Part 400 Roadside Design

Section 401 Introduction

The design of the roadside environment is a critical part of any highway segment. A well-designed roadside can significantly improve the safety and operation of a particular segment. Steep slopes or obstacles should be avoided or mitigated where possible and practical. Fixed object and run off the road often account for a significant number of crashes on a segment of highway. Therefore, providing a safe roadside environment should be a goal of every project. The 2011 AASHTO "Roadside Design Guide" should be used to determine the clear zone distance and mitigation measures to use for different highway conditions. The following sections of Part 400 provide additional information and examples on proper clear zone requirements and roadside design.

As AASHTO's "Roadside Design Guide" directs, the preferred treatment of roadside obstacles is to relocate them outside of the clear zone. Only where this is not possible or cost effective, should shielding be considered. Where a barrier along a roadway is used to shield a roadside obstacle, provide a 2-foot shy distance from the normal edge of shoulder to the face of barrier. This shy distance maintains the useable shoulder width and provides some additional distance from the traveled way to the barrier.

401.1 Evaluation Criteria for Roadside Hardware

NCHRP Reports 230 and 350 - Roadside hardware crash testing has evolved since the 1962 publication of Highway Circular 482. In 1974 NCHRP Report 153, Recommended Procedures for Vehicle Crash Testing for Highway Appurtenances developed the first criteria for crash testing of roadside safety systems, followed by the 1980 NCHRP Report 230, Recommended Procedures for the Safety Performance Evaluation of Highway Safety Appurtenances. This report served as the first national standard for the evaluation and crash testing of roadside hardware. The NCHRP Report 230 was superseded by NCHRP Report 350, Recommended Procedures for the Safety Performance Evaluation of Highway Features, in 1993.

MASH – First published by AASHTO in 2009 and updated in 2016, the Manual for Assessing Safety Hardware (MASH) is an update to and supersedes NCHRP Report 350 for the purposes of evaluating new safety hardware devices. The only substantial update in the current 2016 edition is the criteria for crash testing cable barrier.

401.2 Acronyms

MGS - Midwest Guardrail System

MASH - Manual for Assessing Safety Hardware

NCHRP - National Cooperative Highway Research Program

Section 402 3R Clear Zone and Sideslopes (All Highways)

On all 3R projects, a roadside inventory, along with the crash summary and analysis, gives the designer information necessary to make good design decisions regarding roadside safety improvements. Evaluation and improvement considerations of roadside features should be consistent with the following:

1. Flatten sideslopes of 1:3 or steeper at locations where run-off-road accidents are likely to occur (e.g., on the outside of horizontal curves).
2. Retain current slope ratios. Do not steepen sideslopes when widening lanes and shoulders, unless warranted by special circumstances.
3. Remove, relocate or shield isolated roadside obstacles.
4. Remove vertical drop-offs at the edge of pavement after paving. See Safety Edge in Part 300, Section 321 for shoulders 6 ft or less.

Part 100 outlines the 3R design process that should be used in development of all 3R projects.

For ODOT 3R projects, Clear Zone design decisions are the responsibility of the Region Technical Center and should be documented in the project design narrative or related project files, as well as in a separate depository or library set up for the purpose of long-term retention and future access as needed. Design Exceptions for clear zone on 3R projects are approved by the Region Roadway Manager using the design exception form shown in Part 1000.

Section 403 4R Clear Zone (All Highways)

This section will address elements of roadside design including clear zone; clear zone requirements; clear zone distances; horizontal curve adjustments; and sideslopes. This section will also address the lateral clearances required, both vertical and horizontal, for interstate freeway single lane clearance envelopes.

The AASHTO “Roadside Design Guide - 2011” is the most recent publication written to provide guidance in roadway design regarding roadside clearances. The AASHTO “Roadside Design Guide - 2011” gives procedures and tables to determine the correct clear zone distance for use in the placement of barrier, sign installation, guard rails, ditch location, and other roadside appurtenances. It provides the criteria for the placement or removal of any object which may influence the trajectory of a vehicle which has left the travel lanes, either in a controlled or uncontrolled situation.

The AASHTO "Roadside Design Guide – 2011", in chapter 10, gives additional assistance to designers with clear zone in the urban context. Understanding of the role delineation plays between the travel way and non-travel way along a highly urban environment gives the designer more options than before.

The clear zone is determined by several factors, including design speed, ADT, horizontal curvature, and embankment slope. The distances given in the tables in this section are not absolute and the design options selected to mitigate the effect of roadside obstacles require good engineering judgment in order to balance cost effectiveness with the expected increase in safety.

When water with a depth of 2 feet or more is located with a likelihood of encroachment by an errant vehicle it is considered a roadside obstacle and is to be evaluated for mitigation.

The AASHTO "Roadside Design Guide - 2011" suggests considering the following options when evaluating a roadside obstacle:

1. Removing or redesigning the obstacle
2. Relocating the obstacle
3. Reduce impact severity by breakaway devices
4. Redirection of vehicle by installation of barrier device
5. Delineation of object

General information on clear zone is covered in Section 402 and Section 403. Of specific importance for both rural and urban freeways is the safety slope located at the back of curb or from edge of travel lane. In order to provide a recommended ditch section, the 1:6 rock foreslope and ditch section must be followed by a 1:4 backslope for a minimum of 10 feet. A variable back slope can then be used. These standards should also be followed when designing center medians. In a curbed median section, a 4-foot (2 percent) slope shall be followed by the 1:4 back safety slope.

The clear zone distance can be determined by using Table 400-1 and Table 400-2 shown at the end of this section. These tables were taken from the AASHTO "Roadside Design Guide - 2011". They are provided as a quick reference for the experienced designer who is already familiar with the determination process. Table 400-1 is used to determine general clear zone distance. Table 400-2 is used for horizontal curve adjustments.

Care must be taken in arriving at the proper clear zone distance. Table 400-1 lists the different clear zone distances for cut and fill slopes. Many times, multiple slopes have to be used to determine the appropriate clear zone distance. At times, the roadway typical section will have both a foreslope and backslope. When this occurs the procedure for determining the proper clear zone requires more than pulling a number from Table 400-1. An urban freeway may also include a curbed section that is followed by 2 percent slope for 4 feet. The 2 percent slope must then be followed by a 1:4 or flatter back safety slope for a minimum of 10 feet. The backslope adjacent to the 1:4 safety slope can then be varied. This urban treatment will meet the recommended ditch section requirements of the “Roadside Design Guide - 2011”. Following is an example of the proper procedure for determining clear zone distance for a typical section that includes both a foreslope and a backslope.

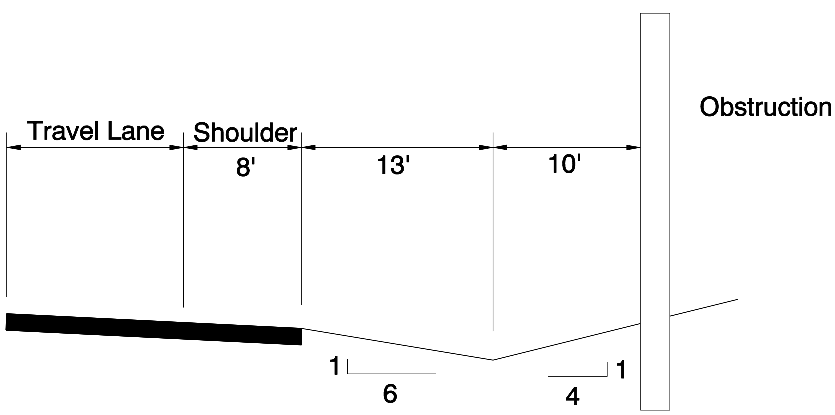
Example:

Design ADT: 7000

Design Speed: 60 mph

Recommended clear zone for 1:6 slope (fill): 30 to 32 feet from Table 400-1

Recommended clear zone for 1:4 slope (cut): 24 to 26 feet from Table 400-1



Discussion: Since the example is within the preferred channel cross section, Table 400-1 can be used to determine the clear zone. However, when the suggested clear zone exceeds the available recovery area for the foreslope, the backslope may be considered as additional available recovery area. The range for the suggested clear zone for the foreslope of 30 to 32 feet extends past the slope break into the backslope. Since the backslope has a suggested clear zone of 24 to 26 feet which is less than the foreslope the larger of the two values should be used. In addition, fixed objects should not be located near the center of the channel where the vehicle is likely to funnel. An appropriate clear zone range for this example is 30 to 32 feet.

For further information and more detailed procedures it is recommended all designers read the AASHTO *“Roadside Design Guide - 2011”*.

Design exceptions for clear zone on 4R projects are approved by the State Traffic-Roadway Engineer.

Table 400-1: Clear Zone Distances

Design Speed (mph)	Design ADT	Fill Slopes			Cut Slopes		
		1V:6H or flatter	1V:5H to 1V:4H	1V:3H	1V:3H	1V:5H to 1V:4H	1V:6H or flatter
≤ 40	UNDER 750	7 - 10	7 - 10	[b]	7 - 10	7 - 10	7 - 10
	750 - 1500	10 - 12	12 - 14	[b]	10 - 12	10 - 12	10 - 12
	1500 - 6000	12 - 14	14 - 16	[b]	12 - 14	12 - 14	12 - 14
	OVER 6000	14 - 16	16 - 18	[b]	14 - 16	14 - 16	14 - 16
45 - 50	UNDER 750 [c]	10 - 12	12 - 14	[b]	8 - 10	8 - 10	10 -12
	750 - 1500	14 - 16	16 - 20	[b]	10 - 12	12 - 14	14 - 16
	1500 - 6000	16 - 18	20 - 26	[b]	12 - 14	14 - 16	16 - 18
	OVER 6000	20 - 22	24 - 28	[b]	14 - 16	18 - 20	20 - 22
55	UNDER 750 [c]	12 - 14	14 - 18	[b]	8 - 10	10 -12	10 - 12
	750 - 1500	16 - 18	20 - 24	[b]	10 - 12	14 - 16	16 - 18
	1500 - 6000	20 - 22	24 - 30	[b]	14 - 16	16 - 18	20 - 22
	OVER 6000	22 - 24	26 - 32 [a]	[b]	16 - 18	20 - 22	22 - 24
60	UNDER 750 [c]	16 - 18	20 - 24	[b]	10 - 12	12 - 14	14 - 16
	750 - 1500	20 - 24	26 - 32 [a]	[b]	12 - 14	16 - 18	20 - 22
	1500 - 6000	26 - 30	32 - 40 [a]	[b]	14 - 18	18 - 22	24 - 26
	OVER 6000	30 - 32 [a]	36 - 44 [a]	[b]	20 - 22	24 - 26	26 - 28
65 - 70	UNDER 750 [c]	18 - 20	20 - 26	[b]	10 - 12	14 - 16	14 - 16
	750 - 1500	24 - 26	28 - 36 [a]	[b]	12 - 16	18 - 20	20 - 22
	1500 - 6000	28 - 32 [a]	34 - 42 [a]	[b]	16 - 20	22 - 24	26 - 28
	OVER 6000	30 - 34 [a]	38 - 46 [a]	[b]	22 - 24	26 - 30	28 - 30

[a] When a site-specific investigation indicates a high probability of continuing crashes or when such occurrences are indicated by crash history, the designer may provide clear-zone distances greater than the clear zone shown in this table. Clear zones may be limited to 30 ft for practicality and to provide a consistent roadway template if previous experience with similar projects or designs indicates satisfactory performance.

[b] Because recovery is less likely on the unshielded traversable 1V:3H fill slopes, fixed objects should not be present in the vicinity of the toe of these slopes. Recovery of high-speed vehicles that encroach beyond the edge of the shoulder may be expected to occur beyond the toe of slope. Determination of the width of the recovery area at the toe of slope should consider right-of-way availability, environmental concerns, economic factors, safety needs, and crash histories. Also, the distance between the edge of the through traveled lane and the beginning of the 1V:3H slope should influence the recovery area provided at the toe of slope.

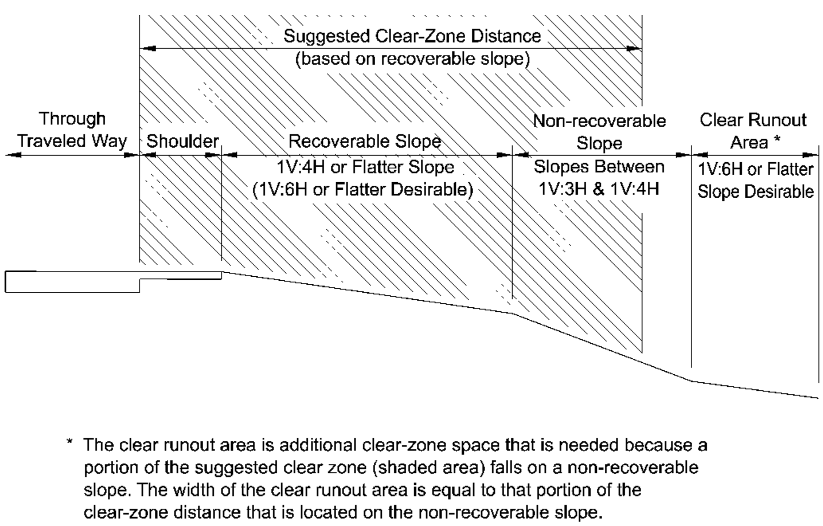
While the application may be limited by several factors, the foreslope parameters that may enter into determining a maximum desirable recovery area are illustrated in Table 400-2. A 10-ft recovery area at the toe of slope should be provided for all traversable, non-recoverable fill slopes.

c For roadways with low volumes it may not be practical to apply even the minimum values found in this table. Refer to Chapter 12 in the AASHTO's "*Roadside Design Guide - 2011*" for additional considerations for low-volume roadways and Chapter 10 for additional guidance for urban applications.

403.1 Clear Zone on Freeways

Of specific importance for both rural and urban freeways is the safety slope located at the back of curb or from edge of travel lane. In order to provide a recommended ditch section, the 1:6 rock foreslope and ditch section must be followed by a 1:4 backslope for a minimum of 10 feet. A variable backslope can then be used. This type of safety slope is also required for urban freeways with ditch sections or curb. Typically, an urban freeway has a curbed section that is followed by 2 percent slope for 4 feet. The 2 percent slope must then be followed by a 1:4 or flatter back safety slope for a minimum of 10 feet. The backslope adjacent to the 1:4 safety slope can then be varied. This urban treatment will meet the recommended ditch section requirements of the "Roadside Design Guide - 2011". These standards should also be followed when designing center medians. In a curbed median section, a 4-foot (2 percent) slope shall be followed by the 1:4 back safety slope.

Figure 400-1 AASHTO Safety Slope



Reference: AASHTO *"Roadside Design Guide – 2011"* Figure 3-2 and Table 3-2

403.2 Horizontal Curve Adjustments

Table 400-2: Horizontal Curve Adjustments

Degree of Curvature	Design Speed (MPH)					
	40	45	50	55	65	70
2°	1.1	1.1	1.1	1.2	1.2	1.2
2°30′	1.1	1.1	1.2	1.2	1.2	1.3
3°	1.1	1.2	1.2	1.2	1.3	1.4
3°30′	1.1	1.2	1.2	1.3	1.3	1.4
4°	1.2	1.2	1.3	1.3	1.4	1.5
4°30′	1.2	1.2	1.3	1.3	1.4	-
5°	1.2	1.2	1.3	1.4	1.5	-
6°	1.2	1.3	1.4	1.5	1.5	-
7°	1.3	1.3	1.4	1.5	-	-
8°30′	1.3	1.4	1.5	-	-	-
11°30′	1.4	1.5	-	-	-	-
17°30′	1.5	-	-	-	-	-

$CZ_c = (L_c)*(K_{cz})$

Where:

CZ_c = Clear zone on outside of curvature, feet

L_c = Clear zone distance, feet (see) AASHTO *"Roadside Design Guide – 2011"* Table 3-1

K_{cz} = Curve correction factor

Note: The clear-zone correction factor is applied to the outside of curves only. Corrections are typically made only to curves with a degree of curvature greater than 2°.

Section 404 Ditches

Figures 300-18, 300-19, and 300-22, outline the typical ditch section for rural highways, and urban and rural freeways. These typical sections create a standard roadside ditch flowline that is 0.5 feet below the subgrade elevation. The peak discharge, longitudinal slope, and ground cover for each ditch affect the ditch capacity. On steep slopes shear stresses on the ditch bottom should be evaluated to assure the ditch does not erode. The discharge contributing to ditches runs off from areas from within the right of way, but this area is often small compared to runoff from outside the right of way. Evaluate each ditch for significant flows from off-site.

The standard traversable ditch should be used on all projects unless the calculated peak flows indicate insufficient capacity or instability. A ditch is considered traversable when the sum of the horizontal components of the ditch foreslope and the ditch backslope is equal to or greater than 10 and both slopes are 1:4 or flatter. When the design speed is greater than 45 mph, the designer needs to give stronger consideration to the configuration of the ditch. Contacting the foreslope of the ditch with the rear bumper can cause the vehicle to roll, and contacting the backslope the ditch with the front bumper can cause an excessive deceleration of the vehicle.

The use of a flat bottom ditch may be appropriate in locations to satisfy water quality treatment requirements. Flat bottom ditches are recommended to be at least 4 feet wide at the ditch bottom with standard surfacing slopes. The 4-foot-wide bottom typically allows a vehicle to safely traverse the ditch. Flat bottom ditches may also be appropriate in open freeway medians. Additional information on ditches is provided in Part 1200, Section 1211.

Section 405 Culvert End Treatments

This subsection briefly describes many commonly used end treatments. Culvert end treatments are available in a variety of configurations and may be prefabricated or constructed in place. Commonly used configurations include projecting culvert barrels, concrete headwalls, prefabricated end sections, and culvert ends mitered to conform to the fill slope.

Culverts typically represent a significant contraction of flow in the upstream and downstream channels and often are a hydraulic control point. In certain flow conditions, end treatments can improve the discharge capacity by reducing the energy losses, at the inlet, associated with flow contraction. The designer must evaluate each for safety, hydraulic efficiency, structural stability, ability to pass debris, scour, and economics.

ODOT policy requires all culverts with diameters of 72 inches or greater, or the equivalent pipe size, to install end treatments on both ends." Refer to the ODOT Hydraulics Design Manual and Section 1211 for additional information regarding hydraulic design.

405.1 Projecting Ends

A projecting end is a treatment where the culvert protrudes out of the embankment. The primary advantages of this type of end treatment are simplicity and cost when installing. Projecting ends also provide excellent strength characteristics because the pipe consists of a complete ring structure out to the culvert end. However, they are vulnerable to various types of failures, especially displacement and buoyancy (concrete will not experience buoyancy) at the culvert ends.

- Projecting ends are the least efficient end type as the thin wall provides no flow transition and results in high energy losses. The only exception is the socket end of a concrete pipe which is highly efficient when the socket end is facing upstream.

Projecting ends are a roadside obstacle and require shielding with roadside barrier when located within the required clear zone or where likely to be hit by an errant vehicle.

405.2 Mitered Ends

A mitered culvert end is formed when the culvert barrel is cut to conform to the plane of the embankment slope. Mitered ends are relatively cost effective, more aesthetically pleasing and less of a hazard to traffic than projecting ends. These ends are slightly more efficient than projecting ends when mitered to conform with the slope. If designed with the use of beveled edges, mitered ends can be highly efficient.

Mitering or extreme skews of metal and thermoplastic pipe considerably weakens the end section to act as a ring in compression. The end sections are structurally inadequate to withstand hydraulic, fill, and impact loads unless they are well anchored with a concrete collar, paved end slope, or headwall. Any size of metal or thermoplastic pipe that is mitered must constructed with anchored with a collar, paved end slope or headwall. The need to shield mitered ends with roadside barrier can be eliminated if the following conditions are met. Safety bars are indicated to reduce the clear opening width in order to make the culvert end traversable.

Parallel Culverts:(parallel to the roadway centerline under driveways, road approaches, etc.)

- Pipe diameters less than or equal to 24 inches and posted speed more than or equal to 45 miles per hour, provide 1V: 6H sloped end or safety end section. No safety bars are required.
- Pipe diameters less than or equal to 24 inches and posted speed less than 45 miles per hour, provide 1V: 4H sloped end or safety end section. No safety bars required.
- Pipe diameters more than 24 inches and posted speed more than or equal to 45 miles per hour, provide 1V: 6H safety end section with safety bars.
- Pipe diameters more than 24 inches and posted speed less than 45 miles per hour, provide 1V: 4H safety end section with safety bars.
- Multiple pipes with diameters more than or equal to 15 inches, provide safety end sections with safety bars, using above criteria.

Cross-culverts:

- Pipe diameters less than or equal to 36 inches, provide either a sloped end to match embankment slope, or a 1V: 6H or 1V: 4H safety end section. No safety bars are required. The embankment slope should be warped and shaped to match the safety end section.
- Pipe diameters more than 36 inches, provide either a sloped end with safety bars to match the embankment slope, or a 1V: 6H or 1V: 4H safety end section with safety bars.
- Multiple pipes with diameters more than or equal to 36 inches, provide either a sloped end, with safety bars to match embankment slope, or a 1V: 6H or 1V: 4H safety end section with safety bars.

405.2.1 Headwalls with Wingwalls

Headwalls with wingwalls or standalone headwalls are the standard end treatment for box culverts and are used on circular, pipe-arch, and bottomless culverts. They can be cast-in-place or prefabricated and attached to the structure.

Headwalls are used for structural stability for culvert ends, eliminates buoyancy or uplift forces, and provides inlet and outlet protection. Incorporating a beveled edge in the upstream headwall allows flows to for a smooth transition constrict into the culvert. The bevels are highly hydraulic efficient under certain flow regimes.

Wingwalls are used to retain and protect the roadway embankment and provide a transition between the channel and culvert. Hydraulic efficiency is improved by maintaining the approach velocity, aligning and guiding drift, and funneling the flow into the culvert entrance. Wingwalls should be flush with box culvert barrels to avoid snagging drift.

Headwalls and wingwalls are roadside obstacles that require shielding with roadside barrier.

405.3 Concrete Boxes with Grates

Concrete boxes with grates are often used on small culverts draining medians, swales, gutters, depressions in paved surfaces, or roadside ditches. Details of these boxes are shown on Standard Drawings RD364, RD366, RD368, RD370, RD374, and RD378. Applicable safety standards apply to these ends within the clear zone.

405.4 Prefabricated End Sections

Prefabricated end sections include precast end sections for concrete pipes and flared sheet metal ends for metal pipes. Prefabricated end sections include precast end sections for concrete pipes and flared sheet metal ends for metal pipes. Flared end sections are used only on circular pipe or pipe arches and are more aesthetically acceptable as they conform to the finished embankment slope. Flared end sections allow flow to smoothly constrict into a culvert entrance and have a similar hydraulic inlet efficiently of a headwall or headwall and wingwalls with a square edge.

Prefabricated end sections are not approved for use within the clear zone that are unshielded from traffic. When the culvert end is within the clear zone and safety is a consideration, use a safety end section with bars as shown on RD321, RD322 or RD324.

405.5 Depressed and Tapered Inlets

A tapered inlet is a flared culvert entrance with an enlarged face section and a hydraulically efficient throat section. Tapered inlets can dramatically improve culvert hydraulic performance for culverts in inlet control. These end types are not appropriate for fish passage design or in high debris systems. Tapered inlets have a relatively high cost compared to other end treatments and are specially designed for each application. However, when tapered inlets are feasible, the improvement in hydraulic performance can be significant.

Depressed and tapered inlets are special applications. The need to shield these culvert ends is determined on a case-by-case basis and depends on their specific design and location relative to the required clear zone.

Section 406 Roadside Barriers

The following subsections provides information regarding design and use of roadside barrier. See Section 320.1 for roadside barrier shy distance requirements.

406.1 Guardrail and Concrete Barrier

406.1.1 General

This section provides information to the designer concerning guardrail and concrete barrier. Information on offsets, single slope barrier, cast in place, and slip form barrier is provided. The AASHTO *"Roadside Design Guide - 2011"* shall be used to determine guardrail and concrete barrier locations. Exceptions to this guide are to be approved by the State Traffic-Roadway Engineer. Standard Drawings in the RD400 series deal with guardrail while Standard Drawings in the RD500 series deal with concrete barrier. Barrier treatment in rural areas should consider impacts to animal crossings and the designer should contact the region environmental representative for assistance.

Regardless of the type of the barrier system used, when a median is proposed to be closed with a barrier system discussion with the Oregon State Police needs to occur to discuss cross over locations for emergency access.

Existing barrier systems used to mitigate lack of clear zone at a minimum shall meet NCHRP Report 350 crash testing criteria. No design exception will be granted to leave existing hardware that does not meet the minimum crash testing requirements on 3R and 4R projects.

406.2 Guardrail

This includes transitions to bridge rail, longitudinal runs of guardrail, and guardrail end terminals.

406.2.1 Upgrades and Height Adjustments

The MGS guardrail (with splice between the posts) passed MASH testing at 28". The previous standard – NCHRP 350 29" guardrail (measured to the top of the rail with the splice on the post) marginally passed MASH testing with steel posts but failed with wood posts. This means the previous standard is right at the Pass/Fail limit. Therefore, it is reasonable to upgrade to 31" MGS on 4R projects when NCHRP 350 29" guardrail is impacted by the project. NCHRP 350 tested guardrail may remain in place on 1R and 3R preservation projects. Where the height is lower than 28", it should be adjusted to a minimum of 29" – See Standard Drawing RD400. On 4R projects, NCHRP 350 tested guardrail may remain place if it is not impacted by the project.

4R Projects:

- Upgrade all unconnected and unprotected bridge rail end treatments within the project limits.
- All NCHRP 230 or older guardrail within the project limits must be upgraded to MGS guardrail.
- All NCHRP 350 guardrail that is impacted by the project must be upgraded to MGS guardrail.
- Existing MGS guardrail that is lower than 28" must be raised to 31".
- A transition for height and splice location may be used for NCHRP 350 guardrail runs that extend more than 250 ft. beyond the project limits (see Oregon Standard Drawing RD481). Where Pre-NCHRP 350 guardrail is impacted, replace the entire run.

    - Consider replacing the entire run of NCHRP 350 guardrail if the run extends more than 250 ft. beyond the project limits if:
        - it is cost effective,
        - the guardrail is disrepair, for example, rotten posts.

3R Projects:

- Upgrade all unconnected and unprotected bridge rail end treatments within the project limits.
- MGS guardrail that is lower than 28″ must be raised to 31″.
- NCHRP 350 guardrail may remain in place. Where the height is lower than 28″, adjust to a minimum of 29″.
    - Note: There is no objection to raising NCHRP 350 guardrail to 31″ if practical. However, this does not result in a MASH compliant barrier (since the splice will still be on the post) and it may not be possible to raise some NCHRP 350 end terminals higher than 29″.

The entire run of pre-NCHRP 350 guardrail must be upgraded to the current standard.

1R Projects

- Upgrade all unconnected and unprotected bridge rail end treatments within the project limits.
- Guardrail height adjustment is not required for resurfacing treatments that do not impact guardrail height.
    - Grind/inlays and chipseals are assumed to have no impact on guardrail height.
- For projects that impact rail height (i.e., overlays):
    - MGS guardrail that is lower than 28″ must be raised to 31″.
    - NCHRP 350 guardrail may remain in place. Where the height is lower than 28″, adjust to a minimum of 29″.
    - Upgrading pre-NCHRP 350 guardrail is not required; however, the functionality of the existing guardrail must be maintained.
        - Seek additional funding to upgrade pre-350 guardrail.
        - If no additional funding is available - adjust guardrail as high as possible up to 29″.

Major Bridge Maintenance (MBM):

- Address all unconnected and unprotected bridge rail end treatments as follows:

- Seek additional funding to upgrade unconnected and unprotected bridge rail end treatments.
- Where it is not possible to include bridge rail end treatments in the project, prioritize and address in a future project through the 1R Roadside Safety Feature Upgrade Program.
- Where unprotected bridge ends cannot be upgraded due to site conditions, document with a design exception.

- Guardrail height adjustment is not required for resurfacing treatments that do not impact guardrail height.
    - Concrete deck sealing and multi-layer polymer concrete overlays (MPCO's) are examples of deck preservation activities that are considered to have on impact guardrail height.
- For projects that impact rail height (i.e., overlays):
    - MGS guardrail that is lower than 28" must be raised to 31".
    - NCHRP 350 guardrail may remain in place. Where the height is lower than 28", adjust to a minimum of 29".
    - Upgrading pre-NCHRP 350 guardrail is not required; however, the functionality of the existing guardrail must be maintained.
        - Seek additional funding to upgrade pre-350 guardrail.
        - If no additional funding is available - adjust guardrail as high as possible up to 29".

406.2.2 Guardrail Design and Length of Need

On any project where guardrail or barrier is being proposed, the length of need calculation is required. This will assure that the fixed objects within the clear zone are shielded as intended. Chapter 5 in AASHTO's "Roadside Design Guide - 2011" contains information and details on length of need calculations.

Designers need to understand where and what the length of need point is on the terminal. The critical impact point of the angled crash test is the length of need point. This is the point where a vehicle should begin to be redirected along the length of the barrier instead of passing through the barrier. Any length of guardrail upstream from the length of need point is not included in the distance provided by the length of need calculation.

$$X = \frac{L_A + \left({}^{b}/_{a}\right)(L_1) - L_2}{\left({}^{b}/_{a}\right) + \left({}^{L_A}/_{L_R}\right)}$$

Example:

Given: ADT = 7,500 vpd

Speed = 50 mph

Select: $^{b}/_{a}$ = 0 – non flared terminal

L_A = Lateral Extent of Area of Concern – Designer selects 15 ft.

L_R = Runout Length – 190 ft.

From table 5-10(b) page 5-50 AASHTO "*Roadside Design Guide - 2011*".

L_1 = Tangent Length of Barrier upstream from the Area of Concern.

If Barrier is installed with no flare, L_1 becomes zero.

(See page 5-51 AASHTO "*Roadside Design Guide - 2011*")

L_2 = Lateral Distance – 4 ft shoulder and 2 ft "E" distance = 6 ft.

Solution: For a parallel installation (i.e., no flare rate), the equation reduces to the following:

$$X = \frac{L_A - L_2}{\left(^{L_A}/_{L_R}\right)}$$

$$X = \frac{15 - 6}{\left(^{15}/_{190}\right)} = \frac{9}{.0789} = 114\ ft.$$

406.2.3 Guardrail Terminals

Guardrail terminals are protective systems that prevent errant vehicles from impacting obstacles, by either gradually decelerating the vehicle to a stop when the terminal is hit head-on, or by redirecting the vehicle away from the obstacle when struck on the side. These systems are connected to the ends of runs of guardrail and work in concert with the guardrail run to shield rigid objects or hazardous conditions that cannot be removed, relocated, or break away.

Some terminals utilize W-Beam rail and breakaway timber posts, which are set in two steel foundation tubes for ease of replacement. Some end terminals utilize hinged breakaway steel posts. The rest of the breakaway posts are drilled. All systems establish the third post from the end as length-of-need point, referred to in the AASHTO "*Roadside Design Guide - 2011*".

Approved end terminals are listed in the Qualified Products List (QPL). Also available are terminals that are designed for a lower speed impact (under 45 mph) that are called Test Level 2 terminals. They are shortened versions of the standard terminals. With the competition as it is, all products undergo routine adjustments to design that make it impractical to list current models. The designer should refer to the QPL, as the QPL stays abreast with all changes and regularly posts updates.

406.2.4 Grading at Guardrail Terminals

In order to create predictable outcomes in actual crashes, conditions that existed during the crash testing should be duplicated as closely as possible. This means that an adequate width of approach at the end post of terminals is essential. This is so an impacting vehicle will be in the same plane as the roadway surface and not dropping off the edge at the instant of impact. A width of 5 feet from the back of the end post to the hinge point should be provided where possible (see RD419).

406.2.5 Establishment of Variable-Sized Recovery Areas

In addition to the grading at guardrail terminals that is needed to provide a relatively flat approach, an adequate recovery area should also be provided where possible. A recovery area consists of traversable slopes (1:3 or flatter) and is free of obstructions. Often, the recovery area can be provided by extending the guardrail run to a location where the desired dimensions can be achieved without extensive grading.

Table 400-3: Desired Recovery Area Dimensions

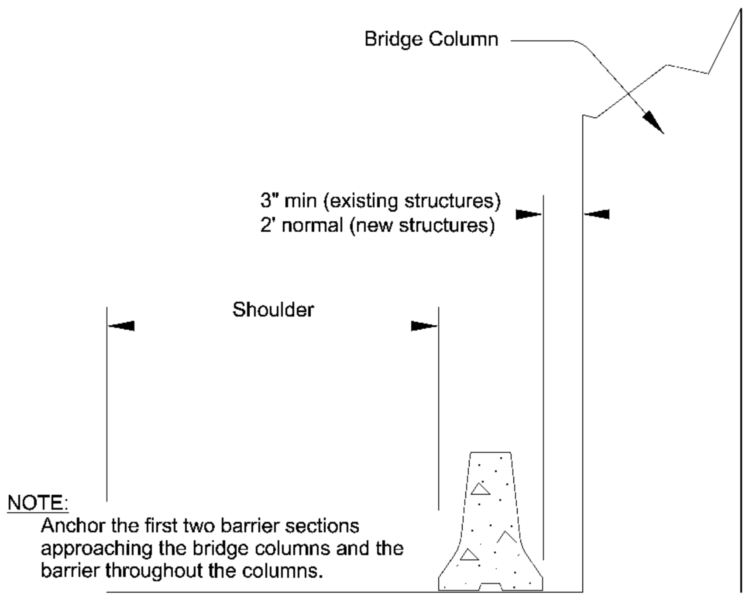
DESIGN SPEED (MPH)	WIDTH (FT.)	LENGTH (FT.)
50 +	20	75
35-45	18	50
< 35	16	40

406.3 Concrete Barrier and Bridge Columns

When the design shoulder width is not encroached upon by placement of the concrete barrier, the concrete barrier should be placed as shown in Figure 400-2. For existing structures, the minimum clearance between the bridge column and barrier is 3 inches. For new structures, the normal clearance between the bridge column and barrier is 2 feet. The roadway designer should consult with the bridge designer to determine the appropriate clearances.

Where the clearance from the traffic face of barrier and the face of the bridge column is at least 3.25 feet, use pinned 42" portable concrete barrier (see Oregon Standard Drawings RD500 series). Where the clearance from the traffic face of barrier to the face of the bridge column is less than 3.25 feet, a 42" MASH crash tested TL5 rigid barrier is required. One option is to use 42" type F bridge rail (see Oregon Standard Drawings BR200 series) installed on a moment slab. The moment slab must be designed in accordance with AASHTO LRFD.

Figure 400-2: Concrete Barrier Placement at Bridge Column



When the design shoulder width is encroached upon by the placement of the concrete barrier, the designer should consult with the bridge designer to develop the best solution to protect the bridge columns.

406.4 Tall Precast Concrete Barrier

See Oregon Standard Drawings RD500 series. This 42-inch-high safety shape is available only as precast, with segments 12.5 feet long, matching the length of ODOT's standard precast barrier.

The tall barrier does not replace the standard, but it is to be used in the medians of interstates and on the State Highway Freight System where median barrier is justified or where existing barrier is to be replaced. The tall barrier is not to be used in the Columbia River Gorge National Scenic Area on Interstate 84. Standard concrete barrier can be used in the median in the Columbia River Gorge National Scenic Area (color approved by USFS).

Use the tall barrier on shoulders of any highway system as needed where adverse geometrics may occur such as curves with a degree of curvature greater than that specified in Tables

300-27, 300-31, 300-33 herein, or where severe consequences at specific locations might occur with penetration of a barrier by a heavy vehicle.

406.4.1 Overlays and Concrete Median Barrier Vertical Face

For relatively straight forward overlay projects, the 3-inch vertical face on concrete median and shoulder barrier may be utilized without adjustment of the barrier. The overlay shall not exceed the vertical face height.

Tapering an overlay so the vertical face height will not be exceeded must be investigated to ensure that recommended slopes adjacent to the median barriers are not exceeded. Chapter 6 in the AASHTO's *"Roadside Design Guide - 2011"* provides additional information on terrain effect and barrier placement.

406.4.2 Concrete Barrier End Treatment

Any barrier end exposed to the flow of traffic must be protected in some manner. Impact attenuators are recommended by AASHTO. Burying ends in the cut slope is another approved method. Sloped ends may be used, but only when the design speed is less than 45 mph and the end is outside of the clear zone. In light of crash tests indicating potential launching hazards, earth mounds are not approved for use.

406.4.3 Concrete Barrier Upgrades

On 4R and 3R projects, barrier that does not meet NCHRP-Report 350 criteria must be replaced except at locations where the backside of the barrier is supported. Backside support can include a cut slope or retaining wall. Backside support must be strong enough to prevent vehicle penetration of the system at the connection point between segments. 1R projects can include barrier replacement with other funding sources. No design exceptions will be given in the case of 4R or 3R projects.

406.5 Cable Barrier

Cable barrier can be used in medians and on outside shoulders. Though cable barrier has been successfully tested on a 1:4 slope, optimum performance can be achieved by placing on a transverse slope of 1:10 or flatter. All cable barrier systems approved for installation on Oregon State Highways are proprietary, so it is necessary to refer to the manufacture's specifications for installation.

406.5.1 For Median Use

Cable barrier is very effective to use in medians as long as there is at least 8 feet of deflection room on both sides of the barrier. The deflection limit is measured from the taut cable to each adjacent fog line. Having less than 8 feet of deflection requires a design exception.

Care must be taken on interstate highways and freight routes where truck mix tends to be higher than the norm, to account for the fact that no cable system has been tested against semitrucks. A semitruck can stretch cable many times more than the design-tested deflection and will usually hold the cable at maximum deflection until the truck and cable are untangled from each other. The designer should account for extra deflection if there is a site-specific history of truck cross-over incidents. For extra measure of protection, the designer should consider use of a MASH Test Level 4 system in cases like this.

Cable barrier use can be considered on Interstate Highways and designated Freight Routes with a median width of 30 feet without an increase in the post spacing. Cable barrier installations in median widths less than 30 feet require consultation with the Senior Roadside Design Engineer.

406.5.2 For Shoulder Use

Cable barrier works well on shoulders as long as the designer ensures at least 8 feet of deflection distance is provided between the cable barrier system and the face of any obstruction. As with median application, account for extra deflection if there is a site-specific history of truck run-off-road incidents.

406.6 Barrier Systems on Retaining Walls

Drop-offs greater than six feet in height at the top of retaining walls shall be protected with a traffic barrier system. As a minimum, barrier located at the top of retaining walls on ODOT projects shall meet Test Level 3 (TL-3) requirements. A higher Test Level may be required for high-speed freeways, expressways, and interstates where traffic includes a mix of trucks and heavy vehicles, or when unfavorable conditions justify a higher level of rail resistance. Barrier options for protection of retaining wall drop-offs include:

1. Fixed Bridge Rail on Self Supporting (Moment) Slab: This option consists of a Type “F” 32” Bridge rail (BR200) on a self-supporting (moment) slab. The Type “F” 32” railing has been crash tested and satisfies TL-3. Barrier moment slabs must be designed in accordance with AASHTO LRFD and the current ODOT Geotechnical Design Manual (GDM) and must be strong enough to resist the ultimate strength of the railing. The moment slab must also be designed to resist overturning and sliding by its own mass

when subjected to a 10-kip static equivalent design load in accordance with AASHTO LRFD 11.10.10.2. ODOT also has a Type “F” 42” railing that has been crash tested and satisfies TL-5 criteria, but the static equivalent design load has not been determined.

2. Anchored Precast Wide Base Median Railing: Where TL-3 traffic railing is acceptable, anchored precast wide base median barrier (Oregon Standard Drawing. RD500) may be used when designed in accordance with AASHTO LRFD and the GDM. Anchored precast barriers shall be located at least 3.0 feet clear from the back of the wall face, and each precast section shall be anchored with four vertical anchors as shown on the “Median Installation” option on Oregon Standard Drawing RD515 and RD516.
3. Guardrail: Where TL-3 traffic railing is acceptable, standard guardrail (Oregon Standard Drawing RD400) may be used when designed in accordance with AASHTO LRFD and the GDM. Locate guardrail posts at least 3.0 ft clear from the back of the wall face, drive or place posts at least 5.0 ft below grade, and place at locations which do not conflict with retaining wall elements and components.

406.7 Freeway Median Barriers Warrant

For warranting median barrier on Interstate freeways and Non-Interstate freeways use the following:

1. Any open median 100 feet in width or less shall be closed with an appropriate barrier. The median width is measured between the inside fog lines of opposing directions of traffic.
2. For freeway medians greater than 100 feet wide, regions should evaluate site specific conditions and crash data to determine if the median should be closed. Regions are also encouraged to identify and evaluate any other sections of divided highways that they determine look and feel like interstate and non-interstate freeways to determine if the median should be closed.

Table 400-4: Interstate/Freeway List

Hwy	Route	Highway Name	Begin MP	End MP	Interstate/ Freeway
1	I-5	Pacific	0.00	308.38	Interstate
2	I-84	Columbia River	0.00	167.58	Interstate
6	I-84	Old Oregon Trail	167.58	378.01	Interstate
61	I-405	Stadium Freeway	-0.04	4.21	Interstate
64	I-205	East Portland Freeway	0.00	26.56	Interstate
70	I-82	McNary	0.00	11.21	Interstate
227	I-105	Eugene-Springfield	0.00	3.49	Interstate
30	OR 22	Willamina-Salem	24.03	26.18	Freeway
47	US 26	Sunset	53.62	73.75	Freeway
69	OR 569	Beltline	4.37	13.00	Freeway
92	US 30	Lower Columbia River	0.95	1.86	Freeway
144	OR 217	Beaverton-Tigard	0.00	7.52	Freeway
162	OR 22	North Santiam	1.68	13.74	Freeway
227	OR 126	Eugene-Springfield	3.49	9.04	Freeway

There are five barrier systems appropriate for use in the medians of freeways in Oregon. They are listed below. The minimum median widths listed in Table 400-5 are to be used as the minimum median width needed in order to use a specific barrier type. Standard median widths are covered in Part 300, Section 309.12 4R Urban and Rural Freeway Medians. Refer to 406.1 for concrete barrier guidance and AASHTO's Roadside Design Guide for barrier deflection.

Table 400-5: Median Barrier Systems

Barrier Type	Test Level	TL 3 Tested Deflection	Minimum Median Width	Comments
42-inch F-Shape Precast Concrete Barrier	NCHRP 350 TL 4 Assumed at least MASH TL 3 (assumed)	30 inches (unanchored)	8′-4″	Anchored deflection estimated to be 0 – 6 inches. Requires asphalt pad for placement. Only tested under NCHRP 350.
Modified Thrie-Beam for Medians	MASH TL3	TBD	8′-4″	Installed system approximately 42 inches wide
High Tension/ Low Maintenance Cable Barrier	MASH TL3, 4	Variable 6 – 9 feet	30 feet	Only system that can be placed on a 1:6 up to a 1:4 slope. Easy to maintain. Consider using TL 4 if trucks are a known problem.
32-inch F-Shape Concrete Barrier	MASH TL 3	30 inches	8′-4″	
Metal Median Guardrail	TBD	24 inches	24 feet	

Median barrier should be installed on a transverse slope of 1:10 or flatter. In medians wider than 30 feet it is preferred to use cable barrier placed near the center of the median. If placed away from the center, ensure that there is enough room for deflection to the closer side. For help in determining how to install barrier in a variable median see Sections 5.6 and 6.6 of "AASHTO's Roadside Design Guide - 2011"

406.8 Impact Attenuators

Impact Attenuators are protective devices that significantly reduce the severity of impacts with fixed objects. This is accomplished by absorbing much of the crash energy and decelerating a vehicle to a safe stop for head on impacts, or by redirecting a vehicle away from the fixed object for a side impact. Impact attenuators are used where fixed objects cannot be removed, relocated, or made to break away, and where fixed objects cannot be adequately shielded by a longitudinal barrier. Impact attenuators may also be used to terminate median barriers. Low maintenance impact attenuators are designed to be relatively easy to repair after an impact with the repair taking 2 hours or less. When selecting an Impact Attenuator that approved for use on Oregon State Highways, there may be a tradeoff between the initial cost and low maintenance. A low maintenance device should be selected where there is a history or high likelihood of multiple impacts and the location and/or high traffic volumes make it desirable to limit exposure to maintenance workers. On the other hand, a device with a lower initial cost may be installed where there is a low likelihood of multiple impacts and the repair or replacement after a crash will not expose maintenance workers to especially hazardous conditions.

Section 407 Roadside and Median Trees

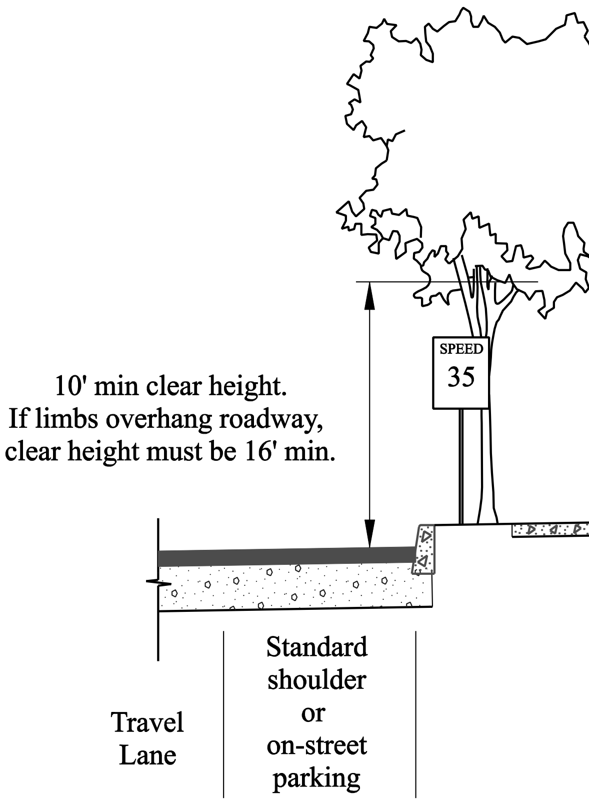
407.1 Roadside Trees

The following is intended to provide for the placement of street trees at the discretion of project teams where the criteria are met. If street trees are to be placed in a location where any of the criteria are not met, a design exception is required. (See Part 300, Section 308 Median Design for the placement of trees in the median.)

Standard criteria to allow roadside trees:

1. Design speed of 45 mph or less.
2. Trees located behind a positive (physical) delineation, i.e., curb.
3. The section is urban, suburban or a rural to suburban transition zone.
4. Trees may be located in the planter strip between the curb and sidewalk where the posted speed is 35 mph or less and there is a 6 ft. shoulder or on-street parking.
5. A minimum clear height of 10 feet from the pavement to the bottom of the branches not overhanging the roadway. This requirement allows for clear height of pedestrian use on sidewalks and allows sight distances to be clear. If the limbs overhang the roadway, a minimum clear height of 16 feet must be provided to prevent high loads from striking the branches.

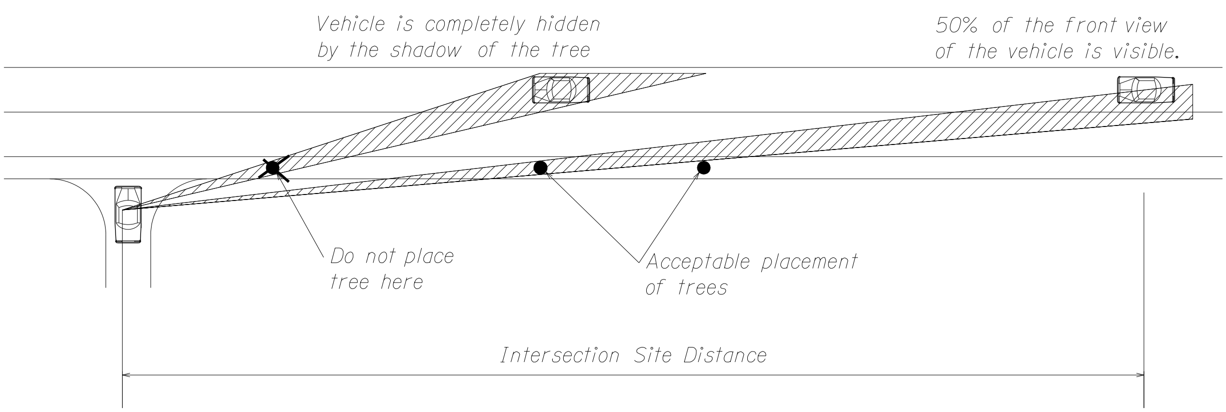
Figure 400-3: Roadside Tree Clearance



6. When the design speed is 45 mph or less and if the shoulder is nonstandard, or if there is no on-street parking, trees should be located such that there is at least 6 feet from the edge of travel to the trunk of the tree at maturity.
7. Where the posted speed is greater than 35 mph, trees should be located behind the sidewalk or at least 6 feet beyond the curb to the trunk of the tree at maturity.
8. If there is no positive delineation such as a curb, or if the design speed is greater than 45 mph, trees should only be located beyond the clear zone recommended in the AASHTO "*Roadside Design Guide - 2011*".
9. Trees may only be placed within the Intersection Sight Distance Triangle (ISD) such that approximately 50 percent or more of an approaching AASHTO defined "P-vehicle" remains visible at all times and at all approaches when the tree reaches maturity. 50 percent visibility is measured against what would otherwise be visible if there were no sight obstructions from trees, street furniture, utility poles, vertical curves, etc. For example, if 25 percent of the vehicle is hidden behind a vertical curve, street trees could only block an additional 25 percent of the vehicle. If 50 percent or more of the vehicle were hidden behind a vertical curve, it would not be appropriate to further reduce visibility by planting trees.

10. Consideration must also be given to pedestrians and bicyclists visibility at intersections when selecting tree species and placement. Nearer to the intersection increases the importance of clear visibility lines for drivers to see all users.
11. The illustration below is only a sample of a shadow diagram. Because of the many variables, shadow diagrams must be drawn on a case-by-case basis. Note that ISD applies equally to all approaches and shall be determined by a design professional. Refer to the AASHTO Green Book for the procedure to determine ISD.

Figure 400-4: Roadside Tree Placement



If the above criteria are met, then the combined effect of the following factors should be considered to determine if street trees are appropriate:

- **Access control** – When the number of approaches is reduced, a greater area is generally available for trees. If there are frequent approaches, it may not be possible to provide trees and at the same time provide adequate visibility at road approaches.
- **Crash history** – Trees should not be placed where there is a history of run-off-the-road crashes or a high potential for such crashes.
- **Environmental value** – Aesthetics, air quality, etc.
- **Clear zone guidelines** – Recognize that if trees are located within the clear zone recommended in the AASHTO *"Roadside Design Guide - 2011"*, they pose a hazard to errant vehicles.
- **Traffic calming** – Tall trees may have a slowing effect on drivers as they provide a tall vertical element on the side of their field of vision.
- **Horizontal alignment** – Run-off-the-road accidents occur more frequently on curves. Trees should not be placed in high-crash locations.

- **Vertical alignment** – If visibility is already compromised due to a poor vertical alignment, street trees may compound the problem.
- **Shy distance to tree** – A minimum of 6 feet from the edge of travel to the trunk of the tree is desirable, when the design speed is 45 mph or less.
- **Signing** – Landscaping plans should show the location of all signs ensuring that trees do not interfere with visibility.
- **Other roadway uses** – Trees need to coexist with utilities, miscellaneous street furniture, etc.
- **Transportation system plans and city ordinances** – Roadside trees are often identified as desirable or required within cities or urban unincorporated areas.

If street trees are included in a project, an appropriate species needs to be selected taking into consideration the dimensions of the tree at maturity, the planter width required to support the root system, etc. An ODOT roadside development professional should be contacted for further information.

407.2 Median Trees

The following is intended to provide for the placement of median trees at the discretion of project teams where the criteria are met. If median trees are to be placed in a location where any of the criteria are not met, a design exception is required.

Standard criteria to allow median trees:

1. Posted speed of 35 mph or less
2. Trees located behind a positive (physical) delineation (i.e., curbed – raised median).
3. The section is urban, suburban or in a rural to suburban transition zone.
4. A minimum clear height of 10′ from the pavement to the bottom of the branches. If the limbs overhang the roadway, a minimum clear height of 16′ must be provided.
5. A minimum median width of 8′ from curb to curb.
6. Trees may only be placed within the Intersection Sight Distance Triangle (ISD) such that approximately 50 percent or more of an approaching AASHTO defined "P-vehicle" remains visible at all times when the tree reaches maturity. 50 percent visibility is measured against what would otherwise be visible if there were no sight obstructions from trees, street furniture, utility poles, vertical curves, etc. For example, if 25 percent of the vehicle is hidden behind a vertical curve, median trees could only block an addition 25 percent of the vehicle – If approximately 50 percent or more of the vehicle were hidden behind a vertical curve, it would not be appropriate to further reduce visibility

by planting trees. Note that ISD applies equally to all approaches & should be determined by a design professional.

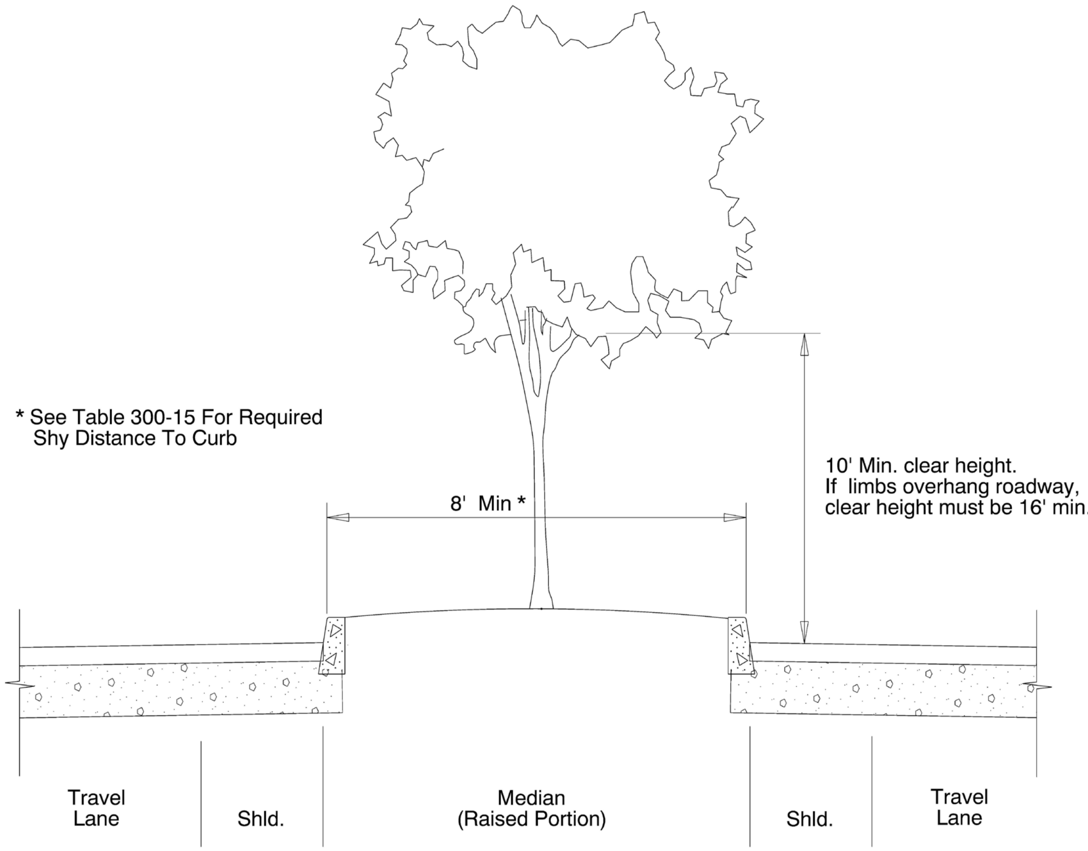
7. Pedestrian use - Consideration must also be given to pedestrians and bicyclists visibility when selecting tree species and placement. Where the median is expected to provide a refuge for crossing pedestrians, there should be frequent open areas where visibility is good. Trees can hide the pedestrian or cause the driver to believe there is a pedestrian crossing, thus taking emergency action.

If the above criteria are met, then the combined effect of the following factors should be considered to determine if median trees are appropriate:

- **Access Control** – When the number of median openings is reduced, a greater area is generally available for trees. If there are frequent openings, it may not be possible to provide trees and at the same time provide adequate visibility between left turning vehicles, oncoming traffic, and other roadway users.
- **Crash history** – Trees should not be placed where there is a history of run-off-the-road crashes or a high potential for such crashes.
- **Environmental value** - aesthetics, air quality, etc.
- **Clear zone guidelines** – recognize that median trees are generally within the clear zone recommended in the AASHTO *"Roadside Design Guide - 2011"* and pose a hazard to errant vehicles.
- **Traffic calming** - tall trees may have a slowing effect on drivers as they provide a tall vertical element on the left side of their field of vision.
- **Horizontal alignment** – run-off-the-road accidents occur more frequently on curves. Trees should not be placed in high crash locations. See AASHTO's Roadside Design Guide 2011 Table 3-2 for Horizontal Curve Adjustment Factors for clear zone widths.
- **Vertical alignment** – If visibility is already compromised due to a poor vertical alignment, median trees may compound the problem.
- **Shy distance to tree** – a minimum of 6' from the edge of travel to the face of the tree is desirable.
- **Other Roadway uses** – Trees need to coexist with utilities, signs, misc. street furniture, etc. Need to consider future needs.

If median trees are included in a project, an appropriate species needs to be selected taking into consideration the dimensions of the tree at maturity, the median width required to support the root system, etc**.** An ODOT roadside development professional should be contacted for further information.

Figure 400-5: Median Tree placement



407.3 Evaluation of Sight Lines

When considering the placement or removal of roadside and median trees, a comprehensive evaluation of sight lines is required. The ODOT Tree Sightline Analysis Flowchart (referenced below) provides a suggested workflow to ensure that all the criteria and other factors in Sections 407.1 and/or 407.2 are satisfied.

https://www.oregon.gov/odot/Engineering/TRSDocs/Tree_Sightline_Flowchart.pdf

Section 408 Fences

408.1 Right Of Way Fence

There are two types of fences typically used as access control or right of way fences. A Type 1 fence is a barbed wire fence with 4 or 5 strands of barbed wire. A Type 2 fence uses a woven wire fabric with 3 strands of barbed wire above the woven wire fabric. When determining the type of fence to use, consideration for the type of livestock present may be a factor.

For all freeways, fence will be placed at the access control line. In other situations, fencing shall be a consideration in the right of way agreement and installed when required by that agreement.

408.2 Chain Link Fence

The installation of chain link fence, located in clear zones, should be done without the use of the top rail. FHWA has reviewed the use of top rail installations and considers the use of top rail or pipe rail hazardous. They do not recommend using this type of support for chain link fences or pedestrian handrails where they can be struck by an errant vehicle. In the event of a crash, the rails can penetrate the passenger compartment of vehicles. Chain link fences with top rails are particularly poor as vehicle impact on the fabric tends to pull the rail down onto the hood of the vehicle and into the windshield. Top rails, or other rigid horizontal rails or members, metal or wood, should not be used within the clear zone on projects.

408.3 Snow Control

On the Cascade and Siskiyou Mountain passes and east of the Cascades, drifting snow may be a serious problem. Snow fencing can eliminate the need for snow removal, lower pavement maintenance costs, and increase visibility and safety on the road. The following factors should be considered:

408.3.1 Investigation

The direction of the prevailing winter winds must be determined before effective measures can be taken to prevent snowdrift problems. Personal observations, interviews with persons familiar with the local winter conditions, including the ODOT maintenance foreman, and reviews of local records may be of value.

408.3.2 Grade

Highway grades above the surrounding ground are much less subject to drifting because of wind action. A cut section of highway may act as a natural fence, impeding the steady flow of wind, resulting in snow being deposited on the roadway.

408.3.3 Cross-Section

It may be possible to reduce or eliminate drifting snow problems by streamlining the roadbed. Steep slopes and obstructions to air movement cause snow drifts. Any flattening of the slopes will reduce the areas where snow is deposited on the road. Guardrail is particularly objectionable and wherever feasible should be eliminated by flattening fill slopes. In cut sections the intersection of the cut with natural ground should be back of a 1:6 slope measured from the edge of the shoulder. Widening the cross section through cuts may be desirable to provide for snow storage.

When considering the use of flat slopes for reducing snowdrift problems, the impacts on the safety and aesthetics of the highway should also be considered.

408.3.4 Control with Snow Fences

Snow fences may be required where control cannot be obtained by other methods. It is necessary that any snow fence be properly located and placed. Snow fences are generally placed parallel to the roadway if the prevailing wind is within 25 degrees of being perpendicular to the roadway otherwise the snow fence is placed perpendicular to the prevailing wind direction and at a distance from the roadway centerline that is equal to 35 times the fence height. If a higher than required fence is used the distance from the roadway centerline can be reduced to 18 times the fence height. Snow fence placement depends on a study of conditions at the site, particularly the direction of prevailing winds. In order to function properly, a snow fence must have an adequate distance behind it to allow for the piling of snow, called snow storage room. The fence itself impedes the wind flow, thereby creating a swirling action behind the fence resulting in the snow being deposited. Ordinarily snow fences should be placed so that the distance from the fence to the top of cut or bottom of fill is 10-15 times the height of the snow fence. If a snow fence is too close to a highway, or a cutbank exists without adequate snow storage room, it can be more of a problem than a solution. A minimum snow storage distance is based on the site conditions.

Two or more parallel rows of fences may be required, but these should be placed far enough apart so the resulting drifts do not overlap, generally 25 times the height of the fence between the snow fences allow non-overlapping snow drifts to form. Snow fences should not be placed any closer than 16 feet to right of way fences or natural parallel barriers.

408.3.5 Control with Landscaping

Trees and shrubs planted at the appropriate location may also provide a permanent and effective type of snowdrift control. An ODOT roadside development professional should be contacted.

Additional information may be obtained from the *ODOT Inspector's Manual* and the *ODOT Maintenance Manual*.