Design Manual Revision Summaries
Design Policy and Standards Revisions

January 2005 Revision

The revision starts after page 5 of this document

Design Manual

Reminder: Revision marks are used throughout to highlight content changes. These consist of sidebars, and underlining. Manual users should periodically check the *Design Manual* Errata webpage. They should also report all undocumented errors they believe they have found.

General

- Review and update references, definitions, titles, & acronyms as appropriate.
- Clean up references to metric units of measure
- The "Documentation" subheadings are revised to direct the reader to the Documentation Check List on line.

***Design Manual* Supplements**

In alignment with the major *Design Manual* revision packages, an occasional *Design Manual* supplement may be issued. One has been issued since May, 2004. It is listed with the chapters that are affected.

Chapter 120 Planning – (January 2005)

- Changes have been made to the chapter to reflect the current organization of WSDOT
- The Regional Transportation Planning Organizations (RTPO) and Metropolitan Planning Organizations (MPO) have changed as a result of the 2000 census. Prior to the 2000 census there were 8 MPOs there are now 11 MPOs in Washington. The revisions to Chapter 120 reflect the changes to urbanized areas and the MPOs and RTPOs as a result of the 2000 census.

Chapter 140 Managing Project Delivery – (January 2005)

This chapter was completely rewritten to more closely reflect how the department applies Managing Project Delivery :

Chapter 141 Project Development Roles and Responsibilities for Projects with Structures (January 2005)

This is a new chapter written to provide information to the designer to get HQ Bridge and Structures involved early in the process if their project includes structures. The flow chart (Figures 141-1a and 1b) shows how this step fits in with the Managing Project Delivery process.

Chapter 325 Design Matrix Procedures – (January 2005)

- Clarification that terminology used in the *Design Manual* may not be the same as that used in outside references.
- Refined Guardrail Upgrades type as it relates to length of need and documentation
- Any element that will be reconstructed as part of a preventative maintenance project is to be addressed in accordance with Full Design Level.
- Expanded information on including/excluding risk project elements with a B/C greater than 1.0
- All matrices have been revised.

(DM Supplement – June 29, 2004 Addressing ADA Accessible Facilities on Road, Street, and Highway Projects)

- Replaced Figures 325-3 through 325-7

Chapter 340 Minor Operational Enhancement Projects

(DM Supplement – June 29, 2004 Addressing ADA Accessible Facilities on Road, Street, and Highway Projects)

- Revised the definitions of Pavement widening projects and Rechannelize existing pavement projects in 340.03(1) to reflect requirement for addressing ADA.

Chapter 430 Basic Design Level – (January 2005)

This chapter incorporated some minor revisions in references.

(DM Supplement – June 29, 2004 Addressing ADA Accessible Facilities on Road, Street, and Highway Projects

- New subsection 430.09 Bike and Pedestrian added to reflect ADA requirement that sidewalk ramps must be addressed for ADA compliance on projects that include HMA or PCCP overlays or inlays.
- Subsequent subsections renumbered.

Chapter 440 Full Design Level – (January 2005)

This chapter was completely rewritten.to incorporate *Design Manual* Supplements "Design Speed" and "Urban Roadways" both dated 3/25/04. All figures in this chapter were revised as well.

Chapter 520 Design of Pavement Structure – (January 2005)

A number of updates and corrections made

- Pavement Design Guide now an interactive reference
- Mineral Aggregate in Stockpile table removed from Figure 1120-1 as asphalt concrete pavement classes no longer exist
- Hot Mix Asphalt (HMA) designation replaces Asphalt Concrete Pavement (ACP) in Figures 520-2a and 2b
- HMA designation replaces Class of Mix A, B, E, F & G in Figure 520-2a. Class D line deleted
- Value corrected in the Paving Quantities portion of Figure 520-2a for 24 ft width at a depth of 0.20 ft.
- Notes reorganized and renumbered in Figures 520-2a and 520-3 to reflect deletion of Mineral Aggregate in Stockpile table from Figure 520-1
- Minor cosmetic changes made to Figures 520-4 and 520-5a through 520-5h

Chapter 620 Geometric Plan Elements – (January 2005)

- Many minor reference changes
- Corrected error in formula for minimum length of lane transition for low speed conditions and deleted superfluous paragraph in 620.07.

Chapter 640 Geometric Cross Section – (January 2005)

The most significant change to this chapter was the splitting its contents into three chapters with material on Turning Roadways being covered in a new Chapter 641 and material on Superelevation covered in new Chapter 642.

- Many references changed
- Removed metric values from newly renumbered figure 640-5b
- Urban Managed Access Roadway Sections added
- Shoulder slopes on high side of superelevated section may slope in opposite direction of adjacent lane.
- Recognition that the Cut Slope Selection tables in the figures are for preliminary estimates and that the final slope should be designed as recommended in the geotechnical report.
- Figures have been renumbered

Chapter 641 Turning Roadways – (January 2005)

This is a new chapter with most of the material coming from the split of Chapter 640.

- Added requirement to document the reasons for using minimum widths for turning roadways, one-lane or two-lane.
- Traveled way lane widening of less than 0.5 ft can be disregarded.
- Widening is not to be done on just the outside of a curve.
- Figures revised and renumbered

Chapter 642 Superelevation – (January 2005)

This is a new chapter with most of the material coming from the split of Chapter 640.

- Incorporated material from *Design Manual* Supplement – "Urban Roadways" dated 3/25/04.
- Updated definitions and references
- Superelevation runoff for highway curves and ramp curves revised
- Figures expanded or revised and renumbered

Chapter 710 Traffic Barriers – (January 2005)

- Added the definition of a hazard
- Revised the policy for replacing existing Breakaway Cable Terminals
- Add additional language to help clarify how flare rates are used
- Added language explaining how to reduce the possibility of backside hits to beam guardrail in medians and added figure 710-11d
- Revised Figure 710-4 to clarify traffic barrier locations on slopes
- Updated terminology from Asphalt Concrete Pavement to Hot Mix Asphalt
- Revised the language describing how curbs are used in conjunction with beam guardrail
- Added a new paragraph regarding High-Tension Cable Barrier systems
- Revised the language explaining the placement of New Jersey shape and single slope barrier
- Revised Figure 710-11b (Barrier Length of Need) to include posted speeds of 35, 30 and 25 MPH
- Revised Case 4 of Figure 710-14 to explain where to install cable barrier in medians

Chapter 720 Impact Attenuator Systems (January 2005)

- Revised the TAU II impact attenuator to the Universal Tau design
- Added the SCI100GM impact attenuator
- Added the Triton CET impact attenuator

Chapter 830 Delineation (January 2005)

Revised type of material used in rubber blade snow removal areas shown in Figure 830-1

Chapter 910 Intersections At Grade – (January 2005)

The chapter had several significant revisions.

- Many reference changes
- Previous unnumbered figure numbered 910-1 and old numbered figure 910-1 deleted or referenced to Chapters 1430 and 1435.
- Desirable intersection angle now stated as 90°
- Split T intersection considered an exception to a nonstandard configuration
- With justification and approval from the region's Traffic Engineer, existing intersections with nonstandard configurations may remain in place when an analysis shows no accident history is related to the configuration.
- Added use of computer generated templates for determining turning path movements
- Treatment of signalized intersections having opposing left-turn vehicle paths less than 4 feet has been expanded.
- Changed requirements for widening for left-turn channelization on divided highways.
- Added material for minimum protected left-turn with a median on divided highways.
- Changed "urban setting" to "managed access highway" for use of TWLTLs
- Clarified use of right-turn lanes at unsignalized intersections
- Added section on shoulder width requirements adjacent to turn lane and speed change lane at intersections.
- Additional guidance provided for U-turns at signal controlled intersections.
- Substantial rewrite of 910.10 Sight Distance at Intersections.
- Additional requirements for intersections plans.
- Figures renumbered
- Figures 910-7 and 910-10a through 18 revised

Chapter 915 Roundabouts – (January 2005)

Some minor editorial cleanup and changes in references.

Chapter 930 Railroad Grade Crossings – (January 2005)

This chapter was completely rewritten.

- All reference to metric values deleted
- Guidelines for railroad crossing protection deleted
- Section 130 Grade Crossing Improvement Projects added

- Light Rail added
- Figures renumbered

Chapter 940 Traffic Interchanges – (January 2205)

- Reference changes
- "Z" on ramp side of gore area in figures 940-11a and b revised
- Arrow depicting ramp angle separation corrected on Figure 940-12d

Chapter 1025 Pedestrian Design Considerations

(DM Supplement – June 29, 2004 Addressing ADA Accessible Facilities on Road, Street, and Highway Projects

- Definitions added for accessible route, detectable warning, landing, and truncated domes
- 1025.04(1) supplemented with requirements for ADA and Figure 1025-10 – ADA Requirements added
- 1025.07(2)(a) rewritten to incorporate ADA considerations

Chapter 1050 High Occupancy Vehicle Facilities – (January 2005)

Reference changes

Chapter 1120 Bridges – (January 2005)

- The designer is directed to Chapter 141 as a reminder to get HQ Bridge and Structures Office involved early
- References updated
- Vertical clearance over dedicated rail corridors having no freight traffic lowered to 22ft-6in with appropriate approvals of the railroad and the WUTC, Figures 1120-1, 1120-2a and 2b revised accordingly.
- Embankment at bridge end subheading added along with Figure 1120-3
- Documentation subheading revised to direct the designer to the Project Development Checklist on the web

Chapter 1300 Roadside Development – (January 2005)

A complete rewrite.

Chapter 1320 Vegetation (January 2005)

This chapter had several significant revisions

- Additions to Design Guidelines
- Addition of material relating to the establishment of vegetation

Washington State Department of Transportation

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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.

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	Pages	Sheets	Pages	Sheets
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1320,“Vegetation”	1-4	2	1-3	2
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Washington State Department of Transportation

Design Manual Supplements and Instructional Letters

January 2005

In Effect	Chapter	Date	Type	Subject/Title
Yes No No	HOV* 940 1050	9/28/99	DM Supplement	Left-Side HOV Direct Access Connections (Chapter 940 revised September 2002) (Chapter 1050 revised May 2003)
Yes No	HOV* 1050	05/03/00	DM Supplement	Left-Side HOV Parallel On-Connection (Chapter 1050 revised May 2003)
Yes	650	10/09/02	DM Supplement	Stopping Sight Distance
No **No** No	**440** **640** 430	3/25/2004	DM Supplement DM Supplement	Urban Roadways (Revised) (Design Speed 3/25/2004)
Yes **No**	430 **440**	3/25/2004	DM Supplement	Design Speed
Yes Yes Yes **No**	340 430 1025 **325**	6/29/2004	DM Supplement	ADA Accessible Facilities on Road, Street, and Highway Projects

* 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/DesignLettersMemInstruction.htm

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Figures

120.01 General

Transportation planning is a decision making process, required by federal and state law that is used to solve complex, interrelated transportation and land use problems. Various transportation interests from affected jurisdictions including local, regional, and state governments, as well as businesses, transportation providers, and community groups typically identify transportation needs. The needs are then evaluated within the framework provided by local, regional, and state land use and transportation policies as well as state and federal laws. These needs are interpreted in terms of constructed or service strategies that would meet those needs and these strategies are then evaluated based on projected fiscal constraints.

120.02 References

Transportation Equity Act for the 21st Century (TEA-21) of 1998

Code of Federal Regulations (CFR)

23 CFR 450 subpart B, "Statewide Transportation Planning"

23 CFR 450 subpart C, "Metropolitan Transportation Planning and Programming"

40 CFR, "Clean Air Act," parts 51 and 93

United States Code (USC)

23 USC 134, "Metropolitan planning"

23 USC 135, "Statewide planning"

Revised Code of Washington (RCW)

RCW 35.58.2795, "Public transportation systems — Six-year transit plans."

RCW 35.77.010(2), "Perpetual advanced six-year plans for coordinated transportation program expenditures — Nonmotorized transportation — Railroad right-of-way"

RCW 36.70A, "Growth management — Planning by selected counties and cities"

RCW 36.81.121(2), "Perpetual advanced six-year plans for coordinated transportation program, expenditures — Nonmotorized transportation — Railroad right-of-way"

RCW 43.21C "State Environmental Protection Act"

RCW 47.05, "Priority Programming for Highway Development"

RCW 47.06, "State-Wide Transportation Planning"

RCW 47.06B, "Coordinating Special Needs Transportation"

RCW 47.38, "Roadside Areas - Safety Rest Areas"

RCW 47.39, "Scenic and Recreational Highway Act of 1967" and changes thereto

RCW 47.50, "Highway Access Management"

RCW 47.76.220, "State rail plan - Contents"

RCW 47.80, "Regional Transportation Planning Organizations"

RCW 70.94, "Washington Clean Air Act" (Includes Commute Trip Reduction Law)

Washington Administrative Code (WAC)

WAC 468-51 and 52, "Highway Access Management"

WAC 468-86, "RTPO Planning Standards and Guidelines"

Roadside Manual, M 25-30, WSDOT

120.03 Acronyms and Definitions

ACCT Agency Council on Coordinated Transportation

ARB Agency Request Budget

B/C Benefit/Cost

CFR *Code of Federal Regulations*

CIPP *Capital Improvement and Preservation Program*

CLB Current Law Budget

CMP Corridor Management Plan

CTR Commute Trip Reduction

FAST Freight Action Strategy for the Everett-Seattle-Tacoma Corridor

FGTS Freight and Goods Transportation System

FHWA Federal Highway Administration

FTA Federal Transit Administration

GMA Growth Management Act

HSP *State Highway System Plan*

HSS Highways of Statewide Significance

ISTEA Intermodal Surface Transportation Efficiency Act of 1991

LOS Level of Service

MTIP Metropolitan Transportation Improvement Program

MPO Metropolitan Planning Organization

PSRC Puget Sound Regional Council

RCW *Revised Code of Washington*

RDP *Route Development Plan*

RTID Regional Transportation Investment District

RTIP Regional Transportation Improvement Program

RTPO Regional Transportation Planning Organization

SEPA State Environmental Policy Act

SHSP *State Highway System Plan* also known as the **HSP**

STIP Statewide Transportation Improvement Program

TDM Transportation Demand Management

TEA-21 Transportation Equity Act for the 21stCentury of 1998

TIP Transportation Improvement Program

TPO Transportation Planning Office

UPO Central Puget Sound Urban Planning Office

USC *United States Code*

WAC *Washington Administrative Code*

WSDOT Washington State Department of Transportation

WTP *Washington's Transportation Plan*

120.04 Legislation and Policy Development

The Washington State Legislature requires the Washington State Department of Transportation (WSDOT) to plan, develop, maintain, and preserve the transportation network in accordance with all state laws and federal requirements. The Washington State Transportation Commission interprets these requirements through a set of policies that guide the process.

The Washington State Transportation Commission consists of seven members who are appointed by the Governor. This body serves as the board of directors for WSDOT and provides oversight to ensure that WSDOT delivers a high quality, multimodal transportation system that moves people and goods safely and efficiently. The Commission also develops plans and funding recommendations for Legislative approval.

The following are highlights of federal and state legal requirements that influence or direct planning activities conducted by WSDOT. These legal requirements must be satisfied for WSDOT to be eligible to receive or expend federal and state transportation funds.

(1) Federal Law: Transportation Equity Act (TEA-21)

The Transportation Equity Act (TEA-21), passed in 1998, authorizes highway safety, transit, and other surface transportation programs through the year 2004. TEA-21 continues the trend initiated in 1991 by the Intermodal Surface Transportation Efficiency Act (ISTEA). ISTEA brought closure to the federal Interstate highway construction era and established new methods for distributing federal transportation dollars.

TEA-21 acknowledges the importance of statewide and metropolitan transportation planning activities at the state and regional levels. Below is a list of mandatory federal planning requirements included in TEA-21.

(a) Statewide Planning. 23 USC 135 and 23 CFR 450 — subpart B outline the federal requirements for statewide planning by state departments of transportation.

(b) Metropolitan Planning. 23 USC 134 and 23 CFR 450 subpart C — outline the federal requirements for Metropolitan Planning Organizations (MPO).

Each urbanized area (an area determined by the US Census Bureau to have a population of 50,000 or more with a density of at least 500 per square mile) is required to have an MPO. The MPO must develop and obtain approval of a metropolitan transportation plan and transportation improvement program to receive and expend federal transportation capital or operating assistance. The 2000 census identified 13 urbanized areas in Washington; these areas have established eleven MPOs. (See ftp://ftp.wsdot.wa.gov/public/Cartography/RTPO/rtpompoSimple.jpg

They are:

- Benton-Franklin Council of Governments (BFCOG)
- Cowlitz – Wahkiakum Council of Governments (CWCOG)
- Lewis-Clark Valley Metropolitan Planning Organization (LCVMPO)
- Puget Sound Regional Council (PSRC)
- Skagit Metropolitan Planning Organization (Skagit MPO)
- Southwest Washington Regional Transportation Council (SWRTC)
- Spokane Regional Transportation Council (SRTC)
- Thurston Regional Planning Council (TRPC)
- Wenatchee Valley Transportation Council (WVTC)
- Whatcom County Council of Governments (WCCOG)
- Yakima Valley Conference of Governments (YVCOG)

MPOs cover the metropolitan areas prescribed by federal law and also serve as the lead agency for Regional Transportation Planning Organizations (RTPOs) as enabled by state law (RCW 47.80), that form to include the MPO area (in some cases RTPOs cover a larger area). MPOs with a population over 200,000 are also designated as Transportation Management Areas (TMA).

Each MPO has a transportation policy board consisting of local elected officials from cities and counties. These boards may also consist of representatives from ports, transit agencies, tribes, WSDOT, major employers, the public, and other local transportation interests. Typically, each MPO also has a technical committee composed of staff from local planning and public works departments, and WSDOT Regional staffs.

The results of this transportation planning process are transportation plans and programs that are consistent with, and implement local comprehensive plans. The MPO planning process provides for:

- A forum for gaining local consensus on regional transportation needs.
- The creation of a metropolitan transportation plan identifying future transportation facilities and services needed to support and implement local comprehensive plans.

- Targeted transportation studies used to develop the metropolitan transportation plan.
- A forum to decide how to allocate certain categories of transportation funds.
- The development of a three-year list of facilities and services (to be funded by member organizations) called the Metropolitan Transportation Improvement Program (MTIP).

Metropolitan transportation plans provide a significant building block for the development of *Washington's Transportation Plan* created by WSDOT.

(2) State Laws: Planning Mandates Shape Project Selection

The state of Washington has adopted several important laws affecting transportation planning at various levels. These laws provide the framework for transportation decision-making, ultimately guiding the programming, design, and construction of transportation facilities and services. The following is a partial list of the state laws that address transportation planning.

(a) Statewide Transportation Planning (RCW 47.06). This set of laws establishes that " . . . the state has an appropriate role in developing statewide transportation plans." RCW 47.06 specifies that state owned transportation facilities and services, as well as those transportation facilities and services of state interest, must be addressed in these plans and that these plans shall guide short-term investment decisions and the long-range vision for transportation system development.

(1) *Washington's Transportation Plan* (WTP). The WTP provides guidance for the development, maintenance, and operation of a comprehensive and balanced multimodal transportation system. The overall direction of the WTP, prepared pursuant to RCW 47.06, is provided by the Washington State Transportation Commission. The WTP provides the direction for investment decision-making at WSDOT for all modes of transportation.

The WTP includes the following subjects concerning all major transportation modes:

- Meeting the federal requirements identified in TEA-21.
- Critical factors affecting transportation.
- Important issues concerning each mode and strategies to solve problems or improve function.
- Plans for development and integration of the various modes of transportation.
- Major improvements in facilities and services to meet transportation needs.
- Financial resources required to implement the recommendations.

The WTP is a dynamic plan that is updated on a regular basis to address changing conditions. Information and recommendations for the WTP are received from WSDOT regions and Headquarters (HQ), Metropolitan Planning Organizations, Regional Transportation Planning Organizations, local governmental agencies, private transportation operators, and the public.

The WTP addresses transportation facilities owned and operated by the state, including state highways, Washington State Ferries, and state-owned airports. It also addresses facilities and services that the state does not own, but has interest in. These include public transportation, freight rail, intercity passenger rail, marine ports and navigation, nonmotorized transportation, and aviation.

(2) *State Highway System Plan* (SHSP or HSP). The *State Highway System Plan* is the highway component of the WTP. The HSP defines *Service Objectives*, *Action Strategies,* and costs to plan for, maintain, operate, preserve, and improve the state highway system for the next 20 years.

Because needs listed in the HSP exceed projected revenue, the Transportation Commission established a set of priorities for funding projects. (See the *State Highway System Plan*.) The Commission has adopted service objectives and action strategies as a way to establish a logical process for identifying and categorizing projects that will receive funding over the next 20 years. These service objectives and action strategies provide the framework for defining 20-years of needs on the state highway system. Work that does not fit any of the action strategies will not be authorized or considered in the development of, the Statewide Transportation Improvement Program (STIP) or any other budget proposal.

The HSP is updated every two years, in coordination with local plan updates, to reflect completed work and changing transportation needs, policies, and revenues.

(3) State Environmental Policy Act. The State Environmental Policy Act (SEPA) requires the environmental effects of state and local agency actions be evaluated per WAC 197-11. Certain categorical exemptions exist. Agencies are required to adopt these regulations by reference and may develop more specific regulations for their own agency to specify how SEPA will be implemented.

WSDOT adopted agency specific SEPA regulations in 1986. Per WAC 468-12-800 (3) the following transportation planning activities are categorically exempt under these rules:

"The development, adoption, and revision of transportation plans and six year construction programs and any other studies, plans and programs which lead to proposals which have not yet been approved, adopted or funded and which do not commit the WSDOT to proceed with the proposals."

It should be noted the local government Comprehensive Plans developed pursuant to the Growth Management Act (GMA) contain a transportation element and these Comprehensive Plans must include a SEPA review.

Typically, transportation planning does not require review under the National Environmental Policy ACT (NEPA) because there is no federal action in the development of state and local transportation plans.

(b) The Growth Management Act (RCW 36.70A). Enacted in March 1990, the state's Growth Management Act (GMA) requires cities and counties that meet certain population or growth-rate thresholds to adopt comprehensive plans. Jurisdictions that are required to or choose to plan under the GMA must also adopt and enforce ordinances that implement the policies adopted in the comprehensive plans. Under the GMA, comprehensive plans carry the force of law and require full public participation in their development.

A comprehensive plan is a series of coordinated policy statements and formal plans that direct growth. Comprehensive plans articulate how a community will be developed in the future. They include elements that address housing, utilities, capital facilities, economic development, land use, and transportation. GMA planning requires that the transportation element be consistent with and support the land use elements in comprehensive plans.

Continuous coordination and open discussion during the development of local comprehensive plans is key to developing valid plans that direct the growth of a community. Representatives from neighboring jurisdictions, special purpose districts, WSDOT, and others with an interest in future development must be involved at the beginning and throughout the planning process. This is to ensure that comprehensive plans are consistent with all other state and local plans.

Local comprehensive plans are important to WSDOT because they influence how state facilities not classified as Transportation Facilities of Statewide Significance, should be addressed, how state highways will be impacted by local land use, and how access requirements will be met or maintained.

WSDOT seeks to work in partnership with local governments as they develop comprehensive plans to help create a balance between the need for mobility and access, while emphasizing design components that improve or maintain the livability of communities. It is also the responsibility of WSDOT to review and comment on local comprehensive plans and amendments.

(c) Regional Transportation Planning Organizations (RTPOs) (RCW 47.80.020). Washington has two types of "regional" or "area wide" transportation planning organizations: MPO and RTPO. MPOs, which serve areas with urbanized populations over 50,000, were introduced in the discussion on federal laws in Section (1)(b). A Regional Transportation Planning Organization (RTPO) is a voluntary organization enabled under state law. In an area where an MPO exists, the MPO is required by state law to be the lead agency for the RTPO.

Although voluntary, cities, counties, ports, tribes, and transit agencies usually become members of the RTPO; their participation is their best way to influence local and statewide transportation planning.

RTPOs perform some functions similar to MPOs and, like MPOs, provide a forum for information exchange and collective decision making between local governments and WSDOT. WSDOT is represented on each RTPO technical advisory committee and on most RTPO Policy Boards.

Fourteen RTPOs exist in Washington State, covering all counties of the state except San Juan County. (See Figure 120-1.) Of the eleven MPOs listed in 120.04(1)(b), only Lewis-Clark Valley MPO is not the lead agency for an RTPO. In addition to the ten RTPOs with MPOs as lead agencies, there are the following RTPOs:

- Palouse RTPO (Asotin County is an Adjunct member)
- Peninsula RTPO
- QUADCO RTPO
- Northeastern Washington RTPO (N. E. W.)

(d) Transportation Facilities and Services of Statewide Significance (RCW 47.06.140). The Legislature has declared certain transportation facilities and services, which promote and maintain significant statewide travel and economic development, to be of statewide significance.

Transportation facilities and services of statewide significance (TFSSS) are considered essential state public facilities. (See RCW 36.70A.200.) Essential state public facilities cannot be precluded from operation or expansion by local comprehensive plans and development regulations. This means that the WSDOT interest in these facilities and services takes precedence over local interests in the planning process. These facilities must comply with local ordinances and permits.

Therefore, planning for TFSSS must be conducted with a statewide perspective in mind. WSDOT, in consultation with transportation providers and regulators, is responsible for development of a statewide, multimodal plan for these facilities and services. The balance between providing for the movement of people and goods and the needs of local communities is the main consideration.

Highways of Statewide Significance (HSS) are one category of transportation facilities and services of statewide significance. The HSS designation was established by the Washington State Transportation Commission, and approved by the Legislature, to identify significant state-owned transportation facilities and establish the following:

1. Standardized levels of service (LOS) for mobility on HSS routes
2. HSS routes receive a higher priority for WSDOT mobility improvement funding
3. HSS routes are specifically exempt from concurrency requirements (except in Island County) and
4. HSS routes will be the focus of Regional Transportation Improvement District funding (King, Pierce, and Snohomish Counties).

The HSS includes the Interstate highway system, interregional state principal arterials, and ferry connections that serve statewide travel.

WSDOT makes the final decision regarding the acceptable Level of Service (LOS) for highways of statewide significance. The MPOs and the RTPOs, in consultation with WSDOT, set the acceptable LOS on Regionally Significant state highways (Non-HSS).

For a list of Highways of Statewide Significance in Washington, see http://www.wsdot.wa.gov/ppsc/hsp/hss.htm.

(e) Functional Classification of Highways and Roadways (RCW 47.05.021). Functional classification is the grouping of highways, roads, and streets that serve similar functions into distinct systems or classes within the existing or future highway network. The objective of functional classification is to define the appropriate role (mobility versus access) of various highways in providing service and influencing development. Generally, the higher functional classification routes provide mobility between communities, have higher travel speeds, and serve longer distance travel. The lower functional classification routes focus on providing localized access to the land adjacent to the roadway. Functional classification is important in:

- Identifying routes for inclusion in the National Highway System.
- Providing the basis for administering the Surface Transportation Program.
- Determining design levels for a specific route.
- Planning.
- Establishing access control.
- Providing information for land use plans and decisions.
- Conducting needs assessments and cost allocation studies.
- Helping to determine the level of maintenance.
- Conducting the priority programming process.

All state highways are subdivided into three functional classifications. See Chapter 440, "Full Design Level," for definitions of the collector, minor arterial and principal arterial classifications.

(f) Freight and Goods Transportation System (FGTS). The FGTS has been established due to increasing interest in developing the most effective and efficient system for moving freight from suppliers to consumers. The FGTS is required by RCW 47.05.021 section 4, which states:

> "The transportation commission shall designate a freight and goods transportation system. This statewide system shall include state highways, county roads, and city streets. The commission, in cooperation with cities and counties, shall review and make recommendations to the legislature regarding policies governing weight restrictions and road closures which affect transportation of freight and goods."

The FGTS ranks state highways, county roads and city streets based on annual tonnage carried.

The Freight Mobility Strategic Investment Board (FMSIB) uses the FGTS to designate strategic freight corridors and is obligated to update the list of designated strategic corridors every two years (RCW 47.06A.020 (3)). WSDOT provides staff and logistical support to FMSIB, including updates to the FGTS.

(g) Access Control (RCW 47.50, WAC 468-51, and WAC 468-52). Access control is a program that combines traffic engineering and land use regulatory techniques. Access control balances the desire and need for access (from adjacent properties to streets and highways) with other elements such as safety, preservation of capacity, support for alternative transportation modes, and preservation and enhancement of communities.

There are two forms of access control within WSDOT: limited access control and managed access control. (See Chapters 1420, 1430, and 1435) For limited access control, WSDOT purchases the right to limit access to a highway. Managed access control is a regulatory program established by a state law that requires that access to state highways in unincorporated areas be managed by WSDOT to protect the public and preserve highway functionality. Cities also have authority to grant access to state highways with managed access within incorporated areas. WSDOT retains authority on state highways with limited access.

WSDOT has established the Master Plan for Limited Access Highways for access control that is consulted when planning transportation improvement strategies.

120.05 Planning at WSDOT

The role of planning at WSDOT is to identify transportation needs and facilitate the development and implementation of sound, innovative investments and strategies. Many groups within WSDOT conduct planning activities that directly or indirectly influence the design of transportation facilities.

These groups serve a variety of departmental purposes including advocating multi-modal strategies, providing technical assistance, and implementing a wide variety of programs, projects, and services.

The following is a list of the groups, involved in planning, with their responsibilities, and their effect on the design of transportation facilities.

(1) Transportation Planning Office

The Transportation Planning Office of the Strategic Planning and Programming Division in WSDOT Headquarters consists of three branches: the Systems Analysis and Program Development Branch, the Policy Development and Regional Coordination Branch, and the Central Puget Sound Urban Planning Office (UPO).

(a) Systems Analysis and Program Development Branch. The major responsibilities of the Systems Analysis and Program Development Branch are to:

- Coordinate planning activities and provide technical assistance to WSDOT regions.
- Oversee the development and programming of *Washington's Highway System Plan (HSP)*.
- Collect and process data, conduct studies, and develop travel forecasts.
- Coordinate project-planning activities and provide technical assistance to WSDOT regions.

(b) Policy Development and Regional Coordination Branch. The Policy Development and Regional Coordination Branch responsibilities include:

- Coordination of planning activities and technical assistance to WSDOT regions, the Central Puget Sound Urban Planning Office, eleven MPOs, and fourteen RTPOs.
- Management oversight of the MPOs to ensure fulfillment of federal metropolitan transportation planning regulations in 23 USC 134, and the RTPOs regarding state requirements in RCW 47.80, WAC 468-86, and the WSDOT Regional Planning Standards.
- Administration of federal and state planning grants for planning organizations.
- Development of the *Washington Transportation Plan* (WTP) in partnership with other WSDOT organizations, MPOs and RTPOs. See 120.04(2)(b) for a description of the WTP.

The responsibilities of the Central Puget Sound Urban Planning Office are discussed under Section 120.05(4).

(2) Public Transportation and Rail Division

The Public Transportation and Rail Division works to enhance mobility options by managing, coordinating, and advocating for rail, commuting options, and public transportation programs throughout the state. The division's mission is to improve transportation choices, connections, coordination, and efficiency. The division promotes freight rail programs and, in cooperation with Amtrak, passenger rail programs. The division also provides planning, project oversight, financial, and technical assistance to public transportation providers. Division staff oversees the state commute trip reduction program and provides technical assistance and grants to help reduce vehicle miles traveled by commuters in urban regions of the state.

Public Transportation and Rail Division's plans and programs add value to highway and roadway design decisions by emphasizing enhancement, improvement, and coordination of intermodal connections. It is recommended that these plans and programs be referenced during the design process to ensure coordination and efficiency.

(a) Public Transportation and Commute Options Office. Programs organized by the Public Transportation and Commute Options Office support passenger transportation systems and services through grants, technical assistance, research, and planning. The office works in partnership with local communities and governments to promote, improve, and expand and coordinate public transportation resources, and access to those resources, throughout the state. The major emphases in the Public Transportation program are:

- Implement projects and strategies identified in the *Public Transportation and Intercity Rail Passenger Plan for Washington State* and *Washington's Transportation Plan*.
- Identify, support, coordinate, and monitor the planning, capital, and operating funding needs of small urban and rural public transportation providers.
- Improve effectiveness and efficiency of public transportation through training, technical assistance, and coordination to all agencies engaged in public transportation including nonprofit agencies, and private for-profit bus and taxi companies.
- Establish mobility options in areas where public transportation is limited or does not exist.
- Develop, implement, and manage grant programs to enhance and sustain statewide mobility.
- Monitor compliance for safety, including the drug and alcohol programs of rural public transportation providers.
- Manage information and data for the efficient coordination of transportation programs and providers.
- Provide leadership and support for the Agency Council on Coordinated Transportation (ACCT). ACCT is an interagency team responsible for recommending policies and guidelines to promote institutional and operational structures that encourages the efficient coordination of transportation programs and providers.

(b) Rail Office. Intercity passenger rail and freight rail are the focus of this office. Passenger and freight rail services are an important part of our state transportation system. Moving people and goods by rail is often safer and more environmentally friendly than adding traffic to our already congested highways. Improvements to the state's rail system, whether funded by the private sector or the public sector, can help mitigate the impacts of our fast growing economy and population.

The *Intercity Rail Passenger Plan for Washington State* defines a passenger rail system that links major population centers throughout the state and provides the blueprint for needed improvements to these intercity rail systems. The plan emphasizes incrementally upgrading the Amtrak passenger rail system along the Pacific Northwest Rail Corridor in western Washington. The vision is to reduce travel times and provide better passenger rail service in the Pacific Northwest. A number of activities unrelated to passenger rail are continuously underway in the corridor, requiring extensive coordination among various agencies and private organizations. The corridor also serves some of the world's busiest ports. WSDOT is working with the Puget Sound Regional Council and other area agencies through the Freight Action Strategy for the Everett-Seattle-Tacoma Corridor (FAST Corridor) project to plan for the elimination of at-grade highway/railroad crossing conflicts and to improve port access.

The *Washington State Freight Rail Plan* fulfills a Federal Railroad Administration requirement that the states establish, update, and revise a rail plan. It also fulfills the Washington State Legislative directive (RCW 47.76.220) that WSDOT prepare and periodically revise a state rail plan that identifies, evaluates, and encourages essential rail services. The plan identifies the abandonment status of various rail lines, provides analysis of the various alternatives to these proposed abandonment's, and provides recommendations that are incorporated into *Washington's Transportation Plan*.

(c) Transportation Demand Management Office. The Transportation Demand Management (TDM) Office advocates for, creates, and develops effective solutions to capacity constraints within the state transportation system. TDM Office staff provides financial and technical support within WSDOT, and external transportation organizations, to help ensure that demand management can be implemented whenever such programs are appropriate and cost effective. Program support is provided in areas such as land use planning, TDM research, parking management, high capacity transportation planning, and policy development for the state's freeway high occupancy vehicle system.

The office also assists public and private employers, jurisdictions, and other interested parties with implementation of RCW 70.94.521 through 551. The goals of the commute trip reduction (CTR) statutes are to reduce air pollution, traffic congestion, and the consumption of fossil fuels. The TDM office provides financial and technical support to employers to meet their mandated CTR requirements.

The TDM Office provides leadership through developing policies and guidelines that help direct public and private investment in the state's transportation system. An essential function of the TDM Office is to develop and maintain a TDM Strategic Plan for WSDOT. This plan helps ensure that *Washington's Transportation Plan* and all other internal planning processes incorporate TDM activities. Regional and local TDM activities and planning functions are further supported by the TDM Office through coordination and implementation of statewide TDM programs, providing public information and marketing tools, and providing training opportunities. The office also administers local TDM grant programs and planning grants that generate commute efficiencies in certain urban areas of the state.

(3) Highways and Local Programs Division

Highways & Local Programs (H&LP) Division of the Washington State Department of Transportation (WSDOT), has been serving the local agencies of Washington State for over 60 years. H&LP is a statewide organization with Local Programs staff located in all six WSDOT regions and in Headquarters. Under WSDOT's stewardship agreement with the Federal Highways Administration (FHWA), H&LP serves as the steward of the local agency federal-aid program by administering and managing federal funds from project development through construction administration. H&LP provides assistance to cities, counties, ports, tribal governments, transit, and metropolitan and regional planning organizations in obtaining federal and state grant funds to build and improve local transportation systems. H&LP, on behalf of the Secretary of WSDOT, is responsible for preparing and submitting the Statewide Transportation Improvement Program (STIP) to FHWA, without which no federal project would be authorized. In addition, H&LP provides federal compliance oversight on federally funded projects, technical assistance and training, and promotes cooperative planning and partnerships between WSDOT and local agencies.

(4) WSDOT Regions and The Central Puget Sound Urban Planning Office (UPO)

The roles of planning at WSDOT regions and at the Central Puget Sound Urban Planning Office (UPO) are similar in many ways. What follows are descriptions of the roles of planning at WSDOT regions and the UPO.

(a) WSDOT Region Planning. Each WSDOT region has a Planning Office that has several roles, such as:

- Conducting and overseeing a variety of long-range planning studies.
- Coordinating and assisting planning organizations outside WSDOT.
- Assisting in development of prioritized plans.
- Administering internal WSDOT programs.
- Overseeing access control activities.
- Performing Development Services activities.

For the Olympic and Northwest Regions, many of these long-range planning functions are assigned to the Central Puget Sound Urban Planning Office (UPO).

Each Region Planning Office conducts long range planning studies such as Route Development Plans, Corridor Master Plans, and site-specific transportation alternatives and studies. These studies evaluate alternative solutions for both existing and projected transportation needs, initiate the long-range public involvement process, and ultimately provide the foundation for inclusion of identified improvement strategies into *Washington's Transportation Plan* (WTP) and the *State Highway System Plan* (HSP).

Each Region Planning Office coordinates with and assists the local Metropolitan Planning Organization (MPO) and Regional Transportation Planning Organizations (RTPO). In some cases, the Region Planning Office provides staff support for the local RTPO.

The region works with the Washington State Patrol to include their weigh site and other highway related needs in WSDOT projects.

Often, the Region Planning Office is responsible for administering internal WSDOT programs such as traffic modeling, the Travel Demand Management program (TDM), and responding to citizen concerns about pedestrian, bicycle, and other transportation related issues.

Development Services is the process of reviewing new developments affecting state highways, such as master planned communities, major subdivisions, and commercial projects. Developers provide mitigation for their impacts to the state highway system under the State Environmental Policy Act (SEPA) and Highway Access Management. The Development Services section works closely with the local lead agency during SEPA reviews and the permitting process to secure appropriate improvements to the state transportation system from developers.

The region's Planning Office also reviews and comments on local Comprehensive Plans so development regulations, local transportation elements, and WSDOT goals and interests are consistent.

(b) The Central Puget Sound Urban Planning Office. The Central Puget Sound Urban Planning Office (UPO), based in Seattle and part of the Strategic Planning and Programming Division, has a similar role to a region Planning Office yet the UPO role is more specialized. The UPO oversees long range planning efforts of WSDOT in the four-county Central Puget Sound area of King, Pierce, Snohomish, and Kitsap Counties. This is the same area covered by the MPO called the Puget Sound Regional Council (PSRC), located in Seattle. The four-county region is geographically split between WSDOT's Olympic and Northwest Regions. UPO also has the responsibility of coordinating plans developed by Washington State Ferries with the strategies contained in the *State Highway System Plan*.

The Central Puget Sound Urban Planning Office also participates in the review of documents mandated by the Growth Management Act (GMA). This includes the review of draft Comprehensive Plans as well as the Draft Environmental Impact Statements that provide supporting documentation to the Comprehensive Plans. The Central Puget Sound Urban Planning Office also provides staffing and logistical support for the Regional Transportation Investment District (RTID). The RTID, a regional transportation planning committee created by legislation, provides funding for major transportation projects in King, Pierce, and Snohomish counties.

Development Services responsibilities remain with the Northwest and Olympic Regions Planning Offices.

(5) Washington State Ferries Division

The *Long Range Ferry System Plan*, prepared by the Washington State Ferries Division, considers recent trends in ferry ridership, system costs, regional economy, and other system and site factors. It is recommended that designers contact the Washington State Ferries planning office during the design phase of any conceptual solution occurring near a ferry terminal or for a project that might add significant traffic to or around a ferry terminal.

(6) Aviation Division

The WSDOT Aviation Division:

- Provides general aviation airport aid, including an award-winning lighting program.
- Provides technical assistance for airspace and incompatible land use matters that may affect airport operations or compromise safety.
- Coordinates all air search, rescue, and air disaster relief.
- Administers pilot and aircraft registration.

This division is responsible for development of the *Washington State Airport System Plan.* The division also operates sixteen state airports strategically placed throughout the state.

120.06 Linking Transportation Plans

A main concern of the traveling public is that the transportation system allows them to move from point A to point B quickly, safely, and with the least possible inconvenience and expense. To fulfill the public's desire for a seamless transportation system, coordination of transportation planning efforts is essential.

(1) Coordination of Planning Efforts

Coordination of planning efforts between city, county, MPO, RTPO, public and private transportation providers, and state transportation plans is not only required by federal and state laws — it makes good business sense. Coordination of transportation planning is a cyclical process and begins as a bottom-up approach. Figure 120-1 is a diagram that explains the general relationships between the various transportation planning processes and organizations.

Cities and counties explore their needs and develop *comprehensive plans.* Among other components, each comprehensive plan contains a land use element and a transportation element, which must be consistent with each other. The transportation element (sometimes known as the *local transportation plan*) supports the land use element. The requirements in the Growth Management Act (see 120.04 (2)(d)) guide most of the comprehensive plans developed in the state of Washington.

MPOs and RTPOs coordinate and develop metropolitan and regional transportation plans. These plans cover multiple cities and, for RTPOs, encompass at least one county. The purpose of metropolitan transportation plans and regional transportation plans is to ensure that all the region's transportation needs are accurately captured in one document, to develop a financial strategy to address the unfunded needs, and to assure local plan consistency across jurisdictional boundaries.

Planning is undertaken to ensure consistent policy among all the various jurisdictions, whether state, regional, or local. It does not matter where the planning process begins because the process is both cyclic and iterative. If one component of a plan changes, it may or may not affect other components. If any one plan changes significantly, it can affect each of the other plans in the cycle. Early communication and coordination of conceptual solutions are critical to ensuring project delivery.

(2) Transportation Improvement Programs

Figure 120-2 shows the coordination of effort that produces consistent and comprehensive transportation plans and programs.

From these transportation plans, each town, city, county and public transportation provider develops a detailed list of projects that will be constructed in the ensuing three to six years. This detailed list of transportation projects is called the six year Regional Transportation Improvement Program also known as the Six-Year RTIP or the three-year Metropolitan Transportation Improvement Program (MTIP).

The six-year RTIP and the three-year MTIP must be financially constrained, meaning that the total cost of all projects cannot exceed the established revenue authority. Financially constraining the RTIP and the MTIP is one method used to ensure that the list of projects represents what the local agency intends to build in the near future to implement local transportation plans. Once each jurisdiction develops its individual TIP, the RTPO and the MPO compile these individual TIPs into a regional or metropolitan TIP.

Each RTPO/MPO completes a Regional or Metropolitan Improvement Program (RTIP or MTIP) at least once every two years (RCW 47.80.023). The RTIP/MTIPs must meet the requirements of federal and state laws regarding transportation improvement programs and plans. To achieve this, the RTIP/MTIP:

- Is developed cooperatively by local government agencies, public transit agencies, and the WSDOT Regions within each area.

- Includes all federally funded WSDOT Highway Construction Program projects.
- Includes all significant transportation projects, programs, and transportation demand management measures proposed to be implemented during each year of the next period.
- Identifies all significant projects, whether funded by state or federal funds.
- Includes all significant projects from the local transit development plans and comprehensive transportation programs required by RCW 35.58.2795, 35.77.010(2), and 36.81.121(2) for transit agencies, cities, towns, and counties.
- Includes all transportation projects funded by the Federal Highway Administration (FHWA) and the Federal Transit Administration (FTA).
- Includes all federally funded public lands transportation projects.
- Includes all WSDOT projects regardless of funding source and clearly designates regionally significant projects as such.
- Complies with all state (RCW 70.94) and federal (40 CFR 51 & 93) Clean Air Act requirements (where applicable).
- Includes only projects consistent with local, regional, and metropolitan transportation plans.
- Includes a financial section outlining how the RTIP/MTIP is financially constrained, showing sources and amounts of funding reasonably expected to be received for each year of the ensuing six/three-year period, and includes an explanation of all assumptions supporting the expected levels of funding.

Funding agencies often give preference to jointly sponsored transportation projects. RTPOs and MPOs can develop jointly sponsored projects since they represent multiple agencies. Major projects backed by an RTPO or an MPO have a heightened chance of receiving funding.

(3) Development of the STIP

An important role of the WSDOT Highways and Local Programs Division is to collect all RTIP, MTIP, and HSP projects in appropriate years and assemble all of the state and federally funded projects, and the projects of regional significance, into the (three-year) Statewide Transportation Improvement Program (STIP).

Development of a new STIP every two years is required by federal law in order to expend federal transportation dollars. The state of Washington, however, develops a new STIP each year to enhance project flexibility and to ensure project delivery.

The Governor’s approval of the MTIPs; plus the Federal Highway Administration’s, and the Federal Transit Administration’s approval of the STIP; are required prior to expenditure of federal funds.

120.07 Linking WSDOT Planning to Programming

Figure 120-3 is a flow chart describing the process conceptual solutions must go through to receive funding. This chart also describes the link between planning and program development. Project Definition is presented in Chapter 330, Design Matrices are in Chapter 325, and Environmental Documentation is in Chapter 220.

The role of WSDOT planning is to determine *what* facilities or services will be provided *where*. The role of WSDOT Systems Analysis and Program Development is to determine *when* the improvements will be provided. The WSDOT Systems Analysis and Program Development Branch prioritizes the projects that are selected from the *State Highway System Plan* component of *Washington’s Transportation Plan*. (See 120.04(2)(b).)

(1) The Role of the Systems Analysis and Program Development Branch

Taking the HSP from the planning stage through the programming stage is one role of the Systems Analysis and Program Development Branch. The Systems Analysis and Program Development Branch and the Project Control and Reporting Office manage the statewide highway construction program including:

- Recommending subprogram funding levels.
- Developing project priorities.
- Preparing, executing, and monitoring the highway construction program.

One responsibility of the Systems Analysis and Program Development Branch is oversight of the *Programming Process*. The legislative authorization for this activity is in RCW 47.05, Priority Programming. The Programming Process describes how projects that have been identified in the HSP are prioritized.

(2) Subprogram Categories

Subprogram categories for the service objectives and action strategies have been established, by the Transportation Commission, within WSDOT's budget to allow decision makers to determine timing and the amount of money to invest in solving transportation needs. (See the HSP for the service objectives and action strategies.) The order of the needs within each subprogram category is usually prioritized based on benefit/cost methodology: however, some subprograms do not have a prioritization methodology attached to them (such as Economic Initiatives).

The Department may combine projects that are scheduled to be constructed within six-years of each other to eliminate projects at the same location just a few years apart.

Following completion of construction, WSDOT evaluates the effectiveness that the project had on the performance of the transportation system.

(3) WSDOT Budgets

WSDOT uses the *State Highway System Plan* component of the twenty-year *Washington's Transportation Plan* as the basis for prioritizing and programming to select projects for the Agency Request Budget (ARB) and Current Law Budget (CLB). To be selected, a project must already be included in the HSP.

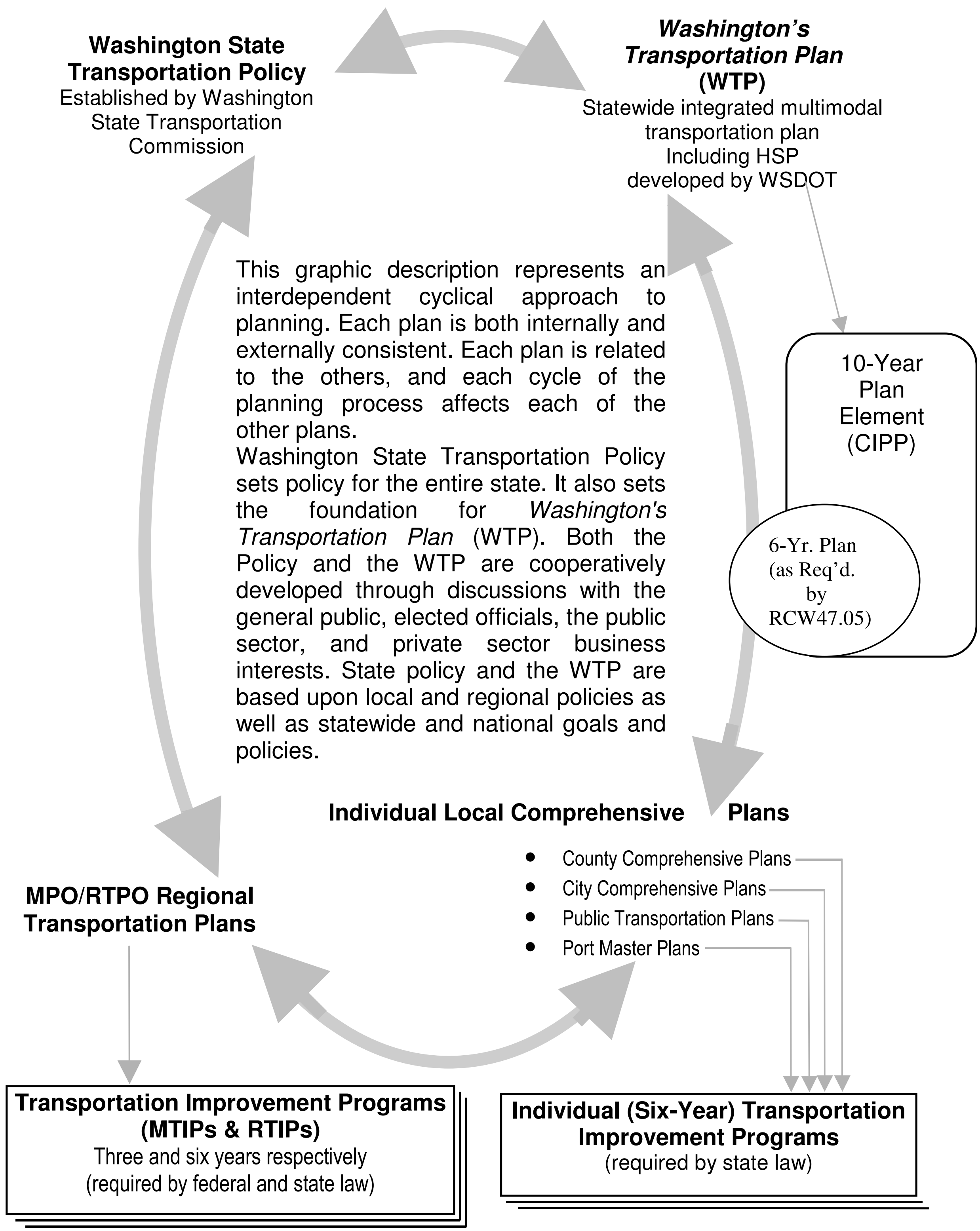
WSDOT operates on a two-year funding cycle. This is primarily because the state Legislature appropriates state transportation funds on a biennial basis. The Washington State Transportation Commission has developed a Six-Year Plan Element and the ten year Capital Improvement and Preservation Program (CIPP). The plans were developed to better implement the intent of federal and state laws influencing transportation and land use, to encourage a longer range perspective in the funding of transportation projects, and to be consistent with local and regional transportation planning processes. These plan elements will be used by the Commission to develop the two-year budget proposals.

When appropriated by the Legislature, WSDOT's two-year budget is forwarded to the appropriate RTPOs and MPOs for any needed revisions to the RTIPs and MTIPs.

(4) Key Points of Planning and Programming at WSDOT

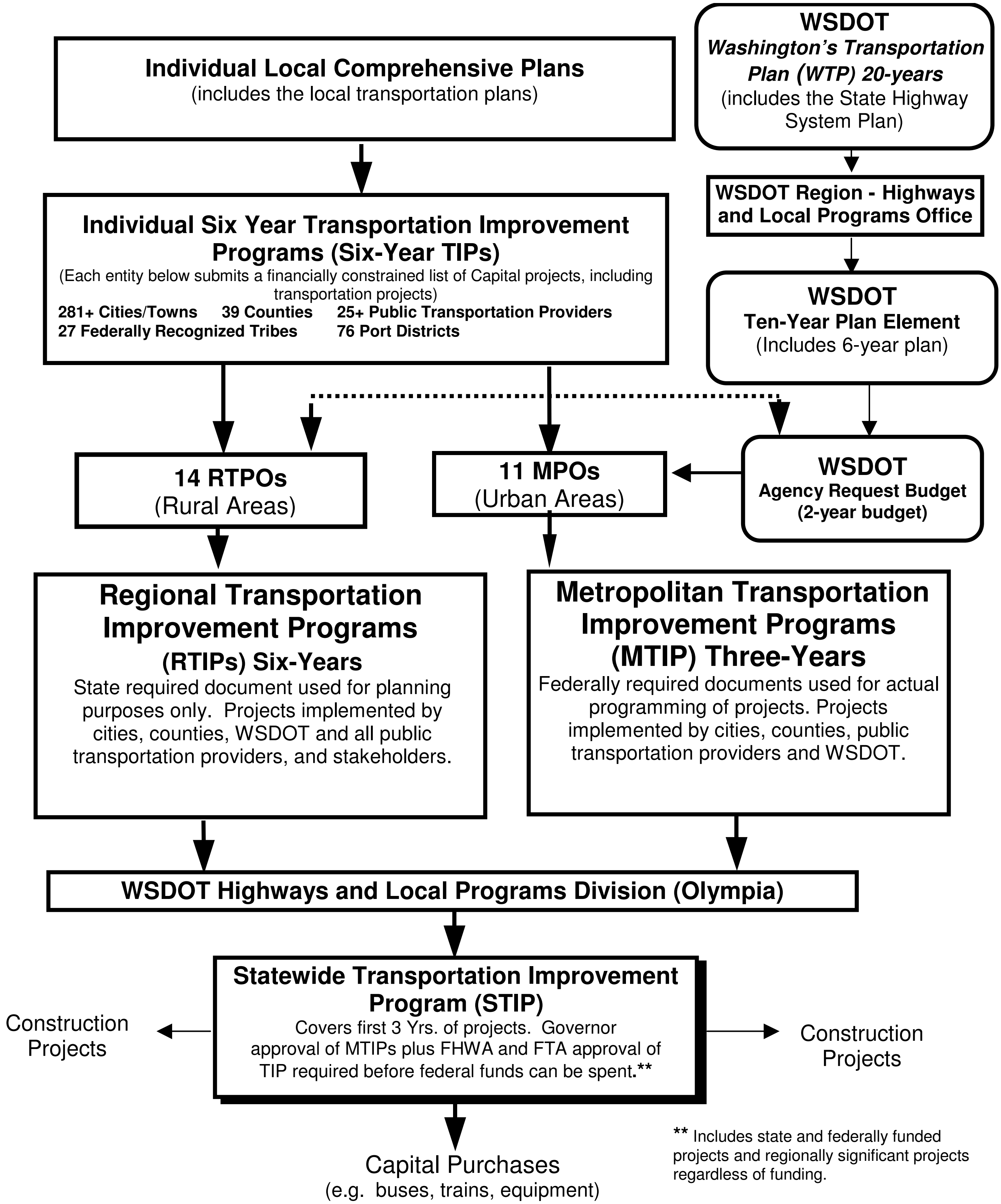
Below is a list of key points to remember about WSDOT's planning and programming process:

- Commission Policy sets the direction for *Washington's Transportation Plan* (WTP).
- Federal transportation laws and state transportation and land use laws guide solutions to address the needs for transportation facilities and services.
- The WTP is developed in partnership with MPOs and RTPOs and is tied to the land use plans of towns, cities, and counties.
- The region's Planning Offices have the main responsibility for meeting many of the state and federal planning requirements.
- The *State Highway System Plan* is a component of the WTP.
- The *State Highway System Plan* sets forth service objectives and action strategies to implement Commission policy.
- Conceptual solutions are prioritized within most budget categories based on benefit/cost analyses to obtain the greatest benefit at the least cost.
- Tradeoffs between project categories are made by policy choice through a multitiered process (WSDOT executives, Commission, and Legislature).
- An improvement strategy must be listed in the *State Highway System Plan* to be considered for project funding.

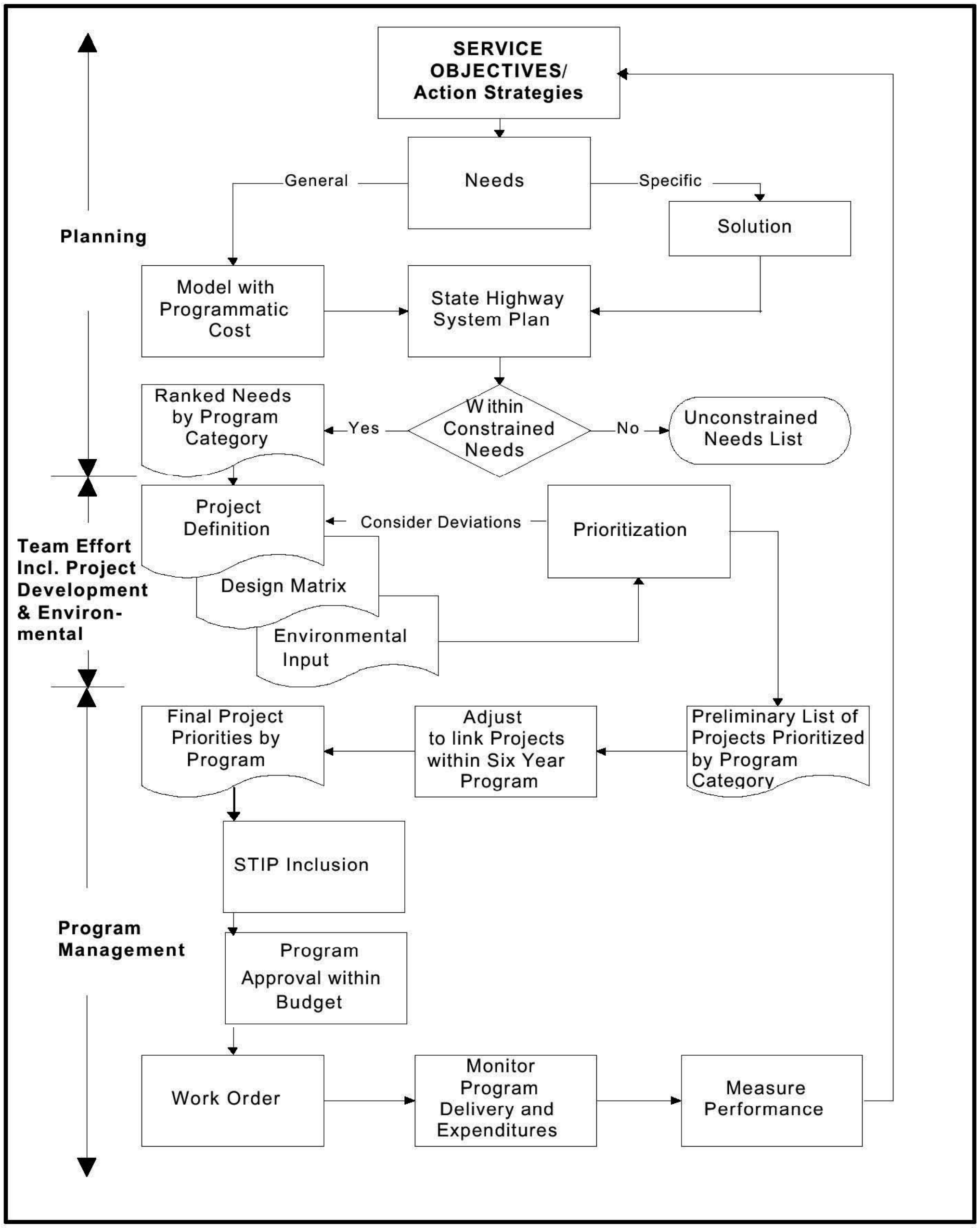


Relationship Between Transportation Plans and Planning Organizations

Figure 120-1



Transportation Improvement Programs
Figure 120-2



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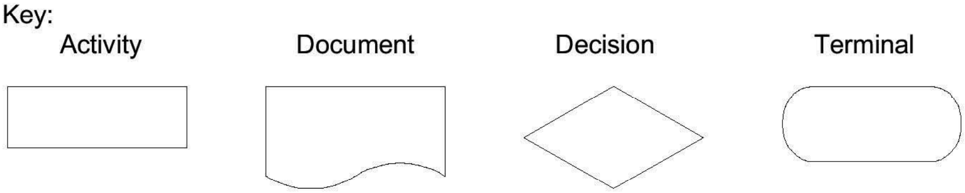


Linking Planning and Programming
Figure 120–3

Chapter 140 Managing Project Delivery

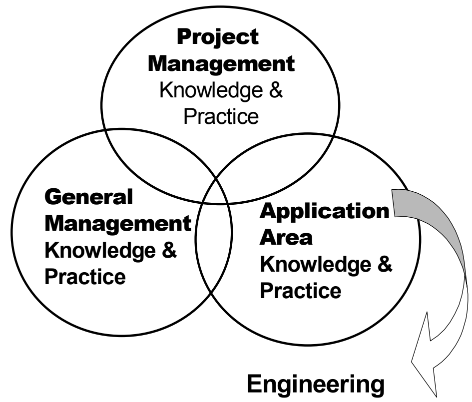
140.01 General

This chapter outlines the principles and methodology adopted by the Washington State Department of Transportation (WSDOT) for successful project management and delivery. Managing Project Delivery (MPD) is the standard practice adopted by WSDOT to manage projects and provides a method to meet the WSDOT Management Principles. (See WSDOT Management Principles at http://www.wsdot.wa.gov/accountability/mgmtprinciples.htm)

Project management requires the application of skills, knowledge, tools, and techniques to deliver the project on time, within budget, and according to specifications. There are proven industry standards for project management, such as the Project Management Body of Knowledge (PMBOK) through the Project Management Institute (PMI). The MPD process, as adopted by WSDOT, is based upon those industry standards.

While terminology may vary, the principles of project management are consistent. A project manager needs more than tools to succeed in delivering quality projects on time and within budget. Project managers with the knowledge and skill to lead a team toward a common goal will optimize team member talents to the best benefit of the team.

The WSDOT project manager must apply three overlapping disciplines (skills) for effective project management as illustrated in Figure 140-1.



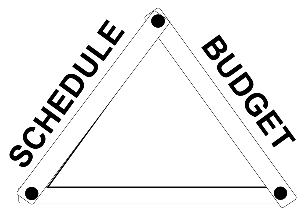
Overlapping Disciplines for Successful Project Delivery
Figure 140-1

Key features of effectively managing project delivery include the following:

- Building an interdisciplinary team with the necessary skills and understanding of the project.
- Effectively defining the project scope and managing that scope throughout the project delivery process.
- Scaling the process based on project complexity and team size.
- Including customers in the project delivery process.
- Effectively and continuously communicating.
- Managing customer expectations.
- Managing change.

Transportation projects are complex and require the coordination of interrelated activities. Meaningful communication between the project manager, team members, sponsor, stakeholders, and customers is a critical component of project management. A skilled, coordinated, and collaborative team will find effective solutions and deliver projects more successfully than individuals working alone. Managing Project Delivery tools align teams by establishing a common understanding of the project. They enable development and execution of a collaborative work plan that is comprehensive, realistic, and deliverable.

Ongoing and active management of the project's scope, schedule, and budget (“Trade-Off” triangle) as shown in Figure 140-2 is a primary focus of project management. Scope, Schedule, & Budget are each project constraints and must be actively monitored and managed throughout the project delivery process.



Project Management Trade-Off Triangle
Figure 140-2

The Project Delivery Information System (PDIS) is a tool for effective and efficient management of project schedules, assigned resources, and the resulting cost to complete projects. PDIS enhances communication and coordination between staff engaged in project and program delivery at the project team, office, region, and statewide levels. See the PDIS definition for the PDIS web address.

140.02 References

WSDOT Management Principles, April 2002

WSDOT “Managing Project Delivery” training manual

A Guide to the Project Management Body of Knowledge (PMBOK), 2000, The Project Management Institute

140.03 Definitions

customers The customers for a project are the users of, and those directly affected by, the project's product.

CIPP The Capital Improvement and Preservation Program for which change management procedures are in place including the Project Control Form at: wwwi.wsdot.wa.gov/ppsc/pgmmgt/dpsb/

CMP Change Management Plan. See 140.05(2)(h).

deliverable A tangible work product; such as Channelization Plans, Environmental reports, Traffic Analysis reports.

MDL The Master Deliverables List implemented as part of the PDIS, is a standardized work breakdown structure, down to the deliverable level. See 140.05(2)(a)

MPD The process called Managing Project Delivery that is described in this chapter.

PDIS The Project Delivery Information System is an MPD tool for project planning, scheduling, resource balancing, and cost management. See wwwi.wsdot.wa.gov/projects/PDIS/

project A temporary endeavor undertaken to create a unique product or service.

project manager The person responsible for conducting the project's effort and delivering the end product.

resources People, tools, and/or materials necessary for project delivery.

scalability Scale, defined by Webster's, is a progressive classification, as of size, amount, importance, or rank. In other words, scalability is the level of work planning required based on the project size, project complexity and team size. The project manager determines the appropriate level of detail.

specialty groups Functional groups responsible for specialized services or products (Environmental, Traffic, Bridge & Structures, Landscape Architecture, Geotech, Right of Way, Materials, and so forth.) Specialty groups are both customers and suppliers to the project design team.

sponsor The person assigning the project manager the responsibility to conduct the project's effort and deliver the end product.

stakeholders Those with a particularly significant interest in the project's outcome including those providing funding or right of way for the project and property owners who are affected by the project. Stakeholders are unique for each project.

team A designated group of people working together with a common purpose.

WBS Work Breakdown Structure. In its simplest form, the WBS is a list of deliverables and tasks to be completed to accomplish the project purpose. The MDL is a standardized WBS developed by WSDOT to assist in the development of a project specific WBS. See 140.05(2)(a) and 140.05(2)(b).

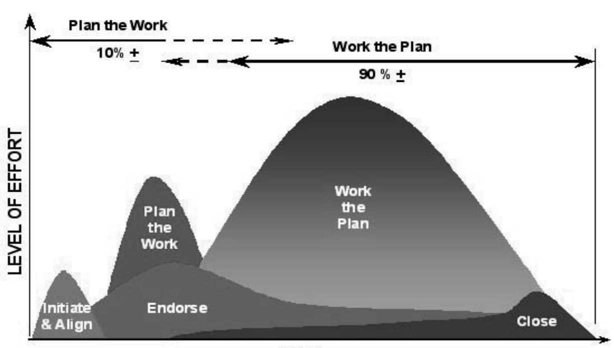
work plan A comprehensive, realistic, and deliverable plan to accomplish the team mission and deliver the project. It includes Plan the Work elements, including a schedule and a budget.

140.04 Resources

The HQ Project Delivery Resource Group (PDRG) provides training, and assistance in implementing the principles of Managing Project Delivery and the use of PDIS tools.

140.05 Managing Project Delivery

Successful project delivery requires active project management and a team that acts with a common purpose. Managing Project Delivery is applied by project managers and teams. It includes five basic steps, each with supporting elements, as shown in Figures 140-3 and 140-4. Each of these steps and elements are described below.



Relative Effort
Figure 140-3

The five steps of Managing Project Delivery can be further simplified into two basic phases:

- Preparation – “Plan the Work”
- Execution – “Work the Plan”

In a typical project application, planning the work, (the first three steps) will constitute approximately 10% of the total project effort and time. Steps four and five will constitute approximately 90% of the project effort and time.

The need for some project tasks to start immediately can be so apparent that “working while planning” is, at times, both necessary and appropriate. The project manager, team, and sponsor must endorse the advance work to be done before work planning is complete. For example, Site surveying, aerial photography, and traffic counts.

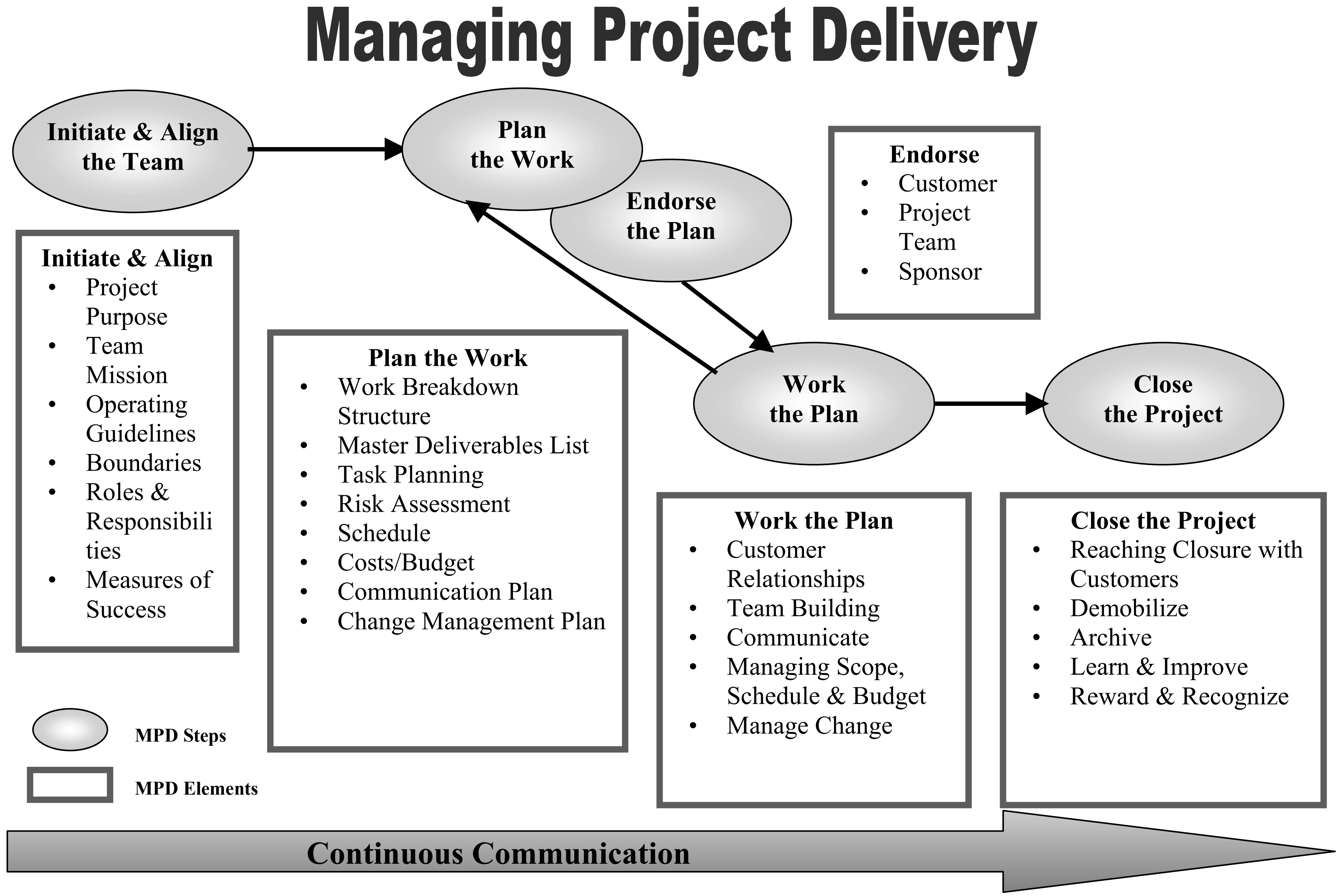
Adapt MPD to Your Project and Team

How and to what degree each of the MPD steps and elements are applied depend on:

- Project Size
- Project Complexity
- Team Size
- Stakeholder Involvement
- Potential resistance to the project

This is called scalability. The project manager determines the appropriate level of detail on a project by project basis. Typically, all steps and elements are applied to large projects, in order to build a common understanding of the project and ensure the development of a comprehensive work plan.

An efficient approach to developing a project work plan is to have a core group develop initial drafts of the various elements (project purpose, team mission, and WBS, for example). The full project team can then review and alter them as appropriate. This reduces the need for involvement by specialty groups who participate in numerous project teams. *However, specialty groups still need to endorse the plan.*



Steps and Elements
Figure 140-4

(1) Initiate and Align the Team

Initiate The process of formally recognizing that a new project exists (this includes transition of projects from one phase to another (Scoping to Design).

Align Building a common understanding of the project and developing a common view of what the solution will and will not address; setting the stage for scope development. A project purpose and mission can help align the team.

While the assignment of organizations and individuals to a project is an essential first step, mere assignment does not result in an effective team. Teams must be built and sustained. For successful project delivery, the participants must conduct their efforts in a coordinated and complementary manner. Establishing communication among the people who will develop and deliver the project is the most important function of this first step of Managing Project Delivery. Gaining each persons understanding of the problem and their buy-in to the solution is key to effectively managing the project scope. (See 140.04(4)(b) for further definition of Team Building)

A project team is a designated group of people, including specialty groups, working together with a common purpose related to a specific project.

The project manager assesses the project and assembles a team with the necessary skills to accomplish the project effort. Most projects require multidisciplinary participation. The project manager must secure individuals from appropriate specialty groups (potentially including Bridge, Environmental, Geotechnical, Landscape Architecture, Local Programs, Materials, Real Estate Services, Traffic, Utilities, and others).

To be effective and efficient, the teams' efforts must complement one another in support of accomplishing a common purpose, in other words, to function as a collaborative team. *This does not mean that all team members must participate in every team meeting or project work session.*

Continuous communication with and seeking endorsement from customers is an essential aspect of successfully managing project delivery. Depending on the scope of the project, participation on the team by customer "partners" is appropriate and can serve to ensure that the product meets customer expectations. Some project managers form a Steering Team or Citizen Advisory Committee to facilitate this communication. Individual representatives of a larger customer group on a steering team must be delegated the authority to make decisions for that group. The group is then held accountable to abide by the decisions made at team meetings. The WSDOT customer base is very diverse. Customers use and are affected by our projects. They have concerns for mobility and safety within their communities. Examples of customers that may have interest in the project are:

- Elected officials at the federal, state, and local level.
- Representatives of Indian tribes.
- Staff from appropriate agencies or jurisdictions.
- Staff from permitting agencies.
- Stakeholders.
- Neighborhood residents.
- Citizen groups.
- Individuals who regularly use the facility.

Meaningful customer interaction involves communicating directly with individuals and groups in a manner that lets them know they have been heard. Such interaction is fundamental to accomplishing context sensitive design. Continuous communication is another key to successful project delivery.

(a) **Project Purpose**

What will be the result of this project?

The project purpose establishes the common goal toward which all project activities and efforts strive. It describes the desired or intended result or effect.

(b) **Team Mission**

How will the team accomplish the project?

The Team Mission describes the overall actions the team will take to accomplish the project. It is usually a short paragraph developed with input from the team, including project sponsors, participating stakeholders and customers.

In this chapter, "the project" means the Team Mission — The word "project" is used throughout this chapter. It is important to understand the distinction between the Team Mission and a "Highway Construction Program project." A Highway Construction Program project is developed in phases [scoping, design/PS&E (including right of way), and construction.] A specific Team Mission may be limited to a specific phase or phases of a Highway Construction Program project. The Team Mission of any given project team may not attain the ultimate end product of the Highway Construction Program project as described by "the project purpose."

The Team Mission statement is of particular importance during project work planning as it clearly defines the scope of the Work Breakdown Structure (WBS) starting with tailoring the Master Deliverables List [140.05(2)(a)].

(c) **Operating Guidelines**

Operating guidelines describe how the team will govern itself. The functions most commonly performed by the team and guidelines to steer it in those functions are identified. Listed below are some guidelines the team might wish to develop:

- Team decision process.
- Team meetings (such as structure, timing).
- Communication (such as methods, uses, frequency, protocols).
- Measuring team performance (such as team surveys, self-assessments/evaluations).
- Managing team disagreement and conflict.
- Managing team change (such as changes in team membership).

(d) **Boundaries**

Boundaries define the limits relevant to the project and the team's mission. Most boundaries are set by the organization and transmitted to the team by the project sponsor. Some boundaries are established by other entities beyond the team. Boundaries might fall within the following areas:

- Geographic.
- Financial.
- Legal and regulatory.
- Mandatory product or project delivery dates.
- Required project activities.
- Excluded project activities.

The identification of project boundaries provides a valuable opportunity for the team, the sponsor, and appropriate customers to enhance their common understanding of the project environment. Well-defined project boundaries are very useful for identifying potential risks or change.

(e) **Roles and Responsibilities** (See 140.06 for further definition)

The definition and mutual acceptance of organizational and individual roles and responsibilities delineates "who will do what". Roles and responsibilities are defined at the organizational level down to the level of each individual on the project team.

The team member's *roles* are the specific titles or positions occupied, such as team leader, designer, permit coordinator, drafter, and so forth. The *responsibility* is the output or outcome expected of the team or individual, such as plan sheets, hydraulic analysis, schedules, and others.

A project-specific table of organization is a good tool for visualizing needed and assigned human resources, their roles and responsibilities, and the relationships between the participants.

(f) **Measures of Success**

Measures of success are tools to assess the accomplishment of critical success factors. Critical success factors define the most important things the team must accomplish to fulfill its mission and achieve project success. These factors are tied to the team mission and project purpose.

The first step is to define critical success factors, and then to determine how to measure accomplishment. Critical success factors are measured incrementally "along the way," not just at the point of project completion. This allows for corrective action (changes) to get "back on track", if needed.

(2) Plan the Work

Development of a work plan begins during Initiate and Align. As the team moves to the next step, Plan the Work, the work plan becomes more refined. The goal is a work plan that is comprehensive, realistic, deliverable and endorsed by all team members.

Planning the work to accomplish the team mission —

It is important to understand and communicate the distinction between the work plan to accomplish the team mission and the completion of the overall project. The overall project includes all phases; Scoping, Design/PS&E (including right of way), and Construction. A team mission is constrained to the phase(s) the team is assigned to work on.

Scoping Project Team Mission

The Scoping Project team develops a work plan, which includes budget estimates and schedules, in PDIS, for Preliminary Engineering (PE), such as Plans, Specifications & Estimates (PS&E); Right of Way (ROW) acquisition activities; and Construction (CN).

Once endorsed, the work product from any phase is a work plan for the subsequent phase(s). For example, the products from the scoping phase are commitments entered into the Capital Improvement & Preservation Program (CIPP). Once in the CIPP, changes to scope, schedule, or budget require completion of the Project Control Form. See the CIPP definition for a web address.

PS&E Project Team Mission

The team that delivers the PS&E project develops a work plan, with a schedule and budget, to perform the work necessary to deliver the products for the Plans, Specifications, and Estimates contract package and advertise for bids. This phase typically includes the Design Documentation package required for design approval, acquisition of right of way, and environmental permits.

(a) **Work Breakdown Structure**

The Work Breakdown Structure (WBS) is a systematic mapping out of all of the project tasks to the lowest level of detail necessary to accomplish the team mission. The WBS is useful toward developing a project scope, schedule, and budget. A task is an assignable item of work, necessary to project delivery that has:

- A definable beginning and end.
- A finite duration.
- An associated level of effort (such as labor, money, equipment, and materials).
- A state of completion that can be estimated at any time.
- A deliverable at the task's completion.

(b) **Master Deliverables List**

WSDOT's standardized Master Deliverables List (MDL) is the starting point for a project-specific Work Breakdown Structure (WBS). The MDL is a comprehensive list that identifies project phases, sub-phases, work processes, and deliverables. In a few cases, the MDL goes to the task level, for example in the environmental area.

Rather than build a work breakdown structure from scratch, project teams eliminate items from the MDL, and add the appropriate tasks. The project team identifies project specific tasks with input from project customers, sponsors, and stakeholders. The tasks developed at the project level must roll up into the deliverables in the standardized MDL. It is to be used by all projects in the Highway Construction Program. The MDL is available on the WSDOT PDIS Internet site; see the PDIS definition for a web address.

(c) Task Planning

Task planning serves as an essential intermediate step in progressing from the WBS to schedule layout. Tasks must be defined completely to develop an accurate schedule. The Task Planning Worksheet is available for use in accomplishing this step. It is available at http://wwwi.wsdot.wa.gov/Projects/PDIS/Resources.htm

Task planning includes:

- **Task scope definition.** Just as the overall project requires a well developed and communicated scope, so do the supporting tasks. For example, for "Public Information Newsletters" task, will there be 1, 3, or 5 mailings, to 500, 5000, or 10,000 addresses, and will they be 1, 3, or 5 pages in length? How will they be distributed?
- **Task sequencing.** The accurate sequencing of tasks is critical to the effective development of a realistic and deliverable schedule. The recurring question asked in this process is "To execute this task, what do I need from some other task, and when do I need it?" Identifying task dependencies between specialty areas (Design and Bridge, Environmental and Design, Hydraulics and Right of Way, and others) is critical.
- **Resource assignments.** What organization and what specific individuals will conduct this task? Will 1 or 3 drafters be assigned to this task? Are the specific individuals highly experienced or "first timers"? What availability constraints apply to the individuals assigned to this task: other project assignments, percentage of time committed to this project, training needs, vacations, and the like?

  A resource loaded schedule is key to creating a project schedule that accurately estimates costs and project timelines. The software entry of resources is dependent on this task planning function.
- **Task duration estimates.** Individuals with the applicable expertise can make the most accurate estimates of task duration. Expert judgment guided by historical information is used whenever possible. Project managers must seek input from those who will accomplish specific tasks to accurately estimate the duration, including estimates from specialty groups.

(d) Risk Assessment

Project risks can be opportunities (positive events) as well as threats (negative events) that might affect scope, schedule, or budget. Risk assessment is the first phase of project risk management. Its purpose is to maximize the results of positive events and minimize the consequences of adverse events. See *A Guide to the Project Management Body of Knowledge* for more details. Risk assessment includes the following:

1. **Risk Identification** is determining which risks are likely to affect the project and the characteristics of each. This includes both internal (things the project team can control) and external (beyond the direct control of the team) risks. Identify risks by reviewing historical information, interviewing stakeholders and subject matter experts, and team brainstorming.
2. **Risk Quantification** is identifying the risks for which a contingency plan will be developed.

An effective tool for quantifying project risks is the Risk Probability – Impact Matrix shown in Figure 140-5. Each identified risk is assessed for probability of occurrence and degree of impact to the project, should it occur. Risks identified as both high probability and high impact (red risk) are potential "show stoppers" and must be addressed immediately. All risks determined to be medium to high in both probability and impact (yellow risk) are given continuous management, and may warrant the development of contingency plans.

3. **Risk Response Development.** Responses to risk threats include the following:

   - Avoidance — eliminating the threat, usually by eliminating the cause.
   - Mitigation — reducing the potential probability of occurrence or resulting adverse impacts.
   - Acceptance — accepting the consequences either actively (with a contingency plan) or passively.

The reason for conducting risk assessment before schedule and budget building is to provide the opportunity to develop and incorporate schedule and budget contingencies for "at risk" tasks.

Impact			
High	Gray Area	Yellow Risk	Red Risk
Med.		Yellow Risk	Yellow Risk
Low			Gray Area
	Low	**Med.**	**High**
	Probability		

Risk Probability – Impact Matrix
Figure 140-5

The Cost Estimate Validation Process (CEVP®) identifies and quantifies potential risks that can impact a project's budget or schedule. CEVP® is an intense workshop, by a team of engineers and risk managers, where transportation projects are evaluated using risk assessment methods to identify cost and schedule risks. Importantly, the process examines how risks can be lowered and cost vulnerabilities managed or reduced. A dividend of CEVP® is promotion of the activities that will improve final cost and schedule results and communicate those results to the public.

Contact the Cost Risk Estimating & Management office (CREM) or visit their website at http://www.wsdot.wa.gov/projects/cevp/ for additional information.

(e) Schedule

All projects in the WSDOT Highway Construction Program are managed using PDIS to schedule required activities that are based on the standardized Master Deliverables List.

The schedule to complete the Team Mission is developed from the Work Breakdown Structure and the subsequent task planning. The schedule is a dynamic tool, that defines the start, order, and duration of project tasks and milestones. A collaboratively developed and comprehensive schedule is a fundamental tool for the management and delivery of the project. It is used to communicate, coordinate, and measure project progress.

Identifying and managing task dependencies between specialty groups (Design to Environmental, Geotechnical to Bridge, Traffic to Design, and so forth) is key to successful project delivery. Establishing milestones and interim deliverables make schedules, and project management easier and more effective by providing short-term goals and clear measurements of progress.

Resource loaded schedules in PDIS allows balancing assigned resources and identifying over-allocated resources. Resource balancing can be accomplished with individual or multiple projects when all schedules are resource loaded. The development of a schedule-based budget is also feasible once a schedule is fully resource loaded.

(f) Costs and Budget

The estimated cost to complete the Team Mission is developed from the Work Breakdown Structure, assigned project resources, and a comprehensive project schedule. This estimate is broken down by specialty groups (Bridge, Environmental, Landscape Architecture, Real Estate, and others.), as well as by month ("aged"). It typically includes an appropriate contingency allowance for identified risk areas and inaccuracies in the cost estimating process.

The estimated cost to accomplish the Team Mission includes all activities that will be directly or indirectly charged against the project such as project management, "planning the work," quality assurance and control, and project closure.

(g) Communication Plan

Communication, the exchange of information to the relevant parties (including ideas, expectations, goals, commitments, requirements, recommendations, and status), is vital to project success. Effective communication cannot be left to chance. While the theme of communication permeates the entire Managing Project Delivery process, a specific communication plan is an essential tool for successful project delivery. See Chapter 210, "Public Involvement and Hearings."

Communication has many dimensions:

- Internal (within the project).
  1. Vertical (up and down the organization).
  2. Horizontal (with peers).
- External (to stakeholders, local agencies, the media, the customers).
- Written, oral, and various media.
  1. Letters, memos, e-mail.
  2. Internet.
  3. Media (radio, TV, newspapers).
  4. Personal contacts.
  5. Public meetings and hearings.

Every project develops or adopts a communication plan. Communication plan elements include the following:

- Requirements — Determining the information and communication needs of the project stakeholders and participants: who needs what information, when will they need it, and how will they get it.
- Distribution Structure – Defining the following:
  1. To whom information will flow (status reports, data, schedule, etc.)
  2. What methods will be used to distribute various types of information (written reports, letters, meetings, e-mail, Internet).
  3. When each type of communication will be produced.
  4. Who, in the project organizational structure, is responsible for preparing and distributing the identified items.

(h) Change Management Plan

Successful project delivery requires active identification and analysis of change when it is encountered. A common human tendency is to deny that change is occurring until it becomes overwhelming. A Change Management Plan (CMP) provides the framework for effective decision making when change occurs. Since it is not possible to foresee all potential changes, a project manager plans the methods by which change will be addressed when encountered.

The CMP includes the following elements:

- A means to anticipate and identify potential changes.
- A process for assessing the effects of a change.
- Techniques and procedures for developing a response strategy.
- A change endorsement process, including identification of the level of endorsement necessary for various types of change. Endorsement of any change is necessary before resources are expended to implement the change.

- A communication strategy to inform all affected parties of the project changes.
- A process for revising the work plan and monitoring performance in accordance with the revised work plan.

WSDOT has adopted standardized change management procedures for the Capital Improvement and Preservation Program (CIPP). These procedures, including a standardized Project Control Form, are used by both Project Development and Program Management. Detailed information on this CIPP change management process, including the Project Control Form, are available on the web. See the definition for CIPP for the web address.

(3) Endorse the Plan

Endorsement constitutes commitment to the work plan and project effort by the key participants. Endorsement is proactive, whereas approval is typically reactive, frequently meaning no more than a lack of objection. By endorsing the work plan, key participants take ownership of the team mission and agree upon the method by which it will be accomplished.

The optimal way to gain endorsement of the project work plan is to include participants in the collaborative development of the work plan. This promotes ownership and facilitates endorsement of the plan by the participants.

The project manager determines whether endorsement for the project work plan will be achieved verbally or documented in writing.

(a) **Customers**

A primary purpose of endorsement is to gain customer commitment to support the project team and work plan. Endorsement by the customers will ensure understanding and acceptance of the project scope, schedule, and budget.

(b) **Project Team**

The project team consists of anyone involved in the development of the project, including specialty groups (such as Environmental, Traffic, Utilities, and others). The purpose of endorsement by the project team is to:

- Share a mutual understanding of the work plan.
- Actively concur that the plan is comprehensive, realistic, and deliverable.
- Build commitment from the entire team to complete the project scope as described in the work plan.

This endorsement validates the working relationship between members of the team and the project manager.

(c) **Sponsor**

Endorsement of the project work plan by the project sponsor, and other managers designated by the project sponsor, provides:

- Sponsor commitments to the defined scope, schedule, and budget.
- Appropriate staff (skill base, knowledge, experience).
- Required tools and resources (computers, technology, office space).
- Sponsor acknowledgement of known risks and associated contingencies.
- Sponsor commitment to advising and assisting in executing the project.
- Sponsor commitment to applying management's authority toward successful accomplishment of the work plan and project.

In order to facilitate sponsor/management endorsement, it is advisable to involve the sponsor(s) in the project work plan development. The level of involvement will vary by project.

(4) Work the Plan

By developing a work plan, the team, project manager, and sponsors comprehensively define project requirements. Endorsement of the work plan represents commitment by key participants and ensures it is consistent with sponsor and customer expectations.

Working the plan is:

- Actively managing those planned elements, including the scope, schedule, & budget.
- Effectively communicating and building on relationships with the team, customers, and sponsors.
- Actively monitoring and managing identified risks and change.
- Communicating changes before they occur.

All projects in the WSDOT Highway Construction Program will maintain current schedules in the PDIS. Project schedules will be updated frequently enough to ensure the project delivery date shown in PDIS is accurate and can be met. Changes that affect the scope, schedule, and budget must be updated in the PDIS schedule.

(a) **Customer Relationships**

- Know the customer's expectations.
- Involve the customers as they wish to be involved.
- Communicate progress to customers.
- Resolve conflict as necessary.
- Manage customer expectations.

(b) **Team Building**

A team must be built and sustained. Teams are dynamic. Team development (forming, storming, norming, performing, excelling) is ongoing and must be continually managed to attain high performance, produce results, and deliver the project.

- A team is a group of individuals who work for a common purpose to produce a specific outcome.
- A team continuously develops group and individual skills to enhance team performance on the project.
- An effective team develops and implements a reward and recognition strategy.
- A team works together to correct mistakes to minimize negative impacts on the project.
- A team works together to learn from accomplishments and mistakes.

(c) **Communicate**

Appropriate frequency and quality of communication between the project manager, team members, sponsor, and customers is essential for project delivery. Project managers and teams apply the Communications Plan adopted for the project.

(d) **Managing Scope, Schedule, and Budget**

Successful project delivery requires active management of the scope, schedule, and budget. Successful project management will meet or exceed customer, sponsor, and stakeholder expectations (on time, within budget, and meeting requirements).

Active management of scope, schedule, and budget includes:

- Endorsing a base line scope, schedule, and budget.
- Ongoing communication with all team members to get frequent and accurate data.
- Regular schedule and budget monitoring and evaluation with revisions to reflect actual progress, as appropriate.
- Regularly reporting progress to customers and stakeholders.

The tradeoff triangle, as shown in Figure 140-2, represents the linkages between the scope, schedule, and budget. It functions as a link and pin truss where the sides must remain connected. When one side changes, the influences or impacts of that change on the other two sides must be managed. One side is prioritized, one side optimized and the remaining side is accepted.

A cardinal rule in project management is that, whenever scope, schedule, or assigned project resources change, a corresponding budget change is mandatory. The application of this rule often requires involvement and assistance from others who will be expected to endorse the resulting updated plan.

(e) **Manage Change**

Frequent and meaningful communication between project participants (including team members, sponsor, and customers/stakeholders) is an essential element of actively managing change. Recognizing and confronting change rather than avoiding it is key to successful project delivery. It is the responsibility of the team members familiar with the scope, schedule, and budget to continuously identify potential changes.

Value can be added through appropriate change management, including dollar and time savings. Active change management, through use of an established Change Management Plan, can minimize adverse effects on project delivery. Proactive endorsement (by the necessary authority) of changes to project scope, schedule, or budget must be obtained before resources are expended to implement the change.

See 140.05(2)(h), Change Management Plan, for additional information on the change management process, including projects in the CIPP.

(5) Close the Project

To conduct an effective closure, or phase transition, it is important for the project manager and team to define what closure means for this team and project. (See Figure 140-6). Adequate time to accurately and sufficiently prepare project documentation for closure should be planned for and included in the project schedule. The following are common closure situations:

- Final closure. The final project purpose has been attained. If so, this is probably an ultimate closure for the overall project effort.
- Transition. One team has accomplished its mission; a transition or handoff is made to a subsequent team tasked to continue development toward the project purpose. This is typical between major project development phases such as design and construction. A smooth transition is critical for successful delivery of the product for the customers.
- Shelf. A project effort that has reached a temporary closure point and is being put "on the shelf" is a transitional event to a future team. Comprehensive documentation of the project status, backup, and decisions (with justifications) is especially critical in this situation to minimize rework when the effort is restarted.

(a) **Reaching Closure With Customers**

This is the process of following up with the project customers and all affected parties. This includes the review of successes and failures in the eyes of the customers, team, and sponsors in relation to the project. This is planned for throughout the project and might occur at multiple intermediate stages of the project.

(b) **Demobilize**

A planned strategy for the reassignment or redistribution of project staff and resources. A demobilization/remobilization strategy is tied to the project schedule and evaluated and updated accordingly.

(c) **Archive**

The team addresses archiving as follows:

- Plan archiving at the beginning of the project.
- Plan the documentation for the permanent design file as required by other *Design Manual* chapters and selected MPD documents including the project work plan.
- Include archiving the PDIS project schedule.
- Budget for archiving effort.
- Tailor the archiving effort based on project size and complexity to comply with legal requirements (including preparedness for Freedom of Information Act requests) and to provide an administrative record of the project.

- Archive throughout the project.
- Adhere to agency-wide archiving process and standards.
- Communicate guidelines to team through the closure plan.

(d) **Learn and Improve**

The purpose of this element is to build corporate knowledge and skills and minimize the need for those in the future to "reinvent the wheel." This evaluation element is valuable for sharing with others (including other WSDOT staff and potential future team members) what was learned on this project: "What went well, what didn't, and why." The areas of evaluation usually include:

- Staff evaluation and development.
- Comparison of initial objectives with results.
- Review of significant changes, reasons, and results.
- Review identified risks; did they occur and what impacts did they have on the project?
- Effectiveness of the work plans.
- Budget assessment.
- Customer satisfaction.
- Comparison to measures of success as established in the work planning process.

(e) **Reward and Recognize**

Rewarding and recognizing team members and customers, as well as celebrating overall team success, are important steps and contribute toward the success of future project team endeavors.

140.06 Responsibilities

(1) Project Sponsor

The project sponsor provides the direction, authority, and resources for implementing Managing Project Delivery on projects. Typically, the project sponsor is a department executive, office manager, or organizational unit manager who assigns the project manager.

(2) Project Manager

The project manager follows the Managing Project Delivery process and applies specialized knowledge, skills, tools, and techniques to carry out the project sponsor's direction through project completion. A project manager has the following responsibilities:

(a) **To the project sponsor:**

- Come to a mutual understanding of the project work plan (including scope, schedule, budget, and other primary elements of the project) to obtain the endorsement of the project sponsor.
- Communicate project progress using appropriate project status reports and meetings.
- Identify when project sponsor endorsement will be required throughout the project.
- Communicate any significant changes in scope, schedule, budget, or customer satisfaction, during the project.
- Deliver the project in accordance with the endorsed work plan, including schedule and budget.

(b) **To the project customers:**

- Understand customer needs and expectations (listen).
- Communicate progress to customers (keep them informed).
- Communicate change and provide options to gain endorsement of preferred choices.
- Deliver the project in accordance with the endorsed project work plan.
- Solicit and incorporate customer feedback in project closure.

(c) **To the project team members:**

- Provide leadership and management.
- Be an advocate for the team.
- Obtain team endorsement on the project work plan, and major changes.

- Facilitate internal and external communication.
- Manage changes in scope, schedule, and budget.
- Initiate and manage ongoing team building.
- Mentor team members in project management.

(d) **To other project managers:**

- Mentor each other by sharing experiences and knowledge.
- Encourage each other to achieve project management excellence.
- Share resources when appropriate.
- Coordinate project work plans.

(3) Project Team

Each member of the project team follows the Managing Project Delivery process and applies specialized knowledge, skills, tools, and techniques to carry out the team's mission through project completion. A project team member has the following responsibilities:

(a) To fellow team members:

- Communicate in an open, honest, and sincere manner.
- Make a deliberate effort to maintain and build team cohesiveness.
- Ask for what you need.
- Deliver what others need.
- Be prepared and willing to work with team members to accomplish project goals.

(b) To the project manager:

- Manage tasks proactively.
- Report progress in a clear, coherent, timely, and accurate manner.
- Offer your best opinions on project issues.
- Present a "get the job done" attitude.

140.07 Documentation

Managing Project Delivery reflects WSDOT best practices along with the industry standards for project management. A project work plan provides team leaders, management and executives a method of communicating all aspects of a project. It is routine for work plans to be reviewed by Executives during regional Quarterly Report Meetings. Documentation of these elements is an effective means of attaining a common understanding among team members, the project sponsor, and customers. Documentation of a project work plan includes:

(a) Team initiation and alignment elements

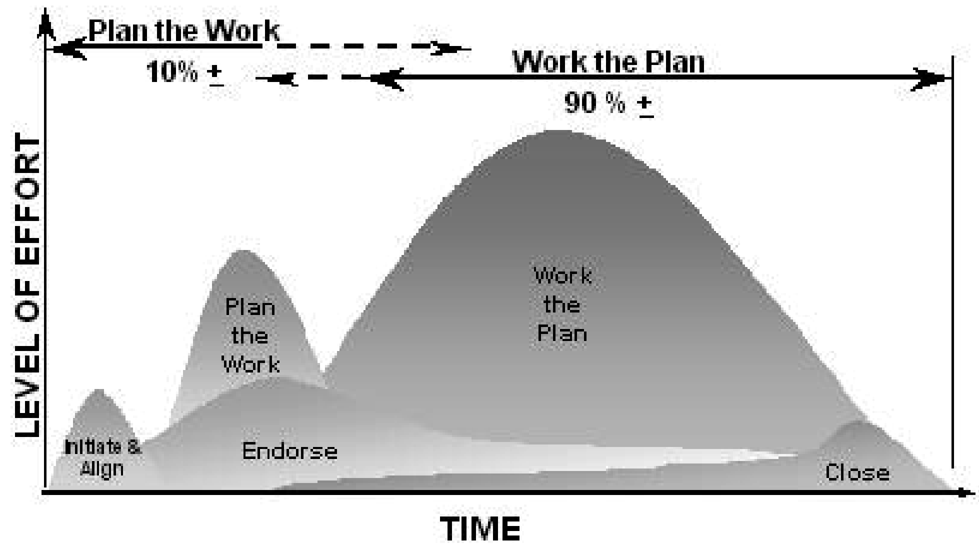
(b) Schedule developed and maintained in PDIS

(c) Budget

(d) Communication Plan

(e) Change Management Plan

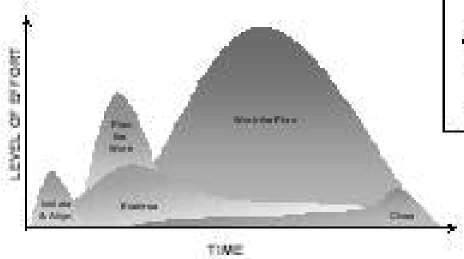
A list of documents that are to be preserved [in the Design Documentation Package (DDP) or the Project File (PF)] is on the following website: http://www.wsdot.wa.gov/eesc/design/projectdev/



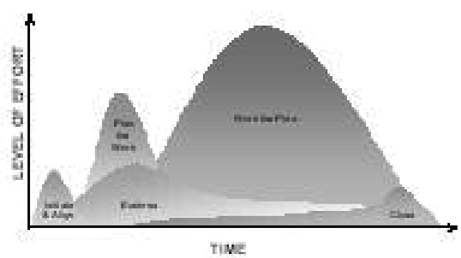
Phase Transition

A project purpose can span the phases of project development. MPD is used **iteratively** at each phase of project development.

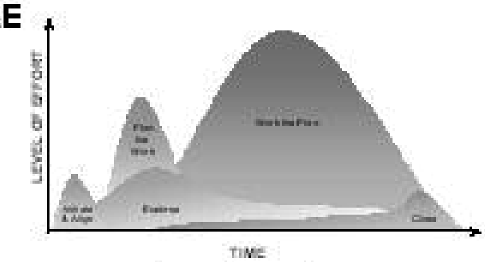
As one team "closes" their phase, a new team initiates and aligns their phase of the project. This repeats until the Project Purpose is attained.



Scoping



Design/PS&E



Construction

Using MPD Iteratively

Figure 140-6

Chapter 141 — Project Development Roles and Responsibilities for Projects with Structures

141.01 General

This chapter presents the project development process used by Washington State Department of Transportation (WSDOT), the Regions and the Bridge and Structures Office together, to determine the roles and responsibilities for projects with structures during the project development phase of a project. This chapter complements chapter 140. See Division 11 chapters and the *Bridge Design Manual* for design procedures.

The primary objective of this process is to provide a consistent means of selecting a bridge design team to perform all or part of the structural design work, whether it be a consultant or the WSDOT Bridge and Structures Office.

If the Local Agency will be requesting any services from WSDOT, the Local Agency will contact WSDOT's Local Program Engineer. The Local Program Engineer will help define the level of WSDOT's involvement in design and construction.

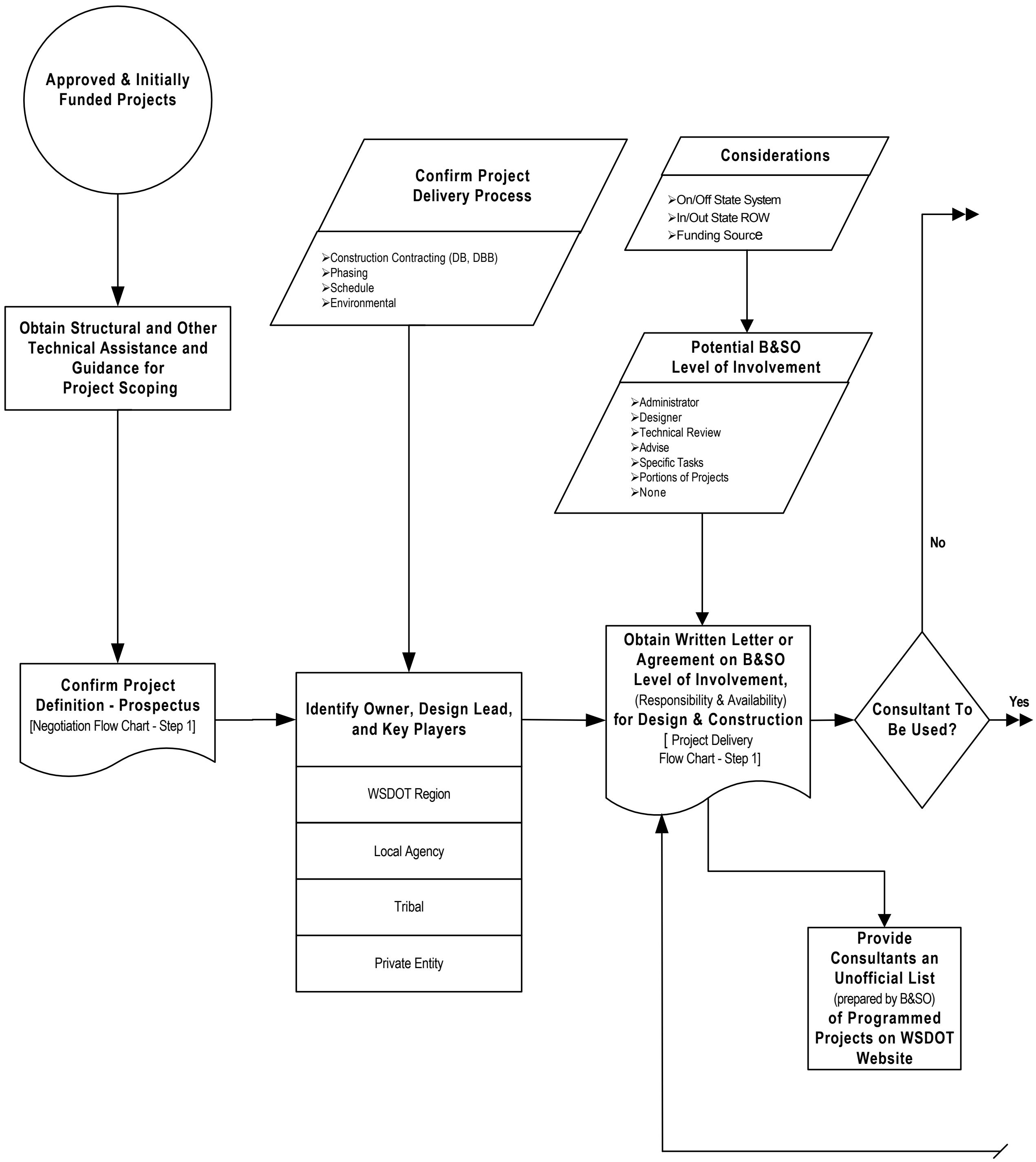
141.02 Procedures

The flow diagram, Figures 141-1a and 141-1b, begins at the left with the initial approval and funding of the project and ends at the right with the start of the project delivery process.

After a project is programmed, WSDOT is tasked with confirming the project scope and defining the structural team's level of involvement in design and construction. If a consultant is not used, all bridge design work will be performed by the Bridge and Structures Office. If a consultant is used, the WSDOT Region and Bridge and Structures Office will determine the level of involvement and responsibility for the design.

Agreements defining the level of involvement and responsibility will be developed and executed between the appropriate Regional office responsible for project development and the Bridge and Structures Office and the appropriate project delivery process will be implemented.

More information on this process and the desired outcomes is available on the Bridge and Structures Office's homepage at http://www.wsdot.wa.gov/eesc/bridge/rrps/index.cfm.



FHWA - Federal Highway Administration

WSDOT - Washington State Department of Transportation

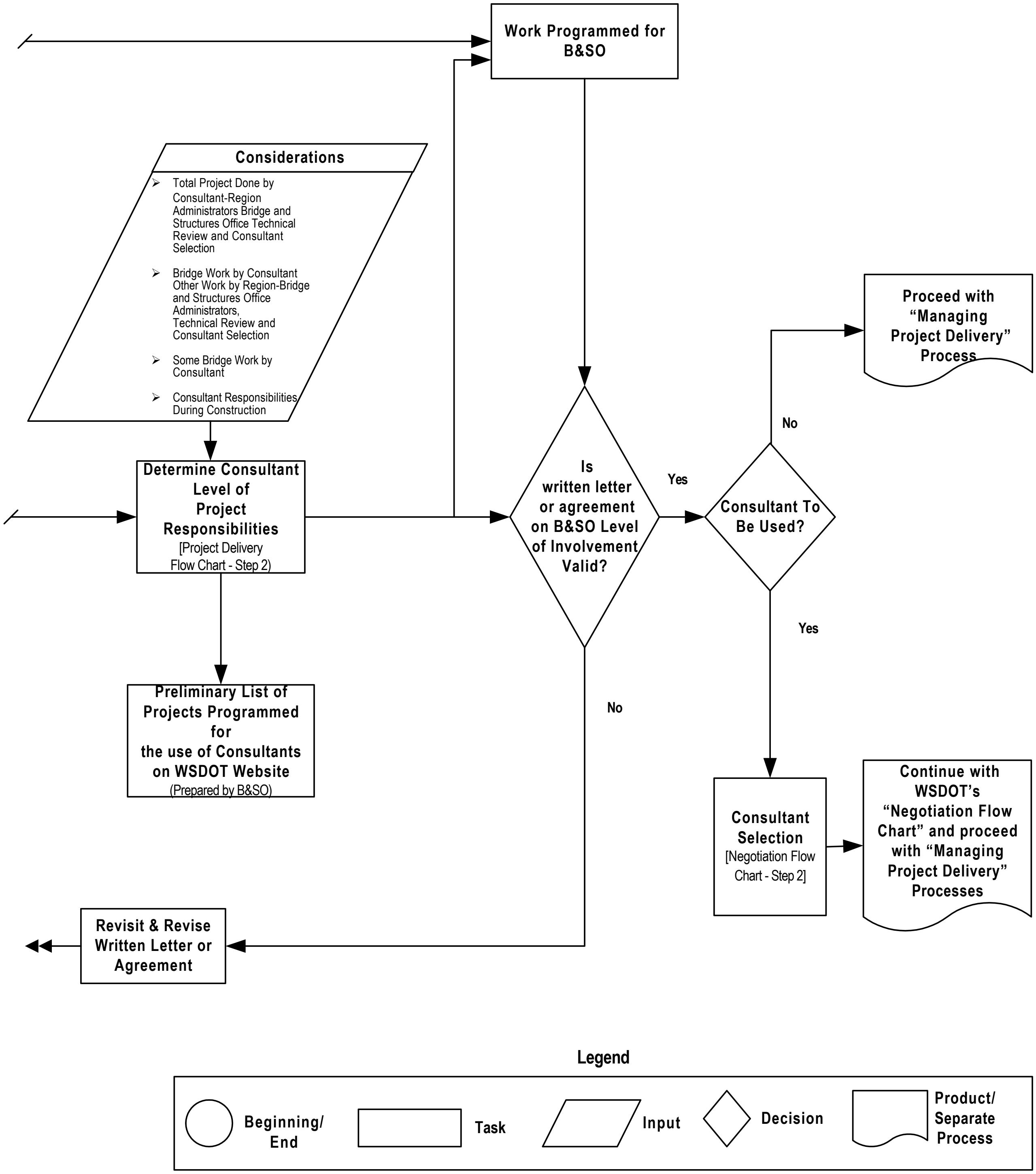
DB - Design Build

DBB - Design Bid Build

B&SO - Bridge & Structures Office

ROW - Right of way

Determination of the Roles and Responsibilities for Projects with Structures (Project Development Phase)
Figure 141-1a



Determination of the Roles and Responsibilities for Projects with Structures (Project Development Phase)
Figure 141-1b

325.01 General

This *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 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 non-Interstate highways and address preservation and improvement projects.

A design matrix is used to determine the design level for the Design Elements of a project. Apply the appropriate design levels and document the design decisions as required by this chapter and Chapter 330.

325.02 Selecting a Design Matrix

Selection of a design matrix is based on highway system (Interstate, NHS excluding Interstate, and non-NHS) and location (main line, interchange). (See Figure 325-1.)

Highway System	Location	
	Main Line	Interchange Area
Interstate	Matrix 1	Matrix 2
NHS(1)	Matrix 3	Matrix 4
Non-NHS	Matrix 5	Matrix 4

(1) Except Interstate.

Design Matrix Selection Guide
Figure 325-1

The **Interstate System** (Matrices 1 and 2) is a network of routes selected by the state and the FHWA under terms of the federal aid acts. These routes are principal arterials that are the most important to the economic welfare and defense of the United States. They connect, as directly as practicable:

- Principal metropolitan areas and cities.
- Industrial centers.
- International border crossings.

The Interstate System also includes important routes into, through, and around urban areas, serves the national defense, and, where possible, connects with routes of continental importance. It serves international and interstate travel and military movements.

The Interstate System is represented on the list of NHS highways, Figures 325-2a and 2b, with the letter "I" before the route number.

The **National Highway System (NHS)** (Matrices 3 and 4) is an interconnected system of principal arterial routes and highways (including toll facilities) that serve:

- Major population centers.
- International border crossings.
- Industrial centers.
- Ports.
- Airports.
- Public transportation facilities.
- Other intermodal transportation facilities.
- Other major travel destinations.

The NHS includes the Interstate System and the Strategic Highway Corridor Network (STRAHNET) and its highway connectors to major military installations (Interstate and non-Interstate).

The NHS meets national defense requirements and serves international, interstate, and interregional travel.

See Figures 325-2a and 2b.

The **Non-NHS** highways (Matrices 4 and 5) are state routes that form a network of highways that supplement the NHS system by providing for freight mobility and, mainly, regional and interregional travel. Non-NHS highways are not shown on Figures 325-2a and 2b. They are shown on WSDOT's (free) Official State Highway Map of Washington.

325.03 Using a Design Matrix

The design matrices are shown in Figures 325-3 through 325-7. Follow *Design Manual* guidance for all projects except as noted in the design matrices and elsewhere as applicable. <u>The definitions presented in this chapter are meant to provide clarification for terminology used in the *Design Manual*. There is no assurance that these terms are used consistently in references outside of the *Design Manual*.</u>

(1) Project Type

For project types not listed in the design matrices (such as unstable slopes), consult the Headquarters Design Office for guidance.

In the design matrices, row selection is based on Project Type. The Project Summary defines and describes the project. (Project Summary is discussed in Chapter 330.) For NHS and non-NHS routes (Matrices 3, 4, and 5), the project's program/subprogram might be sufficient information for identifying Project Type. See the *Programming Manual* for details about funding programs and subprograms.

The various sources of funds for these subprograms carry eligibility requirements that the designers and Project Development must identify and monitor throughout project development — this is especially important to ensure accuracy when writing agreements and to avoid delaying advertisement for bids if the Project Type changes.

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.

Project Types (in alphabetical order) are:

At Grade projects are safety improvements on NHS highways (45 mph or greater) to build grade separation facilities that replace the existing intersections.

Bike Routes (Shldrs) are main line economic development improvements to provide a statewide network of rural bicycle touring routes with shoulders a minimum of four feet wide.

Bike/Ped. Connectivity projects are mobility improvements to provide bicycle/pedestrian connections, along or across state highways within urban growth areas, to complete local networks.

Bridge Deck Rehab<u>ilitation</u> projects are structures preservation, which repair delaminated bridge decks and add protective overlays that will provide a sound, smooth surface; prevent further corrosion of the reinforcing steel; and preserve operational and structural integrity.

Bridge Rail Upgrades are safety improvements to update older bridge rails to improve strength and redirectional capabilities.

Bridge Repl. (Multilane) projects are non-NHS main line structures preservation that replace bridges on multilane highways to improve operational and structural capacity.

Bridge Replacement projects are NHS and two-lane non-NHS (main line and interchange) structures preservation that replace bridges to improve operational and structural capacity.

Bridge Restrictions projects are main line economic development improvements that remove vertical or load capacity restrictions to benefit the movement of commerce.

BST projects are non-NHS roadway preservation to do bituminous surface treatment (BST) work only, to protect the public investment.

BST Routes/Basic Safety projects are non-NHS roadway preservation to resurface highways at regular intervals and restore existing safety features to protect the public investment.

Corridor projects are main line improvements to reduce and prevent collisions (vehicular, nonmotorized, and pedestrian) within available resources.

Diamond Grinding is grinding a concrete pavement, using gang mounted diamond saw blades, to remove surface wear or joint faulting.

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

Four-Lane Trunk System projects are NHS economic development improvements to complete contiguous four-lane limited access facilities on a trunk system consisting of all Freight and Goods Transportation Routes (FGTS) with a classification of 10,000,000 tons/year.

Freight & Goods (Frost Free) projects are main line economic development improvements to reduce delay from weather related closures on high priority freight and goods highways.

Guardrail Upgrades are safety improvement projects limited to the specified roadside Design Elements. These projects focus on W beam with 12'-6" spacing and on guardrail systems with concrete posts. The length of need is examined and minor adjustments are made. Removal is an option if guardrail is no longer needed. For Interstate main line, address length of need as specified in Chapter 710. For non-interstate routes, additional length of more than 5% of the existing length is beyond the intent of this program. In these instances, consider funding in accordance with priority programming instructions, and if the length of need is not met, document to the Design Documentation Package (DDP), that the length of need is not addressed because it is beyond the intent of this program.

HMA/PCCP projects are non-NHS roadway preservation to resurface highways at regular intervals and restore existing safety features to protect the public investment.

HMA/PCCP/BST Overlays are NHS main line roadway preservation projects that resurface the existing surfaces at regular intervals to protect the public investment.

HMA/PCCP/BST Overlays Ramps are NHS and non-NHS ramp roadway preservation projects that resurface the existing surfaces at regular intervals and restore existing safety features to protect the public investment.

HMA Structural Overlays is a hot mix asphalt overlay that is placed to increase the load carrying ability of the pavement structure. Structural overlay thickness is greater than 0.15 ft.

HOV Bypass projects are NHS and non-NHS ramp mobility improvements to improve mobility within congested highway corridors by providing HOV bypass lanes on freeway ramps. Congested highway corridors have high congestion index values as described in the *Highway System Plan* (footnote in text for Improvement/Mobility).

HOV projects are main line mobility improvements completing the freeway Core HOV lane system in the Puget Sound region, and providing level of service C on HOV lanes (including business access transit lanes), within congested highway corridors.

Intersection projects are safety improvements to reduce and prevent collisions, to increase the safety of highways, and to improve pedestrian safety within available resources.

Median Barrier projects are limited safety improvement projects – mainly new median barrier with a focus on cable barrier to reduce median crossover accidents.

Milling with HMA Inlays is removal of a specified thickness of the existing HMA pavement, typically from the traveled lanes, and then overlaying with HMA at the same specified thickness.

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 PCCP or HMA replacement.
- New interchange.
- Changes in interchange type such as diamond to directional or adding a ramp.
- New or replacement bridge (on or over, main line or interchange ramp).

Non-Interstate Freeway (mobility) projects, on non-NHS and NHS interchanges and on NHS main line, are mobility improvements on multilane divided highways, with limited access control, within congested highway corridors.

Non-Interstate Freeway (roadway preservation) projects, on non-NHS and NHS interchanges and on NHS main line, are roadway preservation to overlay or inlay with HMA/PCCP/BST on multilane divided highways, with limited access control, to minimize long-term costs and restore existing safety features.

Non-Interstate Freeway (safety) are NHS and non-NHS (main line and interchanges) safety improvements on multilane divided highways, with limited access control, to increase the safety within available resources.

Nonstructural Overlay is an HMA pavement overlay that is placed to minimize the aging effects and minor surface irregularities of the existing HMA pavement structure. The existing HMA pavement structure is not showing extensive signs of fatigue (longitudinal or alligator cracking in the wheel paths). Nonstructural overlays are less than or equal to 0.15 ft thick, and frequently less than 0.12 ft thick.

PCCP Overlays are Portland cement concrete pavement overlay of an existing PCCP or HMA surface.

Preventive Maintenance 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, slope stabilization, seismic retrofit, scour countermeasures, and painting. Preventive maintenance projects must not degrade any existing safety or geometric aspects of the facility. Any elements that will be reconstructed as part of a preventative maintenance project are to be addressed in accordance with Full Design Level.

Replace HMA w/ PCCP at I/S (intersections) projects are NHS and non-NHS main line roadway preservation that restores existing safety features and replaces existing HMA intersection pavement that has reached the point of lowest lifecycle cost (11-15 years old) with PCCP that has about a 40 year life cycle.

Rest Areas (New) projects are NHS and non-NHS main line economic development and safety improvements to provide rest areas every 60 miles, and some RV dump stations.

Risk, Realignment projects are improvements intended to improve alignment at specific locations where the Risk program has identified a high probability of collisions/accidents.

Risk, Roadside projects are improvements intended to mitigate roadside conditions at specific locations where the Risk program has identified a high probability of vehicular encroachment.

Risk, Roadway Width projects are improvements intended to adjust the roadway width at specific locations where the Risk program has identified a high probability of a vehicle leaving its lane of travel.

Risk, Sight Distance projects are improvements intended to improve sight distance at specific locations where the Risk program has identified a high probability of collisions/accidents.

Rural projects are mobility improvements providing uncongested level of service on rural highways within congested highway corridors. (See HOV Bypass above for cross reference regarding "congested.")

Urban (Multilane) projects are non-NHS mobility improvements within congested urban multilane highway corridors. (See HOV Bypass above for cross reference regarding "congested.")

Urban projects are NHS and two-lane non-NHS (main line and interchange) mobility improvements within congested urban highway corridors. (See HOV Bypass above for cross reference regarding "congested.")

(2) Design Elements

The column headings on a design matrix are **Design Elements.** Not all potential design elements have been included in the matrices.

The Design Elements that are included 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).

If using a design element that is not on the assigned matrix, use full design level as found elsewhere in this manual.

If using a design element that is not covered in this manual, use an approved manual or guidance on the subject and document the decision and the basis for the decision.

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 642 for superelevation, Chapter 650 for stopping sight distance, and Chapters 440 or 940 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 430, 440, 630, and 940 for grades, Chapters 430 and 650 for stopping sight distance, and Chapter 430, 440, or 940 for design speed.)

Lane Width is defined in Chapter 440. (See also Chapters 430, 640, 641, and 940.)

Shoulder Width is defined in Chapter 440. (See also Chapters 430, 640, and 940.) Also see Chapter 710 for shy distance requirements when barrier is present.

Lane Transitions (pavement transitions) are the rate and length of transition of changes in width of lanes. (See Chapter 620.)

On/Off Connection is the widened portion of pavement at the end of a ramp connecting to a main lane of a freeway. (See Chapter 940.)

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 430 and Traveled Way Cross Slope in 640.)

Cross Slope, Shoulder is the rate of elevation change across a shoulder. (See Chapters 430 and 640.)

Fill/Ditch Slope is the downward slope from edge of shoulder to bottom of ditch or catch. (See Chapters 430 and 640.)

Access is the means of entering or leaving a public road, street, or highway with respect to abutting private property or another public road, 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. (The median is part of a clear zone.) (See Chapter 700.)

Signing, Delineation, Illumination are signs, guide posts, pavement markings, and lighting. (See Chapter 820 for signing and 1120 for bridge signs, Chapter 830 for delineation, and Chapter 840 for illumination.)

Vertical Clearance - see Chapter 1120.

Basic Safety is the list of safety items in Chapter 410.

Bicycle and Pedestrian See Chapter 1020, Bicycle Facilities, and Chapter 1025, Pedestrian Design Considerations, for definitions.

Bridges: Lane Width is the width of a lane on a structure. (See Chapters 430, 440, 640, 641, 940, and 1120.)

Bridges: Shoulder Width is the distance between the edge of traveled way and the face of curb or barrier, whichever is less. (See Chapters 430, 440, 640, 940, and 1120.) Also see Chapter 710 for shy distance requirements.

Bridges/Roadway: Vertical Clearance is the minimum height between the roadway, including shoulder, and an overhead obstruction. (See Chapter 1120.)

Bridges: Structural Capacity is the load bearing ability of a structure. (See Chapter 1120.)

Intersections/Ramp Terminals: Turn Radii See Chapter 910 for definition.

Intersections/Ramp Terminals: Angle See Chapter 910 for definition.

Intersections/Ramp Terminals: Intersection Sight Distance See Chapters 910 and 940 for definitions.

Barriers: Terminals and Transition Sections — **Terminals** are crashworthy end treatments for longitudinal barriers that are 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. Beam guardrail terminals include anchorage. — **Transition Sections** are sections of barriers used to produce a gradual stiffening of a flexible or semirigid barrier as it connects to a more rigid barrier or fixed object. (See Chapters 700, 710, and 720.)

Barriers: Standard Run are guardrail and other barriers as found in the *Standard Plans for Road Bridge and Municipal Construction* excluding terminals, transitions, attenuators, and bridge rails. (See Chapter 710.)

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

(3) Design Level

In the non-Interstate matrices, design levels are noted in the cells by B, M, F, and sometimes with a number corresponding to a footnote on the matrix. For Improvement type projects full design level applies to all design elements except as noted in the design matrices and in other chapters as applicable. In the Interstate matrices, only full design level applies.

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 highway system and Project Type. (For example, the investment is higher for an Interstate overlay than for an overlay on a non-NHS route.)

A **blank cell** on a design matrix row signifies that the Design Element will not be addressed because it is beyond the scope of the typical project. In rare instances, a Design Element with a blank cell may be included if that element is linked to the original need that generated the project and is identified in the Project Summary or a Project Control Form.

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

Modified design level (M) preserves and improves existing roadway geometrics, safety, and operational elements. See Chapter 430 for design guidance. Use full design level for design elements or portions of design elements that are not covered in 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.

(4) Design Variances

Types of design variances are design exceptions (DE), evaluate upgrades (EU), and deviations. See Chapter 330 concerning the Design Variance Inventory System (DVIS).

A **design exception (DE)** in a matrix cell indicates that WSDOT has determined that the Design Element is usually outside the scope of the Project Type. Therefore, an existing condition that does not meet or exceed the design level specified in the matrix may remain in place unless a need has been identified in the *Highway System Plan* and prioritized in accordance with the programming process. See Chapter 330 regarding documentation.

An **evaluate upgrade (EU)** in a matrix cell indicates that WSDOT has determined that the Design Element is an item of work that is to be considered for inclusion in the project. For an existing element that does not meet or exceed the specified design level, an analysis is required to determine the impacts and cost effectiveness of including the element in the project. The EU analysis must support the decision regarding whether or not to upgrade that element. See Chapter 330 regarding documentation.

A **deviation** is required when an existing or proposed Design Element differs from the specified design level for the project and neither DE nor EU processing is indicated. See Chapter 330 regarding documentation.

DE or EU with /F or /M in a cell means that the Design Element is to be analyzed with respect to the specified design level. For instance, a DE/F is analyzed with respect to full design level and might be recorded as having an existing Design Element that does not meet or exceed current full design level. An EU/M is analyzed to decide whether or not to upgrade any existing Design Element that does not meet or exceed current modified design level.

(5) Terminology in Notes

F/M Full for freeways/Modified for nonfreeway uses the word **freeway** to mean a divided highway facility that has a minimum of two lanes in each direction, for the exclusive use of traffic, and with full control of access. For matrix cells with an F/M designation, analyze freeway routes at full design level and nonfreeway routes at modified design level.

The **HAL, HAC, and PAL** mentioned in note (1) on Design Matrices 3, 4, and 5 are high accident locations (HAL), high accident corridors (HAC), and pedestrian accident locations (PAL).

The **Access Control Tracking System** mentioned in note (3) on Design Matrices 3, 4, and 5 is a list that is available on the web at http://www.wsdot.wa.gov/eesc/design/access/ under the RELATED SITES heading. See Chapter 1420 for access control basics and 1430 and 1435 for limited and managed access, respectively.

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 design level. The first step is to check for recommendations for future improvements in an approved Route Development Plan. If none are available, an analysis can be based on route continuity and other existing features. See Chapter 330 regarding documentation.

Note **(21) Analyses required** appears only on Design Elements for Risk projects on Design Matrices 3, 4, and 5. These Design Elements are to be evaluated using benefit/cost (B/C) to compare and rank each occurrence of the Design Elements. The B/C evaluation supports engineering decisions regarding which proposed solutions are included in a Risk project.

Most components of a Risk project will have a B/C of 1.0 or greater. Proposed solutions with a B/C ratio less than 1.0 may be included in the project based on engineering judgment of their significant contribution to corridor continuity. Risk program size, purpose and need, or project prioritization may lead to instances where design elements with a ratio greater than 1.0 are excluded from a project. The analysis, design decisions and program funding decisions are to be documented in the Design Documentation Package. Decisions regarding which design elements to include in a project are authorized at the WSDOT region level.

State Route	NHS Route Description	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	US 101 to SR 104	0.00	0.00	60.02	59.81
SR 4	US 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	US 12 to US 101	0.00	0.00	20.67	20.67
SR 9	SR 546 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	US 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 US 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	US 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	US 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	US 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	US 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	US 97 to US 2 (Orondo)	213.36	0.00	213.62	0.26
US 97 Y	SR 970 to US 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	US 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 US 12	0.00	0.00	6.09	6.08
SR 125 Spur	SR 125 to US 12	6.09	0.00	6.76	0.67
SR 127	US 12 to SR 26	0.03	0.00	27.05	27.05
SR 128	US 12 to Idaho State Line	0.00	0.00	2.30	2.30

NHS Highways in Washington
Figure 325-2a

State Route	NHS Route Description	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	US 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	US 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	US 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 US 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 SR 9	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 US 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

NHS Highways in Washington

Figure 325-2b

⇩ Project Type																Bridges			Barriers		
Design Elements ⇨	Horiz. Align.	Vert. Align.	Lane Width	Shldr Width (13)	On/Off Conn.	Median Width	Cross Slope Lane	Cross Slope Shldr	Fill/Ditch Slopes	Clear Zone	Sign. (10)	Delini. (9)	Illumin.	Vert. Clear. (11)	Bike & Ped.	Lane Width	Shldr Width	Structural Capacity	Term. & Trans. Section (12)	Std Run	Bridge Rail (14)(19)
(1-1) Preventive Maintenance																					
Pavement Restoration																					
(1-2) Diamond Grinding										EU	EU	F		DE					F	EU	F
(1-3) Milling with HMA 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) HMA Structural Overlays	EU	DE	F	F	F(17)	DE	F	EU	F	F	EU	F	F	F		F	DE		F	F	F
(1-6) PCCP Overlays	EU	DE	F	F	F(17)	DE	F	EU	F	F	EU	F	F	F		F	DE		F	F	F
(1-7) Dowel Bar Retrofit	EU	DE	F	F	F(17)	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(22)	F
Safety																					
(1-9) Median Barrier				DE															F(20)	F(20)	
(1-10) Guardrail Upgrades				DE						F									F	F(23)	
(1-11) Bridge Rail Upgrades																			F	F(22)	F
Reconstruction (16)																					
(1-12) New/Reconstruction	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. See Chapter 440.
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 Chapters 440 and 640.
(14) Includes crossroad bridge rail. See Chapter 710.
(16) For design elements not in the matrix headings, apply full design level as found in the applicable chapters and see 325.03(2).
(17) DE for existing acceleration/deceleration lanes when length meets posted freeway speed and no significant accidents. See Chapter 940.
(19) The funding sources for bridge rail are a function of the length of the bridge. Consult programming personnel.
(20) Applies to median elements only.
(22) Upgrade barrier, if necessary, within 200 ft of the end of the bridge.
(23) See description of Guardrail Upgrades Project Type, 325.03(1) regarding length of need.

Design Matrix 1
Interstate Routes (Main Line)
Figure 325-3

⇩ Project Type	Ramps and Collector Distributors																				Cross Road										
															Ramp Terminals			Barriers											Barriers		
Design Elements ⇨	Horiz. Align.	Vert. Align.	Lane Width	Shldr Width	Lane Tran-sition	On/Off Conn.	Cross Slope Lane	Cross Slope Shldr	Fill/ Ditch Slopes	Limited Access	Clear Zone	Sign., Del., Illumin. (9)(10)	Vertical Clear. (11)	Bike & Ped.	Turn Radii	Angle	I/S Sight Dist.	Term. & Trans. Section (12)	Std Run	Bridge Rail (14)(19)	Lane Width	Shldr Width	Fill/ Ditch Slopes	Limited Access	Clear Zone	Sign., Del., Illumin. (10)	Vert. Clear. (11)	Ped. & Bike	Term. & Trans. Section (12)	Std Run	Bridge Rail (14)(19)
(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 HMA Inlays									EU		F	F(15)	F	M				F	F	F			EU		F	F(15)		M	F	F	F
(2-4) Nonstructural Overlay							EU	EU	EU		F	F(15)	F	M				F	F	F			EU		F	F(15)		M	F	F	F
Pavement Rehab./Resurf.																															
(2-5) HMA Structural Overlays	EU	DE	F	F	F	F(17)	F	EU	F	F	F	F(15)	F	M	F	F	F	F	F	F	DE	DE	DE	F	F	F(15)	F	M	F	F	F
(2-6) PCCP Overlays	EU	DE	F	F	F	F(17)	F	EU	F	F	F	F(15)	F	M	F	F	F	F	F	F	DE	DE	DE	F	F	F(15)	F	M	F	F	F
(2-7) Dowel Bar Retrofit	DE		DE	DE	F	F(17)	DE		F	F	F	F(15)	DE		F	F	F	F	F	F				F		F(15)			F	F	F
Bridge Rehabilitation																															
(2-8) Bridge Deck Rehabilitation													F	M				F(6)	F(22)	F							F	M	F(6)	F(22)	F
Safety																															
(2-9) Intersection			F	F	F				F	F	F	F		M	F	F	F	F	F	F			F	F	F	F	F	M	F	F	F
(2-10) Guardrail Upgrades				DE							F							F	F(23)										F	F(23)	
(2-11) Bridge Rail Upgrades																		F	F(22)	F									F	F(22)	F
Reconstruction (16)																															
(2-12) 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	F

☐ Not Applicable
F Full design level. See Chapter 440.
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.
(14) Includes crossroad bridge rail. See Chapter 710.
(15) EU for signing and illumination.

(16) For design elements not in the matrix headings, apply full design level as found in the applicable chapters and see 325.03(2).
(17) DE for existing acceleration/deceleration lanes when length meets posted freeway speed and no significant accidents. See Chapter 940.
(19) The funding sources for bridge rail are a function of the length of the bridge. Consult programming personnel.
(22) Upgrade barrier, if necessary, within 200 ft of the end of the bridge.
(23) See description of Guardrail Upgrades Project Type, 325.03(1) regarding length of need.

Design Matrix 2
Interstate Interchange Areas
Figure 325-4

⇩ Project Type																Bridges (11)				Intersections			Barriers		
Design Elements ⇨	Horiz. Align.	Vert. Align.	Lane Width	Shldr Width	Lane Tran-sition	On/Off Conn.	Median Width	Cross Slope Lane	Cross Slope Shldr	Fill/ Ditch Slopes	Access (3)	Clear Zone (18)	Sign., Del., Illumin.	Basic Safety	Bike & Ped.	Lane Width	Shldr Width	Vertical Clear-ance	Structural Capacity	Turn Radii	Angle	I/S Sight Dist.	Term. & Trans. Section (12)	Std Run	Bridge Rail (14)(19)
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					F	B	F
(3-2) HMA/PCCP/BST Overlays	DE/M	DE/M	DE/M	DE/M	DE/F	DE/F	DE/M	DE/M	DE/M	DE/M			B	B	M	DE/M	DE/M	F				B	F	B	F
(3-3) Replace HMA 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	M	DE/M	DE/M	F				B	F	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	F(2)	F(2)	F	F	F(2)	F(2)	F	F	F	F
(3-5) Bridge Deck Rehab.													B	B	M			F					F(6)	F(22)	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	F	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	F(2)	F (2)	F	F	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	F(2)	F (2)	F	F	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	F(2)	F (2)	F	F	F (2)	F (2)	F	F	F	F
(3-10) Bike/Ped. Connectivity	(5)	(5)	(5)	(5)	(5)			(5)	(5)	(5)	(5)	(5)	(5)		F	(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	F
(3-12) Intersection (1)			F(2)	F(2)	F					F (2)	F	F	F		M					F	F	F	F	F	F
(3-13) Corridor (1)(24)	M(4)	M(4)	M(4)	M(4)	F	F(17)	M(4)	M(4)	M(4)	M(4)	F	F	F		F	M(4)	M(4)	F		M(4)	M(4)	F	F	F	F
(3-14) Median Barrier				DE/F																			F(20)	F(20)	
(3-15) Guardrail Upgrades				DE/F																			F	F(23)	
(3-16) Bridge Rail Upgrades																							F	F(22)	F
(3-17) Risk: Roadside										F	EU/F	F	F										F	F	F
(3-18) Risk: Sight Distance	F/M(21)	F/M(21)	F/M(21)	F/M(21)						F/M(21)	F(21)	F(21)	F		F	F(21)	F(21)	F(21)		F/M(21)	F/M(21)	F(21)	F	F	F
(3-19) Risk: Roadway Width			F/M(21)	F/M(21)	F(21)	F(21)	F/M(21)	F/M(21)	F/M(21)	F/M(21)	F	F	F		F	F(21)	F(21)	F(21)		F/M(21)	F/M(21)	F(21)	F	F	F
(3-20) Risk: Realignment	F(2)	F(2)	F(2)	F(2)	F	F(2)	F(2)	F(2)	F(2)	F(2)	F	F	F		F	F(2)	F(2)	F		F(2)	F(2)	F(2)	F	F	F
Economic Development																									
(3-21) 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		EU/F(26)	DE/F	DE/F	F	F	EU/F	EU/F	EU/F	F	F	F
(3-22) Four-Lane Trunk System	F	F	F	F	F	F	F	F	F	F	F	F	F		F	F	F	F	F	F	F	F	F	F	F
(3-23) Rest Areas (New)	F	F	F	F	F	F	F	F	F	F	F	F	F		F	F	F	F		F	F	F	F	F	F
(3-24) Bridge Restrictions	F(2)	F(2)	F(2)	F(2)	F	F(2)	F(2)	F(2)	F(2)	F(2)		F	F		EU/F(26)	F(2)	F(2)	F	F	F(2)	F(2)	F	F	F	F
(3-25) Bike Routes (Shldrs)			EU/M	(7)	EU/F				EU/M	EU/M			B	B	F	EU/M	EU/M	F				B	F	B	EU/F

☐ Not Applicable
F Full design level. See Chapter 440.
M Modified design level. See Chapter 430.
B Basic design level. See Chapter 410.
F/M Full for freeways/Modified for nonfreeway
DE Design Exception
EU Evaluate Upgrade

(1) Collision Reduction (HAL, HAC, PAL), or Collision Prevention (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 325.03(5).
(3) If designated as L/A acquired in the Access Control Tracking System, limited access requirements apply. If not, managed access applies. See 325.03(5).
(4) Full design level may apply based on a corridor or project analysis. See 325.03(5).
(5) For bike/pedestrian design see Chapters 1020 and 1025.
(6) Applies only to bridge end terminals and transition sections.
(7) 4 ft minimum shoulders.
(8) If all weather structure can be achieved with spot digouts and overlay, modified design level applies to NHS highways and basic design level applies to non-NHS highways.
(11) See Chapter 1120.
(12) Impact attenuators are considered as terminals.
(14) Includes crossroad bridge rail. See Chapter 710.
(16) For design elements not in the matrix headings, apply full design level as found in the applicable chapters and see 325.03(2).
(17) DE for existing acceleration/deceleration lanes when length meets posted freeway speed and no significant accidents. See Chapter 940.
(18) On managed access highways within the limits of incorporated cities and towns, City and County Design Standards apply to areas outside the curb or outside the paved shoulder where no curb exists.
(19) The funding sources for bridge rail are a function of the length of the bridge. Consult programming personnel.
(20) Applies to median elements only.
(21) Analyses required. See 325.03(5) for details.
(22) Upgrade barrier, if necessary, within 200 ft of the end of the bridge.
(23) See description of Guardrail Upgrades Project Type, 325.03(1) regarding length of need.
(24) Apply Full design level to projects that realign or reconstruct significant portions of the alignment.
(26) Sidewalk ramps must be addressed for ADA compliance. See Chapter 1025.

Design Matrix 3
Main Line NHS Routes (Except Interstate)
Figure 325-5

Ramps and Collector Distributors

⇩ Project Type / Design Elements ⇨	Horiz. Align.	Vert. Align.	Lane Width	Shldr Width	Lane Tran-sition	On/Off Conn.	Cross Slope Lane	Cross Slope Shldr	Fill/ Ditch Slopes	Access (3)	Clear Zone	Sign., Del., Illumin.	Basic Safety	Bike & Ped.	Ramp Terminals: Turn Radii	Ramp Terminals: Angle	Ramp Terminals: I/S Sight Dist.	Barriers: Term. & Trans. Section (12)	Barriers: Std Run	Barriers: Bridge Rail (14)(19)
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	M	DE/F	DE/F	DE/F	F	B	F
(4-2) HMA/PCCP/BST Overlays Ramps												B	B	M			B	F	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	F
(4-4) Bridge Deck Rehab.												B	B	M				F(6)	F(22)	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	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	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	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	F(2)	F(2)	F	F	F	F
(4-9) Bike/Ped. Connectivity	(5)	(5)	(5)	(5)	(5)		(5)	(5)	(5)	(5)	(5)	(5)		F	(5)	(5)	(5)	(5)	(5)	(5)
Safety																				
(4-10) Non-Interstate Freeway	F	F	F	F	F	F	F	F	F	F	F	F		M	F	F	F	F	F	F
(4-11) At Grade (1)(25)	F(2)	F(2)	F(2)	F(2)	F	F(2)	F(2)	F(2)	F(2)	F	F	F		F	F(2)	F(2)	F	F	F	F
(4-12) Intersection (1)			F(2)	F(2)	F				F(2)	F	F	F		M	F	F	F	F	F	F
(4-13) Guardrail Upgrades				DE/F														F	F(23)	
(4-14) Bridge Rail Upgrades																				
(4-15) Risk: Roadside									F	EU/F	F	F								
(4-16) Risk: Sight Distance	F/M(21)	F/M(21)	F/M(21)	F/M(21)					F/M(21)	F(21)	F(21)	F		F	F/M(21)	F/M(21)	F	F	F	F
(4-17) Risk: Roadway Width			F/M(21)	F/M(21)	F	F(21)	F/M(21)	F/M(21)	F/M(21)	F	F	F		F	F/M(21)	F/M(21)	F	F	F	F
(4-18) Risk: Realignment	F(2)	F(2)	F(2)	F(2)	F	F(2)	F(2)	F(2)	F(2)	F	F	F		F	F/M(21)	F/M(21)	F	F	F	F
Economic Development																				
(4-19) Four-Lane Trunk System	F	F	F	F	F	F	F	F	F	F	F	F		F	F	F	F	F	F	F

Cross Road

⇩ Project Type / Design Elements ⇨	Lane Width	Shldr Width	Fill/ Ditch Slopes	Access (3)	Clear Zone	Sign., Del., Illumin.	Basic Safety	Vert. Clear. (11)	Ped. & Bike	Barriers: Term. & Trans. Section (12)	Barriers: Std. Run	Barriers: Bridge Rail (14)(19)
Preservation												
Roadway												
(4-1) Non-Interstate Freeway	DE/F	DE/F	DE/F			B	B	F	M	F	B	F
(4-2) HMA/PCCP/BST Overlays Ramps						B	B	F	M	F	B	F
Structures												
(4-3) Bridge Replacement	F(2)	F(2)	F(2)	F	F	F		F	F	F	F	F
(4-4) Bridge Deck Rehab.						B	B	F	M	F(6)	F(22)	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(2)	F	F	F		F	F	F	F	F
(4-7) Rural	F(2)	F(2)	F(2)	F	F	F		F	F	F	F	F
(4-8) HOV By Pass	F(2)	F(2)	F(2)	F	F	F		F	F	F	F	F
(4-9) Bike/Ped. Connectivity	(5)	(5)	(5)			(5)		(5)	F	(5)	(5)	(5)
Safety												
(4-10) Non-Interstate Freeway	F	F	F	F	F	F		F	M	F	F	F
(4-11) At Grade (1)(25)	F(2)	F(2)	F(2)	F	F	F		F	F	F	F	F
(4-12) Intersection (1)			F(2)	F	F	F		F	M	F	F	F
(4-13) Guardrail Upgrades										F	F(23)	
(4-14) Bridge Rail Upgrades										F	F(22)	F
(4-15) Risk: Roadside			F	EU/F	F	F				F	F	F
(4-16) Risk: Sight Distance			F/M(21)	F(21)	F(21)			F(21)	F			
(4-17) Risk: Roadway Width	F/M(21)	F/M(21)	F/M(21)	F	F			F(21)	F	F	F	F
(4-18) Risk: Realignment	F(2)	F(2)	F(2)	F	F			F(21)	F	F	F	F
Economic Development												
(4-19) Four-Lane Trunk System	F	F	F	F	F	F		F		F	F	F

☐ Not Applicable
F Full design level. See Chapter 440.
M Modified design level. See Chapter 430.
B Basic design level. See Chapter 410.
F/M Full for freeways/Modified for nonfreeway
DE Design Exception
EU Evaluate Upgrade

(1) Collision Reduction (HAL, HAC, PAL), or Collision Prevention (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 325.03(5).
(3) If designated as L/A acquired in the Access Control Tracking System, limited access requirements apply. If not, managed access applies. See 325.03(5).
(4) Full design level may apply based on a corridor or project analysis. See 325.03(5).
(5) For bike/pedestrian design see Chapters 1020 and 1025.
(6) Applies only to bridge end terminals and transition sections.
(11) See Chapter 1120.
(12) Impact attenuators are considered as terminals.
(14) Includes crossroad bridge rail. See Chapter 710.
(16) For design elements not in the matrix headings, apply full design level as found in the applicable chapters and see 325.03(2).
(19) The funding sources for bridge rail are a function of the length of the bridge. Consult programming personnel.
(21) Analyses required. See 325.03(5) for details.
(22) Upgrade barrier, if necessary, within 200 ft of the end of the bridge.
(23) See description of Guardrail Upgrades Project Type, 325.03(1) regarding length of need.
(25) For main line, use the Project Type row for Safety, Non-Interstate Freeway on Matrix 3 for NHS and on Matrix 5 for non-NHS.

Design Matrix 4
Interchange Areas, NHS (Except Interstate) and Non-NHS
Figure 325-6

⇩ Project Type															Bridges (11)				Intersections			Barriers		
Design Elements ⇨	Horiz. Align.	Vert. Align.	Lane Width	Shldr Width	Lane Tran-sition	Median Width	Cross Slope Lane	Cross Slope Shldr	Fill/ Ditch Slopes	Access (3)	Clear Zone (18)	Sign, Del., Illumin.	Basic Safety	Bike & Ped.	Lane Width	Shldr Width	Vertical Clear.	Structural Capacity	Turn Radii	Angle	I/S Sight Dist.	Term. & Trans. Section (12)	Std Run	Bridge Rail (19)
Preservation																								
Roadway																								
(5-1) HMA/PCCP												B	B	M			F				B	F	B	F
(5-2) BST																								
(5-3) BST Routes/Basic Safety												B	B								B	F	B	F
(5-4) Replace HMA with PCCP at I/S			EU/M	EU/M		EU/M	EU/M					B	B	M			F					F	B	F
Structures																								
(5-5) Bridge Replacement	M	F	M	M	F		M	M	M		F	F		F	F(2)	F(2)	F	F	M	M	F	F	F	F
(5-6) Bridge Repl. (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	F(2)	F(2)	F	F	F	F
(5-7) Bridge Deck Rehab												B	B	M								F(6)	F(22)	F
Improvements (16)																								
Mobility																								
(5-8) Urban (Multilane)	F(2)	F(2)	F(2)	F(2)	F	F(2)	F(2)	F(2)	(2)	F	F	F		F	F(2)	F(2)	F	F	EU/F	EU/F	F	F	F	F
(5-9) Urban	M	M	M	M	F		M	M	M	F	F	F		F	M	M	F	F	EU/M	EU/M	F	F	F	F
(5-10) Rural	M	M	M	M	F	M	M	M	M	F	F	F		F	M	M	F	F	EU/M	EU/M	F	F	F	F
(5-11) HOV	M	M	M	M	F	M	M	M	M	F	F	F		F	M	M	F	F	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)		F	(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	F(2)	F(2)	F		F(2)	F(2)	F	F	F	F
(5-14) Intersection (1)			M(4)	M(4)	F				M(4)	F	F	F		M					M(4)	M(4)	F	F	F	F
(5-15) Corridor (1)	M(4)	M(4)	M(4)	M(4)	F	M(4)	M(4)	M (4)	M(4)	F	F	F		M	M(4)	M(4)	F		M(4)	M(4)	F	F	F	F
(5-16) Median Barrier				DE/F																		F(20)	F(20)	
(5-17) Guardrail Upgrades				DE/F																		F	F(23)	
(5-18) Bridge Rail Upgrades																						F	F(22)	F
(5-19) Risk: Roadside									M(4)	EU/F	F	F										F	F	F
(5-20) Risk: Sight Distance	F/M(21)	F/M(21)	F/M(21)	F/M(21)					F/M(21)	F(21)	F(21)	F		F	F(21)	F(21)	F(21)		F/M(21)	F/M(21)	F(21)	F	F	F
(5-21) Risk: Roadway Width			F/M(21)	F/M(21)	F	F/M(21)	F/M(21)	F/M(21)	F/M(21)	F	F	F		F	F(21)	F(21)	F(21)		F/M(21)	F/M(21)	F(21)	F	F	F
(5-22) Risk: Realignment	F/M	F/M	F/M	F/M	F	F/M	F(2)	F(2)	F/M	F	F	F		F	F(21)	F(21)	F(21)		F/M(21)	F/M(21)	F(21)	F	F	F
Economic Development																								
(5-23) 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/F(26)	EU/M	EU/M	F		EU/M	EU/M	EU/F	F	B	F
(5-24) Rest Areas (New)	F	F	F	F	F	F	F	F	F	F	F	F		F	F	F			F	F	F	F	F	F
(5-25) Bridge Restrictions	M	F	M	M	F	M	M	M	M		F	F		EU/F(26)	M	M	F	F	M	M	F	F	F	F
(5-26) Bike Routes (Shldrs)			EU/M	(7)	EU/F			EU/M	EU/M			B	B	F	EU/M	EU/M					B	F	B	EU/F

☐ Not Applicable
F Full design level. See Chapter 440.
M Modified design level. See Chapter 430.
F/M Full for freeways/Modified for nonfreeway
B Basic design level. See Chapter 410.
DE Design Exception
EU Evaluate Upgrade

(1) Collision Reduction (HAL, HAC, PAL), or Collision Prevention (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 325.03(5).
(3) If designated as L/A acquired in the Access Control Tracking System, limited access requirements apply. If not, managed access applies. See 325.03(5).
(4) Full design level may apply based on a corridor or project analysis. See 325.03(5).
(5) For bike/pedestrian design see Chapters 1020 and 1025.
(6) Applies only to bridge end terminals and transition sections.
(7) 4 ft minimum shoulders.
(8) If all weather structure can be achieved with spot digouts and overlay, modified design level applies to NHS highways and basic design level applies to non-NHS highways.
(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 chapters and see 325.03(2).
(18) On managed access highways within the limits of incorporated cities and towns, City and County Design Standards apply to areas outside the curb or outside the paved shoulder where no curb exists.
(19) The funding sources for bridge rail are a function of the length of the bridge. Consult programming personnel.
(20) Applies to median elements only.
(21) Analyses required. See 325.03(5) for details.
(22) Upgrade barrier, if necessary, within 200 ft of the end of the bridge.
(23) See description of Guardrail Upgrades Project Type, 325.03(1) regarding length of need.
(26) Sidewalk ramps must be addressed for ADA compliance. See Chapter 1025.

Design Matrix 5
Main Line Non-NHS Routes
Figure 325-7

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
- 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 see Chapter 642
- 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 2 ft 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 300 ft apply full design level. See Chapter 641.

Curve Radius (ft)	Lane Width (ft)
Tangent - 4,000	13
3,000 - 2,000	14
1,000 - 300	15

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 2 ft 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.

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) 46.61.575, Additional parking regulations

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), 2001, 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.

divided multilane A roadway with 2 or more through lanes in each direction and a median that physically or legally prohibits left-turns, except at designated locations.

freeway A divided highway that has a minimum of two lanes in each direction, for the exclusive use of traffic, and with full control of access.

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 hot mix asphalt pavement on treated base.

incorporated city or town A city or town operating under either Title 35 or 35A RCW.

intermediate pavement type Hot Mix asphalt 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.

limited access highway All highways where the rights of direct access to or from abutting lands have been acquired from the abutting landowners.

low pavement type Bituminous surface treatment (BST).

managed access highway All highways where the rights of direct access to or from abutting lands have not been acquired from the abutting landowners.

median The portion of a 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 or C-D 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.

rural area An area that meets none of the conditions to be an urban area.

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 edge of traveled way to the edge of the roadway or face of curb.

suburban area A term for the area at the boundary of an urban area. Suburban settings may combine higher speeds common in rural areas with activities that are more similar to urban settings. Separate design values are not given for suburban areas, classify suburban areas as either urban or rural as best fits the existing or design year conditions.

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.

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

undivided multilane A roadway with 2 or more through lanes in each direction on which left-turns are not controlled.

urban area An area defined by one or more of the following:

- An area including and adjacent to a municipality or other urban place having a population of five thousand or more, as determined by the latest available published official Federal census, decennial or special, within boundaries to be fixed by a State highway department, subject to the approval of the FHWA.
- Within the limits of an incorporated city or town
- Characterized by intensive use of the land for the location of structures and receiving such urban services as sewer, water, and other public utilities and services normally associated with an incorporated city or town.
- With not more than twenty-five percent undeveloped land.

urbanized area An urban area with a population of 50,000 or more.

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 <u>criteria</u>. 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 <u>to determine</u> the functional classification consider the following:

- Urban population centers <u>inside</u> and <u>outside</u> 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 <u>inside</u> and <u>outside</u> 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 projects designed to full design level, all highways in rural areas and limited access highways in urban areas the geometric design data is controlled by the functional class (Figures 440-4 through 7b). The urban managed access highway design class (Figure 440-8) may be used on managed access highways in urban areas, regardless of the functional class.

(2) State Highways as City Streets

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 facilities on the NHS, use the *Design Manual* criteria as the minimum for the functional class of the route. For facilities not on the NHS, the *Local Agency Guidelines* may be used as the minimum design criteria; however, the use of *Design Manual* criteria is encouraged where feasible. On managed access highways within the limits of incorporated cities and towns, the cities or towns have full responsibility for design elements outside of curb, or outside the paved shoulder where no curb exists, using the *Local Agency Guidelines.*

(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, 642, 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.

For all rural highways and limited access highways in urban areas, the design speed is given for each design class in Figures 440-4 through 7b.

When terrain or existing development limit the ability to achieve the design speed for the functional class, use a corridor analysis to determine the appropriate design speed. The desirable design speed is not less than given in Figure 440-1. Do not select a design speed less than the posted speed.

Route Type	Posted speed	Desirable Design Speed
Freeways	All	10 mph over the posted speed
non-Freeways	45 mph or less	Not less than the posted speed.
	Over 45 mph	5 mph over the posted speed

Desirable Design Speed
Figure 440-1

On urban highways, that have obvious "street-like" characteristics, operationally and physically, the design speed is less critical to the operation of the facility. Closely spaced intersections and other operational constraints usually limit vehicular speeds more than the design speed.

For managed access facilities in urban areas, select a design speed based on Figure 440-1. In cases where the 440-1 design speed does not fit the conditions, use a corridor analysis to select a design speed. Select a design speed not less than the posted speed and logical with respect to topography, operating speed (or anticipated operating speed for new alignment), adjacent land use, design traffic volume, accident history, access control, and the functional classification. Consider both year of construction and design year. Maintain continuity throughout the corridor, with changes at logical points, such as a change in roadside development.

440.08 Traffic Lanes

Lane width and condition have a great influence on safety and comfort. The minimum lane width is based on the highway design class, terrain type, and whether it is in a rural or urban area. Lanes 12 ft wide provide desirable clearance between large vehicles where traffic volumes are high and a high number of large vehicles are expected. The added cost for lanes 12 ft wide 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.

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 increase the headway, resulting in reduced capacity.

Figures 440-4 through 440-7a give the minimum lane width for the various design classes for use on all rural highways and urban limited access highways. Figure 440-8 gives the minimum lane widths for urban managed access highways.

The roadway on a curve may need to be widened to make the operating conditions comparable to those on tangents. See Chapter 641 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 and the associated minimum widths are given in Figure 440-2.

Shoulder function	Minimum Shoulder Width
Stopping out of the traffic lanes	8 ft
Minimum lateral clearance	2 ft (1)
Pedestrian or bicycle use	4 ft (2)
Large vehicle off tracking on curves.	See Chapters 641 & 910
Maintenance operations.	Varies (3)
Law enforcement	8 ft (4)
Bus stops.	See Chapter 1060.
Slow vehicles turnouts and shoulder driving.	See Chapter 1010
Ferry holding	8 ft (5)
For use as a lane during reconstruction of the through lanes.	8 ft
Structural support	2 ft
Improve sight distance in cut sections.	See Chapter 650
Improve capacity.	See Chapter 610

(1) See Chapters 700 and 710.

(2) Minimum usable shoulder width for bicycles. For additional information, see Chapter 1020 for bicycle and Chapter 1025 for pedestrians.

(3) 10 ft usable width to park a maintenance truck out of the through lane; 12 ft for equipment with outriggers to work out of traffic.

(4) See Chapters 1040 and 1050 for additional information.

(5) Minimum usable shoulder width, 10 ft preferred.

Minimum Shoulder Width
Figure 440-2

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 8 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.

Shoulders also:

- Provide space to escape potential accidents or to reduce their severity.
- Provide a sense of openness, contributing to driver ease and freedom from strain.
- Reduce seepage adjacent to the traveled way by discharging storm water farther away.

Minimum shoulder widths for use on all rural highways and urban limited access highways based on functional classification and traffic volume, see Figures 440-4 through 7b. Figure 440-8 gives the minimum shoulder widths for urban managed access highways without curb.

When curbing with a height less than 24 inches, provide the minimum shoulder widths shown in Figure 440-3. (See 440.11 for information on curb.)

Lane Width	Posted Speed			
	>45 mph	≤45 mph	>45 mph	≤45 mph
	On Left		**On Right** (3)	
12 ft or wider	4 ft	(1)(2)	4 ft	2 ft
11 ft	4 ft	(1)(2)	4 ft	3 ft (4)

Notes:

(1) 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.

(2) 1 ft for curbs with a height of 8 in or less. 2 ft for curbs or barriers with a height between 8 in and 24 in.

(3) When the route has been identified as a local, state, or regional significant bike route, the minimum shoulder width is 4 ft or as indicated in Chapter 1020 for signed bike lanes.

(4) When bikes are not a consideration, may be reduced to 2 ft with justification.

(5) Measured from the edge of traveled way to the face of the curb.

Shoulder Width for Curbed Sections (5)
Figure 440-3

When traffic barrier with a height of 2 ft or greater is used adjacent to the roadway, the minimum shoulder width from the edge of traveled way to the face of the traffic barrier is 4 ft. Additional width for traffic barrier is not normally required on urban managed access highways.

Where there are no sidewalks the minimum shoulder width is 4 ft. Shoulder widths less than 4 ft will require wheelchairs using the roadway to encroach on the through lane. See Chapter 1025 for additional information and requirements on pedestrians and accessible routes.

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 vertical feature. See Chapter 710 for the required widening.

Shoulders on the left between 4 ft and 8 ft are undesirable. Shoulders in this width range might appear to a driver to be wide enough to stop out of the through traffic, when it is not. To prevent the problems that can arise from this, when the shoulder width and any added clearance result in a width in this range, consider increasing the width to 8 ft.

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 2 ft may be used with design exception documentation. See Chapter 700 for design clear zone and safety treatment requirements.

For routes identified as local, state, or regional significant bicycle routes, provide a minimum 4 ft shoulder. Maintain system continuity for the bicycle route, regardless of jurisdiction and functional class. See Chapter 1020 for additional information on bicycle facilities.

Shoulder widths greater than 10 ft may encourage use as a travel lane. Therefore, use shoulders wider than this only where required to meet one of the listed functions.

440.10 Medians

Medians are either restrictive or nonrestrictive. Restrictive medians limit left-turns, physically or legally, to defined locations. Nonrestrictive medians allow left-turns at any point along the route. Consider restrictive medians on multilane limited access highways and multilane managed access highways when the DHV is over 2000.

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.
- Control access.

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 440-8. When selecting a median width, consider future needs such as wider left shoulders when widening from four to six lanes.

A two-way left-turn lane (TWLTL) may be used as a nonrestrictive median for an undivided managed access highway. (See Figure 440-8.) The desirable width of a TWLTL is 13 ft with a minimum width of 11 ft. For more information on traffic volume limits for TWLTLs on managed access highways, see Chapter 1435. See Chapter 910 for additional information on TWLTL design.

A common form of restrictive median on managed access highways in urban areas is the raised median. The width of a raised median can be minimized by using a dual-faced cement concrete traffic curb, a precast traffic curb, or an extruded curb. For more information on traffic volume limits for restrictive medians on managed access highways, see Chapter 1435.

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.

When the median is to be landscaped or where rigid objects are to be placed in the median, see Chapter 700 for traffic barrier and clear zone requirements. When the median will include a turn-lane lane, see Chapter 910 for left-turn lane design.

440.11 Curbs

(1) General

Curbs are divided into vertical curbs and sloped curbs. Vertical curbs have a face batter not flatter than 1H:3V. Sloped curbs have a sloping face that is more readily traversed.

Curbs can also be classified as mountable. Mountable curbs are sloped curb with a height of 6 in or less, preferably 4 in or less. When the face slope is steeper than 1H:1V, the height of a mountable curb is limited to 4 in or less.

Where curbing is to be provided, ensure that surface water that collects at the curb will drain and not pond or flow across the roadway.

When an overlay will reduce the height of a vertical curb, evaluate grinding to maintain curb height, or replacing the curb, versus the need to maintain the height of the curb.

Curbs can hamper snow removal operations. The area Maintenance Superintendent's review and approval is required for the use of curbing in areas of heavy snowfall.

For curbs at traffic islands, see Chapter 910.

(2) Curb Usage

Curbing is used for the following purposes:

- control drainage
- delineate the roadway edge
- delineate pedestrian walkways
- delineate islands
- reduce right of way
- assist in access control
- inhibit mid-block left turns

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

In general, curbs are not 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. Justify the use of curb when the posted speed is greater than 40 mph.

(a) Vertical curbs with a height of 6 in or more are required for:

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

When an overlay is planned, do not reduce the height of the curb to less than 4 inches.

(b) Consider vertical curbs with a height of 6 in or more:

- to inhibit mid-block left turns.
- for divisional and channelizing islands.
- for landscaped islands.

(c) Provide mountable curbs where a curb is needed but higher vertical curb is not justified.

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 8, consider them only in cooperation with the municipality involved. The lane widths given are the minimum for parking, provide wider widths when practical.

Angle parking is not permitted on any state route without approval by WSDOT (RCW 46.61.575). This approval is delegated to the State Traffic Engineer. Angle parking approval is to be requested through the HQ Design Office. Provide an engineering study, approved by the region's Traffic Engineer, with the request that shows the parking will not unduly reduce safety and that the roadway is of sufficient width that the parking will not interfere with the normal movement of traffic.

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 HQ 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 structure not less than the approach roadway width (lanes plus shoulders). The structure widths given in Figures 440-4 through 8 are the minimum structure width for each design class.

Additional width for barriers is not normally added to the roadway width on structures. When a structure is in a run of roadside barrier with the added width, consider adding the width on shorter structures to prevent narrowing the roadway.

440.15 Right of Way Width

Right of way width must be sufficient to accommodate all roadway elements and required appurtenances necessary for the current design and known future improvements. To allow for construction and maintenance activities, provide 10 ft desirable, 5 ft minimum, wider than the slope stake for fill and slope treatment for cut. Chapter 640 and the Standard Plans for slope treatment information.

The right of way widths given in Figures 440-4 through 7b, are desirable minimums for new alignment requiring purchase of new right of way. See Chapter 1410 for additional information and consideration on right of way acquisition.

440.16 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.

440.17 Documentation

A list of the documents that are to be preserved [in the Design Documentation Package (DDP) or the Project File (PF)] is on the following web site: http://www.wsdot.wa.gov/eesc/design/projectdev/

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)	
Urbanized	70 (4)	
Traffic Lanes		
Number	4 or more divided	
Width (ft)	12	
Median Width (ft)	4 lane	6 lanes or more
Rural —Minimum (5)	40	50
Urban —Minimum	16	22
Shoulder Width (ft)		
Right of Traffic	10 (6)	10 (6)
Left of Traffic	4	10 (6)(7)
Pavement Type (8)	High	
Right of Way (9)		
Rural —Width (ft)	63 from edge of traveled way	
Urban—Width (ft)	As required (10)	
Structures Width (ft) (11)	Full roadway width each direction (12)	

Type of Terrain	**Design Speed** (mph) 50	55	60	65	70	75	80
Level	4	4	3	3	3	3	3
Rolling	5	5	4	4	4	4	4
Mountainous	6	6	6	5	5	5	5

Grades (%) (13)

Interstate Notes:

(1) The design year is 20 years after the year the construction is scheduled to begin.

(2) See Chapter 1430 for access control requirements.

(3) 80 mph is the desirable design speed; with a corridor analysis, the design speed may be reduced to 60 mph in mountainous terrain and 70 mph in rolling terrain. Do not select a design speed that is less than the posted speed.

(4) 70 mph is the desirable design speed, with a corridor analysis the design speed may be reduced to 50 mph. Do not select a design speed that is less than the posted speed.

(5) Independent alignment and grade is desirable in all rural areas and where terrain and development permits in urban areas.

(6) 12 ft shoulders are desirable when the truck DDHV is 250 or greater.

(7) For existing 6-lane roadways, existing 6 ft left shoulders may remain with design exception documentation, when they are not being reconstructed, and no other widening is required.

(8) Submit Form 223-528, Pavement Type Determination.

(9) Desirable width. Provide right of way width 10 ft desirable, 5 ft minimum, wider than the slope stake for fill and slope treatment for cut. See 440.15.

(10) In urban areas, make right of way widths not less than those required for necessary cross section elements.

(11) See Chapter 1120 for minimum vertical clearance.

(12) For median widths 26 ft or less, address bridge(s) in accordance with Chapter 1120.

(13) Grades 1% steeper may be provided in urban areas and mountainous terrain with critical right of way controls.

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 Railroads (6)	 All All		 Where Justified All		 Where Justified All (7)		 Where Justified Where Justified (8)		 Where Justified Where Justified (8)		 Where Justified Where Justified (8)	
Design Speed (mph) (9) Minimum (10)	80 60 (11)		70 50 (12)		70 50	60 40 (12)	70 50	60 40 (12)	60 40	60 30 (12)	70 40	60 30 (12)
Traffic Lanes Number Width (ft)	 4 or more divided 12		 4 or 6 divided 12		 2 12		 2 12		 2 12		 4 12	 4 or 6 11 (13)
Shoulder Width (ft) Right of Traffic Left of Traffic	 10 (14) Variable (15)(16)		 10 Variable (15)(16)		 8		 6		 4		 8	 8(17)
Median Width (ft) 4 lane 6 or more lanes	 40 (18) 48 (18)	 16 22	 60 60	 16 22							 4 4	 2 (19) 2 (19)
Parking Lanes Width (ft) — Minimum	None		None		None		None	10	None	10	None	10 (20)
Pavement Type (21)	High				High or intermediate							
Right of Way (22) —Width (ft)	(23)	(24)	(23)	(24)	120	80	120	80	100	80	150	80
Structures Width (ft) (25)	Full roadway width (26)				40		40		32		Full roadway width	
Other Design Considerations-Urban					(27)		(27)		(27)		(27)	

Type of Terrain	Rural — Design Speed (mph)									Urban — Design Speed (mph)						
	40	45	50	55	60	65	70	75	80	30	35	40	45	50	55	60 (28)
Level	5	5	4	4	3	3	3	3	3	8	7	7	6	6	5	5
Rolling	6	6	5	5	4	4	4	4	4	9	8	8	7	7	6	6
Mountainous	8	7	7	6	6	5	5	5	5	11	10	10	9	9	8	8

Grades (%) (29)

Geometric Design Data, Principal Arterial

Figure 440-5a

Principal Arterial Notes:

(1) Justify the selection of a P-6 design class on limited access highways.

(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 Chapters 1430 and 1435 and the Master Plan for Limited Access Highways for access control requirements. Contact the HQ Design Office Access & Hearings Unit for additional information.

(6) Contact the Rail Office of the Public Transportation and Rail Division for input on the needs for the railroad.

(7) All main line and major-spur railroad tracks will be separated. Consider allowing at-grade crossings at minor-spur railroad tracks.

(8) Criteria for railroad grade separations are not clearly definable. Evaluate each site regarding the hazard potential. Provide justification for railroad grade separations.

(9) These are the design speeds for level and rolling terrain in rural areas. They are the preferred design speeds for mountainous terrain and urban areas. Higher design speeds may be selected, with justification.

(10) These design speeds may be selected in mountainous terrain, with a corridor analysis. Do not select a design speed that is less than the posted speed.

(11) In urbanized areas, with a corridor analysis, 50 mph may be used as the minimum design speed. Do not select a design speed that is less than the posted speed.

(12) In urban areas, with a corridor analysis these values may be used as the minimum design speed. Do not select a design speed that is less than the posted speed.

(13) 12 ft lanes are required when the truck DDHV is 150 or greater.

(14) 12 ft shoulders are desirable when the truck DDHV is 250 or greater.

(15) Minimum left shoulder width is to be as follows: four lanes — 4 ft: six or more lanes — 10 ft. Consider 12 ft shoulders on facilities with 6 or more lanes and a truck DDHV of 250 or greater.

(16) For existing 6-lane roadways, existing 6 ft left shoulders may remain with design exception documentation, when they are not being reconstructed, and no other widening is required.

(17) When curb section is used, the minimum shoulder width from the edge of traveled way to the face of curb is 4 ft.

(18) 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.

(19) When signing is required in the median of a six-lane section, the minimum width is 6 ft. If barrier is to be installed at a future date, an 8 ft minimum median is required.

(20) Restrict parking when DHV is over 1500.

(21) Submit Form 223-528, Pavement Type Determination.

(22) Desirable width. Provide right of way width 10 ft desirable, 5 ft minimum, wider than the slope stake for fill and slope treatment for cut. See 440.15.

(23) 63 ft from edge of traveled way.

(24) Make right of way widths not less than those required for necessary cross section elements.

(25) See Chapter 1120 for the minimum vertical clearance.

(26) For median widths 26 ft or less, address bridges in accordance with Chapter 1120.

(27) 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.

(28) For grades at design speeds greater than 60 mph in urban areas, use rural criteria.

(29) Grades 1% steeper may be used in urban areas and mountainous terrain with critical right of way controls.

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	Partial (5)		(5)		(5)		(5)		(5)	
Separate Cross Traffic Highways Railroads (6)	Where Justified All		Where Justified All (7)		Where Justified Where Justified (8)		Where Justified Where Justified (8)		Where Justified Where Justified (8)	
Design Speed (mph) (9) Minimum (10)(11)	70 50		70 50	60 40	70 50	60 40	60 40	60 30	70 40	60 30
Traffic Lanes Number Width (ft)	4 or 6 divided 12		2 12		2 12		2 12		4 12	4 or 6 11 (12)
Shoulder Width (ft) Right of Traffic Left of Traffic	10 Variable (13)(14)		8		6		4		8	8 (15)
Median Width (ft) 4 lane 6 lane	60 60	16 22							4	2 (16)
Parking Lanes Width (ft) — Minimum	None		None		None	10	None	10	None	10 (17)
Pavement Type (18)	High		As required						High or Intermediate	
Right of Way (19) —Width (ft)	(20)	(21)	120	80	120	80	100	80	150	80
Structures (ft) (22)	Full Roadway Width (23)		40		40		32		Full Roadway Width	
Other Design Considerations-Urban			(24)		(24)		(24)		(24)	

Type of Terrain	Rural — Design Speed (mph)									Urban — Design Speed (mph)					
	40	45	50	55	60	65	70	75	80	30	35	40	45	50	55	60 (25)
Level	5	5	4	4	3	3	3	3	3	8	7	7	6	6	5	5
Rolling	6	6	5	5	4	4	4	4	4	9	8	8	7	7	6	6
Mountainous	8	7	7	6	6	5	5	5	5	11	10	10	9	9	8	8

Grades (%)(26)

Geometric Design Data, Minor Arterial

Figure 440-6a

Minor Arterial Notes:

(1) Justify the selection of an M-5 design class on limited access highways.

(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 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 Chapters 1430 and 1435 and the Master Plan for Limited Access Highways for access control requirements. Contact the HQ Design Office Access & Hearings Unit for additional information.

(6) Contact the Rail Office of the Public Transportation and Rail Division for input on the needs for the railroad.

(7) All main line and major-spur railroad tracks will be separated. Consider allowing at-grade crossings at minor-spur railroad tracks.

(8) Criteria for railroad grade separations are not clearly definable. Evaluate each site regarding the hazard potential. Provide justification for railroad grade separations.

(9) These are the design speeds for level and rolling terrain in rural areas. They are the preferred design speeds for mountainous terrain and urban areas. Higher design speeds may be selected, with justification.

(10) In urban areas, with a corridor analysis these values may be used as the minimum design speed. Do not select a design speed that is less than the posted speed.

(11) These design speeds may be selected in mountainous terrain, with a corridor analysis. Do not select a design speed that is less than the posted speed.

(12) When the truck DDHV is 150 or greater, consider 12 ft lanes.

(13) The minimum left shoulder width is 4 ft for four lanes and 10 ft for six or more lanes.

(14) For existing 6-lane roadways, existing 6 ft left shoulders may remain with design exception documentation, when they are not being reconstructed, and no other widening is required.

(15) When curb section is used, the minimum shoulder width from the edge of traveled way to the face of curb is 4 ft.

(16) When signing is required in the median of a six-lane section, the minimum width is 6 ft. If barrier is to be installed at a future date, an 8 ft minimum median is required.

(17) Restrict parking when DHV is over 1500.

(18) Submit Form 223-528, Pavement Type Determination.

(19) Desirable width. Provide right of way width 10 ft desirable, 5 ft minimum, wider than the slope stake for fill and slope treatment for cut. See 440.15.

(20) 63 ft from edge of traveled way

(21) Make right of way widths not less than those required for necessary cross section elements.

(22) See Chapter 1120 for the minimum vertical clearance.

(23) For median widths 26 ft or less, address bridges in accordance with Chapter 1120.

(24) 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.

(25) For grades at design speeds greater than 60 mph in urban areas, use rural criteria.

(26) Grades 1% steeper may be used in urban areas and mountainous terrain with critical right of way controls.

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 Non NHS	Over 900		Over 301 (2) Over 501		201-300 (3) 301-500		200 and under 300 and Under	
Access Control	(4)		(4)		(4)		(4)	
Separate Cross Traffic Highways Railroads (5)	Where Justified Where Justified (6)		Where Justified All (6)		Where Justified Where Justified (6)		Where Justified Where Justified (6)	
Design Speed (mph) (7) Minimum (8)(9)	70 40	60 30	70 50	60 40	70 50	60 40	60 40	60 30
Traffic Lanes Number Width (ft)	4 12	4 or 6 11 (10)	2 12		2 12		2 12	
Shoulder Width (ft)	8	8 (11)	8		6		4	
Median Width — Minimum (ft)	4	2 (12)						
Parking Lanes Width (ft) — Minimum	None	10	None		None	10	None	10
Pavement Type (13)	High or Intermediate		As required					
Right of Way (ft) (14)	150	80	120	80	120	80	100	80
Structures Width (ft) (15)	Full Roadway Width		40		40		32	
Other Design Considerations — Urban	(16)		(16)		(16)		(16)	

Type of Terrain	Rural — Design Speed (mph)										Urban — Design Speed (mph)								
	25	30	35	40	45	50	55	60	65	70	20	25	30	35	40	45	50	55	60(17)
Level	7	7	7	7	7	6	6	5	5	4	9	9	9	9	9	8	7	7	6
Rolling	10	9	9	8	8	7	7	6	6	5	12	12	11	10	10	9	8	8	7
Mountainous	11	10	10	10	10	9	9	8	8	6	14	13	12	12	12	11	10	10	9

Grades (%) (18)

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 Chapters 1430 and 1435 and the Master Plan for Limited Access Highways for access control requirements. Contact the HQ Design Office Access & Hearings Unit for additional information.

(5) Contact the Rail Office of the Public Transportation and Rail Division for input on the needs for the railroad.

(6) Criteria for railroad grade separations are not clearly definable. Evaluate each site regarding the hazard potential. Provide justification for railroad grade separations.

(7) These are the design speeds for level and rolling terrain in rural areas. They are the preferred design speeds for mountainous terrain and urban areas. Higher design speeds may be selected, with justification. Do not select a design speed that is less than the posted speed.

(8) In urban areas, with a corridor analysis these values may be used as the minimum design speed. Do not select a design speed that is less than the posted speed.

(9) These design speeds may be selected in mountainous terrain, with a corridor analysis. Do not select a design speed that is less than the posted speed.

(10) Consider 12 ft lanes when the truck DHV is 200 or greater.

(11) When curb section is used, the minimum shoulder width from the edge of traveled way to the face of curb is 4 ft.

(12) When signing is required in the median of a six-lane section, the minimum width is 6 ft median. If barrier is to be installed at a future date, an 8 ft minimum median is required.

(13) Submit Form 223-528, Pavement Type Determination.

(14) Desirable width. Provide right of way width 10 ft desirable, 5 ft minimum, wider than the slope stake for fill and slope treatment for cut. See 440.15.

(15) See Chapter 1120 for the minimum vertical clearance.

(16) 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.

(17) For grades at design speeds greater than 60 mph in urban areas, use rural criteria.

(18) Grades 1% steeper may be used in urban areas and mountainous terrain with critical right of way controls.

Geometric Design Data, Collector
Figure 440-7b

Design Class	Divided Multilane		Undivided Multilane		Two-Lane	
	$U_{M/A}$-1	$U_{M/A}$-2	$U_{M/A}$-3	$U_{M/A}$-4	$U_{M/A}$-5	$U_{M/A}$-6
DHV in Design Year (1)	Over 700	Over 700	700 – 2,500	Over 700	All	All
Design Speed (mph)	Greater than 45	45 or less	35 to 45	30 or less	Greater than 45	45 or less
Access	(2)	(2)	(2)	(2)	(2)	(2)
Traffic Lanes Number Width (ft) NHS Non NHS	 4 or more 12 (3)(4) 11 (4)	 4 or more 12 (3) 11 (5)	 4 or more 12 (3) 11 (5)	 4 or more 12 (3) 11 (5)	 2 12 (3)(6) 11 (6)	 2 12 (3) 11 (7)
Shoulder Width (ft) Right of Traffic Left of Traffic	 10 4	 10 (8) 4 (8)	 8 (8)	 8 (8)	 8 (9) (8)	 4 (8)
Median Width (ft)	10 (10)	3 (10)(11)	(12)	(12)		
Parking Lane Width (ft)	None	10 (13)	10 (13)	8 (14)	10 (15)	8 (14)
Structures Width (ft) (16)	Full roadway width (17)		Full roadway width		32	30
Other Design Considerations	(18)	(18)	(18)	(18)	(18)	(18)

Urban Managed Access Highways Notes:

(1) The design year is 20 years after the year the construction is scheduled to begin.

(2) The urban managed access highway design is only used on managed access highways. See Chapter 1435.

(3) May be reduced to 11 ft with justification.

(4) Provide 12 ft lanes when truck DDHV is 200 or greater.

(5) Consider 12 ft lanes when truck DDHV is 200 or greater.

(6) Provide 12 ft lanes when truck DHV is 100 or greater.

(7) Consider 12 ft lanes when truck DHV is 100 or greater.

(8) See Figure 440-3 when curb section is used.

(9) When DHV is 200 or less, may be reduced to 4 ft.

(10) 12 ft desirable. At left-turn lanes, the minimum median width is 12 ft to accommodate the turn lane.

(11) The minimum median width is 10 ft when median barrier is used.

(12) 2 ft is desirable. When a TWLTL is present 13 ft is desirable, 11 ft is minimum.

(13) Prohibit parking when DHV is over 1500.

(14) 10 ft desirable.

(15) Prohibit parking when DHV is over 500.

(16) See Chapter 1120 for minimum vertical clearance.

(17) See Chapter 1120 for median requirements.

(18) For bicycle requirements, see Chapter 1020. For pedestrian and sidewalk requirements, see Chapter 1025. Lateral clearances from the face of curb to obstruction are in with Chapter 700. For railroad and other roadway grade separation, maximum grade, and pavement type for the functional class, see Figures 440-5a through 7b. Make right of way widths not less than required for necessary cross section elements.

Geometric Design Data, Urban Managed Access Highways

Figure 440-8

Chapter 520 Design of Pavement Structure

520.01 Introduction

Detailed criteria and methods that govern pavement design are in the *WSDOT Pavement Guide – Interactive*.

520.02 Estimating Tables

Figures 520-1 through 520-5b are to be used when detailed estimates are required. They are for pavement sections, shoulder sections, stockpiles, and asphalt distribution. Prime coats and fog seal are in Figure 520-2a.

Type of Material	Unit Dry Weight			
	Truck Measure		Compacted on Roadway	
	lb/cy	T/cy	lb/cy	T/cy
Ballast	3100	1.55	3900	1.95
Crushed Surfacing Top Course	2850	1.43	3700	1.85
Crushed Surfacing Base Course	2950	1.48	3700	1.85
Screened Gravel Surfacing			3700	1.85
**Gravel Base			3400 – 3800	1.70 – 1.90
Shoulder Ballast			2800	1.40
Maintenance Sand 3/8” – 0	2900	1.45		
Mineral Aggregate 2” – 1”	2600	1.30		
Mineral Aggregate 1 3/4” – 3/4”	2600	1.30		
Mineral Aggregate 1 1/2” – 3/4”	2550	1.28		
Mineral Aggregate 1” – 3/4”	2500	1.25		
Mineral Aggregate 3/4” – 1/2”	2400	1.20		
Mineral Aggregate 1 1/4” – 1/4’”	2600	1.30		
Mineral Aggregate 1” – 1/4”	2600	1.30		
Mineral Aggregate 7/8” – 1/4”	2550	1.28		
Mineral Aggregate 3/4” – 1/4”	2500	1.25		
Mineral Aggregate 5/8” – 1/4”	2650	1.33		
Mineral Aggregate 1/2” – 1/4” or #4	2600	1.30		
Mineral Aggregate 1/4” or #4 – 0	2900	1.45		
Concrete Aggr. No. 2 (1 1/4” - #4)	3000	1.50		
Concrete Sand (Fine Aggregate)	2900	1.45		
Crushed Cover Stone	2850	1.43		

** 3,700 lb/cy (1.85 tons/cy) is recommended as the most suitable factor; however, if the grading approaches the coarseness of ballast, the factor would approach 3,800 lb/cy (1.90 tons/cy), and if the grading contains more than 45% sand, the factor would decrease, approaching 3,400 lb/cy (1.70 tons/cy) for material that is essentially all sand.

General Notes:

Weights shown are dry weights and corrections are required for water contents.

The tabulated weights for the materials are reasonably close; however, apply corrections in the following order:

For specific gravity:

$$\text{Wt.} = \frac{\text{tabular wt. x specific gravity on surface report}}{2.65}$$

For water content:

Wt. = tabular wt. x (1 + free water % in decimals)

If they are to be stockpiled, increase required quantities by 10 percent to allow for waste.

Direct attention to the inclusion of crushed surfacing top course material that may be required for keystone when estimating quantities for projects having ballast course.

Estimating – Miscellaneous Tables

Figure 520-1

General Data [1, 2, 3]							
Hot Mix Asphalt Pavement							
Complete Mix							
Class of Mix	Depth (ft)	Spread per sy		sy per ton	Tons/Mile Width (ft)		
		lb	ton		10	11	12
HMA	0.10	137	0.0685	14.60	402	442	482

Prime Coats and Fog Seal														
Asphalt							Aggregate							
Application	Type of Asphalt[4]	Application gal[5] per sy	Tons[5] per sy	Tons/Mile Width (ft)			Application lb per sy	Tons/Mile Width (ft)			cy per sy	cy/Mile Width (ft)		
				10	11	12		10	11	12		10	11	12
Prime Coat	MC-250	0.25	0.001004	5.9	6.5	7.1	30	88	97	106	0.0105	62	68	74
Fog Seal	CSS-1	0.04	0.000167	1.0	1.1	1.2								

Specific Data [1 2 3]														
Hot Mix Asphalt Paving Quantities (tons/mile)*														
Width (ft)	Depth of Pavement (ft)													
	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75
4	161	241	321	402	482	563	643	723	804	884	964	1045	1125	1206
6	241	362	482	603	723	844	964	1085	1206	1326	1447	1567	1688	1808
8	321	482	643	804	964	1125	1286	1447	1607	1768	1929	2090	2250	2411
10	402	603	804	1005	1206	1407	1607	1808	2009	2210	2411	2612	2813	3014
11	442	663	884	1105	1326	1547	1768	1989	2210	2431	2652	2873	3094	3315
12	482	723	964	1206	1447	1688	1929	2170	2411	2652	2893	3135	3376	3617
22	884	1326	1768	2210	2652	3094	3536	3978	4421	4863	5305	5747	6189	6631
24	964	1447	1929	2411	2893	3376	3858	4340	4822	5305	5787	6269	6751	7234
* Based on 137 lbs/sy of 0.10 ft compacted depth = 2.05 tons/cy														

1 The specific gravity of the aggregate will affect the weight of aggregate in the completed mix.

2 The percentage of fine mineral in the coarse aggregate will affect the ratio of coarse to fine. If the coarse aggregate produced contains an excessive amount of fines (1/4” to 0), increase the percentage of coarse aggregate and decrease the fines accordingly.

3 Quantities shown do not provide for widening, waste from stockpile, or thickened edges.

4 The column “Type of Asphalt” is shown for the purpose of conversion to proper weights for the asphalt being used and does not imply that the particular grade shown is required for the respective treatment.

5 Quantities shown are retained (residual) asphalt.

Estimating – Hot Mix Asphalt Pavement and Asphalt Distribution Tables
Figure 520-2a

Asphalt Distribution (tons/mile) [1]																						
Asphalt Grade	Gal/ ton @ 60° F	Width (ft)	Rate of Application (Gal./cy)																			
			0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00
SC, MC, RC 70	253	10	1.16	2.32	3.48	4.64	5.80	6.96	8.12	9.28	10.46	11.59	12.79	13.91	15.07	16.23	17.39	18.55	19.71	20.87	22.03	23.19
		11	1.28	2.55	3.83	5.10	6.38	7.65	8.93	10.20	11.48	12.75	14.03	15.30	16.58	17.86	19.13	20.41	21.68	22.96	24.23	25.51
		12	1.39	2.78	4.17	5.57	6.96	8.35	9.74	11.13	12.52	13.91	15.30	16.70	18.09	19.48	20.87	22.26	23.65	25.04	26.43	27.83
SC,MC,RC 250	249	10	1.18	2.36	3.53	4.71	5.89	7.07	8.25	9.42	10.60	11.78	12.96	14.14	15.31	16.49	17.67	18.85	20.03	21.20	22.38	23.56
		11	1.30	2.59	3.89	5.18	6.48	7.78	9.07	10.37	11.66	12.96	14.25	15.55	16.85	18.14	19.44	20.73	22.03	23.33	24.62	25.92
		12	1.41	2.83	4.24	5.65	7.07	8.48	9.90	11.31	12.72	14.14	15.55	16.96	18.38	19.79	21.20	22.62	24.03	25.45	26.86	28.27
SC,MC,RC 800	245	10	1.20	2.39	3.59	4.79	5.99	7.18	8.38	9.58	10.78	11.97	13.17	14.37	15.56	16.76	17.96	19.16	20.35	21.55	22.75	23.95
		11	1.30	2.63	3.95	5.27	6.59	7.90	9.22	10.54	11.85	13.17	14.49	15.80	17.12	18.44	19.79	21.07	22.39	23.71	25.02	26.34
		12	1.44	2.87	4.31	5.75	7.18	8.62	10.06	11.49	12.93	14.37	15.80	17.24	18.68	20.11	21.55	22.99	24.42	25.86	27.30	28.73
SC,MC,RC 3000	241	10	1.22	2.44	3.66	4.87	6.09	7.31	8.53	9.75	10.97	12.19	13.41	14.62	15.84	17.06	18.28	19.50	20.72	21.94	23.15	24.37
		11	1.34	2.68	4.02	5.36	6.69	8.03	9.37	10.71	12.05	13.39	14.73	16.07	17.41	18.74	20.08	21.42	22.76	24.10	25.44	26.78
		12	1.46	2.92	4.38	5.84	7.30	8.76	10.22	11.68	13.15	14.61	16.07	17.53	18.99	20.45	21.91	23.37	24.83	26.29	27.75	29.21
Paving Asphalt 200-300 PEN.	239	10	1.23	2.45	3.68	4.91	6.14	7.36	8.59	9.82	11.05	12.27	13.50	14.73	15.96	17.18	18.41	19.64	20.86	22.09	23.32	24.55
		11	1.35	2.70	4.05	5.40	6.75	8.10	9.45	10.80	12.15	13.50	14.85	16.20	17.55	18.90	20.25	21.60	22.95	24.30	25.65	27.00
		12	1.47	2.95	4.42	5.89	7.36	8.84	10.31	11.78	13.26	14.73	16.20	17.67	19.15	20.62	22.09	23.56	25.04	26.51	27.98	29.46
Emulsified Asphalt	240	10	1.22	2.44	3.67	4.89	6.11	7.33	8.56	9.77	11.00	12.22	13.44	14.67	15.89	17.11	18.33	19.56	20.78	22.00	23.22	24.44
		11	1.34	2.67	4.03	5.38	6.72	8.07	9.41	10.76	12.10	13.45	14.79	16.13	17.48	18.82	20.17	21.51	22.86	24.20	25.54	26.89
		12	1.47	2.93	4.40	5.87	7.33	8.80	10.27	11.73	13.20	14.67	16.13	17.60	19.07	20.53	22.00	23.47	24.93	26.40	27.87	29.33

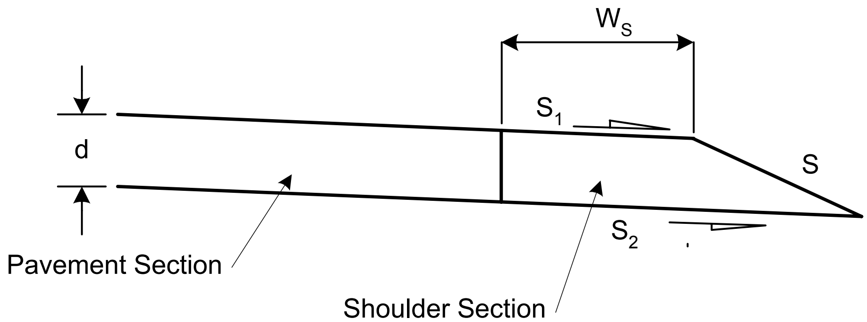
1 Quantities of asphalt shown are based on 60° F temperature. Recompute to the application temperature for the particular grade.

Estimating –Asphalt Distribution Tables
Figure 520-2b

Bituminous Surface Treatment [1]																	
Class of Mix	Type of Application	Average Application		Mineral Aggregate						Average Spread	Asphalt [2, 4, 5]						Basic [3]
				10 ft		11 ft		12 ft			10 ft		11 ft		12 ft		Asphalt Used
		lb/sy	cy/sy	T/mi	cy/mi	T/mi	cy/mi	T/mi	cy/mi	gal/sy	gal/mi	T/mi	gal/mi	T/mi	gal/mi	T/mi	
	Prime Coat									0.48	2787	11.2	3065	12.3	3344	13.4	MC-250
	Crushed Screenings 3/4" – 1/2"	35	0.0146	103	86	113	94	123	103								
	Tack Coat									0.43	2493	10.4	2743	11.4	2992	12.5	CRS-2
	Crushed Screenings 1/2" – 1/4"	28	0.0106	81	62	89	68	97	74								
	Crushed Screenings 1/4" – 0"	5	0.0017	15	10	16	11	18	12								
	Totals	68	0.0269	199	158	218	173	238	189	0.91	5280	21.6	5808	23.7	6336	25.9	
B	Seal Coat									0.50	2933	12.2	3227	13.4	3520	14.7	CRS-2
	Crushed Screenings 5/8" – 1/4"	33	0.0123	95	72	105	79	114	86								
	Crushed Screenings 1/4" – 0"	5	0.0017	15	10	16	11	18	12								
	Totals	38	0.0140	110	82	121	90	132	98	0.50	2933	12.2	3227	13.4	3520	14.7	
C	Seal Coat									0.45	2640	11.0	2904	12.1	3168	13.2	CRS-2
	Crushed Screenings 1/2" – 1/4"	28	0.0106	81	62	89	68	97	74								
	Crushed Screenings 1/4" – 0"	5	0.0017	15	10	16	11	18	12								
	Totals	33	0.0123	96	72	105	79	115	86	0.45	2640	11.0	2904	12.1	3168	13.2	
D	Seal Coat									0.43	2493	10.4	2743	11.4	2992	12.5	CRS-2
	Crushed Screenings 3/8" - #10	25	0.0088	73	51	81	57	88	62								
Preseal for B, C & D	Preseal									0.18	1027	4.3	1129	4.7	1232	5.1	CRS-2
	Crushed Screenings 1/4" – 0"	12	0.0040	34	23	37	26	40	28								

1 Quantities shown do not provide for widening, waste from stockpile, or thickened edges.
2 Quantities of asphalt shown are based on 60°F temperature. Recompute to the application temperature for the particular grade.
3 The column "Basic Asphalt Used" is shown for the purpose of conversion to proper weights for the asphalt being used and does not imply that the particular grade shown is required for the respective treatment.
4 For cutbacks, decrease asphalt by 25 percent.
5 For stress absorbing membrane (rubberized asphalt), increase asphalt by 25 percent.

Estimating – Bituminous Surface Treatment
Figure 520-3



W_S = Shoulder Width – (Varies 4 ft, 6 ft, 8 ft, 10 ft, 12 ft)
d = Depth of Section – (Varies 0.05 ft to 2 ft)
S = Side Slope (H:V) – (Varies 2:1, 3:1, 4:1, and 6:1)
S_1 = Top Shoulder Slope – (Varies –0.02 ft/ft or –0.05 ft/ft)
S_2 = Bottom Shoulder Slope – (Varies –0.02 ft/ft or –0.05 ft/ft)

Formula for Shoulder Section		
Tons/mile = (A)(K) K=(5280/27)(1.85 tons/cy) $A = \frac{[d + W_S(1/S - S_1)]^2 S}{2(1 - SS_2)} - \frac{W_S^2}{2}(1/S - S_1)$		
Case 1	$S_1 = S_2 = -0.02$ ft/ft	$A = \frac{[d + W_S(1/S - 0.02)]^2 S}{2(1 - 0.02S)} - \frac{W_S^2}{2}(1/S - 0.02)$
Case 2	$S_1 = -0.02$ ft/ft, $S_2 = -0.05$ ft/ft	$A = \frac{[d + W_S(1/S - 0.02)]^2 S}{2(1 - 0.05S)} - \frac{W_S^2}{2}(1/S - 0.02)$
Case 3	$S_1 = -0.05$ ft/ft, $S_2 = -0.02$ ft/ft	$A = \frac{[d + W_S(1/S - 0.05)]^2 S}{2(1 - 0.02S)} - \frac{W_S^2}{2}(1/S - 0.05)$ *
Case 4	$S_1 = S_2 = -0.05$ ft/ft	$A = \frac{[d + W_S(1/S - 0.05)]^2 S}{2(1 - 0.05S)} - \frac{W_S^2}{2}(1/S - 0.05)$
*Limit: Positive Values of A only when $d = W_S(0.03)$		

EXAMPLE: Shoulder Section

Given –		Shoulder Width 8 ft
	Top Course	0.25 ft
	Base Course	0.80 ft
	Total Depth	1.05 ft
	Side Slope	3:1
	Shoulder Slope	-0.05
	Subgrade Slope	-0.02

Depth 1.05 ft (Case 3) = 3070 tons/mile
Top Course 0.25 ft (Case 4) = <u>763</u> tons/mile
Base Course = 2307 tons/mile

Top Course = 763 tons/mile
Base Course = 2307 tons/mile

Estimating – Base and Surfacing Typical Section Formulae and Example
Figure 520-4

Shoulder Section												
Shldr. Width W_s(ft)	Side Slope S:1	Case	Quantity in tons per mile*									
			Surfacing Depth (ft)									
			0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50
4	2	1	73	148	226	304	385	468	553	639	728	818
		2	171	251	333	417	504	592	682	774	869	965
		3	N/A	N/A	131	205	281	360	440	522	605	691
		4	73	149	226	306	387	470	556	643	733	824
	3	1	74	150	230	313	398	486	577	671	768	868
		2	178	262	350	442	536	634	734	838	945	1056
		3	N/A	N/A	131	206	285	366	450	537	627	720
		4	74	151	231	315	402	492	585	681	780	883
	4	1	74	153	235	321	411	505	603	705	810	920
		2	185	275	370	469	572	681	793	910	1032	1158
		3	N/A	N/A	131	208	288	373	461	554	650	750
		4	75	154	237	326	418	516	617	724	834	950
	6	1	75	157	245	339	439	545	658	776	901	1032
		2	204	307	417	535	661	794	936	1085	1242	1406
		3	N/A	N/A	131	210	296	387	485	589	699	815
		4	76	160	252	351	459	574	696	827	965	1111
6	2	1	109	221	334	449	566	685	806	929	1053	1180
		2	325	444	565	688	812	939	1068	1199	1332	1467
		3	N/A	N/A	N/A	239	349	461	575	691	809	929
		4	110	221	335	450	568	687	809	933	1058	1186
	3	1	110	223	339	457	579	703	830	961	1094	1230
		2	338	462	590	722	856	994	1134	1278	1426	1576
		3	N/A	N/A	N/A	239	350	464	581	701	824	949
		4	110	223	340	460	583	709	838	970	1106	1245
	4	1	110	225	343	466	592	722	856	994	1136	1282
		2	352	483	619	760	905	1055	1209	1368	1531	1699
		3	N/A	N/A	N/A	239	351	467	587	711	839	971
		4	111	226	346	470	599	733	871	1013	1160	1311
	6	1	112	229	353	483	620	762	911	1066	1227	1394
		2	386	534	690	853	1025	1204	1391	1585	1788	1998
		3	N/A	N/A	N/A	239	353	474	600	733	871	1016
		4	112	233	360	496	640	791	950	1116	1291	1473
8	2	1	146	293	443	594	747	902	1059	1218	1379	1541
		2	526	683	843	1004	1167	1333	1500	1670	1841	2015
		3	N/A	N/A	N/A	N/A	376	522	670	820	972	1125
		4	146	293	443	595	749	904	1062	1222	1384	1548
	3	1	146	295	447	602	760	920	1084	1250	1419	1591
		2	546	711	879	1050	1224	1402	1583	1766	1954	2144
		3	N/A	N/A	N/A	N/A	376	523	673	825	981	1139
		4	146	296	448	604	763	926	1091	1260	1432	1607
	4	1	147	297	452	610	773	939	1109	1284	1462	1644
		2	568	741	919	1101	1288	1479	1675	1875	2080	2290
		3	N/A	N/A	N/A	N/A	376	524	675	831	990	1153
		4	147	298	454	615	780	950	1124	1302	1486	1673
	6	1	148	302	462	628	801	979	1164	1355	1552	1755
		2	622	816	1017	1226	1443	1668	1900	2140	2388	2643
		3	N/A	N/A	N/A	N/A	376	525	681	842	1009	1183
		4	149	305	469	641	820	1008	1203	1406	1616	1835

Estimating - Base and Surfacing Quantities

Figure 520-5a

Shoulder Section												
Shldr. Width W_s(ft)	Side Slope S:1	Case	Quantity in tons per mile*									
			Surfacing Depth (ft)									
			0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00
4	2	1	910	1004	1100	1198	1297	1399	1502	1608	1715	1824
		2	1063	1163	1266	1370	1476	1585	1695	1807	1922	2038
		3	779	868	960	1053	1148	1245	1344	1445	1548	1652
		4	918	1013	1110	1210	1311	1415	1520	1628	1738	1849
	3	1	971	1076	1185	1296	1410	1527	1647	1770	1896	2024
		2	1169	1286	1406	1529	1655	1785	1918	2053	2193	2335
		3	816	914	1016	1120	1228	1338	1451	1567	1686	1807
		4	989	1098	1210	1326	1444	1566	1691	1820	1951	2086
	4	1	1034	1151	1273	1398	1528	1661	1798	1939	2085	2234
		2	1289	1424	1564	1708	1857	2010	2168	2330	2497	2668
		3	855	963	1075	1191	1311	1435	1562	1694	1830	1969
		4	1070	1194	1323	1456	1594	1737	1884	2035	2191	2352
	6	1	1169	1312	1462	1617	1779	1947	2121	2301	2488	2680
		2	1579	1759	1947	2142	2346	2557	2776	3002	3237	3479
		3	937	1066	1200	1341	1488	1641	1800	1966	2138	2315
		4	1265	1426	1596	1773	1957	2150	2350	2558	2774	2998
6	2	1	1308	1438	1570	1704	1840	1978	2117	2259	2402	2548
		2	1603	1742	1883	2026	2171	2318	2467	2618	2771	2926
		3	1050	1174	1299	1426	1555	1686	1819	1954	2090	2229
		4	1315	1447	1581	1716	1854	1994	2135	2279	2425	2573
	3	1	1369	1510	1655	1802	1953	2106	2262	2421	2583	2748
		2	1729	1886	2046	2209	2376	2545	2718	2894	3073	3255
		3	1078	1209	1343	1480	1620	1763	1909	2058	2209	2363
		4	1387	1532	1681	1832	1987	2145	2306	2471	2638	2809
	4	1	1432	1586	1743	1905	2070	2240	2413	2591	2772	2957
		2	1871	2048	2229	2415	2606	2801	3000	3204	3412	3625
		3	1106	1246	1389	1537	1688	1843	2003	2166	2333	2504
		4	1467	1628	1793	1963	2137	2315	2499	2686	2878	3075
	6	1	1567	1746	1932	2124	2322	2526	2736	2953	3175	3404
		2	2215	2441	2674	2916	3164	3421	3685	3957	4237	4525
		3	1167	1325	1488	1658	1833	2015	2203	2398	2598	2805
		4	1663	1861	2066	2279	2500	2729	2965	3209	3461	3721
8	2	1	1706	1872	2040	2211	2383	2557	2732	2910	3090	3271
		2	2190	2367	2547	2728	2912	3097	3285	3475	3666	3860
		3	1281	1438	1597	1758	1921	2086	2253	2422	2592	2765
		4	1713	1881	2051	2223	2397	2573	2751	2930	3112	3296
	3	1	1766	1944	2125	2309	2495	2685	2877	3072	3271	3472
		2	2338	2534	2734	2937	3144	3353	3566	3782	4001	4223
		3	1300	1464	1631	1801	1974	2149	2328	2509	2693	2880
		4	1785	1966	2151	2339	2530	2724	2921	3122	3326	3533
	4	1	1830	2020	2214	2411	2613	2819	3028	3242	3459	3681
		2	2504	2722	2945	3172	3404	3641	3882	4128	4378	4632
		3	1320	1491	1666	1845	2028	2215	2405	2600	2799	3001
		4	1865	2062	2263	2469	2679	2894	3114	3337	3566	3799
	6	1	1965	2181	2402	2630	2864	3105	3351	3604	3863	4128
		2	2907	3178	3457	3743	4038	4340	4650	4967	5292	5626
		3	1363	1549	1741	1940	2144	2355	2572	2795	3024	3259
		4	2061	2295	2536	2786	3043	3308	3580	3861	4149	4445

Estimating - Base and Surfacing Quantities
Figure 520-5b

Shoulder Section												
Shldr. Width W_S(ft)	Side Slope S:1	Case	Quantity in tons per mile*									
			Surfacing Depth (ft)									
			0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50
10	2	1	182	366	551	739	928	1119	1312	1507	1704	1903
		2	773	969	1167	1367	1569	1773	1979	2187	2397	2609
		3	N/A	N/A	N/A	N/A	N/A	543	724	908	1094	1281
		4	182	366	552	740	930	1122	1315	1511	1709	1909
	3	1	182	368	556	747	941	1137	1337	1539	1745	1953
		2	802	1007	1215	1426	1640	1858	2079	2303	2530	2760
		3	N/A	N/A	N/A	N/A	N/A	543	725	910	1098	1289
		4	182	368	557	749	944	1143	1344	1549	1757	1968
	4	1	183	370	560	755	954	1156	1363	1573	1787	2006
		2	834	1049	1268	1492	1721	1954	2191	2433	2679	2930
		3	N/A	N/A	N/A	N/A	N/A	543	726	912	1103	1298
		4	183	371	563	760	961	1167	1377	1592	1811	2035
	6	1	184	374	570	773	982	1196	1417	1644	1878	2117
		2	913	1153	1399	1654	1916	2186	2464	2750	3043	3344
		3	N/A	N/A	N/A	N/A	N/A	543	727	917	1113	1316
		4	185	377	578	786	1001	1225	1456	1695	1942	2197
12	2	1	218	438	660	883	1109	1336	1566	1797	2030	2265
		2	1066	1301	1537	1776	2016	2259	2504	2750	2999	3249
		3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	956	1175	1397
		4	218	438	660	884	1110	1339	1569	1801	2035	2271
	3	1	219	440	664	891	1121	1354	1590	1829	2071	2315
		2	1106	1351	1599	1850	2104	2362	2623	2887	3154	3424
		3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	956	1177	1401
		4	219	441	666	894	1125	1360	1598	1839	2083	2330
	4	1	219	442	669	900	1134	1373	1616	1862	2113	2367
		2	1151	1407	1668	1933	2203	2478	2757	3040	3328	3621
		3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	956	1179	1405
		4	219	443	672	904	1142	1384	1630	1881	2137	2397
	6	1	220	446	679	918	1162	1413	1671	1934	2203	2479
		2	1259	1544	1836	2136	2444	2759	3083	3414	3752	4099
		3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	957	1182	1413
		4	221	450	686	930	1182	1442	1709	1985	2268	2558
Pavement Section												
Width W_P (ft)			0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50
11			199	398	597	796	995	1194	1393	1592	1791	1990
12			217	434	651	868	1085	1302	1519	1737	1954	2171
22			398	796	1194	1592	1990	2388	2786	3184	3582	3980
24			434	868	1302	1737	2171	2605	3039	3473	3907	4341
*Tabulated quantities are based on compacted weight of 1.85 tons/yd^3												

Estimating - Base and Surfacing Quantities

Figure 520-5c

Shoulder Section												
Shldr. Width W_S(ft)	Side Slope S:1	Case	Quantity in tons per mile*									
			Surfacing Depth (ft)									
			0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00
10	2	1	2104	2306	2511	2717	2925	3135	3347	3561	3777	3995
		2	2823	3039	3257	3477	3699	3923	4149	4378	4608	4840
		3	1471	1662	1855	2050	2247	2446	2646	2849	3053	3260
		4	2111	2315	2521	2729	2939	3151	3366	3582	3800	4020
	3	1	2164	2378	2595	2815	3038	3264	3492	3724	3958	4195
		2	2994	3230	3470	3714	3960	4209	4462	4718	4977	5239
		3	1483	1680	1880	2082	2288	2496	2707	2921	3138	3358
		4	2183	2401	2621	2845	3072	3303	3536	3773	4013	4256
	4	1	2228	2454	2684	2918	3156	3398	3643	3893	4147	4404
		2	3186	3446	3710	3980	4253	4531	4814	5101	5393	5689
		3	1496	1699	1905	2116	2330	2548	2770	2996	3227	3460
		4	2263	2496	2734	2976	3222	3473	3729	3989	4253	4522
	6	1	2363	2615	2873	3137	3407	3684	3966	4255	4550	4851
		2	3653	3969	4294	4626	4965	5313	5668	6031	6402	6781
		3	1524	1739	1960	2187	2420	2660	2906	3157	3415	3679
		4	2459	2729	3007	3292	3585	3887	4195	4512	4836	5168
12	2	1	2502	2740	2981	3224	3468	3714	3962	4212	4464	4718
		2	3502	3757	4013	4272	4533	4795	5060	5327	5596	5866
		3	1620	1845	2072	2301	2532	2765	2999	3236	3474	3714
		4	2509	2750	2992	3236	3482	3730	3981	4233	4487	4743
	3	1	2562	2813	3066	3322	3581	3843	4107	4375	4645	4919
		2	3698	3975	4255	4538	4824	5114	5406	5702	6001	6304
		3	1627	1857	2089	2324	2562	2803	3047	3294	3544	3796
		4	2581	2835	3092	3352	3615	3882	4151	4424	4700	4980
	4	1	2626	2888	3154	3424	3698	3976	4258	4544	4834	5128
		2	3918	4220	4526	4837	5152	5472	5796	6125	6458	6796
		3	1635	1869	2107	2348	2594	2844	3098	3355	3617	3882
		4	2661	2930	3204	3482	3765	4052	4344	4640	4941	5246
	6	1	2761	3049	3343	3643	3950	4262	4581	4906	5237	5575
		2	4453	4815	5185	5562	5948	6341	6742	7150	7566	7991
		3	1651	1894	2144	2400	2662	2930	3205	3485	3772	4065
		4	2857	3163	3477	3799	4128	4465	4810	5163	5524	5892
Pavement Section												
Width W_P (ft)			0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00
11			2189	2388	2587	2786	2985	3184	3383	3582	3781	3980
12			2388	2605	2822	3039	3256	3473	3690	3907	4124	4341
22			4378	4775	5173	5571	5969	6367	6765	7163	7561	7959
24			4775	5210	5644	6078	6512	6946	7380	7814	8249	8683
*Tabulated quantities are based on compacted weight of 1.85 tons/yd^3												

Estimating - Base and Surfacing Quantities

Figure 520-5d

Shoulder Section												
Shldr. Width W_S(ft)	Side Slope S:1	Case	Quantity in tons per mile*									
			Surfacing Depth (ft)									
			1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40	1.45	1.50
4	2	1	1935	2048	2163	2279	2398	2518	2640	2765	2891	3019
		2	2157	2277	2399	2524	2650	2779	2909	3042	3176	3312
		3	1759	1867	1977	2089	2203	2319	2437	2557	2678	2802
		4	1963	2078	2196	2315	2437	2561	2686	2814	2943	3075
	3	1	2156	2290	2428	2568	2711	2857	3006	3157	3312	3470
		2	2480	2629	2781	2936	3094	3255	3420	3588	3759	3933
		3	1932	2059	2190	2323	2459	2598	2740	2885	3033	3183
		4	2223	2364	2509	2656	2806	2960	3117	3277	3441	3607
	4	1	2387	2543	2704	2869	3038	3210	3387	3567	3752	3940
		2	2844	3025	3210	3399	3593	3792	3995	4202	4415	4631
		3	2113	2260	2412	2567	2726	2890	3057	3228	3403	3582
		4	2517	2686	2860	3039	3222	3410	3602	3799	4000	4206
	6	1	2879	3084	3295	3513	3736	3966	4201	4443	4691	4946
		2	3729	3986	4252	4525	4806	5094	5391	5695	6007	6327
		3	2499	2689	2886	3088	3297	3512	3733	3960	4193	4433
		4	3229	3468	3715	3969	4232	4502	4779	5065	5358	5659
6	2	1	2695	2844	2995	3147	3302	3459	3617	3778	3940	4104
		2	3083	3242	3403	3566	3731	3898	4067	4238	4411	4586
		3	2369	2511	2655	2802	2949	3099	3251	3404	3560	3717
		4	2722	2874	3028	3184	3341	3501	3663	3827	3993	4160
	3	1	2916	3086	3260	3436	3615	3798	3983	4170	4361	4555
		2	3440	3629	3821	4016	4214	4416	4620	4828	5039	5253
		3	2521	2681	2844	3010	3179	3351	3525	3703	3883	4067
		4	2983	3160	3341	3524	3711	3901	4094	4290	4490	4692
	4	1	3146	3339	3536	3737	3942	4151	4364	4580	4801	5026
		2	3843	4065	4291	4523	4758	4998	5243	5492	5746	6004
		3	2679	2858	3041	3228	3418	3613	3812	4014	4221	4431
		4	3276	3482	3692	3907	4127	4350	4579	4812	5049	5291
	6	1	3639	3880	4127	4381	4640	4906	5178	5456	5741	6031
		2	4820	5123	5434	5753	6079	6413	6755	7105	7462	7827
		3	3017	3236	3461	3693	3930	4174	4423	4679	4941	5210
		4	3989	4264	4547	4837	5136	5442	5756	6078	6407	6745
8	2	1	3454	3640	3827	4016	4207	4399	4594	4791	4989	5189
		2	4055	4253	4452	4654	4858	5063	5271	5480	5692	5906
		3	2939	3115	3293	3473	3655	3839	4024	4212	4401	4592
		4	3482	3670	3860	4052	4246	4442	4640	4840	5042	5246
	3	1	3675	3882	4092	4304	4520	4738	4959	5183	5410	5640
		2	4449	4677	4909	5144	5382	5624	5869	6116	6367	6622
		3	3070	3263	3459	3658	3859	4064	4271	4481	4695	4911
		4	3743	3956	4173	4392	4615	4841	5071	5303	5539	5778
	4	1	3906	4135	4368	4606	4847	5092	5341	5593	5850	6111
		2	4891	5155	5423	5696	5973	6255	6541	6832	7127	7427
		3	3208	3418	3632	3851	4073	4299	4529	4763	5001	5243
		4	4036	4278	4524	4775	5031	5291	5556	5825	6098	6376
	6	1	4399	4676	4959	5249	5545	5847	6155	6469	6790	7116
		2	5966	6315	6671	7035	7407	7787	8174	8569	8972	9383
		3	3501	3749	4002	4262	4529	4801	5079	5364	5655	5952
		4	4748	5060	5379	5706	6040	6383	6733	7091	7456	7830

Estimating - Base and Surfacing Quantities
Figure 520-5e

Shoulder Section												
Shldr. Width W_S(ft)	Side Slope S:1	Case	Quantity in tons per mile*									
			Surfacing Depth (ft)									
			1.55	1.60	1.65	1.70	1.75	1.80	1.85	1.90	1.95	2.00
4	2	1	3148	3280	3414	3549	3687	3826	3967	4110	4255	4402
		2	3451	3591	3734	3878	4025	4173	4324	4477	4631	4788
		3	2927	3054	3183	3314	3447	3582	3718	3857	3997	4139
		4	3209	3344	3482	3622	3763	3907	4053	4201	4350	4502
	3	1	3630	3793	3959	4129	4300	4475	4653	4834	5017	5203
		2	4110	4291	4475	4662	4852	5045	5242	5441	5644	5850
		3	3337	3493	3652	3814	3979	4147	4318	4492	4668	4848
		4	3777	3950	4126	4305	4488	4673	4862	5054	5250	5448
	4	1	4133	4329	4529	4733	4941	5153	5369	5589	5812	6040
		2	4852	5078	5308	5543	5782	6026	6274	6527	6784	7046
		3	3764	3951	4142	4337	4535	4738	4944	5155	5369	5587
		4	4416	4631	4850	5074	5302	5535	5773	6015	6261	6512
	6	1	5206	5473	5745	6024	6310	6601	6898	7202	7512	7828
		2	6654	6989	7332	7683	8041	8407	8781	9163	9552	9950
		3	4678	4930	5188	5452	5722	5999	6282	6570	6865	7166
		4	5968	6285	6609	6941	7281	7628	7984	8347	8718	9096
6	2	1	4270	4438	4608	4779	4953	5128	5306	5485	5666	5849
		2	4763	4942	5123	5306	5491	5678	5868	6059	6252	6447
		3	3876	4038	4201	4365	4532	4701	4871	5044	5218	5394
		4	4330	4502	4676	4852	5030	5210	5391	5575	5761	5949
	3	1	4752	4951	5153	5359	5567	5778	5992	6208	6428	6651
		2	5471	5691	5915	6142	6372	6605	6842	7082	7325	7571
		3	4253	4442	4634	4829	5026	5227	5430	5637	5846	6058
		4	4898	5107	5320	5535	5754	5976	6201	6429	6660	6895
	4	1	5254	5486	5723	5963	6207	6455	6707	6963	7223	7487
		2	6267	6534	6806	7082	7363	7648	7938	8233	8532	8835
		3	4645	4864	5086	5312	5542	5776	6014	6256	6501	6751
		4	5537	5788	6044	6304	6569	6838	7111	7389	7672	7959
	6	1	6328	6630	6939	7254	7576	7903	8237	8577	8923	9275
		2	8200	8581	8969	9365	9769	10181	10600	11028	11463	11905
		3	5484	5765	6051	6344	6643	6949	7260	7578	7901	8231
		4	7090	7442	7803	8171	8547	8931	9322	9721	10128	10543
8	2	1	5391	5595	5801	6009	6219	6431	6644	6859	7077	7296
		2	6121	6339	6559	6780	7004	7230	7457	7687	7919	8153
		3	4785	4980	5177	5376	5577	5779	5984	6190	6398	6608
		4	5452	5660	5870	6082	6296	6512	6730	6950	7172	7396
	3	1	5873	6109	6347	6589	6833	7080	7330	7583	7839	8098
		2	6879	7140	7403	7670	7940	8214	8490	8770	9053	9339
		3	5129	5351	5576	5803	6034	6267	6503	6743	6985	7229
		4	6020	6265	6514	6765	7020	7278	7539	7804	8071	8342
	4	1	6376	6644	6917	7193	7473	7758	8046	8338	8634	8934
		2	7731	8040	8354	8671	8994	9321	9652	9988	10329	10674
		3	5488	5738	5992	6249	6511	6776	7046	7319	7596	7877
		4	6659	6946	7238	7534	7835	8140	8450	8764	9083	9406
	6	1	7449	7788	8133	8485	8842	9206	9575	9951	10333	10722
		2	9801	10227	10661	11103	11552	12009	12474	12947	13427	13915
		3	6255	6565	6880	7202	7530	7864	8204	8550	8903	9262
		4	8211	8600	8997	9401	9813	10233	10661	11096	11539	11990

Estimating - Base and Surfacing Quantities

Figure 520-5f

Shoulder Section												
Shldr. Width W_S(ft)	Side Slope S:1	Case	Quantity in tons per mile*									
			Surfacing Depth (ft)									
			1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40	1.45	1.50
10	2	1	4214	4436	4659	4884	5111	5340	5571	5804	6038	6275
		2	5074	5310	5548	5788	6031	6275	6521	6769	7019	7272
		3	3468	3678	3890	4104	4320	4537	4757	4978	5201	5427
		4	4242	4466	4692	4920	5150	5382	5617	5853	6091	6331
	3	1	4435	4678	4924	5173	5424	5679	5936	6196	6460	6726
		2	5505	5774	6045	6320	6599	6880	7165	7453	7744	8038
		3	3581	3806	4035	4266	4501	4738	4978	5221	5467	5715
		4	4503	4752	5005	5261	5520	5782	6048	6316	6588	6863
	4	1	4666	4931	5201	5474	5751	6032	6317	6606	6899	7196
		2	5990	6295	6605	6919	7238	7561	7889	8221	8558	8900
		3	3698	3940	4186	4436	4689	4947	5208	5474	5743	6017
		4	4796	5074	5357	5644	5935	6232	6532	6838	7147	7462
	6	1	5158	5472	5792	6117	6449	6787	7132	7482	7839	8202
		2	7167	7561	7963	8373	8790	9215	9648	10088	10537	10993
		3	3950	4226	4509	4798	5093	5394	5701	6015	6334	6660
		4	5508	5856	6211	6574	6945	7323	7710	8104	8506	8915
12	2	1	4974	5231	5491	5752	6015	6281	6548	6816	7087	7360
		2	6139	6414	6691	6969	7250	7533	7818	8104	8393	8684
		3	3956	4200	4446	4694	4944	5195	5449	5704	5961	6220
		4	5002	5262	5524	5788	6055	6323	6593	6866	7140	7416
	3	1	5195	5474	5756	6041	6329	6619	6913	7209	7509	7811
		2	6609	6918	7230	7545	7863	8184	8509	8837	9168	9502
		3	4052	4310	4571	4836	5103	5372	5645	5921	6199	6481
		4	5262	5548	5837	6129	6424	6723	7024	7329	7637	7948
	4	1	5425	5727	6033	6342	6656	6973	7294	7619	7948	8282
		2	7138	7485	7836	8192	8553	8917	9287	9661	10039	10422
		3	4151	4425	4702	4983	5268	5557	5850	6147	6448	6753
		4	5556	5870	6189	6512	6840	7172	7509	7851	8197	8547
	6	1	5918	6268	6624	6986	7354	7728	8109	8495	8888	9287
		2	8422	8862	9309	9764	10227	10698	11176	11662	12156	12657
		3	4364	4669	4981	5298	5622	5952	6288	6630	6979	7333
		4	6268	6652	7043	7442	7849	8264	8687	9117	9555	10001

Pavement Section										
Width W_P (ft)	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40	1.45	1.50
11	4179	4378	4576	4775	4974	5173	5372	5571	5770	5969
12	4558	4775	4993	5210	5427	5644	5861	6078	6295	6512
22	8357	8755	9153	9551	9949	10347	10745	11143	11541	11939
24	9117	9551	9985	10419	10853	11287	11722	12156	12590	13024

*Tabulated quantities are based on compacted weight of 1.85 tons/yd^3

Estimating - Base and Surfacing Quantities

Figure 520-5g

Shoulder Section												
Shldr. Width W_S(ft)	Side Slope S:1	Case	Quantity in tons per mile*									
			Surfacing Depth (ft)									
			1.55	1.60	1.65	1.70	1.75	1.80	1.85	1.90	1.95	2.00
10	2	1	6513	6753	6995	7239	7485	7733	7983	8234	8488	8743
		2	7526	7782	8041	8301	8563	8827	9094	9362	9632	9905
		3	5654	5883	6113	6346	6581	6817	7056	7296	7538	7782
		4	6573	6818	7064	7312	7562	7814	8069	8325	8583	8843
	3	1	6995	7266	7541	7819	8099	8382	8669	8958	9250	9545
		2	8335	8636	8940	9247	9557	9870	10187	10506	10829	11156
		3	5967	6221	6479	6739	7002	7268	7537	7809	8084	8361
		4	7141	7423	7707	7995	8286	8581	8878	9179	9482	9789
	4	1	7497	7802	8111	8423	8740	9060	9385	9713	10045	10381
		2	9246	9596	9951	10311	10675	11043	11416	11794	12176	12563
		3	6294	6575	6860	7149	7442	7739	8040	8344	8653	8966
		4	7780	8104	8432	8764	9101	9442	9788	10139	10494	10853
	6	1	8571	8946	9327	9715	10108	10508	10914	11326	11744	12169
		2	11457	11928	12408	12895	13390	13892	14403	14921	15447	15980
		3	6992	7330	7674	8025	8382	8744	9113	9488	9870	10257
		4	9333	9758	10191	10631	11079	11536	11999	12471	12950	13437
12	2	1	7634	7911	8189	8469	8751	9035	9321	9609	9899	10190
		2	8977	9272	9569	9868	10168	10471	10776	11083	11392	11703
		3	6481	6744	7009	7276	7544	7814	8087	8361	8637	8915
		4	7695	7975	8258	8542	8828	9117	9407	9700	9994	10291
	3	1	8116	8424	8735	9049	9365	9685	10007	10333	10661	10992
		2	9840	10180	10524	10871	11221	11575	11931	12291	12654	13020
		3	6765	7052	7342	7635	7931	8230	8532	8836	9144	9454
		4	8263	8581	8901	9225	9553	9883	10216	10553	10893	11236
	4	1	8619	8960	9304	9653	10006	10363	10723	11088	11456	11829
		2	10810	11202	11599	12000	12405	12816	13230	13650	14073	14502
		3	7061	7374	7691	8011	8335	8664	8996	9332	9672	10017
		4	8902	9262	9626	9994	10367	10745	11127	11514	11905	12300
	6	1	9692	10103	10521	10945	11374	11810	12253	12701	13155	13616
		2	13167	13684	14209	14741	15282	15830	16386	16949	17521	18100
		3	7694	8061	8434	8813	9199	9590	9988	10392	10802	11218
		4	10454	10915	11384	11861	12346	12838	13338	13846	14361	14885
Pavement Section												
Width W_P (ft)			1.55	1.60	1.65	1.70	1.75	1.80	1.85	1.90	1.95	2.00
11			6168	6367	6566	6765	6964	7163	7362	7561	7760	7959
12			6729	6946	7163	7380	7597	7814	8031	8249	8466	8683
22			12337	12735	13133	13530	13928	14326	14724	14122	15520	15918
24			13458	13892	14326	14761	15195	15629	16063	16497	16931	17365
*Tabulated quantities are based on compacted weight of 1.85 tons/yd^3												

Estimating - Base and Surfacing Quantities

Figure 520-5h

Chapter 620 Geometric Plan Elements

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
641	Open highway and ramp lane widths on turning roadways for full design level
642	Superelevation rate and transitions
650	Sight distance
910	Requirements for islands
940	Ramp lane and shoulder requirements

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, USDOT, FHWA; including the *Washington State Modifications to the MUTCD*, WSDOT (MUTCD) http://www.wsdot.wa.gov/biz/trafficoperations/mutcd.htm

Right of Way Manual M 26-01, WSDOT

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

A Policy on Geometric Design of Highways and Streets (Green Book), 2001, AASHTO

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 traveled way for through traffic and the nearest edge of traveled way of a frontage road or collector/distributor 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 620-2a through 2c show desirable and undesirable alignment examples for use with the following considerations:

(a) Make the highway alignment as direct as practical 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 642 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 500 ft.

(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 drivers.

(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. Median barriers, bridges, walls, cut slopes, wooded areas, buildings, and guardrails are examples of sight obstructions. 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 642.
- Coordinate vertical and horizontal alignment. (see Chapter 630.)

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 horizontal curvature rate increasing from tangent to the central curve and decreasing from curve to tangent. Spirals do not pose an operational concern and may remain in place. See the “Green Book” for information on spirals.

(3) Horizontal Curve Length

A curve is not required for small deflection angles. Figure 620-1 gives the maximum allowable angle without a curve. See Chapter 910 for guidance on angle points or short radii curves in the vicinity of intersections at grade.

Design Speed (mph)	Maximum Angle Without Curve
25	2º17’
30	1º55’
35	1º38’
40	1º26’
45	1º16’
50	1º09’
55	1º03’
60	0º57’
65	0º53’
70	0º49’
75	0º46’
80	0º43’

Maximum Angle Without Curve
Figure 620-1

To avoid the appearance of a kink in the road, the desirable length of curve for deflection angles larger than given in Figure 620-1 is at least 500 ft long.

620.05 Distribution Facilities

(1) General

In addition to the main 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
- On and off connections
- Parallel arterial routes with connections between them and the main highway
- Loop highways around large metropolitan areas

A city or county may be asked to accept a proposed distribution facility as a city street or county road. Plan and design these facilities according to the applicable design values as city streets or county roads. (See Chapter 440.)

(2) Frontage Roads

Frontage roads constructed as part of highway development may serve any of the following purposes:

- To reestablish continuity of an existing road severed by the highway.
- To provide service connections to adjacent property that would otherwise be isolated as a result of construction of the highway.
- To control access to the highway.
- To maintain circulation of traffic on each side of the highway.
- To segregate local traffic from the higher speed through traffic and intercept driveways of residences and commercial establishments along the highway.
- To relieve congestion on the arterial highway during periods of high use or in emergency situations.

Frontage roads are generally not permanent state facilities. They are usually turned back to the local jurisdiction. Plan and design frontage roads as city streets or county roads. (See Chapter 440.) Initiate coordination with the local agency that will be the recipient of the facility early in the planning process, and carry through design and construction. See Chapter 1430 for additional guidance on frontage roads and turnbacks.

Outer separations function as buffers between the through traffic on the highway and the local traffic on the frontage road. The width is governed by requirements for grading, signing, barriers, aesthetics, headlight glare, and ramps. Where possible, make the separation wide enough to allow for development on both sides of the frontage road. Wider separations also move the intersection with the frontage road and a cross road farther from the intersection with the through roadway. It also can reduce the amount of limited access control rights to be acquired. (See Chapter 1430.)

Where two-way frontage roads are provided, a driver on the highway must contend with approaching traffic on the right (opposing frontage road traffic) as well as opposing traffic on the left. Make the outer separation wide enough to minimize the effects of approaching traffic, particularly the headlight glare. See Chapter 700 for information on headlight glare considerations. With one-way same-direction frontage roads, the outer separation need not be as wide as with two-way frontage roads.

Wide separations lend themselves to landscape treatment and can enhance the appearance of both the highway and the adjoining property.

A substantial width of outer separation is particularly advantageous at intersections with cross streets. The wider separation reduces conflicts with pedestrians and bicycles.

Where ramp connections are provided between the through roadway and the frontage road, the minimum outer separation width will depend on design requirements for the ramp termini.

620.06 Number of Lanes and Arrangement

(1) General

The basic number of lanes is designated and maintained over a length of highway. The total number of lanes is the basic number of lanes plus any auxiliary lanes required to meet:

- Level of service (volume-capacity).
- Lane balance.
- Flexibility of operation.

(2) Basic Number of Lanes

Keep the basic number of lanes constant over a highway route, or a significant portion thereof, regardless of changes in traffic volume. See Chapter 440 for the minimum number of lanes for each functional class of highway.

Change the basic number of lanes only for general changes in traffic volume over a substantial length of the route. The recommended location for a reduction in the basic number of lanes is on a tangent section between interchanges or intersections.

To accommodate high traffic volumes for short distances, such as between adjacent interchanges, use auxiliary lanes. When consecutive sections between interchanges require auxiliary lanes, consider increasing the basic number of lanes through the entire length.

(3) Auxiliary Lanes

Auxiliary lanes are added to the basic number of lanes to allow additional traffic movements on short segments. These added lanes are based primarily on volume-to-capacity relationships (Chapter 610).

To ensure efficient operation of auxiliary lanes see the following:

910	Left and right turn lanes and storage for turning
940	Weaving and auxiliary lanes associated with interchanges
1010	Truck climbing and passing lanes

620.07 Pavement Transitions

(1) Lane Transitions

(a) **For lane width changes** that create an angle point in an adjacent lane, the maximum angle is given in Figure 620-1. When a lane width change does not create an angle point in an adjacent lane, a 25:1 taper is sufficient.

(b) To **reduce the number of lanes**, a transition is required. The following guidelines apply:

- Locate transitions where decision sight distance exists, preferably on a tangent section and on the approach side of any crest vertical curve (except the end of climbing lanes which are transitioned in accordance with Chapter 1010).
- Supplement the transition with traffic control devices.
- Reduce the number of lanes by dropping only one at a time from the right side in the direction of travel. (When dropping a lane on the left side, an approved deviation is required.) See the MUTCD when more than one lane in a single direction must be dropped.

- Use the following formula to determine the minimum length of the lane transition for high speed conditions (45 mph or more):

  $L = VT$

  Where:

  L = length of transition (ft)
  V = design speed (mph)
  T = tangential offset width (ft)

- Use the following formula to determine the minimum length of the lane transition for low speed conditions (less than 45 mph):

  $$L = \frac{TV^2}{60}$$

  Where:

  L = length of transition (ft)
  V = design speed (mph)
  T = tangential offset width (ft)

(c) **To increase the number of lanes**, a tangential rate of change in the range of 1:4 to 1:15 is sufficient. Aesthetics are the main consideration.

(d) **For turning roadway** widening width transitions, see Chapter 641.

(2) Median Width Transitions

Whenever two abutting sections have different median widths, use long, smooth transitions (L = VT or flatter). When horizontal curves are present, this can be accomplished by providing the transition throughout the length of the curve. When required on a tangent section, the transition may be applied about the center line or on either side of the median based on whether or not the abutting existing section is programmed for the wider median in the future. To satisfy aesthetic requirements, make the transition length as long as feasible.

620.08 Procedures

When the project will realign the roadway, develop horizontal alignment plans for inclusion in the PS&E. Show the following as needed to maintain clarity and provide necessary information:

- Horizontal alignment details (tangent bearing, curve radius, and superelevation rate)
- Stationing
- Number of lanes
- Intersections, road approaches, railroad crossings, and interchanges (Chapters 910, 920, 930, and 940)
- Existing roadways and features affecting or affected by the project

See the *Plans Preparation Manual* for additional plan requirements.

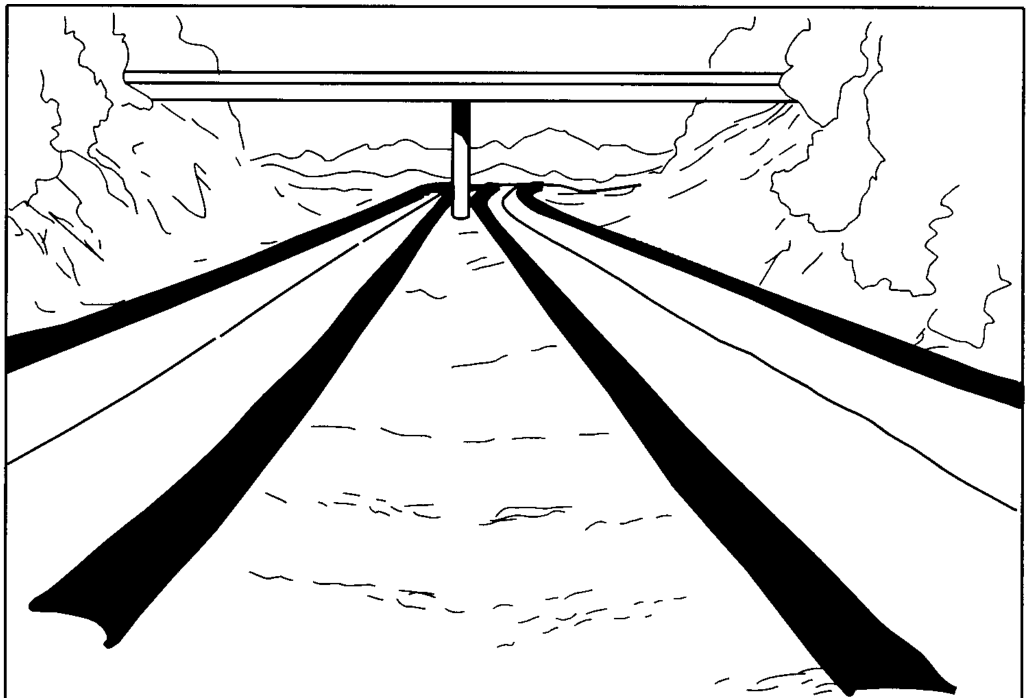
Justify any realignment of the roadway. Include the reasons for the realignment, profile considerations, alternatives considered, and the reasons the selected alignment was chosen.

When the project will change the number of lanes, include a capacity analysis supporting the number selected (Chapter 610) with the justification for the number of lanes.

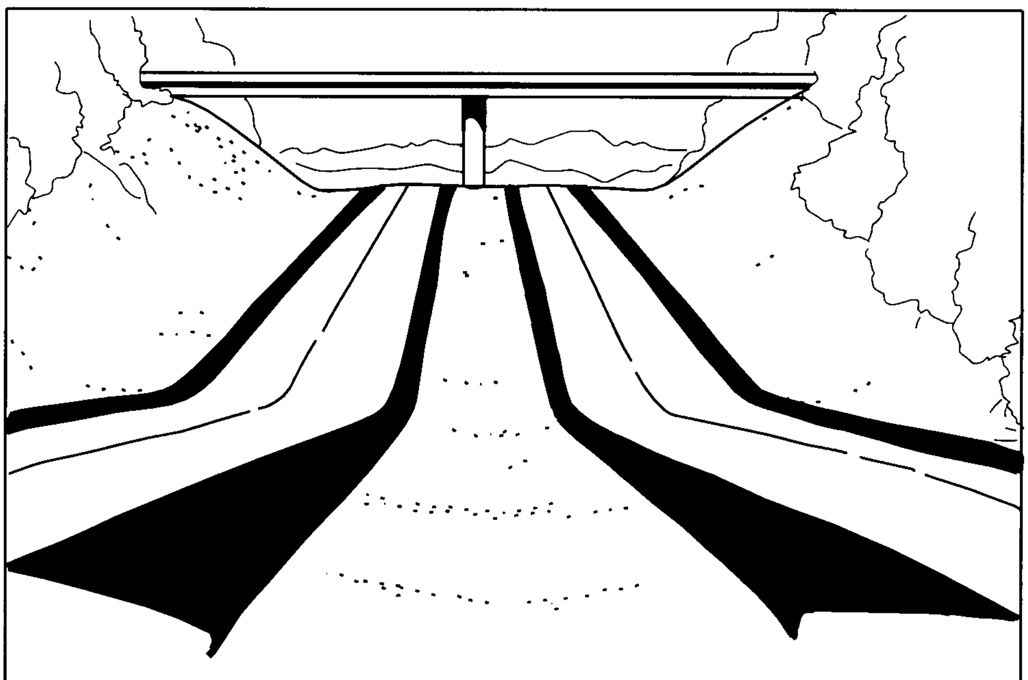
Include with the justification for a frontage road any traffic analyses performed, the social, environmental, and economic considerations, the options considered, and the reasons for the final decision.

620.09 Documentation

A list of the documents that are to be preserved [in the Design Documentation Package (DDP) or the Project File (PF)] is on the following web site: http://www.wsdot.wa.gov/eesc/design/projectdev/



Desirable - Vertical Curves Lengthened



Undesirable - Minimum Vertical Curves Used

Alignment Examples
Figure 620-2a

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. (See 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. See Chapter 440 for guidance on geometric design data when a state highway within an incorporated city or town is a portion of a city street.

See the following chapters for additional information:

Chapter	Subject
430	roadway widths and cross slopes for modified design level
440	minimum lane and shoulder widths for full design level
440	shoulder widths at curbs
510	geotechnical investigation
520	pavement type
641	turning roadway width
642	superelevation
910	requirements for islands
940	lane and shoulder widths for ramps

640.02 References

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

Plans Preparation Manual, M 22-31, WSDOT

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.

A Policy on Geometric Design of Highways and Streets (Green Book), 2001, 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.

divided multilane A roadway with 2 or more through lanes in each direction and a median that physically or legally prohibits left-turns, except at designated locations.

freeway A divided highway that has a minimum of two lanes in each direction, for the exclusive use of traffic, and with full control of access.

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

intermediate pavement type Hot mix asphalt 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.

low pavement type Bituminous surface treatment (BST).

median The portion of a 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 or collector/distributor road.

roadway The portion of a highway, including shoulders, for vehicular use.

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.

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.

undivided multilane A roadway with 2 or more through lanes in each direction on which left-turns are not controlled.

640.04 Roadways

The cross sections shown in Figures 640-1, 2, 3, 4a, and 4b represent minimum values for full design level. See Chapter 440 for additional design information for full design level. See Chapter 430 for cross sections and design information for modified design level.

(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 the cross slope may be increased to 3% to allow for reduced construction control and greater settlement.

Superelevation on curves is a function of the design speed and the radius of the curve. See Chapter 642 for guidance on superelevation design.

(2) Turning Roadways

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. See Chapter 641 for width requirements on turning roadways.

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. See Chapter 642 for superelevation requirements.

(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%. On the high side of a roadway with a plane section, such as a turning roadway in superelevation, the shoulder may slope in the opposite direction from the adjacent lane. 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 slope 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 extruded 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 (design speed above 45 mph). 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 640-5a and 5b represent shoulder details and requirements.

640.05 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
- Access control

(2) Design

Figures 640-6a through 6c, give minimum design requirements for medians. See Chapters 430 and 440 for minimum median widths. Median widths in excess of the minimums are highly desirable. When the horizontal and vertical alignments of the two roadways of a divided highway are independent of each other, determine median side slopes in conformance with Figure 640-1. Independent horizontal and vertical alignment, rather than parallel alignment, is 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.

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. See Chapter 620 for minimum taper lengths.

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.

640.06 Roadsides

(1) Side Slopes

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 4H:1V, 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 3H:1V. If there will be continuous traffic barrier on a fill slope, and mowing is not contemplated, the slope may be steeper than 3H:1V.

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.

With justification, fill slopes steeper than shown in the Fill and Ditch Slope Selection tables on Figures 640-1, 2, 3, and 4b may be used when traffic barrier is installed. Do not install traffic barrier unless a hazard requiring mitigation is present. The steepest slope is determined by the soil conditions. Where favorable soil conditions exist, fill slopes may be as steep as $1^{1}/_{2}$H:1V. See Chapter 700 for clear zone and barrier requirements.

The Cut Slope Selection tables on Figures 640-1, 2, 3, and 4b are for preliminary estimates or where no other information is available. Design the final slope as recommended in the geotechnical report. Do not disturb existing stable cut slopes just to meet the slopes given in the Cut Slope Selection tables. 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 640.06(4) for drainage ditches in embankment areas details.

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 640-7a and 7b, 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. Headquarters Materials Lab concurrence is required.

There are two basic design treatments applicable to rock excavation (Figures 640-7a and 7b). 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 640-7a.

- Stage 1 is used where the anticipated quantity of rockfall is small, adequate fallout width can be provided, and the rock slope is $^{1}/_{2}$H:1V 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 200 ft 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 640-7a.

The necessity for benches, their width, and vertical spacing is established only after an evaluation of slope stability. Make benches at least 20 ft 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 640-7b). 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 0.25 cy in size, and the length of the slope is greater than 350 ft.
- Fence position b is the preferred location for most applications.
- Fence position c is used when the cliff generates boulders greater than 0.25 cy in size, regardless of the length of the slope. On short slopes, this may require placing the fence less than 100 ft 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 640-8 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.

(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 HQ Bridge and Structures Office and the region is necessary to ensure proper slope treatment (Chapter 1120).

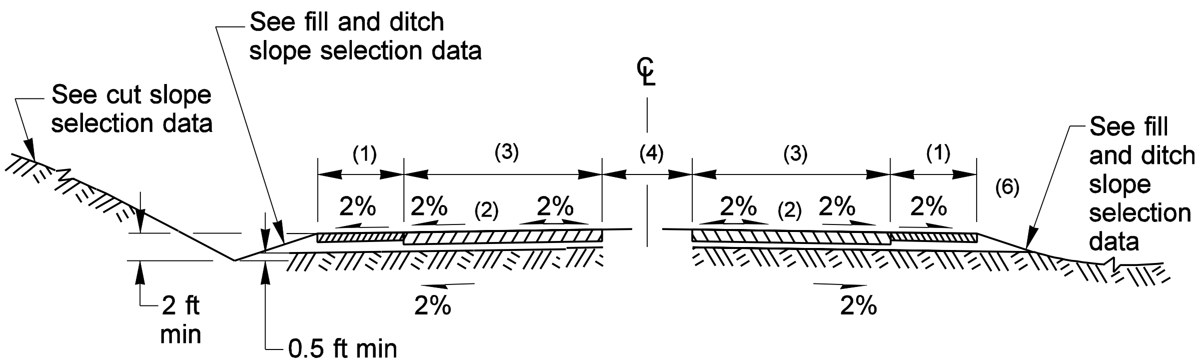
Early in the preliminary bridge plan development, determine preliminary bridge geometrics, end slope rates, and toe of slope treatments. Figure 640-9a provides guidelines for use of slope rates and toe of slope treatments for overcrossings. Figure 640-9b shows toe of slope treatments to be used on the various toe conditions.

640.07 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.

640.08 Documentation

A list of the documents that are to be preserved [in the Design Documentation Package (DDP) or the Project File (PF)] is on the following web site: http://www.wsdot.wa.gov/eesc/design/projectdev/



Design Class I-1, P-1, P-2, M-1, UM/A-1, UM/A-2

Height of fill/depth of ditch (ft)	Slope not steeper than (5)
10	6H:1V
10 – 20	4H:1V
20 – 30	3H:1V (6)
over 30	2H:1V (6)(8)

Fill and Ditch Slope Selection

Height of cut (ft)*	Slope not steeper than
0 - 5	6H:1V
5 – 20	3H:1V
over 20	2H:1V (7)

* From bottom of ditch

Cut Slope Selection (9)

Notes:

(1) See Figures 640-5a and 5b for shoulder details. See Chapters 430 and 440 for minimum shoulder width.

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

- Four-lane highway — slope all lanes away from the median (plane section).
- 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 Chapters 430 and 440 for minimum number and width of lanes. See Chapter 641 for turning roadway width.

(4) See Figures 640-6a through 6c for median details. See Chapters 430 and 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 4H:1V as shown on Figure 640-5b.

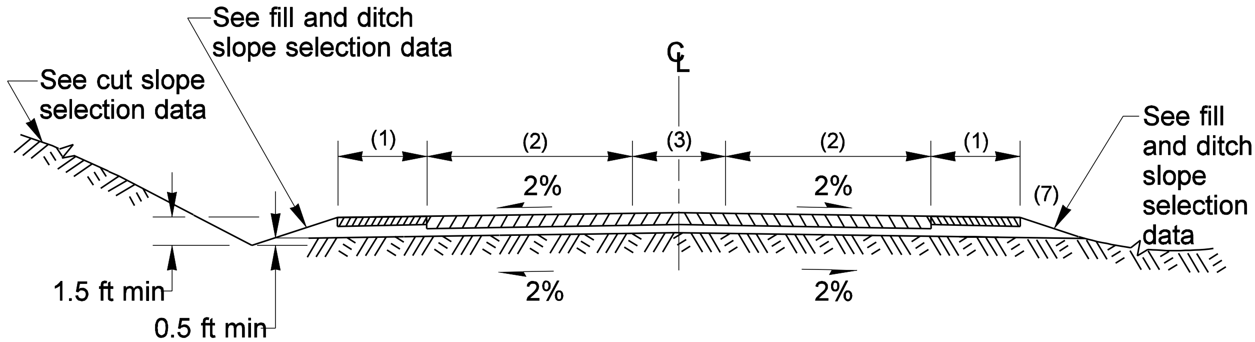
(7) Cut slopes steeper than 2H:1V may be used where favorable soil conditions exist or stepped construction is used. See Chapter 700 for clear zone and barrier requirements.

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

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

Divided Highway Roadway Sections

Figure 640-1



Design Class P-6, M-5, C-1, $U_{M/A}$-3, $U_{M/A}$-4

Height of fill/depth of ditch (ft)	Slope not steeper than (4)
0 – 5	6H:1V
5 – 20	4H:1V
20 – 30	3H:1V (7)
over 30	2H:1V (6)(7)

Fill and Ditch Slope Selection

Height of cut (ft)*	Slope not steeper than
0 - 5	4H:1V
over 5	2H:1V (5)

* From bottom of ditch

Cut Slope Selection (8)

Notes:

(1) See Figures 640-5a and 5b for shoulder details. See Chapters 430 and 440 for minimum shoulder width.

(2) See Chapters 430 and 440 for minimum number and width of lanes. See Chapter 641 for turning roadway width.

(3) See Chapters 430 and 440 for minimum median width. See Chapter 910 for width when median is a two-way left-turn lane.

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

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

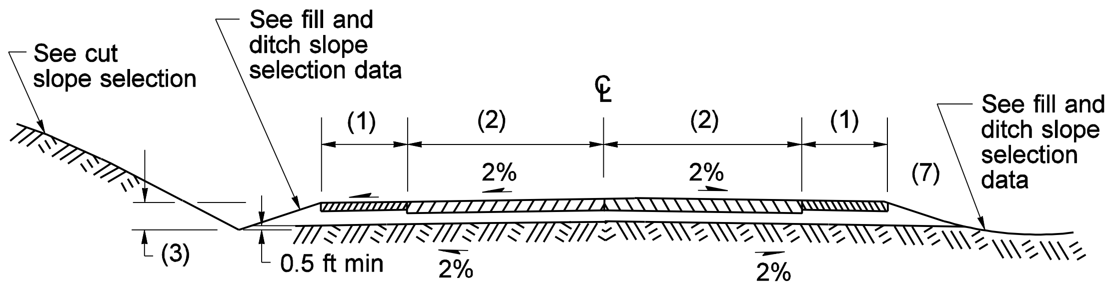
(6) Fill slopes up to $1^1/_2$H:1V may be used where favorable soil conditions exist. See Chapter 700 for clear zone and barrier requirements.

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

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

Undivided Multilane Highway Roadway Sections

Figure 640-2



Design Class P-3, P-4, P-5. M-2, M-3, M-4, C-2, C-3, C-4, $U_{M/A}$-5, $U_{M/A}$-6

Design Class of highway	**P-3, P-4, M-2, C-2, $U_{M/A}$-5**	**P-5, M-3, M-4, C-3, C-4, $U_{M/A}$-6**
Height of fill/depth of ditch (ft)	**Slope not steeper than** (4)	
0 – 10	6H:1V	4H:1V
10 – 20	4H:1V	4H:1V
20 – 30	3H:1V (7)	3H:1V (7)
over 30	2H:1V (5)(7)	2H:1V (5)(7)

Fill and Ditch Slope Selection

Design Class of highway	**P-3, P-4, M-2, C-2, $U_{M/A}$-5**	**P-5, M-3, M-4, C-3, C-4, $U_{M/A}$-6**
Height of cut (ft)*	**Slope not steeper than**	
0 - 5	6H:1V	4H:1V
5 – 20	3H:1V	2H:1V (6)
over 20	2H:1V (6)	2H:1V (6)

* From bottom of ditch

Cut Slope Selection (8)

Notes:

(1) See Figures 640-5a and 5b for shoulder details. See Chapters 430 and 440 for minimum shoulder width.

(2) See Chapters 430 and 440 for minimum width of lanes. See Chapter 641 for turning roadway width.

(3) The minimum ditch depth is 2 ft for Design Class P3 and 1.5 ft for Design Class P-4, P-5, M-2, M-3, M-4, C-2, C-3, C-4, $U_{M/A}$-5, and $U_{M/A}$-6.

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

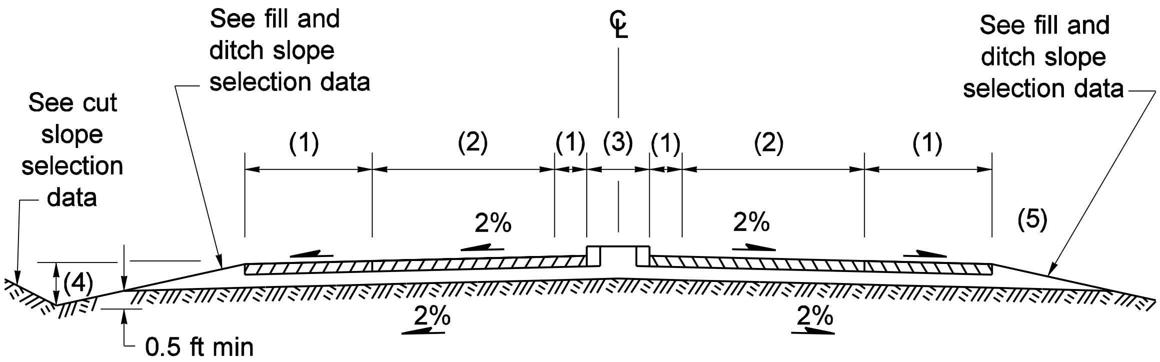
(5) Fill slopes up to $1^1/_2$H:1V may be used where favorable soil conditions exist. See Chapter 700 for clear zone and barrier requirements.

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

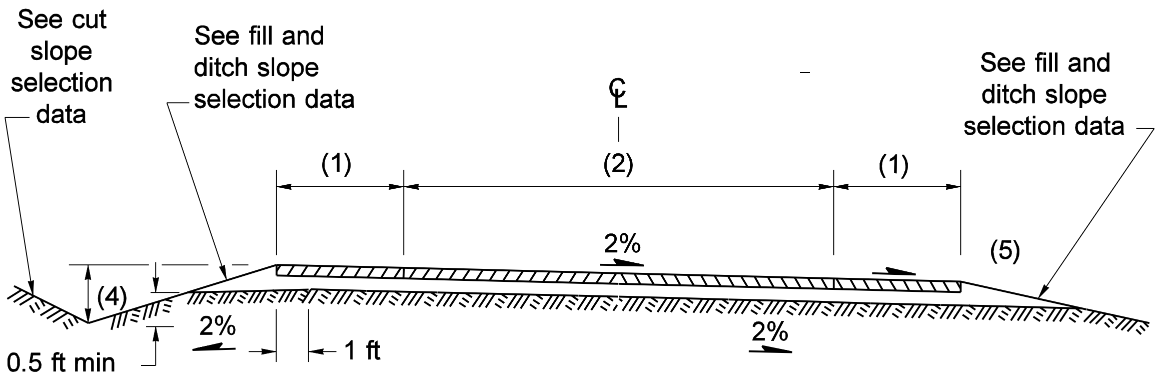
(7) Widen and round foreslopes steeper than 4H:1V, as shown on Figure 640-5b.

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

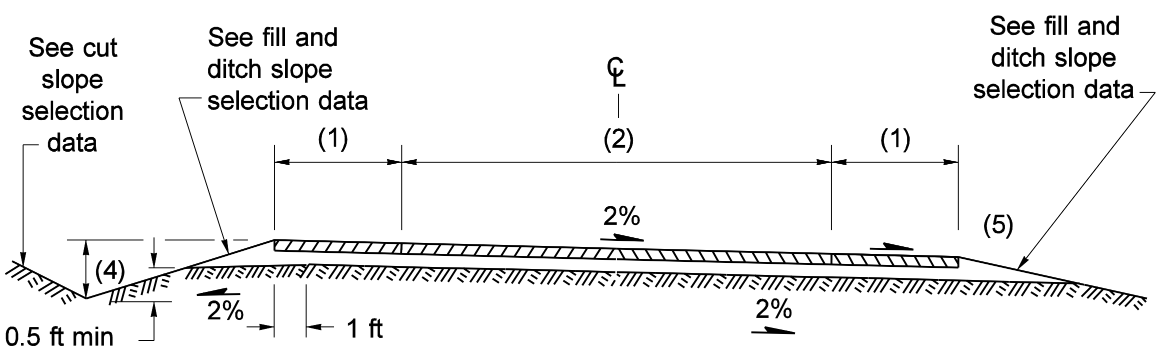
Two-Lane Highway Roadway Sections
Figure 640-3



Two-Lane Two-Way Ramp



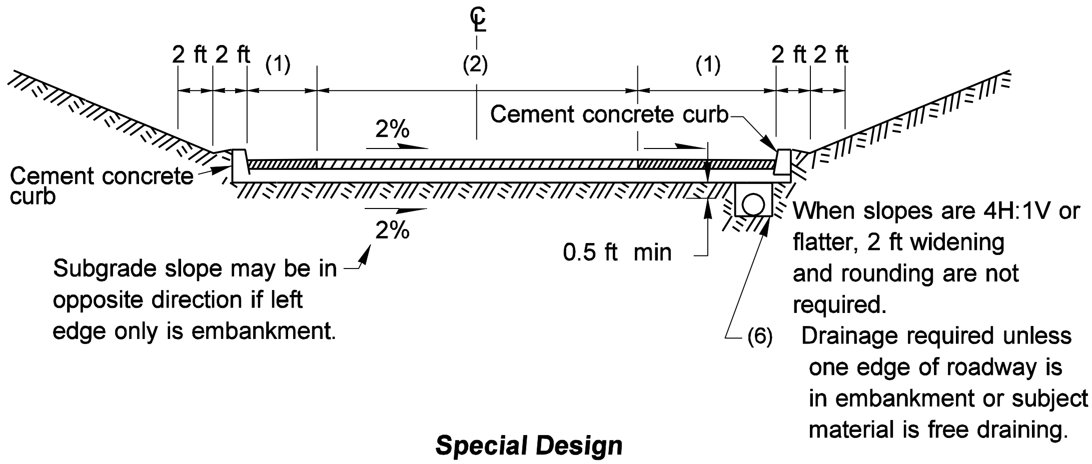
Two-Lane One-Way Ramp



One-Lane Ramp

For notes, dimensions, and slope selection tables see Figure 640-4b

Ramp Roadway Sections
Figure 640-4a



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 (ft)	Slope not steeper than (7)
0 – 10	6H:1V
10 – 20	4H:1V
20 – 30	3H:1V (5)
over 30	2H:1V (5) (9)

Fill and Ditch Slope Selection

Height of cut (ft)*	Slope not steeper than
0 - 5	6H:1V
5 - 20	3H:1V
over 20	2H:1V (8)

* From bottom of ditch

Cut Slope Selection (10)

Notes:

(1) See Figures 640-5a and 5b for shoulder details. See Chapter 940 for minimum shoulder widths.

(2) See Chapter 940 for minimum ramp lane widths. See Chapter 641 for turning roadway 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 2 ft for design speeds over 40 mph and 1.5 ft for design speeds of 40 mph or less. Rounding may be varied to fit drainage requirements when minimum ditch depth is 2 ft.

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

(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.

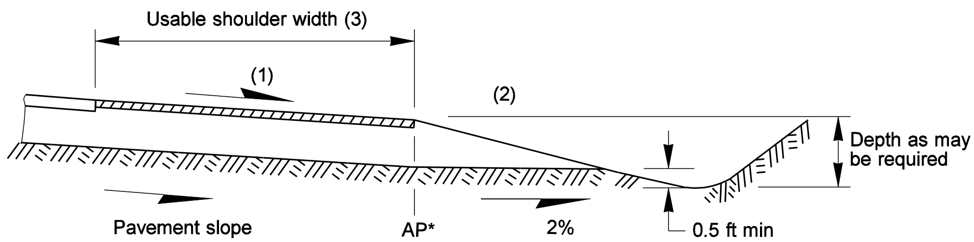
(8) Cut slopes steeper than 2H:1V may be used where favorable soil conditions exist or stepped construction is used. See Chapter 700 for clear zone and barrier requirements.

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

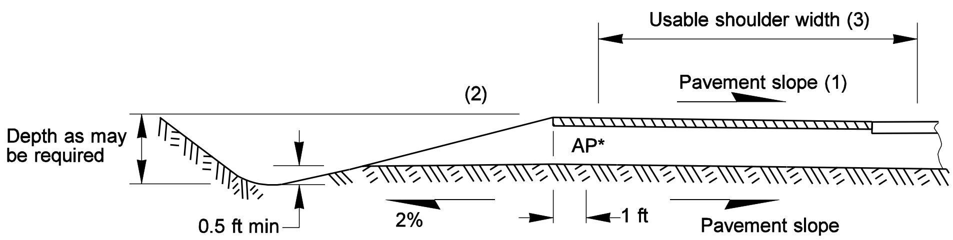
(10) The Cut Slope Selection table is for preliminary estimates or where no other information is available. Design the final slope as recommended in the geotechnical report. Do not disturb existing stable slopes just to meet the slopes given in this table.

Ramp Roadway Sections

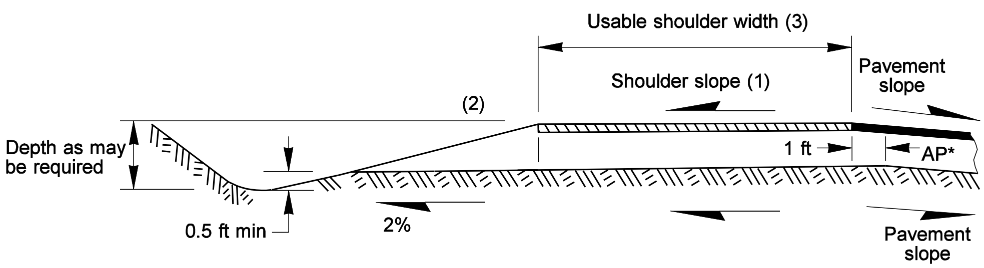
Figure 640-4b



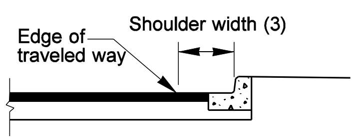
Shoulder Design On The Low Side Of The Roadway For Cross Slopes Greater Than 2%.



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 Shoulder Slopes Away From Roadway.



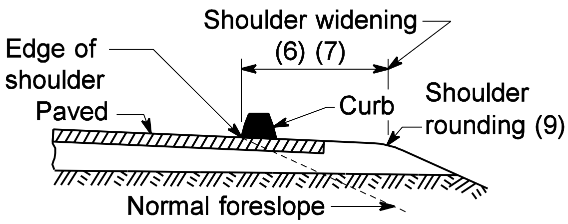
Shoulder Design with Curb (5)(6)

*AP = angle point in the subgrade.

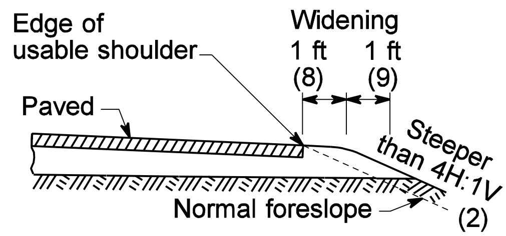
For notes, see Figure 640-5b.

Shoulder Details

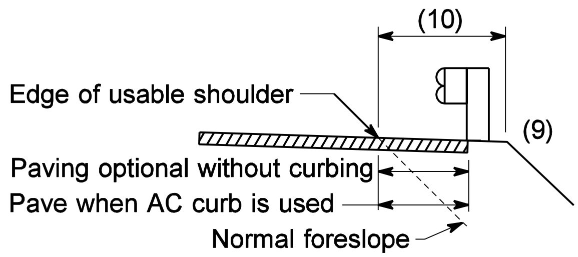
Figure 640-5a



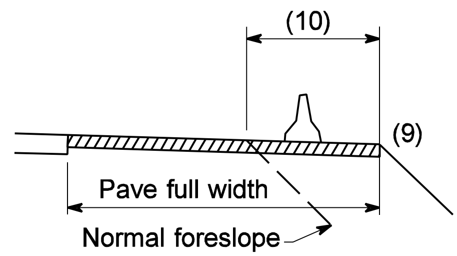
Asphalt Concrete Curb Placement



Shoulder Rounding



Shoulder Widening for Guardrail



Shoulder Widening for Barrier

Notes:

(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 4H:1V.

(3) See Chapters 430, 440, and 940 for minimum shoulder width.

(4) On divided multilane highways see Figures 640-6a through 6c 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 extruded curb is placed. Use curb 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.

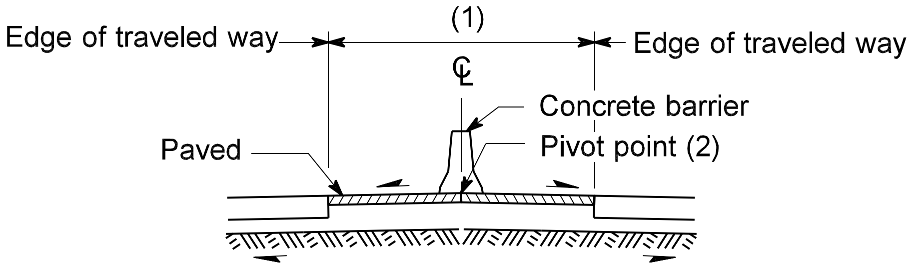
End rounding on the crossroad just beyond the ramp terminals and at a similar location where only a grade separation is involved.

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

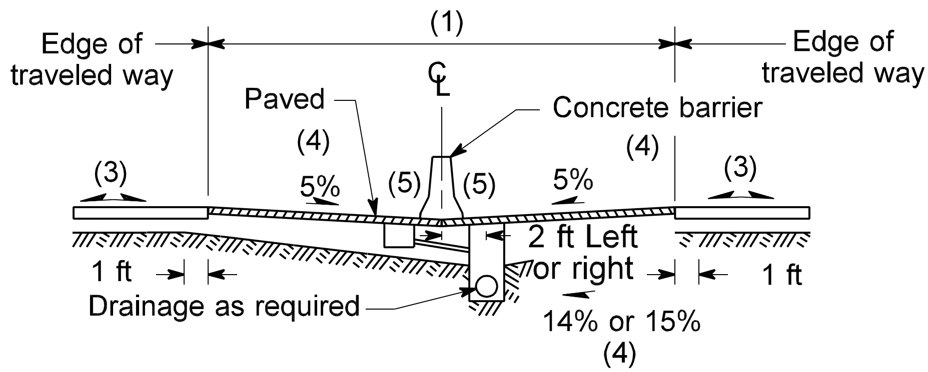
(10) See Chapter 710 for required widening for guardrail and concrete barrier.

Shoulder Details

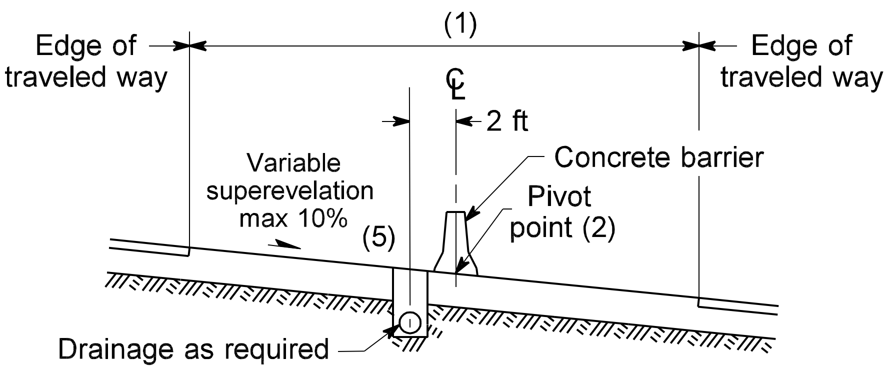
Figure 640-5b



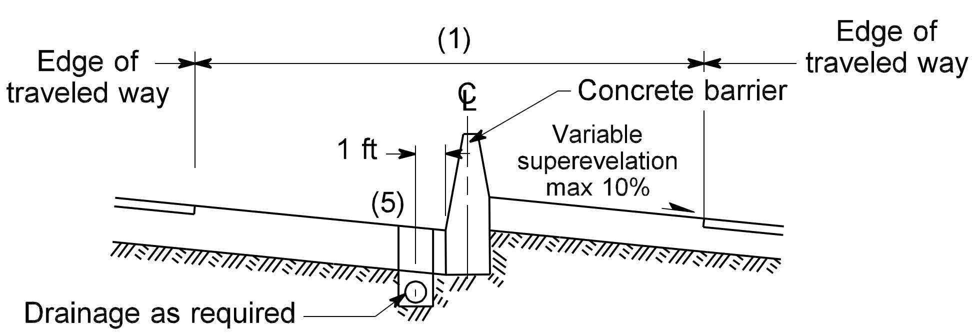
Design A Crowned Median



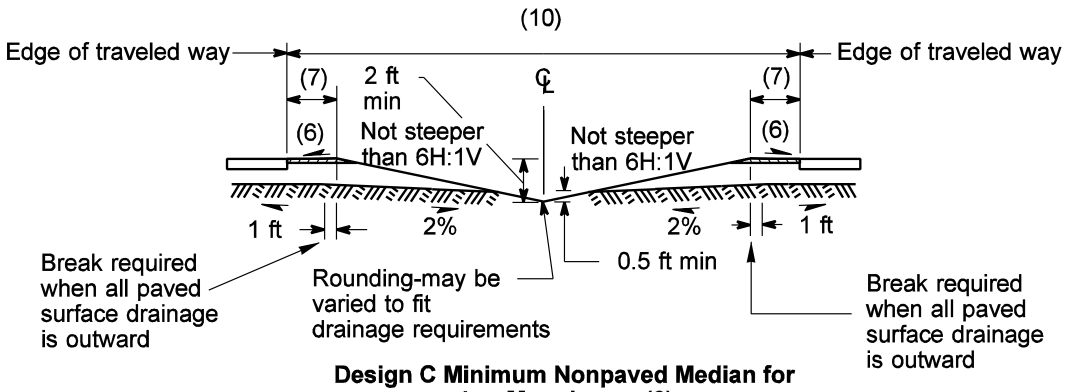
Design B Depressed Median



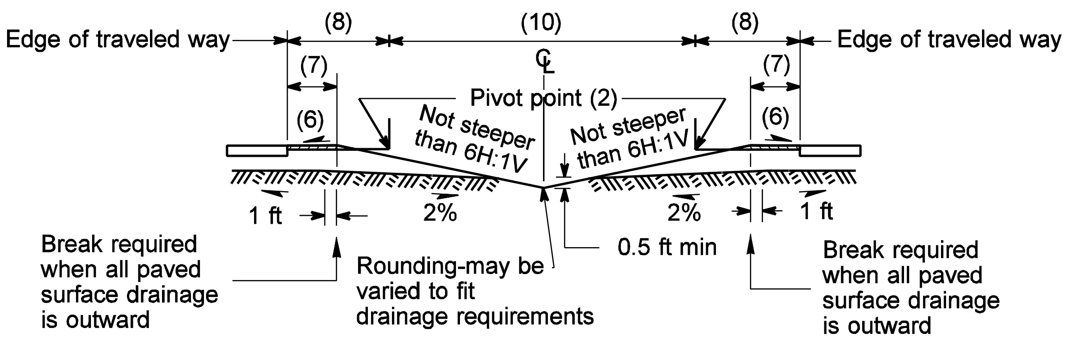
Alternate Design 1 Treatment on Curves



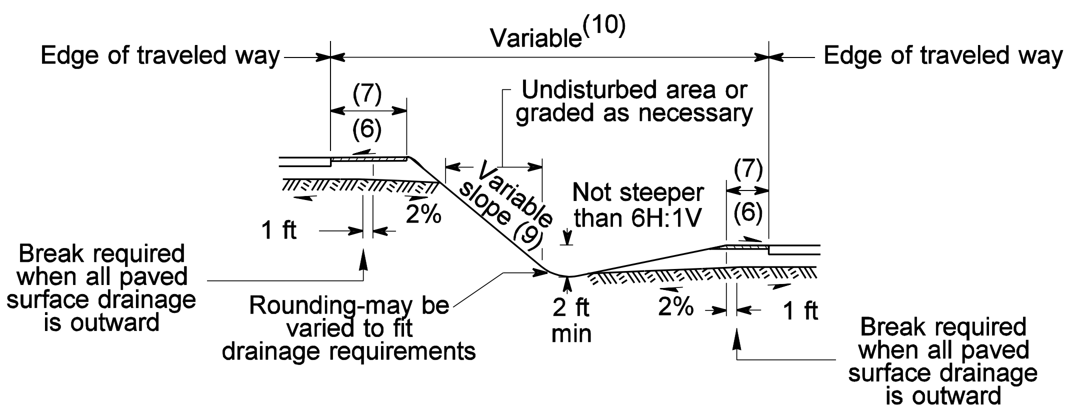
Divided Highway Median Sections
Figure 640-6a



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



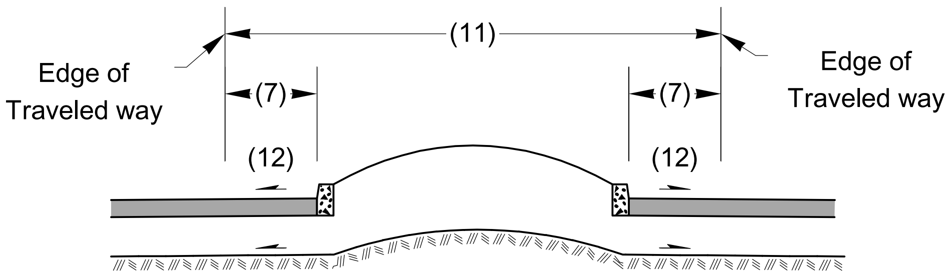
Design D Minimum for 4 or More Lanes with Future Lanes in Median



Design E Minimum for 4 or More Lanes with Independent Alignment

For notes, see Figure 640-6c

Divided Highway Median Sections
Figure 640-6b



Design F Raised Median (13)

(1) See Chapters 430, and 440 for minimum 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 justify. See Figure 640-1 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. 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.

(7) See Chapters 430, and 440 for minimum shoulder width.

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

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

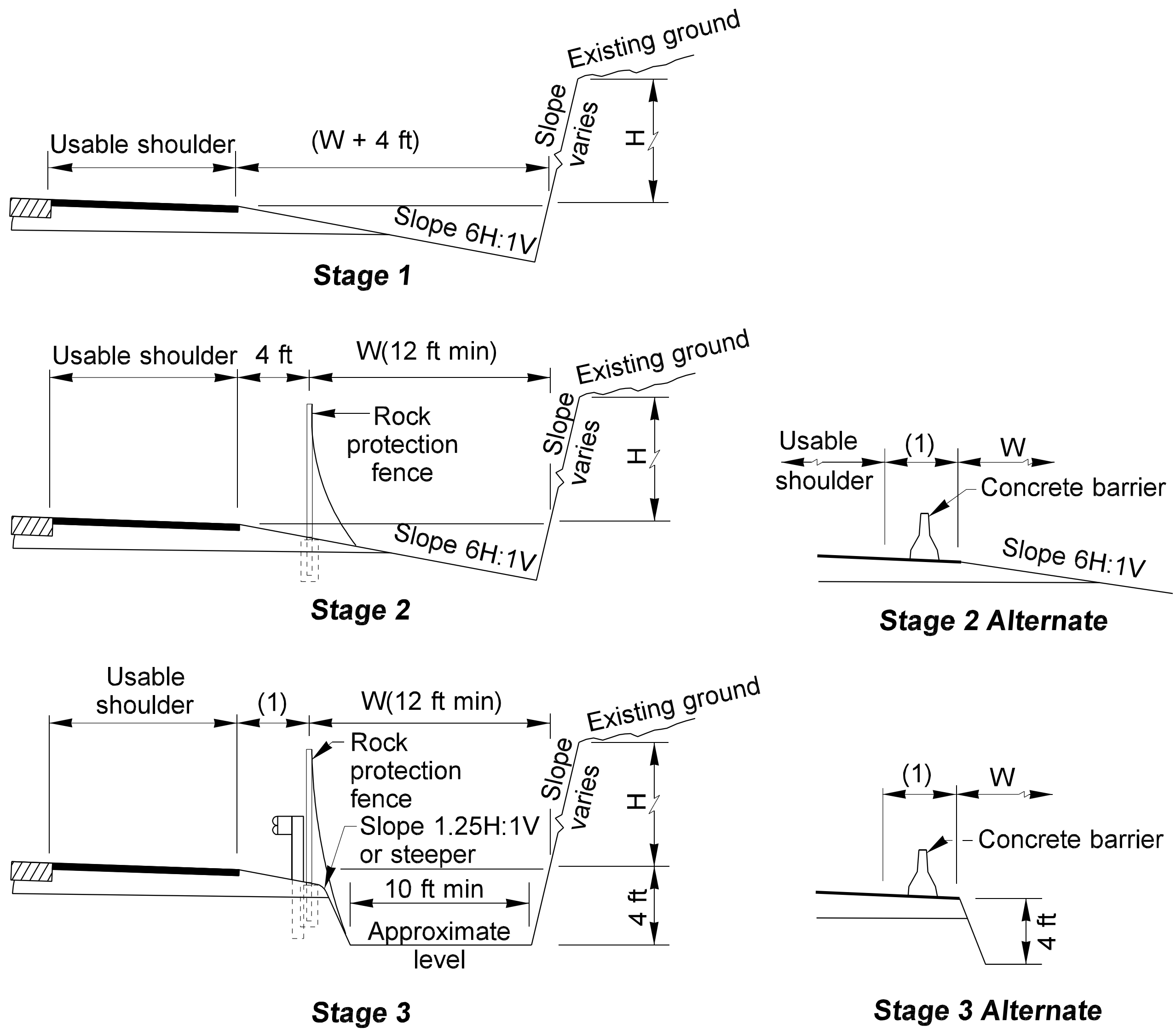
(10) Designs C, D, and E are rural median designs, see Chapter 440 for minimum rural median widths. Rural median designs may be used in urban areas when minimum rural median widths can be achieved.

(11) See Chapter 440 for minimum median width. Raised medians may be paved or landscaped. See Chapter 700 for clear zone and barrier requirements when fixed objects or trees are in the median.

(12) Lane and shoulders normally slope away from raised medians. When they slope toward the median, provide for drainage.

(13) The desirable maximum design speed for a raised median is 45 mph. When the design speed is above 45 mph Design A or Design B is preferred.

Divided Highway Median Sections
Figure 640-6c



Rock Slope	H (ft)	W (ft)
Near Vertical	20-30	12
	30 – 60	15
	> 60	20
0.25H:1V through 0.50H:1V	20-30	12
	30-60	15
	60-100	20
	>100	25

Notes:

Cut heights less than 20 ft shall be treated as a normal roadway unless otherwise determined by the region Materials Engineer.

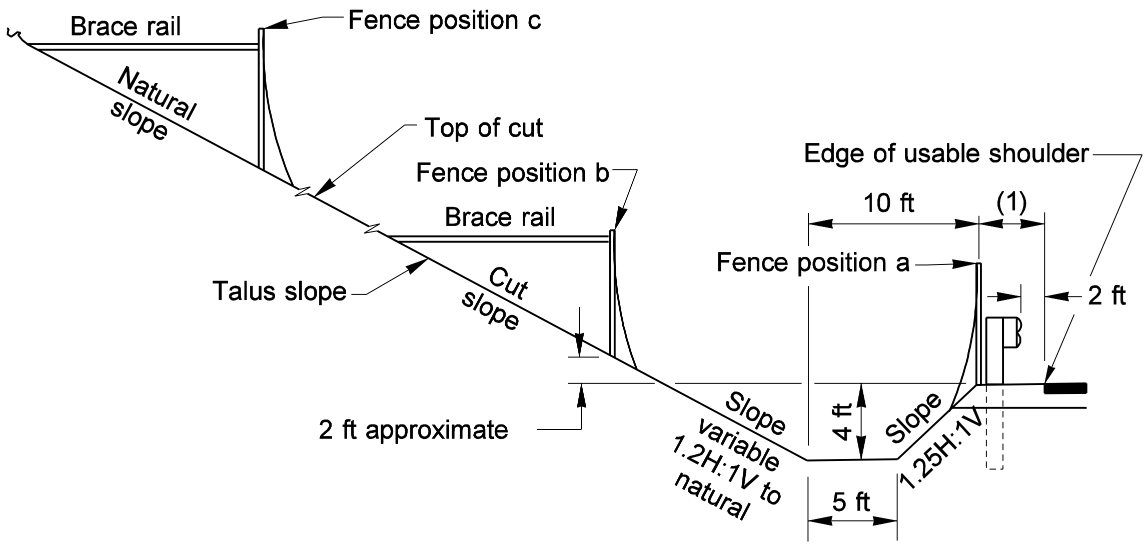
Stage 2 and 3 Alternatives may be used when site conditions dictate.

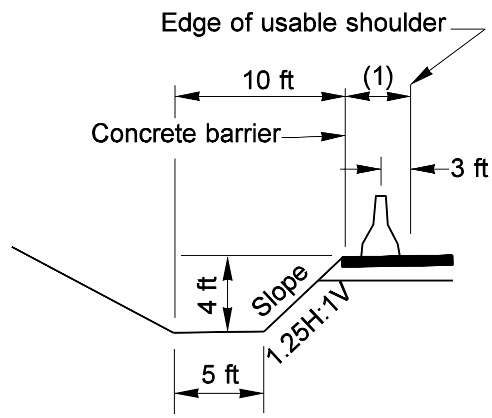
Fence may be used in conjunction with the Stage 3 Alternative. See Chapter 700 for clear zone requirements.

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

Roadway Sections in Rock Cuts, Design A

Figure 640-7a





Shoulder Barrier Alternate

Notes:

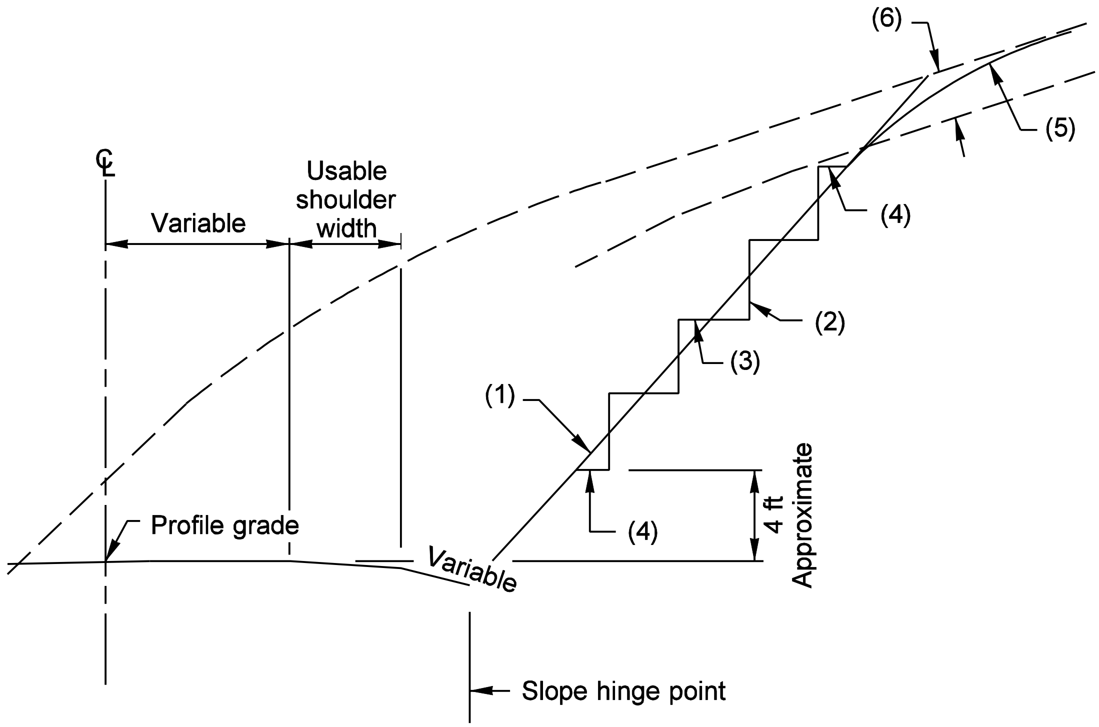
Ordinarily, place fence within a zone of 100 ft to 200 ft maximum from base of cliff measured along slope.

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 640-7b



Notes:

(1) Staked slope line – Maximum slope 1H:1V.
(2) Step rise – height variable 1 ft to 2 ft
(3) Step tread – width = staked slope ratio x step rise.
(4) Step termini – width ½ step tread width.
(5) Slope rounding.
(6) Overburden area – variable slope ratio.

Roadway Sections With Stepped Slopes
Figure 640-8

Bridge End Condition	Toe of Slope End Slope Rate		Lower Roadway Treatment (1)		Slope Rate
End Piers on Fill	Height	Rate	Posted speed of lower roadway.	Treatment	
	≤ 35 ft > 35 ft	$1\frac{3}{4}$H:1V 2H:1V (2)	> 50 mph ≤ 50 mph	Rounding 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 > 8 ft and length is > 100 ft, match cut slope of the lower roadway.		When the cut depth is > 8 ft and length is > 100 ft, no rounding, toe at center line of the lower roadway ditch.		(4)
	When the cut depth is ≤ 5 ft or the length is ≤ 100 ft, it is designers choice.		When the cut depth is ≤ 5 ft or the length is ≤ 100 ft, it is designers choice.		(4)

Notes:

(1) See Figure 640-9b

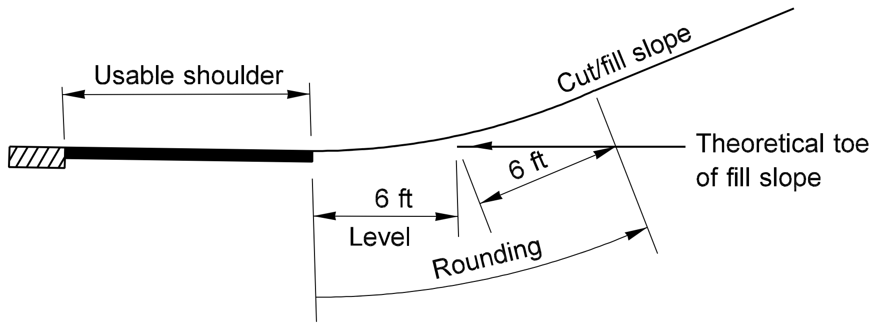
(2) Slope may be $1\frac{3}{4}$H:1V in special cases.

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

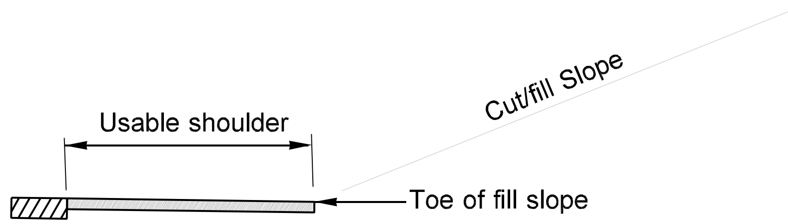
(4) See 640.06.

Bridge End Slopes

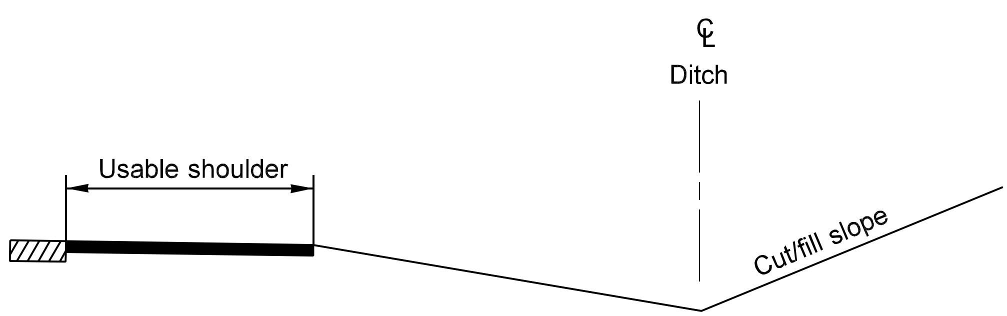
Figure 640-9a



Rounding



No Rounding



Toe at ℄ of Roadway Ditch

Bridge End Slopes

Figure 640-9b

641.01 General

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.

See the following chapters for additional information:

Chapter	Subject
430	roadway widths and cross slopes for modified design level
440	minimum lane and shoulder widths for full design level
642	superelevation
940	lane and shoulder widths for ramps

641.02 References

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.

A Policy on Geometric Design of Highways and Streets (Green Book), 2001, AASHTO

641.03 Definitions

divided multilane A roadway with 2 or more through lanes in each direction and a median that physically or legally prohibits left-turns, except at designated locations.

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.

roadway The portion of a highway, including shoulders, for vehicular use.

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.

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.

undivided multilane A roadway with 2 or more through lanes in each direction on which left-turns are not controlled.

641.04 Turning Roadway Widths

(1) Two-lane two-way roadways.

Figure 641-1a 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 foot.

Minimum traveled way width W based on the delta angle of the curve, shown in Figure 641-1b, may be used. Document the reasons for using the minimum width. Round W to the nearest foot.

Widths given in Figures 641-1a and 1b are for facilities with 12 ft lanes, when 11 ft lanes are called for, width W may be reduced by 2 ft.

(2) Two-lane one-way roadways.

Figure 641-2a shows the traveled way width W for two-lane one-way turning roadways, including two lane ramps and four-lane highways. For values of R between those given, interpolate W and round up to the next foot. Treat each direction of travel of four-lane facilities as a one-way roadway.

Minimum traveled way width W based on the delta angle of the curve, shown in Figure 641-2b, may be used. Document the reasons for using the minimum width. Round W to the nearest foot.

Widths given in Figures 641-2a and 2b are for facilities with 12 ft lanes, when 11 ft lanes are called for, width W may be reduced by 2 ft.

To keep widths to a minimum, traveled way widths for Figures 641-2a and 2b were calculated using the WB-40 design vehicle. When volumes are high for both trucks larger than the WB-40 and other traffic, consider using the widths from Figures 641-1a and 1b.

(3) One-lane roadways.

Figure 641-3a shows the traveled way width W for one-lane turning roadways, including one-lane ramps. For values of R between those given, interpolate W and round up to the next foot.

Minimum width W based on the delta angle of the curve for one-lane roadways, shown in Figure 641-3b using the radius to the outer edge of the traveled way and Figure 641-3c using the radius on the inner edge of the traveled way, may be used. Document the reasons for using the minimum width. Round W to the nearest foot.

Build shoulder pavements at full depth for one-lane roadways because, to keep widths to a minimum, traveled way widths were calculated using the WB-40 design vehicle which may force larger vehicles to encroach on the shoulders.

(4) Other roadways.

- For roadways with more than two lanes in any direction, for each lane in addition to two, add the lane width for the highway functional class from Chapter 440 to the width from 641.04(2).
- For three-lane ramps with HOV lanes, see Chapter 1050.

(5) Total roadway width.

Full design shoulder widths for the highway functional class or ramp are added to the traveled way width to determine the total roadway width.

Small amounts of widening will add cost with little benefit. When the required traveled way widening is less than 0.5 ft per lane, it may be disregarded. If the total roadway width deficiency is less than 2 ft on existing roadways that are to remain in place, correction is not normally required.

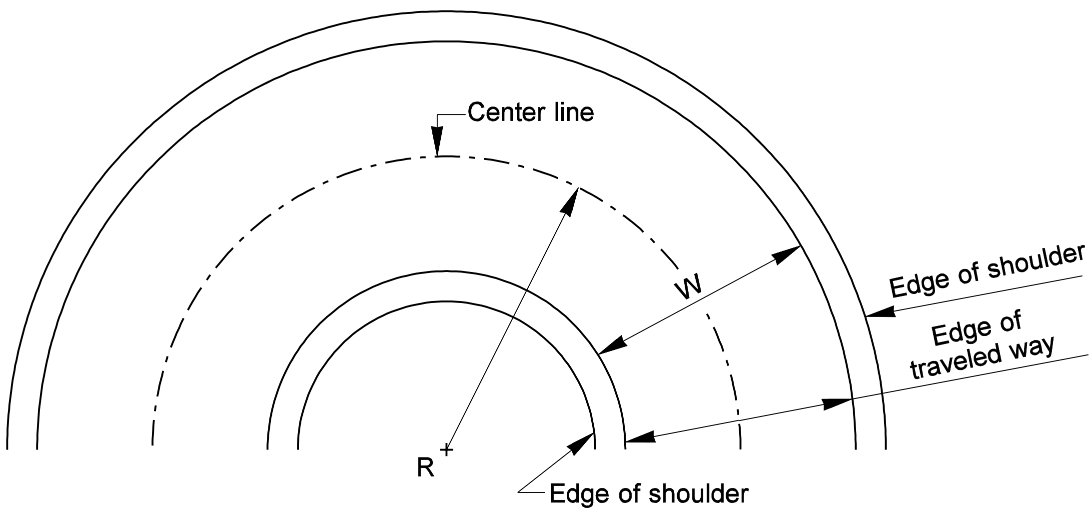
When widening the traveled way:

- Widening may be constructed on the inside of the traveled way or divided equally between the inside and outside. Do not construct widening only on the outside of a curve.
- Place final marked lane lines, and any longitudinal joints, at equal spacing 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 6 ft or less, use a 1:25 taper, for widths greater than 6 ft use a 1:15 taper.

641.05 Documentation

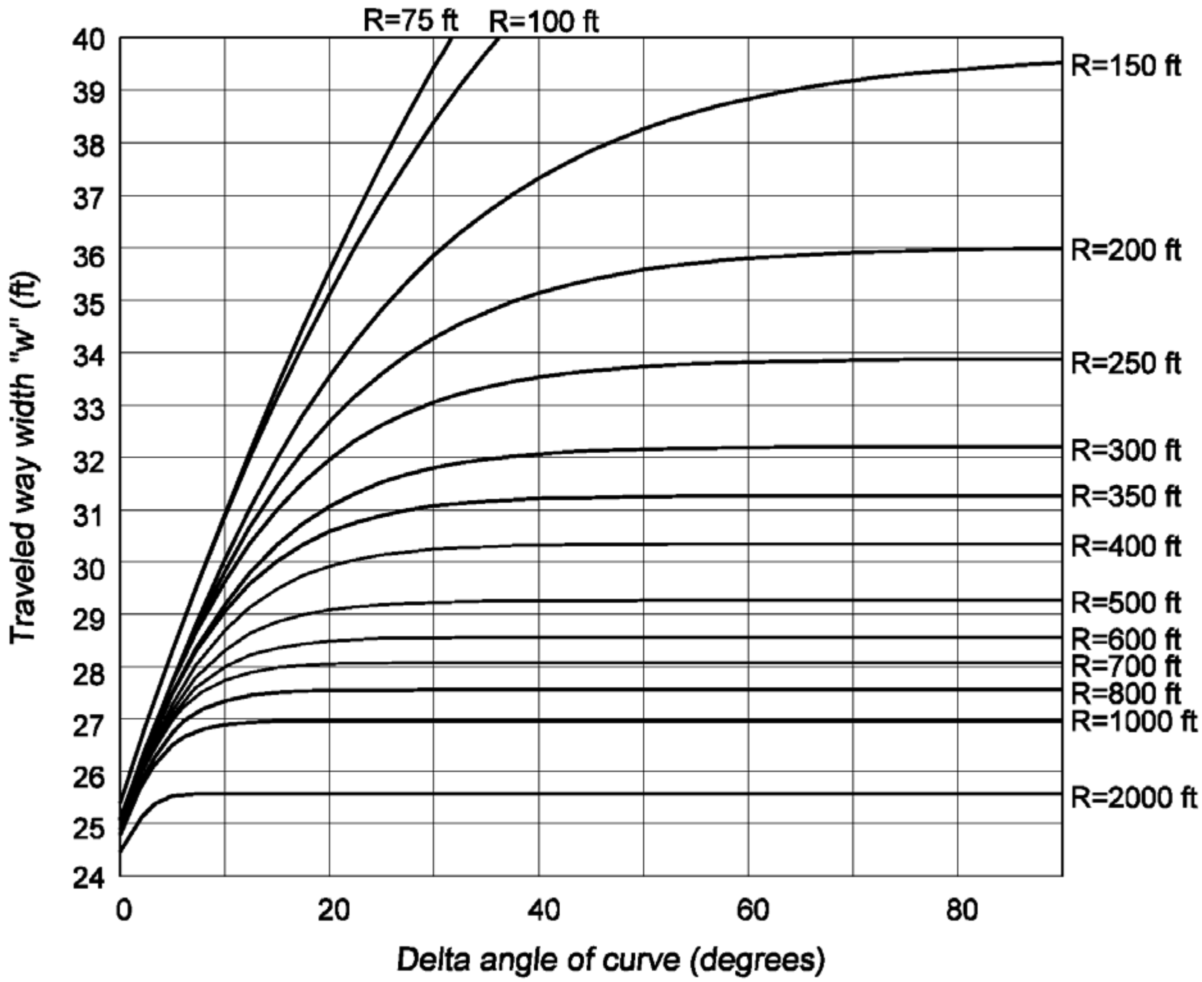
A list of the documents that are to be preserved [in the Design Documentation Package (DDP) or the Project File (PF)] is on the following web site: http://www.wsdot.wa.gov/eesc/design/projectdev/

Radius on center line of traveled way (ft)	Design traveled way width (W) (ft)(1)
3,000 to tangent	24
2,999	25
2,000	26
1,000	27
800	28
700	28
600	29
500	29
400	30
350	31
300	32
250	34
200	36
150	40



(1) Width (W) is for facilities with 12 ft lanes, when 11 ft lanes are called for, width may be reduced by 2 ft.

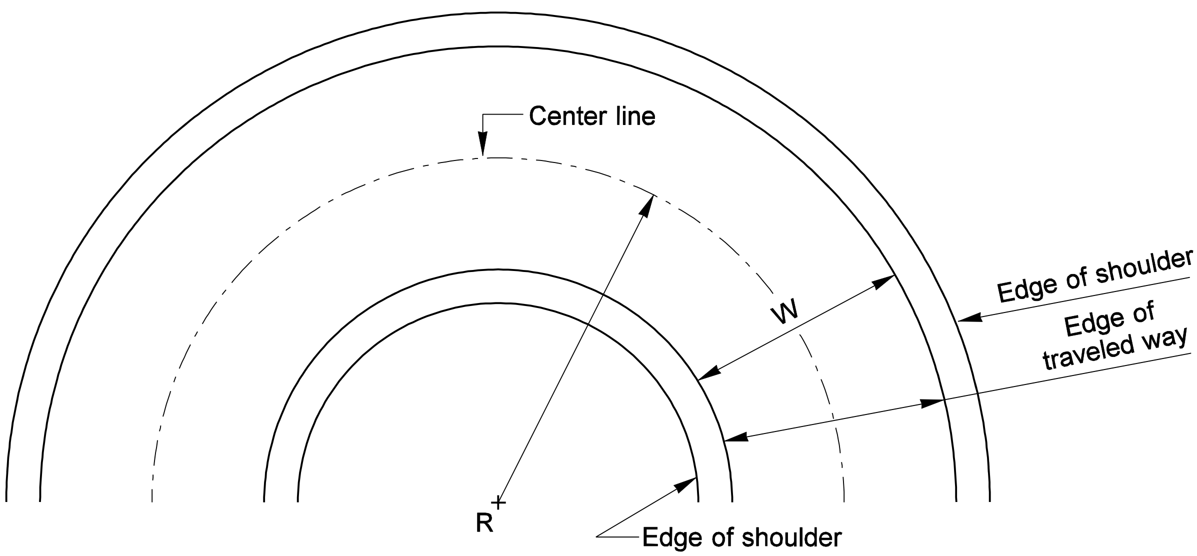
Traveled Way Width for Two-Lane Two-Way Turning Roadways
Figure 641-1a



(2) Width (W) is for facilities with 12 ft lanes, when 11 ft lanes are called for, width may be reduced by 2 ft.

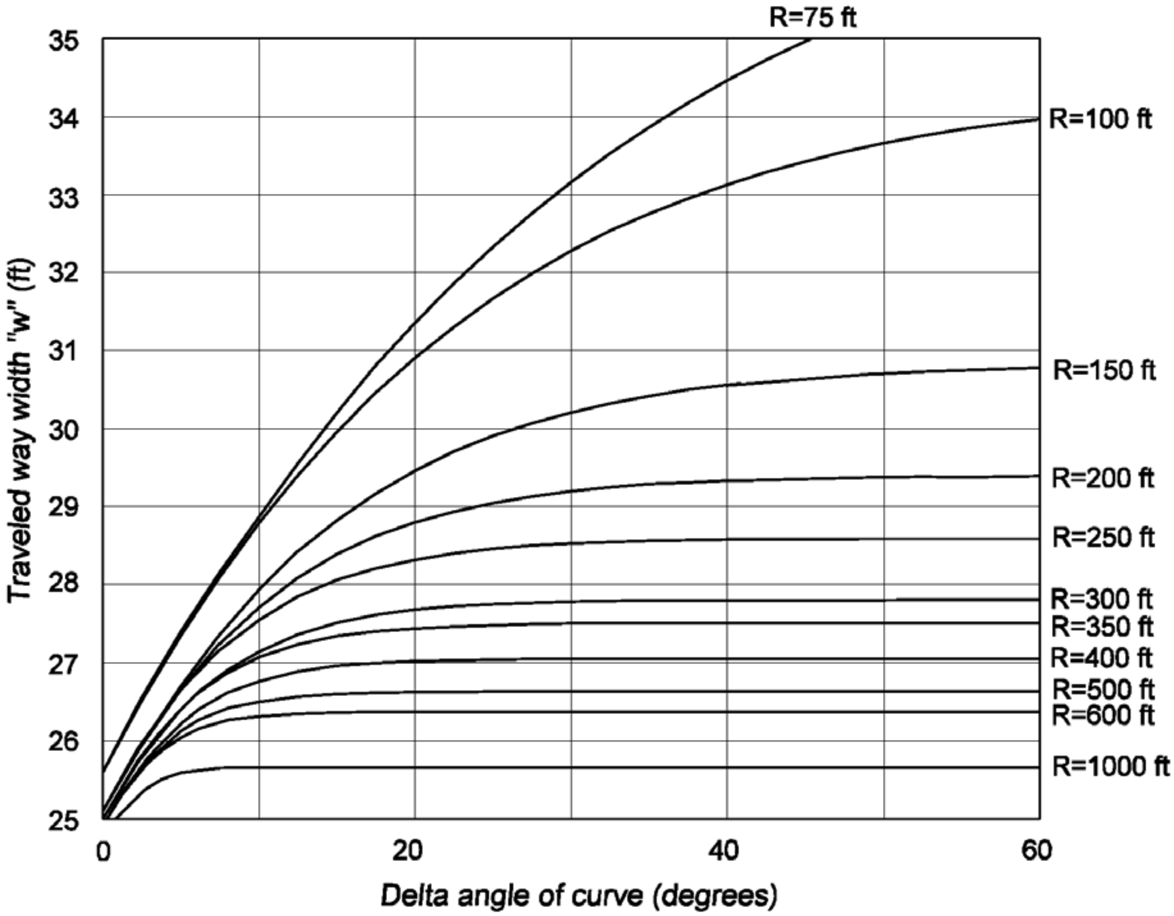
Traveled Way Width for Two-Lane Two-Way Turning Roadways
Figure 641-1b

Radius on center line of traveled way (ft)	Design traveled way width (W) (ft)(1)
3,000 to tangent	24
1,000 to 2,999	25
999	26
600	26
500	27
400	27
350	28
300	28
250	29
200	29
150	31
100	34



(3) Width (W) is for facilities with 12 ft lanes, when 11 ft lanes are called for, width may be reduced by 2 ft.

Traveled Way Width for Two-Lane One-Way Turning Roadways
Figure 641-2a



(1) Width (W) is for facilities with 12 ft lanes, when 11 ft lanes are called for, width may be reduced by 2 ft.

Traveled Way Width for Two-Lane One-Way Turning Roadways
Figure 641-2b

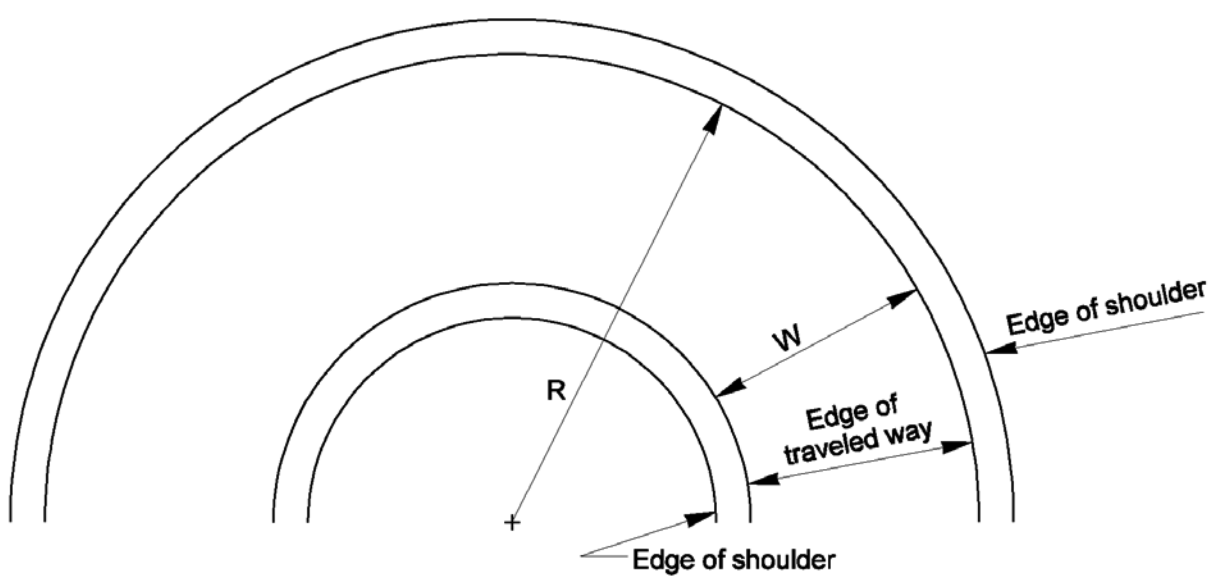
Radius (ft)	Design traveled way width (W) (ft)
7500 to tangent	13 (1)
1600	14
300	15
250	16
200	17
150	17
100	19 (2)
75	21 (3)
50	25 (4)

(1) On tangents, the minimum lane width may be reduced to 12 ft.

(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 18 ft.

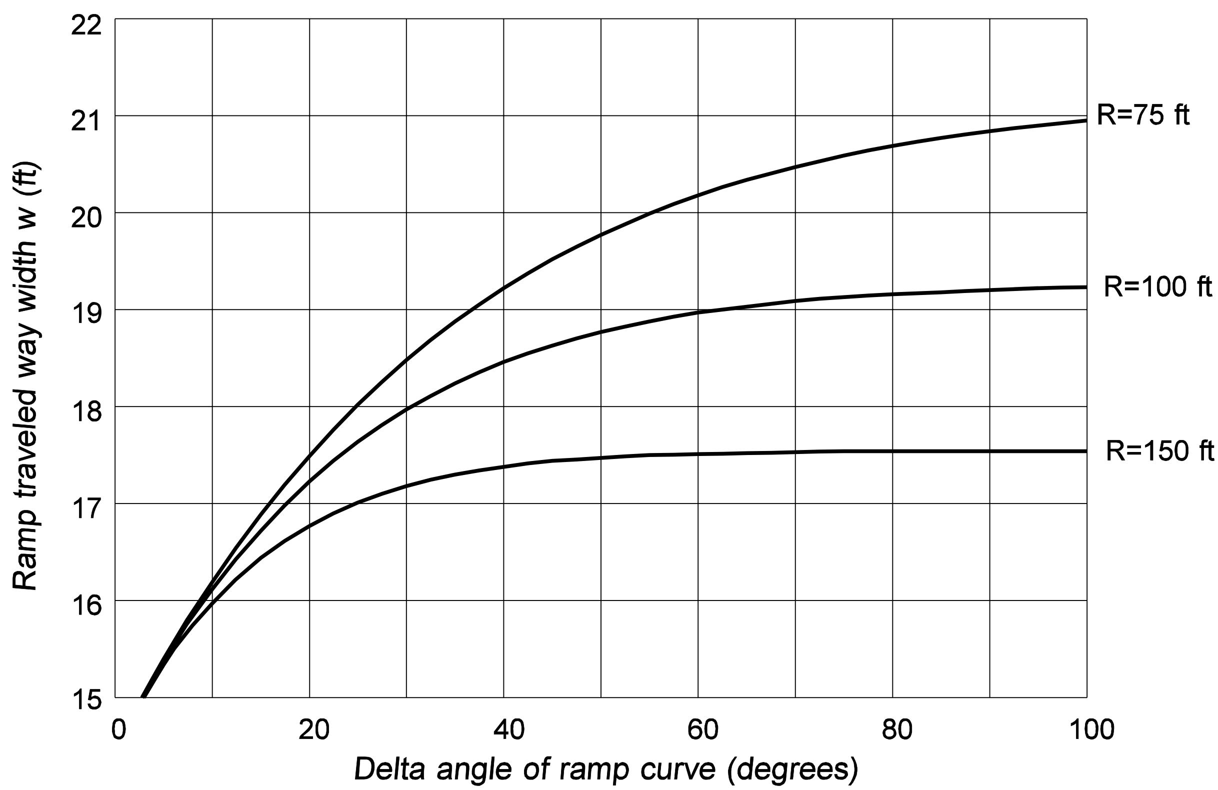
(3) The width given is for a radius on the outside edge of the traveled way. When the radius is on the inside edge of traveled way, the width may be 19 ft.

(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 22 ft.



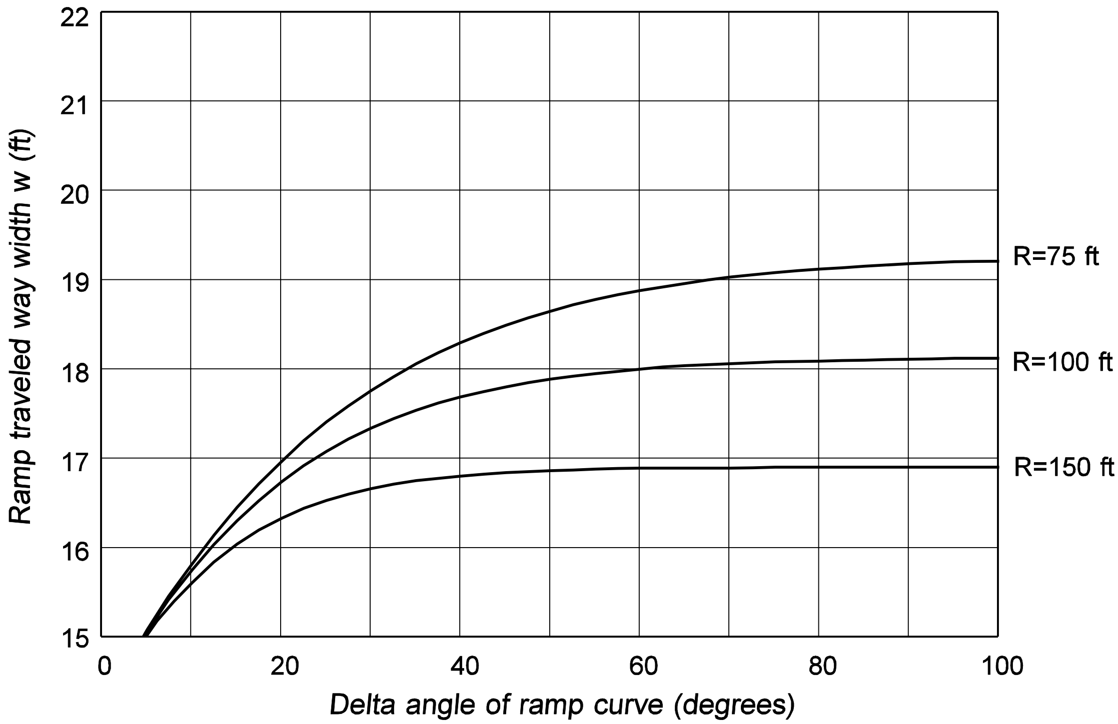
Traveled Way Width for One-Lane Turning Roadways

Figure 641-3a



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

Traveled Way Width for One-Lane Turning Roadways
Figure 641-3b



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

Traveled Way Width for One-Lane Turning Roadways
Figure 641-3c

642.01 General

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.

See the following chapters for additional information:

Chapter	Subject
430	roadway widths and cross slopes for modified design level
440	minimum lane and shoulder widths for full design level
940	lane and shoulder widths for ramps

642.02 References

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

Plans Preparation Manual, M 22-31, WSDOT

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

A Policy on Geometric Design of Highways and Streets (Green Book), 2001, AASHTO

642.03 Definitions

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.

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

roadway The portion of a highway, including shoulders, for vehicular use.

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 section with adverse crown removed (level) 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.

642.04 Rates for Open Highways and Ramps

The maximum superelevation rate allowed for open highways or ramps is 10%. (See Figure 642-3a.)

Base superelevation rate and its corresponding radius for open highways on Figure 642-3a, Superelevation Rate (10% Max), with the following exceptions:

- Figure 642-3b, Superelevation Rate (6% Max), may be used under the following conditions:

    1. Urban non freeways.

    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 642-3c, Superelevation Rate (8% Max), may be used for existing roadways, urban freeways, and areas where the 6% rate is allowed but will not work; for example, where a curve with a radius less than the minimum for the 6 % rate at the design speed is required.

Design the superelevation for ramps the same as for open highways. With justification, superelevation for ramps in urban areas with a design speed of 40 mph or less, may be determined as an urban managed access highway [642.05 & Figure 642-4].

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. The minimum radii for normal crown sections are shown in Figure 642-1. Superelevate curves with smaller radii in accordance with the appropriate superelevation from Figures 642-3a through 3c.

Design Speed (mph)	Minimum Radius for Normal Crown Section (ft)
15	955
20	1695
25	2,450
30	3,340
35	4,375
40	5,545
45	6,860
50	8,315
55	9,920
60	11,675
65	13,130
70	14,675
75	16,325
80	18,065

Minimum Radius for Normal Crown Section

Figure 642-1

642.05 Rates for Low-Speed Urban Managed Access Highway

Curves on low-speed Urban Managed Access Highways may be superelevated using a higher side friction than used for open highways. Figure 642-4 may be used to determine superelevation for Urban Managed Access Highways with a design speed of 40 mph or less. Figure 642-4 was developed using the higher side friction.

642.06 Existing Curves

Evaluate the superelevation on an existing curve to determine its adequacy. Use the following equation to determine the minimum radius for a given superelevation and design speed:

$$R = \frac{6.69V^2}{e + f}$$

Where:

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

V = Design speed in mph

e = Superelevation rate in percent

f = Side friction factor from Figure 642-2

Superelevation is deficient when the existing radius is less than 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.

Corrective action is required to address deficient superelevation, when the existing radius is less than the minimum radius calculated using the equation or when the maximum speed determined by a ball banking analysis is less than the design speed. Provide superelevation as given in 642.04.

Design Speed (mph)	Side Friction Factor (*f*)
15	17.5
20	17
25	16.5
30	16
35	15.5
40	15
45	14.5
50	14
55	13
60	12
65	11
70	10
75	9
80	8

Side Friction Factor

Figure 642-2

642.07 Turning Movements at Intersections

Curves associated with the turning movements at intersections are superelevated using the side friction factors for low-speed urban managed access highway curves. Since speeds of turning vehicles are not constant and curve lengths are not excessive, these higher friction factors can be tolerated. Use superelevation rates as high as practical, consistent with curve length and climatic conditions. Figure 642-4 shows the minimum superelevation for given design speed and radius. 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.

642.08 Runoff for Highway Curves

For added comfort and safety, provide uniform superelevation runoff over a length adequate for the likely operating speeds. The length of the runoff is based on a maximum allowable difference between the grades on the pivot point and the outer edge of the traveled way for one 12 ft lane.

Provide transitions for all superelevated highway curves as specified in Figures 642-5a through 5e. 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 full 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 642-5c and 5d except full super will be attained rather than the normal pavement slope as shown.

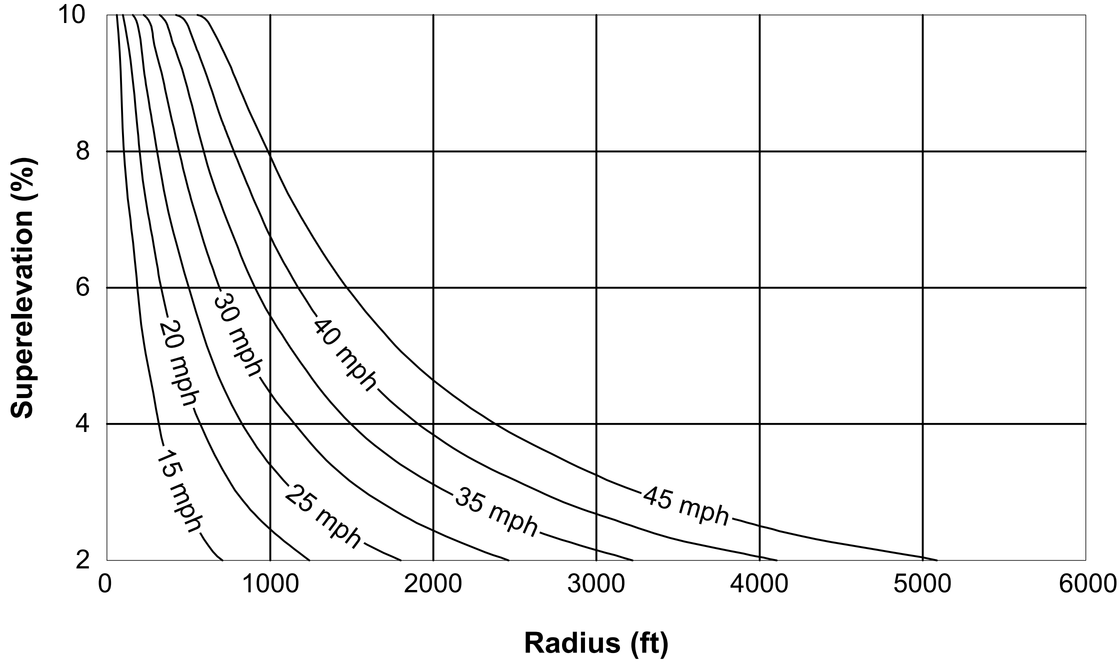
Superelevation runoff is permissible on structures but not desirable. Whenever practical, strive for full super or normal crown slopes on structures.

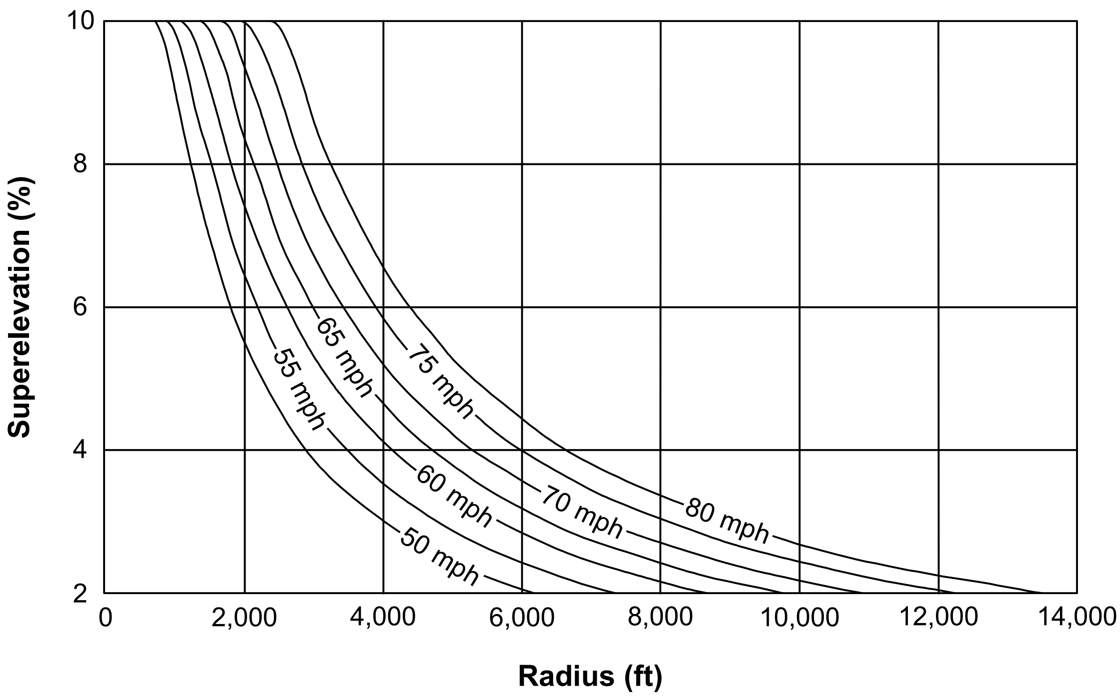
642.09 Runoff for Ramp Curves

Superelevation runoff for ramps use the same maximum relative slopes for specific design speeds used for highway curves. Multilane ramps have a width similar to the width for highway lanes; therefore, Figures 642-5a through 5e are used to determine the superelevation runoff for ramps. Single lane ramps have a lane width of 15 ft in curves, requiring the runoff length to be adjusted. Superelevation transition lengths (L_T) for single-lane ramps are given in Figures 642-6a and 6b. Additional runoff length for turning roadway widening is not required.

642.10 Documentation

A list of the documents that are to be preserved [in the Design Documentation Package (DDP) or the Project File (PF)] is on the following web site: http://www.wsdot.wa.gov/eesc/design/projectdev/

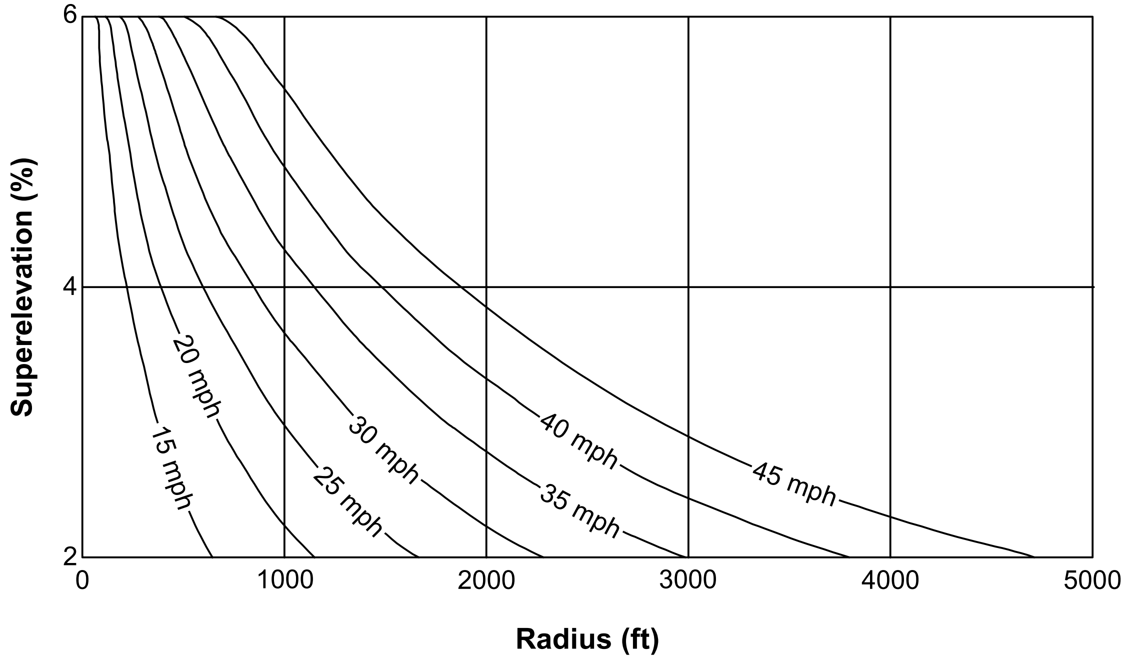


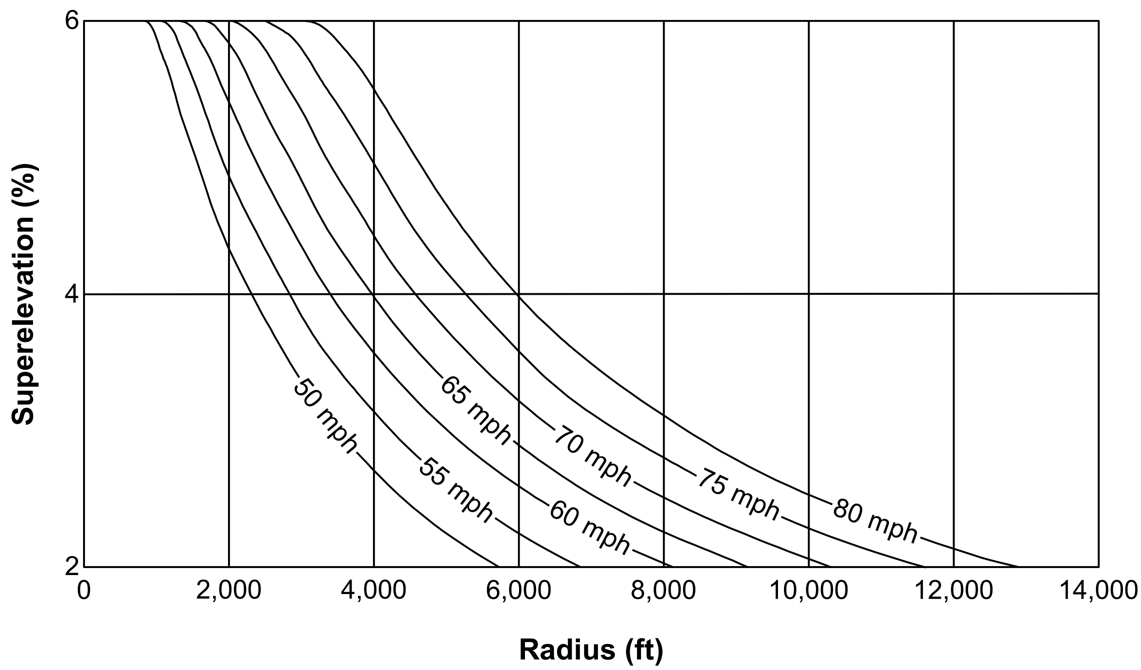


Design Speed (mph)	15	20	25	30	35	40	45	50	55	60	65	70	75	80
Minimum Radius (ft)	55	100	160	235	325	430	555	700	880	1095	1345	1640	1980	2380

Superelevation Rates (10% max)

Figure 642-3a

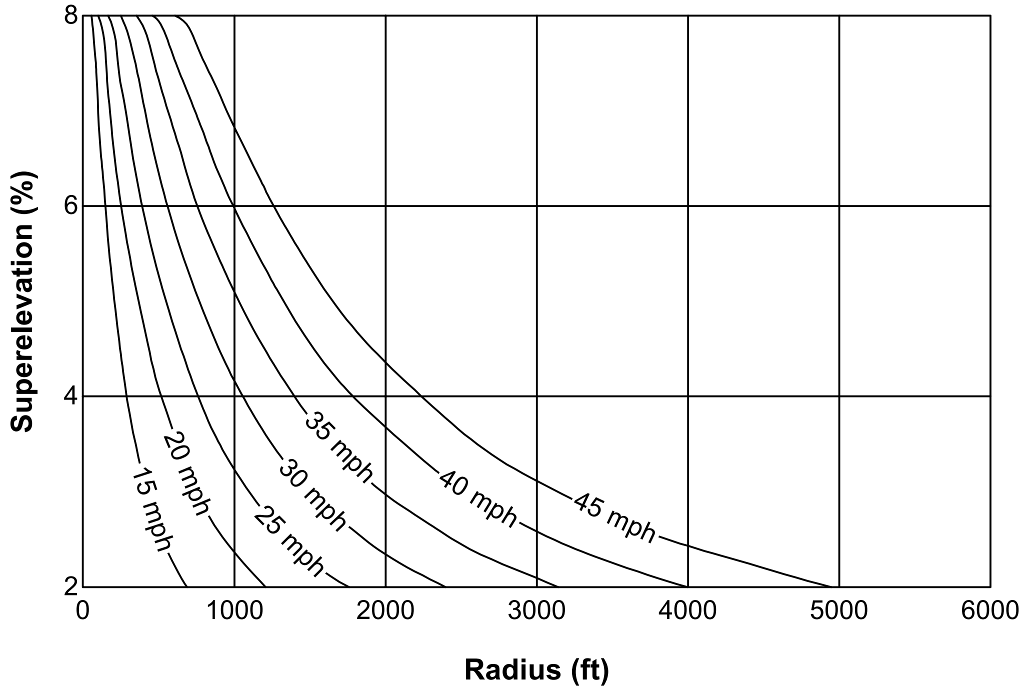


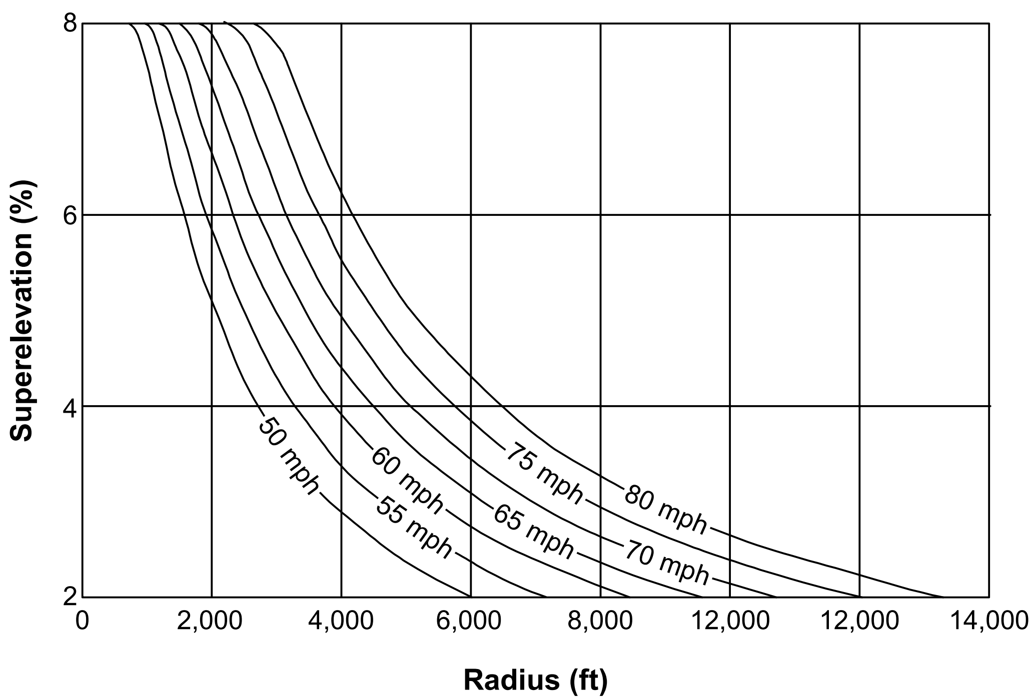


Design Speed (mph)	15	20	25	30	35	40	45	50	55	60	65	70	75	80
Minimum Radius (ft)	65	120	190	270	385	510	660	840	1065	1340	1665	2050	2510	3055

Superelevation Rates (6% max)

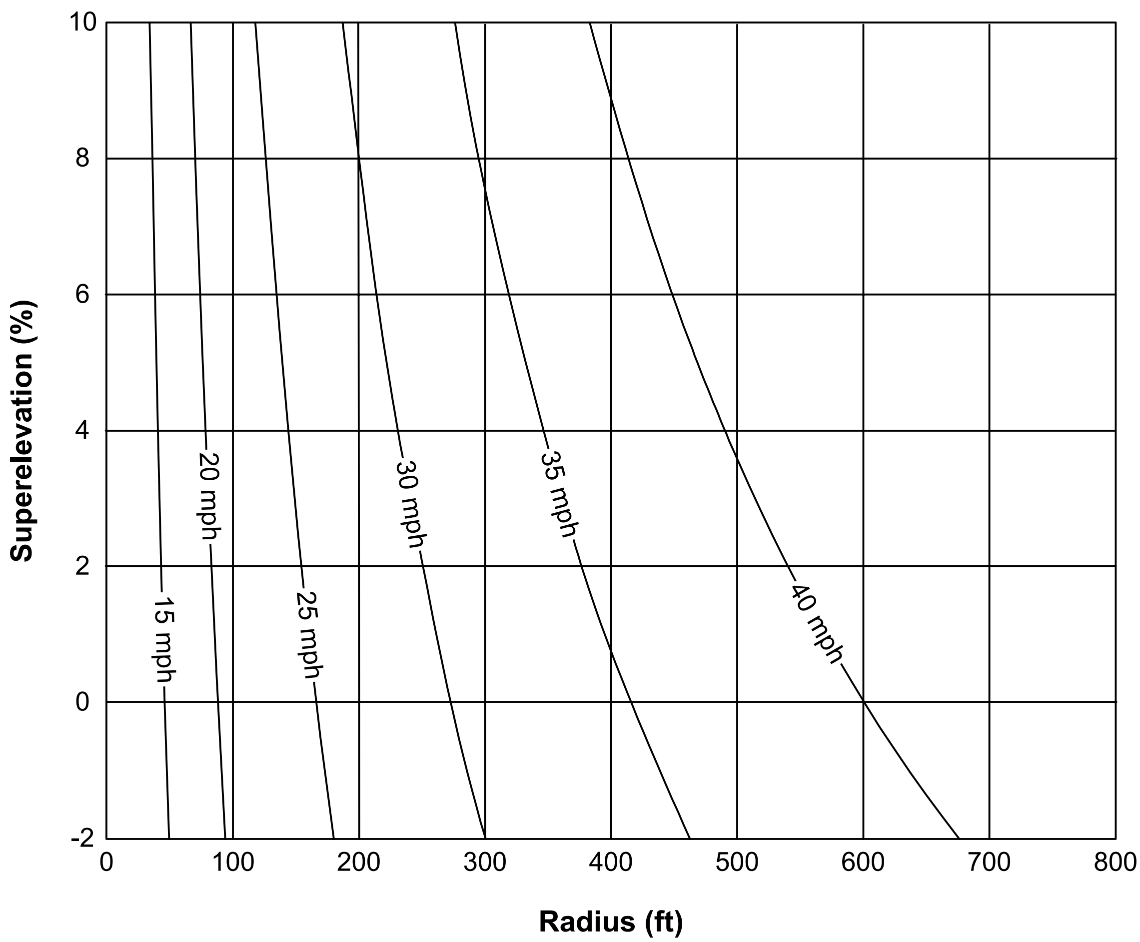
Figure 642-3b





Design Speed (mph)	15	20	25	30	35	40	45	50	55	60	65	70	75	80
Minimum Radius (ft)	60	110	175	255	350	465	605	760	965	1205	1490	1820	2215	2675

Superelevation Rates (8% max)
Figure 642-3c

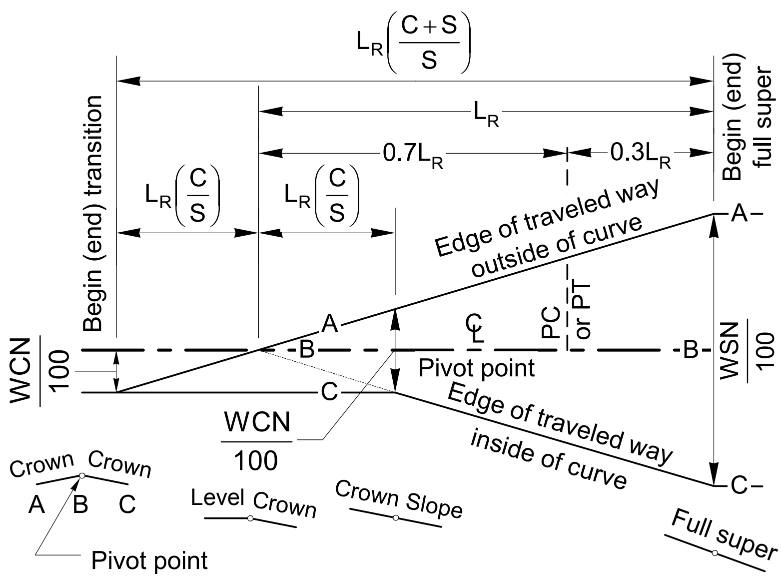


Superelevation Rates for Low-Speed Urban Managed Access Highways
Figure 642-4

S (%)	L_B=Basic runoff in feet for Design Speed of:													
	15 mph	**20 mph**	**25 mph**	**30 mph**	**35 mph**	**40 mph**	**45 mph**	**50 mph**	**55 mph**	**60 mph**	**65 mph**	**70 mph**	**75 mph**	**80 mph**
2	30	30	35	35	40	40	45	50	50	55	55	60	65	70
3	45	50	50	55	60	60	65	70	75	80	85	90	95	105
4	60	65	70	75	75	85	90	95	100	105	110	120	125	135
5	75	80	85	90	95	105	110	120	130	135	140	150	160	170
6	90	95	105	110	115	125	135	145	155	160	170	180	190	205
7	110	115	120	130	135	145	155	170	180	185	195	210	220	240
8	125	130	135	145	155	165	180	190	205	215	225	240	250	275
9	140	145	155	165	175	185	200	215	230	240	250	270	285	310
10	155	160	170	180	195	205	220	240	255	265	280	300	315	345

* Based on one 12 ft lane between the pivot point and the edge of traveled way. When the distance exceeds 12 ft use the following equation to obtain L_R:
$L_R = L_B(1+0.04167X)$

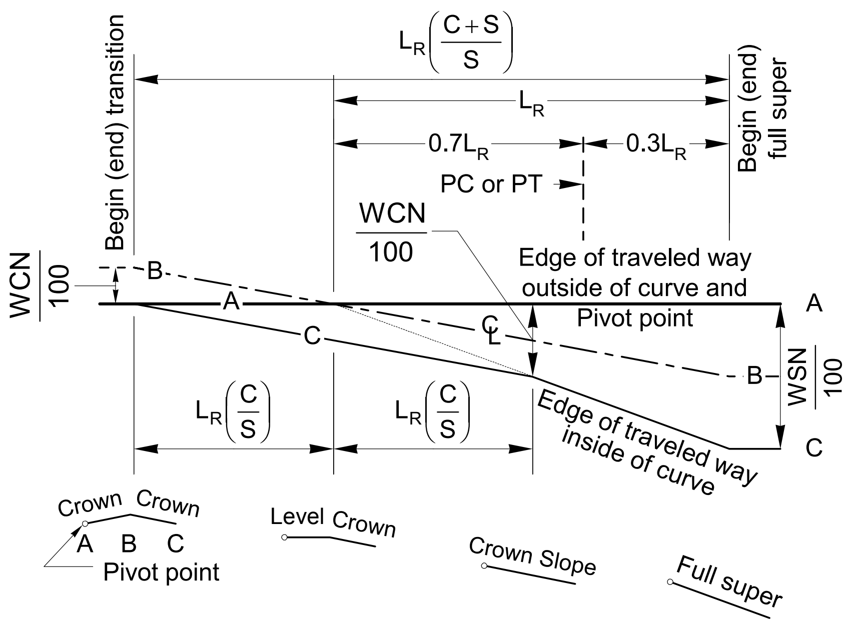
Where:
X = The distance in excess of 12 ft between the pivot point and the furthest edge of traveled way, in feet



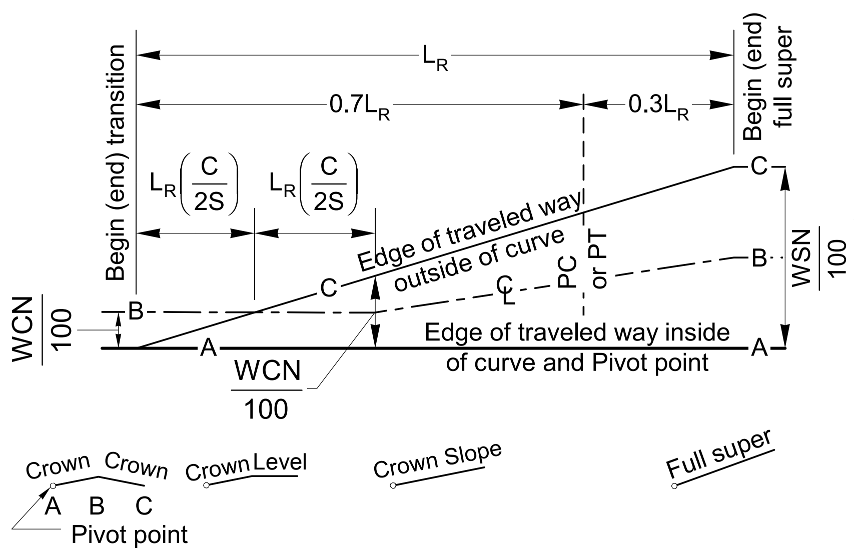
Design A Pivot Point on Center Line
Crown Section

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

Superelevation Transitions for Highway Curves
Figure 642-5a



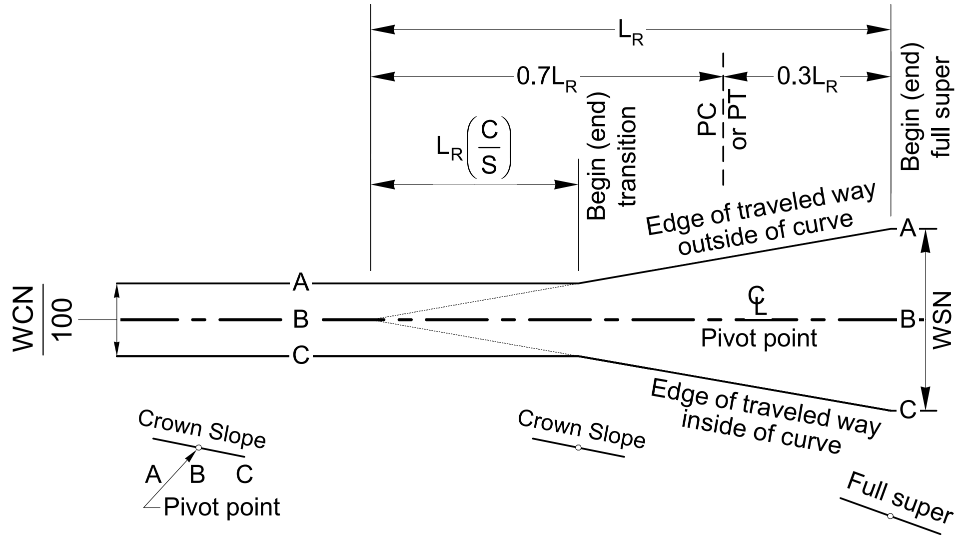
Design B[1] Pivot Point on Edge of Traveled Way
Outside of Curve Crowned Section



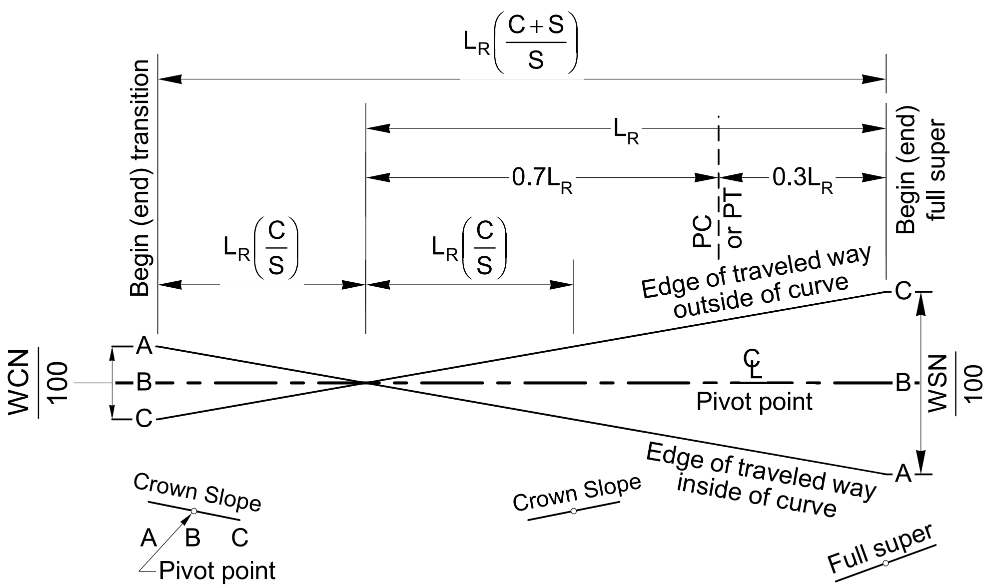
Design B[2] Pivot Point on Edge of Traveled Way
Inside of Curve Crowned Section

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

Superelevation Transitions for Highway Curves
Figure 642-5b



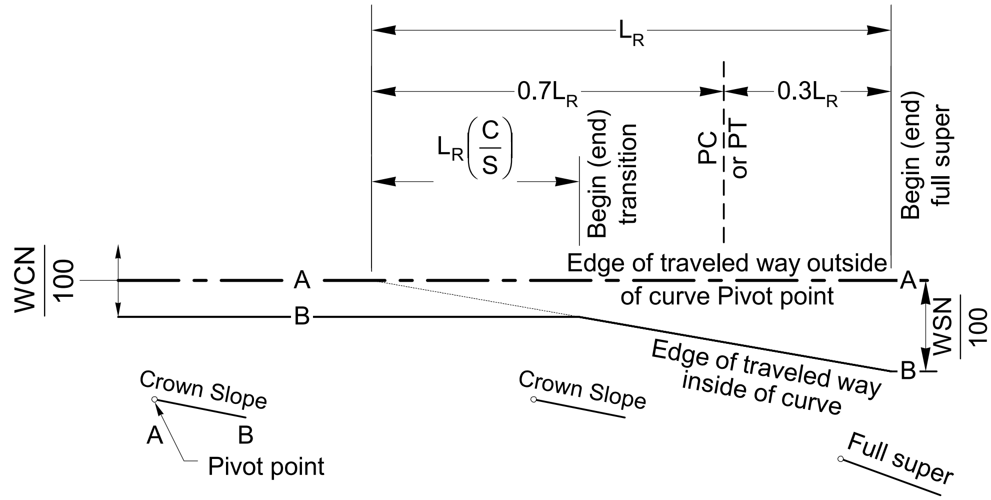
Design C^1 Pivot point on center line curve in direction of normal pavement slope - plane section



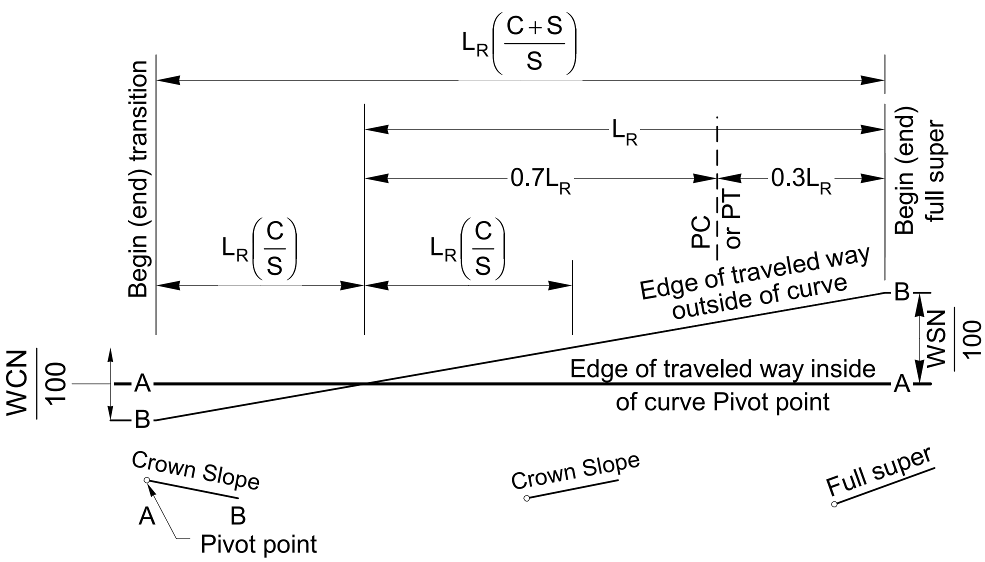
Design C^2 Pivot point on center line curve opposite to normal pavement slope - plane section

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

Superelevation Transitions for Highway Curves
Figure 642-5c



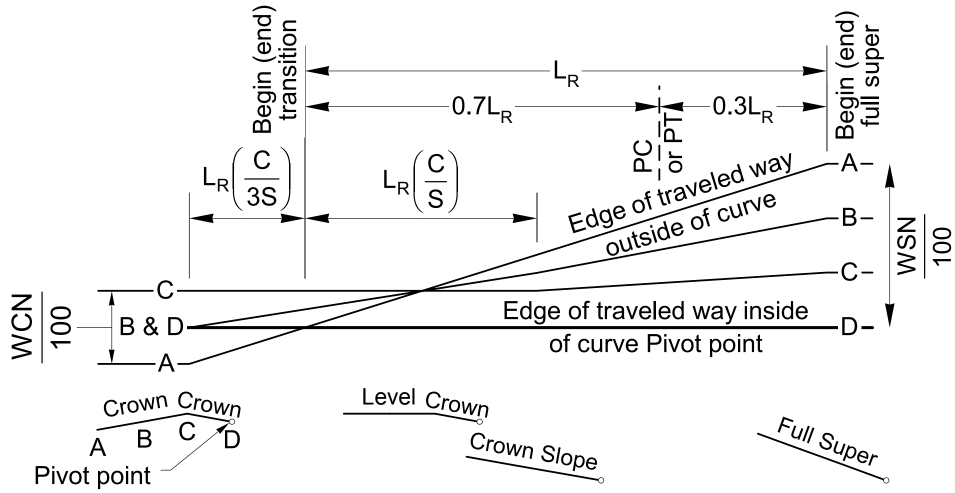
Design D[1] Pivot point on edge of traveled way curve in direction of normal pavement slope - plane section



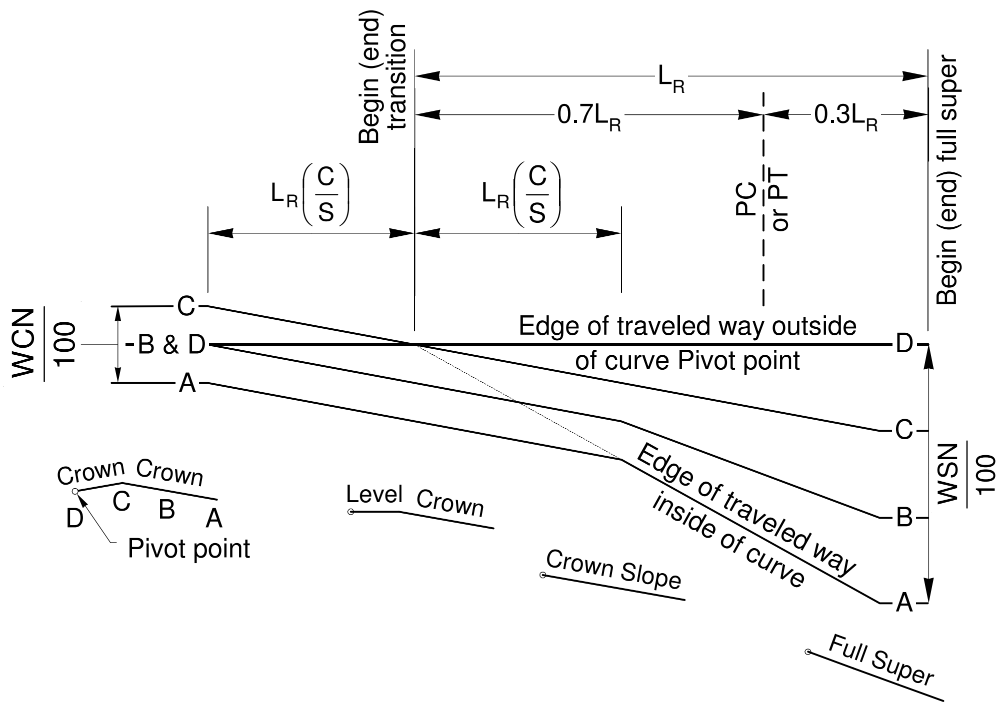
Design D[2] Pivot point on <u>edge of traveled way</u> curve opposite to normal pavement slope - plane section

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

Superelevation Transitions for Highway Curves
Figure 642-5d



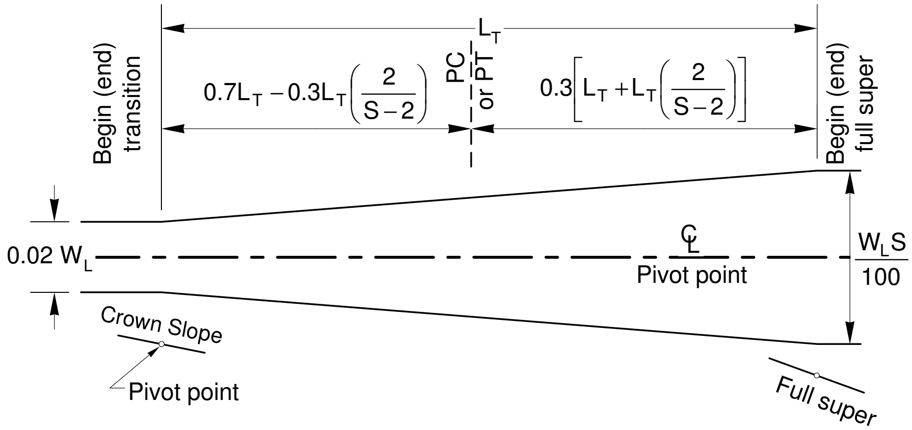
Design E[1] Six lane with median, pivot point on edge of traveled way inside of curve crown section



Design E[2] Six lane with median, pivot point on edge of traveled way outside of curve crown section

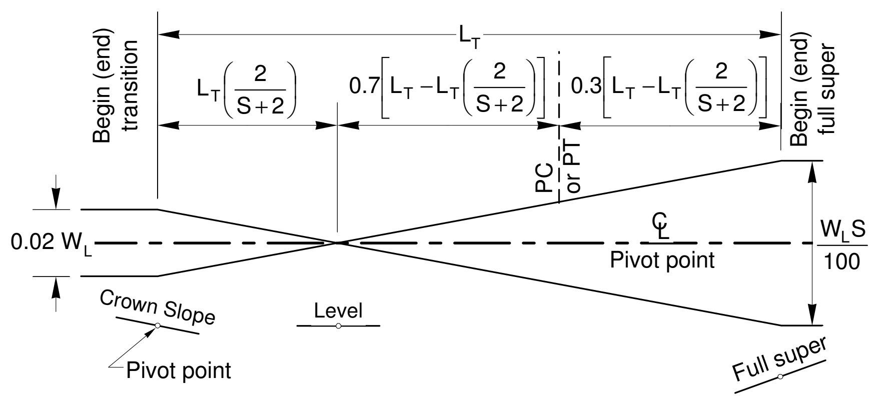
C = Normal crown(%)
S = Superelevation rate (%)
N = Number of lanes between points
W = Width of lane

Superelevation Transitions for Highway Curves
Figure 642-5e



S (%)	Length of transition in feet for Design Speed of:							
	20 mph	25 mph	30 mph	35 mph	40 mph	45 mph	50 mph	55 mph
	L_T	L_T	L_T	L_T	L_T	L_T	L_T	L_T
3	10	15	15	15	15	15	15	15
4	20	25	25	25	25	30	30	35
5	30	35	35	35	40	45	45	50
6	40	45	45	50	55	55	60	65
7	50	55	55	60	65	70	75	80
8	60	65	70	75	80	85	90	95
9	70	75	80	85	95	100	105	110
10	80	85	90	100	105	115	120	130

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

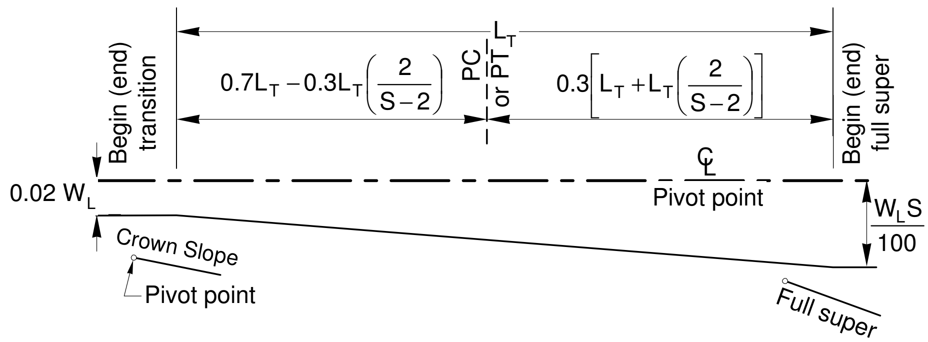


S (%)	Length of transition in feet for Design Speed of:							
	20 mph	25 mph	30 mph	35 mph	40 mph	45 mph	50 mph	55 mph
	L_T	L_T	L_T	L_T	L_T	L_T	L_T	L_T
2	40	40	45	50	55	55	60	65
3	50	55	55	60	65	70	75	80
4	60	65	70	75	80	85	90	95
5	70	75	80	85	90	100	105	110
6	80	85	90	95	105	115	120	130
7	90	95	100	110	120	125	135	145
8	100	105	115	120	130	140	150	160
9	110	120	125	135	145	155	165	175
10	120	130	135	145	160	170	180	190

Table 2 Pivot Point on Center Line — Curve in Direction Opposite to Normal Pavement Slope
W_L=width of ramp lane.

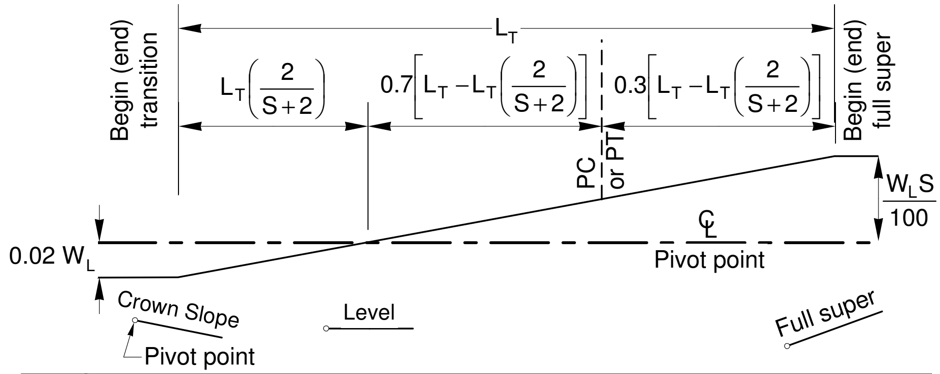
Superelevation Transitions for Ramp Curves

Figure 642-6a



S (%)	Length of transition in feet for Design Speed of:							
	20 mph	25 mph	30 mph	35 mph	40 mph	45 mph	50 mph	55 mph
	L_T	L_T	L_T	L_T	L_T	L_T	L_T	L_T
3	20	25	25	25	25	30	30	35
4	40	45	45	50	55	55	60	65
5	60	65	70	75	80	85	90	95
6	80	85	90	100	105	115	120	130
7	100	105	115	120	130	140	150	160
8	120	130	135	145	160	170	180	190
9	140	150	160	170	185	195	210	225
10	160	170	180	195	210	225	240	255

Table 3 Pivot point on edge of traveled way — curve in direction of normal pavement slope



S (%)	Length of transition in feet for Design Speed of:							
	20 mph	25 mph	30 mph	35 mph	40 mph	45 mph	50 mph	55 mph
	L_T	L_T	L_T	L_T	L_T	L_T	L_T	L_T
2	80	85	90	100	105	115	120	130
3	100	105	115	120	130	140	150	160
4	120	130	135	145	160	170	180	190
5	140	150	160	170	185	195	210	225
6	160	170	180	195	210	225	240	255
7	180	190	205	220	235	255	270	290
8	200	210	225	245	265	280	300	320
9	220	235	250	265	290	310	330	350
10	240	255	270	290	315	340	360	385

Table 4 Pivot point on edge of traveled way — curve in direction opposite to normal pavement slope
W_L=width of ramp lane.

Superelevation Transitions for Ramp Curves
Figure 642-6b

Chapter 710 Traffic Barriers

710.01 General

Traffic barriers are used to reduce the severity of accidents that occur when an errant vehicle leaves the traveled way. However, traffic barriers are obstacles that the vehicle will encounter and must only be used when justified by accident history or the criteria in Chapter 700.

710.02 References

Roadside Design Guide, AASHTO

Bridge Design Manual, M 23-50, WSDOT

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

Traffic Manual, M 51-02, WSDOT

710.03 Definitions

barrier terminal A 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. Beam guardrail terminals include anchorage.

controlled releasing terminal (CRT) post A standard length guardrail post that has two holes drilled through it so that it will break away when struck.

crashworthy A feature that has been proven acceptable for use under specified conditions either through crash testing or in-service performance.

guardrail transition A section of barrier used to produce a gradual stiffening of a flexible or semirigid barrier as it connects to a more rigid barrier or fixed object.

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

impact attenuator system A device that acts primarily to bring an errant vehicle to a stop at a deceleration rate tolerable to the vehicle occupants or to redirect the vehicle away from a hazard.

length of need The length of a traffic barrier needed to shield a hazard.

longitudinal barrier Traffic barrier oriented parallel or nearly parallel to the roadway. The purpose is to contain or redirect errant vehicles. Beam guardrail, cable barrier, bridge rail, and concrete barrier are longitudinal barriers. Longitudinal barriers are categorized as rigid, unrestrained rigid, semirigid, and flexible. They can be installed as roadside or median barriers.

shy distance The distance from the edge of the traveled way beyond which a roadside object will not be perceived as an immediate hazard by the typical driver to the extent that the driver will change the vehicle's placement or speed.

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.

710.04 Project Requirements

This section identifies the barrier elements that must be addressed according to the Design Matrices in Chapter 325. Remove any barrier that is not needed (based on the criteria in Chapter 700) or poses a more severe hazard than the hazard it is shielding.

(1) Barrier Terminals and Transitions

Install, replace, or upgrade transitions as discussed in 710.06(3), Transitions and Connections.

Impact attenuators must meet the requirements found in Chapter 720, Impact Attenuators.

When installing new terminals, consider extending the guardrail to meet the length of need criteria in 710.05(4) as a spot safety enhancement.

Concrete barrier terminals must meet the requirements found in 710.08(2). When the end of a concrete barrier has been terminated with a small mound of earth (a design formerly known as a Concrete Barrier Berm), remove and replace with a crashworthy terminal, except as noted in 710.09.

Redirectional land forms, also referred to as earth berms, were installed to mitigate hazards located in depressed medians and at roadsides. They were constructed of materials that provided support for a traversing vehicle. With slopes in the range of 2H:1V to 3H:1V, they were intended to redirect errant vehicles. The use of redirectional land forms has been discontinued as a means for mitigating fixed objects. Where redirectional land forms currently exist as mitigation for a fixed object, ensure that the hazard they were intended to mitigate is removed, relocated, made crashworthy, or shielded with barrier. Landforms may be used to provide a smooth surface at the base of a rock cut slope.

Replace guardrail terminals that do not have a crashworthy design with crashworthy guardrail terminals. See 710.06(2), Terminals and Anchors. Common features of noncrashworthy designs:

- No cable anchor.
- A cable anchored into concrete in front of the first post.
- Second post not breakaway (CRT).
- Design A end section. (Design C end sections may be left in place.)
- Beam guardrail on both sides of the posts (two sided).
- Buried guardrail terminals that slope down such that the guardrail height is reduced to less than 2 feet.

One terminal that was used extensively on Washington's highways was the Breakaway Cable Terminal (BCT). This system used a parabolic flare similar to the SRT and a Type 1 anchor. Type 1 anchor posts are wood set in a steel tube or a concrete foundation.

Replace BCTs on Interstate routes. On non-Interstate routes BCTs that have at least a 3 foot offset may remain in place unless the guardrail run or anchor is being reconstructed or reset. (Raising the rail element is not considered reconstruction or resetting.) Replace all BCTs that have less than a 3 foot offset.

Existing transitions that do not have a curb but are otherwise consistent with the designs shown in the Standard Plans may remain in place.

For preservation projects, terminal and transition work may be programmed under a separate project as described in Chapter 410.

(2) Standard Run of Barrier

In Chapter 325, the matrices have Design Elements "Standard Run" under Barriers. A "Standard Run" of barrier consists of longitudinal barrier that can be found in the Standard Plans manual.

(a) **Basic Design Level (B).** When the basic design level (B) is indicated in the Standard Run column of a Design Matrix and the height of W-beam guardrail is or would be reduced to less than 2 feet from the ground to the top of the rail element, adjust the height to that shown in the Standard Plans. If Type 1 Alternate W-beam guardrail is present, raise the rail element after each overlay.

Overlays in front of safety shaped concrete barriers can extend to the top of the lower, near-vertical face of the barrier before adjustment is required. Allow no more than 1 foot-1 inch from the pavement to beginning of the top near-vertical face on either the F or NJ shape barriers. Allow no less than 2 feet-8 inches from the pavement to the top of the single slope barrier. Allow no less than 2 feet-3 inches from the ground to the top cable of the Type 1 cable barrier and no less than 2 feet-6 inches for the Type 2 and Type 3 cable barrier.

(b) **Full Design Level (F).** When the full design level (F) is indicated, in addition to the requirements for the basic design level, the barrier must meet the requirements found in the following:

700.06	Median Considerations
710.05(1)	Shy Distance
710.05(2)	Barrier Deflections
710.05(3)	Flare Rate
710.05(4)	Length of Need
710.05(5)	Median Barrier Selection and Placement Considerations
710.06	Beam Guardrail
710.07	Cable Barrier
710.08	Concrete Barrier

Examples of barriers that are not acceptable as a "standard run" are:

- W-beam guardrail with 12 foot-6 inch post spacing and no blockouts.
- W-beam guardrail on concrete posts.
- Cable barrier on wood or concrete posts.
- Half-moon or C shape rail elements.

(3) Bridge Rail

When the Bridge Rail column of a matrix applies to the project, the bridge rails must meet the following requirements:

Use an approved, crash tested concrete bridge rail on new bridges or bridges to be widened. The *Bridge Design Manual* provides examples of typical bridge rails. Consult the HQ Bridge and Structures Office regarding bridge rail selection and design and for design of the connection to an existing bridge.

An existing bridge rail on a highway with a posted speed of 30 mph or less may remain in place if it is not located on a bridge over a National Highway System (NHS) highway. When Type 7 bridge rail is present on a bridge over a NHS highway with a posted speed of 30 mph or less it may remain in place, regardless of the type of metal rail installed. All other bridge rails must be evaluated for strength and geometrics. See 710.11 for guidance on retrofit techniques. The funding source for retrofit of existing bridge rail is dependent on the length of the structure. Bridge rail retrofit, for bridges less than 250 feet in length (or a total bridge rail length of 500 feet), is funded by the project (Preservation or Improvement). For longer bridges, the retrofit can be funded by the I2 subprogram. Contact programming personnel to determine if funding is available.

The Type 7 bridge rail is common. Type 7 bridge rails have a curb, a vertical-face parapet, and an aluminum top rail. The curb width and the type of aluminum top rail dictate the adequacy of the Type 7 bridge rail as shown on Figure 710-1. Consult the HQ Bridge and Structures Office for assistance in evaluating other bridge rails.

710.05 Barrier Design

When selecting a barrier, consider the flexibility, cost, and maintainability of the system. It is generally desirable to use the most flexible system possible to minimize damage to the impacting vehicle and injury to the vehicle's occupant(s). However, since nonrigid systems sustain more damage during an impact, the exposure of maintenance crews to traffic might be increased.

Concrete barrier maintenance costs are lower than for other barrier types. Deterioration due to weather and vehicle impacts is limited. Unanchored precast concrete barrier can usually be realigned or repaired when moved from its alignment. However, heavy equipment may be required to reposition or replace barrier segments. Therefore, in medians, consider the shoulder width and the traffic volume when determining the acceptability of unanchored precast concrete barrier versus a rigid concrete barrier.

Drainage, alignment, and drifting snow or sand are considerations that can influence the selection of barrier type. Beam guardrail and concrete barrier can contribute to snow drifts. Consider long-term maintenance costs associated with snow removal at locations prone to snow drifting. Slope flattening is highly recommended, even at additional cost, to eliminate the need for the barrier. Cable barrier is not an obstruction to drifting snow and can be used if slope flattening is not practical.

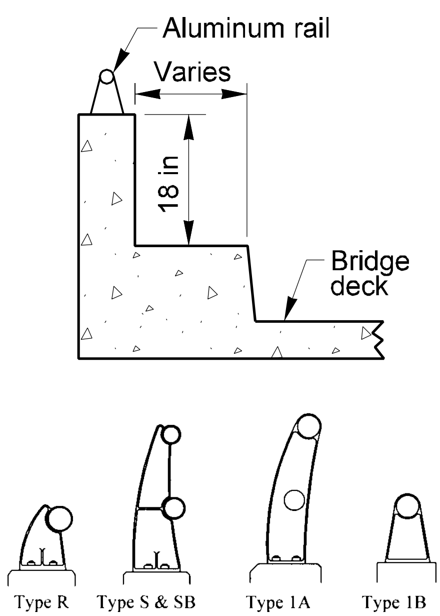
When designing a barrier for use on a Scenic Byway or Heritage Tour Route (formerly Scenic and Recreational Highway), consider barriers that are consistent with the recommendations in the associated Corridor Management Plan (if one is available). Contact the region's Landscape Architect or the Headquarters' Scenic Byways (formerly known as Heritage Corridors) Program manager to determine if the project is on such a designated route. Low cost options, such as using weathering steel beam guardrail (710.06) or cable barrier (710.07) might be feasible on many projects. Higher cost options, such as steel backed timber rail and stone guardwalls (710.09) might require a partnering effort to fund the additional costs. Grants might be available for this purpose if the need is identified early in the project definition phase. (See Chapter 120.)

(1) Shy Distance

Provide 2 feet of additional widening for shy distance when a barrier is to be installed in areas where the roadway is to be widened and the shoulder width will be less than 8 feet. This shy distance is not required when the section of roadway is not being widened or the shoulders are at least 8 feet wide.

(2) Barrier Deflections

All barriers except rigid barriers (concrete bridge rails for example) will deflect when hit by an errant vehicle. The amount of deflection is primarily dependent on the stiffness of the system. Vehicle speed, angle of impact, and weight also affect the amount of barrier deflection. For flexible and semirigid roadside barriers, the deflection distance is designed



	Curb Width	
Aluminum Rail Type	9 inches or less	Greater than 9 inches*
Type R, S, or SB	Bridge rail adequate	Bridge rail adequate
Type 1B or 1A	Bridge rail adequate	Upgrade bridge rail
Other	Consult the HQ Bridge and Structures Office	

* When the curb width is greater than 9 inches, the aluminum rail must be able to withstand a 5 kip load.

Type 7 Bridge Rail Upgrade Criteria
Figure 710-1

to prevent the impacting vehicle from striking the object being shielded. For unrestrained rigid systems (unanchored precast concrete barrier), the deflection distance is designed to prevent the barrier from being knocked over the side of a drop-off or steep fill slope (2H:1V or steeper).

In median installations, the deflected system must not become a hazard to oncoming traffic. In addition, narrow medians provide little space for maintenance crews to repair or reposition the barrier. Avoid installing deflecting barriers in medians that provide less than 8 feet from the edge of the traveled way to the face of the barrier.

Use a rigid system where deflection cannot be tolerated such as in narrow medians or at the edge of a bridge deck (vertical drop-off). Runs of rigid concrete barrier can be cast-in-place, extruded with appropriate footings, or, for precast concrete barrier, anchored to the underlying material.

See Figure 710-2 for barrier deflection design values to be used when selecting a longitudinal barrier. The deflection distances for cable and beam guardrail are the minimum measurements from the face of the barrier to the hazard. The deflection distance for unanchored concrete barrier is the minimum measurement from the back edge of the barrier to the drop-off or slope break.

(3) Flare Rate

Flare the ends of longitudinal barriers where possible. There are four functions of the flare:

- To locate the barrier and its terminal as far from the traveled way as is feasible.
- To reduce the length of need.
- To redirect an errant vehicle without serious injuries to its occupants.
- To minimize a driver's reaction to the introduction of an object near the traveled way.

Keeping flare rates as flat as practical preserves the barrier's redirectional performance and minimizes the angle of impact. But, it has been shown that an object (or barrier) close to the traveled way might cause a driver to shift laterally, slow down, or both. The flare reduces this reaction by gradually introducing the barrier so that the driver does not perceive the barrier as a hazard. The flare rates in Figure 710-3 satisfy all four functions listed above. More gradual flares may be used. Flare rates are offset parallel to the edge of traveled way. Transition sections are not normally flared.

Barrier Type	System Type	Deflection
Cable barrier or beam guardrail on G-2 posts	Flexible	up to 12 ft (face of barrier to object)
Beam guardrail Types 1, 1a, 2, and 10	Semirigid	3 ft (face of barrier to object)
Two-sided W-beam guardrail Types 3 and 4	Semirigid	2 ft (face of barrier to object)
Permanent concrete barrier, unanchored	Unrestrained Rigid	3 ft (1) (back of barrier to object)
Temporary concrete barrier, unanchored	Unrestrained Rigid	2 ft (2) (back of barrier to object)
Concrete barrier, anchored	Rigid	no deflection

(1) When placed in front of a 2H:1V or flatter fill slope, the deflection distance can be reduced to 2 ft.

(2) When used as temporary bridge rail, anchor all barrier that is within 3 ft of a drop-off.

Longitudinal Barrier Deflection

Figure 710-2

Posted Speed mph	Rigid System	Unrestrained Rigid System	Semirigid System
70	20:1	18:1	15:1
60	18:1	16:1	14:1
55	16:1	14:1	12:1
50	14:1	12:1	11:1
45	12:1	11:1	10:1
40 or below	11:1	10:1	9:1

Longitudinal Barrier Flare Rates
Figure 710-3

(4) Length of Need

The length of traffic barrier required to shield a hazard (length of need) is dependent on the location and geometrics of the hazard, direction(s) of traffic, posted speed, traffic volume, and type and location of traffic barrier. When designing a barrier for a fill slope as recommended in Chapter 700, the length of need begins at the point where barrier is recommended. For fixed objects and water hazards, Figures 710-11a and b show design parameters for determining the necessary length of a barrier for both adjacent and opposing traffic on relatively straight sections of highway. When the barrier is to be installed on the outside of a horizontal curve, the length of need can be determined graphically as shown on Figure 710-11c. For installations on the inside of a curve, determine the length of need as though it was straight. Consider the flare rate, barrier deflection, and barrier end treatment to be used when determining the length of need. When beam guardrail is placed in a median, consider the potential for impact from opposing traffic when conducting a length of need analysis. When guardrail is placed on either side of objects in the median, consider whether the trailing end of each run of guardrail will shield the leading end of the opposing guardrail. Shield the leading end when it is within the clear zone of opposing traffic. (See figure 710-11d.)

Before the actual length of need is determined, establish the lateral distance between the proposed barrier installation and the item shielded. This distance must be greater than or equal to the anticipated deflection of the longitudinal barrier. (See Figure 710-2 for barrier deflections.) Place the barrier as far from the edge of the traveled way as possible while maintaining the deflection distance.

If the end of the length of need is near an adequate cut slope, extend the barrier and embed it in the slope. (See 710.06(2)(a).) Avoid gaps of 300 feet or less. Short gaps are acceptable when the barriers are terminated in a cut slope. If the end of the length of need is near the end of an existing barrier, it is recommended that the barriers be connected to form a continuous barrier. Consider maintenance access when determining whether to connect barriers.

(5) Median Barrier Selection and Placement Considerations

As with all barriers, the most desirable installation uses a system that is the most flexible system appropriate for the location and is placed as far from the traveled way as practical. With median barriers, the deflection characteristics and placement of the barrier for a traveled way in one direction can have an impact on the traveled way in the opposing direction. In addition, the median slopes and environmental issues might influence the type of barrier that is appropriate.

In narrow medians, the deflected system must not become a hazard to oncoming traffic. In addition, narrow medians provide little space for maintenance crews to repair or reposition the barrier. Avoid installing deflecting barriers in medians that provide less than 8 feet from the edge of the traveled way to the face of the barrier. In wider medians, the selection of barrier might depend on the slopes in the median.

At locations where the median slopes are relatively flat (10H:1V or flatter), unrestrained precast concrete barrier, beam guardrail, and cable barrier can be used depending on the available deflection distance. At these locations, position the barrier as close to the center as possible so that the recovery distance can be maximized for both directions. It might be necessary to offset the barrier from the flow line to avoid impacts to the drainage flow. Cable barrier is recommended with medians that are 30 feet or wider. For medians wider than 30 feet, provide justification for placing a barrier closer than 15 feet from the edge of a traveled way.

In wide medians where the slopes are steeper than 10H:1V but not steeper than 6H:1V, cable barrier placed near the center of the median is preferred. Placement of beam guardrail requires that the barrier be placed at least 12 feet from the slope break as is shown on Figure 710-4. Do not use concrete barrier at locations where the foreslope into the face of the barrier is steeper than 10H:1V.

At locations where the roadways are on independent alignments and there is a difference in elevation between the roadways, the slope from the upper roadway might be steeper than 6H:1V. In these locations, position the median barrier along the upper roadway and provide deflection and offset distance as discussed previously. Barrier is generally not necessary along the lower roadway except where there are fixed objects in the median.

710.06 Beam Guardrail

(1) Beam Guardrails

Beam guardrail systems are shown in the Standard Plans.

Strong post W-beam guardrail (Types 1 through 4) and thrie beam guardrail (Types 10 and 11) are semirigid barriers used predominately on roadsides. They also have limited application as median barrier. Installed incorrectly, strong post beam guardrail can cause vehicle snagging or spearing. This can be avoided by lapping the rail splices in the direction of traffic as shown in the Standard Plans, by using crashworthy end treatments, and by blocking the rail away from the strong posts. Do not use more than two 8 inch blockouts.

On highways that are constructed of hot mix asphalt (where overlays are anticipated), the Type 1 Alternate guardrail can be used to allow raising of the guardrail without having to adjust the posts.

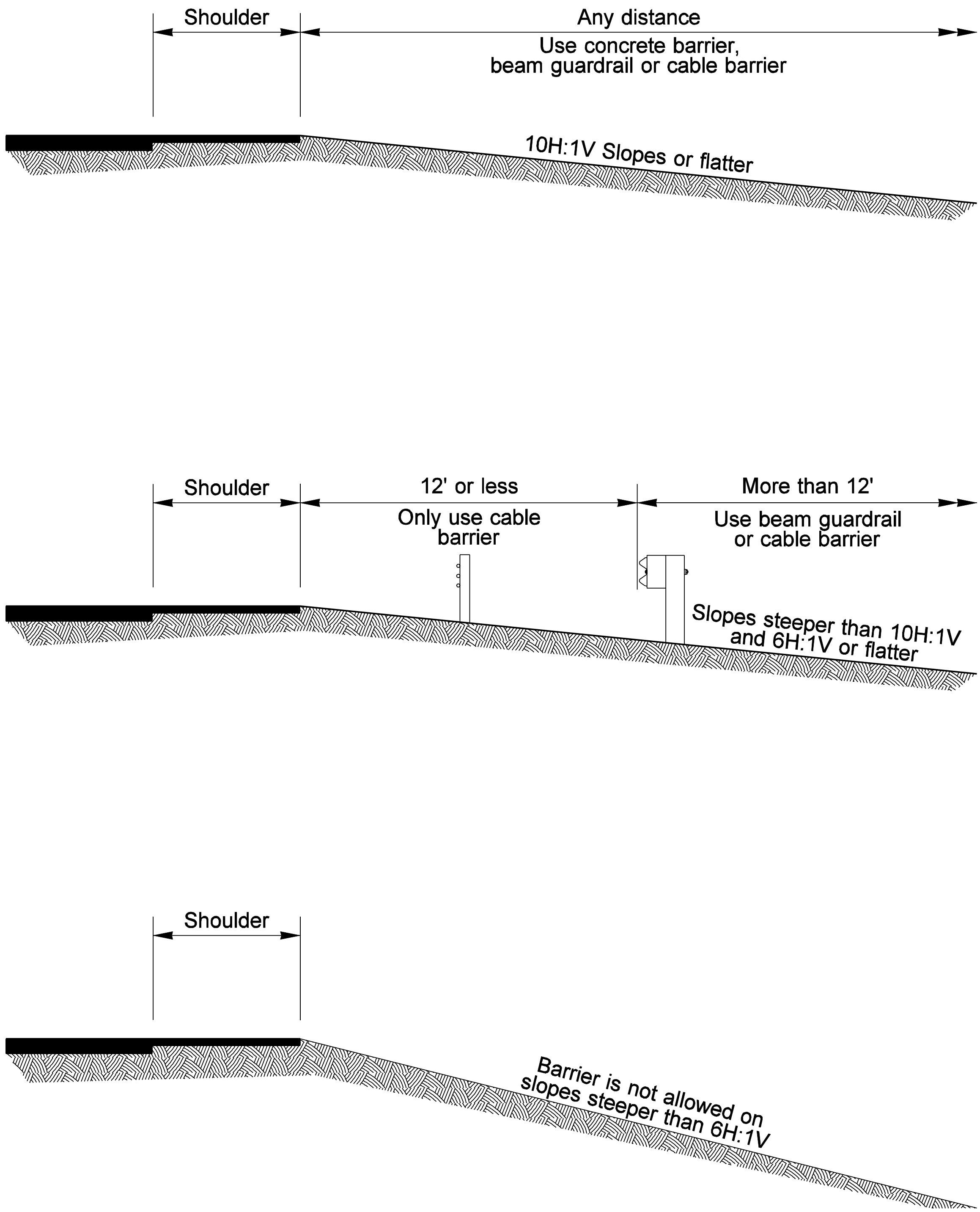
Weak post W-beam guardrail (Type 20) and thrie beam guardrail (Type 21) are flexible barrier systems that can be used where there is adequate deflection distance. These systems use weak steel posts. The primary purpose of these posts is to position the guardrail vertically and they are designed to bend over when struck. These more flexible systems will result in less damage to the impacting vehicle. Since the weak posts will not result in snagging, blockouts are not necessary.

Keep the slope of the area between the edge of shoulder and the face of the guardrail 10H:1V or flatter. Do not place beam guardrail on a fill slope steeper than 6H:1V. On fill slopes between 6H:1V and 10H:1V, beam guardrail must not be placed within 12 feet of the break point. (See Figure 710-4.)

On the high side of superelevated sections, place beam guardrail at the edge of shoulder.

Generally, 2 feet of shoulder widening behind the barrier is provided from the back of the post to the beginning of a fill slope. If the slope is 2H:1V or flatter, this distance can be measured from the face of the guardrail rather than the back of the post. (See Figure 710-12, Case 1.)

On projects where no roadway widening is proposed and the minimum 2 foot shoulder widening behind the barrier is not practical, long post installations are available as shown on Figure 710-12, Cases 3, 4, 5, and 6. When guardrail is to be installed in areas where the roadway is to be widened, the use of Cases 4, 5, or 6 requires a design deviation.



Traffic Barrier Locations on Slopes

Figure 710-4

Rail washers on beam guardrail are not normally used. If rail washers are present, they are not required to be removed. However, if the rail element is removed for any reason, do not reinstall the rail washers. In areas where heavy snow accumulations are expected to cause the bolts to pull out, specify snow load post and rail washers in the contract documents. (Snow load post washers are used to prevent the bolts from pulling through the posts and snow load rail washers are used to prevent the bolt head from pulling through the rail.) Rail washers are never to be used within the limits of a guardrail terminal except at the end post where they are required for anchorage of the rail.

The use of curb in conjunction with beam guardrail is discouraged. However, if a curb is necessary, the 3 inch high curb is preferred. The 4 inch high curb can only be used at locations where the 3 inch curb will not be adequate. In new installations, do not use 6 inch high curb in conjunction with beam guardrails. Existing 6 inch high curb is allowed to remain in place. If work requires replacement of an existing 6 inch curb, it must be replaced with a 3 inch or 4 inch curb, whichever is appropriate.

When used in conjunction with beam guardrail, locate curb behind the face of the rail element as shown in the Standard Plans.

Beam guardrail is usually galvanized and has a silver color. It can also be provided in a weathering steel that has a brown or rust color. Weathering steel guardrail might be desirable on Scenic Byways or Heritage Tour Routes. (See 710.05.)

(2) Terminals and Anchors

A guardrail anchor is required at the end of a run of guardrail to develop its tensile strength throughout its length. In addition, when the end of the guardrail is subject to head-on impacts, a crashworthy guardrail terminal is required. (See the Standard Plans.)

(a) **Buried Terminals.** The buried terminal (BT) is designed to terminate the guardrail by burying the end in a backslope. The BT is the preferred terminal because it eliminates the exposed end of the guardrail.

The BT uses a Type 2 anchor to develop the tensile strength in the guardrail. The entire BT can be used within the length of need.

The backslope required to install a BT must be 3H:1V or steeper and at least 4 feet in height above the roadway. Flare the guardrail into the backslope using a flare rate that meets the criteria in 710.05(3). Provide a 10H:1V or flatter foreslope into the face of the guardrail (and up to 4H:1V in the ditch section of the Type 2 buried terminal) and maintain the full guardrail height to the foreslope/backslope intersection. This might require filling ditches and installing culverts in front of the guardrail face.

(b) **Flared Terminal.** If a BT cannot be installed as described above, consider a flared terminal. (See Figure 710-13.) There are currently two acceptable sole source proprietary designs: the Slotted Rail Terminal (SRT) and the Flared Energy Absorbing Terminal (FLEAT). Both of these designs include an anchor for developing the tensile strength of the guardrail. The length of need begins at the third post for both flared terminals.

1. The SRT uses W-beam guardrail with slots cut into the corrugations and wood breakaway and controlled release terminal (CRT) posts that are designed to break away when hit. The end of the SRT is offset from the tangent guardrail run by the use of a parabolic flare. When struck head on, the first 2 posts are designed to break away and the parabolic flare gives the rail a natural tendency to buckle, minimizing the possibility of the guardrail end entering the vehicle. The buckling is facilitated by the slots in the rail. The CRT posts provide strength to the system for redirection and deceleration without snagging the vehicle. The SRT has a 4 foot offset of the first post.
2. The FLEAT uses W-beam guardrail with a special end piece that fits over the end of the guardrail and wood breakaway and CRT posts. The end of the FLEAT is offset from the tangent guardrail run by the use of a straight flare. When struck head on, the end piece is forced over the rail, bending the rail and forcing it away from the impacting vehicle.

The FLEAT is available in two designs based on the posted speed of the highway. For high speed highways (posted speed of 45 mph or greater) use a FLEAT 350 that has a 4 foot offset at the first post. For lower speed highways (posted speed of 40 mph or less), use a FLEAT TL-2 that has a 1 foot-8 inch offset at the first post.

When a flared terminal is specified, it is critical that embankment also be specified so that the area around the terminal can be flattened as shown on the Standard Plans. For every foot of height of the embankment, 13 cubic yards of "Embankment in Place" must be specified.

No snow load rail washers are allowed within the limits of these terminals.

The FHWA has granted approval to use these sole source proprietary terminals without justification on a project by project basis.

(c) **Nonflared Terminal.** Where widening to provide the offset for a flared terminal is not practical, consider a nonflared terminal. (See Figure 710-13.) There are currently two acceptable sole source proprietary designs; the ET PLUS and the Sequential Kinking Terminal (SKT). Both of these systems use W-beam guardrail with a special end piece that fits over the end of the guardrail and wood breakaway and CRT posts. When hit head-on, the end piece is forced over the rail and either flattens or bends the rail and then forces the rail away from the impacting vehicle.

Both of these terminals include an anchor for developing the tensile strength of the guardrail. The length of need begins at the third post for both terminals.

Both of these terminals are available in two designs based on the posted speed of the highway. The primary difference in these designs is the length of the terminal. For high speed highways (posted speed of 45 mph or greater), use the ET PLUS TL3 or SKT 350 that are 50 feet long. For lower speed highways (posted speed of 40 mph or less), use the ET PLUS TL2 or SKT-TL2 that are 25 feet long.

While these terminals do not require an offset at the end, a flare is recommended so that the end piece does not protrude into the shoulder. These terminals may have a 1 foot offset to the first post. Four feet of widening is required at the end posts to ensure that the system is properly anchored. For every foot of height of embankment, 3 cubic yards of "Embankment in Place" must be specified.

No snow load rail washers are allowed within the limits of these terminals.

The FHWA has granted approval to use these sole source proprietary terminals without justification on a project by project basis.

(d) **Other Anchor Applications.** Use the Type 1 anchor to develop the tensile strength of the guardrail on the end of guardrail runs where a crashworthy terminal is not required. Use the Type 4 anchor to develop the tensile strength of the guardrail on the trailing end of guardrail runs along one-way highways. Use the Type 5 anchor with the Weak Post Intersection Design. (See 710.06(4) Cases 12 and 13.) Use the Type 7 anchor to develop tensile strength in the middle of a guardrail run when the guardrail curves and weak posts are used. (See 710.06(4) cases 9, 12, and 13.)

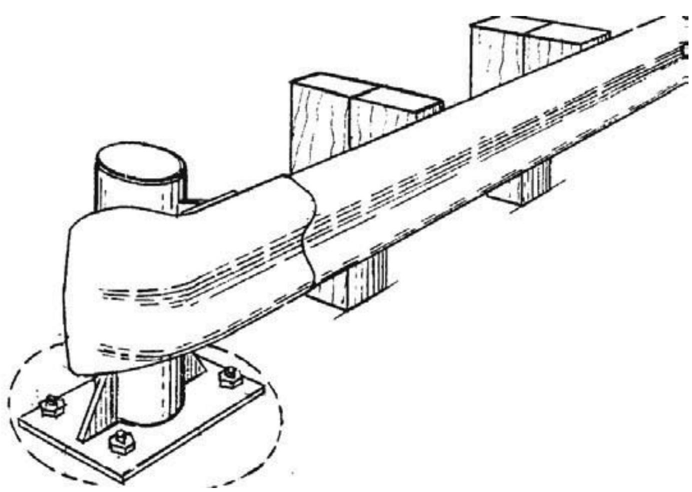
The old Type 3 anchor was primarily used at bridge ends. (See Figure 710-5.) This anchor consisted of a steel pipe mounted vertically in a concrete foundation. Bridge approach guardrail was then mounted on the steel pipe. On one-way highways, these anchors were usually positioned so that neither the anchor nor the bridge rail posed a snagging hazard. In these cases, the anchor may remain in place if a stiffened transition section is provided at the connection to the post. On two-way highways the anchor may present a snagging hazard. In these cases, install a connection from the anchor to the bridge rail if the offset from the bridge rail, to the face of the guardrail is, 1 foot-6 inches or less. If the offset is greater than 1 foot-6 inches, remove the anchor and install a new transition and connection.

Locations where crossroads and driveways cause gaps in the guardrail require special consideration. Elimination of the need for the barrier is the preferred solution. Otherwise, a barrier flare might be required to provide sight distance. If the slope is 2H:1V or flatter and there are no hazards on or at the bottom of the slope, a terminal can be used to end the rail. Place the anchor of this installation as close as possible to the road approach radius PC. If there is a hazard at or near the bottom of the slope that cannot be mitigated, then the Weak Post Intersection Design (see 710.04(4) and the Standard Plans) can be used. This system can also be used at locations where a crossroad or road approach is near the end of a bridge and installing a bridge approach guardrail placement (including guardrail transition and terminal) is not possible.

(3) Transitions and Connections

When there is an abrupt change from one barrier type to a more rigid barrier type, a vehicle hitting the more flexible barrier is likely to be caught in the deflected barrier pocket and directed into the more rigid barrier. This is commonly referred to as pocketing. A transition stiffens the more flexible barrier by decreasing the post spacing, increasing the post size, and using stiffer beam elements to eliminate the possibility of pocketing.

When connecting beam guardrail to a more rigid barrier or a structure, or when a rigid object is within the deflection distance of the barrier, use the transitions and connections that are shown on Figures 710-6 and 10 and detailed in the Standard Plans. The transition pay item includes the connection.



Old Type 3 Anchor
Figure 710-5

	Connection
Unrestrained concrete barrier	A
Rigid untapered safety shaped bridge rails or barriers (1)	B
Bridge rails with curbs 9 inches or less in width	B
Bridge rails with curbs between 9 and 18 inches wide	C
Vertical walls or tapered safety shape barrier (1)	D

(1) New safety shaped bridge rails are designed with the toe of the barrier tapered so that it does not project past the face of the approach guardrail.

Guardrail Connections
Figure 710-6

(4) Guardrail Placement Cases

The Standard Plans contain placement cases that show all of the beam guardrail elements required for typical situations. The following is a description of each.

Case 1 is used only where there is one-way traffic. It uses a crashworthy terminal on the approach end and a Type 4 anchor on the trailing end.

Case 2 is used where there is two-way traffic. A crashworthy terminal is used on both ends. When flared terminals are used on both ends, a minimum of 25 feet of guardrail is required between the terminal limits.

Case 3 is used at railroad signal supports on one-way or two-way roadways. A terminal is used on the approach end but usually cannot be used on the trailing end because of its proximity to the railroad tracks. For one-way roadways, a Type 4 anchor is used on the trailing end. On two-way roadways a Type 1 anchor is used on the trailing end. If there is a history of crossover accidents, consider additional protection, such as an impact attenuator.

Case 4 is used where guardrail on the approach to a bridge is to be shifted laterally to connect with the bridge rail. A terminal is used on the approach end and a transition is required at the bridge end. A curve in the guardrail is shown to shift it to the bridge rail. However, the length of the curve is not critical and the only requirement is to provide a smooth curve that is not more abrupt than the allowable flare rate. (See Figure 710-3.)

Case 5 is a typical bridge approach where a terminal and a transition are required.

Case 6 is used on bridge approaches where opposing traffic is separated by a median that is 36 feet or wider. This case is designed so that the end of the guardrail will be outside of the clear zone for the opposing traffic.

Cases 7 and 8 are used with beam guardrail median barrier when median hazards such as bridge piers are encountered. A transition is required on the approach end for each direction and the flare rate must not be more abrupt than the allowable flare rate. (See Figure 710-3.)

Case 9 (A, B, and C) is used on bridge approaches where opposing traffic is separated by a median less than 36 feet wide. This design, called a "Bull Nose Terminal," treats both bridge ends and the opening between the bridges. The "nose" is designed to collapse when struck head-on and the ribbon strength of the rail brings the vehicle to a controlled stop. Type 7 anchors are installed on each side of the nose to develop the ribbon strength.

Since an impacting vehicle will penetrate into the system, it is critical that no fixed object be located within the first 30 feet of the system.

Case 10 (A, B, and C) is used at roadside hazards (such as bridge piers) when 3 feet or more is available from the face of the guardrail to the hazard. The approach end is the same for one-way or two-way traffic. Case 10A is used with two-way traffic and, therefore, a terminal is required on the trailing end. Case 10B is used for one-way traffic when there is no need to extend guardrail past the bridge pier and a Type 4 anchor is used to end the guardrail. Case 10C is used for one-way traffic when the guardrail will extend for a distance past the bridge pier.

Case 11 (A, B, and C) is used at roadside hazards (such as bridge piers) when the guardrail is to be placed within 3 feet of the hazard. Since there is no room for deflection, the rail in front of the hazard must be considered a rigid system and a transition is necessary. The trailing end cases are the same as described for Placement Case 10.

Cases 12 and 13 are called "Weak Post Intersection Designs." They are used where an intersection requires a gap in the guardrail or there is not adequate space for a bridge approach installation that includes a transition and/or terminal. These placements are designed to collapse when hit at the nose, and the ribbon strength of the rail brings the vehicle to a stop. A Type 7 anchor is used to develop the ribbon strength. These designs include a Type 5 transition for connection with bridge rail and a Type 5 anchor at the other end of the rail. The Type 5 anchor is not a breakaway anchor and, therefore, can only be used on low speed side roads and driveways.

Since an impacting vehicle will penetrate into the system, it is critical that no fixed object be located within the clear area shown on the standard plan. The 25 feet along the side road is critical for the operation of this system.

These designs were developed for intersections that are approximately perpendicular. Evaluate installation on skewed intersections on a case-by-case basis. Use the Case 22 placement if it is not feasible to install this design according to the standard plan.

Case 14 shows the approach rail layout for a Service Level 1 bridge rail system. Type 20 guardrail is used on the approach and no transition is required between the Type 20 guardrail and the Service Level 1 bridge rail since they are both weak post systems. A Type 6 transition is used when connecting the Type 20 to a strong post guardrail or a terminal.

Case 15 is used to carry guardrail across a box culvert where there is insufficient depth to install standard posts for more than 17 feet-8 inches. This design uses steel posts anchored to the box culvert to support the rail. Newer designs, Cases 19, 20, and 21, have replaced this design for shorter spans.

Cases 16 and 17 are similar to Cases 1 and 2, except that they flare the rail and terminal as far from the road as possible and reduce the length of need.

Case 18 is used on the trailing end of bridge rail on a one-way roadway. No transition is necessary.

Cases 19 (A and B) are used where it is not possible to install a post at the 6 foot-3 inch spacing. These designs omit one post (which results in a span of 11 feet-6 inches which is consistent with a post spacing of 12 feet-6 inches) and use nested W-beam to stiffen the rail. The cases differ by the location of the splice. No cutting of the rail or offsetting of the splices is necessary or desirable.

Case 20 is similar to Cases 19A and B, except that it allows for two posts to be omitted (which results in a span consistent with a post spacing of 18 feet-9 inches).

Case 21 has a similar intent as Cases 19A, 19B, and 20 in that it allows for the omission of posts to span an obstruction. This design uses CRT posts with additional post blocks for three posts before and after the omitted posts. The design allows for 3 posts to be omitted (which results in a span consistent with a post spacing of 25 feet).

Case 22 is the Strong Post Intersection Design that provides a stiff barrier. This design is only to be used as a last resort at crossroads or road approaches where a barrier is necessary and there isn't a clear area behind the nose or minimum distances for a "Weak Post Intersection Design." (See Cases 12 and 13.)

710.07 Cable Barrier

Cable barrier is a flexible barrier system that can be used on a roadside or as a median barrier.

This system consists of three steel cables mounted to steel posts (weak posts). The maximum spacing for the steel posts is 16 feet on tangent sections and curves of 700 feet radius or greater. A deflection of 11 feet-6 inches is anticipated with this post spacing. A smaller spacing is required on radii less than 700 feet. For tangent sections and large radius curves, the deflection can be reduced to 7 feet by reducing the post spacing to 4 feet.

At each end of the barrier run, the cable is turned down and anchored to concrete blocks. A coil spring and turnbuckle are required on each cable to maintain tension on the system.

Cable barrier can be installed up to one foot in front of side slopes as steep as 2H:1V. This barrier is the only barrier that can be placed on a side slope steeper than 10H:1V within the 12 foot area immediately beyond the breakpoint. Do not place this barrier on a side slope steeper than 6H:1V. Figure 710-14 shows the placement of cable barrier.

When cable barrier is to be connected to a more rigid barrier, a transition section is required. Contact the HQ Design Office for details.

The primary advantage of cable barrier is that it provides effective vehicle containment and redirection while imposing the lowest deceleration forces on the vehicle's occupants. It also has advantages in heavy snowfall areas and it does not present a visual barrier, which may make it desirable on Scenic Byways. (See 710.05.)

Maintenance is a consideration because routine maintenance is necessary to keep tension in the cables and a comparatively long run of cable barrier will have to be repaired after an impact. However, the effort (time and materials) required to maintain and repair cable barrier is much less than the effort required for a W-beam system.

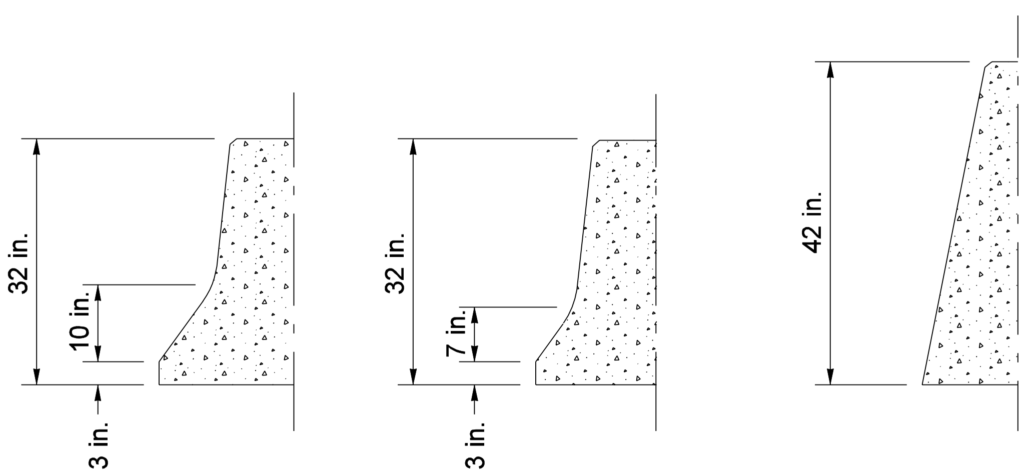
In addition to the standard cable barrier system described above, high-tension cable barrier systems are now available from a few different manufacturers. These systems deflect less than the standard WSDOT design and might have some maintenance benefits. The high-tension cable barrier systems are being evaluated by WSDOT. For more information about high-tension cable barrier systems, contact the HQ Design Office.

710.08 Concrete Barrier

Concrete barriers are rigid or unrestrained rigid systems. They are also used as shoulder barriers. These systems are stiffer than beam guardrail or cable barrier and impacts with these barriers will tend to be more severe.

Light standards mounted on top of concrete median barrier must not have breakaway features. See the Standard Plans for the concrete barrier light standard section.

Where drainage might be a problem, contact the HQ Hydraulics Branch for guidance.



NJ-Shape (Type 2)

F-Shape

Single-Slope Concrete Barrier

Concrete Barrier Shapes

Figure 710-7

(1) Concrete Barrier Shapes

Concrete barriers use a safety shaped (New Jersey shape and, on bridges, the F-Shape) or single-sloped face to redirect vehicles while minimizing vehicle vaulting, rolling, and snagging. A comparison of these barrier shapes is shown on Figure 710-7.

The New Jersey shaped face is used on precast concrete barrier.

The single-slope barrier face is recommended when separating roadways with different elevations (stepped medians). The single-slope barrier face can be used for bridge rails (median or outside) when it is to be used on any approach to a bridge and an existing bridge rail is to be replaced.

The F-Shape face is used on all other bridge rails and on cast-in-place barrier where the New Jersey and single-slope face are not appropriate. When the F-Shape face is used and precast barrier is to be used on the approaches, a cast-in-place transition section is required so that no vertical edges of the barriers are exposed to oncoming traffic. For details on the F-Shape barrier or any of the bridge rail designs, see the *Bridge Design Manual*.

For aesthetic reasons, avoid changes in the shape of the barrier face within a project or corridor.

(a) **New Jersey Shape Barrier.** The New Jersey shaped face is primarily used on precast concrete barrier.

Concrete barrier Type 2 (see the Standard Plans) is a precast barrier that has the New Jersey shape on two sides and can be used for both median and shoulder installations. This barrier is 2 feet-8 inches in height, which includes 3 inches for future pavement overlay.

The cost of precast Type 2 barrier is significantly less than the cost of the cast-in-place barriers. Therefore, consider the length of the barrier run to determine whether transitioning to precast Type 2 barrier is desirable. If precast Type 2 barrier is used for the majority of a project, use the New Jersey face for small sections that require cast-in-place barrier, such as for a light standard section.

Concrete barrier Type 4 is also a precast, single-faced New Jersey shaped barrier. These units are not freestanding and must be placed against a rigid structure or anchored to the pavement. If Type 4 barriers are used back to back, consider filling any gap between them to prevent tipping.

Concrete barrier Type 5 is a precast barrier that has a single New Jersey face and is intended for use at bridge ends where the flat side is highly visible. Both Type 2 and Type 5 designs are freestanding, unanchored units connected with steel pins through wire rope loops. For permanent installation, this barrier is placed on a paved surface and a 2 foot wide paved surface is provided beyond the barrier for its displacement during impact. (See Chapter 640.)

Precast barrier can be anchored where a more rigid barrier is desired. Anchoring methods are shown in the Standard Plans. The Type 1 and 2 anchors are for temporary installations on a rigid pavement. Type 3 anchors can be used in temporary or permanent installations on an asphalt pavement. Consult the HQ Bridge and Structures Office for details when anchoring permanent precast concrete barrier to a rigid pavement.

Precast barrier used on the approach to bridge rail must be connected to the bridge rail by installing wire rope loops embedded 1 foot-3 inches into the bridge rail with epoxy resin.

Place unrestrained (unanchored) precast concrete barrier, on foundation slopes of 5 percent or flatter. In difficult situations, a maximum slope of 8 percent may be used. Keep the slope of the area between the edge of the shoulder and the face of the traffic barrier as flat as possible. The maximum slope is 10H:1V (10 percent).

(b) **Single Slope Barrier.** The single slope concrete barrier can be cast-in-place, slipformed, or precast. The most common construction technique for this barrier has been slipforming but some precast single slope barrier has been installed. The primary benefit of using precast barrier is that it can be used as temporary barrier during construction and then reset into a permanent location.

This barrier is considered a rigid system regardless of the construction method used. For new installations, the minimum height of the barrier above the roadway is 2 feet-10 inches which allows 2 inches for future overlays. The minimum total height of the barrier section is 3 feet-6 inches with a minimum of 3 inches embedded in the roadway wearing surface. This allows for use of the 3 foot-6 inch barrier between roadways with grade separations of up to 5 inches. The Standard Plans allow for a grade separation of up to 10 inches. The barrier must have a depth of embedment equal to or greater than the grade separation. Contact HQ Bridge and Structures for grade separations greater than 10 inches. (See the Standard Plans.)

(2) Concrete Barrier Terminals

Whenever possible, bury the end of the concrete barrier in the backslope. The backslope required to bury the end must be 3H:1V or steeper and at least 4 feet in height above the roadway. Flare the concrete barrier into the backslope using a flare rate that meets the criteria in 710.05(3). Provide a 10H:1V or flatter foreslope into the face of the barrier and maintain the full barrier height to the foreslope/backslope intersection. This might require filling ditches and installing culverts in front of the barrier face.

A precast or cast-in-place terminal section having a minimum length of 48 feet and a maximum length of 80 feet is another end treatment. It can only be used for posted speeds of 35 mph or less. Contact the HQ Design Office for details on this end treatment.

The 7 foot long precast concrete terminal end section for Concrete Barrier Type 2 may be used:

- Outside the Design Clear Zone.
- On the trailing end of the barrier when it is outside the Design Clear Zone for opposing traffic.
- On the trailing end of one-way traffic.
- Where the posted speed is 25 mph or less.

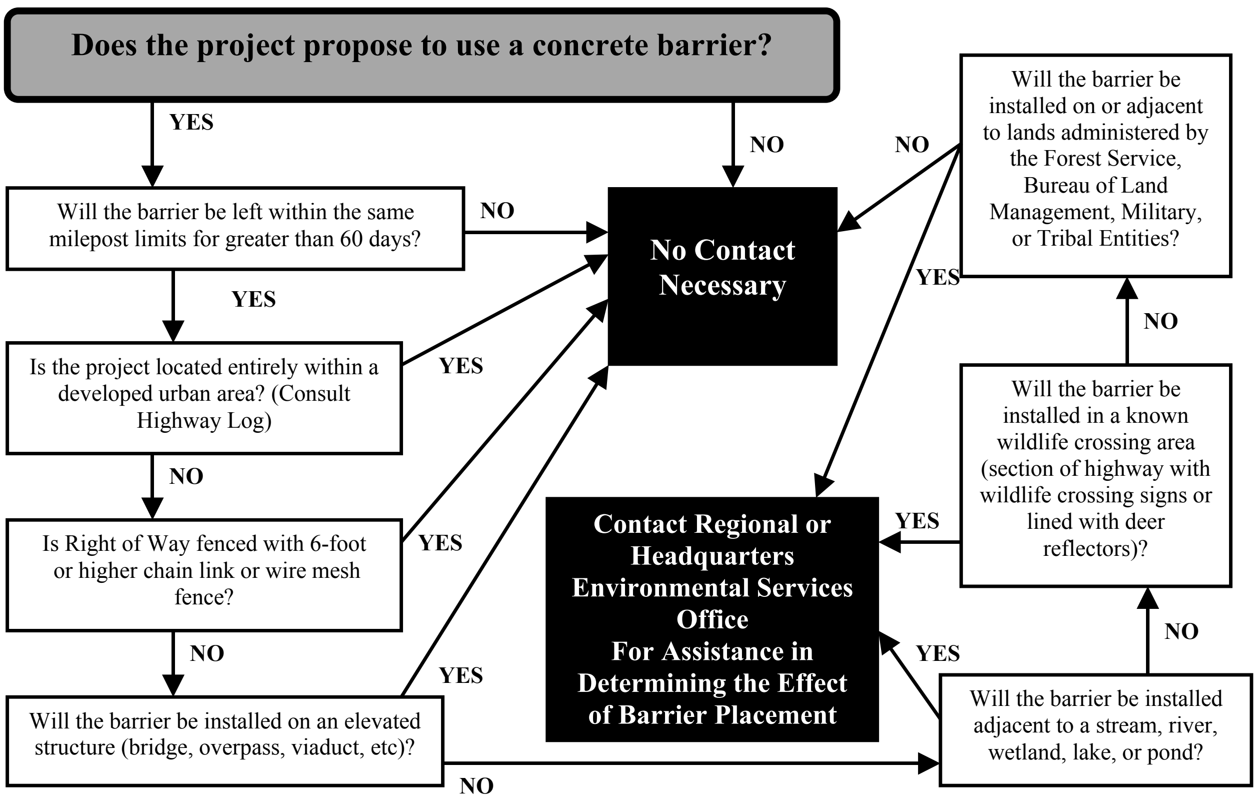
When the Barrier Terminals and Transitions column of a design matrix applies to a project, existing sloped down concrete terminals that are within the Design Clear Zone must be replaced when they do not meet the criteria above.

When the end of a concrete barrier cannot be buried in a backslope or terminated as described above, terminate the barrier using a guardrail terminal and transition or an impact attenuator. (See Chapter 720.)

(3) Assessing Impacts to Wildlife

The placement of concrete barriers in locations where wildlife frequently cross the highway can influence traffic safety and wildlife mortality. When wildlife encounter physical barriers that are difficult for them to cross, they often travel parallel to those barriers. With traffic barriers, this means that they often remain on the highway for a longer period, increasing the risk of wildlife/vehicle collisions or vehicle/vehicle collisions as motorists attempt avoidance.

Traffic-related wildlife mortality may play a role in the decline of some species listed under the Endangered Species Act. To address public safety and wildlife concerns, see Figure 710-8 to determine if concrete barrier placement requires an evaluation by the Environmental Services Office to determine its effect on wildlife. Make this evaluation early in the project development process to allow adequate time for discussion of options.



Concrete Barrier Placement Guidance <u>**(Assessing Impacts to Wildlife)**</u>
Figure 710-8

710.09 Special Use Barriers

The following barriers may be used on designated Scenic Byway and Heritage Tour routes if funding can be arranged. (See 710.05 and Chapter 120.)

(1) Steel Backed Timber Guardrail

Steel backed timber guardrails consist of a timber rail with a steel plate attached to the back to increase it's tensile strength. There are several variations of this system that have passed crash tests. The nonproprietary systems use a beam with a rectangular cross section that is supported by either wood or steel posts. A proprietary (patented) system called the Ironwood guardrail is also available. This system uses a beam with a round cross section and is supported by steel posts with a wood covering to give the appearance of an all-wood system from the roadway. The Ironwood guardrail can be allowed as an alternate to the nonproprietary system. However, specifying this system exclusively requires the approval, from the Assistant State Design Engineer, of a public interest finding for the use of a sole source proprietary item.

The most desirable method of terminating the steel backed timber guardrail is to bury the end in a back slope as described in 710.06(2). When this type of terminal is not possible, the use of the barrier is limited to highways with speeds of 45 mph or less. On these lower speed highways, the barriers can be flared away from the traveled way and terminated in a berm.

For details of these systems, contact the HQ Design Office.

(2) Stone Guardwalls

Stone guardwalls function like rigid concrete barriers but have an appearance of natural stone. These walls can be constructed of stone masonry over a reinforced concrete core wall or of simulated stone concrete. These types of barriers are designed to have a limited projection of the stones that will not affect the redirectional characteristics of the barrier. The most desirable method of terminating this barrier is to bury the end in a backslope as described in 710.08(2). When this type of terminal is not possible, the use of the barrier is limited to highways with posted speeds of 45 mph or less. On these lower speed highways, the barrier can be flared away from the traveled way and terminated in a berm.

For details of these systems, contact the HQ Design Office.

710.10 Bridge Rails

Bridge rails are traffic barriers that redirect errant vehicles and prevent them from going over the side of the structure. See the *Bridge Design Manual* for information on bridge rail on new bridges and replacement bridge rail on existing bridges.

For most new bridge rail installations, use a 2 foot-8 inch high safety shape (F-Shape) bridge rail. The single slope bridge rail that is 2 feet-10 inches high can be used to be consistent with the heights of connecting single slope barrier (710.08(1)(b)).

Use taller, 3 foot-6 inch, safety shape or single slope bridge rails on Interstate or freeway routes where accident history suggests a need or where roadway geometrics increase the possibility of larger trucks hitting the barrier at a high angle (such as on ramps for freeway to freeway connections with sharp curvature in the alignment).

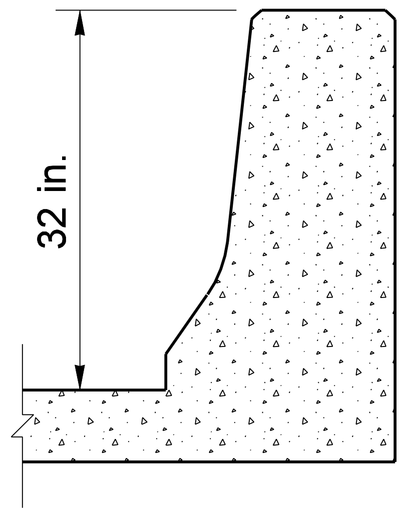
For bridges where high volumes of pedestrian traffic are anticipated, see Chapter 1020 for further guidance.

Approach barriers, transitions, and connections are usually required on all four corners of bridges carrying two-way traffic and on both corners of the approach end for one-way traffic. See 710.06(3) for guidance on transitions.

If the bridge rail system does not meet the criteria for strength and geometrics, modifications to improve its redirectional characteristics and its strength may be required. The modifications can be made using one of the retrofit methods described below.

(1) Concrete Safety Shape

Retrofitting with a new concrete bridge rail (see Figure 710-9) is costly and requires justification when no widening is proposed. Consult the HQ Bridge and Structures Office for design details and to determine if the existing bridge deck and other superstructure elements are of sufficient strength to accommodate this bridge rail system.



Safety Shaped Concrete Bridge Rail Retrofit
Figure 710-9

(2) Thrie Beam Retrofit

Retrofitting with thrie beam is an economical way to improve the strength and redirectional performance of bridge rails. The thrie beam can be mounted to steel posts or the existing bridge rail, depending on the structural adequacy of the bridge deck, the existing bridge rail type, the width of curb (if any), and the curb-to-curb roadway width carried across the structure.

The HQ Bridge and Structures Office is responsible for the design of thrie beam bridge rail. A key concern is that the existing bridge deck has adequate strength to withstand an impact without causing significant damage to the deck. Contact the HQ Bridge and Structures Office for assistance with thrie beam retrofit design.

Consider the Service Level 1 (SL-1) system on bridges with wooden decks and for bridges with concrete decks that do not have adequate strength to accommodate the thrie beam system. Contact the HQ Bridge and Structures Office for information required for the design of the SL-1 system.

Figure 710-15 shows typical installation criteria.

Many bridge rail retrofit projects involve bridges over 250 feet in length. These projects will normally be funded from the I2 program. Shorter bridges may be funded as a spot safety improvement. Contact HQ Project Control and Reporting for clarification.

710.11 Other Barriers

(1) Dragnet

The Dragnet Vehicle Arresting Barrier consists of chain link or fiber net that is attached to energy absorbing units. When a vehicle hits the system, the Dragnet brings the vehicle to a controlled stop with a minimum of damage. Possible uses for this device are as follows:

- Reversible lane entrances and exits.
- Railroad crossings.
- Truck escape ramps (instead of arrester beds – Chapter 1010).
- T-intersections.
- Work zones.

For permanent installations, this system can be installed between towers that lower the unit into position when needed and lift it out of the way when it is no longer needed. For work zone applications, it is critical to provide deflection space for stopping the vehicle between the system and the work zone. For additional information on the Dragnet, contact the HQ Design Office.

710.12 Documentation

A list of documents that are to be preserved [in the Design Documentation Package (DDP) or the Project File (PF)] is on the following website: http://www.wsdot.wa.gov/eesc/design/projectdev/

Connecting W-Beam Guardrail to: Transitions and Connections			Transition Type*	Connection
Bridge Rail	New		1 (1) 4 (5)	D
	Existing Concrete	Concrete Parapet > 20 in	1 (1) 4 (5)	Figure 710-6
		Concrete Parapet < 20 in	2 4 (5)	Figure 710-6
		Existing W-Beam Transition	2 (2)(6) 4 (5)	(2)
	Thrie Beam at face of curb (4)	Approach end	10	na
		Trailing end (two way traffic only)	11 12	na
	Thrie Beam at bridge rail (curb exposed) (4)	Approach end	13	na
		Trailing end (two way traffic only)	14 15	na
	Weak Post Intersection Design (see 710.06(4) cases 12 & 13)		5	Figure 710-6
Concrete Barrier	Rigid/Restrained		1 4 (5)	Figure 710-6
	Unrestrained		2 4 (5)	A
Weak Post Barrier Systems (Type 20 and 21)			6	na
Rigid Structures such as Bridge Piers	New installation (see Case 11)		16 17 18	na
	Existing W-Beam Transition		(3)	na
Connecting Thrie Beam Guardrail to:				
Bridge Rail or Concrete Barrier	New installation (ex. Used with thrie beam bull nose)		1 B	Figure 710-6

*Consult section C of the Standard Plans for detail on transition types.

(1) A Type 1A transition can be used where there is a problem placing a post within 2’-5” from the end of the bridge in which case a B or E connection is required. When the E connection is to be used, a special detail for the end of the bridge is required. Contact the HQ Bridge and Structures Office.

(2) If work requires reconstruction or resetting of the transition, upgrade as shown above. Raising the guardrail is not considered reconstruction. If the transition is not being reconstructed, the existing connection may remain in place.

See 710.06(2)(d) for guidance when Type 3 anchors are encountered.

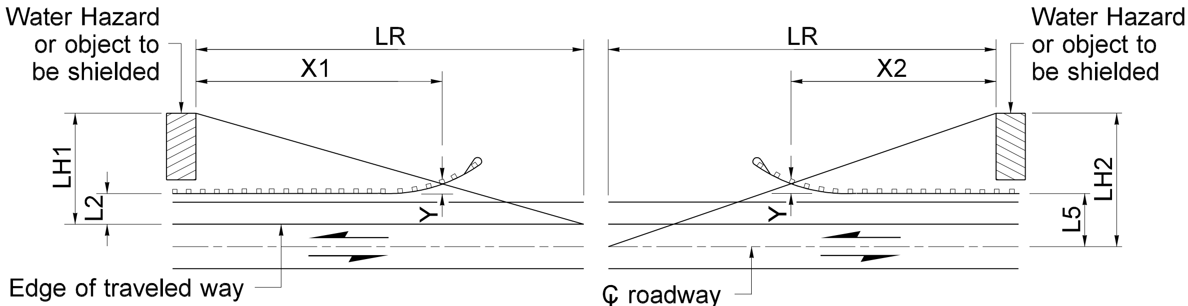
(3) For new/reconstruction, use Case 11 (thrie beam). For existing Case 11 with W-beam, add a second W-beam rail element.

(4) For Service Level 1 bridge rail see 710.06(4), case 14.

(5) Use on highways with speeds 45 MPH or less.

(6) If existing transition has adequate guardrail height, three 10”x10” (nominal) posts and three 6”x8” (nominal) posts spaced 3’-1.5” apart, it is acceptable to nest existing single W-beam element transitions.

Transitions and Connections
Figure 710-10



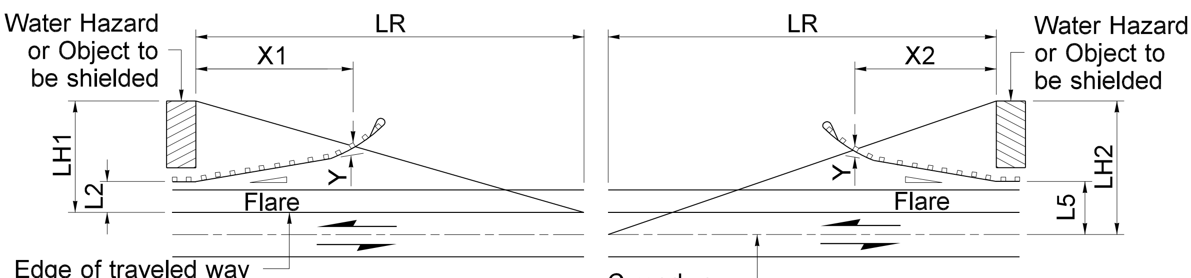
$$X1 = \frac{LH1 - (L2+Y)}{(LH1/LR)}$$

Adjacent-Side Hazard
Barrier Parallel to Roadway

$$X2 = \frac{LH2 - (L5+Y)}{(LH2/LR)}$$

Opposite-Side Hazard
Barrier Parallel to Roadway

Barrier Length of Need for Sheilding Objects Along Tangent Sections of Roadway



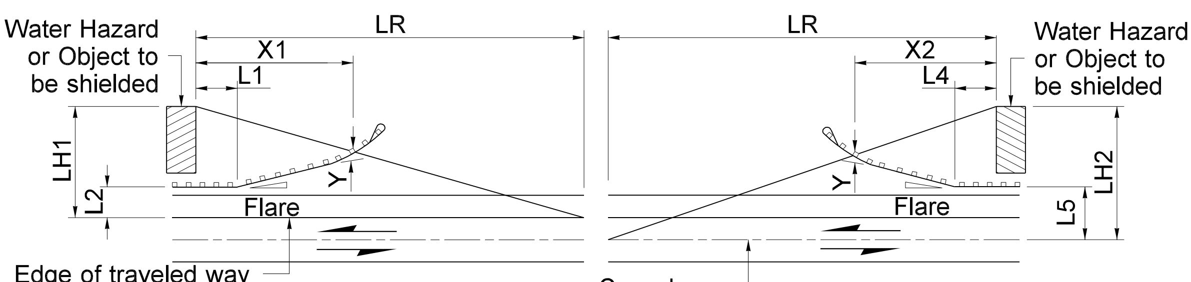
$$X1 = \frac{LH1 - (L2+Y)}{(1/F) + (LH1/LR)}$$

Adjacent-Side Hazard
Barrier Flare Begins at Hazard

$$X2 = \frac{LH2 - (L5+Y)}{(1/F) + (LH2/LR)}$$

Opposite-Side Hazard
Barrier Flare Begins at Hazard

Barrier Length of Need for Sheilding Objects Along Tangent Sections of Roadway



$$X1 = \frac{(LH1 + L1/F) - (L2+Y)}{(1/F) + (LH1/LR)}$$

Adjacent-Side Hazard
Barrier Flare Begins Before Hazard

$$X2 = \frac{(LH2 + L4/F) - (L5+Y)}{(1/F) + (LH2/LR)}$$

Opposite-Side Hazard
Barrier Flare Begins Before Hazard

Barrier Length of Need for Sheilding Objects Along Tangent Sections of Roadway

Barrier Length of Need
Figure 710-11a

Design Parameters							
Posted Speed	ADT						
	Over 10,000	5,000 to 10,000	1,000 to 4,999	Under 1,000	Rigid Barrier		
(mph)	LR (ft)	LR (ft)	LR (ft)	LR (ft)	F	F	F
70	460	395	345	295	20	18	15
60	360	295	260	230	18	16	14
55	310	260	230	195	16	14	12
50	260	215	180	165	14	12	11
45	245	195	165	150	12	11	10
40	215	180	150	130	11	10	9
35	185	155	130	115	11	10	9
30	165	135	115	105	11	10	9
25	150	125	105	95	11	10	9

L1 = Length of barrier parallel to roadway from adjacent-side hazard to beginning of barrier flare. This is used if a portion of the barrier cannot be flared (such as a bridge rail and the transition).

L2 = Distance from adjacent edge of traveled way to portion of barrier parallel to roadway.

L4 = Length of barrier parallel to roadway from opposite-side hazard to beginning of barrier flare.

L5 = Distance from center line of roadway to portion of barrier parallel to roadway. Note: if the hazard is outside of the Design Clear Zone when measured from the center line, it may only be necessary to provide a crashworthy end treatment for the barrier.

LH1 = Distance from outside edge of traveled way to back side of adjacent-side hazard. Note: if a hazard extends past the Design Clear Zone, the Design Clear Zone can be used as LH1.

LH2 = Distance from center line of roadway to back side of opposite-side hazard. Note: if a hazard extends past the Design Clear Zone, the Design Clear Zone can be used as LH2.

LR = Runout length (measured parallel to roadway).

X1 = Length of need for barrier to shield an adjacent-side hazard.

X2 = Length of need for barrier to shield an opposite-side hazard.

F = Flare rate value.

Y = Offset distance required at the beginning of the length of need.

Different end treatments require different offsets.

For the SRT 350 and FLEAT 350, use Y = 1.8 feet

For evaluating existing BCT's, use Y = 1.8 feet

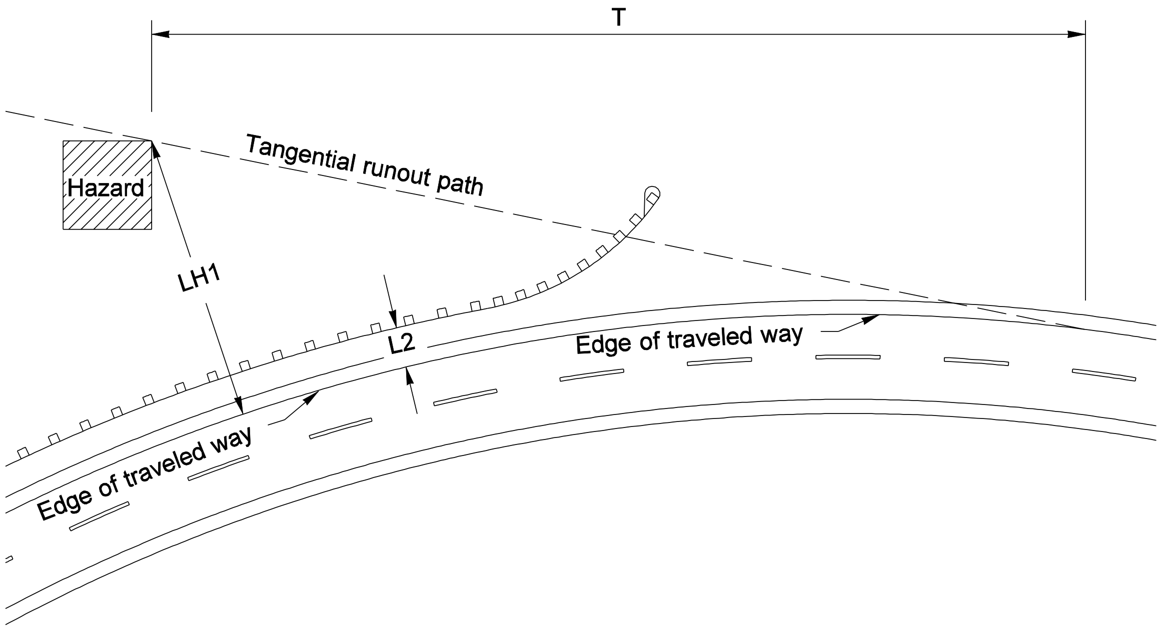
For the FLEAT TL-2, use Y = 0.8 feet

No offset is required for the nonflared terminals, or impact attenuator systems. Use Y = 0.

Buried terminal end treatments are used with barrier flares and have no offset. Use Y = 0.

Barrier Length of Need

Figure 710-11b



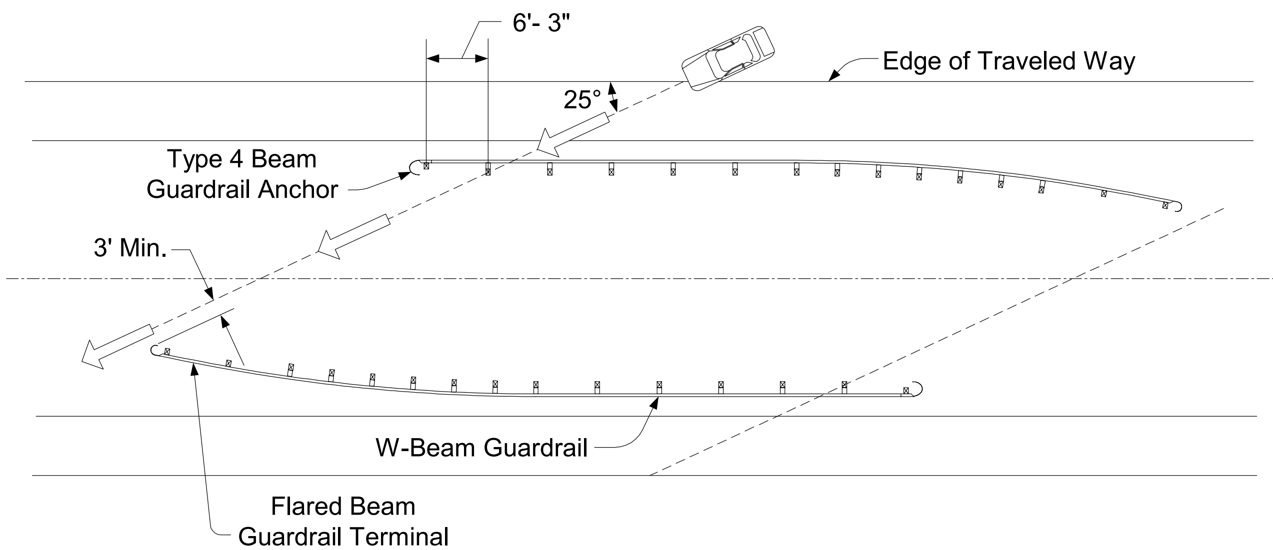
Note:

This is a graphical method for determining the length of need for barrier on the outside of a curve. On a scale drawing, draw a tangent from the curve to the back of the hazard. Compare T to LR from Figure 710-11b and use the shorter value.

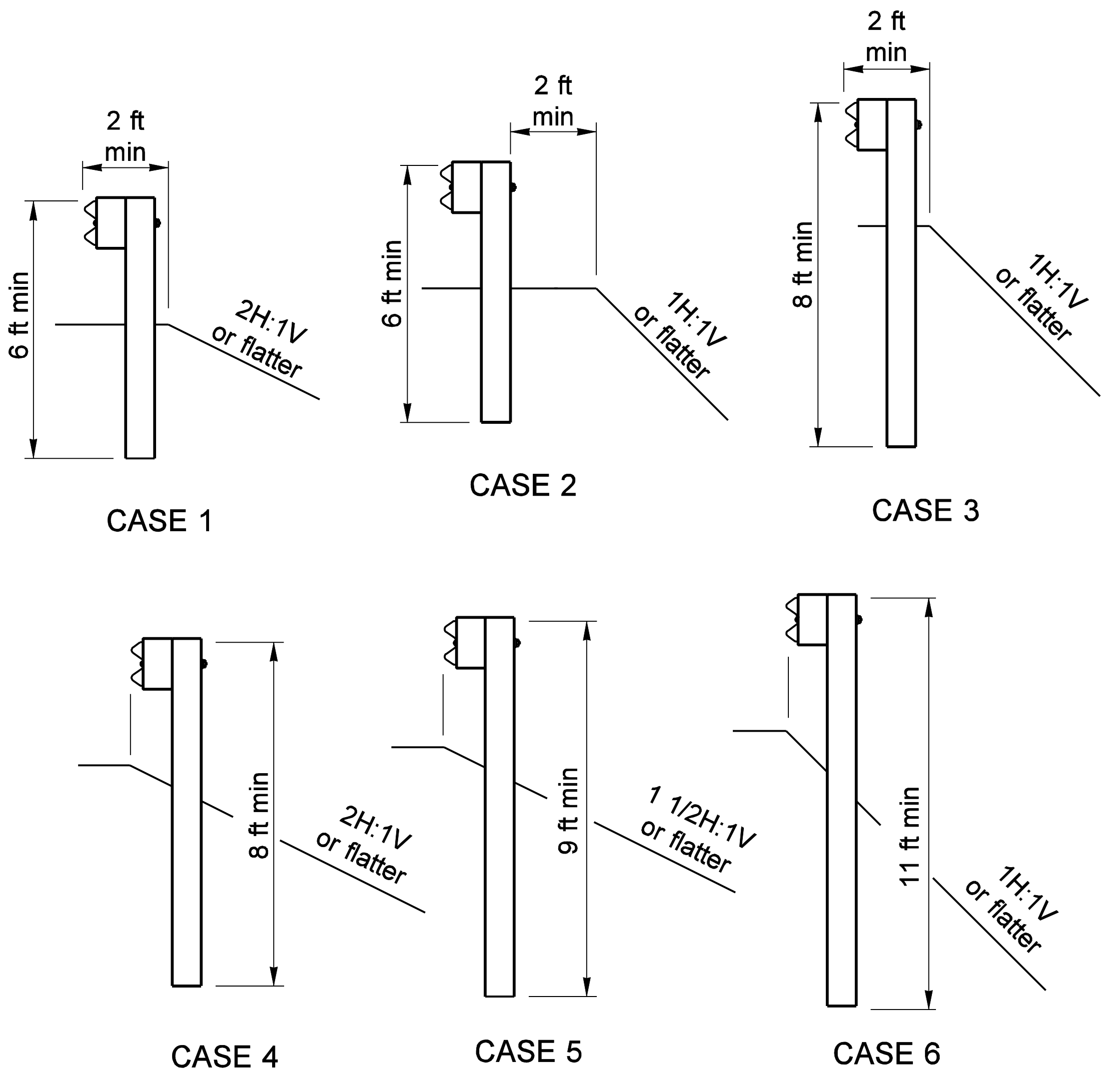
If using LR, follow Figures 710-11a and b.

If using T, draw the intersecting barrier run to scale and measure the length of need.

Barrier Length of Need on Curves
Figure 710-11c



W-Beam Guardrail Trailing End Placement for Divided Highways
Figure 710-11d

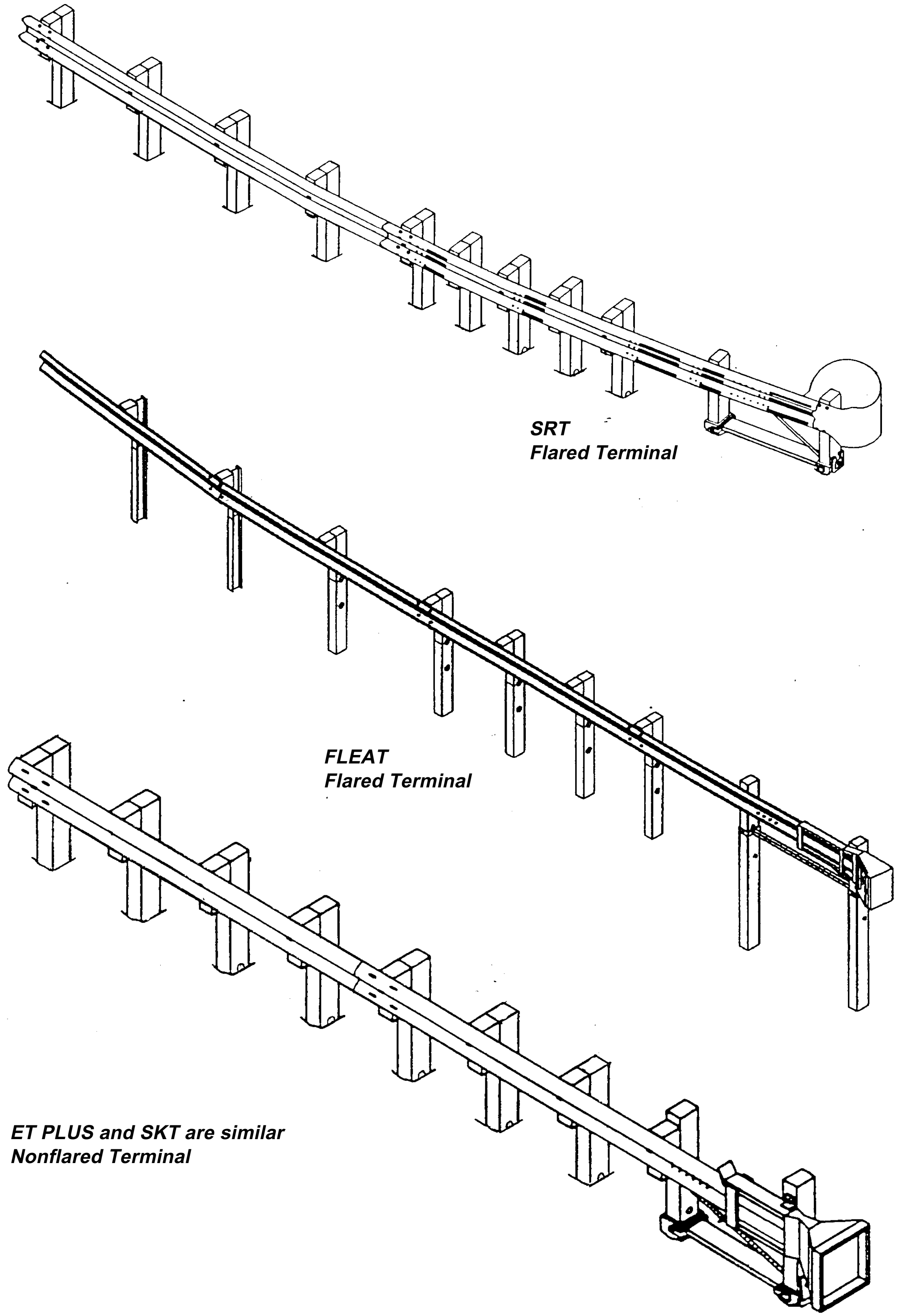


Notes:

Use cases 1, 2, and 3 when there is 2 ft or greater shoulder widening from face of guardrail to the breakpoint.

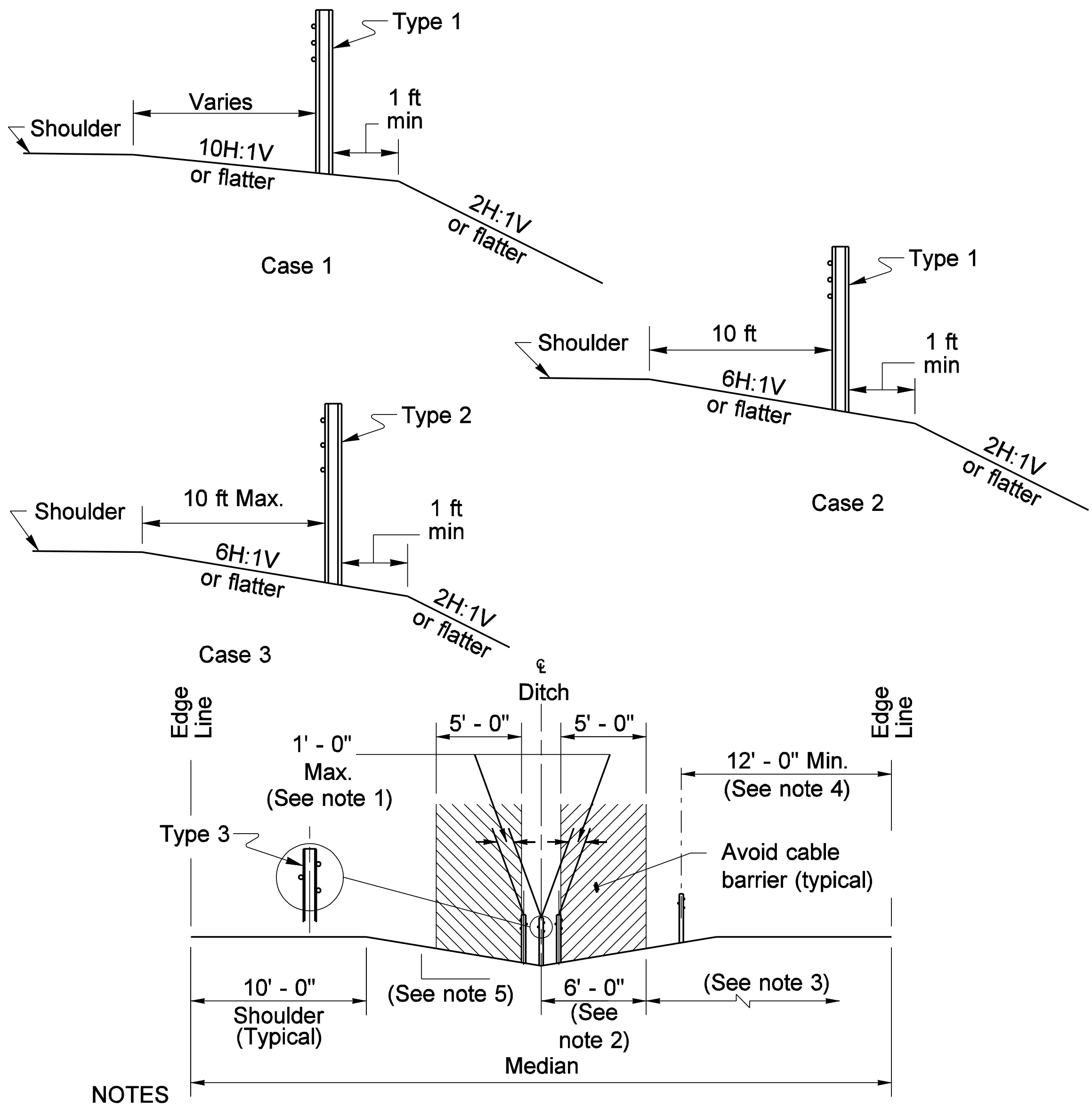
Use cases 4, 5, and 6 when there is less than 2 ft shoulder widening from face of guardrail to the breakpoint.

Beam Guardrail Post Installation
Figure 710-12



Beam Guardrail Terminals

Figure 710-13



NOTES

1. Cable barrier may be installed in the center of the ditch. The cable barrier may be offset from the ditch centerline a maximum of 1 foot in either direction.
2. Avoid installing cable barrier within 1' to 6' offset of the ditch center line.
3. Cable barrier may be installed a distance of 6' or greater from the ditch center line.
4. Do not install cable barrier closer than 12' to the edge of travelled way.
5. Applies to slopes between 6H:1V or flatter and 10H:1V or steeper.

Case 4
Median Installation

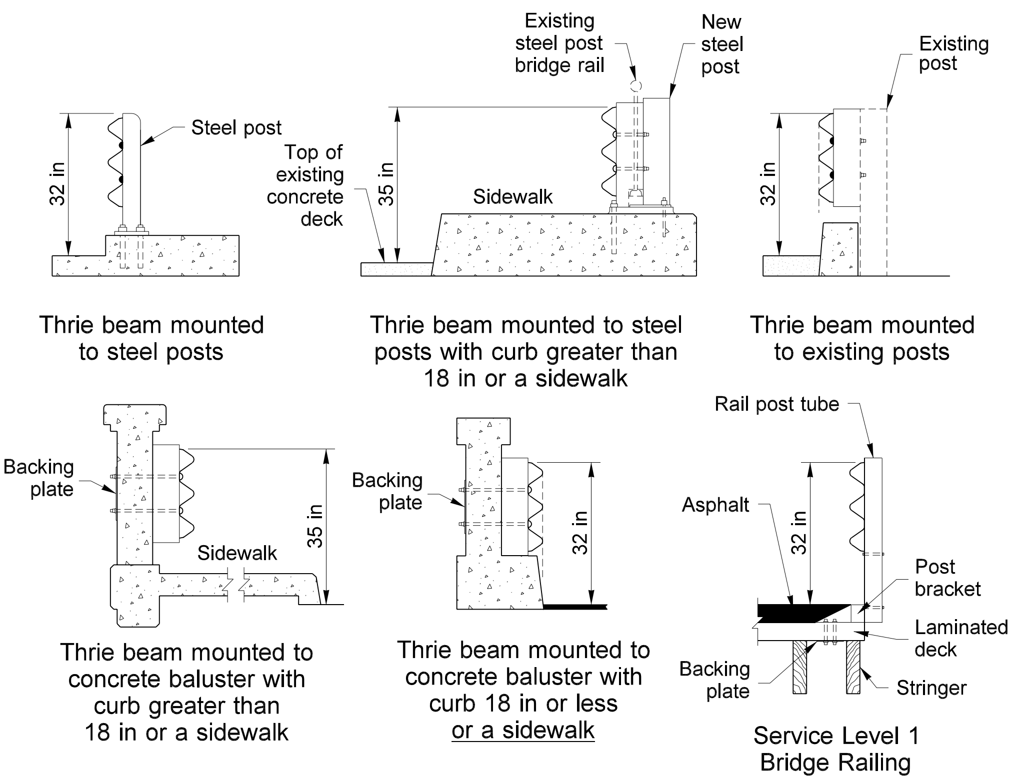
Cable Barrier Locations on Slopes

Figure 710-14

		Concrete Bridge Deck		Wood Bridge Deck or Low Strength Concrete Deck
Curb Width	Bridge Width	**Concrete Bridge Rail (existing)**	**Steel or Wood Post Bridge Rail (existing)**	
< 18 inches		Thrie beam mounted to existing bridge rail[2] and blocked out to the face of curb. Height = 32 in	Thrie beam mounted to steel posts[2] at the face of curb. Height = 32 in	Service Level 1 Bridge Rail[2]
> 18 inches	**> 28 ft (curb to curb)**	Thrie beam mounted to steel posts[2] at the face of curb[1] . Height = 32 in		Height = 32 in
> 18 inches	**< 28 ft (curb to curb)**	Thrie beam mounted to existing bridge rail[2] . Height = 35 in	Thrie beam mounted to steel posts[2] in line with existing rail. Height = 35 in	Curb or wheel guard must be removed

(1) Thrie beam may be mounted to the bridge rail to accommodate pedestrians (height = 35 in)

(2) Contact the HQ Bridge and Structures Office for design details on bridge rail retrofit projects.



Thrie Beam Rail Retrofit Criteria

Thrie Beam Rail Retrofit Criteria
Figure 710-15

720.01 Impact Attenuator Systems

Impact attenuator systems are protective systems that prevent an errant vehicle from impacting a hazard by either gradually decelerating the vehicle to a stop when hit head-on or by redirecting it away from the hazard when struck on the side. These barriers are used for rigid objects or hazardous conditions that cannot be removed, relocated, or made breakaway.

Approved systems are shown on Figures 720-2a through 4b and on the Design Office web page at:

http://www.wsdot.wa.gov/EESC/Design/Policy/RoadsideSafety/Chapter720/Chapter720B.htm

(1) Permanent Installations

A description of each permanent installation system's purpose, parts, and function as well as requirements for; transition, foundation, and slope are provided as follows and in Figure 720-5:

(a) **Crash Cushion Attenuating Terminal (CAT)**

1. **Purpose**: The CAT is an end treatment for W-beam guardrail. It can also be used for concrete barrier if a transition is provided.

2. **Description**: The system consists of slotted W-beam guardrail mounted on both sides of breakaway timber posts. Steel sleeves with soil plates hold the timber posts in place. See Figure 720-2a.

3. **Function**: When hit head-on, the slotted guardrail is forced over a pin that shears the steel between the slots. This shearing dissipates the energy of the impact.

4. **Foundation:** Concrete footings or foundations are not required.

5. **Slope:** 10H:1V or flatter slope between the edge of the traveled way and the near face of the unit.

6. **Manufacturer/Supplier:** Trinity Industries, Inc.

(b) **Brakemaster**

1. **Purpose:** The Brakemaster system is an end treatment for W-beam guardrail. It can also be used for concrete barrier if a transition is provided.

2. **Description:** The system contains an embedded anchor assembly, W-beam fender panels, transition strap, and diaphragm. See Figure 720-2a.

3. **Function:** The system uses a brake and cable device for head-on impacts and for redirection. The cable is embedded in a concrete anchor at the end of the system.

4. **Foundation:** A concrete foundation is not required for this system but a paved surface is recommended.

5. **Slope:** 10H:1V or flatter slope between the edge of the traveled way and the near face of the unit.

6. **Manufacturer/Supplier:** Energy Absorption Systems

(c) **QuadTrend 350**

1. **Purpose:** The QuadTrend 350 is an end treatment for 2 feet-8inch high concrete barriers. The system's short length allows it to be used at the ends of bridges where the installation of a beam guardrail transition and terminal is not feasible.

2. **Description:** This system consists of telescoping quadruple corrugated fender panels mounted on steel breakaway posts. See Figure 720-2a.

3. **Function:** Sand-filled boxes attached to the posts dissipate a portion of the energy of an impact. An anchored cable installed behind the fender panels directs the vehicle away from the barrier end.

4. **Foundation:** The system is installed on a concrete foundation to support the steel posts.

5. **Slope:** A 6H:1V or flatter slope is required behind the barrier to allow for vehicle recovery.

6. **Manufacturer/Supplier:** Energy Absorption Systems

(d) **Universal TAU**

1. **Purpose:** The Universal TAU crash cushion system is an end treatment for concrete barrier, beam guardrail, and fixed objects up to 8 feet wide.

2. **Description:** The system is made up of independent collapsible bays containing energy absorbing cartridges that are guided and supported during a head-on hit by high strength galvanized steel cables and thrie beam rail panels. Each bay is composed of overlapping thrie beam panels on the sides and structural support diaphragms on the ends. Structural support diaphragms are attached to two cables running longitudinally through the system and attached to foundations at each end of the system. See Figure 720-2c.

3. **Function:** Overlapping panels, structural support diaphragms, cable supports, cables, and foundation anchors allow the system to resist angled impacts and mitigate head-on impacts.

4. **Foundation:** The system is installed on a concrete foundation.

5. **Slope:** 10H:1V or flatter slope between the edge of the traveled way and the near face of the unit.

6. **Manufacturer/Supplier:** Barrier Systems, Inc.

(e) **QuadGuard, Wide QuadGuard**

1. **Purpose:** The QuadGuard is an end treatment for concrete barrier and beam guardrail and is also used to mitigate fixed objects up to 7 feet-6 inches wide.

2. **Description:** The system consists of a series of Hex-Foam cartridges surrounded by a framework of steel diaphragms and quadruple corrugated fender panels. See Figure 720-2b.

3. **Function:** The internal shearing of the cartridges and the crushing of the energy absorption material absorb impact energy from end-on hits. The fender panels redirect vehicles impacting the attenuator on the side.

4. **Foundation:** The system is installed on a concrete foundation.

5. **Slope:** If the site has excessive grade or cross slope, additional site preparation or modification to the units in accordance with the manufacturer's literature is required. Excessive is defined as steeper than 8% for the QuadGuard.

6. **Manufacturer/Supplier:** Energy Absorption Systems

(f) **QuadGuard Elite**

1. **Purpose:** The QuadGuard Elite is an end treatment for concrete barrier and beam guardrail and is also used for fixed objects up to 7 feet-6 inches wide.

2. **Description:** The system consists of telescoping quadruple corrugated fender panels mounted on both sides of a series of polyethylene cylinders. See Figure 720-2b.

3. **Function:** The cylinders are compressed during a head-on impact and will return to their original shape when the system is reset. It is anticipated that this system will require very few replacement parts or extensive repair.

4. **Foundation:** The system is installed on a concrete foundation.

5. **Slope:** If the site has excessive grade or cross slope, additional site preparation or modification to the units in accordance with the manufacturer's literature is required. Excessive is defined as steeper than 8% for the QuadGuard Elite.

6. **Manufacturer/Supplier:** Energy Absorption Systems

(g) **Reusable Energy Absorbing Crash Terminal (REACT 350), Wide REACT 350**

1. **Purpose:** The REACT 350 is an end treatment for concrete barriers and is also used for fixed objects up to 9 feet wide.

2. **Description:** The system consists of polyethylene cylinders with varying wall thickness, redirecting cables, a steel frame base, and a backup structure. See Figure 720-2d.

3. **Function:** The redirecting cables are anchored in the concrete foundation at the front of the system and in the backup structure at the rear of the system. When hit head-on, the cylinders compress and absorb the impact energy, but the system returns to approximately 80% of its original length immediately. For side impacts, the cables restrain the system enough to prevent penetration and redirect the vehicle. It is anticipated that this system will require very few replacement parts or extensive repair.

4. **Foundation:** The system is installed on a concrete foundation.

5. **Slope**: If the site has excessive grade or cross slope, additional site preparation or modification to the units in accordance with the manufacturer's literature is required. Excessive is defined as steeper than 8% for the REACT 350.

6. **Manufacturer/Supplier:** Energy Absorption Systems

(h) **Inertial Barrier**

Inertial barrier configurations are shown in the Standard Plans. If a situation is encountered where configurations in the Standard Plans are not appropriate, contact the Headquarters Design Office for further information.

1. **Purpose:** Inertial barrier is an end treatment for concrete barrier and to mitigate fixed objects. This system does not provide redirection from a side impact.

2. **Description:** This system consists of an array of plastic containers filled with varying weights of sand. See Figure 720-2d.

3. **Function:** The inertial barriers slow an impacting vehicle by the transfer of the momentum of the vehicle to the mass of the barrier. This system is not suitable where space is limited to less than the widths shown in the Standard Plans. Whenever possible, align inertial barriers so that an errant vehicle deviating from the roadway by 10 degrees would be on a parallel path with the attenuator alignment (See the Standard Plans). In addition, inertial barriers do not provide any redirection and are not appropriate where high angle impacts are likely.

4. **Foundation**: A paved surface is not required.

5. **Slope**: If the site has excessive grade or cross slope, additional site preparation or modification to the units in accordance with the manufacturer's literature is required. Excessive is defined as steeper than 5% for inertial barriers.

(i) **SCI100GM**

1. **Purpose:** The SCI100GM is an end treatment for concrete barrier and beam guardrail.

2. **Description:** The system consists of telescoping quadruple corrugated fender panels mounted on both sides of a series of tubular steel support frames. See Figure 720-2e.

3. **Function:** A hydraulic cylinder is compressed during a head-on impact. It is anticipated that this system will require very few replacement parts or extensive repair.

4. **Foundation:** The system is installed on a concrete foundation.

5. **Slope:** 10H:1V or flatter slope between the edge of the traveled way and the near face of the unit.

6. **Manufacturer/Supplier:** Work Area Protection Corp.

(2) Work Zone (Temporary) Installation

A description of each work zone (or other temporary) system's purpose, parts and functionality as well as requirements for; transition, foundation, and slope are provided as follows and in Figure 720-5:

(a) **ABSORB 350**

1. **Purpose:** The ABSORB 350 is an end treatment limited to temporary installations for both concrete barrier and the Quickchange Moveable Barrier (QMB).

2. **Description:** The system contains water filled Energy Absorbing Elements. Each element is 2 feet wide, 2 feet-8 inches high, and 3 feet-3 ½ inches long. See Figure 720-3.

3. **Function:** The low speed (below 45 mph) system uses 5 Energy Absorbing Elements and the high-speed (45 mph and above) system uses 8. The energy of an impact is dissipated as the elements are crushed.

4. **Foundation:** The system does not require a paved foundation.

5. **Slope:** 10H:1V or flatter slope between the edge of the traveled way and the near face of the unit.

6. **Manufacturer/Supplier:** Barrier Systems, Inc.

(b) **Advanced Dynamic Impact Extension Module 350 (ADIEM 350)**

1. **Purpose:** The ADIEM 350 is an end treatment for concrete barrier. At this time, it is limited to temporary installations. Existing permanent installations are experimental and are being used to evaluate long-term durability. Existing permanent units may be reset.

2. **Description:** The system is 30 feet long and consists of 10 lightweight concrete modules on an inclined base. See Figure 720-3.

3. **Functionality:** An inclined base provides a track for placement of the modules and provides redirection for side impacts for roughly half the length. The energy of an impact is dissipated as the concrete modules are crushed.

4. **Foundation:** The system does not require a paved foundation.

5. **Slope:** If the site has excessive grade or cross slope, additional site preparation or modification to the units in accordance with the manufacturer's literature is required. Excessive is defined as steeper than 8% for the ADIEM 350.

6. **Manufacturer/Supplier:** Trinity Industries, Inc.

(c) **QuadGuard cz**

This system is like the permanent QuadGuard listed for permanent systems above except that it can be installed on a 6 inch minimum depth asphalt concrete surface that has a 6 inch minimum depth compacted base. See Figure 720-2b.

(d) **Reusable Energy Absorbing Crash Terminal (REACT 350)**

This is the same system listed for permanent systems above except that it can be installed on a 4 inch minimum depth asphalt concrete surface that has a 6 inch minimum depth compacted base. See Figure 720-2d.

(e) **Non-Redirecting Energy Absorbing Terminal (N-E-A-T)**

1. **Purpose:** The N-E-A-T system is an end treatment for temporary concrete barrier where vehicle speeds are 45 mph or less.

2. **Description:** The N-E-A-T System's cartridge weighs about 300 pounds and is 9 feet-8 inches long. The system consists of aluminum cells encased in an aluminum shell with steel backup, attachment hardware, and

transition panels. It can be attached to the ends of New Jersey shaped portable concrete barrier and the moveable QuickChange Barrier. See Figure 720-3.

3. **Functionality:** The energy of an impact is dissipated as the aluminum cells are crushed.

4. **Foundation:** The system does not require a paved foundation.

5. **Slope:** 10H:1V or flatter slope between the edge of the traveled way and the near face of the unit.

6. **Manufacturer/Supplier:** Energy Absorption Systems

(f) **Trinity Attenuating Crash Cushion (TRACC)**

1. **Purpose:** The TRACC is an end treatment for concrete barriers. It is limited to use in construction or other work zones on a temporary basis.

2. **Description:** The 21 foot long TRACC includes four major components: a pair of guidance tracks, an impact sled, intermediate steel frames, and 10 gauge W-beam fender panels. See Figure 720-3.

3. **Functionality:** The sled (impact face) is positioned over the upstream end of the guidance tracks and contains a hardened steel blade that cuts the metal plates on the sides of the guidance tracks as it is forced backwards when hit head-on.

4. **Foundation:** The system requires a concrete foundation.

5. **Slope:** 10H:1V or flatter slope between the edge of the traveled way and the near face of the unit.

6. **Manufacturer/Supplier:** Trinity Industries, Inc.

(g) **Inertial Barrier**

This is the same system listed for permanent systems above. It is not suitable where space is limited to less than the widths shown in the Standard Plans. See Figure 720-2d.

(h) **Truck Mounted Attenuator (TMA)**

TMAs are portable systems mounted on trucks. They are intended for use in work zones and for temporary hazards.

(i) **TRITON CET**

1. **Purpose:** The Triton CET is an end treatment limited to temporary concrete barrier installations.

2. **Description:** The system contains water filled Energy Absorbing Elements. See Figure 720-3.

3. **Function:** The system uses 6 Energy Absorbing Elements. The energy of an impact is dissipated as the elements are crushed.

4. **Foundation:** The system does not require a paved foundation.

5. **Slope:** 10H:1V or flatter slope between the edge of the traveled way and the near face of the unit.

6. **Manufacturer/Supplier:** Energy Absorption, Inc.

(3) Older Systems

The following systems are in use on Washington State highways and may be left in place or reset. New installations of these systems require approval from the Headquarters (HQ) Design Office.

(a) **Sentre**

The Sentre is a guardrail end treatment. Its overall length of 17 feet allowed it to be used where space was not available for a guardrail transition and terminal. The system is very similar to the QuadTrend 350 in both appearance and function except that it uses thrie beam fender panels instead of the quadruple corrugated panels. This system requires a transition when used to terminate rigid barriers. See Figure 720-4a.

(b) **TREND**

The TREND is an end treatment with a built-in transition and was used at the end of rigid barriers including bridge rails. The system is similar to the QuadTrend 350 except that it uses thrie beam fender panels. See Figure 720-4a.

(c) **G-R-E-A-T (Guard Rail Energy Absorption Terminal)**

This system was primarily used as an end treatment for concrete barrier. It is similar to the QuadGuard except that it uses thrie beam fender panels. See Figure 720-4a.

(d) **Low Maintenance Attenuator System (LMA)**

The LMA is an end treatment for concrete barrier and beam guardrail and was used for fixed objects up to 3 feet wide. The system is similar to the QuadGuard Elite except that it uses thrie beam fender panels and rubber cylinders. See Figure 720-4b.

(e) **Hex-Foam Sandwich**

The Hex-Foam Sandwich system is an end treatment for beam guardrail and concrete barrier and was also used for fixed objects 3 feet or more in width. This system consists of a number of Hex-Foam cartridges containing an energy absorption material separated by a series of diaphragms and restrained by anchor cables. It is installed on a concrete slab. Impact energy is absorbed by the internal shearing of the cartridges and crushing of the energy absorption material. The lapped panels on the perimeter serve to redirect vehicles for side impacts. If the site has grade or cross slope in excess of 5%, additional site preparation or modification to the units in accordance with the manufacturer's literature is required. See Figure 720-4b.

720.02 Design Criteria

The following design criteria applies to all new or reset permanent and temporary impact attenuators. The design criteria also applies to existing systems to be left in place when the Barrier Terminals and Transition Sections columns on a design matrix applies to the project. (See Chapter 325.)

Impact attenuators must be placed so that they do not present a hazard to opposing traffic. For median and reversible lane locations, the backup structure or attenuator-to-object connection must be designed to prevent opposing traffic from being snagged. It is desirable that all existing curbing be removed and the surface smoothed with asphalt or cement concrete pavement before an impact attenuator is installed. However, curbs 4 inches or less in height, may be retained depending on the practicality of their removal.

In general, attenuators are aligned parallel to the roadway except the inertial barriers.

720.03 Selection

When selecting an impact attenuator system, consider the following:

- Posted speed
- Available space (length and width)
- Maintenance costs
- Initial cost
- Duration (permanent or temporary use)

The posted speed is a consideration for the QuadGuard, REACT 350 (narrow model only), Universal TAU and the inertial barrier systems. Use Figure 720-1 to select permanent system sizes required for the various posted speeds.

Posted Speed (mph)	Quad Guard (Bays)	Universal TAU *(Bays)	REACT 350 (Cylinders)	Inertial Barrier (Type)
40 or less	3	2-3	4	1
45	4	3-4	6	2
50	5	4-5	6	3
55	6	5-7	9	4
60	6	7-8	9	5
65	8	7-8	9	6
70	9	7-8	11	6

*Dependent on width of system

Impact Attenuator Sizes
Figure 720-1

If it is anticipated that a large volume of traffic will be traveling at speeds greater than the posted speed limit, then the next larger unit may be specified.

See Figure 720-5 for a summary of space and initial cost information related to the impact attenuator systems.

When considering maintenance costs, anticipate the average annual impact rate. If few impacts are anticipated, lower cost devices such as inertial barriers might meet the need. Inertial barriers have the lowest initial cost and initial site preparation. However, maintenance will be costly and necessary after every impact. Labor and equipment are necessary to clean up the debris and install new containers (barrels). Also, inertial barriers must not be used where flying debris might be a danger to pedestrians.

The REACT 350 and the QuadGuard Elite have a higher initial cost, requiring substantial site preparation, including a backup or anchor wall in some cases and cable anchorage at the front of the installation. However, repair costs are comparatively low, with labor being the main expense. Maintenance might not be required after minor side impacts with these systems.

For new installations where at least one impact is anticipated per year, limit the selection of impact attenuators to the low maintenance devices (QuadGuard Elite and REACT 350). Consider upgrading existing ADIEM, G-R-E-A-T, and Hex-Foam impact attenuators with these low maintenance devices when the repair history shows one to two impacts per year over a three to five year period.

In selecting a system, one consideration that must not be overlooked is how dangerous it will be for the workers making repairs. In areas with a high exposure to danger, a system that can be repaired quickly is most desirable. Some systems require nearly total replacement or replacement of critical components (such as cartridges or braking mechanisms) after a head-on impact, while others only require resetting.

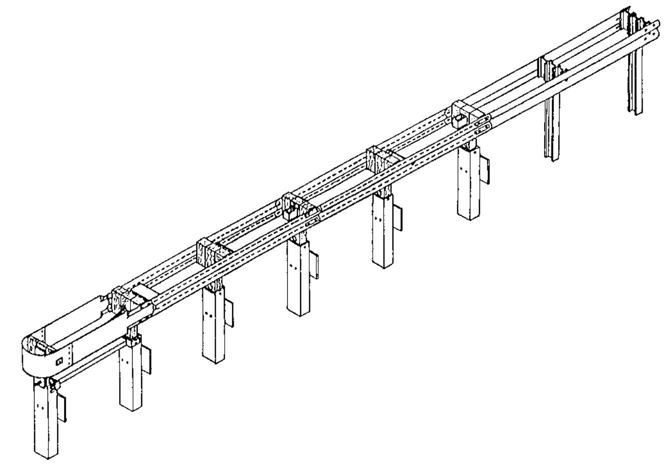
When specifying the system or systems that can be used at a specific location, the list shown in Figure 720-5 is to be used as a starting point. As the considerations discussed previously are analyzed, inappropriate systems may be identified and eliminated from further consideration. Systems that are not eliminated may be appropriate for the project. When the site conditions vary, it might be necessary to have more than one list of acceptable systems within a contract. Systems are not to be eliminated without documented reasons. Also, wording such as *or equivalent* is not to be used when specifying these systems. If only one system is found to be appropriate, then approval from the Assistant State Design Engineer of a public interest finding for the use of a sole source proprietary item is required.

When a transition to connect with a concrete barrier (see Figure 720-5) is required, the transition type and connection must be specified and are included in the cost of the impact attenuator. See Chapter 710 for information on the transitions and connections to be used.

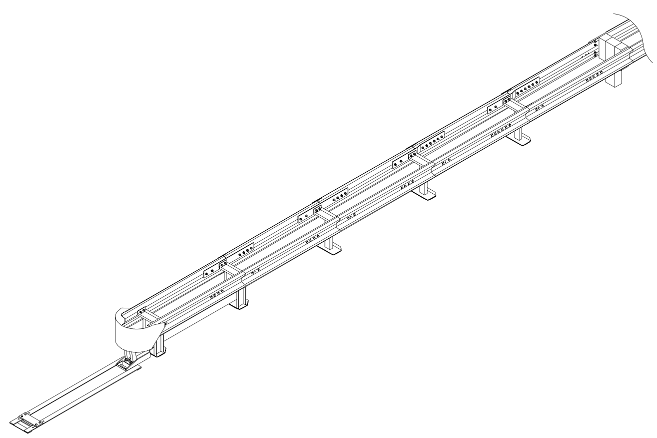
Contractors can be given more flexibility in the selection of work zone (temporary) systems, since long-term maintenance and repair are not a consideration.

720.04 Documentation

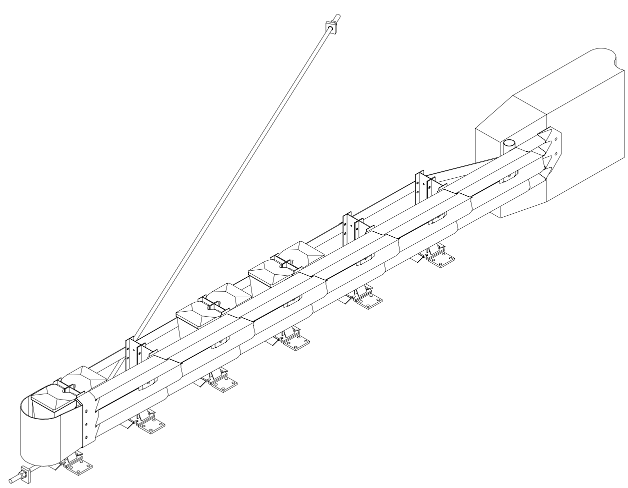
A list of documents that are to be preserved [in the Design Documentation Package (DDP) or the Project File (PF)] is on the following website: http://www.wsdot.wa.gov/eesc/design/projectdev/



CAT



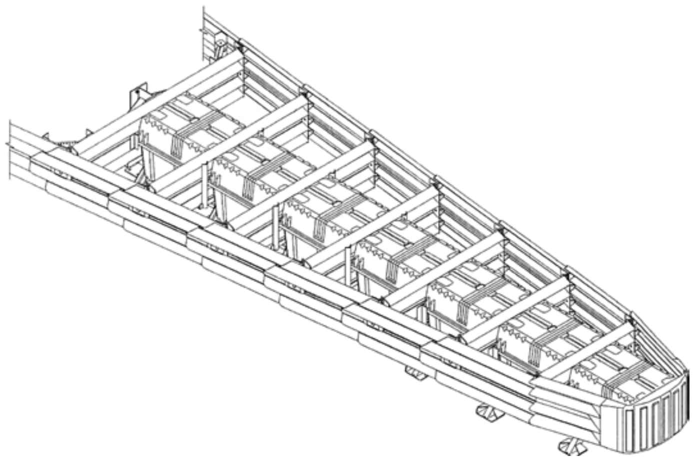
Brakemaster



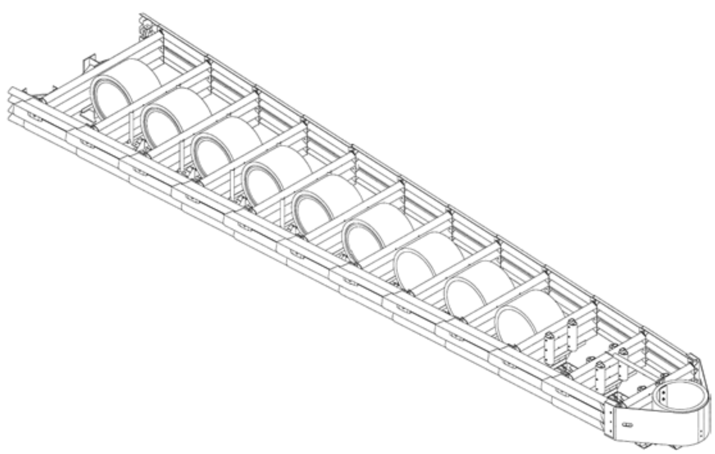
QuadTrend 350

Impact Attenuator Systems — Permanent Installations
Figure 720-2a

QuadGuard CZ



Wide QuadGuard

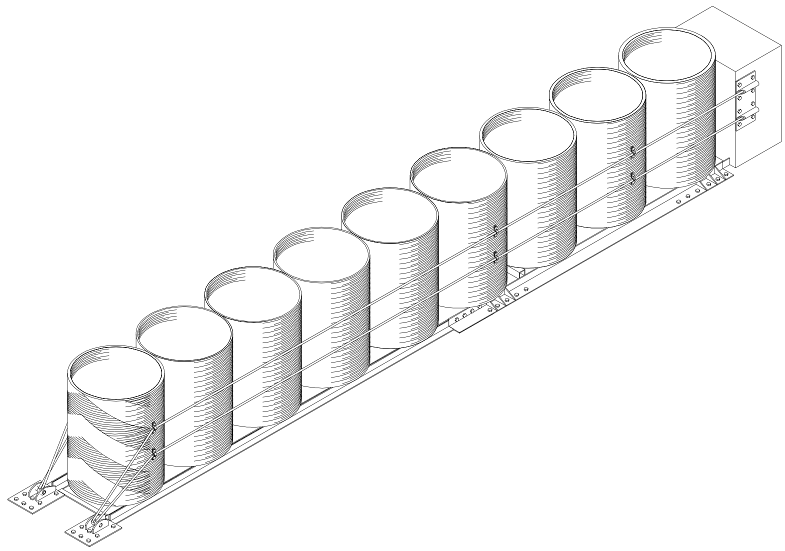


Wide QuadGuard Elite

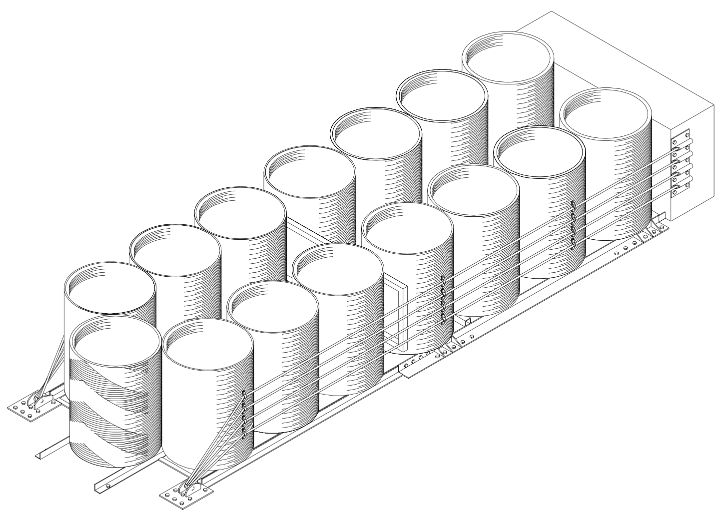
Impact Attenuator Systems — Permanent Installations
Figure 720-2b

Universal TAU

Impact Attenuator Systems — Permanent Installations
Figure 720-2c



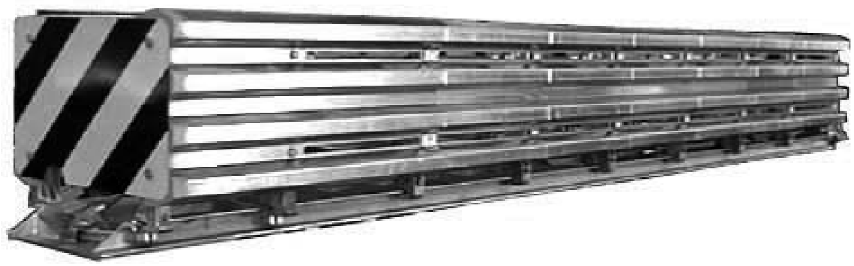
REACT 350



Wide REACT 350

Inertial Barrier

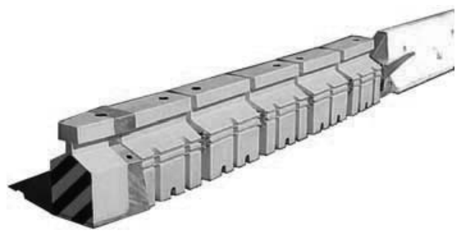
Impact Attenuator Systems — Permanent Installations
Figure 720-2d



SCI100GM

Impact Attenuator Systems—Permanent Installations
Figure 720-2e

ADIEM 350



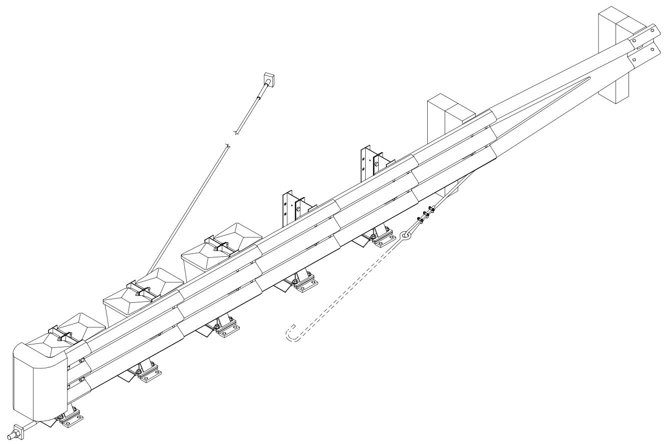
ABSORB 350

TRACC

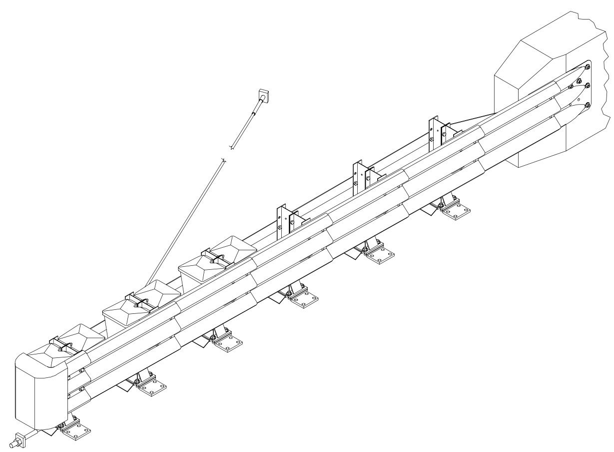
N-E-A-T

TRITON CET

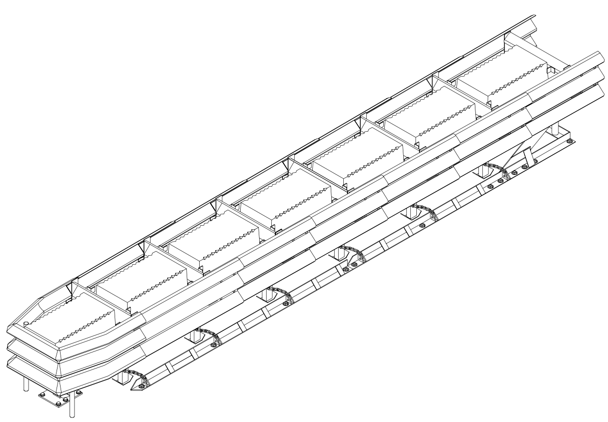
Impact Attenuator Systems — Work Zone Installations
Figure 720-3



Sentre

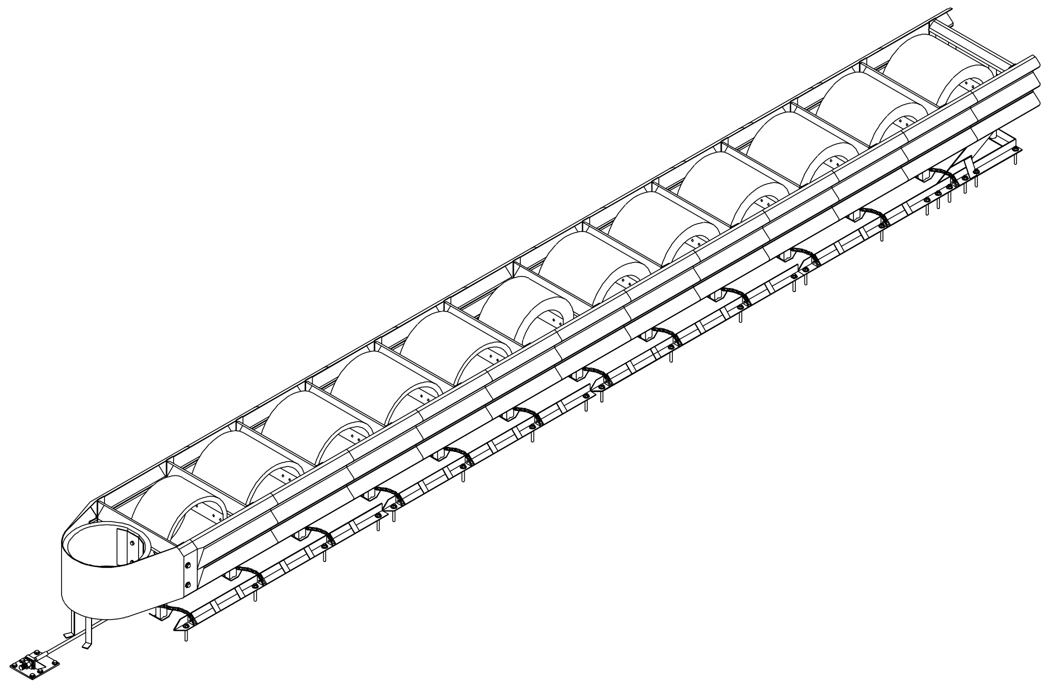


TREND

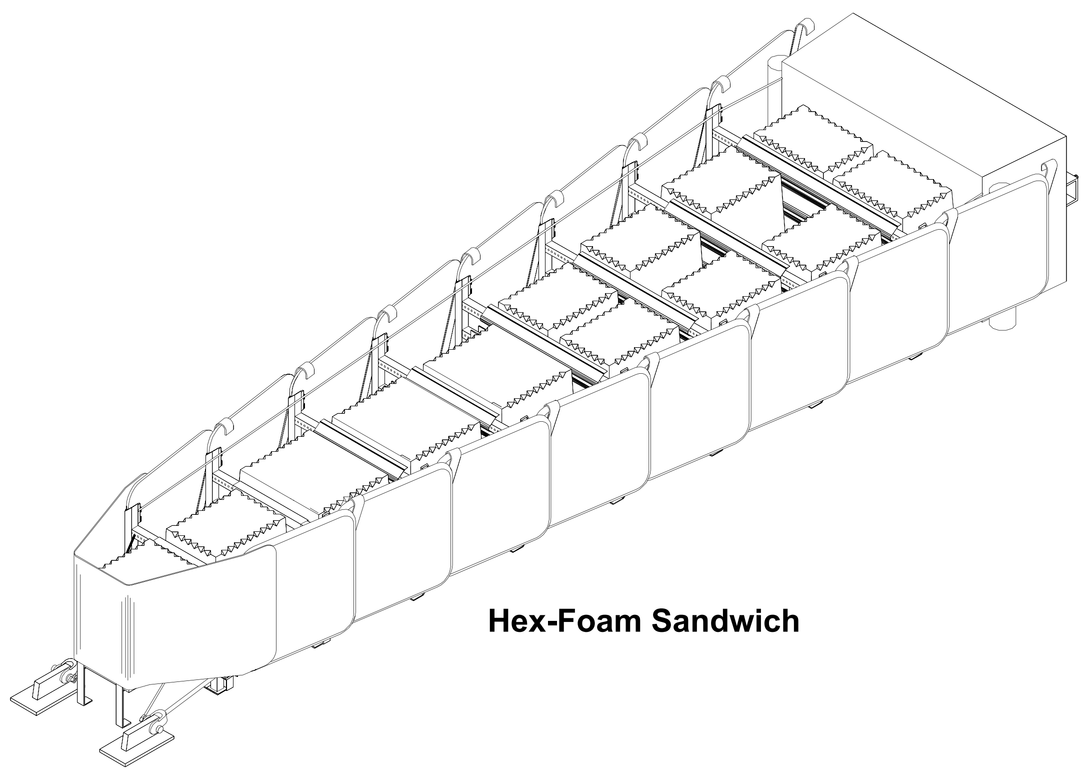


G-R-E-A-T

Impact Attenuator Systems — Older Systems
Figure 720-4a



L.M.A.



Hex-Foam Sandwich

Impact Attenuator Systems — Older Systems
Figure 720-4b

Impact Attenuator Systems (All dimensions in feet)

System	(P) Permanent (T) Temporary (B) Both	Width	Length	Transition to Rigid System Required?	Distance Beyond Length of Need	Initial Cost Category(1)
CAT(2)	P	2	31.25	Y	18.8	A
Brakemaster(2)	P	2	31.5	Y	15.8	A
QuadTrend – 350(6)	P	2	20.7	N	10.5	A
Universal TAU	P	2.9 - 8.7	14 - 26(4)	N	3	B(5)
QuadGuard	B	2, 2.5, 3, 5.75, 7.5, 10	12-30(4)	N	3.3	C(5)
QuadGuard Elite	B	2, 2.5, 3, 5.75, 7.5	35.5	N	3.3	C
REACT 350	B	3	15.25 - 36.25(4)	N	4.3	C(5)
Wide REACT 350	B	6 - 9	23.25	N	4.3	D(5)
Inertial Barriers	B	7	17 - 30(4)	N	(3)	A(5)
SCI100GM	B	2	21.5	N	3	C
ABSORB 350(9)	T	2	17.7 or 27	Y	17.7 or 27(3)	A(5)
ADIEM 350(7)	T	2	30	N	14.1	B
QuadGuard cz	T	2, 2.5, 3, 5.75, 7.5	22	N	3.3	B(5)
N-E-A-T(8)	T	1.9	9.7	N	(3)	A(5)
TRACC	T	2.6	21	N	8	B
TRITON CET(10)	T	2	41	N	(3)	A

1) A ($5,000 to $10,000); B ($10,000 to $15,000); C ($15,000 to $25,000); D ($25,000 to $40,000). These are rough initial cost estimates - verify actual costs through manufacturers/suppliers. Some products are priced very close to the margin between cost categories.
2) Generally for use with double-sided beam guardrail. Use as an end treatment for concrete barrier requires a transition.
3) The N-E-A-T, inertial barriers, and ABSORB 350 may only be used beyond the required length of need.
4) See Figure 720-1 for sizes or configuration type.
5) The length of the QuadGuard, REACT 350, Universal TAU, ABSORB 350, and inertial barriers varies since their designs are dependent upon speed. For a typical 60 mph design: the QuadGuard = 21 ft, the REACT 350 = 31 ft, the ABSORB 350 = 27 ft, the Universal TAU = 26 ft, and the inertial barrier = 30 ft. Costs indicated are for a typical 60 mph design. (except N-E-A-T)
6) Generally for use at the ends of bridges where installation of a beam guardrail transition and terminal is not feasible.
7) Generally for use with concrete barrier. Other uses may require a special transition design.
8) Use limited to highways with posted speeds of 45 mph or less.
9) The ABSORB 350 was primarily intended for the Quickchange Moveable Barrier (QMB) but may be used with other temporary barrier if beyond the length of need.
10) Test Level 3 version on high speed facilities should be limited to locations where the likelihood of being hit is low.

Impact Attenuator Comparison

Figure 720-5

830.05 Barrier Delineation

Traffic barriers are delineated where guide posts are required, such as bridge approaches, ramps, and other locations on unilluminated roadways. See Figure 830-2. At these locations, the barrier delineation has the same spacing as that of guide posts. Barrier delineation is also required when the traffic barrier is 4 ft or less from the traveled way. Use a delineator spacing of no more than 40 ft at these locations.

Beam guardrail is delineated by either mounting flexible guide posts behind the rail or by attaching shorter flexible guide posts to the wood guardrail posts.

Concrete barrier is delineated by placing retroreflective devices on the face of the barrier about 6″ down from the top. Consider mounting these devices on the top of the barrier at locations where mud or snow accumulates against the face of the barrier.

The terminal ends of impact attenuators are delineated with modified Type 3 Object Markers. These are the impact attenuator markers in the *Sign Fabrication Manual*. When the impact attenuator is used in a roadside condition, the marker with diagonal stripes pointing downward toward the roadway is used. When the attenuator is used in a gore where traffic will pass on either side, the marker with chevron stripes is used.

830.06 Wildlife Warning Reflectors

(1) Reflector System

Collisions between automobiles and wildlife (predominately deer) produce a substantial economic cost through damage to vehicles, human injuries, fatalities, and loss of the wildlife resources.

A wildlife warning reflector system has been developed to reduce this accident potential. This system consists of a series of reflectors mounted adjacent to the roadway. During the hours of low natural light (dusk, dawn, and night), light from the headlights of an approaching vehicle is reflected to the adjacent roadside by the reflectors. This reflected light creates an “optical fence” causing deer to remain motionless until the vehicle has passed.

The Headquarters (HQ) Environmental Services biologist maintains a history of vehicle-deer collisions on state highways and can furnish the region with prospective “optical fence” locations. The biologist is available to assist with a benefit/cost analysis of proposed reflector installations. Consider wildlife reflectors where the deerkill for any one mile section exceeds five kills per year. Also, consider wildlife reflectors for special circumstances such as at a high use deer crossing where a short section of this reflector system might be appropriate. After-installation maintenance costs can be a prohibitive factor when considering a wildlife reflector system. To remain effective, dirty reflectors must be cleaned periodically and reflector posts damaged by snow plowing or errant vehicles must be replaced.

(2) Reflector Placement

Spacing of the wildlife reflectors along the shoulder edges is dependent upon the geometric configuration of the highway and upon the roadside conditions. Reflectors are placed along both sides of the roadway in a staggered arrangement with the longitudinal spacing roughly equal to the combined transverse width of the roadway and reflector offset. See Figures 830-3 and 830-4 for examples of wildlife reflector placements. More detailed information for reflector placement in different locations is available from the manufacturer. Contact the HQ Environmental Services biologist or the HQ Traffic Office.

830.07 Documentation

A list of the documents that are to be preserved [in the Design Documentation Package (DDP) or the Project File (PF)] is on the following website: http://www.wsdot.wa.gov/eesc/design/projectdev/

Ice Chisel Snow Removal Areas					
Roadway Classification	Marking Type				
	Center Lines	Lane Lines	Edge Lines	Wide Lines	Special Markings
Interstate	N.A.	Plastic Insets	Paint	Paint	Paint
Major Arterial	Paint & RRPMs	Paint	Paint	Paint	Paint
Minor Arterial	Paint	Paint	Paint	Paint	Paint
Collector	Paint	Paint	Paint	Paint	Paint
Steel Blade Snow Removal Areas					
Roadway Classification	**Marking Type**				
	Center Lines	**Lane Lines**	**Edge Lines**	**Wide Lines**	**Special Markings**
Interstate-Urban	N.A.	Plastic	Paint or Plastic	Paint or Plastic	Paint or Plastic
Interstate-Rural	N.A.	Paint	Paint or Plastic	Paint or Plastic	Paint or Plastic
Major Arterial	Paint & RRPMs or Plastic	Paint	Paint or Plastic	Paint or Plastic	Paint or Plastic
Minor Arterial	Paint	Paint	Paint	Paint or Plastic	Paint or Plastic
Collector	Paint	Paint	Paint	Paint or Plastic	Paint or Plastic
Rubber Blade Snow Removal Areas					
Roadway Classification	**Marking Type**				
	Center Lines	**Lane Lines**	**Edge Lines**	**Wide Lines**	**Special Markings**
Interstate-Urban	N.A.	MMA only or (8) MMA & RPMs	Paint or Plastic	Plastic (9)	MMA (10)
Interstate-Rural	N.A.	MMA only or (8) MMA & RPMs	Paint	Plastic (9)	MMA (10)
Major Arterial	Paint & RPMs or Plastic & RPM's	(9)	Paint	Plastic (9)	Plastic (9)
Minor Arterial	Paint & RPMs	Paint & RPMs	Paint	Plastic	Plastic
Collector	Paint & RPMs	Paint	Paint	Plastic	Plastic

Notes
1. Insets are grooves ground into the pavement and filled with material, usually methyl methacrylate.
2. Plastic refers to methyl methacrylate, thermoplastic, or preformed tape.
3. See Standard Plan H-5d for RPM substitute applications.
4. See Standard Plan H-3 and H-3a for RPM applications with paint or plastic.
5. Special Markings include arrows, symbols, letters, channelizing lines, and transverse markings.
6. RRPMs refers to RPMs installed in a groove ground into the pavement.
7. Type 2 RPMs are not required with painted or plastic center or lane line in continuously illuminated sections. See Section 830.03(2).
8. MMA refers to profiled methyl methacrylate.
9. Consult Region striping policy.
10. MMA refers to flat methyl methacrylate.

Pavement Marking Material Guide
Figure 830-1

Chapter 910 Intersections At Grade

910.01 General

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

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

Chapter	Subject
915	Roundabouts
920	Road Approaches
940	Interchanges

If an intersection design situation is not covered in this chapter, contact the Headquarters (HQ) 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, USDOT, FHWA; including the *Washington State Modifications to the MUTCD*, M 24-01, WSDOT (MUTCD)

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

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

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

A Policy on Geometric Design of Highways and Streets (Green Book), 2001, 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

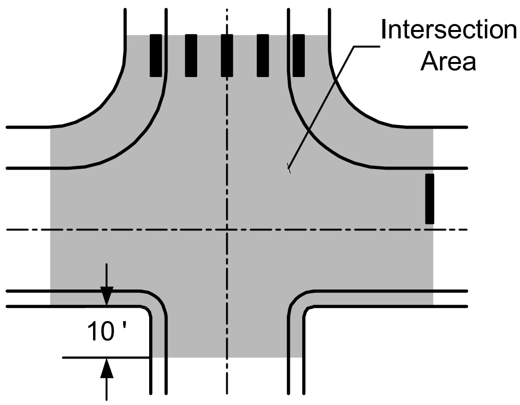
bulb out A curb and sidewalk bulge or extension out into the roadway used to decrease the length of a pedestrian crossing. (See chapter 1025.)

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 intersecting 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 10 ft from the edge of shoulder of the intersecting roadway. See Figure 910-1.



Intersection Area
Figure 910-1

intersection at grade The general area where a 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.

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 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 desirable intersection angle is 90°, with 75° to 105° allowed for new, reconstructed, or realigned intersections.

Existing intersections with an intersection angle between 60° and 120° may remain. Intersection angles outside this range tend to restrict visibility, increase the area required for turning, increase the difficulty 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 100 ft 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 910-18).

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

(c) **Split Tee.** Avoid split tee intersections where there is less than the required intersection spacing. 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 main line left-turn lanes, 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 required intersection spacing [see 910.04(4)] 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, except for split tee intersections [910.04(2)(c)].
- Intersections with more than four legs.
- Tee intersections with the major traffic movement making a turn.
- Wye intersections that are not a one-way merge or diverge.

A roundabout might be an alternative to these nonstandard configurations. (See 910.08 and Chapter 915.)

With justification and approval from the region's Traffic Engineer existing intersections with nonstandard configurations may remain in place when an analysis shows no accident history related to the configuration.

(3) Crossroads

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

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 60 ft long to connect to the grade of the crossroad.

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

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. The minimum spacing for highways with limited access control is covered in Chapter 1430. For other highways, the minimum spacing is dependent on the Highway Access Management Class. See Chapter 1435 for minimum intersection spacing on Managed Access highways.

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

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-40	Semitrailer truck, overall wheelbase of 40 ft
WB-50	Semitrailer truck, overall wheelbase of 50 ft
WB-67	Semitrailer truck, overall wheelbase of 67 ft
MH	Motor home
P/T	Passenger car pulling a camper trailer
MH/B	Motor home pulling a boat trailer

Design Vehicle Types
Figure 910-2

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, larger turn radii are used. This results in increased pavement areas, longer pedestrian crossing distances, and longer traffic signal arms.

To reduce the intersection area, a smaller design vehicle is used or encroachment is allowed. This reduces the potential for vehicle/pedestrian conflicts, decreases pedestrian crossing distance, and controls speeds of turning vehicles. The negative impacts include possible 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 radii 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-67
Junction of State Routes	WB-50
Ramp Terminals	WB-50
Other Rural	WB-50
Industrial	WB-40
Commercial	SU(1)(2)
Residential	SU(1)(2)

(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 910-6a through 6c, templates from another published source, or computer generated templates) 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.

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

910.06 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 the speeds of turning vehicles. This normally leads to right-corner designs with smaller turning radii. The negative impacts include possible capacity reductions and greater speed differences between turning vehicles and through vehicles.

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

Figure 910-7 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 910-7 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 910-8a, 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 910-8b 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 910-9a through 9c. On four-lane highways use Figure 910-8b. 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
100	125	125	150	150	150
150	175	200	200	200	200
200	225	250	275	300	300
250	275	300	325	350	375
300	350	375	400	400	400
*Length from Figures 910-8b, 9a, 9b, or 9c.					

Left-Turn Storage With Trucks (ft)
Figure 910-4

Design opposing left-turn vehicle paths with a minimum 4 ft (12 ft desirable) clearance between opposing turning paths. Existing signalized intersections that do not meet the 4 ft clearance may remain with split signal phasing, an evaluate upgrade, and concurrence from the HQ Traffic Office.

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

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

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

Figures 910-10a through 10e show one-way left-turn geometrics. Figure 910-10a shows widening to accommodate the new lane. Figures 910-10c and 10d show the use of a median. Figure 910-10e shows the minimum protected left-turn with a median.

1. **Widening (Figure 910-10a).** 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 910-10b through 10d).** Widening is not required for left-turn lane channelization where medians are 11 ft wide or wider. For medians between 13 ft and 23 ft or where the acceleration lane is not provided, it is desirable to design the left-turn lane adjacent to the opposing lane, as shown on Figure 910-10b, to improve sight distance.

A median acceleration lane, shown on Figures 910-10c and 10d, may be provided where the median is 23 ft 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. Where medians have sufficient width, provide a 2 ft shoulder adjacent to a left-turn lane.

3. **Minimum Protected Left-Turn with a Median (Figure 910-10e).** At intersections on divided highways where channelized left-turn lanes are not provided, consider the minimum protected storage area.

With justification, left-turn lane designs given in Figures 910-10a through 10d may be modified. Document the benefits and impacts of the modified design including: changes to vehicle pedestrian conflicts, vehicle encroachment, deceleration length, capacity restrictions for turning vehicles or other degradation of intersection operations, and the effects on other traffic movements. The modified design must be able to accommodate the design vehicle and provide for the striping requirements of the Standard Plans and the MUTCD. To verify that the design vehicle can make the turn, include a plot of the design showing the design vehicle turning path template.

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

Use TWLTLs only on managed access highways 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 existing 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 and can encourage strip development with additional closely spaced access points. Consider other alternatives, before using TWLTL, such as prohibiting midblock left-turns and providing for U-turns. See Chapters 440 and 1435 for additional restrictions on the use of TWLTLs.

The basic design for a TWLTL is illustrated on Figure 910-10f. Additional criteria are:

- The desirable length of a TWLTL is not less than 250 ft.
- 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 at unsignalized intersections:

- Recommendation from Figure 910-11 based on same direction approach and right-turn traffic volumes for multilane roadways with a posted speed 45 mph or above and for all two-lane roadways.
- An accident study indicates that a right-turn lane will result in an overall accident reduction.
- Presence of pedestrians who require right-turning vehicles to stop.
- Restrictive geometrics that require right-turning vehicles to slow greatly below the speed of the through traffic.
- Less than decision sight distance at the approach to the intersection.

For unsignalized intersections, see 910.07(3) Speed Change Lanes for guidance on right-turn lane lengths. For signalized intersections, use a traffic signal analysis to determine if a right-turn lane is needed and the length requirement. (See Chapter 850.)

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

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

The right-turn pocket or the right-turn taper (Figure 910-12) 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 910-11. 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 910-12 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 100 ft 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 1500 ft. For facilities with a posted speed less than 45 mph, provide a lane of sufficient length so that the advanced lane reduction warning sign will be placed not less than 100 ft 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 910-13 and 14. 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) Shoulders

Shoulder width requirements adjacent to turn lanes and speed change lanes at intersections are reduced. For roadways without curb sections, the shoulder adjacent to turn lanes and speed change lanes may be reduced to 2 ft on the left and 4 ft on the right. When a curb and sidewalk section is used with a turn lane 400 ft or less in length, the shoulder adjacent to the turn lane may be eliminated. The design of the intersection might need to be adjusted to allow for vehicle tracking. On routes where provisions are made for bicycles, continue the bicycle facility between the turn lane and the through lane. (See Chapter 1020 for information on bicycle facilities.)

Reducing the shoulders for turn and speed change lanes reduces the pavement widening for the lane and discourages drivers from using the shoulder to bypass the other turning vehicles.

(5) 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 4 ft wide and 20 ft long. (Mountable curb, used to discourage turn movements, is not a divisional island.)

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

Design triangular shaped islands as shown on Figure 910-15a through 15c. The shoulder and offset widths illustrated are for islands with vertical curbs 6 in or higher. Where painted islands are used, such as in rural areas, these widths are desirable but may be omitted. See Chapter 641 for turning roadway widths.

Island markings may be supplemented with reflective raised pavement markers.

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

(b) **Location.** Design the approach ends of islands to provide adequate visibility to alert 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 910-15b). This design forces the turning traffic to slow down.

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

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

In addition consider curbing for:

- Divisional and channelizing islands.
- Landscaped islands.

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

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

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

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 cross road 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 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)	1,000 ft	(2)
Suburban	1/2 mi	1/4 mi(3)
Rural	1 mi	1/2 mi

(1) For design speeds greater than 45 mph use suburban spacing.

(2) The minimum spacing is the acceleration lane length from a stop (Figure 910-14) plus 300 ft.

(3) For design speeds 60 mph or greater, the minimum spacing is the acceleration lane length from a stop (Figure 910-14) plus 300 ft.

U-Turn Spacing
Figure 910-5

When designing U-turn locations, use Figure 910-16 as a guide. Where the median is less than 40 ft wide and a large design vehicle is required, consider the use of a U-turn roadway (jug handle).

Document the need for U-turn locations, the spacing used, and justify the selected design vehicle.

U-turns at signal controlled intersections do not require the acceleration lanes shown in Figure 910-16. At new U-turn locations at signal controlled intersections, ensure that right-turning vehicles from side streets will not conflict with U-turning vehicles. Warning signs on the cross street might be appropriate.

910.10 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 910-17a to determine minimum sight distance along the through roadway.

The sight triangle is determined as shown in Figure 910-17b. 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. In order to maintain the sight distance, the sight trianlge must be within the right of way or a state maintenance easement (see Chapter 1410).

The minimum setback distance for the sight triangle is 18 ft from the edge of traveled way. This is for a vehicle stopped 10 ft from the edge of traveled way. The driver is almost always 8 ft or less from the front of the vehicle; therefore, 8 ft is added to the setback. When the stop bar is placed more than 10 ft from the edge of traveled way, consider providing the sight triangle to a point 8 ft 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-50 or WB-67 rather than the SU. In areas where SU or WB vehicles are minimal, and right of way restrictions prohibit adequate sight triangle clearing, only the P vehicle need be considered.

At existing intersections, when sight obstructions within the sight triangle cannot be removed due to limited right of way, the intersection sight distance may be modified. A driver that does not have the desired sight distance will creep out until the sight distance is available; therefore, the 10 ft stopping distance from the edge of traveled way may be reduce to 2 ft, reducing the setback to 10 ft. Also, the time gap (t_g) may be reduced by the 2 sec perception/reaction time. Document the right of way width and provide a brief analysis of the intersection sight distance clarifying the reasons for reduction. Verify and document that there is not an accident problem at the intersection. Document as a design exception.

If the intersection sight distance cannot be provided using the reductions in the preceding paragraph, the calculated sight distance may be reduced, with HQ Design Office approval. Provide as much sight distance as practical, but not less than the stopping sight distance required for the major roadway, with visibility at the 10 ft setback point. (For required stopping sight distance, see Chapter 650.) Document the right of way width and provide a brief analysis of the intersection sight distance clarifying the reasons for reduction. Verify and document that there is not an accident problem at the intersection. Document as a design exception.

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

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

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

Design ramp terminal sight distance as at-grade intersections considering only left- and right- turning movements. An added element at ramp terminals is the grade separation structure. Figure 910-17b 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 6 ft and an object height of 1.5 ft.

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. 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 Headquarters 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 910-18. 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 limited access control, see Chapter 1430 for requirements.

(1) Approval

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

- Traffic analysis.
- Deviations approved in accordance with Chapter 330.
- Preliminary traffic signal plan approved by the HQ Traffic Office. (See Chapter 850.)
- HQ Design Office approval for intersections with roundabouts. See Chapter 915 for approval procedures.

(2) Intersection Plans

Intersection plans are required for any increases in capacity (turn lanes) 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, pedestrian use, 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.
- Profiles for the main line and crossroad.
- ADA considerations.
- Right of way lines.
- Location and type of channelization.
- Width of lanes and shoulders on main line and crossroads (Chapter 440, 640 and 641).
- Proposed access control treatment (Chapters 1420, 1430, and 1435).
- Traffic data including volumes for all movements and vehicle classifications.
- Classes of highway and design speeds for main line and crossroads (Chapter 440).

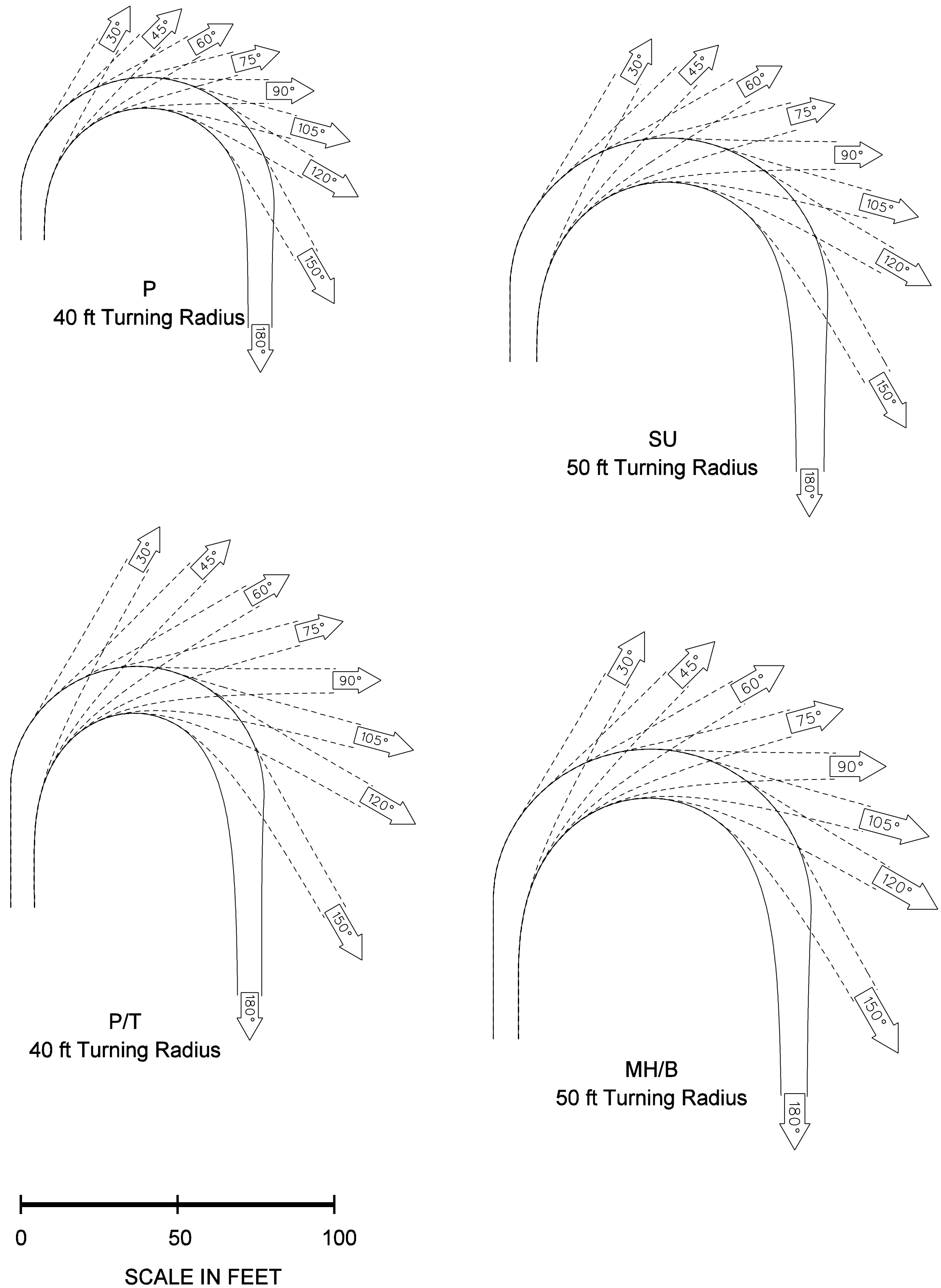
- Whether or not the intersection will be signalized or illuminated.
- A copy of all deviations and justifications, if any.

(3) Local Agency or Developer Initiated Intersections

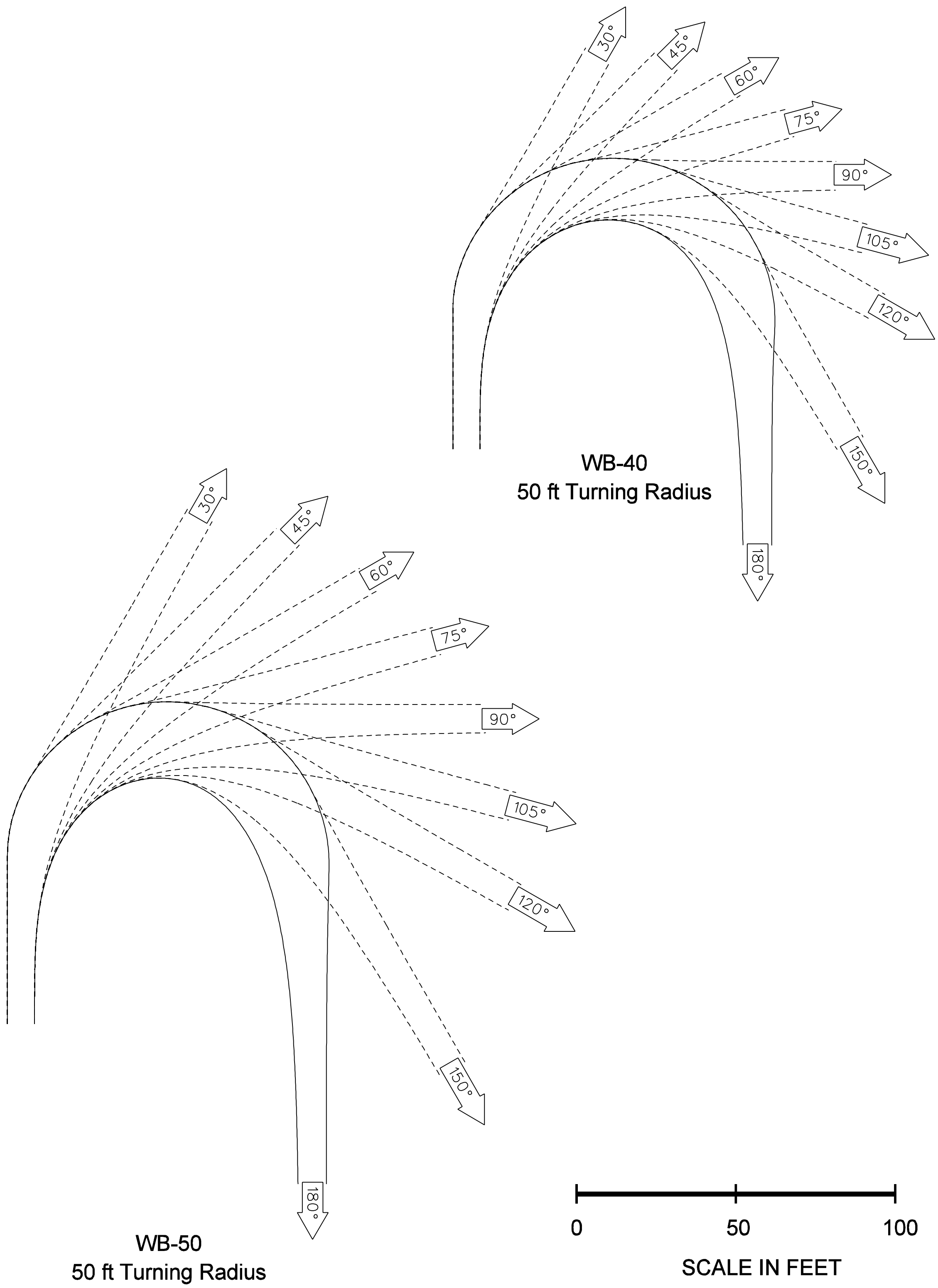
There is a separate procedure for local agency or developer-initiated projects at intersections with state routes. The project initiator submits an intersection plan, and the documentation of design considerations that led to the plan, to the region for approval. For those plans requiring a deviation, 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

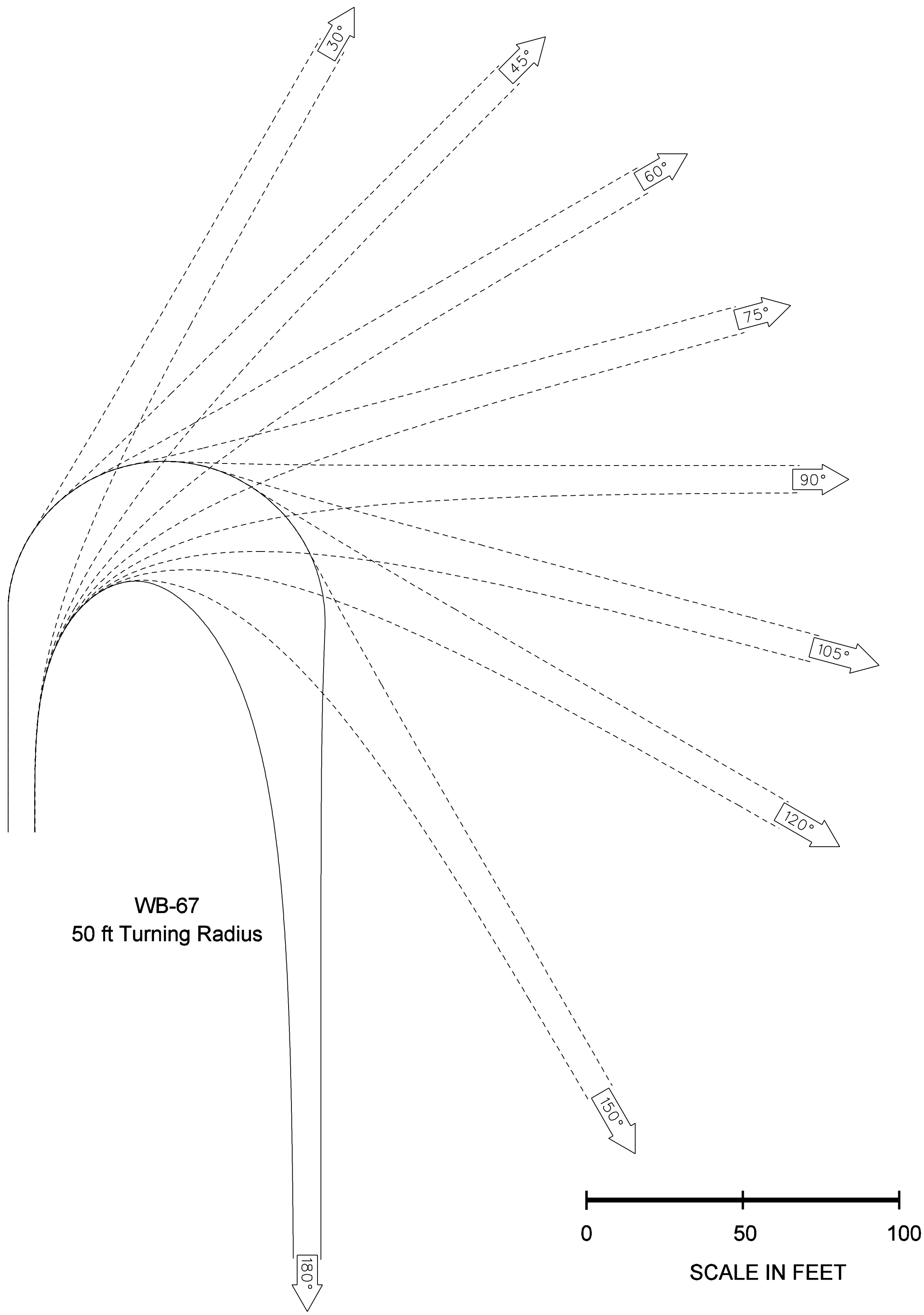
A list of the documents that are to be preserved [in the Design Documentation Package (DDP) or the Project File (PF)] is on the following web site: http://www.wsdot.wa.gov/eesc/design/projectdev/



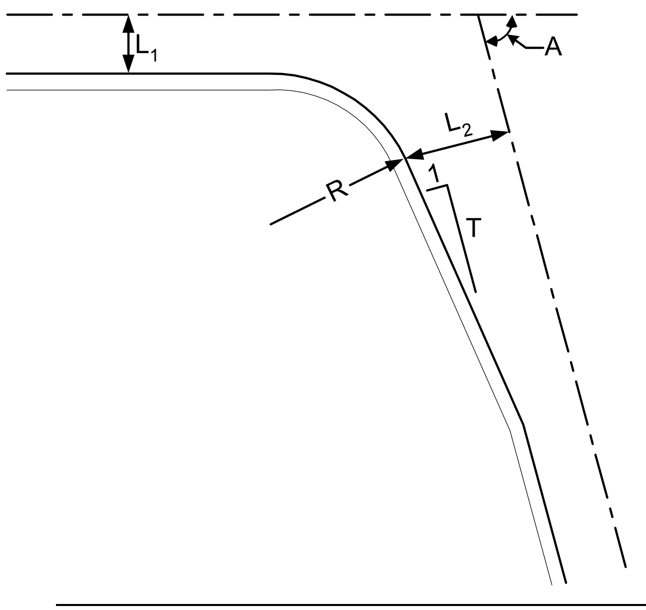
Turning Path Template
Figure 910-6a



Turning Path Template
Figure 910-6b



Turning Path Template
Figure 910-6c



L_1 = Minimum available roadway width (2) that the vehicle is turning from.

L_2 = Minimum available roadway width (2) 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

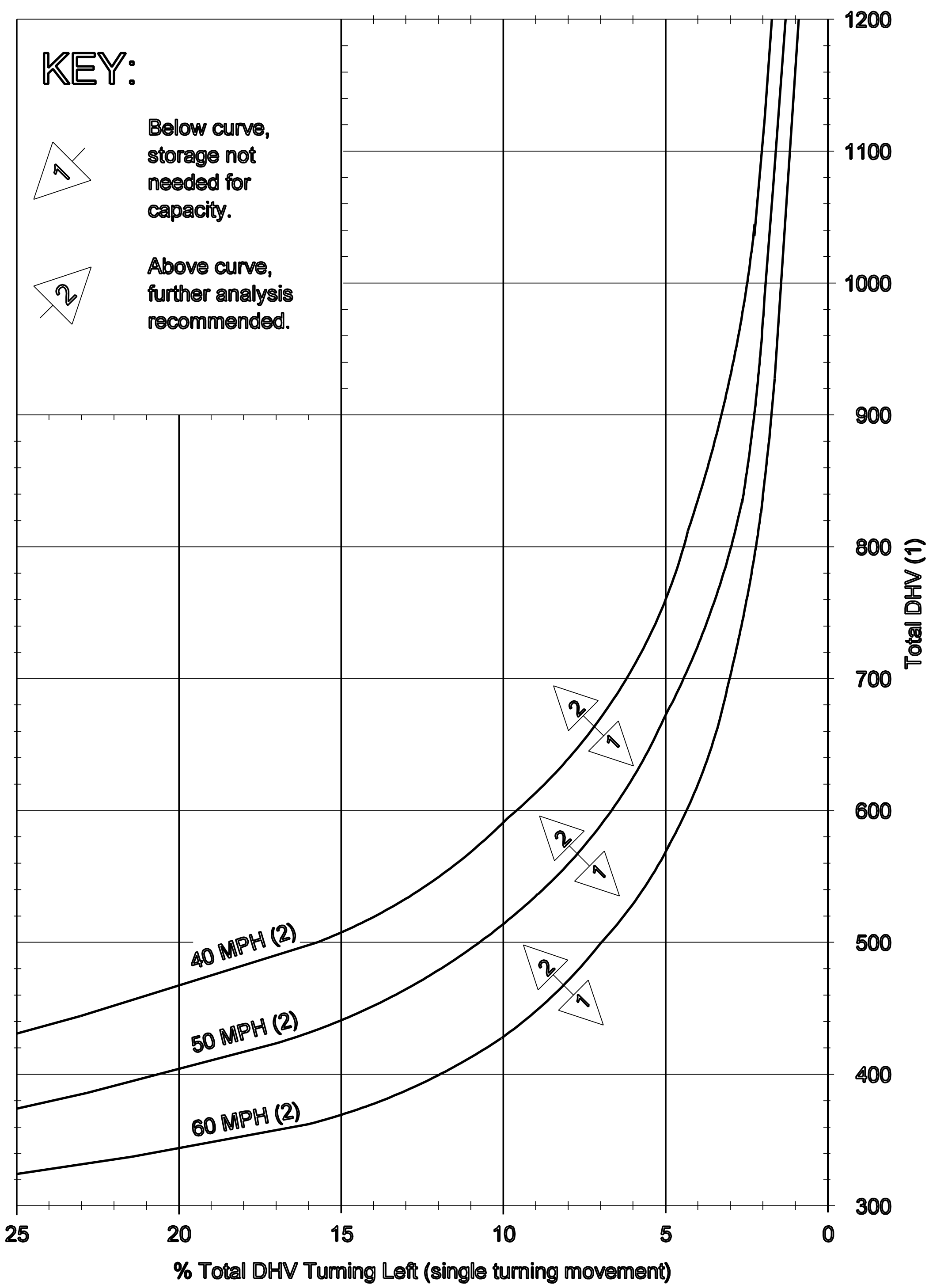
Vehicle	A	R	L_1 (1)	L_2 (1)	T	Vehicle	A	R	L_1 (1)	L_2 (1)	T
WB-67	60	85	11	22	7	WB-40	60	55	11	15	7.5
	75	75	11	21	8		75	55	11	15	7.5
	90	70	11	21	8		90	55	11	14	7.5
	105	55	11	24	7		105	45	11	16	7.5
	120	50	11	24	7		120	45	11	15	7.5
WB-50	60	55	11	19	6	SU & BUS	All	50	11	11	25
	75	55	11	18	6	P	All	35	11	11	25
	90	55	11	17	6						
	105	50	11	17	6						
	120	45	11	18	6						

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

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

(3) All distances given in feet and angles in degrees.

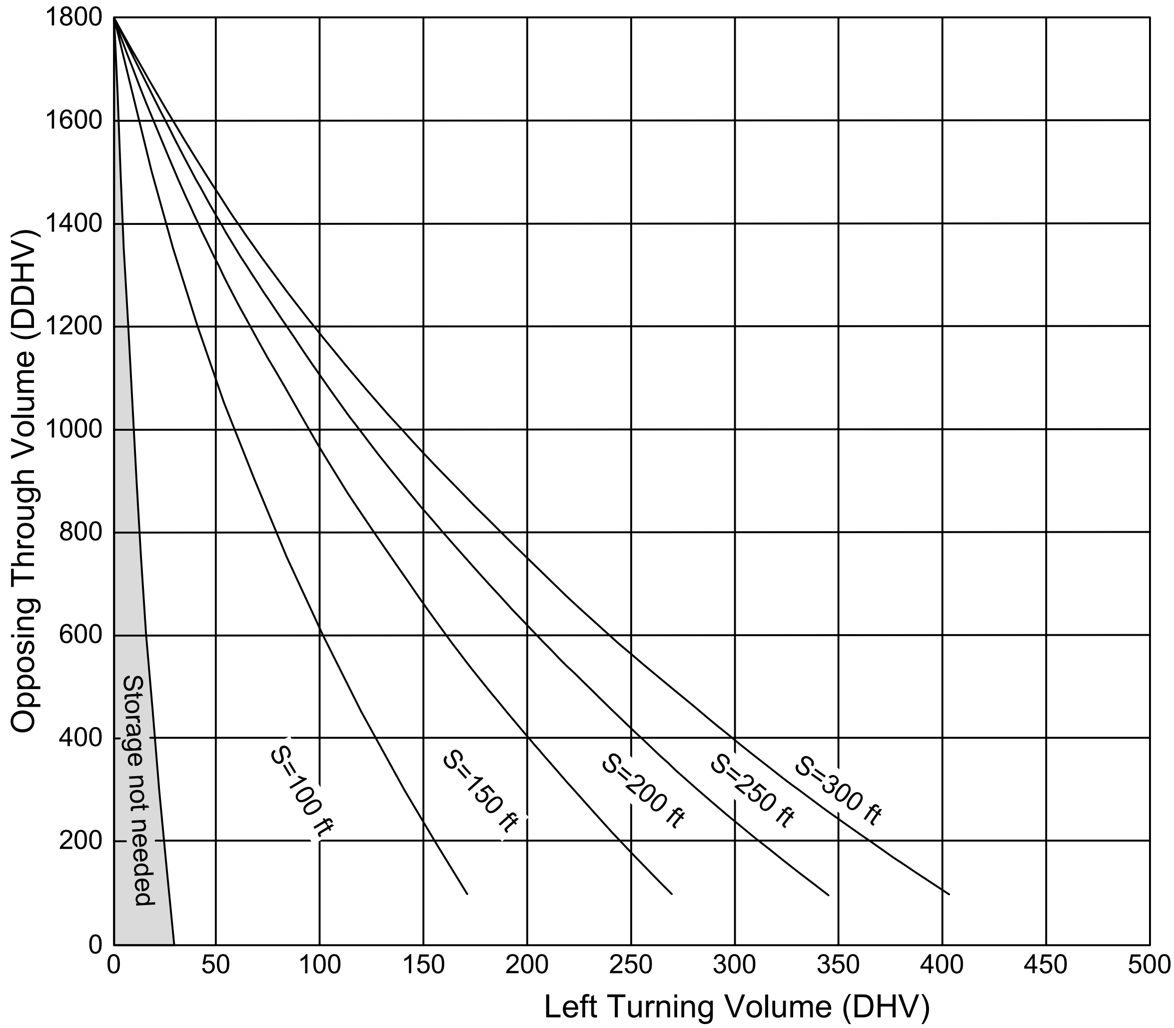
Right-Turn Corner
Figure 910-7



(1) DHV is total volume from both directions.

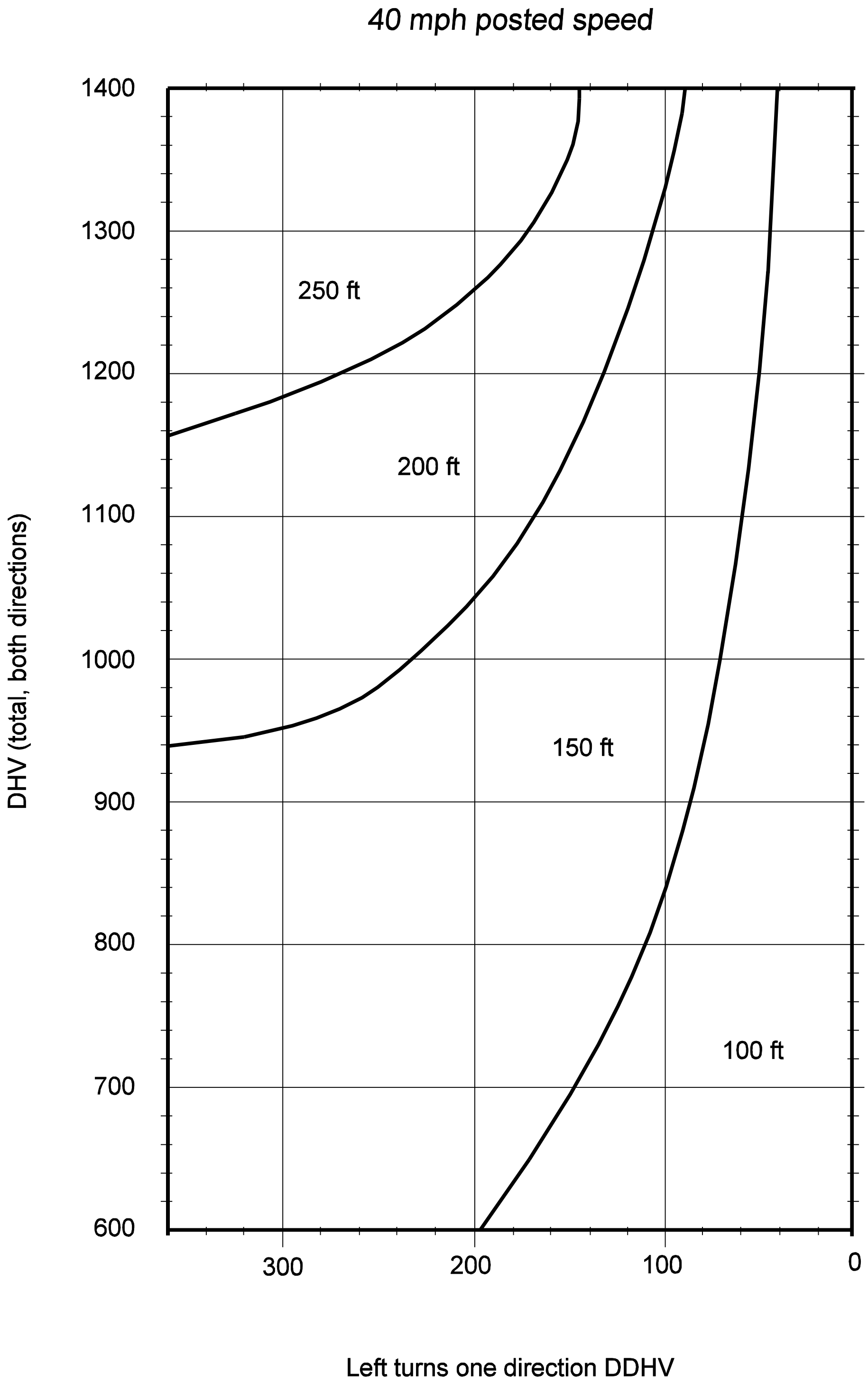
(2) Speeds are posted speeds.

Left-Turn Storage Guidelines (Two-Lane, Unsignalized)
Figure 910-8a

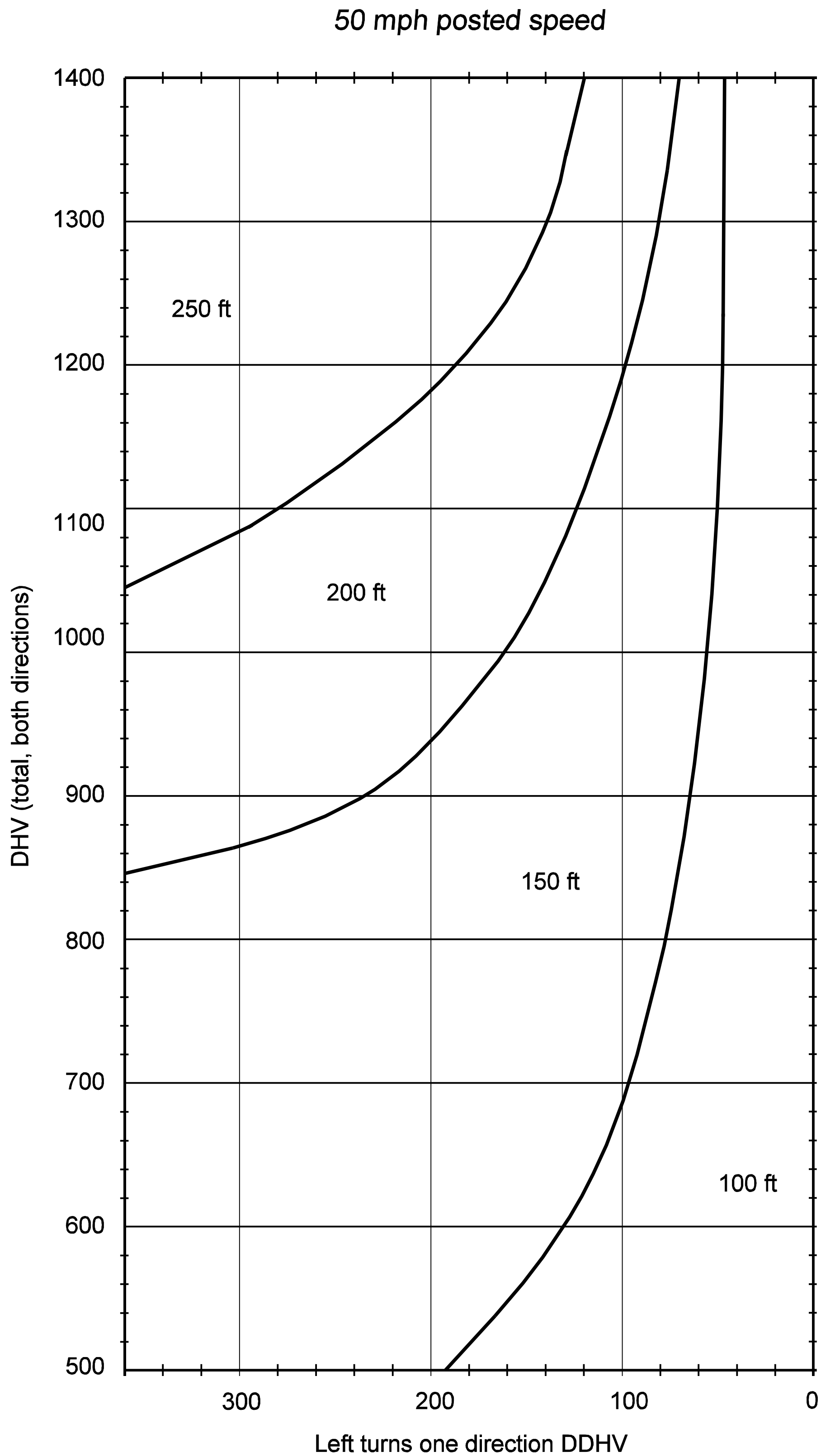


S = Left-Turn storage length

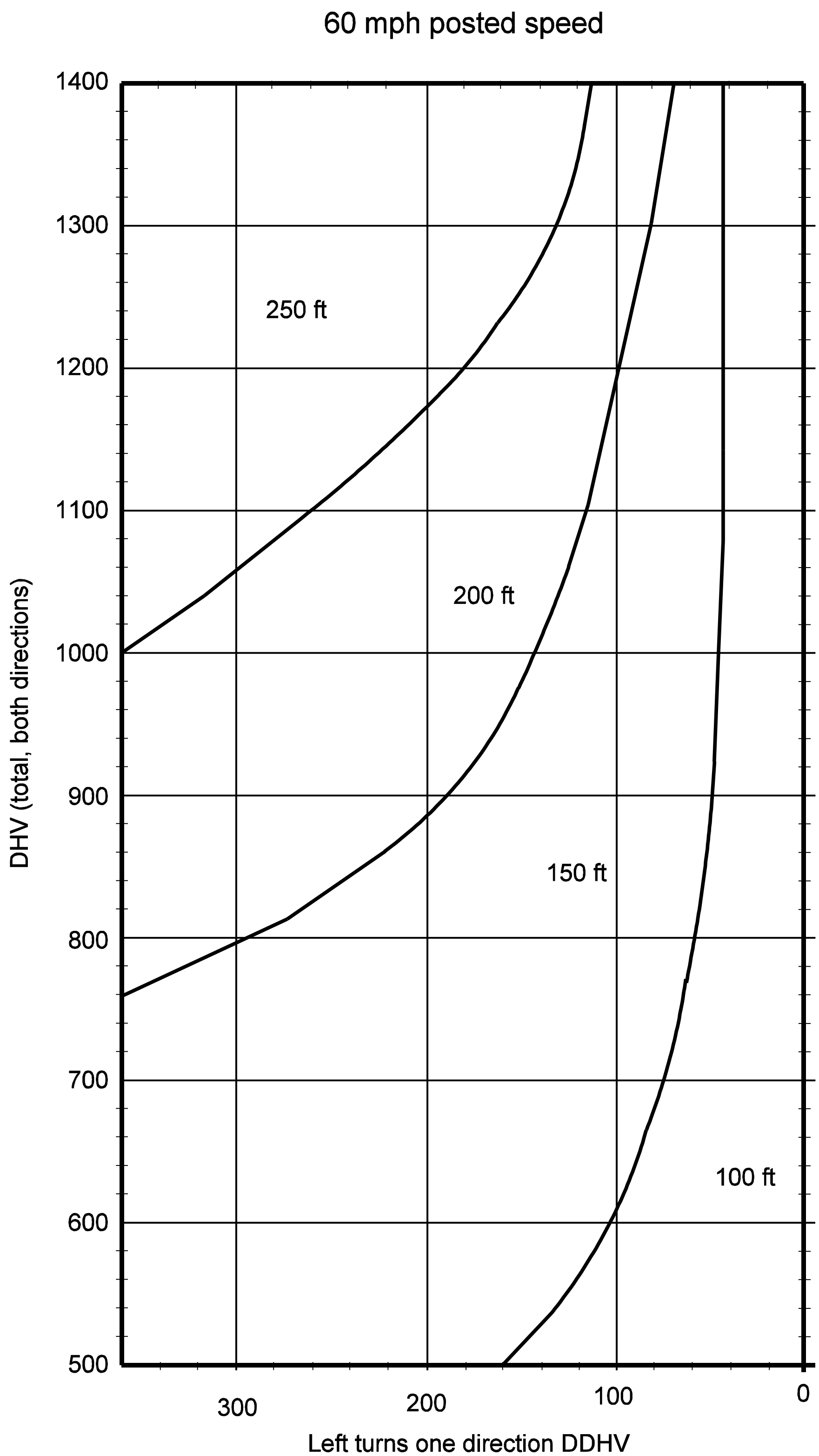
Left-Turn Storage Guidelines (Four-Lane, Unsignalized)
Figure 910-8b



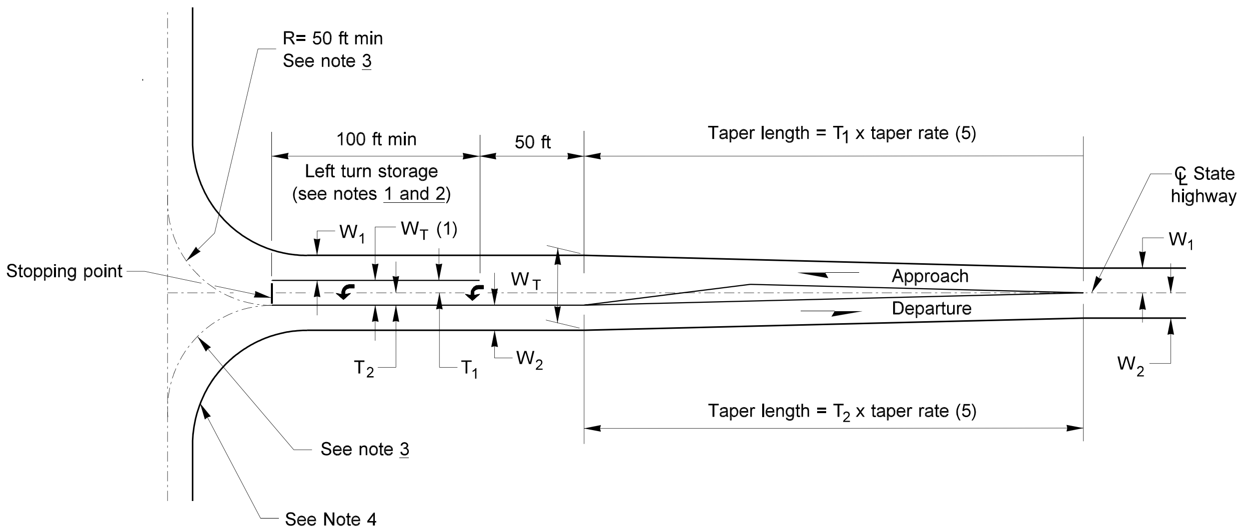
Left-Turn Storage Length (Two-Lane, Unsignalized)
Figure 910-9a



Left-Turn Storage Length (Two-Lane, Unsignalized)
Figure 910-9b



Left-Turn Storage Length (Two-Lane, Unsignalized)
Figure 910-9c



Notes:

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

(2) For left-turn storage length, see Figures 910-8b for 4-lane roadways or 9a through 9c for 2-lane roadways.

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

(4) See Figure 910-7 for right-turn corner design.

(5) See Table 1 for desirable taper rates. With justification, taper rates from Table 2, Figure 910-10c, may be used.

(6) See Standard Plans and MUTCD for pavement marking details.

W_1 = Approaching through lane.

W_2 = Departing lane.

T_1 = Width of left-turn lane on approach side of center line.

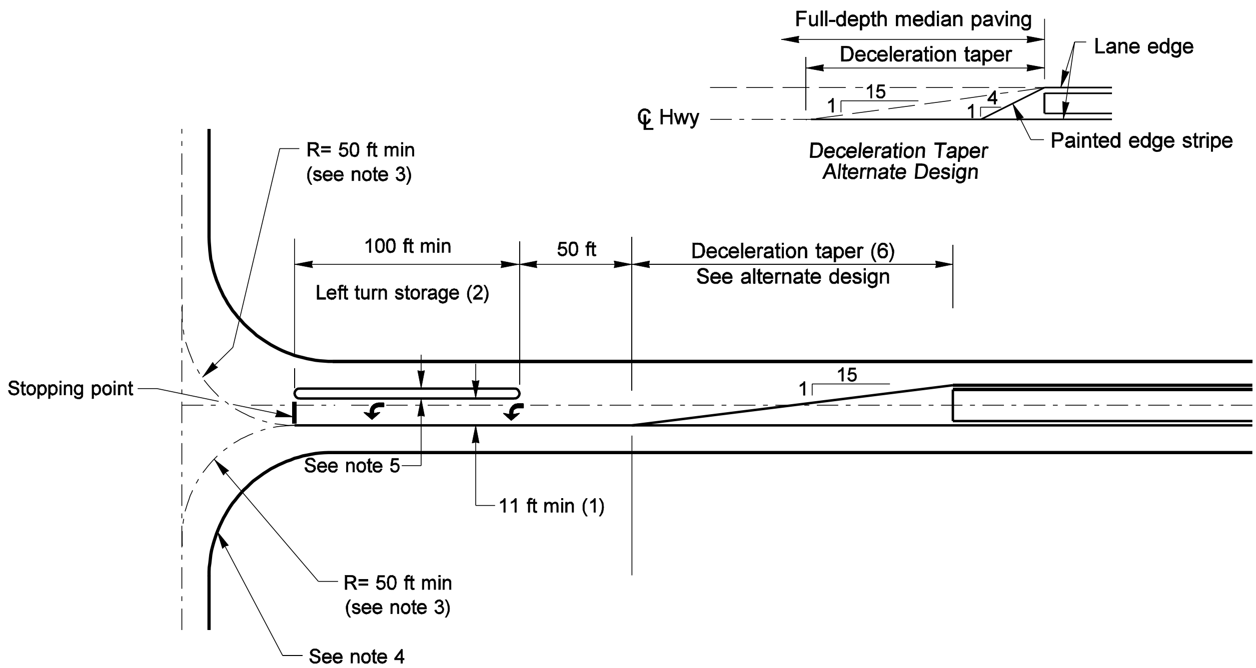
T_2 = Width of left-turn lane on departure side of center line.

W_T = Total width of channelization. (W_1+W_2+T_1+T_2)

Posted Speed	Taper Rate
55 mph	55:1
50 mph	50:1
45 mph	45:1
40 mph	40:1
35 mph	35:1
30 mph	30:1
25 mph	25:1

Table 1

Median Channelization (Widening)
Figure 910-10a



Notes:

(1) Lane width of 13 ft is desirable.

(2) For left-turn storage length, see Figures 910-8b for 4-lane roadways or 9a through 9c for 2-lane roadways.

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

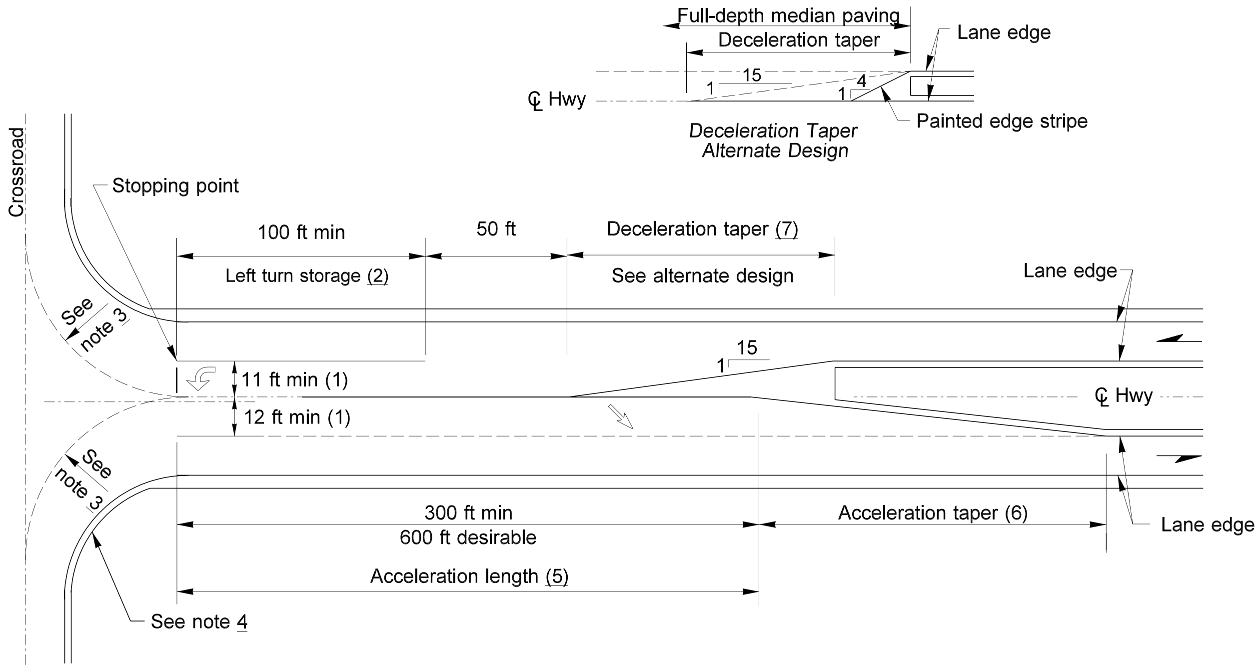
(4) See Figure 910-7 for right-turn corner design.

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

(6) For increased storage capacity, consider the left-turn deceleration taper alternate design.

(7) See Standard Plans and MUTCD for pavement marking details.

Median Channelization (Median Width 11 ft or more)
Figure 910-10b



Notes:

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

(2) For left-turn storage length, see Figures 910-8b for 4-lane roadways or 9a throug9c for 2-lane roadways.

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

(4) See Figure 910-7 for right-turn corner design.

(5) The minimum total length of the median acceleration lane is shown in Figure 910-14.

(6) See Table 2, for acceleration tape rate.

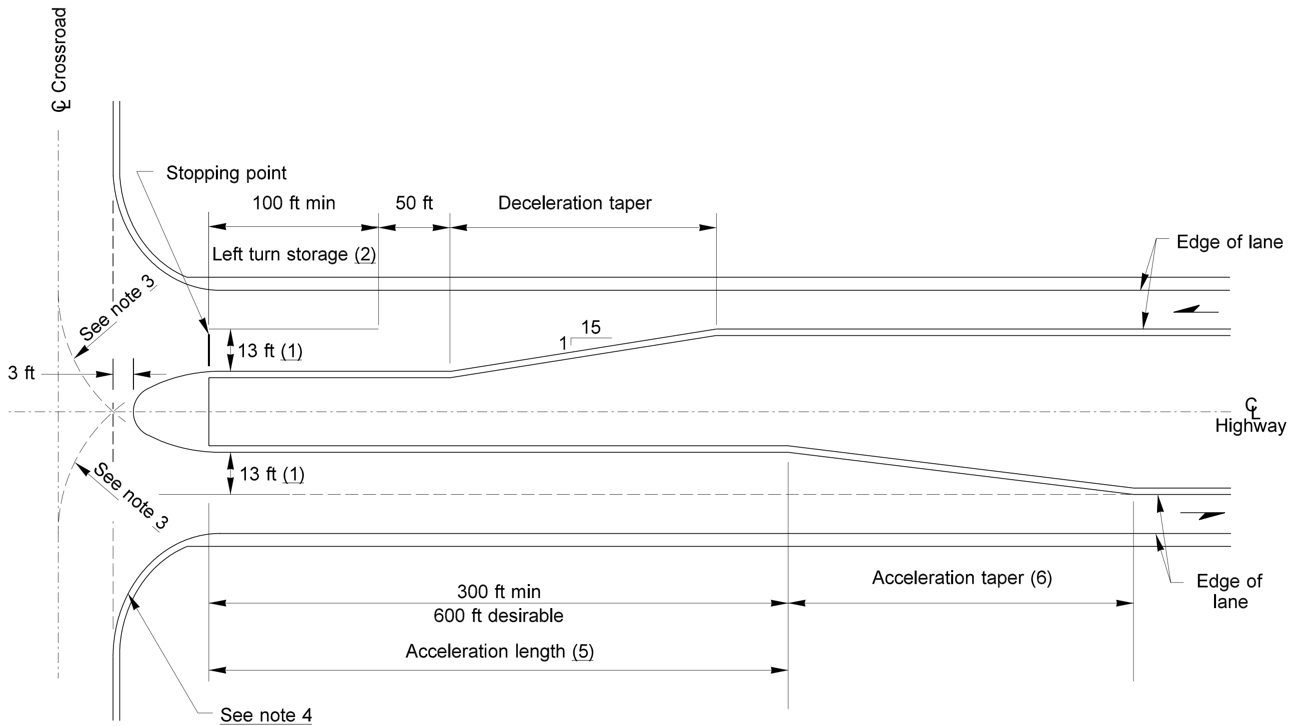
(7) For increased storage capacity, consider the left-turn deceleration taper alternate design.

(8) See Standard Plans and MUTCD for pavement marking details.

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

Table 2

Median Channelization (Median Width 23 ft to 26 ft)
Figure 910-10c



Notes:

(1) May be reduced to 11 ft, with justification.

(2) For left-turn storage length, see Figures 910-8b for 4-lane roadways or 9a through 9c for 2-lane roadways.

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

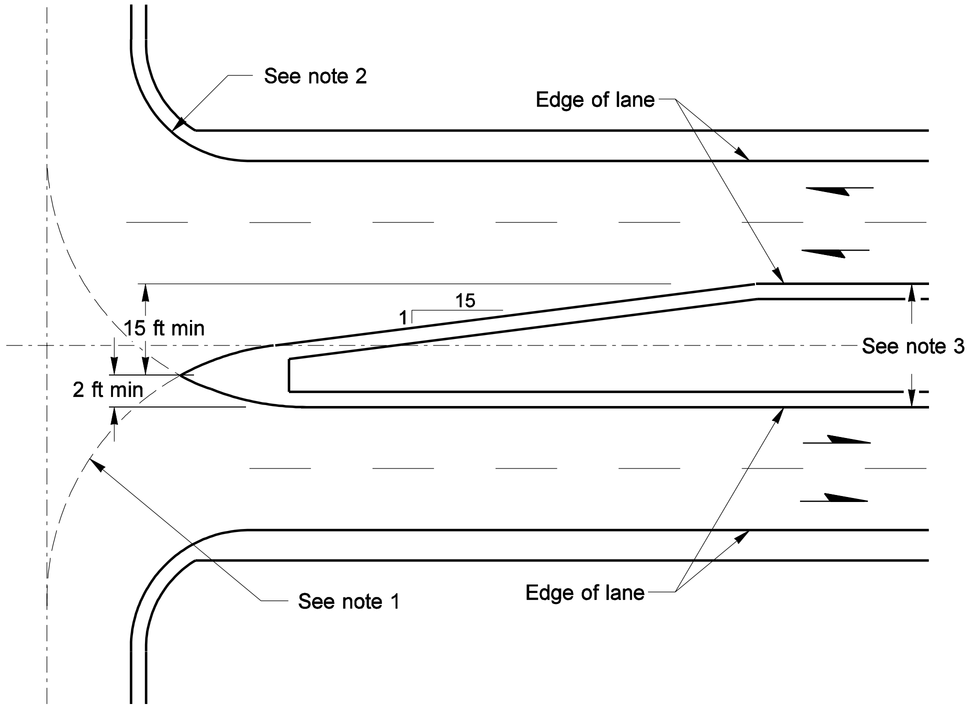
(4) See Figure 910-7 for right-turn corner design.

(5) The minimum length of the median acceleration lane is shown in Figure 910-14.

(6) See Table 2 Figure 910-10c for acceleration tape rate.

(7) See Standard Plans and MUTCD for pavement marking details.

Median Channelization (Median Width of More Than 26 ft)
Figure 910-10d



Notes:

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

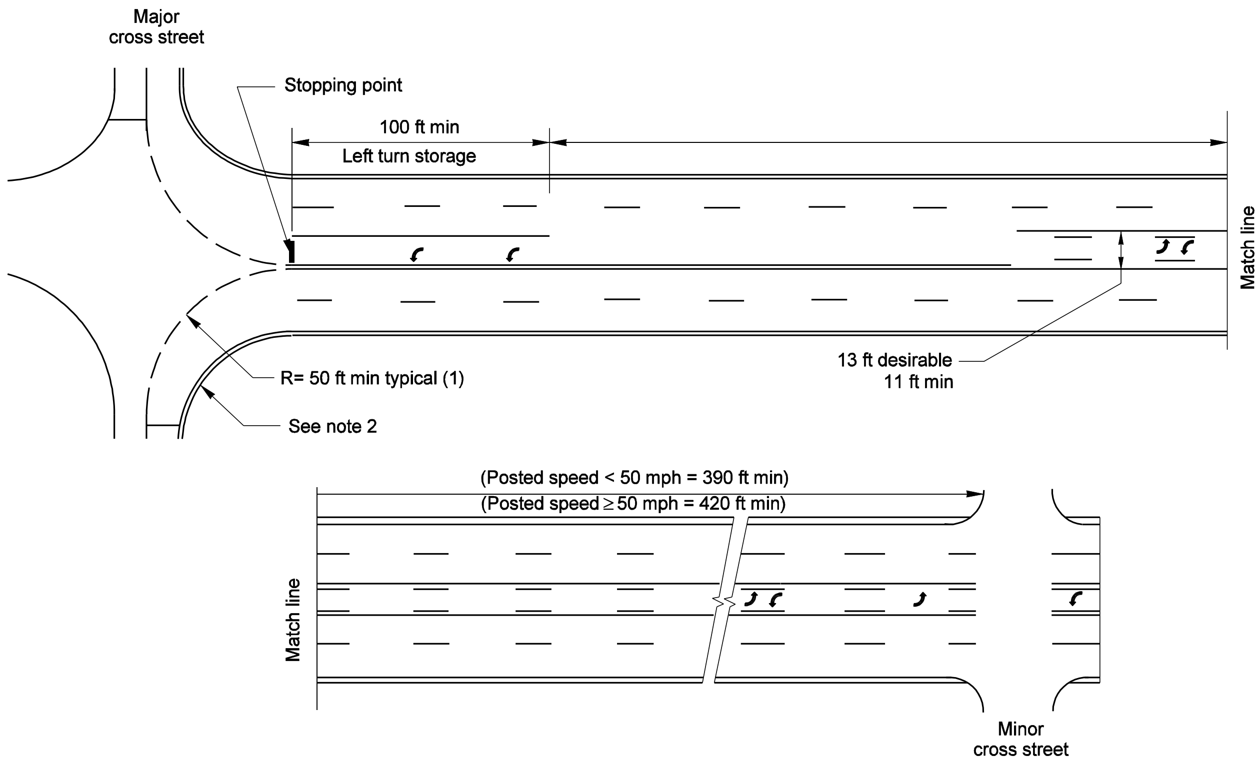
(2) See Figure 910-7 for right-turn corner design.

(3) For median width 17 ft or more. For median width less than 17 ft, widen to 17 ft or use Figure 910-10b.

(4) See Standard Plans and MUTCD for pavement marking details.

Median Channelization (Minimum Protected Storage)

Figure 910-10e



Notes:

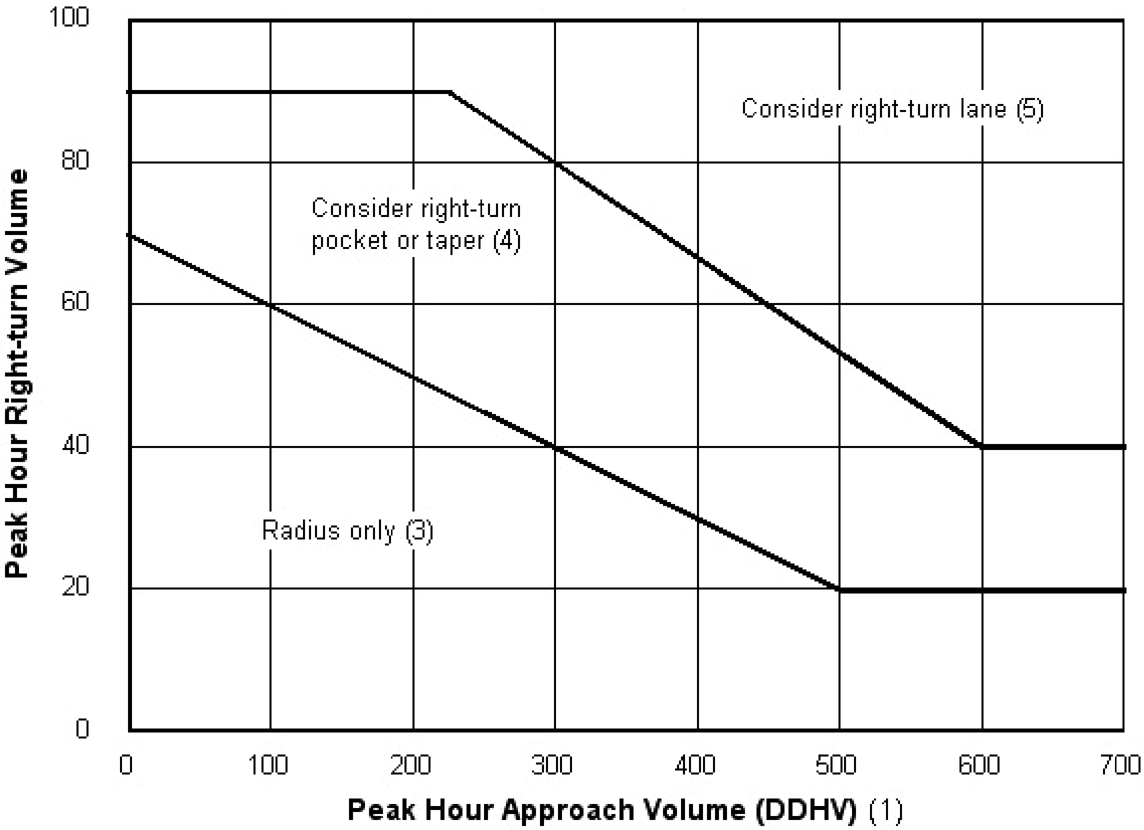
(1) Desirable radius not less than 50 ft. Use templates to verify that the design vehicle can make the turn.

(2) See Figure 910-7 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 910-10f



Notes:

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

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

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

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

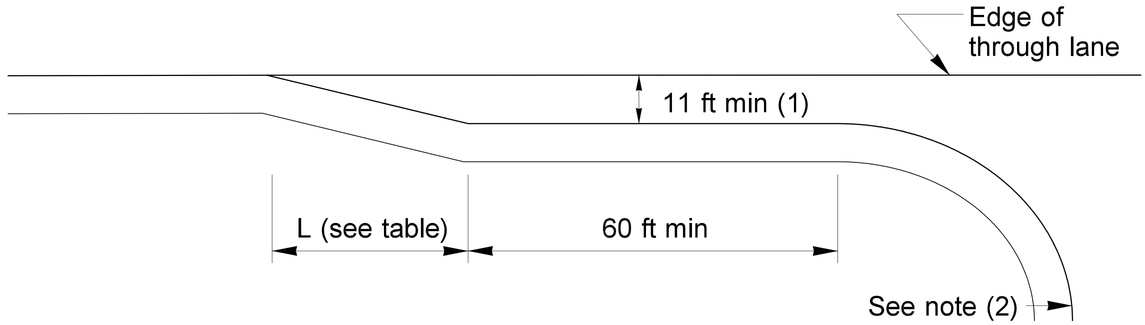
(3) See Figure 910-7 for right-turn corner design.

(4) See Figure 910-12 for right-turn pocket or taper design.

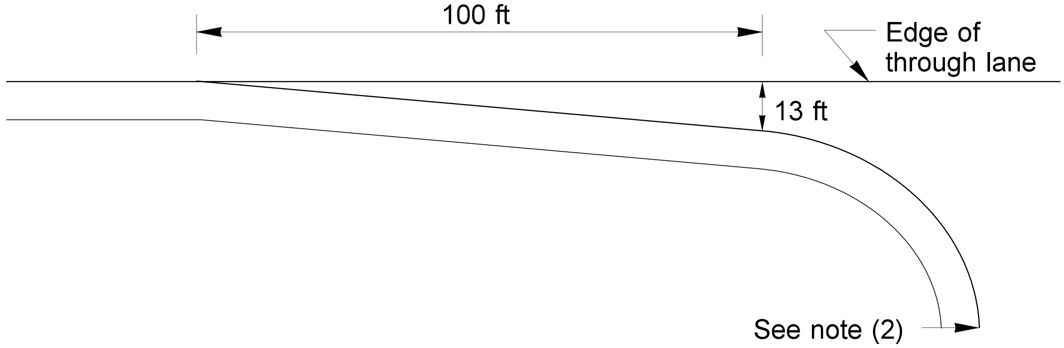
(5) See Figure 910-13 for right-turn lane design.

(6) For additional guidance, see 910.07(2) in the text.

Right-Turn Lane Guidelines (6)
Figure 910-11



Right-Turn Pocket



Right-Turn Taper

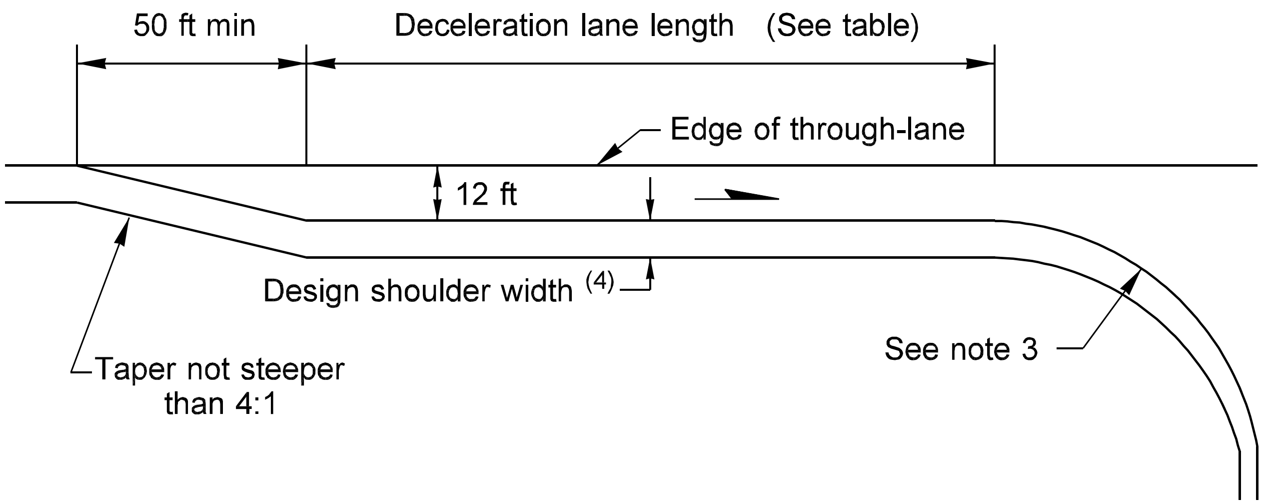
Posted speed limit	L
Below 40 mph	40 ft
40 mph or above	100 ft

Notes:

(1) 12 ft desirable.

(2) See Figure 910-7 for right-turn corner design.

Right-Turn Pocket and Right-Turn Taper
Figure 910-12



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

Minimum Deceleration Lane Length (ft)

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

Adjustment Multiplier for Grades 3% or Greater

Notes:

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

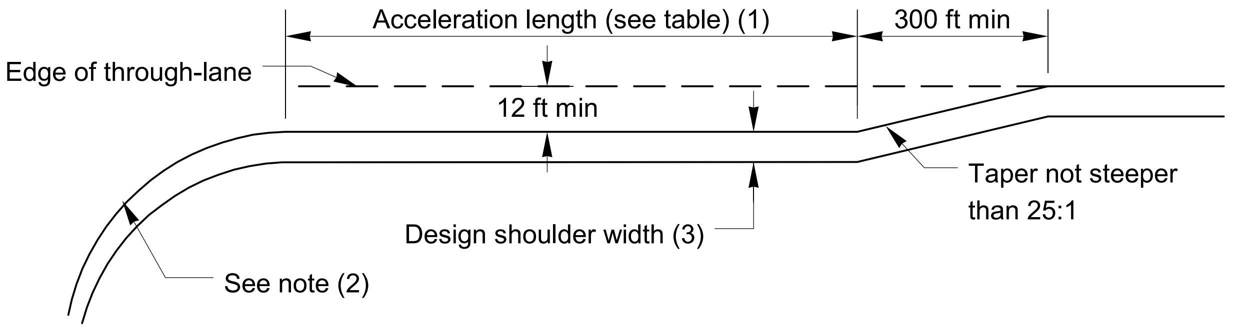
(2) When adjusting for grade, do not reduce the deceleration lane to less than 150 ft.

(3) See Figure 910-7 for right-turn corner design.

(4) May be reduced, see 910.07(4) in the text.

(5) See the Standard Plans and the MUTCD for pavement marking details.

Right-Turn Lane
Figure 910-13



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

Minimum Acceleration Lane Length (ft) (1)

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

Adjustment Multiplier for Grades 3% or Greater

Notes:

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

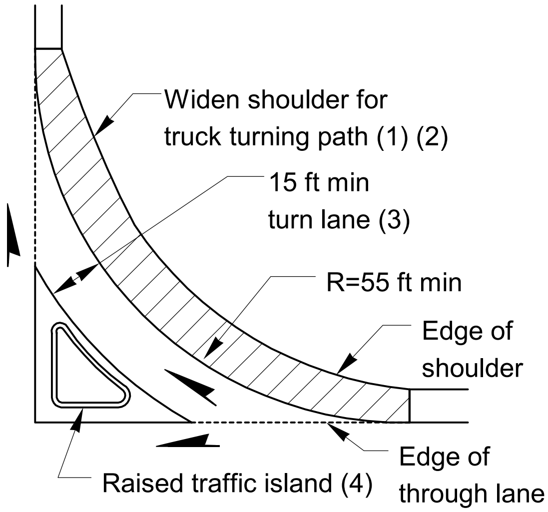
(2) See Figure 910-7 for right-turn corner design.

(3) May be reduced, see 910.07(4) in the text.

(4) See the Standard Plans and the MUTCD for pavement marking details.

Acceleration Lane

Figure 910-14



Small Traffic Island Design (5)

Notes:

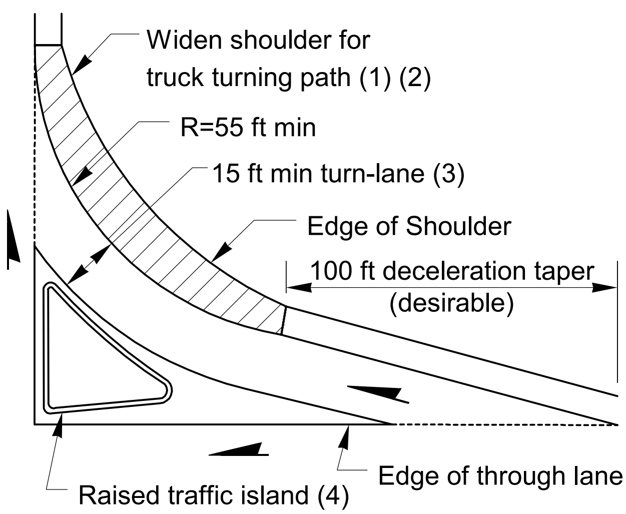
(1) Widen shoulders when adequate right-turn radii or roadway width cannot be provided for large trucks. Design widened shoulder pavement the same depth as the right-turn lane.

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

(3) See Chapter 641 for turning roadway widths.

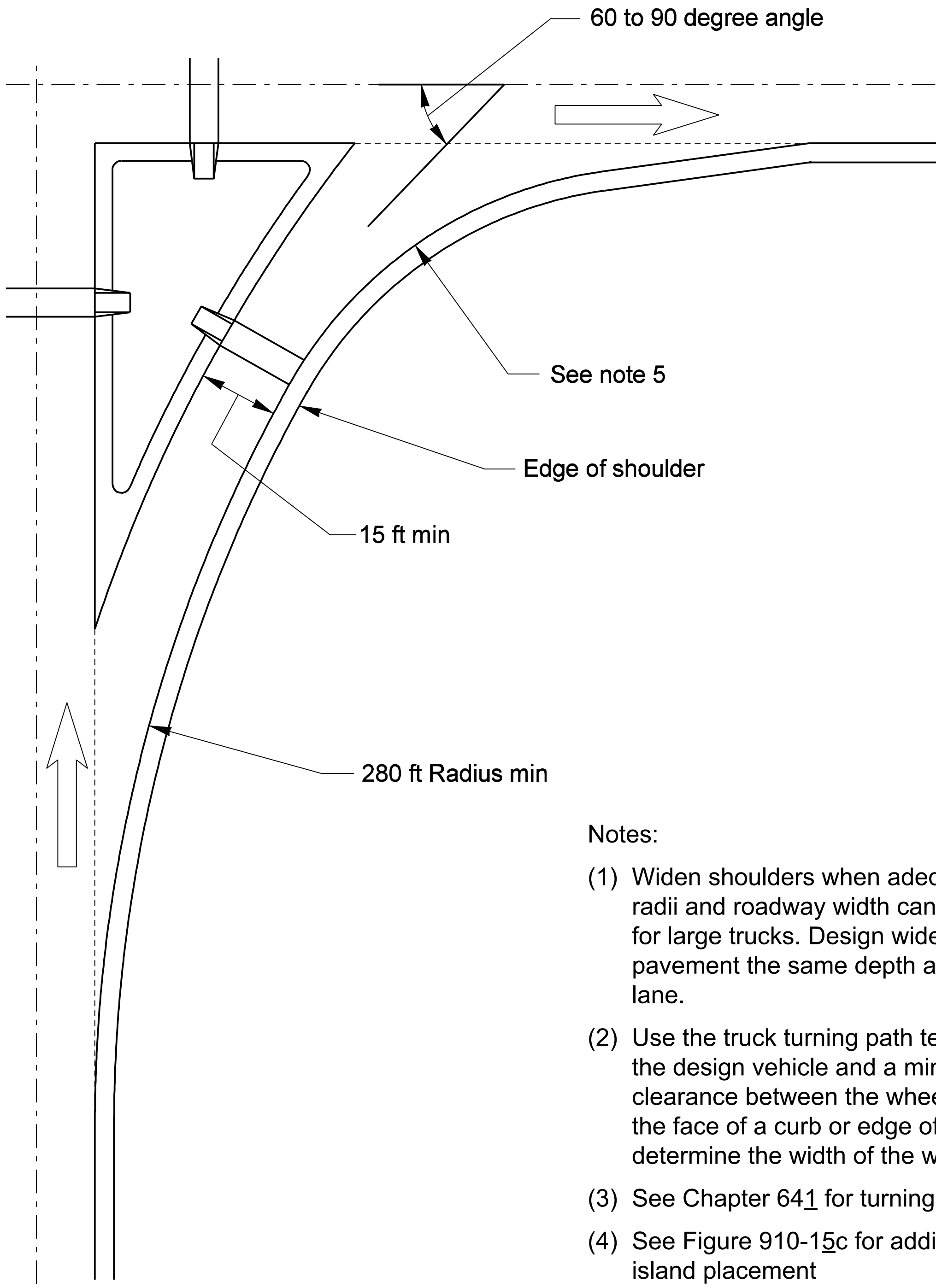
(4) See Figure 910-15c for additional details on island placement

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



Large Traffic Island Design (5)

Traffic Island Designs
Figure 910-15a



Notes:

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

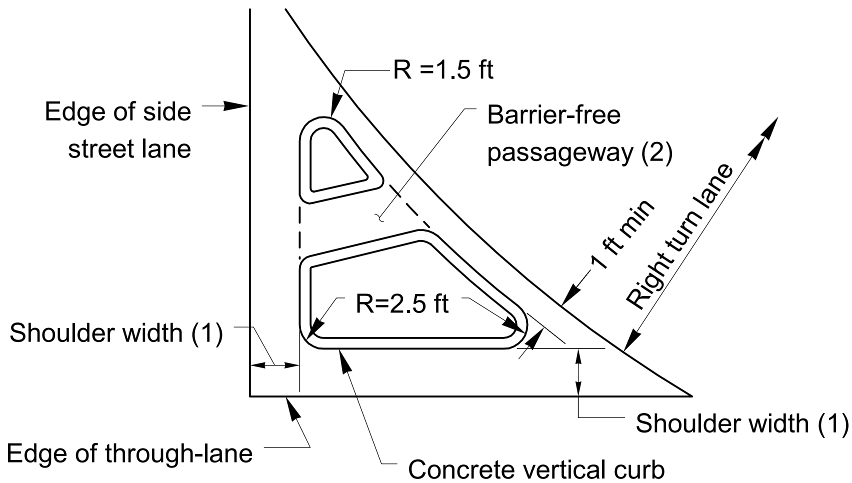
(2) Use the truck turning path templates for the design vehicle and a minimum of 2 ft clearance between the wheel paths and the face of a curb or edge of shoulder to determine the width of the widened shoulder.

(3) See Chapter 641 for turning roadway widths.

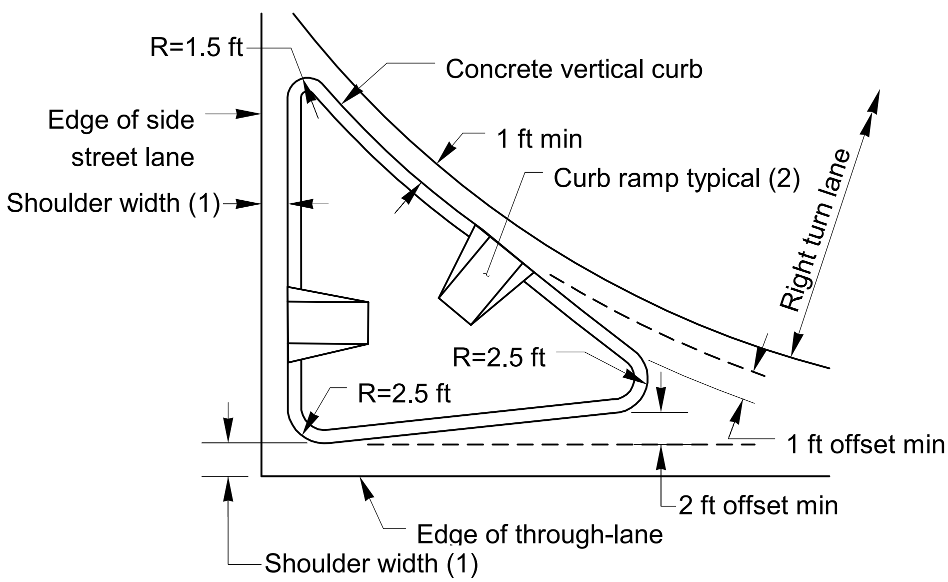
(4) See Figure 910-15c for additional details on island placement

(5) See Figure 910-7 for right-turn corner design.

Traffic Island Designs (Compound Curve)
Figure 910-15b



Small Raised Traffic Island (3)



Large Raised Traffic Island

Notes:

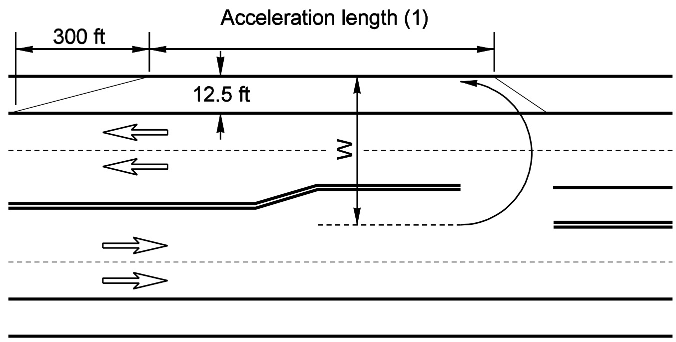
(1) See Chapter 440 for minimum shoulder width. See the text for additional information on shoulders at islands.

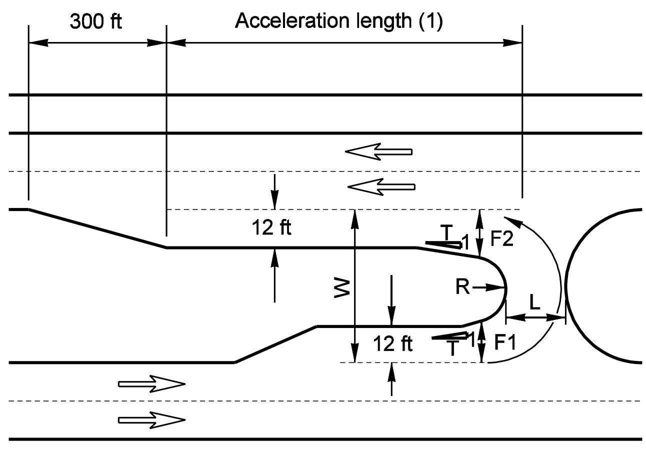
(2) Provide barrier-free passageways or curb ramps when required, see Chapter 1025.

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

Traffic Island Designs

Figure 910-15c





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

U-Turn Design Dimensions

Notes:

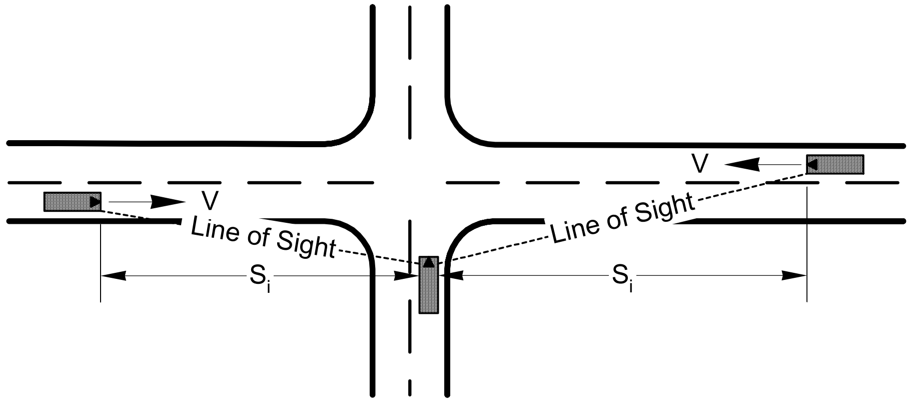
(1) The minimum length of the acceleration lane is shown in Figure 910-14. Acceleration lane may be eliminated at signal controlled intersections.

(2) All dimensions in feet.

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

U-Turn Locations

Figure 910-16



$S_i = 1.47Vt_g$
Where:
S_i = Intersection Sight Distance (ft)
V = Design speed of the through roadway (mph)
t_g = Time gap for the minor roadway traffic to enter or cross the through roadway (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-40, WB-50, & WB-67)	13.5
Note: Values are for a stopped vehicle to turn left onto a two-lane two-way roadway with no median and grades 3% or less. 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:

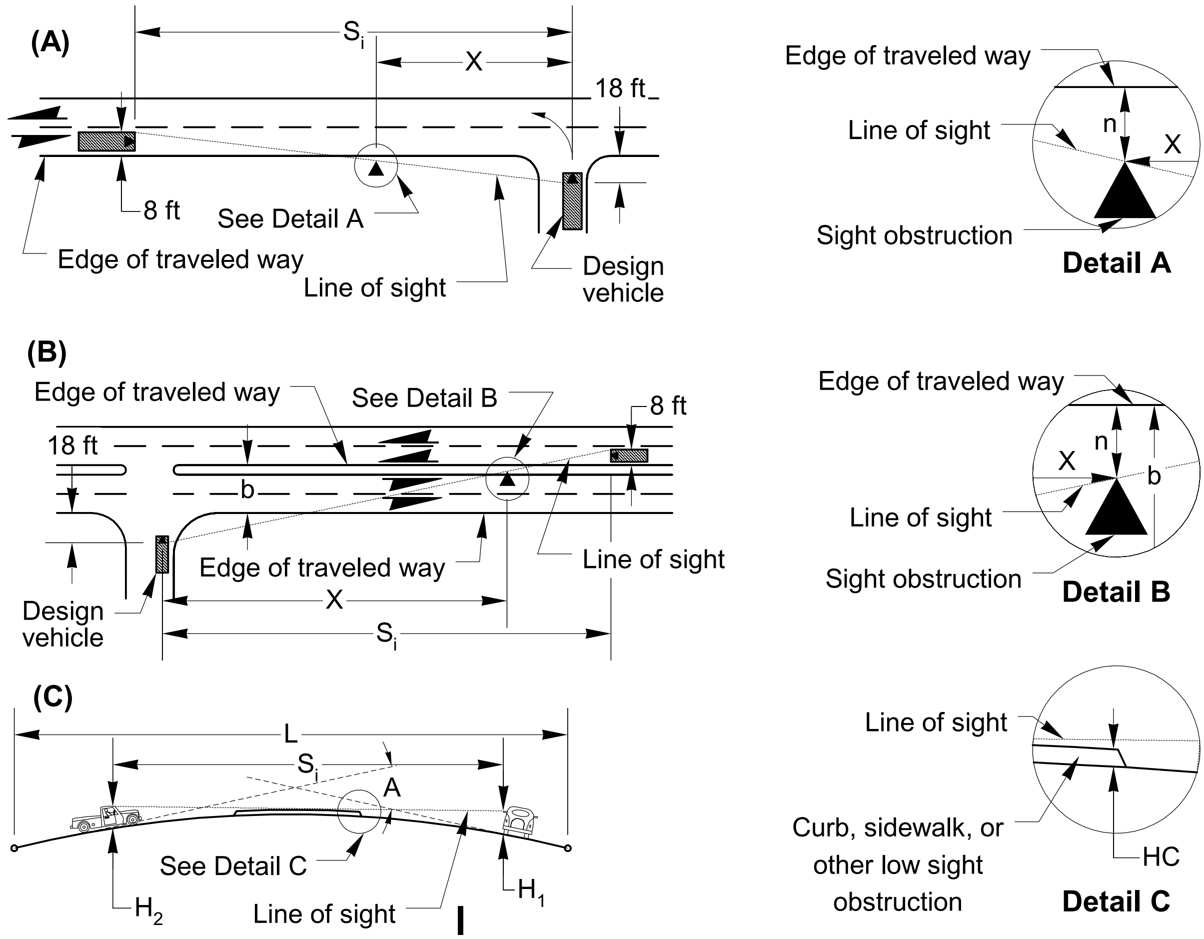
Crossing or right-turn maneuvers:

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 4 ft:
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 4 ft:
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 at Intersections
Figure 910-17a



For sight obstruction driver cannot see over:

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

Where:

S_i = Available intersection sight distance (ft).

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

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

X = Distance from center line of lane to sight obstruction (ft).

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

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

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

Where:

S = Available sight distance (ft).

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

H_2 = Object height (4.25 ft).

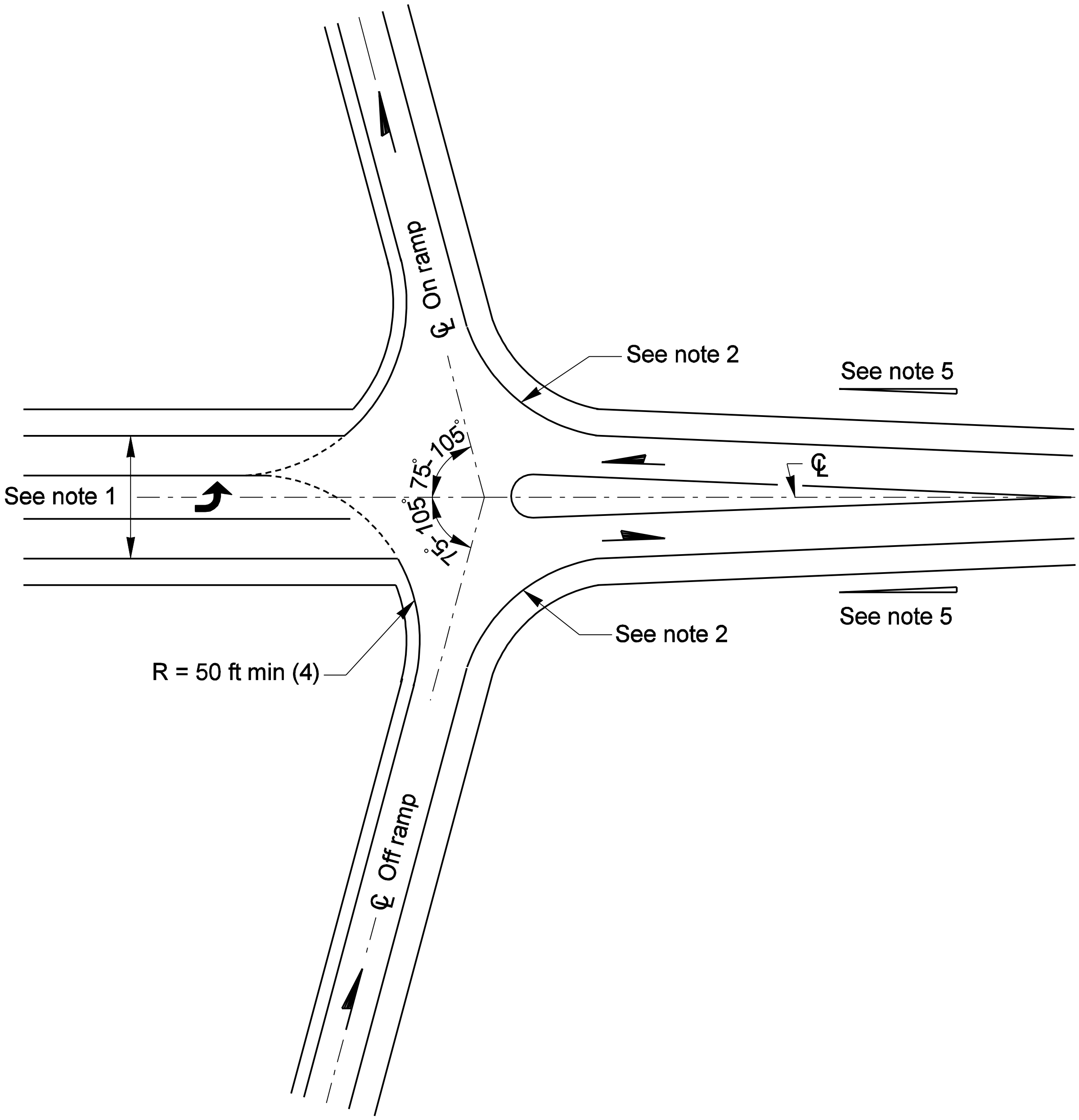
HC = Sight obstruction height (ft).

L = Vertical curve length (ft).

A = Algebraic difference in grades (%).

Sight Distance at Intersections

Figure 910-17b



Notes:

(1) 12 ft through-lanes and 13 ft left-turn lane desirable.

(2) For right-turn corner design see Figure 910-7.

(3) Intersections may be designed individually.

(4) Use templates to verify that the design vehicle can make the turn.

(5) See Figure 910-10a, Table 1 for taper rates.

Interchange Ramp Details
Figure 910-18

When a double-lane roundabout is required for the design year but traffic projections indicate that one lane will be sufficient for 10 years or more, consider restricting it to one lane until traffic volumes require a double-lane roundabout.

(5) Rural Single-Lane Roundabouts

Rural single-lane roundabouts generally have high approach speeds. They require supplementary geometric and traffic control device treatments on approaches to encourage drivers to slow to an appropriate speed before entering the roundabout. Rural roundabouts may have larger diameters than urban roundabouts to allow slightly higher speeds at the entries, on the circulating roadway, and at the exits. This is possible if current and anticipated future pedestrian volumes are low.

Design rural roundabouts that might become part of an urban area with slower speeds and pedestrian treatments. However, in the interim, provide supplementary approach and entry features to achieve safe speed reduction. Supplemental geometric design elements include extended and raised splitter islands, a nonmountable central island, and adequate horizontal deflection.

The central island needs to have "target value" to give cues to approaching drivers that there is something that they must drive around. Designers will need to mound the planting area and plant native materials that are out of clear zone and provide "target value".

The geometric design includes a truck apron where necessary for WB-50 and larger trucks to use the roundabout. Design the roundabout so that a WB-40 will not be required to use the truck apron.

(6) Rural Double-Lane Roundabouts

Rural double-lane roundabouts have speed characteristics similar to rural single-lane roundabouts. They differ in having two entry lanes, or entries flared from one to two lanes, on one or more approaches. Consequently, many of the characteristics and design features of rural double-lane roundabouts mirror those of their urban counterparts. The main design differences are higher entry speeds and larger diameters, and recommended supplementary approach treatments. Design rural roundabouts that might become part of an urban area for slower speeds, with design details that fully accommodate pedestrians and bicyclists. However, in the interim, design approach and entry features to achieve safe speed reduction.

The central island needs to have "target value" to give cues to approaching drivers that there is something that they must drive around. Designers will need to mound the planting area and plant native materials that are out of clear zone and provide "target value".

When a double-lane roundabout is required for the design year but traffic projections indicate that one lane will be sufficient for at least 5 to 10 years, consider restricting it to one lane until traffic volumes require a double-lane roundabout.

915.05 Capacity Analysis

A capacity analysis is required for each proposed roundabout to compare it to other types of intersection control.

Design roundabouts so that the demand volume to capacity ratio is 0.85 or less and the anticipated delays are comparable to other types of intersection control.

There are two methods of performing the capacity analysis:

- An analysis based on gap acceptance (the Australian method). Use the method given in the *Austroad Guide* or the *Highway Capacity Manual*.
- An empirical formula based on measurements at a saturated roundabout (the British method). Use the method given in TRRL Report 942.

While each method has advantages, it is felt there is currently not enough United States performance data on which to base the empirical method analysis. Therefore, the gap acceptance method is preferred.

Figure 915-<u>8</u> may be used to estimate the entry capacity of <u>each</u> roundabout <u>entry leg</u>; however, perform a capacity analysis using other methods to verify roundabout capacity.

915.06 Geometric Design

(1) Design Vehicle

The physical characteristics of the design vehicle are one of the elements that control the geometric design of a roundabout. See Chapter 910 for guidance on the selection of a design vehicle. As with other intersections, the design vehicle may differ for each movement. Use the largest vehicle selected for any movement as the design vehicle for the circulating roadway. For a roundabout on a state highway, this is the WB-50 vehicle. Design a roundabout so that the design vehicle can use it with 2 ft clearance from the turning radius to any curb face. The rear wheel of a semitrailer may encroach on the truck apron.

It is desirable to design the circulating roadway so that a BUS design vehicle in urban areas and a WB-40 in rural areas can use the roundabout without encroaching on the truck apron.

Design roundabouts on state routes so the WB-67 can use it without leaving the truck apron or encroaching on a curb. Use vehicle turning path templates to verify that this vehicle can make all state highway to state highway movements.

The vehicle path through a roundabout will normally contain reverse or compound curves. To check the roundabout for the design vehicles, a computer generated template for each path is recommended.

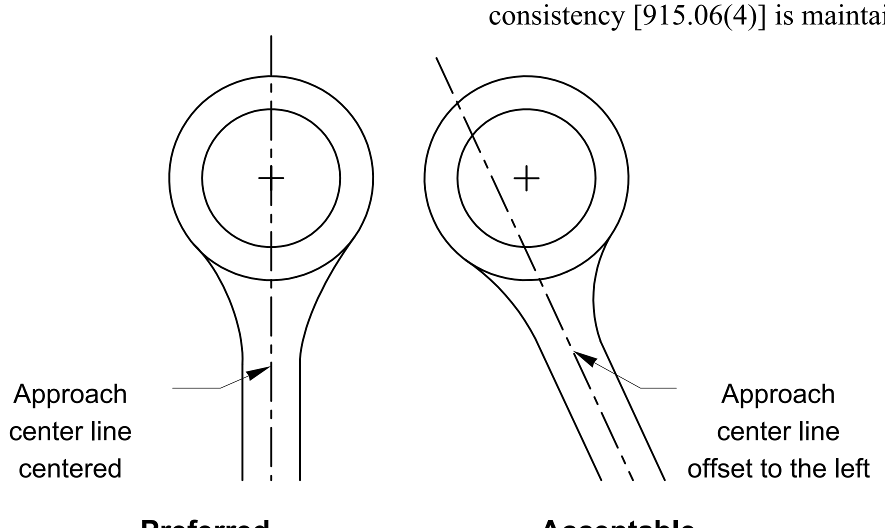
(2) Approach Alignment

The preferred alignment of an approach leg to a roundabout is with the centerline passing through the center of the inscribed circle. (See Figure 915-4.) This allows the roundabout to be designed so that vehicles will maintain slow speeds at both the entries and the exits. This alignment makes the central island more conspicuous to approaching drivers.

Where it is not possible to align an approach leg through the center of the inscribed circle, a slight offset to the left is acceptable. (See Figure 915-4.) This will allow adequate curvature at the entry, which is of greatest importance. In some cases, it may be beneficial to offset the approach slightly to the left to enhance the entry curvature. However, this will create a more tangential exit with increased exit speed and might increase the risk for pedestrians.

Approach alignment offset to the right of the roundabout's center point is unacceptable. This alignment results in a more tangential approach allowing vehicles to enter the roundabout at a higher speed. This will normally result in a reduction in safety.

It is desirable to equally space the angles between entries. This will optimize the separation between successive entries and exits. When site conditions make equal spacing impractical, spacing may be varied to a minimum of 40°. When reducing the angle between approaches, ensure that speed consistency [915.06(4)] is maintained.



Approach Leg Alignment
Figure 915-4

(3) Deflection and Design Speed

For a roundabout to work properly, it must be designed to reduce the relative speeds between conflicting traffic streams. The most significant feature that will control the speed is adequate deflection. The deflection is expressed as the radius of the center line of a vehicle path through the roundabout. Figures 915-9a and 9b illustrate the vehicle paths for determining deflection.

The vehicle path can be adjusted by:

- Changing the alignment and width of the entry and the shape, size, and position of the approach splitter island.
- Changing the central island size.
- Staggering alignment between entrance and exit.

The deflection design speed is controlled by the path radius and cross slope of the roadway. Figure 915-5 gives the deflection radii for design speeds for roadways that slope down to the outside of the curve (-2%), that are level (0%), and that slope down to the inside of the curve (2%). Use the following equation to make the final adjustments for speeds between those given:

$$V = \sqrt{\frac{R(c+f)}{6.69}}$$

Where:

V	=	Design speed in mph
R	=	The deflection radius in feet.
c	=	Slope of the roadway in percent
f	=	Side friction factor from Figure 915-5

Design roundabouts so that deflection limits the entry speed to 30 mph or less and achieves speed consistency. In areas with a large number of pedestrians or bicyclists, design roundabouts for a maximum speed of 15 to 20 mph.

Design Speed (mph)	Deflection Radius (ft) Cross Slope			Side Friction actor *f*
	-2%	0%	2%	
10	20	20	20	38
15	50	50	45	32
20	110	100	95	27
25	200	185	170	23
30	335	300	275	20
35	515	455	410	18

Deflection
Figure 915-5

(4) Speed Consistency

Speed consistency for all movements is an important element of roundabout design. Speed consistency is achieved when the differences between speeds of paths that merge, cross, or parallel each other do not exceed 12 mph.

Figure 915-10 shows five critical path radii to be checked for each leg. The entry path (R_1) is the minimum radius for through traffic approaching the yield point. The circulating path (R_2) is the minimum radius for through traffic around the central island. The exit path (R_3) is the minimum radius for through traffic into the exit. The left-turn path (R_4) is the minimum radius for the conflicting left-turn movement. The right-turn path (R_5) is the minimum radius for a right-turning vehicle. These vehicular path radii are determined as shown on Figures 915-9a and 9b.

Make R_1 smaller than or equal to R_2, and R_2 smaller than or equal to R_3 ($R_1 \leq R_2 \leq R_3$). This ensures that speeds will be reduced to their lowest at the roundabout entry reducing the likelihood of problems in the roundabout.

(5) Inscribed Diameter

The inscribed diameter is controlled by the space available, the design speed, design vehicle and the number of legs. The size of the inscribed diameter is a balance between designing for large vehicles and providing adequate deflection for the design speed. Select a diameter that will result in a speed at or below the desired design speed.

To meet the need to provide an adequate turning radius, the right-turn movement might require that the inscribed diameter be increased for roundabouts with more than four legs or with high skew angles. On state routes, make the turning radius 50 ft minimum with 2 ft clearance to the face of a curb.

The inscribed circle is not always circular, with a constant-radius circulating roadway; ovals and tear drops have been used. Noncircular shapes are allowed when the smaller turning radius is at least 50 ft. When a noncircular roundabout is used, where possible align it so that the heavier traffic uses the larger radius.

(6) Entry

Design the entry width to accommodate the design vehicles and required entry lanes while providing adequate deflection. Design the entry so that the entry angle is between 20° and 60°, preferably between 30° and 40°. Figure 915-11 provides additional guidance for entry design.

When the approach width, including shoulders and parking lanes, is wider than needed for the entry width, consider curb bulbs to reduce the width. For information on parking limitation at roundabouts, see 915.11.

When the roundabout is on a state route, the minimum turning radius is 50 ft to provide for large trucks. It is desirable for the entry radius to be smaller than both the circulating radius and the exit radius. This makes the speeds the lowest at the roundabout entry. It also helps to reduce the speed differential between entering and circulating traffic.

Design the entry radius, R_1 on Figure 915-10, to limit entry speeds to not more than 25 mph in urban areas and 30 mph in rural area.

At single-lane roundabouts, it is not difficult to reduce the value of the entry radius. The curb radius at the entry can be reduced or the alignment of the approach can be shifted to the left to achieve a slower entry speed. This is more difficult at double-lane roundabouts. When entry and exit curve radii are too small, the natural path of adjacent traffic can overlap. Path overlap occurs when the geometry leads a vehicle in the left lane to cross into the right lane to avoid the central island. (See Figure 915-12.) Path overlap can reduce capacity and increase accidents. Take care when designing double-lane roundabouts to avoid path overlap. For more information on path overlap, see *Roundabouts: An Informational Guide*.

Flaring is an effective means of introducing a double-lane roundabout without requiring as much right of way as a full lane addition. 130 ft is the optimum flare length to add a second lane at a double-lane roundabout. However, if right of way is constrained, shorter flare lengths may be used with decreased capacity.

At rural locations, consider the speed differential between the approaches and entries. If the posted speed of the approach is greater than 15 mph above the design speed of the entry curve, consider introducing speed reduction measures before the entry curve.

(7) Circulating Roadway

Keep the circulating width constant throughout the roundabout with the minimum width equal to or slightly wider (120%) than the maximum entry width.

At single-lane roundabouts, provide a circulating roadway width plus truck apron to just accommodate the design vehicle. Use appropriate vehicle-turning templates or a computer program to determine the swept path of the design vehicle through each turning movement. Provide a minimum clearance of 2 ft between the vehicle's tire track and all vertical curbs with a height of 6 in or more.

Design the circulating radius, R_2 on Figure 915-10, to be larger than the entry radius. In some cases where capacity is not a concern, it might not be possible for the circulating radius to be greater than the entry radius. In such cases, the entry radius may be greater than the circulating radius, provided the difference in speeds is less than 12 mph and preferably less than 6 mph.

(8) Exit

Design the exit width to accommodate the design vehicles while providing adequate deflection. Figure 915-11 provides additional guidance for exit design.

Generally, design the exit radius, R_3 on Figure 915-10, larger than both the entry radius (R_1) and the circulating radius (R_2). The larger exit curve radii improve the ease of exit and minimize the likelihood of congestion at the exits. This, however, is balanced by the need to maintain low speeds at the pedestrian crossing on exit. If the exit path radius is smaller than the circulating path radius, vehicles might be traveling too fast to negotiate the exit and crash into the splitter island or into oncoming traffic.

At single-lane roundabouts with pedestrian activity, design exit radii the same as or slightly larger than the circulating radius to minimize exit speeds. However, at double-lane roundabouts, additional care must be taken to minimize the likelihood of exit path overlap. Exit path overlap can occur when a vehicle on the left side of the circulating roadway exits into the right exit lane. Where no pedestrians are expected, make the exit radii large enough to minimize the likelihood of exiting path overlap. Where pedestrians are present, tighter exit curvature might be necessary to ensure low speeds at the pedestrian crossing.

When the departure roadway width, including shoulders and parking lanes, is wider than needed for the exit width, consider curb bulbs to reduce the width.

(9) Turning movements

Evaluate the left- and right-turn radii, R_4 and R_5 on Figure 915-10, to ensure that the maximum speed differential between entering and circulating traffic is no more than 12 mph. The left-turn movement is the lowest circulating speed. The left-turn radius can be determined by adding 5 ft to the central island radius.

(10) Sight Distance

The operator of a vehicle approaching a roundabout needs to have an unobstructed view of the splitter island, central island, yield point, and sufficient lengths of the intersecting roadways to permit recognition of the roundabout and to initiate the required maneuvers to maintain control of the vehicle and to avoid collisions. To do this, two aspects of the sight distance are necessary:

- **Stopping Sight Distance.** Provide the stopping sight distance given on Figure 915-6 at all points on the approach roadways, the circulating roadway, and the departure roadways. Check each vehicle path using the deflection speed. See Chapter 650 for additional information on stopping sight distance.

Speed (mph)	Stopping Sight Distance (ft)
10	47
15	77
20	113
25	153
30	198
35	248

Stopping Sight Distance for Roundabouts
Figure 915-6

- **Intersection Sight Distance.** For intersection sight distance at roundabouts, provide a clear view of traffic on the circulating roadway and approaching the roundabout on the leg to the left for a distance equal to that traveled in 4.5 seconds. The required gap is also a function of capacity and, at lower volumes, a larger gap may be required. However, do not use an intersection sight distance (Figure 915-13) less than the stopping sight distance (Figure 915-6).

  Because traffic is approaching a yield condition and might not be required to stop before entering a roundabout, provide the sight distance along the approach for 50 ft. Momentary sight obstructions that do not hide a vehicle, such as poles, sign posts, and narrow trees, are acceptable in the sight triangles including the central island. Guidance for intersection sight distance at a roundabout is shown on Figure 915-13.

Providing adequate sight distance will also provide clear zone for the central island.

(11) Islands

Raised islands are important for effective operation of a roundabout. Their primary purpose is to control deflection.

(a) **Central Island**. The central island is a raised, nontraversable area and may include a truck apron (Figure 915-14). The truck apron is the outer part of the central island, designed to allow for encroachment by the rear wheels of large trucks.

The primary control of the central island size is the inscribed diameter, the required circulating width, and the required deflection. When the required circulating width for the large vehicles results in a deflection radius larger than the maximum for the design speed, increase the central island diameter to achieve the desired deflection radius and provide a truck apron. Make the surfacing of the truck apron different from the circulating roadway. However, make the surfacing of the apron different from the sidewalks so that pedestrians are not encouraged to cross the circulating roadway. Use a 3 in mountable curb between the circulating roadway and the truck apron.

Use a 6 in or higher vertical curb between the truck apron and the nontraversable area. Landscape or mound the raised, nontraversable area to improve the visual impact of the roundabout to approaching drivers. When designing landscaping, consider sight distance and roadside safety. Also, consider maintenance needs for access to the landscaping in the central island.

When designing the landscaping for the central island, do not use items that might tempt people to take a closer look. Do not place street furniture or other objects that may attract pedestrian traffic to the central island, such as benches or monuments with small text. Design fountains or monuments in the central island in a way that will enable proper viewing from the perimeter of the roundabout. In addition, design and locate all objects in the center island to maintain sight distance, minimize driver distraction, and minimize the possibility of impact from an errant vehicle.

(b) **Splitter Island**. Splitter islands are built at each two-way leg. They serve to:

- Control the entry and exit speeds by providing deflection.
- Prevent wrong way movements.
- Provide pedestrian refuge.
- Provide a place to mount signs.

The desirable length of a splitter island envelope is equal to the stopping sight distance for the design speed of the roadway approaching the roundabout. (See Chapter 650.) Make the extensions of the curves that form the splitter islands tangent to the outside edge of the central island. The minimum width of the island at any crosswalk is 6.5 ft. Figure 915-15 gives guidance on the design of splitter islands.

For information on shoulders at islands, island nose radii, nose offsets, and other details, see Chapter 910.

(12) Grades and Superelevation

It is preferred that the grade on all of the intersecting roadways at a roundabout is 4% or flatter and that the grades be constant through the roundabout or that the roundabout be in a sag vertical curve. Grade in excess of 4% can result in reduces sight distance, increased difficulty slowing or stopping, and higher possibility of vehicle rollover.

When a roundabout must be built at or near the crest of a vertical curve on one of the roadways, pay special attention to the sight distances. For additional information on grades at roundabouts, see *Roundabouts: An Informational Guide*.

Do not use superelevation for the circulating roadway. It is desirable to maintain the normal 2% cross slope from the central island to the outside of the circle. (See Figure 915-5) This will improve drainage and help reduce the speed of circulating traffic.

(13) Right-Turn Slip Lane

Right-turn slip lanes may be used, with justification, when a right-turn movement is heavy enough to lead to a breakdown in roundabout operation and the radius produces a speed comparable to the speed through the roundabout.

For additional information on channelization for right-turn slip lanes, see right turn lanes at islands in Chapter 910 and *Roundabouts: An Informational Guide*.

(14) Design Clear Zone

For the right side of the circulating roadway, see Chapter 700 using the R_2 speed for the required design clear zone. Do not place light standards or other poles without breakaway features in splitter islands or on the right side just downstream of an exit point. When any approach leg has a posted speed of 45 mph or higher, place no fixed object, water features with a depth of 2 ft or more, or other hazards in the central island. At roundabouts with all approach legs posted at 40 mph or less, avoid water features with a depth of 2 ft or more in the central island. Avoid fixed objects in central islands when the island diameter is less than 65 ft. Within the central island, clear zone is desirable to provide both a recovery area for errant vehicles and sight distance. When necessary to protect features in the central island, provide a central island low profile barrier 18 in high or higher.

915.07 Pedestrians

Pedestrian crossings are unique at roundabouts in that the pedestrian is required to cross at a point behind the vehicles entering the roundabout. The normal crossing point at intersections is in front of these vehicles. For this reason, mark all pedestrian crosswalks at urban roundabouts and at rural roundabouts when pedestrian activity is anticipated. Position the crosswalk one car length, approximately 20 ft, from the yield point and use the raised splitter island as a pedestrian refuge. (See Figures 915-15 and 16.) Consider landscaping strips to discourage pedestrians crossing at undesirable locations.

Provide a barrier-free passageway at least 6 ft wide, 10 ft desirable, through this island for persons with disabilities. Whenever a raised splitter island is provided, also provide pedestrian refuge. This facilitates the pedestrian crossing in two separate movements.

Give special attention to assisting pedestrians who are visually impaired through design elements such as providing tactile cues through the installation of truncated domes at curb ramps, splitter islands, and any other pedestrian facility that might lead to conflicts with pedestrians and vehicular traffic. These pedestrians typically attempt to maintain their approach alignment to continue across a street in the crosswalk. A roundabout requires deviation from that alignment. Provide appropriate informational cues to pedestrians regarding the location of the sidewalk and the crosswalk.

See Chapter 1025 for sidewalk ramps and additional information on pedestrian needs.

915.08 Bicycles

The operating speed of vehicles within smaller low speed roundabouts is, in most cases, the same speed as that of bicyclists and both can use the same roadway without conflict or special treatment. Larger roundabouts with higher operating speeds can present problems for the bike rider and an alternate bike path, a shared use sidewalk, or warning signs might be necessary. If the bike riders are children, as in the case of a nearby elementary school, consider signing and pavement markings directing them to use the adjacent sidewalk. End all bicycle lanes before they enter a roundabout, with the bicycles either entering traffic to use the circulating roadway or leaving the roadway on a separate path or a shared use sidewalk. See Figure 915-16 for the recommended design for ending a bicycle lane with a shared use sidewalk at a roundabout.

915.09 Signing and Pavement Marking

Roundabouts, being a new concept in Washington State, require consistent signing and pavement markings to familiarize motorists with their intended operation.

Roundabout signing is shown on Figure 915-17. Locate signs where they have maximum visibility for road users but a minimal likelihood of obscuring other signs, pedestrians, or bicyclists. Use only signs contained in the MUTCD. A diagrammatic guide sign, as shown in the figure, can be used to provide the driver with destination information. Provide a route confirmation sign on all state routes shortly after exiting the roundabout.

Pavement markings are shown in the MUTCD. Optional lane lines between lanes within the circulating roadway may be used on multilane roundabouts. When evaluating whether or not to provide lane lines within the circulating roadway, consider the following potential impacts:

- Reduce confusion
- Reduce flexibility
- Improve lane alignment
- Reduce capacity
- Provide a more normal situation
- Might require advanced signing for proper lane usage at the entry

When lane lines are to be used, include the striping plan with the roundabout approval request.

915.10 Illumination

For a roundabout to operate satisfactorily, a driver must be able to enter, move through, and exit the roundabout in a safe and efficient manner. To accomplish this, a driver must be able to see the layout and operation in time to make the appropriate maneuvers. Adequate lighting is needed for this at night.

Provide illumination for roundabouts with any one of the following:

- At least one leg is a state route or ramp terminal.
- It is necessary to improve the visibilityof pedestrians and bicyclists.
- One or more of the legs are illuminated.
- An illuminated area in the vicinity can distract the driver's view.
- Heavy nighttime traffic is anticipated.

Provide illumination for each of the conflict points between circulating and entering traffic in the roundabout and at the beginning of the raised splitter islands. Figure 915-18 depicts the light standard placement for a four-legged roundabout. See Chapter 840 for additional information and requirements on illumination. A single light source located in the central island is not acceptable. When one or more of the legs are illuminated, provide a light level within the roundabout approximately 50% higher than the highest level on any leg. Use a high pressure sodium vapor luminaire with a medium or short cut-off light distribution for the light source. Position the luminaire over the outside edge of the roundabout to use the "house side" lighting to illuminate the pedestrian crosswalks.

915.11 Access, Parking, and Transit Facilities

No road approach connections to the circulating roadway are allowed at roundabouts, unless it is designed as a leg to the roundabout appropriate for the traffic volume using the approach. Road approach connections to the circulating roadway are allowed only when no other reasonable access is available. It is preferred that road approaches not be located on the approach or departure legs within the length of the splitter island. The minimum distance from the circulating roadway to a road approach is controlled by the corner clearance using the circulating roadway as the crossroad. (See Chapter 1435.)

Parking is not allowed in the circulating roadway or on the approach roadway past the crosswalk. It is also desirable that no parking be allowed on the approach or departure legs for the length of the splitter island. See Chapter 1025 for additional information on parking limitations near a crosswalk.

Transit stops are not allowed in the circulating roadway or on the approach roadway past the crosswalk. Locate transit stops on departure legs in a pullout or where the pavement is wide enough that a stopped bus will not block the through movement of traffic. Locate transit stops on approach or departure legs where they will not obstruct sight distance.

915.12 Procedures

(1) Selection

Use the following steps when selecting a roundabout for intersection control:

(a) Consider the context. Are there constraints that must be addressed? Are there site-specific and community impact reasons why a roundabout of a particular size would not be a good choice?

(b) Determine the roundabout category (Figure 915-7) and a preliminary lane configuration (Figure 915-8) based on capacity requirements.

(c) Identify the justification category. See 915.12(2). This establishes why a roundabout might be the preferred choice and determines the need for specific information.

(d) Perform the analysis appropriate to the selection category. If the selection is to be based on operational performance, use the appropriate comparisons with alternative intersections

(e) Determine the right of way requirements and feasibility.

(f) If additional right of way must be acquired or alternative intersection forms are viable, an economic evaluation will be useful.

(g) Contact all approving authorities to obtain concurrence that a roundabout is an acceptable concept at the proposed location. On state routes this includes the HQ Design Office.

(2) Justification

Consider roundabouts only when fulfilling one or more of the following justification categories:

(a) **Safety Improvement.** At high accident location intersections, a roundabout might be a method of reducing accidents by reducing the number of conflict points. At conventional intersections, many accidents involve left-turning or crossing vehicles; with roundabouts these movements are eliminated. With the low operating speeds and low entry angles, accidents at roundabouts are generally less severe.

Roundabouts in this category require an accident analysis that shows high accidents of a type that a roundabout can reduce in number or severity. In the analysis, consider any potential shift of accidents to another accident type.

(b) **Improve Intersection Capacity.** A roundabout may be analyzed as an alternative to traditional traffic control options to increase the capacity of an intersection. With traffic signals, alternating traffic streams through the intersection can cause a loss of capacity when the intersection clears between phases. In a roundabout, vehicles may enter available gaps simultaneously from multiple approaches. This can result in an advantage in capacity. This advantage becomes greater when the volume of left turning vehicles is high.

Justify roundabouts in this category with a capacity analysis showing that it can provide the required capacity comparable to the optimum design for a conventional intersection. Discuss the effects on “off-peak” traffic.

(c) **Queue Reduction.** Roundabouts can improve operations at locations where the space for queuing is limited. Roadways are often widened for queuing at traffic signals, but the reduced delays and continuous flows at roundabouts allow the use of fewer lanes. Possible applications are at interchanges where left turn volumes are high. Roundabouts at ramp terminals can improve capacity without widening a structure.

Roundabouts in this category require an analysis showing that the roundabout will eliminate the need to build additional lanes or widen a structure without additional impacts to the main line operations.

(d) **Special Conditions.** The special conditions where a roundabout might be preferred over a conventional intersection include locations with unusual geometrics; right of way limitations; closely spaced intersections; wye (Y) intersections; and, on nonstate routes, for traffic calming. Roundabouts might be better suited for intersections with unusual geometrics; such as high skew angle and offset legs. Roundabouts can provide adequate levels of operation without significant realignment or complicated signing or signal phasing.

Roundabouts can avoid the need to obtain additional right of way along the intersection legs. Roundabouts can shift any required right of way from the roadway between the intersections to the area of the intersection.

Roundabouts can eliminate closely spaced intersections, and any associated operational problems, by combining them into one intersection. The ability of roundabouts to serve high turning volumes make them a practical design at wye (Y) or tee (T) intersections.

Roundabouts proposed for a special condition require documentation indicating what the condition is and how the roundabout will address it.

(3) Approval

A proposal to install a roundabout on any route, either NHS or non-NHS, with a posted speed limit of 45 mph or higher requires an analysis of alternatives. See Chapter 910 for requirements.

HQ Design Office approval of the design is required when a roundabout is to be used on a state highway. Submit to the HQ Design Office:

- Supporting engineering data.
- Concurrence that a roundabout is an acceptable concept 915.12(1)(g).
- An intersection plan.
- Roundabout justification from 915.12 (2).
- A comparison of the roundabout to alternative intersection types with an explanation as to why the roundabout is the preferred alternative.
- A traffic analysis of the roundabout and alternative intersection types, including a discussion of any loss in level of service or increase in delay. Include the effects on "off-peak" traffic and discuss any adverse impacts of the roundabout.
- An analysis of pedestrian and bicycle activities.
- An approved analysis of alternatives for roundabouts on any state route with a posted speed of 45 mph or higher.
- The approval of the State Design Engineer or designee for roundabouts within the limits of limited access control.
- The calculated design speeds for the entry path, the circulating path, the exit path, the left-turn path, and the right-turn path for each leg of the roundabout.
- A corridor and network analysis.
- Current or projected traffic control or safety problems at the roundabout.
- Demonstration that the proposed configuration can be implemented and that it will provide adequate capacity on all approaches.
- All potential complicating factors, their relevance to the location, and any mitigation efforts that might be required.
- An economic analysis, indicating that a roundabout compares favorably with lternative control modes from a benefit-cost perspective.

915.13 Documentation

A list of the documents that are to be preserved [in the Design Documentation Package (DDP) or the Project File (PF)] is on the following web site: http://www.wsdot.wa.gov/eesc/design/projectdev/

	Design Element	Mini (1)	Urban (2) Compact	Urban Single-Lane	Urban Double-Lane	Rural Single-Lane	Rural Double-Lane
General	Number of Lanes	1	1	1	2	1	2
	Typical max. (3) ADT	12,000	15,000	20,000	40,000	20,000	40,000
	Splitter Island Treatment	Painted, raised if possible	Raised	Raised	Raised	Raised extended	Raised extended
	Max. Design(4) Vehicle	SU	SU/BUS	WB-50	WB-50	WB-67	WB-67
Circulating	Inscribed Circle Diameter	45’-80’	80’-100’(5)	100’-130’(6)	150’-180’	115’-130’(6)	180’-200’
	Circulating Roadway Design Speed	15-18 mph	16-20 mph	20-25 mph	22-28 mph	22-27 mph	25-30 mph
	Circulating Roadway Width	14’-19’	14’-19’	14’-19’	29’-32’	14’-19’	29’-32’
Entry	Max. Entry Design Speed	15 mph	15 mph	20 mph	25 mph	25 mph	30 mph
	Entry Radius	25’-45’	25’(7)-100’	35’(7)-100’	100’-200’	40’(7)-120’	130’-260’
	Entry Lane Widths	14’-16’	14’-16’	14’-16’	25’-28’	14’-16’	25’-28’

(1) Mini roundabouts are not suitable for use on a state route.

(2) Urban compact roundabouts are normally not suitable for use on a state route.

(3) Total ADT entering a 4-leg roundabout with 33% of the volume on the minor roadway. Multiply by 1.2 for 4-leg roundabouts with equal volume on both roadways. Multiply by 0.9 for 3-leg roundabouts.

(4) See Chapter 910 for selecting a design vehicle on a state route.

(5) Use 100 ft minimum on state routes.

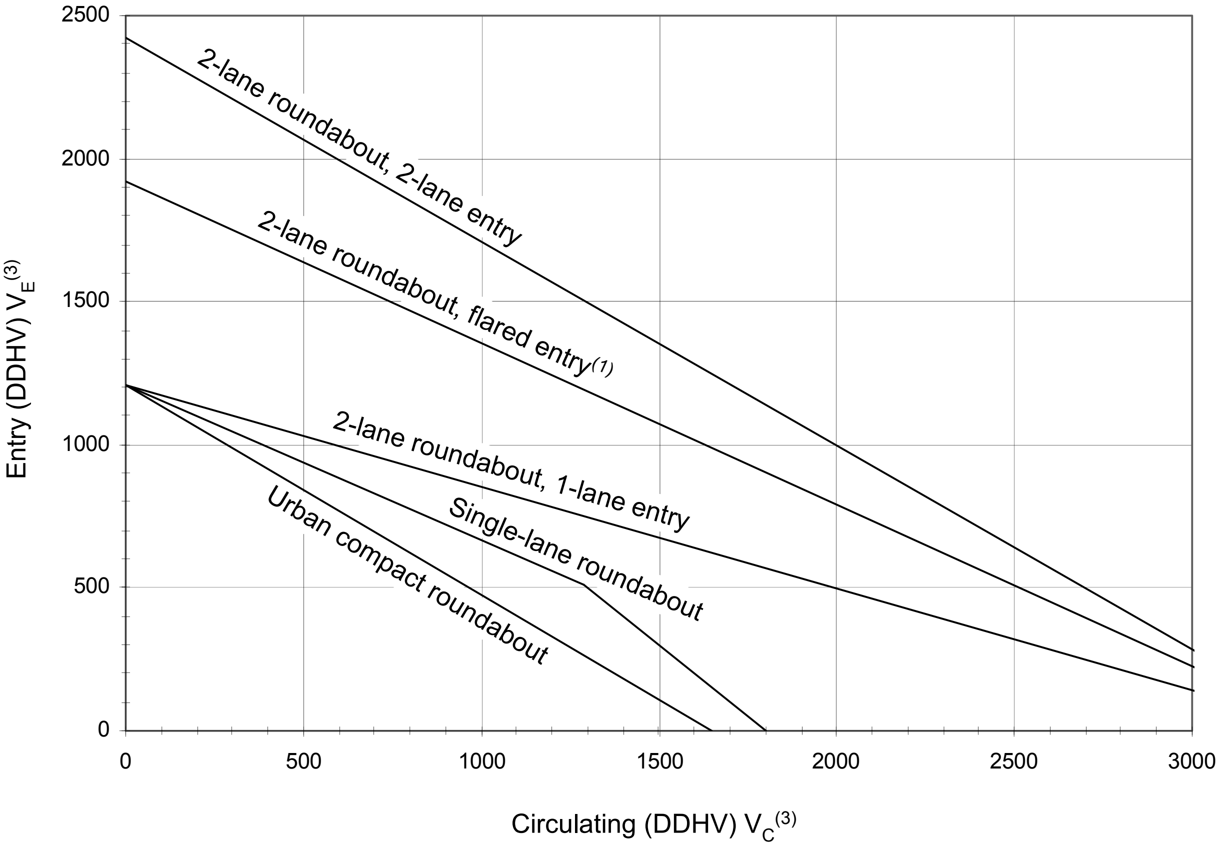
(6) When roundabout might be expanded to a double-lane roundabout, consider using a double-lane roundabout diameter.

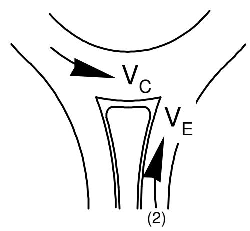
(7) Use 50 ft minimum on state routes.

Note:
The values given in this figure are approximate. They are intended for planning and preliminary design. Final design values may vary.

Roundabout Categories Design Characteristics

Figure 915-7





Note:

(1) Entry flared with 2 vehicle storage lane.

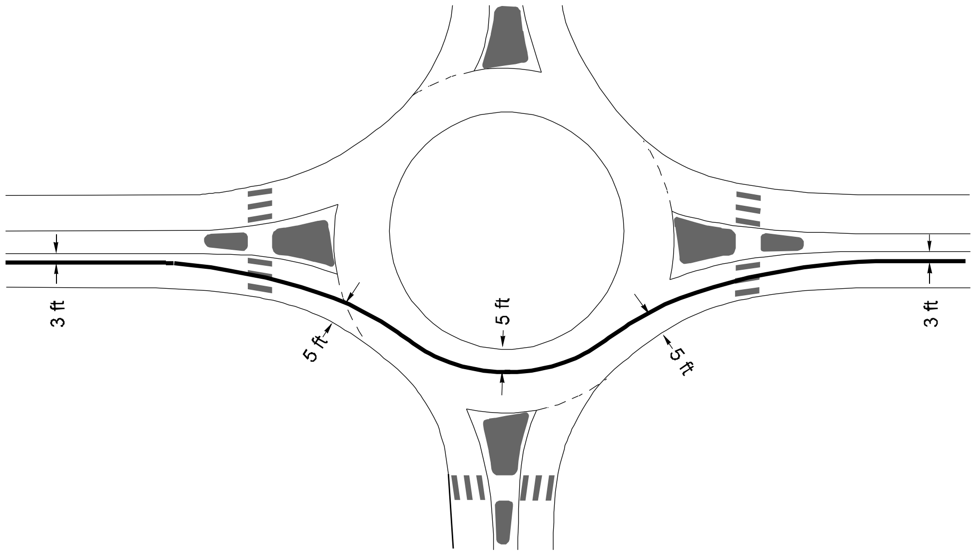
(2) Check for each entry.

(3) DDHV in passenger car equivalents.

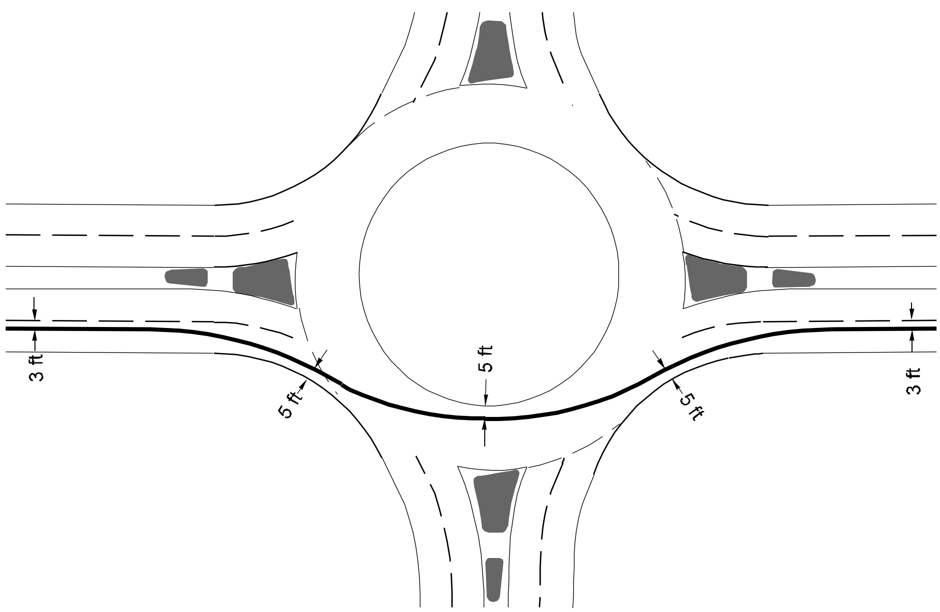
Vehicle Type	Passenger Car Equivalent
Car	1.0
SU or BUS	1.5
Other truck	2.0
Bicycle or Motorcycle	0.5

Approximate Entry Capacity

Figure 915-8

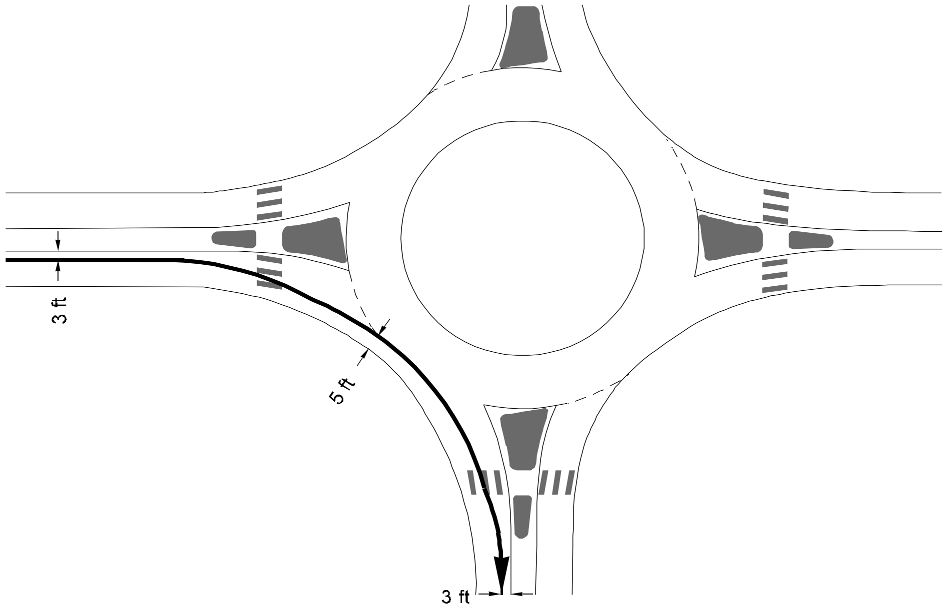


Single-Lane Roundabout

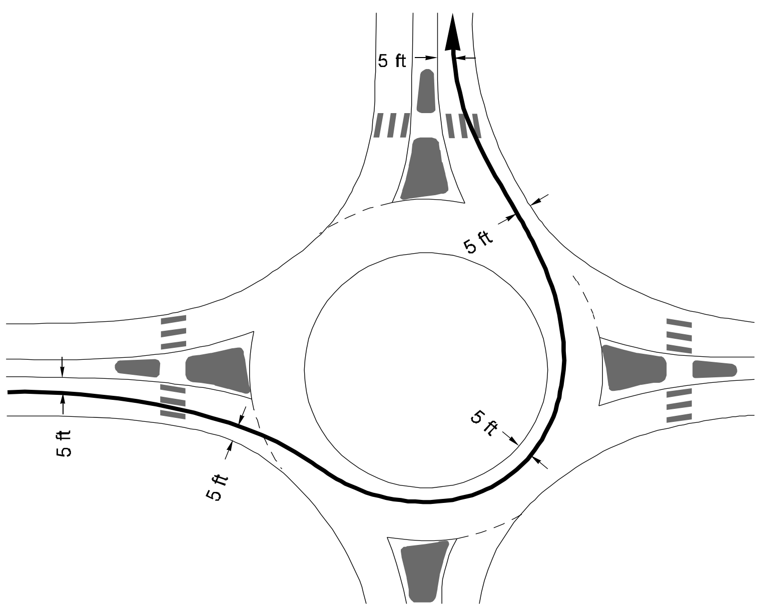


Double-Lane Roundabout

Deflection Path
Figure 915-9a

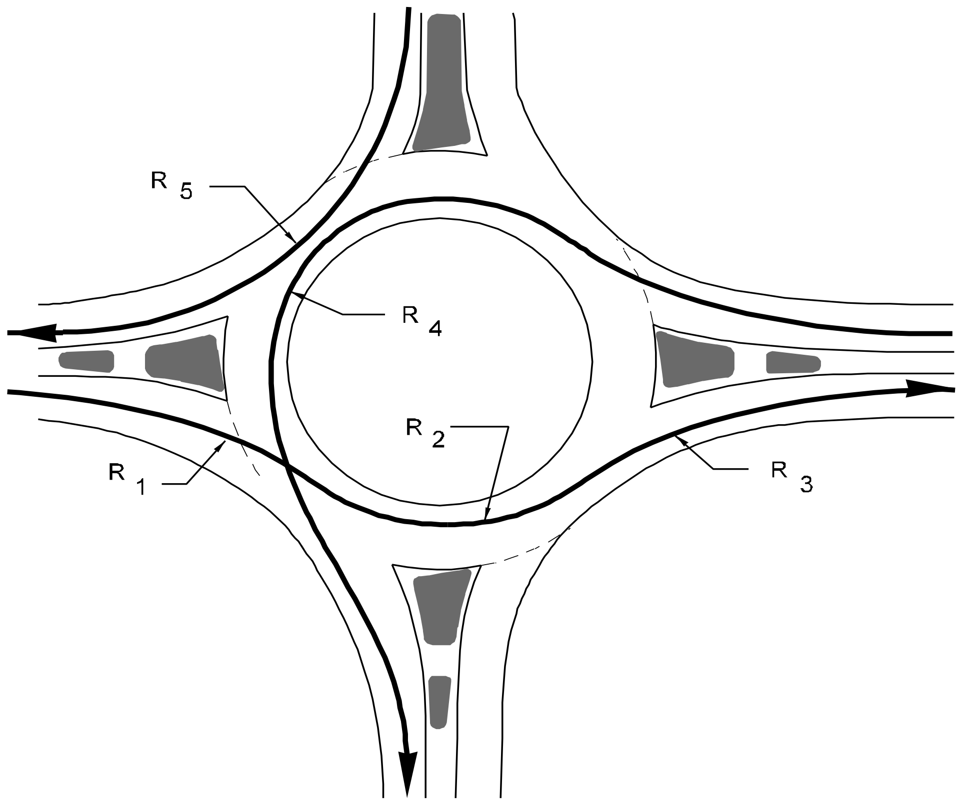


Right-Turn Movement



Left-Turn Movement

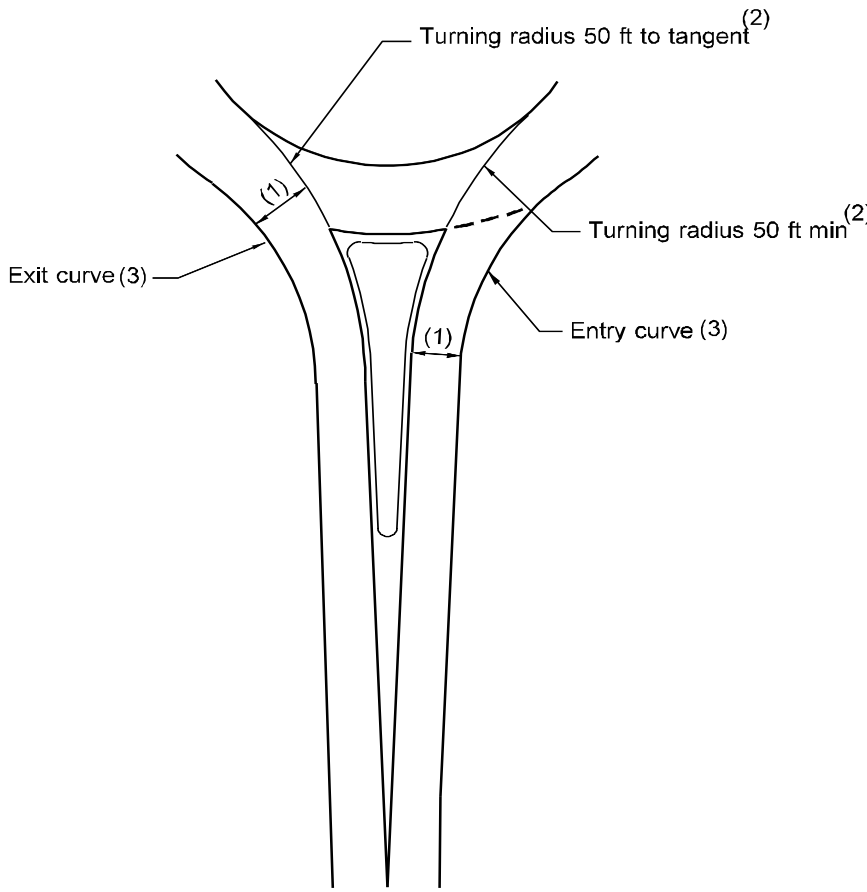
Deflection Path
Figure 915-9b



Where:

R_1 = entry path radius.
R_2 = circulating path radius.
R_3 = exit path radius.
R_4 = left-turn path radius.
R_5= right-turn path radius.

Deflection Path Radius
Figure 915-10



Notes:

(1) Minimum width is 15 ft for 1-lane and 25 ft for 2-lane. Entry and exit widths based on capacity needs (see Figure 915-8) and design vehicle requirements (see Chapter 641 or use templates).

(2) Continuation of splitter island envelope curve tangential to central island.

(3) Entry and exit curves tangential to outside edge of circulating roadway.

Entry and Exit
Figure 915-11

930.01 General

Most railroads in Washington were in operation long before our system of roads was developed and generally have prescriptive rights and underlying property interests that supersede those of road authorities. In general, right of way is not acquired in fee from a railroad company. Rather than selling property, railroads typically convey easements, access rights, and construction permits. Therefore, most roads exist on railroad property by easement from the railroads. Any widening or realignment of an existing roadway, construction upon, over or under, or installation of wires or pipes on railroad property requires permission from the railroad in the form of a permit or an agreement.

Projects that require the railroad to do work, or for which they are to be reimbursed or compensated will require an agreement. It is not unusual for a railroad agreement to take 6 months or more to be developed, reviewed and executed, therefore, it is important for the designer to establish early contact with the HQ WSDOT Railroad Liaison in the Design Office.

Agreements are developed and negotiated by the WSDOT Railroad Liaison. Permits are typically acquired directly from the railroad or its property manager by the Region. Contact your Regional Utilities Engineer or the HQ Railroad Liaison for assistance. Include copies of any executed permits or agreements in the Design Documentation Package. Include a copy of the "Notice to Proceed" (required in the agreement to authorize the railroad to commence work) in the Project file.

Railroad grade crossings are, in effect, intersections with two legs of rail traffic that never stop. Due consideration must be given by the roadway designer to the traffic control for the rail crossing. Grade crossing traffic controls (railroad signals, gates, pavement markings, signs, and controllers) are typically located within the area of railroad property. Railroad signal and gate maintenance is the responsibility of the railroad. Railroads are also responsible for the maintenance of crossing surfaces for the 12 inches outside the edge of rail (WAC 480-62-225). Most railroads will insist on designing and constructing their own signals, gates, and crossing surfaces.

The Washington Utilities and Transportation Commission (WUTC) has statutory authority over grade crossing safety in Washington State. Any changes to a grade crossing or the associated safety appurtenances require initial approval by the WUTC. This is accomplished by submitting a Petition to the WUTC. The Railroad Liaison has copies of WUTC forms and can help with their preparation. The WUTC will review the Petition and issue an Order granting or denying the Petition with or without conditions, depending on situation. Include a copy of any Petition or Order in the Design Documentation Package.

930.02 References

Manual on Uniform Traffic Control Devices for Streets and Highways, USDOT, FHWA, including the *Washington State Modifications to the MUTCD*, WSDOT (MUTCD) http://www.wsdot.wa.gov/biz/trafficoperations/mutcd.htm

Railroad-Highway Grade Crossing Handbook, FHWA TS-86-215

Guidance On Traffic Control Devices At Highway-Rail Grade Crossings, HIGHWAY/RAIL GRADE CROSSING TECHNICAL WORKING GROUP (TWG), FHWA, November 2002 (http://safety.fhwa.dot.gov/media/twgreport.htm#2)

Agreements Manual, WSDOT M22-99

Traffic Control Devices Handbook, ITE, 2001.

A Policy on Geometric Design of Highways and Streets, AASHTO, 2001

Revised Code of Washington (RCW) 81.53 Railroad Crossings

Washington Administrative Code (WAC) 480-62-150 Grade crossing petitions

930.03 Plans

Include plans for state constructed improvements to existing crossings and any new crossings within the normal process. In addition to basic roadway dimensions, signs, and markings, indicate angle of the crossing, number of tracks, location of signals and other railway facilities (e.g., electrical and communications lines, control boxes). Also indicate railroad stationing at the point where highway centerline crosses the center of the tracks.

For any project proposing to alter the horizontal or vertical alignment at a grade crossing (including grade separations), show the alignment and profile for both the railroad and the roadway for a minimum of 500 feet on all legs of the crossing. Show all other important features that might affect the safety, operation, and design of the crossing such as nearby crossroads, driveways or entrances, buildings, and highway structures on the plans.

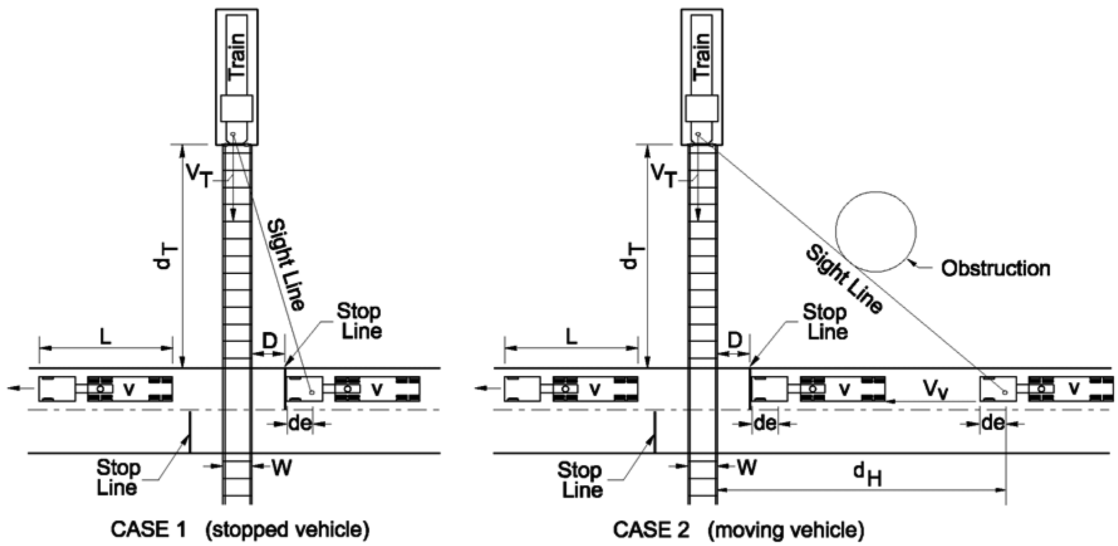
Sight distance is a primary consideration at grade crossings. A railroad grade crossing is comparable to the intersection of two highways where a sight triangle must be kept clear of obstructions or it must be protected by a traffic control device. The desirable sight distance allows an approaching driver to see an approaching train at such a distance that the vehicle can stop well in advance of the crossing if signals or gates and signals are not present. See Figures 930-1, Case 2 and 930-2. Sight distances of the order shown are desirable at any railroad grade crossing not controlled by railroad signal lights or gates (active warning devices).. Their attainment, however, is often difficult and impracticable due to topography and terrain. Even in flat open terrain, the growth of crops or other seasonal vegetation can create a permanent or seasonal sight distance obstruction. Furthermore, the properties upon which obstructions might exist are commonly owned by the railroad or others. Evaluate installation of active devices at any location where adequate sight distances cannot be assured. Include communication with the railroad and Washington Utilities and Transportation Commission in your evaluation.

The driver of a vehicle stopped at a crossing with signal lights but no gates needs to be able to see far enough down the tracks from the stop bar to be able to safely cross the tracks before a train, approaching at maximum allowable speed, reaches the crossing. See Figures 930-1, Case 1 and 930-2.

In some cases lights and gates alone will not provide adequate safety for motorists whose impatience may encourage them to drive around a gate. Evaluate train and traffic volumes and accident history to assess the feasibility of installing a median separator to prevent vehicles from driving around gates. Close call incident logs are sometimes available from the railroad or WUTC, these too can provide an indication of need for additional active control devices. Consult with the railroad or the HQ Railroad Liaison since the railroad may have information on numbers of gate violators at the crossing. Where sufficient space is available, median separators should be at least 60 feet in length.

Construct highway grades so that low-slung vehicles will not hang-up on tracks or damage them. See Chapter 630 for information on vertical alignment at railroad grade crossings. Whenever possible design the roadway to cross grade crossings at right angles. If bicycle traffic uses the crossing (this can be assumed for most roads), provide a shoulder through the grade crossing at least as wide as the approach shoulder width. If a skew is unavoidable, wider shoulders may be necessary to permit bicycles to maneuver to cross the tracks at right angles. See Chapter 1020 for information on bikeways crossing railroad tracks.. Consider installation of advance warning signs indicating the presence of a skewed crossing for crossings where engineering judgment suggests a benefit.

Include any engineering studies or sight distance measurements in the Design Documentation Package.



d_T = Sight distance along railroad tracks
d_H = Sight distance along highway
d_e = Distance from driver to front of vehicle (assumed 8 ft.)
D = Distance from stop line to nearest rail (assumed 15 ft.)
W = Distance between outer rails (single track W=5 ft.)
V_V = Velocity of vehicle
f = Coefficient of friction
V_T = Velocity of train
L = Length of vehicle (assumed 65 ft.)

Adjustments must be made for skew crossings.
Assumed flat highway grades adjacent to and at crossings.

Sight Distance at Railroad Crossing
Figure 930-1

Case 1 Departure from stop		Case 2 Moving Vehicle						
Train Speed (mph) V_T	0	Vehicle Speed (mph) V_V						
		10	20	30	40	50	60	70
		F=0.40	0.40	0.35	0.32	0.30	0.29	0.28
		Distance Along Railroad from Crossing d_T(ft)						
10	240	150	100	100	100	110	120	130
20	480	290	210	200	210	220	240	270
30	720	440	310	300	310	340	370	400
40	960	580	410	390	410	450	490	540
50	1200	730	520	490	520	560	610	670
60	1440	870	620	590	620	670	730	810
70	1880	1020	720	690	720	790	860	940
80	1920	1160	830	790	830	900	980	1070
90	2160	1310	930	890	930	1010	1100	1210
		Distance Along Highway from Crossing d_H(ft)						
		69	135	220	324	447	589	751
Required design sight distance for combination of highway and train vehicle speeds; 65 ft truck crossing a single set of tracks at 90°. (AASHTO)								

Sight Distance at Railroad Crossing
Figure 930-2

930.04 Traffic Control Systems

Traffic control systems permit safe and efficient operation of railroad-highway traffic crossings. These systems may include one or more of the following:

(a) Passive Elements

(1) Signing elements are shown in Part 8, *Traffic Control for Highway-Rail Grade Crossings*, of the MUTCD and include one or more of the following:

a. Railroad Crossing Sign (crossbuck). The railroad is responsible for maintenance of the crossbucks.

b. Railroad Crossing Auxiliary Sign (Inverted "T" sign). This sign is mounted below the crossbuck to indicate the number of tracks when 2 or more tracks are involved -- Railroad Responsibility.

c. Railroad Advance Warning Sign. Road Authority installs and maintains.

d. Exempt Crossing Sign. This is a supplemental sign that, when authorized by the WUTC, may be mounted below the crossbuck. When this sign is approved, certain classes of vehicles, otherwise required to stop before crossing the tracks, may proceed without stopping, provided no train is approaching. Road Authority installs and maintains.

e. Do Not Stop On Tracks Sign. Road Authority Responsibility.

(2) Pavement Markings on all paved approaches are the responsibility of the road authority and consist of RR Crossing markings per the Standard Plans, no passing markings and pullout lanes as appropriate.

(3) Consider the installation of illumination at and adjacent to railroad crossings where an engineering study determines that better nighttime visibility of the train and the grade crossing is needed. For example:

- where a substantial amount of railroad operations are conducted at night.
- where grade crossings are blocked for long periods at night by slow speed trains.
- where crash history indicates that drivers experience difficulty seeing trains during hours of darkness.

(b) Active Elements

(1) Railroad Signals and gates. Maintenance of these devices is the responsibility of the railroad. Funding for installation and upgrades to these devices, commonly comes from the road authority.

(2) Repeater Signals (also known as "pre-signals"). These are traffic signals installed in advance of a railroad grade crossing when the grade crossing is adjacent to a parallel roadway with a far side traffic signal. They are installed and maintained by the road authority and used to discourage traffic from stopping on the tracks.

(3) Locomotive Horn. By law, trains are required to sound their horn in advance of grade crossings. In some locations this can be a problem for adjacent residents or businesses. This requirement may be waived provided current Federal Railroad Administration (FRA) requirements are met. (See Federal Register Vol 68, Number 243, Dec. 18, 2003) and (http://www.fra.dot.gov/Content3.asp?P=1318).

(4) Traffic signal interconnects (also known as "railroad pre-emption") provide linkage between the railroad signals and adjacent traffic signals to prevent vehicles from getting trapped at a traffic signal as a train approaches. These are typically funded by the road authority and require cooperation with the railroad for installation. Include copies of any signal pre-emption timings or calculations in the Project File.

In general, passive controls notify drivers that they are approaching a grade crossing and should be on the lookout for trains. Passive controls are typically found at low (train) volume and (train) speed crossings.

For crossings of state highways with low to moderate train speeds and volumes or for crossings with limited sight distance per Figure 930-1 Case 2 consider active controls. For crossings without adequate stopped vehicle sight distance per Figure 930-2, Case 1, consider including gates.

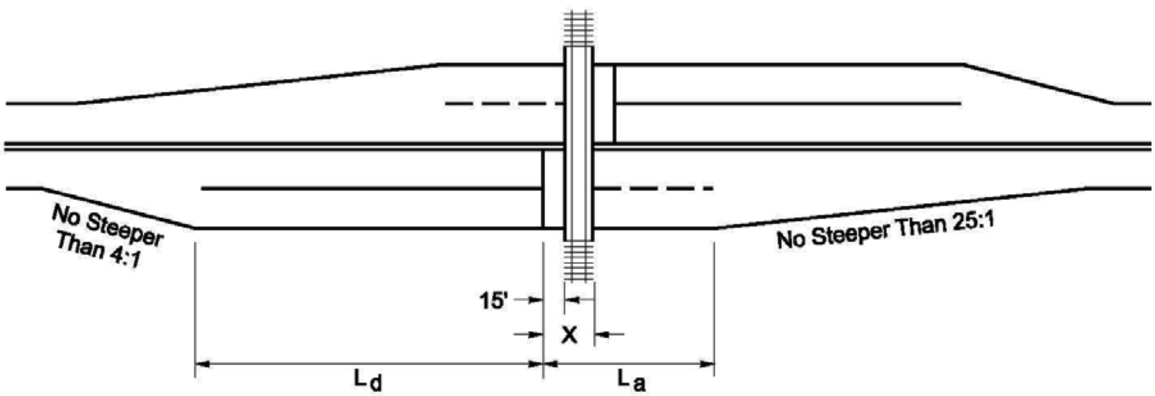
At the time of this writing no National or State warrants have been developed for installation of traffic controls at grade crossings. Furthermore, due to the large number of significant variables that must be considered, there is no single standard system of active traffic control devices universally applicable for grade crossings. Base the determination of the appropriate type of traffic control system on an engineering and traffic investigation including input from the railroad and the WUTC. Significant factors to consider are train and highway volumes and speeds, pedestrian volume, accident history, and sight distance restrictions.

Evaluate railroad signal supports and gate mechanisms as roadside hazards. Use traffic barrier or impact attenuators as appropriate per Division 7 of this manual.

930.05 Pullout Lanes

Per RCW 46.61.350 certain vehicles are required to stop at all railroad crossings without signals or not posted with an “Exempt” sign. Consider the installation of "pullout lane" when grade crossings have no active protection. Some school districts have a policy that school buses must stop at all grade crossings regardless of the type of control. Consider the installation of pullout lanes at any public grade crossing used regularly by school buses and for which the school buses must stop.

Design pullout lane geometrics in accordance with Figure 930-3. The minimum shoulder width adjacent to the pullout lane is 3 feet.



L_d = Total length of pullout lane, approach
L_a = Total length of pullout lane, exit
X = Distance from stopping point to downstream side of crossing surface

Approach Length of Pullout Lane, L_d		Downstream Length of Pullout Lane, L_a	
Vehicle Speed (mph)	**Length (ft)**	**Vehicle Speed (mph)**	**Length (ft)**
30	175	30	0
40	265	40	80
50	385	50	460
60	480	60	870

Typical Pullout Lane at Railroad Crossing
Figure 930-3

930.06 Crossing Surfaces

Railroads are responsible for the maintenance of crossing surfaces up to 12 inches outside the edge of rail (WAC 480-62-225). Crossing surfaces can be constructed of a number of different materials including asphalt, concrete, steel, timber, rubber, or plastic. The most common surface types used on state highway crossings are asphalt, precast concrete, and rubber. Timbered crossings are frequently used for low volume roads and temporary construction crossings.

The life of a crossing surface depends on the volume and weight of highway and rail traffic using it. Highway traffic not only dictates the type of crossing surface but also has a major influence on the life of the crossing. Rough crossing surfaces impact the motoring public far more than the railroad. Therefore, when a highway project passes through a railroad grade crossing consider the condition of the crossing surface. While the existing condition might not warrant railroad investment in replacing it, the surface might have deteriorated sufficiently to increase vehicle operating costs and motorist inconvenience. In such cases it may be effective to partner with the railroad to replace the crossing as part of the highway project. Such partnerships typically consist of the state reimbursing the railroad for all or a portion of the cost of the work.

930.07 Crossing Closure

The MUTCD states, "Any highway-rail grade crossing which cannot be justified should be eliminated". Coordination with the appropriate railroad and the Washington Utilities and Transportation Commission is required before any changes can be made to track structure or railroad signal systems. If a state route grade crossing appears unused, consult the Headquarters Railroad Liaison Engineer before taking any action. At-grade crossings which are replaced by grade separations should be closed.

930.08 Traffic Control During Construction And Maintenance

Work Zone Traffic Control at highway-rail grade crossings is required as in any other project with the addition of the need to provide protection from train traffic. When highway construction or maintenance activities will affect a railroad crossing, the railroad company must be notified at least ten days before performing the work (WAC 480-62-305 (4)). Furthermore, any time highway construction or maintenance crews or equipment are working within 25 feet of an active rail line or grade crossing, consult the railroad to determine if a railroad flagger is required to ensure work zone safety. Current contact numbers for railroads may be obtained by contacting your Regional Utilities Engineer. Railroad flaggers differ from highway flaggers in that they have information on train schedules and can generally communicate with trains by radio. When flaggers are required, the railroad generally sends the road authority a bill for the cost of providing this service.

Work zone traffic must never be allowed to stop or queue up on a nearby rail-highway grade crossing unless railroad flaggers are present. Without proper protection, vehicles might be trapped on the tracks when a train approaches. See the MUTCD for more detailed guidance.

For projects requiring temporary access across a set of railroad tracks, contact the Headquarters Railroad Liaison Engineer early in the design process since a Railroad Agreement will likely be required.

930.09 Railroad Grade Crossing Petitions And WUTC Orders

The Washington Utilities and Transportation Commission (WUTC) is authorized by statute (Title 81 RCW) with regulatory authority over railroad safety at grade-crossings. Any modifications to grade crossings or safety equipment including grade separations, widening, realignment, and profile must be approved by the WUTC (WAC 480-62-150). This is accomplished by submitting a formal Petition to the WUTC for which they will issue a formal Order. Provide Section, Township, & Range; posted speed limit;

ADT, percentage of trucks; number of daily school bus trips; and a 20 year projection of the ADT, truck percentage, and school bus trips. The Headquarters Railroad Liaison Engineer can help in the preparation and submittal of this petition. Include a copy of the Petition and WUTC Findings and Order in the Design Documentation Package.

930.10 Section 130 Grade Crossing Improvement Projects

WSDOT Highway and Local Programs administers the Section 130 Grade Crossing safety improvement program. Project proposals are submitted by local agencies, railroads, and WSDOT. Funding is provided from the Surface Transportation 10 percent "Safety Set Aside" authorized by the TEA-21.

Eligibility: All public railroad grade crossing safety improvements are eligible for funding. Project types include signing and pavement markings; active warning devices; illumination; crossing surfaces; grade separations (new and reconstructed); sight-distance improvements; geometric improvements to the roadway approaches; and closing and/or consolidating crossings. Section 130 funds are generally available at a 90 percent Federal share and up to 100% for signing; pavement markings; active warning devices; elimination of hazards; and crossing closures.

Most Section 130 projects on state highways are low cost grade crossing signal upgrades entirely within existing railroad right of way. Work is typically done by the railroad under agreement and generally takes a very short time. Consider Section 130 grade crossing signal upgrade projects, constructed by the railroad or its contractor, which are not part of a larger state highway project to be Minor Operational Enhancements funded under Program Q barring extenuating circumstances.

Contact the Railroad Liaison in the HQ Design Office for more information.

930.11 Light Rail

Light Rail, also known as streetcars, is developing in some urban areas of the state. For the most part, criteria for light rail are very similar to those for freight and passenger rail with the exception of locations where light rail shares a street right of way with motor vehicles. The MUTCD now includes a chapter devoted exclusively to Light Rail. Consult this reference as the situation warrants http://mutcd.fhwa.dot.gov/HTM/2003/part10/part10-toc.htm.

930.12 Documentation

A list of the documents that are required to be preserved in the Design Documentation Package (DDP) and the Project File (PF) is on the following website:

http://www.wsdot.wa.gov/eesc/design/projectdev/

940.01 General

The primary purpose of an interchange is to eliminate conflicts caused by vehicle crossings and to minimize conflicting left-turn movements. Interchanges are provided on all Interstate highways, freeways, other routes on which full access control is required, and at other locations where traffic cannot be controlled safely and efficiently by intersections at grade.

See the following chapters for additional information:

Chapter	Subject
640	Ramp Sections
641	Turning Widths
642	Superelevation
910	Intersections
1050	HOV Lanes
1420	Access Control
1425	Access Point Decision Report
1430	Limited Access

940.02 References

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

Plans Preparation Manual, M 22-31, WSDOT

HOV Direct Access Design Guide, Draft M 22-98, WSDOT

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

A Policy on Geometric Design of Highways and Streets (Green Book), 2001, AASHTO

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

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

Procedure for Analysis and Design of Weaving Sections, A User's Guide, October 1985, Jack E. Leisch

940.03 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.

collector distributor road (C-D road) A parallel roadway designed to remove weaving from the main line and to reduce the number of main line entrances and exits.

decision sight distance The sight distance required for a driver to detect an unexpected or difficult-to-perceive information source or hazard, interpret the information, recognize the hazard, select an appropriate maneuver, and complete it safely and efficiently.

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

gore The area downstream from the intersection of the shoulders of the main line and exit ramp. Although generally the area between a main line and an exit ramp, the term may also be used to refer to the area between a main line and an entrance ramp.

intersection at grade The general area where a state highway or ramp terminal is met or crossed at a common grade or elevation by another state highway, a county road, or a city street.

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 transportation system. The Interstate System is part of the principal arterial system.

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

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.

painted nose The point where the main line and ramp lanes separate.

physical nose The point, upstream of the gore, with a separation between the roadways of 16 to 22 ft. See Figures 940-11a and 11b.

ramp A short roadway connecting a main lane of a freeway with another facility for vehicular use such as a local road or another freeway.

ramp connection The pavement at the end of a ramp, connecting it to a main lane of a freeway.

ramp meter A traffic signal at a freeway entrance ramp that allows a measured or regulated amount of traffic to enter the freeway.

ramp terminal The end of a ramp at a local road.

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

sight distance The length of highway visible to the driver.

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 (where permitted) use by bicyclists and pedestrians.

stopping sight distance The sight distance required to detect a hazard and safely stop a vehicle traveling at design speed.

traffic interchange A system of interconnecting roadways, in conjunction with one or more grade separations, providing for the exchange of traffic between two or more intersecting highways or roadways.

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.

940.04 Interchange Design

(1) General

All freeway exits and entrances, except HOV direct access connections, are to connect on the right of through traffic. Deviations from this requirement will be considered only for special conditions.

HOV direct access connections may be constructed on the left of through traffic when they are designed in accordance with the *HOV Direct Access Design Guide.*

Provide complete ramp facilities for all directions of travel wherever possible. However, give primary consideration to the basic traffic movement function that the interchange is to fulfill.

Few complications will be encountered in the design and location of rural interchanges that simply provide a means of exchanging traffic between a limited access freeway and a local crossroad. The economic and operational effects of locating traffic interchanges along a freeway through a community requires more careful consideration, particularly with respect to local access, to provide the best local service possible without reducing the capacity of the major route or routes.

Where freeway to freeway interchanges are involved, do not provide ramps for local access unless they can be added conveniently and without detriment to safety or reduction of ramp and through-roadway capacity. When exchange of traffic between freeways is the basic function and local access is prohibited by access control restrictions or traffic volume, it may be necessary to provide separate interchanges for local service.

(2) Interchange Patterns

Basic interchange patterns have been established that can be used under certain general conditions and modified or combined to apply to many more. Alternatives must be considered in the design of a specific facility, but the conditions in the area and on the highway involved must govern and rigid patterns must not be indiscriminately imposed.

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 <u>typical</u> 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 mi in urban areas and 2 mi in rural areas. In urban areas, spacing less than 1 mi may be used with C-D roads or grade separated (braided) ramps. Generally, the average interchange spacing is not less than 2 mi in urban areas and not less than 4 mi 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 requires 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 and 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.

It is desirable for the ramp design speed at the connection to the freeway be equal to the free-flow speed of the freeway. Meet or exceed the upper range values from Figure 940-1 for the design speed at the ramp connection to the freeway. Transition the ramp design speed to provide a smooth acceleration or deceleration between the speeds at the ends of the ramp. However, do not reduce the ramp design speed below the lower range speed of 25 mph. For loop ramps, use a design speed as high as practical, but not less than 25 mph.

These design speed guidelines do not apply to the ramp in the area of the ramp terminal at-grade intersection. In the area of the intersection, a design speed of 15 mph for turning traffic or 0 mph for a stop condition is adequate. Use the allowed skew at the ramp terminal at-grade intersection to minimize ramp curvature.

For freeway-to-freeway ramps and C-D roads, the design speed at the connections to both freeways is the upper range values from Figure 940-1; however, with justification, the midrange values from Figure 940-1 may be used for the remainder of the ramp. When the design speed for the two freeways is different, use the higher design speed.

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 642.

Main Line Design Speed mph		50	55	60	65	70	80
Ramp Design Speed (mph)	Upper Range	45	50	50	55	60	70
	Midrange	35	40	45	45	50	60
	Lower Range	25	25	25	25	25	25

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.

Ramp Design Speed (mph)	25-30	35-40	45 and above
Desirable Grade (%)	5	4	3
Maximum Grade (%)	7	6	5
On one-way ramps down grades may be 2% greater.			

Maximum Ramp Grade
Figure 940-2

(4) Cross Section

Provide the minimum ramp widths given in Figure 940-3. Ramp traveled ways may require additional width to these minimums as one-way turning roadways. See Chapters 640 and 641 for additional information and roadway sections.

Number of Lanes		1	2
Traveled Way(1)		15(2)	25(3)
Shoulders	Right	8	8
	Left	2	4
Medians(4)		6	8

(1) See Chapter 641 for turning roadway widths. See Chapter 1050 for additional width when an HOV lane is present.
(2) May be reduced to 12 ft on tangents.
(3) Add 12 ft for each additional lane.
(4) The minimum median width is not less than that required for traffic control devices and their respective clearances.

Ramp Widths (ft)
Figure 940-3

Cross slope and superelevation requirements for ramp traveled way and shoulders are as given in Chapters 640 and 642 for roadways.

Whenever feasible, make the ramp cross slope at the ramp beginning or ending station equal to the cross slope of the through lane pavement. Where space is limited and superelevation runoff is long or when parallel connections are used, the superelevation transition may be ended beyond (for on-ramps) or begun in advance of (for off-ramps) the ramp beginning or ending station, provided that the algebraic difference in cross slope at the edge of the through lane and the cross slope of the ramp does not exceed 4%. In such cases, ensure smooth transitions for the edge of traveled way.

(5) Ramp Lane Increases

When off-ramp traffic and left-turn movement volumes at the ramp terminal at-grade intersection cause congestion, it may be desirable to add lanes to the ramp to reduce the queue length caused by turning conflicts. Make provision for the addition of ramp lanes whenever ramp exit or entrance volumes, after the design year, are expected to result in poor service. See Chapter 620 for width transition design.

(6) Ramp Meters

Ramp meters are used to allow a measured or regulated amount of traffic to enter the freeway. When operating in the "measured" mode, they release traffic at a measured rate to keep downstream demand below capacity and improve system travel times. In the "regulated" mode, they break up platoons of vehicles that occur naturally or result from nearby traffic signals. Even when operating at near capacity, a freeway main line can accommodate merging vehicles one or two at a time, while groups of vehicles will cause main line flow to break down.

The location of the ramp meter is a balance between the storage and acceleration requirements. Locate the ramp meter to maximize the available storage and so that the acceleration lane length, from a stop to the freeway main line design speed, is available from the stop bar to the merging point. With justification, the average main line running speed during the hours of meter operation may be used for the highway design speed to determine the minimum acceleration lane length from the ramp meter. See 940.06(4) for information on the design of on-connection acceleration lanes. See Chapter 860 for additional information on the design of ramp meters.

Driver compliance with the signal is required for the ramp meter to have the desired results. Consider enforcement areas with ramp meters.

Consider HOV bypass lanes with ramp meters. See Chapter 1050 for design data for ramp meter bypass lanes.

940.06 Interchange Connections

Provide uniform geometric design and uniform signing for exits and entrances, to the extent possible, in the design of a continuous freeway. Do not design an exit ramp as an extension of a main line tangent at the beginning of a main line horizontal curve.

Provide spacing between interchange connections as given by Figure 940-5.

Avoid on-connections on the inside of a main line curve, particularly when the ramp approach angle is accentuated by the main line curve, the ramp approach requires a reverse curve to connect to the main line, or the elevation difference will cause the cross slope to be steep at the nose.

Keep the use of mountable curb at interchange connections to a minimum. Justification is required when it is used adjacent to traffic expected to exceed 40 mph.

(1) Lane Balance

Design interchanges to the following principles of lane balance:

(a) At entrances, make the number of lanes beyond the merging of two traffic streams not less than the sum of all the lanes on the merging roadways less one. (See Figure 940-6a.)

(b) At exits, make the number of approach lanes equal the number of highway lanes beyond the exit plus the number of exit lanes less one. (See Figure 940-6a.) Exceptions to this are at a cloverleaf or at closely spaced interchanges with a continuous auxiliary lane between the entrance and exit. In these cases the auxiliary lane may be dropped at a single-lane, one lane reduction, off-connection with the number of approach lanes being equal to the sum of the highway lanes beyond the exit and the number of exit lanes. Closely spaced interchanges have a distance of less than 2,100 ft between the end of the acceleration lane and the beginning of the deceleration lane.

Maintain the basic number of lanes, as described in Chapter 620, through interchanges. When a two-lane exit or entrance is used, maintain lane balance with an auxiliary lane. (See Figure 940-6b.) The only exception to this is when the basic number of lanes is changed at an interchange.

(2) Main Line Lane Reduction

The reduction of a basic lane or an auxiliary lane may be made at a two-lane exit or may be made between interchanges. When a two-lane exit is used, provide a recovery area with a normal acceleration taper. When a lane is dropped between interchanges, drop it 1,500 to 3,000 ft from the end of the acceleration taper of the previous interchange. This will allow for adequate signing but not be so far that the driver will become accustomed to the number of lanes and be surprised by the reduction. (See Figure 940-7.)

Reduce the traveled way width of the freeway by only one lane at a time.

(3) Sight Distance

Locate off-connections and on-connections on the main line to provide decision sight distance for a speed/path/direction change as described in Chapter 650.

(4) On-Connections

On-connections are the pavement at the end of on-ramps, connecting them to the main lane of a freeway. They have two parts, an acceleration lane and a taper. The acceleration lane allows entering traffic to accelerate to the freeway speed and evaluate gaps in the freeway traffic. The taper is for the entering vehicle to maneuver into the through lane.

On-connections are either taper type or parallel type. The tapered on-connection provides direct entry at a flat angle, reducing the steering control needed. The parallel on-connection adds a lane adjacent to the through lane for acceleration with a taper at the end. Vehicles merge with the through traffic with a reverse curve maneuver similar to a lane change. While the taper requires less steering control, the parallel is narrower at the end of the ramp and has a shorter taper at the end of the acceleration lane.

(a) Provide the minimum acceleration lane length, given on Figure 940-8, for each ramp design speed on all on-ramps. When the average grade of the acceleration lane is 3% or greater, multiply the distance from the Minimum Acceleration Lane Length table by the factor from the Adjustment Factor for Grades table.

For existing ramps that do not have significant accidents in the area of the connection with the freeway, the freeway posted speed may be used to calculate the acceleration lane length for preservation projects. If corrective action is indicated, use the freeway design speed to determine the length of the acceleration lane. Document existing ramps to remain in place with an acceleration lane length less than to the design speed as a design exception. Also, include the following documentation in the project file: the ramp location, the acceleration length available, and the accident analysis that shows that there are not significant accidents in the area of the connection.

The acceleration lane is measured from the last point designed at each ramp design speed (usually the PT of the last curve for each design speed) to the last point with a ramp width of 12 ft. Curves designed at higher design speeds may be included as part of the acceleration lane length.

(b) For parallel type on-connections, provide the minimum gap acceptance length (L_g) to allow entering traffic to evaluate gaps in the freeway traffic and position the vehicle to use the gap. The length is measured beginning at the point that the left edge of traveled way for the ramp intersects the right edge of traveled way of the main line to the ending of the acceleration lane. (See Figures 940-9b and 9c.) The gap acceptance length and the acceleration length overlap with the ending point controlled by the longer of the two.

(c) Single-lane on-connections may be either taper type or parallel type. The taper type is preferred; however, the parallel may be used with justification. Design single-lane taper type on-connections as shown on Figure 940-9a and single lane parallel type on-connections as shown on Figure 940-9b.

(d) For two-lane on-connections, the parallel type is preferred. Design two-lane parallel on-connections as shown on Figure 940-9c. A capacity analysis will normally be the basis for determining whether a freeway lane or an auxiliary lane is to be provided.

When justification is documented, a two-lane tapered on-connection may be used. Design two-lane tapered on-connections in accordance with Figure 940-9d.

(5) Off-Connections

Off-connections are the pavement at the beginning of an off-ramp, connecting it to a main lane of a freeway. They have two parts, a taper for maneuvering out of the through traffic and a deceleration lane to slow to the speed of the first curve on the ramp. Deceleration is not assumed to take place in the taper.

Off-connections are either taper type or parallel type. The taper type is preferred because it fits the path preferred by most drivers. When a parallel type connection is used, drivers tend to drive directly for the ramp and not use the parallel lane. However, when a ramp is required on the outside of a curve, the parallel off-connection is preferred. An advantage of the parallel connection is that it is narrower at the beginning of the ramp.

(a) Provide the minimum deceleration lane length given on Figure 940-10 for each design speed for all off-ramps. Also, provide deceleration lane length to the end of the anticipated queue at the ramp terminal. When the average grade of the deceleration lane is 3% or greater, multiply the distance from the Minimum Deceleration Lane Length table by the factor from the Adjustment Factor for Grades table.

For existing ramps that do not have significant accidents in the area of the connection with the freeway, the freeway posted speed may be used to calculate the deceleration lane length for preservation projects. If corrective action is indicated, use the freeway design speed to determine the length of the deceleration lane.

Document existing ramps to remain in place with a deceleration lane length less than to the design speed as a design exception. Also, include the following documentation in the project file: the ramp location, the deceleration length available, and the accident analysis that shows that there are not significant accidents in the area of the connection.

The deceleration lane is measured from the point where the taper reaches a width of 12 ft to the first point designed at each ramp design speed (usually the PC of the first curve for each design speed). Curves designed at higher design speeds may be included as part of the deceleration lane length.

(b) Gores, Figures 940-11a and 11b, are decision points that must be clearly seen and understood by approaching drivers. In a series of interchanges along a freeway, it is desirable that the gores be uniform in size, shape, and appearance.

The paved area between the physical nose and the gore nose is the reserve area. It is reserved for the installation of an impact attenuator. The minimum length of the reserve area is controlled by the design speed of the main line. (See Figures 940-11a and 11b.)

In addition to striping, raised pavement marker rumble strips may be placed for additional warning and delineation at gores. See the Standard Plans for striping and rumble strip details.

The accident rate in the gore area is greater than at other locations. Keep the unpaved area beyond the gore nose as free of obstructions as possible to provide a clear recovery area. Grade this unpaved area as nearly level with the roadways as possible. Avoid placing obstructions such as heavy sign supports, luminaire poles, and structure supports in the gore area.

When an obstruction must be placed in a gore area, provide an impact attenuator (Chapter 720) and barrier (Chapter 710). Place the beginning of the attenuator as far back in the reserve area as possible, preferably after the gore nose.

(c) For single-lane off-connections, the taper type is preferred. Use the design shown on Figure 940-12a for tapered single-lane off-connections. When justification is documented, a parallel single-lane off-connection, as shown on Figure 940-12b, may be used.

(d) The single-lane off-connection with one lane reduction, Figure 940-12c, is only used when the conditions from lane balance for a single lane exit, one lane reduction, are met.

(e) The tapered two-lane off-connection design shown on Figure 940-12d is preferred where the number of freeway lanes is to be reduced, or where high volume traffic operations will be improved by the provision of a parallel auxiliary lane and the number of freeway lanes is to be unchanged.

The parallel two-lane off-connection, Figure 940-12e, allows less operational flexibility than the taper, requiring more lane changes. Use a parallel two-lane off-connection only with justification.

(6) Collector Distributor Roads

A C-D road can be within a single interchange, through two closely spaced interchanges, or continuous through several interchanges. Design C-D roads that connect three or more interchanges to be two lanes wide. All others may be one or two lanes in width, depending on capacity requirements. Consider intermediate connections to the main line for long C-D roads. See Figure 940-13a for designs of collector distributor outer separations. Use Design A, with concrete barrier, when adjacent traffic in either roadway is expected to exceed 40 mph. Design B, with mountable curb, may be used only when adjacent traffic will not exceed 40 mph.

(a) The details shown in Figure 940-13b apply to all single-lane C-D road off-connections. Where conditions require two-lane C-D road off-connections, a reduction in the number of freeway lanes, the use of an auxiliary lane, or a combination of these, design it as a normal off-connection per 940.06(5).

(b) Design C-D road on-connections as required by Figure 940-13c.

(7) Loop Ramp Connections

Loop ramp connections at cloverleaf interchanges are distinguished from other ramp connections by a low speed ramp on-connection followed closely by an off-connection for another low speed ramp. The loop ramp connection design is shown on Figure 940-14. The minimum distance between the ramp connections is dependent on a weaving analysis. When the connections are spaced far enough apart that weaving is not a consideration, design the on-connection per 940.06(4) and off-connection per 940.06(5).

(8) Weaving Sections

Weaving sections are highway segments where one-way traffic streams cross by merging and diverging. Weaving sections may occur within an interchange, between closely spaced interchanges, or on segments of overlapping routes. Figure 940-15 gives the length of the weaving section for preliminary design. The total weaving traffic is the sum of the traffic entering from the ramp to the main line and the traffic leaving the main line to the exit ramp in equivalent passenger cars. For trucks, a passenger car equivalent of two may be estimated. Use the *Highway Capacity Manual* for the final design of weaving sections.

Because weaving sections cause considerable turbulence, interchange designs that eliminate weaving or remove it from the main roadway are desirable. Use C-D roads for weaving between closely spaced ramps when adjacent to high speed highways. C-D roads are not required for weaving on low speed roads.

940.07 Ramp Terminal Intersections at Crossroads

Design ramp terminal intersections at grade with crossroads as intersections at grade. (See Chapter 910.) Whenever possible, design ramp terminals to discourage wrong way movements. Review the location of ramp intersections at grade with crossroads to ensure signal progression if the intersection becomes signalized in the future. Provide intersection sight distance as described in Chapter 910.

In urban and suburban areas, match design speed at the ramp terminal to the speed of the crossroad. Provide steeper intersection angles between the ramp terminal and crossroad to slow motor vehicle traffic speeds and reduce crossing distances for bicyclists and pedestrians.

The intersection configuration requirements for ramp terminals is normally the same as for other intersections. One exception to this is an angle point is allowed between an off ramp and an on ramp. This is because the through movement of traffic getting off the freeway, going through the intersection, and back on the freeway is minor.

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

940.08 Interchanges on Two-Lane Highways

Occasionally, the first stage of a conventional interchange will be built with only one direction of the main roadway and operated as a two-lane two-way roadway until the ultimate roadway is constructed.

The design of interchanges on two-lane two-way highways may vary considerably from traditional concepts due to the following conditions:

- The potential for center-line-crossing related accidents due to merge conflicts or motorist confusion.
- The potential for wrong way or U-turn movements.
- Future construction considerations.
- Traffic type and volume.
- The proximity to multilane highway sections that might influence the driver's impression that these roads are also multilane.

The deceleration taper is required for all exit conditions. Design the entering connection with either the normal acceleration taper or a "button hook" type configuration with a stop condition before entering the main line. Consider the following items:

- Design the stop condition connection in accordance with the requirements for a Tee intersection in Chapter 910. Use this type of connection only when an acceleration lane is not possible. Provide decision sight distance as described in Chapter 650.
- Since each design will probably vary from project to project, analyze each project for most efficient signing placement such as one way, two way, no passing, do not enter, directional arrows, guide posts, and traffic buttons.
- Prohibit passing through the interchange area on two lane highways by means of signing, pavement marking, or a combination of both. A 4 ft median island highlighted with raised pavement markers and diagonal stripes is the preferred treatment. When using a 4 ft median system, extend the island 500 ft beyond any merging ramp traffic acceleration taper. The width for the median can be provided by reducing each shoulder 2 ft through the interchange. (See Figure 940-16.)
- Inform both the entering and through motorists of the two-lane two-way characteristic of the main line. Include signing and pavement markings.
- Use as much of the ultimate roadway as possible. Where this is not possible, leave the area for future lanes and roadway ungraded.
- Design and construct temporary ramps as if they were permanent unless second stage construction is planned to rapidly follow the first. In all cases, design the connection to meet the safety needs of the traffic. (See Figure 940-16.)

940.09 Interchange Plans

Figure 940-17 is a sample showing the general format and data required for interchange design plans.

Compass directions (W-S Ramp) or crossroad names (E-C Street) may be used for ramp designation to realize the most clarity for each particular interchange configuration and circumstance.

Include the following as applicable:

- Classes of highway and design speeds for main line and crossroads (Chapter 440).
- Curve data on main line, ramps, and crossroads.
- Numbers of lanes and widths of lanes and shoulders on main line, crossroads, and ramps.

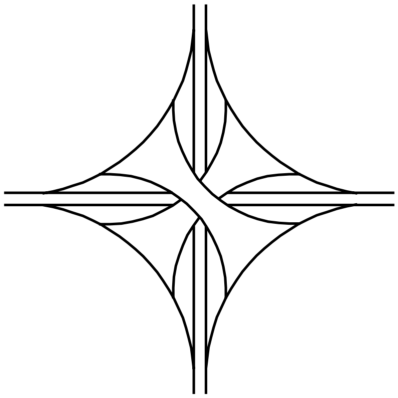
- Superelevation diagrams for the main line, the crossroad, and all ramps (may be submitted on separate sheets).
- Channelization (Chapter 910).
- Stationing of ramp connections and channelization.
- Proposed right of way and access control treatment (Chapters 1410, 1420, and 1430).
- Delineation of all crossroads, existing and realigned (Chapter 910).
- Traffic data necessary to justify the proposed design. Include all movements.
- For HOV direct access connections on the left, include the statement that the connection will be used solely by HOVs or will be closed.

Prepare a preliminary contour grading plan for each completed interchange. Show the desired contours of the completed interchange including details of basic land formation, slopes, graded areas, or other special features. Coordinate the contour grading with the drainage design and the roadside development plan.

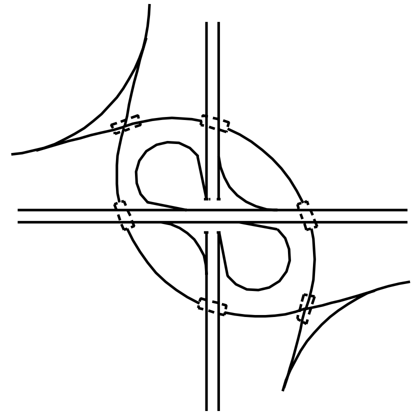
Alternative designs considered, studied, and rejected may be shown as reduced scale diagrams with a brief explanation of the advantages and disadvantages of the alternative designs, including the recommended design.

940.10 Documentation

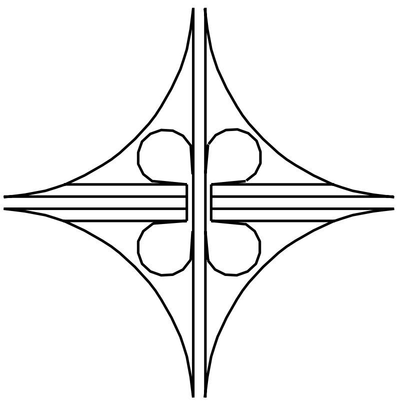
A list of documents that are to be presereved [in the Design Documentation Package (DDP) or the project File (PF) is on the following website: http://www.wsdot.wa.gov/eesc/design/projectdev/



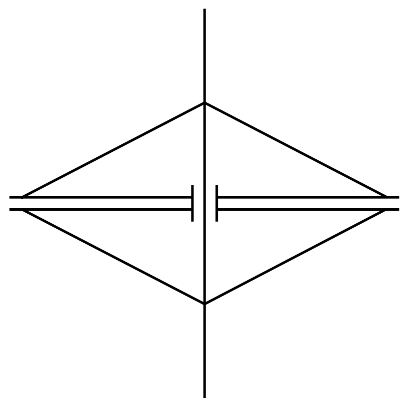
Directional



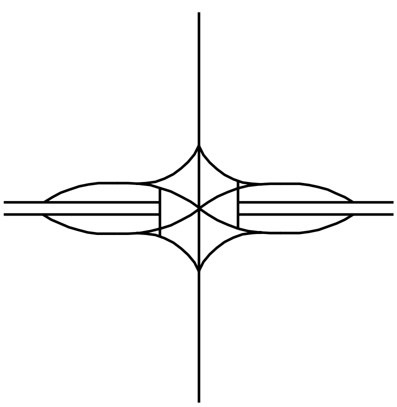
Semidirectional



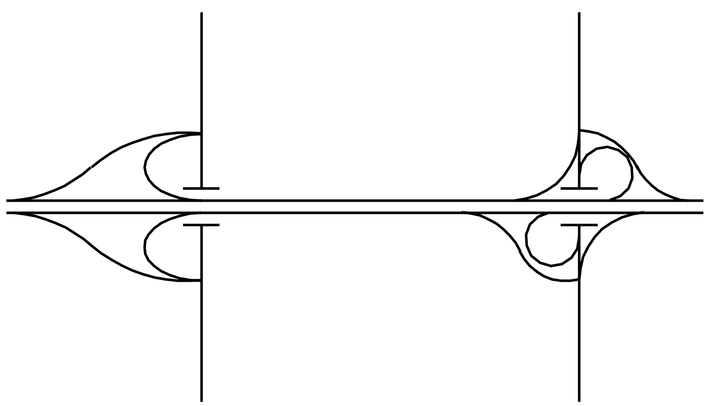
Cloverleaf with C-D Roads



Diamond

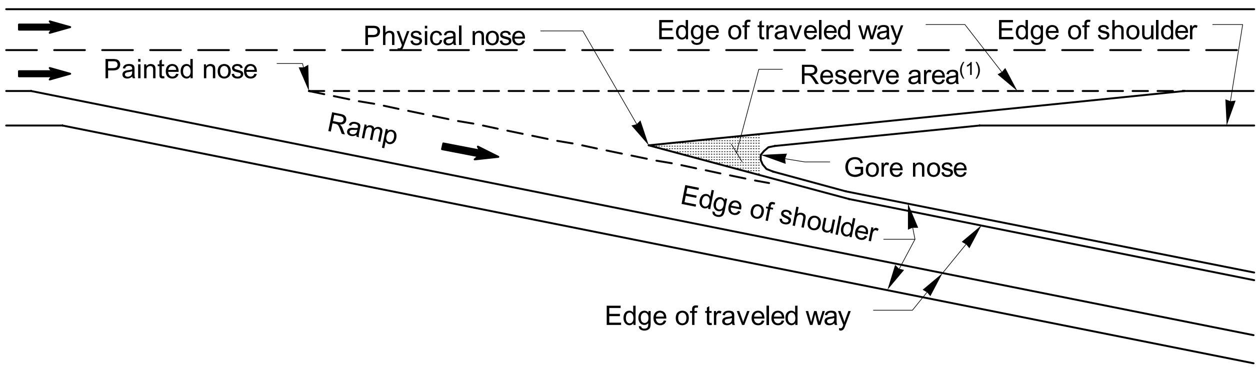


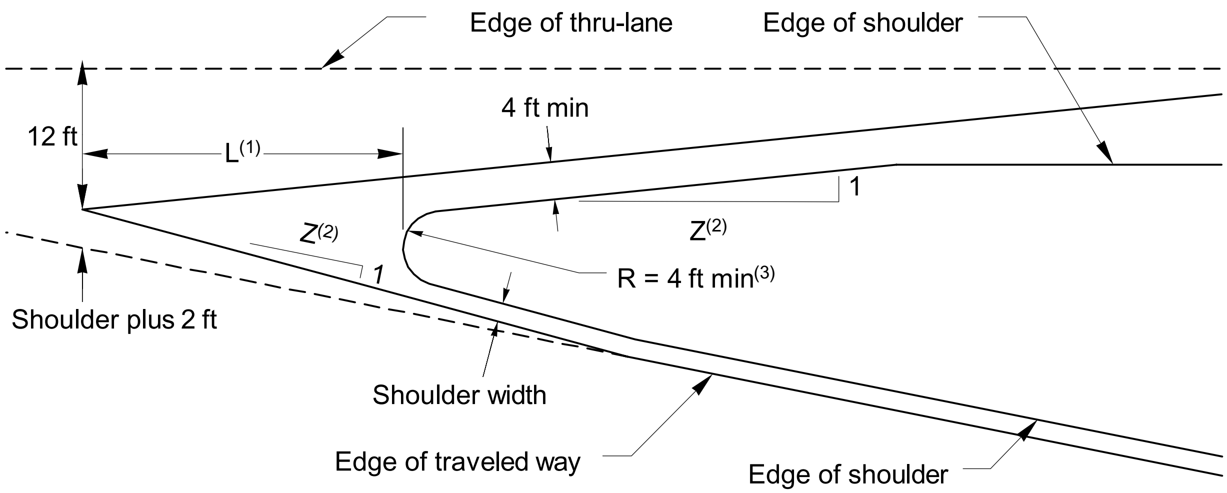
Single Point (Urban)



Partial Cloverleaf

Basic Interchange Patterns
Figure 940-4





Notes:

(1) The reserve area length (L) is not less than:

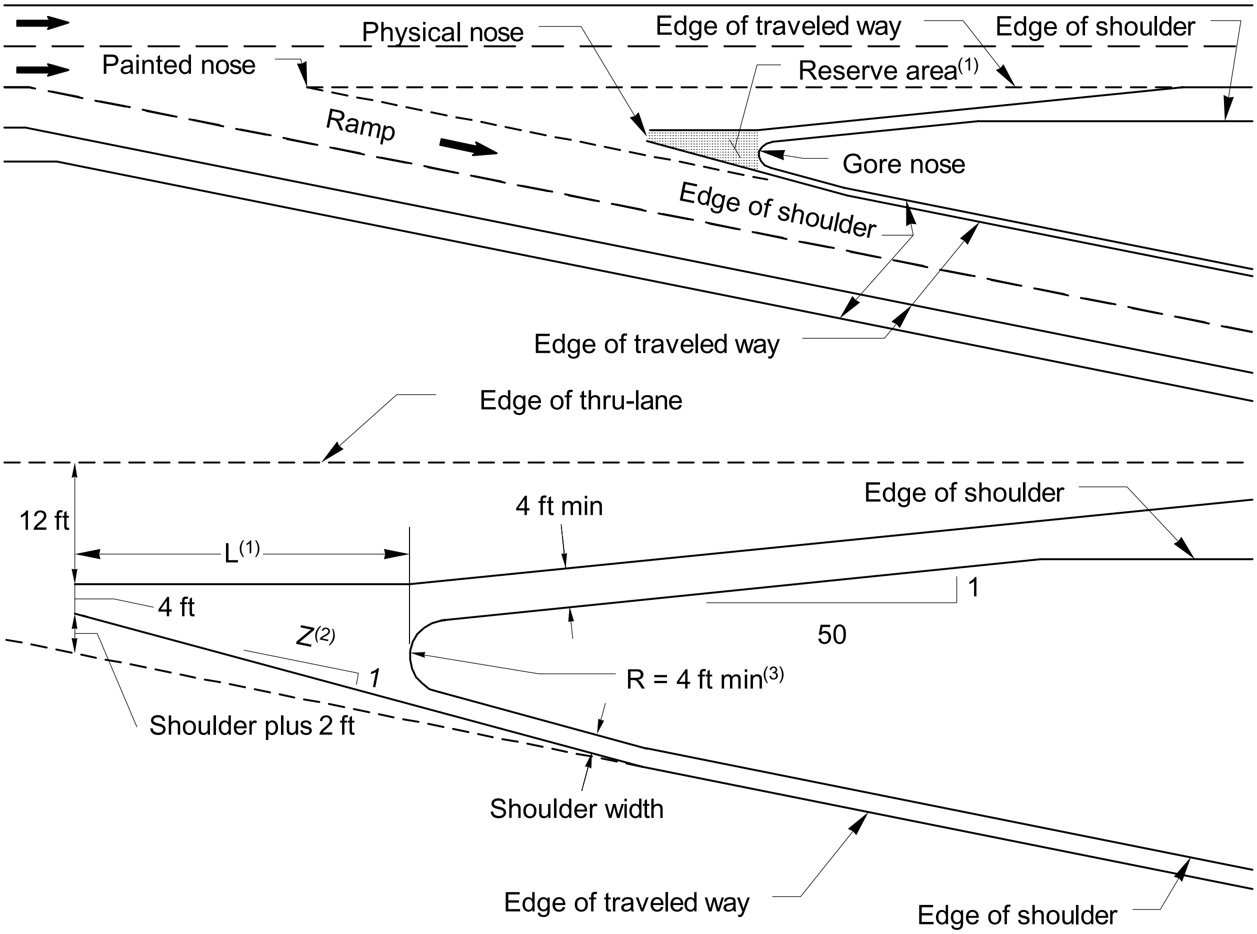
Main Line Design Speed (mph)	40	45	50	55	60	65	70	80
L (ft)	25	30	35	40	45	50	55	70

(2) $Z = \frac{\text{Design Speed}}{2}$, Design speed is for the main line.

(3) R may be reduced, when protected by an impact attenuator.

Gore Area Characteristics

Figure 940-11a



Notes:

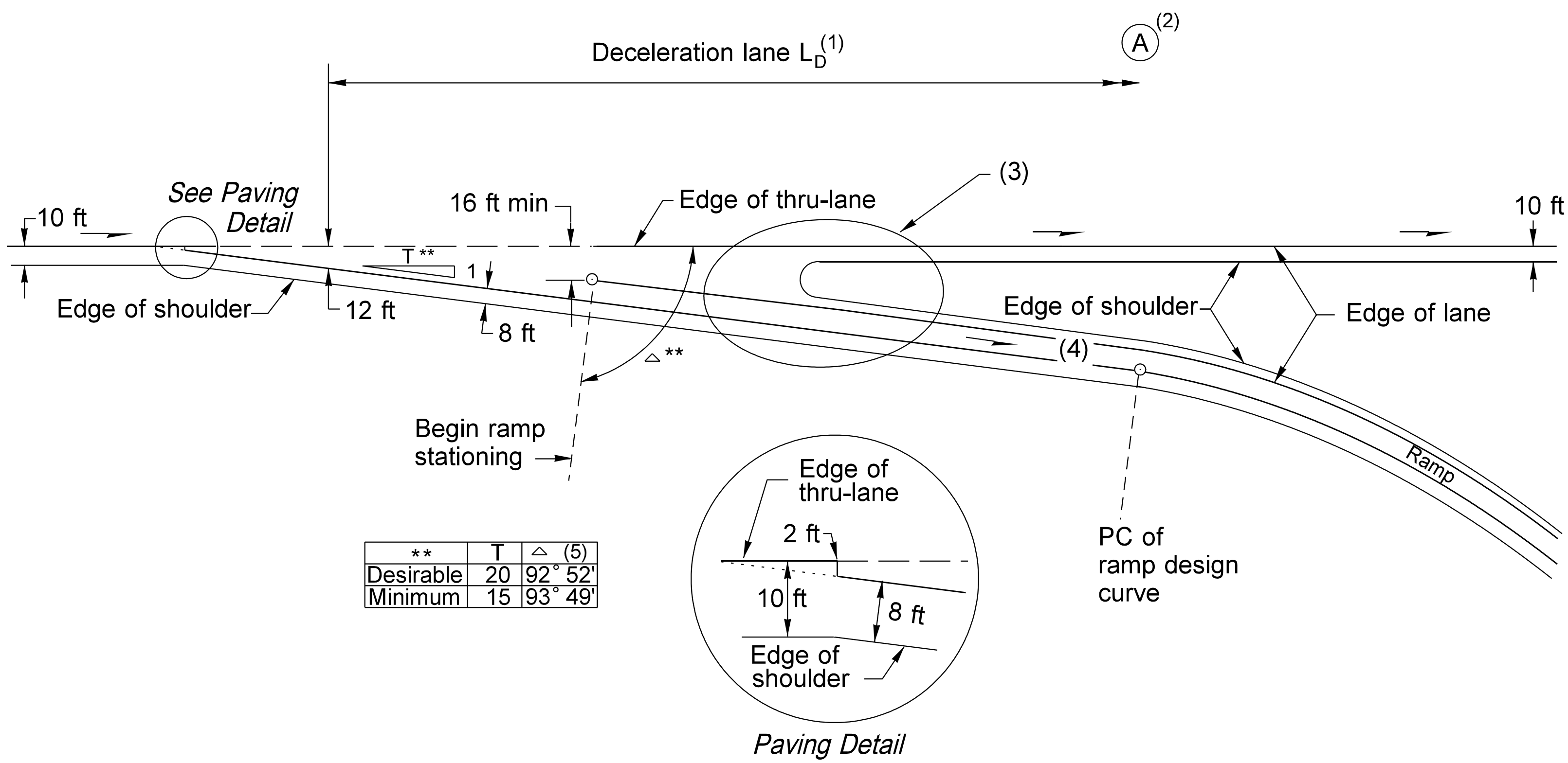
(1) The reserve area length (L) is not less than:

Main Line Design Speed (mph)	40	45	50	55	60	65	70	80
L (ft)	25	30	35	40	45	50	55	70

(2) $Z=\frac{\text{Design Speed}}{2}$, Design speed is for the main line.

(3) R may be reduced, when protected by an impact attenuator.

Gore Area Characteristics
Figure 940-11b



**	T	△ (5)
Desirable	20	92° 52'
Minimum	15	93° 49'

Notes:

(1) See Figure 940-10 for deceleration lane length L_D.

(2) Point (A) is the point controlling the ramp design speed.

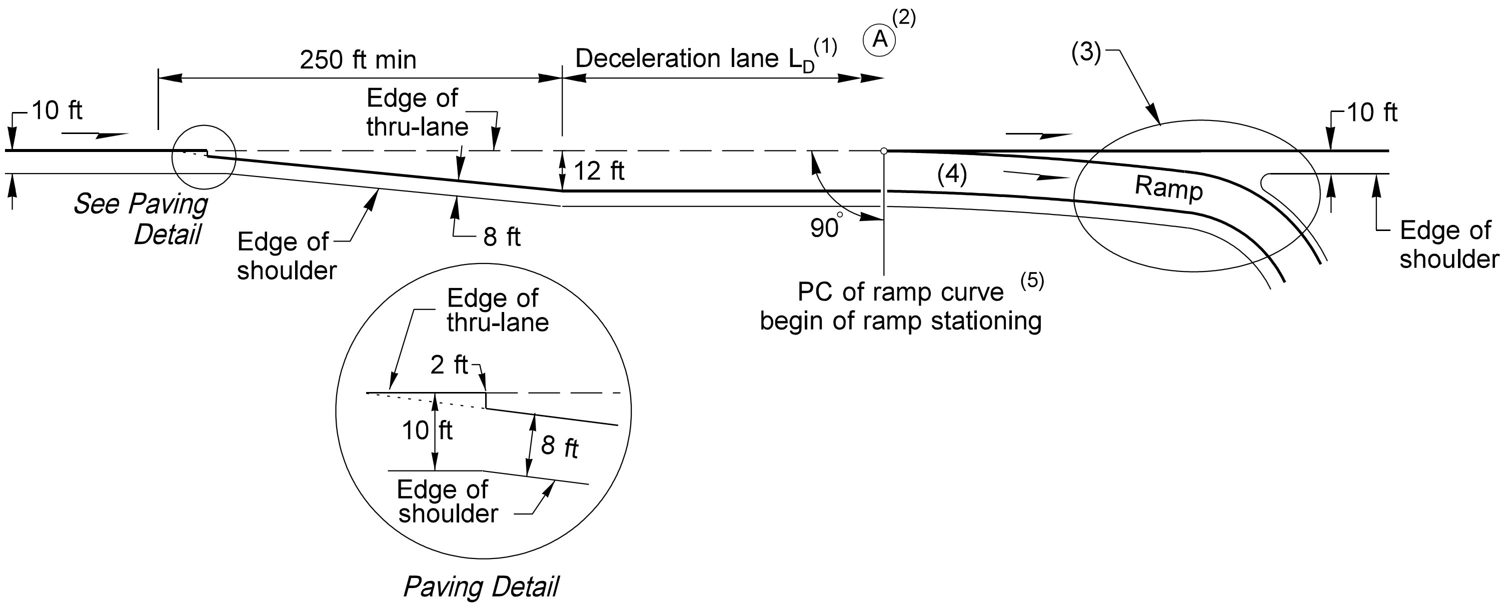
(3) See Figure 940-11a for gore details.

(4) For ramp lane and shoulder widths, see Figure 940-3.

(5) Approximate angle to establish ramp alignment.

(6) For striping, see the Standard Plans.

Off-Connection (Single-Lane, Taper Type)
Figure 940-12a



Notes:

(1) See Figure 940-10 for deceleration lane length L_D.

(2) Point A is the point controlling the ramp design speed.

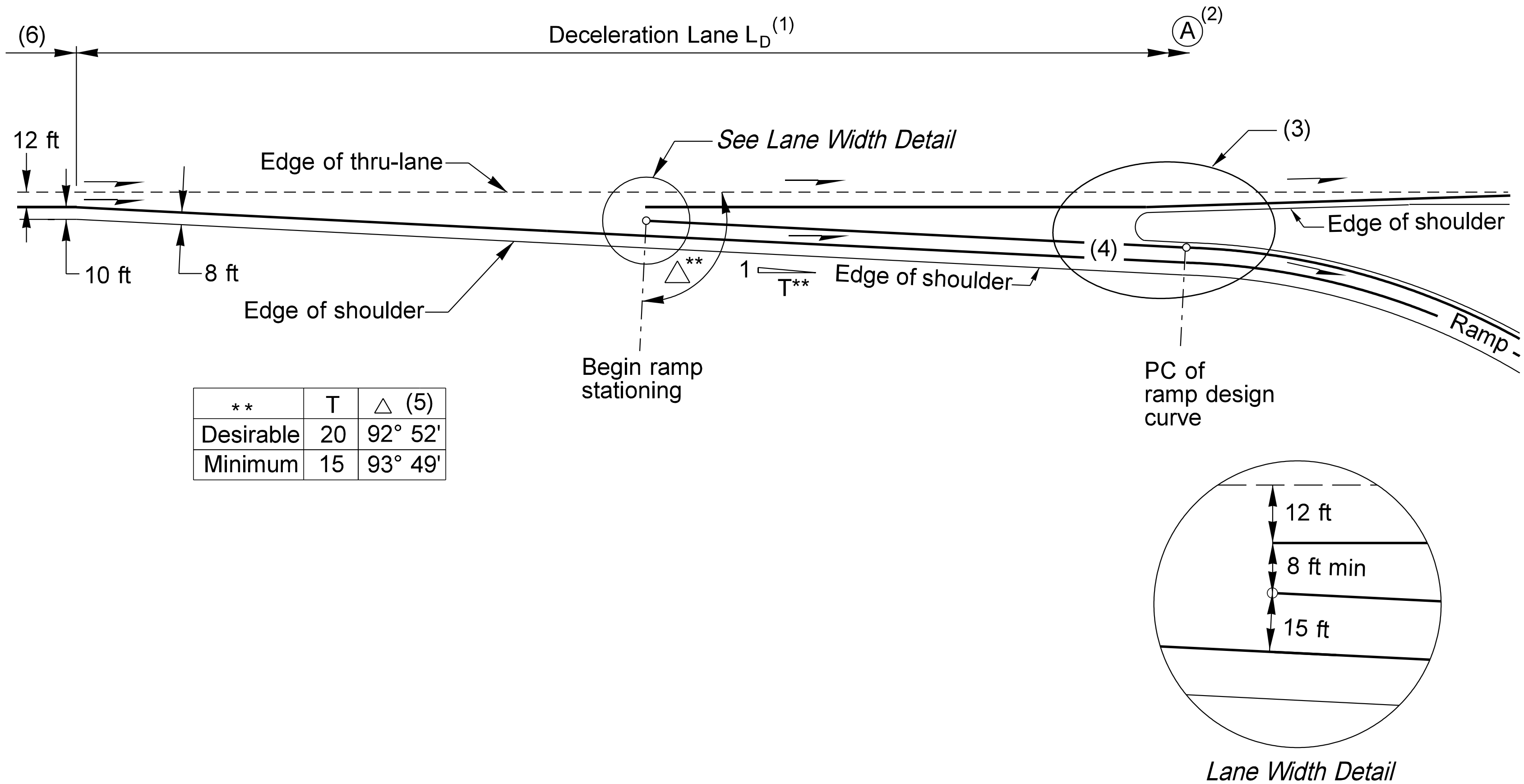
(3) See Figure 940-11a for gore details.

(4) For ramp lane and shoulder widths, see Figure 940-3.

(5) Ramp Stationing may be extended to accommodate superelevation transition.

(6) For striping, see the Standard Plans.

Off-Connection (Single-Lane, Parallel Type)
Figure 940-12b



**	T	△ (5)
Desirable	20	92° 52'
Minimum	15	93° 49'

Notes:

(1) See Figure 940-10 for deceleration lane length L_D.

(2) Point Ⓐ is the point controlling the ramp design speed.

(3) See Figure 940-11b for gore details.

(4) For ramp lane and shoulder widths, see Figure 940-3.

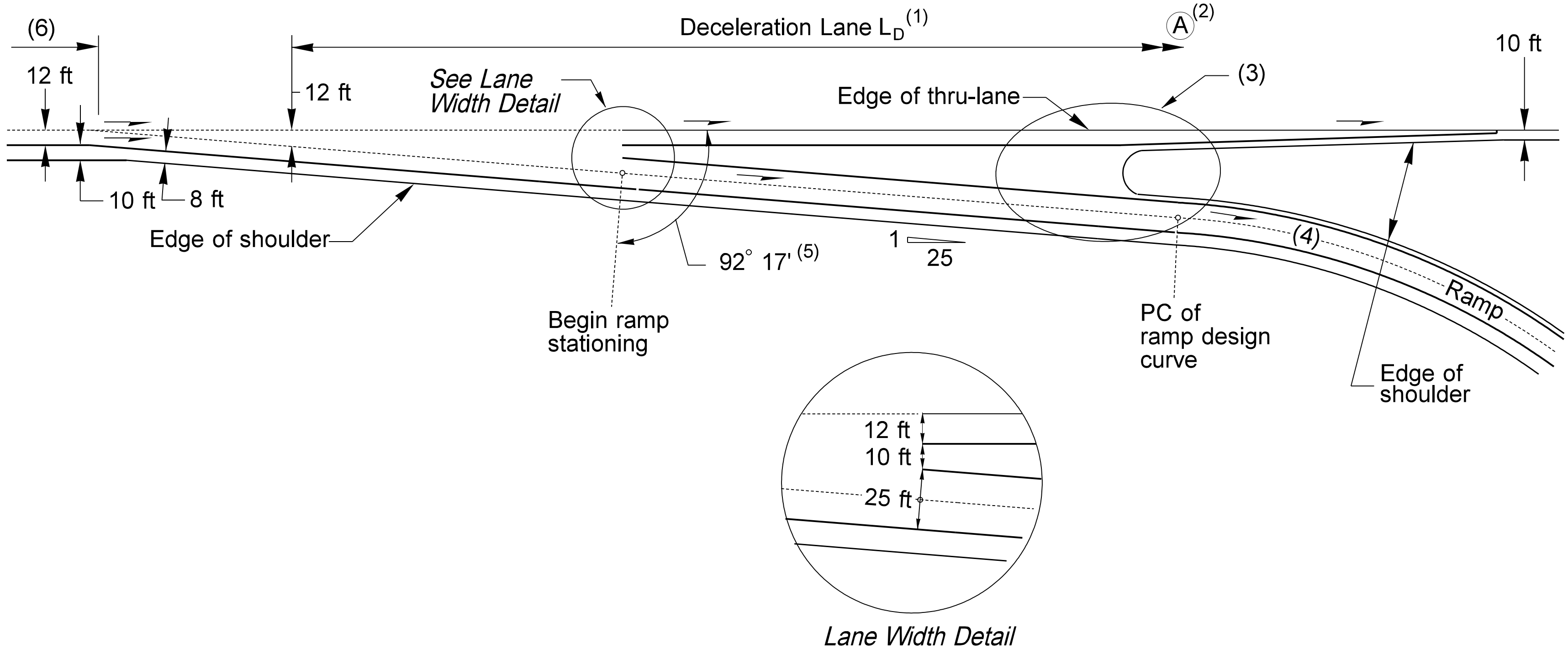
(5) Approximate angle to establish ramp alignment.

(6) Auxiliary lane between closely spaced interchanges to be dropped.

(7) For striping, see the Standard Plans.

Off-Connection (Single-Lane, One-Lane Reduction)

Figure 940-12c



Notes:

(1) See Figure 940-10 for deceleration lane length L_D.

(2) Point (A) is the point controlling the ramp design speed.

(3) See Figure 940-11b for gore details.

(4) For ramp lane and shoulder widths, see Figure 940-3.

(5) Approximate angle to establish ramp alignment.

(6) Lane to be dropped or auxiliary lane with a minimum length of 1,500 ft with a 300 ft taper.

(7) For striping, see the Standard Plans.

Off-Connection (Two-Lane, Taper Type)
Figure 940-12d

Chapter 1050 High Occupancy Vehicle Facilities

1050.01 General

High occupancy vehicle (HOV) facilities include separate HOV roadways, HOV lanes, transit lanes, HOV direct access ramps, and flyer stops. The objectives for the HOV facilities are:

- Improve the capability of corridors to move more people by increasing the number of people per vehicle.
- Provide travel time savings and a more reliable trip time to HOV lane users.
- Provide safe travel options for HOVs without adversely affecting the safety of the general-purpose lanes.

Plan, design, and construct HOV facilities that ensure intermodal linkages. Give consideration to future highway system capacity needs. Whenever possible, design HOV lanes so that the level of service for the general-purpose lanes will not be degraded.

In urban corridors that do not currently have planned or existing HOV lanes, complete an analysis of the need for HOV lanes before proceeding with any projects for additional general-purpose lanes. In corridors where both HOV and general-purpose facilities are planned, construct the HOV lane before or simultaneously with the construction of new general-purpose lanes.

See the following chapters for additional information:

Chapter	Subject
430	general-purpose roadway widths for modified design level
440	general-purpose roadway widths for full design level
640	other cross section data
641	general-purpose turning roadway widths

1050.02 References

Revised Code of Washington (RCW) 46.61.165, High-occupancy vehicle lanes

RCW 47.52.025, Additional powers — Controlling use of limited access facilities — High-occupancy vehicle lanes

Washington Administrative Code (WAC) 468-510-010, High occupancy vehicles (HOVs)

Standard Plans for Road, Bridge, and Municipal Construction (Standard Plans), M 21-01, Washington State Department of Transportation (WSDOT)

HOV Direct Access Design Guide, Draft, M 22-98, WSDOT

Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD), 2000, U.S. Department of Transportation, Federal Highway Administration; including the *Washington State Modifications to the MUTCD*, M 24-01, WSDOT

Traffic Manual, M 51-02, WSDOT

Guide for the Design of High Occupancy Vehicle Facilities, American Association of State Highway and Transportation Officials (AASHTO)

Design Features of High Occupancy Vehicle Lanes, Institute of Traffic Engineers (ITE)

High-Occupancy Vehicle Facilities: Parsons Brinkerhoff, Inc.

NCHRP Report 414, *HOV Systems Manual*

1050.03 Definitions

buffer-separated HOV lane An HOV lane that is separated from the adjacent same direction general-purpose freeway lanes by a designated buffer.

bus rapid transit (BRT) An express rubber tired transit system operating predominantly in roadway managed lanes. It is generally characterized by separate roadway or buffer-separated HOV lanes, HOV direct access ramps, and a high occupancy designation (3+ or higher).

business access transit (BAT) lanes A transit lane that allows use by other vehicles to access abutting businesses.

enforcement area A place where vehicles may be stopped for ticketing by law enforcement. It also may be used as an observation point and for emergency refuge.

enforcement observation point A place where a law enforcement officer may park and observe traffic.

flyer stop A transit stop inside the limited access boundaries.

high occupancy toll (HOT) lane A managed lane that combines a high occupancy vehicle lane and a toll lane.

high occupancy vehicle (HOV) A vehicle that fits one of the following:

(1) Rubber tired municipal transit vehicles.

(2) Buses with a carrying capacity of sixteen or more persons, including the operator.

(3) Motorcycles.

(4) Recreational vehicles that meet the occupancy requirements of the facility.

(5) All other vehicles that meet the occupancy requirements of the facility, except trucks in excess of 10,000 lb gross vehicle weight.

HOV direct access ramp An on or off ramp exclusively for the use of HOVs that provides access between a freeway HOV lane and a street, transit support facility, or another freeway HOV lane without weaving across general-purpose lanes.

HOV facility A priority treatment for HOVs.

level of service A qualitative measure describing operational conditions within a traffic stream, incorporating factors of speed and travel time, freedom to maneuver, traffic interruptions, comfort and convenience, and safety.

managed lane A lane that increases efficiency by packaging various operational and design actions. Lane management operations may be adjusted at any time to better match regional goals.

nonseparated HOV lane An HOV lane that is adjacent to and operates in the same direction as the general-purpose lanes with unrestricted access between the HOV lane and the general-purpose lanes.

occupancy designation The minimum number of occupants required for a vehicle to use the HOV facility.

separated HOV facility An HOV roadway that is physically separated from adjacent general-purpose lanes by a barrier, median, or on a separate right of way.

single occupant vehicle (SOV) Any motor vehicle other than a motorcycle carrying one occupant.

transit lane A lane for the exclusive use of transit vehicles.

violation rate The total number of violators divided by the total number of vehicles on an HOV facility.

1050.04 Preliminary Design and Planning

(1) Planning Elements for Design

In order to determine the appropriate design options for an HOV facility, the travel demand and capacity must first be established; identify suitable corridors, evaluate the HOV facility location and length, and estimate the HOV demand. A viable HOV facility will satisfy the following criteria:

- Be part of an overall transportation plan.
- Have the support of the community and public.

(b) **Nonseparated Freeway HOV Lanes.** For both inside and outside HOV lanes, the minimum lane width is 12 ft and the minimum shoulder width is 10 ft. (See Figure 1050-2.)

When a left shoulder less than 10 ft wide is proposed for distances exceeding 1.5 mi, enforcement and observation areas must be provided at 1- to 2-mi intervals. See 1050.06(7).

Where left shoulders less than 8 ft wide are proposed for lengths of roadway exceeding 0.5 mi, safety refuge areas must be provided at 0.5- to 1-mi intervals. These can be in addition to or in conjunction with the enforcement areas.

Allow general-purpose traffic to cross HOV lanes at on-and off-ramps.

(c) **Buffer-Separated HOV lanes.** Design buffer-separated HOV lanes the same as for inside nonseparated HOV lanes, except for a buffer 2 to 4 ft in width or 10 ft or greater in width with pavement marking, with supplemental signing, to restrict crossing. For buffer-separated HOV lanes with a buffer at least 4 ft wide, the left shoulder may be reduced to 8 ft. Buffer widths between 4 and 10 ft are not desirable since they may be used as a refuge area for which the width is not adequate. Provide gaps in the buffer to allow access to the HOV lane.

(d) **Arterial Street HOV Lanes.** The minimum width for an arterial street HOV lane is 12 ft. Allow general-purpose traffic to cross the HOV lanes to turn at intersections and to access driveways. (See Figure 1050-2.)

For right side HOV lanes adjacent to curbs, provide a 4 ft shoulder between the HOV lane and the face of curb. The shoulder may be reduced to 2 ft with justification.

For HOV lanes on the left, a 1 ft left shoulder between the HOV lane and the face of curb is required. When concrete barrier is adjacent to the HOV lane, the minimum shoulder is 2 ft.

(e) **HOV Ramp Meter Bypass.** The HOV bypass may be created by widening an existing ramp, construction of a new ramp where right of way is available, or reallocation of the existing pavement width provided the shoulders are full depth.

Ramp meter bypass lanes may be located on the left or right of metered lanes. Typically, bypass lanes are located on the left side of the ramp. Consult with local transit agencies and the region's Traffic Office for direction on which side to place the HOV bypass.

Consider the existing conditions at each location when designing a ramp meter bypass. Design a single lane ramp with a single metered lane and an HOV bypass as shown on Figure 1050-4a. Make the total width of the metered and bypass lanes equal to a 2-lane ramp (Chapters 641 and 940). Design a ramp with two metered lanes and an HOV bypass as shown on Figure 1050-4b. Make the width of the two metered lanes equal to a 2-lane ramp (Chapters 641 and 940) and the width of the bypass lane as shown on Figure 1050-3. The design shown on Figure 1050-4b requires that the ramp operate as a single lane ramp when the meter is not in operation.

Both Figures 1050-4a and 4b show an observation point/enforcement area. Document any other enforcement area design as a design exception. One alternative (a design exception) is to provide a 10-ft outside shoulder from the stop bar to the main line.

(5) HOV Direct Access Ramps

HOV direct access ramps provide access between an HOV lane and another freeway, a local arterial street, a flyer stop, or a park and ride facility. Design HOV direct access ramps in accordance with the *HOV Direct Access Design Guide*.

(6) HOV Lane Termination

Locate the beginning and end of an HOV lane at logical points. Provide decision sight distance, signing, and pavement markings at the termination points.

The preferred method of terminating an inside HOV lane is to provide a straight through move for the HOV traffic, ending the HOV restriction and dropping a general-purpose lane on the right. However, analyze volumes for both the HOV lanes and general-purpose lanes, and the geometric conditions, to optimize the overall operational performance of the facility.

(7) Enforcement Areas

Enforcement of the inside HOV lane can be done with a minimum 10 ft inside shoulder. For continuous lengths of barrier exceeding 2 mi, a 12 ft shoulder, for the whole length of the barrier, is recommended.

For inside shoulders less than 10 ft, locate enforcement and observation areas at 1- to 2-mi intervals or based on the recommendations of the WSP. These areas can also serve as safety refuge areas for disabled vehicles. See Figures 1050-5a and 5b.

Provide observation points approximately 1300 ft before enforcement areas. They can be designed to serve both patrol cars and motorcycles or motorcycles only. Coordinate with the WSP during the design stage to provide effective placement and to ensure utilization of the observation points. Median openings give motorcycle officers the added advantage of being able to quickly respond to emergencies in the opposing lanes. (See Figure 1050-5b.) The ideal observation point places the motorcycle officer 3 ft above the HOV lane and outside the shoulder so the officer can look down into a vehicle.

Locate the enforcement area on the right side for queue bypasses and downstream from the stop bar so the officer can be an effective deterrent (Figures 1050-4a and 4b).

An optional signal status indicator for enforcement may be placed at HOV lane installations that are metered. The indicator faces the enforcement area so that a WSP officer can determine if vehicles are violating the ramp meter. The indicator allows the WSP officer to simultaneously enforce two areas, the ramp meter and the HOV lane. Consult with the WSP for use at all locations.

See the *Traffic Manual* regarding HOV metered bypasses for additional information on enforcement signal heads.

(8) Signs and Pavement Markings

(a) **Signs.** Provide post-mounted HOV preferential lane signs next to the HOV lane or overhead mounted over the HOV lane. Make the sign wording clear and precise, stating which lane is restricted, the type of HOVs allowed, and the HOV vehicle occupancy designation for that section of road. The sign size, location, and spacing are dependent upon the conditions under which the sign is used. Roadside signs can also be used to convey other HOV information such as the HERO program, carpool information telephone numbers, and violation fines. Some situations may call for the use of variable message signs.

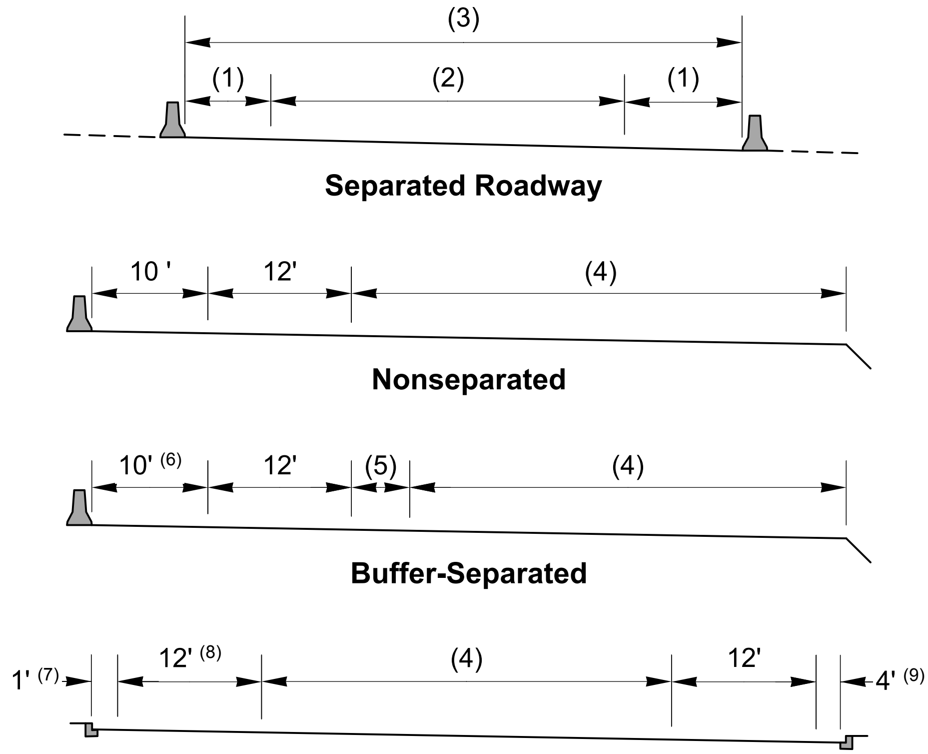
Place overhead signs directly over the HOV lane to provide maximum visibility. Use a sequence of overhead signs at the beginning and end of all freeway HOV facilities. Overhead signs can also be used in conjunction with roadside signs along the roadway.

(b) **Pavement Markings.** Provide pavement markings that conform to the *Traffic Manual* and the Standard Plans.

(c) **Interchanges.** In the vicinity of interchange on and off connections where merging or exiting traffic crosses an HOV lane, make provisions for general-purpose traffic using the HOV lane. These provisions include signing and striping that clearly show the changes in HOV versus general traffic restrictions. See the Standard Plans for pavement markings and signing.

1050.07 Documentation

A list of the documents that are to be preserved [in the Design Documentation Package (DDP) or the Project File (PF)] is on the following web site: http://www.wsdot.wa.gov/eesc/design/projectdev/



Notes:

(1) The sum of the two shoulders is 12 ft for one-lane and 14 ft for two-lane facilities. One of the shoulders must have a width of at least 10 ft for disabled vehicles. The wider shoulder may be on the left or the right as needed to best match the conditions. Maintain the wide shoulder on the same side throughout the facility. See 1050.06(4)(a)2.

(2) 12 ft minimum for single lane, 24 ft minimum for two lanes. Wider width is required on curves. See 1050.06(4)(a)1. and Figure 1050-1.

(3) For total width requirements see 1050.06(4)(a)3.

(4) Width as required for the design level, functional class, and the number of lanes.

(5) Buffer 2 to 4 ft or 10 ft or more.

(6) When buffer width is 4 ft or more, may be reduced to 8 ft.

(7) 2 ft when adjacent to concrete barrier.

(8) Arterial HOV lanes on the left operate in the same direction as the adjacent general-purpose lane.

(9) May be reduced to 2 ft with justification.

Typical HOV Lane Sections

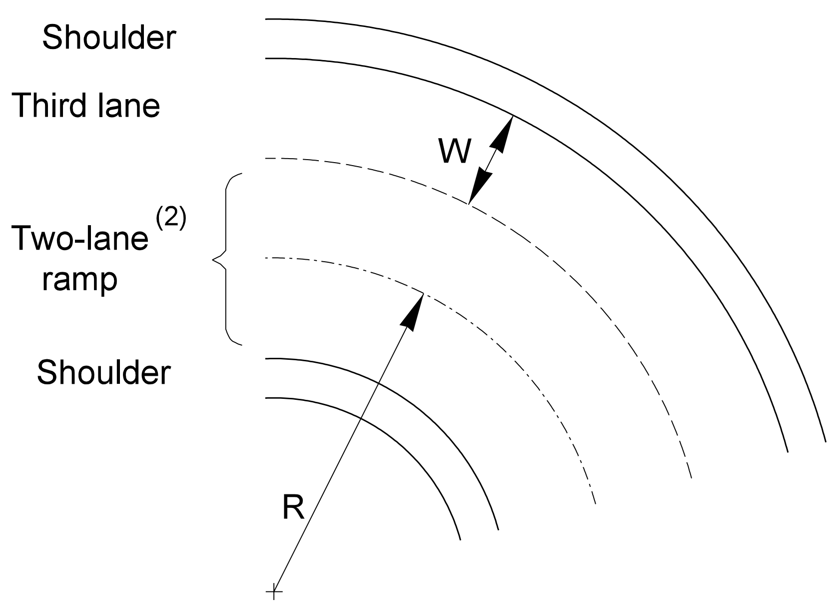
Figure 1050-2

Radius of Two-Lane Ramp R (ft)	Design Width of Third Lane(1) W (ft)
1000 to Tangent	12
999 to 500	13
499 to 250	14
249 to 200	15
199 to 150	16
149 to 100	17

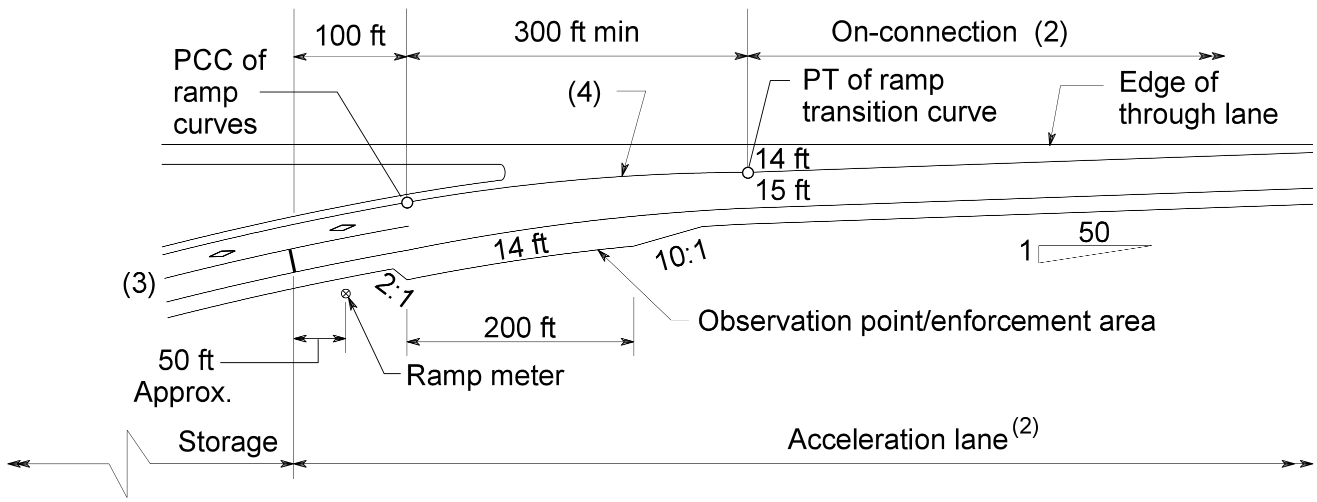
Notes:

(1) Apply additional width to 2-lane ramp widths.

(2) See traveled way width for two-lane one-way turning roadways in Chapter 641 for turning roadway widths.



Roadway Widths for Two-Lane Ramps with an HOV Lane
Figure 1050-3



Notes:

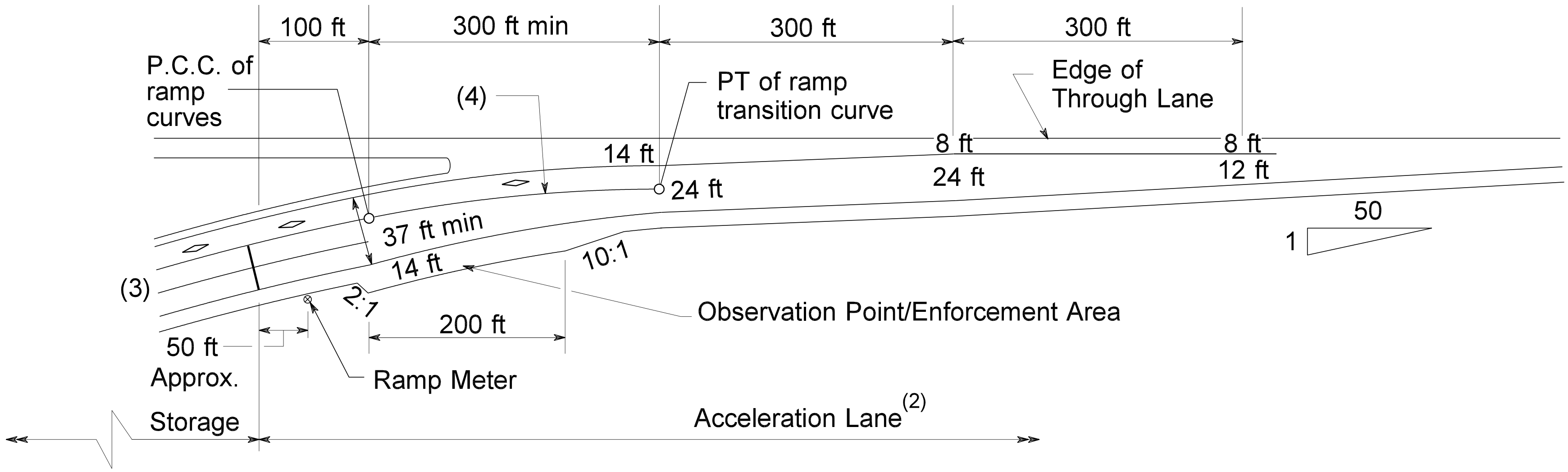
(1) See Standard Plans for striping details.

(2) See Chapter 940 for on-connection details and for acceleration lane length.

(3) See Chapters 940 & 641 for ramp lane and shoulder widths for a 2-lane ramp.

(4) A transition curve with a minimum radius of 3,000 ft is desirable. The minimum length is 300 ft. When the main line is on a curve to the left, the transition may vary from a 3,000 ft radius to tangent to the main line.

Single-Lane Ramp Meter With HOV Bypass
Figure 1050-4a



NOTES

(1) See Standard Plans for Striping Details.

(2) See Chapter 940 for acceleration lane length.

(3) See Chapters 940 & 641 for 2-lane ramp lane and shoulder widths. See Figure 1050-3 for 3rd lane width.

(4) A transition curve with a minimum radius of 3,000 ft is desirable. The minimum length is 300 ft. When the main line is on a curve to the left, the transition may vary from a 3,000 ft radius to tangent to the main line.

Two-Lane Ramp Meter With HOV Bypass
Figure 1050-4b

Chapter 1120 Bridges

1120.01 General

A bridge is a structure having a clear span of 20 ft or more. Bridge design is the responsibility of the Bridge and Structures Office in Olympia. A project file is required for all bridge construction projects. The Bridge Office develops a preliminary bridge plan for a new or modified structure in collaboration with the region. This chapter provides basic design considerations for the development of this plan. Unique staging requirements, constructibility issues, and other considerations are addressed during the development of this plan. Contact the Bridge Office early in the planning stage on issues that might affect the planned project. See Chapter 141, Roles and Responsibilities for Projects with Structures, and Figures 141-1a and 1b, Determination of the Roles and Responsibilities for Projects with Structures (Project Development Phase).

1120.02 References

Bridge Design Manual, M 23-50, WSDOT

Local Agency Guidelines, M 36-63, WSDOT

Manual on Uniform Traffic Control Devices for Streets and Highways USDOT, Washington DC, including the *Washington State Modifications to the MUTCD*, WSDOT (MUTCD) http://www.wsdot.wa.gov/biz/trafficoperations/mutcd.htm

LRFD Bridge Design Specifications, third edition, Washington D.C.: AASHTO 2004

A Policy on Geometric Design of Highways and Streets (Green Book), 2001, AASHTO

Traffic Manual, M 51-02, WSDOT

1120.03 Bridge Location

Bridges are located to conform to the alignment of the highway. Providing the following conditions can simplify design efforts, minimize construction activities, and reduce structure costs:

- A perpendicular crossing.
- The minimum required horizontal and vertical clearances.
- A constant bridge width (without tapered sections).
- A tangential approach alignment of sufficient length to not require superelevation on the bridge.
- A crest vertical curve profile that will facilitate drainage.
- An adequate construction staging area.

1120.04 Bridge Site Design Elements

(1) Structural Capacity

The structural capacity of a bridge is a measure of the structure's ability to carry vehicle loads. For new bridges, the bridge designer chooses the design load that determines the structural capacity. For existing bridges, the structural capacity is calculated to determine the "load rating" of the bridge. The load rating is used to determine whether or not a bridge is "posted" for legal weight vehicles or if the bridge is "restricted" for overweight permit vehicles.

(a) **New Structures.** All new structures that carry vehicular loads are designed to HL-93 notional live load in accordance with AASHTO LRFD Bridge Design Specifications or HS-25 live loading in accordance with the AASHTO Standard Specifications for Highway Bridges.

(b) **Existing Structures.** When the Structural Capacity column of a design matrix applies to the project, request a Structural Capacity Report from the Risk Reduction Engineer in the HQ Bridge and Structures Office. The report will state:

- The structural capacity status of the structures within the project limits.
- What action, if any, is appropriate.
- Whether a deficient bridge is included in the six-year or 20 year plans for replacement or rehabilitation under the P2 program and, if so, in which biennium the P2 project is likely to be funded.

Include the Structural Capacity Report in the design documentation file.

The considerations used to evaluate the structural capacity of a bridge are as follows:

1. On National Highway System (NHS) routes (including Interstate routes):

- Operating load rating is at least 36 tons (which is equal to HS-20).
- The bridge is not permanently posted for legal weight vehicles.
- The bridge is not permanently restricted for vehicles requiring overweight permits.

2. On non-NHS routes:

- The bridge is not permanently posted for legal weight vehicles.
- The bridge is not permanently restricted for vehicles requiring overweight permits.

(2) Bridge Widths for Structures

(a) **New Structures.** Full design level widths are provided on all new structures. See Chapter 440. All structures on city or county routes crossing over a state highway must conform to the *Local Agency Guidelines*. Use local city or county adopted and applied criteria when their minimums exceed state criteria.

(b) **Existing Structures.** See the design matrices in Chapter 325 for guidance.

(3) Horizontal Clearance

Horizontal clearance for structures is the distance from the edge of the traveled way to bridge piers and abutments, bridge rail ends, or bridge end embankment slopes. Minimum distances for this clearance vary depending on the type of structure. The *Bridge Design Manual* provides guidance on horizontal clearance.

(4) Medians

For multilane highways, the minimum median widths for new bridges are as shown in Chapters 430 and 440. An open area between two bridges is undesirable when the two roadways are separated by a median width of 26 ft or less. The preferred treatment is to provide a new, single structure that spans the area between the roadways. When this is impractical, consider widening the two bridges on the median sides to reduce the open area to 6 in. When neither option is practical, consider installing netting or other elements to enclose the area between the bridges. Consideration and analysis of all site factors are necessary if installation of netting or other elements is proposed. Document this evaluation in the design documentation file and obtain the approval of the State Design Engineer.

(5) Vertical Clearance

Vertical clearance is the critical height under a structure that will safely accommodate vehicular and rail traffic based on its design characteristics. This height is the least height available from the lower roadway surface (including usable shoulders), or the plane of the top of the rails, to the bottom of the bridge. Usable shoulders are the design shoulders for the roadway and do not include paved widened areas that may exist under the structure.

(a) **Minimum Clearance for New Structures.** For new structures, the minimum vertical clearances are as follows:

1. A bridge over a roadway. The minimum vertical clearance is 16.5 ft.

2. A bridge over a railroad track. The minimum vertical clearance is 23.5 ft. A lesser clearance may be considered for closed or dedicated rail corridors that do not intermix with general freight rail traffic. Any such reduced clearance established for a corridor requires an agreement between the department and the railroad company and approval of the Washington State Utilities and Transportation Commission (WUTC). Vertical clearance is provided for the width of the railroad freight car. (See Figure 1120-2a.) Coordinate railroad clearance issues with the WSDOT Railroad Liaison Engineer.

3. A pedestrian bridge over a roadway. The minimum vertical clearance is 17.5 ft.

(b) **Minimum Clearance for Existing Structures.** The criteria used to evaluate the vertical clearance of existing structures depends on the work that is being done on or under that structure. When evaluating an existing structure on the Interstate system, see 1120.04(5)(d) "Coordination." This guidance applies to bridge clearances over state highways and under state highways at interchanges. For state highways over local roads and streets, city or county vertical clearance requirements may be used as minimum design criteria. See Figure 1120-1 for a table of bridge vertical clearances.

1. For a project that will widen an existing structure over a highway or where the highway will be widened under an existing structure, the vertical clearance can be as little as 16.0 ft on the Interstate System or other freeways, or 15.5 ft on nonfreeway routes. An approved deviation is required for clearance less than 16.0 ft on Interstate routes or other freeways, and 15.5 ft on nonfreeway routes.

2. For a planned resurfacing of the highway under an existing bridge, if the clearance will be less than 16.0 ft on the Interstate System or other freeways and 15.5 ft on nonfreeway routes, evaluate the following options and include in a deviation request:

   - Pavement removal and replacement.
   - Roadway excavation and reconstruction to lower the profile of the roadway.
   - Providing a new bridge with the required vertical clearance.

   Reducing roadway paving and surfacing thickness under the bridge to achieve the minimum vertical clearance can cause accelerated deterioration of the highway and is not recommended. Elimination of the planned resurfacing in the immediate area of the bridge might be a short term solution if recommended by the region's Materials Engineer. Solutions that include milling the existing surface followed by overlay or inlay must be approved by the region's Materials Engineer to ensure that adequate pavement structure is provided.

3. For other projects that include an existing bridge where no widening is proposed on or under the bridge, and the project does not affect vertical clearance, the clearance can be as little as 14.5 ft. For these projects, document the clearance to the design documentation file. <u>For an existing bridge with less than 14.5 ft vertical clearance in this situation, an approved deviation request is required.</u>

4. For an existing structure over a railroad track, the vertical clearance can be as little as 22.5 ft. (See Figure 1120-2b.) A lesser clearance can be used with the agreement of the railroad company and <u>approval of</u> the Washington State Utilities and Transportation Commission. Coordinate railroad clearance issues with the WSDOT Railroad Liaison Engineer.

(c) **Signing.** Low clearance warning signs are necessary when the vertical clearance of an existing bridge is less than 15 ft 3 in. Other requirements for low clearance signing are contained in the *Manual on Uniform Traffic Control Devices* and the *Traffic Manual*.

(d) **Coordination.** The Interstate system is used by the Department of Defense (DOD) for the conveyance of military traffic. The Military Traffic Management Command Transportation Engineering Agency (MTMCTEA) represents the DOD in public highway matters. The MTMCTEA has an inventory of vertical clearance deficiencies over the Interstate system in Washington State. Contact the MTMCTEA, through FHWA, if any of the following changes are proposed to these bridges:

- A project would create a new deficiency of less than 16.0 ft vertical clearance over an Interstate highway.
- The vertical clearance over the Interstate is already deficient (less than 16.0 ft) and a change (increase or decrease) to vertical clearance is proposed.

Coordination with MTMCTEA is required for these changes on all rural Interstate highways and for one Interstate route through each urban area.

Project Type	Vertical Clearance	Documentation Requirement (see notes)
Interstate and Other Freeways [1]		
New Bridge	> 16.5 ft	2
Widening Over or	> 16 ft	2
Under Existing Bridge	< 16 ft	4
Resurfacing Under	> 16 ft	2
Existing Bridge	< 16 ft	4
Other with No Change	>14.5	3
to Vertical Clearance	<14.5	4
Nonfreeway Routes		
New Bridge	>16.5 ft	2
Widening Over or	>15.5 ft	2
Under Existing Bridge	<15.5 ft	4
Resurfacing Under	>15.5 ft	2
Existing Bridge	<15.5 ft	4
Other with No Change	> 14.5 ft	3
to Vertical Clearance	< 14.5 ft	4
Bridge Over Railroad Tracks [7]		
New Bridge	> 23.5 ft <u>≤23.5 ft</u>	2 <u>4, 5</u>
Existing Bridge	> 22.5 ft < 22.5 ft	2 4, 5
Pedestrian Bridge Over Roadway		
New Bridge	> 17.5 ft	2
Existing Bridge		6

Notes:
1. Applies to all bridge vertical clearances over highways and under highways at interchanges
2. No documentation required
3. Document to design documentation file
4. Approved deviation required
5. Requires written agreement between railroad company and <u>the department and the approval via petition from the</u> Washington State Utilities and Transportation Commission
6. Use the same criteria as other existing bridges previously listed in the figure
7. See Figure 1120-2a and 2b

Bridge Vertical Clearances
Figure 1120-1

<u>(6)</u> Pedestrian and Bicycle Facilities

When pedestrians or bicyclists are anticipated on bridges, provide facilities consistent with guidance in Chapters 1020 and 1025.

<u>(7)</u> Bridge Approach Slab

Bridge approach slabs are reinforced concrete pavement installed across the full width of the bridge ends. They provide a stable transition from normal roadway cross section to the bridge ends and compensate for differential expansion and contraction of the bridge and the roadway. Bridge approach slabs are provided on all new bridges. If an existing bridge is being widened and it has an approach slab, slabs are required on the widenings. The region, with the concurrence of the State Geotechnical Engineer and the State Bridge Engineer, may decide to omit bridge approach slabs.

(8) Bridge Rail End Treatment

Plans for new bridge construction and bridge rail modifications include provisions for the connection of traffic barriers to the bridge rail. Indicate the preferred traffic barrier type and connection during the review of the bridge preliminary plan.

(9) <u>Bridge End Embankments</u>

The design of the embankment slopes at bridge ends depends on several factors. The width of the embankment is determined not only by the width of the roadway but also by the presence of traffic barriers, curbs, and sidewalks, all of which create the need for additional widening. Examples of the additional widening required for these conditions are shown in the Standard Plans.

The end slope is determined by combining the recommendations of several technical experts within the department. Figure 1120-3 illustrates the factors taken into consideration and the experts who are involved in the process.

(10) Bridge Slope Protection

Slope protection provides a protective and aesthetic surface for exposed slopes under bridges. Slope protection is normally provided under:

- Structures over state highways.
- Structures within an interchange.
- Structures over other public roads unless requested otherwise by the public agency.
- Railroad overcrossings, if requested by the railroad.

Slope protection is usually not provided under pedestrian structures. The type of slope protection is selected at the bridge preliminary plan stage. Typical slope protection types are concrete slope protection, semi-open concrete masonry, and rubble stone.

(11) Slope Protection at Watercrossings

The WSDOT Headquarters (HQ) Hydraulics Branch determines the slope protection requirements for structures that cross waterways. The type, limits, and quantity of the slope protection are shown on the bridge preliminary plan.

(12) Protective Screening for Highway Structures

The Washington State Patrol classifies the throwing of an object from a highway structure as an assault, not an accident. Therefore, records of these assaults are not contained in the Patrol's accident databases. Contact the region's Maintenance Engineer's office and the Washington State Patrol for the history of reported incidents.

Protective screening might reduce the number of incidents but will not stop a determined individual. Enforcement provides the most effective deterrent.

Installation of protective screening is analyzed on a case-by-case basis at the following locations:

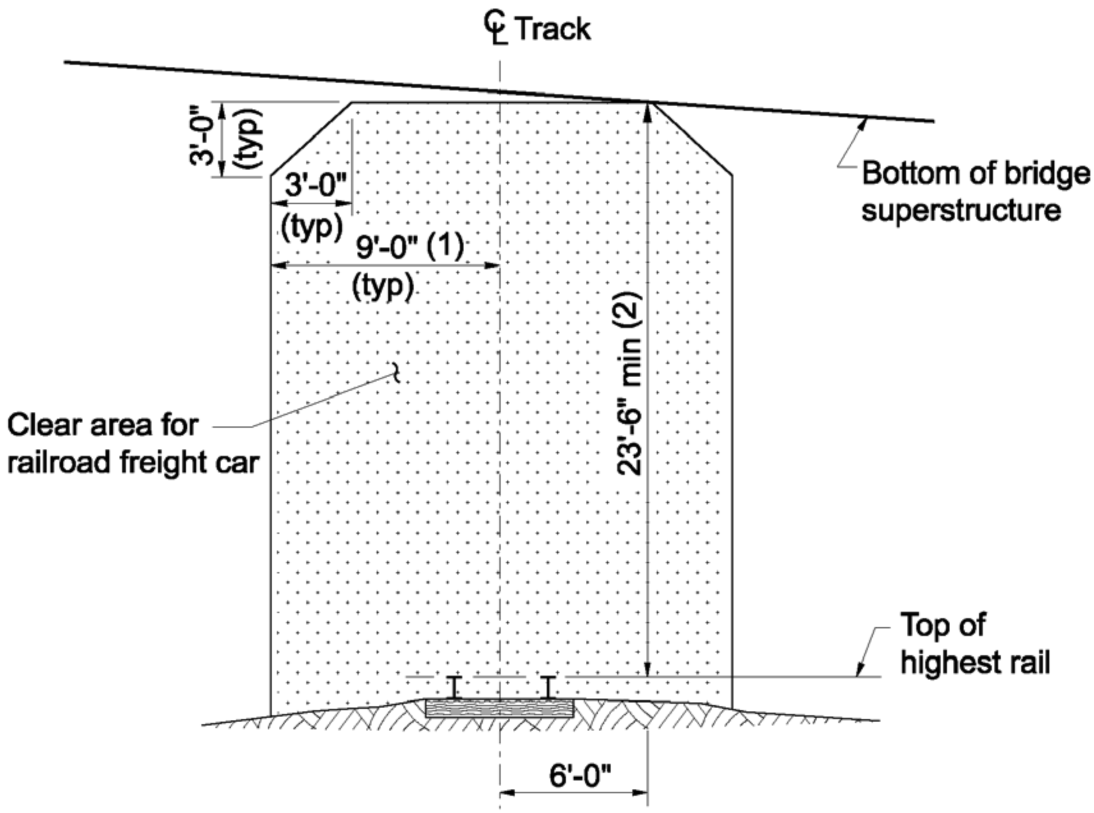
- On existing structures where there is a history of multiple incidents of objects being dropped or thrown and enforcement has not changed the situation.
- On a new structure near a school, a playground, or where frequently used by children not accompanied by adults.
- In urban areas, on a new structure used by pedestrians where surveillance by local law enforcement personnel is not likely.
- On new structures with walkways where experience on similar structures within a 1 mile radius indicates a need.
- On structures over private property that is subject to damage, such as buildings or power stations.

In most cases, the installation of a protective screen on a new structure can be postponed until there are indications of need.

Submit all proposals to install protective screening on structures to the State Design Engineer for approval. Contact the Bridge and Structures Office for approval to attach screening to structures and for specific design and mounting details.

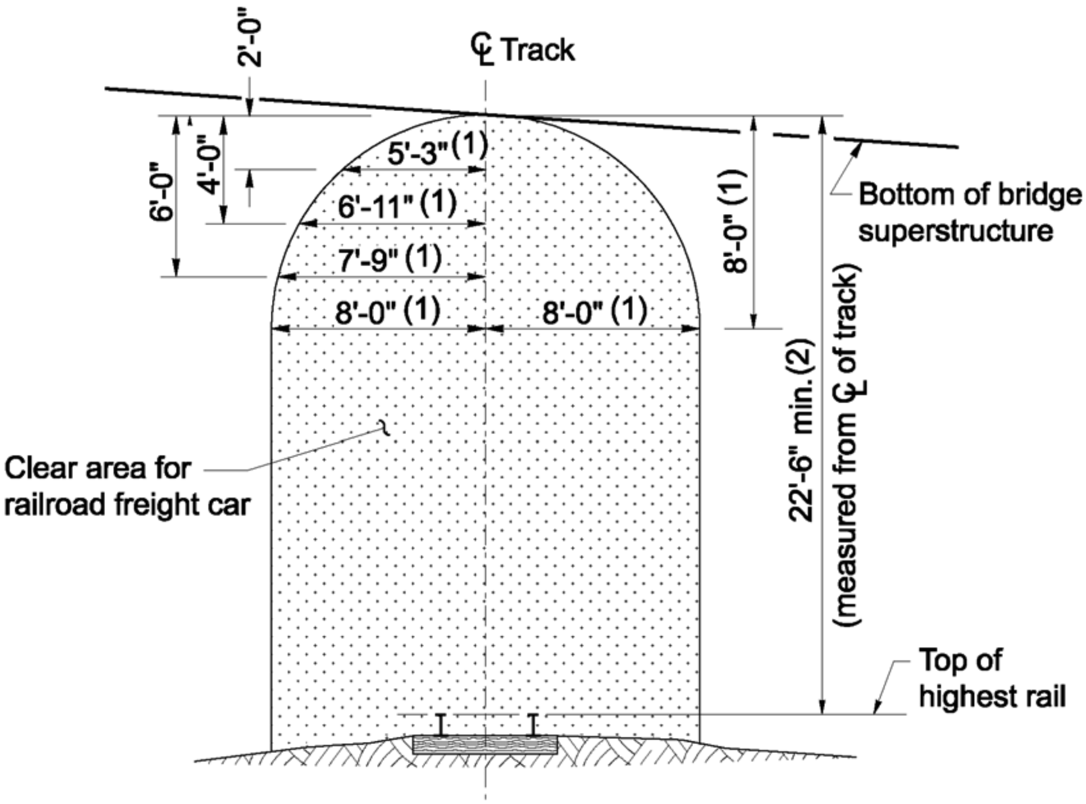
1120.05 Documentation

A list of documents that are to be preserved [in the Design Documentation Package (DDP) or the Project File (PF)] is on the following website: http://www.wa.gov/eesc/design/projectdev/



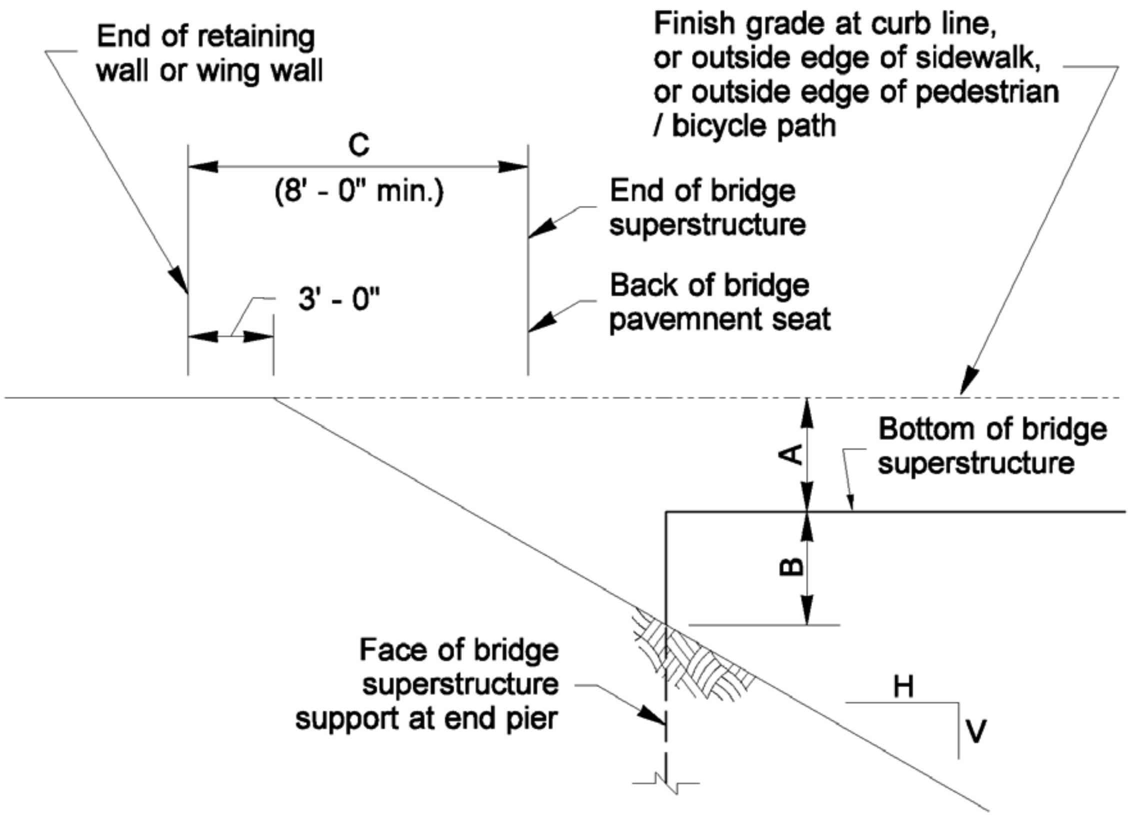
(1) Increase 1.5” for each degree of railroad alignment curve.
(2) Minimum clearances less than 23’-6” may be considered for closed or dedicated rail corridors, that do not intermix with general purpose freight rail traffic. Any such reduced clearance established for a corridor, must be approved by the railroad company and the WUTC.

Railroad Vertical Clearance for New Bridge Construction
Figure 1120-2a



(1) Increase 1.5” for each degree of railroad alignment curve.
(2) Minimum clearances less than 22’-6” may be considered for closed or dedicated rail corridors, that do not intermix with general purpose freight rail traffic. Any such reduced clearance established for a corridor, must be approved by the railroad company and the WUTC.

Railroad Vertical Clearance for Existing Bridge Modifications
Figure 1120-2b



BRIDGE END ELEVATION

Applies with retaining wall or wing wall (or combination) extending beyond bridge superstructure (barrier omitted for clarity)

LEGEND

A = Superstructure depth: Recommended by Bridge Design Office
B = Vertical clearance from bottom of superstructure to embankment: Recommended by Bridge Preservation Engineer
C = Distance from the end of retaining wall or wing wall to back of pavement seat: Recommended by Bridge Design Office
H & V = Embankment slope: Recommended by Geotechnical Engineer

Embankment Slope at Bridge Ends
Figure 1120-3

1300.01 General

It is WSDOT policy to employ roadside treatments for the protection and restoration of community and roadside character as designated in the *Roadside Classification Plan* (RCP) and described in the *Roadside Manual*. WSDOT is committed to community-based context sensitive design, which is reflected in the Context Sensitive Solutions Executive Order (E 1028.00) and the 2003-2022 Washington Transportation Plan (WTP).

Whenever a project disturbs, or adds elements to, the roadside, the project is responsible for restoring roadside functions. This includes contour grading, visual elements (such as walls, lighting, signs, and bridges), pedestrian movement, vegetation, and stormwater treatment. The extent of restoration is dependent upon the source of funding. Figure 1300-1 and the following paragraph summarize the guidance found in the *Roadside Classification Plan*.

Funding	Restore Roadside Functions Beginning to End of Project R/W Line to R/W Line	Restore Only Roadside Functions That are Impacted by the Project
Mobility (I1) Economic Development (I3)	√	
Safety Improvement (I2) Environmental Retrofit (I4) Preservation (P)		√

Funding Source Determines Extent of Restoration
Figure 1300-1

For Mobility (I1) and Economic Development (I3) programs, the project is responsible for restoring the entire roadside from right of way line to right of way line and from beginning to end of project using the guidelines found in the RCP. For Preservation (P), Safety Improvement (I2), and Environmental Retrofit Program (I4) projects, the project is responsible for restoring roadside functions that are disturbed by the project, using the guidelines found in the RCP.

The *roadside* is the area outside the traveled way. This applies to all lands managed by WSDOT and may extend to elements outside the right of way boundaries. This includes unpaved median strips and auxiliary facilities such as rest areas, roadside parks, viewpoints, heritage markers, pedestrian and bicycle facilities, wetlands and their associated buffer areas, stormwater treatment facilities, park and ride lots, and quarries and pit sites.

The roadside is managed to fulfill operational, environmental, visual, and auxiliary functions. In reality, these functions are interrelated and inseparable. One element, such as vegetation, can provide multiple functions simultaneously. For example, vegetation provides erosion prevention and sediment control, stormwater quality and quantity control, may provide distraction screening, and may provide screening of the road from the view of adjacent residents. Roadside functions are described in detail in the *Roadside Manual,* (M 25-30).

The design of a roadside project incorporates site conditions, commitments, and the extent of need. Roadside development concepts covered elsewhere in the *Design Manual* are:

- Contour grading (Chapter 1310)
- Fencing (Chapter 1460)
- Irrigation (Chapter 1330)
- Jurisdiction (Chapters 325, 330, 700)
- Noise barriers (Chapter 1140)
- Retaining walls (Chapter 1130)

- Roadside safety (Chapter 700)
- Safety rest areas, roadside parks, view-points, and historical markers (Chapter 1030)
- Signs (Chapter 820)
- Traffic barriers (Chapter 710)
- Utilities (*Utilities Manual* and *Utilities Accommodation Policy*)
- Vegetation (Chapter 1320)

1300.02 References

Roadside Design Guide, AASHTO

Roadside Classification Plan, M 25-31, WSDOT

Roadside Manual, M 25-30, WSDOT

Utilities Accommodation Policy, M 22-86, WSDOT

Utilities Manual, M 22-87, WSDOT

Maintenance Manual, M 51-01, WSDOT

Understanding Flexibility in Transportation Design – Washington, WSDOT (Dec 2004)

1300.03 Legal Requirements

The following paragraphs represent a partial list of legal requirements relating to roadside work. Further laws, regulations, and policies can be found in the *Roadside Manual*, Section 200.

Washington Administrative Code (WAC) 173-270-040 requires the department to establish and maintain stable plant communities that resist encroachment by undesirable plants, noxious weeds, and other pests. It also requires a vegetation management plan that includes operational, aesthetic, and environmental standards. http://www.leg.wa.gov/wac/index.cfm?fuseaction=Section&Section=173-270-040

WAC 468-34-340 requires utilities to repair or replace unnecessarily removed or disfigured trees and shrubs, and specifies vegetation management practices when utilities use highway right of way. http://www.leg.wa.gov/wac/index.cfm?fuseaction=Section&Section=468-34-340

Revised Code of Washington (RCW) 47.40.010 states that planting and cultivating of any shrubs, trees, hedges or other domestic or native ornamental growth, the improvement of roadside facilities and view points, and the correction of unsightly conditions upon the right of way of any state highway is declared to be a proper state highway purpose.

RCW 47.40.020 authorizes the department to expend funds for this purpose. http://www.leg.wa.gov/RCW/index.cfm?fuseaction=chapterdigest&chapter=47.40

RCW 47.40.040 requires screening or removal of junkyards, located outside a zoned industrial area and within 1000 feet of the nearest edge of the right of way, so they are not visible from the traveled way. The department is authorized to acquire land for the purposes of screening these junkyards. http://www.leg.wa.gov/RCW/index.cfm?section=47.41.040&fuseaction=section

Code of Federal Regulation (CFR) 23 CFR 752 "Highway Beautification Act" furnishes guidelines and prescribes policies regarding landscaping and scenic enhancement programs, safety rest areas, scenic overlooks, and information centers. Policy statement (a) states "highway esthetics is a most important consideration in the Federal aid highway program. Highways must not only blend with our natural social, and cultural environment, but also provide pleasure and satisfaction in their use." http://frwebgate6.access.gpo.gov/cgi-bin/waisgate.cgi?WAISdocID=44327678878+12+0+0&WAISaction=retrieve

United States Code 23 USC 319, On Federal-aid highways, the costs of landscape and roadside development, including acquisition and development of rest areas and land necessary for the restoration, preservation, and enhancement of scenic beauty adjacent to such highways is authorized. http://uscode.house.gov/uscode-cgi/fastweb.exe?search

For any work in, or near wetlands, **Section 404 of the Clean Water Act** may apply. The act requires a permit to discharge dredged or fill materials into most waters of the United States, including wetlands. The Section 404 permitting process requires advanced planning and coordination with the permitting agency: the U.S. Army Corps of Engineers. Work with the regional environmental office for guidance on the 404 permit.

The *Roadside Classification Plan* and the *Roadside Manual* provide policy and guidance for the manner in which WSDOT implements these laws.

1300.04 *Roadside Classification Plan*

The *Roadside Classification Plan* (M25-31) coordinates and guides the management of Washington State highway roadsides within a framework of roadside character classifications. It provides policy and criteria for roadside restoration and advocates the use of native plants, integrated vegetation management (IVM), and a long-term management approach to achieve sustainable roadsides.

1300.05 *Roadside Manual*

The *Roadside Manual* establishes a common basis for consistent roadside management decisions statewide. It shows the links and coordination necessary between all WSDOT partners responsible for roadside activities.

It also establishes a convenient and accessible reference for new and previously unpublished material related to roadside management including planning, design, construction, and maintenance. In addition, the manual supplements statewide roadside criteria established in the *Roadside Classification Plan*.

A partial example of information to be found in the *Roadside Manual* includes:

- Federal, state, and departmental roadside law and policy.
- Americans with Disabilities Act.
- Safety Rest Areas and Scenic Byways.
- Roadside treatments such as erosion control, landform grading, soil bioengineering, wetland mitigation, and vegetation restoration.

See the *Roadside Manual* table of contents for more information on chapters in the manual.

1300.06 Project Development

The region's Landscape Architect designs, supervises, has approval authority of, and stamps roadside restoration and revegetation plans, and is responsible for coordinating the visual elements within highway corridors. The region's Landscape Architect also designs and supervises other roadside work, such as site design for park and ride lots or safety rest areas, to ensure roadside restoration is designed and constructed to WSDOT standards. The Landscape Architect is also responsible for visual discipline reports for environmental documentation. The Headquarters (HQ) Roadside & Site Development Unit will do roadside design, visual impact assessment, and construction inspection work for the project offices in regions without a Landscape Architect.

There are typically two types of roadside restoration projects pertaining to vegetation that are related to roadway construction projects. The first type is work related to regulatory requirements. This work typically must occur at the time of impact to an identified resource in order to meet permit requirements. These projects will typically be a part of the roadway construction contract. The second type of project is the restoration of construction impacts to meet WSDOT policy requirements as outlined in the RCP. It is often advisable to do this revegetation work as a separate contract because roadside restoration is done after the road construction is completed. At that time, all impacts can be identified that may be different than anticipated during the original project design, the prime contractor can be specialized in roadside work, and plant establishment periods can last between 3 and 10 years and extend the roadway contract period. The Landscape Architect typically administers this contract with funding from the project.

1300.07 Documentation

A list of the documents that are required to be preserved in the Design Documentation Package (DDP) or the Project File (PF) is on the following website: http://www.wsdot.wa.gov/eesc/design/projectdev/

1320.01 General

Roadside vegetation provides operational, environmental, and visual benefits to WSDOT roadway users. Vegetation preservation and restoration is an integral part of roadside planning and design. When a project disturbs a roadside segment, that project is responsible for meeting the requirements of the roadside classification for that road segment. This may include working outside the actual disturbed area for buffering and blending into the surrounding landscape.

Consult early in the project process with the region Landscape Architect, or the Headquarters (HQ) Roadside & Site Development Unit for regions without a Landscape Architect, for all projects involving revegetation.

1320.02 References

Roadside Classification Plan, M 25-31, WSDOT

Roadside Manual, M 25-30, WSDOT

Integrated Vegetation Management for Roadsides, WSDOT

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

State Highway System Plan (HSP)

1320.03 Discussion

Operational, Environmental and Visual Functions of Roadside Vegetation

Roadside vegetation serves various functions. Vegetation is used to:

- Prevent soil erosion.
- Enhance water quality.
- Provide for water storage and slow runoff.
- Aid in de-watering soils.
- Stabilize slopes.
- Protect or restore wetlands and sensitive areas.
- Preserve and provide habitat.
- Prevent noxious weed infestation.
- Provide positive driver cues for guidance and navigation.
- Provide for corridor continuity.
- Screen glare and distractions, and buffer view of neighboring properties from the roadway.
- Buffer view of roadway by neighboring property owners.
- Preserve scenic views.
- Reduce driver monotony.
- Provide a transition between the transportation facility and adjacent land uses.
- Provide for a pleasing roadside experience.

1320.04 Design Guidelines

(1) General

The type and extent of vegetation will vary depending on the roadside character classification of the road segment, the approved treatment level of the project, the affected roadside management zone, and the planting environment. Select and maintain vegetation so that it does not present a hazard or restrict sight distances of drivers to other vehicles and to signs.

Apply the following guidelines when designing roadside revegetation projects:

- Meet the requirements of the *Roadside Classification Plan*.
- Review Corridor Master Plans and the *State Highway System Plan* for future projects and corridor goals.

- Design revegetation plans, including wetland mitigation sites and detention/retention ponds, to be sustainable over time and to require a low level of maintenance.
- Design roadside revegetation and restoration plans to reduce pesticide use.
- Select and maintain plants to achieve required clear zone, sight distance, clear sight to signing, and headlight screening.
- Evaluate the mature characteristics of plant species to meet safety requirements. Consider size and extent of vegetation at maturity for sight distance, clear zone, and shading problems.
- Preserve existing desirable vegetation and topsoil to the maximum extent reasonable.
- Select plants adaptable to the site conditions. Select native plants as the first choice, unless conditions warrant non-native species to be sustainable. (See the *Roadside Manual* for more information.)
- Consider stripping, stockpiling, and reapplying topsoil if construction will disturb topsoil. When this is not feasible, amend remaining soil to meet horticultural requirements, to reduce compaction, and to increase moisture retention.
- Consider design speeds in the selection and location of plants. For example, as traffic speed increases, include larger groupings of fewer species in the landscape since the motorist's perception of detail along the roadside diminishes.
- Accommodate existing and proposed utilities.
- When selecting vegetation, consider screening undesirable views, or consider allowing openings to reveal or maintain desirable views.
- Design roadsides, particularly areas under bridges, to reduce potential for homeless encampments. Keep clear lines of sight where this potential exists.

Roadway geometrics will also affect the type and extent of vegetation in specific locations. The maximum allowable diameter of trees within the Design Clear Zone is 4 in. measured at 6 in. above the ground when the tree has matured. Consider limiting vegetation diameters on the outside of curves beyond the Design Clear Zone to improve safety. See the *Roadside Manual* for more information.

(2) Existing Vegetation.

Avoid destruction of desirable existing vegetation, reduce impacts on desirable existing vegetation, and restore desirable damaged vegetation.

- Protect desirable existing vegetation wherever possible.
- Delineate trees that are to remain within the construction zone and provide adequate protection of the root zone (extending from the tree trunk to a minimum of 3 ft beyond the drip line).
- Encourage desirable vegetation by using revegetation techniques to prevent or preclude the establishment of undesirable vegetation. See *Integrated Vegetation Management for Roadsides.*
- Limit clearing and grubbing (especially grubbing) to the least area possible.

Selectively remove vegetation to:

- Remove dead and diseased trees when they are a hazard (including those outside the clear zone).
- Maintain clear zone and sight distance.
- Increase solar exposure and reduce accident rates, if analysis shows that removing vegetation will improve safety.
- Open up desirable views.
- Encourage understory development.
- Encourage individual tree growth.
- Prevent plant encroachment on adjacent properties.
- Ensure long-term plant viability.

Refer to Division 8 of the *Roadside Manual* for more information.

(3) Plant Material Selection.

Select noninvasive vegetation (not having the potential to spread onto roadways, ditches and adjacent lands).

Base plant material selection on:

- Functional needs of the roadside.
- Maintenance requirements.
- Site analysis and conditions expected after the facility is constructed.
- Horticultural requirements.
- Plant availability.
- Plant success rates in the field.
- Plant cost.
- Traffic speed.

The *Roadside Manual* provides more detailed guidelines on plant selection, sizing, and location.

(4) Establishment of Vegetation

Most WSDOT projects have 1 to 3-year plant establishment periods. Wetland mitigation projects often include additional years of monitoring and plant establishment to ensure that mitigation standards of success, defined in the permit conditions, are met. The goal of plant establishment is to promote a healthy, stable plant community and a project that has achieved a reasonable aerial coverage prior to WSDOT Maintenance taking over the responsibility and associated costs.

Soil treatments, for example incorporation of soil amendments such as compost into the soil layer, surface mulching, and the use of slow release fertilizer will improve the success rate of revegetation after highway construction activities have removed or disturbed the original topsoil. Woody native plants will grow faster and require less weed control through the combined use of compost and bark mulch. (Check with the local maintenance office or the local jurisdiction's comprehensive plan for any restrictions on fertilizer use, such as those in well-head protection areas or restricted watershed areas.)

- Use soil amendments based on the soil analysis done for the project. Soil testing is coordinated through the HQ Horticulturist or the Landscape Architect. Soil amendments will enhance the soil's moisture holding capacity.
- Use surface mulches to conserve soil moisture and moderate soil temperatures. Mulches also help keep weeds from competing with desirable plants for water and nutrients, and provide organic matter and nutrients to the soil.
- Permanent irrigation systems are only to be used in urban or semiurban areas where vegetation is surrounded by paved surfaces or it does not have available groundwater. Use temporary systems to establish vegetation when needed. If irrigation is required, see Chapter 1330 for design guidelines and the *Roadside Manual* for more detail.
- Weed control is necessary for plant establishment success. Include funding for weed control in the project budget to cover the full plant establishment period. The duration of this period is dependent upon plant and permit requirements.

1320.05 Documentation

A list of documents that are to be preserved in the Design Documentation Package (DDP) or the Project File (PF) is on the following website: http://www.wsdot.wa.gov/eesc/design/projectdev/

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