaft.
- Use backplates for all overhead mounted displays.
- Use Type E mountings for pedestrian displays mounted on signal standard shafts.
- Consider installing supplemental signal displays when the approach is in a horizontal or vertical curve and the intersection visibility requirements cannot be met.

The minimum mounting heights for cantilevered mast arm signal supports and span wire installations is 5.0 m from the roadway surface to the bottom of the signal housing or back plate. There is also a maximum height for signal displays. The roof of a vehicle can obstruct the motorist's view of a signal display. The maximum heights from the roadway surface to the bottom of the signal housing with 300-mm sections are shown in Figure 850-1.

Distance	Signal Display	Maximum Height
Signal displays 12.2 m from the stop bar	Vertical 3 section	5.3 m
	Vertical 4 section	5.1 m
	Vertical 5 section*	5.0 m
Signal displays 13.7 m from the stop bar	Vertical 3 section	5.8 m
	Vertical 4 section	5.5 m
	Vertical 5 section*	5.1 m
Signal displays 15.2 m from the stop bar	Vertical 3 section	6.4 m
	Vertical 4 section	6.0 m
	Vertical 5 section*	5.6 m
Signal displays 16.2 to 45.7 m from the stop bar	Vertical 3 section	6.6 m
	Vertical 4 section	6.3 m
	Vertical 5 section*	6.0 m

* Note: The 5 section cluster display is the same height as a vertical 3-section signal display.

Signal Display Maximum Heights
Figure 850-1

Install an advanced signalized intersection warning sign assembly to warn motorists of a signalized intersection when either of the two following conditions exists:

- The visibility requirements in Table 4-1 of the MUTCD are not achievable.
- The 85th percentile speed is 55 mph or higher and the nearest signalized intersection is more than three kilometers away.

This warning sign assembly consists of a W3-3 sign, two continuously flashing beacons, and sign illumination. Locate the sign in advance of the intersection in accordance with Table II-1 (Condition A) of the MUTCD.

(9) Signal Supports

Signal supports for vehicle displays consist of metal vertical shaft standards (Type I), cantilevered mast arm standards (Type II, Type III, and Type SD Signal Standards), metal strain poles (Type IV and Type V Signal Standards), or timber strain poles. See the Standard Plans. Mast arm installations are preferred because they provide greater stability for signal displays in high wind areas and reduce maintenance costs. Preapproved mast arm signal standard designs are available with arm lengths up to 19.8 m. Use mast arm standards for permanent installations unless display requirements cannot be met. Metal strain poles are allowed when signal display requirements cannot be achieved with mast arm standards or the installation is expected to be in place less than 5 years. Timber strain pole supports are generally used for temporary installations that will be in place less than 2 years.

Pedestrian displays can be mounted on the shafts of vehicle display supports or on individual vertical shaft standards (Type PS). The push buttons used for the pedestrian detection system can also be mounted on the shafts of other display supports or on individual pedestrian push button posts. Do not place the signal standard at a location that blocks pedestrian or wheelchair activities. Locate the pedestrian push buttons so they are ADA accessible to pedestrians and persons in wheelchairs.

Terminal cabinets mounted on the shafts of mast arm standards and steel strain poles are recommended. The cabinet provides electrical conductor termination points between the controller cabinet and signal displays that allows for easier construction and maintenance. Terminal cabinets are usually located on the back side of the pole to reduce conflicts with pedestrians and bicyclists.

In the placement of signal standards, the primary consideration is the visibility of signal faces. Place the signal supports as far as practicable from the edge of the traveled way without adversely affecting signal visibility. The MUTCD provides additional guidance for locating signal supports. Initially, lay out the location for supports for vehicle display systems, pedestrian detection systems, and pedestrian display systems independently to determine the optimal location for each type of support. If conditions allow and optimal locations are not compromised, pedestrian displays and pedestrian detectors can be installed on the vehicular display supports.

Another important consideration that can influence the position of signal standards is the presence of overhead and underground utilities. Verify the location of these lines during the preliminary design stage to avoid costly changes during construction.

Mast arm signal standards are designed based on the total wind load moment on the mast arm. The moment is a function of the XYZ value and this value is used to select the appropriate mast arm fabrication plan. The preapproved mast arm fabrication plans are listed in the special provisions. To determine the XYZ value for a signal standard, the cross sectional area for each component mounted on the mast arm is determined. Each of these values is then multiplied by its distance from the vertical shaft. These values are then totaled to determine the XYZ value. All signal displays and mast arm mounted signs, including street name signs, are included in this calculation. The effect of emergency preemption detectors and any required preemption indicator lights are negligible and are not included. For mast arm mounted signs, use the actual sign area to determine the XYZ value. An example of this calculation is shown in Figure 850-13. Cross sectional areas for vehicle displays are shown in Figure 850-2.

Signal Display	Area
Vertical 3 section	0.85 m^2
Vertical 4 section	1.02 m^2
Vertical 5 section	1.22 m^2
5 section cluster	1.34 m^2

Signal Display Areas
Figure 850-2

Foundation design is a critical component of the signal support. A soils investigation is required to determine the lateral bearing pressure and the friction angle of the soil and whether ground water might be encountered. The XYZ value is used in determining the foundation depth for the signal standard. Select the appropriate foundation depth from Figure 850-13. A special foundation design for a mast arm signal standard is required if the lateral bearing pressure is less than 48 MPa or the friction angle is less than 26 degrees. The regional materials group determines if these unusual soil conditions are present and a special foundation design is required. They then send this information to the OSC Materials Office for confirmation. That office forwards the findings to the OSC Bridge and Structures Office and requests the special foundation design. The Bridge and Structures Office designs foundations for the regions and reviews designs submitted by private engineering groups performing work for the regions.

Steel strain poles are used in span wire installations and are available in a range of pole classes. A pole class denotes the strength of the pole. The loads and resultant forces imposed on strain poles are calculated and a pole class greater than that load is specified. Figures 850-14a and 850-14b show the procedure for determining the metal strain pole class and foundation. Figure 850-15 shows an example of the method of calculation. The foundation depth is a product of the pole class and the soil bearing pressure. A special design is required for metal strain pole or timber strain pole support systems if the span exceeds 45 m, the tension on the span exceeds 31680 N, or the span wire attachment point exceeds 8.8 m in height. Contact the OSC Bridge and Structures Office for assistance.

(10) Preliminary Signal Plan

Develop a preliminary signal plan for the project file. Include with the preliminary signal plan a discussion of the problem that is being addressed by the project. Provide sufficient level of detail on the preliminary signal plan to describe all aspects of the signal installation, including proposed channelization modifications. Use a plan scale of 1:200 and include the following information:

- Stop bars
- Crosswalks
- Left-turn radii, including beginning and ending points
- Corner radii, including beginning and ending points
- Vehicle detector locations

- Pedestrian detector locations
- Signal standard types and locations
- Vehicle signal displays
- Pedestrian signal displays
- Phase diagram including pedestrian movements
- Emergency vehicle preemption requirements
- Illumination treatment

Submit a copy of the preliminary signal plan to the State Traffic Engineer for review and comment. When the proposed traffic signal is on an NHS highway, also submit a copy of the preliminary signal plan to the Assistant State Design Engineer for review and concurrence. After addressing review comments, finalize the plan and preserve as noted in the documentation section of this chapter. Prepare the contract plans in accordance with the *Plans Preparation Manual*.

If OSC is preparing the contract plans, specifications, and estimates for the project, submit the above preliminary signal plan with the following additional items:

- Contact person.
- Charge numbers.
- Critical project schedule dates.
- Existing utilities, both underground and overhead.
- Existing intersection layout, if different from the proposed intersection.
- Turning movement traffic counts; peak hour for isolated intersections; and AM, Midday, and PM peak hour counts if there is another intersection within 150 m.
- Speed study indicating 90th and 10th percentile speeds for all approaches.
- Electrical service location, source of power, and utility company connection requirements.

After the plans, specifications, and estimate are prepared, the entire package is transmitted to the region for incorporation into their contract documents.

(11) Electrical Design

(a) **Circuitry Layout.** Consider cost, flexibility, construction requirements, and ease of maintenance when laying out the electrical circuits for the traffic signal system. Minimize roadway crossings whenever possible.

(b) **Junction Boxes.** Provide junction boxes at each end of a roadway crossing, where the conduit changes size, where detection circuit splices are required, and at locations where the sum of the bends for the conduit run equals or exceeds 360°. Signal standard or strain pole bases are not used as junction boxes. In general, locate junction boxes out of paved areas and sidewalks. Placing the junction boxes within the traveled way is rarely an effective solution and will present long-term maintenance problems. If there is no way to avoid locating the junction box in the traveled way, use traffic-bearing boxes. Avoid placing junction boxes in areas of poor drainage. In areas where vandalism can be a problem, consider junction boxes with locking lids. The maximum conduit capacities for various types of junction boxes are shown in the Standard Plans.

(c) **Conduit.** Use galvanized steel conduit for all underground raceways for the traffic signal installation on state highways. Thick-walled polyvinyl chloride (Schedule 80 PVC) conduit is used by many local agencies for ease of installation. At existing intersections, where roadway reconstruction is not proposed, place these conduits beyond the paved shoulder or behind existing sidewalks to reduce installation costs. With the exception of the 16 mm conduit for the service grounding electrode conductor, the minimum size conduit is 27 mm. The minimum size conduit for installations under a roadway is 35 mm. Size all conduits to provide 26% maximum conductor fill for new signal installations. A 40% fill area can be used when installing conductors in existing conduits. See Figure 850-16 for conduit and signal conductor sizes.

(d) **Electrical Service and other components.** Electrical service types, overcurrent protection, and other components are covered in Chapter 840.

850.07 Documentation

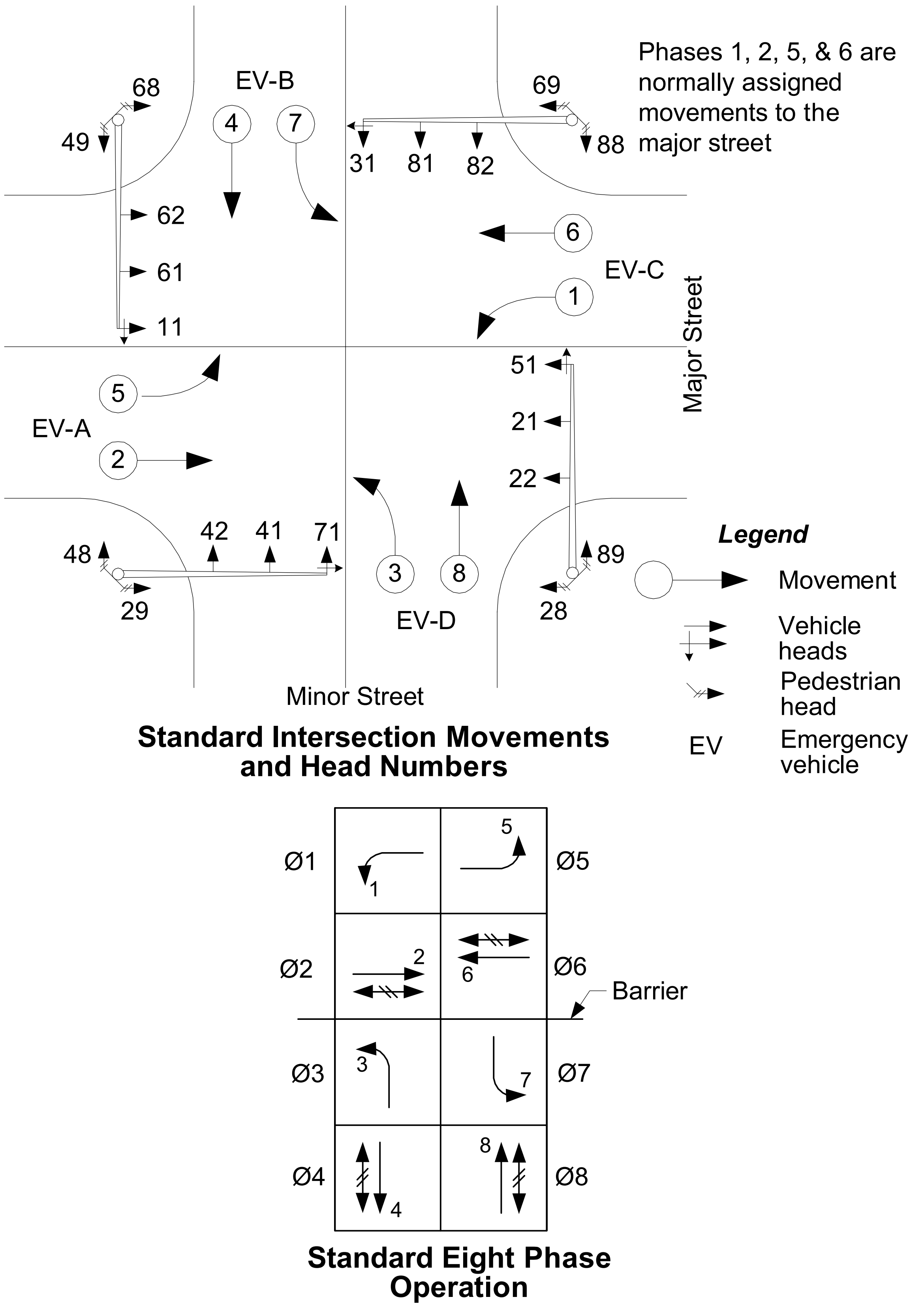
Preserve the following documents in the project file. See Chapter 330.

- ☐ All traffic study information used in the signal analysis.
- ☐ A copy of the approved traffic signal permit.
- ☐ A copy of the preliminary signal plan.
- ☐ Alternative analysis for traffic signals on high speed highways
- ☐ Explanation for using normally uncorrectable accidents to justify a traffic signal
- ☐ Explanation of why the desired level of service cannot be obtained

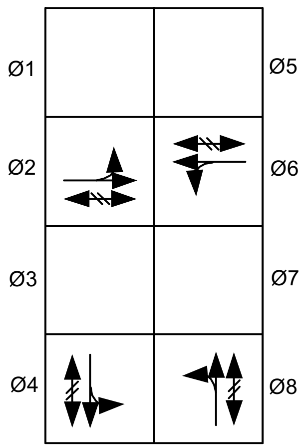
Responsibility for Various Types of Facilities on State Highways				
Area	Responsibility	Emergency vehicle signals	Traffic signals, school signals, & intersection control beacons	Reversible lane signals & moveable bridge signals
Cities with less than 22,500 population	Finance	ESD (1)	State	State
	Construct	ESD (1)	State	State
	Maintain	ESD (1)	State	State
	Operate	ESD (1)	State	State
Cities with 22,500 or greater population	Finance	ESD (1)	City (2)	City (2)
	Construct	ESD (1)	City (2)	City (2)
	Maintain	ESD (1)	City (2)	City (2)
	Operate	ESD (1)	City (2)	City (2)
Beyond corporate limits	Finance	ESD (1)	State Country (3)	State
	Construct	ESD (1)	State	State
	Maintain	ESD (1)	State	State
	Operate	ESD (1)	State	State
Access control	Finance	ESD (1)	State	State
	Construct	ESD (1)	State	State
	Maintain	ESD (1)	State	State
	Operate	ESD (1)	State	State

Notes:
(1) ESD refers to the applicable Emergency Service Department.
(2) State highways without established limited access control. See 850.04(2)b.
(3) See 850.04(2)d.

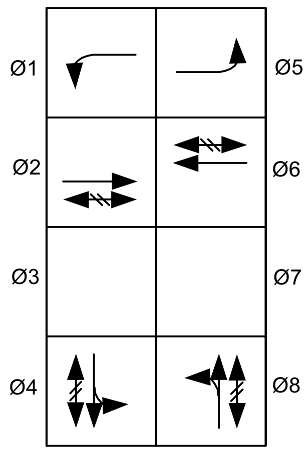
Responsibility for Facilities
Figure 850-3



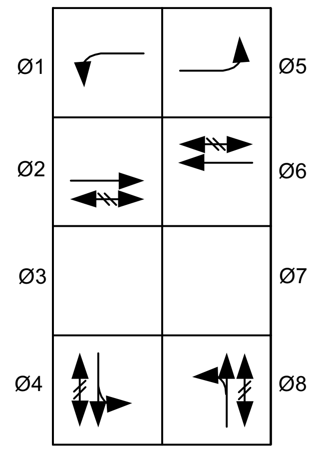
Standard Intersection Movements and Head Numbers
Figure 850-4



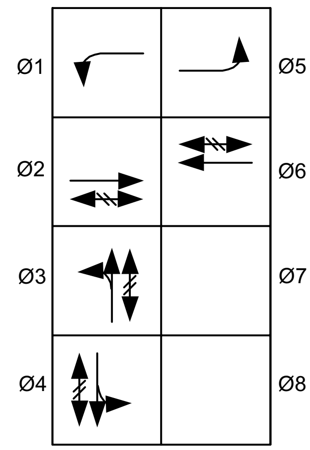
Two Phase Operation
Permissive lefts



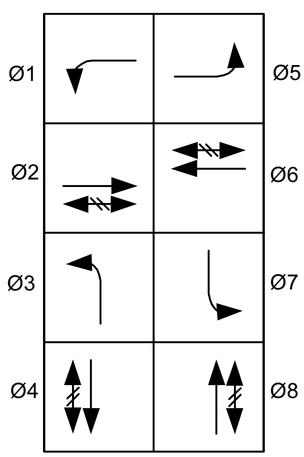
Five Phase Operation
Main St. protected lefts
Minor St. permissive lefts



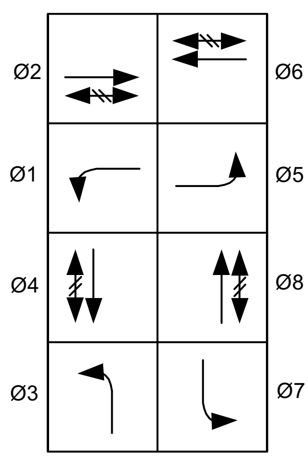
Six Phase Operation
Main St. protected leading lefts
Minor St. split phasing
(Ø4 first, then Ø8)



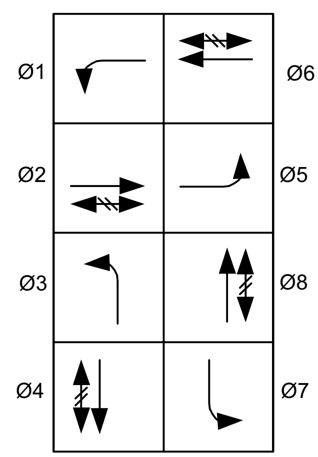
Six Phase Operation
Alternate phasing
Main St. protected leading lefts
Minor St. split phasing



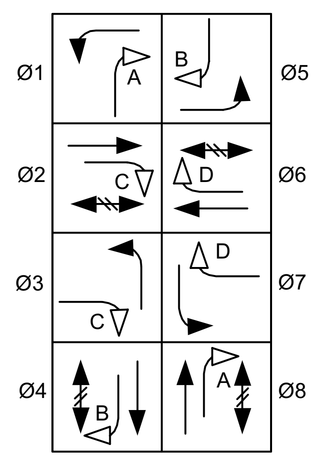
Eight Phase Operation
Main St. protected leading lefts
Minor St. protected leading lefts



Eight Phase Operation
Main St. protected lagging lefts
Minor St. protected lagging lefts

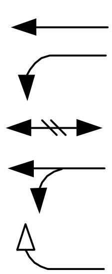


Eight Phase Operation
Main St. protected lead & lag lefts
Minor St. protected lead & lag lefts



Eight Phase Operation
Protected leading lefts
and overlapped rights

Legend



Vehicular through movement

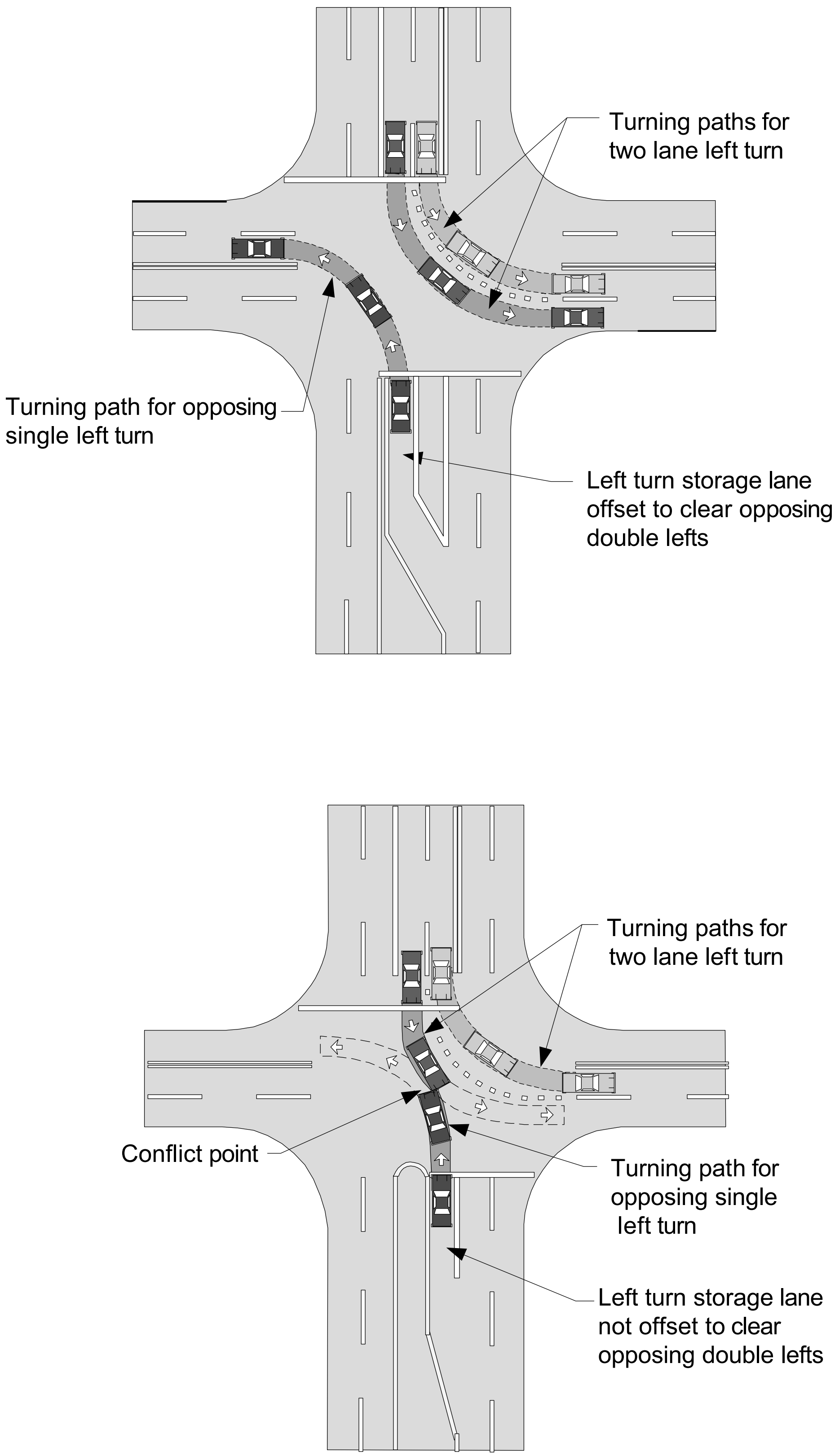
Vehicular left turn movement

Pedestrian movement

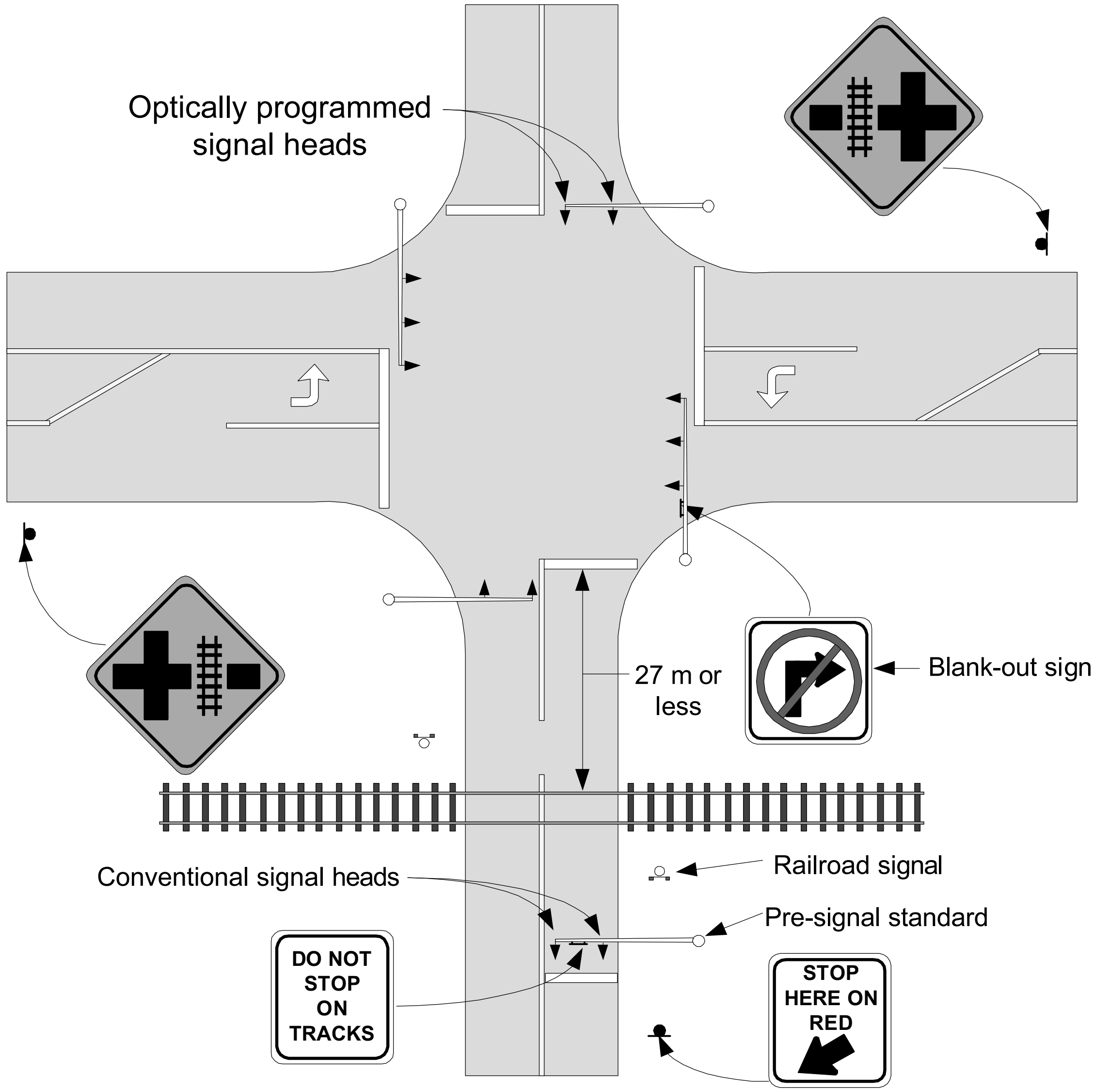
Vehicular through and left turn movement

Vehicular overlapped right turn movement

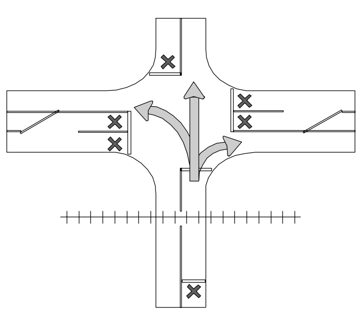
Phase Diagrams — Four Way Intersections
Figure 850-5



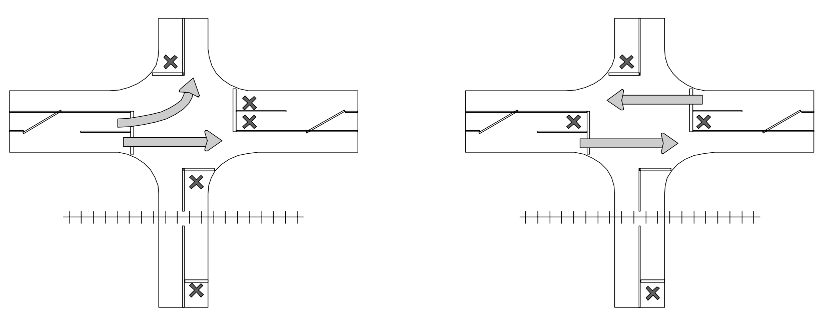
Turn Lane Configuration Preventing Concurrent Phasing
Double Left Turn Channelization
Figure 850-6



Typical Signal Installation Adjacent to Railroad

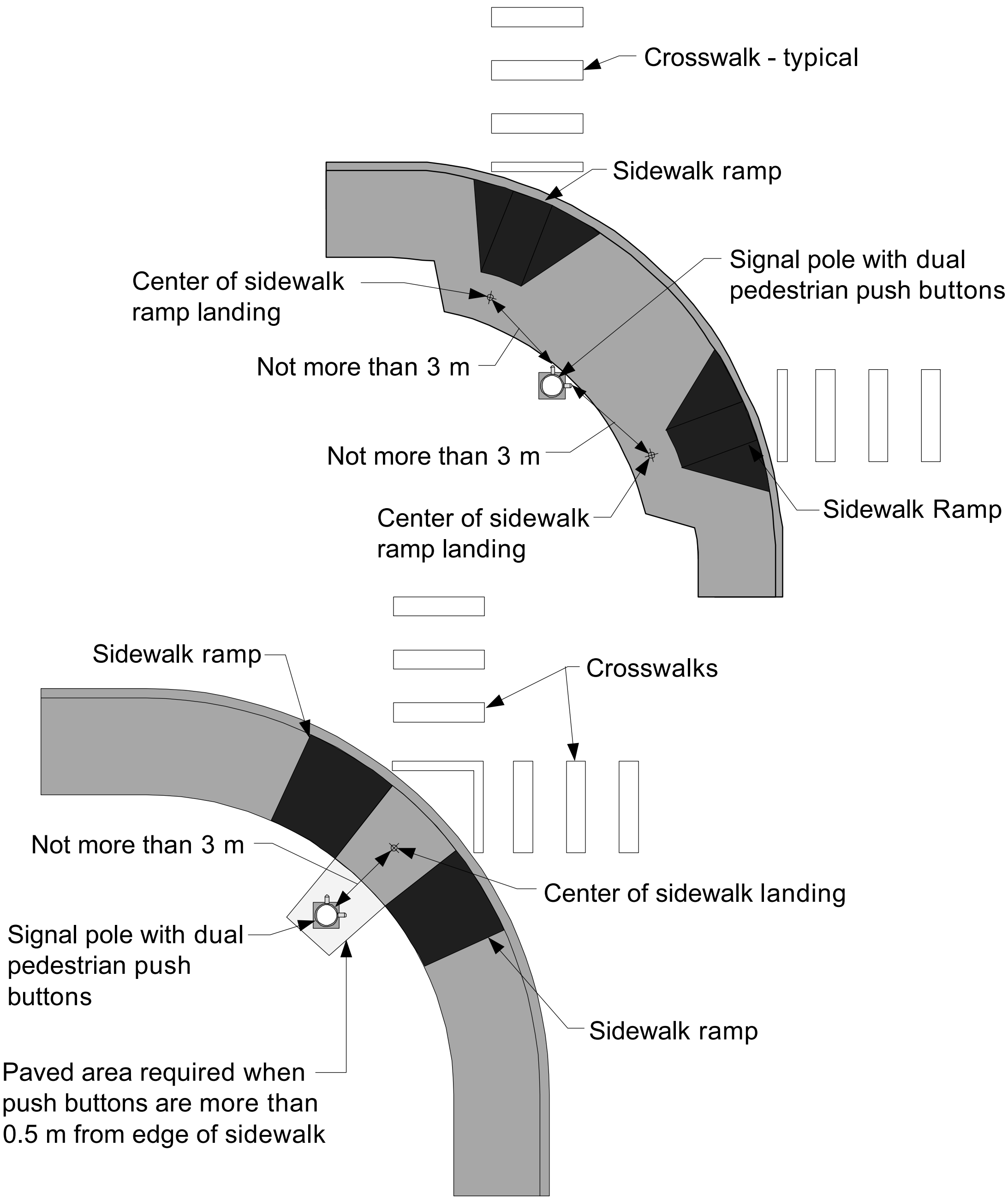


Clearance Phase before Train Arrival

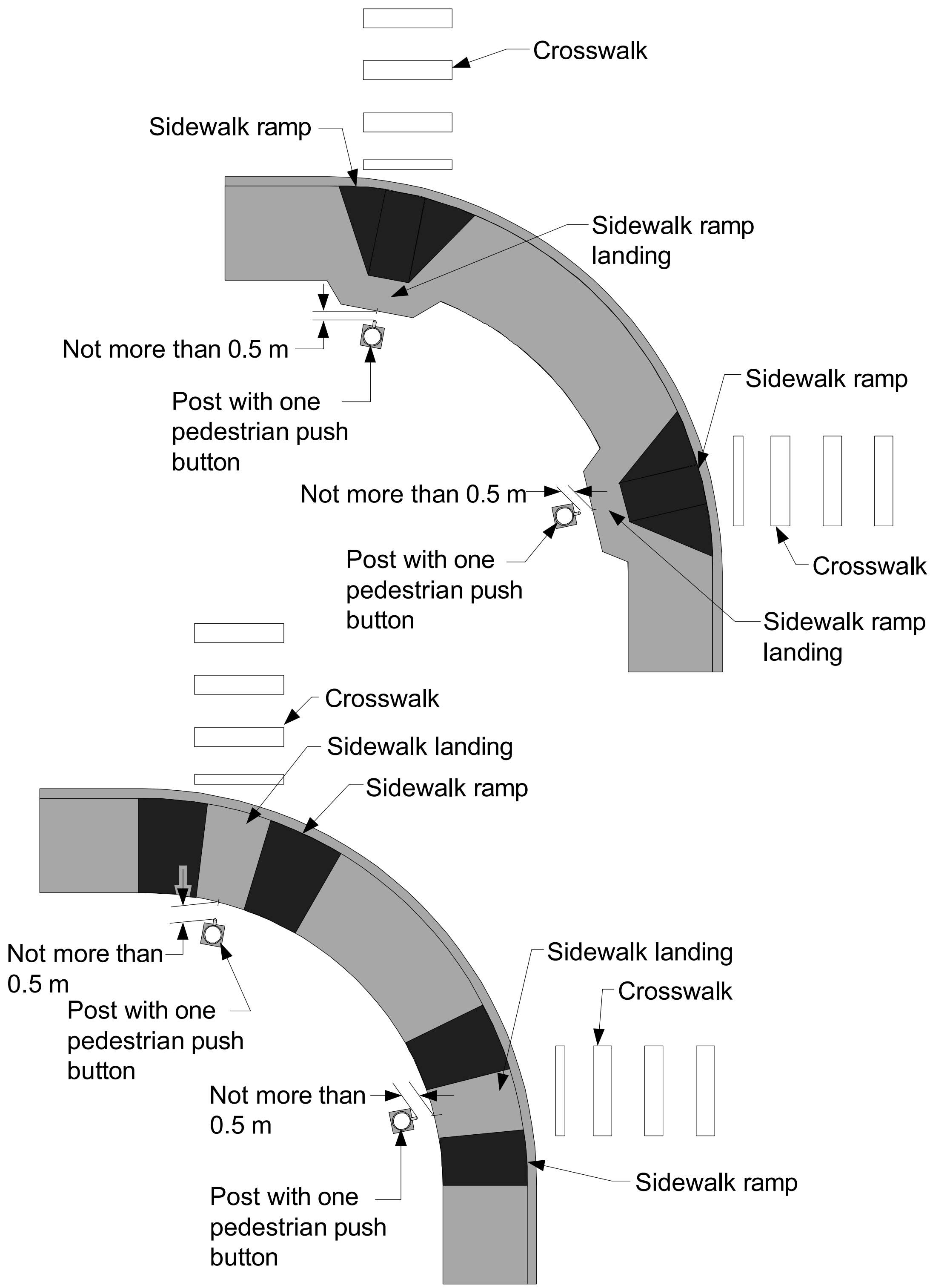


Phase Sequence During Train Crossing

Railroad Preemption Phasing
Figure 850-7



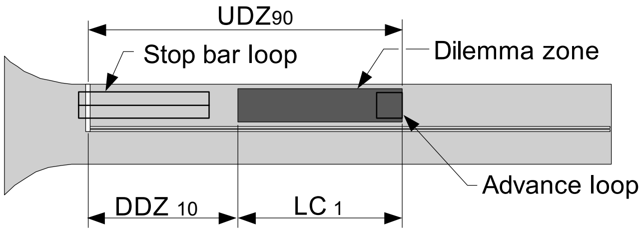
Pedestrian Push Button Locations
Figure 850-8a



Pedestrian Push Button Locations
Figure 850-8b

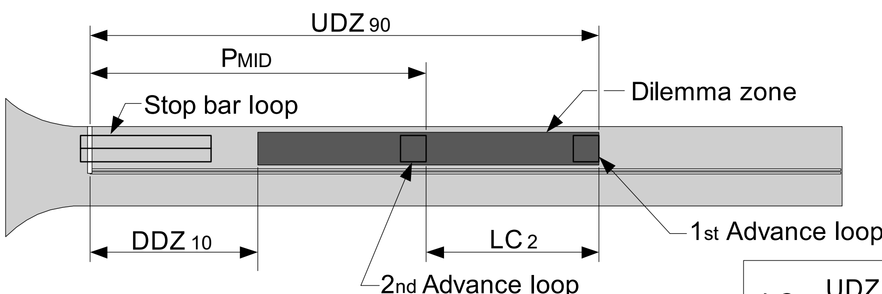
Where : V_{90} = 90th pecentile speed in meters per second
V_{10} = 10th percentile speed in meters per second
UDZ_{90} = Upstream end of dilemma zone for 90th percentile speed
DDZ_{10} = Downstream end of dilemma zone for 10th percentile speed

LC_1 = V_{10} travel time to downstream DDZ_{10}
LC_2 = V_{10} travel time from 1st loop to 2nd loop
LC_3 = V_{10} travel time from 3rd loop to DDZ_{10}



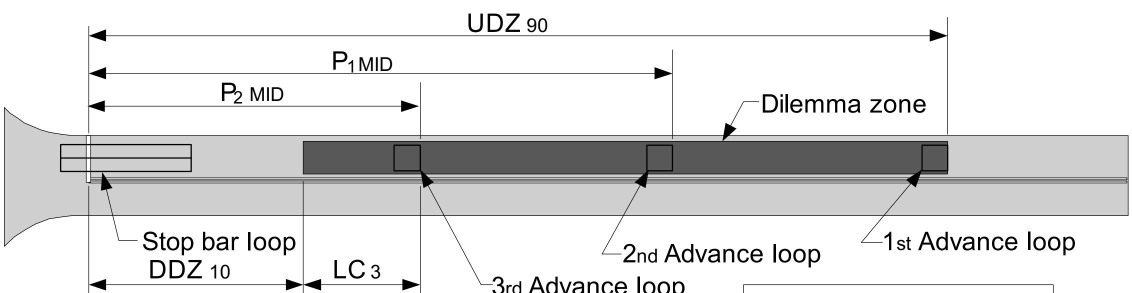
$$UDZ_{90} = \frac{V_{90}^2}{16} + V_{90}$$
$$DDZ_{10} = \frac{V_{10}^2}{40} + V_{10}$$
$$LC_1 = \frac{UDZ_{90} - DDZ_{10}}{V_{10}}$$

Single Advance Loop Design
When LC_1 is equal to or less than 3 seconds



$$LC_2 = \frac{UDZ_{90} - P_{MID}}{V_{10}}$$
$$P_{MID} = \frac{UDZ_{90} + DDZ_{10}}{2}$$

Double Advance Loop Design
When LC_2 is equal to or less than 3 seconds



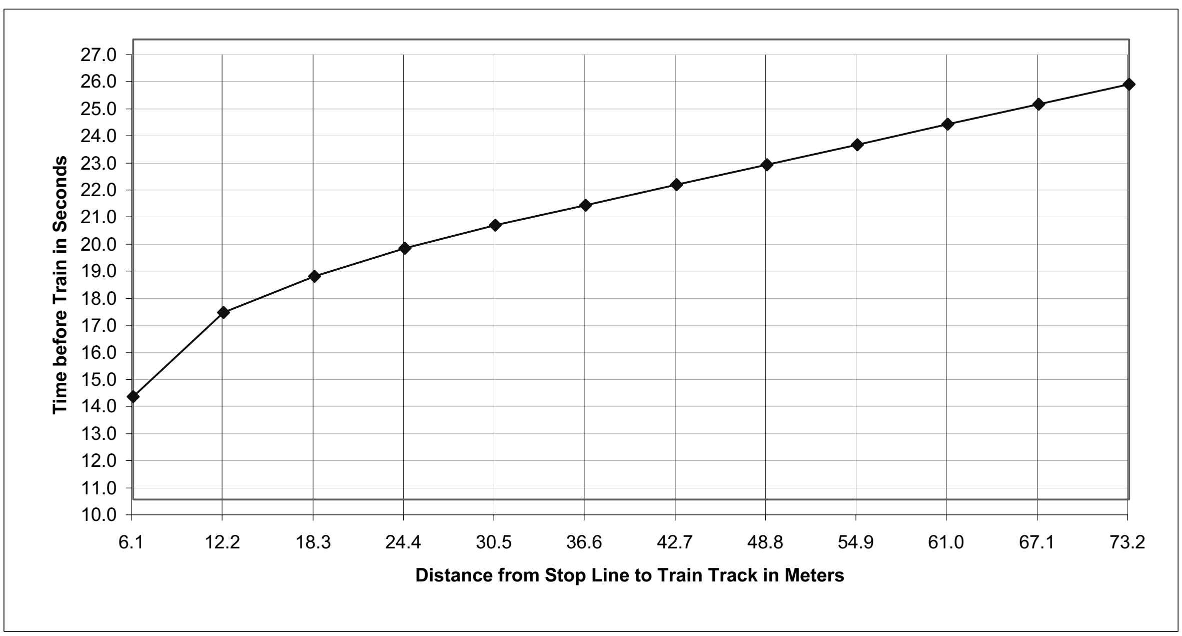
$$LC_3 = \frac{P_{2MID} - DDZ_{10}}{V_{10}}$$
$$P_{1MID} = UDZ_{90} - 3V_{10}$$
$$P_{2MID} = UDZ_{90} - 6V_{10}$$

Triple Advance Loop Design
When LC_2 is greater than 3 seconds

Dilemma Zone Loop Placement
Figure 850-9

Traffic Signal Railroad Track Clearance Interval Table (Single Track)							
Queue	Start-Up Time	Queue Length	Intersection Clearance	Start-Up Time	Queue Clear Time	Time from PE start to Q	Time Before Train
Vehicles	Seconds	Meters	Seconds	Seconds	Seconds	Seconds	Seconds
A	B	C	D	E	F	G	H
1	3.8	6.1	10	3.8	3.8	13.8	13.8
2	3.1	12.2	10	3.1	6.9	16.9	16.9
3	2.7	18.3	10	2.7	9.6	19.6	18.2
4	2.4	24.4	10	2.4	12.0	22.0	19.3
5	2.2	30.5	10	2.2	14.2	24.2	20.1
6	2.1	36.6	10	2.1	16.3	26.3	20.9
7	2.1	42.7	10	2.1	18.4	28.4	21.6
8	2.1	48.8	10	2.1	20.5	30.5	22.4
9	2.1	54.9	10	2.1	22.6	32.6	23.1
10	2.1	61.0	10	2.1	24.7	34.7	23.9
11	2.1	67.1	10	2.1	26.8	36.8	24.6
12	2.1	73.2	10	2.1	28.9	38.9	25.4

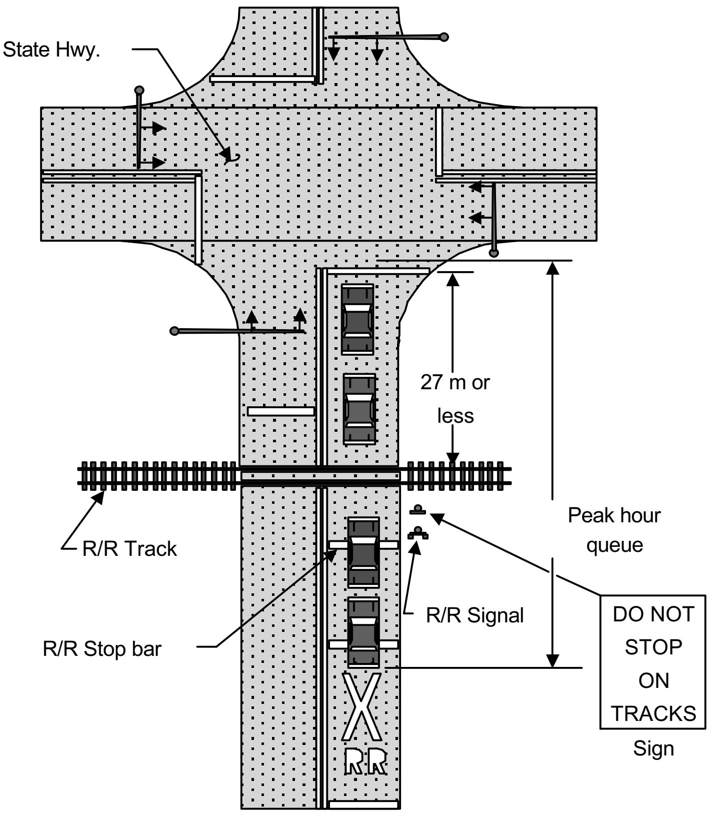
A = Number of Vehicles in the queue.
B = Vehicle startup time.
C = Distance from intersection stop bar to R/R gate or R/R stop bar. For single track, stop bar is 6.1 m upstream from the nearest rail.
D = Worst Case intersection clearance (5 seconds mainline green/flashing "don't walk" + 5 seconds yellow/all red = 10 seconds).
E = Startup time for each vehicle by position in queue.
F = Cumulative startup time, includes the track approach green time (7 seconds minimum).
G = Total time from railroad relay closure until last car in the queue has cleared the intersection stop bar. G = D + F
H = Total time from railroad relay closure until last car in the queue is 6.1 m beyond nearest rail. This assumes a departure speed of 10 mph. H = G ((C-12.2m) ÷ (14.7)



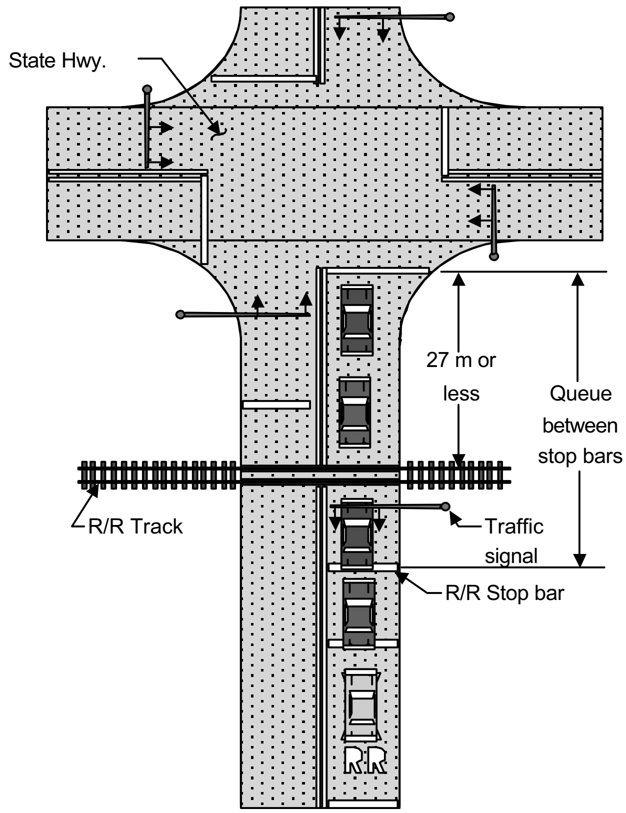
Example: A location where it is 18.3m from stop bar to nearest rail of a single track crossing.
Solution: Enter table at queue length of 24.4m (18.3m + 6.1m to RR stop bar). Read 19.3 seconds.

Railroad Queue Clearance

Figure 850-10

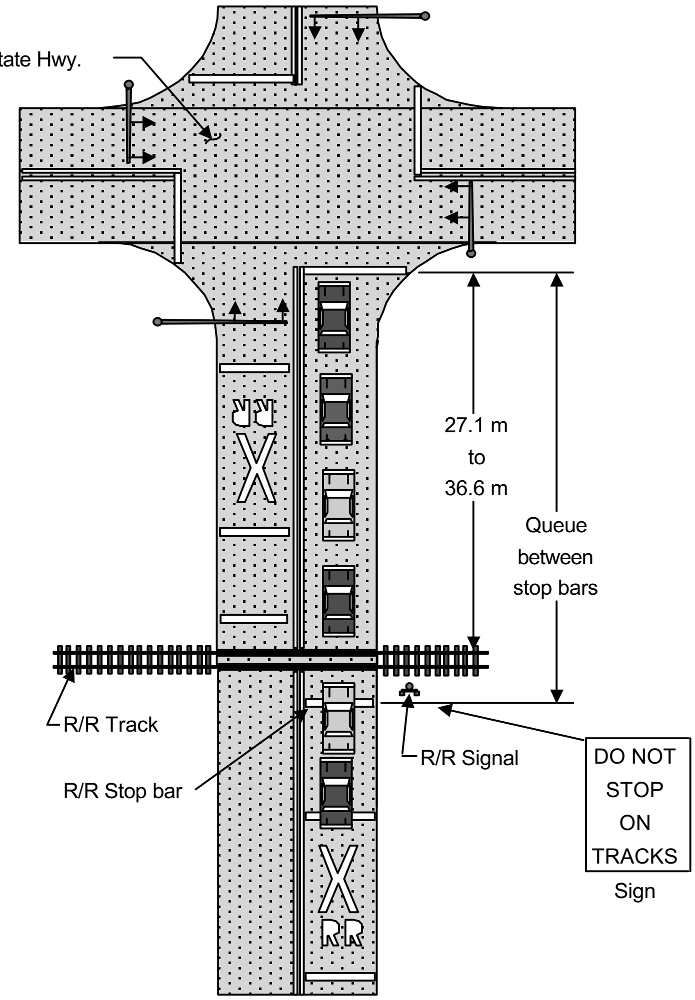


Railroad Crossing with Low Exposure Factor
(See Chapter 930 for R/R crossing protection guidelines)



Railroad Crossing with High Exposure Factor
(See Chapter 930 for R/R crossing protection guidelines)

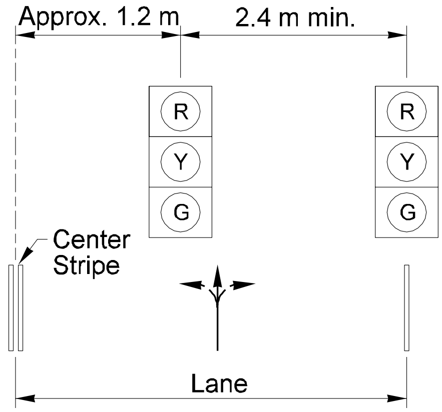
Intersections With Railroad Crossings
Figure 850-11a



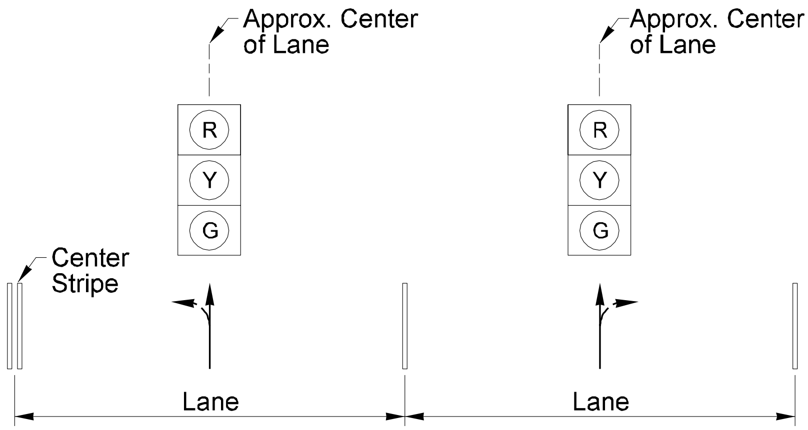
Railroad Crossing more than 88 Ft from Intersection

Intersections With Railroad Crossings

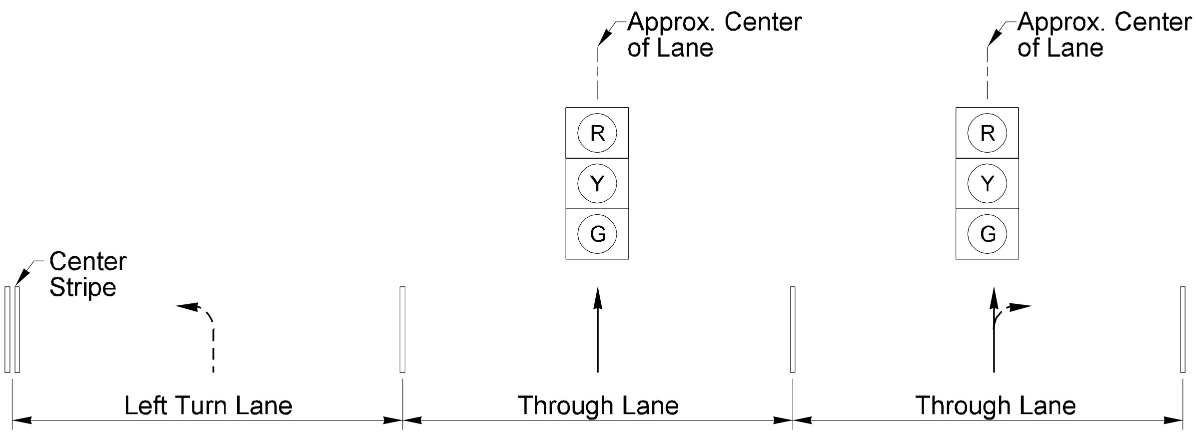
Figure 850-11b



One Through Lane
With Permissive Left Turn

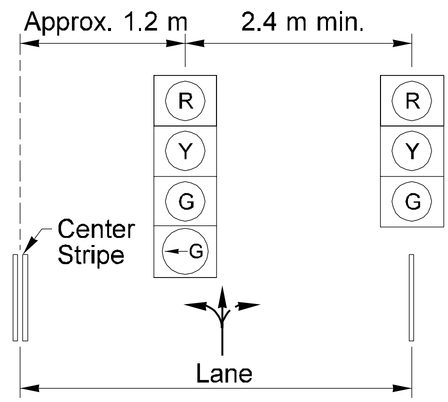


Two Through Lanes
With Permissive Left Turn

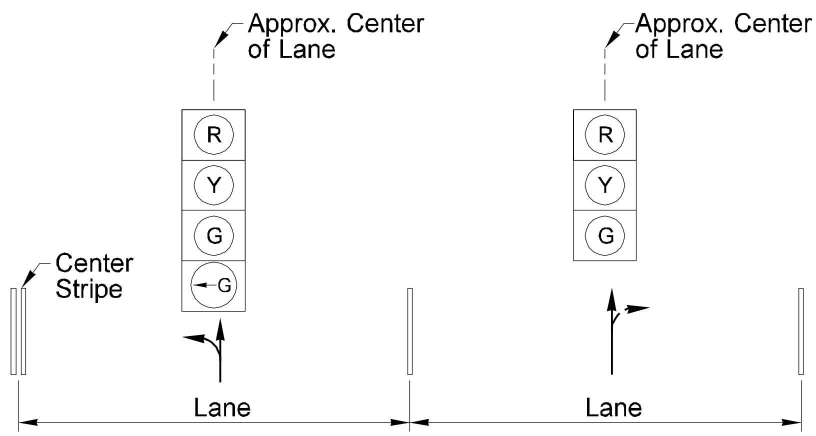


Two Through Lanes and One Left Turn Storage Lane
With Permissive Left Turn

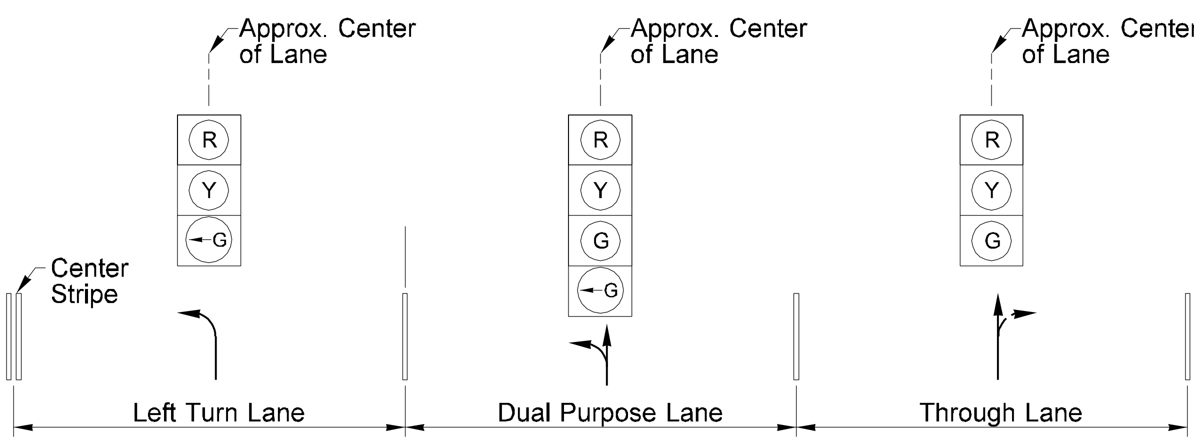
Traffic Signal Display Placements
Figure 850-12a



One Through Lane
With Protected Left Turn Phasing

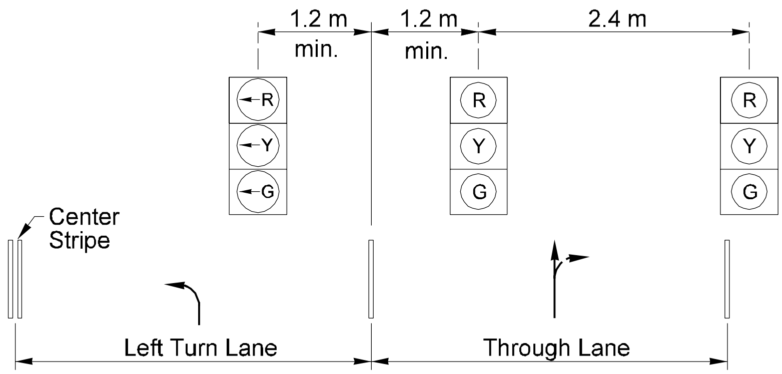


Two Through Lanes
With Split Phasing for Protected Left Turns
(Left turn and through movements terminate together.)



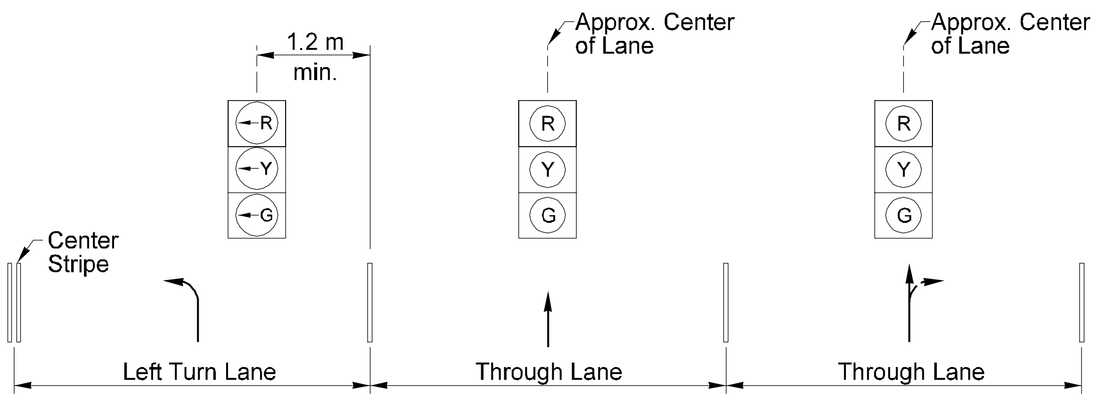
One Through Lane, a Dual Purpose (Left or Through) Lane
and One Left Turn Storage Lane With Split Phasing for Protected Left Turns
(Left turn and through movements terminate together.)

Traffic Signal Display Placements
Figure 850-12b



One Through Lane and One Left Turn Storage Lane
With Protected Left Turn Phasing

(Left turn and through movements terminate independently.)

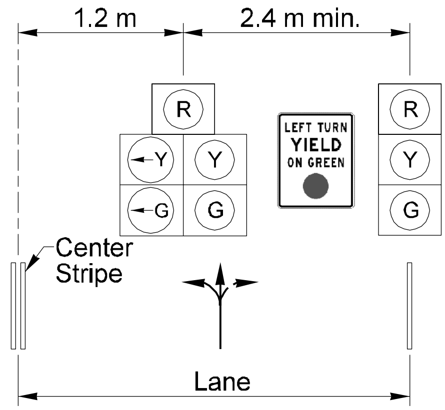


Two Through Lanes and One Left Turn Storage Lane
With Protected Left Turn Phasing

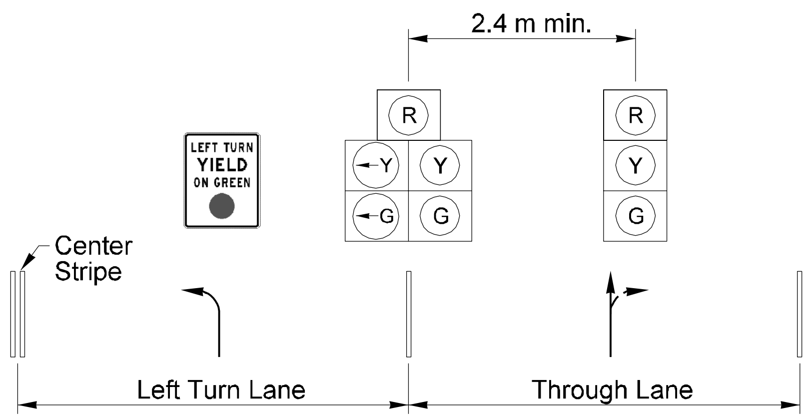
(Left turn and through movements terminate independently.)

Traffic Signal Display Placements

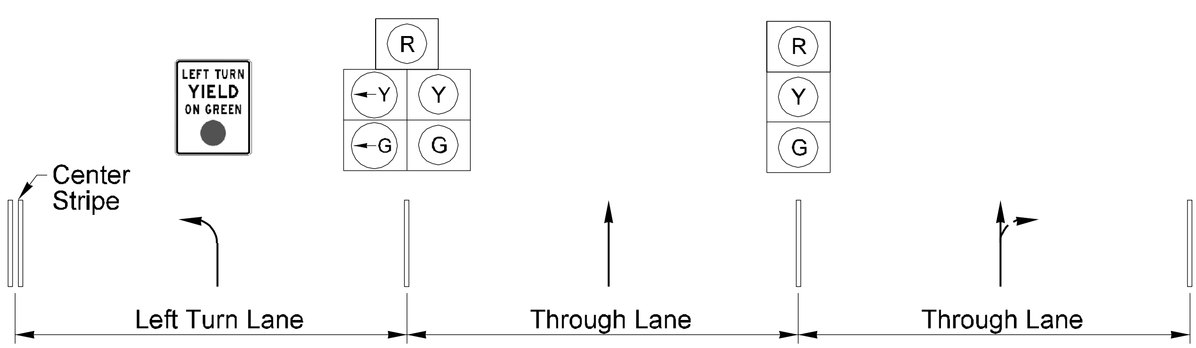
Figure 850-12c



One Through Lane
With Protected / Permissive Left Turn Phasing



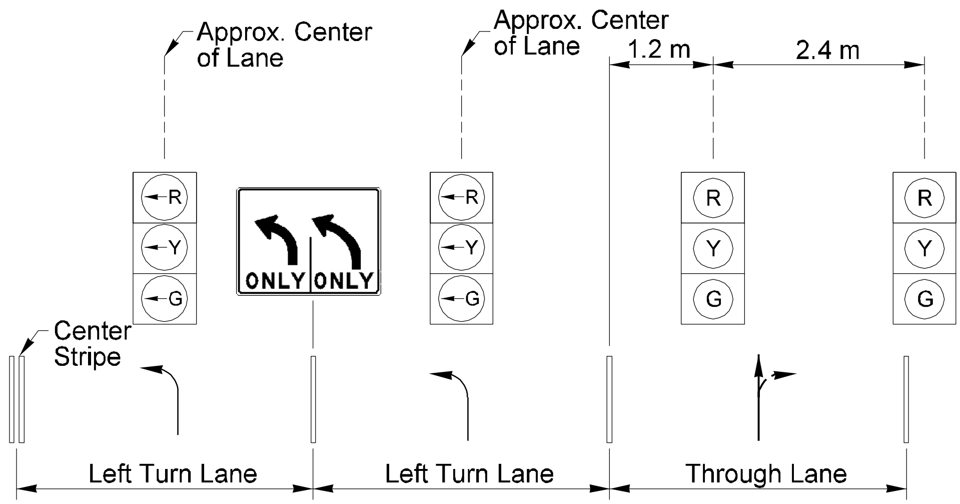
One Through Lane and One Left Turn Storage Lane
With Protected / Permissive Left Turn Phasing



Two Through Lanes and One Left Turn Storage Lane
With Protected / Permissive Left Turn Phasing

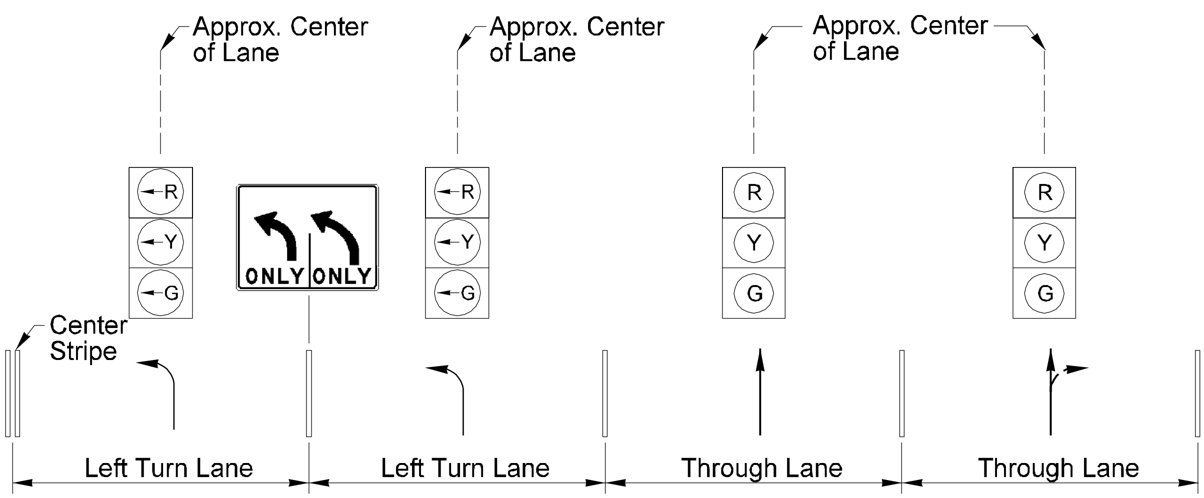
Traffic Signal Display Placements

Figure 850-12d



One Through Lane and Two Left Turn Storage Lanes With Protected Left Turn Phasing

(Left Turn and Through Movements Terminate Independently.)

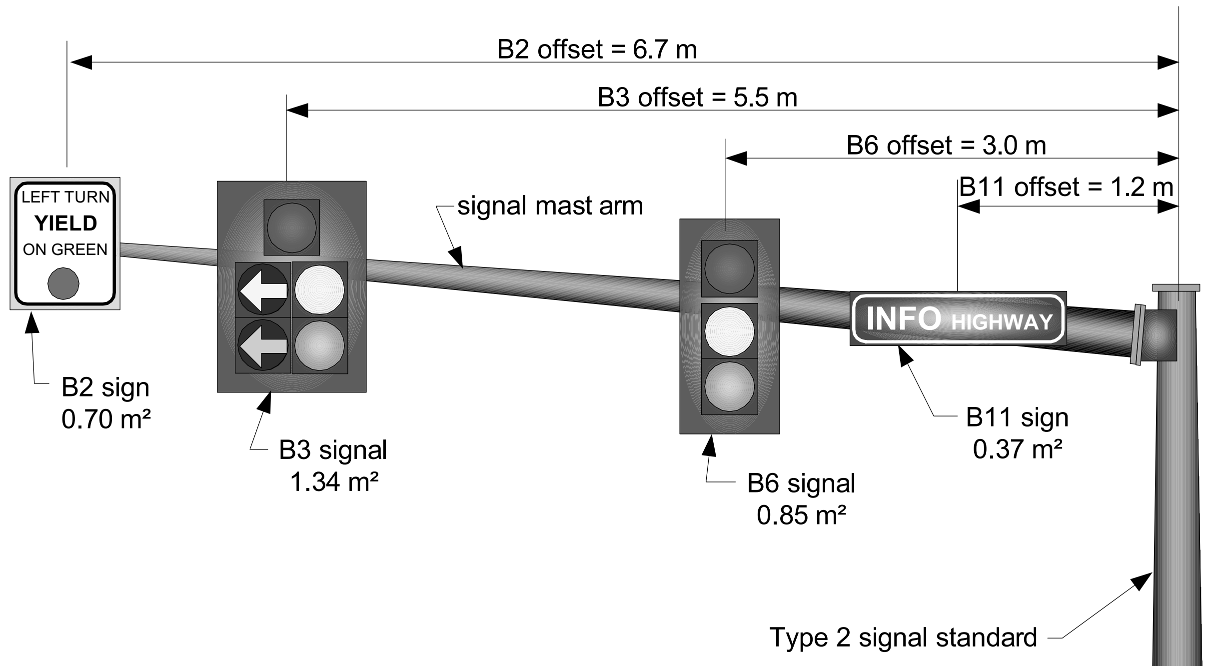


Two Through Lanes and Two Left Turn Storage Lanes With Protected Left Turn Phasing

(Left turn and through movements terminate independently.)

Traffic Signal Display Placements

Figure 850-12e



First

Total windload calculation (XYZ)

B2 area X B2 offset

$0.70\ m^2 \times 6.7\ m = 4.69\ m^3$

B3 area X B3 offset

$1.34\ m^2 \times 5.5\ m = 7.37\ m^3$

B6 area X B6 offset

$0.85\ m^2 \times 3.0\ m = 2.55\ m^3$

B11 area X B11 offset

$0.37\ m^2 \times 1.2\ m = 0.44\ m^3$

Total XYZ $= 15.05\ m^3$

Then

Determine foundation depth from chart

If the lateral bearing pressure is 72 MPa and the XYZ is $15.05\ m^3$,

Then the foundation depth is:

2.5 m ~ 0.9 m round foundation type
2.2 m ~ 0.9 m square foundation type
2.2 m ~ 1.2 m round foundation type

FOUNDATION DEPTH TABLE

Lateral Bearing Pressure	Foundation Type	XYZ (cubic meters)					
		Type II, III, and SD mast arm standards					
		$17.0\ m^3$	$25.5\ m^3$	$34.0\ m^3$	$42.5\ m^3$	$53.8\ m^3$	$65.2\ m^3$
48 Mpa	0.9 m Rd.	3.0 m	3.0 m	3.4 m	3.4 m	4.0 m	4.6 m
	0.9 m Sq.	2.5 m	2.5 m	2.8 m	2.8 m	3.0 m	3.4 m
	1.2 m Rd.	2.5 m	2.5 m	2.8 m	2.8 m	3.0 m	3.4 m
72 Mpa	0.9 m Rd.	2.5 m	2.5 m	2.8 m	3.4 m	4.0 m	4.6 m
	0.9 m Sq.	2.2 m	2.2 m	2.2 m	2.5 m	2.5 m	2.8 m
	1.2 m Rd.	2.2 m	2.2 m	2.2 m	2.5 m	2.5 m	2.8 m
120 Mpa	0.9 m Rd.	1.9 m	1.9 m	2.2 m	3.4 m	4.0 m	4.6 m
	0.9 m Sq.	1.9 m	1.9 m	1.9 m	1.9 m	2.2 m	2.2 m
	1.2 m Rd.	1.9 m	1.9 m	1.9 m	1.9 m	2.2 m	2.2 m

Mast Arm Signal Moment and Foundation Depths

Figure 850-13

Selection Procedure

1. Determine span length
.
2. Calculate the total dead load (P) per span. Use 178 newtons per signal section and 300 newtons per square meter of sign area.

3. Calculate the average load (G) per span. G = P/n where (n) is the number of signal head assemblies plus the number of signs.

4. Determine cable tension (T) per span. Enter the proper chart with the average load (G) and number of loads (n). If (n) is less than minimum (n) allowed on chart, use minimum (n) on chart.

5. Calculate the pole load (PL) per pole. If only one cable is attached to the pole, the pole load (PL) equals the cable tension (T). If more than one cable is attached, (PL) is obtained by
computing the vector resultant of the (T) values.

6. Select the pole class from the "Foundation Design Table". Choose the pole class closest to but greater than the (PL) value.

7. Calculate the required foundation depth (D). Use the formula: $D = a\frac{DT}{\sqrt{S}}$

   Select the table foundation depth (DT) from the "Foundation Design Table". Lateral soil bearing pressure (S) is measured in pounds per square foot (psf). The formula value (a) is a variable for the cross-sectional shape of the foundation. The values for these shapes are:
   a = 10.94 for a 0.9 m round foundation
   a = 9.41 for a 1.2 m round foundation
   a = 8.97 for a 0.9 m square foundation
   Round (D) upwards to nearest whole number if 30 mm or greater,

8. Check vertical clearance (5 m minimum) assuming 8.8 m maximum cable attachment height and 5% minimum span sag.

Notes:
A special design by the Bridge and Structures Office is required if:
The span length exceeds 45 m.
The (PL) value exceeds 31680 N
The vertical distance between the base plate and the first cable attachment exceeds 8.8 meters.

1. Charts are based on a cable weight of 44 newtons per meter (18 N/m, cable and conductors, 26 N/m ice). Total dead load (P) includes weight of ice on sign and signal section.
2. On timber strain pole designs, specify two down guy anchors when the (PL) value exceeds 2000 N.

Foundation Design Table	
Pole Class (Newtons)	Foundation Depth (DT)
8360 N	1.8 m
11880 N	2.1 m
16820 N	2.4 m
21120 N	2.9 m
24640 N	3.0 m
27720 N	3.4 m
31680 N	3.7 m

Strain Pole and Foundation Selection Procedure
Figure 850-14a

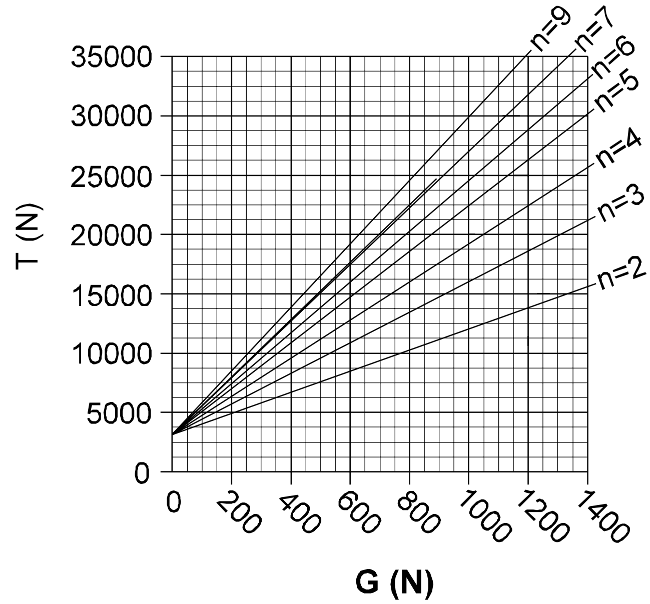


CHART 1 - Span Length 27 m and Less

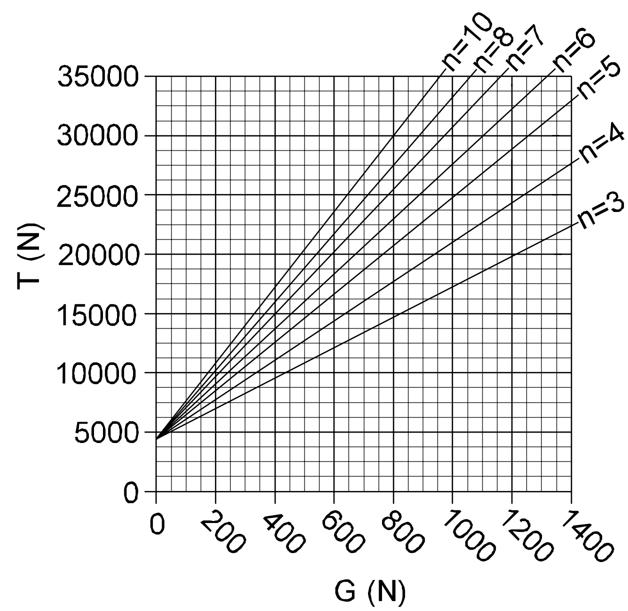


CHART 2 - Span Length 27.1 m to 36 m

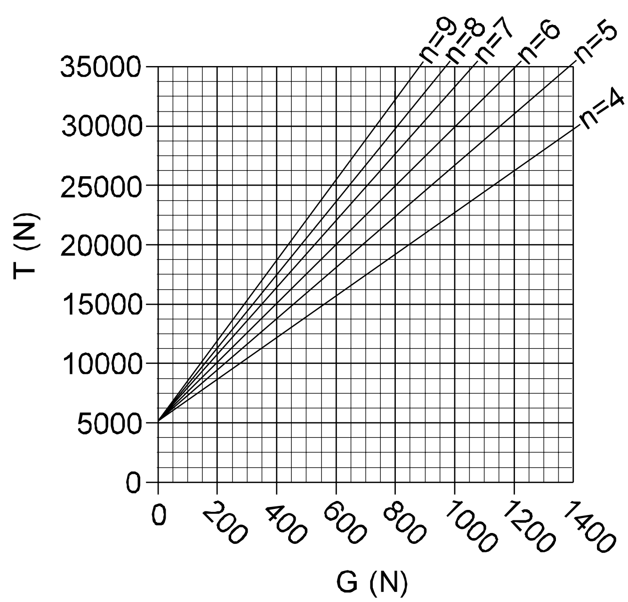
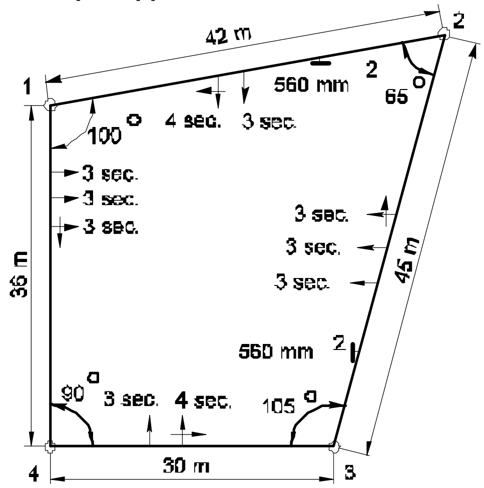


CHART 3 - Span Length 36.1 m to 45 m

Strain Pole and Foundation Selection Procedure

Figure 850-14b

Example Application:



Determine the following:

- Cable Tensions (T)
- Pole Loads (PL)
- Pole Classes
- Foundation Depths (D)

Step 1.
Span lengths given above.
Step 2.
Calculate (P) and (G) values.

Span 1-2, n = 3

7 sections x 178 N/sec = 1246 newtons
560 mm^2 sign x 0.3 N/mm^2 = 168 newtons
Total (P) = 1414 newtons
G = P/n = 1414/3 = 471 newtons

Span 2-3, n = 4

9 sections x 178 N/sec = 1602 newtons
560 mm^2 sign x 0.3 N/mm^2 = 168 newtons
Total (P) = 1770 newtons
G = P/n = 1770/4 = 443 newtons

Span 3-4, n =2

7 sections x 178 N/sec = 1246 newtons
Total (P) = 1246 newtons
G = P/n = 1246/2 = 623 newtons

Span 4-1, n = 3

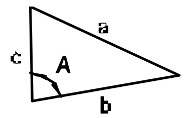
9 sections x 178 N/sec = 1602 newtons
Total (P) = 1602 newtons
G = P/n = 1602/3 = 534 newtons

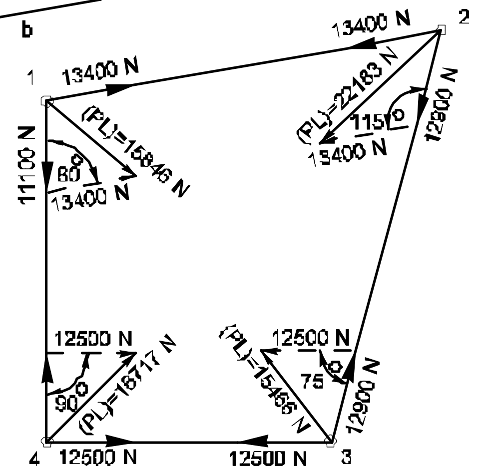
Step 3.
Determine (T) values.

Span	Length	G	Chart	n	min n	T
1-2	42 m	471 N	III	3	4	13400 N
2-3	45 m	443 N	III	4	4	12900 N
3-4	30 m	623 N	II	2	3	12500 N
4-1	36 m	534 N	II	3	3	11100 N

Step 4.
Calculate (PL) values by computing the vector resultant of the (T) values.

$$a = \sqrt{b^2 + c^2 - 2bc(\cos A)}$$





Step 5.
Select the pole class from the "Design Table".

Pole Number	(PL)	Pole Class
1	15846 N	16820 N
2	22183 N	24640 N
3	15466 N	16820 N
4	16717 N	16820 N

Step 6.
Calculate the required foundation depths.
Given: (S) = 48 MPa.

$$D = a\frac{DT}{\sqrt{S}}$$

			Foundation Depths (D)		
Pole No.	Pole Class	DT	1 m Rd (a=10.94)	1.3 m Rd (a=9.41)	1 m Sq (a=8.97)
1	16820 N	2.4 m	4.0 m	3.5 m	3.5 m
2	24640 N	3.0 m	5.0 m	4.0 m	4.0 m
3	16820 N	2.4 m	4.0 m	3.5 m	3.5 m
4	16820 N	2.4 m	4.0 m	3.5 m	3.5 m

Strain Pole and Foundation Selection Example
Figure 850-15

Conduit Sizing Table			
Trade Size	Inside Diam. (mm)	Maximum Fill (inch²)	
		26%	40%
16	16.05	53	81
21	21.23	92	142
27	27.00	149	229
35	35.41	256	394
41	41.25	347	535
53	52.91	572	879
63	63.22	816	1256
78	78.49	1258	1935
91	90.68	1679	2583
103	102.87	2161	3324

Conductor Size Table			
Size (AWG)	Area (mm²)	Size (AWG)	Area (mm²)
# 14 USE	19.4	2cs (# 14)	58.1
# 12 USE	22.6	3cs (# 20)	45.2
# 10 USE	29.0	4cs (# 18)	38.7
# 8 USE	54.8	5c (# 14)	90.3
# 6 USE	67.7	7c (# 14)	109.7
# 4 USE	87.1	10c (# 14)	187.1
# 3 USE	98.1	6pcc (# 19)	206.5
# 2 USE	112.9		

Conduit and Conductor Sizes

Figure 850-16

910.01 General

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

This chapter provides guidance for designing intersections at grade, including at-grade ramp terminals. Guidelines for road approaches are in Chapter 920 and interchanges are in Chapter 940.

If an intersection design situation is not covered in this chapter, contact the Olympic Service Center (OSC) Design Office, for assistance.

910.02 References

Americans with Disabilities Act of 1990 (ADA)

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"

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

Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD), USDOT, FHWA; including the *Washington State Modifications to the MUTCD*, M 24-01, WSDOT

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

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

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

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

NCHRP 279
Intersection Channelization Design Guide

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

910.03 Definitions

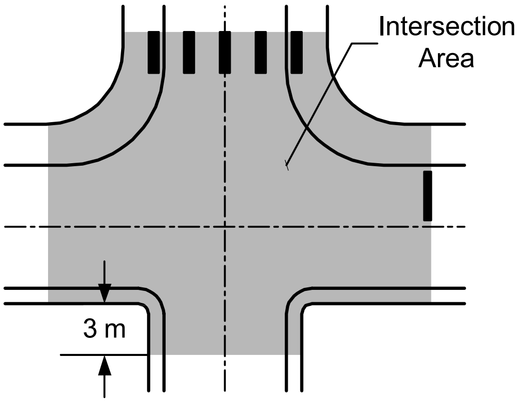
bulb out A curb and sidewalk bulge or extension out into the roadway used to decrease the length of a pedestrian crossing. (See chapter 1025.)

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.

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

intersection angle The angle between any two intersectioning legs at the point that the center lines 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 end of the corner radii, any marked crosswalks adjacent to the intersection, or stop bar, but not less than 3 m from the edge of shoulder of the intersecting roadway.



intersection at grade The general area where a state route or ramp terminal is met or crossed at a common grade or elevation by another state route, a county road, or a city street.

four leg intersection An intersection with four legs, as where two highways cross.

tee (T) intersection An intersection with three legs in the general form of a "T."

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

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

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

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

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

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 distance that the driver of a vehicle on the crossroad can see along the through roadway, as compared to the distance required for safe operation.

intersection turning radii The geometric design of the intersection to allow the design vehicle for each turning movement to complete the turn without encroachment.

island A defined area within an intersection, between traffic lanes, for the separation of vehicle movements or for pedestrian refuge. It may be outlined with pavement markings or delineated by curbs. Within an intersection, a median is considered an island.

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

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

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

median crossover An opening in a median provided for crossings by maintenance, law enforcement, emergency, and traffic service vehicles. (See Chapter 960.)

roundabout A circular intersection at which all traffic moves counterclockwise around a central island. (See IL 4019.01 [Chapter 915])

rural intersection An intersection in a nonurban area.

urban intersection An intersection that is in one of the following areas:

- The area within the federal urban area boundary as designated by FHWA.
- An area characterized by intensive use of the land for the location of structures and receiving such urban services as sewers, water, and other public utilities and services normally associated with urbanized areas.
- An area with not more than twenty-five percent undeveloped land.

910.04 Design Considerations

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

In addition to reducing the number of conflicts, minimize the conflict area as much as possible while still providing for the required design vehicle (910.05). This is done to control the speed of turning vehicles and reduce vehicle, bicyclist, and pedestrian exposure.

(1) Traffic Analysis

Conduct a traffic analysis and an accident analysis to determine the design characteristics of each intersection. Include recommendations for channelization, turn lanes, acceleration and deceleration lanes, intersection configurations, illumination, bicycle and pedestrian accommodations, ADA requirements, and traffic control devices in the traffic analysis.

(2) Intersection Configurations

(a) **Intersection angle.** An important intersection design characteristic is the intersection angle. The allowable intersection angles are 75° to 105° for new, reconstructed, or realigned intersections.

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

(b) **Lane alignment.** Design intersections with entrance lanes aligned with the exit lanes. Do not put angle points on the roadway alignments within intersection areas or on the through roadway alignment within 30 m 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 (Figure 910-19).

When practical, locate intersections so that curves do not begin or end within the intersection area.

(c) **Split Tee.** Avoid split tee intersections where there is less than the intersection spacing for the Highway Access Management Class. See 910.04(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 in driving through the intersection and a more complicated traffic signal design.

Split tee intersections with the offset to the right have the additional disadvantages of overlapping left-turns, increased possibility of wrong way movements, and traffic signal design that is even more complicated. Do not design a split tee intersection with an offset to the right less than the intersection spacing for the class unless traffic is restricted to right-in right-out only.

(d) **Other Nonstandard Configurations.** Do not design intersections with nonstandard configurations such as:

- Intersections with offset legs.
- Intersections with more than four legs.
- Tee intersections with the major traffic movement making a turn.
- Wye intersections that are not a one-way merge or diverge.

A roundabout may be an alternative to these nonstandard configurations. (See 910.08 and IL 4019.01 [Chapter 915].)

(3) Crossroads

When the crossroad is a city street or county road, design the crossroad crossroad <u>beyond the intersection area</u> according to the applicable standards shown in:

- Chapter 468-18 WAC.
- The LAG manual.

- The standards of the local agency that will be requested to accept the facility.

When the crossroad is a state facility, design the crossroad according to the applicable design level and functional class (Chapters 325, 430, and 440). Continue the cross slope of the through roadway shoulder as the grade for the crossroad. Use a vertical curve that is at least 18 m long to connect to the grade of the crossroad.

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

(4) Intersection Spacing

Adequate intersection spacing is required to provide for safety and the desired operational characteristics for the highway. 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. It is desirable to space intersections so that queues will not block an adjacent intersection.

The minimum spacing for highways with limited access control is covered in Chapter 1420. For other highways, the minimum spacing is dependent on the Highway Access Management Class. Figure 910-1 gives the minimum spacing between intersections for each Highway Access Management Class.

Highway Access Management Class	Intersection Spacing (m)
1	1610
2	805
3(1)	805
4(1)	805
5(1)	403

(1)Spacing is for rural intersections and urban intersections that might require signalization.

Minimum Intersection Spacing
Figure 910-1

A deviation for less than the minimum spacing in Figure 910-1 will be considered only when no reasonable alternative access exists. For Class 1 highways, intersection spacing less than $^1/_2$ mi is not permitted (WAC 468-52-040).

910.05 Design Vehicle

The physical characteristics of the design vehicle control the geometric design of the intersection. The following design vehicle types are commonly used:

Design Symbol	Vehicle Type
P	Passenger car, including light delivery trucks.
BUS	Single unit bus
A-BUS	Articulated bus
SU	Single unit truck
WB-12	Semitrailer truck, overall wheelbase of 12 m
WB-15	Semitrailer truck, overall wheelbase of 15 m
WB-20	Semitrailer truck, overall wheelbase of 20 m
MH	Motor home
P/T	Passenger car pulling a camper trailer
MH/B	Motor home pulling a boat trailer

Design Vehicle Types
Figure 910-2

The geometric design of an intersection requires identifying and addressing the needs of all intersection users. There are competing design objectives when considering the turning requirements of the larger design vehicles and the crossing requirements of pedestrians. To reduce the operational impacts of large design vehicles, turn radii are designed so that large vehicles can complete their turn without encroaching on the adjacent lanes at either the entrance or the exit legs of the turn. This results in larger radii that causes 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 on the adjacent same direction lanes at exit legs of the turn is allowed. This reduces the potential for vehicle/pedestrian conflicts, decreases pedestrian crossing distance, and controls speeds of turning vehicles. The negative impacts include capacity reductions and greater speed differences between turning vehicles and through vehicles.

Select a design vehicle that is the largest vehicle that normally uses the intersection. The primary use of the design vehicle is to determine turning radius requirements for each leg of the intersection. It is possible for each leg to have a different design vehicle. Figure 910-3 shows the minimum design vehicles. As justification to use a smaller vehicle, include a traffic analysis showing that the proposed vehicle is appropriate.

Intersection Type	Design Vehicle
Junction of Major Truck Routes	WB-20
Junction of State Routes	WB-15
Ramp Terminals	WB-15
Other Rural	WB-15
Industrial	WB-12
Commercial	SU[1][2]
Residential	SU[1][2]

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

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

Intersection Design Vehicle
Figure 910-3

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 (Figures 910-7a through 7c or templates from another published source) to verify that the design vehicle can make the turning movements.

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

Design each turning movement so the largest vehicle that is anticipated to occasionally use the intersection can make the turn without leaving the paved shoulders or encroaching on a sidewalk. Use the WB-20 as the largest vehicle at all state route to state route junctions. Document and justify any required encroachment into other lanes, and any degradation of intersection operation.

910.06 Right-Turn Corners

The geometric design of an intersection requires identifying and addressing the needs of all intersection users. For the design of right turn corners, there can be competing design objectives when considering the turning requirements of the design vehicle and the crossing requirements of pedestrians. To reduce the operational impacts of large trucks, right-turn radii are designed so that the truck can complete its turn without encroaching on the adjacent lanes at either the entrance or the exit legs of the turn. This results in larger corner radii, increased pavement area and pedestrian crossing distance, a larger conflict area, and higher vehicle turning speeds.

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

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

Figure 910-8 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 justification, right-turn corner designs given in Figure 910-8 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.

910.07 Channelization

Channelization is the separation or regulation of traffic movements into delineated paths of travel to facilitate the safe and orderly movement of vehicles, bicycles, and pedestrians.

Painted or plastic pavement markings are normally used to delineate travel paths. (See Chapter 830 and the standard plans for details.)

(1) Left-Turn Lanes

Left-turn lanes provide storage, separate from the through lanes, for left-turning vehicles waiting for a signal to change or for a gap in opposing traffic. (See 910.07(3) for a discussion on speed change lanes.)

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

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

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

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

- A traffic analysis indicates that a left-turn lane will reduce congestion. On two-lane highways, use Figure 910-9a, based on total traffic volume (DHV) for both directions and percent left-turn traffic, to determine if further investigation is needed. On four-lane highways, use Figure 910-9b to determine if a left-turn lane is recommended.
- An accident study indicates that a left-turn lane will reduce accidents.
- Restrictive geometrics require left-turning vehicles to slow greatly below the speed of the through traffic.
- There is less than decision sight distance at the approach to the intersection.

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

Determine the storage length required on two-lane highways by using Figures 910-10a through 10c. On four-lane highways use Figure 910-9b. These lengths do not consider trucks. Use Figure 910-4 for storage length when trucks are present.

Storage* Length (ft)	% Trucks in Left-Turn Movement				
	10	20	30	40	50
30	38	38	46	46	46
46	53	61	61	61	61
61	69	76	84	91	91
76	84	91	99	107	114
91	107	114	122	122	122
*Length from Figures 910-9b, 10a, 10b, or 10c.					

Left-Turn Storage With Trucks (m)
Figure 910-4

Design opposing left-turn vehicle paths with a minimum 1.2 m clearance between opposing turning paths.

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

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

At signalized intersections with high left-turn volumes, double left-turn lanes may be needed to maintain the desired level of service. A throat width of 9 to 10.8 m 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-12 or larger and the truck volumes are low, consider providing for the design vehicle and an SU turning abreast rather than two design vehicles turning abreast.

Figures 910-11a through 11d show one-way left-turn geometrics. Figure 910-11a shows widening to accommodate the new lane. Figures 910-11b and 11c show the use of a median.

1. **Widening (Figure 910-11a).** It is desirable that offsets and pavement widening be symmetrical about the center line or base line. 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 (Figure 910-11b and 11c).** Widening is not required for left-turn lane channelization where medians are 3.9 m wide or wider. The median acceleration lane shown on the figures can also be provided where the median is 6.9 m or wider. The median acceleration lane might not be necessary at a signalized intersection. When a median acceleration lane is to be used, design it in accordance with 910.07(3) Speed Change Lanes.

At intersections on divided highways where channelized left turn lanes are not provided, consider a minimum protected storage area as shown on Figure 910-11d.

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

Use TWLTLs only in an urban setting where there are no more than two through lanes in each direction. Consider installation of TWLTLs where:

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

TWLTL can reduce delays to through traffic, reduce rear-end accidents, and provide separation between opposing lanes of traffic. However, they do not provide a safe refuge for pedestrians, can create problems with closely spaced access points, and can encourage strip development with closely spaced access points. Consider other alternatives, before using TWLTL, such as prohibiting midblock left-turns and providing for U-turns.

The basic design for a TWLTL is illustrated on Figure 910-11e. Additional criteria are:

- The desirable length of a TWLTL is not less than 75 m.

- Provide illumination in accordance with the guidelines in Chapter 840.
- Pavement markings, signs, and other traffic control devices must be in accordance with the MUTCD and the Standard Plans.
- Provide clear channelization when changing from TWLTL to one-way left-turn lanes at an intersection.

(2) Right-Turn Lanes and Drop 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 as guidelines to determine when to consider right-turn lanes:

- Recommendation from Figure 910-12 based on same direction approach and right-turn traffic volumes.
- An accident study indicates that a right-turn lane will result in an overall accident reduction.
- Presence of pedestrians who require right-turning vehicles to stop in the through lanes.
- Restrictive geometrics that require right-turning vehicles to slow greatly below the speed of the through traffic.
- Less than decision sight distance at the approach to the intersection.

For unsignalized intersections, see 910.07(3) Speed Change Lanes for guidance on right-turn lane lengths. For signalized intersections, see Chapter 850 to determine if a right-turn lane is needed and the length requirement.

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

When designing right-turn lanes at signalized intersections, consider reducing the shoulder width to not more than 1.2 m. This reduces the pavement widening for the turn lane and removes the temptation for vehicles to use the shoulder to bypass the other vehicles in the turn lane.

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

The right-turn pocket or the right-turn taper (Figure 910-13) may be used at any minor intersection where a deceleration lane is not required and turning volumes indicate a need as set forth in Figure 910-12. These designs will cause less interference and delay to the through movement by offering an earlier exit to right-turning vehicles.

If the right-turn pocket is used, Figure 910-13 shows taper lengths for various posted speeds.

A lane may be dropped at an intersection with a turn-only lane or beyond the intersection with an acceleration lane (Figure 910-14.) Do not allow a lane-reduction taper to cross an intersection or end less than 30 m before an intersection.

When a lane is dropped beyond a signalized intersection, 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 450 m. For facilities with a posted speed less than 45 mph, provide a lane of sufficient length so that the advanced lane reduction warning sign will be placed not less than 30 m beyond the intersection area.

(3) 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 such as speed, traffic volumes, capacity, type of highway, the design and frequency of intersections, and accident history.

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

An acceleration lane is not as advantageous because entering drivers can wait for an opportunity to merge without disrupting through traffic.

When either deceleration or acceleration lanes are to be used, design them in accordance with Figures 910-14 and 15. When the design speed of the turning traffic is greater than 20 mph, design the speed change lane as a ramp in accordance with Chapter 940. When a deceleration lane is used with a left-turn lane, add the deceleration length to the storage length.

(4) 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 these functions:

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

(a) **Size and Shape.** Divisional and refuge islands are normally elongated and at least 1.2 m wide and 6 m long. (Mountable curb, used to discourage turn movements, is not a divisional island.)

Channelization islands are normally triangular. In rural areas, 7 m^2 is the minimum island area and 9 m^2 is desirable. In urban areas where posted speeds are 25 mph or less, smaller islands are acceptable. Use islands with at least 19 m^2 if pedestrians will be crossing or traffic control devices or luminaires will be installed.

Design triangular shaped islands as shown on Figure 910-16a through 16c. The shoulder and offset widths illustrated are for islands with barrier curbs. Where painted islands are used, such as in rural areas, these widths are desirable but may be omitted.

Avoid shoulders wider than 2 m at islands because the wider shoulders can appear to be another lane.

Island markings may be supplemented with reflective raised pavement markers.

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

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

(c) **Compound Right-Turn Lane.** To design large islands, the common method is to use a large radius curve for the turning traffic. While this does provide a larger island, it also encourages higher turning speeds. Where pedestrians are a concern, higher turning speeds are undesirable. An alternative is a compound curve with a large radius followed by a small radius (Figure 910-16c). This design forces the turning traffic to slow down.

(d) **Curbing.** Provide barrier curb for:

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

In addition consider curbing for:

- Divisional and channelizing islands.
- Landscaped islands.

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

Where curbing is to be provided, ensure that surface water will drain.

Snow removal operations can be hampered by curbs and raised islands. Contact the region's Operations Engineer when considering raised channelization in areas of heavy snowfall.

In general, neither mountable nor barrier curbs are used on facilities with a posted speed of 45 mph or greater.

910.08 Roundabouts

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

Modern roundabouts differ from the old rotaries and traffic circles in two important respects: they have a smaller diameter, which lowers speeds; and they have splitter islands that provide entry constraints, slowing down the entering speeds.

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

Consider roundabouts at intersections with the following characteristics:

- Where stop signs result in unacceptable delays for the crossroad traffic. Roundabouts reduce the delays for the cross road, but increase the delays for the through roadway.
- With a high left-turn percentage. Unlike most intersection types, roundabouts can operate efficiently with high volumes of left-turning traffic.
- With more than four legs. When the intersection cannot be modified by closing or relocating legs, a roundabout can provide a solution.
- Where a disproportionately high number of accidents involve crossing or turning traffic.
- Where the major traffic movement makes a turn.
- Where traffic growth is expected to be high and future traffic patterns are uncertain.
- Where it is not desirable to give priority to either roadway.

There are some disadvantages with roundabouts. Roundabouts do not allow for a primary roadway to have priority because all legs entering a roundabout are treated the same. Also, all traffic entering a roundabout is required to reduce speed. Therefore, roundabouts are not appropriate on high speed facilities, where traffic flows are unbalanced, or where an arterial intersects a collector or local road.

See IL 4019.01 [Chapter 915] for information and requirements on the design of roundabouts.

910.09 U-turns

For divided highways without full access control that have access points where a median prevents left turns, consider providing locations designed to allow U-turns. Normally, the U-turn opportunities are provided at intersections; however, where intersections are spaced far apart, consider median openings between intersections to accommodate U-turns. Use the desirable U-turn spacing (Figure 910-5) as a guide to determine when to consider U-turn locations between intersections. When the U-turning volumes are low, use longer spacing.

	U-Turn Spacing	
	Desirable	**Minimum**
Urban(1)	300 m	(2)
Suburban	1 km	400 m(3)
Rural	2 km	800 m

(1)For design speeds greater than 45 mph use suburban spacing.

(2)The minimum spacing is the acceleration lane length from a stop plus 90 m.

(3)For design speeds greater than 50 mph, the minimum spacing is the acceleration lane length from a stop plus 90 m.

U-Turn Spacing
Figure 910-5

When designing U-turn locations, use Figure 910-17 as a guide. Where the median is less than 12 m wide and a large design vehicle is required, consider the use of a U-turn roadway.

Document the need for U-turn locations, the spacing used, and justify the selected design vehicle.

910.10 Sight Distance at Intersections

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

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

The driver of a vehicle that is stopped, waiting to cross or enter a through roadway, needs obstruction-free sight triangles in order to see enough of the through roadway to safely complete all legal maneuvers before an approaching vehicle on the through roadway can reach the intersection. Use Figure 910-18a to determine minimum sight distance along the through roadway.

The sight triangle is determined as shown in Figure 910-18b. Within the sight triangle, lay back the cut slopes and remove, lower, or move hedges, trees, signs, utility poles, and anything else large enough to be a sight obstruction. Consider eliminating parking so sight distance is not obstructed.

The 5.4 m from the edge of traveled way for the sight triangle in Figure 910-18b is for a vehicle 3 m from the edge of traveled way. This is the minimum distance for the sight triangle. When the stop bar is placed more than 3 m from the edge of traveled way, consider providing the sight triangle to a point 2.4 m back of the stop bar.

Provide a clear sight triangle for a P vehicle at all intersections. In addition to this, provide a clear sight triangle for the SU vehicle for rural highway conditions. If there is significant combination truck traffic, use the WB-15 or WB-20 rather than the SU. In areas where SU or WB vehicles are minimal, and right of way restrictions prohibit adequate sight triangle clearing, only the P vehicle need be considered.

At some intersections, the turning volume from a stop-controlled crossroad is significant enough to conflict with vehicles on the through roadway. Sight distances shown on Figure 910-6 are desirable at these intersections. This is the sight distance required for a P vehicle to turn left or right onto a two-lane highway and attain average running speed without being overtaken by an approaching vehicle going the same direction at the average running speed.

Design Speed (mph)	Sight Distance (m)
25	90
30	115
35	145
40	180
45	225
50	260
60	350
70	475

Sight Distance for Turning Vehicles
Figure 910-6

Designs for movements that cross divided highways are influenced by the median widths. If the median is wide enough to store the design 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 ramp terminal sight distance as for at-grade intersections with a turning movement. An added element at ramp terminals is the grade separation structure. Figure 910-18b gives the sight distance considerations 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 1830 mm and an object height of 460 mm.

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

910.11 Traffic Control at Intersections

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

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

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

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

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

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

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

910.12 Interchange Ramp Terminals

The design to be used or modified for use on one-way ramp terminals with stop or traffic signal control at the local road is shown on Figure 910-19. Higher volume intersections with multiple ramp lanes are designed individually.

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

Determine the number of lanes for each leg by capacity analysis methods assuming a traffic signal cycle, preferably 45 or 60 seconds in length, regardless of whether a signal is used or not. Consider all terminals in the analysis.

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

910.13 Procedures

Document design considerations and conclusions in accordance with Chapter 330. For highways with access control, see Chapter 1420 for access control requirements.

(1) Approval

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

- Traffic analysis
- Deviations approved in accordance with Chapter 330
- Preliminary traffic signal plan approved by the OSC Traffic Office. (See Chapter 850.)
- Intersections with roundabouts require OSC Design Office approval. See IL 4019.01 [Chapter 915] for approval procedures.

(2) Intersection Plans

Intersection plans are required for any increases in capacity (turn lanes) of 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, public meeting comments, and so forth.

Include the following as applicable:

- Drawing of the intersection showing existing and new alignment of the main line and crossroad.
- Main line stationing of the intersection and angle between intersection legs.
- Curve data on main line and crossroads.
- Right of way lines.
- Location and type of channelization.
- Width of lanes and shoulders on main line and crossroads (Chapter 440 and 640).
- Proposed access control treatment (Chapter 1420).
- Traffic data including volumes for all movements and vehicle classifications.
- Classes of highway and design speeds for main line and crossroads (Chapter 440).
- Whether or not the intersection will be signalized or illuminated.
- A copy of all deviations, if any.

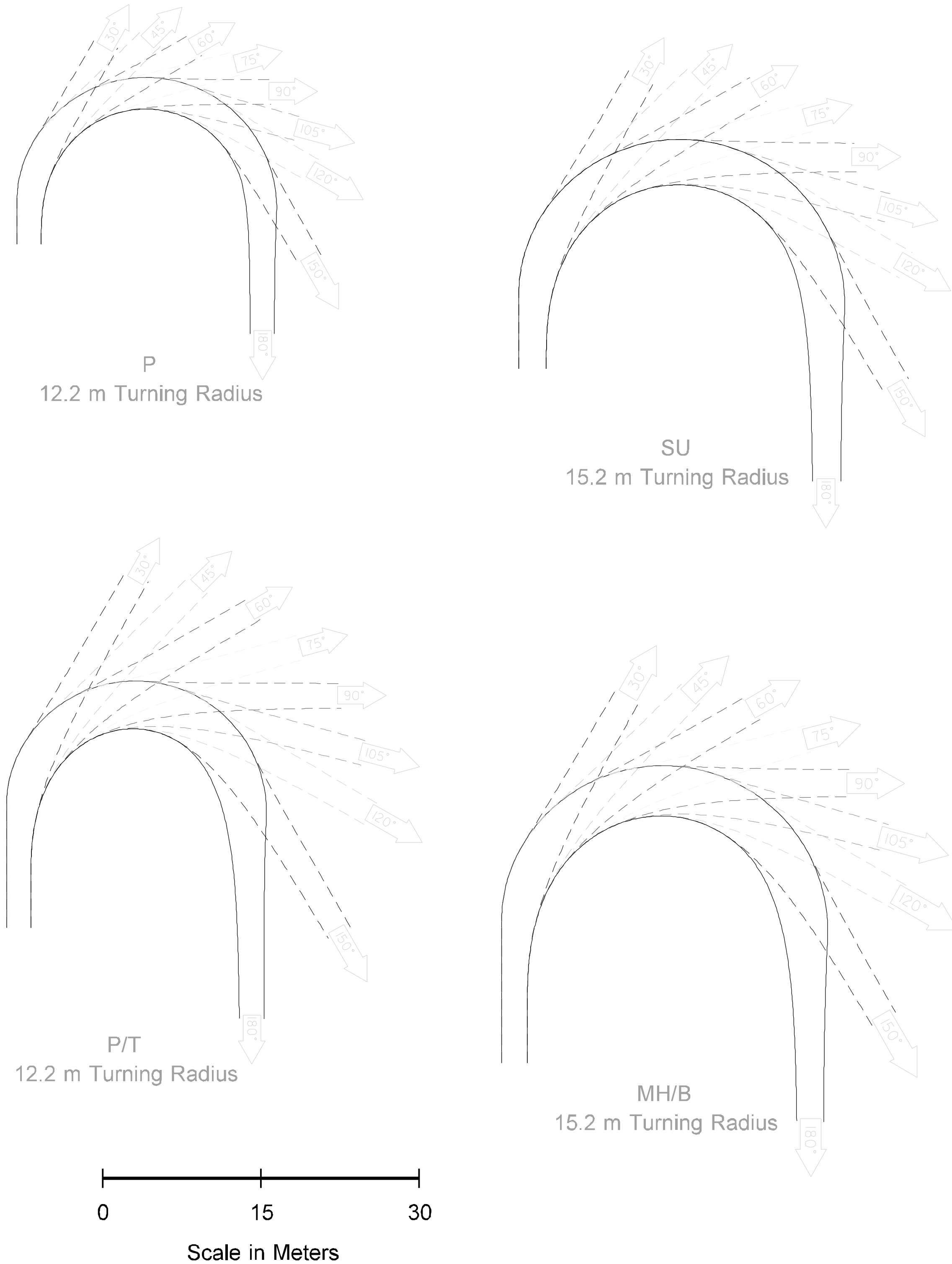
(3) Local Agency or Developer Initiated Intersections

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 considerations that led to the plan, to the region for approval. For those plans requiring a deviation, the deviation must be approved in accordance with Chapter 330 prior to approval of the plan. After the plan approval, the region prepares a construction agreement with the project initiator. (See the *Utilities Manual*.)

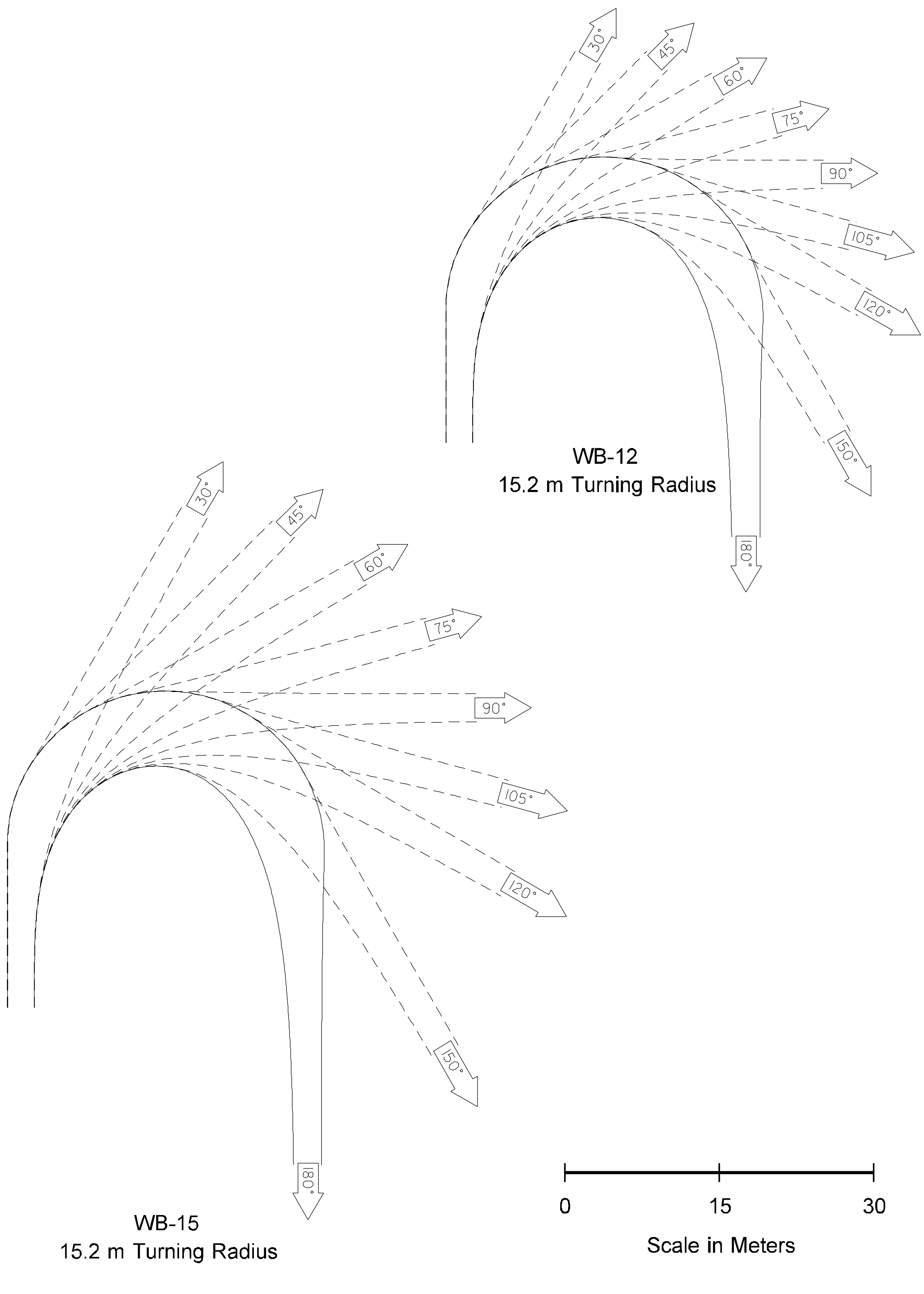
910.14 Documentation

The following documents are to be preserved for future reference in the project file. See Chapter 330.

- ☐ Traffic analyses
- ☐ Accident studies
- ☐ Split tee intersection evaluation
- ☐ Design vehicle selection justifications
- ☐ Justification for encroachment on other lanes
- ☐ Largest vehicle documentation and justification
- ☐ Justification for right-turn corner design modification
- ☐ Left-turn lane justification
- ☐ Two-way left-turn lane justification
- ☐ Right-turn lane justification
- ☐ U-turn documentation
- ☐ Sight distance documentation
- ☐ Approved traffic signal plans
- ☐ Intersection plans and supporting information

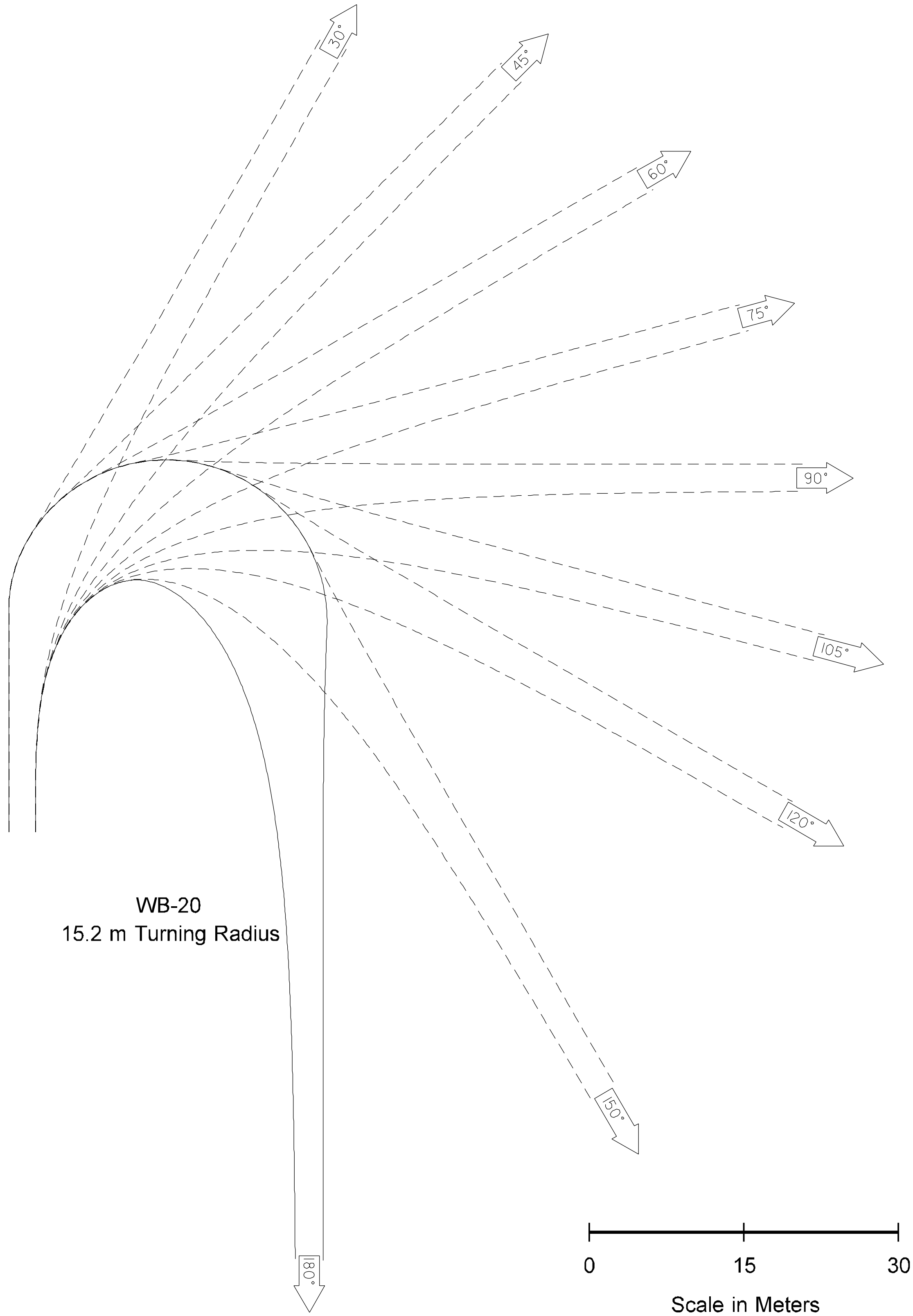


Turning Path Template
Figure 910-7a

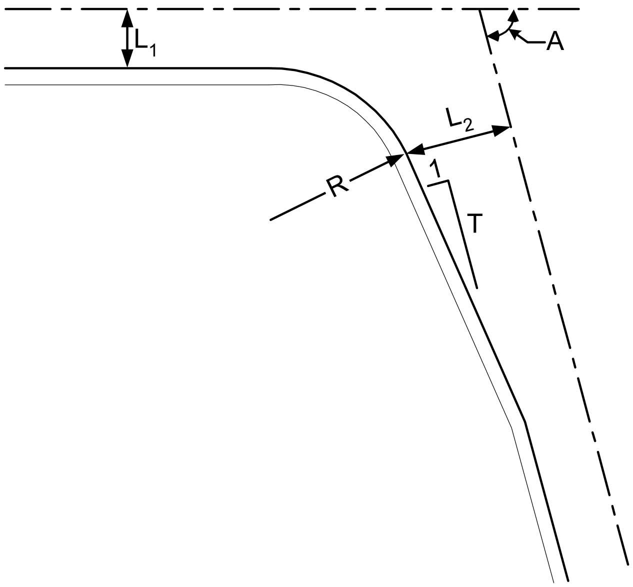


Turning Path Template

Figure 910-7b



Turning Path Template
Figure 910-7c



L_1 = <u>Minimum</u> width of the lane that the vehicle is turning from.

L_2 = <u>Minimum</u> width of the roadway that the vehicle is turning into.

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

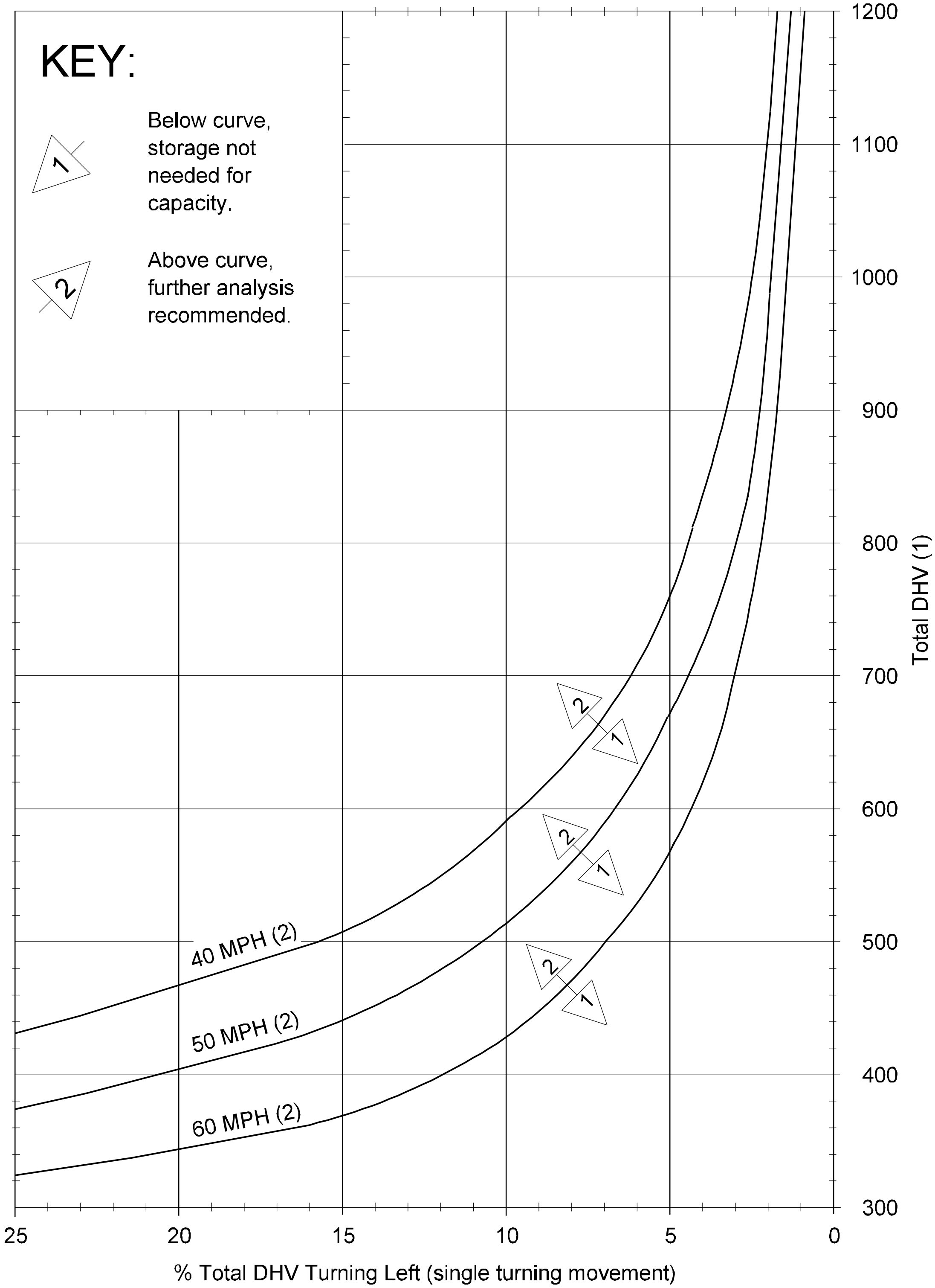
Vehicle	A	R	L_1	L_2 (1)	T (2)	Vehicle	A	R	L_1	L_2 (1)	T (2)
WB-67	60	25.9	3.4	6.7	7	WB-40	60	16.8	3.4	4.6	7.5
	75	22.9	3.4	6.4	8		75	16.8	3.4	4.6	7.5
	90	21.3	3.4	6.4	8		90	16.8	3.4	4.3	7.5
	105	16.8	3.4	7.3	7		105	13.7	3.4	4.9	7.5
	120	15.2	3.4	7.3	7		120	13.7	3.4	4.6	7.5
WB-50	60	16.8	3.4	5.8	6	SU	All	15.2	3.3	3.3	
	75	16.8	3.4	5.5	6	P	All	10.7	3.3	3.3	
	90	16.8	3.4	5.2	6						
	105	15.2	3.4	5.2	6						
	120	13.7	3.4	5.5	6						

(1) At signalized intersections, include all lanes of the exit leg.

(2) When widening is required to obtain the given values of L_1 or L_2 and no taper rate (T) is given, widen at 25:1.

(3) All distances given in meters and angles in degrees

Right-Turn Corner
Figure 910-<u>8</u>

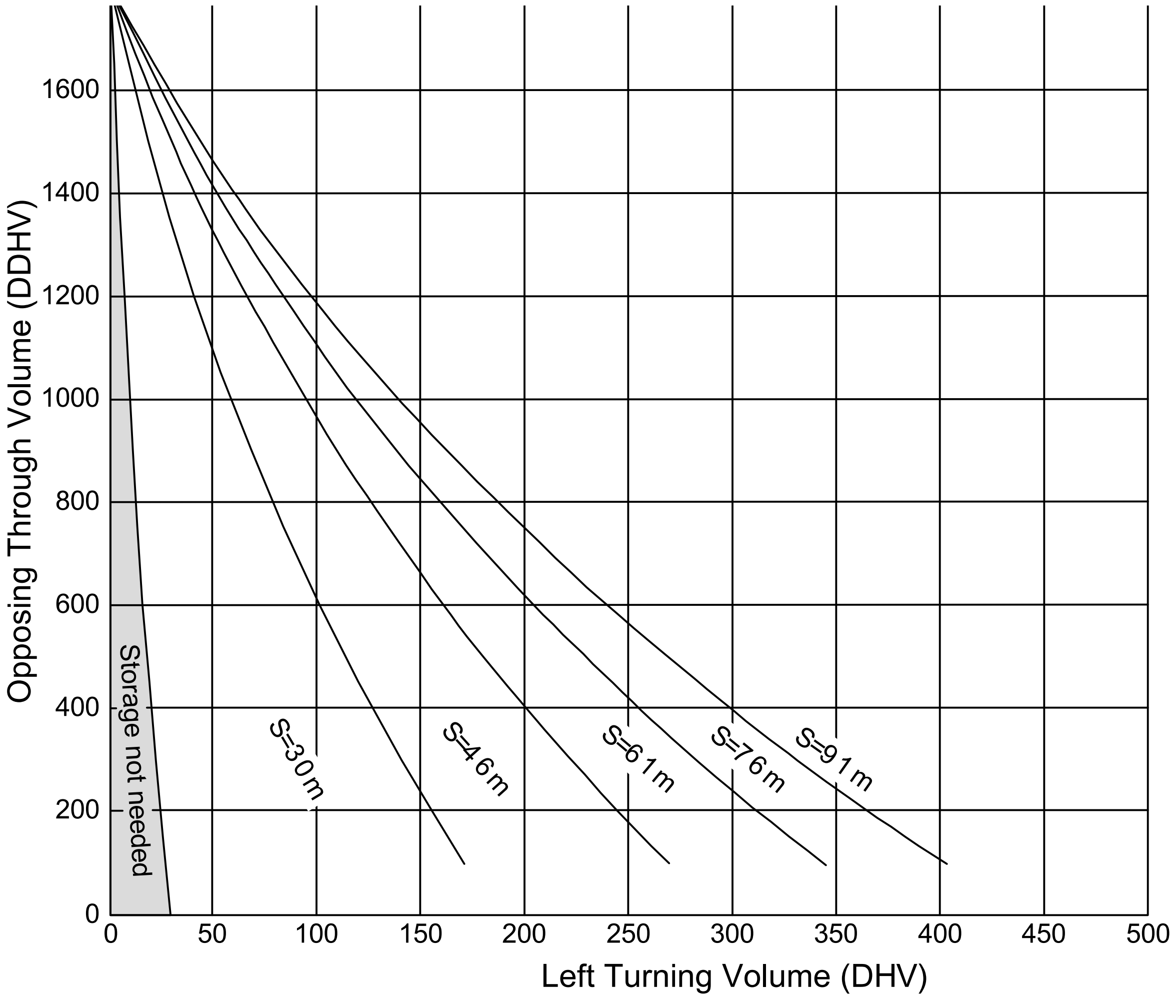


(1) DHV is total volume from both directions.

(2) Speeds are posted speeds.

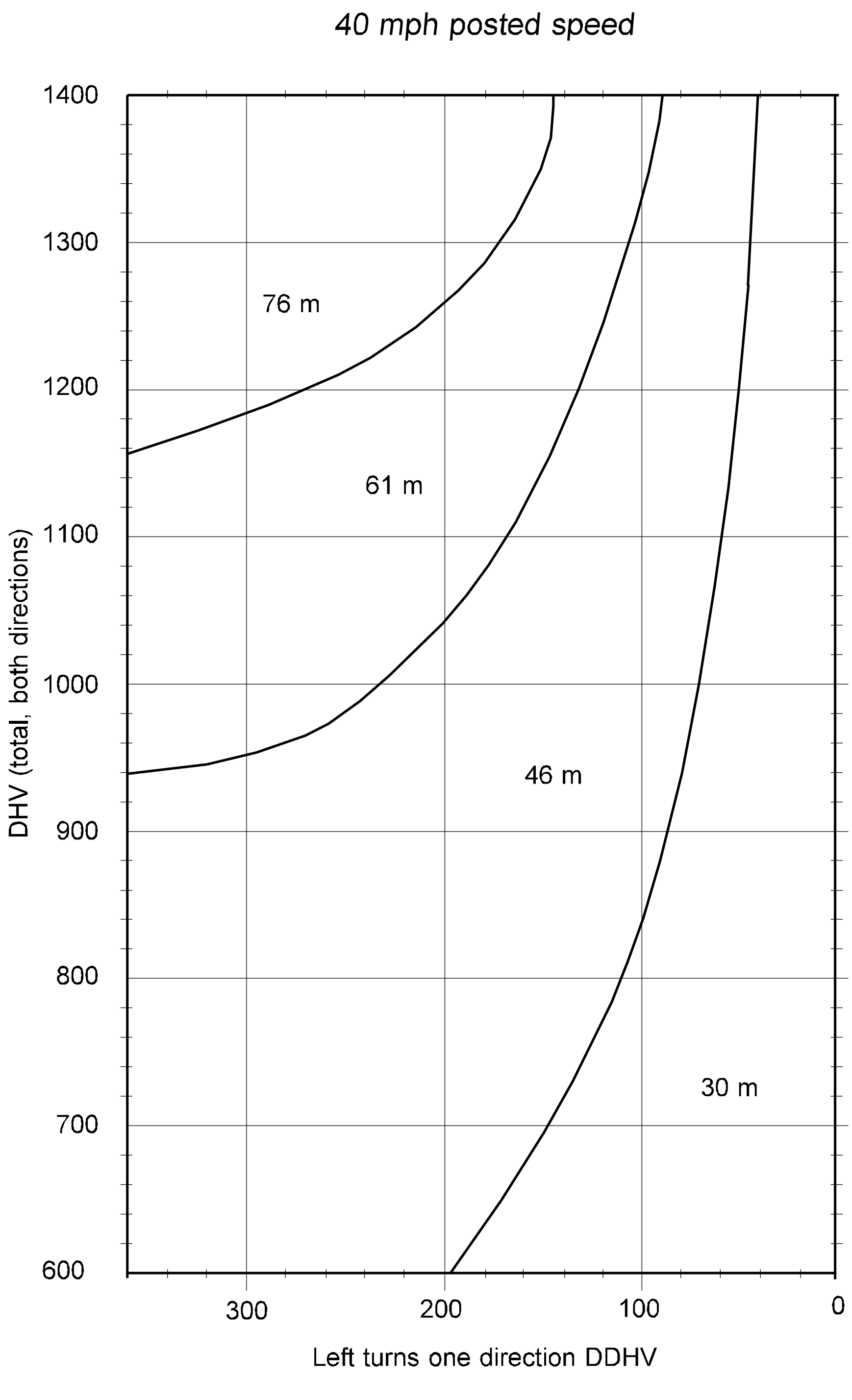
Left-Turn Storage Guidelines <u>(Two-Lane, Unsignalized)</u>

Figure 910-<u>9a</u>

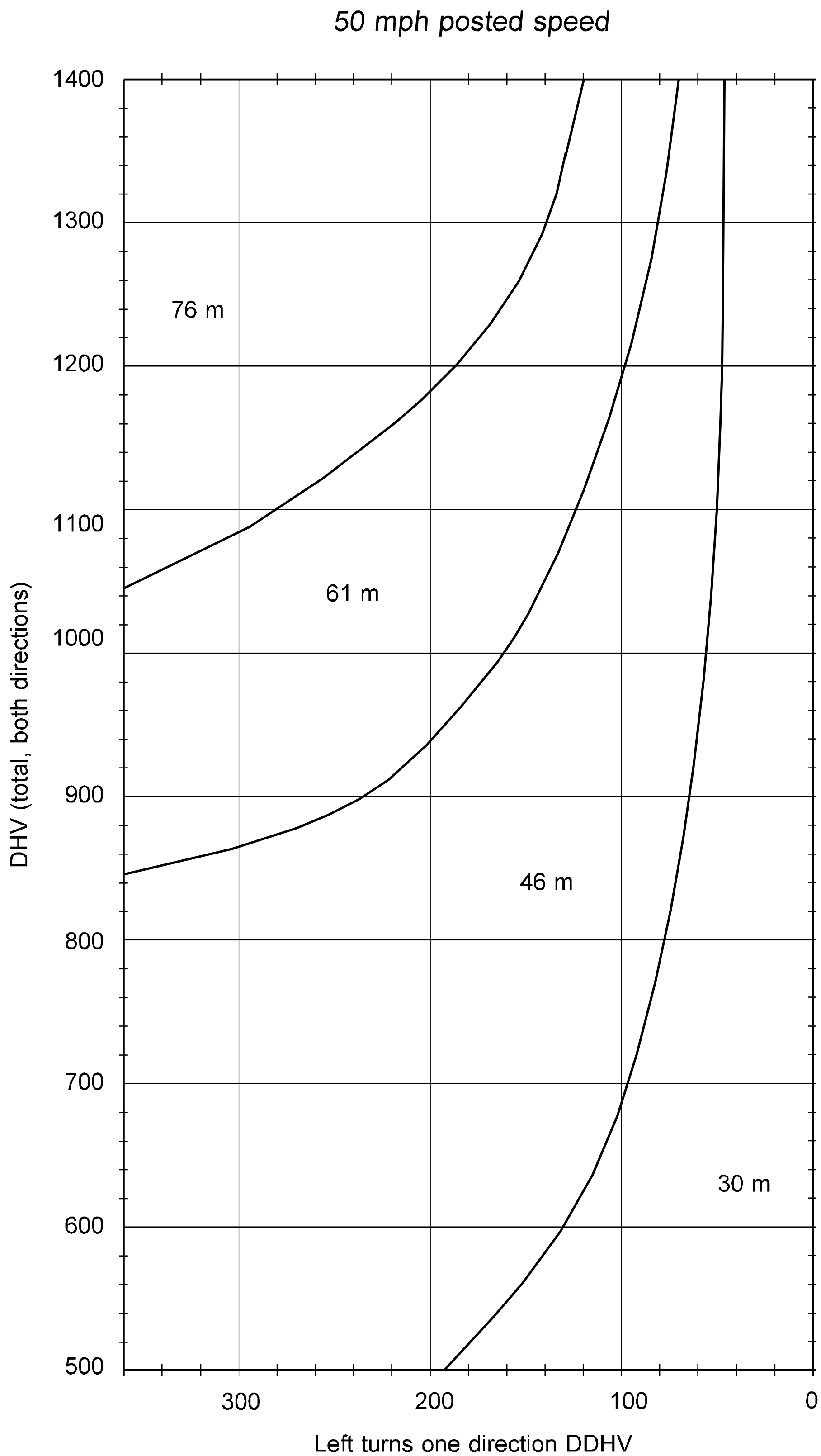


S = Left-Turn storage length

Left-Turn Storage Guidelines (Four-Lane, Unsignalized)
Figure 910-9b

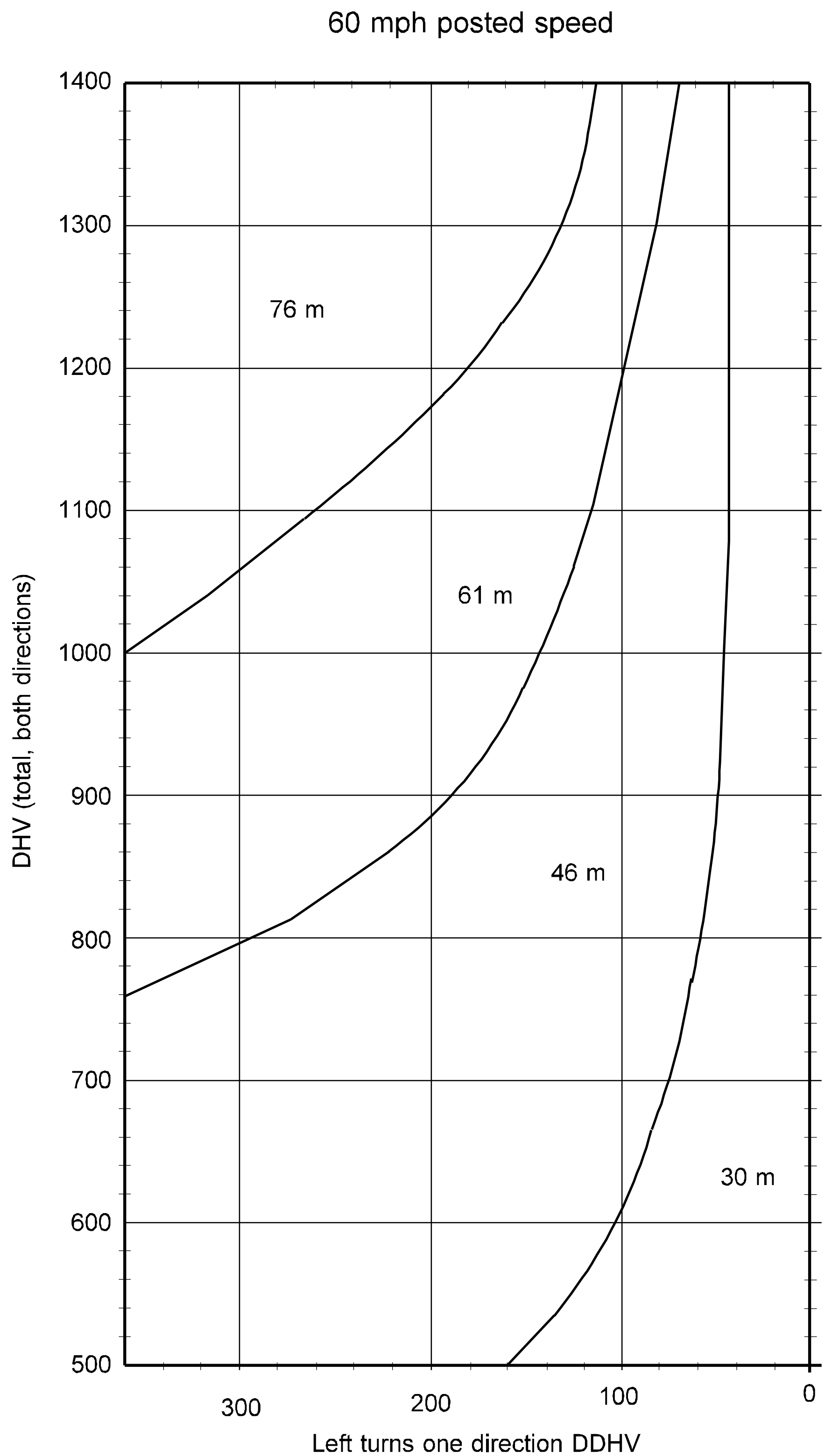


Left-Turn Storage Length <u>(Two-Lane, Unsignalized)</u>
Figure 910-<u>10</u>a

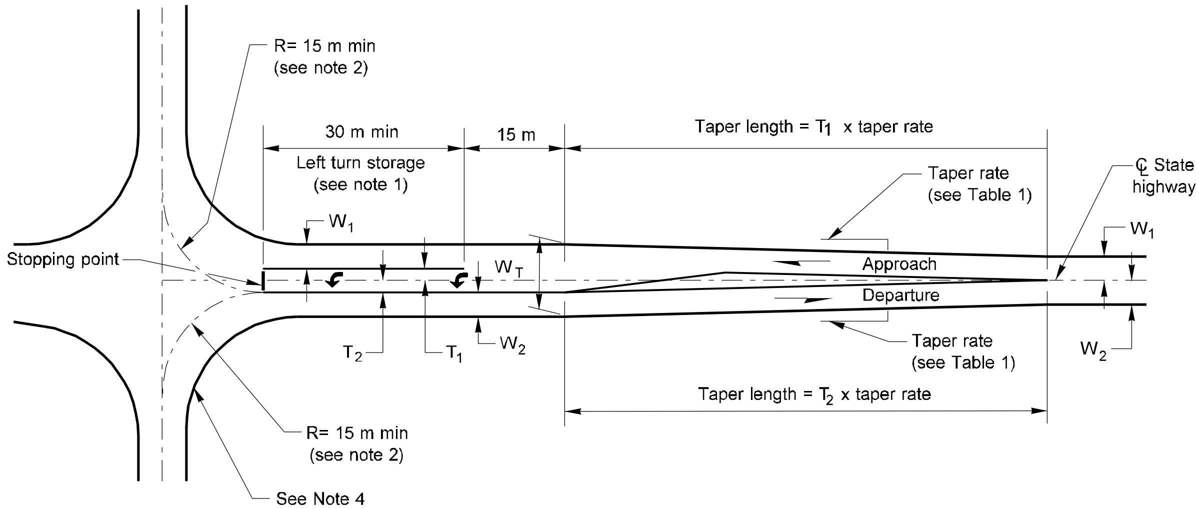


Left-Turn Storage Length **(Two-Lane, Unsignalized)**

Figure 910-10b



Left-Turn Storage Length (Two-Lane, Unsignalized)
Figure 910-10c



Notes:

(1) The minimum width of the left-turn storage lane (T_1+T_2) is 3.3 m. The desirable width is 3.6 m. For left-turn storage length, see Figures 910-9b for 4-lane roadways or 10a through 10c for 2-lane roadways.

(2) Use templates for WB-67 design vehicles.

(3) See Standard Plans and MUTCD for pavement marking details.

(4) See Figure 910-8 for right-turn corner design.

Posted Speed	Acceleration 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 1

W_1 = Approaching through lane.

W_2 = Departing lane.

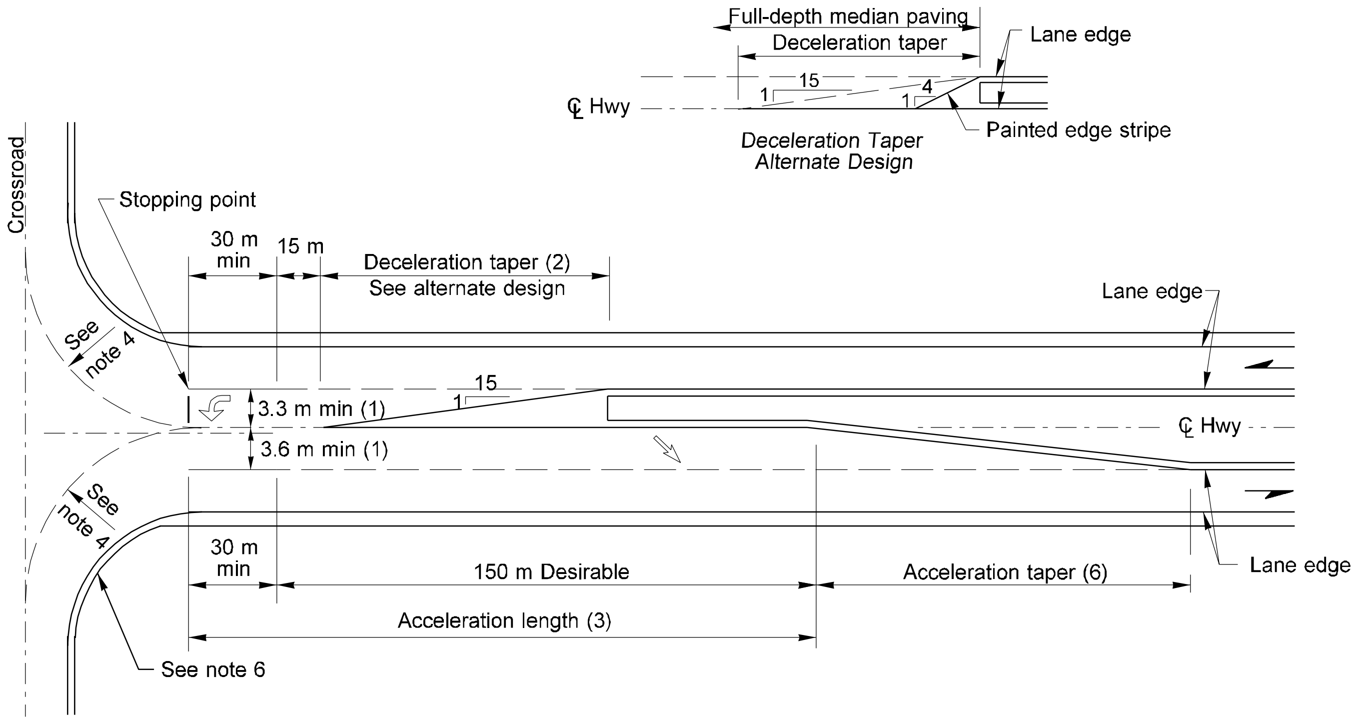
T_1 = Width of left-turn lane on approach side of center line.

T_2 = Width of left-turn lane on departure side of center line.

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

Median Channelization (Widening)

Figure 910-11a



Notes:

(1) Lane widths of 3.9 m are desirable for both the left-turn storage lane and the median acceleration lane.

(2) For increased storage capacity, consider the left-turn deceleration taper alternate design.

(3) The minimum total length of the median acceleration lane is shown in Figure 910-15.

(4) R = 15 m min; use templates for WB-67 design vehicles.

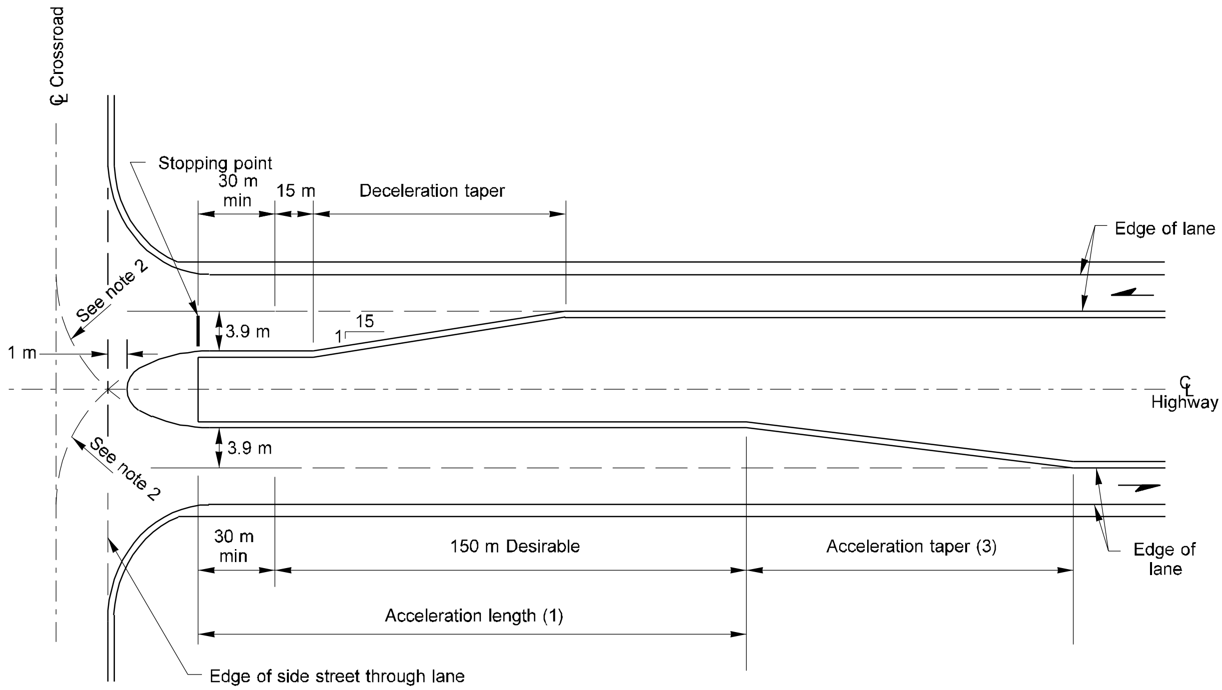
(5) See Figure 910-8 for right-turn corner design.

(6) See Table 1, Figure 910-11a for acceleration tape rate.

(7) See Standard Plans and MUTCD for pavement marking details.

Median Channelization — Median Width 7 m to 8 m

Figure 910-11b



Notes:

(1) The minimum length of the median acceleration lane is shown in Figure 910-15.

(2) R = 15 m min. Use templates for WB-67 design vehicles.

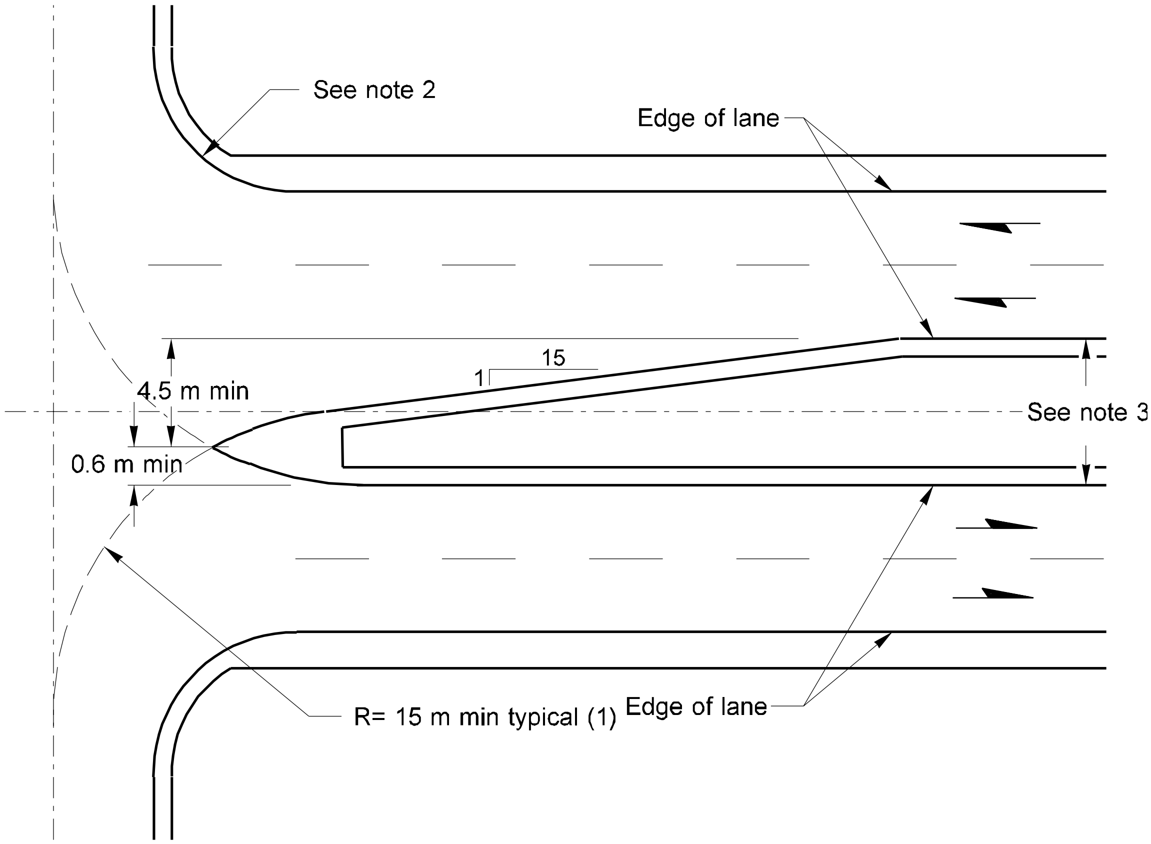
(3) See Table 1 Figure 910-11a for acceleration tape rate.

(4) See Figure 910-8 for right-turn corner design.

(5) See Standard Plans and MUTCD for pavement marking details.

Median Channelization — Median Width of More Than 8 m

Figure 910-11c



Notes:

(1) Use templates for WB-67 design vehicle.

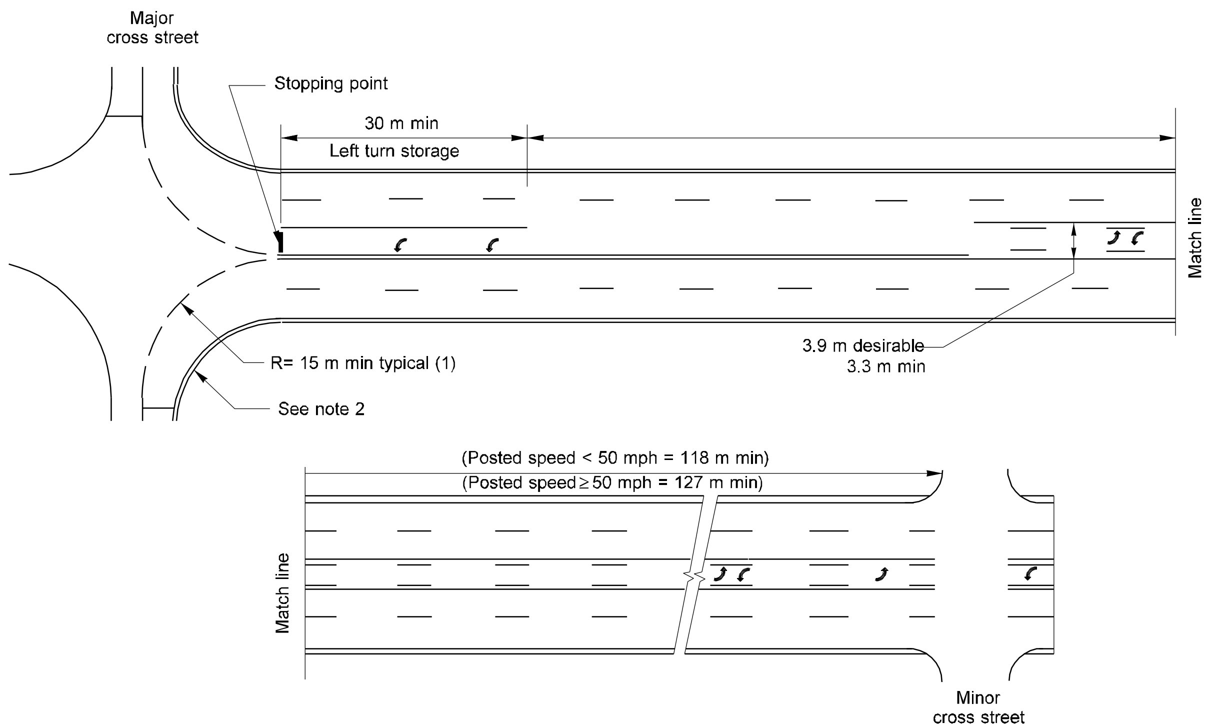
(2) See Figure 910-8 for right-turn corner design.

(3) For median width 5.2 m or more. For median width less than 5.2 m, widen to 5.2 m or use Figure 910-11b without median acceleration lane.

(4) See Standard Plans and MUTCD for pavement marking details.

<u>Median Channelization</u> (Minor Intersection)

Figure 910-11d



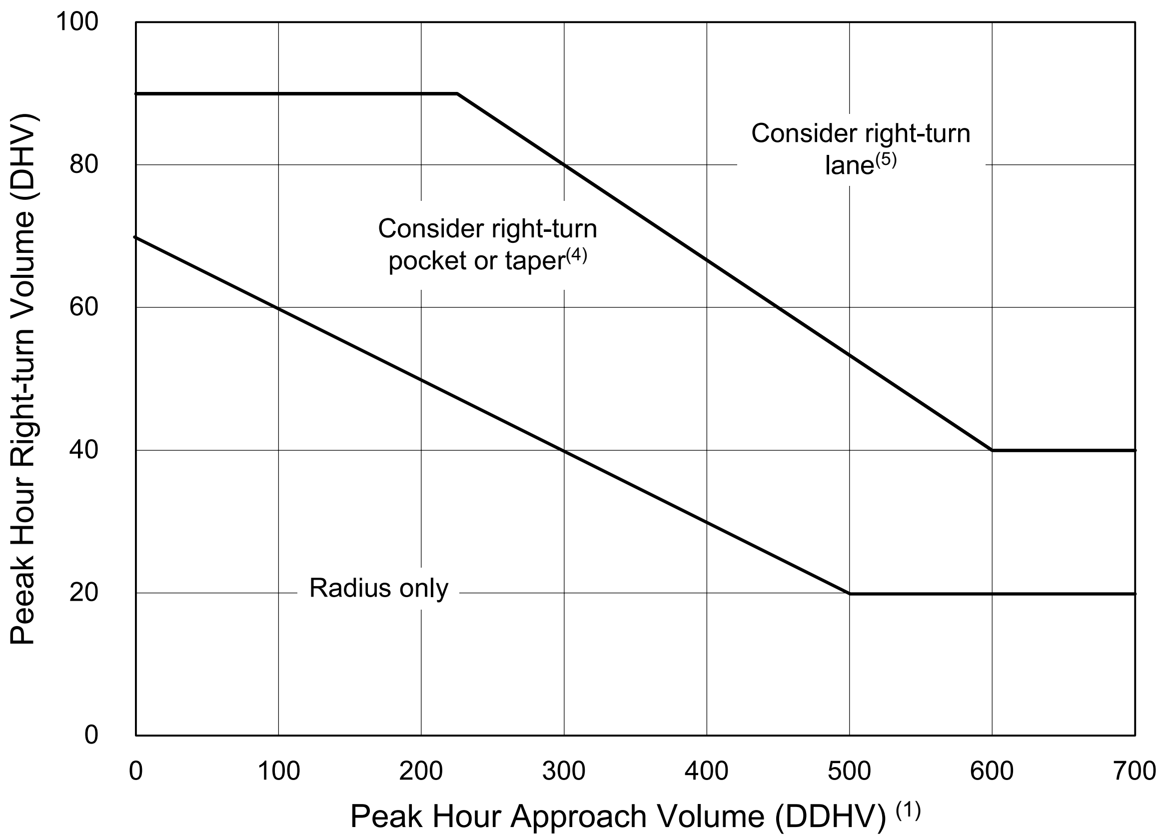
Notes:

(1) Use templates for WB-67 design vehicle.

(2) See Figure 910-8 for right-turn corner design.

(3) See the Standard Plans and the MUTCD for pavement marking details and signing criteria.

Median Channelization (Two-Way Left-Turn Lane)
Figure 910-11e



(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).

For multilane, low speed highways (posted speed less than 45 mph), there is no traffic volume right-turn lane or taper requirement.

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

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

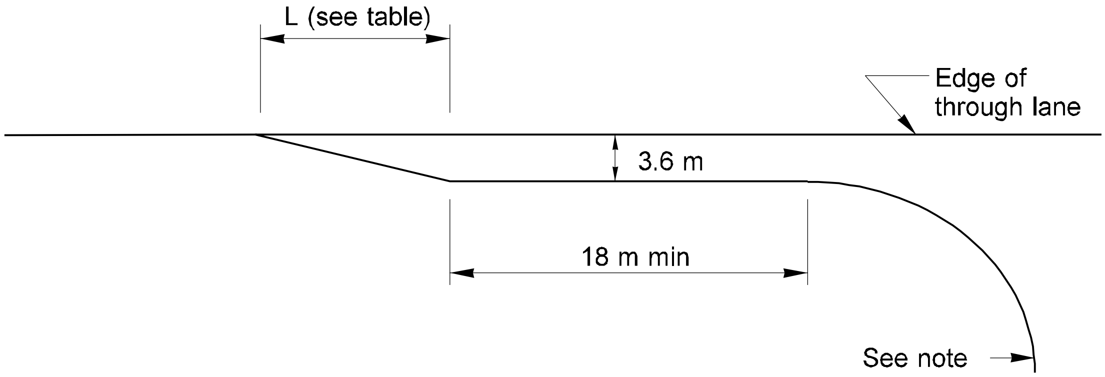
(3) See Figure 910-8 for right-turn corner design.

(4) See Figure 910-13 for right-turn pocket or taper design.

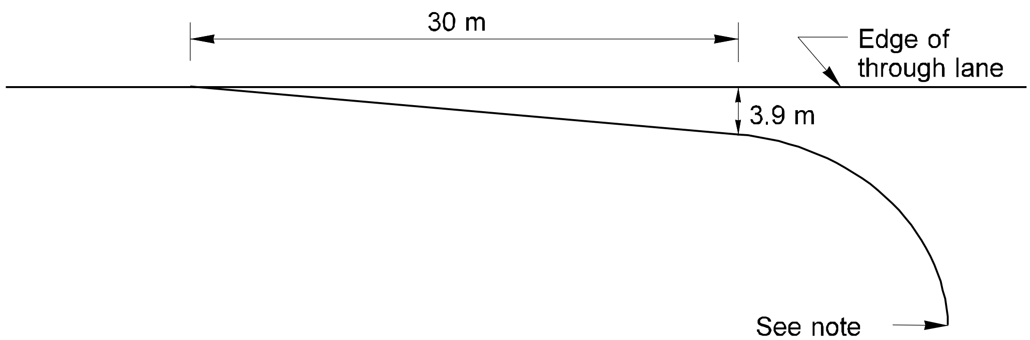
(5) See Figure 910-14 for right-turn lane design.

(6) For additional guidance, see 910.07(2) in the text.

Right-Turn Lane Guidelines(6)
Figure 910-12



Right-Turn Pocket

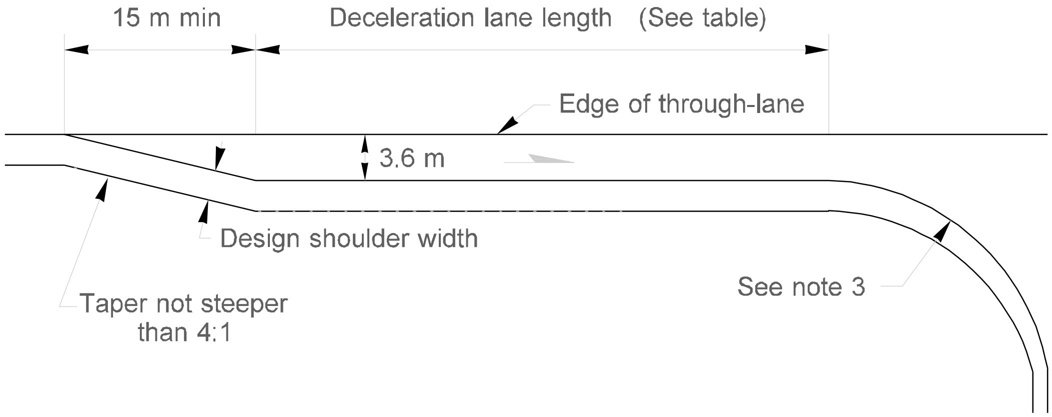


Right-Turn Taper

Posted speed limit	L
Below 40 mph	30 m
40 mph or above	50 m

Note: See Figure 910-8 for right-turn corner design.

Right-Turn Pocket and Right-Turn Taper
Figure 910-13



Highway Design Speed (mph)	Turning Roadway design speed (mph)		
	Stop(1)	15	20
30	75	55(2)	50(2)
40	105	95	85
50	130	120	110
60	160	150	145
70	185	180	175

Minimum Deceleration Lane Length (mph)

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:

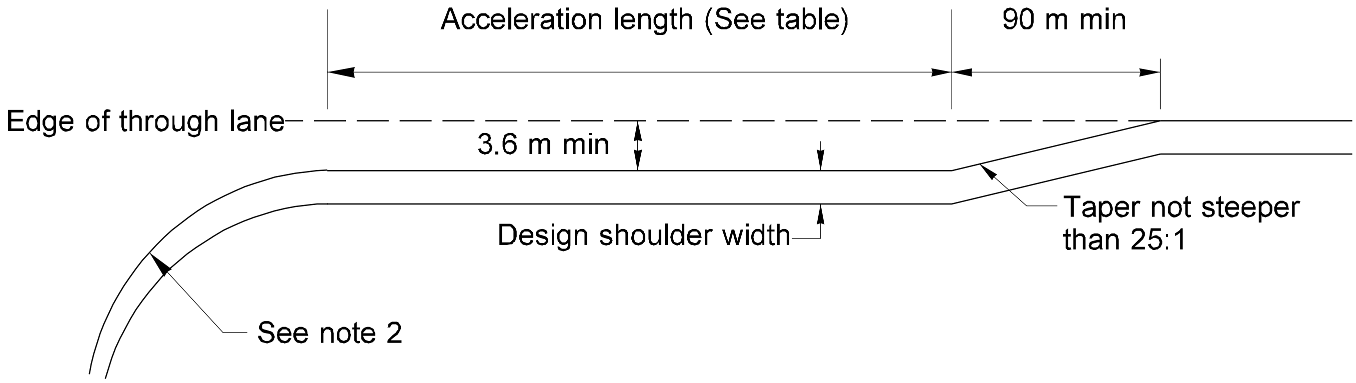
(1) For use when the turning traffic is likely to stop before completing the turn. (For example, where pedestrians are present.)

(2) When adjusting for grade, do not deduce the deceleration lane to less than 45 m.

(3) See Figure 910-8 for right-turn corner design.

Right-Turn Lane

Figure 910-14



Highway Design Speed (mph)	Turning Roadway Design Speed (mph)		
	Stop	15	20
30	55		
40	120	100	85
50	195	170	155
60	340	310	290
70	455	430	410

Minimum Acceleration Lane Length (ft)

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

Adjustment Multiplier for Grades 3% or Greater

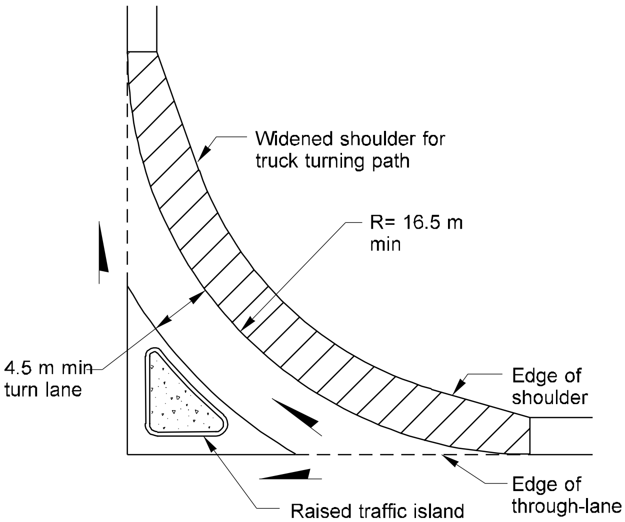
Notes:

(1) The minimum acceleration lane length for freeways and expressways is 270 m.

(2) See Figure 910-8 for right-turn corner design.

Acceleration Lane

Figure 910-15



Small Island Design

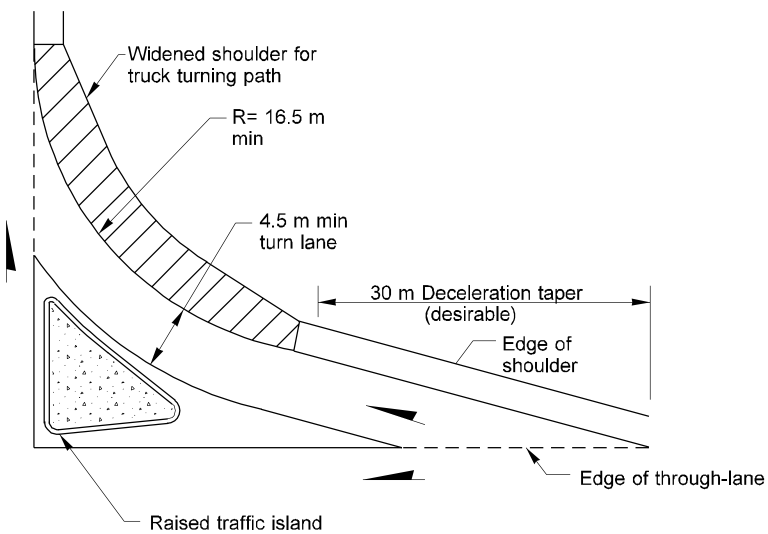
Notes:

(1) Widen shoulders when adequate right-turn radii <u>or roadway width</u> cannot be provided for <u>large</u> trucks. <u>Design widened shoulder pavement the same depth as the right-turn lane.</u>

(2) Use the truck turning path templates <u>for the design vehicle and a minimum of 0.6 m clearance between the wheel paths and the face of a curb or edge of shoulder</u> to determine the width of the widened shoulder.

(3) See Chapter 640 for turning roadway widths.

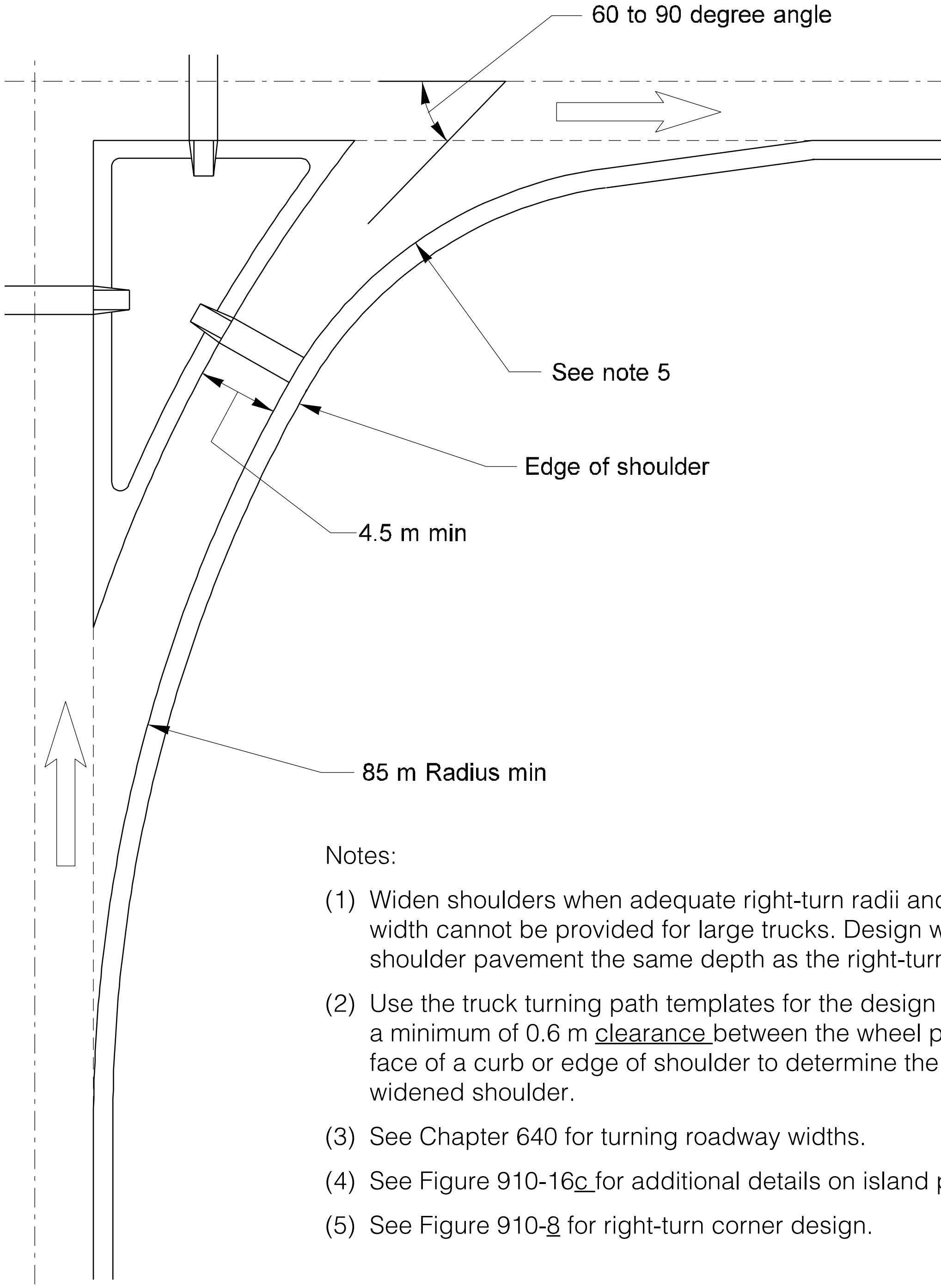
(4) See Figure 910-16c for additional details on island placement



Large Island Design

Traffic Island Designs

Figure 910-1<u>6</u>a



Notes:

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

(2) Use the truck turning path templates for the design vehicle and a minimum of 0.6 m clearance between the wheel paths and the face of a curb or edge of shoulder to determine the width of the widened shoulder.

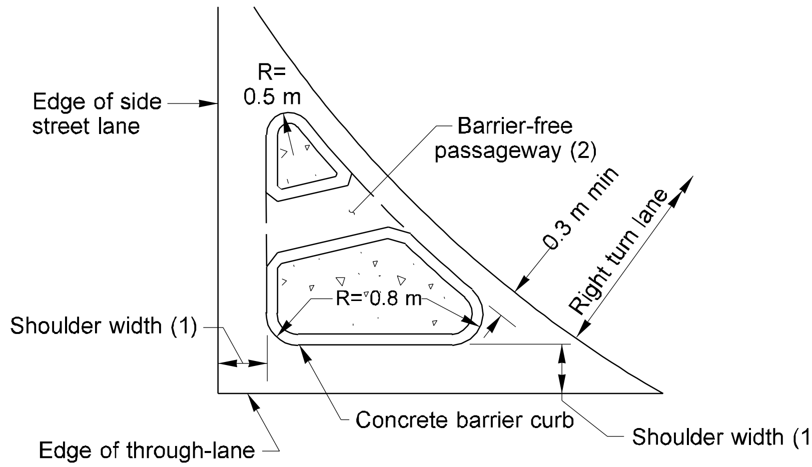
(3) See Chapter 640 for turning roadway widths.

(4) See Figure 910-16c for additional details on island placement

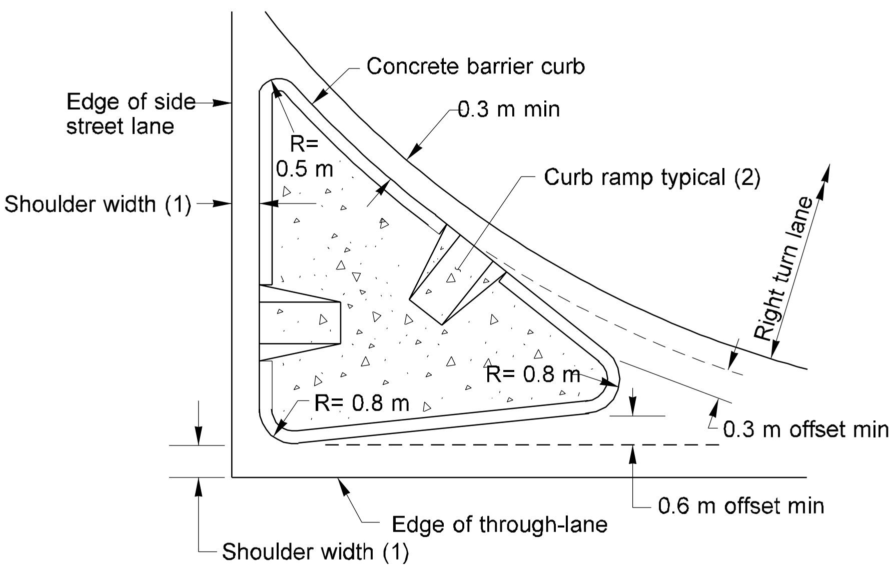
(5) See Figure 910-8 for right-turn corner design.

Traffic Island Designs (Compound Curve)

Figure 910-16b



Small Raised Traffic Island



Large Raised Traffic Island

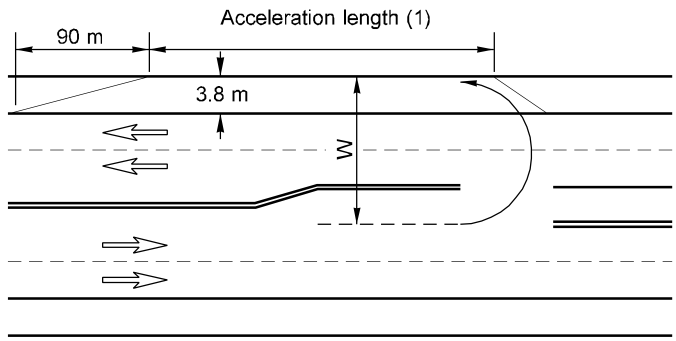
Notes:

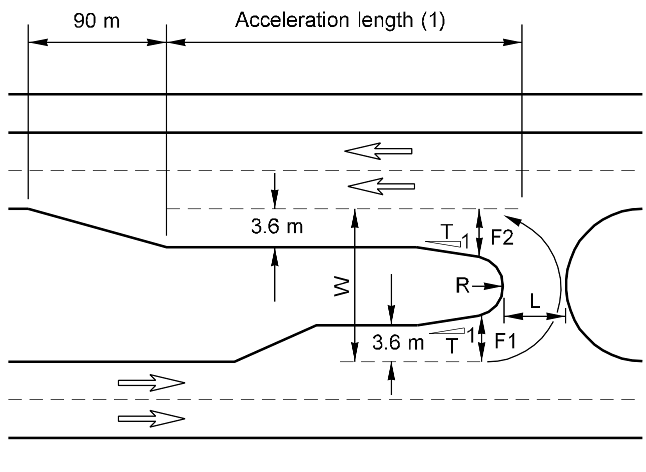
(1) See Chapter 440 for minimum shoulder width. See the text for additional information on shoulders at islands.

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

Traffic Island Designs

Figure 910-16c





Vehicle	W	R	L	F1	F2	T
P	15.6	4.2	4.2	3.6	3.6	—
SU	26.6	9.0	5.9	4.0	4.6	10:1
BUS	26.6	8.5	7.0	4.1	5.5	10:1
WB-40	25.4	7.5	8.0	4.4	6.2	6:1
WB-50	28.4	8.0	9.5	4.9	7.7	6:1
WB-67	28.4	6.8	14.8	4.5	10.5	6:1
MH	25.4	8.0	5.9	4.5	4.9	10:1
P/T	15.6	3.3	3.8	3.6	5.4	6:1
MH/B	31.4	11.0	6.5	4.5	5.0	10:1

U-Turn Design Dimensions (ft)

Notes:

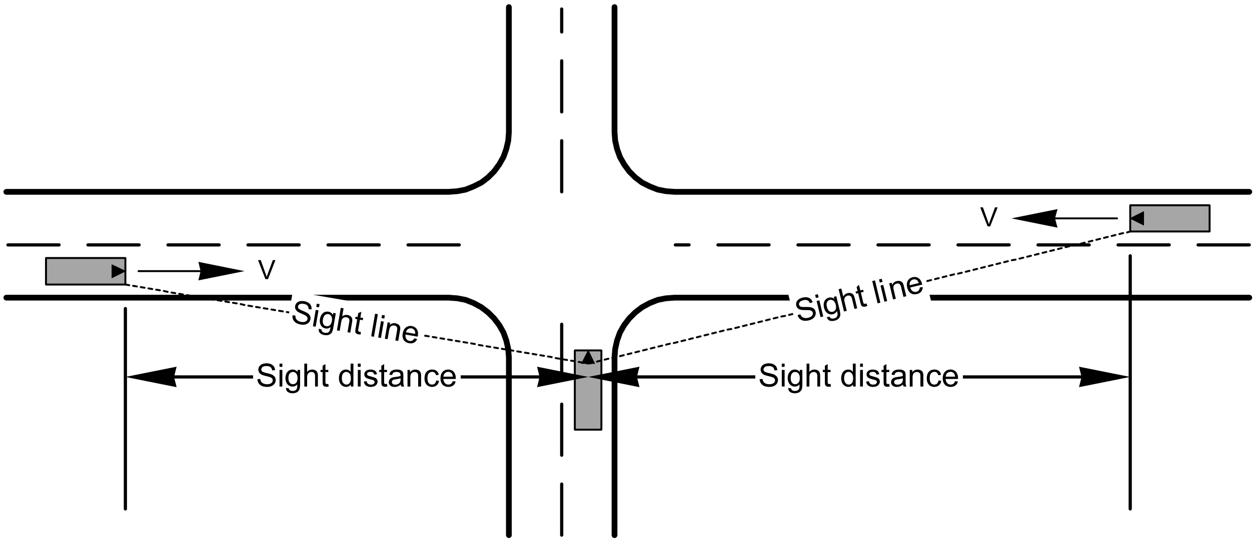
(1) The minimum length of the median acceleration lane is shown in Figure 910-15.

(2) All dimensions in meters.

(3) When U-turn uses the shoulder, provide 3.8 m shoulder width and shoulder pavement designed to the same depth as the through lanes for the acceleration length and taper.

U-Turn Locations

Figure 910-17



$SD = 0.45Vt_g$
Where: SD = Sight Distance (m) V = Design speed of the through roadway (mph) t_g = Time gap for the minor roadway traffic to enter or cross the through roadway (s)

Intersection Sight Distance Equation
Table 1

Design Vehicle	Time Gap (t_g) in seconds
Passenger car (P)	9.5
Single unit trucks and buses (SU & BUS)	11.5
Combination trucks (WB-12, WB-15, & WB-20)	13.5
Note: Values are for a stopped vehicle to turn left or right onto a two-lane two-way roadway with no median and grades 3% or less. Includes 2 sec for perception/reaction time.	

Intersection Sight Distance
Gap Times (t_g)
Table 2

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

Crossing maneuvers:

All vehicles subtract 1.0 s

Multilane roadways:

Left-turns, for each lane in excess of one to be crossed and for medians wider than 1.2 m:

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

Crossing maneuvers, for each lane in excess of two to be crossed and for medians wider than 1.2 m:

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

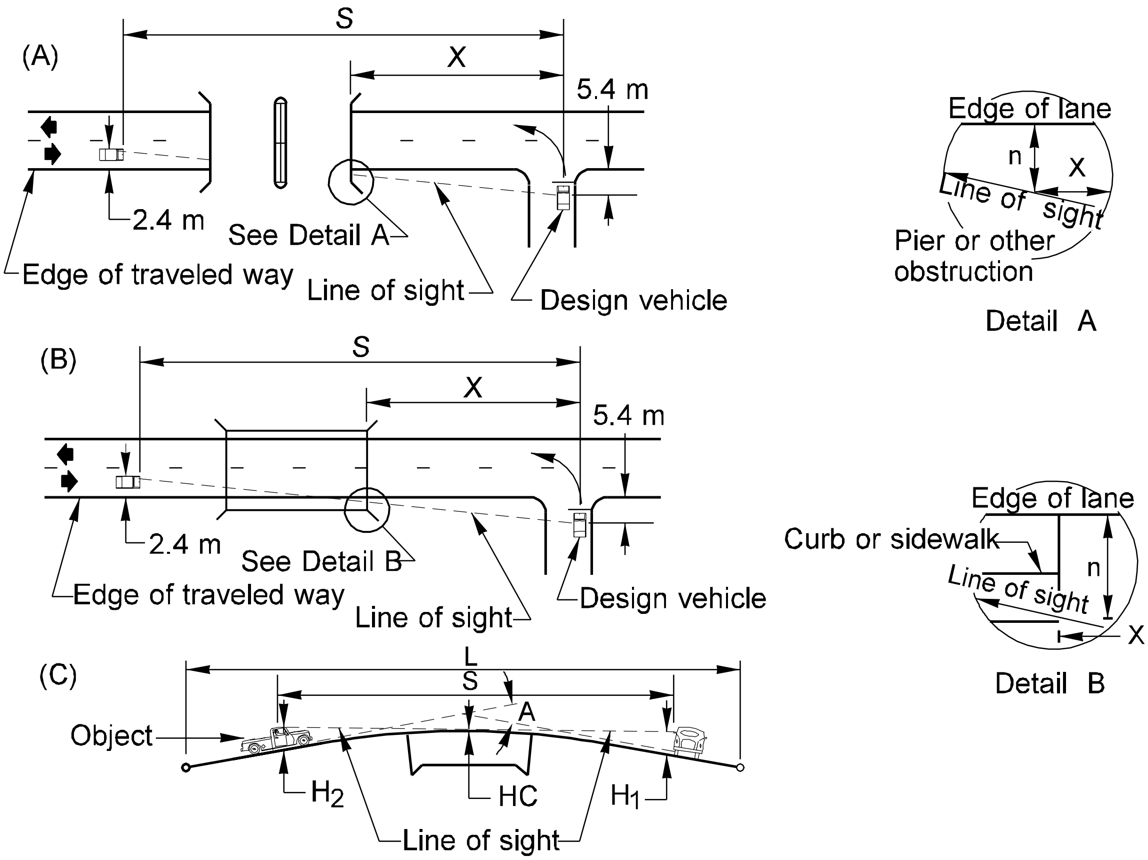
Note: Where medians are wide enough to store the design vehicle, determine the sight distance as two maneuvers.

Crossroad grade greater than 3%:

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

All vehicles add 0.2 s

Sight Distance for Grade Intersection With Stop Control
Figure 910-18a



For bridge pier or bridge rail:

$$S = \frac{7.8(x)}{5.4 - n}$$

Where:

S = Available sight distance (m)

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

X = Distance from center line of lane to sight obstruction (m)

For crest vertical curve over a curb where S<L:

$$S = \sqrt{\frac{0.1L\left[\sqrt{2(H_1 - HC)} + \sqrt{2(H_2 - HC)}\right]^2}{A}}$$

$$L = \frac{AS^2}{0.1\left[\sqrt{2(H_1 - HC)} + \sqrt{2(H_2 - HC)}\right]^2}$$

Where:

S = Available sight distance (m)

H_1 = Eye height (1070 mm)

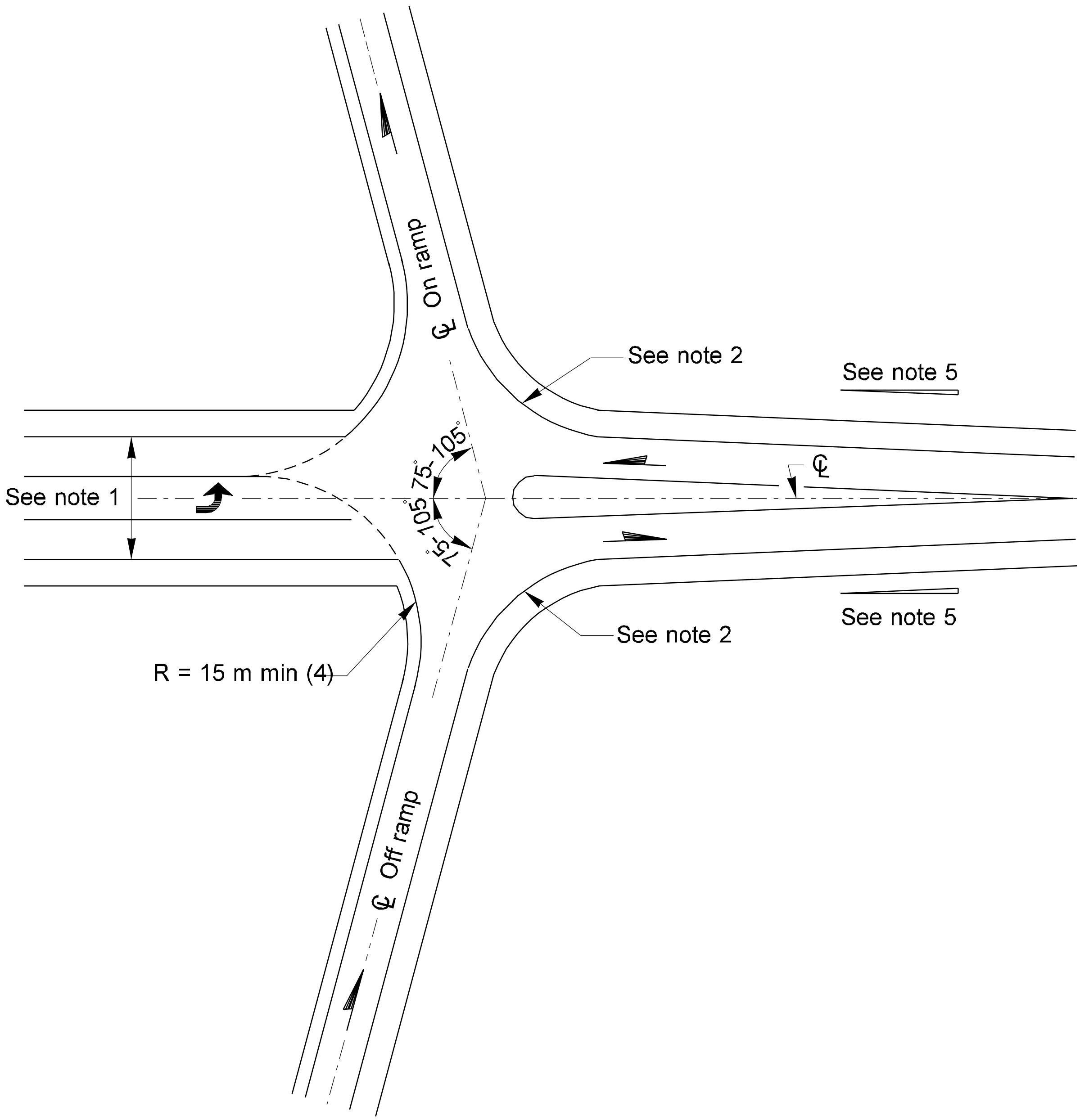
H_2 = Object height (1300 mm)

HC = Curb height (mm)

L = Vertical curve length (m)

A = Algebraic difference in grades (%)

Sight Distance at Intersections
Figure 910-18b



Notes:

(1) 3.6 m through-lanes and 3.9 m left-turn lane desirable.

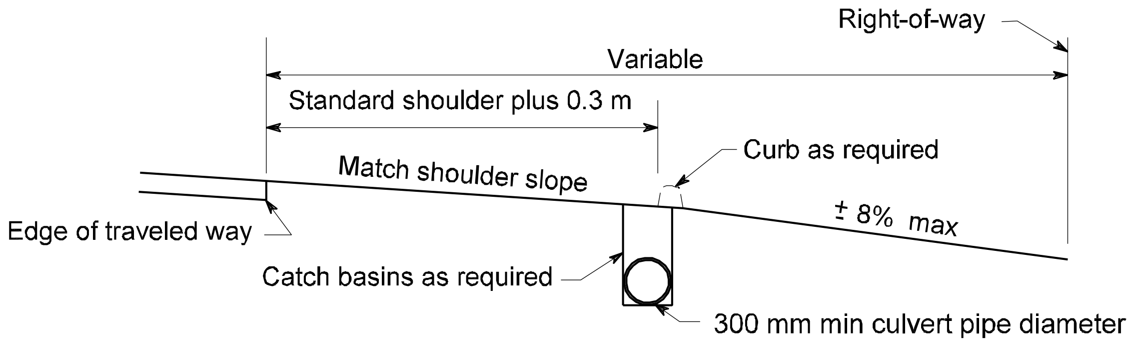
(2) For right-turn corner design see Figure 910-8.

(3) Intersections may be designed individually.

(4) Use templates for the WB-67 design vehicle.

(5) See Figure 910-11a, Table 1 for taper rates.

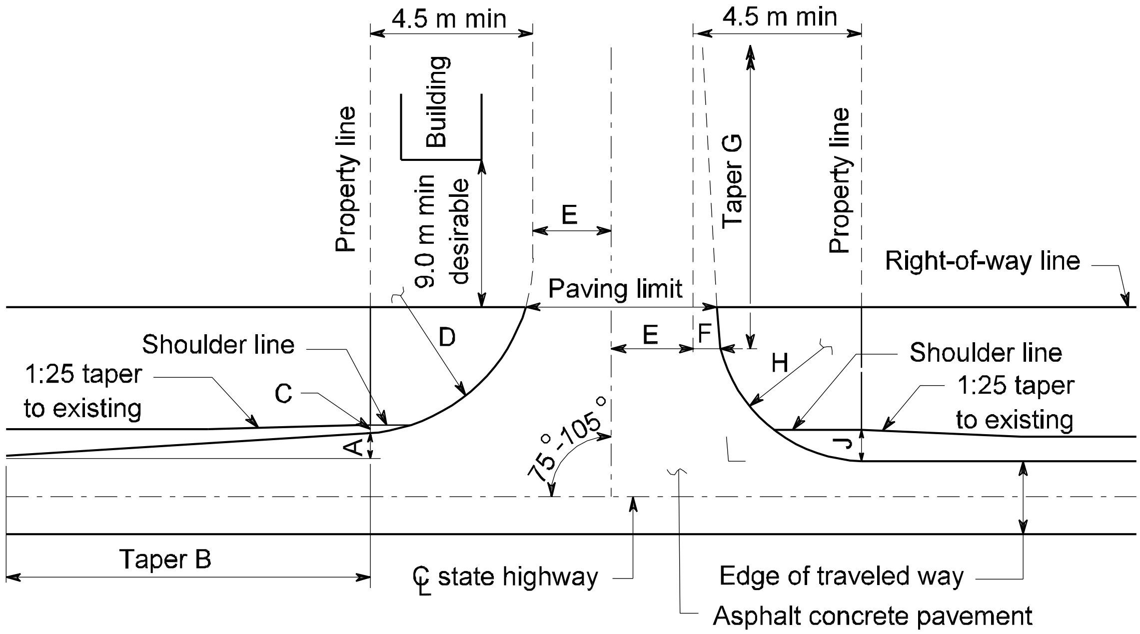
Interchange Ramp Details
Figure 910-19



Profile Controls

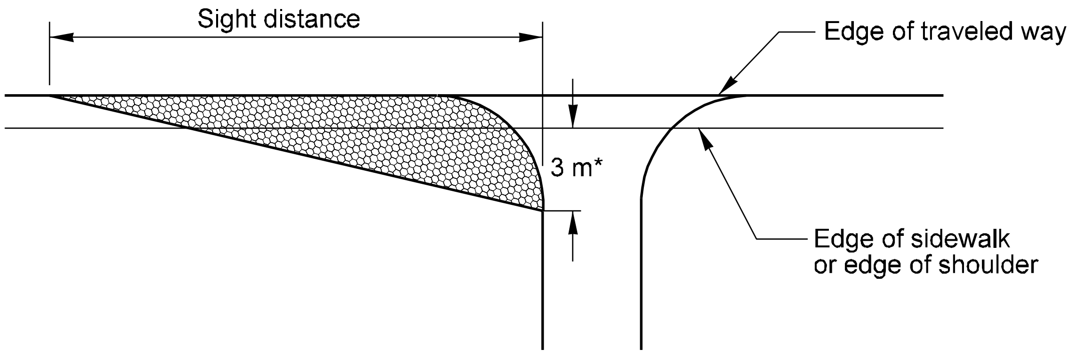
Condition	A	B	C	D	E	F	G	H	J
Primary SU and less	—	—	3.0	9.0	4.5	—	—	9.0	3.0
Primary combination vehicle WB 12		—	3.0	19.5	4.5	—	—	16.5	3.0
	1.2	7.5	1.8	15.0	4.5	2.1	7.5	13.5	3.0
Primary combination vehicle WB 15 and doubles	—	—	3.0	21.0	6.0	—	—	15.0	3.0
	1.2	7.5	1.8	16.5	6.0	—	—	15.0	3.0

All values in meters
For larger vehicles, use turning templates



Note: Vertical curves between the shoulder slope and the approach grade not to exceed a 85 mm hump or a 50 mm depression in a 3.0 m chord.

Commercial Approach — Single Approach Design Template D
Figure 920-5



*Not to exceed 5.4 m from the edge of traveled way.

Posted Speed Limit (mph)	25	30	35	40	50	60	70
Category I Road Approach	45	55	70	85	115	155	190
Category II Road Approach	45	60	80	100	145	195	260

These distances require an approaching vehicle to reduce speed or stop to prevent a collision.

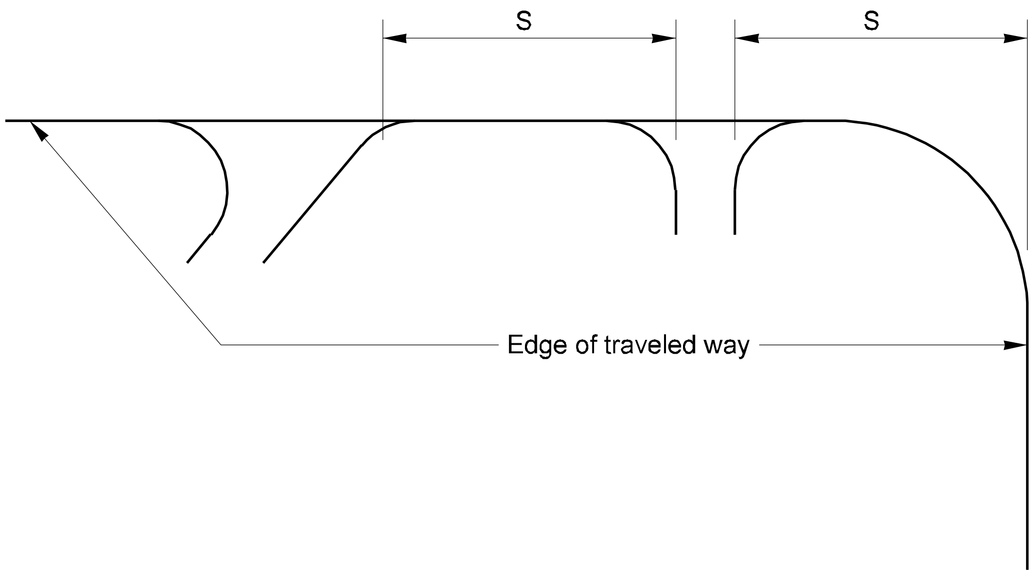
Design Category III road approach sight distance as an intersection (see Chapter 910).

For road approaches where left turns are not allowed, a sight triangle need only be provided to the left, as shown.

For road approaches where left turns are allowed, provide a sight triangle to the right in addition to the one to the left. The sight distance to the right is measured along the center line of the roadway.

For additional information on calculating the sight triangle, see Chapter 910.

Road Approach Sight Distance
Figure 920-6



Highway Access Management Class	1	2	3	4	5
S	402.4 m	201.2 m	100.6 m	76.2 m	38.1 m

Road Approach Spacing and Corner Clearance

Note:

For Road Approach Spacing, S is the distance between closest edge of the traveled way of the two road approaches, measured along the edge of the traveled way of the highway.

For corner clearance, S is measured from the closest edge of the traveled way of the crossroad to the closest edge of the traveled way of the road approach, measured along the edge of the traveled way of the highway.

Road Approach Spacing and Corner Clearance
Figure 920-7

Selection of the final design must be based on a study of projected traffic volumes, site conditions, geometric controls, criteria for intersecting legs and turning roadways, driver expectancy, consistent ramp patterns, continuity, and cost.

The patterns most frequently used for interchange design are those commonly described as directional, semidirectional, cloverleaf, partial cloverleaf, diamond, and single point (urban) interchange. (See Figure 940-4.)

(a) **Directional** A directional interchange is the most effective design for connection of intersecting freeways. The directional pattern has the advantage of reduced travel distance, increased speed of operation, and higher capacity. These designs eliminate weaving and have a further advantage over cloverleaf designs in avoiding the loss of sense of direction drivers experience in traveling a loop. This type of interchange is costly to construct, commonly using a four-level structure.

(b) **Semidirectional** A semidirectional interchange has ramps that loop around the intersection of the highways. This requires multiple single-level structures and more area than the directional interchange.

(c) **Cloverleaf** The full cloverleaf interchange has four loop ramps that eliminate all the left-turn conflicts. Outer ramps provide for the right turns. A full cloverleaf is the minimum type interchange that will suffice for a freeway-to-freeway interchange. Cloverleaf designs often incorporate a C-D road to minimize signing difficulties and to remove weaving conflicts from the main roadway.

The principal advantage of this design is the elimination of all left-turn conflicts with one single-level structure. Because all movements are merging movements, it is adaptable to any grade line arrangement.

The cloverleaf has some major disadvantages. The left-turn movement has a circuitous route on the loop ramp, the speeds are low on the loop ramp, and there are weaving conflicts between the loop ramps. The cloverleaf also requires a large area. The weaving and the radius of the loop ramps are a capacity constraint on the left-turn movements.

(d) **Partial Cloverleaf (PARCLO)** A partial cloverleaf has loop ramps in one, two, or three quadrants that are used to eliminate the major left-turn conflicts. These loops may also serve right turns for interchanges that have one or two quadrants that must remain undeveloped. Outer ramps are provided for the remaining turns. Design the grades to provide sight distance between vehicles approaching these ramps.

(e) **Diamond** A diamond interchange has four ramps that are essentially parallel to the major arterial. Each ramp provides for one right and one left-turn movement. Because left-turns are made at grade across conflicting traffic on the crossroad, intersection sight distance is a primary consideration.

The diamond design is the most generally applicable and serviceable interchange configuration and usually requires less space than any other type. Consider this design first when a semidirectional interchange is required unless another design is clearly dictated by traffic, topography, or special conditions.

(f) **Single Point (Urban)** A single point urban interchange is a modified diamond with all of its ramp terminals on the crossroad combined into one signalized at-grade intersection. This single intersection accommodates all interchange and through movements.

A single point urban interchange can improve the traffic operation on the crossroad with less right of way than a standard diamond interchange; however, a larger structure is required.

(3) Spacing

To avoid excessive interruption of main line traffic, consider each proposed facility in conjunction with adjacent interchanges, intersections, and other points of access along the route as a whole.

The minimum spacing between adjacent interchanges is 1.5 km in urban areas and 3.0 km in rural areas. In urban areas, spacing less than 1.5 km may be used with C-D roads or grade separated (braided) ramps. Generally, the average interchange spacing is not less than 3.0 km in urban areas and not less than 6.0 km in suburban areas. Interchange spacing is measured along the freeway center line between the center lines of the crossroads.

The spacing between interchanges may also be dependent on the spacing between ramps. The minimum spacing between the noses of adjacent ramps is given on Figure 940-5.

Consider either frontage roads or C-D roads when it is necessary to facilitate the operation of near-capacity volumes between closely spaced interchanges or ramp terminals. C-D roads may be required where cloverleaf loop ramps are involved or where a series of interchange ramps that require overlapping of the speed change lanes. Base the distance between successive ramp terminals on capacity requirements and check the intervening sections by weaving analysis to determine whether adequate capacity, sight distance, and effective signing can be ensured without the use of auxiliary lanes or C-D roads.

(4) Route Continuity

Route continuity refers to the providing of a directional path along the length of a route designated by state route number. Provide the driver of a through route a path on which lane changes are minimized and other traffic operations occur to the right.

In maintaining route continuity, interchange configuration may not always favor the heavy traffic movement, but rather the through route. In this case, design the heavy traffic movements with multilane ramps, flat curves, and reasonably direct alignment.

(5) Drainage

Avoid interchanges located in proximity to natural drainage courses. These locations often result in complex and unnecessarily costly hydraulic structures.

The open areas within an interchange can be used for storm water detention facilities when these facilities are required.

(6) Uniformity of Exit Pattern

While interchanges are of necessity custom designed to fit specific conditions, it is desirable that the pattern of exits along a freeway have some degree of uniformity. From the standpoint of driver expectancy, it is desirable that each interchange have only one point of exit, located in advance of the crossroad.

940.05 Ramps

(1) Ramp Design Speed

The design speed for a ramp is based on the design speed for the freeway main line.

The guidelines shown in Figure 940-1 are for the ramp at the interchange connection. Vary the ramp design speed to provide a smooth speed transition from the interchange connection to the crossroad speed or the stop at the intersection. Existing ramps meet design speed requirements if acceleration or deceleration requirements are met (Figure 940-8 or 940-10) and superelevation meets or will be corrected to meet the requirements in Chapter 640. Variations in curvature may prevent design of an interchange ramp for a constant design speed, but under no conditions may design speed be reduced below 35 mph for freeway to freeway ramps and 25 mph for other ramps. For loop ramps the design speed may be reduced to 25 mph; however, it is desirable that the design speed be as high as practical. For C-D roads the design speed is 10 mph below the main line design speed. Use the allowed skew at the crossroad intersection to minimize ramp curvature.

Main Line Design Speed mph	40	50	60	70	80
Ramp Design Speed (mph)	35	45	50	60	70

Ramp Design Speed
Figure 940-1

(2) Sight Distance

Design ramps in accordance with provisions in Chapter 650 for stopping sight distances.

(3) Grade

The maximum grade for ramps for various design speeds is given in Figure 940-2.

1010.01 General

Auxiliary lanes are used to comply with capacity requirements; to maintain lane balance; to accommodate speedx change, weaving, and maneuvering for entering and exiting traffic; or to encourage carpools, vanpools, and the use of transit.

See the Traffic Manual and the MUTCD for signing of auxiliary lanes.

Although slow vehicle turnouts, shoulder driving for slow vehicles, and chain-up areas are not auxiliary lanes they are covered in this chapter because they perform a similar function.

See the following chapters for additional information:

Chapter	Subject
910	Turn lanes
910	Speed change lanes at intersections
940	Speed change lanes at interchanges
940	Collector distributor roads
940	Weaving lanes
1050	High occupancy vehicle lanes

1010.02 References

Revised Code of Washington (RCW) 46.61, Rules of the Road.

Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD), USDOT, FHWA; including the *Washington State Modifications to the MUTCD*, M 24-01. WSDOT

Traffic Manual, M 51-02, WSDOT.

A Policy on Geometric Design of Highways and Streets (Green Book), AASHTO, 1994

Emergency Escape Ramps for Runaway Heavy Vehicles, FHWA-T5-79-201, March 1978

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

NCHRP Synthesis 178, *Truck Escape Ramps*, Transportation Research Board

1010.03 Definitions

auxiliary lane The portion of the roadway adjoining the through lanes for parking, speed change, turning, storage for turning, weaving, truck climbing, passing, and other purposes supplementary to through-traffic movement.

climbing lane An auxiliary lane used for the diversion of slow traffic from the through lane.

emergency escape ramp A roadway leaving the main roadway designed for the purpose of slowing and stopping out-of-control vehicles away from the main traffic stream.

lane A strip of roadway used for a single line of vehicles.

lateral clearance The distance from the edge of traveled way to a roadside object.

posted speed The maximum legal speed as posted on a section of highway using regulatory signs.

passing lane An auxiliary lane on a two-lane highway used to provide the desired frequency of safe passing zones.

roadway The portion of a highway, including shoulders, for vehicular use. A divided highway has two or more roadways.

shoulder The portion of the roadway contiguous with the traveled way, primarily for accommodation of stopped vehicles, emergency use, lateral support of the traveled way, and use by pedestrians and bicycles.

slow moving vehicle turnouts A widened shoulder area to provide room for a slow moving vehicle to pull safely out of the through traffic, allow vehicles following to pass, and return to the through lane.

traveled way The portion of the roadway intended for the movement of vehicles, exclusive of shoulders and lanes for parking, turning, and storage for turning.

Warrant A minimum condition for which an action is authorized. Meeting a warrant does not attest to the existence of an unsafe or undersirable condition. Further justification is required.

1010.04 Climbing Lanes

(1) General

Normally, climbing lanes are associated with truck traffic, but they may also be considered in recreational or other areas that are subject to slow moving traffic. Climbing lanes are designed independently for each direction of travel.

Generally, climbing lanes are provided when the requirements of two warrants - speed reduction and level of service - are exceeded. The requirements of either warrant may be waived if, for example, slow moving traffic is demonstrably causing a high accident rate or congestion that could be corrected by the addition of a climbing lane. However, under most conditions climbing lanes are built when the requirements of both warrants are satisfied.

(2) Warrant No. 1 — Speed Reduction

Figure 1010-2a shows how the percent and length of grade affect vehicle speeds. The data is based on a typical heavy truck.

The maximum allowable entrance speed, as reflected on the graphs, is 55 mph. Note that this is the maximum value to be used regardless of the posted speed of the highway. When the posted speed is above 55 mph, use 55 mph in place of the posted speed. Examine the profile at least 0.4 km preceding the grade to obtain a reasonable approach speed.

If a vertical curve makes up part of the length of grade, approximate the equivalent uniform grade length.

Whenever the gradient causes a 15 mph speed reduction below the posted speed limit for typical heavy truck for either two-lane or multilane highways, the speed reduction warrant is satisfied (see Figure 1010-2b for an example).

(3) Warrant No. 2 — Level of Service (LOS)

The level of service warrant for two-lane highways is fulfilled when the up-grade traffic volume exceeds 200 VPH and the up-grade truck volume exceeds 20 VPH. On multilane highways, use Figure 1010-3.

(4) Design

When a climbing lane is justified, design it in accordance with Figure 1010-4. Provide signing and delineation to identify the presence of the auxiliary lane. Begin climbing lanes at the point where the speed reduction warrant is met and end them where the warrant ends for multilane and 90 m beyond for 2-lane highways. Consider extending the auxiliary lane over the crest to improve vehicle acceleration and the sight distance.

Design climbing lane width equal to that of the adjoining through lane and at the same cross slope as the adjoining lanes. When ever possible, maintain the shoulders at standard width for the class of highway. However, on two-way two-lane highways, the shoulder may be reduced to 1.2 m with justification.

1010.05 Passing Lanes

(1) General

Passing lanes are desirable where a sufficient number and length of safe passing zones do not exist and the speed reduction warrant for a climbing lane is not satisfied. Figure 1010-5 may be used to determine if a passing lane is recommended.

(2) Design

When a passing lane is justified, design it in accordance with Figure 1010-6. Make the lane long enough to permit several vehicles to pass. Passing lanes longer than 3 km can cause the driver to lose the sense that the highway is basically a two-lane facility.

Passing lanes are preferably four-lane sections.

A three-lane section may be used, however. Alternate the direction of the passing lane at short intervals to ensure passing opportunities for both directions and to discourage illegal actions of frustrated drivers.

Make the passing lane width equal to the adjoining through lane and at the same cross slope. Full-width shoulders for the highway class are preferred; however, with justification, the shoulders may be reduced to 1.2 m. Provide adequate signing and delineation to identify the presence of an auxiliary lane.

1010.06 Slow Moving Vehicle Turnouts

(1) General

On a two-lane highway where passing is unsafe, a slow moving vehicle is required, by RCW 46.61.427, to turn off the through lane wherever a safe turnout exists, in order to permit the following vehicles to proceed. A slow moving vehicle is one that is traveling at a speed less than the normal flow of traffic, behind which five or more vehicles are formed in a line.

A slow moving vehicle turnout is not an auxiliary lane. Its purpose is to provide sufficient room for a slow moving vehicle to safely pull out of through traffic and stop if necessary, allow vehicles following to pass, then return to the through lane. Generally, a slow moving vehicle turnout is provided on existing roadways where passing opportunities are limited, where slow moving vehicles such as trucks and recreational vehicles are predominant, and where the cost to provide a full auxiliary lane would be prohibitive.

(2) Design

Base the design of a slow moving vehicle turnout primarily on sound engineering judgment and Figure 1010-7. Design may vary from one location to another. A minimum length of 30 m provides adequate storage, since additional storage is provided within the tapers and shoulders. The maximum length is 0.5 km including tapers. Surface turnouts with a stable unyielding material such as BST or ACP with adequate structural strength to support the heavier traffic.

Locate slow vehicle turnouts where at least Design Stopping Sight Distance (Chapter 650) is available, decision sight distance is preferred, so that vehicles can safely reenter the through traffic. Sign slow moving vehicle turnouts to identify their presence.

When a slow moving vehicle turnout is to be built, document the location and why it was selected.

1010.07 Shoulder Driving for Slow Vehicles

(1) General

For projects where climbing or passing lanes are justified, but are not within the scope of the project, or where meeting the warrants for these lanes are borderline, the use of a shoulder driving section is an alternative.

Review the following when considering a shoulder driving section:

- Horizontal and vertical alignment
- Character of traffic
- Presence of bicycles
- Clear zone (Chapter 700)

(2) Design

When designing a shoulder for shoulder driving, use a minimum length of 180 m. The minimum shoulder width is 2.4 m with 3.0 m preferred. When barrier is present, the minimum width is 3.0 m with 3.6 m preferred. Adequate structural strength for the anticipated traffic is necessary and may require reconstruction. Select locations where the side slope meets the requirements of Chapter 640 for new construction and Chapter 430 for existing roadways. When a transition is required at the end of a shoulder driving section, use a 50:1 taper.

Signing for shoulder driving is required. Install guideposts when shoulder driving is to be permitted at night.

Document the need for shoulder driving and why a lane is not being built.

1010.08 Emergency Escape Ramps

(1) General

Consider an emergency escape ramp whenever long steep down grades are encountered. In this situation the possibility exists of a truck losing its brakes and going out of control at a high speed. Consult local maintenance personnel and check traffic accident records to determine if an escape ramp is justified.

(2) Design

(a) **Type.** Escape ramps are one of the following types:

- Gravity escape ramps are ascending grade ramps paralleling the traveled way. They are commonly built on old roadways. Their long length and steep grade can present the driver with control problems, not only in stopping, but with rollback after stopping. Gravity escape ramps are the least desirable design.
- Sand pile escape ramps are piles of loose, dry sand dumped at the ramp site, usually not more than 120 m in length. The deceleration is usually high and the sand can be affected by weather conditions; therefore, they are less desirable than arrester beds. However, where space is limited they may be suitable.
- Arrester beds are parallel ramps filled with a smooth, coarse, free-draining gravel. They stop the out-of-control vehicle by increasing the rolling resistance. Arrester beds are commonly built on an up grade to add the benefits of gravity to the rolling resistance. However, successful arrester beds have been built on a level or descending grade.

(b) **Location.** The location of an escape ramp will vary depending on terrain, length of grade, and roadway geometrics. The best locations include in advance of a critical curve, near the bottom of grade, or before a stop. It is desirable that the ramp leave the roadway on a tangent at least 5 km from the beginning of the down-grade.

(c) **Length.** Lengths will vary depending on speed, grade, and type of design used. The minimum length is 60 m. Calculate the stopping length using the following equation:

$$L = \frac{V^2}{0.98(R \pm G)}$$

Where:

L = stopping distance (m)
V = entering speed (mph)
R = rolling resistance (see Figure 1010-1)
G = grade of the escape ramp (%)

Speeds of out-of control trucks rarely exceed 90 mph; therefore, an entering speed of 90 mph is preferred. Other entry speeds may be used when justification and the method used to determine the speed is documented.

Material	R
Roadway	1
Loose crushed aggregate	5
Loose noncrushed gravel	10
Sand	15
Pea gravel	25

Rolling Resistance (R)
Figure 1010-1

(d) **Width.** The width of each escape ramp will vary depending on the needs of the individual situation. It is desirable for the ramp to be wide enough to accommodate more than one vehicle. The desirable width of an escape ramp to accommodate two out-of-control vehicles is 12 m and the minimum width is 8 m.

(e) The following items are additional considerations in the design of emergency escape ramps:

- If possible, at or near the summit, provide a pull-off brake-check area. Also, include informative signing about the upcoming escape ramp in this area.
- A free draining, smooth, noncrushed gravel is preferred for an arrester bed. To assist in smooth deceleration of the vehicle, taper the depth of the bed from 75 mm at the entry to a full depth of 600 to 750 mm in not less than 30 m.
- Mark and sign in advance of the ramp. Discourage normal traffic from using or parking in the ramp. Sign escape ramps in accordance with the guidance contained in the MUTCD for runaway truck ramps.

- Provide drainage adequate to prevent the bed from freezing or compacting.
- Consider including an impact attenuator at the end of the ramp if space is limited.
- A surfaced service road adjacent to the arrester bed is needed for wreckers and maintenance vehicles to remove vehicles and make repairs to the arrester bed. Anchors are desirable at 90 m intervals to secure the wrecker when removing vehicles from the bed.

A typical example of an arrester bed is shown in Figure 1010-8.

Include justification, all calculations, and any other design considerations in the documentation of an emergency escape ramp documentation.

1010.09 Chain-Up Area

Provide chain-up areas to allow chains to be put on vehicles out of the through lanes at locations where traffic enters chain enforcement areas. Provide chain-off areas to remove chains out of the through lanes for traffic leaving chain enforcement areas.

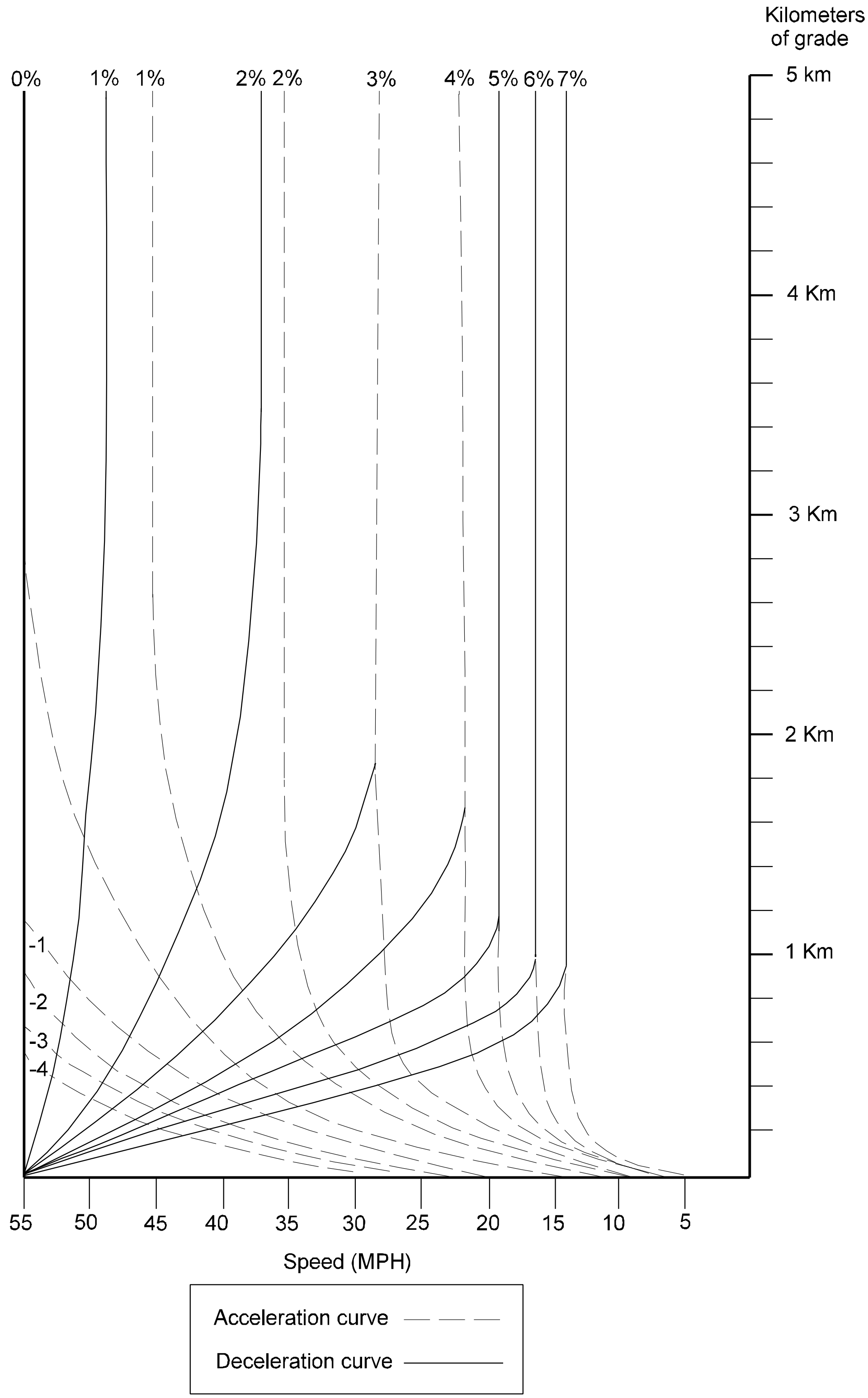
Chain-up or chain-off areas are widened shoulders, designed as shown in Figure 1010-9. Locate chain-up and chain-off areas where the grade is 6% or less and preferably on a tangent section.

Consider illumination for chain-up and chain-off areas on multilane highways. When deciding whether or not to install illumination, consider traffic volumes during the hours of darkness and the availability of power.

1010.10 Documentation

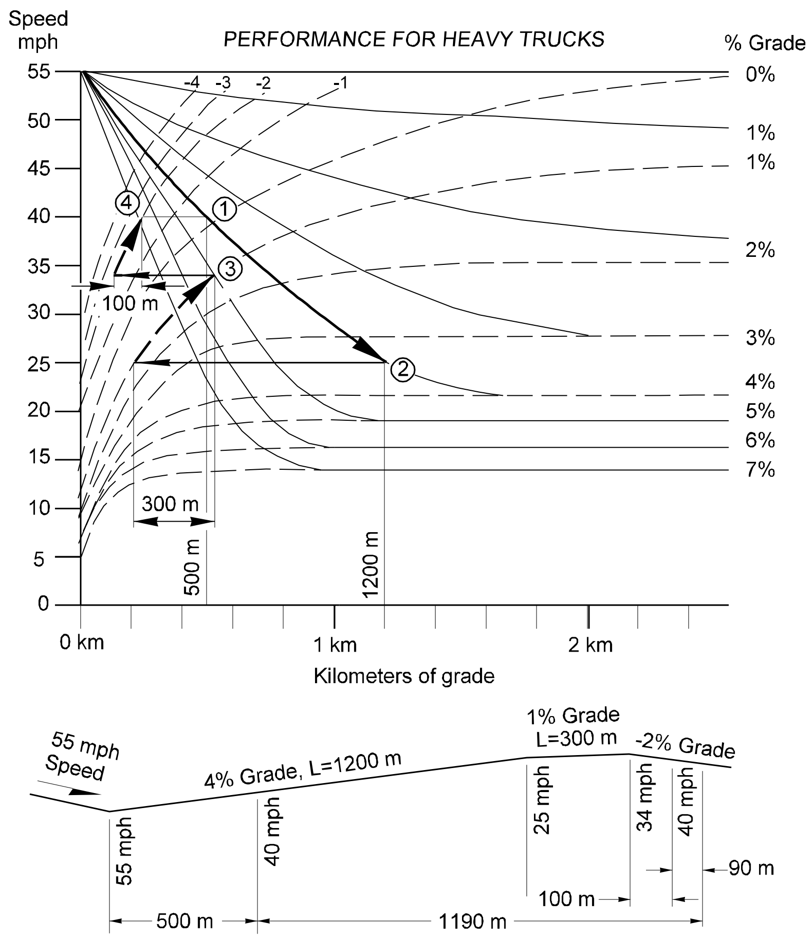
The following documents are to be preserved in the project file. See Chapter 330.

- ☐ Documentation that climbing lane warrant 1 has been met
- ☐ Documentation that climbing lane warrant 2 has been met
- ☐ Justification for waiving climbing lane warrant 1 or 2
- ☐ Justification for passing lanes
- ☐ Slow moving vehicle turnout documentation
- ☐ Emergency escape ramp documentation



Performance For Heavy Truck

Figure 1010-2a



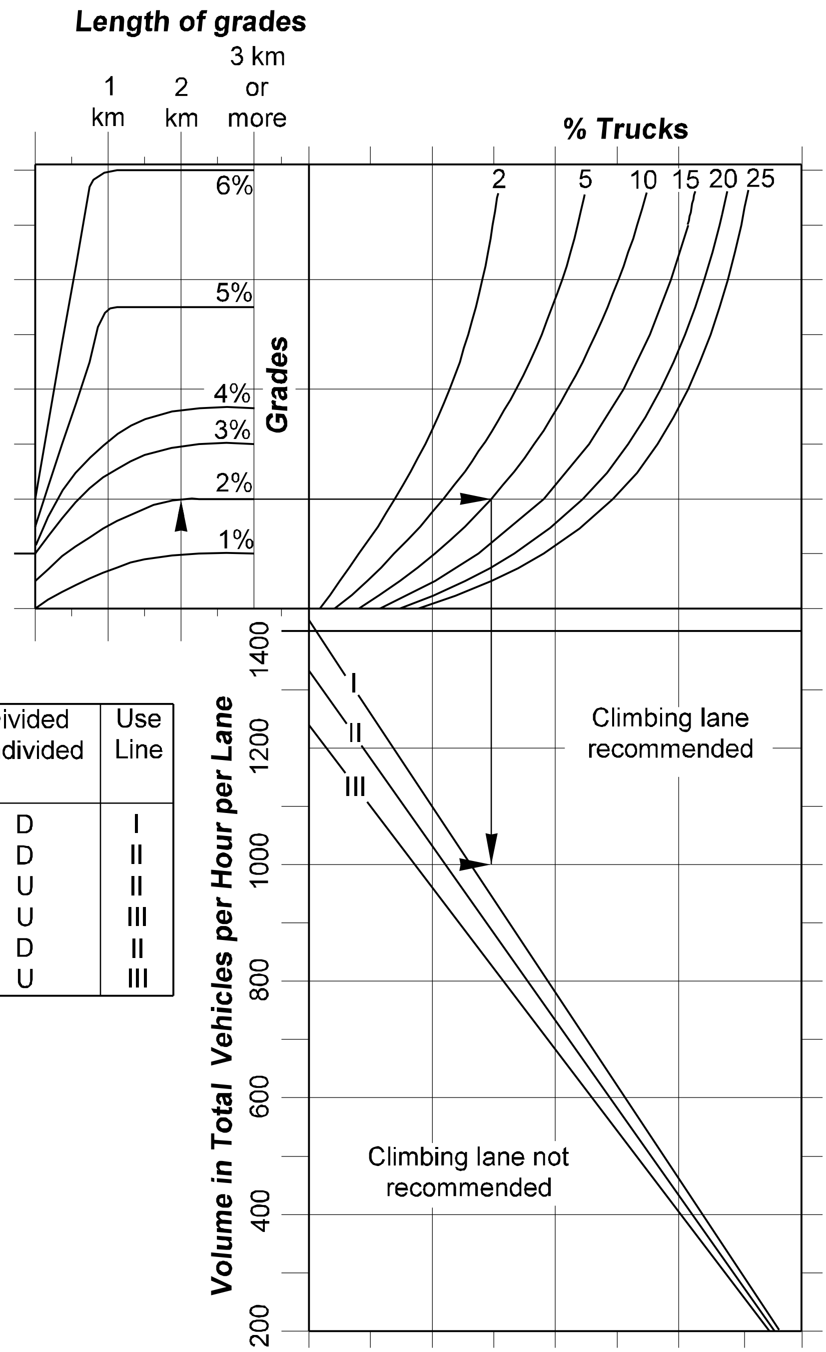
Given: A 2-lane highway meeting the level of service warrant, with the above profile, and a 55 mph posted speed.

Determine: Is the climbing lane warranted and, if so, how long?

Solution:

1. Follow the 4% grade deceleration curve from a speed of 55 mph to a speed of 40 mph at 500 m. The speed reduction warrant is met and a climbing lane is needed.
2. Continue on the 4% grade deceleration curve to 1200 m. Note that the speed at the end of the 4% grade is 25 mph.
3. Follow the 1% grade acceleration curve from a speed of 25 mph for 300 m. Note that the speed at the end of the 1% grade is 34 mph.
4. Follow the -2% grade acceleration curve from a speed of 34 mph to a speed of 40 mph, ending the speed reduction warrant. Note the distance required is 100 m.
5. The total auxiliary lane length is (1200-500)+300+100+90=1190 m. 90 m is added to the speed reduction warrant for a 2-lane highway, see the text and Figure 1010-4.

Speed Reduction Example
Figure 1010-2b



Lane Width (m)	Lateral Clearance (m)	Divided Undivided	Use Line
3.6	≥ 1.8	D	I
3.6	< 1.8	D	II
3.6	≤ 1.8	U	II
3.6	< 1.8	U	III
3.3	All	D	II
3.3	All	U	III

Example

2% grade for 2 km
10% trucks
3.6 m lanes
lateral clearance
≥ 1.8
4 lane, divided
DDHV = 2000
From the chart, climbing lane is recommended.

Level of Service — Multilane
Figure 1010-3

1020 Bicycle Facilities

1020.01 General

The Washington State Department of Transportation (WSDOT) encourages multimodal use of its transportation facilities. Bicycle facilities or improvements for bicycle transportation are included in the project development and highway programming processes where bicycle use is likely and can be accommodated safely.

This chapter is to serve as a guide for selecting and designing the most useful and cost-effective bicycle facility possible and for how to include the region's Bicycle Coordinator in the design process. These guidelines apply to normal situations encountered during project development. Unique design problems are resolved on a project-by-project basis using guidance from the region's Bicycle Coordinator.

State law (46.61.710 RCW) prohibits the operation of mopeds on facilities specifically designed for bicyclists, pedestrians, and equestrians. Mopeds are not considered in the design process for the purposes of this chapter.

In general, do not mix equestrian and bicycle traffic on a shared use path. Consider designing a bridle trail that is separate from the shared use path in common equestrian corridors.

1020.02 References

Guide for the Development of Bicycle Facilities, 1999, AASHTO

*A Policy on Geometric Design of Highways and Streets (*Green Book), 1994, AASHTO

Manual on Uniform Traffic Control Devices (MUTCD), Federal Highway Administration (FHWA), National Advisory Committee on Uniform Traffic Control Devices including the *Washington State Modifications to the MUTCD,* M 24-01, WSDOT

Washington Administrative Code (WAC) 468-95-035, Pavement Edge and Raised Pavement Markers Supplementing Other Markings

Revised Code of Washington (RCW) 46.61, Rules of the Road

RCW 46.61.710, Mopeds, electric-assisted bicycles—General requirements and operation

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

State Highway System Plan, WSDOT

1020.03 Definitions

bicycle route A system of bikeways, designated by the jurisdiction(s) having the authority, featuring appropriate directional and informational route markers. A series of bikeways may be combined to establish a continuous route and may consist of any or all types of bicycle facilities.

bike lane A portion of a highway or street identified by signs and/or pavement markings reserved for bicycle use.

bikeway Any trail, path, part of a highway or shoulder, or any other traveled way specifically signed and/or marked for bicycle travel.

Category A bicyclist Advanced or experienced riders who are generally using their bicycles as they would a motor vehicle. They want direct access to destinations with a minimum of delay and are comfortable riding with motor vehicle traffic. When touring, their vehicles are commonly heavily loaded with a tandem rider(s), children, or camping gear. They need sufficient operating space on the traveled way or shoulder to eliminate the need for them or passing vehicles to shift position.

Category B bicyclist Basic or less confident adult bicyclists who might be using their bicycles for transportation purposes. They prefer to avoid roads with fast and busy motor vehicle traffic unless there is ample roadway width. Basic bicyclists are comfortable riding on neighborhood streets and shared use paths; however, on busier streets, they prefer designated facilities such as bike lanes or wide shoulder lanes.

Category C bicyclist Children, riding alone or with their parents, who need access to key destinations in the community such as schools, friends, recreational facilities, and convenience stores. Residential streets with low motor vehicle speeds (linked with shared use paths and busier streets with well-defined pavement marking between bicycles and motor vehicles) can accommodate children without encouraging them to ride in the traveled lane of major arterials.

rural bicycle touring routes State highways or sections of state highways that are used or have a high potential for use by Category A bicyclists riding long distance on single or multiday trips.

shared roadway A roadway that is open to both bicycle and motor vehicle travel. Shared roadways do not have dedicated facilities for bicycle travel.

signed shared roadway (designated as a bike route) A shared roadway that has been designated by signing as a preferred route for bicycle use. Appropriate bike route signs are installed to assure bicyclists that improvements such as widening shoulders have been made to improve safety.

shared use path A facility on exclusive right of way with minimal cross flow by motor vehicles. It is designed and built primarily for use by bicycles but is also used by pedestrians, joggers, skaters, wheelchair users (both nonmotorized and motorized), and others.

1020.04 Planning

(1) General

Bikeway planning includes provisions and facilities for safe and efficient bicycle travel. An effective multimodal transportation program addresses the issue of upgrading highways to accommodate shared use by bicyclists and motorists.

Bicyclists of all skill levels will use well-designed facilities. Bicyclists will avoid a poorly designed facility.

To enhance bicycle travel, consider upgrading existing roads that are used regularly by Category A or B bicyclists. The upgrading includes improving the width and quality of the surface and maintaining the right-hand portion in a condition suitable for bicycle riding.

Consider bicycle facilities when designing construction projects and normal safety and operational improvements. Shoulder widening projects along existing highways, might be an opportunity to encourage bicycle traffic and enhance bicycle safety. Correcting short areas of restricted width (such as bridges, cuts, or fills) to provide bikeways might not be cost effective. However, the presence of these short, restricted areas does not diminish the importance of widening the adjoining shoulder sections.

Bikeway planning is an integral part of the facility planning for other transportation modes and land use development. Use the location criteria that follow for long-term planning and project development as applicable.

(2) Programming

The *State Highway System Plan* identifies two elements of bicycle project funding:

- Urban Bicycle Projects: Complete local bicycle networks by building short sections of appropriate bicycle facilities along or across state highways.
- Rural Bicycle Touring Routes: Shoulder improvements along sections of designated state routes.

Urban Bicycle Projects have been prioritized by the region's Planning Offices, the OSC Bicycle Program, and the department's Bicycle Advisory Committee and are listed in the *State Highway System Plan*. Urban Bicycle Projects are selected in each region, prioritized, and will compete for funding.

Rural Bicycle Touring Routes (RBTR) programming priority areas are listed in the *State Highway System Plan*. Each region's Planning Office has a map with the priority areas marked. The purpose of the RBTR program is to add funding to a project in an RBTR shoulder deficiency area. Designers are to consult the region's Planning Office to determine if their project is within an RBTR shoulder deficiency area. If the project is within an RBTR shoulder deficiency area, the designer requests the region's Program Management to determine RBTR funding availability.

Consider spot bikeway improvements in other types of projects such as P1 paving and I2 safety improvement projects. Identify small improvements in the project definition phase. Consult the region's Bicycle Coordinator for recommendations and the limits of the work. Funding from other sources such as the Urban Bicycle and Rural Bicycle programs might be available.

(3) Selection of the Type of Facility

In selecting an appropriate facility, ensure that the proposed facility will not encourage or require bicyclists or motorists to operate in a manner that is inconsistent with the Rules of the Road (RCW 46.61).

An important consideration is route continuity. Alternating bikeways from side to side along a route is generally unacceptable. Designing a route that requires bicyclists to cross the roadway could result in inappropriate maneuvers and/or encourage Rules of the Road violations. In addition, wrong-way bicycle travel might occur beyond the ends of shared use paths because of the inconvenience of having to cross the street.

Many factors are involved in determining which type of facility will benefit the greatest number of bicyclists. Outlined below are the most common applications for each type.

Shared Use Path
Figure 1020-1

(a) **Shared Use Path.** The most common applications for shared use paths (See Figure 1020-1) are along rivers and streams, ocean beachfronts, canals, utility rights of way, and abandoned railroad rights of way; within college campuses; and within and between parks. There might also be situations where such facilities can be provided as part of planned developments. Another common application of shared use paths is to close gaps in bicycle travel caused by construction of freeways, or the existence of natural barriers (rivers, mountains, and other large geographic features).

Generally, shared use paths are used to serve corridors not served by streets and highways or where wide rights of way exist permitting such facilities to be constructed away from the influence of parallel roadways. Shared use paths offer opportunities not provided by the road system. They can either provide a recreational opportunity or serve to minimize motor vehicle interference by providing direct high-speed bicycle commute routes.

Bike Lane
Figure 1020-2

(b) **Bike Lane.** Bike lanes are established along streets in corridors where there is or, in the future, might be significant bicycle demand. (See Figure 1020-2.) Bike lanes delineate the rights of way assigned to bicyclists and motorists and provide for movements that are more predictable by each. An important reason for establishing bike lanes is to better accommodate bicyclists through corridors where insufficient room exists for safe bicycling on existing streets. This can be accomplished by reducing the number of lanes or prohibiting parking in order to delineate bike lanes.

Where street improvements are not possible, improve the bicyclist's environment by providing shoulder sweeping programs and special signal facilities.

When considering the selection of appropriate streets for bike lanes, refer to the location criteria discussed in 1020.04(4).

Do not designate sidewalks as bike lanes.

Shared Roadway
Figure 1020-3

(c) **Shared Roadway.** Most bicycle travel in Washington occurs on highways and streets without bikeway designations. (See Figure 1020-3.) In most instances, entire street systems are fully adequate for safe and efficient bicycle travel and signing and pavement markings for bicycle use are unnecessary.

The region's Traffic are responsible for determining sections of state highways where bicycle traffic is inappropriate. The State Traffic Engineer, after consultation with the Bicycle Advisory Committee, prohibits bicycling on sections of state highways through the traffic regulation process. Also, see Chapter 1420 "Access Control Design Policy".

Bicyclists traveling between cities, or on recreational trips, may use many rural highways. In most cases, rural highways are not designated as bike routes because of the limited use and the lack of continuity with other bike routes. However, the development and maintenance of paved shoulders, with or without a standard edge stripe, can significantly improve safety and convenience for bicyclists and motorists along such routes.

Signed Shared Roadway
(Designated Bike Route)
Figure 1020-4

(d) **Signed Shared Roadway.** Designate signed shared roadways as bike routes by posting bike route signs. (See Figure 1020-4.) These routes provide continuity to other bicycle facilities and designate preferred routes through high bicycle-demand corridors. As with bike lanes, designating shared roadways as bike routes is an indication to bicyclists that there are particular advantages to using these bike routes as compared with alternative routes. This means that the responsible agencies have taken action to ensure that these routes are suitable as bike routes and are maintained in a manner consistent with the needs of bicyclists. Signing also alerts motor vehicle operators that bicycles are present.

Use the following criteria to aid in determining whether or not to designate and sign a bike route:

- The route offers a higher degree of service than alternative streets.
- It provides for through and direct travel in bicycle-demand corridors.
- It connects discontinuous segments of bikeways.
- Traffic control devices have been adjusted to accommodate bicyclists.
- Street parking is restricted for improved safety where lane width is critical.
- Surface hazards to bicyclists have been corrected.
- Maintenance of the route is to a higher standard than comparable streets, such as more frequent street sweeping and repair.

In general, do not designate sidewalks as bikeways for the following reasons:

- Sidewalks tend to be used in both directions, despite any signing to the contrary.
- At approaches to intersections, parked cars might impede sight distance of motorists and bicyclists. At driveways, property fences, shrubs, and other obstructions often impair sight distances.
- At intersections, motorists are not looking for bicyclists entering the crosswalk area, particularly when motorists are making a turn.
- Sidewalks are typically designed for pedestrian speeds, and might not be safe for higher-speed use. Conflicts between bicyclists and pedestrians are common, as are conflicts with fixed objects such as parking meters, utility poles, signposts, bus shelters, benches, trees, hydrants, and mailboxes. In addition, bicyclists riding on the curb side of sidewalks might accidentally drop off the sidewalk into the path of motor vehicle traffic.

Only consider a sidewalk as a bike route under special circumstances, such as on long, narrow bridges. Even then, the preferred solution is to widen the roadway to provide space for bicyclists. In residential areas, sidewalk riding is commonly done by Category B and C bicyclists who are not comfortable riding in the street. However, it is inappropriate to sign these facilities as bike routes.

(4) Location Criteria

Factors to consider in determining the location of a bikeway are:

(a) **Potential Use.** Locate bikeways along corridors or a convenient road parallel to the corridor to maximize use. However, to attract commuting bicyclists, the roadway must offer through route conditions.

(b) **Directness.** Locate facilities along a direct line and in such a way that they connect bicycle traffic generators for the convenience of the users. Bicyclists are interested in the same destinations as motorists.

(c) **Access.** When locating a shared use path, provide adequate access points. The more access points, the more the facility will be used. Adequate access for emergency and service vehicles is also necessary.

(d) **Shared Use Path Widths.** Figure 1020-13 shows the widths and minimum horizontal clearances needed when a shared use path is on an alignment separate from a highway right of way.

Figure 1020-14 shows shared use path width when adjacent to a roadway and within its right of way. See 1020.05(2)(e) to find if a barrier will be needed.

(e) **Available Roadway Width.** For a bike lane or shared roadway (with or without signing), the overall roadway width must meet or exceed the highway minimum design criteria. See Chapter 430 "Modified Design Level" and 440 "Full Design Level" and Figures 1020-14 and 1020-15 for further width information.

(f) **On-Street Motor Vehicle Parking.** Consider the density of on-street parking and the safety implications, such as opening car doors. If possible, select a route where on-street parking is light or where it can be prohibited.

(g) **Delays.** Bicyclists have a strong desire to maintain momentum. If bicyclists are required to make frequent stops, they might avoid the route.

(h) **Traffic Volumes and Speeds.** For an on-street bikeway, the volume and speed of auto traffic, along with the available width, are factors in determining the best location. Commuting bicyclists generally ride on arterial streets to minimize delay and because they are normally the only streets offering continuity for trips of several miles. The FHWA has developed a spreadsheet to evaluate roadways for bicycle compatibility. The Bicycle Compatibility Index (BCI) measures roadways based on traffic volume, speed, lane width, and other factors. A copy of the BCI and supporting information is found at http://www.hsrc.unc.edu/research/pedbike/bci/index.html

(i) **Truck and Bus Traffic.** High-speed truck, bus, and recreational vehicle traffic can cause problems along a bikeway because of aerodynamic effects and vehicle widths. Evaluate the need to widen shoulders or change the location of the bicycle facility if it is on a roadway with this type of traffic.

(j) **Existing Physical Barriers.** In some areas there are physical barriers to bicycle travel caused by topographical features such as rivers, limited access highways, or other impediments. In such cases, developing a facility that allows a bikeway to cross an existing barrier can provide access opportunities for bicyclists.

(k) **Collision History.** Check the collision experiences along a prospective bicycle route to determine its relative safety compared to other candidate routes. This involves analysis of the collision types to determine which of them might be reduced. (See 1020.04(4)(p).) Consider both the impacts caused by adding bicycle traffic and the potential for introducing new accident problems. The region's Traffic Office is a good resource when considering collision factors.

(l) **Grades.** Avoid steep grades on bikeways whenever possible. Refer to 1020.05(2)(k) for specific criteria.

(m) **Pavement Surface Quality.** Establish an on-street bikeway only where pavement can be brought to a reasonable condition for safe bicycle travel. Dense graded asphalt concrete surfaces are preferable to open-graded asphalt concrete, Portland cement concrete, and seal-coated surfaces.

(n) **Maintenance.** Ease of maintenance is an important consideration in locating and developing a bikeway. Consider the ease of access by maintenance vehicles. Bicyclists will often shun a poorly maintained bikeway in favor of a parallel roadway. Consult with area maintenance personnel during the planning stage.

(o) **Environmental Compatibility.** Consider scenic value, erosion and slope stability, and compatibility with the surrounding terrain when developing a bikeway. Provide landscaping to minimize adverse environmental effects.

(p) **Use Conflicts.** Different types of facilities produce different types of conflicts. On-street bikeways involve conflicts with motor vehicles. Shared use paths usually involve conflicts with other bicyclists, pedestrians, skaters, and runners on the path, and with motor vehicles at street intersections. Conflicts between bicyclists and motorists can also occur at highway and driveway intersections, tight corners, and narrow facilities like bridges and tunnels.

(q) **Security.** The potential for criminal acts against bicyclists and other users of bikeways exists anywhere, especially along remote stretches. There also is the possibility of theft or vandalism at parking locations. Consult local law enforcement agencies for guidance in making these areas safer. Also consider installation of telephones in high risk areas.

(r) **Cost/Funding.** Location selection will normally involve a cost comparison analysis of alternatives. Funding availability will often eliminate some alternatives; however, it is more desirable to delay constructing a bicycle facility than to construct an inadequate facility.

(s) **Structures.** Continuity can be provided to shared use path by using an overpass, underpass, tunnel, bridge, or by placing the facility on a highway bridge to cross obstacles. See 1020.05(2)(m) for design information.

Retrofitting bicycle facilities on existing bridges involves a large number of variables; compromises in desirable design criteria are often inevitable. The planner, with the assistance of the region's Bicycle Coordinator and the Bridge and Structures Office, on a case-by-case basis, will determine the desirable design criteria.

Consider the following alternatives when placing a shared use path on an existing highway bridge:

- On one side of a bridge. Do this where: the bridge facility connects at both ends to the path; there is sufficient width on that side of the bridge or additional width can be gained by remarking the pavement; and provisions have been made to physically separate the motor vehicle traffic from the bicycle traffic. See Figure 1020-16.
- Provide bicycle lanes, shoulders, or wide curb lanes over a bridge. This is advisable where: bike lanes and shoulders connect on either end of the structure, and when sufficient width exists or can be obtained by widening or remarking the pavement. Use this option only if the bike lane or wide outside lane can be accessed without increasing the potential for wrong-way riding or inappropriate crossing movements.

(v) **Lighting.** Illumination of bicycle facilities might be necessary to achieve minimum levels of safety, security, and visibility.

(w) **Support Facilities.** Where bicycles are used extensively for utility trips or commuting, consider placing adequate bicycle parking and/or storage facilities at common destinations (such as park and ride lots, transit terminals, schools, and shopping centers). Contact the region's Bicycle Coordinator for additional information.

1020.05 Design

(1) Project Requirements

For urban bicycle mobility improvement projects (Bike/Ped connectivity projects in the matrices, Chapter 325), apply the guidance in this chapter to the bikeway.

For highway design elements affected by the project, apply the appropriate design level (Chapter 325) and as found in the applicable *Design Manual* chapters.

For highway design elements not affected by the project, no action is required.

(2) Design Criteria for Shared Use Path

Shared use paths are facilities for the primary use of bicyclists but are also used by pedestrians, joggers, skaters, and others.

(a) **Widths.** The geometric guidelines for shared use paths are shown in Figures 1020-13 and 1020-14.

A path width of 2.4 m may be used when all the following conditions apply:

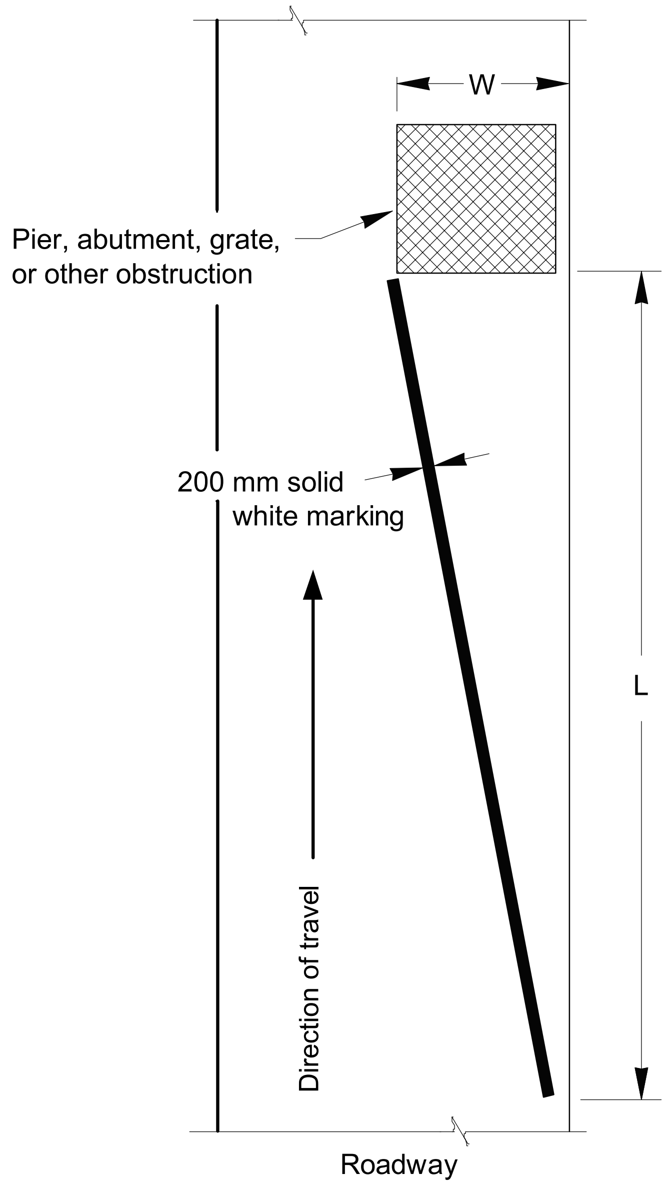
- Bicycle traffic is expected to be low (less than 60 bicycles per day [bpd]).
- Pedestrian use is not expected to be more than occasional.
- The horizontal and vertical alignment adequately provide safe and frequent passing opportunities.
- Normal maintenance activities can be performed without damaging the pavement edge.

The minimum paved width for a one-way shared use path is 1.8 m. Use this minimum width only after ensuring that one-way operation will be enforced and maintenance can be performed.

Where the shared use path is adjacent to canals, ditches, or fill slopes steeper than 1V:3H, consider a wider separation. A minimum 1.5 m separation from edge of the pavement to the top of slope is desirable. A physical barrier, such as dense shrubbery, railing, or chain link fence is needed at the top of a high embankment and where hazards exist at the bottom of an embankment.

(b) **Clearance to Obstructions**. The desirable horizontal clearance from the edge of pavement to an obstruction (such as a bridge pier) is at least 0.6 m. Where this cannot be obtained; install signs and pavement markings to warn bicyclists of the condition. See Figure 1020-5 for pavement marking details.

The required minimum vertical clearance from bikeway pavement to overhead obstructions is 2.4 m. However, a higher vertical clearance might be needed for passage of maintenance and emergency vehicles.



L = WV, where V is bicycle approach speed (mph)

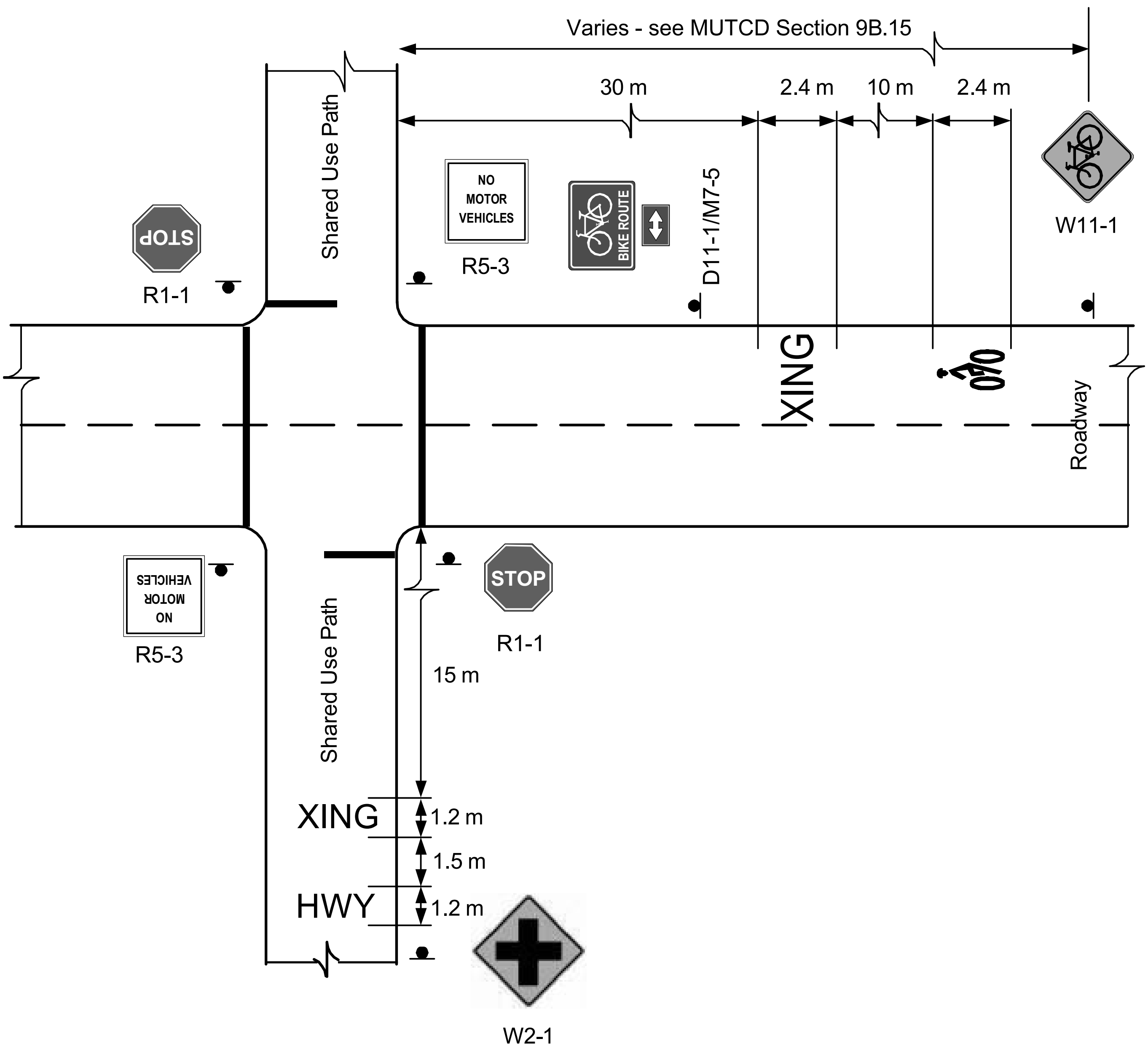
Obstruction Marking
Figure 1020-5

(c) **Intersections with Highways.** Collisions at intersections are the most common type of motor vehicle/bicycle collision. Shared use path and roadway intersections must clearly define who has the right of way and provide adequate sight distance for both users. There are three types of shared use path/roadway at-grade intersection crossings: midblock, adjacent path, and complex. Only at-grade midblock and adjacent crossings are addressed here. Complex intersections involve special designs which must be considered on a case-by-case basis.

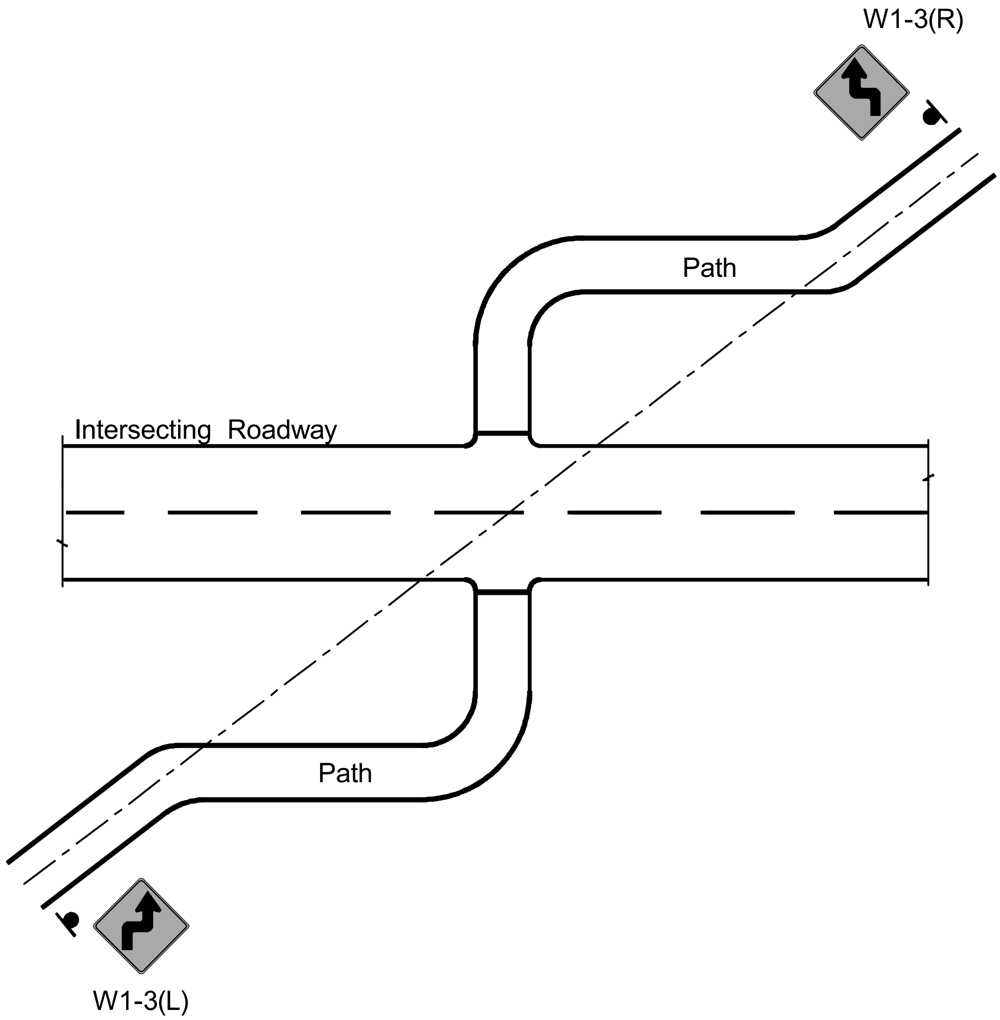
At-grade crossings at existing intersections are usually placed with existing pedestrian crossings where motorists can be expected to stop. If alternate intersection locations for a shared use path are available, select the one with the greatest sight distance.

When possible, place a crossing away from an intersection in order to eliminate conflicts.

Midblock crossings are the least complex of the other types of crossings. Locate midblock path crossings far enough away from intersections so that there is no conflict between the path crossing and the intersection motor vehicle traffic activities. A 90-degree intersection crossing is preferable (Figure 1020-6). A 75-degree angle is acceptable. A 45-degree angle is the minimum acceptable to minimize right of way requirements. A diagonal midblock crossing can be altered as shown in Figure 1020-7.



Midblock Type Shared Use Path Crossing
Figure 1020-6



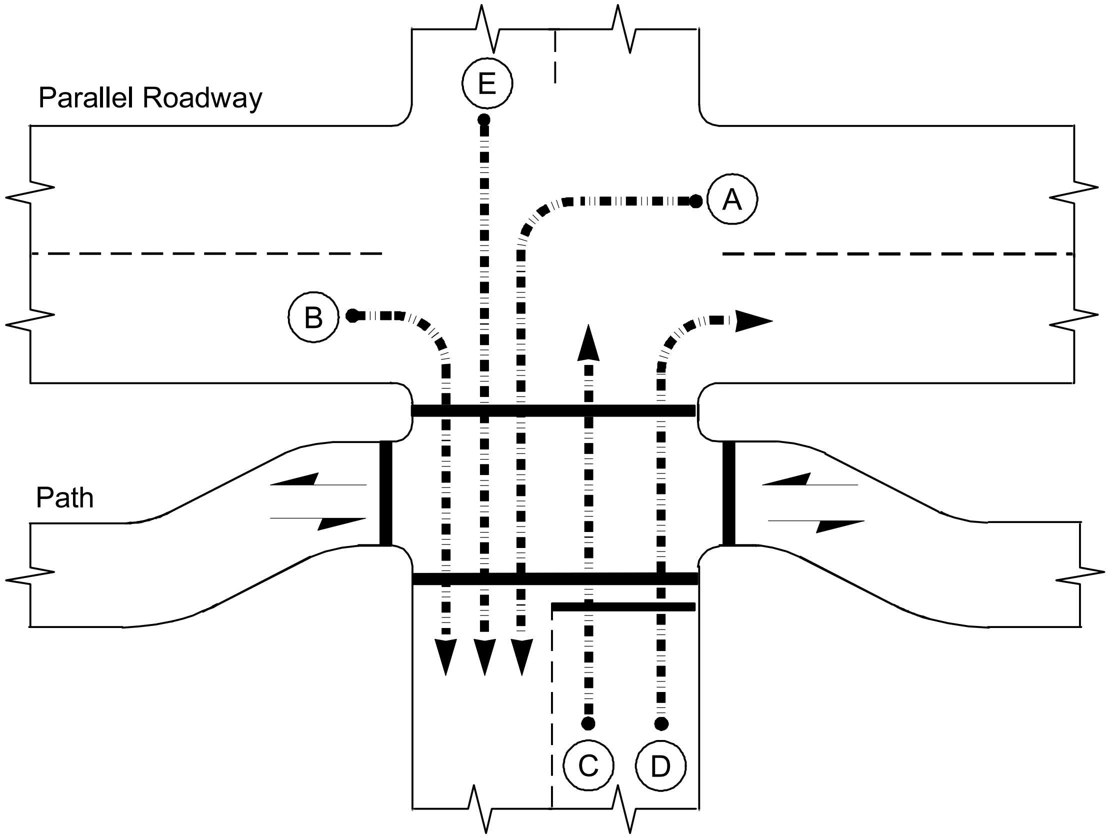
Note: The path and highway signing and markings are the same as in Figure 1020-6

Typical Redesign of a Diagonal Midblock Crossing
Figure 1020-7

There are other considerations when designing midblock crossings, including right of way assignment, traffic control devices, sight distances for both bicyclists and motor vehicle operators, refuge island use, access control, and pavement markings.

Adjacent path crossings occur where a path crosses an existing intersection of two roadways, a T intersection (including driveways), or a four-way intersection as shown in Figure 1020-8. It is preferable to integrate this type of crossing close to an intersection so that motorists and path users recognize each other as intersecting traffic. The path user faces potential conflicts with motor vehicles turning left (A) and right (B) from the parallel roadway, and on the crossed roadway (C, D, E).

Complex intersection crossings are all other types of path/roadway or driveway junctions. These include a variety of configurations where the path crosses directly through an existing intersection of two or more roadways and where there can be any number of motor vehicle turning movements.



Note: Signing will be the same as shown in Figure 1020-6.

Adjacent Shared Use Path Intersection
Figure 1020-8

Improvements to complex crossings must be considered on a case-by-case basis. Suggested improvements include: move the crossing, install a signal, change signization timing, or provide a refuge island and make a two-step crossing for path users.

The major road might be either the parallel or the crossed roadway. Important elements that greatly affect the design of these crossings are: right of way assignment, traffic control devices, and separation distance between path and roadway.

Other roadway/path design considerations:

- **Traffic signals/stop signs**. Determine the need for traffic control devices at all path/roadway intersections by using MUTCD warrants and engineering judgment. Bicycles are considered vehicles in Washington State and bicycle path traffic can be classified as vehicular traffic for MUTCD warrants. Ensure that traffic signal timing is set for bicycle speeds.
- **Manually operated signal actuation mechanisms.** Locate the bicyclist's signal button where it is easily accessible to bicyclists and 1.2 m above the ground and place a detector loop in the path pavement.
- **Signing**. Place path stop signs as close to the intended stopping point as possible. Four-way stops at shared use path and roadway intersections are not advisable due to confu-

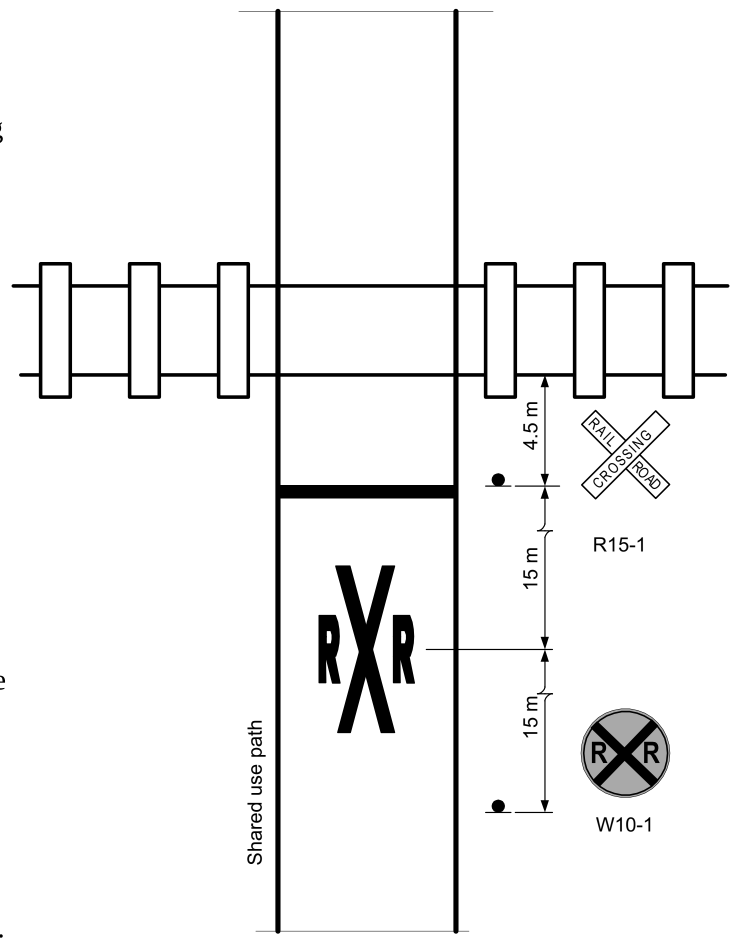
sion about or disregard for right of way laws. Yield signs for path traffic are acceptable at some locations, such as low-volume, low-speed neighborhood streets. Sign type, size, and location must be in accordance with the MUTCD. Do not place the shared use path signs where they will confuse motorists or place roadway signs where they will confuse bicyclists.

- **Approach treatments.** Design shared use path and roadway intersections with flat grades and adequate sight distances. Evaluate stopping sight distance at the intersection. Provide adequate advance warning signs and pavement makings (see MUTCD and Washington State Modifications to the MUTCD) that alert and direct bicyclists to stop before reaching the intersection, especially on downgrades. Provide unpaved shared use paths with paved aprons extending a minimum of 3.0 m from the paved road surfaces. Speed bumps or other similar surface obstructions intended to cause bicyclists to slow down are not appropriate.
- **Transition zones.** Integrate the shared use path into the roadway where the path terminates. Design these terminals to transition the bicycle traffic into a safe merging or diverging condition. Appropriate signing is necessary to warn and direct both bicyclist and motorist at the transition areas.
- **Ramp widths.** Design ramps for curb cuts with the same width as the shared use path. Curb cuts and ramps are to provide a smooth transition between the shared use path and the roadway. Consider a 1.5 m radius or flare to facilitate right turns for bicycles. This same consideration applies to intersections of two shared use paths.
- **Refuge islands**. Consider refuge islands when one or more of the following applies: high motor vehicle traffic volume and speeds; wide roadways; crossing will be used by elderly, children, disabled, or other slow moving users. See Figure 1020-17 for details.

(d) **At-Grade Railroad Crossings**. Whenever a bikeway crosses railroad tracks, continue the crossing at least as wide as the approach bikeway. Wherever possible, design the crossing at right angles to the rails. See Figure 1020-18.

For on-street bikeways, where a skew is unavoidable, widen the shoulder (or bike lane) to permit bicyclists to cross at right angles. If this is not possible, consider using special construction and materials to keep the flangeway depth and width to a minimum.

Seen Figure 1020-9 and the MUTCD for the signing and marking for a shared use path crossing a railroad track.



Railroad Crossing for Shared Use Path
Figure 1020-9

(e) **Separation, Barrier, and Fencing.** When possible, provide a wide separation between a shared use path and the traveled way where the path is located near the traveled way.

If the shared use path is inside the Design Clear Zone, provide a traffic barrier. (See Chapter 700, "Roadside Safety," for Design Clear Zone. See Chapter 710, "Traffic Barriers," for barrier location and deflection.) A concrete barrier presents less of a hazard to bicyclists than a W-beam guardrail and is preferred. However, if the edge of the path is farther than 3.0 m from the barrier, a W-beam guardrail is also acceptable.

If the roadway shoulder is less than 1.8 m wide and the edge of path is within 1.5 m of a barrier, provide a taller barrier (minimum of 1.1 m) to reduce the potential for bicyclists falling over the barrier into the traveled way. If the roadway shoulder is more than 1.8 m wide and the edge of path is more than 1.5 m from a barrier, a standard height barrier may be used.

Where the path is to be located next to a limited access facility, there is also a need for an access barrier. Where space permits, fencing, as is described in Chapter 1460, can be provided in conjunction with a standard height barrier. Otherwise, provide a taller barrier (1.37 m minimum height). Provide a taller barrier (1.37 m minimum) on structures specifically designed for bicycle use as is shown on Figure 1020-16.

Fencing between a shared use path and adjacent property may also be necessary to restrict access to the private property. Discuss the need for fencing and the appropriate height with the property owners during project design.

Consider the impacts of barriers and fencing on the sight distances.

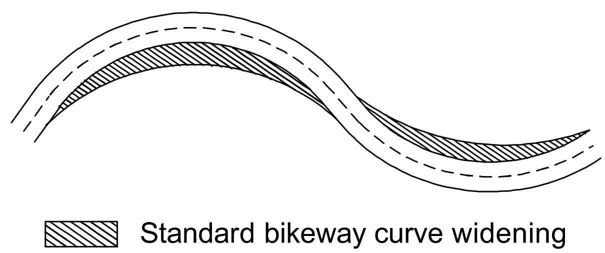
(f) **Design Speed.** The design speed for a shared use path is dependent on the expected conditions of use and on the terrain. See Figure 1020-10 for values.

Conditions	Design Speed MPH	Min. Curve Radius M
Open country (level or undulating); separate shared use path in urban areas	20	22.5
Long down grades (steeper than 4% and longer than 500 ft)	30	49.5

Bicycle Design Speeds
Figure 1020-10

(g) **Horizontal Alignment and Superelevation.** A straight 2% cross slope on tangent path sections is recommended. This is the maximum superelevation used. A greater superelevation can cause maneuvering difficulties for adult tricyclists and wheelchair users.

Increase pavement width up to 1.2 m on the inside of a curve to compensate for bicyclist lean. (See Figure 1020-11.) In sharp curve conditions, consider center line pavement marking on two way facilities.



Radius	Additional Pavement Width
0 m to 7.5 m	1.2 m
7.5 m to 15 m	0.9 m
15 m to 22.5 m	0.6 m
22.5 m to 30 m	0.1 m
30 m +	0 m

Bikeway Curve Widening
Figure 1020-11

(h) **Stopping Sight Distance.** Figure 1020-19 indicates the minimum stopping sight distances for various design speeds and grades. The values are based on a 1.4 m eye height for the bicyclist and 0 m height for the object (roadway surface). On grades, the descending direction controls the design for two-way shared use paths. (Passing sight distance is not considered due to the relatively low speed of bicyclists. Intersection sight distance is not a consideration because of the presence of either signals or stop signs at roadway crossings.)

(i) **Sight Distance of Crest Vertical Curves.** Figure 1020-20, Sight Distance for Crest Vertical Curves, indicates the minimum lengths of crest vertical curves for varying design speeds.

(j) **Lateral Clearance on Horizontal Curves.** Figure 1020-21 indicates the minimum clearances to line-of-sight obstructions for horizontal curves. Obtain the lateral clearance by entering, on the chart, the stopping sight distance from Figure 1020-19 and the proposed horizontal curve radius. Where minimum clearances cannot be obtained, provide standard curve warning signs and use supplemental pavement markings in accordance with the MUTCD.

(k) **Grades.** Some bicyclists are unable to negotiate long, steep uphill grades. Long downgrades can also cause problems on shared use paths. The maximum grade recommended for a shared use path is 5%. It is desirable that sustained grades (245 m or longer) be limited to 2% to accommodate a wide range of users.

The following grade length limits are suggested:

5-6% for up to 245 m
7% for up to 120 m
8% for up to 90 m
9% for up to 60 m
10% for up to 30 m
11+% for up to 15 m

Grades steeper than 3% might not be practicable for shared use paths with crushed stone or other unpaved surfaces for both bicycle handling and traction, and for drainage and erosion reasons.

Options to mitigate steep grades are:

- When using a steeper grade add an additional 1.2 to 1.8 m of width to permit slower speed maneuverability and to provide a place where bicyclists can dismount and walk.
- Use signing in accordance with MUTCD to alert bicyclists of the steep down grades and the need to control their speed.
- Provide adequate stopping sight distance.
- Increase horizontal path side clearances (1.2 to 1.8 m is recommended), and provide adequate recovery area and/or bike rails.

(l) **Pavement Structural Section.** Design the pavement structural section of a shared use path in the same manner as a highway, considering the quality of the subgrade and the anticipated loads on the bikeway. Principle loads will normally be from maintenance and emergency vehicles.

Unless otherwise justified, use asphalt concrete pavement (ACP) in the construction of a shared use path. Asphalt concrete pavement is to be 0.60 mm thick.

Contact the Materials Laboratory for determination of the subgrade R value.

R Value	Subsurfacing Thickness (mm)
< 40	0.105
40 to 65	0.75
> 65	0.60

R Values and Subsurfacing Needs
Figure 1020-12

(m) **Structures.** Structures intended to carry a shared use path only are designed using pedestrian loads and emergency and maintenance vehicle loading for live loads. Provide the same minimum clear width as the approach paved shared use path, plus the graded clear areas. See Figure 1020-13 for path and graded areas.

Carrying full widths across all structures has two advantages:

- The clear width provides a minimum horizontal shy distance from the railing or barrier.
- It provides needed maneuvering room to avoid pedestrians and other bicyclists who have stopped on the bridge.

Undercrossings and tunnels are to have a minimum vertical clearance of 3.0 m from the bikeway pavement to the structure. This allows access by emergency, patrol, and maintenance vehicles on the shared use path.

See Figure 1020-16 for barrier and rail placement on bridges. Consult with Maintenance and the Bridge Preservation Office to verify that these widths are adequate for their needs. If not, widen to their specifications.

Provide a smooth, nonskid surface for bicycles to traverse bridges with metal grid bridge decking. The sidewalk may be used as a bikeway or place signs instructing the bicyclist to dismount and walk for the length of a bridge with this type of decking.

Use bicycle-safe expansion joints for all decks with bikeways.

(n) **Drainage.** Sloping the pavement surface to one side usually simplifies longitudinal drainage design and surface construction and is the preferred practice. (See 1020.05(2)(g) for maximum permitted slope.) Generally, surface drainage from the path will be adequately dissipated as it flows down the gently sloping shoulder. However, a shared use path constructed on the side of a hill might require a drainage ditch on the uphill side to intercept the hillside drainage. Where necessary, install catch basins with drains to carry intercepted water under the path. Refer to Chapter 1210 for other drainage criteria.

Locate drainage inlet grates and manhole covers off the pavement of shared use paths. If manhole covers are needed on a path, install them to minimize the effect on bicyclists. Manhole covers are installed level with the surface of the path.

Drainage inlet grates on bikeways must have openings narrow enough and short enough to ensure that bicycle tires will not drop into the grates. Where it is not immediately feasible to replace existing grates with standard grates designed for bicycles or where grate clogging is a problem, steel cross straps may be installed with a spacing of 150 to 200 mm on centers, to adequately reduce the size of the openings.

(o) **Bollards.** Install bollards at entrances to shared use paths to prevent motor vehicles from entering. When locating such installations, ensure that barriers are well marked and visible to bicyclists, day or night. Installing reflectors or reflectorized tape are ways to provide visibility. See Standard Plan H-13 Type 1 Bollard.

A single bollard installed in the middle of the path reduces the users' confusion. Where more than one post is necessary, use 1.5 m spacing to permit passage of bicycle-towed trailers, wheelchairs, and adult tricycles and to ensure adequate room for safe bicycle passage without dismounting. Design bollard installations so they are removable to permit entrance by emergency and service vehicles, and with breakaway features when in the Design Clear Zone. Ensure that the bollard sleeve is flush with pavement surface.

(p) **Signing and Pavement Markings.** Refer to the MUTCD for guidance and directions for signing and pavement markings for bikeways. Consider a 100 mm yellow center line to separate opposing directions of travel where there is heavy use, on curves where there is restricted sight distance, and where the path is unlighted and nighttime riding is expected. A 100 mm white line on each edge of the path helps to delineate the path if nighttime use is expected. Lateral and vertical clearance for signs is shown on Figure 1020-13.

(q) **Lighting**. The level of illumination required on a bicycle facility is dependent upon the amount of nighttime use expected and the nature of the area surrounding the facility Refer to Chapter 840 for additional guidance concerning illumination of bikeways. Bikeway/roadway intersection lighting is recommended.

(3) Design Criteria for Bike Lane

(a) **Widths**. Some typical bike lane configurations are illustrated in Figure 1020-15 and are described below:

Figure 1020-15, Design A, depicts bike lanes on an urban-type curbed street where parking stalls (or continuous parking stripes) are marked. Locate bike lanes between the parking area and the traffic lanes. Minimum widths are shown.

Do not place bike lanes between the parking area and the curb. Such facilities create hazards for bicyclists, such as opening car doors and poor visibility at intersections. Also, they prevent bicyclists from leaving the bike lane to turn left and they cannot be effectively maintained.

Figure 1020-15, Design B, depicts bike lanes on an urban-type curbed street, where parking is permitted. Establish bike lanes in conjunction with the parking areas. As indicated, 3.6 m is the minimum width of the bike lane where parking is permitted. This type of lane is satisfactory where parking is not extensive and where turnover of parked cars is infrequent. However, an additional width of 0.3 to 0.6 m is recommend if parking is substantial or turnover of parked cars is high.

Figure 1020-15, Design C, depicts bike lanes along the outer portions of an urban-type curbed street where parking is prohibited. This configuration eliminates potential conflicts with motor vehicle parking. Opening car doors is an example. Minimum widths are shown. Both minimum widths shown must be achieved. With a normal 0.6 m gutter, the minimum bike lane width is 1.5 m. Post NO PARKING signs when necessary.

Figure 1020-15, Design D, depicts bike lanes on a highway without curbs and gutters. Minimum widths are shown. Additional width is desirable, particularly where motor vehicle operating speeds exceed 40 mph.

High-speed truck, bus, and recreational vehicle traffic can cause problems along a bike lane because of aerodynamic effects and vehicle widths. Increase shoulder width to accommodate the large vehicles and bicycle traffic when 5% or more of the daily traffic is truck, bus, or recreational vehicle traffic.

Bike lanes are not advisable on long, steep downgrades where bicycle speeds greater than 30 mph can be expected. As grades increase, downhill bicycle speeds will increase, which increases the handling problems if riding near the edge of the roadway. In such situations, bicycle speeds can approach those of motor vehicles, and Category A bicyclists will generally move into the motor vehicle lanes to increase sight distance and maneuverability. However, Category B & C bicyclists might be placed in a hazardous position, thus signing in accordance with the MUTCD is needed to alert them of the grade and the need to control their speeds.

Bike lanes are usually placed on the right side of one-way streets. Consider placing the bike lane on the left side only when it produces fewer conflicting movements between bicycles and motor vehicles.

(b) **Intersection and Signal Design**. Most motor vehicle/bicycle collisions occur at intersections. For this reason, design bike lanes at intersections in a manner that will minimize confusion for motorists and bicyclists and will permit both users to operate in accordance with the Rules of the Road. *(RCW 46.61)*

Figure 1020-22 illustrates a typical intersection of multilane streets, with bike lanes on all approaches. Some common movements of motor vehicles and bicycles are shown. At intersections where there are bike lanes and traffic signals, consider the installation of loop detectors within the bike lane (in advance of the intersection). Select loop detectors sensitive enough to detect bicycles. Bicyclists generally prefer not to use push button actuators, as they must go out of the way to actuate the signal. For additional guidance on signal design at intersections involving bike lanes, refer to Chapter 850.

Figures 1020-23a and b illustrate two pavement marking pattern options where bike lanes cross freeway off and on-ramps. Option 1 provides a defined crossing point for bicyclists that want to stay on their original course. This option is desirable when bicyclists for various reasons do not have a good view of traffic. Use Option 2 where bicyclists normally have a good view of traffic entering or exiting the roadway and will adjust their path to cross ramp traffic. A bike crossing sign is intended for use on highways to warn motorists of the possibility of bicyclists crossing the roadway.

Dashed lines across the off-ramp are not permitted.

Figure 1020-24 illustrates the recommended pavement marking patterns where bike lanes cross a channelized right turn only lane. When approaching such intersections, bicyclists will have to merge with right-turning motorists. Since bicyclists are typically traveling at speeds less than motorists, they can signal and merge where there is a sufficient gap in right-turning traffic, rather than at any predetermined location. For this reason, it is most effective to eliminate all delineations at the approach of the right turn lane (or off-ramp) or to extend a single, dashed bike lane line at a flat angle across the right turn lane. A pair of parallel lines (delineating a bike lane crossing) to channelize the bike merge is not recommended as this encourages bicyclists to cross at a predetermined location. In addition, some motorists might assume they have the right of way and neglect to yield to bicyclists continuing straight.

A dashed line across the right-turn-only lane is not recommended where there are double right-turn-only lanes. For these types of intersections, drop all pavement markings to permit judgment by the bicyclists to prevail.

(c) **Traffic Signals**. At signalized intersections, consider bicycle traffic when timing the traffic signal cycle and when selecting the method of detecting the presence of the bicyclist. Contact the region's Bicycle Coordinators for assistance in determining the timing criteria.

(d) **Signing and Pavement Markings**. Use the general guidelines in the MUTCD, Part IX, and the Washington State Modifications to the MUTCD for acceptable signing and pavement marking criteria. Additional guidelines are shown on Figures 1020-15, 1020-25, and 1020-26. Lateral and vertical clearance for signs is shown on Figure 1020-13.

(f) **Drainage Grates and Manhole Covers**. Locate drainage inlet grates and manhole covers to avoid bike lanes. When drainage grates or manhole covers are located on a bike lane, minimize the effect on bicyclists. A minimum of 0.9 m of lateral clearance is needed between the edge of a drainage inlet grate and the shoulder stripe. Install and maintain grates and manhole covers level with the surface of the bike lane.

For more information see 1020.05(2)(n).

(4) Design Criteria for Shared Roadway

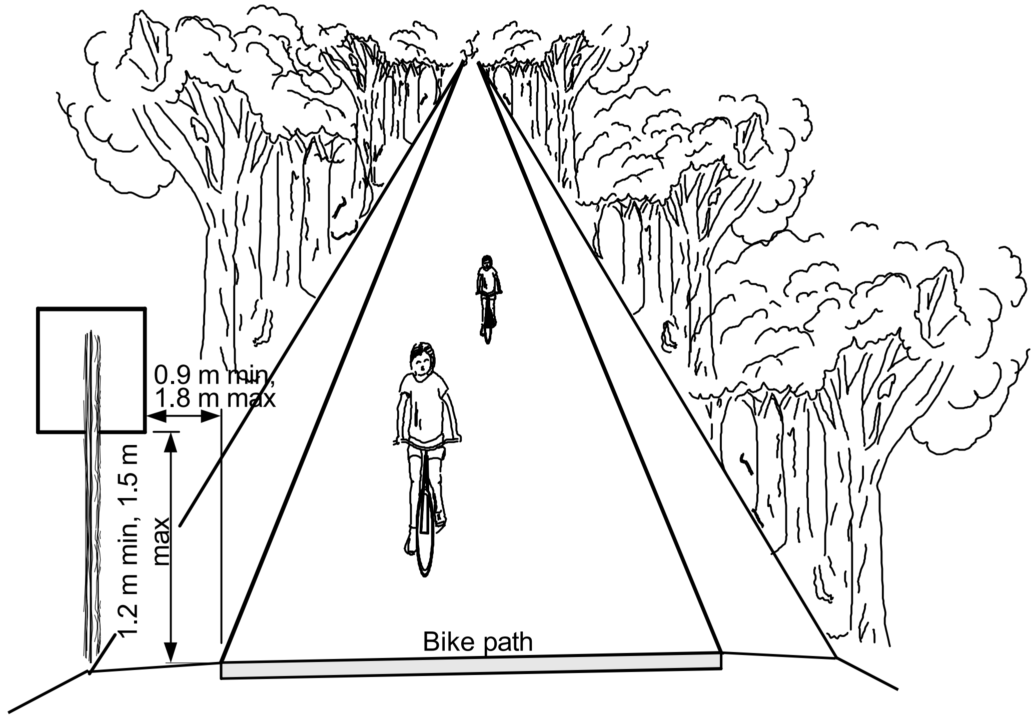
Any improvements for motor vehicle traffic on a shared roadway will also improve the traveling conditions for bicycles.

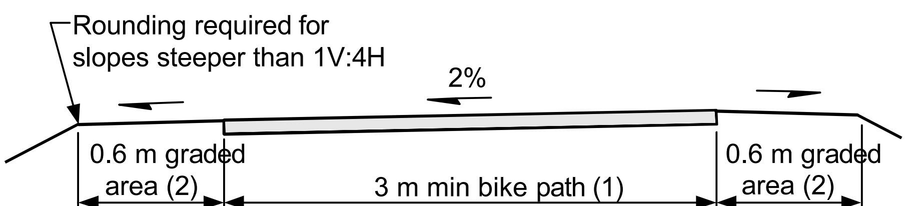
A shared roadway designated as a bike route offers a greater degree of service to bicyclists than other roadways. Establish a bike route by placing the MUTCD Bicycle Route signs or markers along the roadway. Improvements might have to be made for safer bicycle travel. Some improvements for facilitating better bicycle travel are widening the shoulders using the shoulder criteria in Chapter 430 "Modified Design Level" and 440 "Full Design Level", adding pavement markings, improving roadside maintenance, removing surface hazards such as drain grates not compatible with bicycle tires, and other facilities to provide better traveling for bicyclists.

1020.06 Documentation

The following documents are to be preserved in the project file. See Chapter 330.

- ☐ Justification for reduction of roadway cross sections
- ☐ Justification for reduction of bikeway cross sections
- ☐ New or major improvement projects where bike lanes or bike paths are not accommodated (except where prohibited).



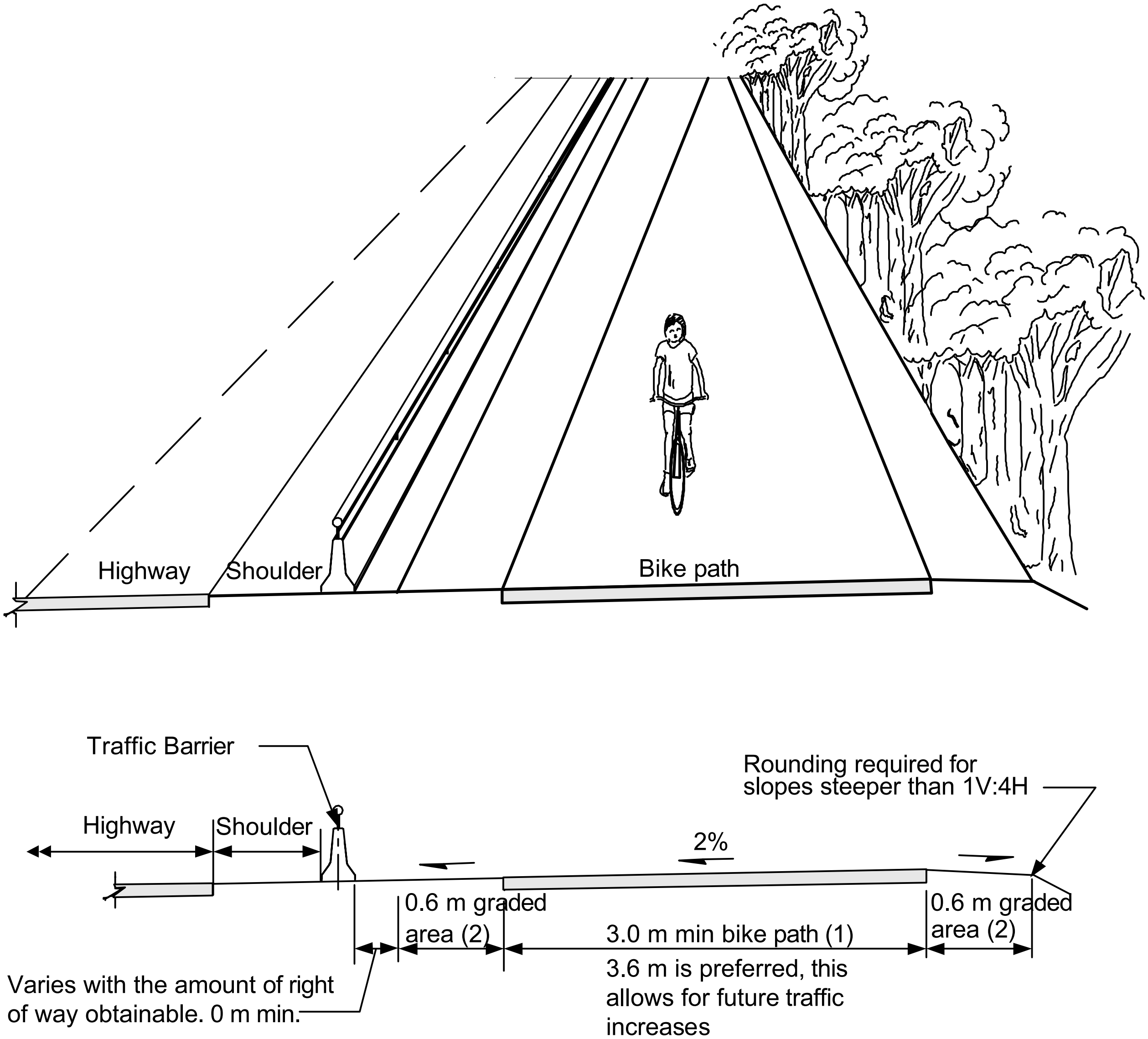


NOTE:

(1) Use 3.6 to 4.2 m when maintenance vehicles use a shared use path as an access road for utilities. Use of 3.6 to 4.2 m paths is recommended when there will be substantial use by bicycles ($\geq$ 60 bicycles per day), or joggers, skaters, and pedestrians (20 per hour). Contact region's Bicycle Coordinator for bicycle use information. See 1020.05(2)(a) for more discussion on bicycle path widths.

(2) Where the paved width is wider than the minimum required, reduce the graded area accordingly.

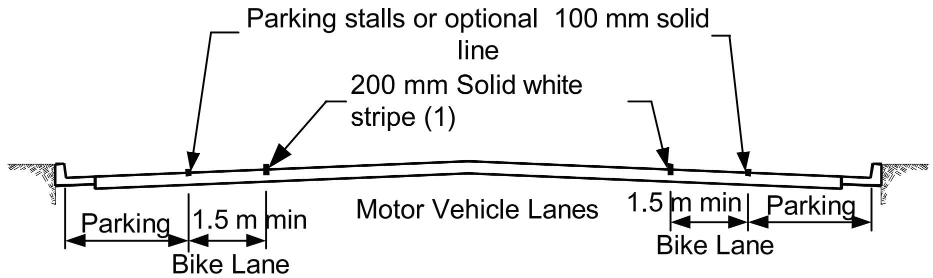
Two-Way Shared Use Path on Separate Right of Way
Figure 1020-13



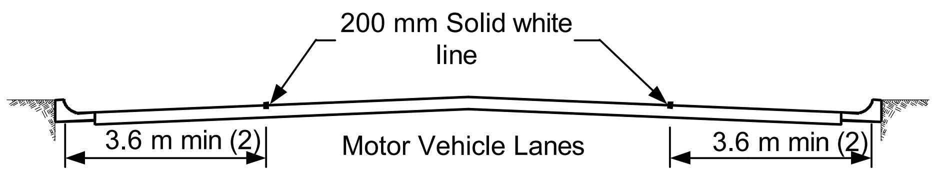
For Notes (1) and (2) see Figure 1020-13

See 1020.05(2)(e) for selecting barriers between bicycle path and shoulder and the need for fencing on limited access roadways.

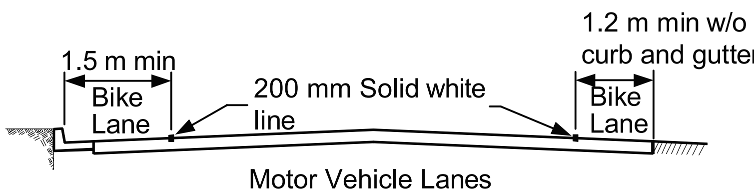
Two-Way Shared Use Path Adjacent to Roadway
Figure 1020-14



Design A marked parking

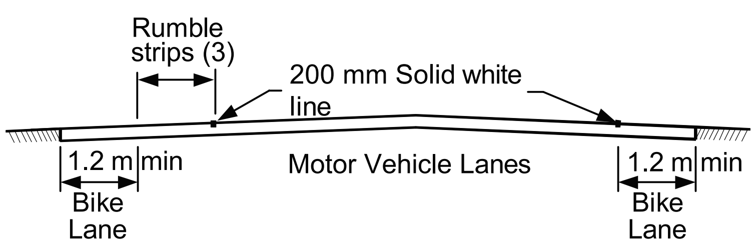


Design B parking permitted without parking line or stall



Design C parking prohibited

Post NO PARKING signs as required



Design D typical roadway

Note:

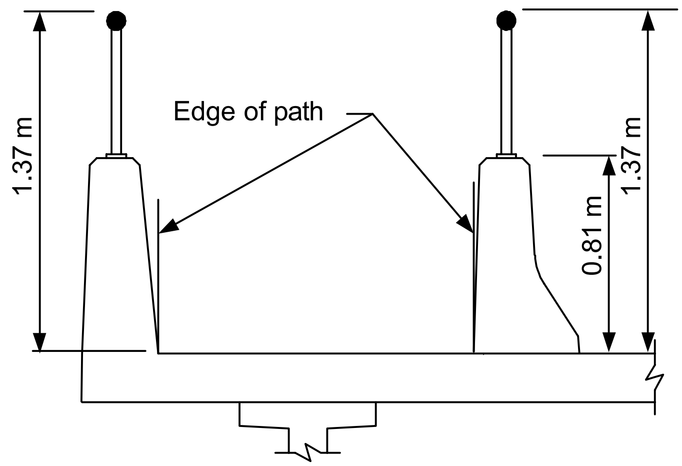
(1) The optional solid white line might be advisable where stalls are unnecessary (because parking is light) but there is concern that motorists might misconstrue the bike lane to be a traffic lane.

(2) 3.9 m to 4.3 m is recommended where there is substantial parking or turnover of parked cars is high.

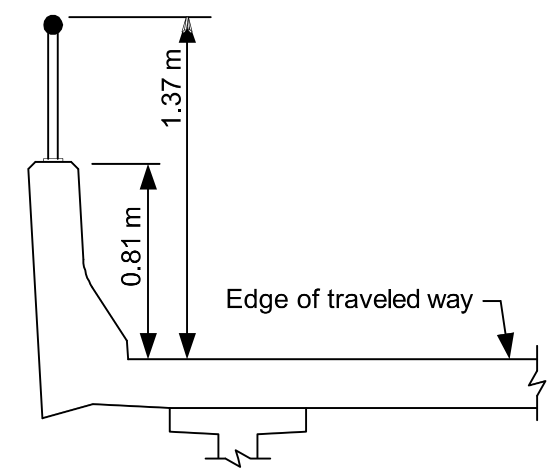
(3) If rumble strips exist, provide 1.2 m minimum from the rumble strips to the outside edge of the shoulder.

Typical Bike Lane Cross Sections

Figure 1020-15



Separated (shared use paths only)



Unseparated (bike lanes and shared roadway)

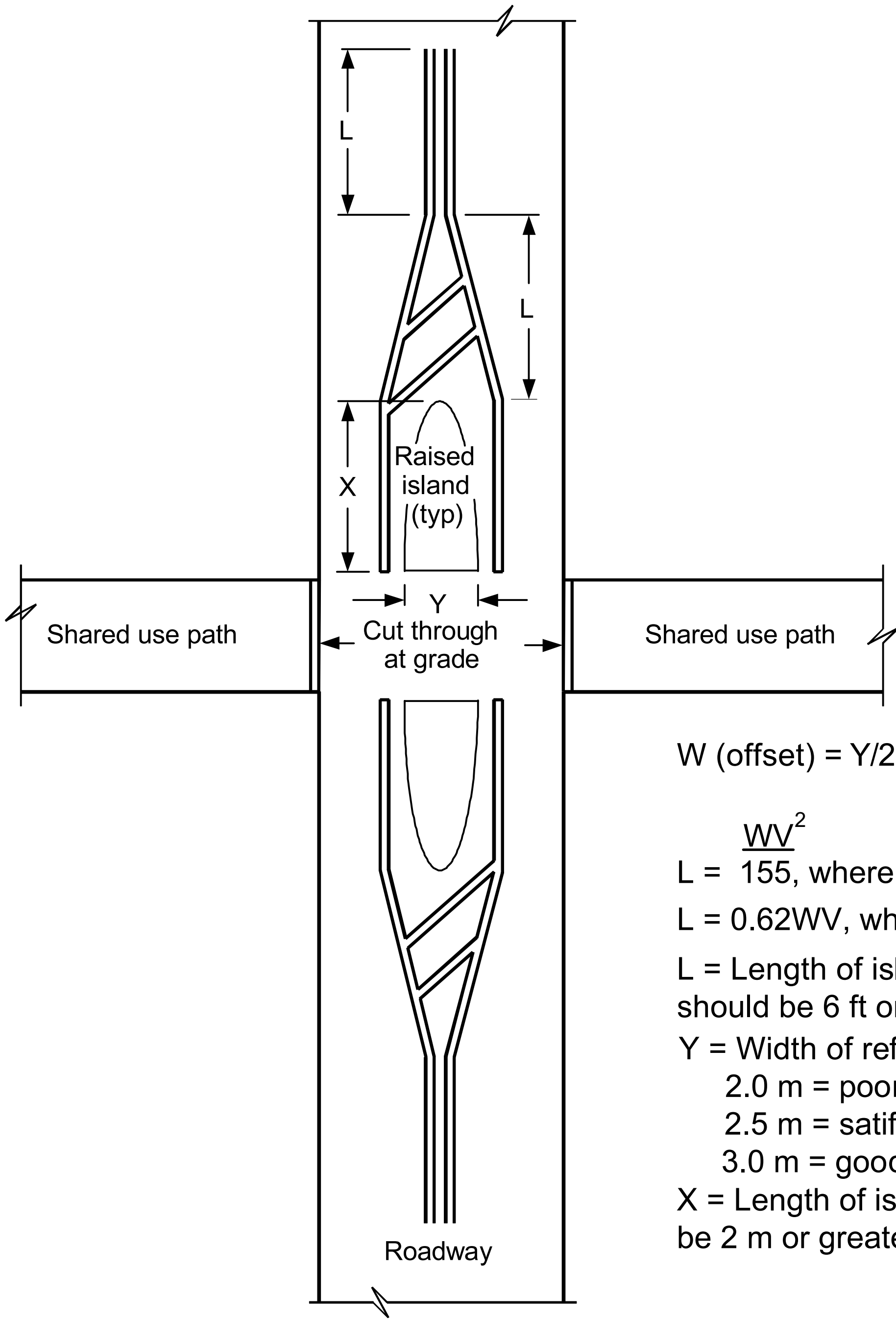
Bicyclists use the shoulder between the edge of traveled way and the bridge rail.

Note:

The above applies to bike lanes and shared use paths. The 0.81 m barrier is used for shared use roadways.

Bikeways on Highway Bridges

Figure 1020-16



W (offset) = Y/2

$L = \frac{WV^2}{155}$, where V < 70 km/h

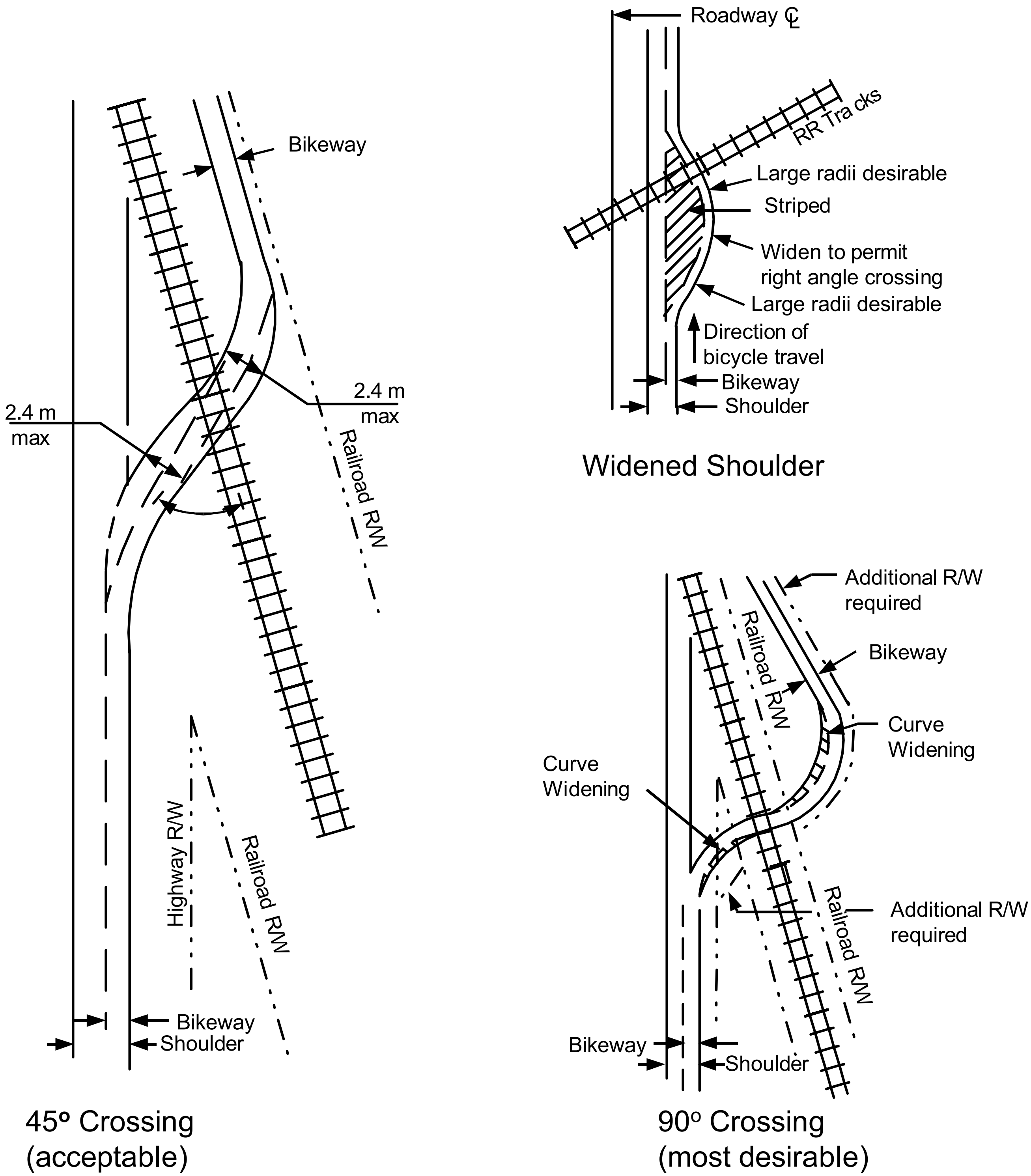
L = 0.62WV, where V $\geq$ 70 km/h

L = Length of island
should be 6 ft or greater

Y = Width of refuge
2.0 m = poor
2.5 m = satifactory
3.0 m = good

X = Length of island sould
be 2 m or greater

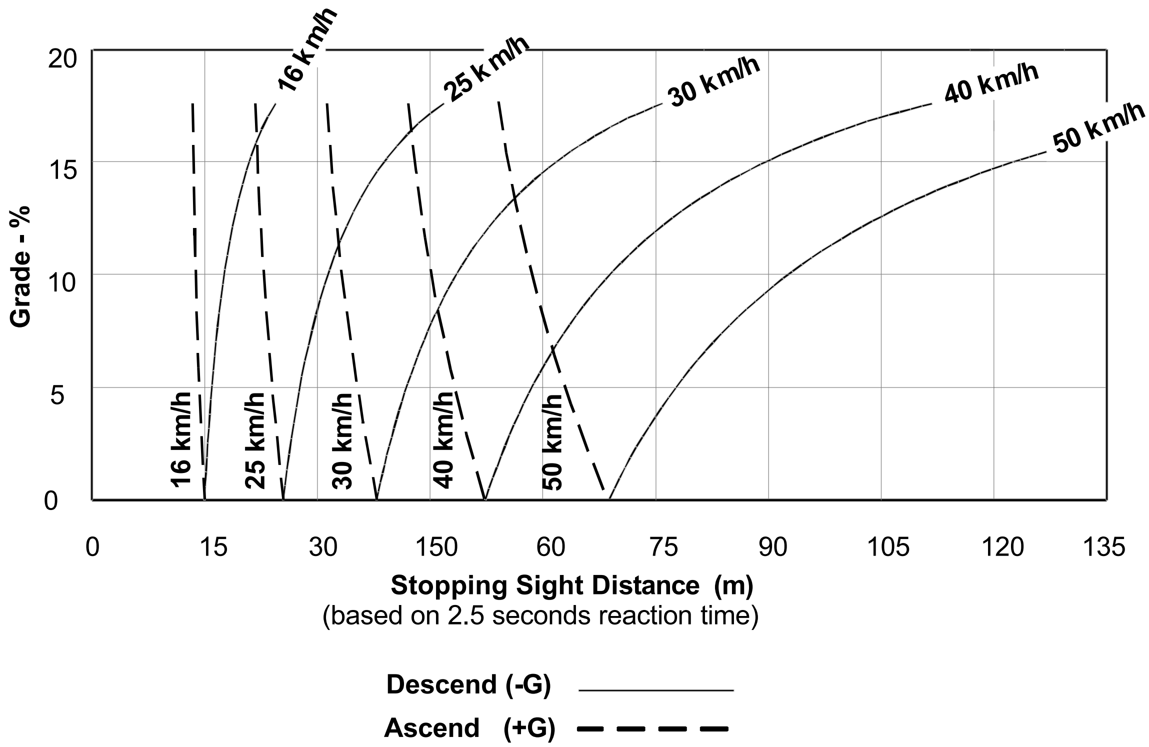
Refuge Area
Figure 1020-17



Note:

Provide additional width to 4.2 m to be provided at railroad crossing to allow bicyclists to choose their own crossing routes.

At-Grade Railroad Crossings
Figure 1020-18

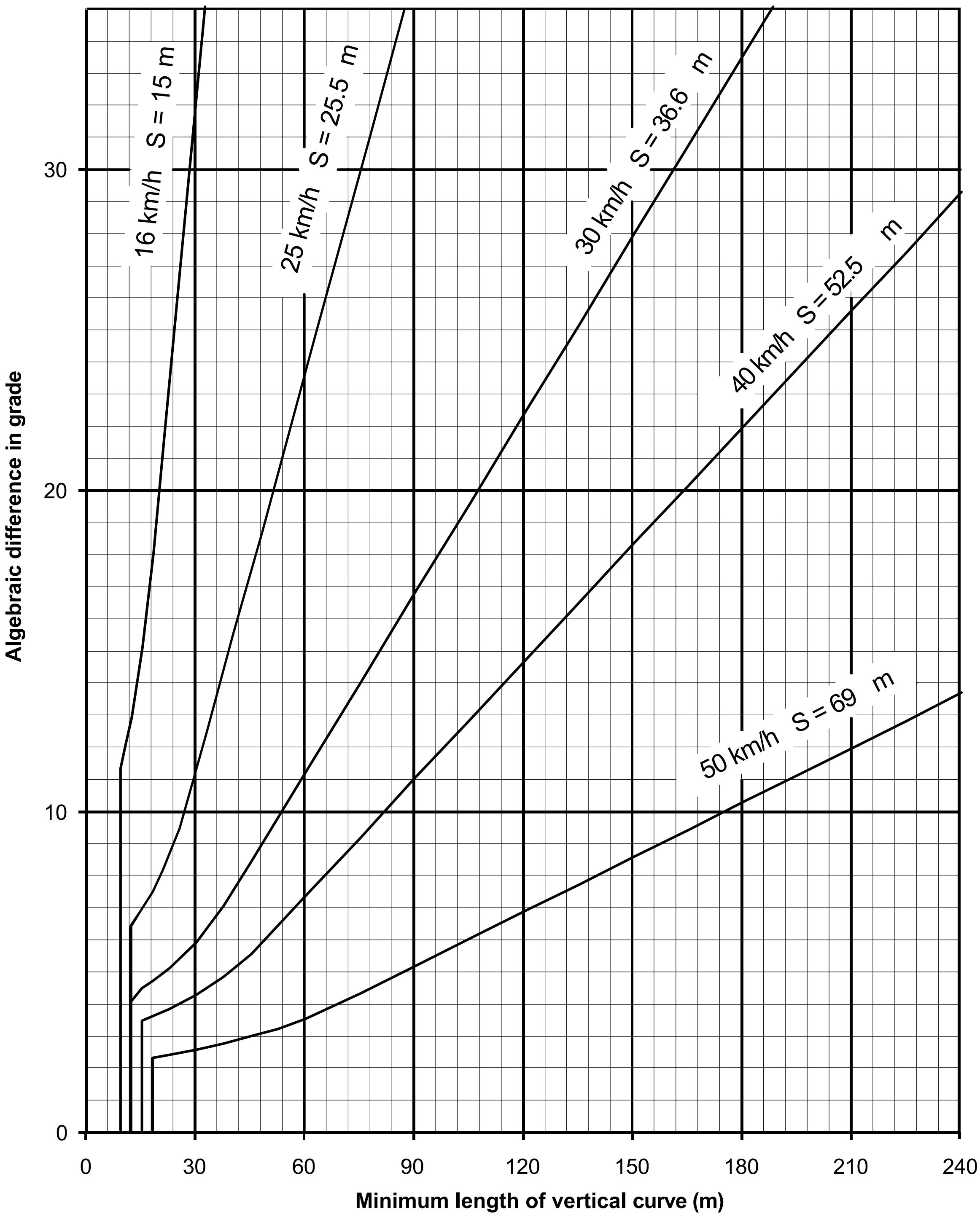


$$S = \frac{V^2}{254\,(f \pm G)} + \frac{V}{1.4}$$

Where:

S = Stopping Sight Distance, m.
f = Coefficient of Friction (use 0.25)
V = Velocity, km/h
G = Grade m/m (rise/run)

Stopping Sight Distance
Figure 1020-19



$$L = \frac{AS^2}{100\left(\sqrt{2h_1}+\sqrt{2h_2}\right)^2} \quad \text{when } S < L$$

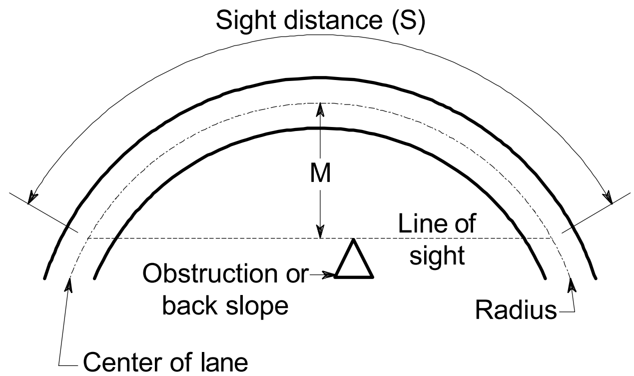
$$L = 2S - \frac{200\left(\sqrt{h_1}+\sqrt{h_2}\right)^2}{A} \quad \text{when } S > L$$

Where:

S = Stopping sight distance.
A = Algebraic difference in grade.
h_1 = 1.4 m (eye height of cyclist)
h_2 = 0 m (height of object)
L = Minimum vertical curve length.

Sight Distances for Crest Vertical Curves
Figure 1020-20

Height of eye: 1.4 m
Height of object: 0.0 m
Line of sight is normally 0.6 m above center line of inside lane at point of obstruction provided no vertical curve is present in horizontal curve.

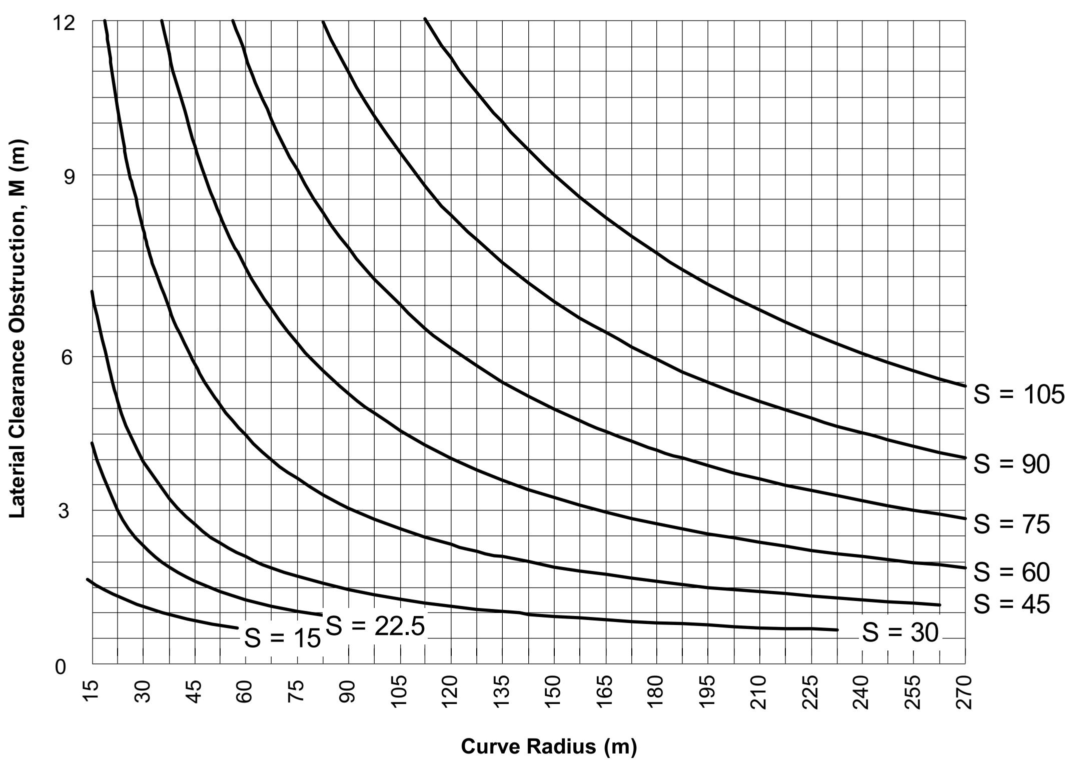


$$M = R\left(1 - \cos\frac{28.65\,S}{R}\right)$$

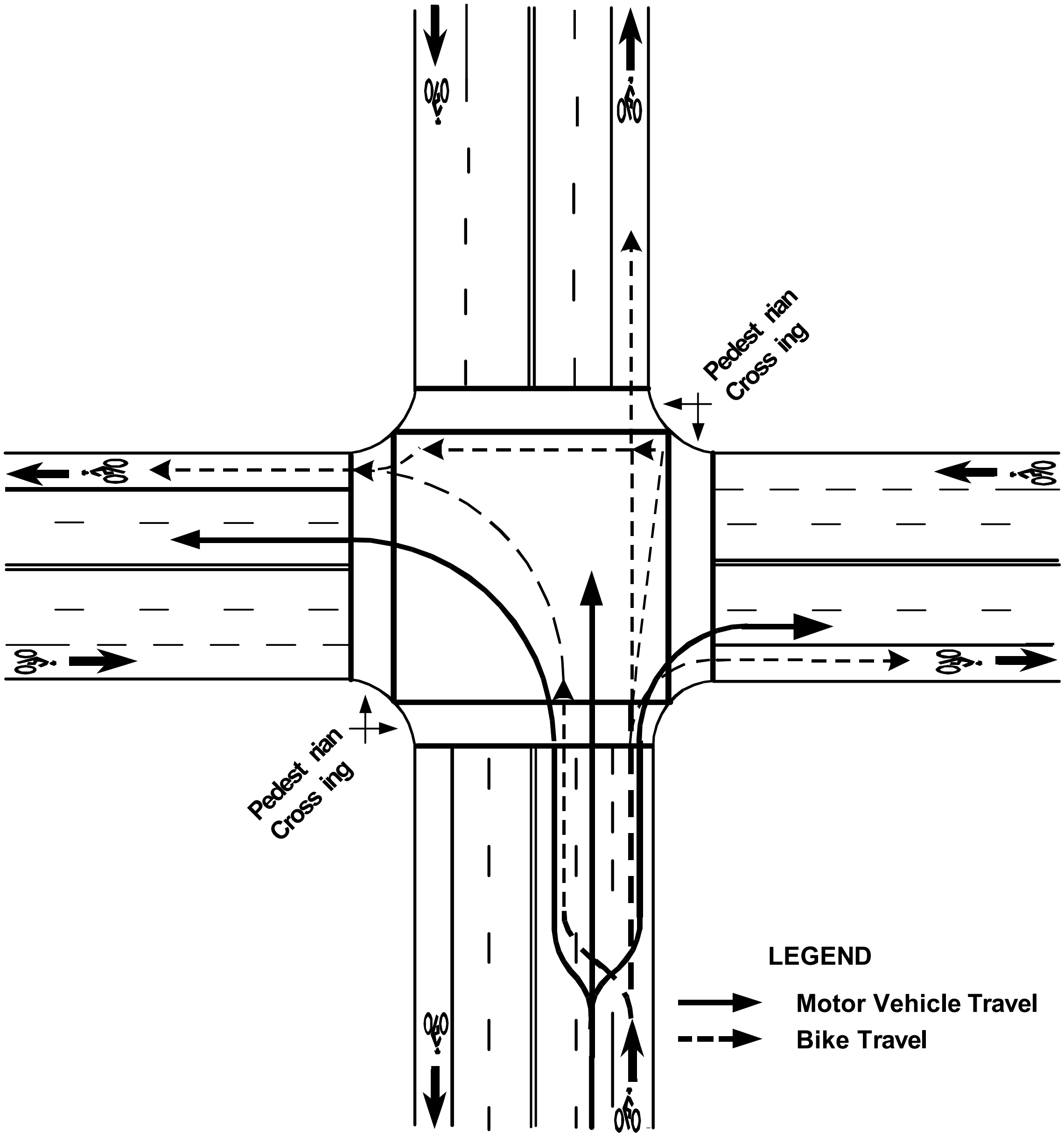
$$S = \frac{R}{28.65}\left[\cos^{-1}\left(\frac{R-M}{R}\right)\right]$$

S ≤ Length of curve
Angle is expressed in degrees

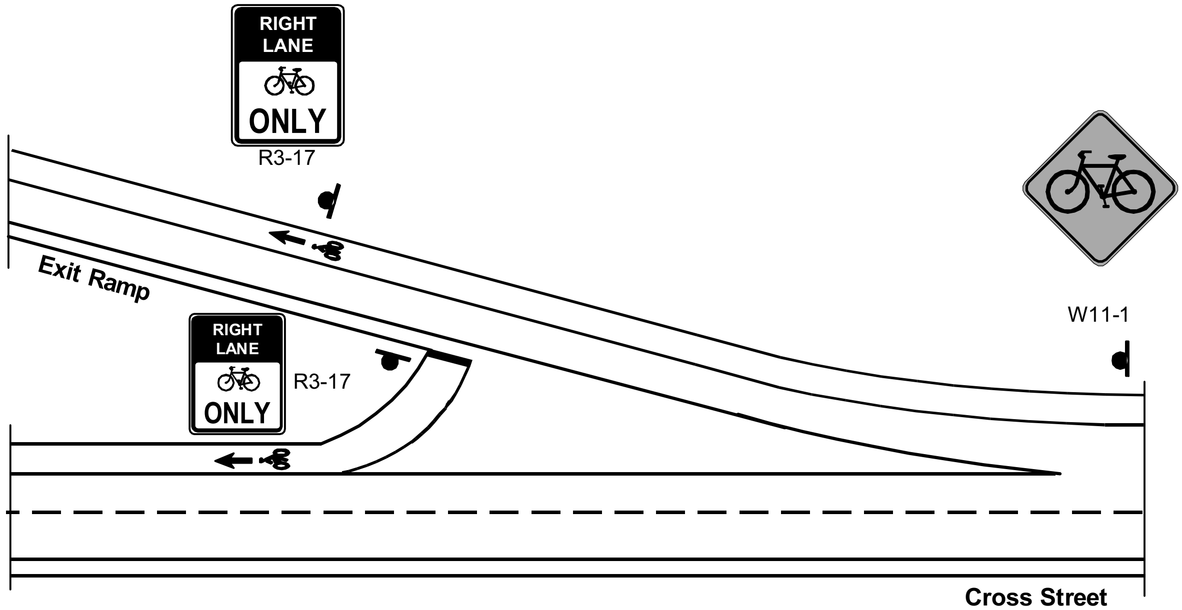
Where:
S = Sight distance in meters
R = Radius of center line inside lane in meters
m = Disance from center line inside lane in meters



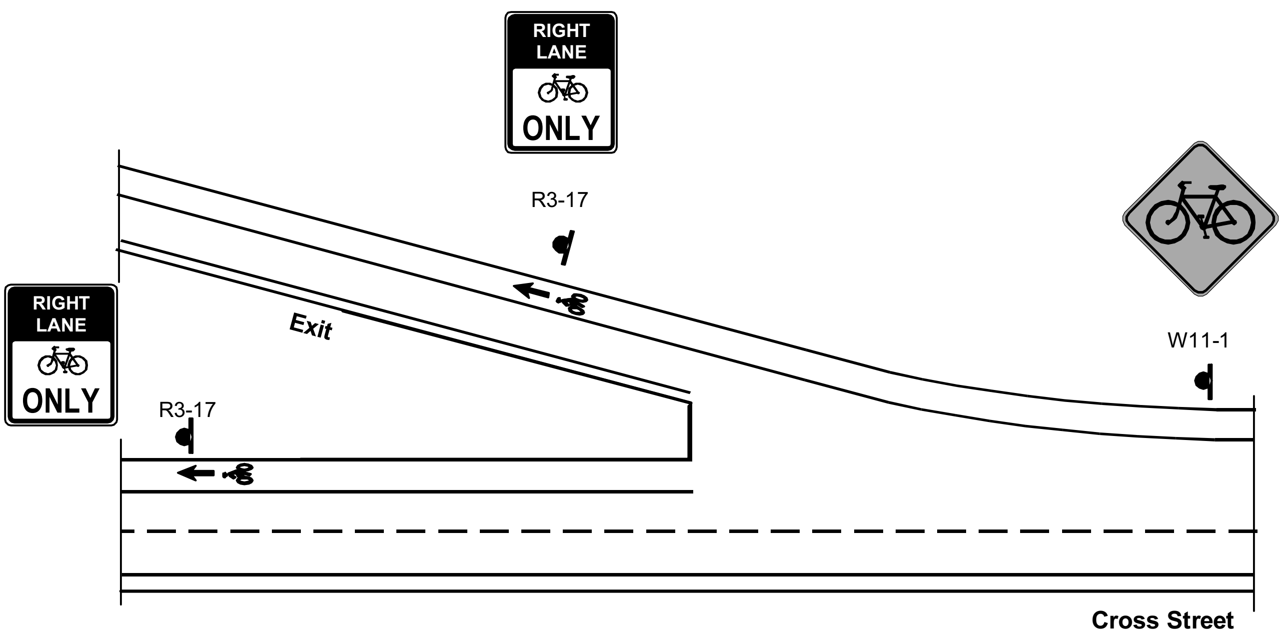
Lateral Clearance on Horizontal Curves
Figure 1020-21



Typical Bicycle/Auto Movements at Intersection of Multilane Streets
Figure 1020-22



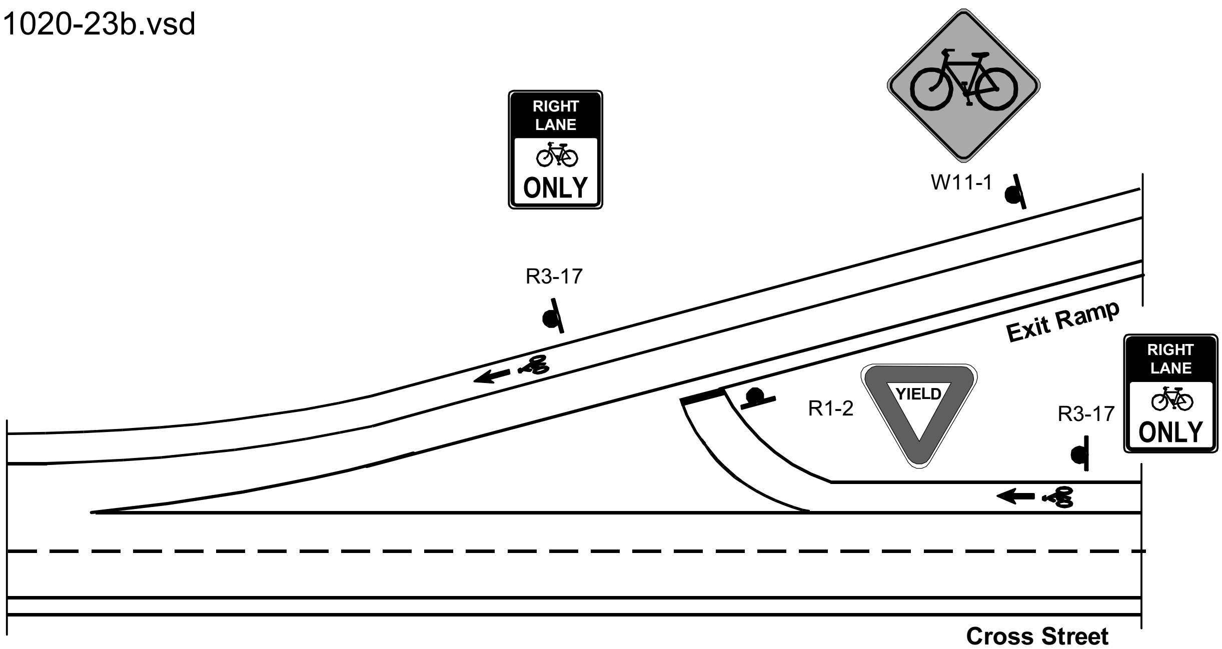
Option 1



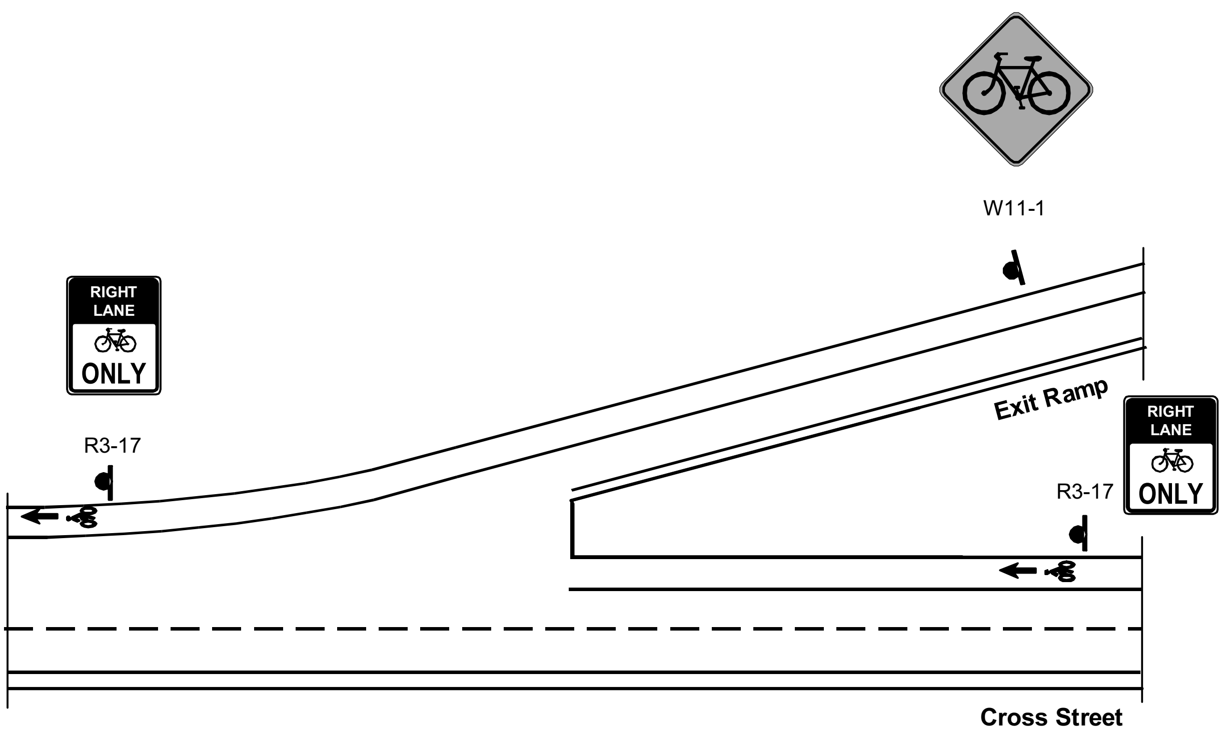
Option 2

Bicycle Crossing of Interchange Ramp
Figure 1020-23a

1020-23b.vsd

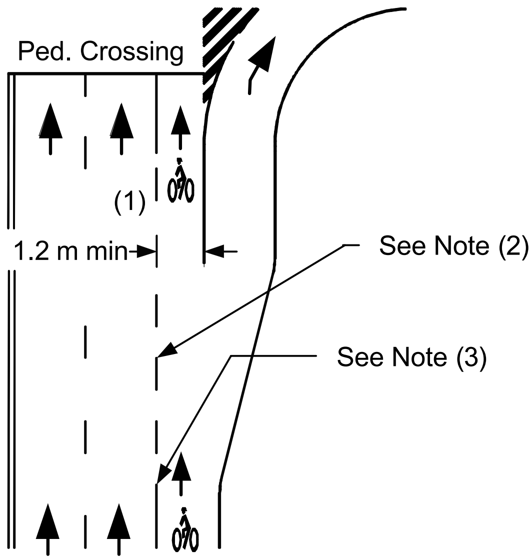


Option 1

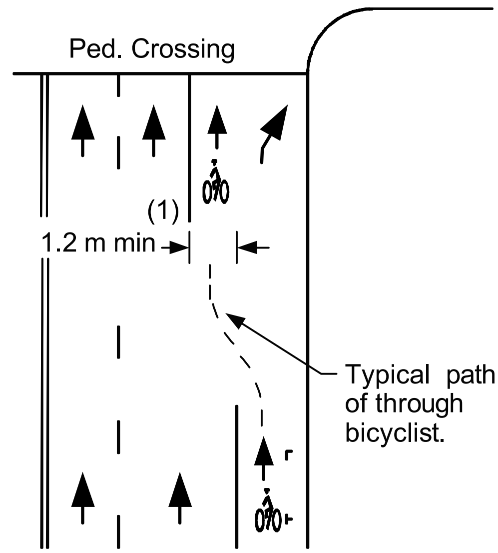


Option 2

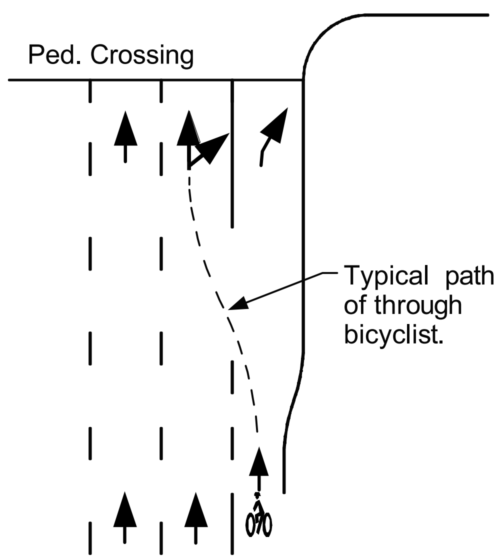
Bicycle Crossing of Interchange Ramp
Figure 1020-23b



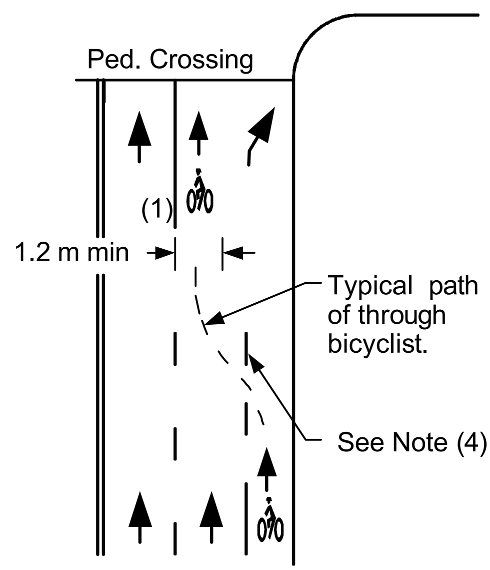
RIGHT-TURN-ONLY LANE



PARKING AREA BECOMES RIGHT-TURN-ONLY LANE



OPTIONAL DOUBLE RIGHT-TURN-ONLY LANE



RIGHT LANE BECOMES RIGHT-TURN-ONLY LANE

Note:

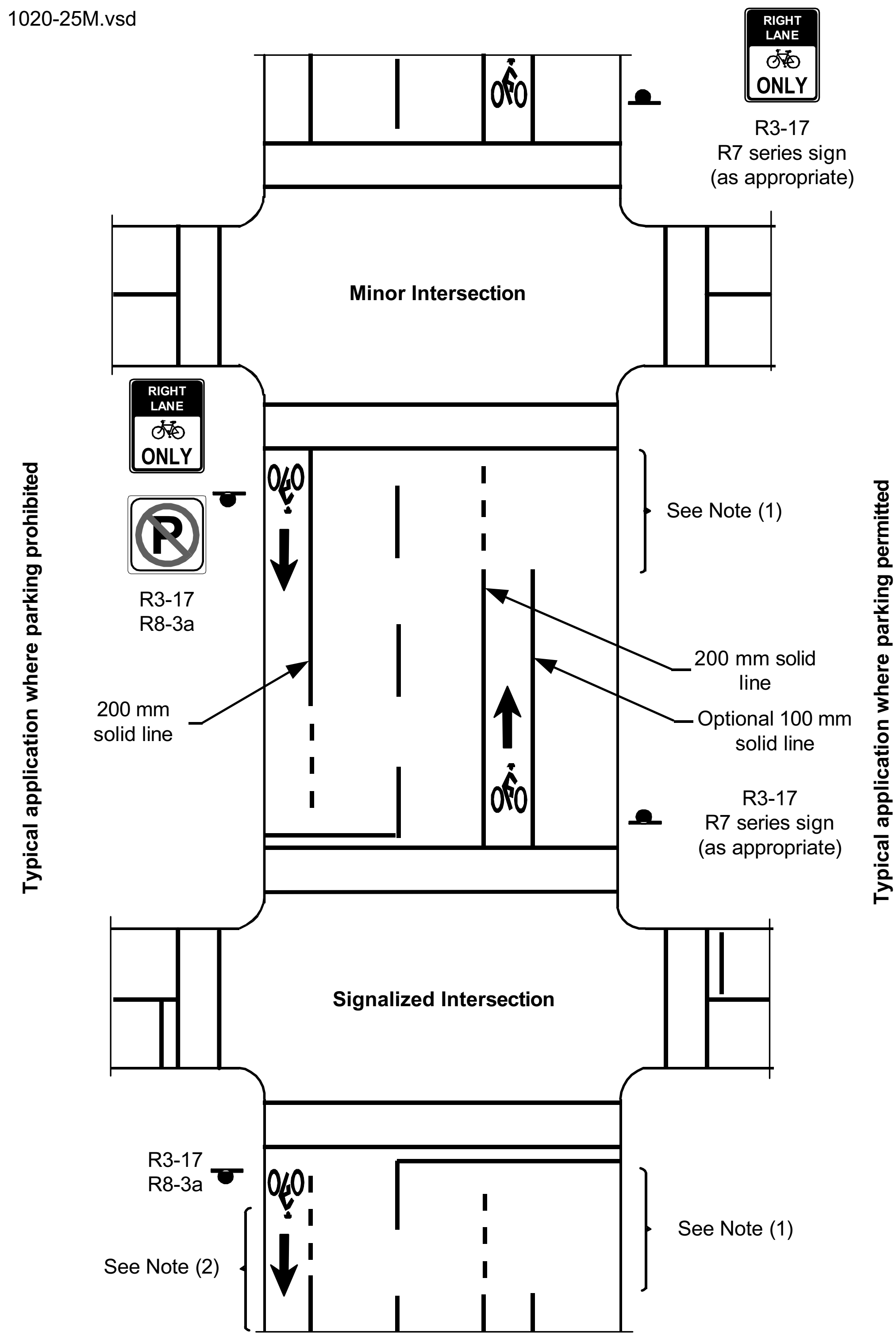
(1) If space is available.

(2) Optional dashed line. Not recommended where a long right-turn-only lane or double turn lanes exist.

(3) Otherwise, drop all delineation at this point.

(4) Drop bike lane line where right-turn-only designated.

Bike Lanes Approaching Motorists' Right-Turn-Only Lanes
Figure 1020-24

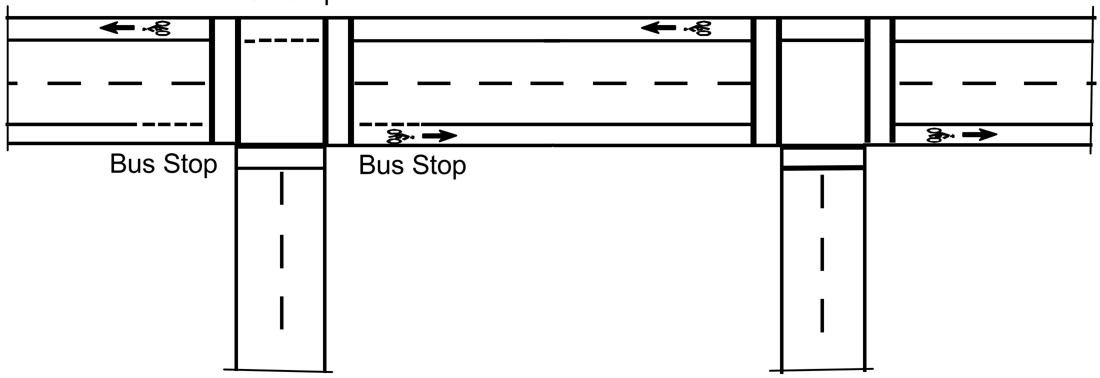


Note:

(1) 15 to 60 m dotted line if bus stop or heavy right-turn volume, otherwise solid line.

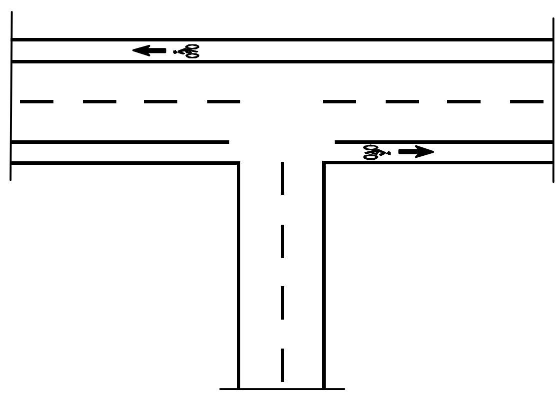
(2) Dotted line for bus stops immediately beyond the intersection is optional; otherwise use 200 mm solid line

Typical Pavement Marking for Bike Lane on Two-Way Street
Figure 1020-25



T-Intersection
with bus stops
and painted crosswalks

T-Intersection
with painted crosswalks
and no bus stops



T-Intersection
with no painted crosswalks

Typical Bike Lane Pavement Markings at T-Intersections
Figure 1020-26

1025 Pedestrian Design Considerations

1025.01 General

Pedestrians are present on most highways and transportation facilities, yet their travel mode differs vastly and sometimes is in conflict with the requirements for vehicular travel. The challenge is to provide safe and efficient facilities that address these two competing interests within a limited amount of right of way. Sidewalks and trails serve as critical links in the transportation network. Facilities that encourage pedestrian activities are a part of comprehensive transportation planning and development programs for urban and rural communities.

1025.02 References

Design Guidance, Accommodating Bicycle and Pedestrian Travel. A Recommended Approach, USDOT Policy Statement, 2001

Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD), USDOT, Washington DC, 1988, including the *Washington State Modifications to the MUTCD*, M 24-01, WSDOT, 1996

RCW 46.04.160, "Crosswalk"

RCW 46.61.240, "Crossing at other than crosswalks"

RCW 47.24.010, City streets as part of state highways, "Designation-construction, maintenance-return to city or town"

RCW 47.24.020, City streets as part of state highways, "Jurisdiction, control"

HOV Direct Access Design Guide, M 22-98, WSDOT

Roadside Manual, M 25-30, WSDOT

Sidewalk Details, WSDOT, 2000

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

Pedestrian Facilities Guidebook, incorporating Pedestrians into Washington's Transportation System, OTAK, 1997

1025.03 Definitions

accessible route An unobstructed pedestrian route that meets the requirements of the Americans with Disabilities Act accessibility guidelines.

ADA An abbreviation for the Americans with Disabilities Act of 1990. The ADA is a civil rights law that identifies and prohibits discrimination based on disability. The ADA requires public entities to design new facilities or alter existing facilities, including sidewalks and trails that are accessible to people with disabilities. Preservation projects, usually, are not considered an alteration of existing facilities. Accessibility can be addressed in preservation projects as a spot safety improvement.

bulb out A curb and sidewalk bulge or extension out into the roadway used to decrease the length of a pedestrian crossing.

crosswalk That marked or unmarked portion of a roadway designated for a pedestrian crossing.

landing A level area at the top of a pedestrian ramp.

midblock pedestrian crossing A marked pedestrian crossing located between intersections.

pedestrian facilities Walkways such as sidewalks, highway shoulders, walking and hiking trails, shared use paths, pedestrian grade separations, crosswalks, and other improvements provided for the benefit of pedestrian travel.

pedestrian-friendly A term for an environment that is safe, pleasant, and inviting to pedestrians.

pedestrian refuge island A raised area between traffic lanes that provides a place for pedestrians to wait to cross the street.

raised median A raised island in the center of a road used to restrict vehicle left turns and side street access. Pedestrians often use this median as a place of refuge when crossing a roadway.

1025.04 Policy

(1) General

Pedestrian facilities are required along and across most sections of state routes and are an integral part of the transportation system. Walkways and other pedestrian facilities are considered in the project definition phase. The only factors that will preclude providing pedestrian facilities in a project are as follows:

- Pedestrians are prohibited by law from using the facility.
- The cost of the improvements is excessive and disproportionate to the original need or probable use (as a guide, more than 20% of the original estimate).
- Low population density or other factors indicate that there is no need.

(2) Funding Programs

The adequacy of appropriate pedestrian facilities is addressed in mobility, safety, bridge replacement, and economic initiative projects in both the Highway Capitol Improvement and Preservation Programs. Federal, state, and local funds are available for pedestrian facility projects.

(a) **Improvement Program**

Mobility Program (I-1). Pedestrian facilities are included in improvement projects in urban areas unless the facility is restricted to motor vehicle use. In urban areas, pedestrian facilities can include traffic control devices, grade separations, crosswalks, sidewalks, and illumination. Other technologies, design features, or strategies, such as creating a pedestrian-friendly atmosphere, are generally beyond the scope of usual highway construction projects. These design features, however, can be included in a highway project when a local agency desires to participate and can provide the necessary funding. Partnership agreements between the state and local agencies to provide pedestrian amenities are effective ways to address seemingly different goals.

In rural areas, paved roadway shoulders are usually sufficient as pedestrian facilities. In high pedestrian use areas adjacent to the highway (state parks, recreation areas, and public-owned parking lots) additional signing, marked crosswalks, and separate pedestrian paths and trails might be necessary. Separate pedestrian paths or trails are appropriate, in some circumstances, as connections between activity centers or as part of a comprehensive trails plan.

Safety Program (I-2). Pedestrian Accident Locations (PALs) are sections of state routes with four or more pedestrian collisions with vehicles in a six-year period. PALs usually have a high societal cost and compete favorably with High Accident Locations (HALs) for safety funding.

Pedestrian Risk Projects are sections of state highways that have a high risk of pedestrian collisions with vehicles based on adjacent land use, roadway geometric design, and traffic conditions. Each region has a funding allotment to address pedestrian risk locations. Short sections of sidewalks, illumination, raised medians, and other pedestrian facilities are eligible for safety funding where there are pedestrian collisions, such as part of PAL or a High Accident Corridor (HAC).

Economic Initiatives (I-3). Projects supporting tourism development, promoting the interpretation of heritage resources, and ensuring public access to rest room equipped facilities can include limited pedestrian facility improvements if the site generates pedestrian activity.

(b) **Preservation Program**

Roadway Program (P-1). Projects funded by the Highway Capitol Preservation Program usually do not include enhancement of existing pedestrian facilities except as minor pedestrian spot safety improvements. Other funding sources, including local agency participation through federal grants, can be used for sidewalks, walkways, or other pedestrian facilities in these projects.

Structures Program (P-2). Bridge replacement funding can be used to replace existing pedestrian facilities or to match shoulder width or sidewalks of adjacent roadways on bridges.

Other Facilities (P-3). This funding source can be used to refurbish pedestrian facilities and address ADA requirements within existing rest areas.

(3) Project Requirements

For urban mobility improvement projects (Pedestrian connectivity projects in the matrices, Chapter 325), apply the guidance in this chapter to the pedestrian facility.

For highway design elements affected by the project, apply the appropriate design level (Chapter 325) and design requirements in the applicable *Design Manual* chapters.

For highway design elements not affected by the project, no action is required.

1025.05 Pedestrian Human Factors

Understanding the human behavior of pedestrians aids in the design of effective facilities. Young children tend to dart out into traffic because they have no understanding of vehicle stopping distances or sight limitations. Older children and teenagers are more likely to cross midblock, or step out in front of oncoming traffic. Adults are more capable of perceiving and dealing with risk. Senior adults and persons with disabilities are most likely to obey crosswalk laws and make predictable movements. Senior pedestrians, as a group, also tend to have reduced vision, balance, speed, stamina, and have trouble distinguishing objects in low light and nighttime conditions.

Walking rates are an important consideration in intersection design. The average walking speed for pedestrians is 1.2 m per second. Actual walking speeds, however, can vary from 0.7 to 1.8 m per second depending on the age group. In addition, people with disabilities require more time to cross a roadway. In areas with a higher senior adult population, a walking rate of 0.9 m per second is more realistic. This can be mitigated at locations with traffic signals by providing longer pedestrian signal timings, or pedestrian refuge areas, such as islands and medians.

Factors that contribute to deterring pedestrian travel include:

- High vehicle volumes and speeds
- Lack of separated pedestrian facilities
- Lack of a continuous walkway system (missing links)
- Poor nighttime lighting
- Lack of connections to pedestrian activity generators
- Inaccessible to people with disabilities
- Concerns for personal safety
- Barriers on walking route (rivers, railroads, bridges without sidewalks)
- Narrow walkway width
- Lack of transit shelter

To encourage multimodal transportation, livable communities, and pedestrian safety, many agencies provide pedestrian-friendly features along their streets, roads, and highways. The following are several pedestrian-friendly practices in current use:

- ADA accessible routes
- More direct alignment of walkways to reduce travel distances
- A complete network of pedestrian connections
- Ramps and handrails for persons with disabilities
- Medians and pedestrian refuge islands
- Buffers between the walkway and roadway
- Lower vehicular speeds
- Adequate pedestrian signs, signals, and markings
- Pedestrian furniture and vegetation
- Bulb outs or curb extensions
- Adequate illumination
- Audible warning signals

1025.06 Pedestrian Activity Generators

The types of land uses that indicate high pedestrian activity are residential developments with four or more housing units per 0.4 hectares interspersed with multifamily dwellings or hotels located within 800 m of other attractions. These attractions might be retail stores, schools, recreation areas, or senior citizen centers. Certain types of businesses, such as “deli-mart” type stores, fast food restaurants, and skateboard parks, can cater to a specific pedestrian age group and generate high activity levels.

Information on land use, development, and estimated pedestrian densities is available from metropolitan planning organizations, region planning offices, and city and county planning department comprehensive plans.

School districts designate walking routes for every elementary school. In general, children within 1.6 kilometers of the school are required to walk unless there are hazardous walking conditions. Contact the school district’s safety manager to determine the walking routes, average student age, transit stops, and the distance from the school to attractions. Sports, school plays, and other special events occurring after normal school hours can also generate exceptionally high levels of pedestrian activity. Consider the impact of these events when providing pedestrian facilities.

1025.07 Pedestrian Facility Design

(1) Facilities

The type of pedestrian facility provided is based on local transportation plans, the roadside environment, pedestrian volumes, user age group, safety-economic analysis, and continuity of local walkways along or across the roadway. Sidewalks can be either immediately adjacent to streets and highways or separated from them by a buffer. Walking trails, hiking trails, and shared use paths are independently aligned and generally serve recreational activities.

The type of walkway also depends on the access control of the highway as follows:

Full Access Control. Walking and hiking trails and shared use paths within the right of way are separated from vehicular traffic with physical barriers that discourage pedestrians from entering the roadway. These trails can connect with other trails outside the right of way if the access permit is modified. Grade separations are provided when the trail crosses the highway.

Partial or Modified Access Control. Walking and hiking trails and shared use paths are located between the access points of interchanges or intersections. Pedestrian crossings are usually either at-grade with an intersecting cross road or a grade separation. Midblock pedestrian crossings can be considered at pedestrian generators when the roadway has predominately urban characteristics.

Managed Access Control. In rural areas, paved shoulders are usually used for pedestrian travel. When pedestrian activity is high, separate walkways are provided. Sidewalks are used in urban areas where there is an identified need for pedestrian facilities. Trails and paths, separated from the roadway alignment, are used to connect areas of community development. Pedestrian crossings are at-grade.

(2) Pedestrian Travel Along Streets and Highways

(a) **General.** On state highways within the corporate limits of cities, the city has the responsibility for maintenance of all appurtenances beyond the curb. See RCW 47.24.020. Proposed projects that will damage or remove existing sidewalks or other walkways within the city’s jurisdiction must include reconstruction of these facilities. Examples of various types of pedestrian walkways are shown in Figures 1025-2a and 1025-2b.

The minimum clear width required by a person in a wheelchair or a walker is 0.9 m. Utility poles and other fixtures located in the sidewalk can be obstacles for pedestrians with disabilities. Utility company lines, poles, and other fixtures are accommodated within the right of way. When relocation of these fixtures is necessary in a project, determine the impact of their new location on any pedestrian walkways. Utility vaults and junction boxes with special lids are used for installations in sidewalks to reduce tripping hazards. Improvement projects might provide opportunities to eliminate existing poorly located utilities that are hazards to pedestrians.

Hanging or protruding objects within the walkway are also hazards for pedestrians with visual impairments. The minimum vertical clearance for objects overhanging a walkway, including signs, is 2.1 m.

Where the walkway is located behind guardrail, protruding guardrail bolts are cut off or a rub rail is installed to prevent snagging on the bolts. These construction requirements are specified in the contract.

Provide a smooth finish to vertical concrete surfaces adjacent to a pedestrian facility to prevent snagging or abrasive injuries from accidental contact with the surface.

(b) **Shoulders.** Pedestrian activity is usually minimal along rural roadways when the adjacent land use is one or less dwelling units per 0.4 hectare. Determine if the roadway's shoulders are of sufficient width and condition to permit safe travel for pedestrians. Paved shoulders are preferable for an all-weather walking surface. A 1.2 m wide shoulder is acceptable where pedestrian activity is minor. Wider shoulders, up to 2.4 or 3.0 m are desirable along high-speed highways, particularly when truck volumes are high or pedestrian activity is significant.

(c) **Shared Use Paths.** Shared use paths are used by pedestrians and bicyclists. Pedestrian facilities differ from bicycle facilities in their design requirements and goals and they are not always compatible. A busy sidewalk might not be safe for bicycle travel and a well-used bike path might be unsuitable as a pedestrian walkway. When a shared use path is determined to be in the best interests of both groups, see Chapter 1020, "Bicycle Facilities," regarding shared use paths.

(d) **Walking and Hiking Trails.** Walking and hiking trails are supplemental features and are considered on a project-by-project basis. These trails are less developed than other walkways and shared use paths and are usually unpaved. Because of their primitive nature, ADA requirements for accessibility are far less restrictive. See Figure 1025-1 for trail widths and grades. The clear area is the cross-sectional area of the trail that is cleared of limbs, exposed roots, brush, and other obstacles that might be a hazard to the hiker.

	Clear Area	Trail Width	Maximum Grade
Walking trail	2.4 m high & 3.0 m wide	1.2 m	10% *
Hiking trail	2.4 m high & 3.0 m wide	0.9 m	10% sustained, 20% (150 m or less)

Trail Width and Grades
Figure 1025-1

* Note: When grades of 5% or more are used, provide 1.2 m square resting areas adjacent to the trail every 150 m.

(e) **Sidewalks.** Details for raised sidewalks are shown in the Standard Plans. Roadway classification and land use are important factors when considering sidewalks. Figure 1025-3 provides a generalized method of assessing the need for and adequacy of sidewalks and does not establish minimum requirements for their installation. When sidewalks are recommended for a particular roadway in this figure, conduct a more extensive study to determine if they can be justified. The most desirable installation for the pedestrian is a sidewalk separated from the traveled way by a planted buffer strip. The minimum width for the sidewalk is 1.5 m and the buffer is not less than 0.9 m. Where a sidewalk is separated from the traveled way with only a curb, the minimum sidewalk width is 1.8 m. Wider sidewalks are used in areas of high pedestrian traffic. Sidewalks 2.4 m or wider are more appropriate at these locations. In areas with heavy snowfall, snowplows might need to use the sidewalk for snow storage if there is no adjacent shoulder. Consider wider sidewalks or a sidewalk with a buffer to minimize the disruption to pedestrian travel.

A grade of 8.33% or less is required when the sidewalk is on an independent alignment and does not follow an adjacent roadway grade. Sidewalks located adjacent to a street or highway follow that facility's grade and can exceed 8.33%. On roadways with prolonged severe grades, consider providing level landings adjacent to the sidewalk at approximately 150 m intervals as resting areas for people with physical disabilities. The cross slope of a sidewalk cannot exceed 2%. More extreme cross slopes are difficult for people in wheelchairs to negotiate.

The side slope adjacent to the sidewalk is a critical design element. See Figures 1025-2a and 2b. On embankment slopes of 1V:4H or flatter, provide a 0.3 m widening at the edge of the sidewalk. On steeper embankment slopes provide a 1.2 m embankment widening or use a sidewalk design with a 0.6 m widening and a raised 150 mm high lip at the back edge of the sidewalk. When the adjacent roadway has a posted speed of 35 mph or less and there is a vertical drop-off of 760 mm or more behind the sidewalk, provide a pedestrian railing when embankment widening is not possible. Pedestrian railings are not designed to withstand vehicular impacts and cannot redirect errant vehicles. When a vertical drop off is present on a higher speed roadway, the Design Clear Zone is the primary consideration and a crash-worthy traffic barrier is required. See Chapter 700. In some cases, where the walkway is adjacent to a vertical drop off and is separated from the roadway, consider installing the traffic barrier between the travel way and the walkway. The pedestrian railing is then installed between the walkway and the vertical drop off.

Provide either raised sidewalks or ramps on the approaches to bridges when there are raised sidewalks on the bridge. The ramp is constructed of either asphalt or cement concrete and the slope of 1V:20H or flatter. These ramps can also be used as a transition from a raised sidewalk down to a paved shoulder. The ramp provides pedestrian access and mitigates the raised, blunt end of the concrete sidewalk.

(3) Pedestrian Crossings At-Grade

Wide, multilane streets are difficult for pedestrians to cross, particularly when there are insufficient gaps in vehicular traffic because of heavy volumes. The chart in Figure 1025-4 provides guidance in determining feasible pedestrian crossings based on vehicular traffic volume and speed. Appropriate additional safety features necessary for the crossing are also recommended in this chart.

Pedestrian crossings are permitted along the length of most highways. Pedestrian crossing of all legs of an intersection is also permitted. An illegal pedestrian crossing only occurs when signs prohibit a particular crossing at an intersection or the crossing occurs between two signalized intersections. See RCW 46.61.240. Pedestrian crossings of the roadway are inevitable. Simply prohibiting a crossing without providing a reasonable option is not an effective solution and fails to address the pedestrian's needs.

Crosswalks, whether marked or not, exist at all intersections. An unmarked crosswalk is the 3.0 m wide area across the intersection behind a prolongation on the curb or edge of the through traffic lane. See RCW 46.04.160. A marked crosswalk is required when the intended pedestrian route is different than that cited in the RCW. See Figure 1025-5. At roundabouts and intersections with triangular refuge islands or offset legs, the desired pedestrian crossings might not be consistent with the definition of an unmarked crosswalk and markings become necessary. Marked crosswalks also clearly define the pedestrian route and permit enforcement of pedestrian crossing laws.

The standard crosswalk marking consists of a series of wide white lines aligned with the longitudinal axis of the roadway. The lines are positioned at the edges and centers of the traffic lanes to place them out of the normal wheel path of vehicles. This type of crosswalk is a Ladder Bar and is shown in the Standard Plans.

Specially textured crosswalks (consisting of colored pavement, bricks, or other materials) are sometimes used by local agencies in community enhancement projects. These crosswalks do not fall within the legal definition of a marked crosswalk and parallel white crosswalk lines are required to define the crosswalk.

When locating crosswalks at intersections, consider the visibility of the pedestrian from the motorist's point of view. Shrubbery, signs, parked cars, and other roadside appurtenances can block the motorist's view of the pedestrian. Figures 1025-6a and 6b illustrate these sight distance problems.

In urban areas where vehicle speeds are in the range of 25 to 35 mph, a sidewalk bulb out is sometimes used to place the pedestrian at a more visible location. The bulb out also shortens the length of the pedestrian crossing and reduces the pedestrian's exposure time. At intersections with traffic signals, the bulb out can be used to reduce both pedestrian signal timing and the mast arm lengths of the signal supports. Examples of sidewalk bulb outs are shown in the Figure 1025-7. The right turn path of the design vehicle or the vehicle most likely to make this turn is a critical element in determining the size and shape of the bulb out. Sidewalk bulb outs tend to restrict the width of the roadway and can make right turns difficult for extremely long trucks. Any proposal to install bulb outs on state highways is a deviation that requires approval and documentation.

On roadways with two-way left-turn lanes with pedestrian crossing traffic caused by nearby pedestrian generators, consider removing a portion of the turn lane and installing a raised median refuge and a midblock pedestrian crossing. The installation of a midblock pedestrian crossing on a state highway, however, is a design deviation that requires approval and documentation. An example of a midblock crossing is shown in Figure 1025-8.

An engineering study is required when considering a midblock pedestrian crossing on a state highway. Conditions that might favor a midblock crossing are:

- Significant pedestrian crossings and substantial pedestrian and vehicle conflicts occur.
- The proposed crossing can concentrate or channel multiple pedestrian crossings to a single location.
- The crossing is at an approved school crossing on a school walk route.
- The adjacent land use creates high concentrations of pedestrians needing to cross the highway.
- The pedestrians fail to recognize the best or safest place to cross along a highway and there is a need to delineate the optimal location.
- There is adequate sight distance for motorists and pedestrians.

Midblock pedestrian crossings on state highways are not desirable at the following locations:

- Immediately downstream (less than 90 m) from a traffic signal or bus stop where motorists do not expect a pedestrian to cross.
- Within 180 m of another pedestrian crossing.
- On high speed roadways as noted in Figure 1025-4.
- Where pedestrians must cross three or more lanes of traffic in the same direction.

The minimum width of a raised median refuge area is 1.8 m to accommodate people in wheelchairs. Raised medians are usually too narrow to allow the installation of ramps and a level landing. When the median is 4.9 m or less in width, provide a passageway through the median. This passageway connects with the two separate roadways and cannot exceed a grade of 5%.

(4) Sidewalk Ramps

Sidewalk ramps are required at all legal crossing. These ramps provide an easily accessible connection from a raised sidewalk down to the roadway surface. To comply with ADA requirements, these ramps are at least 0.9 m wide and have slopes 1V:12H or flatter. Examples of sidewalk ramps are shown in the Standard Plans and the *Sidewalk Details* guide.

The lower terminus of the sidewalk ramp is always located at the beginning of a marked or unmarked crosswalk when separate ramps are used for each direction. Diagonal ramps are used at the junction of two crosswalks. A separate sidewalk ramp is preferred for each crossing because the crossing distance is shorter and people with vision impairments have fewer difficulties with this arrangement. Diagonal ramps are sometimes necessary when altering an existing roadway because of right of way constraints.

Surface water runoff from the roadway can flood the lower end of a sidewalk ramp. Determine the grades along the curb line and provide catch basins or inlets to prevent the flooding of the ramps. Figure 1025-9 shows examples of how drainage structures are located. Verify that the drainage structure will not be in the path of a wheelchair user.

A level landing is necessary at the top of a sidewalk ramp. This landing is provided to allow a person in a wheelchair room to maneuver into a position to use the ramp or to bypass it. In alterations of existing roadways, the landings must be at least 0.9 m square. In new construction, a 1.2 m square landing is required. When right of way constraints are not an issue, provide a larger 1.5 m square landing. If the landing is next to a vertical wall, a 1.5 m wide clear area is desirable to allow a person in a wheelchair more room to maneuver. Examples of these wheelchair maneuvers are shown in the *Sidewalk Details* guide. When the upper area of a sidewalk ramp is adjacent to a vertical wall, a 1.5 m clearance from the edge of the ramp to the wall is desirable.

At signalized intersections, the pedestrian push buttons are located near the sidewalk ramps for ADA accessibility. See Chapter 850, “Traffic Control Signals,” for information on pedestrian requirements at traffic signal locations.

(5) Pedestrian Grade Separations

In areas where heavy pedestrian traffic is present and opportunities to cross the roadway are infrequent, consider providing a pedestrian grade separation. When considering a pedestrian structure, determine if the conditions that require the crossing are permanent. If there is a likelihood that the pedestrian activity generator might not exist in the near future, consider less costly solutions. Locate the grade separated crossing where pedestrians are most likely to cross the roadway. A crossing might not be used if the pedestrian is required to deviate significantly from a more direct route. A structure might be under-utilized if the additional average walking distance for 85 percent of the pedestrians exceeds 400 m. It is sometimes necessary to install fencing or other physical barriers to channel the pedestrians to the structure and reduce the possibility of undesired at-grade crossings. Pedestrian grade separations are more effective when the roadway is below the natural ground line as in a “cut” section. Elevated grade separations, where the pedestrian is required to climb stairs or use long approach ramps, tend to be under-utilized.

Grade separated structures are proposed during the planning stage of a project because of the high costs associated with their design and construction. Consider grade-separated crossings under the following conditions:

- Where there is moderate to high pedestrian demand to cross a freeway or expressway
- Where there is a large number of young children, particularly on schools routes, who regularly cross a high speed or high volume roadway
- On streets with high vehicular volumes and high pedestrian crossing volumes, and crossings are extremely hazardous for pedestrians

The Olympia Service Center Bridge and Structures Office designs pedestrian grade separation bridges and tunnels on a project-by-project basis. Railings 1070 mm high are provided on pedestrian bridges. The bridge rail is designed so that a 150-mm sphere cannot pass through any part of the railing. In addition, a 760 to 806 mm high handrail is provided for grades greater than 5%. The minimum width between the railings of an overhead structure or the vertical walls of a tunnel is 2.4 m. The minimum overhead clearance for a tunnel is 3.0 m. Protective screening to prevent objects from being thrown from an overhead pedestrian structure is sometimes necessary. See Chapter 1120, “Bridges.”

The minimum vertical clearance from the bottom of the pedestrian structure to the roadway beneath is 5.3 m. This minimum height requirement can affect the length of the pedestrian ramps to the structure. To comply with ADA requirements, a ramp cannot have a grade exceeding 8.33% and the maximum rise of the ramp cannot exceed 760 mm without landings. Landings are a minimum of 1.5 m wide and 1.5 m long except the landing at the bottom of the ramp, which is 1.8 m in length. When ramps are not feasible, provide both elevators and stairways. Stairways are designed in accordance with the Standard Plans.

Pedestrian tunnels are an effective method for providing crossings for roadways located in embankment sections. When possible, design the tunnel with a nearly level profile to provide complete vision from portal to portal. Pedestrians are reluctant to enter a tunnel with a depressed profile because they are unable to see if the tunnel is occupied. Police officers also have difficulty patrolling depressed profile tunnels. Provide day and nighttime illumination within the pedestrian tunnel. Installing gloss-finished tile walls and ceilings can also enhance light levels within the tunnel.

(6) Transit Stops

The location of transit stops is an important consideration in providing appropriate pedestrian facilities. See Chapter 1060, "Transit Benefit Facilities." A transit stop on one side of a street usually has a counterpart on the opposite side because transit routes normally function in both directions on the same roadway. When passengers use this type of route, they will either cross the street at the beginning of a trip or the end of the return trip. Pedestrian collisions are more frequent at these locations. When analyzing high pedestrian accident locations, consider the presence of nearby transit stops and the opportunities for a pedestrian to safely cross the street. At-grade midblock pedestrian crossings are effective at transit stop locations on roadways with lower vehicular volumes. Pedestrian grade separations are appropriate at midblock locations when vehicular traffic volumes prohibit pedestrian crossings at grade.

School bus stops are typically adjacent to sidewalks in urban areas and along shoulders in rural areas. Determine the number of children using the stop and provide an appropriate waiting area. Children, because of their smaller size, might be difficult for motorists to see at crossings or stops. Determine if utility poles, vegetation, and other roadside features interfere with the motorist's ability to see the children. When necessary, relocate the obstructions or move the bus stop. Parked vehicles can also block visibility and parking prohibitions might be necessary near the bus stop.

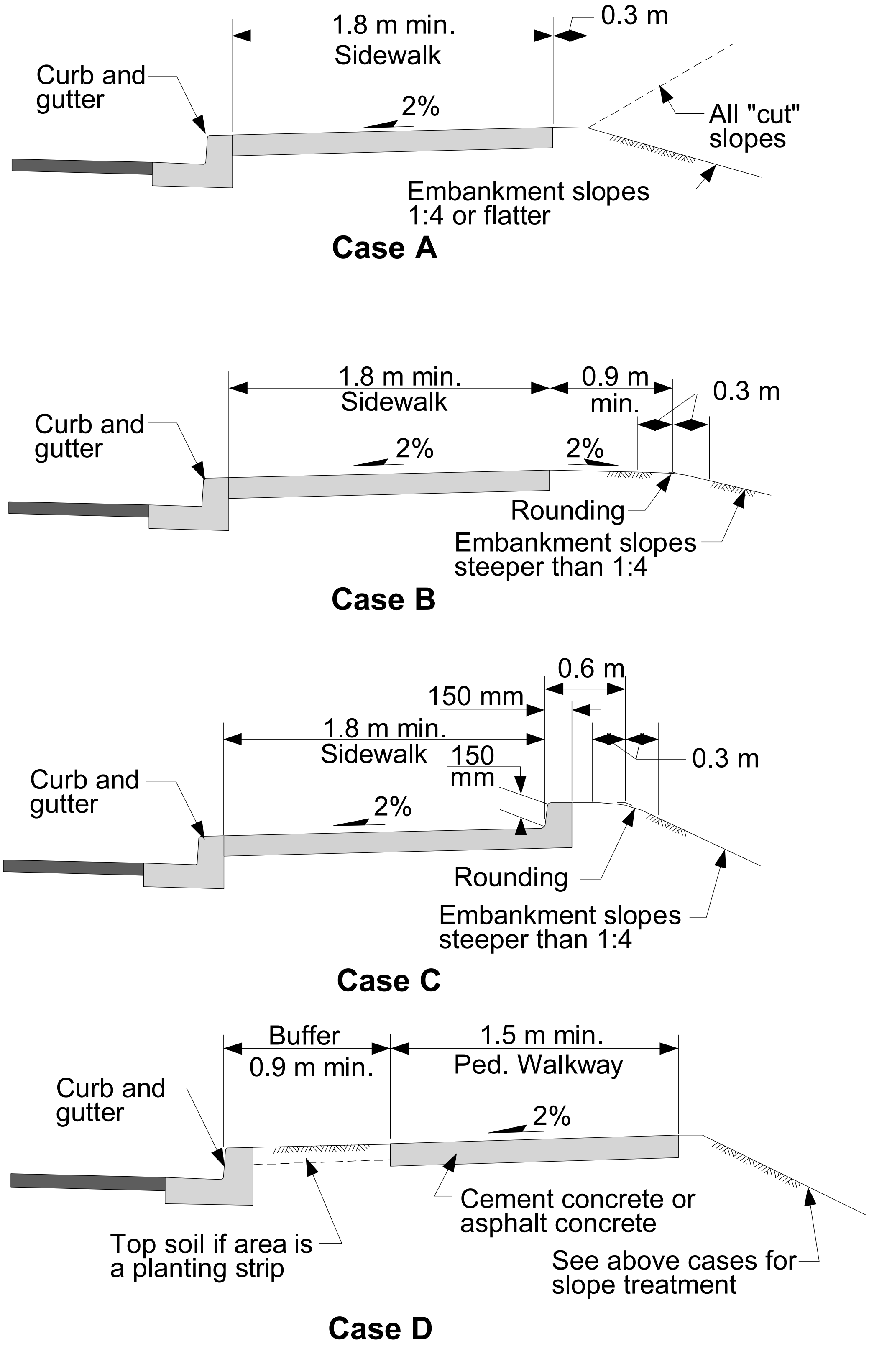
(7) Illumination and Signing

In Washington State, the highest number of collisions between vehicles and pedestrians occur in the months November through February when there is poor visibility and fewer daylight hours. At high pedestrian accident locations, illumination of pedestrian crossings and other walkways is an important design consideration. Illumination provided solely for vehicular traffic is not always effective in lighting parallel walkways for pedestrians. Consider additional lighting, mounted at a lower level, for walkways with considerable nighttime pedestrian activity. Design guidance for illumination is in Chapter 840. See Chapter 820 and the MUTCD for pedestrian related signing.

1025.08 Documentation

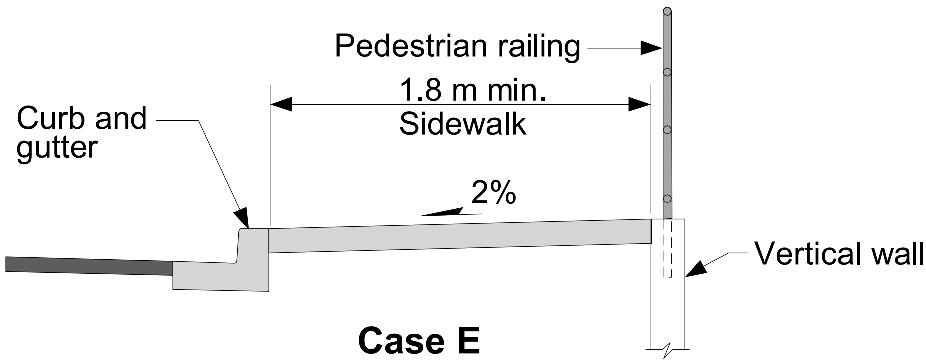
Preserve the following documents in the project file: See Chapter 330.

- ☐ Decisions to prohibit pedestrians from a state highway.
- ☐ Decisions to prohibit a pedestrian crossing at an intersection.
- ☐ Approval of the installation of a midblock pedestrian crossing.
- ☐ Agreements with cities to install pedestrian sidewalks or walkways along state highways within their jurisdiction.
- ☐ Approval of the installation of a bulb out on a state highway.



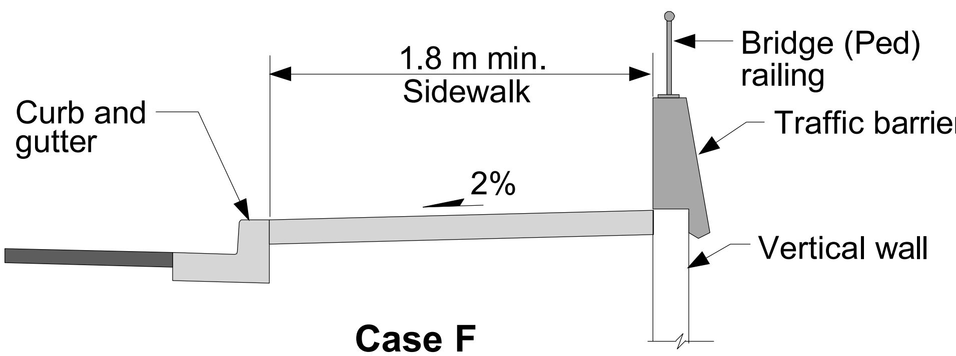
Pedestrian Walkways

Figure 1025-2a



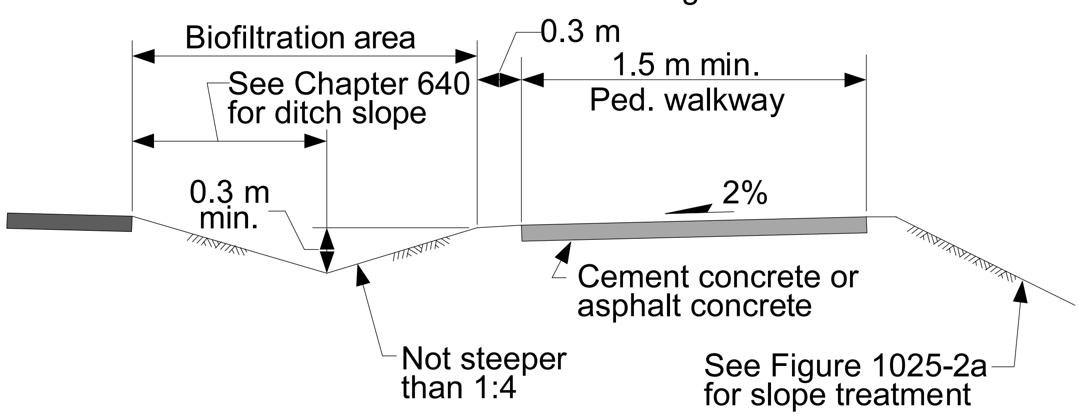
Case E

When the wall is outside of the Design Clear Zone

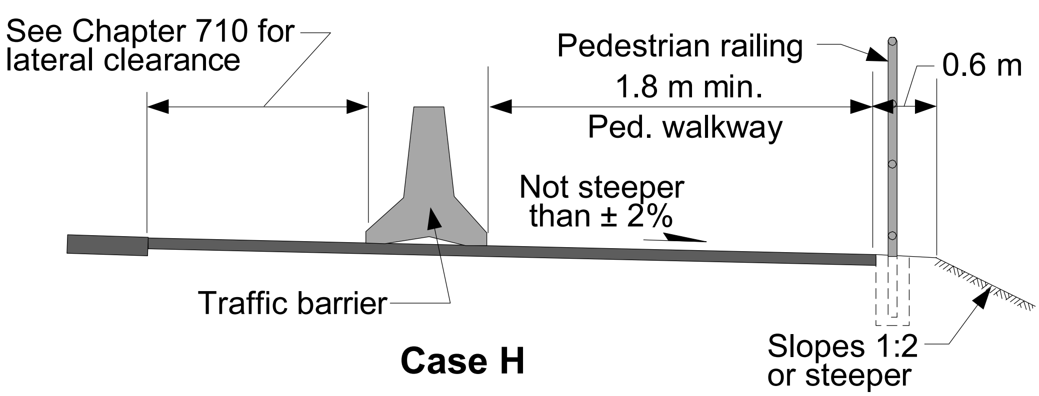


Case F

When the wall is within the Design Clear Zone



Case G



Case H

Pedestrian Walkways

Figure 1025-2b

Roadway classification & land use	Sidewalk recommendations
Rural highways (less than one dwelling unit per 0.4 hectare)	No sidewalk recommended. Shoulder (1.2 meter minimum width) adequate.
Suburban highways (one or less dwelling units per 0.4 hectare)	Sidewalk on one side desirable. 1.2 meter wide shoulders adequate.
Suburban highway (2 to 4 dwelling units per 0.4 hectare)	Sidewalks on both sides of roadway desirable. Sidewalk on one side recommended.
Major arterial in residential area	Sidewalks on both sides of roadway recommended.
Collector or minor arterial in residential area	Sidewalks on both sides of roadway recommended.
Local street in residential area with less than 1 dwelling unit per 0.4 hectare	Sidewalk on one side desirable. 1.2 meter wide shoulders adequate.
Local street in residential area with 1 to 4 dwelling units per 0.4 hectare	Sidewalks on both sides of roadway desirable. Sidewalk on one side recommended.
Local street in residential area with more than 4 dwelling units per 0.4 hectare	Sidewalks on both sides of roadway recommended.
Streets in commercial area	Sidewalks on both sides of roadway recommended
Streets in industrial area	Sidewalks on both sides of roadway desirable. Sidewalk on one side recommended.

Sidewalk Recommendations

Figure 1025-3

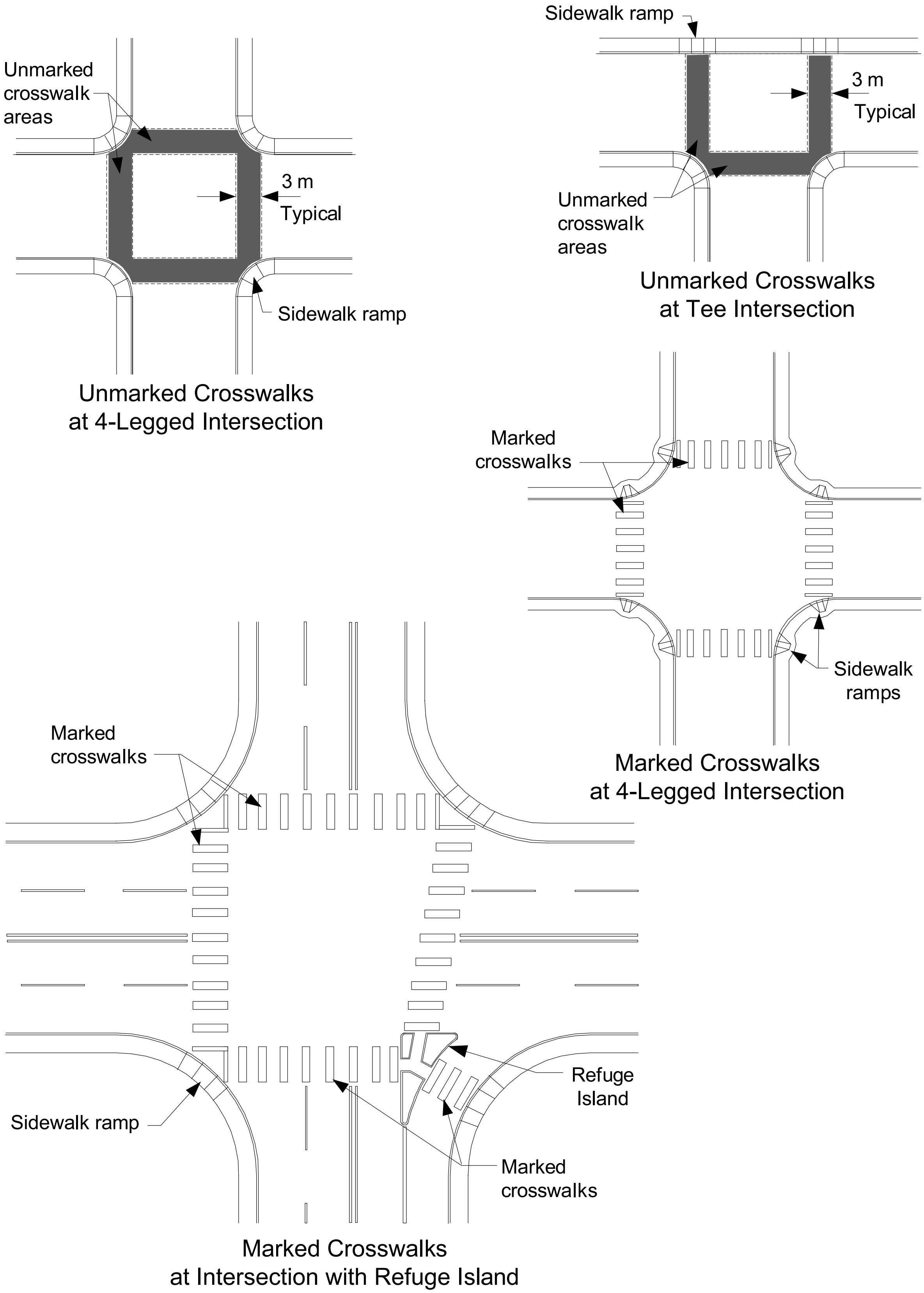
Traffic Volume ADT	Speed	Roadway Type			
		Two Lane	Three Lane	Multilane (4 or more lanes) with raised median	Multilane (4 or more lanes) without raised median
Less Than 9,000	30 mph or less	marked crosswalk	marked crosswalk	marked crosswalk	marked crosswalk
	35 mph	marked crosswalk	marked crosswalk	marked crosswalk	marked crosswalk
	40 mph or higher	marked crosswalk	marked crosswalk	marked crosswalk	marked crosswalk
9,000 to 11,999	30 mph or less	marked crosswalk	marked crosswalk	marked crosswalk	marked crosswalk
	35 mph	marked crosswalk	marked crosswalk	marked crosswalk	additional enhancement
	40 mph or higher	marked crosswalk	marked crosswalk	marked crosswalk	additional enhancement
12,000 to 14,999	30 mph or less	marked crosswalk	marked crosswalk	additional enhancement	additional enhancement
	35 mph	marked crosswalk	additional enhancement	additional enhancement	not recommended
	40 mph or higher	additional enhancement	not recommended	not recommended	not recommended
More than 15,000	30 mph or less	marked crosswalk	additional enhancement	additional enhancement	not recommended
	35 mph	additional enhancement	not recommended	not recommended	not recommended
	40 mph or higher	additional enhancement	not recommended	not recommended	not recommended

Notes:
These guidelines include intersection and midblock location with no traffic control signals or stop signs on the approach to the crossing. They do not apply to school crossings. A two-way left-turn lane is not considered a median. This chart is used in conjunction with an engineering study of pedestrian volumes, model vehicle operating speeds, sight distance, vehicle mix, and comparison to similar sites.

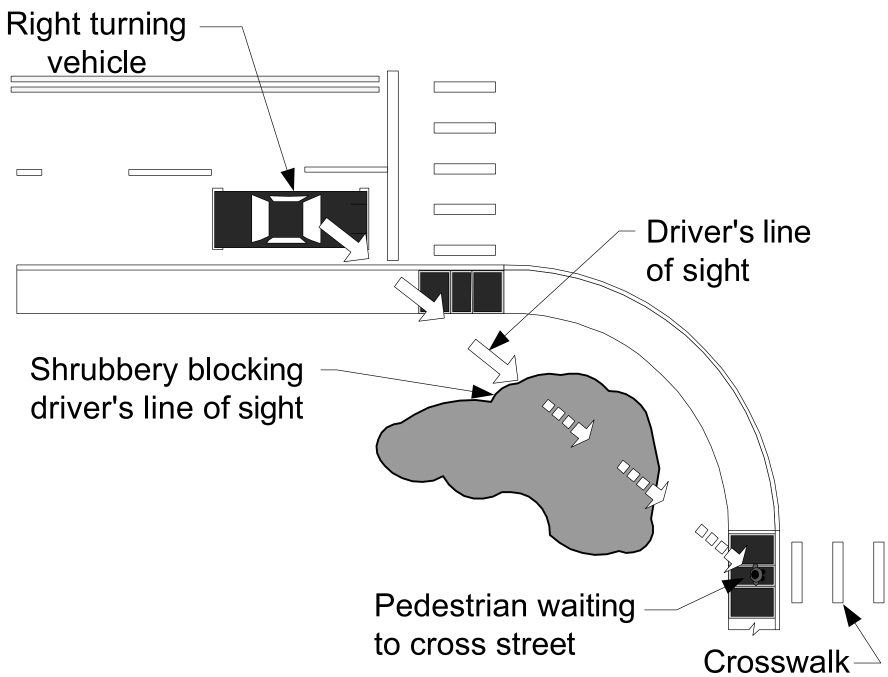
Meaning of terms in chart:

Marked crosswalk: Marked crosswalk can be installed at these locations.
Additional enhancements: Marked crosswalks can be used with additional safety items such as overhead illumination, curb bulb outs, flashing beacons, illuminated signing, or an in-roadway flashing light system.
Not recommended: A marked crosswalk is not recommended under these conditions without positive vehicular traffic control such as stop signs or traffic control signals.

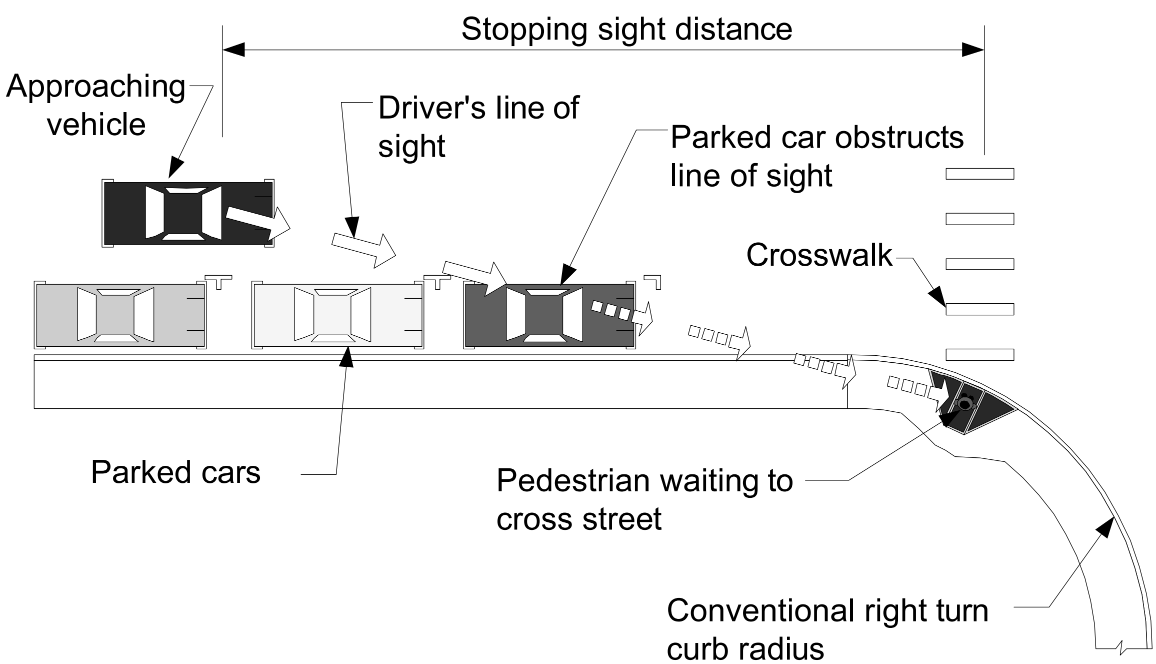
Marked Crosswalk Recommendations at Unsignalized Pedestrian Crossings
Figure 1025-4



Crosswalk Locations
Figure 1025-5

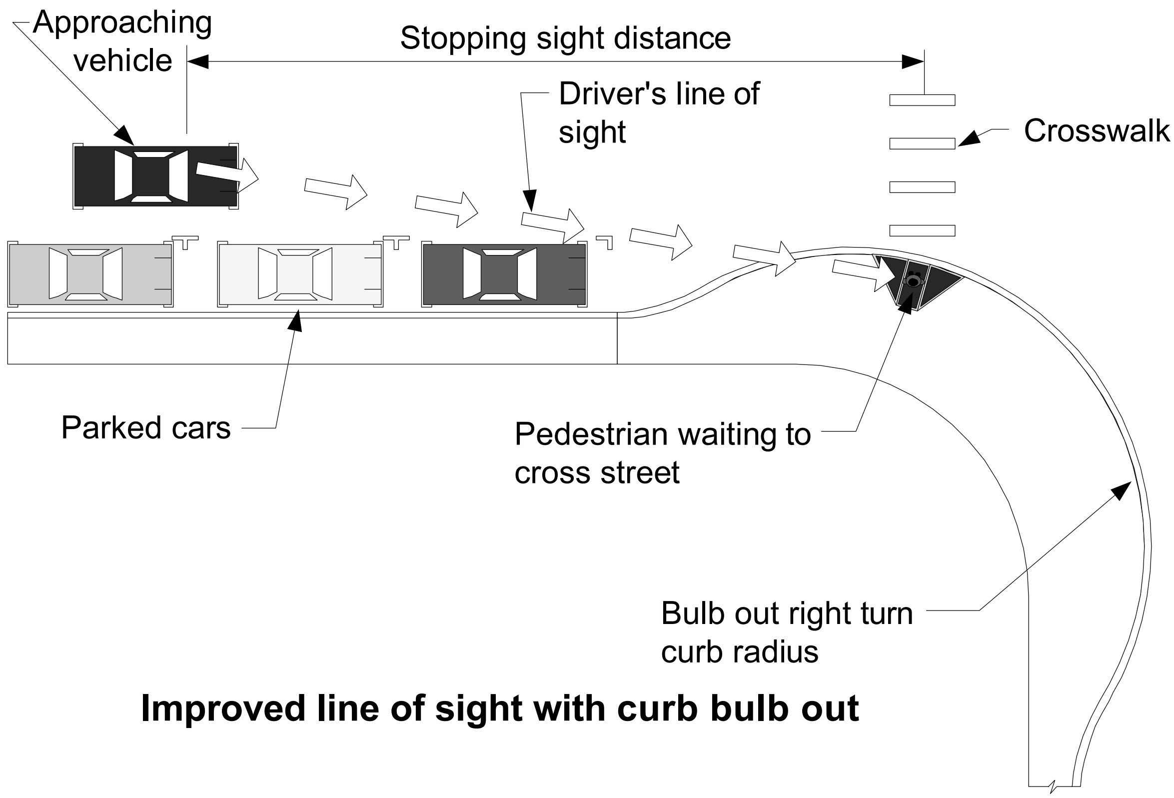


Shrubbery blocking line of sight

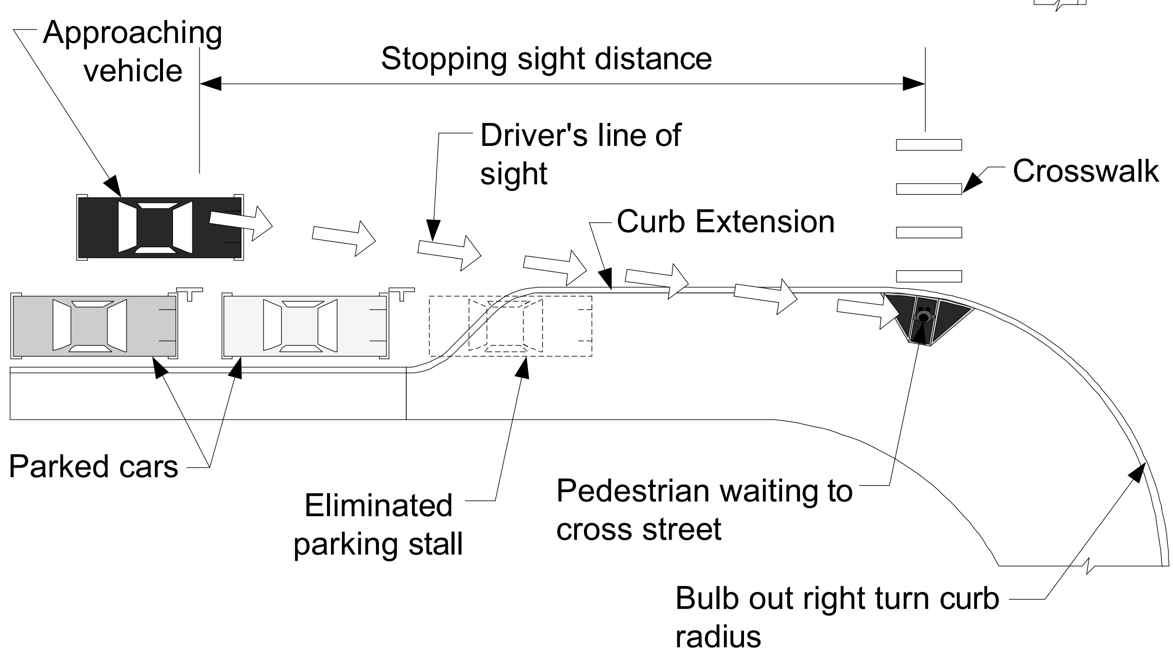


Parked car blocking line of sight

Sight Distance at Intersections
Figure 1025-6a



Improved line of sight with curb bulb out

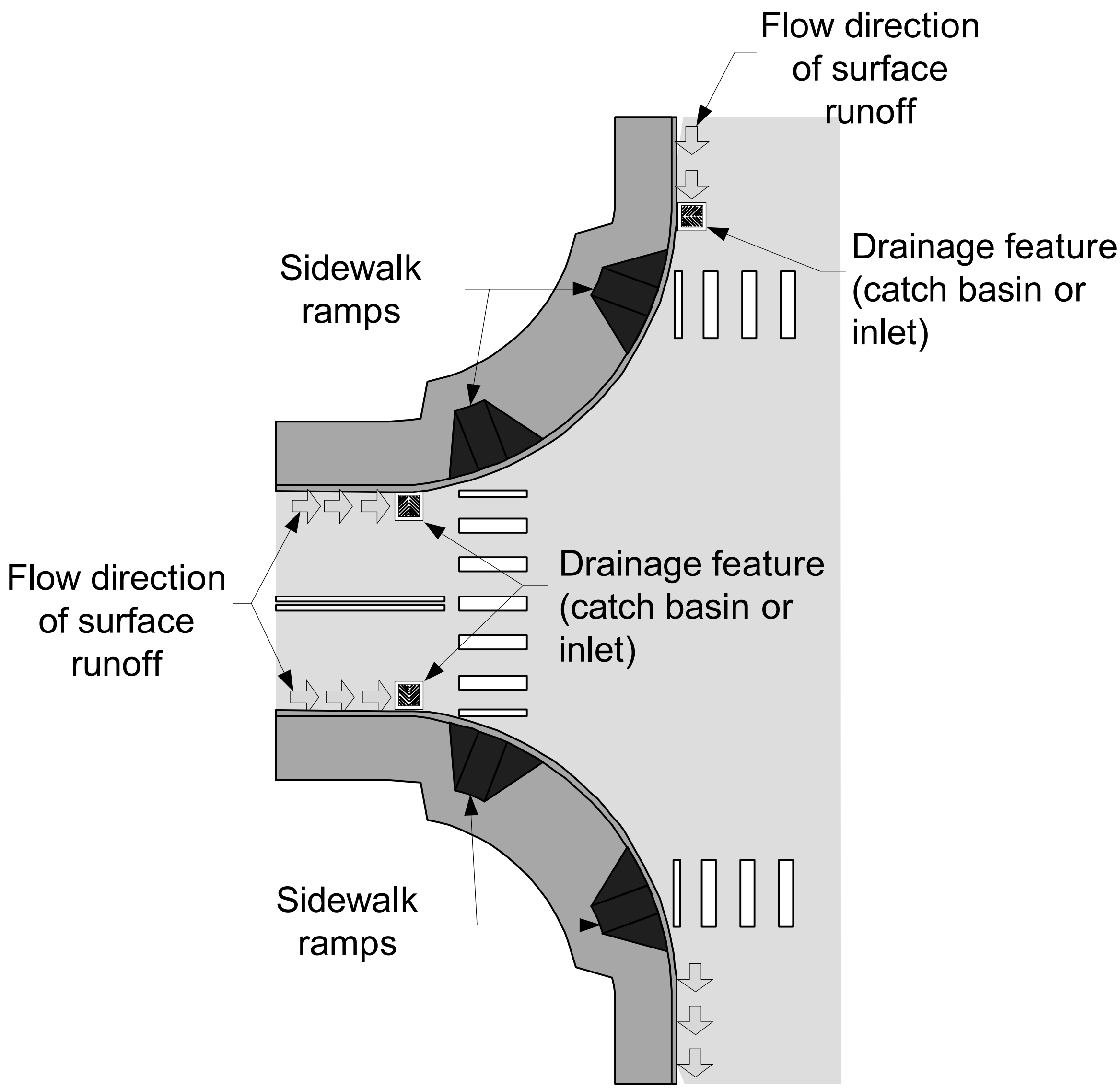


Improved line of sight with curb extension

Sight Distance at Intersections
Figure 1025-6b

Sidewalk Bulb Outs
Figure 1025-7

Midblock Pedestrian Crossing
Figure 1025-8



Sidwalk Ramp Drainage
Figure 1025-9

1130 Retaining Walls and Steep Reinforced Slopes

113.01 References

Bridge Design Manual, M 23-50, WSDOT

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

Plans Preparation Manual, M 22-31, WSDOT

Roadside Manual, M 25-39, WSDOT

1130.02 General

The function of a retaining wall is to form a nearly vertical face through confinement and/or strengthening of a mass of earth or other bulk material. Likewise, the function of a reinforced slope is to strengthen the mass of earth or other bulk material such that a steep (up to 2V:1H) slope can be formed. In both cases, the purpose of constructing such structures is to make maximum use of limited right of way. The difference between the two is that a wall uses a structural facing whereas a steep reinforced slope does not require a structural facing. Reinforced slopes typically use a permanent erosion control matting with <u>low</u> vegetation as a slope cover to prevent erosion. See the *Roadside Manual* for more information.

To lay out and design a retaining wall or reinforced slope, consider the following items:

- Functional classification
- Highway geometry
- Design Clear Zone requirements (Chapter 700)
- The amount of excavation required
- Traffic characteristics
- Constructibility
- Impact to any adjacent environmentally sensitive areas
- Impact to adjacent structures
- Potential added lanes
- Length and height of wall
- Material to be retained
- Foundation support and potential for differential settlement
- Ground water
- Earthquake loads
- Right of way costs
- Need for construction easements
- Risk
- Overall cost
- Visual appearance

If the wall or toe of a reinforced slope is to be located adjacent to the right of way line, consider the space needed in front of the wall/slope to construct it.

(1) Retaining Wall Classifications

Retaining walls are generally classified as gravity, semigravity, nongravity cantilever, or anchored. Examples of the various types of walls are provided in Figures 1130-1a through 1c.

Gravity walls derive their capacity to resist lateral soil loads through a combination of dead weight and sliding resistance. Gravity walls can be further subdivided into rigid gravity walls, prefabricated modular gravity walls, and Mechanically Stabilized Earth (MSE) gravity walls.

Rigid gravity walls consist of a solid mass of concrete or mortared rubble and use the weight of the wall itself to resist lateral loads.

Prefabricated modular gravity walls consist of interlocking soil or rock filled concrete, steel, or wire modules or bins (gabions, for example). The combined weight of these modules or bins resist the lateral loads from the soil.

MSE gravity walls use strips, bars, or mats of steel or polymeric reinforcement to reinforce the soil and create a reinforced soil block behind the face. The reinforced soil block then acts as a unit and resists the lateral soil loads through the dead weight of the reinforced mass. MSE walls may be constructed as fill walls, with fill and reinforcement placed in alternate layers to create a reinforced mass, or reinforcement may be drilled into an existing soil/rock mass using grouted anchor technology to create a reinforced soil mass (soil nail walls).

Semigravity walls rely more on structural resistance through cantilevering action of the wall stem. Generally, the backfill for a semigravity wall rests on part of the wall footing. The backfill, in combination with the weight of the wall and footing, provides the dead weight for resistance. An example of a semigravity wall is the reinforced concrete wall provided in the Standard Plans.

Nongravity cantilever walls rely strictly on the structural resistance of the wall in which vertical elements of the wall are partially embedded in the soil or rock to provide fixity. These vertical elements may consist of piles (soldier piles or sheet piles, for example), caissons, or drilled shafts. The vertical elements may form the entire wall face or they may be spanned structurally using timber lagging or other materials to form the wall face.

Anchored walls derive their lateral capacity through anchors embedded in stable soil or rock below or behind all potential soil/rock failure surfaces. Anchored walls are similar to nongravity cantilevered walls except that anchors embedded in the soil/rock are attached to the wall facing structure to provide lateral resistance. Anchors typically consist of deadmen or grouted soil/rock anchors.

Reinforced slopes are similar to MSE walls in that they also use fill and reinforcement placed in alternate layers to create a reinforced soil mass. However, the face is typically built at a 1V:1.2H to 2V:1H slope.

Rockeries (rock walls) behave to some extent like gravity walls. However, the primary function of a rockery is to prevent erosion of an oversteepened but technically stable slope. Rockeries consist of large well-fitted rocks stacked on top of one another to form a wall.

An example of a rockery and reinforced slope is provided in Figure 1130-1d. The various wall types and their classifications are summarized in Table 1(a-f).

1130.03 Design Principles

The design of a retaining wall or reinforced slope consists of seven principal activities:

- Developing wall/slope geometry
- Adequate subsurface investigation
- Evaluation of loads and pressures that will act on the structure
- Design of the structure to safely withstand the loads and pressures
- Design of the structure to meet aesthetic requirements
- Wall/slope constructibility
- Coordination with other design elements

The structure and adjacent soil mass must also be stable as a system, and the anticipated wall settlement must be within acceptable limits.

1130.04 Design Requirements

(1) Wall/Slope Geometry

Wall/slope geometry is developed considering the following:

- Geometry of the transportation facility itself
- Design Clear Zone requirements (Chapter 700)
- Flare rate and approach slope when inside the Design Clear Zone (Chapter 710)

- Right of way constraints
- Existing ground contours
- Existing and future utility locations
- Impact to adjacent structures
- Impact to environmentally sensitive areas
- For wall/slope geometry, also consider the foundation embedment and type anticipated, which requires coordination among the various design groups involved.

Retaining walls must not have anything (such as bridge columns, light fixtures, or sign supports) protruding in such a way as to present a potential for snagging vehicles.

Provide a traffic barrier shape at the base of a new retaining wall constructed 3.6 m or less from the edge of the nearest traffic lane. The traffic barrier shape is optional at the base of the new portion when an existing vertical-faced wall is being extended (or the existing wall may be retrofitted for continuity). Standard Concrete Barrier Type 4 is recommended for both new and existing walls except when the barrier face can be cast as an integral part of a new wall. Deviations may be considered but require approval as prescribed in Chapter 330. For deviations from the above, deviation approval is not required where sidewalk exists in front of the wall or in other situations where the wall face is otherwise inaccessible to traffic.

(2) Investigation of Soils

All retaining wall and reinforced slope structures require an investigation of the underlying soil/rock that supports the structure. Chapter 510 provides guidance on how to complete this investigation. A soil investigation is critical for the design of any retaining wall or reinforced slope. The stability of the underlying soils, their potential to settle under the imposed loads, the usability of any existing excavated soils for wall/reinforced slope backfill, and the location of the ground water table are determined through the geotechnical investigation.

(3) Geotechnical and Structural Design

The structural elements of the wall or slope and the soil below, behind, and/or within the structure must be designed together as a system. The wall/slope system is designed for overall external stability as well as internal stability. Overall external stability includes stability of the slope of which the wall/reinforced slope is a part and the local external stability (overturning, sliding, and bearing capacity). Internal stability includes resistance of the structural members to load and, in the case of MSE walls and reinforced slopes, pullout capacity of the structural members or soil reinforcement from the soil.

(4) Drainage Design

One of the principal causes of retaining wall/slope failure is the additional hydrostatic load imposed by an increase in the water content in the material behind the wall or slope. This condition results in a substantial increase in the lateral loads behind the wall/slope since the material undergoes a possible increase in unit weight, water pressure is exerted on the back of the wall, and the soil shear strength undergoes a possible reduction. To alleviate this, adequate drainage for the retaining wall/slope must be considered in the design stage and reviewed by the Region Materials Engineer during construction. The drainage features shown in the Standard Plans are the minimum basic requirements. Underdrains behind the wall/slope must daylight at some point in order to adequately perform their drainage function. Provide positive drainage at periodic intervals to prevent entrapment of water.

Native soil may be used for retaining wall and reinforced slopes backfill if it meets the requirements for the particular wall/slope system. In general, use backfill that is free-draining and granular in nature. Exceptions to this can be made depending on the site conditions as determined by the Geotechnical Services Branch of the Olympia Service Center (OSC) Materials Laboratory.

A typical drainage detail for a gravity wall (in particular, an MSE wall) is shown in Figure 1130-2. Typical drainage details for a standard reinforced concrete cantilever wall are provided in the DETAILS.CEL library. Always include drainage details such as these with a wall unless otherwise recommended to be deleted by the region's Materials Engineer or OSC Geotechnical Services Branch.

(5) Aesthetics

Retaining walls and slopes should have a pleasing appearance that is compatible with the surrounding terrain and other structures in the vicinity. To the extent possible within functional requirements and cost effectiveness criteria, this aesthetic goal should be met for all visible retaining walls and reinforced slopes.

Aesthetic requirements include consideration of the wall face material, the top profile, the terminals, and the surface finish (texture, color, and pattern). Where appropriate, provide planting areas and irrigation conduits. These will visually soften them and blend the them with adjacent areas. Avoid short sections of retaining wall or steep slope where possible.

In higher walls, variations in slope treatment are recommended for a pleasing appearance. High, continuous walls are generally not desirable from an aesthetic standpoint, as high, continuous walls can be quite imposing. Consider stepping high or long retaining walls in areas of high visibility. Plantings could be considered between wall steps.

Approval from the Principle Architect of the Bridge and Structures Office is required on all retaining wall aesthetics including finishes.

(6) Constructibility

Consider the potential effect site constraints may have on the constructibility of the specific wall/slope. Constraints to be considered include, but are not limited to, site geometry, access, time required to construct the wall, environmental issues, and impact on traffic flow and other construction activities.

(7) Coordination with Other Design Elements

(a) **Other Design Elements.** Retaining wall and slope designs must be coordinated with other elements of the project that could interfere with or impact the design and/or construction of the wall/slope. Also consider drainage features, utilities, luminaire or sign structures, adjacent retaining walls or bridges, concrete traffic barriers, and beam guardrails. Locate these design elements in a manner that will minimize the impacts to the wall elements. In general, locate obstructions within the wall backfill (such as guardrail posts, drainage features, and minor structure foundations) a minimum of 1 m from the back of the wall facing units. Greater offset distances may be required depending on the size and nature of the interfering design element. If possible, locate these elements to miss reinforcement layers or other portions of the wall system. Conceptual details for accommodating concrete traffic barriers and beam guardrails are provided in Figure 1130-3.

Where impact to the wall elements is unavoidable, the wall system must be designed to accommodate these impacts. For example, it may be necessary to place drainage structures or guardrail posts in the reinforced backfill zone of MSE walls. This may require that holes be cut in the upper soil reinforcement layers, or that discrete reinforcement strips be splayed around the obstruction. This causes additional load to be carried in the adjacent reinforcement layers due to the missing soil reinforcement or the distortion in the reinforcement layers.

The need for these other design elements and their impact on the proposed wall systems must be clearly indicated in the wall site data that is submitted so that the walls can be properly designed. Contact the Bridge and Structures Office (or the Geotechnical Services Branch, for geosynthetic walls/slopes and soil nail walls) for assistance regarding this issue.

(b) **Fall Protection.** Department of Labor and Industries regulations require that, when employees are exposed to the possibility of falling from a location 3 m or more above the roadway (or other lower area), the employer is to ensure that fall restraint or fall arrest systems are provided, installed, and implemented.

Consider fall protection when a wall retains 3 m or more of material. Any need for maintenance of the wall's surface or the area at the top can expose employees to a possible fall. If the area at the top will be open to the public, see Chapter 1025, "Pedestrian Design Considerations," and Chapter 1460, "Fencing."

For maintenance of a tall wall's surface, consider harness tie-offs if other protective means are not provided.

For maintenance of the area at the top of a tall wall, a fall restraint system is required when all of the following conditions will exist:

- The wall is on a cut slope.
- A possible fall would be of 3 m or more.
- Periodic maintenance will be performed on the area at the top.
- The area at the top is not open to the public.

Recommended fall restraint systems are:

- Wire rope railing with top and intermediate rails of one-half inch diameter steel wire rope.
- Brown vinyl coated chain link fencing.
- Steel pipe railing with one and one-half inch nominal outside diameter pipe as posts and top and intermediate rails.
- Concrete as an extension of the height of the retaining wall.

A fall restraint system must be 91 mm to 106 mm high, measured from the top of the finished grade, and capable of withstanding a 90 kg force from any direction, at the top, with minimal deflection. Post spacing is no more than 2.5 m on centers.

During rail system selection, the designer is to contact Maintenance regarding debris removal considerations.

Contact the Bridge and Structures Office for design details for any retrofit to an existing retaining wall and for any attachments to a new retaining wall.

1130.05 Guidelines for Wall/Slope Selection

Wall/slope selection is dependent on the following considerations:

- Whether the wall/slope will be located primarily in a cut or fill (how much excavation/shoring will be required to construct the wall or slope?)
- If located in a cut, the type of soil/rock present
- The need for space between the right of way line and the wall/slope or easement
- The amount of settlement expected
- The potential for deep failure surfaces to be present
- The structural capacity of the wall/slope in terms of maximum allowable height
- The nature of the wall/slope application
- Whether or not structures or utilities will be located on or above the wall
- Architectural requirements
- Overall economy

(1) Cut and Fill Considerations

Due to the construction technique and base width required, some wall types are best suited for cut situations whereas others are best suited for fill situations. For example, anchored walls and soil nail walls have soil reinforcements drilled into the in-situ soil/rock and, therefore, are generally used in cut situations. Nongravity cantilevered walls are drilled or cut into the in-situ soil/rock, have narrow base widths, and are also well suited to cut situations. Both types of walls are constructed from the top down. Such walls are also used as temporary shoring to allow other types of walls or other structures to be constructed where considerable excavation would otherwise be required.

MSE walls and reinforced slopes, however, are constructed by placing soil reinforcement between layers of fill from the bottom up and are therefore best suited to fill situations. Furthermore, the base width of MSE walls is typically on the order of 70 percent of the wall height, which would require considerable excavation in a cut situation. Therefore, in a cut situation, base width requirements usually make MSE structures uneconomical and possibly unconstructible.

Semigravity (cantilever) walls, rigid gravity walls, and prefabricated modular gravity walls are free-standing structural systems built from the bottom up but they do not rely on soil reinforcement techniques (placement of fill layers with soil reinforcement) to provide stability. These types of walls generally have a narrower base width than MSE structures, (on the order of 50 percent of the wall height). Both of these factors make these types of walls feasible in fill situations as well as many cut situations.

Reinforced slopes generally require more room overall to construct than a wall because of the sloping face, but are typically a feasible alternative to a combination wall and fill slope to add a new lane. Reinforced slopes can also be adapted to the existing ground contours to minimize excavation requirements where fill is placed on an existing slope. Reinforced slopes may also be feasible to repair slopes damaged by landslide activity or deep erosion.

Rockeries are best suited to cut situations, as they require only a narrow base width, on the order of 30 percent of the rockery height. Rockeries can be used in fill situations, but the fill heights that they support must be kept relatively low as it is difficult to get the cohesive strength needed in granular fill soils to provide minimal stability of the soil behind the rockery at the steep slope typically used for rockeries in a cut (such as 6V:1H or 4V:1H).

The key considerations in deciding which walls or slopes are feasible are the amount of excavation or shoring required and the overall height. The site geometric constraints must be well defined to determine these elements. Another consideration is whether or not an easement will be required. For example, a temporary easement may be required for a wall-in a fill situation to allow the contractor to work in front of the wall. For walls in cut situations, especially anchored walls and soil nail walls, a permanent easement may be required for the anchors or nails.

(2) Settlement and Deep Foundation Support Considerations

Settlement issues, especially differential settlement, are of primary concern for selection of walls. Some wall types are inherently flexible and can tolerate a great deal of settlement without suffering structurally. Other wall types are inherently rigid and cannot tolerate much settlement. In general, MSE walls have the greatest flexibility and tolerance to settlement, followed by prefabricated modular gravity walls. Reinforced slopes are also inherently very flexible. For MSE walls, the facing type used can affect the ability of the wall to tolerate settlement. Welded wire and geosynthetic wall facings are the most flexible and the most tolerant to settlement, whereas concrete facings are less tolerant to settlement. In some cases, concrete facing can be placed, after the wall settlement is complete, such that the concrete facing does not limit the wall's tolerance to settlement. Facing may also be added for aesthetic reasons.

Semigravity (cantilever) walls and rigid gravity walls have the least tolerance to settlement. In general, total settlement for these types of walls must be limited to approximately 25 mm or less. Rockeries also cannot tolerate much settlement, as rocks could shift and fall out. Therefore, semigravity cantilever walls, rigid gravity walls, and rockeries are not used in settlement prone areas.

If very weak soils are present that will not support the wall and that are too deep to be overexcavated, or if a deep failure surface is present that results in inadequate slope stability, the wall type selected must be capable of using deep foundation support and/or anchors. In general, MSE walls, prefabricated modular gravity walls, and some rigid gravity walls are not appropriate for these situations. Walls that can be pile supported such as concrete semigravity cantilever walls, nongravity cantilever walls, and anchored walls are more appropriate for these situations.

(3) Feasible Wall and Slope Heights and Applications

Feasible wall heights are affected by issues such as the capacity of the wall structural elements, past experience with a particular wall, current practice, seismic risk, long-term durability, and aesthetics.

See Table 1 for height limitations.

(4) Supporting Structures or Utilities

Not all walls are acceptable to support other structures or utilities. Issues that must be considered include the potential for the wall to deform due to the structure foundation load, interference between the structure foundation and the wall components, and the potential long-term durability of the wall system. Using retaining walls to support other structures is considered to be a critical application, requiring a special design. In general, soil nail walls, semigravity cantilever walls, nongravity cantilever walls, and anchored walls are appropriate for use in supporting bridge and building structure foundations. In addition to these walls, MSE and prefabricated modular gravity walls may be used to support other retaining walls, noise walls, and minor structure foundations such as those for sign bridges and signals. On a project specific basis, MSE walls can be used to support bridge and building foundations, as approved by the Bridge and Structures Office.

Also consider the location of any utilities behind the wall or reinforced slope when making wall/slope selections. This is mainly an issue for walls that use some type of soil reinforcement and for reinforced slopes. It is best not to place utilities within a reinforced soil backfill zone because it would be impossible to access the utility from the ground surface without cutting through the soil reinforcement layers, thereby compromising the integrity of the wall.

Sometimes utilities, culverts, pipe arches, etc. must penetrate the face of a wall. Not all walls and facings are compatible with such penetrations. Consider how the facing can be formed around the penetration so that backfill soil cannot pipe or erode through the face. Contact the Bridge and Structures Office for assistance regarding this issue.

(5) Facing Options

Facing selection depends on the aesthetic and the structural needs of the wall system. Wall settlement may also affect the feasibility of the facing options. More than one wall facing may be available for a given system. The facing options available must be considered when selecting a particular wall.

For MSE walls, facing options typically include the following:

- Precast modular panels
- In some cases, full height precast concrete panels. (Full height panels are generally limited to walls with a maximum height of 6 m placed in areas where minimal settlement is expected.)
- Welded wire facing
- Timber facing
- Shotcrete facing with various treatment options that vary from a simple broom finish to a textured and colored finish
- Segmental masonry concrete blocks
- Cast-in-place concrete facing with various texturing options.

Plantings on welded wire facings can be attempted in certain cases. The difficulty is in providing a soil at the wall face that is suitable for growing plants and meets engineering requirements in terms of soil compressibility, strength, and drainage. If plantings in the wall face are attempted, use only small plants, vines, and grasses. Small bushes could be considered for plantings between wall steps. Larger bushes or trees are not considered in these cases due to the loads on the wall face that they can create.

Geosynthetic facings are not acceptable for permanent facings due to potential facing degradation when exposed to sunlight. For permanent applications, geosynthetic walls must have some type of timber, welded wire, or concrete face. (Shotcrete, masonry concrete blocks, cast-in-place concrete, welded wire, or timber are typically used for geosynthetic wall facings.)

Soil nail walls can use either architecturally treated shotcrete or a cast-in-place facia wall textured as needed to produce the desired appearance.

For prefabricated modular gravity walls, the facing generally consists of the structural bin or crib elements used to construct the walls. For some walls, the elements can be rearranged to form areas for plantings. In some cases, textured structural elements may also be feasible. This is also true of rigid gravity walls, though planting areas on the face of rigid gravity walls are generally not feasible. The concrete facing for semigravity cantilever walls can be textured as needed to produce the desired appearance.

For nongravity cantilevered walls and anchored walls, a textured cast-in-place or precast facia wall is usually installed to produce the desired appearance.

(6) Cost Considerations

Usually, more than one wall type is feasible for a given situation. Consider cost throughout the selection process. Decisions in the selection process that may affect the overall cost might include the problem of whether to shut down a lane of traffic to install a low cost gravity wall system that requires more excavation room or to use a more expensive anchored wall system that would minimize excavation requirements and impacts to traffic. In this case, determine if the cost of traffic impacts and more excavation justifies the cost of the more expensive anchored wall system.

Decisions regarding aesthetics can also affect the overall cost of the wall system. In general, the least expensive aesthetic options use the structural members of the wall as facing (welded wire, concrete or steel cribbing or bins, for example), whereas the most expensive aesthetic options use textured cast-in-place concrete facias. In general, concrete facings increase in cost in the following order: shotcrete, segmental masonry concrete blocks, precast concrete facing panels, full height precast concrete facing panels, and cast-in-place concrete facing panels. Special architectural treatment usually increases the cost of any of these facing systems. Special wall terracing to provide locations for plants will also tend to increase costs. Therefore, the value of the desired aesthetics must be weighed against costs.

Other factors that affect costs of wall/slope systems include wall/slope size and length, access at the site and distance to the material supplier location, overall size of the project, and competition between wall suppliers. In general, costs tend to be higher for walls or slopes that are high, but short in length, due to lack of room for equipment to work. Sites that are remote or have difficult local access increase wall/slope costs. Small wall/slope quantities result in high unit costs. Lack of competition between materials or wall system suppliers can result in higher costs as well.

Some of the factors that increase costs are required parts of a project and are, therefore, unavoidable. Always consider such factors when estimating costs because a requirement may not affect all wall types in the same way. Current cost information can be obtained by consulting the *Bridge Design Manual* or by contacting the Bridge and Structures Office.

(7) Summary

For wall/slope selection, consider factors such as the intended application, the soil/rock conditions in terms of settlement, need for deep foundations, constructibility, impact to traffic, the overall geometry in terms of wall/slope height and length, location of adjacent structures and utilities, aesthetics, and cost. Table 1 provides a summary of many of the various wall/slope options available, including their advantages, disadvantages, and limitations. Note that specific wall types in the table may represent multiple wall systems, some or all of which may be proprietary.

1130.06 Design Responsibility and Process

(1) General

The retaining walls available for a given project include standard walls, nonstandard walls, and reinforced slopes.

Standard walls are those walls for which standard designs are provided in the WSDOT Standard Plans. Standard plans are provided for reinforced concrete cantilever walls up to 11 m in height. The internal stability design, and the external stability design for overturning and sliding stability, have already been completed for these standard walls. However, overall slope stability and allowable soil bearing capacity (including settlement considerations) must be determined for each standard-design wall location.

Nonstandard walls may be either proprietary (patented or trademarked) or nonproprietary. Proprietary walls are designed by a wall manufacturer for internal and external stability, except bearing capacity, settlement, and overall slope stability which are determined by WSDOT. Nonstandard nonproprietary walls are fully designed by WSDOT.

The geosynthetic soil reinforcement used in nonstandard nonproprietary geosynthetic walls is considered to be proprietary. It is likely that more than one manufacturer can supply proprietary materials for a nonstandard nonproprietary geosynthetic wall.

Reinforced slopes are similar to nonstandard nonproprietary walls in terms of their design process.

Some proprietary wall systems are preapproved. Preapproved proprietary wall systems have been extensively reviewed by the Bridge and Structures Office and the Geotechnical Services Branch. Design procedures and wall details for preapproved walls have already been agreed upon between WSDOT and the proprietary wall manufacturers, allowing the manufacturers to competitively bid a particular project without having a detailed wall design provided in the contract plans.

Note that proprietary wall manufacturers may produce several retaining wall options, and not all options from a given manufacturer have necessarily been preapproved. For example, proprietary wall manufacturers often offer more than one facing alternative. It is possible that some facing alternatives are preapproved, whereas other facing alternatives are not preapproved. WSDOT does not preapprove the manufacturer, but specific wall systems by a given manufacturer can be preapproved.

It is imperative with preapproved systems that the design requirements for all preapproved wall alternatives for a given project be clearly stated so that the wall proprietor can adapt the preapproved system to specific project conditions. For a given project, coordination of the design of all wall alternatives with all project elements that impact the wall (such as drainage features, utilities, luminaires and sign structures, noise walls, traffic barriers, guardrails, or other walls or bridges) is critical to avoid costly change orders or delays during construction.

In general, standard walls are the easiest walls to incorporate into project plans, specifications, & estimate (PS&E), but they may not be the most cost effective option. Preapproved proprietary walls provide more options in terms of cost effectiveness and aesthetics and are also relatively easy to incorporate into a PS&E. Nonstandard state-designed walls and nonpreapproved proprietary walls generally take more time and effort to incorporate into a PS&E because a complete wall design must be developed. Some nonstandard walls (state-designed geosynthetic walls, for example) can be designed relatively quickly, require minimal plan preparation effort, and only involve the region and the Geotechnical Services Branch. Other nonstandard walls such as soil nail and anchored wall systems require complex designs, involve both the Bridge and Structures Office and the Geotechnical Services Branch, and require a significant number of plan sheets and considerable design effort.

The Bridge and Structures Office maintains a list of the proprietary retaining walls that are preapproved. The region should consult the

Bridge and Structures Office for the latest list. The region should consult the Geotechnical Services Branch for the latest geosynthetic reinforcement list to determine which geosynthetic products are acceptable if a critical geosynthetic wall or reinforced slope application is anticipated.

Some proprietary retaining wall systems are classified as experimental by the FHWA. The Bridge and Structures Office maintains a list of walls that are classified as experimental. If the wall intended for use is classified as experimental, a work plan must be prepared by WSDOT and approved by the FHWA.

Gabion walls are nonstandard walls that must be designed for overturning, sliding, overall slope stability, settlement, and bearing capacity. A full design for gabion walls is not provided in the Standard Plans. Gabion baskets are typically 0.9 m high by 0.9 m wide, and it is typically safe to build gabions two baskets high (1.8 m) but only one basket deep, resulting in a wall base width of 50 percent of the wall height, provided soil conditions are reasonably good (medium dense to dense granular soils are present below and behind the wall).

(2) Responsibility and Process for Design

A flow chart illustrating the process and responsibility for retaining wall/reinforced slope design is provided in Figure 1130-4. As shown in the figure, the region initiates the process, except for walls developed as part of a preliminary bridge plan. These are initiated by the Bridge and Structures Office. In general, it is the responsibility of the design office initiating the design process to coordinate with other groups in the department to identify all wall/slope systems that are appropriate for the project in question. Coordination between the region, Bridge and Structures Office, Geotechnical Services Branch, and the Principle Architect should occur as early in the process as possible.

OSC or region consultants, if used, are considered an extension of the OSC staff and must follow the process summarized in Figure 1130-4. All consultant designs, from development of the scope of work to the final product, must be reviewed and approved by the appropriate OSC offices.

(a) Standard Walls. The regions are responsible for detailing retaining walls for which standard designs are available.

For standard walls greater than 3 m in height, and for all standard walls where soft or unstable soil is present beneath or behind the wall, a geotechnical investigation must be conducted, or reviewed and approved, by the Geotechnical Services Branch. Through this investigation, provide the foundation design including bearing capacity requirements and settlement determination, overall stability, and the selection of the wall types most feasible for the site.

For standard walls 3 m in height or less where soft or unstable soils are not present, it is the responsibility of the region materials laboratory to perform the geotechnical investigation. If it has been verified that soil conditions are adequate for the proposed standard wall that is less than or equal to 3 m in height, the region establishes the wall footing location based on the embedment criteria in the *Bridge Design Manual*, or places the bottom of the wall footing below any surficial loose soils. During this process, the region also evaluates other wall types that may be feasible for the site in question.

Figure 1130-5 provides design charts for standard reinforced concrete cantilever walls. These design charts, in combination with the Standard Plans, are used to size the walls and determine the applied bearing stresses to compare with the allowable soil bearing capacity deter-mined from the geotechnical investigation. The charts provide two sets of bearing pressures: one for static loads, and one for earthquake loads. Allowable soil bearing capacity for both the static load case and the earthquake load case can be obtained from the Geotechnical Services Branch for standard walls over 3 m in height and from the region materials laboratories for standard walls less than or equal to 3 m in height. If the allowable soil bearing capacity exceeds the values provided in Figure 1130-5, the Standard Plans can be used for the wall design. If one or both of the allowable soil bearing capacities does not exceed the values provided in Figure 1130-5, the Standard Plans cannot be used for wall design and the Bridge and Structures Office must be contacted for a nonstandard wall design.

If the standard wall must support surcharge loads from bridge or building foundations, other retaining walls, noise walls, or other types of surcharge loads, a special wall design is required. The wall is considered to be supporting the surcharge load and is treated as a nonstandard wall if the surcharge load is located within a 1V:1H slope projected up from the bottom of the back of the wall. Contact the Bridge and Structures Office for assistance

The Standard Plans provide six types of reinforced concrete cantilever walls (which represent six loading cases). Reinforced concrete retaining wall Types 5 and 6 are not designed to withstand earthquake forces and are not used in Western Washington (west of the Cascade crest).

Once the geotechnical and architectural assessment have been completed, the region completes the PS&E for the standard wall option(s) selected including a generalized wall profile and plan, a typical cross-section as appropriate, details for desired wall appurte-nances, drainage details, and other details as needed.

Metal bin walls, Types 1 and 2, have been deleted from the Standard Plans and are there-fore no longer standard walls. Metal bin walls are seldom used due to cost and undesirable aesthetics. If this type of wall is proposed, contact the Bridge and Structures Office for plan details and toe bearing pressures. The applied toe bearing pressure would then have to be evaluated by the Geotechnical Services Branch to determine if the site soil conditions are appropriate for the applied load and anticipated settlement.

(b) Preapproved Proprietary Walls. Final design approval of preapproved proprietary walls, with the exception of geosynthetic walls, is the responsibility of the Bridge and Structures Office. Final approval of the design of preapproved proprietary geosynthetic walls is the responsibility of the Geotechnical Services Branch. It is the region's responsibility to coordinate the design effort for all preapproved wall systems.

The region materials laboratory performs the geotechnical investigation for preapproved proprietary walls 3 m in height or less that are not bearing on soft or unstable soils. In all other cases, it is the responsibility of the Geotechnical Services Branch to conduct, or review and approve, the geotechnical investigation for the wall. The region also coordinates with the Principal Architect to ensure that the wall options selected meet the aesthetic requirements for the site.

Once the geotechnical and architectural assessments have been completed and the desired wall alternatives selected, it is the responsibility of the region to contact the suppliers of the selected preapproved systems to confirm in writing the adequacy and availability of the systems for the proposed use.

A minimum of three different wall systems must be included in the PS&E for any project with federal participation that includes a proprietary wall system unless specific justification is provided. Standard walls can be alternatives.

Once confirmation of adequacy and availability has been received, the region contacts the Bridge and Structures Office for special provisions for the selected wall systems and proceeds to finalize the contract PS&E in accordance with the *Plans Preparation Manual*. Provide the allowable bearing capacity and foundation embedment criteria for the wall, as well as backfill and foundation soil properties, in the special provisions. In general, assume that Gravel Borrow or better quality backfill material will be used for the walls when assessing soil parameters.

Complete wall plans and designs for the proprietary wall options will not be developed until after the contract is awarded, but will be developed by the proprietary wall supplier as shop drawings after the contract is awarded. Therefore, include a general wall plan, a profile showing neat line top and bottom of the wall, a final ground line in front of and in back of the wall, a typical cross-section, and the generic details for the desired appurtenances and drainage requirements in the contract PS&E for the proprietary walls. Estimate the ground line in back of the wall based on a nominal 0.5 m facing thickness (and state this on the wall plan sheets). Include load or other design acceptance requirements for these appurtenances in the PS&E. Contact the Bridge and Structures Office for assistance regarding this.

It is best to locate catch basins, grate inlets, signal foundations, and the like outside the reinforced backfill zone of MSE walls to avoid interference with the soil reinforcement. In those cases where conflict with these reinforcement obstructions cannot be avoided, the location(s) and dimensions of the reinforcement obstruction(s) relative to the wall must be clearly indicated on the plans. Contact the Bridge and Structures Office for preapproved wall details and designs for size and location of obstructions, and to obtain the generic details that must be provided in the plans. If the obstruction is too large or too close to the wall face, a special design may be required to accommodate the obstruction, and the wall is treated as a nonpreapproved proprietary wall.

A special design is required if the wall must support structure foundations, other retaining walls, noise walls, signs or sign bridges, luminaires, or other types of surcharge loads. The wall is considered to be supporting the surcharge load if the surcharge is located within a 1V:1H slope projected from the bottom of the back of the wall. For MSE walls, the back of the wall is considered to be the back of the soil reinforcement layers. If this situation occurs, the wall is treated as a nonpreapproved proprietary wall.

For those alternative wall systems that have the same face embedment criteria, the wall face quantities depicted in the plans for each alternative must be identical. To provide an equal basis for competition, the region determines wall face quantities based on neat lines.

Once the detailed wall plans and designs are available as shop drawings after contract award, the Bridge and Structures Office will review and approve the wall shop drawings and calculations, with the exception of geosynthetic walls which are reviewed and approved by the Geotechnical Services Branch.

(c) Nonpreapproved Proprietary Walls. Final design approval authority for nonpreapproved proprietary walls is the same as for preapproved proprietary walls. The region initiates the design effort for all nonpreapproved wall systems by submitting wall plan, profile, cross-section, and other information for the proposed wall to the Bridge and Structures Office, with copies to the Geotechnical Services Branch and the Principal Architect. The Bridge and Structures Office coordinates the wall design effort.

Once the geotechnical and architectural assessments have been completed and the desired wall types selected, the Bridge and Structures Office contacts suppliers of the nonpreapproved wall systems selected to obtain and review detailed wall designs and plans to be included in the contract PS&E.

To ensure fair competition between all wall alternatives included in the PS&E, the wall face quantities for those wall systems subject to the same face embedment requirements should be identical.

The Bridge and Structures Office develops the special provisions and cost estimates for the nonpreapproved proprietary walls and sends the wall PS&E to the region for inclusion in the final PS&E in accordance with the *Plans Preparation Manual*.

(d) Nonstandard Nonproprietary Walls. With the exception of rockeries over 1.5 m high, nonproprietary geosynthetic walls and reinforced slopes, and soil nail walls, the Bridge and Structures Office coordinates with the Geotechnical Services Branch and the Principal Architect to carry out the design of all nonstandard, nonproprietary walls. In this case, the Bridge and Structures Office develops the wall preliminary plan from site data provided by the region, completes the wall design, and develops the nonstandard nonproprietary wall PS&E package for inclusion in the contract.

For rockeries over 1.5 m high, nonproprietary geosynthetic walls and reinforced slopes, and soil nail walls, the region develops wall/slope profiles, plans, and cross-sections and submits them to the Geotechnical Services Branch to complete a detailed wall/slope design.

For geosynthetic walls and slopes, and for rockeries, the region provides overall coordination of the wall/slope design effort, including coordination with the Principal Architect regarding aesthetics and finishes, and the Region or OSC Landscape Architect if the wall uses vegetation on the face. The Geotechnical Services Branch has overall design approval authority. Once the wall design has been completed, the Geotechnical Services Branch, and in some cases the Bridge and Structures Office, provides geotechnical and structural plan details to be included in the region plan sheets and special provisions for the PS&E. The region then completes the PS&E package.

For soil nail walls, once the Geotechnical Services Branch has performed the geotechnical design, the Bridge and Structures Office, in cooperation with the Geotechnical Services Branch, coordinates the design effort and completes the PS&E package.

(3) Guidelines for Wall/Slope Data Submission for Design

(a) Standard Walls, Proprietary Walls, Geosynthetic Walls/Slopes, and Soil Nail Walls. Where OSC involvement in retaining wall/slope design is required (as for standard walls and preapproved proprietary walls over 3 m in height, gabions over 2 m in height, rockeries over 1.5 m in height, all nonpreapproved proprietary walls, geosynthetic walls/slopes, and all soil nail walls), the region submits the following information to the Geotechnical Services Branch or Bridge and Structures Office as appropriate:

- Wall/slope plans.
- Profiles showing the existing and final grades in front of and behind the wall.
- Wall/slope cross-sections (typically every 15 m) or CAiCE files that define the existing and new ground-line above and below the wall/slope and show stations and offsets.
- Location of right of way lines as well as other constraints to wall/slope construction.
- Location of adjacent existing and/or proposed structures, utilities, and obstructions.
- Desired aesthetics.
- Date design must be completed.
- Key region contacts for the project.

Note that it is best to base existing ground measurements, for the purpose of defining the final wall geometry, on physical survey data rather than solely on photogrammetry. In addition, the region must complete a Retaining Wall/Reinforced Slope Site Data Check List, DOT Form 351-009 EF, for each wall or group of walls submitted.

(b) Nonstandard Walls, Except Geosynthetic Walls/Slopes and Soil Nail Walls. In this case, the region must submit site data in accordance with Chapter 1110. Additionally, a Retaining Wall Site Data Check List, DOT361-009EF, for each wall or group of walls must be completed by the region.

1130.07 Documentation

The following documents are to be preserved in the project file. See Chapter 330.

- ☐ Wall Site Data Check List, DOT361-009EF, and attachments
- ☐ Final selection approval

Specific Wall Type	Advantages	Disadvantages	Limitations
Steel soil reinforcement with full height precast concrete panels	Relatively low cost	Can tolerate little settlement; generally requires high quality backfill; wide base width required (70% of wall height)	Applicable primarily to fill situations; maximum feasible height is approximately 6 m
Steel soil reinforcement with modular precast concrete panels	Relatively low cost; flexible enough to handle significant settlement	Generally requires high quality backfill; wide base width required (70% of wall height)	Applicable primarily to fill situations; maximum height of 10 m; heights over 10 m require a special design
Steel soil reinforcement with welded wire and cast in place concrete face	Can tolerate large short-term settlements	Relatively high cost; cannot tolerate long-term settlement; generally requires high quality wall backfill soil; wide base width required (70% of wall height); typically requires a settlement delay period during construction	Applicable primarily to fill situations; maximum height of 10 m for routine designs; heights over 10 m require a special design
Steel soil reinforcement with welded wire face only	Can tolerate large long-term settlements; low cost	Aesthetics, unless face plantings can be established; generally requires high quality backfill; wide base width required (70% of wall ht.)	Applicable primarily to fill situations; maximum height of 10 m for routine designs; heights over 10 m require a special design

Table 1(a).
Summary of mechanically stabilized earth (MSE) gravity wall/slope options available.

1210.01 General

Hydraulic design factors can significantly influence the corridor, horizontal alignment, grade, location of interchanges, and the necessary appurtenances required to convey water across, along, away from, or to a highway or highway facility. An effective hydraulic design conveys water in the most economical, efficient, and practical manner to ensure the public safety without incurring excessive maintenance costs or appreciably damaging the highway or highway facility, adjacent property, or the total environment.

This chapter is intended to serve as a guide to highway designers so they can identify and consider hydraulic related factors that impact the design. Detailed criteria and methods that govern highway hydraulic design are in WSDOT's *Hydraulics Manual* and *Highway Runoff Manual*.

Some drainage, flood, and water quality problems can be easily recognized and resolved; others might require extensive investigation before a solution can be developed. Specialists experienced in hydrology and hydraulics can contribute substantially to the planning and project definition phases of a highway project by recognizing potentially troublesome locations, making investigations and recommending practical solutions. Regions may request that the Olympia Service Center (OSC) Hydraulics Branch provide assistance regarding hydraulic problems.

Since hydraulic factors can affect the design of a proposed highway or highway facility from its inception, consider these factors at the earliest possible time during the planning phase.

In the project definition phase, begin coordination with all state and local governments and Indian tribes that issue or approve permits for the project.

1210.02 References

(1) Existing Criteria and References

Existing criteria and additional information for hydraulic design requirements, analyses, and procedures are contained in the following references:

Hydraulics Manual, M 23-03, WSDOT

Highway Runoff Manual, M 31-16, WSDOT

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

Standard Specifications for Road, Bridge and Municipal Construction, M 41-10, Amendments, and General Special Provisions, WSDOT

Utilities Manual, M 22-87, Section 1-19, "Storm Drainage," WSDOT

(2) Special Criteria

Special criteria for unique projects are available on request from the OSC Hydraulics Branch.

1210.03 Hydraulic Considerations

(1) The Flood Plain

Encroachment of a highway or highway facility into a flood plain might present significant problems. A thorough investigation considers the following:

(a) The effect of the design flood on the highway or highway facility and the required protective measures.

(b) The effect of the highway or highway facility on the upstream and downstream reaches of the stream and the adjacent property.

(c) Compliance with hydraulic related environmental concerns and hydraulic aspects of permits from other governmental agencies per Chapters 220 and 240.

Studies and reports published by the Federal Emergency Management Agency (FEMA) and the Corps of Engineers are very useful for flood plain analysis. The OSC Hydraulics Branch has access to all available reports and can provide any necessary information to the region.

(2) Stream Crossings

When rivers, streams, or surface waters (wetland) are crossed with bridges or culverts (including open bottom arches and three-sided box culverts), consider the following:

- Locating the crossing where the stream is most stable.
- Effectively conveying the design flow(s) at the crossing.
- Providing for passage of material transported by the stream.
- The effects of backwater on adjacent property.
- Avoiding large skews at the crossing.
- The effects on the channel and embankment stability upstream and downstream from the crossing.
- Location of confluences with other streams or rivers.
- Fish and wildlife migration.
- Minimizing disturbance to the original streambed.
- Minimizing wetland impact.

Also see the *Hydraulics Manual* Chapter 8 for further design details.

(3) Channel Changes

It is generally desirable to minimize the use of channel changes because ongoing liability and negative environmental impacts might result. Channel changes are permissible when the designer determines that a reasonable, practical alternative does not exist. When used, consider:

(a) Restoration of the original stream characteristics as nearly as practical. This includes:

- Meandering the channel change to retain its sinuosity.
- Maintaining existing stream slope and geometry (including meanders) so stream velocity and aesthetics do not change in undisturbed areas.
- Excavation, selection, and placement of bed material to promote formation of a natural pattern and prevent bed erosion.
- Retention of stream bank slopes.
- Retention or replacement of streamside vegetation.

(b) The ability to pass the design flood.

(c) The effects on adjacent property.

(d) The effects on the channel and embankment upstream and downstream from the channel change.

(e) Erosion protection for the channel change.

(f) Environmental requirements such as wetlands, fish migration, and vegetation re-establishment.

Do not redirect flow from one drainage basin to another. (Follow the historical drainage pattern.)

Consult the OSC Hydraulic section for the best guidance when channel changes are considered.

(4) Roadway Drainage

Effective collection and conveyance of storm water is critical. Incorporate the most efficient collection and conveyance system considering initial highway costs, maintenance costs, and legal and environmental considerations. Of particular concern are:

(a) Combinations of vertical grade and transverse roadway slopes that might inhibit drainage.

(b) Plugging of drains on bridges as the result of construction projects. This creates maintenance problems and might cause ponding on the structure. The use of drains on structures can be minimized by placing sag vertical curves and crossovers in superelevation outside the limits of the structure.

1440 Surveying and Mapping

1440.01 General

The Washington State Department of Transportation (WSDOT) is permitted, by an agreement with the Board of Registration for Professional Engineers and Land Surveyors, to "practice land surveying" under the "direct supervision of either a licensed professional land surveyor or a licensed professional engineer." See Figure 1440-1, Interagency Agreement.

1440.02 References

RCW 58.09, "Surveys -- Recording"

RCW 58.20.120, "System designation -- Permitted uses"

RCW 58.24.040(8), ". . . temporary removal of boundary marks or monuments"

WAC 332-120, "Survey Monuments -- Removal or Destruction"

WAC 332-130, "Minimum Standards for Land Boundary Surveys and Geodetic Control Surveys and Guidelines for the Preparation of Land Descriptions"

Interagency Agreement Between the Washington State Department of Transportation and the Board of Registration for Professional Engineers and Land Surveyors

Construction Manual, M 41-01, WSDOT

Highway Surveying Manual, M 22-97, WSDOT

Plans Preparation Manual, M 22-31, WSDOT

WSDOT Monument Database at http://www.wsdot.wa.gov/monument/

1440.03 Procedures

For WSDOT projects, it is recommended that surveying activities include (if appropriate) but not be limited to the following items.

(1) During the Project Definition Phase

(a) Include any pertinent surveying information in the Project Summary.

(b) Research for recorded survey monuments existing within the project area.

(c) Determine and prioritize project survey needs and tasks to be completed.

- Cadastral issues
- Right of way issues
- Geodetic control issues
- Photogrammetry issues
- Other issues as needed

(2) During Design and Development of the Plans, Specifications, and Estimate

(a) Hold a presurvey conference.

(b) Schedule tasks with surveyors.

(c) Perform field reconnaissance, mark existing recorded survey monuments, and determine location of possible new survey monuments. Also mark found unrecorded monuments for preservation if practical.

(d) Determine impact to geodetic monuments and notify OSC Geographic Services.

(e) See the *Highway Surveying Manual* to:

- Convert Washington state plane coordinates to project datum.
- Document the procedure and combined factor used for converting between datums.

- Determine survey collection methods.
- Collect primary, secondary, and tertiary survey data.
- Process and import secondary, tertiary, or other survey data into design software for use by designers.

(f) Apply to the Department of Natural Resources (DNR) for permits for monuments that will be disturbed or removed (Chapter 1450).

(g) Archive new primary and secondary survey control data in the WSDOT Monument Database and GIS, as appropriate, for future retrieval.

(h) Ensure that all survey monuments within the right of way of the project are shown on the contract plans in order to avoid accidental damage.

(i) Develop a Record of Survey (RCW 58.09) or a Monumentation Map as required (Chapter 1450).

(3) After Construction is Completed

(a) Complete "Post Construction" survey as described in the *Highway Surveying Manual* and the *Construction Manual*.

(b) Have DNR Completion Report signed and stamped by the appropriate professional in direct responsible charge of the surveying work, then file with DNR as described in Chapter 1450.

1440.04 Datums

A datum is a geometrical quantity or set of quantities that serves as a reference, forming the basis for computation of horizontal and vertical control surveys in which the curvature of the earth is considered. Adjusted positions of the datum, described in terms of latitude and longitude, may be transformed into plane coordinates on a state system.

(1) Horizontal

WAC 332-130-060 states that "The datum for the horizontal control network in Washington shall be NAD83 (1991) as officially adjusted and published by the National Geodetic Survey of the United States Department of Commerce and as established in accordance with chapter 58.20 RCW. The datum adjustment shall be identified on all documents prepared; i.e., NAD83 (1991)." For further information, see the *Highway Surveying Manual*.

(2) Vertical

The Federal Geodetic Control Subcommittee (FGCS) has affirmed the North American Vertical Datum of 1988 (NAVD88) as the official civilian datum for surveying and mapping activities in the United States. WSDOT has adopted this datum. For further information, see the *Highway Surveying Manual.*

1440.05 Global Positioning System

A Global Positioning System (GPS) uses a constellation of satellites and earth stationed receivers to determine geodetic positions (latitude and longitude) on the surface of the earth. This survey technology is used by WSDOT personnel. See the *Highway Surveying Manual* for more detailed discussions.

GPS technology is changing rapidly. The key point is for the designer and surveyor to select the best tool (GPS application) for doing the survey. Often times a combination of GPS and traditional (Total Station) surveying is appropriate.

1440.06 WSDOT Monument Database

The WSDOT Monument Database provides storage and retrieval capabilities for data associated with survey control monuments set by WSDOT. This database supports and tracks the Report of Survey Mark and aids in fulfilling WSDOT's obligation to contribute to the body of public record, thereby minimizing the duplication of survey work.

The Internet address http://www.wsdot.wa.gov/monument/ is used to access the WSDOT Monument Database.

1450.01 General

Proper monumentation is important in referencing a highway's alignment that is used to define its right of way and the department can contribute to the body of public records and minimize duplication of survey work by establishing and recording monuments that are tied to a state plane and to a standard vertical datum. In addition, the department is required by law to perpetuate existing recorded monuments. (See RCW 58.09.) Consequently, the department shall provide monuments for realignments and new highway alignments and shall perpetuate existing monuments impacted by a project.

Both the Department of Natural Resources (DNR) and the Geographic Services Branch maintain records of surveys performed and survey monuments established. New monuments are to be reported to both operations.

Existing monuments are not to be disturbed without first obtaining the DNR permits required by state law. DNR allows the temporary covering of a string of monuments under a single permit. State law requires replacement of land boundary monuments after temporary removal according to permit procedures. WSDOT control and alignment monuments may be removed without replacement if approved by the Geographic Services Branch. (Notify DNR.)

Other requirements pertaining to specific monuments are discussed below.

Figure 1450-1 summarizes the documentation requirements for new and existing monuments.

The region is responsible for obtaining all required permits before any existing monument is disturbed and for the research to locate existing monuments as required by WAC 332-120-030 as follows:

> *(2) Any person, corporation, association, department, or subdivision of the state, county or municipality responsible for an activity that may cause a survey monument to be removed or destroyed shall be responsible for ensuring that the original survey point is perpetuated. It shall be the responsibility of the governmental agency or others performing construction work or other activity (including road or street resurfacing projects) to adequately search the records and the physical area of the proposed construction work or other activity for the purpose of locating and referencing any known or existing survey monuments.*

1450.02 References

"Engineers and Land Surveyors," RCW 18.43

"Surveys — Recording," RCW 58.09

"State Agency for Surveys and Maps — Fees," RCW 58.24

"Survey Monuments--Removal or Destruction," WAC 332-120

"Minimum Standards for Land Boundary Surveys and Geodetic Control Surveys and Guidelines for the Preparation of Land Descriptions," WAC 332-130

"*Manual of Instructions for the Survey of the Public Lands of the United States* 1973 BLM, U.S. Department of Interior"

1450.03 Definitions

monument, as defined for this chapter, is any physical object or structure which marks or references a survey point. This includes a point of curvature (P.C.), a point of tangency (P.T.), a property corner, a section corner, a General Land Office (GLO) survey point, a Bureau of Land

Management (BLM) survey point, and any other permanent reference set by a governmental agency or private surveyor.

removal or destruction the physical disturbance or covering of a monument such that the survey point is no longer visible or readily accessible.

1450.04 Control Monuments

Horizontal and vertical control monuments are permanent references required for the establishment of project coordinates tied to a state plane and elevations tied to a standard vertical datum. By establishing and recording permanent control monuments, the department eliminates duplication of survey work and contributes to the body of public records.

Horizontal and vertical control monuments are required for highway projects requiring the location of existing or proposed alignment or right of way limits. Monuments set by other agencies may be used if within two kilometers (1.24 miles) of the project and the required datum and accuracy were used. To omit monumentation when it is impractical, a variance must be sought from the State Survey Support Engineer.

When control monuments are required for a given project, either show the existing and proposed control monuments on the contract plans or include an approved variance in the design report.

For horizontal control:

- Use North American Datum 1983, revised 1991 (NAD83/91).
- Use a minimum of second order, Class II procedures as defined in the *Highway Surveying Manual* (M 22-97).
- Provide two monuments near the beginning of the project.
- Provide two monuments near the end of the project.
- Provide a pair of monuments at about five kilometer (or 3-mile) intervals throughout the length of the project.

For vertical control:

- Use North American Vertical Datum 1988 (NAVD88). See the *Highway Surveying Manual* for orders of accuracy required.
- Use at least third order procedures within project limits as defined in the *Highway Surveying Manual*.
- Provide vertical control throughout the length of the project. Desirable spacing is at or near each milepost or every other kilometer. Maximum spacing is five kilometers (3.11 miles) apart.

All control monuments that are established, reestablished, or reset must be filed with the county engineer and DNR. Submit a Monumentation Map that has been signed by the supervising, licensed, professional engineer, or land surveyor (or, if the monument is not used to reference right of way or land corners, submit a Record of Survey Mark).

1450.05 Alignment Monuments

Alignment monuments are permanent references required for the establishment or reestablishment of the highway and its right of way. Generally, highway and ramp center line P.C.s and P.T.s are monumented. Establishment, reestablishment, or resetting of alignment monuments is required on the following highway projects:

- New highway alignment projects.
- Highway realignment projects involving new right of way. (Monuments are only required for the realigned highway section.)
- Highway projects where alignment monuments already exist.

Before an existing alignment monument is reestablished or reset, a DNR permit is required.

All alignment monuments that are established, reestablished or reset must be filed with the appropriate county engineer and DNR. A copy of a Monumentation Map is filed with the county engineer of the county in which the monument is located and the original is sent to the Olympia Service Center Right of Way Plans Branch. The Olympia Service Center will forward a copy to DNR for their records.

1450.06 Property Corners

A new property corner monument will be provided where an existing recorded monument has been invalidated as a direct result of a right of way purchase by the department. The new property corner monument shall be set by or under the direct supervision of a licensed professional land surveyor. The licensed professional land surveyor must record the survey with the county auditor and send copies to DNR and the Olympia Service Center Right of Way Plans Branch.

1450.07 Other Monuments

A DNR permit is required before any monument may be removed or destroyed.

Existing section corners and BLM or GLO monuments impacted by a project shall be reset to perpetuate their existence. After completing the work, a Land Corner Record is required.

Other permanent monuments established by any other governmental agency must not be disturbed until the agency has been contacted to determine specific requirements for the monument. If assistance is needed to identify a monument, contact the Olympia Service Center Geographic Services Branch.

Resetting monuments must be done by or under the direct supervision of a licensed professional engineer or a licensed professional land surveyor. A copy of a Monumentation Map is filed with the county engineer of the county in which the monument is located and the original is sent to the Olympia Service Center Right of Way Plans Branch. The Olympia Service Center will forward a copy to DNR for their records.

1450.08 Documentation

The following documents are to be preserved for future reference in the project's design documents file. See Chapter 330.

- ☐ A general statement about the project's impacts on existing monuments.
- ☐ A general statement concerning new monuments.

1450.09 Filing Requirements

(1) DNR Permit

When a DNR permit is required, use the application form shown in Figure 1450-2a. The completed application must be signed by a licensed professional engineer or a licensed professional land surveyor and submitted to DNR.

Monumentation work cannot be done until DNR has approved the permit. Verbal permission may be granted by DNR pending the issuance of a written permit.

After resetting the monument, the survey method used must be filed with DNR using the completion report form shown in Figure 1450-2b. The form must be signed by a licensed professional engineer or a licensed professional land surveyor.

(2) Monumentation Map

When a Monumentation Map is required, a plan sheet is prepared. Generally, the plan sheet is based on a right of way plan obtained from the Olympia Service Center Right of Way Plans Branch. A Monumentation Map contains a description of all new and existing monuments indicating their kind, size, and location. In addition, it must contain the seal and signature of a licensed professional engineer or a licensed professional land surveyor. See the *Plans Preparation Manual*.

A copy of a Monumentation Map is filed with the county engineer of the county in which the monument is located and the original is sent to the Olympia Service Center Right of Way Plans Branch. The Olympia Service Center will forward a copy to DNR for their records.

(3) Land Corner Record

When a Land Corner Record is required, use the forms shown in Figures 1450-3a and 3b. The completed forms must be signed and stamped by a licensed professional engineer or a licensed professional land surveyor and submitted to the county auditor for the county in which the monument is located. Copies are sent to DNR and the Olympia Service Center Right of Way Plans Branch.

SET NEW

WSDOT Control Monument

Before: No permit required.

After: File a copy of a Monumentation Map with the county engineer. Send the original to the OSC R/W Plans Branch.

Alignment Monument

Before: No permits required.

After: File a copy of a Monumentation Map with the county engineer. Send the original to the OSC R/W Plans Branch.

Property Corner Monument*

Before: Engage a licensed professional land surveyor.

After: Licensed professional land surveyor files Record of Survey with county auditor and DNR and send a copy to the OSC R/W Plans Branch.

DISTURB EXISTING*

Control Monument

Before: Obtain DNR permit.

After: File a copy of a Monumentation Map with the county engineer. Send the original to the OSC R/W Plans Branch.

Alignment Monument

Before: Obtain DNR permit.

After: File a copy of a Monumentation Map with the county engineer. Send the original to the OSC R/W Plans Branch.

Section Corner, BLM, or GLO Monument

Before: Obtain DNR permit.

After: File Land Corner Record with the county auditor and DNR and send a copy to the OSC R/W Plans Branch.

All Other Monuments

Before:

- Obtain DNR permit.
- Contact governmental agency.

After: File a copy of a Monumentation Map with the county engineer. Send the original to the OSC R/W Plans Branch.

*Property corner monuments must be filed within 90 days of establishment, reestablishment, or restoration.

Monument Documentation Summary

Figure 1450-1

APPLICATION FOR PERMIT TO REMOVE OR DESTROY A SURVEY MONUMENT

PERMIT NO.

You are hereby authorized to remove or destroy the described survey monument(s):

AUTHORIZING SIGNATURE/DATE
(DNR or Other Authorizing Agency)

APPLICANT INFORMATION:

NAME: TELEPHONE NO: DATE:

COMPANY OR AGENCY NAME AND ADDRESS:

I estimate that this work will be finished by (date)____________________.

_________I request a variance from the requirement to reference to the Washington Coordinate System. (Please provide your justification in the space below.)

The variance request is ___ approved; ___ not approved. (FOR DNR USE ONLY) Reason for not approving:

MULTIPLE MONUMENTS:

______Check here if this form is being used for more than one monument. You must attach separate sheets showing the information required below for each monument affected. You must seal, sign and date each sheet.

INDEXING INFORMATION FOR AN INDIVIDUAL MONUMENT:

1) THE MONUMENT IS LOCATED IN: SEC_________TWP_________RGE_________1/4-1/4________

2) ADDITIONAL IDENTIFIER: (e.g., BLM designation for the corner, street intersection, plat name, block, lot, etc.)

MONUMENT INFORMATION: Describe: 3) the monument/accessories found marking the position, 4) the temporary references set to remonument the position (include coordinates when applicable), and 5) the permanent monument(s) to be placed on completion (if a permanent witness monument(s) is set include the references to the original position).

SEAL/SIGNATURE/DATE SIGNED

(Form prescribed 2/94 by the Public Land Survey Office, Dept. of Natural Resources, pursuant to RCW 58.24.040 (8).)

DNR Permit Application
Figure 1450-2a

COMPLETION REPORT FOR MONUMENT REMOVAL OR DESTRUCTION

(TO BE COMPLETED AND SENT TO THE DNR AFTER THE WORK IS DONE.)

_____ I have perpetuated the position(s) as per the detail shown on the application form.

SEAL/SIGNATURE/DATE SIGNED

OR

_____ I was unable to fulfill the plan as shown on the application form. Below is the detail of what I did do to perpetuate the original position(s). (If the application covered multiple monuments attach sheets providing the required information. Seal, sign and date each sheet.)

SEAL/SIGNATURE/DATE SIGNED

DNR Completion Report Form

Figure 1450-2b

LAND CORNER RECORD

(THIS FORM PRESCRIBED BY THE PUBLIC LAND SURVEY OFFICE, DEPARTMENT OF NATURAL RESOURCES, PURSUANT TO RCW 58.09.. ALPHA-NUMERIC INDEX DIAGRAM ON THE BACK.)

CORNER INDEXING INFORMATION:

TWP_______________ RGE_______________ CORNER CODE____________________
(Willamette Meridian) (See instructions on back of LCR)

ADDITIONAL IDENTIFIER: (e.g., BLM designation for the corner, street intersection, plat name, block, lot, etc.)

COUNTY: AUDITOR'S USE

LAND SURVEYOR INFORMATION: (or Public Officer as per RCW 58.09.090)

This corner record correctly represents work performed by me or under my direction in conformance with the Survey Recording Act.

COMPANY OR AGENCY:

ADDRESS:

SEAL/SIGNATURE/DATE

WASHINGTON PLANE COORDINATES: N: E:

ORDER: ZONE: DATUM (Date of adjustment):

CORNER INFORMATION: Use the space below to provide the following information regarding the corner: (1) Pertinent Corner History, (2) Evidence Found at the Corner, and (3) Corner Perpetuation Information. Please title and number the parts of your discussion accordingly. If additional space is needed use the back. (For (3), diagram the references. Also, provide the cross-reference to a map of record, if applicable, the surveyor's field book no./page no., and the date of work.) (See the back of this form for the requirements of the Survey Recording Act.)

DATE OF FORM: 2/92

Land Corner Record
Figure 1450-3a

MARK THE CORNER LOCATION ON THE DIAGRAM BELOW AND FILL IN THE CORNER CODE BLANK ON THE OTHER SIDE:

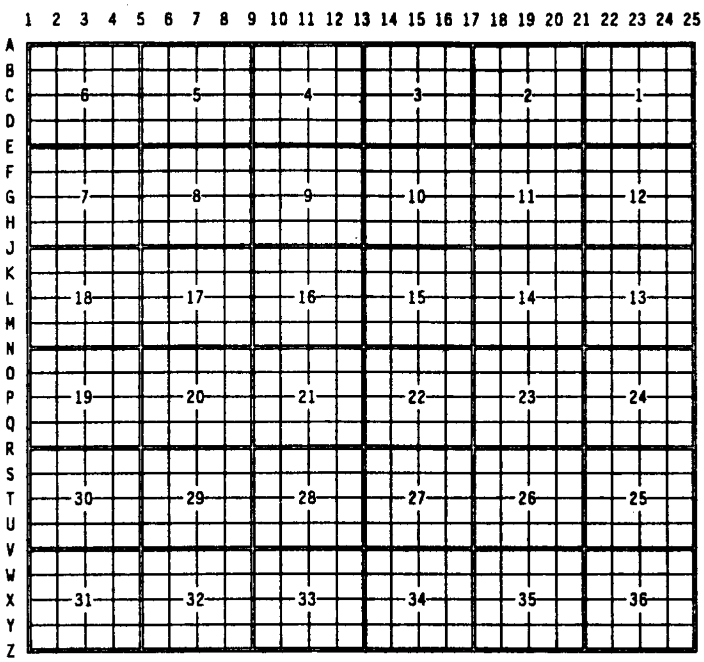
(1) For corners located at the intersection of two lines (Section corners, quarter corners and sixteenth corners):

(a) The corner code is the alpha-numeric coordinate from the diagram below that corresponds to the appropriate intersection of lines.

(2) For corners that are not located at the intersection of two lines (Meander corners, DLC's, HES's, reservation boundaries, mining claims, etc.):

(a) For corners that are on one line only the corner code is the line designation and the related line segment; i.e., a corner on line 5 between "B" and "C" is designated BC-5.

(b) For corners that are between lines the corner code is both line segments; i.e., a corner in the SE1/4 of the SE1/4 of section 18 is designated MN-4-5.



RCW 58.09.060 (2) requires the following information on this form: an accurate description and location, in reference to the corner position, of all monuments and accessories (a) found at the corner and (b) placed or replaced at the corner; (c) basis of bearings used to describe or locate such monuments or accessories; and (d) corollary information that may be helpful to relocate or identify the corner position.

SPACE FOR ADDITIONAL COMMENT:

Land Corner Record

Figure 1450-3b

A

B

D

E

F

G

H

I

J

L

M

N

O

P

Q

R

S

U

V

W

Z