LOCATION AND DESIGN MANUAL - VOLUME 1



OHIO DEPARTMENT OF TRANSPORTATION

Preface

Purpose

Many manuals, policies, guides, standards etc. have been published regarding roadway design. Most of these have been written using wide ranges of design recommendations (minimums and maximums) since the contents were intended to apply nationally. The purpose of this manual is to reduce the selection of design alternatives to those most appropriate for the State of Ohio, to document Ohio's interpretation of various policies, and to include design criteria which may be unique to the State of Ohio.

Application

The criterion included in this manual has been developed to closely conform to the following publications:

- AASHTO - A Policy on Geometric Design of Highways and Streets (2018 Green Book)
- AASHTO - A Policy on Design Standards - Interstate System (2016)
- AASHTO - Roadside Design Guide (2011)

This manual is neither a textbook nor a substitute for engineering knowledge, experience or judgment. It is intended to provide uniform procedures for implementing design decisions, assure quality and continuity in design of highways in Ohio, and assure compliance with Federal criteria. Although the manual is considered a primary source of reference by personnel involved in highway design in Ohio, it must be recognized that the practices suggested may be inappropriate for some projects because of fiscal limitations or other reasons.

Consideration must also be given to design standards adopted by city, county or other local governments when designing facilities under their jurisdiction.

In lieu of the geometric design guidelines presented in this manual, the geometric design guidelines presented in the AASHTO publication **"Guidelines for Geometric Design of Low-Volume Roads" (2nd Edition 2019)** may be used for low-volume collectors and local roads with a design average daily traffic volume of 2000 vehicles per day or less.

Format and Revisions

Updating the manual is intended to be a continuous process and revisions will be issued biannually (January and July).

Unit of Measure

Plans are to be prepared using the English system of units. Any metric units are provided for reference only.

For design purposes, the relationships between the two units are not exact or interchangeable. The user is therefore cautioned to work entirely within one system and not attempt to convert directly between the two.

Ohio Districts and Counties

ODOT's District and County map can be accessed here.

Glossary

Arterial - A functional classification for a facility primarily used for through traffic, usually on a continuous route.

Attenuator (Crash Cushion) - Protective devices that prevent an errant vehicle from impacting fixed objects by gradually decelerating the vehicle to a safe stop or by redirecting the vehicle away from the obstacle.

Backslope - The slope from the back of a ditch to the existing ground surface. (Sometimes referred to as a cut slope.)

Barrier - A device which provides a physical limitation through which a vehicle would not normally pass. It is intended to contain or redirect a vehicle.

Barrier Clearance - The distance required between the face of a barrier and the face of an obstacle to permit adequate shielding.

Barrier Grading - The shaping of the roadside when a barrier is required for slope protection. (See Figure 307-4).

Bicycle Lane or Bike Lane – A portion of roadway that has been designated by pavement markings and signs
for preferential or exclusive use by bicycles.

Border - The area between the face of curb and the right of way line. Usually referred to as the border area when no sidewalk is used.

Buffer - The space between the back of the curb and the sidewalk for the purpose of providing snow storage, a buffer between cars and pedestrians, a place for signs and to improve aesthetics.

Clear Zone - The unobstructed, traversable area provided beyond the edge of the through traveled way for the recovery of errant vehicles. The clear zone includes shoulders, bike lanes, and auxiliary lanes, except those auxiliary lanes that function like through lanes.

Clear Zone Grading - The shaping of the roadside using 4:1 or flatter foreslopes and traversable ditches within the clear zone area. (See Figure 307-3).

Cloverleaf Interchange - An interchange with loop ramps and outer ramps for directional movements. A full cloverleaf has ramps in every quadrant.

Collector - A functional classification for a facility in an intermediate functional category connecting smaller local or street systems with larger arterial systems.

Collector-Distributor (C-D) - A directional roadway adjacent to a freeway used to reduce the number of conflicts (merging, diverging and weaving) on the mainline facility.

Common Grading - The shaping of the roadside using 3:1 or flatter slopes and normal ditches. (See Figure 307-4).

Converging Roadway - Separate and nearly parallel roadways or ramps which combine into a single continuous roadway or ramp having a greater number of lanes beyond the nose than the number of lanes on either approach roadway.

Controlled Access - (Partial control of access) - Highway right of way where preference is given to through traffic. In addition to access connections with selected public roads, there may be some private drive connections.

Crest Vertical Curve - A vertical curve such that the point of intersection of the approach grades is above the roadway profile. Crest vertical curves are concave downward.

Critical Slope - A slope, steeper than 3:1, on which vehicles are likely to overturn.

Cross Slope - The rate of change of elevation along a straight line from one point in cross section to another.

Cut Slope - See Backslope.

Decision Sight Distance - The distance required for a driver to detect an unexpected or otherwise difficult to perceive information source or hazard in a roadway environment that may be visually cluttered, recognize the hazard or its threat potential, select an appropriate speed and path, and initiate and complete the required maneuver safely.

Degree of Curve (Arc Definition) - The angle subtended at the center by an arc of 100 foot length.

Design Exception - A document which explains the engineering and/or other reasons for allowing certain design criteria to be relaxed in extreme, unique, or unusual circumstances.

Design Hour - The 30th highest hourly volume of the design year.

Design Hourly Volume - The total volume of traffic in the design hour, usually a forecast of peak hour volume, measured in vehicles per hour.

Design Speed - A selected speed used to determine the various geometric design features of the roadway.

Diamond Interchange - The simplest and most common type of interchange, formed when one-way diagonal ramps are provided in each quadrant and left turns are provided on the minor highway.

Directional Interchange - An interchange, generally having more than one grade separation, with direct connections for all movements.

Diverging Roadway - Where a single roadway branches or forks into two separate roadways without the use of a speed change lane.

Edge of Traveled Way - The intersection of the mainline pavement with the treated or turf shoulder or the curb and gutter.

Expressway - A divided arterial highway with full or partial control of access and generally with grade separations at major intersections.

Fill Slope - See Foreslope.

Foreslope - The slope from the edge of the graded shoulder to the bottom of the ditch. (Also called Fill Slope.)

Freeway - An expressway with full access control and no at-grade intersections.

Functional Classification - The grouping of highways by the character of service they provide.

Glare Screen - A device used to shield a driver's eye from the headlights of an oncoming vehicle. Graded Shoulder - The area located between the edge of traveled way and the foreslope.

Headlight Sight Distance - The stopping sight distance required on an unlighted sag vertical curve.

Horizontal Sight Distance - The sight distance available in consideration of various horizontal alignment features, such as: degree of curvature and the horizontal distance to roadside obstructions.

Intersection Sight Distance (ISD) - The sight distance required within the corners of intersections to safely allow a variety of vehicular maneuvers based on the type of traffic control at the intersection.

Interstate - Those roadways on the Federal System which have the highest design speeds and the most stringent design standards.

“K” Factor - The length of a vertical curve divided by the algebraic difference in grades expressed as a percent. “K” factors are only applicable where the length of curve is greater than the necessary stopping sight distance.

Lateral Clearance - The distance measured horizontally from the edge of traveled way to the face of an object (parapet, abutment, pier, wall, etc.).

Legal Speed - The legislated or agency authorized maximum speed limit of a section of roadway.

Length of Need (LON) Point – That point on the terminal or longitudinal barrier at which it will contain and redirect an impacting vehicle along the face of the terminal or barrier.

Level of Service - A qualitative measure describing the operational flow of traffic.

Limited Access (Full control of access) - Highway right-of-way where rights of access of properties abutting the highway are acquired, such that all access to and from the highway are prevented except at designated locations.

Local Road - A functional classification used for rural roadways whose primary function is to provide access to residences, businesses or other abutting properties.

Local Street - A functional classification used for urban roadways whose primary function is to provide access to residences, businesses or other abutting properties.

Non-Recoverable Slope - A slope that a vehicle can traverse, but it is generally too steep to allow the vehicle to stop or return to the roadway. Traversable nonrecoverable slopes are between 1V:4H and 1V:3H and are NOT included in the specified clear zone distance.

Normal Design Criteria - The criteria used for the design of new or reconstructed projects (all projects that do not qualify as 3R).

Normal Ditch - A trapezoidal-shaped ditch having a bottom width of 2 feet and rounding of 4 feet (See
Figure 307-4).

Passing Sight Distance (PSD) - The visible length of highway required for a vehicle to execute a normal passing maneuver as related to design conditions and design speed.

Peak Hour - The maximum traffic volume hour of the day.

Reconstructed Bridge - Any improvement to an existing bridge involving the replacement of the bridge deck or more.

Recoverable Ditch - A rounded ditch having a radius of either 20 or 40 feet (See Figure 307-2).

Recoverable Slope - A slope on which a motorist may, to a greater or lesser extent, retain or regain control of a vehicle. Slopes flatter than 1V:4H are generally considered recoverable.

Resurfacing, Restoration and Rehabilitation (3R) - Improvements to existing roadways, which have as their main purpose, the restoration of the physical features (pavement, curb, guardrail, etc.) without altering the original design elements.

Resurfacing, Restoration, Rehabilitation and Reconstruction (4R) - Much like 3R, except that 4R allows for the complete reconstruction of the roadway and alteration of certain design elements (i.e., lane widths, shoulder width, SSD, etc.).

Roadside - The area between the outside shoulder edge and the right-of-way limits. The area between roadways of a divided highway may also be considered roadside.

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

Safety Grading - The shaping of the roadside using 6:1 or flatter slopes within the clear zone area and 3:1 or flatter foreslopes and recoverable ditches extending beyond the clear zone (See Figure 307-1).

Sag Vertical Curve - A vertical curve such that the point of intersection of the approach grades is below the profile line. Sag vertical curves are concave upward.

Shared Lane – A lane of a traveled way that is open to both bicycle and motor vehicle travel.

Shared Use Path – Facilities physically separated from motor vehicle traffic by an open space or barrier, either within the highway right-of-way or within an independent right-of-way. Shared use paths may be used by a mix of non-motorized users such as bicyclists, walkers, runners, wheel chair users and skaters.

Sidepath – A shared use path located immediately adjacent and parallel to a roadway.

Shy Distance – The space adjacent to fixed objects, such as walls, fences, shrubs, buildings, parked cars and other features that pedestrians typically avoid.

Shy-line Offset - The distance from the edge of the traveled way beyond which a roadside object will not be perceived as an obstacle by the typical driver to the extent that the driver will change the vehicle's placement or speed.

Sloped Curb (mountable) - Curbs 6 inches or less in height with a sloping face designed to be traversable by vehicles when required.

Spiral - A transition curve from a tangent to a circular curve, or a circular curve to a circular curve, designed to affect a more gradual change of direction. The Euler spiral (clothoid) is used in design.

Stopping Sight Distance (SSD) - The cumulative distance traversed from the time a driver sees a hazard necessitating a stop, actually applies the brakes and comes to a stop.

Superelevation - The cross-slope of the pavement used to compensate for the effect of centrifugal force on horizontal curves.

System Interchange - An interchange that connects two or more freeways via a network of ramps and connectors.

Service Interchange - An interchange that connects a freeway with local surface streets or arterials.

Temporary Road - Any crossover, ramp, roadway, etc. whose sole purpose is to temporarily maintain traffic during construction which is normally removed upon project completion.

Through Traveled Way – The portion of roadway for the movement of vehicles, exclusive of shoulders and auxiliary lanes.

Traveled Way - The portion of the roadway for the movement of vehicles, exclusive of shoulders and bicycle lanes.

Traversable Ditch (preferred ditch) - An open ditch with a preferred combination of foreslope, backslope, bottom width and rounding that allows the ditch shape to be used within the clear zone. (See Figures 307-10 & 307-11).

Traversable Slope - A slope from which a motorist will be unlikely to steer back to the roadway but may be able to slow and stop safely. Slopes between 1V:3H and 1V:4H generally fall into this category.

Treated Shoulder - That portion of the graded shoulder which has some type of surface treatment. Tree Lawn - see Buffer.
Trumpet Interchange - A semi-directional “T” interchange.

3R Values - Special values developed for certain design features on 3R improvements.

Vertical Clearance - The distance, measured vertically, from the surface (pavement, shoulder, ground, etc.) to a fixed overhead object (bridge superstructure, sign, signal, etc.).

Vertical Curb (barrier) - A steep faced curb 6 inches or more in height.

Vulnerable Road User (VRU) - A road user who is unprotected by a car, truck, or bus when traveling, and therefore at a greater risk of injury in a crash with a motor vehicle:

- Pedestrians, including persons engaged in work upon a roadway facility or emergency services within the right-of-way.
- A person operating a bicycle, motorcycle, scooter, moped, horse-drawn carriage, or other "non-car" means of transportation.

Design Reference Documents

ODOT Publications

Contact ODOT Office of Contracts (614) 466-3778 to purchase.

The current revision of those listed should be used.

- Bridge Design Manual (BDM)
- Construction and Material Specifications
- Geotechnical Design Manual (GDM)
- Location and Design Manual
    - Volume Two - Drainage Design
    - Volume Three - Highway Plan
    - Volume Four - Survey, Mapping, & Subsurface Utility Location Services Specifications
- Multimodal Design Guide (MDG)
- ODOT Analysis and Traffic Simulation (OATS) Manual
- Ohio Supplement to the Manual of Uniform Traffic Control Devices
- Pavement Design Manual (PDM)
- Railroad Coordination Policy & Procedures Manual
- Real Estate Manual
- State Highway Access Management Manual (SHAMM)
- Standard Construction Drawings (SCDs)
- Traffic Engineering Manual (TEM)

AASHTO Publications

Website

- Guidelines for Geometric Design of Low-Volume Roads (2019)

- A Policy on Design Standards - Interstate System (2016)
- A Policy on Geometric Design of Highways and Streets (2018)
- Roadside Design Guide (2011)
- Highway Safety Manual (2010)
- Manual for Assessing Safety Hardware (2016)
- Manual on Uniform Traffic Control Devices for Streets and Highways (2023)

TRB Publications

Website

- Guide for Roundabouts (NCHRP Report 1043)
- Highway Capacity Manual (2022)
- Recommended Procedures for the Safety Performance Evaluation of Highway Features (NCHRP Report 350)

100 - Design Control and Exceptions

In order to determine the criteria to be used for a project, it is necessary to initially identify some basic information about the facility. This information is known collectively as the design designation and includes: functional classification, traffic data, terrain, locale, design speed and legal speed. Figure 100-1 shows how these design controls relate to many of the design features included in this manual.

101 - Functional Classification

101.1 - General

Functional classification, the systematic grouping of highways by the character of service they provide, is an important tool that has been used for many years in comprehensive transportation planning. Its adoption by highway designers to categorize basic highway systems serves as an effective transition from the planning process to the design process. Under a functional classification system, standards and level of service vary according to the function of the highway facility. Traffic volumes are used to refine the standards for each class.

101.2 - Urban & Rural

Functional classification is initially divided into urban and rural categories. **Urban areas** are comprised of: (1) places with a population of 5,000 or more, that are incorporated as cities, villages, and towns but excluding the rural portions of extended cities; (2) census designated places with 5,000 or more persons; and (3) other territory, incorporated or unincorporated, included in urbanized areas.

Extended cities are those cities whose boundaries include territory that is essentially rural in character (e.g., uncurbed pavement with open drainage, where a rural typical section would be more consistent with the existing roadway).Urbanized areas consist of one or more places (central places) and the adjacent densely populated surrounding territory (urban fringe) that together have a minimum population of 50,000. The urban fringe generally consists of contiguous territory having a density of at least 1,000 persons per square mile.

Rural areas are those outside the boundaries of urban areas. To determine if a project location is urban or rural see the Transportation Information Mapping System (TIMS) and select Create a Map. Once the Create a Map has been selected go to the Boundaries layer and toggle on the Adjusted Urban Areas to view whether the project location is within a designated urban area or outside.

101.3 - Classification Used in ODOT Design Criteria

The rural and urban functional classifications are further defined for design purposes as follows:

- Interstate
- Other Freeways and Expressways
- Principal Arterial Roads (rural) and Streets (urban)
- Minor Arterial Roads (rural) and Streets (urban)
- Collector Roads (rural) and Street (urban)
- Local Roads (rural) and Streets (urban)

The functional classifications for streets and highways in Ohio are kept on record in the Office of Technical Services.

102 - Traffic Data

102.1 - General

Traffic data is the foundation upon which designs are based; consequently, it is important that adequate traffic data be available early in the development of a project's design. It is equally important that this data be coordinated within various geographic regions of the State to avoid inconsistencies between projects under the same traffic influences.

All forecasted traffic data used shall be developed following state traffic forecasting guidelines provided by Division of Planning, Office of Statewide Planning & Research, Modeling & Forecasting section. Documents containing forecasting guidelines are available on the office internet web page.

102.2 - Traffic Data Content

The design criteria tables in this manual require basic traffic data for the design year. The traffic design year is generally considered to be the following:

Project Type	Traffic Design Year (After Opening Day)
New Construction	20 years hence
Reconstruction	20 years hence
Major Pavement Rehabilitation	20 years hence
Minor Pavement Rehabilitation	12 years hence
Two-Lane Resurfacing	12 years hence

Except for Minor Pavement Rehabilitation (maintenance resurfacing), all project types on the Interstate require 20-year design traffic (Title 23 - HIGHWAYS). For most projects, the following data are required:

- Average Daily Traffic (ADT) for opening day (for lighting and signal warrants).
- Average Daily Traffic (ADT) for design year.
- Design Hourly Volume (DHV). AM and PM DHV are required for interchange design.
- The percentage of B and C trucks (T24) during the 24-hour period for the design year.
- The percentage of B and C trucks (TD) during the design hour traffic for the design year (for adjusting capacity analyses).

- Directional Distribution Factor (D) for the design year (used to obtain the Directional Design Hour Volume (DDHV) for the design hour).

Projects on low-volume facilities (current ADT<400) without a design year traffic forecast may use the current ADT for design purposes.

Average Daily Traffic (ADT) volumes should be subdivided into the following classes:

- **P - Passenger Cars** - including station wagons, mini-vans, sport utility vehicles and motorcycles.
- **A - Commercial** - including motorized recreational vehicles, school buses, and light delivery trucks such as panel trucks and pick-up trucks which do not use dual tires.
- **B - Commercial** - including tractors, trucks with semi-trailers and truck-trailer combinations.
- **C - Commercial** - including buses or dual tired trucks having either single or tandem rear axles.

Estimated Design Year ADT may be subdivided into P & A vehicles and B & C trucks if data for each vehicle class is not readily available, since these classes have similar operational characteristics. Current ADTs for various sections of Interstate, United States and State Highways for each county are available in the Traffic Survey Report published by the Office of Technical Services. Counts at specific points in the section may vary from the average and are available upon request from the Office of Technical Services.

103 - Terrain & Locale

103.1 - General

Many rural design features are significantly influenced by the topography of the land through which the roadway is constructed. To characterize variations, Ohio topography is categorized into three types of terrain: level, rolling or hilly. Locale is used to describe the type of area and generally refers to the character and extent of development in the vicinity. Urban, rural, residential, and commercial/industrial are characteristics often used to describe locale.

103.2 - Terrain Types

- **Level -** Any combination of grades and horizontal and vertical alignment permitting heavy vehicles to maintain approximately the same speed as passenger cars. This generally includes grades of no more than 2 percent for a distance of no more than 2 miles.
- **Rolling** - Any combination of grades and horizontal and vertical alignment causing heavy vehicles to reduce their speeds substantially below those of passenger cars, but not causing heavy vehicles to operate at crawl speeds.
- **Hilly** - Any combination of grades and horizontal and vertical alignment causing heavy vehicles to operate at crawl speeds. Hilly terrain in Ohio conforms to mountainous terrain used in the American Association of State Highway Transportation Officials (AASHTO) publications.

For design purposes a heavy vehicle is defined as a vehicle with a mass/power ratio of approximately 200 lb/hp. This represents a typical semi-truck. Crawl speed is the maximum sustained speed that a heavy vehicle can maintain on an extended upgrade and varies with the weight of the vehicle and the steepness of the grade.

104 - Design & Legal Speed

104.1 - General

Design speed is defined in the AASHTO publication, "A Policy on Geometric Design of Highways and Streets" (Green Book), as a selected speed used to determine the various geometric design features of the roadway. The assumed design speed should be a logical one with respect to the topography, anticipated operating speed, the adjacent land use and the functional classification of highway.

104.2 - Design Speed Values

The design speed should be at least the legal speed for facilities with a legal speed of 35 mph or less. For facilities with a legal speed of 40 or 45 mph the design speed shall either match the legal speed, or be 5 mph greater than the legal speed, depending on the context of the area. For facilities with a legal speed 50 mph or greater, the design speed shall be 5 mph greater than the legal speed. Design speeds must be specified in 5 mph increments. For resurfacing projects, the design speed is the legal speed, or alternately, the 85th percentile speed for individual or series of horizontal and vertical curves. Refer to part

1200 of the Traffic Engineering Manual for guidance establishing the 85th percentile speed. Ramp design speeds are included in **Section 503.2**. Design speeds of 50 mph and higher are considered high speed and design speeds less than 50 mph are considered low speed.

105 - Design Exceptions

105.1 - General

Designers and engineers are faced with many complex tradeoffs when designing highways and streets. A good design balances cost, safety, mobility, social and environmental impacts, and the needs of a wide variety of roadway users.

Highway design criteria that have been established through years of practice and research form the basis by which roadway designers achieve this balance. These criteria are expressed as minimum dimensional values or ranges of values for various elements of the three-dimensional design features of the highway. The criteria are intended to deliver an acceptable, generally cost-effective level of performance (traffic operations, safety, maintainability, and constructability). The criteria are updated and refined as research and experience increase knowledge in the field of highway engineering, traffic operations, and safety.

A design exception is a documented decision to design a highway element or a segment of highway to design criteria that do not meet minimum values or ranges established for that highway or project. The minimum values or ranges of design criteria, also known as controlling criteria for design, that require design exceptions when they are not met or exceeded are set forth in **Section 105.2** and Figure 105-1. The designer should call attention to any design features that require a design exception as soon as possible, but no later than the first stage review submittal as defined in the Location & Design Manual, Volume Three.

Other design values, policies, practices, etc. that are mentioned in this Manual are guidelines intended to promote uniformity and good design. Deviation from these guidelines does not require a formal design exception; however, it may still be necessary to justify or otherwise seek approval from ODOT of the proposed design when deviations are necessary. This should be accomplished through the normal review process.

Ramps do not have continuous design speeds throughout their lengths. However, design exceptions are required for not meeting the lower range for speed related items (see **Section 503.2** for directional and loop ramps). In addition, design exceptions for non-speed related items (e.g., lane width, shoulder width, bridge width, and lateral clearance) are required.

A design exception should be reevaluated if the project has not sold within five years of the approved design exception.

Design exceptions will not be required for projects that do not change or provide the opportunity to change the basic highway cross-section or geometry due to the scope of work; e.g. resurfacing, bridge deck overlays, rest areas, lighting, signing, signalization, fencing, guardrail, slide corrections, etc. A change in the basic highway cross section would include any change to the lane width, shoulder width, pavement cross slope or additional earthwork beyond the graded shoulder. Design Exceptions are required for major rehabilitation projects such as full depth pavement replacement even if they do not change the basic highway geometry; however, full-depth pavement reclamation projects will not require a design exception unless an applicable safety study for the project area documents a historical crash trend or if the project area overlaps with an ODOT Safety HSIP priority location. See **Section 106** for additional information.

Side roads with more than 600’ of approach work do require design exceptions.

105.2 - Design Controlling Criteria that Require a Design Exception

Exceptions must be processed for the following design controlling criteria when they will not be attained: **High Speed Roadways** (Interstate highways, other freeways and roadways with a design speed ≥50 mph)

1. Lane Width
2. Shoulder Width - See Note (A) (B)
3. Horizontal Curve Radius
4. Maximum Grade
5. Stopping Sight Distance (Horizontal and Crest Vertical Curves)

6. Superelevation Rate
7. Vertical Clearance
8. Pavement Cross Slope
9. Design Loading Structural Capacity

Low Speed Roadways (design speed <50 mph)

1. Design Loading Structural Capacity
2. Lane Width (only if required for the National Network, see **Section 105.3** below)

Note (A) - The Design Exception should focus on the Treated Shoulder Width for Interstate, Freeways, Expressways or other Multilane Divided Facilities. All other facilities should focus on the Graded Shoulder Width.

Note (B) - Portions of a shoulder dedicated exclusively to bicycle usage cannot be included in the determination of the shoulder width. In addition to the above geometric design features, design exceptions are also required when existing non-standard bridge parapets and curb configurations are to be retained. For details on non-standard bridge parapets see ODOT Bridge Design Manual or contact the Office of Structural Engineering.

See Section 503.2 for design exception requirements for ramps.

105.3 - National Network (or National Truck Network)

The National Network was established by Congress in 1982 with the Surface Transportation Assistance Act as the network of highways designated for use by large trucks. In Ohio, the National Network consists of all Interstate Routes and the old Federal Aid Primary (FAP) Routes. One of the criteria for the National Network is, “The route consists of lanes designed to be a width of 12 feet or more or is otherwise consistent with highway safety.”

In lieu of providing 12’ lane widths for all lanes on the National Network, a single 12’ lane in each direction can be provided. For low-speed facilities (45 mph design speed or lower) a lane width design exception shall be required only if a single 12’ lane in each direction cannot be provided. For high-speed facilities (50 mph design speeds or higher) a lane

width design exception shall be required if a single 12’ lane in each direction cannot be provided and if the proposed widths for all lanes doesn’t meet the criteria shown in Fig. 301-2, Fig. 301-4 or Fig. 303-1. The emphasis of the lane width design exception should focus on the impacts of the truck traffic such as truck involved crashes (existing and expected), truck off-tracking, etc. Design exceptions are not required for projects that do not change the cross-section or geometry of the roadway as described in Section 105.1 on the National Network unless an applicable safety study for the project area documents a historical crash trend or if the project area overlaps with an ODOT Safety HSIP priority location.

105.4 - Local Projects

On National Highway System (NHS) roadways, local jurisdictions shall use the ODOT Location & Design Manual (L&D) and any appropriate AASHTO publications. On non-NHS roadways, local jurisdictions may use roadway design guides recognized by FHWA and adopted by the local jurisdiction. Design exceptions for Local-let projects should follow the guidelines in the Local Programs manual on Project Development and Design. Design exceptions for Local ODOT-let projects should follow the L&D Manual. The design exception format for both should follow **Section 105.5.1**. All Local project (both Local-let and ODOT-let) design exceptions are approved by the District Capital Programs Administrator. The District Capital Programs Administrator may defer the review and approval of lane width design exceptions on the National Truck Network for local projects to the Administrator of the Office of Roadway Engineering, following the design exception process for non-local projects.

105.5 - Design Exception Documentation and Approval Process

105.5.1 - Documentation Format

The Design exception document must contain at least the following information:

1. The Design Designation for the project.
2. A Title Sheet Location map and a schematic or plan sheet if needed for clarity.
3. The controlling criteria affected by the proposed design exceptions. (As noted in Figure 105-1, normal design criteria must be used as the basis for all design exceptions.)

4. A description of the project.
5. Proposed mitigation for the deviation (if any).
6. Support for the proposed deviation based upon sound engineering practices, cost comparison/ analysis, impact on the environment, the relationship between any crash patterns and the proposed design exception, etc.
7. The GCAT/CAM Tool must be attached. HSM Analysis may also be required by ORE or CPA based upon the nature of the exception request. Refer to the Safety Analysis Guidelines maintained by the Office of Transportation and Economic Development for information to conduct the analysis. The GCAT/CAM Tool should include the three most recent years of complete crash data. The GCAT/CAM Tool analysis area should encompass approximately 250' in advance and past the project limits.

105.5.2 - Processing and Approval Authority

All design exception requests shall be prepared or processed by the District using the electronic submission process found on the Office of Roadway Engineering website. Design exceptions must be prepared and sealed by a licensed professional engineer.

Design Exceptions for local-let projects will be approved by the District Capital Programs Administrator.

Design exceptions for access permit projects are required to be approved by the District Capital Program Administrator.

All non-local project Design Exceptions will be approved by Administrator of the Office of Roadway Engineering.

The Office of Roadway Engineering will coordinate with FHWA for all projects requiring FHWA approval. The Office of Roadway Engineering will be advised in writing of the action taken by the FHWA on Federal oversight projects. The original of such correspondence will be retained by the Office of Roadway Engineering and copies will be forwarded to the District. The District shall advise all involved LPAs and the Office of Estimating.

All exceptions to the 16' vertical clearance standard on rural interstate routes or on a single interstate route through urban areas must be coordinated with the Surface Deployment

and Distribution Command Transportation Engineering Agency (SDDCTEA) by the District. For details refer to the FHWA Memorandum of April 15, 2009.

105.5.3 - Amendments to Design Exceptions

A previously approved design exception may be amended to accommodate additional elements (that do not invalidate previously approved items) by submitting an **addendum** to the design exception. The original may be amended to change previously approved items or remove items that no longer require an exception by submitting a **revision** to the design exception. In either case, the procedure follows the same formatting and approval process as the original design exception.

106 - Data-Driven Safety Analysis

106.1 - General

The purpose of the Data-Driven Safety Analysis (DDSA) is to better understand the safety performance of a project and each of the alternatives. Additionally, it can be used to determine if there is a pattern or concentration of crashes within the project limits that can be reasonably and practically addressed through the inclusion of countermeasures in the project. Factors that can affect countermeasures being “reasonable and practical” include but are not limited to:

1. Cost;
2. Environmental or R/W impacts;
3. Countermeasure work type being compatible with the planned project;
4. Schedule impacts

A minimum safety assessment should be performed in the early phases of project development (i.e. project programming). This will allow schedule, scope, and budget considerations to be accounted for when reasonable and practical countermeasures are to be included in the project. Reference Safety Analysis Guidelines maintained by the Office of Transportation and Economic Development for items included in the minimum safety assessment.

106.2 - Applicable Projects

(DDSA) is applicable to ODOT Let projects, except those whose primary purpose are noted below. While Local Let projects are exempt from performing DDSA, the analysis is strongly recommended to understand the impacts of the project on crash frequency and severity. Typical projects where the DDSA is not applicable:

1. Maintenance projects such as guardrail repair, mowing, striping, signing, RPM's, etc.;
2. Districtwide Bridge and Culvert Preservation Projects*
    A. A Non-Complex Project Safety Analysis must be completed for individual locations that overlap with HSIP priority locations.
3. Pavement surface treatment projects as defined by Section 550 of the Pavement Design Manual;
4. Spot repairs;
5. Slot paving;

106.3 - Data-Driven Safety Analysis

(DDSA) is defined as using real data and established methods to analyze crash and roadway data to estimate the safety impacts of highway projects, assess existing safety conditions, and prioritize locations for safety analysis and/or funding. This allows agencies to target investments with greater confidence that will improve safety on the roadway.

Each project is categorized depending on the project size, complexity, and/or potential impact to the environment. Based on the complexity of the project, one of three safety assessment processes should be followed as part of the project development process to qualitatively assess safety. The analysis process is outlined in the Safety Analysis Guidelines maintained by the Office of Transportation and Economic Development.

A minimum assessment for all projects involves reviewing any applicable studies for the project area, reviewing the ODOT Safety HSIP Priority Lists/Maps, documenting any other safety priorities in the area (state or local), and reviewing historical crash trends.

Where in the opinion of the district there is a noteworthy location or pattern of crashes, a determination should be made if there is a reasonable and practical

countermeasure(s) that can be incorporated into the project and if a safety funding request will be made. There may be situations when there are reasonable and practical countermeasures, but they can't be incorporated into the project due to factors such as schedule or work type incompatibility. In these cases, consideration should be given to creating a standalone safety project to address the high-priority location.

Projects that have an identified location on the HSIP Priority Lists/Maps, regional safety priority maps, or meet safety program funding eligibility criteria, are eligible for supplemental safety funding.

Refer to the Safety Analysis Guidelines maintained by the Office of Transportation and Economic Development for detailed analysis requirements. The Office of Transportation and Economic Development also maintains the SIP Maps, the Statewide HSIP Priority Location Lists and data related to historical crash trends that can be used to conduct a minimum project assessment. Abbreviated Safety Applications should be coordinated through the District Safety Review Team (DSRT) coordinator.

106.4 - Data-Driven Safety Analysis Documentation

Safety should be considered and evaluated for every project. Projects without safety in the purpose and need should be evaluated to determine if there is a reasonable and practical countermeasure(s) that can be incorporated without major impacts to the project scope. Decisions should be documented on the appropriate Safety Analysis Checklist. Refer to the Safety Analysis Guidelines maintained by the Office of Transportation and Economic Development for documentation templates.

DESIGN CONTROL/DESIGN FEATURE RELATIONSHIP

100-1

REFERENCE SECTION
100.1

DESIGN FEATURES	DESIGN CONTROLS				
	Functional Classification	Traffic Data	Terrain	Local	Design Speed
Lane Width (Rural)	X	X	X		X
Lane Width (Urban)	X			X	
Shoulder Width & Type (Rural)	X	X			
Shoulder Width & Type (Urban)	X			X	
Guardrail Offset	X	X			
Degree of Curvature				X	X
Grades	X		X	X	X
Bridge Clearances (Horizontal & Vertical)	X	X			
Stopping Sight Distance					X
Passing & Intersection Sight Distances					X
Decision Sight Distance					X
Superelevation				X	X
Curve Widening					X
Design Speed (Rural)	X	X	X		
Design Speed (Urban)	X			X	
Vertical Alignment	X		X	X	X
Horizontal Alignment				X	X

APPROPRIATE DESIGN CRITERIA GUIDE

105-1

REFERENCE SECTION
105.1 & 105.5.1

Key Highway Design Features Requiring Design Exceptions	Normal Design Criteria (1) (2)	
	Section	Figure
Lane Width	301.1.2 & 303.1	301-2, -4 & 303-1
Shoulder Width	301.2.3, 302.1 & 303.1	301-3, -4, 302-1, -2, -3 & 303-1
Design Loading Structural Capacity	302.1	See Bridge Design Manual
Horizontal Curve Radius	202.3	202-2
Maximum Grade	203.2	203-1
Stopping Sight Distance (Horizontal & Crest Vertical Curve)	201.2	201-1, 201-2, 203-3, -4
Pavement Cross Slope	301.1.5	301-6
Superelevation rate	202.4.1 & 202.4.3	202-3, -7, thru -10
Vertical Clearance	302.1	302-1, -2, -3

1) Normal design criteria must be used as the basis for all design exceptions.

2) AASHTO's 2019 Guidelines for Geometric Design of Low Volume Roads, 2nd Edition can be used on Collectors and Local Streets with ADT's of 2000 or less. Design Exceptions if required in Section 105.2 still need to be provided.

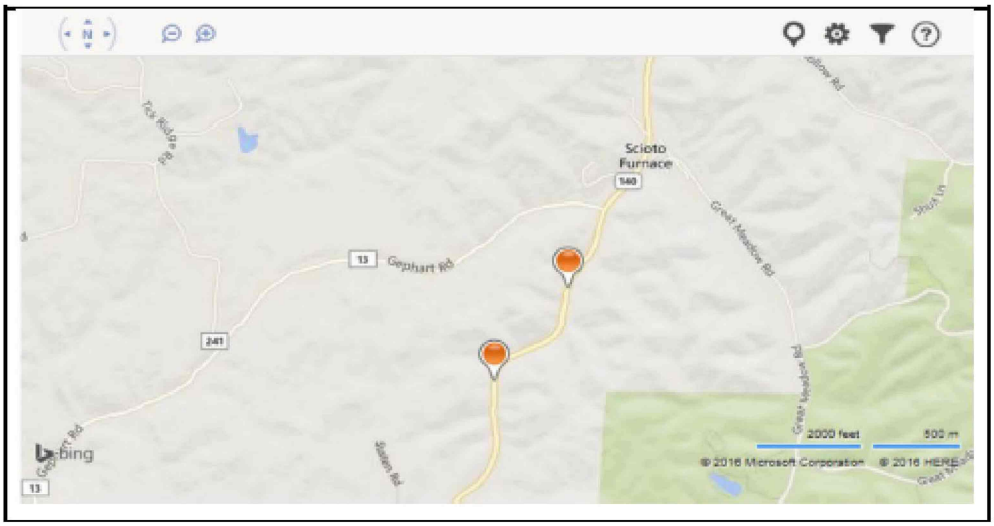
Design Exception Request

SCI-140-7.28

PID: 93794

Letting Type: ODOT-Let

Design Designation				
Current ADT (2016)	4,310		Td	0
Design Year ADT (2035)	4,840		Design Speed	55
Design Hourly Volume (2016)	460		Legal Speed	55
Directional Distribution	0.57		Design Functional Class	5
Trucks (24hr B&C)	0.05		Functional Class Area Type	Urban
			NHS Project	No



Submitted by:

_____

(Engineer of Record)

Engineer of Record Seal

Approved by:

_____

Design Exception Request

SCI-140-7.28

PID: 93794

	Controlling Criteria Identification		
Controlling Criteria	Standard	Existing (a.)	Proposed
Lane Width			
Shoulder Width			
Horizontal Curve Radius	955'	Curve 1-1300'; Curve 2 - 495'	Curve 1 - 1300'; Curve 2 - 495'
Maximum Grade			
SSD (horizontal & Crest Vertical)	495'	Curve 1 - 367'; Curve 2 - 221'	Curve 1 - 381'; Curve 2 - 345'
Superelevation Rate	Curve 1 - 0.074; Curve 2 - 0.080	Curve 1 - 0.042; Curve 2 - 0.077	Curve 1 - 0.050; Curve 2 - 0.079
Pavement Cross Slope			
Vertical Clearance			
Design Loading Structural Capacity			
"Existing" may be N/A (i.e. New alignment or new ramp)			

Project Description

The proposed project will improve safety by widening the lane and shoulder width and improving the stopping sight distance by increasing the guardrail offset through the reverse horizontal curves.

Proposed Mitigation

Oversized curve warning signs, chevrons and arrow signs were installed in 2011 and will be reinstalled with this project. Flashing beacons will be installed on the two curve signs and the two arrow signs for Curve 2.

Support for Deviation (Benefit-cost, R/W, Environmental, Constructability, Coordination with Other Projects, Relationship between any crash patterns and proposed design exception, etc.):

The lane width is being increased from 11.1' to 12' and the paved shoulders are being increased from 2.8' to 4'. To correct the horizontal alignment, the roadway would need to be relocated through a sizable hill with cuts as deep as 31'.

200 - Horizontal & Vertical Design

This section provides a brief discussion together with several figures of design criteria needed to properly design horizontal and vertical alignments. More detailed information can be found in the 2018 edition of **A Policy on Geometric Design of Highways and Streets** (AASHTO Green Book) and the **AASHTO Guidelines for Geometric Design of Low-Volume Roads (2nd Edition 2019)**.

201 - Sight Distance

201.1 - General

A primary feature in highway design is the arrangement of the geometric elements so that sufficient sight distance is provided for safe and efficient operation. The most important sight distance considerations are: distance required for stopping, distance required for operation at intersections, distance required for passing vehicles and distance needed for making decisions at complex locations.

- **Stopping Sight Distance (SSD)** - the cumulative distance traversed by a vehicle from the instant a motorist sights an unexpected object in the roadway, applies the brakes, and is able to bring the vehicle to a stop.
- **Intersection Sight Distance (ISD)** - the distance a motorist should be able to see other traffic operating on the intersecting roadway in order to enter or cross the roadway safely and to avoid or stop short of any unexpected conflicts in the intersection area.
- **Passing Sight Distance (PSD)** - the distance a motorist should be able to observe oncoming traffic on a two-lane, two-way road in order to pass a vehicle safely.
- **Decision Sight Distance (DSD)** - the distance needed for a motorist to detect, recognize, select, initiate and complete an appropriate course of action for an unexpected or otherwise difficult- to-perceive condition in the roadway.

When evaluating sight distance, the two most critical features to be considered are the height of eye and the height of the object. The driver’s height of eye remains constant at 3.5 ft. for each of the sight distance categories. The height of the object, on the other hand, varies between 2 ft. and 3.5 ft. The 2 ft. object height, used for the decision and stopping

sight distances, represents the taillight of the typical passenger vehicle. Research has shown that object heights below 2 ft. would result in longer crest vertical curves without providing documented safety benefits. The 3.5 ft. height, used for the intersection and passing sight distances, represents the portion of the vehicle that needs to be visible for another driver to recognize that vehicle.

201.2 - Stopping Sight Distance

Stopping sight distance is the sum of two distances:

1. Brake Reaction Distance - The distance traversed by the vehicle from the instant the driver sights an object necessitating a stop to the instant the brakes are applied. 2.5 seconds is used for the break reaction time.
2. Braking distance - the distance needed to stop the vehicle from the instant brake application begins. 11.2 ft/s2 is used for the deceleration rate.

Figure 201-1 lists the recommended sight distance values for the given design speeds along with the corresponding equation.

201.2.1 - Horizontal Sight Distance

The sight distance on horizontal curves may be restricted by obstructions on the inside of a curve, such as bridge piers, buildings, median barriers, guardrail, cut slopes, etc. Figure 201-2 shows the relation of sight distance, horizontal curvature, line of sight, and obstruction offset. In using this figure, the designer should enter the required stopping sight distance from Figure 201-1 and the degree of curvature or radius [curve radius]. Where these two lines intersect, the offset of the obstruction needed to satisfy the sight distance requirements may be read from the curved lines.

Where the horizontal sight distance is restricted by a cut slope in the inside of the curve, the offset shall be measured to a point on the cut slope that is at the same elevation as the roadway. This would allow a line of sight which is 3.5 ft. above the roadway to pass over a cut slope with 2.75 ft. of vegetative growth and view a 2.0 ft. high object on the far side.

When a combination of spirals, tangents and/or curves is present, the horizontal sight distance should be determined graphically.

201.2.2 - Vertical Stopping Sight Distance

The sight distance on crest vertical curves is based on a driver's ability to see a 2.0 ft. high object in the roadway without being blocked out by the pavement surface. The height of eye for the driver used in the calculation is 3.5 ft. See Figures 203-3 & 203-4.

The sight distance on sag curves is dependent on the driver's ability to see the pavement surface as illuminated by headlights at night. The height of headlight is assumed to be 2.0 ft., the height of object 0" and the upward divergence angle of the headlight beam is assumed to be 1º00'. See Figure 203-6 & 203-7.

201.3 - Intersection Sight Distance (ISD)

Intersections generally have a higher potential for vehicular conflict than a continuous section of roadway due to the occurrence of numerous traffic movements. Providing adequate sight distance at the intersection can greatly reduce the likelihood of these conflicts.

The driver of a vehicle approaching an intersection should have an unobstructed view of the entire intersection and sufficient lengths along the intersecting highway to permit the driver to anticipate and avoid potential collisions. When entering or crossing a highway, motorists should be able to observe the traffic at a distance that will allow them to safely make the desired movement.

The methods for determining sight distance needed by drivers approaching an intersection are based on the same principles as stopping sight distance, but incorporate modified assumptions based on observed driver behavior at intersections.

To enhance traffic operations, intersection sight distance should be provided at all intersections. If intersections sight distance cannot be provided due to environmental or right-of-way constraints, then as a minimum, the stopping sight distance for vehicles on the major road should be provided. By providing only stopping sight distance, this will require the major-road vehicle to stop or slow down to accommodate the maneuver of the minor-road vehicle. If the intersection sight distance cannot be attained, additional safety measures should be provided. These may include, but are not limited to, advance warning signs and flashers and/or reduced speed limit zones in the vicinity of the intersection.

201.3.1 - Sight Triangles

Specified areas along intersection approach legs and across their included corners should be clear of obstructions that might block a driver's view of potentially conflicting vehicles. These unobstructed areas are known as sight triangles (see Figure 201-4). The waiting vehicle is assumed to be located at a minimum of 14.5 ft. and preferably 18.0 ft. from the through road edge of traveled way. The position of the waiting vehicle is the vertex of the sight triangle on the minor road, otherwise referred to as the decision point. It represents the typical position of the minor-road driver's eye when a vehicle is stopped relatively close to the major road. The left edge of the moving vehicle on the through road is assumed to be a ½ lane width for vehicles approaching from the left, or 1½ lane widths for vehicles approaching from the right. The design speed of the through road is used to select the appropriate ISD length (see Figure 201-5). The dimension "b" in Figure 201-4 is the ISD length.

The provision of sight triangles allows the driver on the major road to see any vehicles stopped on the minor road approach and to be prepared to slow or stop, if necessary.

201.3.1.1 - Identification of Sight Obstructions with Sight Triangles

The profiles of the intersecting roadways should be designed to provide the recommended sight distances for drivers on the intersection approaches. Within a sight triangle, any object at a height above the elevation of the adjacent roadways that would obstruct the driver's view should be removed or lowered, if practical. Particular attention should be given to the evaluation of sight triangles at interchange ramps or crossroad intersections where features such as bridge railings, piers, and abutments are potential sight obstructions.

The determination of whether an object constitutes a sight obstruction should consider both the horizontal and the vertical alignment of both intersecting roadways, as well as the height and position of the object. In making this determination, it should be assumed that the driver's eye is 3.5 ft. above the roadway surface and the object to be seen is 3.5 ft. above the surface of the roadway. When the object height and the driver's eye are equivalent, the intersection sight distances become reciprocal (i.e., if one driver can see another vehicle, then the driver of that vehicle can also see the first vehicle).

201.3.2 - Intersection Control

The recommended dimensions of the sight triangles vary with the type of traffic control used at an intersection, because different types of control impose different legal constraints on drivers and, therefore, result in different driver behavior.

At signalized intersections and all-way stop control, the first vehicle stopped on one approach should be visible to the driver of the first vehicle stopped on each of the other approaches. Left turning vehicles should have sufficient sight distance to select gaps in oncoming traffic and complete left turns. Generally, sight distances are not needed for signalized intersections.

The most critical intersection control is the stop control on the minor roadway. Sight triangles for intersections with stop control on the minor road should be considered for three situations:

1. Left turns from the minor road
2. Right turns from the minor road
3. Crossing the major road from the minor road approach.

201.3.2.1 - Left Turn from the Minor Road

The intersection sight distance along the major road is determined by the following formula:

English Units: $ISD = 1.47x\ V_{major} \times t_g$

- ISD = intersection sight distance (length of the leg of sight triangle along the major road) (ft)
- V_{major} = design speed of major road (mph)
- t_g = time gap for minor road vehicle to enter the major road (sec.)

The design values for intersection sight distance for passenger cars are shown in Figure 201-5.

The values for t_g can vary (see Figure 201-5) due to deviations of the intersection approach grade, truck usage, and the numbers of lanes of the facility. The values provide sufficient time for the minor-road vehicle to accelerate from a stop and complete a left turn without unduly interfering with major-road traffic operations. Where substantial volumes of heavy vehicles enter the major road (such as a ramp terminal), the t_g value for the single-unit or combination truck values should be considered.

Sight distances for left turns at divided highway intersections have special considerations. If the design vehicle can be stored in the median with adequate clearance to the through lanes, a sight triangle to the right for left turns should be provided for that design vehicle turning left from the median roadway. Where the median is not wide enough to store the design vehicle, a sight triangle should be provided for that design vehicle to turn left from the minor-road approach.

Also, the median width should be considered in determining the number of lanes to be crossed. The median width should be converted to equivalent lanes.

201.3.2.2 - Right Turn from the Minor Road

The intersection sight distance for right turns is determined using the same methodology as that used for left turns, except that the time gaps differ. The time gap for right turns is decreased by 1.0 second. Also, the sight triangle for traffic approaching from the left should be used for right turns onto a major road. The design values for intersection sight distance for passenger cars are shown in Figure 201-5.

201.3.2.3 - Crossing Maneuver from the Minor Road

In most cases, the sight distance provided by the sight triangles (for right or left turns) are adequate for a minor road vehicle to cross a major roadway. However, if the following situations exist, the sight distance for a crossing maneuver should, in of itself, be checked:

1. Where left and or right turns are not permitted from a particular approach and the crossing maneuver is the only legal maneuver
2. Where the crossing vehicle would cross the equivalent of more than six lanes
3. Where substantial volumes of heavy vehicles cross the highway and steep grades that might slow the vehicle while its back portion is still in the intersection are present

on the departure roadway on the far side of the intersection

The formula for the sight distance at a crossing maneuver is the same as that for right turns. The time gap adjustments listed in Figure 201-5 must be used to modify the formula for a crossing maneuver.

201.3.3 - Vertical ISD

Also shown on Figure 201-5 are "K" curvature rates for crest vertical curves based on ISD. The K rates are derived using the height of eye as 3.50 ft. and height of object as 3.50 ft. Appropriate equations are shown on Figure 201-5.

If a road or drive intersection occurs on or near a crest vertical curve, the length of curve should be at least as long as that calculated from the K rate for ISD or the K rate for stopping sight distance, whichever is greater.

In some areas, the sight distance will be limited due to projections above the pavement surface, such as raised medians, curb and sidewalks. An illustration of this type of obstruction is shown in Figure 201-4, Diagram B, where the left sight distance is limited by a portion of the bridge abutment. Locations such as this should be checked graphically and corrected by lengthening the vertical curve, eliminating the obstruction or moving the intersection.

201.4 - Passing Sight Distance

Figure 201-3 lists the distance required for passing an overtaken vehicle at various design speeds. These distances are applicable to two-lane roads only. It is important to provide adequate passing sight distance for as much of the project length as possible to compensate for missed opportunities due to oncoming traffic in the passing zone.

Figure 201-3 also contains "K" curvature rates for crest vertical curves based on passing sight distance. The K rates are derived using a 3.50 ft. height of eye and a 3.50 ft. height of object. Appropriate equations are included on Figure 201-3.

201.4.1 - Available Passing Sight Distance

On 2-lane highways with design hourly volume (DHV) exceeding 400, the designer should investigate the effect of available passing sight distance on highway capacity using the

procedures contained in the current edition of TRB **Highway Capacity Manual**. The designer should select the level of service to be used for design in accordance with Figure 301-1.

If the available passing sight distance restricts the capacity from meeting the design level of service, adjustments should be made to the profile to increase the available passing sight distance. If, after making all feasible adjustments to the profile, capacity is still restricted below the design level of service due to the lack of sufficient passing sight distance, consideration should be given to providing passing lane sections or constructing a divided multi-lane facility.

201.5 - Decision Sight Distance (DSD)

Although stopping sight distance is usually sufficient to allow reasonably competent and alert drivers to come to a hurried stop under ordinary circumstances, it may not provide sufficient visibility distances for drivers when information is difficult to perceive, or when unexpected maneuvers are required. In these circumstances, decision sight distance provides the greater length needed by drivers to reduce the likelihood for error in either information reception, decision making, or control actions.

The following are examples of locations where decision sight distance should be provided:

- entrance ramps and exit ramps at interchanges
- diverging roadway terminals
- changes in cross section such as toll plazas and lane drops
- and areas of concentrated demand where there is apt to be "visual noise" (i.e., where sources of information compete, as those from roadway elements, traffic, traffic control devices, and advertising signs).

The decision sight distances in Figure 201-6:

- provide values for sight distances that are appropriate at critical locations
- serve as criteria in evaluating the suitability of the available sight distances at these critical locations.

The decision sight distance is measured from a point on the entrance ramp where the driver, on the entrance ramp, has an unobstructed view of the mainline to where the lane width becomes less than 10 ft. and the driver must merge. This is the distance that the driver merging from the entrance ramp must decide whether they can safely merge into the mainline traffic. This distance should also be unobstructed for the mainline driver to react to the vehicle on the entrance by either a lane or speed change.

For an exit ramp, the decision sight distance is where the driver has an unobstructed view from the mainline roadway to the physical gore at an exit ramp.

It is recommended that decision sight distances be provided at critical locations or that critical decision points be moved to locations where sufficient decision sight distance is available. If it is not practical to provide decision sight distance because of horizontal or vertical curvature constraints or if relocation of decision points is not practical, special attention should be given to the use of suitable traffic control devices for providing advance warning of the conditions that are likely to be encountered.

The decision sight distances listed in Figure 201-6 vary depending on whether the location is on a rural or urban road and on the type of avoidance maneuver required to negotiate the location properly. For example, the recommended decision sight distance for a rural entrance ramp would be found in the avoidance maneuver C column opposite the appropriate design speed for the ramp location in question.

202 - Horizontal Alignment

202.1 - General

A horizontal change in direction should, as far as economically feasible, be accomplished in a safe and comfortable manner. In addition to sight distance requirements, the most important design features to horizontal alignment design are:

- degree of curve (curve radius)
- superelevation
- spirals

202.2 - Maximum Centerline Deflection without Horizontal Curve

Figure 202-1 lists the maximum deflection angle which may be permitted without the use of a horizontal curve. The angle varies with the design speed of the facility.

202.3 - Degree of Curve (Curve Radius)

The maximum degree of curve (minimum curve radius) is a limiting value of curvature for a given design speed and a maximum rate of superelevation. Figure 202-2 shows this relationship.

202.4 - Superelevation

202.4.1 - Superelevation Rate

Superelevation rates for horizontal curves vary with location (urban/rural), degree of curvature (curve radius), and design speed.

Recommended superelevation rates for horizontal curves are shown in Figures 202-7, 202-8, 202-9, 9a and 202-10. The rates in Figure 202-7 apply to all rural highways and are based on a maximum superelevation rate of 0.08. Figure 202-8 contains the rates for high-speed urban highways (design speeds of 50 mph or greater). These are based on a maximum rate of 0.06. Figure 202-10 is an extension of Figure 202-8 in that it provides superelevation rates for curves with design speeds of 25-45 mph based on the maximum rate of 0.06. This table is to be used only for ramps or other interchange connector roadways in urban areas where horizontal alignment constraints preclude a higher design speed. The rates for low speed urban highways (45 mph or less) are contained in Figures 202-9 and 9a and are based on a maximum rate of 0.04

The table rates are derived by first calculating the maximum degree of curvature [minimum curve radius] for the design speed and assigning the maximum rate of superelevation to this curve. The maximum rates for flatter curves with the same design speed are then derived using AASHTO Method 5 (Figures 202-7, 202-8 and 202-10) or AASHTO Method 2 (Figures 202-9 and 9a) as described in the AASHTO Green Book under "Horizontal Alignment".

In attempting to apply the recommended superelevation rates for low-speed urban streets (Figures 202-9 and 9a) in built-up areas, various factors may combine to make these rates impractical to obtain. These factors would include wide pavements, adjacent development, drainage conditions, and frequent access points. In such cases, curves may

be designed with reduced or no superelevation, although crown removal is a recommended minimum.

A design exception for superelevation rate is required whenever the superelevation rate required by Figures 202-7 through 202-10 is not provided. A design exception for superelevation rate will not be required if a higher superelevation rate than what is required by Figures 202-7 through 202-10 is provided as long as the respective maximum superelevation rate (0.08, 0.06 or 0.04) is not exceeded. Prior to the current update of this Manual, the maximum superelevation rate for rural highways was 0.083. A design exception for superelevation rate will not be required for existing rural highways that provide a superelevation rate greater than 0.08 but less than or equal to 0.083.

202.4.2 - Effect of Grades on Superelevation

On long and fairly steep grades, drivers tend to travel somewhat slower in the upgrade direction and somewhat faster in the downgrade direction than on level roadways. In the case of divided highways, where each pavement can be superelevated independently, or on one-way roadways, such as ramps, this tendency should be recognized to see whether some adjustment in the superelevation rate would be desirable and/or feasible. On grades of 4 percent or greater with a length of 1000 ft. or more and a superelevation rate of 0.06 or more, the designer may adjust the superelevation rate by assuming a design speed which is 5 mph less in the upgrade direction and 5 mph higher in the downgrade direction, providing that the assumed design speed is not less than the legal speed. On two-lane, two-way roadways and on other multi-lane undivided roadways, such adjustments are less feasible, and should be disregarded.

202.4.3 - Maximum Curvature Without Superelevation (Minimum Curve Radius Without Superelevation)

Figure 202-3 gives the maximum degree of curvature [minimum curve radius] which does not require superelevation based on the design speed and the rural/urban condition. This figure should be used in conjunction with Figures 202-7, 202-8, and 202-9 to determine at what point in the “ed” columns that superelevation becomes a design consideration. The corresponding data for Figure 202-10 is contained on the figure.

202.4.4 - Superelevation Methods

Figure 202-5 shows four methods by which superelevation is developed leading into and coming out of horizontal curves.

- Method 1 involves revolving the pavement about the centerline and is the most commonly used method. This method could be applied to multi-lane divided roadway sections where the divided segments are not crowned in a normal section. In this case, the median pavement edge acts as the "centerline".
- Method 2 shows the pavement being revolved about the inner edge of traveled way and Method 3 uses the outer edge of traveled way as a rotation point. Both of these methods are used on a multi-lane divided roadway where the divided segments are crowned in a normal section. Since the control point for revolving the pavement is the median pavement edge, Method 2 would apply to the outer lanes and Method 3 would apply to the inner lanes. Method 2 is also used on undivided roadways where drainage problems preclude the use of Method 1.
- Method 4 revolves the pavement having a straight cross slope about the outside edge of traveled way. Method 4 would apply to single-lane or multi-lane ramps or roadways that are not crowned.

In reference to the above discussion on the superelevation of divided roadways, it is always preferable to use the median edge of traveled way as the rotation point. This greatly reduces the amount of distortion in grading the median area.

202.4.5 - Superelevation Transition

The length of highway needed to change from a normal crown pavement section to a fully superelevated pavement section is referred to as the superelevation transition. The superelevation transition is divided into two parts - the tangent runout and the superelevation runoff.

The tangent runout (”L_t”) is the length required to remove the adverse pavement cross slope. As is shown on Method 1 of Figure 202-5, this is the length needed to raise the "outside" edge of traveled way from a normal slope to a half-flat section (cross section A to cross section B of Figure 202-5, Method 1).

The superelevation runoff ("L_r") is the length required to raise the "outside" edge of traveled way from a "half flat" section to a fully superelevated section (cross section B to cross section E of Figure 202-5, Method 1). The length of transition required to remove the pavement crown is the distance between cross section A and cross section C Figure 202-5 and is generally equal to twice the ”L_t” distance.

The minimum superelevation transition length is determined by multiplying the edge of traveled way correction by the equivalent slope rate ("G") shown on Figure 202-4. The rate of change of superelevation should be constant throughout the transition. The values for "L_r" given in Figures 202-7, 202-8 and 202-9 are based on two 12-foot lanes revolved about the centerline. "L_r" in Figure 202-10 is based on one 16-foot lane revolved about the edge of traveled way. Use the equations provided on Figure 202-4 to determine “L_r” for cases involving other lane widths or where more than one lane is being revolved about the centerline or baseline.

Figures 202-5a through 202-5d have been provided to show the designer how to develop the superelevation transitions for a two-lane undivided highway (Figure 202-5a), a four-lane divided highway (Figure 202-5b) and a six-lane divided highway (Figures 202-5c & d). Figure 202-5c could also be used for a four-lane divided highway with future median lanes and Figure 202-5d could also be used for a four-lane divided highway with future outside lanes.

202.4.6 - Superelevation Position

Figures 202-5a through 202-5d show the recommended positioning of the proposed superelevation transition in relationship to the horizontal curve.

For those curves with spirals, the transition from adverse crown removal to full superelevation shall occur within the limits of the spiral. In other words, the spiral length shall equal the "L_r" value.

For simple curves without spirals, the "L_r" transition shall be placed so that 50 percent to 70 percent of the maximum superelevation rate is outside the curve limits (P.C., P.T.). It is recommended that, whenever possible, 2/3 of the full superelevation rate be present at the P.C. and P.T. In addition, whenever possible, full superelevation should be maintained for at least 1/3 the length of the curve.

202.4.7 - Profiles and Elevations

Breakpoints at the beginning and end of the superelevation transition should be rounded to obtain a smooth profile. One suggestion is to use a "vertical curve" on the edge of traveled way profile with a length in feet equal to the design speed in mph (i.e., 45 ft. for 45 mph).

The final construction plans should have superelevation tables or pavement details showing the proposed elevations at the centerline, edges of traveled way, and if applicable, lane lines or other breaks in the cross slope. Pavement or lane widths should be included where these widths are in transition.

Edge of traveled way profiles should be plotted to an exaggerated scale within the limits of the superelevation transition to check calculations and to determine the location of drainage basins. Adjustments should be made to obtain smooth profiles. These profiles should be submitted as part of the Stage 1 submission in order to facilitate review of the proposed data. Special care should be used in determining edge elevations in a transition area when the profile grade is on a vertical curve.

202.4.8 - Superelevation Between Reverse Horizontal Curves

Figure 202-6 illustrates schematically two methods for positioning the superelevation transition between two reverse horizontal curves. In both diagrams each curve has its own "L_r" value (L_{r1}, L_{r2}) depending on the degree of curvature, and the superelevation is revolved about the centerline.

The first (top) diagram involves two simple curves. In the case of new or relocated alignment, the P.T. of the first curve and P.C. of the second curve should be separated by enough distance to allow a smooth continuous transition between the curves at a rate not exceeding the "G" value in the table on Figure 202-4 for the design speed. This requires that the distance be not less than 50 percent nor greater than 70 percent of $L_{r1} + L_{r2}$. Two-thirds is the recommended portion. When adapting this procedure to existing curves where no alignment revision is proposed, the transition should conform as closely as possible to the above criteria. These designs will be reviewed on a case by case basis.

The second (or lower) diagram involves two spiral curves. Where spiral transitions are used, the S.T. of the first curve and the T.S. of the second curve may be at, or nearly at, the same point, without causing superelevation problems. In these cases, the crown

should not be re-established as shown in Figure 202-5, but instead, both edges of traveled way should be in continual transition between the curves, as shown in Figure 202-6.

202.5 - Spirals

The combination of high speed and sharp curvature leads to longer transition paths, which can result in shifts in lateral position and sometimes actual encroachment on adjoining lanes. Spirals make it easier for the driver to keep the vehicle within its own lane. Spirals are to be used on projects involving new alignment or substantial modifications to the existing alignment based on the maximum degree of curve as shown in Figure 202-11. The length of the spiral should be equal to or greater than the superelevation runoff length "L_r" for the curve, as determined in **Section 202.4.5**. This section also discussed the role of the spiral in attaining proper superelevation for the curve.

The above criterion for using spirals is not intended to discourage their use in other design situations. In fact, spirals are recommended for use as a good mitigation feature in achieving full superelevation regardless of design speed or degree of curvature (curve radius). See Figure 1303-2 of the Location and Design Manual, Volume 3, for more details on spiral curve elements and layout.

203 - Vertical Alignment

203.1 - General

In addition to sight distance requirements, design features most important to vertical alignment design are grades and vertical curves.

203.2 - Grades

203.2.1 - Maximum Grades

Maximum percent grades based on functional classification, terrain and design speed are shown in Figure 203-1. The maximum design grade should be used infrequently, rather than a value to be used in most cases.

203.2.2 - Minimum Grades

Flat and level grades on uncurbed pavements are virtually without objection when the pavement is adequately crowned to drain the surface laterally. With curbed pavements,

sufficient longitudinal grades should be provided to facilitate surface drainage. The preferred minimum grade for curbed pavements is 0.5 percent, but a grade of 0.3 percent may be used where there is a high-type pavement accurately crowned and supported on firm subgrade.

203.2.3 - Critical Lengths of Grades

Freedom and safety of operation on 2-lane highways are adversely affected by heavily loaded vehicles operating on grades of insufficient lengths to result in speeds that could impede following vehicles.

The term “critical length of grade” is used to describe the maximum length of a designated upgrade on which a loaded truck can operate without an unreasonable reduction in speed.

The length of any given grade that will cause the speed of a typical heavy truck (200 lb/hp) to be reduced by various amounts below the average running speed of all traffic is shown graphically in Figure 203-1a. The curve showing a 10-mph speed reduction is used as the general design guide for determining the “critical lengths of grade”.

If after investigation of the project grade line, it is found that critical length of grade must be exceeded, an analysis of the effect of long grades on the level of service should be made. Where speeds resulting from trucks climbing up long grades are calculated to fall within the range of service level D, or lower, consideration should be given to constructing added uphill lanes on critical lengths of grade. When uphill lanes are added for truck traffic, the lane should extend a sufficient distance past the crest of the hill to allow truck traffic to obtain a reasonable speed before being required to merge into the through lanes.

Where the length of added lanes needed to preserve the recommended level of service on sections with long grades exceeds 10 percent of the total distance between major termini, consideration should be given to the ultimate construction of a divided multi-lane facility.

203.3 - Vertical Curves

203.3.1 - General

A vertical curve is used to provide a smooth transition between vertical tangents of different slope rates. It is a parabolic curve and is usually centered on the intersection point of the vertical tangents.

One of the basic principles of parabolic curves is that the rate of change of grade at successive points on the curve is a constant amount for equal increments of horizontal distance. The total length (L) of a vertical curve divided by the algebraic difference in its tangent grades (A) reflects the distance along the curve at any point to effect a 1 percent change in gradient and is, therefore, a measure of curvature. The rate L/A, termed "K", is useful in determining minimum lengths of vertical curves for the various required sight distances.

203.3.2 - Grade Breaks

The maximum break in grade permitted without using a vertical curve is shown in Figure 203-2. The maximum grade change is based on comfort control and varies with the design speed.

203.3.3 - Crest Vertical Curves

The major control for safe operation on crest vertical curves is the provision for ample sight distances for the design speed.

Figure 203-3 includes "K" values for crest vertical curves along with other appropriate equations.

Figure 203-4 shows the relationship between the length of crest vertical curve to the stopping sight distance.

In addition to being designed for safe stopping sight distance, crest vertical curves should be designed for comfortable operation and a pleasing appearance. Accordingly, the length of a crest vertical curve in feet should be, as a minimum, 3 times the design speed in mph.

203.3.4 - Sag Vertical Curves

For sag vertical curves the primary design criteria is headlight sight distance. When a vehicle traverses an unlighted sag vertical curve at night, the portion of highway lighted ahead is dependent on the position of the headlights and the direction of the light beam. For overall safety on highways, the required headlight sight distance is assumed to be equal to stopping sight distance. Based on a headlight height of 2 ft., and a 1 degree upward divergence of the light beam, equations showing the relationship of curve length,

algebraic grade difference, and stopping sight distance are included on Figure 203-6. Figure 203-7 shows this same relationship in graphic form.

It should be noted that, for sag curves, when the algebraic difference of grades is 1.75 percent or less, stopping sight distance is not restricted by the curve. In these cases the formula on Figure 203-6 will not provide meaningful answers.

Minimum lengths of sag vertical curves are necessary to provide a pleasing general appearance to the highway. Accordingly, the length of sag vertical curves in feet in should be, as a minimum, 3 times the design speed.

203.3.5 - Tangent Offsets for Vertical Curves

For the designer's convenience,Figure 203-8, showing tangent offsets, is included.

204 - Horizontal and Vertical Alignment Considerations

204.1 - General

There are many controls to consider when designing horizontal and vertical alignments. These controls are separated into horizontal, vertical and horizontal/vertical coordination. It would be virtually impossible to meet each of these. Some even tend to conflict, and compromises will have to be made. The considerations listed in each category are guidelines and suggestions to assist the designer in obtaining a more optimal design.

204.2 - Horizontal Considerations

- Alignment should be as directional as possible while still being consistent with topography and the preservation of developed properties and community values.
- Use of maximum degree of curvature [minimum curve radius] should be avoided wherever possible.
- Consistent alignment should be sought.
- Curves should be long enough to avoid the appearance of a sudden or abrupt change in direction.
- Tangents and/or flat curves should be provided on high, long fills.

- Compound curves should only be used with caution.

204.3 - Vertical Considerations

- A smooth grade with gradual changes consistent with the type of facility and character of terrain should be strived for.
- The "roller-coaster" or the "hidden-dip" type of profile should be avoided.
- Undulating gradelines involving substantial lengths of steeper grades should be appraised for their effect on traffic operation since they may encourage excessive truck speeds.
- Broken-back gradelines (two crest or sag vertical curves separated by short tangent grade) generally should be avoided.
- Special attention should be given on curbed sections to drainage where vertical curves having a K value in excess of 167 are used.
- It is preferable to avoid long sustained grades by breaking them into shorter intervals with steeper grades at the bottom.

204.4 - Coordination of Horizontal and Vertical Alignments

Curvature and grades should be properly balanced. Normally horizontal curves will be longer than vertical curves.

- Vertical curvature superimposed on horizontal curvature is generally more pleasing. P.I.'s of both vertical and horizontal curves should nearly coincide.
- Sharp horizontal curvature should not be introduced at or near the top of a pronounced crest vertical curve or at or near the low point of a pronounced sag vertical curve.
- On two-lane roads, long tangent sections are desirable to provide adequate passing sections.
- Horizontal and vertical curves should be as flat as possible at intersections.
- On divided highways the use of variable median widths and separate horizontal and vertical alignments should be considered

- In urban areas, horizontal and vertical alignments should be designed to minimize nuisance factors.
- These might include directional adjustment to increase buffer zones and depressed roadways to decrease noise.
- And vertical alignments may often be adjusted to enhance views of scenic areas.

STOPPING SIGHT DISTANCE

201-1

REFERENCE SECTION
201.2 & 201.2.1

HEIGHT OF EYE 3.50′

HEIGHT OF OBJECT 2.00′

$$SSD = 1.47Vt + 1.075\frac{V^2}{a}$$

SSD = stopping sight distance, ft;
t = brake reaction time, 2.5s;
V = design speed, mph;
a = deceleration rate, 11.2ft/s^2

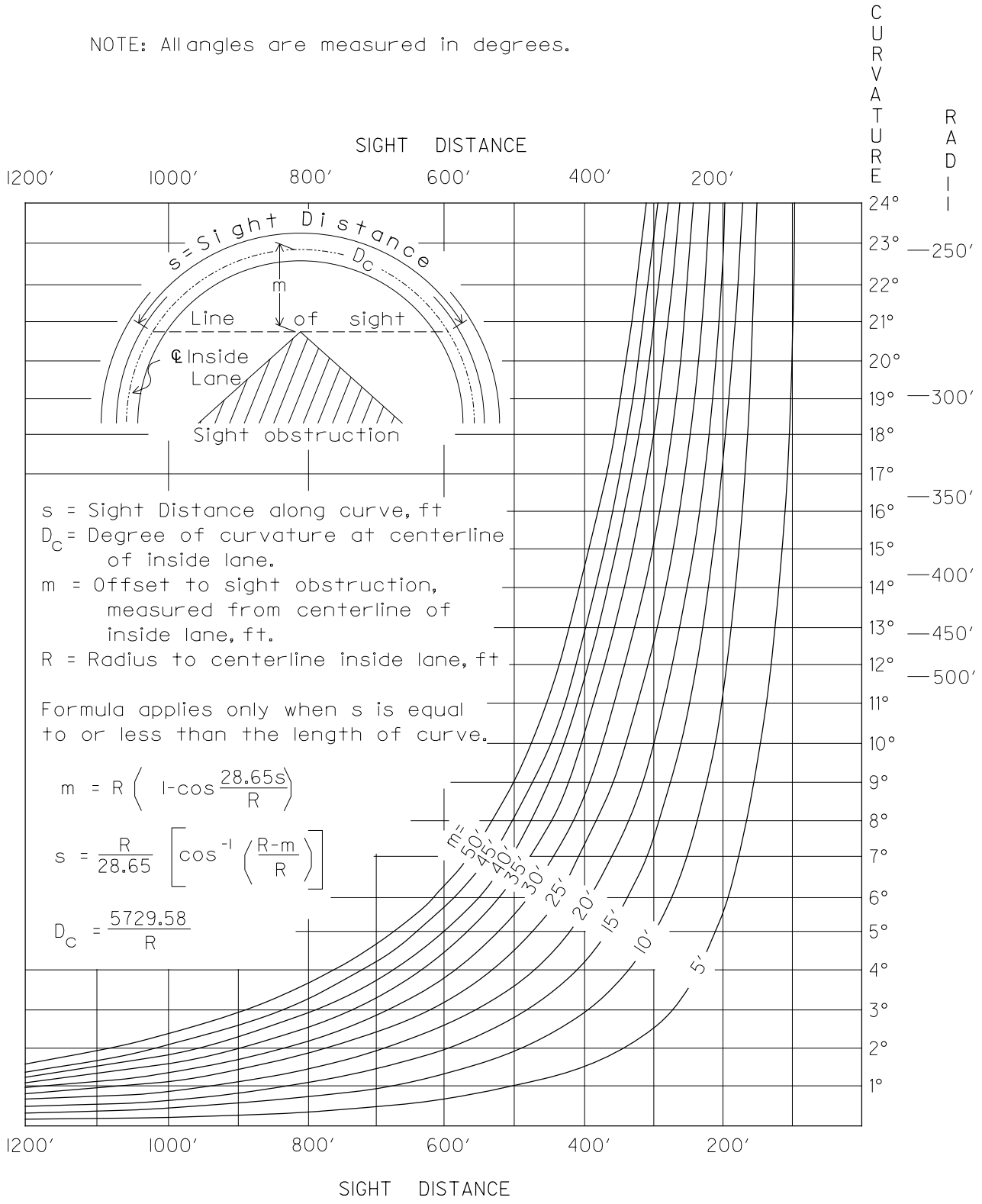
DESIGN SPEED (mph)	DESIGN SSD (feet)	DESIGN SPEED (mph)	DESIGN SSD (feet)
20	115	48	400
21	120	49	415
22	130	50	425
23	140	51	440
24	145	52	455
25	155	53	465
26	165	54	480
27	170	55	495
28	180	56	510
29	190	57	525
30	200	58	540
31	210	59	555
32	220	60	570
33	230	61	585
34	240	62	600
35	250	63	615
36	260	64	630
37	270	65	645
38	280	66	665
39	290	67	680
40	305	68	695
41	315	69	715
42	325	70	730
43	340	71	745
44	350	72	765
45	360	73	780
46	375	74	800
47	385	75	820

HORIZONTAL SIGHT DISTANCE

201-2

REFERENCE SECTION
201.2.1

NOTE: All angles are measured in degrees.



s = Sight Distance along curve, ft
D_C = Degree of curvature at centerline of inside lane.
m = Offset to sight obstruction, measured from centerline of inside lane, ft.
R = Radius to centerline inside lane, ft

Formula applies only when s is equal to or less than the length of curve.

$$m = R\left(1-\cos\frac{28.65s}{R}\right)$$

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

$$D_C = \frac{5729.58}{R}$$

When a combination of spirals, tangents and/or curves are present, the horizontal sight distance should be determined graphically.

MINIMUM PASSING SIGHT DISTANCE

201-3

REFERENCE SECTION
201.4

HEIGHT OF EYE 3.50' - HEIGHT OF OBJECT 3.50'

DESIGN SPEED (mph)	PASSING SIGHT DISTANCE (PSD)	
	Minimum PSD (ft.)	K-Crest Vert. Curv.
20	400	57
25	450	72
30	500	89
35	550	108
40	600	129
45	700	175
50	800	229
55	900	289
60	1000	357
65	1100	432
70	1200	514

Using: S = Minimum Passing Sight Distance
L = Length of Crest Vertical Curve
A = Algebraic Difference in Grades (%), Absolute Value
K = Rate of Vertical Curvature

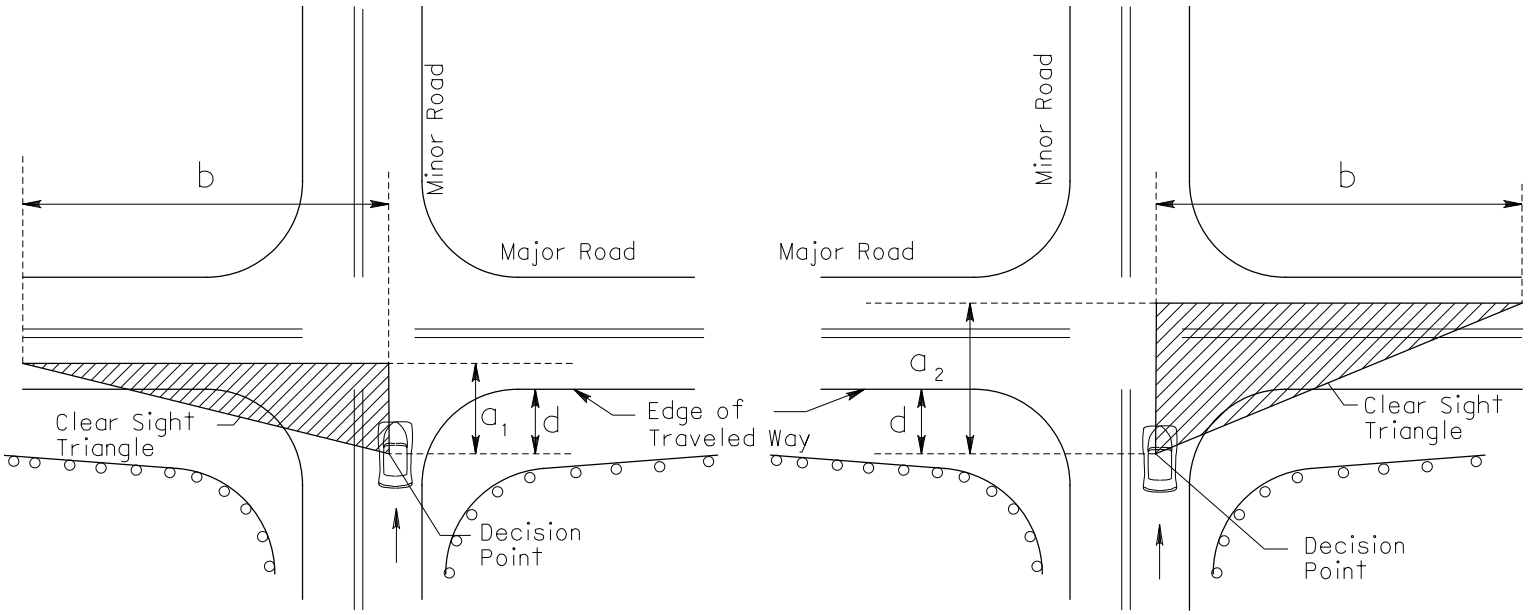
- For a given design speed and an "A" value, the calculated length "L" = K x A

- To determine "S" with a given "L" and "A", use the following:
For S<L: $S = 52.92\sqrt{K}$, where K = L/A
For S>L: S = 1400/A + L/2

INTERSECTION SIGHT TRIANGLES

201-4

REFERENCE SECTION
201.3.1 & 201.3.3



Sight Triangle for Viewing Traffic Approaching from the Left

Sight Triangle for Viewing Traffic Approaching from the Right

DIAGRAM A - SIGHT TRIANGLES

a_1 = The distance, along the minor road, from the decision point to 1/2 the lane width of the approaching vehicle on the major road.

a_2 = The distance, along the minor road, from the decision point to 1 1/2 the lane width of the approaching vehicle on the major road.

b = Intersection Sight Distance

d = The distance from the edge of the traveled way of the major road to the decision point. The distance should be a minimum of 14.5′ and 18.0′ preferred.

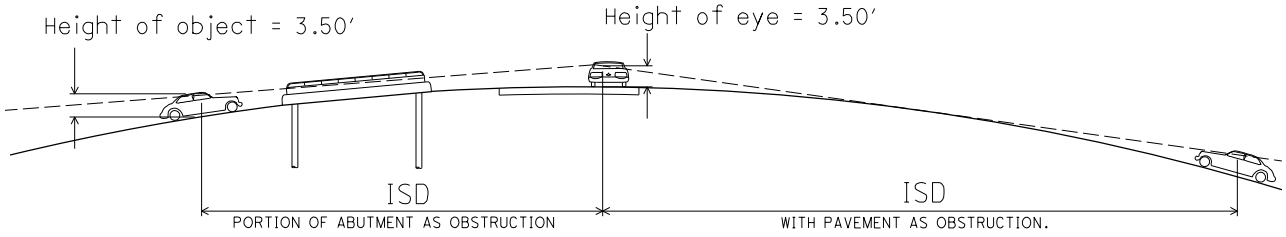


DIAGRAM B - VERTICAL COMPONENTS (Sec. 201.3.3)

INTERSECTION SIGHT DISTANCE

201-5

REFERENCE SECTION
201.3, 201.3.1, 201.3.2 & 201.3.3

(See Following Page for Additional Figures & Notes)

HEIGHT OF EYE 3.50′ HEIGHT OF OBJECT 3.50′

DESIGN SPEED (mph)	Passenger Cars Completing a Left Turn from a Stop (assuming a t_g of 7.5 sec.)		Passenger Cars Completing a Right Turn from a Stop or Crossing Maneuuver (assuming a t_g of 6.5 sec.)	
	ISD (ft.)	K-CREST VERT. CURVE	ISD (ft.)	K-CREST VERT. CURVE
15	170	10	145	8
20	225	18	195	14
25	280	28	240	21
30	335	40	290	30
35	390	54	335	40
40	445	71	385	53
45	500	89	430	66
50	555	110	480	82
55	610	133	530	100
60	665	158	575	118
65	720	185	625	140
70	775	214	670	160

If ISD cannot be provided due to environmental or R/W constraints, then as a minimum, the SSD for vehicles on the major road should be provided.

$$ISD = 1.47 \times V_{major} \times t_g$$

ISD = intersection sight distance (ft.)

V_{major} = design speed of major road (mph)

t_g = time gap for minor road vehicle to enter the major road (sec.)

Using: S = Intersection Sight Distance
L = Length of Crest Vertical Curve
A = Algebraic Difference in Grades (%), Absolute Value
K = Rate of Vertical Curvature

- For a given design speed and an "A" value, the calculated length "L" = K x A

- To determine "S" with a given "L" and "A", use the following:

For S<L: $S = 52.92\sqrt{K}$, where K = L/A

For S>L: $S = 1400/A + L/2$

(Continued Figures & Notes)

Time Gaps

		Design Vehicle	Time gap(s) at design speed of major road (t_g)
(A)	Left Turn from a Stop	Passenger car	7.5 sec.
		Single-unit truck	9.5 sec.
		Combination truck	11.5 sec.
(B)	RightTurn from a Stop or Crossing Manuever	Passenger car	6.5 sec.
		Single-unit truck	8.5 sec.
		Combination truck	10.5 sec.

A. Note: The ISD & time gaps shown in the above tables are for a stopped vehicle to turn left onto a two-lane highway with no median and grades of 3% or less. For other conditions, the time gap must be adjusted as follows:

For multilane highways:

For left turns onto two-way highways with more than two lanes, add 0.5 seconds for passenger cars or 0.7 seconds for trucks for each additional lane, from the left, in excess of one, to be crossed by the turning vehicle.

For minor road approach grades:

If the approach grade is an upgrade that exceeds 3%, add 0.2 seconds for each % grade for left turns.

B. Note: The ISD & time gaps shown in the above tables are for a stopped vehicle to turn right onto a two-lane highway with no median and grades of 3% or less. For other conditions, the time gap must be adjusted as follows:

For multilane highways:

For crossing a major road with more than two lanes, add 0.5 seconds for passenger cars or 0.7 seconds for trucks for each additional lane to be crossed and for narrow medians that cannot store the design vehicle.

For minor road approach grades:

If the approach grade is an upgrade that exceeds 3%, add 0.1 seconds for each % grade.

DECISION SIGHT DISTANCE

201-6

REFERENCE SECTION

201.5

HEIGHT OF EYE 3.50′ HEIGHT OF OBJECT 2.00′

DESIGN SPEED (mph)	DECISION SIGHT DISTANCE (ft)				
	AVOIDANCE MANEUVER				
	A	B	C	D	E
30	220	490	450	535	620
35	275	590	525	625	720
40	330	690	600	715	825
45	395	800	675	800	930
50	465	910	750	890	1030
55	535	1030	865	980	1135
60	610	1150	990	1125	1280
65	695	1275	1050	1220	1365
70	780	1410	1105	1275	1445
75	875	1545	1180	1365	1545

The Avoidance Maneuvers are as follows:

A - Rural Stop
B - Urban Stop
C - Rural Speed/Path/Direction Change
D - Suburban Speed/Path/Direction Change
E - Urban Speed/Path/Direction Change

Decision Sight Distance (DSD) is calculated or measured using the same criteria as Stopping Sight Distance; 3.50 ft eye height and 2.00 ft object height.

Use the equations on Figures 201-2, 203-3, and 203-6 to determine the DSD at vertical and horizontal curves.

MAXIMUM CENTERLINE DEFLECTION WITHOUT HORIZONTAL CURVE

202-1

REFERENCE SECTION
202.2

	DESIGN SPEED	MAX. DEFLECTION *
LOW SPEED	25	5° 30'
	30	3° 45'
	35	2° 45'
	40	2° 05'
	45	1° 40'
HIGH SPEED	50	1° 05'
	55	1° 00'
	60	0° 55'
	65	0° 50'
	70	0° 45'
	75	0° 45'

* ROUNDED TO NEAREST 5'

Based on the Allowable Pavement Transition formulae (301.1.4):
High Speed: Tan $\triangle = 1.0/V$
Low Speed: Tan $\triangle = 60/V^2$
Where: V = Design Speed
$\triangle$ = Deflection Angle

Note:
The recommended minimum distances between consecutive horizontal deflections is:
High Speed - 200'
Low Speed - 100'

MAXIMUM DEGREE OF CURVE

202-2

REFERENCE SECTION
202.3

DESIGN SPEED (mph)	MAXIMUM DEGREE OF CURVE (A)				DESIGN SPEED (mph)	MAXIMUM DEGREE OF CURVE (A)			
	RURAL	HIGH-SPEED URBAN	LOW-SPEED URBAN RAMPS/ INTERCHANGE	LOW-SPEED URBAN		RURAL	HIGH-SPEED URBAN	LOW-SPEED URBAN RAMPS/ INTERCHANGE	LOW-SPEED URBAN
	MAXIMUM SUPERELEVATION RATE					MAXIMUM SUPERELEVATION RATE			
	.08	.06	.06	.04		.08	.06	.06	.04
20	--	–	–	66°35'	45	9°45'	–	8°55'	8°05'
21	--	–	–	60°25'	46	9°15'	–	--	--
22	--	–	–	53°15'	47	8°50'	–	--	--
23	--	–	–	47°05'	48	8°20'	–	--	--
24	--	–	–	41°45'	49	7°55'	–	--	--
25	42°40'	–	39°55'	37°10'	50	7°35'	6°55'	--	--
26	38°40'	–	36°05'	33°35'	51	7°10'	6°35'	--	--
27	35°10'	–	32°45'	30°25'	52	6°50'	6°15'	--	--
28	32°00'	–	29°50'	27°35'	53	6°35'	5°55'	--	--
29	29°15'	–	27°10'	25°10'	54	6°15'	5°40'	--	--
30	26°45'	–	24°50'	22°55'	55	6°00'	5°25'	--	--
31	24°40'	–	22°55'	21°05'	56	5°40'	5°10'	--	--
32	22°50'	–	21°10'	19°30'	57	5°25'	4°55'	--	--
33	21°10'	–	19°35'	18°00'	58	5°15'	4°40'	--	--
34	19°40'	–	18°10'	16°40'	59	5°00'	4°30'	--	--
35	18°15'	–	16°50'	15°25'	60	4°45'	4°15'	--	--
36	17°00'	–	15°40'	14°20'	61	4°35'	4°05'	--	--
37	15°50'	–	14°35'	13°20'	62	4°25'	3°55'	--	--
38	14°45'	–	13°35'	12°25'	63	4°10'	3°45'	--	--
39	13°45'	–	12°40'	11°30'	64	4°00'	3°35'	--	--
40	12°55'	–	11°50'	10°45'	65	3°50'	3°25'	--	--
41	12°10'	–	11°10'	10°05'	66	3°45'	3°20'	--	--
42	11°30'	–	10°30'	9°35'	67	3°35'	3°10'	--	--
43	10°55'	–	9°55'	9°00'	68	3°25'	3°05'	--	--
44	10°20'	–	9°25'	8°30'	69	3°15'	2°55'	--	--
					70	3°10'	2°50'	--	--
					71	3°00'	2°40'	--	--
					72	2°55'	2°35'	--	--
					73	2°50'	2°30'	--	--
					74	2°40'	2°25'	--	--
					75	2°35'	2°15'	--	--

(A) See Superelevation Tables 202-7, 8, 9, and 10 for corresponding radii values.

MAXIMUM DEGREE OF CURVE WITHOUT SUPERELEVATION

202-3

REFERENCE SECTION
202.4.3

		DEGREE OF CURVE			
	DESIGN SPEED (mph)	RURAL HIGHWAYS		URBAN STREETS & HIGHWAYS	
LOW SPEED	20	--	FIGURE 202-7	54°23′	FIGURE 202-9
	25	2°35′		29°20′	
	30	1°53′		17°30′	
	35	1°26′		11°28′	
	40	1°08′		7°42′	
	45	0°55′		5°40′	
HIGH SPEED	50	0°45′		0°47′	FIGURE 202-8
	55	0°38′		0°39′	
	60	0°32′		0°33′	
	65	0°28′		0°29′	
	70	0°25′		0°26′	
	75	0°23′		0°23′	

SUPERELEVATION TRANSITIONS

202-4

REFERENCE SECTION
202.4.5 & 202.4.8

Maximum Relative Gradient for Profiles Between the Edge of Traveled Way and the Centerline or Reference Line (Axis of Rotation)		
Design Speed (mph)	Maximum Relative Gradient (Percent) "△"	Equivalent Maximum Relative Slope "G"
20	0.74	135:1
25	0.70	143:1
30	0.66	152:1
35	0.62	161:1
40	0.58	172:1
45	0.54	185:1
50	0.50	200:1
55	0.47	213:1
60	0.45	222:1
65	0.43	233:1
70	0.40	250:1
75	0.38	263:1

Adjustment Factors, b_w		
Number of Lanes, Rotated n_1	Divided * Roadways b_w	Undivided Roadways b_w
1	1.00	1.00
1.5	1.00	0.83
2	1.00	0.75
2.5	1.00	0.70
3	1.00	0.67
3.5	1.00	0.64

* Interstates, Freeways, Expressways and Ramps

In Figures 202-7, 202-8 and 202-10, the table values for the Minimum Length of Superelevation Runoff, L_r, were determined by the following equation:

$$L_r = \frac{(w \times n_1)\, e_d}{\triangle} (b_w) \times 100 \qquad \text{or} \qquad L_r = (w \times n_1)(e_d)(G)(b_w)$$

The equation can also be used to determine L_r, when more than one lane is rotated about the centerline or the edge or if the lane width is other than 12 feet for Figures 202-7 and 202-8 or 16 feet for Figure 202-10.

Once L_r has been determined, the Minimumum Length of Tangent Runout, L_t,should be determined by the following equation:

$$L_t = (e_{NC} \div e_d)\, L_r$$

The equation for L_t can be used by Figures 202-7, 202-8, 202-9 and 202-10.

Where:

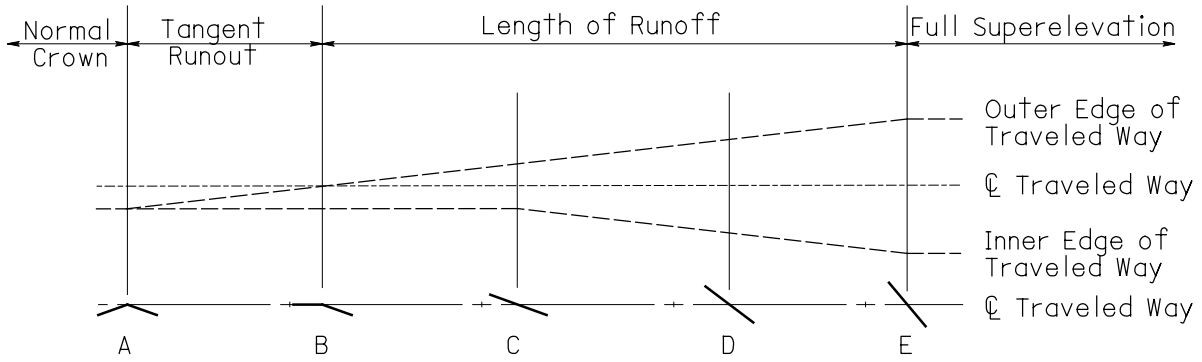
L_r = minimum length of superelevation runoff, ft
L_t = minimum length of tangent runout, ft
$\triangle$ = maximum relative gradient, percent
n_1 = number of lanes rotated
w = width of one traffic lane, ft (typically 12 ft)
e_d = design superelevation rate
e_{NC} = normal cross slope rate, (0.016)
G = equivalent maximum relative slope, (the reciprocal of $\triangle$)
b_w = adjustment factor for number of lanes rotated

METHODS OF SUPERELEVATION ROTATION

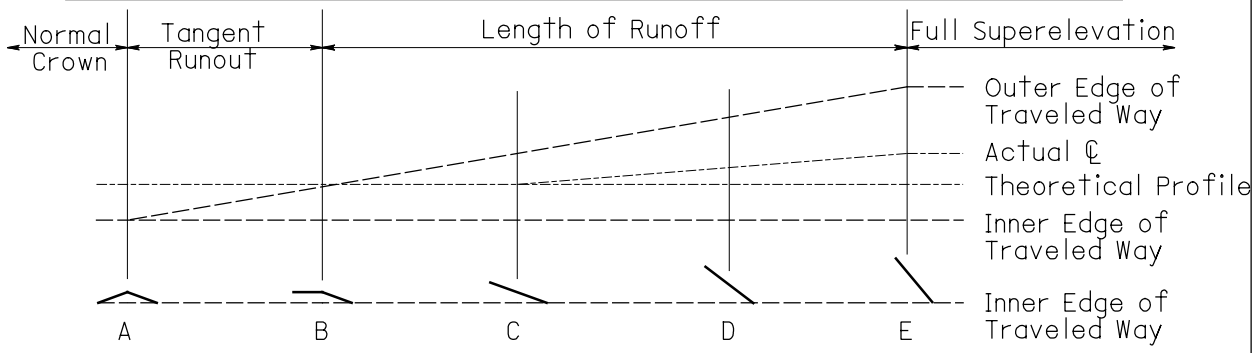
202-5

REFERENCE SECTION
202.4.4

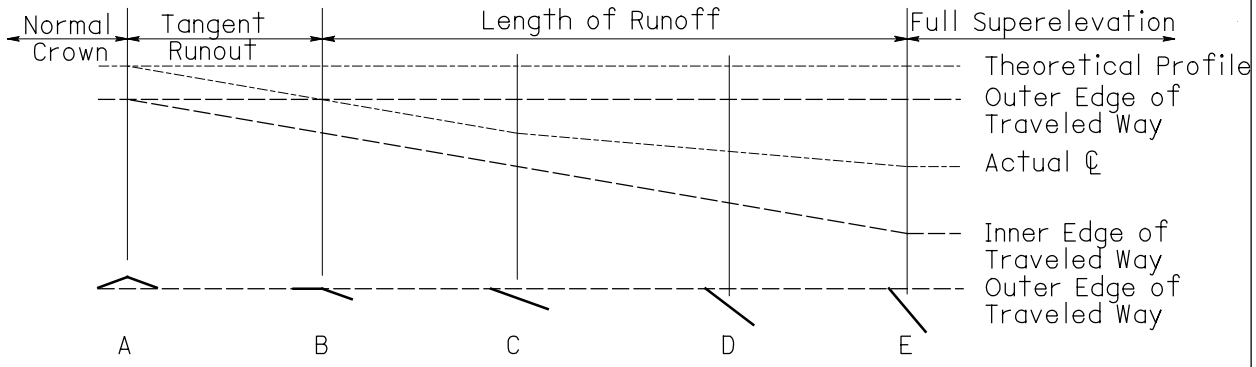
METHOD 1 - PAVEMENT REVOLVED ABOUT THE CENTERLINE (Crowned)



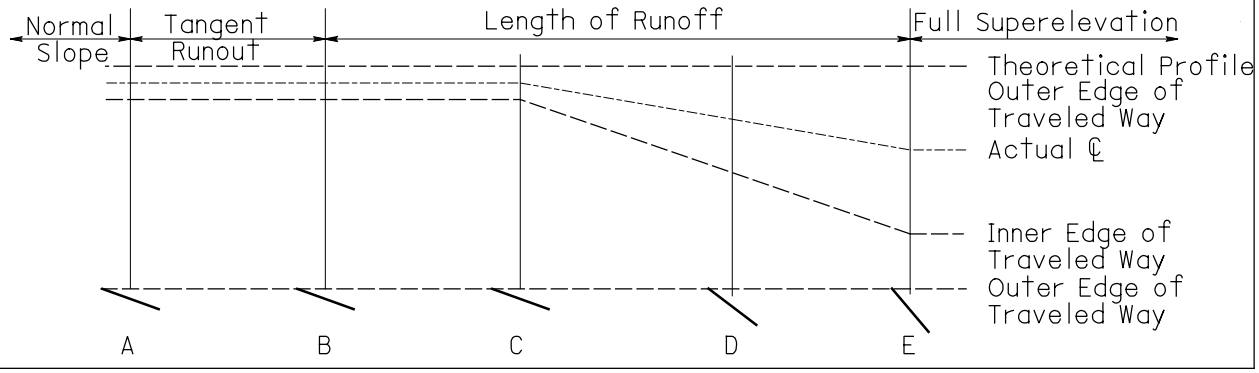
METHOD 2 - PAVEMENT REVOLVED ABOUT THE INNER EDGE (Crowned)



METHOD 3 - PAVEMENT REVOLVED ABOUT THE OUTER EDGE (Crowned)



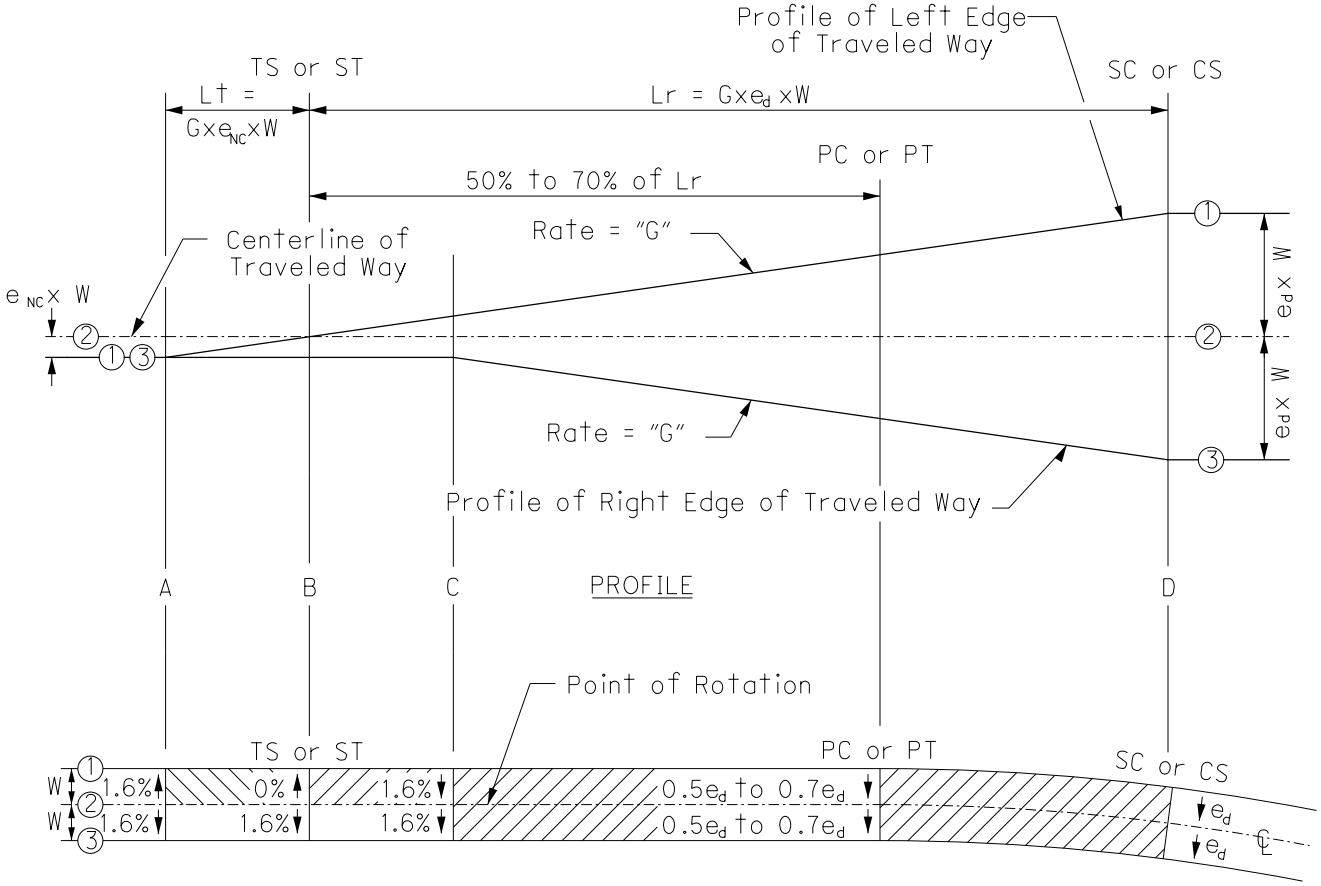
METHOD 4 - PAVEMENT REVOLVED ABOUT THE OUTER EDGE (Straight Cross Slope)

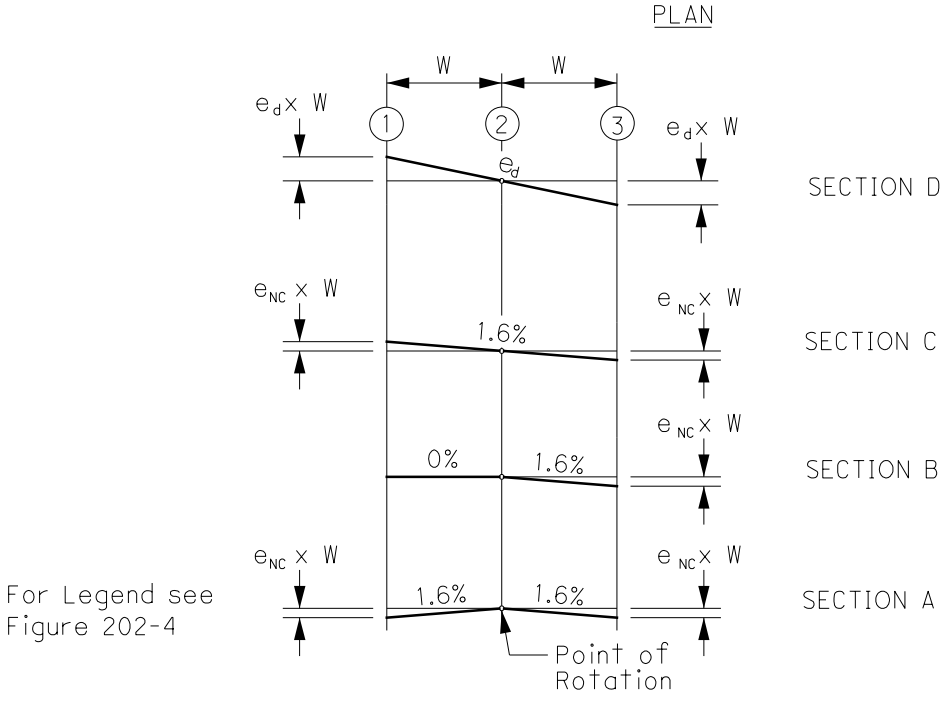


SUPERELEVATION DEVELOPMENT TWO-LANE UNDIVIDED

202-5a

REFERENCE SECTION 202.4.4 - 202.4.6, 202.4.8



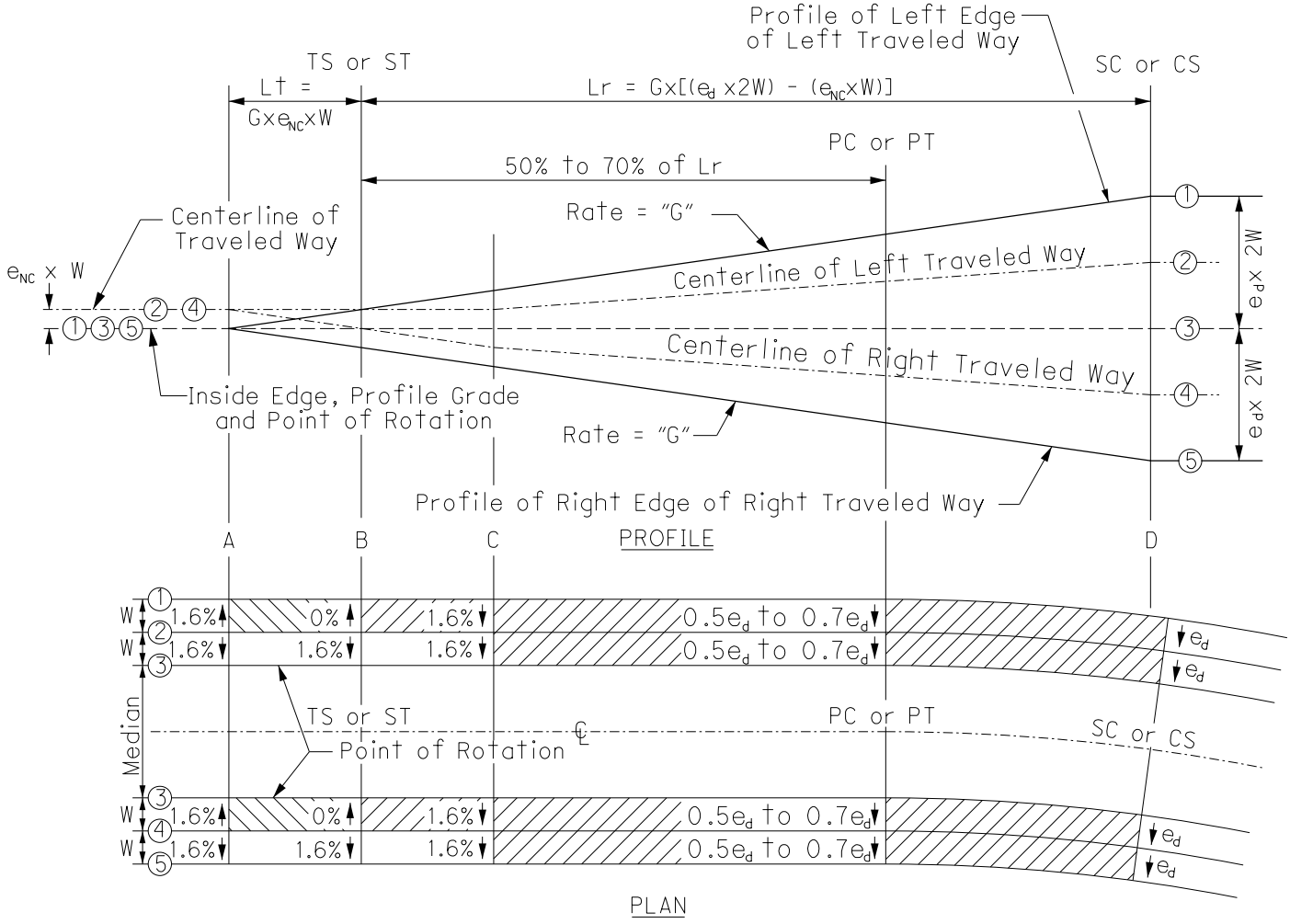


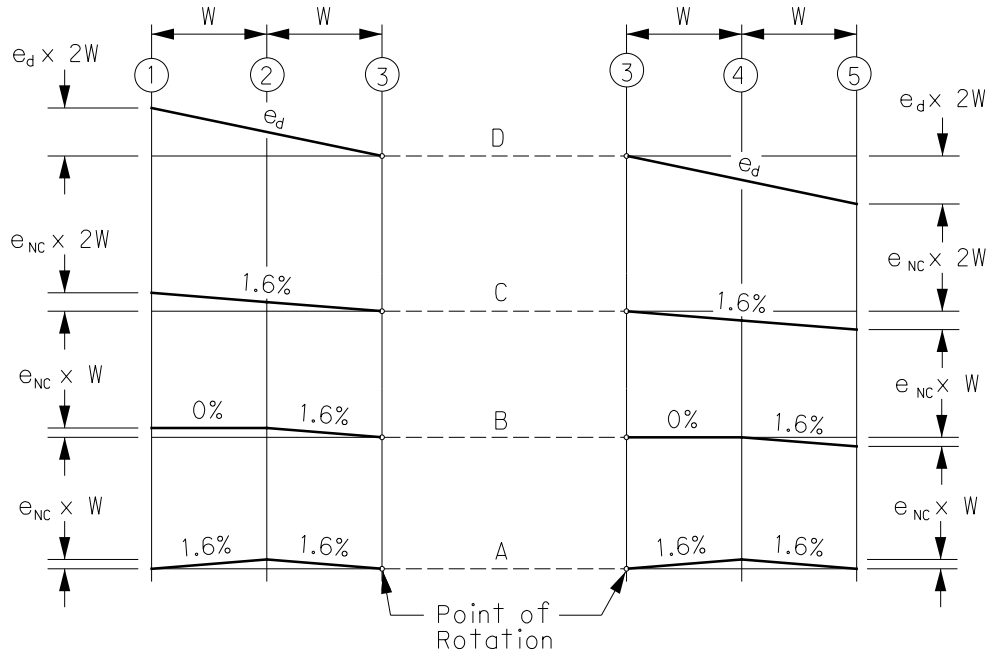
For Legend see Figure 202-4

SUPERELEVATION DEVELOPMENT FOUR-LANE DIVIDED

202-5b

REFERENCE SECTION
202.4.4 - 202.4.6, 202.4.8





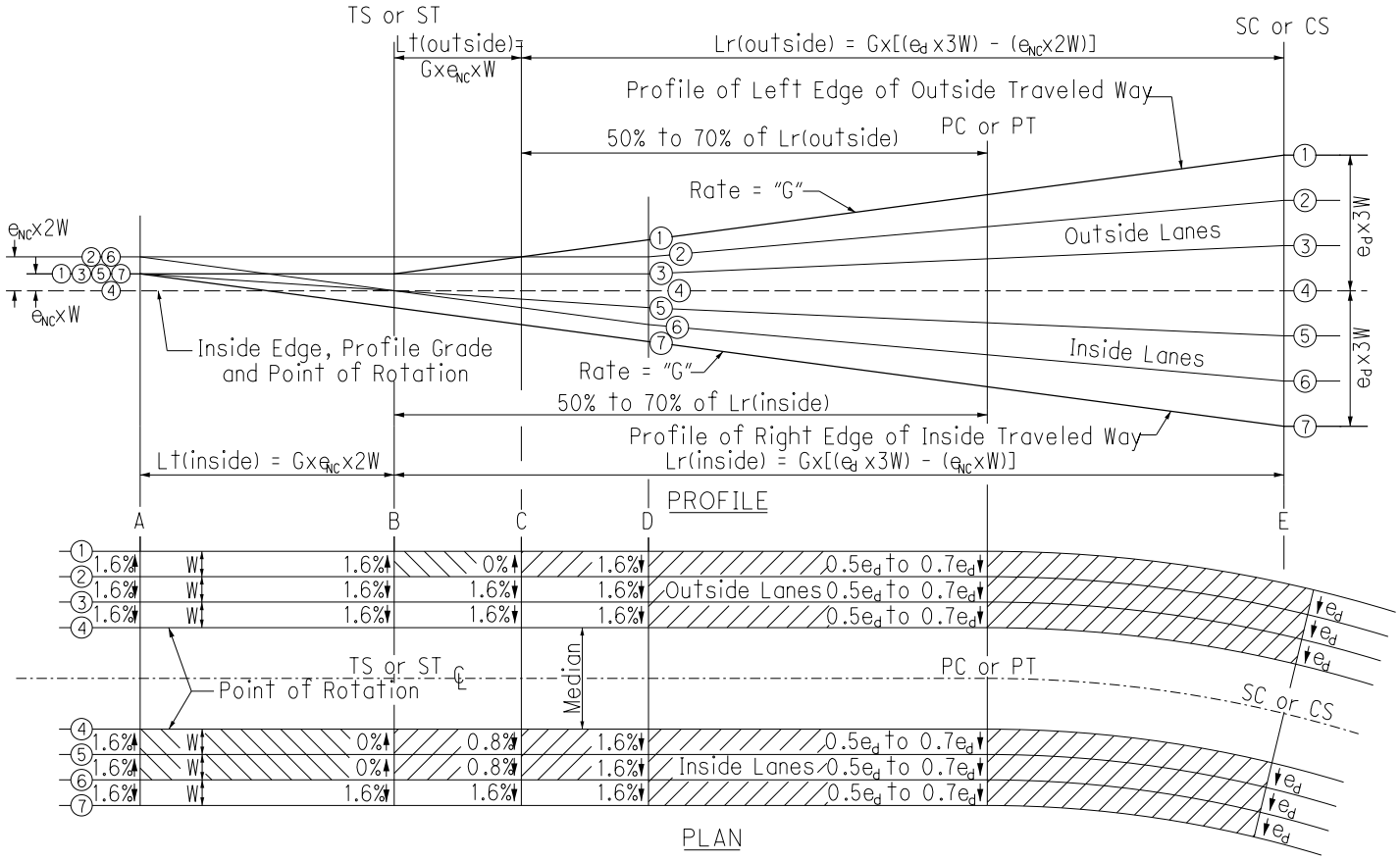
For Legend see Figure 202-4

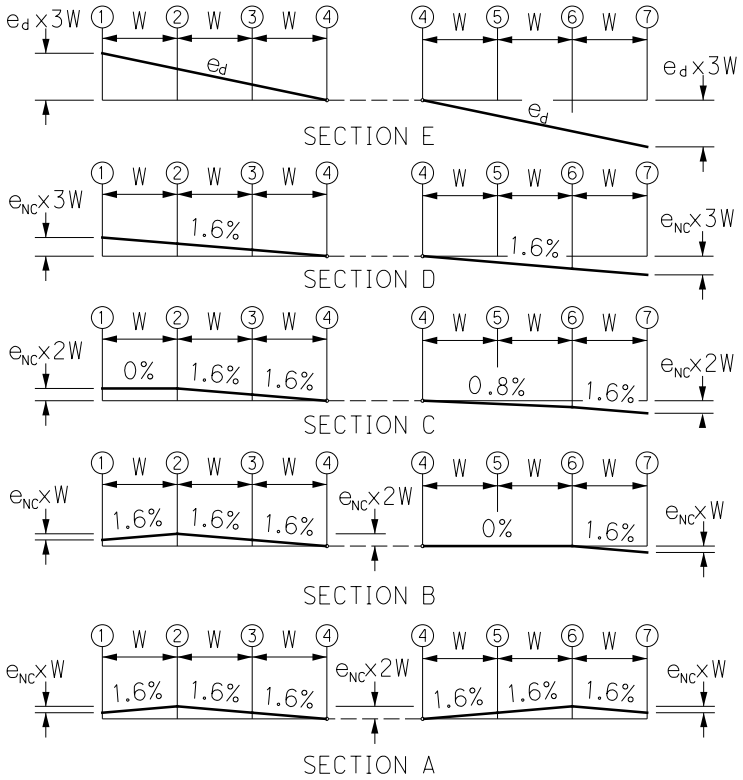
JANUARY 2006

SUPERELEVATION DEVELOPMENT SIX-LANE OR MORE DIVIDED (OR FOUR-LANE DIVIDED WITH FUTURE MEDIAN LANES)

202-5c

REFERENCE SECTION
202.4.4 - 202.4.6, 202.4.8



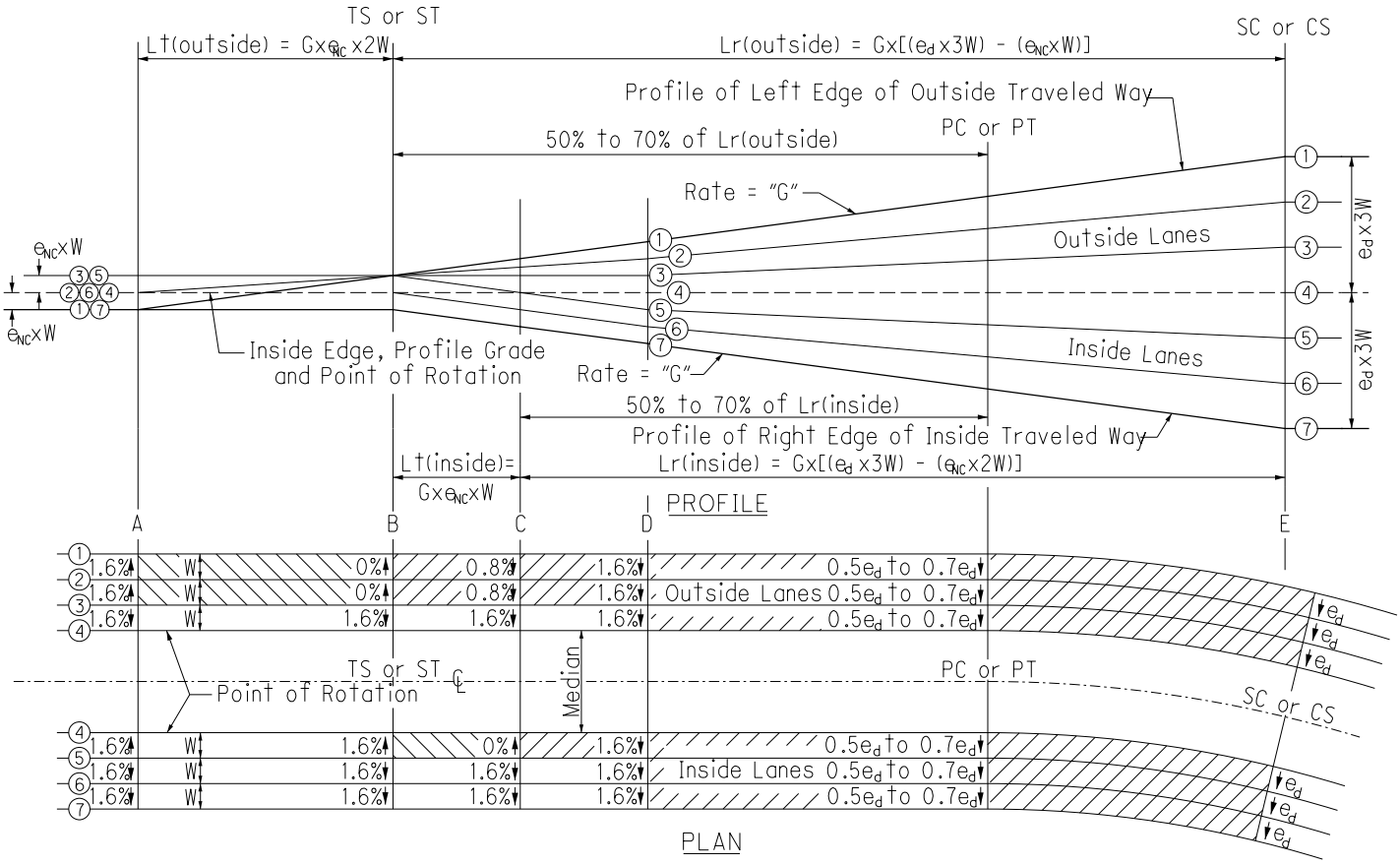


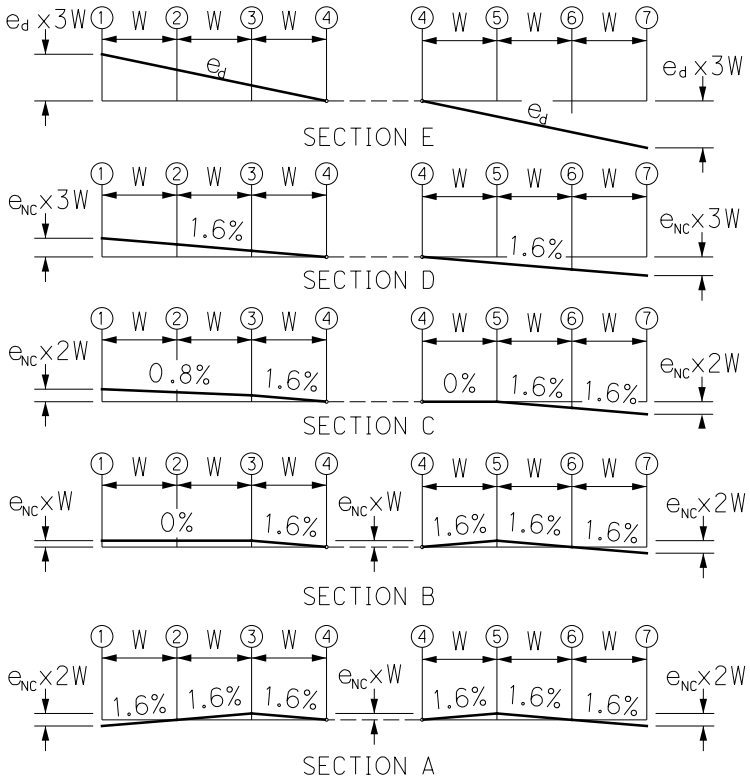
For Legend see Figure 202-4

SUPERELEVATION DEVELOPMENT SIX-LANE OR MORE DIVIDED (OR FOUR-LANE DIVIDED WITH FUTURE OUTSIDE LANES)

202-5d

REFERENCE SECTION
202.4.4 - 202.4.6, 202.4.8





For Legend see Figure 202-4

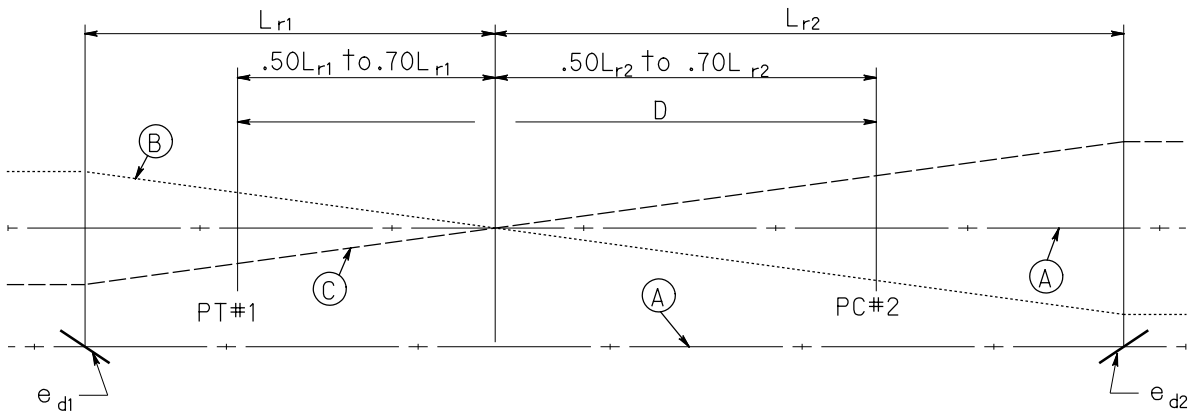
JANUARY 2006

SUPERELEVATION TRANSITION BETWEEN REVERSE HORIZONTAL CURVES

202-6

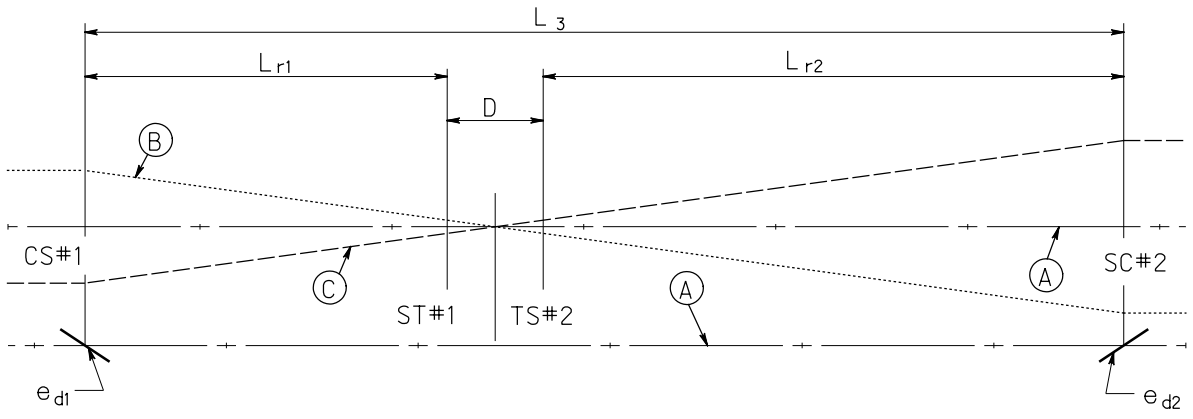
REFERENCE SECTION
202.4.8

PAVEMENT REVOLVED ABOUT THE CENTERLINE



SIMPLE CURVES

PAVEMENT REVOLVED ABOUT THE CENTERLINE



SPIRAL CURVES

LEGEND:

- (A) - Centerline Pavement
- (B) - Outside E.P. Curve 1, Inside E.P. Curve 2
- (C) - Inside E.P. Curve 1, Outside E.P. Curve 2
- e_{d1}, e_{d2} = Design Superelevation Rates - Curves 1 & 2
- L_{r1}, L_{r2} = Superelevation Transition Lengths - Curves 1 & 2
- D = Distance Between Curves
- L_3 = Total Superelevation Transition Between Spiral Curves

SUPERELEVATION AND RUNOFF LENGTHS FOR HORIZONTAL CURVES ON RURAL HIGHWAYS - Based on Max. S.E. of 0.08 ft/ft -

202-7

REFERENCE SECTION 202.4.1, 202.4.3, & 202.4.5

Dc	RADIUS	DESIGN SPEED 25		30		35		40		45		50		55		60	
		e_d	L_r	e_d	L_r	e_d	L_r	e_d	L_r	e_d	L_r	e_d	L_r	e_d	L_r	e_d	L_r
0°15′	22918	NC	--	NC	--	NC	--	NC	--	NC	--	NC	--	NC	--	NC	--
0°30′	11459	NC	--	NC	--	NC	--	NC	--	NC	--	NC	--	NC	--	NC	--
0°45′	7639	NC	--	NC	--	NC	--	NC	--	NC	--	.016	39	.019	49	.022	59
1°00′	5730	NC	--	NC	--	NC	--	NC	--	.017	38	.021	51	.025	64	.029	78
1°30′	3820	NC	--	NC	--	.017	33	.021	44	.025	56	.030	72	.035	90	.041	110
2°00′	2865	NC	--	.017	32	.022	43	.027	56	.032	72	.038	92	.045	116	.051	136
2°30′	2292	NC	--	.021	39	.026	51	.033	69	.039	87	.046	111	.053	136	.061	163
3°00′	1910	.018	31	.024	44	.031	60	.038	79	.045	100	.053	128	.060	154	.068	182
3°30′	1637	.021	37	.028	52	.035	68	.043	89	.050	111	.058	140	.066	169	.074	198
4°00′	1432	.024	42	.031	57	.039	76	.047	98	.055	123	.063	152	.071	182	.078	208
4°30′	1273	.026	45	.034	63	.042	82	.051	106	.059	131	.068	164	.075	192	.080	214
5°00′	1146	.029	50	.037	68	.046	89	.055	114	.063	140	.071	171	.078	200	△=4°45′	
5°30′	1042	.031	54	.040	73	.049	95	.058	120	.066	147	.074	178	.080	205	▲=0°32′	
6°00′	955	.033	57	.042	77	.051	99	.061	126	.070	156	.077	185	△=6°			
6°30′	881	.035	61	.045	83	.054	105	.063	131	.072	160	.079	190	▲=0°38′			
7°00′	819	.037	64	.047	86	.056	109	.066	137	.074	165	.080	192				
7°30′	764	.039	67	.049	90	.058	113	.068	141	.076	169	.080	192				
8°00′	716	.041	71	.051	94	.060	116	.070	145	.078	174	△=7°35′					
8°30′	674	.042	73	.052	95	.062	120	.072	149	.079	176	▲=0°45′					
9°00′	637	.044	76	.054	99	.064	124	.074	153	.080	178						
9°30′	603	.046	79	.055	101	.066	128	.075	155	.080	178						
10°00′	573	.047	81	.057	104	.067	130	.077	159	△=9°45′							
10°30′	546	.048	83	.058	106	.069	134	.078	161	▲=0°55′							
11°00′	521	.049	85	.059	108	.070	136	.079	164								
11°30′	498	.050	86	.061	112	.071	138	.079	164								
12°00′	477	.051	88	.062	114	.073	142	.080	166								
12°30′	458	.052	90	.063	115	.074	143	.080	166								
13°00′	441	.053	91	.064	117	.075	145	△=12°55′									
13°30′	424	.054	93	.066	121	.076	147	▲= 1°08′									
14°00′	409	.055	95	.067	123	.077	149										
14°30′	395	.056	97	.068	125	.077	149										
15°00′	382	.057	98	.069	126	.078	151										
16°30′	347	.059	102	.071	130	.079	153										
18°00′	318	.062	107	.074	135	.080	155										
20°00′	286	.064	110	.076	139	△=18°15′											
22°00′	260	.067	115	.078	143	▲= 1°26′											
23°00′	249	.068	117	.079	145												
25°00′	229	.071	122	.080	146												
26°30′	216	.072	124	.080	146												
28°00′	205	.074	127	△=26°45′													
31°00′	185	.076	131	▲= 1°53′													
34°00′	169	.078	134														
36°00′	159	.079	136														
38°00′	151	.079	136														
40°00′	143	.080	138	△=42°40′													
42°00′	136	.080	138	▲= 2°35′													

NC = Normal Crown

△ = Max. Dc for the Design Speed

▲ = Max. Dc Without Superelevation

Dc	RADIUS	DESIGN SPEED 65		70		75	
		e_d	L_r	e_d	L_r	e_d	L_r
0°15′	22918	NC	--	NC	--	NC	--
0°30′	11459	.017	48	.019	57	.021	67
0°45′	7639	.025	70	.028	84	.031	98
1°00′	5730	.032	90	.036	108	.040	127
1°15′	4584	.039	110	.044	132	.049	155
1°30′	3820	.046	129	.051	153	.058	184
1°45′	3274	.052	146	.058	174	.066	209
2°00′	2865	.058	163	.065	195	.073	231
2°15′	2546	.063	177	.071	213	.078	247
2°30′	2292	.068	191	.075	225	.080	253
2°45′	2083	.072	202	.078	234	△=2°35′	
3°00′	1910	.075	210	.080	240	▲=0°23′	
3°15′	1763	.078	219	△=3°10′			
3°30′	1637	.079	221	▲=0°25′			
3°45′	1528	.080	224				
		△=3°50′					
		▲=0°28′					

e_d= Design Superelevation Rate

L_r= Min. Runoff Length, 2-Lane Highway Rotated About the Centerline, Lane Width of 12 feet

JULY 2025

SUPERELEVATION AND RUNOFF LENGTHS FOR HORIZONTAL CURVES ON HIGH-SPEED* URBAN HIGHWAYS

- Based on a Maximum Superelevation of 0.06 ft/ft -

202-8

REFERENCE SECTION 202.4.1, 202.4.3, & 202.4.5

* 50 mph or greater

		DESIGN SPEED											
		50		55		60		65		70		75	
Dc	RADIUS	e_d	L_r	e_d	L_r	e_d	L_r	e_d	L_r	e_d	L_r	e_d	L_r
0°15′	22918	NC	--	NC	--	NC	--	NC	--	NC	--	NC	--
0°30′	11459	NC	--	NC	--	NC	--	.016	45	.018	54	.020	64
0°45′	7639	NC	--	.018	47	.021	56	.024	68	.026	78	.029	92
1°00′	5730	.020	48	.023	59	.027	72	.030	84	.033	99	.037	117
1°15″	4584	.024	58	.028	72	.032	86	.036	101	.040	120	.045	143
1°30′	3820	.028	68	.032	82	.037	99	.041	115	.046	138	.051	161
1°45″	3274	.032	77	.036	93	.041	110	.046	129	.051	153	.056	177
2°00′	2865	.035	84	.040	103	.045	120	.050	140	.055	165	.059	187
2°15″	2546	.038	92	.043	110	.048	128	.053	149	.057	171	.060	190
2°30′	2292	.040	96	.045	116	.051	136	.056	157	.059	177	△=2°15′	
2°45′	2083	.042	101	.048	123	.053	142	.058	163	.060	180	▲=0°23′	
3°00′	1910	.045	108	.050	128	.055	147	.059	165	△=2°50′			
3°30′	1637	.048	116	.054	139	.058	155	△=3°25′		▲=0°26′			
4°00′	1432	.052	125	.057	146	.060	160	▲=0°29′					
4°30′	1273	.054	130	.059	151	△=4°15′							
5°00′	1146	.056	135	.060	154	▲=0°33′							
5°30′	1042	.058	140	△=5°25′									
6°00′	955	.059	142	▲=0°39′									
6°30′	881	.060	144										
6°45′	849	.060	144										
		△=6°55′											
		▲=0°47′											

NC = Normal Crown

△ = Max. Dc for the Design Speed
▲ = Max. Dc Without Superelevation

e_d= Design Superelevation Rate
L_r= Min. Runoff Length, 2-Lane Highway Rotated About the Centerline, Lane Width of 12 feet

See Figure 202-4 for the calculation of Lr and adjustments to Lr when more than one lane is rotated about the centerline or the lane width is other than 12 feet.

SUPERELEVATION AND RUNOFF LENGTHS FOR HORIZONTAL CURVES ON LOW-SPEED URBAN STREETS* - Based on Max. S.E. of 0.04 ft/ft

202-9

REFERENCE SECTION 202.4.1, 202.4.3, & 202.4.5

Dc	RADIUS	DESIGN SPEED 20		25		30		35		40		45	
		e_d	L_r	e_d	L_r	e_d	L_r	e_d	L_r	e_d	L_r	e_d	L_r
5°00′	1146	NC	--	NC	--	NC	--	NC	--	NC	--	NC	--
5°30′	1042	NC	--	NC	--	NC	--	NC	--	NC	--	NC	--
6°00′	955	NC	--	NC	--	NC	--	NC	--	NC	--	RC	36
7°00′	819	NC	--	NC	--	NC	--	NC	--	NC	--	RC	36
7°30′	764	NC	--	NC	--	NC	--	NC	--	NC	--	.027	61
8°00′	716	NC	--	NC	--	NC	--	NC	--	RC	34	.039	87
9°00′	637	NC	--	NC	--	NC	--	NC	--	RC	34	△=8°05′	
9°30′	603	NC	--	NC	--	NC	--	NC	--	.017	37	▲=5°40′	
10°00′	573	NC	--	NC	--	NC	--	NC	--	.027	56		
10°30	546	NC	--	NC	--	NC	--	NC	--	.036	75		
11°00′	521	NC	--	NC	--	NC	--	NC	--	△=10°45′			
11°30′	498	NC	--	NC	--	NC	--	RC	31	▲=7°42′			
12°00′	477	NC	--	NC	--	NC	--	RC	31				
13°00′	441	NC	--	NC	--	NC	--	RC	31				
14°00′	409	NC	--	NC	--	NC	--	.020	40				
15°00′	382	NC	--	NC	--	NC	--	.035	67				
15°30′	370	NC	--	NC	--	NC	--	△=15°25′					
17°00′	337	NC	--	NC	--	NC	--	▲=11°28′					
17°30′	327	NC	--	NC	--	NC	--						
18°00′	318	NC	--	NC	--	RC	30						
20°00′	286	NC	--	NC	--	RC	30						
20°30′	279	NC	--	NC	--	RC	30						
21°00′	273	NC	--	NC	--	.021	38						
22°00′	260	NC	--	NC	--	.031	57						
22°45′	252	NC	--	NC	--	.039	72						
25°00′	229	NC	--	NC	--	△=22°55′							
29°00′	198	NC	--	NC	--	▲=17°30′							
29°30′	194	NC	--	RC	28								
30°00′	191	NC	--	RC	28								
33°00′	174	NC	--	RC	28								
33°45′	170	NC	--	.016	28								
35°00′	164	NC	--	.025	44								
36°00′	159	NC	--	.033	57								
37°00′	155	NC	--	.040	69								
40°00′	143	NC	--	△=37°10′									
50°00′	116	NC	--	▲=29°19′									
54°30′	105	RC	26										
56°00′	102	RC	26										
58°00′	99	RC	26										
61°00′	94	RC	26										
61°15′	93	.016	26										
62°00′	92	.020	32										
63°00′	91	.024	40										
64°00′	90	.029	47										
65°00′	88	.034	55										
66°00′	87	.038	62										
66°30′	86	.040	65										
△=66°35′													
▲=54°23′													

* 45 mph or less

NC = Normal Crown
RC = Remove Crown

e_d= Design Superelevation Rate
L_r= Minimum Runoff Length, 12-foot Wide Lane Rotated About the Centerline

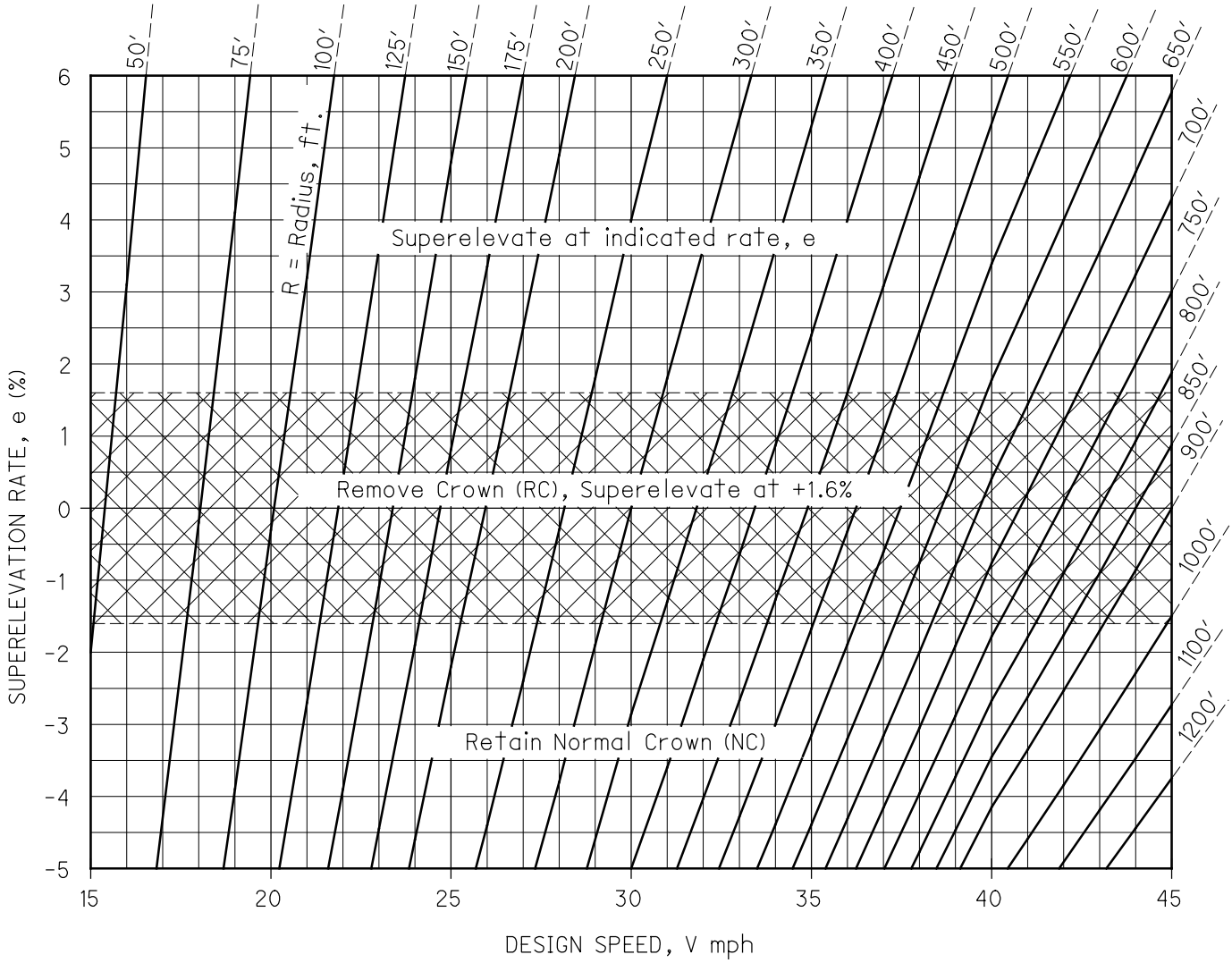
△ = Maximum Degree of Curve for the Design Speed
▲ = Maximum Degree of Curve for Normal Crown

See Figure 202-4 for the calculation of L_r and adjustments to L_r when more than one lane is rotated about the centerline or the lane width is other than 12 feet.

SUPERELEVATION RATES FOR HORIZONTAL CURVES ON LOW-SPEED URBAN STREETS

202-9a

REFERENCE SECTION
202.4.1, 202.4.3, & 202.4.5



NOTES:

1. The Figure provides a range of curves and superelevation rates which apply to a selected design speed for low-speed urban streets. AASHTO Method 2 was used to distribute superelevation and side-friction.

2. For curves that fall within the shaded area, it is desirable to remove the crown and superelevate the roadway at a uniform slope of +1.6%.

3. Dc = 5729.58 / R

JANUARY 2006

SUPERELEVATION AND RUNOFF LENGTHS FOR HORIZONTAL CURVES ON LOW-SPEED* URBAN RAMPS AND OTHER INTERCHANGE ROADWAYS - Based on Max. S.E. of 0.06 ft/ft -

202-10

REFERENCE SECTION 202.4.1, 202.4.3, & 202.4.5

* = 45 m.p.h. or less

Dc	RADIUS	DESIGN SPEED 25		30		35		40		45	
		e_d	L_r	e_d	L_r	e_d	L_r	e_d	L_r	e_d	L_r
0°15′	22918	NC	--	NC	--	NC	--	NC	--	NC	--
0°30′	11459	NC	--	NC	--	NC	--	NC	--	NC	--
0°45′	7639	NC	--	NC	--	NC	--	NC	--	NC	--
1°00′	5730	NC	--	NC	--	NC	--	NC	--	.017	51
1°30′	3820	NC	--	NC	--	.016	42	.020	56	.024	72
2°00′	2865	NC	--	.016	39	.021	54	.025	69	.030	89
2°30′	2292	NC	--	.020	49	.025	65	.030	83	.035	104
3°00′,	1910	.018	42	.023	56	.028	73	.034	94	.039	116
3°30′	1637	.020	46	.026	64	.032	83	.037	102	.043	128
4°00′	1432	.022	51	.028	69	.034	88	.040	111	.046	137
4°30′	1273	.024	55	.031	76	.037	96	.043	119	.049	146
5°00′	1146	.026	60	.033	81	.039	101	.045	124	.051	151
5°30′	1042	.028	65	.035	86	.041	106	.047	130	.053	157
6°00′	955	.030	69	.036	88	.042	109	.049	135	.055	163
6°30′	881	.031	71	.038	93	.044	114	.051	141	.057	169
7°00′	819	.033	76	.039	95	.045	116	.053	146	.058	172
7°30′	764	.034	78	.040	98	.047	122	.054	149	.059	175
8°00′	716	.035	81	.041	100	.048	124	.055	152	.060	178
8°30′	674	.036	83	.042	103	.050	129	.056	155	.060	178
9°00′	637	.037	85	.043	105	.051	132	.057	157	◎=8°55′	
9°30′	603	.038	87	.045	110	.052	135	.058	160	▲=0°57′	
10°00′	573	.038	87	.046	112	.053	137	.059	163		
10°30′	546	.039	90	.046	112	.054	140	.059	163		
11°00′	521	.040	92	.047	115	.055	142	.060	166		
11°30′	498	.040	92	.048	117	.056	145	.060	166		
12°00′	477	.041	94	.049	120	.057	147	◎=11°50′			
12°30′	458	.042	97	.050	122	.057	147	▲=1°10′			
13°00′	441	.042	97	.051	125	.058	150				
13°30′	424	.043	99	.052	127	.058	150				
14°00′	409	.044	101	.052	127	.059	152				
14°30′	395	.044	101	.053	129	.059	152				
15°00′	382	.045	103	.054	132	.060	155				
16°30′	347	.047	108	.055	134	.060	155				
18°00′	318	.048	110	.057	139	◎=16°50′					
20°00′	286	.050	115	.058	142	▲=1°29′					
22°00′	260	.052	119	.059	144						
23°00′	249	.053	122	.060	146						
25°00′	229	.055	126	◎=24°50′							
28°00′	205	.057	131	▲=1°58′							
31°00′	185	.058	133								
34°00′	169	.059	135								
36°00′	159	.060	138								
38°00′	151	.060	138	◎=39°55′							
39°30′	145	.060	138	▲=2°42′							

NC = Normal Crown
e_d= Design Superelevation Rate
L_r= Minimum Runoff Length, 16-foot Wide Lane Rotated About the Edge

◎ = Maximum Degree of Curve for the Design Speed
▲ = Maximum Degree of Curve Without Superelevation

See Figure 202-4 for the calculation of Lr and adjustments to Lr when more than one lane is rotated about the edge or the lane width is other than 16 feet.

MAXIMUM CURVE WITHOUT A SPIRAL

202-11

REFERENCE SECTION
202.5

DESIGN SPEED (mph)	MAX. DEGREE OF CURVE	MIN. RADIUS (feet)
50	4°30′	1273
55	3°45′	1528
60	3°00′	1910
65	2°30′	2292
70	2°15′	2546
75	2°00′	2865

MAXIMUM GRADES (PERCENT)

203-1

REFERENCE SECTION
203.2.3

	FUNCTIONAL CLASSIFICATION	TERRAIN	DESIGN SPEED (mph)										
			25	30	35	40	45	50	55	60	65	70	75
URBAN	Interstate, Other [A] Freeways and Expressways	LEVEL						4	4	3	3	3	3
		ROLLING						5	5	4	4	4	4
		HILLY						6	6	6	5	5	
	ARTERIAL STREET	LEVEL	7	7	7	7	6	6	5	5			
		ROLLING	10	9	8	8	7	7	6	6			
		HILLY	12	11	10	10	9	9	8	8			
	COLLECTOR [B] STREETS	LEVEL	9	9	9	9	8	7	7	6			
		ROLLING	12	11	10	10	9	8	8	7			
		HILLY	13	12	12	12	11	10	10	9			
	LOCAL STREETS	LEVEL	10	9	9	9	9	8	8	7			
		ROLLING	13	12	12	11	11	10	10	8			
		HILLY	15	15	15	14	14	12	12	10			
RURAL	Interstate, Other [A] Freeways and Expressways	LEVEL						4	4	3	3	3	3
		ROLLING						5	5	4	4	4	4
		HILLY						6	6	6	5	5	
	ARTERIAL STREET	LEVEL	5	5	5	5	5	4	4	3	3	3	
		ROLLING	8	7	7	6	6	5	5	4	4	4	
		HILLY	9	8	8	8	7	7	6	6	5	5	
	COLLECTOR [B] STREETS	LEVEL	7	7	7	7	7	6	6	5			
		ROLLING	10	9	9	8	8	7	7	6			
		HILLY	11	10	10	10	10	9	9	8			
	LOCAL STREETS	LEVEL	7	7	7	7	7	6	6	5			
		ROLLING	11	10	10	10	9	8	7	6			
		HILLY	15	14	14	13	12	10	10				

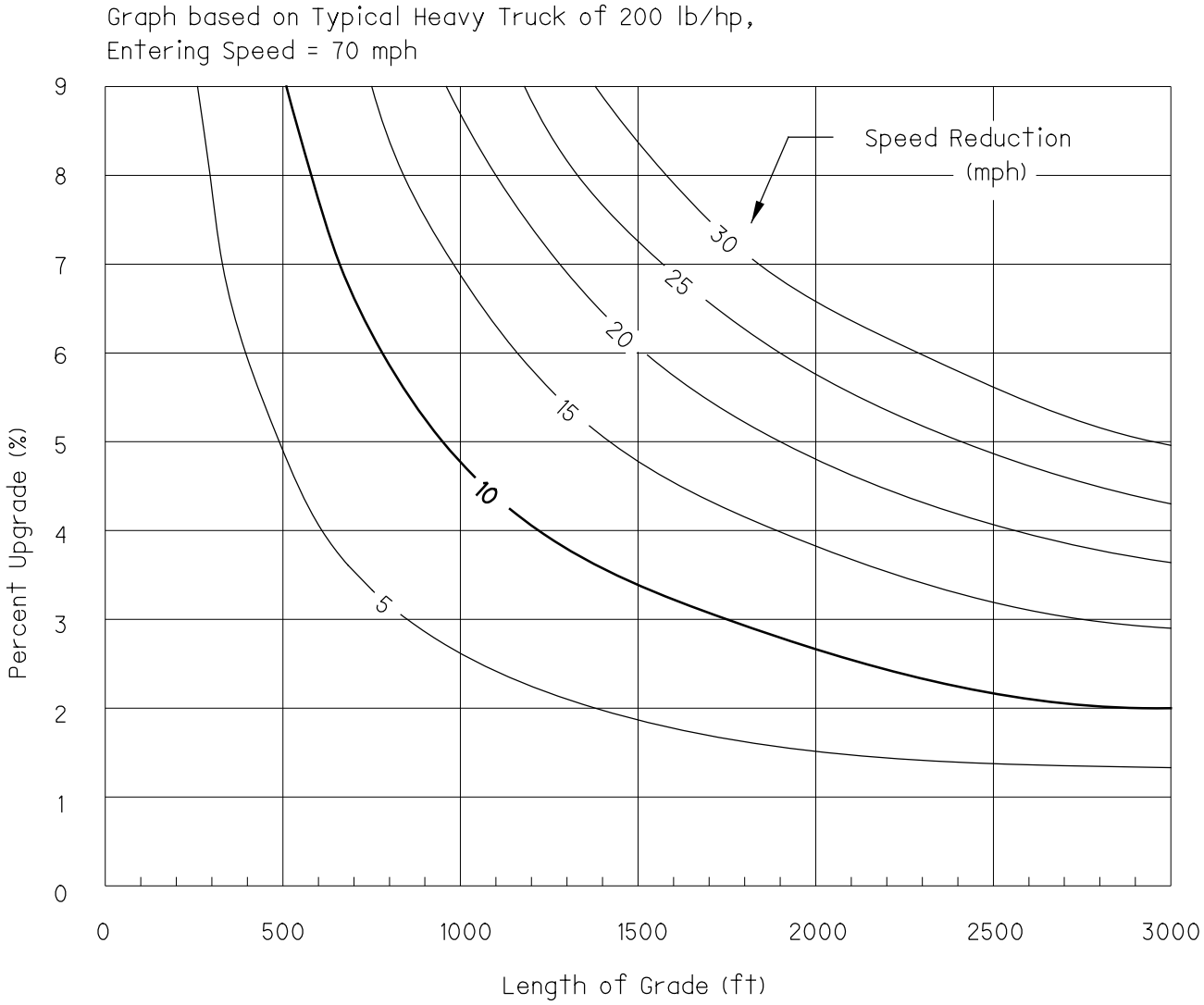
(A) Grades 1% steeper may be used where development in urban areas precludes the use of flatter grades. Grades 1% steeper may also be used for one-way down-grades, except in hilly terrain.

(B) Grades 2% steeper may be used for short lengths (less than 500 ft.), on one-way down-grades, and on low-volume rural collectors with current AADT less than 2,000 veh/day.

CRITICAL LENGTHS OF GRADE

203-1a

REFERENCE SECTION
203.2.3



The above figure can also be used to compute the critical length of grade for grade combinations. For example, find the critical length of grade for a 4% upgrade preceded by 2000 feet of 2% upgrade and a tolerable speed reduction of 15 mph. From the figure, 2000 feet of 2% upgrade results in a speed reduction of 7 mph. Subtracting 7 mph from the tolerable speed reduction of 15 mph gives the remaining tolerable speed reduction of 8 mph. The figure shows that the remaining tolerable speed reduction of 8 mph would occur on 1000 feet of the 4% upgrade.

The critical length of grade is the length of tangent grade. When a vertical curve is part of the critical length of grade, an approximate equivalent tangent grade should be used. Where A <= 3%, then the vertical tangent lengths can be used (VPI to VPI). Where A > 3%, then about one-quarter of the vertical curve length should be used as part of the tangent grade.

MAXIMUM CHANGE IN VERTICAL ALIGNMENT WITHOUT VERTICAL CURVE

203-2

REFERENCE SECTION
203.3.2

DESIGN SPEED (mph)	MAX. GRADE CHANGE △
25	1.85%
30	1.30%
35	0.95%
40	0.75%
45	0.55%
50	0.45%
55	0.40%
60	0.30%
65	0.30%
70	0.25%
75	0.20%

Based on the AASHTO comfort formula for sag vertical curves:

$$A = 46.5\ L / V^2 = 1162.5 / V^2$$

Where:

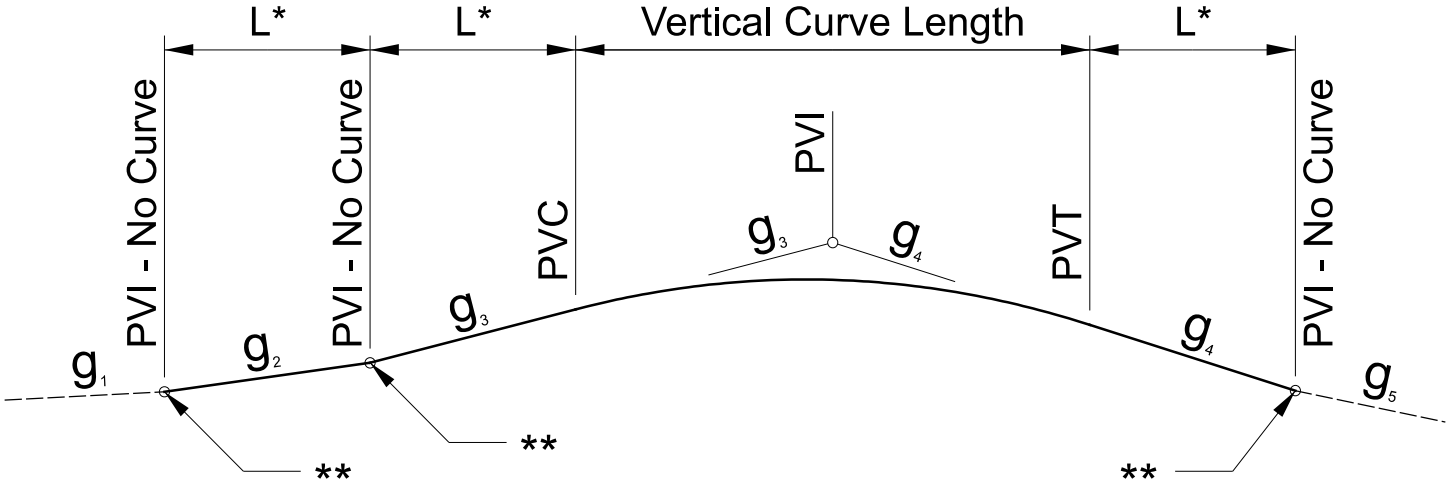
A = Maximum Grade Change (%)

L = Length of Vertical Curve (assume 25')

V = Design Speed (mph)

△ ROUNDED TO NEAREST 0.05%

RELATIONSHIP BETWEEN VERTICAL CURVES AND GRADE BREAKS



* The minimum distance between consecutive deflections is:
100' where design speed is 50 mph or greater
50' where design speed is less than 50 mph

** Allowable grade break location.

CREST VERTICAL CURVES

203-3

REFERENCE SECTION
203.3.3

HEIGHT OF EYE 3.50′ - HEIGHT OF OBJECT 2.00′

DESIGN SPEED	DESIGN SSD	DESIGN K
20	115	7
21	120	7
22	130	8
23	140	10
24	145	10
25	155	12
26	165	13
27	170	14
28	180	15
29	190	17
30	200	19
31	210	21
32	220	23
33	230	25
34	240	27
35	250	29
36	260	32
37	270	34
38	280	37
39	290	39
40	305	44
41	315	46
42	325	49
43	340	54
44	350	57
45	360	61
46	375	66
47	385	69

DESIGN SPEED	DESIGN SSD	DESIGN K
48	400	75
49	415	80
50	425	84
51	440	90
52	455	96
53	465	101
54	480	107
55	495	114
56	510	121
57	525	128
58	540	136
59	555	143
60	570	151
61	585	159
62	600	167
63	615	176
64	630	184
65	645	193
66	665	205
67	680	215
68	695	224
69	715	237
70	730	247
71	745	257
72	765	271
73	780	282
74	800	297
75	820	312

Using: S = Stopping Sight Distance, ft.
L = Length of Crest Vertical Curve, ft.
A = Algebraic Difference in Grades (%), Absolute Value
K = Rate of Vertical Curvature

- For a given design speed and an "A" value, the calculated length "L" = K x A
- To determine "S" with a given "L" and "A", use the following:

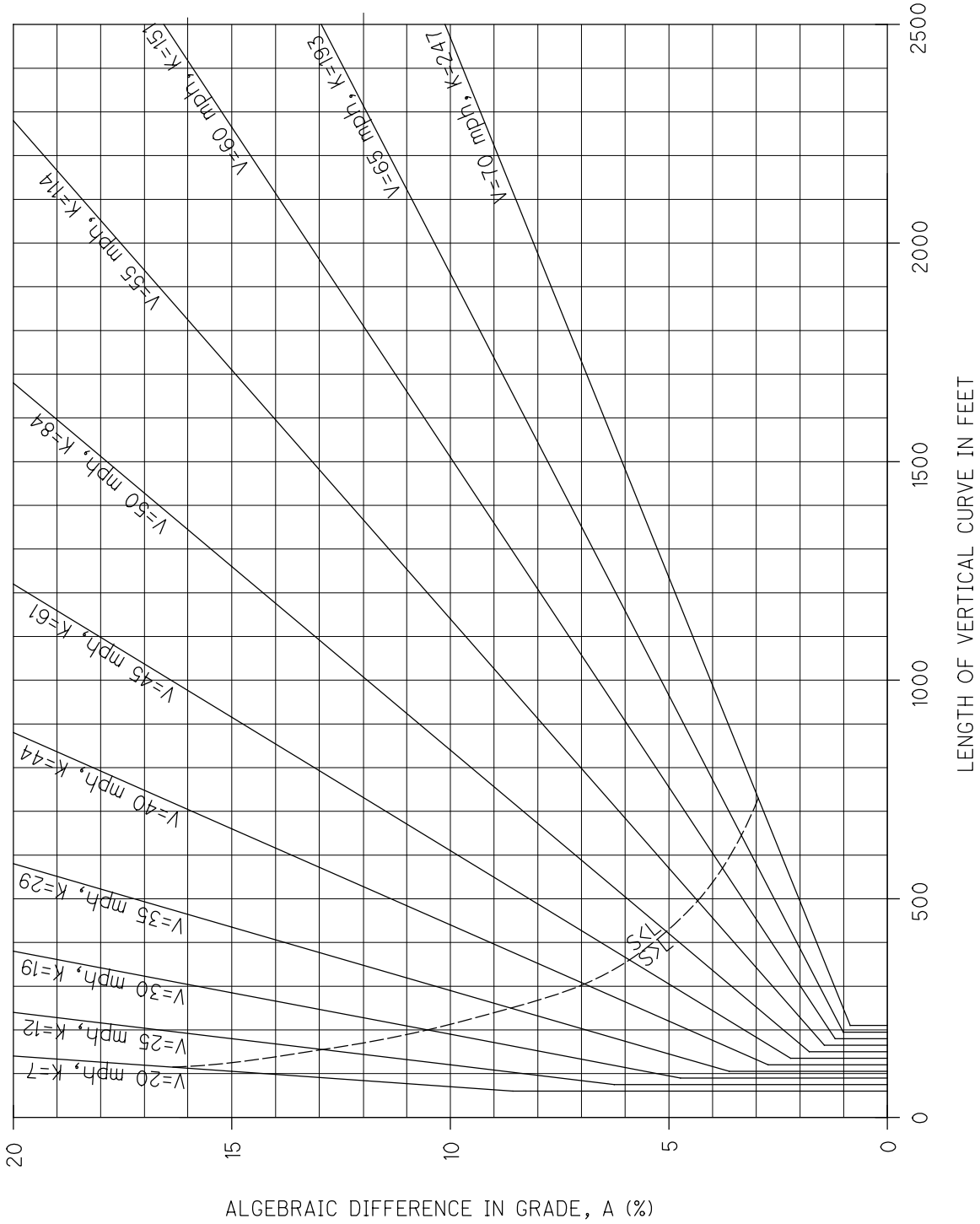
For S<L: $S = 46.45 \sqrt{K}$, where K = L/A

For S>L: $S = 1079/A + L/2$

DESIGN CONTROLS
STOPPING SIGHT DISTANCE
CREST VERTICAL CURVES

203-4

REFERENCE SECTION
201.2.2 & 203.3.3



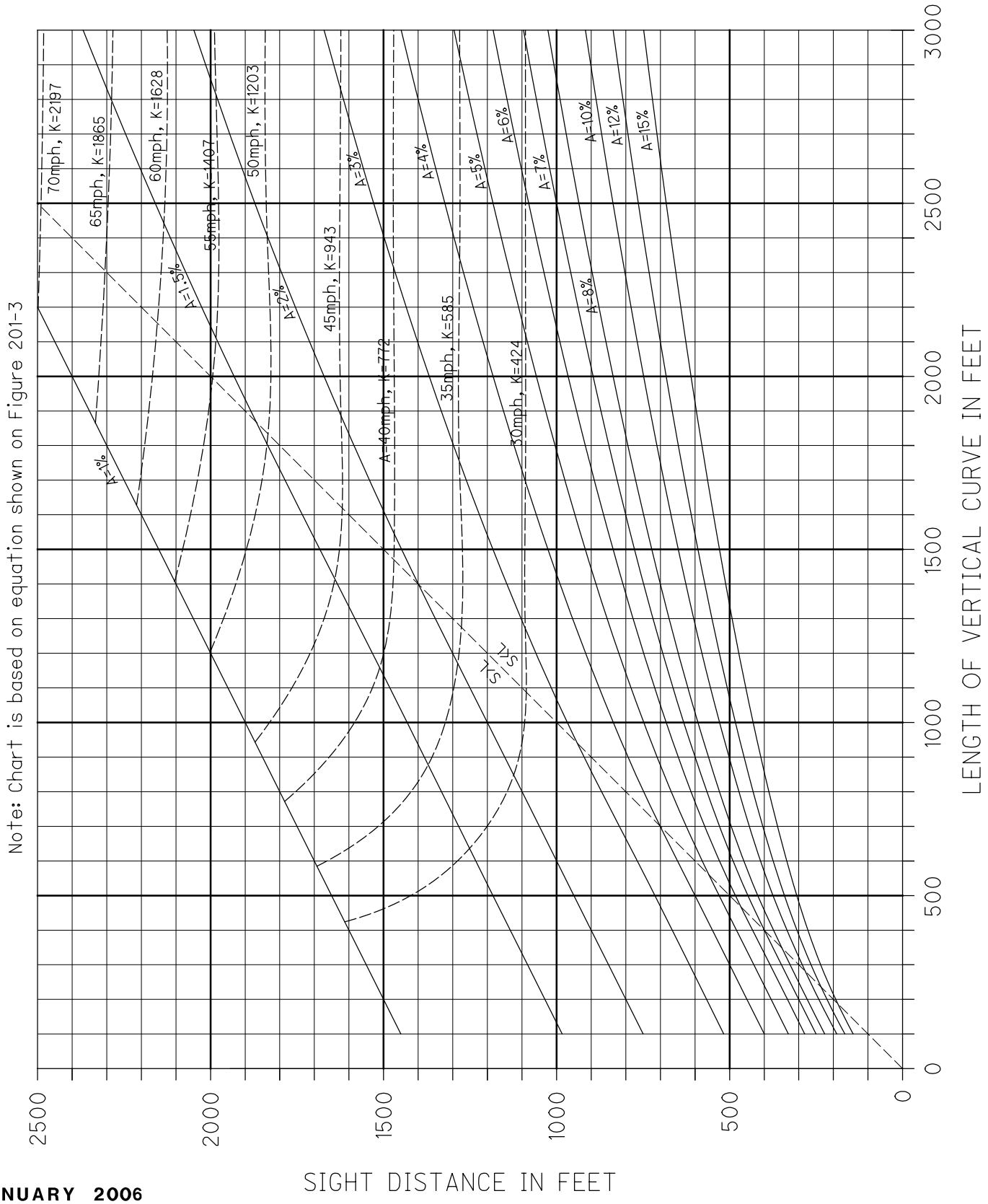
Note 1. Chart is based on equations shown on Figure 203-3 and Lmin = 3xV, where "V" is the design speed in mph and L is in feet.

2. To determine the Design Speed for a given "A" and "L" when S>L, use equation for S>L on Figure 203-3.

DESIGN CONTROLS
PASSING SIGHT DISTANCE
CREST VERTICAL CURVES

203-5

REFERENCE SECTION
203.3.3



SAG VERTICAL CURVES

203-6

REFERENCE SECTION
201.2.2 & 203.3.4

HEIGHT OF HEADLIGHT = 2.00′

DESIGN SPEED	DESIGN SSD	DESIGN K
20	115	17
21	120	18
22	130	20
23	140	22
24	145	24
25	155	26
26	165	28
27	170	29
28	180	32
29	190	34
30	200	37
31	210	39
32	220	42
33	230	44
34	240	47
35	250	49
36	260	52
37	270	55
38	280	57
39	290	60
40	305	64
41	315	66
42	325	69
43	340	73
44	350	76
45	360	79
46	375	83
47	385	85

UPWARD LIGHT BEAM DIVERGENCE = 1° 00′

DESIGN SPEED	DESIGN SSD	DESIGN K
48	400	89
49	415	93
50	425	96
51	440	100
52	455	104
53	465	107
54	480	111
55	495	115
56	510	119
57	525	123
58	540	128
59	555	132
60	570	136
61	585	140
62	600	144
63	615	148
64	630	153
65	645	157
66	665	162
67	680	167
68	695	171
69	715	176
70	730	181
71	745	185
72	765	190
73	780	194
74	800	200
75	820	206

Using: S = Stopping Sight Distance
L = Length of Sag Vertical Curve
A = Algebraic Difference in Grades (%), Absolute Value
K = Rate of Vertical Curvature

- For a given design speed and an "A" value, the calculated length "L" = K x A
- To determine "S" with a given "L" and "A", use the following:

For S<L: $S = \dfrac{3.5L + \sqrt{12.25L^2 + 1600AL}}{2A}$

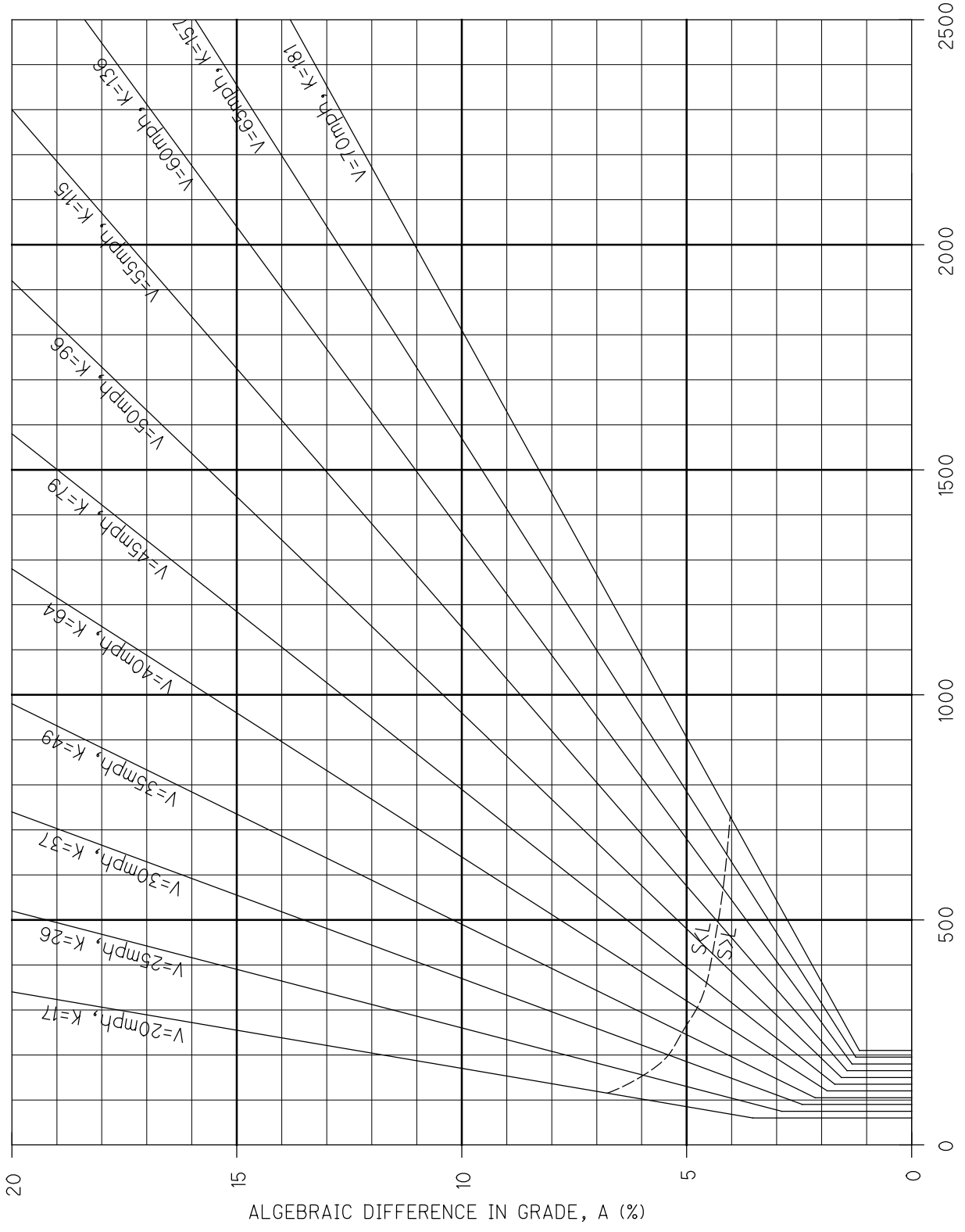
For S>L: $S = (AL + 400)/(2A - 3.5)$

Note: When the algebraic difference, A, is 1.75% or less, SSD is not restricted by the vertical curve.

DESIGN CONTROLS
SSD DISTANCE
SAG VERTICAL CURVES

203-7

REFERENCE SECTION
201.2.2 & 203.3.4



Note: Chart is based on equations shown on Figure 203-6 and Lmin = 3xV, where V is the design speed in mph and L is in feet.

TANGENT OFFSETS FOR VERTICAL CURVES

203-8

REFERENCE SECTION
203.3.5

Basic formulae are: $d=\frac{L}{800}(g-g')$

and: $d'=\left[\frac{I}{\left(\frac{L}{2}\right)}\right]^2 \times d$

P.C. P.I. P.T. g g′ d d′ I L

d′=tangent offset

To find offset from tanget for any 25′ interval from PC or PT, use factor from table for I and multiply by g-g′

(Example) Given; L=1200′
I=225′
g=+2%
g′=-4%
g-g′= 6

Then the factor for 225′ (L=1200′), is 0.2109 and offset = 0.2109 x 6 or d′=1.265′

LENGTH OF VERTICAL CURVE IN FEET	L/800	I= 25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	575	600	625	650	675	700	725	750
200	.2500	.0156	.0625	.1406	.2500																										
250	.3125	.0125	.0500	.1125	.2000	.3125																									
300	.3750	.0104	.0417	.0938	.1667	.2604	.3750																								
350	.4375	.0089	.0357	.0803	.1429	.2232	.3214	.4375																							
400	.5000	.0078	.0313	.0703	.1250	.1953	.2812	.3828	.5000																						
450	.5625	.0069	.0278	.0625	.1111	.1736	.2500	.3403	.4444	.5625																					
500	.6250	.0063	.0250	.0563	.1000	.1563	.2250	.3063	.4000	.5063	.6250																				
600	.7500	.0052	.0208	.0469	.0833	.1302	.1875	.2552	.3333	.4219	.5208	.6302	.7500																		
700	.8750	.0045	.0179	.0402	.0714	.1116	.1607	.2188	.2857	.3616	.4464	.5402	.6429	.7545	.8750																
800	1.000	.0039	.0156	.0352	.0625	.0977	.1406	.1914	.2500	.3164	.3906	.4727	.5625	.6602	.7656	.8789	1.0000														
900	1.125	.0035	.0139	.0313	.0556	.0868	.1250	.1701	.2222	.2813	.3472	.4201	.5000	.5868	.6806	.7813	.8889	1.0035	1.1250												
1000	1.250	.0031	.0125	.0281	.0500	.0781	.1125	.1531	.2000	.2531	.3125	.3781	.4500	.5281	.6125	.7031	.8000	.9031	1.0125	1.1281	1.2500										
1100	1.375	.0028	.0114	.0256	.0455	.0710	.1023	.1392	.1818	.2301	.2841	.3438	.4091	.4801	.5568	.6392	.7273	.8210	.9205	1.0256	1.1365	1.2528	1.3750								
1200	1.500	.0026	.0104	.0234	.0417	.0651	.0938	.1276	.1667	.2109	.2604	.3151	.3750	.4401	.5104	.5859	.6667	.7526	.8438	.9401	1.0417	1.1484	1.2604	1.3776	1.5000						
1300	1.625	.0024	.0096	.0216	.0385	.0601	.0865	.1178	.1538	.1947	.2404	.2909	.3462	.4063	.4712	.5409	.6154	.6947	.7788	.8678	.9615	1.0601	1.1635	1.2716	1.3846	1.5024	1.6250				
1400	1.750	.0022	.0089	.0201	.0357	.0558	.0804	.1094	.1429	.1808	.2232	.2701	.3214	.3772	.4375	.5022	.5714	.6451	.7232	.8058	.8929	.9844	1.0804	1.1808	1.2857	1.3951	1.5089	1.6272	1.7500		
1500	1.875	.0021	.0083	.0188	.0333	.0521	.0750	.1021	.1333	.1688	.2083	.2521	.3000	.3521	.4083	.4688	.5333	.6021	.6750	.7521	.8333	.9188	1.0083	1.1021	1.2000	1.3021	1.4083	1.5188	1.6333	1.7521	1.8750

INTERMEDIATE DISTANCES FROM P.C. OR P.T. IN FEET

300 - Cross Section Design

301 - Roadway Criteria

301.1 - Pavement

301.1.1 - General

This section will assist the designer in determining lane width and pavement cross slope. The number of lanes required is determined through the use of a capacity analysis. This process is explained in detail in the current **Highway Capacity Manual**, published by the Transportation Research Board. See Figure 301-1 for Level of Service Goals.

Pavement type is determined by the volume and composition of traffic, soil characteristics, performance of pavements in the area, availability of materials, initial cost, annual maintenance cost and service life cost. The determination of pavement type and structural design is included in the Pavement Design Manual published by the Office of Pavement Engineering.

301.1.1.1 - Disposition of Pavement Required Due to Maintenance of Traffic

ODOT Policy 21-08(P) (and related Standard Procedure 123-01(SP)), Traffic Management in Work Zones, establishes criteria intended to eliminate or reduce traffic delays caused by work zones. Application of this policy to major rehabilitation projects typically results in the need for additional pavement to satisfy the policy. In some situations, this has caused debate on whether the additional pavement should be permanent, full depth design that would be opened to traffic upon completion of the project or a temporary, thinner design that would be removed after construction. The following is intended to provide guidance in making these decisions. This guidance should be considered during the earliest steps of the Project Development Process, and should not supersede any planning or PDP requirements.

The Districts should first request 20 year design traffic for the project and run capacity analyses to determine the need for future permanent lanes. Refer to Figure 301-1, for the appropriate level-of-service goal for the roadway. If the analyses indicate additional lanes will be needed within the next 20 years, the District should proceed with the environmental documentation required, including a Major Investment Study (MIS) in Metropolitan

Planning Organization (MPO) areas. This may result in changing the original project path (see Section 5 of the Project Development Process Manual for details on path classifications). If stream coordination, noise impacts, air quality and planning requirements can be addressed satisfactorily, FHWA will support further development of a project which includes additional permanent, full-depth pavement. Gap closure will not be accepted as the principal Purpose and Need for adding permanent lanes in the future if the capacity analysis does not indicate a need. Median treatments must also be analyzed to determine barrier requirements.

Projects which are approved for additional pavement that will be opened to traffic upon completion must be submitted to TRAC for their concurrence even if Major New funds are not being requested.

Due to the 1 mile signing requirements on freeways to warn motorists of a lane drop ahead, the additional lane/s which were permanently added should not be opened to traffic unless their total length is 5 miles or greater if the adjoining pavement sections at either end of the project have not been widened to match.

Where the need for additional lanes has been determined, the Districts should also look at the need for modifying any existing interchanges which are in the project boundaries of the additional through lanes. Since approval for Interchange Justification Studies are based on not significantly impacting the level-of-service of the Interstate or freeways from the no-build alternative to the build alternative, adding additional capacity to the roadway almost always permits existing interchanges to be expanded to handle additional traffic. Even if funding is not readily available for modifying interchanges at the time the additional through lanes are being added to the freeway, the District should still check the capacity need for modifying the existing interchanges. Many times auxiliary lanes are needed on the freeway from one interchange to another, and these lanes, along with bridge widening to accommodate these lanes could be performed at the same time the additional lanes are constructed.

If Districts determine additional capacity will not be needed within the next 20 years, the additional widening required to maintain traffic should be a temporary buildup sufficient for the duration of the construction project and then be removed upon completion of the project. It is not cost effective to construct full-depth pavement and open it to traffic at the conclusion of the project if the capacity is not required within a 20-year planning horizon.

301.1.2 - Lane Width

Lane width in rural areas is dependent upon functional classification, traffic volumes and design speed and is shown in Figure 301-2. Figure 301-4 shows lane widths in urban areas based on functional classification and locale. See Section 105.3 for the National Network lane width requirements.

301.1.3 - Traveled Way Widening on Highway Curves

Additional widening may be necessary on curves depending on the design speed, curvature and traveled way width. The Traveled Way Widening values Figure 301-5c are based on the WB-62 [WB-19] vehicle and are applicable to either one-way or two-way, two-lane traveled ways, and other similar type facilities. A WB-62 [WB-19] design vehicle is to be used on state-maintained roadways. The design vehicle for other than state-maintained roadways should be determined by the maintaining authority. Note that widening less than 2.0 ft. is not required.

Curve widening should be placed on the inside edge of the curve. Where spirals are used, the widening should begin at the TS and reach maximum width at the SC. On alignments without spirals, the widening should be developed over the same distance as the superelevation transition. See Section 202.4 and Figure 301-5a. The transition ends should be rounded to avoid an angular break at the traveled way edge and intermediate points should be widened proportionately. The longitudinal center joint and the centerline marking should be placed equidistant from the traveled way edges.

301.1.4 - Pavement Transition/Taper Rates

Where traveled way widths decrease, the length of transition should be calculated using the following:

- Design Speed of 50 mph or more:
    - $L=WS$
- Design Speed of less than 50 mph:
    - $L=WS^2/60$

- Where:
    - L = Taper length in feet
    - W = Offset width in feet
    - S = Design speed

The transition length for increases in traveled way width (diverging tapers) may be more abrupt. The diverging taper for turn lanes should be 50’. Ramps should have a 100’ taper length.

301.1.5 - Pavement Cross Slope

Normal crowned pavements in Ohio are sloped at the rate of 0.016. There are occasions when, because of drainage or pavement type, this rate may be increased to 0.02. An increase in the 0.016 slope rate normally takes place on facilities maintained by local governmental agencies and usually at design speeds less than 50 mph.

Cross slope arrangements for normal crowned sections vary based on features such as the number of lanes, whether or not the highway is divided or undivided, the type and width of the median, and drainage. Figure 301-6 shows examples normally used in Ohio. Generally, the following are applicable on normal crowned pavements:

1. Crowns are to be located between lanes.
2. For three or four lane roadways, no more than two lanes should slope in the same direction.
3. When 3 or more lanes are sloped in the same direction on a high-speed roadway (50 mph or greater), the first two lanes from the crown point should have the normal cross slope of 0.016 and any adjacent outside lanes may have an increased maximum cross slope of 0.02.
4. On new roadway designs or major pavement rehabilitation projects when 3 or more lanes are sloped in the same direction on a high-speed roadway (65 mph or greater) and the profile grade is 3% or steeper, the first two lanes from the crown

point should have the normal cross slope of 0.016 and any adjacent outside lanes should have an increased maximum cross slope of 0.025 when feasible.

5. Narrow raised median sections are crowned such that the majority of the pavement will drain toward the outside.
6. Pavement sections on either side of wide, depressed medians are to be treated similarly to undivided pavement sections (See Item 3 above), with the majority of the pavement sloped to the outside.

Special conditions on individual projects may result in deviations from the above and from those examples shown inFigure 301-6.

301.2 - Shoulders

301.2.1 - General

Shoulders are used to provide an area adjacent to the pavement to accommodate stopped vehicles, for emergency use, for use while maintaining traffic through construction work zones, for the lateral support of the pavement and to generally improve the safety of a highway. They are also available for the use of pedestrians and bicyclists. When discussing shoulders in this manual, the following meanings are applicable. (See Figure 301-7.)

- Traveled Way - The portion of roadway used for the movement of vehicles, exclusive of shoulders and bicycle lanes.
- Graded Shoulder Width - The width measured from the edge of the traveled way to the intersection of the shoulder slope and foreslope.
- Treated Shoulder Width - The width of that portion of the graded shoulder improved with aggregate base or better.

301.2.2 - Shoulder Type

Four basic types of shoulders are used. These include paved, surface treated, aggregate base, and turf. Structural design of shoulders and shoulder typical sections are covered in the Pavement Design Manual published by the Office of Pavement Engineering. Figures 301-3 and 301-4 show the type shoulder to use based on functional classification and

traffic or locale. The shoulder should be paved if bicycles and pedestrians are expected to be frequent users.

301.2.3 - Shoulder Width

Graded and treated shoulder widths vary depending on functional classification and traffic or locale. The criteria for graded and treated shoulder widths are shown in Figures 301-3 and 301-4. Consideration should be given to providing paved shoulders of sufficient width and strength to accommodate temporary traffic on Interstates, other freeways and expressways. Paved shoulder width reductions of less than 2’ at sign or luminaire foundations or bridge piers will not require a design exception. The 4’ minimum lateral clearance must still be provided. The shoulder should be of sufficient width if bicycles and pedestrians are expected to be frequent users. See MDG Sections 4.3.2 and 6.3.3 for more information.

301.2.3.1 - Right Turn Lane Shoulder Width

Under normal roadway conditions, it is desirable to maintain the required mainline shoulder width throughout the length of the right turn lane. Where the roadway has constrained R/W limits and a low volume truck traffic, the width of the shoulder adjacent to the turn lane may be reduced, but to no less than 4 ft. paved and 6 ft. graded. The normal mainline shoulder width should still be maintained in advance of the diverging taper for the turn lane. The transition between the mainline shoulder width and the reduced shoulder width should take place during the span of the right turn taper. The reduced shoulder width may then be carried out throughout the length of the right turn lane. It should be noted that any shoulders or auxiliary lanes (i.e., right turn lanes) are considered part of the mainline clear zone. See MDG Section 6.5 for more information on accommodating bicyclists along shoulders at intersections.

301.2.3.2 - Shoulder Taper Rate

A 25:1 taper should be used to transition to a reduced shoulder width. The transition length for increases in shoulder width (diverging tapers) may be more abrupt, i.e. 5:1 ratio.

301.2.4 - Shoulder Cross Slope

Figures 301-8, 301-9 and 301-10show cross slopes to be used depending on the shoulder type and pavement cross slope.

If the bridge shoulder cross slope is different than the approach roadway shoulder cross slope, then the shoulder cross slope shall be transitioned on the roadway section, off the bridge and approach slabs, within a distance of 100 feet.

The shoulder cross slope must be designed to account for stormwater and melting snow/ice draining across the traveled way. The high side shoulder of superelevated sections typically includes a grade break at the edge of traveled way or within the paved shoulder. This grade break directs drainage away from the traveled lanes and often reduces the footprint of the project. The algebraic difference varies but is 7% or less to reduce the risk for rollover when a vehicle traverses the grade break. It is typically preferred that the grade break occurs within the paved surface instead of at the edge of paved shoulder where the surface material changes. In curbed sections the shoulder break on the high side may be eliminated when engineering judgement is used and hydraulic calculations demonstrate that it is acceptable, especially where curb inlets would only be needed on the high side to capture the broken width of a narrow shoulder.

301.2.5 - Lateral Clearance

In general, roadside objects and barriers should be placed as far away from the traveled way as conditions permit. Proper lateral placement enhances a driver's comfort level of the roadway, allows for a greater chance of recovery for errant vehicles, and provides for improved sight distance.

The distance from the edge of the traveled way, beyond which a roadside object will not be perceived as an obstacle and result in a motorist reducing speed or changing vehicle position on the roadway is called the shy line offset. As a minimum, the designer should provide a shy line offset of at least 4 ft. When an obstacle is placed too closely to the traveled way, it may interfere with the sight distance of the roadway.

302 - Bridge Criteria

302.1 - General

This section provides overall physical bridge dimensions such as width, lateral clearance at underpasses and vertical clearance over roadways. This information is given for New and Reconstructed Bridges in Figure 302-1 and for Existing Interstate and Other Freeway Bridges to Remain in Figure 302-2. Similar information for existing non-freeway bridges that are to be left in place and not reconstructed is shown in Figure 302-3. For additional

design information, including Minimum Design Loading, refer to the Bridge Design Manual, published by the Office of Structural Engineering.

303 - Interchange Elements

303.1 - General

An interchange is a system of interconnecting roadways, with one or more grade separations, used to efficiently manage traffic between different types and levels of highways. Interchanges are composed of various elements such as Acceleration-Deceleration Lanes, One and Two-lane Directional Roadways, and Ramps. Figure 303-1shows information relating to the design of interchange elements including pavement and shoulder dimensions, as well as medians between adjacent ramps.

304 - Medians

304.1 - General

A median is the portion of the highway separating opposing directions of the traveled way. Medians are highly desirable elements on all streets or roads with four or more lanes. This is especially true on rural arterials. All rural arterials, on new locations requiring four or more lanes, should be designed with a median.

The principal functions of a median are to prevent interference of opposing traffic, to provide a recovery area for out-of-control vehicles, to provide areas for emergency stopping and left turn lanes, to minimize headlight glare and to provide width for future lanes. A median should be highly visible both day and night and in definite contrast to the roadway.

304.2 - Width

The width of a median is the distance between the inside edges of the traveled way. See Figure 304-1. Width depends upon the type of facility, cost, topography and right-of-way.

304.2.1 - Rural

In flat or rolling terrain, the desirable median width for rural freeways is 60 to 84 ft. The 84 foot wide median allows for a future 12 foot wide lane in each direction of travel, and the 60

ft. median. The minimum median width is normally 40 ft. However, in rugged terrain, narrower medians ranging from 10 to 30 ft. may be used. A constant width median is not necessary and independent profiles may be used for the two roadways. For narrower medians, see Section 601.2 for Median Barrier warrants.

304.2.2 - Urban

Barrier medians are normally used in urban areas. The median width is dependent upon the width of the barrier and the shoulder width required in Figure 301-4. The minimum median width for a four-lane urban freeway should be 10 ft. which provides for two 4 ft shoulders and a 2 ft median barrier. For freeways with six or more lanes, the minimum width should be 22 ft. The minimum median widths noted above do not take into account the extra width required if median piers are encountered. Where median piers are encountered either widen the median throughout or apply for a design exception. Preferably, use a 26 ft. wide median when the DDHV for truck traffic exceeds 250 vehicles per hour to provide a wider median shoulder to accommodate a truck.

304.3 - Types

Medians are divided into types depending upon width and treatment of the median area and drainage arrangement. In general, raised or barrier medians are applicable to urban areas, while wide, depressed medians apply to rural areas. See Figure 304-1.

304.3.1 - Rural

Medians in rural areas are normally depressed to a swale in the center and constructed without curbs.

304.3.2 - Urban

There are various types of medians applicable to urban areas. The type selected depends upon the traffic volume, speed, degree of access and available right-of-way.

On major streets with numerous business drives, a median consisting of an additional lane, striped as a continuous two-way left turn lane is desirable.

The solid 6-inch high concrete median, at a minimum width of 4ft. (See **Standard Construction Drawing RM-3.1**) may be used where the design speed is less than 50 mph

and where an all-paved section is appropriate and a wider median cannot be justified. Barrier medians, described in Section 601.2, are normally recommended for urban facilities where the design speed is 50 mph or greater. However, care must be exercised when barrier medians are used on expressways with unsignalized at-grade intersections because of sight distance limitations.

304.4 - U-turn Median Openings

304.4.1 - Purpose

U-turn median openings may be provided on expressways, freeways or interstate highways with non- barrier medians where space permits as outlined below and when needed for proper operation of police and emergency vehicles, as well as equipment engaged in physical maintenance, traffic service, and snow and ice control.

304.4.2 - Location

U-turn crossings should not be constructed in barrier-type medians.

When U-turn median openings are required, they should be spaced as close to 3-mile intervals as possible.

Crossings should be located at points approximately 1,000 ft. beyond the end of each interchange speed change lane. Additional crossings may be constructed at maintenance borders, District borders, State lines and other desired locations in accordance with the 3-mile spacing interval requirement. Examples of the allowable number of crossings between interchanges, in addition to crossings provided at interchange speed change lanes, are shown below:

Interchange Spacing	Number of Crossings
3 miles or less	None
3 to 6 miles	One
6 to 9 miles	Two
9 to 12 miles	Three

U-turn median crossings should be located to fit the median drainage pattern. Each should be placed either immediately downstream from a catch basin or on a crest. They should be located so that visibility is not restricted by structures, vertical curves or horizontal curves.

304.4.3 - Design Details

Median crossings should be constructed as shown on Figure 304-2 which indicates geometric features applicable to the design of crossings located in medians of widths ranging from 40 to 84 ft. Tapers should be 200 ft. in length for all median widths. The profile grade line should normally be an extension of the cross slope of the shoulder paving, rounded at the lowest point.

305 - Curbs

305.1 - General

The type of curb and its location affect driver behavior patterns which, in turn, affect the safety and utility of a road or street. Curbs, or curbs and gutters, are used mainly in low speed urban areas (See **Section 305.3**). Following are various reasons for justifying the use of curbs, or curbs and gutters:

1. Where required for drainage.
2. Where needed for channelization, delineation, control of access or other means of improving traffic flow and safety.

3. To control parking where applicable.
4. To reduce right-of-way requirements.

Conventional concrete or asphalt concrete curbs offer little visible contrast to the pavement surface, particularly during fog or at night when the surface is wet. The visibility of the curbs can be greatly enhanced with the use of reflectorized paints. Curb markings should be placed in accordance with OMUTCD.

305.2 - Types and Uses

There are two general types of curbs; vertical curbs and sloped curbs. Vertical curbs are relatively high (6 inches or more) and steep-faced. Sloped curbs are 6 inches or less in height and have flatter, sloping faces so that vehicles can cross them with varying degrees of ease.

The curb sections detailed on **Standard Construction Drawing RD-5.1** are approved types to be used as stated below:

- Type 1 Curb (asphalt curb) is a sloping 6 inch curb used mostly for temporary situations, such as correcting special drainage problems.
- Type 2, 2-A, and 2-B curbs are 6 inches high with a steep sloped face. They are widely used along the edges of traveled way in urban areas where design speeds are less than 50 mph. Type 2 curb is preferred to Type 6 curb to eliminate the joint between the curb and the gutter.
- Types 3, 3-A, 3-B and Type 4, 4-A, 4-B and 4-C curbs are 4 inches high with a sloped face. They are used for channelizing islands and occasionally along medians and edges of traveled way. Type 3 is preferred for channelizing islands with the gutter sloped at the same rate as the adjacent pavement.
- Type 6 Curb is a 6 inch high steep faced vertical curb. It is used in situations similar to Type 2 described above.
- Type 7 Curb is a vertical type used in low speed areas (design speed of less than 50 mph) for protection at bridge approaches. It may also be used to control traffic in areas involving heavy trucks.

- Type 8 Curb is not frequently installed but can be used to negotiate a grade differential between the back of sidewalk and adjacent pavement (e.g. a parking lot).
- Type 9 Curb is a sloping 3 inch high curb used around the truck apron of a roundabout.
- Type 10 is a sloping curb used along separated bicycle lanes. Type 10 and 10-A/10-B should be used to reduce pedal strikes along street level and intermediate level separated bicycle lanes respectively. See Section 6.3.7 of the Multimodal Design Guide for curbing considerations along separated bicycle lanes. Type 10 Curb may also be used around the truck apron of a roundabout.
- Type 11 Curb is a mountable curb and gutter used along the edge of traveled way of a roundabout.

305.3 - Position of Curb

305.3.1 - Urban Areas (Design Speed less than 50 mph)

Curbs are normally used at the edge of traveled way on urban streets where the design speed is less than 50 mph. Curbs at the edge of traveled way have an effect on the lateral placement of moving vehicles. Drivers tend to shy away from them. Therefore, all curbs should be offset at least 1 foot from the edge of the traffic lane. Where curb and gutter are used, the standard gutter width is 2 ft.

305.3.2 - Urban and Rural High Speed Areas

On roads where the design speed is 50 mph or greater, the use of curb should be avoided. Curbs should only be used in special cases. Special cases may include, but are not limited to, the use of curb to control surface drainage or to reduce right-of-way requirements in restricted areas. When it is necessary to use curbs on roads where the design speed is 50 mph or greater, they should not be closer to the traffic than 4 ft. or the edge of the treated shoulder, whichever is greater and their height should not exceed 4 inches.

305.3.3 - Curb/Guardrail Relationship

Refer to Section 602.1.5.

305.4 - Curb Transitions

305.4.1 - Curb Vertical Height Tapers

The approach and trailing ends of curbs should be tapered from the curb height to 0” in 10 ft. For raised curb medians and splitter islands, the approach and trailing ends should be tapered from the raised curb median/splitter island height to 2” in 10 ft.

305.4.2 - Curbed to Uncurbed Transitions

When an urban type section with curbs at the edge of traveled way changes to a rural type section without curbs, the curb should be transitioned laterally at a 4:1 (longitudinal: lateral) rate to the outside edge of the treated shoulder or 3 ft., whichever is greater. See Figure 401-4b, Option 2.

305.4.3 - Curbed Approach to Uncurbed Mainline

When a curbed side road intersects a mainline that is not curbed, the curb should be terminated no closer to the mainline edge of traveled way than 8 ft. or the edge of the treated shoulder, whichever is greater. See Figure 401-4a.

306 - Pedestrian Facilities

See Multimodal Design Guide for Pedestrian Facilities information.

307 - Grading and Sideslopes

307.1 - General

This section is concerned with the design of slopes, ditches, parallel channels and interchange grading. It incorporates into the roadside design, the concepts of vehicular safety developed through dynamic testing. Designers are urged to consider flat foreslopes and backslopes, wide gentle ditch sections and elimination of barriers in their initial design approach.

307.2 - Slopes

307.2.1 - Roadside Grading

There are several combinations of slopes and ditch sections that may be used in the grading of a project. Details and use of these combinations are discussed in subsequent paragraphs. In general, slopes should be made as flat as possible to minimize the

necessity for barrier protection and to maximize the opportunity for a driver to recover control of a vehicle after leaving the traveled way. Regardless of the type of grading used, projects should be examined in an effort to obtain flat slopes at low costs. For instance, fill slopes can be flattened with material which otherwise might be wasted and backslopes can be flattened to reduce borrow.

ODOT does not allow non-ODOT agencies to use ODOT right of way for the purpose of locating stormwater Best Management Practices (BMPs).

In order to more fully understand the discussions on the various types of grading, the designer should become familiar with the need for barrier protection and the clear zone concept covered in Section 600.

Safety grading is the shaping of the roadside using 6:1 or flatter slopes within the clear zone area (Section 600.2) and 3:1 or flatter foreslopes and recoverable ditches extending beyond the clear zone. Safety grading is used on Interstate, other freeways and expressways. Figures 307-1 and 307-2 show many of these details.

Clear zone grading is the shaping of the roadside using 4:1 or flatter foreslopes and traversable ditches within the clear zone area. Foreslopes of 3:1 may be used, but are not measured as part of the clear zone distance. Clear zone grading is recommended for undivided rural facilities where the design speed is 50 mph or greater, the design hourly volume is 100 or greater, and when at least one of the following conditions exists:

1. The wider cross section is consistent with present or future planning for the facility.
2. The project is new construction or major reconstruction involving significant length.
3. The wider cross section can be provided at little or no additional cost.

Figure 307-3 shows examples of clear zone grading and traversable ditches.

Common grading is the shaping of the roadside using 3:1 or flatter foreslopes and normal ditches. It is used on undivided facilities where the conditions for the use of safety grading or clear zone grading do not exist. The designer should ensure that all obstacles within the clear zone receive proper consideration. Figure 307-4 shows examples of common grading and normal ditches.

Barrier grading is the shaping of the roadside when barrier is required for slope protection. Normally 2:1 foreslopes and normal ditch sections are used. Figure 307-4 gives an example of barrier grading.

307.2.2 - Slope Transitions

The need for barrier protection of a fixed object may be eliminated when the fixed object has been relocated beyond the clear zone boundary and clear zone grading has been provided through the required limits on the approach and trailing ends. The clear zone grading shall extend (at a minimum) longitudinally for the distance of the Runout Length ("LR") for the fixed object as determined from Figure 602-1. The clear zone measurement should be used for the Lateral Extent of the Hazard (“LH”), which is the minimum lateral limit that clear zone grading is required for the elimination of barrier. The clear zone grading is required throughout the entire rectangular “box” created by the LR and LH on each side of the fixed object. Clear Zone grading should not be utilized unless the required lane and shoulder widths are present.

As shown in these conditions, Clear Zone grading is desirable throughout a roadway corridor. It does little to increase the safety of a roadway if Clear Zone grading is only done on spot projects such as culvert replacements, if the rest of the corridor will be maintained with common grading.

307.2.3 - Rounding of Slopes

Slopes should be rounded at the break points and at the intersection with the existing ground line to reduce the chance of a vehicle becoming airborne and to harmonize with the existing topography. Recommended rounding at the edge of the graded shoulder is shown in Figure 301-3. Rounding at other locations is shown in Figures 307-1, 307-3 and 307-4.

307.2.4 - Special Median Grading

Figure 307-5shows some examples of median grading when separate roadway profiles are used.

307.2.5 - Rock Slopes (See Figure 307-5)

In rock cuts, determine the cut slope angle(s) and necessary slope benches using design guidance presented in GDM Section 1000. The designer should examine the project to

ascertain whether flatter slopes could be used to the advantage of reducing borrow within a reasonable haul distance. Such a situation should also be discussed with the Office of Geotechnical Engineering.

307.2.6 - Curbed Streets

The slope treatment adjacent to curbed streets is shown on Figure 307-6.

307.2.7 - Driveways and Cross Roads

At driveways or crossroads, where the roadside ditch is within the clear zone distance and where clear zone grading can be obtained, the ditch and pipe should be located as shown onFigure 307-7.

Requirements for pipe location should be applied to all new construction, reconstruction, widening and resurfacing projects if regrading of the roadsides to safety or clear zone grading is included in the work. New driveways constructed by permit should also conform to the above if other such installations on the route conform, otherwise the new driveway pipe may be located in the existing roadside ditch.

307.3 - Ditches

When the depth or velocity of the design discharge accumulating in a roadside or median ditch exceeds the desirable maximum established for the various highway classifications, a storm sewer will be required to intercept the flow and carry it to a satisfactory outlet. If right-of-way and earth work considerations are favorable, a deep parallel side ditch (seeFigure 307-5) may be more practical and should be considered instead of a storm sewer.

In some cases where large areas contribute flow to a highly erodible soil cut, an intercepting ditch may be considered near the top of the cut to intercept the flow from the outside and thereby relieve the roadside ditch.

Constant depth ditches (usually 18 inches deep) are desirable. Where used, the minimum pavement profile grades should be 0.24% to 0.48%. Where flatter pavement grades are necessary, separate ditch profiles are developed and the ditch flow line elevations are shown on each cross section.

307.4 - Parallel Channels

Where it is desirable that a stream intercepted by the improvement be relocated parallel to the roadway, the channel should be located beyond the limited access line in a channel easement. This does not apply to conventional intercepting erosion control ditches located at the top of cut slopes in rolling terrain. This arrangement locates the channel beyond the right-of-way fence. See Figure 307-5.

In areas of low fill and shallow cut, protection along a channel by a wide bench is usually provided. Fill slopes should not exceed 6:1 when this design is used and the maximum height from shoulder edge to bench should generally not exceed 10 ft. If it should become necessary to use slopes steeper than 6:1, guardrail may be necessary and fill slopes as steep as 2:1 may be used.

In cut sections 5 ft. or more in depth, earth barrier protection can be provided. Where very deep channels are constructed, this design probably affords greater protection and requires less excavation. See Figure 307-5. Where the sections alternate between cut and fill and it is desired to use a single design, earth barrier protection would be less costly if waste is a problem. Likewise, bench protection would be less costly if borrow is needed.

Earth bench or earth barrier protection provided adjacent to parallel channels should not be breached for any reason other than to provide an opening for a natural or relocated stream requiring a drainage structure larger than 42 inches in rise. Outlet pipes from median drains or side ditches shall discharge directly into the parallel channel.

Channels and toe-of-slope ditches, used in connection with steep fill slopes, should be removed from the normal roadside section by benches. The designer shall establish control offsets to the center of each channel or ditch at appropriate points which will govern their alignment so they will flow in the best and most direct course to the outlet. Bench width shall be varied as necessary (See Figure 307-5).

307.5 - Interchange Grading

Interchange interiors should be contour graded so the least amount of guardrail is required and so maximum safety is provided with corresponding ease of maintenance. Sight distance is critical for passenger vehicles on ramps as they approach entrance or merge

areas, especially if barrier is erected on the merging side of the vehicle. Therefore, sight distance shall be unobstructed by landscaping, earth mounds or other barriers.

307.5.1 - Crossroads

At a road crossing within an interchange area, bridge spill-through slopes should be 2:1, unless otherwise required by structure design. They should be flattened to 3:1 or flatter in each corner cone and maintained at 3:1 or flatter if within the interior of an interchange. Elsewhere in interchange interiors, fill slopes should not exceed 3:1.

307.5.2 - Ramps

Roadside design for ramps should be based on the mainline grading concept.

307.5.3 - Gore Area (See Figure 307-8)

Gore areas of trumpets, diamonds and exteriors of loops adjacent to the exit point, should be graded to obtain slopes (6:1 or flatter) which will not endanger a vehicle which is unable to negotiate the curvature because of excessive speed.

307.5.4 - Trumpet Interiors (See Figure 307-8)

Interior areas of trumpets should be graded to slopes not in excess of 8:1, sloping downward from each side of the triangle to a single rounded low point. Roadside ditches should not be used. Exteriors should be graded in accordance with the mainline or ramp standards.

307.5.5 - Loop Interiors (See Figure 307-9)

In cut, the interior should be graded to form a normal ditch section adjacent to the lower part of the loop and the backslope should be extended to intersect the opposite shoulder of the upper part of the loop, unless the character and the amount of material or the adjacent earth work balances indicate that the cost would be prohibitive. Roadside cleanup and landscaping should be provided in undisturbed areas of loop interiors.

If channels are permitted to cross the loop interior, slopes should not be steeper than 4:1.

307.5.6 - Diamonds

If the location of the ramp intersection at the crossroad is relatively near to the main facility, a continuous slope between the upper roadway shoulder and the lower roadway ditch will provide the best and most pleasing design.

If the ramp intersection at the crossroad is located a considerable distance from the main facility, then both ramp and mainline roadsides should have independent designs, until the slopes merge near the gore. If the quadrant is entirely, or nearly so, in cut, it is suggested that the combination of a 3:1 backslope at the low roadway ditch and a gentle downslope from the high roadway shoulder will provide the best design in the wide portion of the quadrant. Approaching the gore, the slopes should transition to continuous 4:1 and 6:1 or flatter slopes.

Quadrants located entirely in fill areas should have independently designed roadways for ramp, mainline and crossroad. Each should be provided with normal slopes not greater than 3:1, with the otherwise ungraded areas sloped to drain without using ditches.

If the quadrant is located partially in cut and partially in fill, the best design would feature a gentle fill slope at the upper roadway and a gentle backslope at the lower roadway joined to a bench at the existing ground level which is sloped to drain.

The combination of a long diamond ramp having gentle alignment with a loop ramp in the same interchange quadrant is not to be treated as a trumpet. Each ramp should be designed independently of the other in accordance with the suggested details set forth above.

307.6 - Disposal of Construction Debris and Waste Material within ODOT R/W

All projects with pavement removal, particularly non-recyclable concrete pavement, or an excess of excavation should be evaluated for acceptable disposal areas within the state right-of-way. This material cannot be arbitrarily dumped within the limits of state right-of-way. If improperly placed, the material may interfere with adequate sight distance and may create an unnecessary hazard.

Acceptable disposal areas would preferably enhance highway operations and should not in any way reduce safety. Instead of hauling the material offsite or improperly placing the material, the excess fill may be used throughout the state right-of-way limits to improve

grading and general roadside safety. For example, all interstate and interstate look-alike systems should use safety grading. If safety grading currently exists, consider extending it to the right-of-way limit. If clear zone grading currently exists, consider using safety grading or extend the clear zone grading to the right-of-way limit. Each barrier location should be evaluated to see if the application of safety grading, or at a minimum clear zone grading, would eliminate the need for barrier. Adjustments to drainage or drainage structures may also be required.

The determination as to whether or not to allow the disposal of waste material within the right-of-way of a project should be made as soon as possible in the project development process. Possible waste areas within the project right-of-way limits should be identified during the field review prior to final scope preparation. Areas deemed acceptable should be identified accordingly in the construction plans. If none of the areas are considered acceptable, this should also be clearly noted in the construction plans in the form of a plan note.

For the full text of the guidelines see Guidelines for Identifying Acceptable Locations for the Disposal of Waste Material and Construction Debris or the Excavation of Borrow Material within ODOT Right-of-Way located in the Reference section of this manual.

307.6.1 - Exit Ramps

Fill material may be placed in the infield areas of exit ramps as long as the decision sight distance is provided and 6:1 or flatter slopes are provided in the gore areas. Decision sight distances, Avoidance Maneuver A or B, as per Figure 201-6 should be provided for the design speed of the ramp. Also note that with respect to a diamond interchange, the placement of the fill material in the infields should not be such that it interferes with the intersection sight distance at the intersection of the crossroad and the exit ramp.

307.6.2 - Entrance Ramps

Excess or disposable fill material should not be placed adjacent to an entrance ramp such that it interferes with the available sight distance. Decision sight distance, Avoidance Maneuver C or E, as per Figure 201-6 should be provided for the design speed of the ramp. The decision sight distance is measured from a point on the ramp where the driver, on the ramp, has an unobstructed view of the mainline to where the lane width becomes

less than 10 ft. and the driver must merge. This is the distance that the driver merging from the ramp must decide whether they can safely merge into the mainline traffic.

This distance should also be unobstructed for the mainline driver to react to the ramp vehicle by either a lane or speed change.

307.6.3 - Loop Ramps

In general, the infields of loop ramps should not be filled unless it is to eliminate barrier or provide safety graded slopes. Filling these areas may decrease sight distance and diminish the driver's ability to anticipate the sharpness and total path of the ramp. It is important to have an unobstructed view of the ramp in order that driver may have adequate time to react to possible obstructions and delays ahead. Loop ramps are more susceptible to run off the road crashes due to the sharp curvature and high speeds.

If a designer chooses to fill the infield, as a minimum, the decision sight distance, Avoidance Maneuver A or B, as per Figure 201-6, using the ramp design speed, should be provided for the exit portion of the ramp. Likewise, Avoidance C or E, using the ramp design speed, should be provided for the entrance portion of the ramp. The fill height should not exceed 20 ft. in height or as determined by the Office of Geotechnical Engineering. Slopes should not exceed 4:1 for ease of maintenance.

307.6.4 - Adjacent to Noise Sensitive Areas

Excess or disposable fill material may be placed adjacent to a noise sensitive area via the construction of a small height berm. Consult with the Office of Environmental Services-Statewide Noise Wall Coordinator regarding opportunities. A minimum 3'-6" tall berm height is recommended. Consult with the Office of Geotechnical Engineering regarding taller berm heights. Designer must adhere to clear zone requirements in LDM Vol 1 **Section 600** and grading requirements in LDM **Section 307**. The designer must consider issues including but not limited to underground utilities, tower lighting, signage, landfills, floodplains, utility markers, valve boxes, nameholes, hydrants, exposed conduits, drainage concerns, tree removal, ecological items, etc.

308 - On-Road Bicycle Facilities

See Multimodal Design Guide for On-Road Bicycle Facilities information.

LEVEL OF SERVICE GOALS

301-1

REFERENCE SECTIONS
201.4.1 & 301.1.1

Uninterrupted Flow (Mainline analyses including Basic segment, Merge, Diverge, Weave and Overlap)	
Result	**Operational Goal**
LOS (Level of Service)	D or better
d/c (Demand-to-Capacity ratio)	< 0.93

Interrupted Flow (Intersection analyses including All-Way Stop-Control, Two-Way Stop-Control, Roundabout, and Signalized	
Result	**Operational Goal**
Intersection LOS	D or better (See Note 1)
Approach LOS	E or better
Control LOS	E or better
v/c (Volume-to-Capacity ratio)	All movements < 1.0 with ≤ 0.93 preferred.
QSR (Queue-Storage ratio)	All movements < 1.0 from HCS, otherwise TransModeler may be needed to determine if queuing impacts upstream intersections

Note 1: A LOS E may be acceptable at locations where a vulnerable road user project on a low-speed facility is implemented if the Build condition does not have a significant adverse impact on the safety and operations within the study area.

LEVEL OF SERVICE (UNINTERRUPTED FLOW)

A - Free flow, with low volumes and high speeds.
B - Stable flow, speeds beginning to be restricted by traffic conditions.
C - In stable flow zone, but most drivers are restricted in freedom to select own speed.
D - Approaching unstable flow; drivers have little room to maneuver.
E - Unstable flow, may be short stoppages.
F - Forced or breakdown flow.

* This table should be used as guidance. The designer should use judgement to choose an appropriate level of service that is practical for each location.

RURAL LANE WIDTHS (A)

301-2

REFERENCE SECTIONS
301.1.2

Functional Classifcation	Traffic	Minimum Lane Widths (ft.)										
	Design Year ADT	Design Speed (mph)										
		20	25	30	35	40	45	50	55	60	65	70 or >
Interstate, Other Freeways, and Expressways	ALL	--	--	--	--	--	--	12	12	12	12	12
Arterial	> 2000	--	--	--	--	12	12	12	12	12	12	12
	400 to 2000	--	--	--	--	11	11	11	12	12	12	12
	< 400	--	--	--	--	10	10	11	11	11	11	11
Collector	> 2000	11	11	11	11	11	11	11	11(C)	11(C)	--	--
	400 to 2000	10	10	10	11	11	11	11	11	11	11	--
	< 400	10	10	10	10	10	10	10	11	11	11	--
Local	> 2000	11	11	11	11	11	11	11	11(C)	11(C)	--	--
	400 to 2000	10	10	10	10	10	11	11	11	11	--	--
	< 400	9	9	9	9	9	10	10	11	11	--	--

NOTES:

(A) There may be some rural locations that are urban in character. An example would be a village where adjacent development and other conditions resemble and urban area. In such cases, urban design criteria (Figure 301-4) may be used.

(B) The number of lanes should be determined by a capacity analysis.

(C) Consider using a 12' lane width where substantial truck volumes are present or agricultural equipment frequently use the road.

(D) For National Network lane width requirements, see Section 105.3

Note: For the design criteria pertaining to Collectors and Local Roads with ADT's of 2000 or less, refer to the **AASHTO publication Guidelines for Geometric Design of Low-Volume Roads (2nd Edition 2019)**

RURAL SHOULDER CRITERIA

301-3

REFERENCE SECTIONS
301.2.2, 301.2.3, 307.2.3, & 602.1.1

Functional Classifcation	Traffic	Graded Width			Treated Width (S)	Type (I) (S)	Rounding (K)		Guardrail Offset (From Traveled Way)
							Design Speed		
	Design Year ADT	With Barrier	Without Barrier and Foreslope Steeper than 6:1	Without Barrier 6:1 or Flatter Foreslope			≥ 50	< 50	
Interstate, Other Freeways, & Expressways (Q)	ALL	15' Rt. 9' Med. (B)(P)	15' Rt. 9' Med. (B)	10' Rt. 4' Med. (D)	10' Rt. (C) (R) 4' Med. (D)	Paved	10'	--	(L) (G)
Arterial (N)	>2000	13' (P)	12'	8'	8'	PVD (O)	8'	4'	10' (G)
	1501 to 2000	11' (P)	10'	6'	6'	PVD (O)	8'	4'	8' (G)
	400 to 1500	11' (P)	10'	6'	6'	PVD (O)	4'	4'	8' (G)
	< 400	9' (P)	8'	4'	4'	PVD (O)	4'	4'	6' (G)
Collector (N)	>2000	11' (P)	10'	8'	4'	SRF. TRT. (J)	8'	4'	8' (M)
	1501 to 2000	9' (P)	8'	6' (E)	4'	AGG. BASE	8'	4'	6' (M)
	400 to 1500	7' (P)	6'	5'	4'	AGG. BASE	4'	4'	4'
	< 400	7' (P)	6'	(F)	(F)	AGG. BASE	4'	4'	4'
Local	>2000	11' (P)(H)	10' (H)	8' (H)	4'	SRF. TRT. (J)	8'	4'	8' (M)
	1501 to 2000	9' (P)	8'	6' (E)	4'	AGG. BASE	8'	4'	6' (M)
	400 to 1500	7' (P)	6'	5'	4'	AGG. BASE	4'	4'	4'
	< 400	7' (P)	6'	(F)	(F)	AGG. BASE	4'	4'	4'

See the following sheet for corresponding notes.

Notes to Figure 301-3: Rural Shoulder Criteria

(A) There may be rural locations that are urban in character. An example would be a village where adjacent development and other conditions resemble an urban area. In such cases, urban design criteria (**Figure 301-4**) may be used.

(B) If 6 or more lanes, use 15 ft.

(C) Where truck traffic exceeds 250 DDHV, additional shoulder width may be beneficial. IF the treated shoulder width is increased then the graded shoulder width should be increased by the same amount.

(D) If 6 or more lanes, use 10 ft. See note (R).

(E) A 6-ft. turf shoulder may be used with a 4:1 or flatter foreslope.

(F) See AASHTO's 2019 Guidelines for Geometric Design Low-Volume Roads 2nd Edition for values.

(G) Concrete barrier may be placed at the edge of treated shoulder when used in lieu of guardrail.

(H) An 8-ft. graded shoulder may be used with a 4:1 or flatter foreslope.

(I) Turf shoulders may be used on non-state maintained roads at option of local government if current year ADT includes less than 250 B and C truck units. Turf shoulders are not to be used on State maintained roads.

(J) On state maintained roads, the treatment is based on the number of B and C unit trucks in the design year ADT. Refer to PDM Figures 303-1 & 403-1 for aggregate and surface treated shoulder build ups. Less than 250 trucks, aggregate base may be used. 250 to 500 trucks, surface treated aggregate base (single layer) may be used. Greater than 500 to 1000 trucks, surface treated on two layers of aggregate base may be used. Over 1000 trucks, paved shoulders are recommended.

(K) Rounding should be 4-ft. where the foreslope begins beyond the clear zone or where guardrail is installed and foreslope is steeper than 6:1. No rounding is required when the foreslope is 6:1 or flatter.

(L) Guardrail offset is treated width plus 2-ft.

(M) Whenever a design exception is approved for graded shoulder width, the guardrail offset may be reduced but shall not be less than 4-ft.

(N) The median and right shoulder width criteria for Interstates, other freeways, and expressways shall apply to the shoulders of divided arterials and divided collectors.

(O) A fully paved shoulder is preferred, but may not be economically feasible. Therefore, a minimum 2-ft. of the treated shoulder should be paved. The remainder of the treated shoulder may be either aggregate shoulder or surface treated according to the criteria stipulated in Note (J). If pedestrians or bicyclists are known to be frequent users, a fully paved shoulder should be provided.

(P) Total Graded Width may be reduced as much as 3-ft. where MGS guardrail with the longer posts is used. See Section 603.1.2 and SCD MGS-2.1 for post length and position details.

(Q) Paved shoulder width reductions of less than 2-ft. at sign or luminaire foundations or bridge piers will not require a design exception. The 4-ft. minimum lateral clearance must still be provided.

(R) Prior to the January 2017 update of L&D Manual Vol. 1, a 12-ft. shoulder width was the standard. A 12-ft. shoulder width may be retained or perpetuated, if desired.

(S) Consider increasing the treated shoulder width or using a paved surface to provide additional accommodations for pedestrians and bicyclists per MDG guidance.

Note: For the design criteria pertaining to Collectors and Local Roads with ADT's of 2000 or less, refer to the **AASHTO publication Guidelines for Geometric Design of Low-Volume Roads (2nd Edition 2019)**

URBAN ROADWAY CRITERIA LANE & SHOULDER WIDTHS (A)

301-4

REFERENCE SECTIONS
301.1.2, 301.2.2, 301.2.3, & 304.2.2

Functional Classifcation	Locale	Minimum Lane Width (ft.)	Minimum Curbed Shoulder Width (ft.) (F)	
			w/o Parking	w/ Parking (E)
Interstate, Other Freeways, and Expressways (J)	All	12	10 Rt. Paved (H) 4 Med. Paved (D)	
Arterial	50 mph or more	12	8 Each Side Paved (G)	
	Less than 50 mph	11 (B)(K)	1-2 Paved (N)	7-10 Paved
Collector Streets (I)	Commercial/ Industrial (L)	11 (K)(M)	1-2 Paved (N)	8-11 Paved
	Residential	10	1-2 Paved (N)	7-8 Paved
Local Streets (I)	Commercial/ Industrial (L)	11 (K)(M)	1-2 Paved (N)	8 Paved
	Residential	10 (C)	1-2 Paved (N)	7 Paved

NOTES:

(A) Use rural criteria (Figure 301-3) for uncurbed shoulders. Rural functional classification should be determined after checking the urban route extension into a rural area.
(B) On all Federal Aid Primary (FAP) roadways at least one 12 ft. lane in each direction is required. FAP listings may be obtained from Office of Technical Services' Roadway inventory reports. See Section 105.3 for more information on the lane width requirements for the FAP and National Network.
(C) Lane width may be 9 ft. where right-of-way is limited and current ADT is less than 250.
(D) Use 10 ft. median shoulder on facilities with 6 or more lanes.
(E) Use minimum lane width, if, in the foreseeable future, the parking lane will be used for through traffic during peak hours or continuously.
(F) See **Sections 305.3.2 and 305.3.3** for use of curbs and **Section 602.1.5** for curb/guardrail relationships.
(G) The median and right shoulder width for divided arterials shall follow the shoulder criteria for Interstates, other Freeways, and Expressways.
(H) Where truck traffic exceeds 250 DDHV, additional shoulder width may be beneficial.
(I) The AASHTO's 2019 Guidelines for Geometric Design Low-Volume Roads 2nd Edition may be used for the design criteria of Collector and Local Streets with ADT's of 2000 or less.
(J) Paved shoulder width reductions of less than 2' will not require a design exception at sign or luminaire foundations or bridge piers. The minimum 4' lateral clearance must still be provided.
(K) To help accommodate bicycle and pedestrian traffic, 10 ft. lanes may be used in constrained environments where the legal speed is 35 mph or less and the truck and bus volumes are relatively low.
(L) Residential criteria may be used in Commercial areas where truck and bus volumes are relatively low.
(M) Lane width may be increased to 12 ft. if truck volumes are high and right-of-way imposes no restrictions.
(N) In locations with guardrail, concrete barrier, or bridge parapet a minimum offset of at least 4 feet from the edge of traveled lane should be provided.

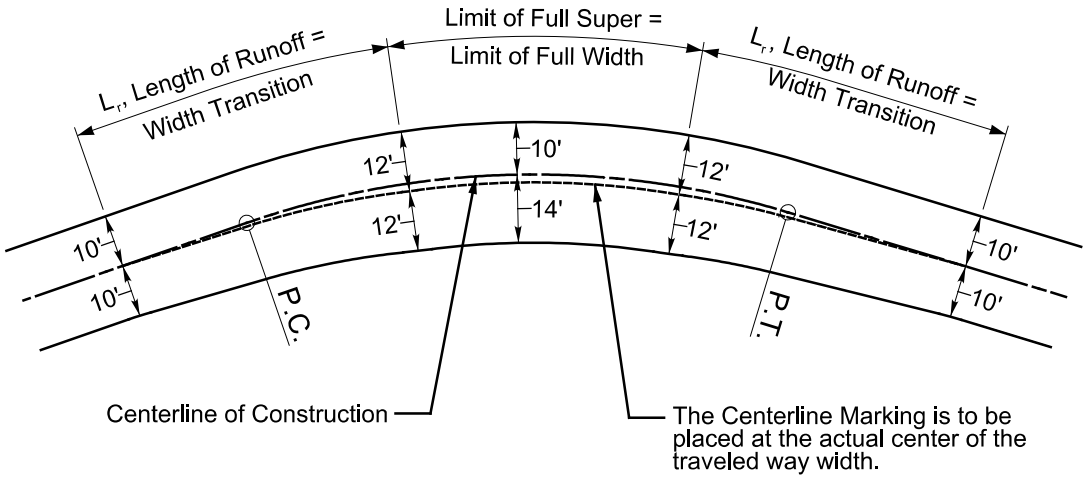
TRAVELED WAY WIDENING AT CURVES

301-5a

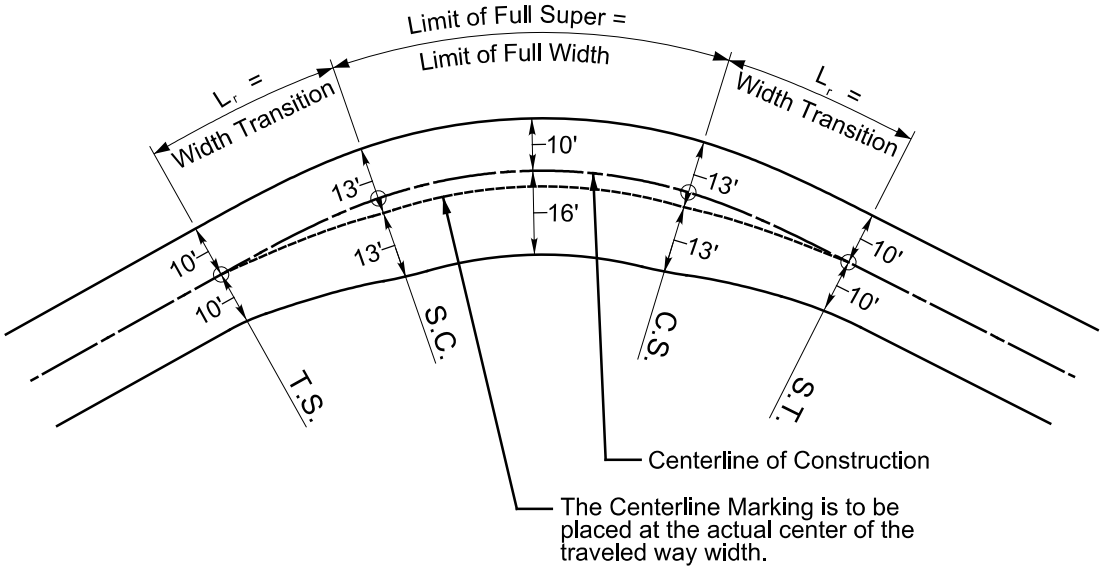
REFERENCE SECTIONS
301.1.3

LOCATION OF TRAVELED WAY TRANSITION IN RELATIONSHIP TO THE SUPERELEVATION TRANSITION

Traveled Way Widening for a Simple Curve:



Traveled Way Widening for a Spiral Curve:



TRAVELED WAY WIDENING ON OPEN HIGHWAY CURVES FOR WB-62 DESIGN VEHICLES

301-5c

REFERENCE SECTIONS
301.1.3

D_C	RADIUS	TRAVELED WAY ON TANGENT (ft.)												
		24 ft.					22 ft.				20 ft.			
		Design Speed (mph)					Design Speed (mph)				Design Speed (mph)			
		30 to 39	40 to 49	50 to 59	60 to 69	≥ 70	30 to 39	40 to 49	50 to 59	≥ 60	30 to 39	40 to 49	50 to 59	≥ 60
1°00'	5730'	0	0	0	0	0	1.0	1.0	1.0	1.0	1.5	2.0	2.0	2.0
2°00'	2865'	0	1.0	1.0	1.0	1.0	1.5	1.5	1.5	1.5	2.5	3.0	3.0	3.0
3°00'	1910'	1.0	1.5	1.5	1.5	1.5	2.0	2.5	2.5	2.5	3.0	3.5	3.5	3.5
4°00'	1432'	1.5	1.5	2.0	2.0	2.0	2.5	2.5	3.0	3.0	3.5	3.5	4.0	4.0
5°00'	1146'	2.0	2.0	2.5	3.0		3.0	3.5	3.5	3.5	4.0	4.0	4.5	4.5
6°00'	955'	2.5	2.5	3.0	3.5		4.0	4.0	4.5	4.5	4.5	4.5	5.5	5.5
7°00'	819'	3.0	3.0	4.0			4.0	4.5	5.0		5.0	5.5	6.0	
8°00'	716'	3.5	4.0	4.0			4.5	5.0	5.0		5.5	6.0	6.0	
9°00'	637'	4.0	4.0	4.5			5.0	5.0	5.5		6.0	6.0	6.5	
10°00'	573'	4.0	4.5				5.0	5.5			6.5	6.5		
11°00'	521'	5.0	5.5				6.0	6.5			7.0	7.5		
12°00'	477'	5.5	5.5				6.5	6.5			7.5	7.5		
13°00'	441'	5.5	5.5				6.5	6.5			7.5	7.5		
14°00'	409'	6.0	6.0				7.0	7.0			8.0	8.0		
14°30'	395'	6.0	6.5				7.0	7.0			8.0	8.5		
15°00'	382'	6.5					7.5				9.0			
18°00'	318'	7.5					9.0				9.5			
19°00'	300'	8.0					9.0				10.5			
21°00'	265'	9.0					10.0				11.0			
22°00'	260'	9.0					10.0				11.0			
25°00'	229'	10.5					11.5				12.5			
26°00'	223'	10.5					11.5				12.5			
26°30'	219'	11.0					12.0				13.0			

NOTE:

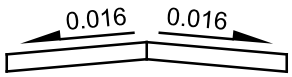
Values are for two-lane highways, one-way or two-way. Values less than 2.0 ft. may be disregarded. Multiply tables by 1.5 for 3-lanes and by 2.0 for 4-lanes.
For traveled way widening for other design vehicles, refer to the AASHTO "Green Book".

NORMAL CROSS SLOPE ARRANGEMENTS

301-6

REFERENCE SECTIONS
301.1.5

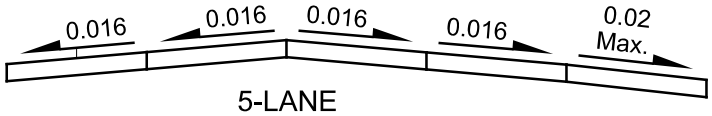
UNDIVIDED



2-LANE

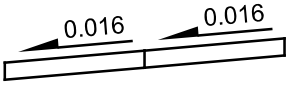


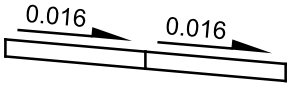
3-LANE



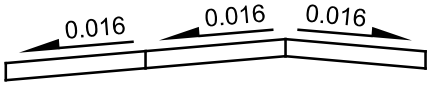
5-LANE

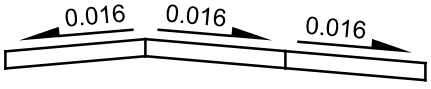
DIVIDED (RAISED MEDIAN)



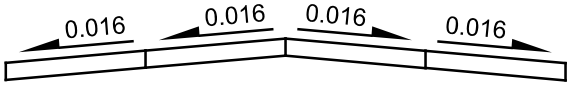


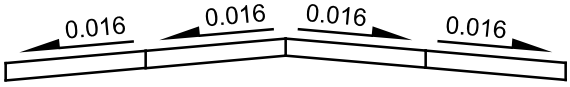
4-LANE





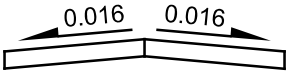
6-LANE

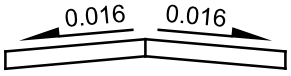




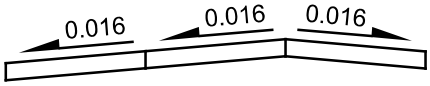
8-LANE

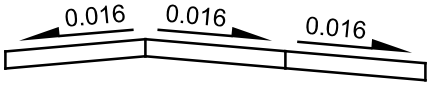
DIVIDED (DEPRESSED MEDIAN)



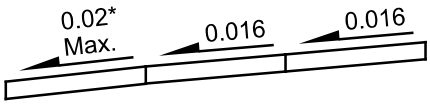


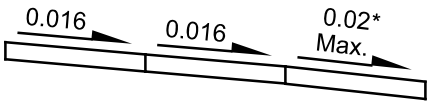
4-LANE



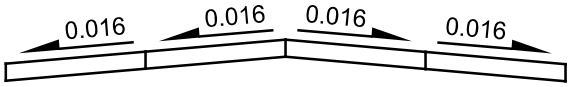


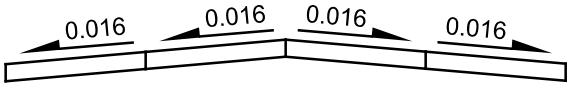
6-LANE





6-LANE





8-LANE

Note: All grade breaks should not exceed 0.032.

July 2023

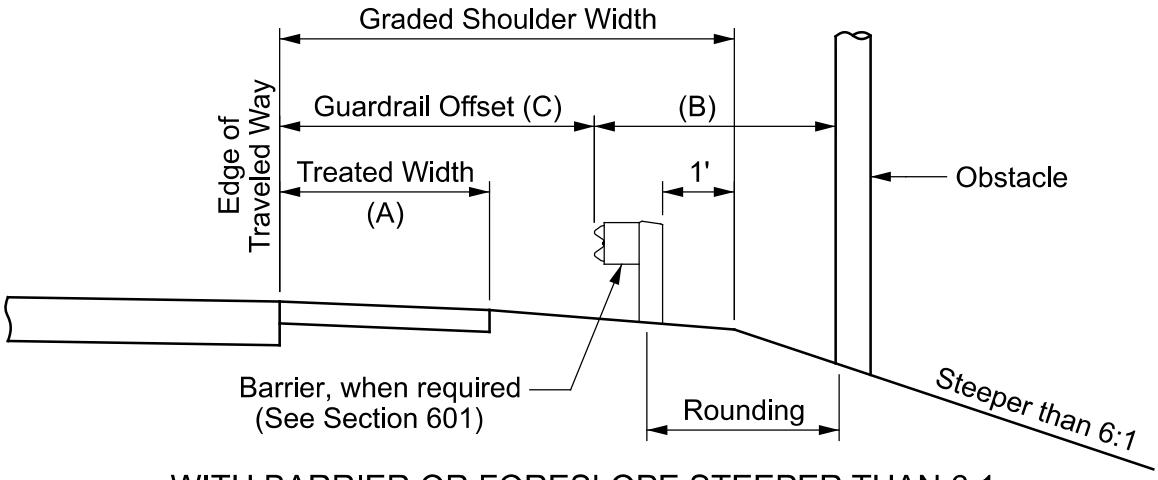
* - See Section 301.1.5

GRADED AND TREATED SHOULDER WIDTHS

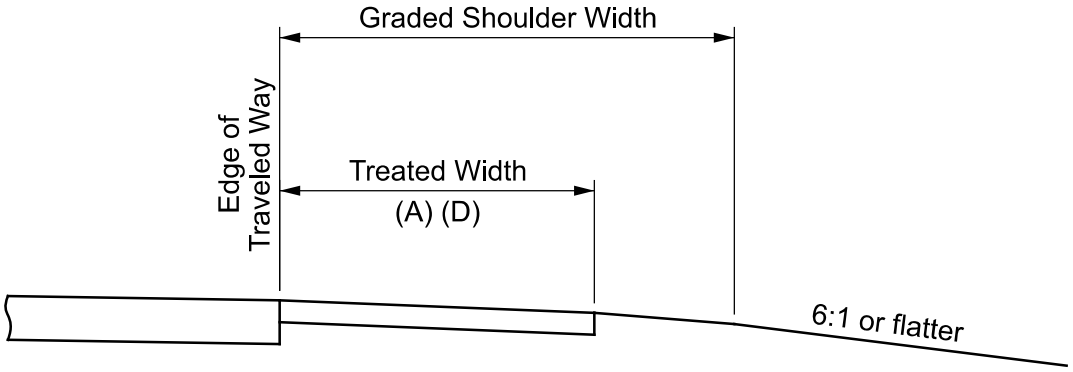
301-7

REFERENCE SECTIONS
301.2.1

See Figure 301-3 for recommended dimensions



WITH BARRIER OR FORESLOPE STEEPER THAN 6:1



WITHOUT BARRIER AND FORESLOPE 6:1 OR FLATTER

NOTES:

(A) The "Treated Width" is that portion of the shoulder improved with stabilized aggregate or better.

(B) See Figure 603-2 for minimum barrier clearance.

(C) Concrete barrier may be placed at the edge of treated shoulder when used in lieu of guardrail.

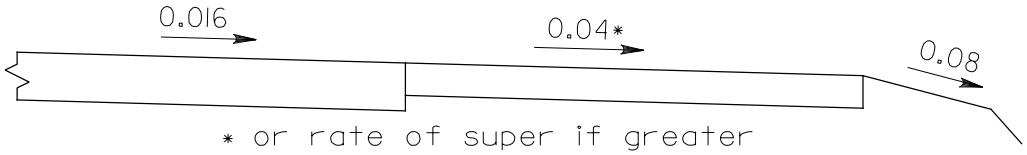
(D) Treated shoulder width may equal graded shoulder width in some cases.

PAVED SHOULDER CROSS SLOPES

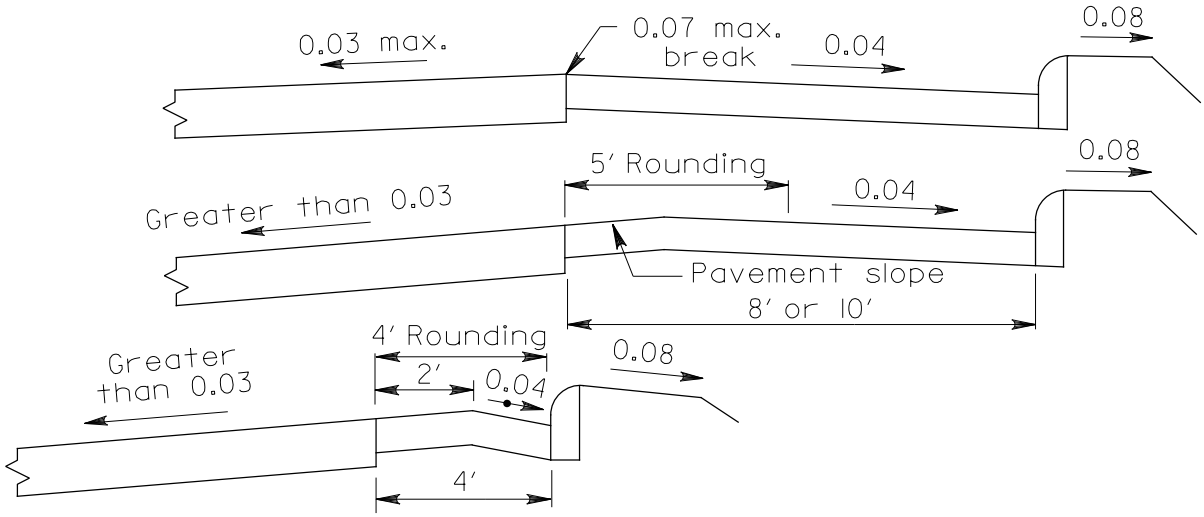
301-8

REFERENCE SECTIONS
301.2.4

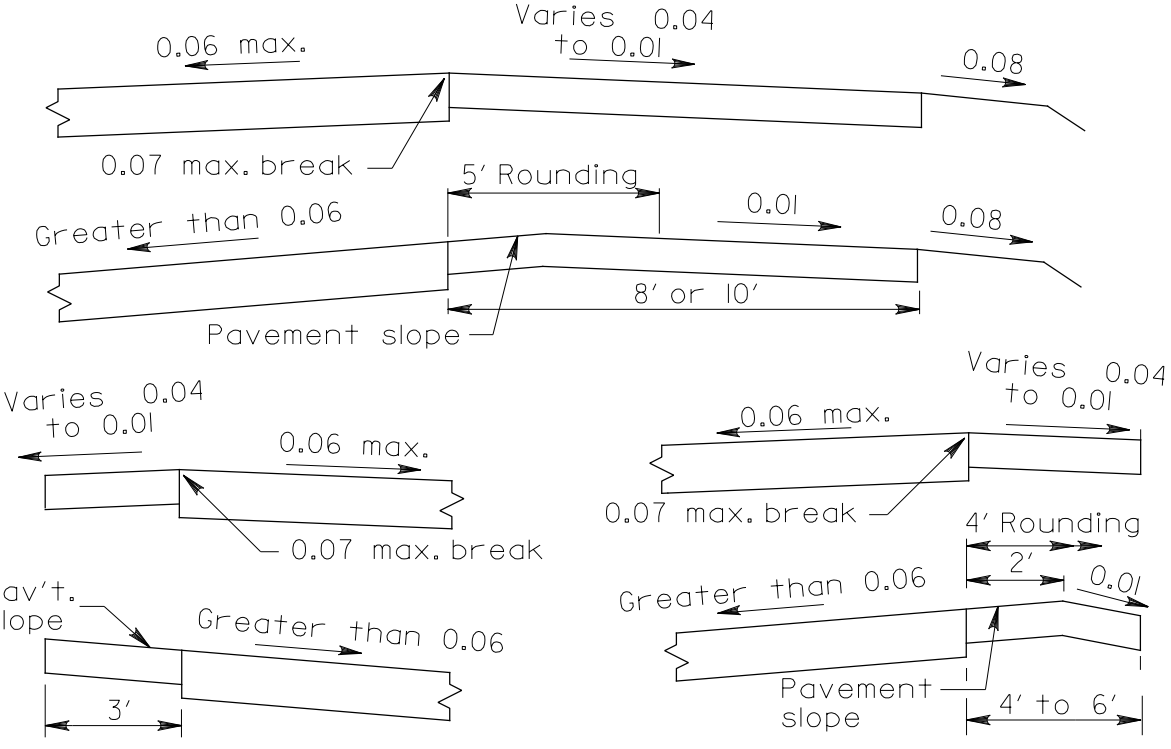
NORMAL AND LOW SIDE OF SUPERELEVATED SECTIONS



CURBED-HIGH SIDE OF SUPERELEVATED SECTIONS



UNCURBED-HIGH SIDE OF SUPERELEVATED SECTIONS

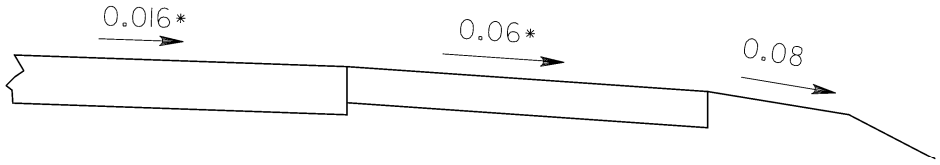


SURFACE TREATED OR AGGREGATE BASE SHOULDER CROSS SLOPE

301-9

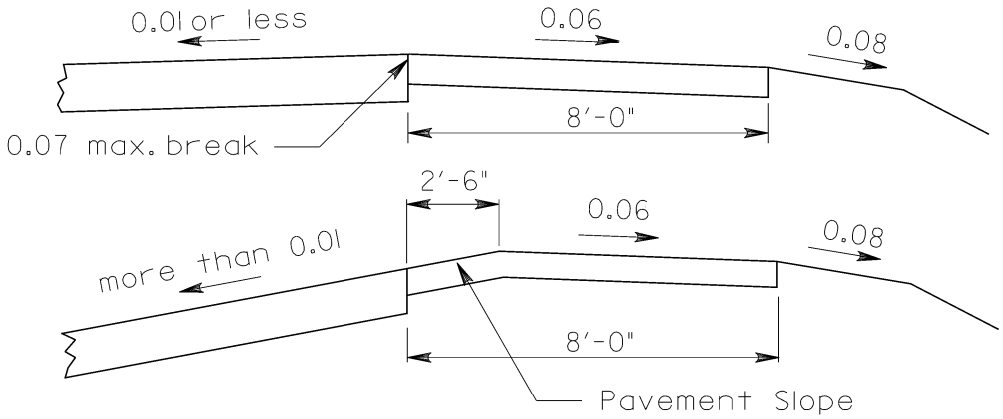
REFERENCE SECTIONS
301.2.4

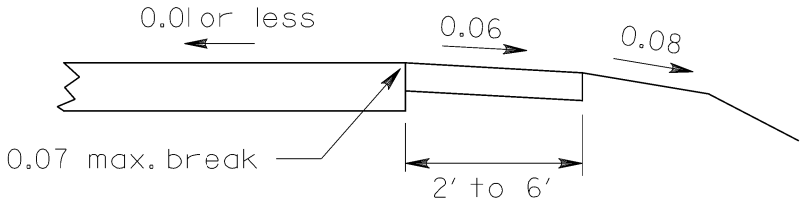
NORMAL AND LOW SIDE OF SUPERELEVATED SECTIONS

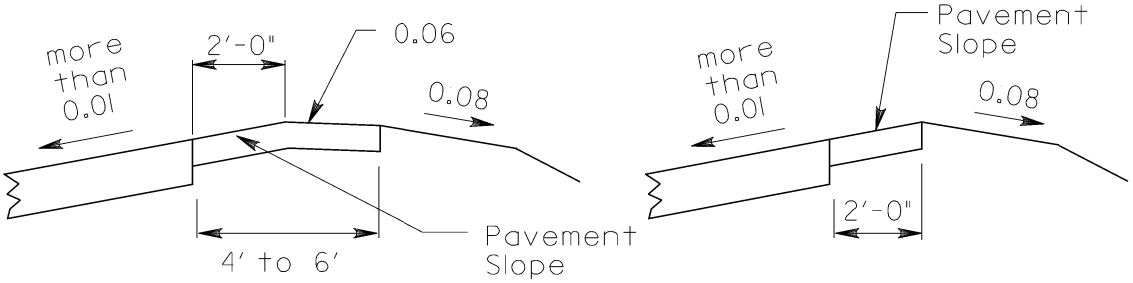


* or rate of super if greater

HIGH SIDE OF SUPERELEVATED SECTIONS





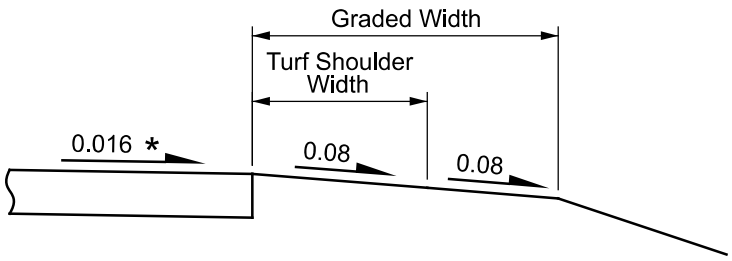


TURF SHOULDER CROSS SLOPES

301-10

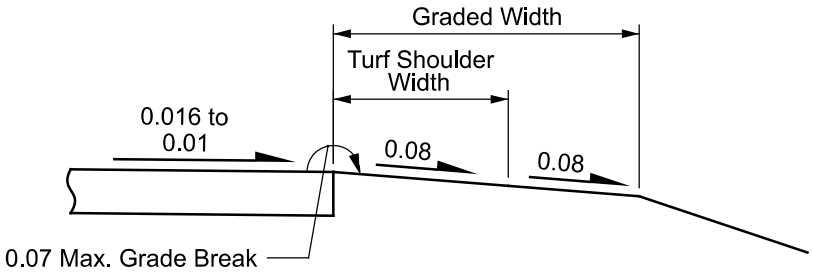
REFERENCE SECTIONS
301.2.4

NORMAL AND LOW SIDE OF SUPERELEVATED SECTIONS

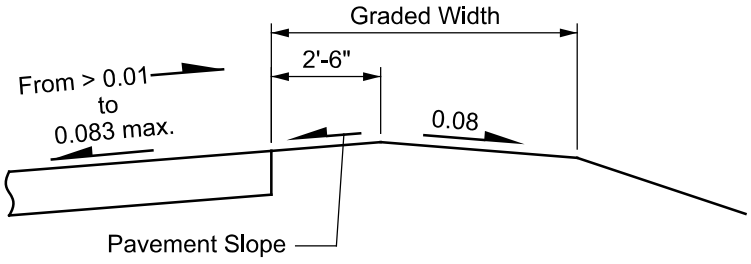


* or rate of superelevation if greater than 0.016

RISING SIDE OF SUPERELEVATED SECTIONS IN TRANSITION



HIGH SIDE OF SUPERELEVATED SECTIONS



The break at the edge of the traveled way shall not exceed 0.07.

DESIGN CRITERIA NEW AND RECONSTRUCTED(J) BRIDGES

302-1

REFERENCE SECTION
302.1

Functional Classifcation	Traffic Design Year ADT	Lateral Clearance (K) On Bridge (A) Rural Min.	Lateral Clearance (K) On Bridge (A) Urban Min.	Lateral Clearance (K) Under Bridge (F) Minimum	Vertical Clearance Over Roadway (H) Minimum
Interstates, Other Freeways, & Expressways	All	10' Rt. (B)(D) 4' Lt. (E)(B)	For curbed shoulders, use shoulder widths from Figure 301-4. For uncurbed shoulders, use rural criteria at left.	Curbed or treated shoulder widths, see Figures 301-3 & 301-4 plus barrier clearance from Figure 603-2.	16.5' (I)
Arterial	> 2000	8' (B)			
	1501 - 2000	6' (B)			
	400 - 1500	6' (B)		(G)	16.5' (I)
	< 400	4'			
Collector	> 2000	6'			
	1501 - 2000	4'			
	400 - 1500	4'		(G)	14.5'
	< 400	(C)			
Local	> 2000	6'			
	1501 - 2000	4'			
	400 - 1500	4'		(G)	14.5'
	< 400	(C)			

SEE THE FOLLOWING SHEET FOR CORRESPONDING NOTES

For structure design criteria not contained in this table such as minimum design loading, refer to the Bridge Design Manual for the Office of Structural Engineering.

WHERE THE APPROACH ROADWAY WIDTH (TRAVELED WAY PLUS SHOULDERS) IS SURFACED, AT A MINIMUM, THAT SURFACE WIDTH SHOULD BE CARRIED ACROSS THE STRUCTURE.

Notes to Figure 302-1: Design Criteria - New and Reconstructed Bridges

A. Lateral Clearance is the distance measured from the edge of the traveled lane to the face of the curb (or railing if no curb is present).
B. If a bridge is considered to be a major structure having a length of 200 ft. or more, the width may be reduced, subject to economic studies, but not less than a lateral clearance of 4 ft.
C. See AASHTO's 2019 Guidelines for Geometric Design Low-Volume Roads 2nd Edition for values.
D. Where truck traffic exceeds 250 DDHV, additional shoulder width may be beneficial.
E. If 6 or more lanes, provide 10 ft. width.
F. Distance measured from the edge of traveled lane to the face of walls of abutments and piers.
G. For low-speed facilities, refer to Section 602.5.
H. The minimum vertical clearance includes an allowance for future resurfacing equal to 0.5 ft. Sign supports and pedestrian structures shall have a 1 ft. additional clearance. Clearances shown shall be over paved shoulder as well as traveled way width.
I. A 15.5 minimum clearance may be used in highly developed urban areas if attainment of 16.5 ft. clearance would be unreasonably costly **and** if there is an alternate freeway route or bypass which provides a minimum 16.5 ft. vertical clearance.
J. A reconstructed bridge is any improvement to an existing bridge involving the replacement of the bridge deck or more.
K. Consider increasing the lateral clearance width to provide accommodations for pedestrians and bicyclists per MDG guidance.

CRITERIA FOR EXISTING INTERSTATE AND OTHER FREEWAY BRIDGES TO REMAIN

302-2

REFERENCE SECTIONS
302.1

Functional Classifcation	Design Year ADT	Minimum Lateral Clearance		Minimum Vertical Clearance (E)
		On Bridge (A)	Under Bridge (C)	
Urban Interstate	All	10' Rt. (B) 3.5' Lt.	Curbed or treated Shoulder Width Plus Barrier Clearance (D)	14.5' (F)
Rural Interstate	All	10' Rt. (B) 3.5' Lt.		16.0'
Other Freeways	All	10' Rt. (B) 3.5' Lt.		14.5'

This table is applicable to all bridges except those classified as new or reconstructed (See **Figure 302-1**).

For structural criteria not contained in this table, including Minimum Design Loading, see **Structural Engineering's Bridge Design Manual**.

NOTES:

(A) Distance measured to curb or railing, whichever is less, in no case shall the minimum width be less than the approach roadway (traveled way plus shoulders).
(B) On mainline bridges that are 200 ft. long or longer, the minimum may be reduced to 3.5 ft. for Interstate and 3 ft. for other freeways.
(C) Distance measured to face of walls, abutments, or piers.
(D) See **Figure 603-2** for minimum barrier clearnace.
(E) Includes height over shoulders.
(F) Minimum vertical clearance is 16 ft. if there is no alternative Interstate routing with the minimum 16 ft. vertical clearance.

CRITERIA FOR EXISTING NON-FREEWAY BRIDGES TO REMAIN

302-3

REFERENCE SECTION 302.1

Functional Classifcation	Design Year ADT	Minimum Lateral Clearance (A)		Minimum Vertical Clearance
		On Bridge (B)	Under Bridge (E)	
Expressways and Arterials	> 4000	6 ft. (C)	Note (G)	14 ft.
	≤ 4000	3 ft.		
Collector	> 4000	6 ft. (C)		14 ft.
	2001 - 4000	3 ft.		
	1001-2000	2 ft.		
	400-1000	2 ft.		
	< 400	0		
Local	> 4000	6 ft.		14 ft.
	2001 - 4000	3 ft.		
	1001-2000	2 ft.		
	400-1000	2 ft. (D)		
	< 400	0 (D)		

This table is applicable to all bridges except those classified as new or reconstructed (See **Figure 302-1**).

For structural criteria not contained in this table, including Minimum Design Loading, see **Structural Engineering's Bridge Design Manual**.

NOTES:

(A) Divided facilities shall have a minimum of 3 ft. lateral clearance on the median side.
(B) Distance measured to curb or railing, whichever is less. In no case shall the minimum width be less than the approach roadway (traveled way plus shoulders).
(C) On mainline bridges having a length of 100 ft. or more, the minimum may be reduced to 3 ft.
(D) One lane bridges have a total minimum width of 18 ft.
(E) Distance measured to face of walls, abutments, or piers.
(F) See **Figure 603-2** for minimum barrier clearance.
(G) For low-speed facilities, refer to Section 602.5.

Note: For the design criteria pertaining to Collectors and Local Roads with ADT's of 2000 or less, refer to the AASHTO's 2019 Guidelines for Geometric Design Low-Volume Roads 2nd Edition.

INTERCHANGE ELEMENTS - TRAVELED WAY, SHOULDERS AND MEDIANS

303-1

REFERENCE SECTIONS
303.1

INTERCHANGE ELEMENTS	TOTAL TRAVELED WAY WIDTH	Graded Shoulder Width				Paved Shoulder Width		Normal Rounding (E)	Guardrail Offset (From Traveled Way) (G)	
		Left		Right						
		With Barrier or Foreslope steeper than 6:1 (I)	w/o Barrier slopes 6:1 or flatter	With Barrier or Foreslope steeper than 6:1 (I)	w/o Barrier slopes 6:1 or flatter	LT	RT		LT	RT
Ramp	16' (A)	9' (C)	6'	11'	8'	3'	6'	10'	6'	8'
1-Lane Directional Roadway	16' (A)	9'	6'	11'	8'	4'	6'	10'	6'	8'
2-Lane Directional Roadway or Multilane Ramps	Var. (B)	9' (H)	6' (H)	15' (D)	10' (D)	4' (H)	10'	10'	6' (H)	12' (D)
Accel/Decel Lane or Combined	Var.	NA	NA	13' (D)(F)	8' (D)(F)	NA	8' (F)	10'	NA	10' (D)(F)

NOTES:

(A) Use 18 ft. when inside traveled way edge radius is less than 200 ft.

(B) For 2-lane directional roadways and 2-lane multilane ramps, the traveled way width shall be 24 ft.

(C) May be reduced 1 ft. if the face of the mainline barrier is 2 ft. from the outside edge of the graded shoulder.

(D) Or match mainline dimension if lesser.

(E) Rounding is 4 ft. when barrier is used. No rounding is required when foreslope is 6:1 or flatter.

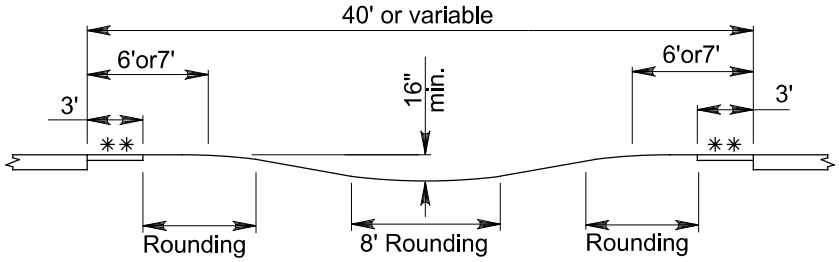
(F) Match Multilane Ramp dimensions when used with Multilane Ramps.

(G) Concrete barrier may be placed at the edge of the paved shoulder when used in lieu of guardrail, but no closer than 4'.

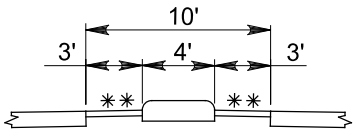
(H) For 3 or more lanes, use right side widths or dimensions.

(I) Total Graded Width may be reduced as much as 3-ft. where MGS guardrail with the longer posts is used. See Section 603.1.2 and SCD MGS-2.1 for post length and position details

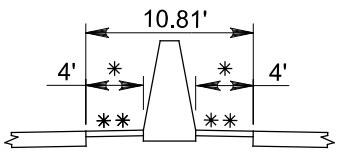
TWO-WAY RAMP MEDIAN



MINIMUM TWO-WAY RAMP - CONCRETE MEDIAN



MINIMUM TWO-WAY RAMP - CONCRETE BARRIER MEDIAN



* Check horizontal stopping sight distance

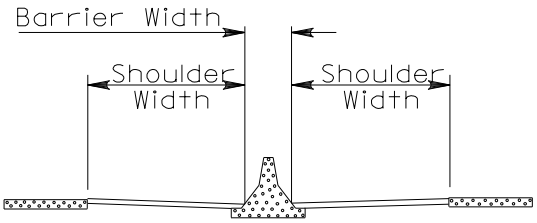
** See Figure 301-8 for shoulder cross slope

TYPICAL MEDIAN DESIGNS

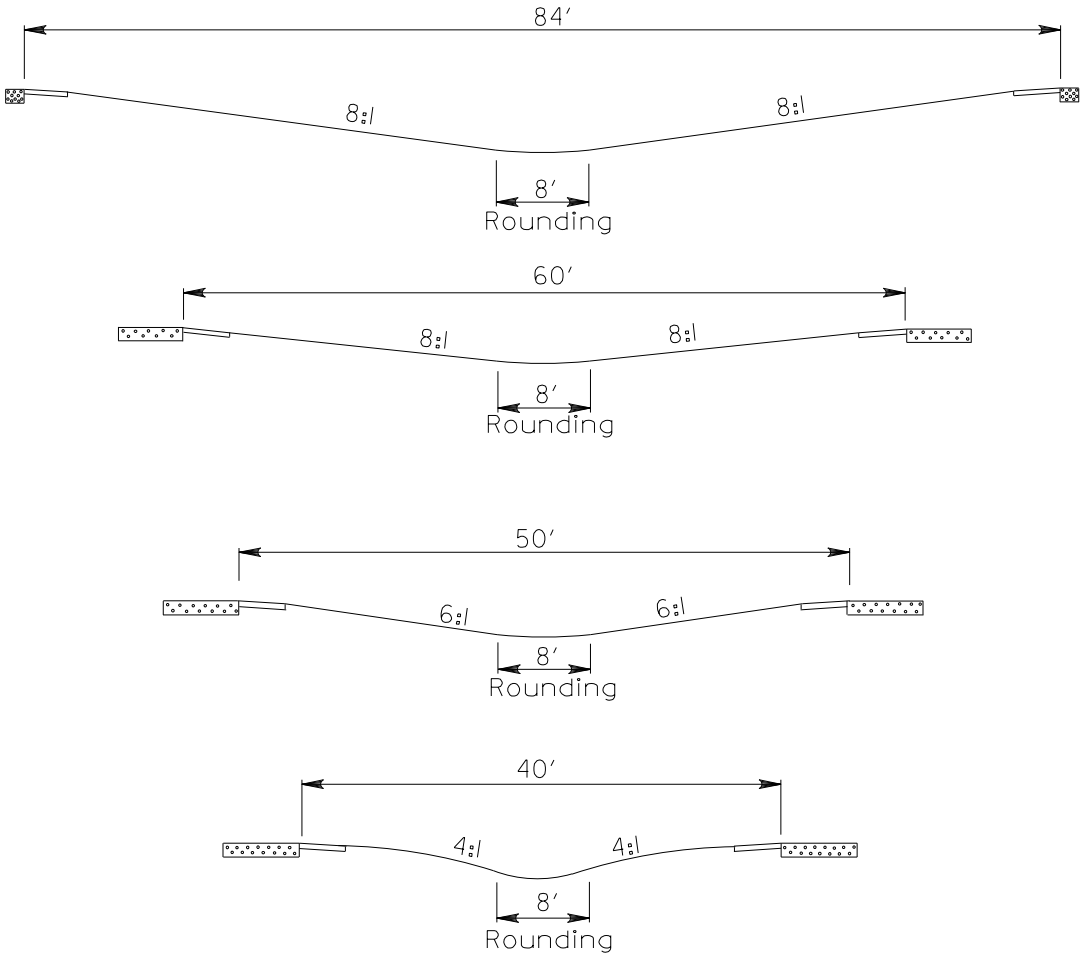
304-1

REFERENCE SECTIONS
304.3

BARRIER MEDIAN



DEPRESSED MEDIANS

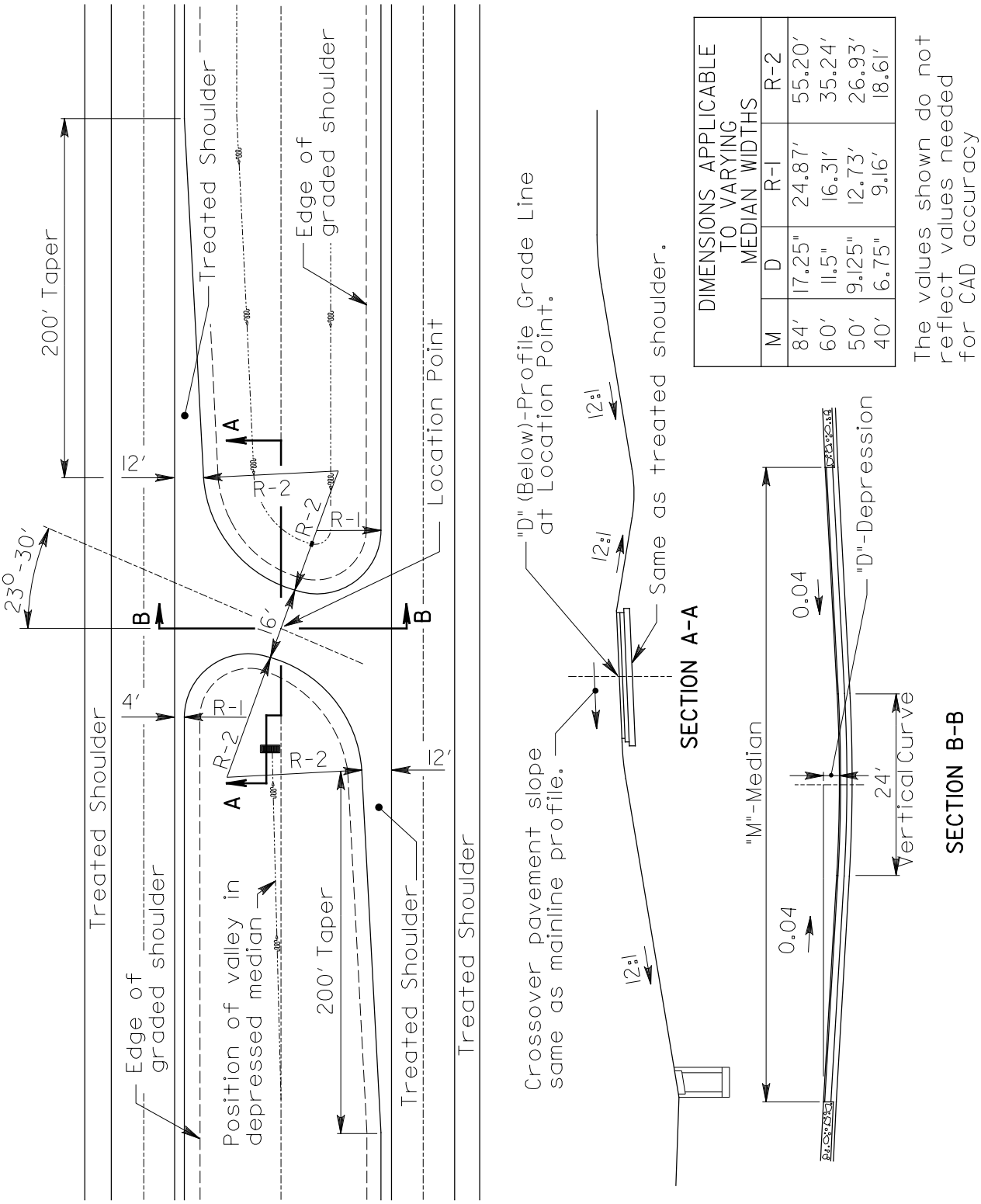


November 2002

STANDARD U-TURN MEDIAN OPENINGS

304-2

REFERENCE SECTIONS
304.4.3



DIMENSIONS APPLICABLE TO VARYING MEDIAN WIDTHS			
M	D	R-1	R-2
84'	17.25"	24.87'	55.20'
60'	11.5"	16.31'	35.24'
50'	9.125"	12.73'	26.93'
40'	6.75"	9.16'	18.61'

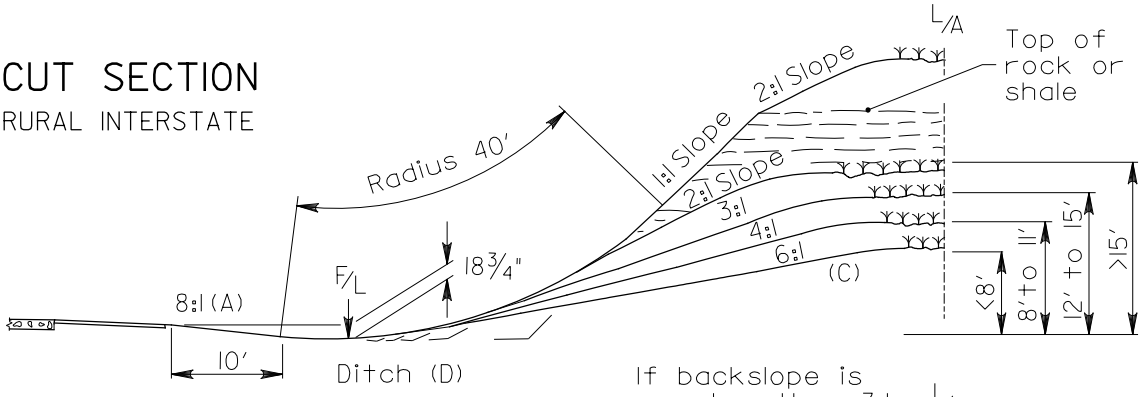
The values shown do not reflect values needed for CAD accuracy

SAFETY GRADING SECTIONS

307-1

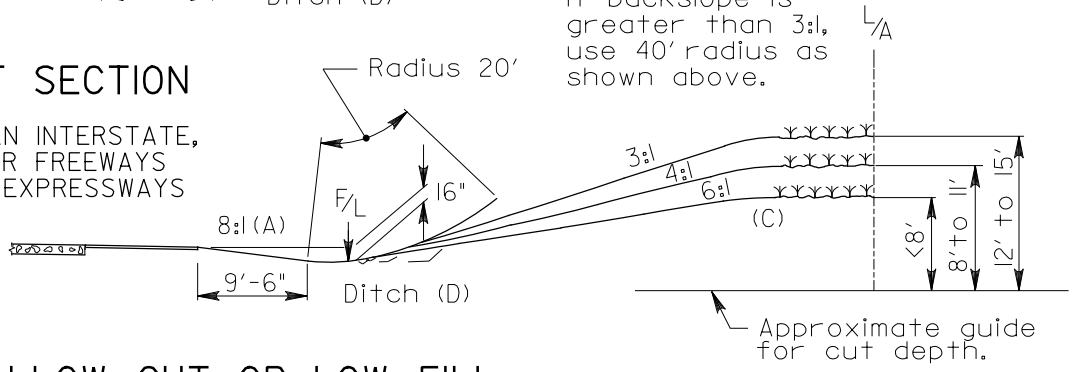
REFERENCE SECTIONS
307.2.1 & 307.2.3

CUT SECTION
RURAL INTERSTATE



CUT SECTION
URBAN INTERSTATE, OTHER FREEWAYS AND EXPRESSWAYS

If backslope is greater than 3:1, use 40' radius as shown above.

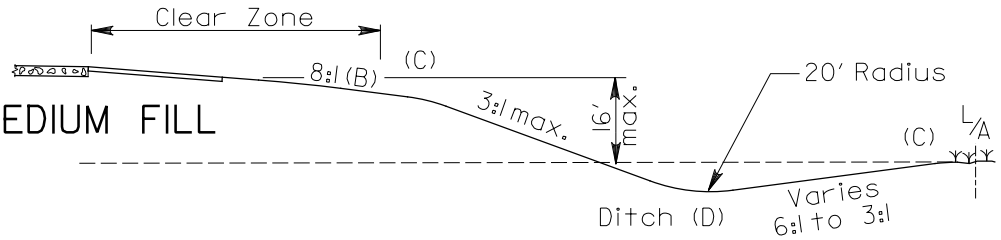


SHALLOW CUT OR LOW FILL



Slope transition between low fill design and medium fill design should be such that the flowline of the roadside ditch does not turn towards the roadway.

MEDIUM FILL



Application of these sections may vary to avoid frequent slope changes and to maintain reasonably straight ditches.

NOTES:

(A) 6:1 slope may be used with horizontal distance remaining the same to increase the ditch depth.

(B) 6:1 slope may be used

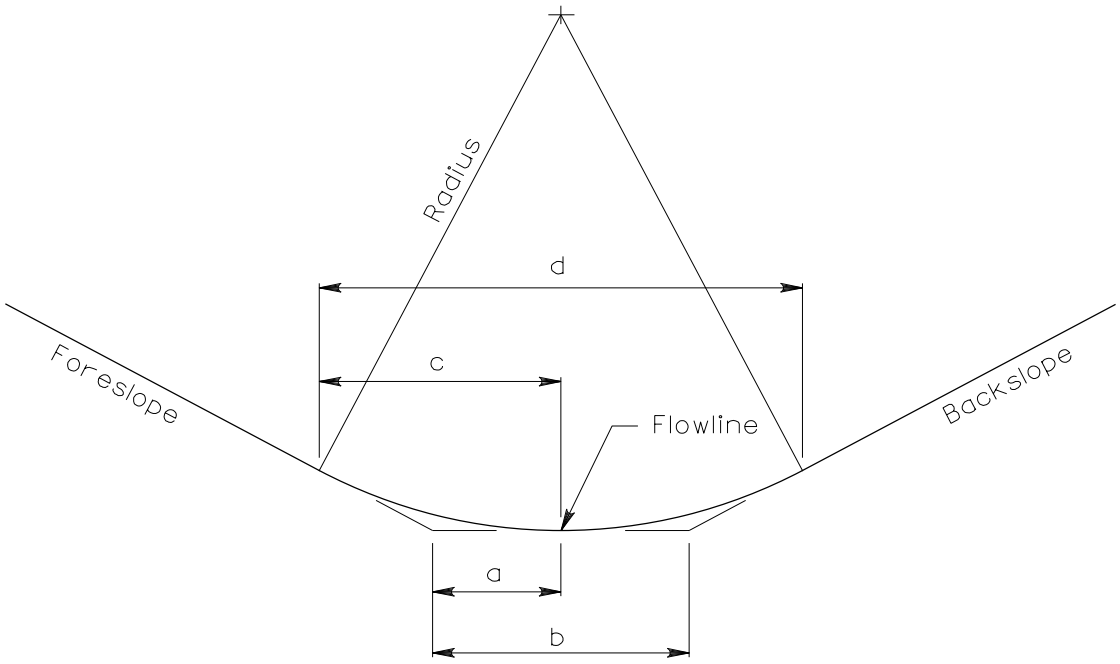
(C) 4' Rounding

(D) See Fig. 307-2 for ditch sections to be used with safety grading

DITCH SECTIONS FOR SAFETY GRADING

307-2

REFERENCE SECTIONS
307.2.1



Fore-slope	40' RADIUS		Backslope									
			6:1		4:1		3:1		2:1		1:1	
	a	c	b	d	b	d	b	d	b	d	b	d
8:1	2'-6"	5'-0"	5'-10"	11'-6"	7'-5"	14'-8"	9'-0"	17'-7"	11'-11"	22'-10"	19'-0"	33'-3"
6:1	3'-4"	6'-7"	6'-7"	13'-2"	8'-3"	16'-3"	9'-10"	19'-3"	12'-9"	24'-6"	19'-11"	34'-10"

Fore-slope	20' RADIUS		Backslope					
			6:1		4:1		3:1	
	a	c	b	d	b	d	b	d
8:1	1'-3"	2'-6"	2'-11"	5'-9"	3'-8"	7'-4"	4'-6"	8'-10"
6:1	1'-8"	3'-3"	3'-4"	6'-7"	4'-1"	8'-2"	4'-11"	9'-7"
4:1	2'-6"	4'-10"	4'-1"	8'-2"	4'-11"	9'-8"		
3:1	3'-3"	6'-4"	4'-11"	9'-7"				

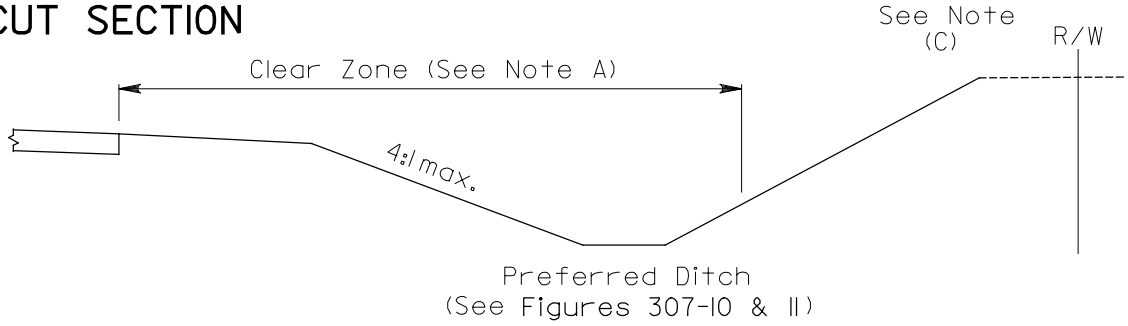
January 2005

CLEAR ZONE GRADING SECTIONS

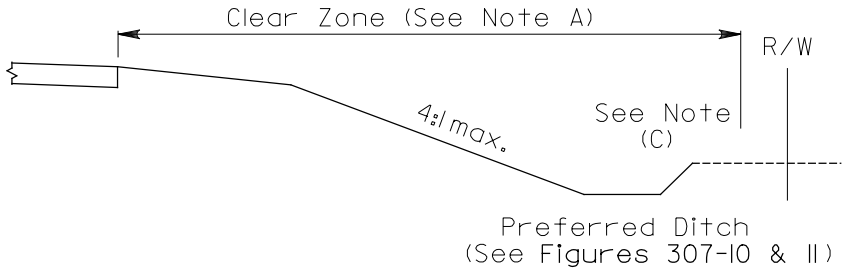
307-3

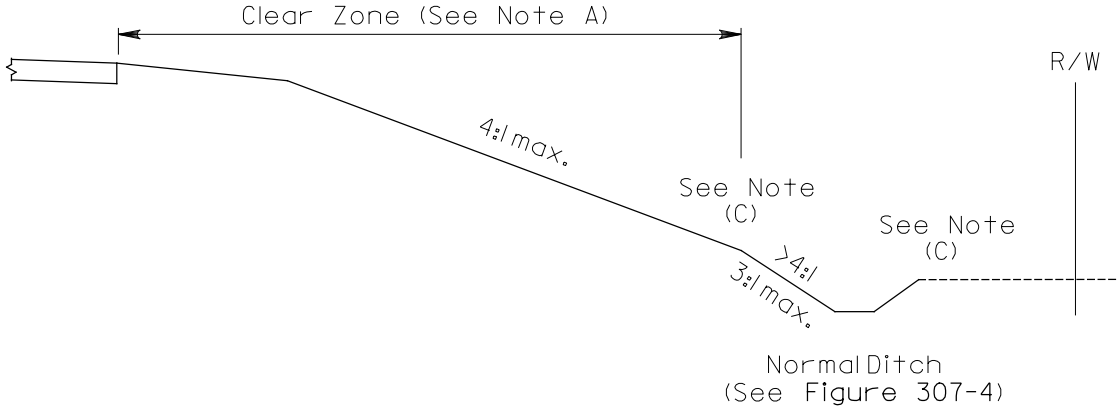
REFERENCE SECTIONS 307.2.1 & 307.2.3

CUT SECTION



FILL SECTIONS (B)





NOTES:

(A) See Figure 600-1 for Clear Zone widths.

(B) For fill heights over 16 ft., use barrier grading (See Figure 307-4)

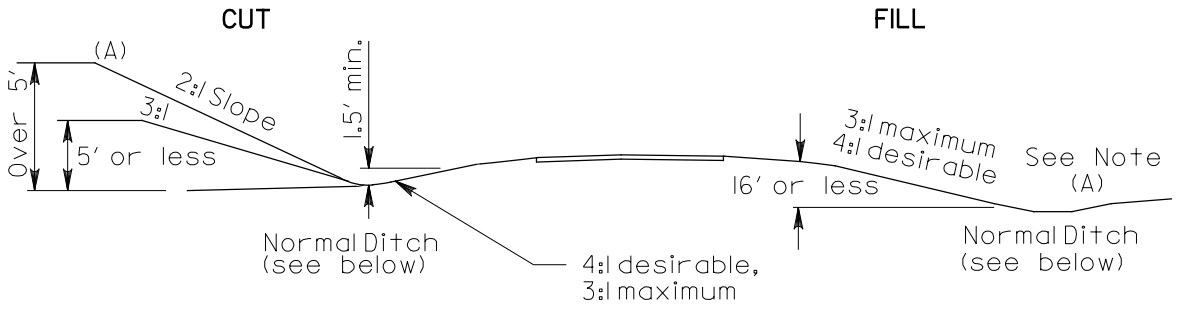
(C) 4 ft. Rounding

COMMON AND BARRIER GRADING SECTIONS

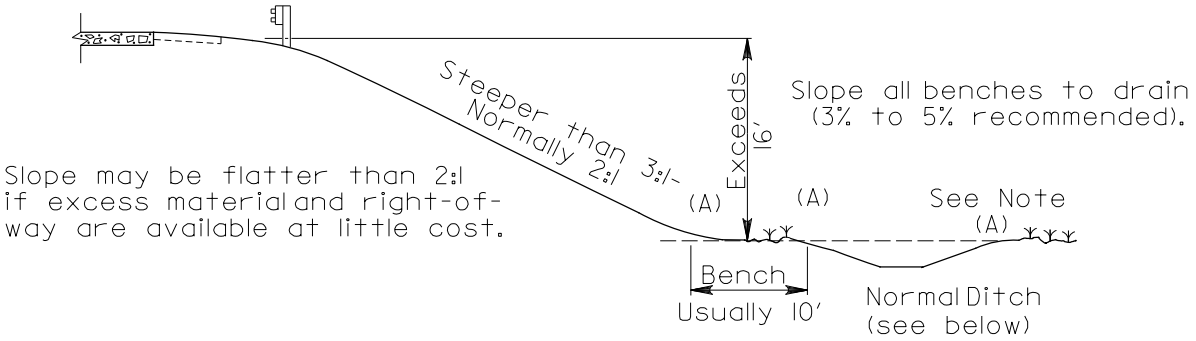
307-4

REFERENCE SECTIONS
307.2.1 & 307.2.3

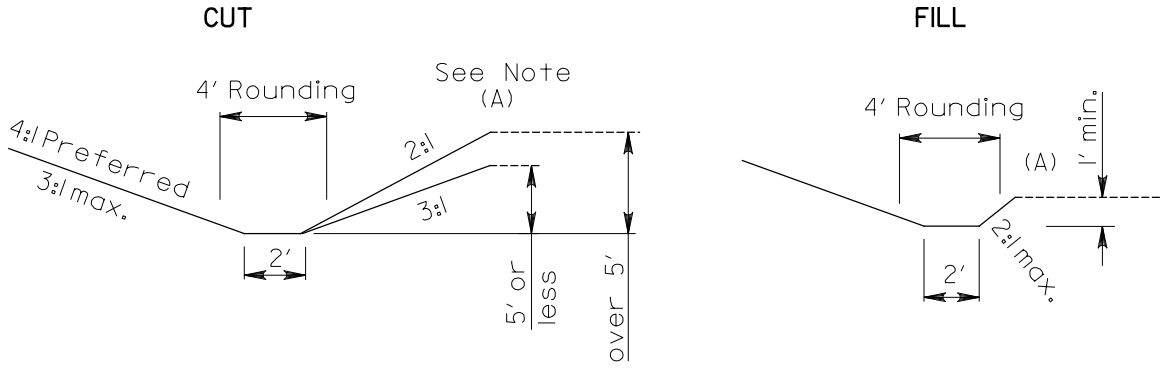
COMMON GRADING



BARRIER GRADING



NORMAL DITCH SECTIONS



NOTES: (A) 4' Rounding

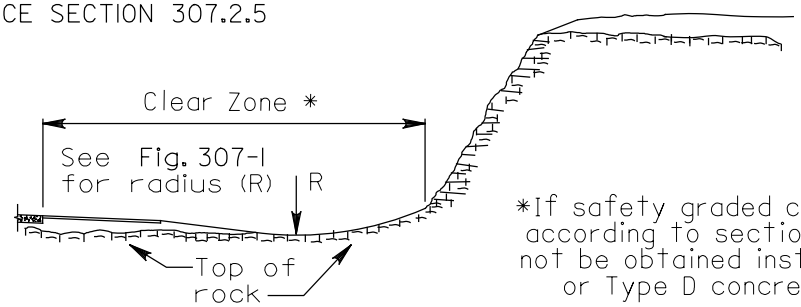
SPECIAL DESIGNS

307-5

REFERENCE SECTIONS
307.2.4, 307.2.5,
307.3 & 307.4

DESIGNS FOR ROCK CUTS WITH SAFETY GRADING

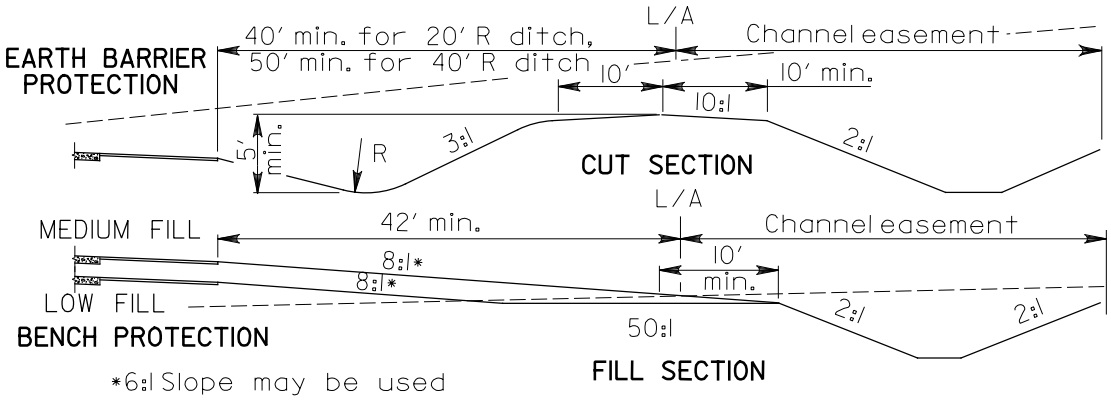
REFERENCE SECTION 307.2.5



*If safety graded cross sections according to section 307.2.1 can not be obtained install guardrail or Type D concrete barrier

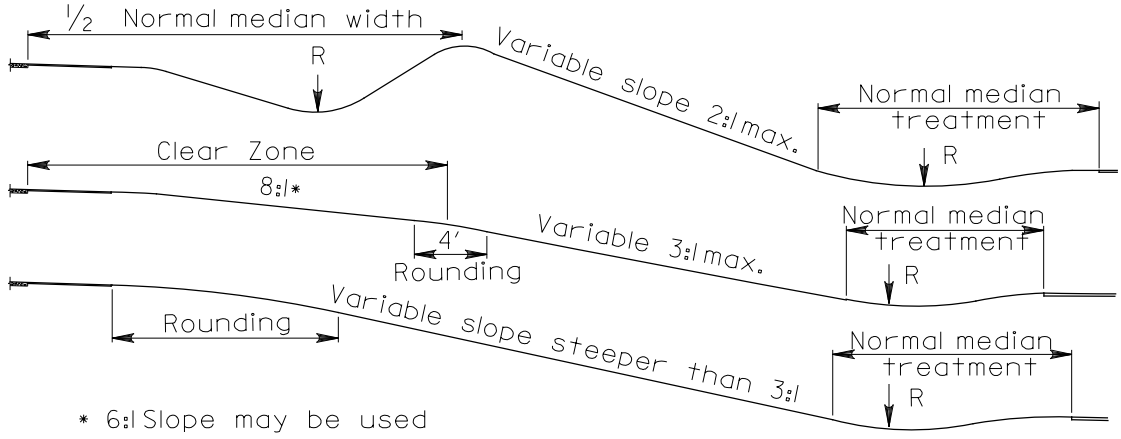
DESIGNS FOR DEEP PARALLEL SIDE DITCHES

REFERENCE SECTIONS 307.3 & 307.4



ALTERNATE MEDIAN DESIGNS-SEPARATE PROFILES

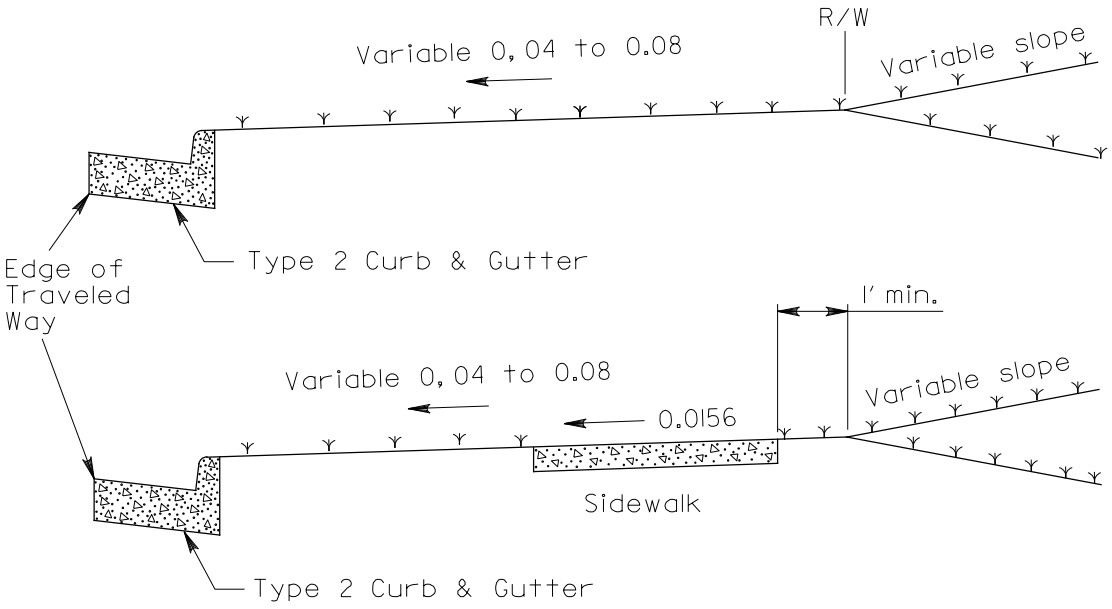
REFERENCE SECTION 307.2.4



SLOPE TREATMENT ADJACENT TO CURBED STREETS

307-6

REFERENCE SECTIONS
307.2.6

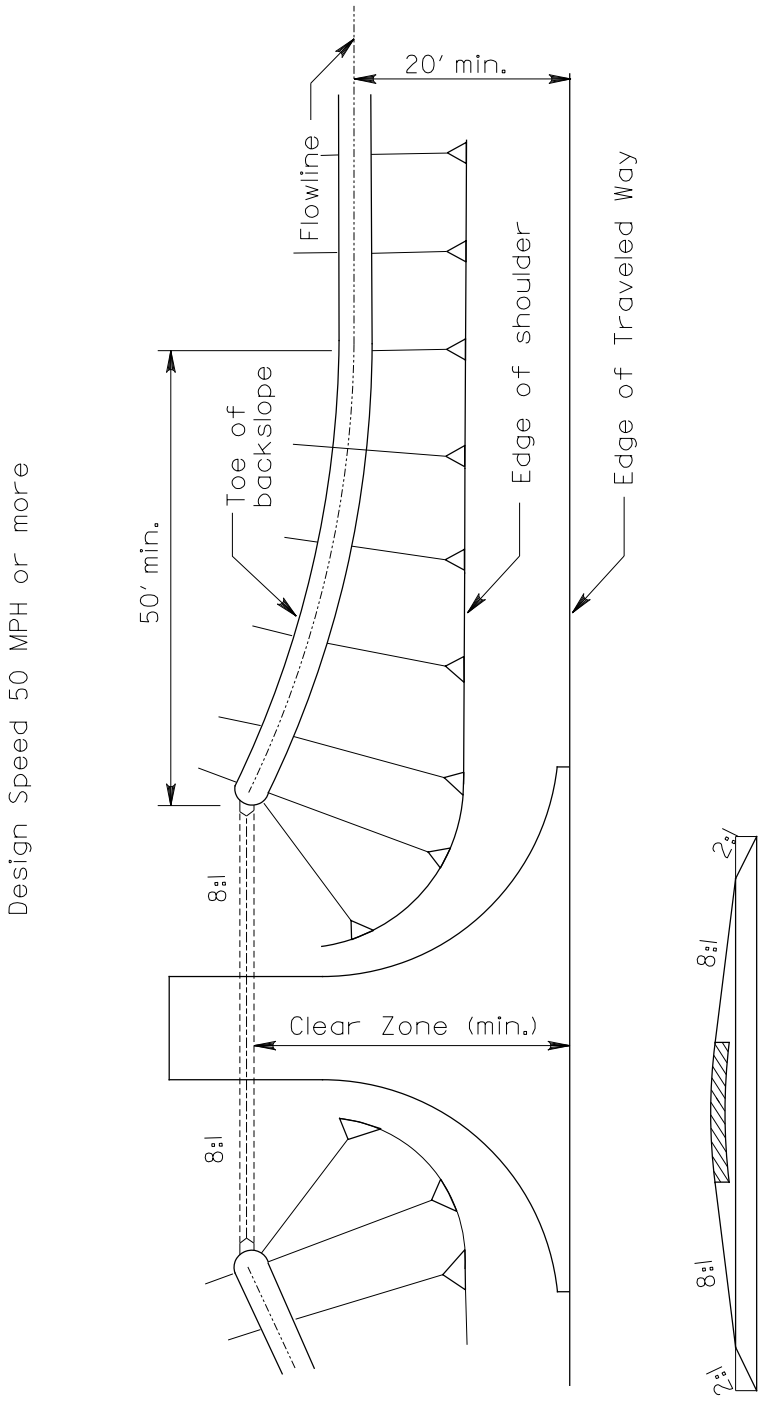


The 4% to 8% slopes in the top detail were extended to the R/W line to prevent runoff from the right-of-way entering private property. This slope may be broken if the highway runoff can be maintained within the highway right-of-way.

SLOPES AND DITCHES AT DRIVEWAYS AND CROSSROADS IN CUT OR LOW FILL

307-7

REFERENCE SECTIONS
307.2.7



Design Speed 50 MPH or more

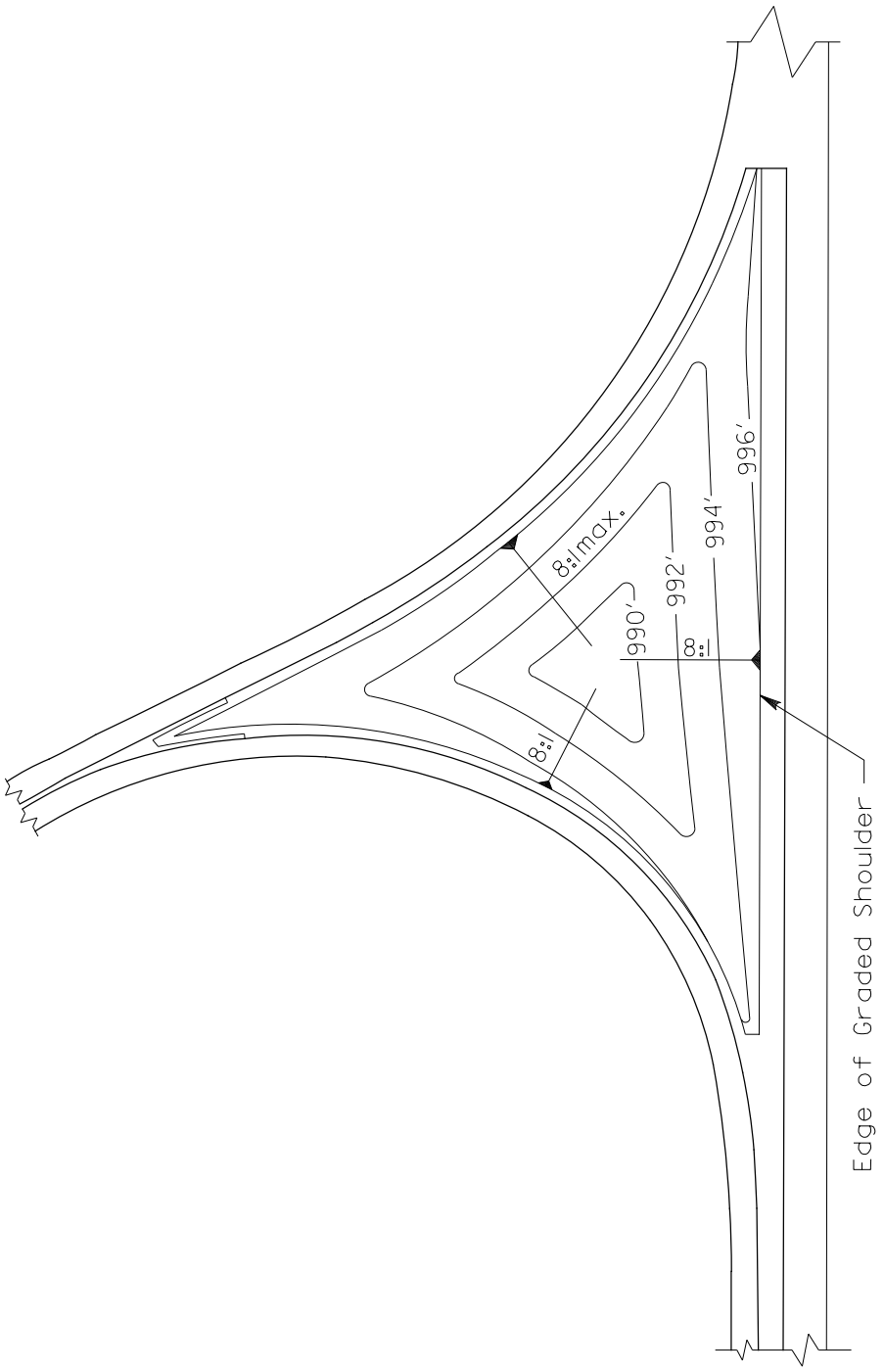
To be used on Clear Zone grading projects where the roadside ditch flowline is located within the Clear Zone distance

November 2002

CONTOUR GRADING OF TRUMPET INTERIORS

307-8

REFERENCE SECTIONS
307.5.3 & 307.5.4

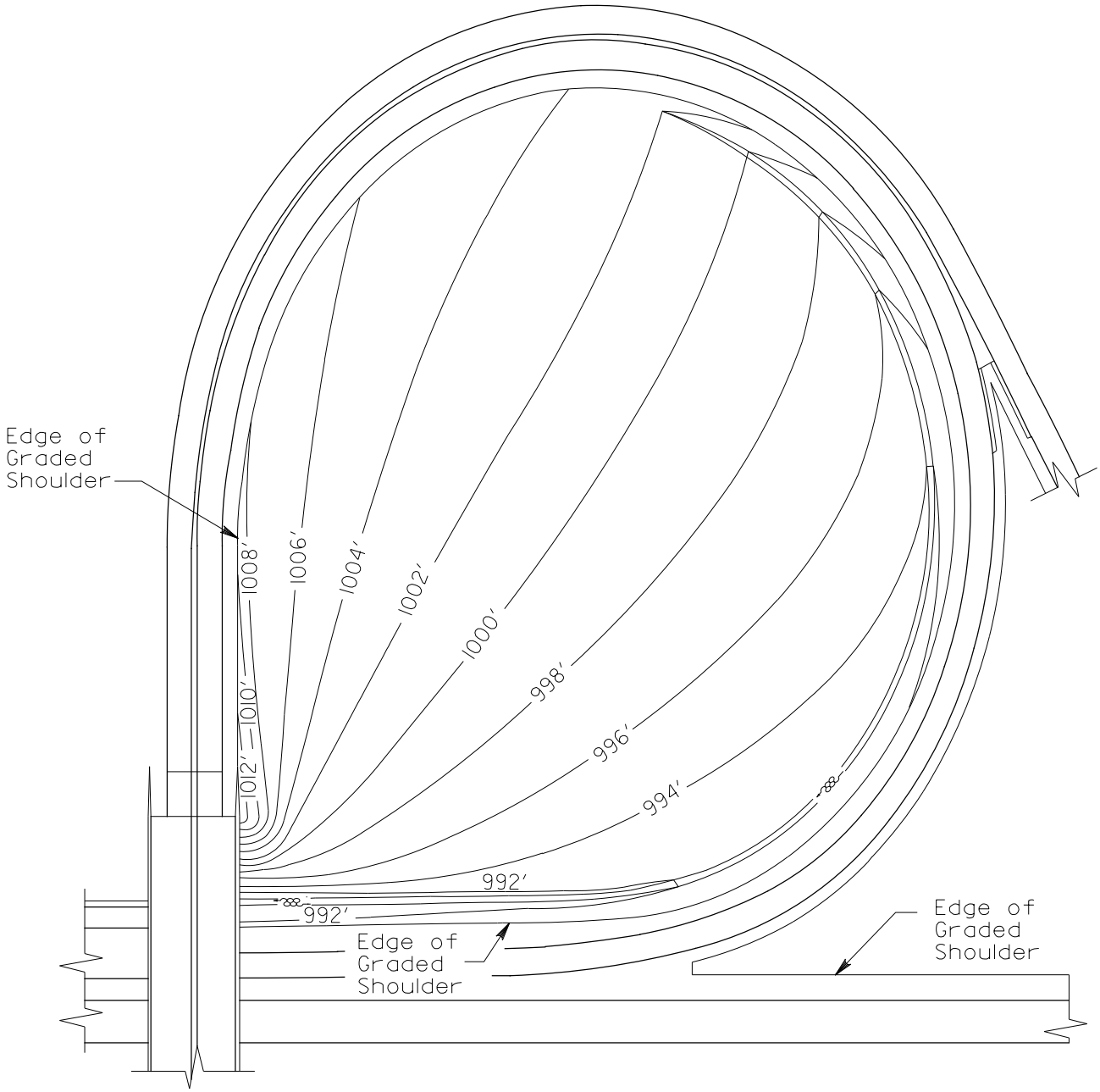


November 2002

CONTOUR GRADING OF LOOP INTERIORS IN CUT

307-9

REFERENCE SECTIONS
307.5.5

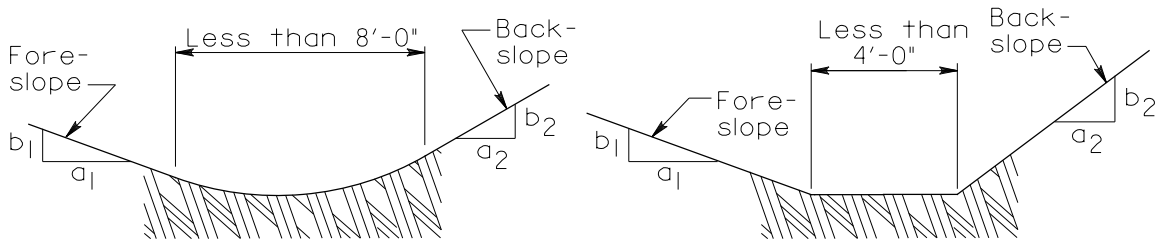


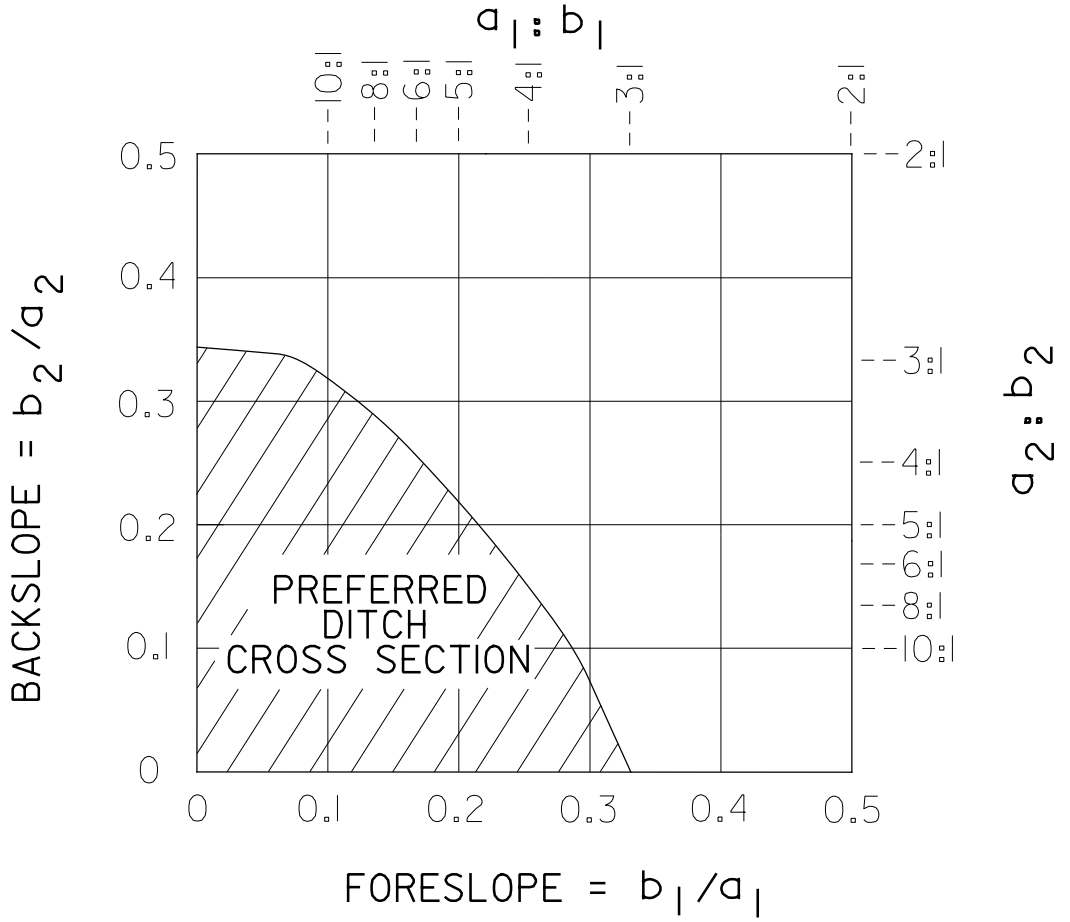
November 2002

PREFERRED CROSS SECTIONS FOR DITCHES WITH ABRUPT SLOPE CHANGES

307-10

REFERENCE SECTIONS
600.2.1





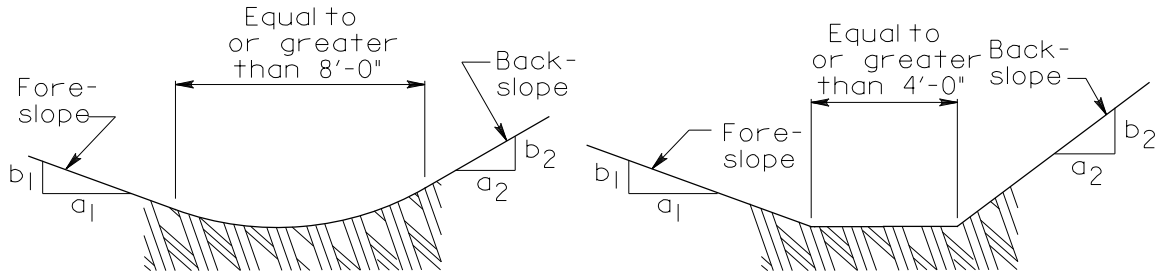
This chart is applicable to vee ditches, rounded ditches with bottom widths less than 8'-0", and trapezoidal ditches with bottom widths less than 4'-0".

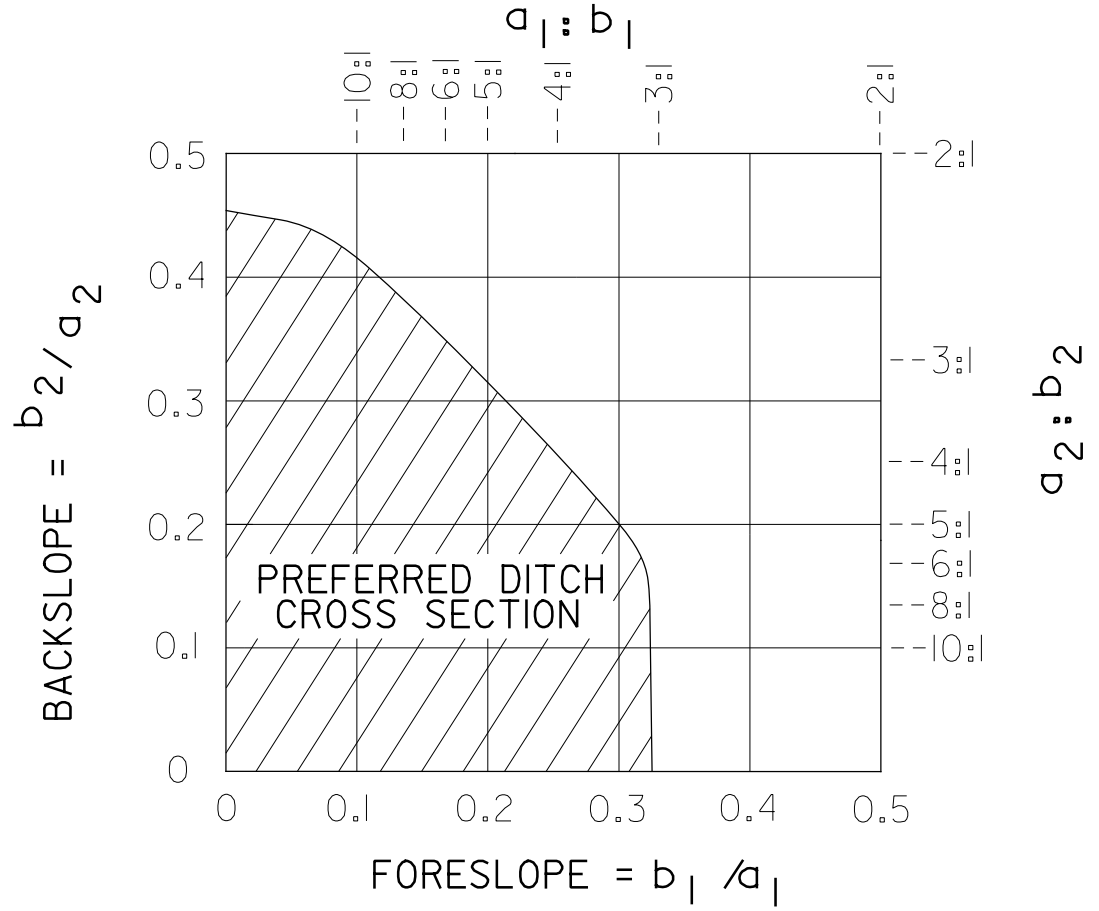
Ditch sections that fall within the shaded areas of the figure above are considered traversable and are preferred for use within the Clear Zone. Ditch sections that fall outside the shaded areas are considered non-traversable and should generally be located outside the Clear Zone.

PREFERRED CROSS SECTIONS FOR DITCHES WITH GRADUAL SLOPE CHANGES

307-11

REFERENCE SECTIONS 600.2.1





This chart is applicable to rounded ditches with bottom widths of 8′-0" or more, and to trapezoidal ditches with bottom widths equal to or greater than 4′-0".

Ditch sections that fall within the shaded areas of the figure above are considered traversable and are preferred for use within the Clear Zone. Ditch sections that fall outside the shaded areas are considered non-traversable and should generally be located outside the Clear Zone.

400 - Intersection Design

401 - Intersections At-Grade

401.1 - Intersection Locations

Care should be taken in locating new at-grade intersections. The alignment and grade on the mainline roadway should, as a minimum, provide stopping sight distance as discussed in Section 201.2. The criteria for intersection sight distance (see Section 201.3) should also be met wherever possible.

It is best to avoid locating an intersection on a curve. Since this is often impossible, it is recommended that intersection sites be selected where the curve superelevation is 0.04 or less. It is also recommended that intersections be located where the grade on the mainline roadway is 6 percent or less, with 3 percent being the desirable maximum.

401.2 - Intersection Traffic Control and Operational Analysis

The type of traffic control at intersections directly affects the geometric design. An early determination of the type of intersection control must be made (i.e. stop signs, signal, or roundabout). Whenever there is doubt as to the adequacy of stop control during the design life of the project, traffic signal warrants, as outlined in the Ohio Manual of Uniform Traffic Control Devices (OMUTCD) should be investigated.

Perform the intersection capacity analyses as outlined in the ODOT Analysis and Traffic Simulation (OATS) manual. Guidance on which software to use to perform the analyses is found in Chapter 3 of the OATS.

An Intersection Control Evaluation is recommended for the following scenarios:

- Changing control at an existing intersection, such as converting a stop-controlled intersection to a traffic signal or converting a signalized intersection to a roundabout
- Installation of a new intersection between two or more public roads where two-way stop control will result in failing operations.
- Installation of a high-volume driveway as defined by ODOT's State Highway Access Management Manual, Table 4-1 (more than 200 vehicles per hour in the peak hour)

- Adding a leg to an existing intersection, unless the leg is a medium volume, low volume, or minimal use driveway (less than 200 vehicles per hour in the peak hour) or a low volume road (per AASHTO, a road with less than 2000 vehicles per day)
- Adding multiple turn lanes or one or more through lanes at an existing intersection

401.2.1 - Signals

Optimize the signal timings with the goal of minimizing the delay, without having significantly unbalanced approaches. When evaluating signal timings, the minor street will often have more delay than the major street. This is acceptable as long as all individual lane v/c ratios are less than 1.0, and preferably less than 0.93. Refer to the ODOT Analysis and Traffic Simulation (OATS) manual for further information.

401.2.2 - Stop Control

For stop-controlled intersections, where signal warrants are not anticipated to be met by the design year or would not be installed due to access management controls, Figures 401-5a thru 401-6d are provided to determine the need for turn lanes. The stopped approaches may be evaluated using the appropriate analysis software to determine the necessary number and type of lanes to improve the Levels of Service.

401.2.3 - Roundabouts

Per the ODOT Analysis and Traffic Simulation (OATS) manual, ODOT uses HCS and TransModeler to analyze roundabouts. TransModeler is to be used for configurations that HCS cannot analyze. Configurations that HCS cannot analyze include: when more than two lanes enter a roundabout on an approach (not including a right-turn bypass lane), or when there are more than two lanes within the circulatory roadway. Turn lane lengths for the approach lanes of the roundabout must be determined by accommodating the 95th percentile queue lengths as identified by HCS or TransModeler.

While it is important to plan for future traffic volumes and capacity needs, the immediate effects on users should also be considered including costs. A roundabout constructed with a wide cross section (multilane) can negatively impact user (pedestrian, bicycle, unfamiliar drivers) movements. Therefore, a phased implementation on multilane roundabouts is required if the single lane construction of the roundabout can meet acceptable levels of service based on an interim design year. The phased implementation should be based on

the available and future funding resources and location (rural or urban, drivers familiar or unfamiliar). The current users' needs will be accommodated while still providing an opportunity for the roundabout to be expected for future traffic volume growth.

When using a phased approach, it is important to design the full build layout footprint to ensure right- of-way is secured for future planned improvements. It is also beneficial to plan the construction of the roundabout to potentially allow for easier expansion in the future.

401.3 - Crossroad Alignment

Intersection angles of 70 degrees to 90 degrees are to be provided on all new or relocated highways. An angle of 60 degrees may be satisfactory if: (1) the intersection is signalized; or (2) the intersection is skewed such that a driver stopped on the side road has the acute angle (at center of intersection) on their left side (vision not blocked by their own vehicle).Relocation of the crossroad is often required to meet the desired intersection location, to avoid steep crossroad profile grades and to adjust intersection angles. Horizontal curves on crossroads should be designed to meet the design speed of the crossroad. The crossroad alignment should be as straight as possible. Figure 401-1 shows an example of a crossroad relocation. Both curve 1 and curve 3 may be reduced per the figure.

The design speed for horizontal curves on a crossroad approaching a stop-controlled intersection may be reduced from the design speed of the crossroad since the vehicles will be decelerating to a stop. The design speed of the horizontal curve approaching the stop bar may be based on the estimated speed of a vehicle as it enters the curve while decelerating. Calculate the estimated speed of a vehicle during deceleration utilizing Figure 2-34 (Deceleration Distances for Passenger Vehicles Approaching Intersections) from A Policy on Geometric Design of Highways and Streets (The Green Book, 7th Edition). First, determine the total deceleration distance with Figure 2-34 using the initial speed (design speed of the crossroad) to a speed of 0 MPH at the stop bar (line E on the chart). Then, interpolate the estimated speed using the distance from the entry of the curve to the stop bar with the total deceleration distance. The design speed for the curve may be the estimated speed rounded down to the nearest 5 mph increment, but must be no lower than 25 MPH.

401.4 - Crossroad Profile

401.4.1 - Intersection Area

The portion of the intersection located within 60 ft. of the mainline edge of traveled way, measured along the crossroad centerline, is considered to be the "intersection area". The pavement surface within this "intersection area" should be visible to drivers within the limits of the minimum stopping sight distance shown on Figure 201-1. By being able to see the pavement surface (height of object of 0), drivers (height of eye of 3.5 ft.) will be able to observe the radius returns, pavement markings, and recognize that they are approaching an intersection. Figure 401-2 shows the "intersection area".

Combinations of pavement cross slopes and profile grades may produce unacceptable edge of traveled way profiles in the "intersection area". For this reason, edge of traveled way profiles should be plotted and graphically graded to provide a smooth profile.

401.4.2 - Drainage

Within the intersection area, the profile of the crossroad should be sloped wherever possible so the drainage from the crossroad will not flow across the through road pavement. For a stop condition, the 10 ft. of crossroad profile adjacent to the through pavement is normally sloped away from the through pavement, using at least a 1.6 percent grade, as shown on Figure 401-2.

401.4.3 - Profile at Stop Intersections

Profile grades within the "intersection area" for stop conditions are shown in Figures 401-2and 401-3. The grade outside the "intersection area" is controlled by the design speed of the crossroad. Normal design practices can be used outside the "intersection area" with the only restriction on the profile being the sight distance required in **Section 401.4.1.**

Grade breaks are permitted at the mainline edge of traveled way for a stop condition as discussed in Note 3 of Figures 401-2. If these grade breaks are exceeded, they should be treated according to Note 3 on Figure 401-3. Several examples are shown on Figure 401-3 of the use of grade breaks or short vertical curves adjacent to the mainline edge of traveled way.

401.4.4 - Profile at Signalized Intersections

Signalized intersections require a more sophisticated crossroad profile. Whenever possible, profiles through the intersection area of a signalized intersection should be designed to meet the design speed of the crossroad. Figure 401-4 shows three examples of crossroad profiles at intersections. On Examples A and B (Figure 401-4), the mainline cross slopes will need to be adjusted to match the crossroad profile within the intersection area. Grade breaks shown on Examples A and C should be in accordance with Section 203.3.2. Since the grade break across a normal crowned pavement is 3.2 percent, it should be noted that the crown must be flattened (See Example C). This will allow vehicles on the crossroad to pass through the intersection on a green signal safely without significantly adjusting their speed. The sight distance requirements of **Section 401.4.1** within the "intersection area" are also applicable for signalized intersections.

401.5 - Approach Radii

401.5.1 - Rural

Approach radii in rural areas are typically 50 ft., except that radii less than 50 ft. (minimum 35 ft.) may be used at minor intersecting roads if judged appropriate for the volume and character of turning vehicles. If significant pedestrian traffic is expected the radius should be the smallest possible for the circumstances and still accommodate the design vehicle since a large approach radii can increase the speed of turning motorists and lengthen the crossing distance for pedestrians, creating increased exposure risks. See **Section 401.9** for more information on intersection design.

Radii larger than 50 ft., a radius with a taper, or a three center curve, should be used at any intersection where the design must routinely accommodate semi-trailer truck turning movements. Truck turning templates should be used to determine proper radii and stop bar location. When truck turning templates are used, a 2 foot clearance should be provided between the edge of traveled way and the closest tire path.

Normally the approach width at the ends of the radius returns should be 24 ft. The pavement width shall be tapered back to the normal pavement width at a rate of 10:1 if the taper is adjacent to the radius returns.

401.5.2 - Urban

Corner radii at street intersections should consider the right of way available, the intersection angle, pedestrian accommodations as described in Section 401.8, approach

width and number of lanes. Perform swept path analyses with the design and check vehicles to provide the smallest radius possible while meeting the requirements described in **Section 401.9**. The following should be used as a guide:

1. 15 to 25 ft. radii are adequate for passenger vehicles and may be provided at minor cross streets where there are few trucks or at major intersections where there are parking lanes.
2. 25 ft. or more radii should be provided at minor intersections on new or reconstruction projects where space permits.
3. 30 ft. radii or more should be used where feasible at major cross street intersections.
4. Radii of 40 ft. or more, three-centered compound curves or simple curves with tapers to fit truck paths should be provided at intersections used frequently by buses or large trucks.

401.5.3 - Curbed to Uncurbed Transitions

Figures 401-4a and 401-4b show acceptable methods to transition from curbed to uncurbed roadways at intersections. Figure 401-4a shows two options to transition from an uncurbed mainline roadway to a curbed approach roadway. Figure 401-4b shows the transition from a curbed mainline roadway to an uncurbed approach roadway. See Section 305.4 for additional information.

401.6 - Approach Lanes

401.6.1 - Left Turn Lanes

Probably the single item having the most influence on intersection operation is the treatment of left turn vehicles. Left turn lanes are generally desirable at most intersections. However, cost and space requirements do not permit their inclusion in all situations. Intersection capacity analysis procedures of the current edition of the **Highway Capacity Manual** should be used to determine the number and use of left turn lanes. For unsignalized intersections, left turn lanes may also be needed if they meet warrants as provided in Figures 401-5a, 401-5b, and 401-5c. The warrants apply only to the free-flow approach of the unsignalized intersection. Refer to **Section 401.2** and the ODOT Analysis and Traffic Simulation (OATS) manual for analysis criteria and software guidance.

At a minimum, left turn lanes should be placed opposite each other on opposing approaches (zero offset) to enhance sight distance. A positive offset of left turn lanes increases visibility by providing improved sightlines. The safety benefits of a positive left turn lane offset is a proven safety measure especially at locations with higher speeds, or where free-flow or permissive movements are possible.

Left turn lanes are developed in several ways depending on the available width. The first example on Figure 401-7 shows the development required when additional width must be generated. The additional width is normally accomplished by widening on both sides. However, it could be done all on one side or the other. In the second example on Figure 401-7, the median width is sufficient to permit the development of the left turn lane. Figure 401-8 shows the condition where an offset left turn lane is required to obtain adequate sight distance in wide medians.

In developing turn lanes, several types of tapers may be involved as shown in Figure 401-7.

1. Approach Taper - An approach taper directs through traffic to the right. Approach taper lengths are calculated using the following:

- Design Speed of 50 mph or more: $L=WS$
- Design speed less than 50 mph: $L=WS^2/60$
    - L = Approach taper length in feet
    - W = Offset width in feet
    - S = Design Speed

Where:

1. Departure Taper - The departure taper directs through traffic to the left. Its length should not be less than that calculated using the approach taper equations. Normally, however, the departure taper begins opposite the beginning of the full width turn lane and continues to a point opposite the beginning of the approach taper.

2. Diverging Taper - The diverging taper is the taper used at the beginning of the turn lane. The recommended length of a diverging taper is 50 ft.

Figures 401-9 and 401-10 have been included to aid in determining the required lengths of left turn lanes at intersections. An example problem that illustrates the use of these figures is included along with Figure 401-10.

After determining the length of a left turn lane, the designer must also check the queue length in the adjacent/through lane(s) to assure that access to the turn lane is not blocked by the adjacent/through lane(s) queue. Calculate the average number of adjacent/through vehicles per cycle then determine the queue length per Figure 401-10. If the turn or adjacent/through movement has two or more lanes, the required turn lane length and adjacent/through lane queue is based on a volume per lane. See example included with Figure 401-10.

It is recommended that the left turn lane length be a minimum of 100 ft. long and a maximum of 600 ft.The width of a left turn lane should desirably be the same as the normal lane widths for the facility. A minimum width of 11 ft. may be used in moderate and high-speed areas, while 10 ft. may be provided in low speed areas. Additional width should be provided whenever the lane is adjacent to a curbed median as discussed in Section 305.3.

401.6.2 - Double Left Turn Lanes

Double left turn lanes should be considered at any signalized intersection with left turn demands of 300 vehicles per hour or more. The actual need shall be determined by performing a signalized intersection capacity analysis. Refer to **Section 401.2** and the ODOT Analysis and Traffic Simulation (OATS) manual for analysis criteria and software guidance.

When the signal phasing permits simultaneous left turns from opposing approaches, it may be necessary to laterally offset the double left turn lanes on one approach from the left turn lane(s) on the opposing approach to avoid conflicts in turning paths. All turning paths of double left turn lanes should be checked with truck turning templates allowing 2 ft. between the tire path and edge of each lane. Expanded throat widths are necessary for double left turn lanes. The recommended design vehicles for the swept path analysis is a WB-62 for the outside lane (right-hand left-turn lane) and a SU-30 for the inside lane (left- hand left-turn lane). For details on double left turn lanes, see Figures 401-11 and 401-12.

401.6.3 - Right Turn Lanes

Exclusive right turn lanes are less critical in terms of safety than left turn lanes. Right turn lanes can significantly improve the level of service of signalized intersections. They also provide a means of safe deceleration for right turning traffic on high-speed facilities and separate right-turning traffic at stop-controlled intersections. In locations with pedestrian and bicycle traffic, the addition of right turn lanes degrades safety for those users. Pedestrians are vulnerable to conflicts with vehicles due to the increase in crossing distance. Refer to **Figure 301-1** for level of service goals at VRU locations. To determine the need for right turn lanes, intersection capacity analysis procedures of the current edition of the **Highway Capacity Manual** should be used. For unsignalized intersections, right turn lanes may also be needed if they meet warrants as provided inFigures 401-6a, 401-6b, 401-6c and 401-6d. The warrants apply only to the free-flow approach of the unsignalized intersection. Refer to **Section 401.2** and the ODOT Analysis and Traffic Simulation (OATS) manual for analysis criteria and software guidance.

Figure 401-7 shows the design of right turn lanes. Figure 401-10 may be used in preliminary design to estimate the storage required at signalized intersections. It is recommended that the right turn lane length be a minimum of 100 ft long and a maximum of 800 ft. The blockage of the right turn lane by the through vehicles should also be checked using Figure 401-10. With right-turn-on-red operation, it is imperative that access to the right turn lane be provided to achieve full utilization of the benefits of this type of operation.

The width of right turn lanes should desirably be equal to the normal through lane width for the facility. In low speed areas, a minimum width of 10 ft. may be provided. Additional lane width should be provided when the right turn lane is adjacent to a curb.

401.6.4 - Double Right Turn Lanes

When they are justified, it is generally at an intersection involving either an off-ramp or a one-way street. Double right turn lanes require a larger intersection radius (usually 75 ft. or more) and a throat width comparable to a double left turn (See **Section 401.6.2** and Figure 401-11). The introduction of double right turn lanes will result in unequal lane utilization unless no right-turn-on-red signage is installed. Additionally, in locations with pedestrian and bicycle traffic, the addition of right turn lanes degrades the safety for those users unless no right-turn-on-red signage is installed. Unless field data is available, it should be

assumed that 80% of the right turns will be made in the right turn lane closest to the curb due to the ability to turn right on red. When dual right turns are used, no right turn on red should be considered to improve lane utilization.

401.6.5 - Additional Through Lanes

Normally the number of through lanes at an intersection is consistent with the number of lanes on the basic facility. Occasionally, through lanes are added on the approach to enhance signal design. As a general suggestion, enough main roadway lanes should be provided so that the total through plus turn volumes does not exceed 450 vehicles per hour per lane. See Figure 402-1. In locations with pedestrian and bicycle traffic, the addition of through lanes degrades safety for those users. Pedestrians are vulnerable to conflicts with vehicles due to the increase in crossing distance. Refer to **Figure 301-1** for level of service goals at VRU locations.

401.6.6 - Recovery Area at Curbed Intersections

When a through lane becomes a right turn lane at a curbed intersection, an opposite-side tapered recovery area should be considered. The taper should be long enough to allow a trapped vehicle to escape, but not so long as to appear like a merging lane. See Figure 402-1.

401.7 - Islands

401.7.1 - Characteristics

An island is a defined area between traffic lanes used for control of vehicle movement. Islands also provide an area for pedestrian refuge and traffic control devices. Islands serve three primary functions:

1. to control and direct traffic movement, usually turning;
2. to divide opposing or same direction traffic streams usually through movements; and
3. to provide refuge for pedestrians. Most islands combine functions.

Although certain situations require the use of islands, they should be used sparingly and avoided wherever possible.

401.7.2 - Channelizing Islands

Channelizing islands control and direct traffic into the proper paths for the intended use and are an important part of intersection design. They may be of many shapes and sizes, depending on the conditions and dimensions of the intersection. A common form is the corner triangular shape that separates right turning traffic from through traffic. Figures 401-13a, 401-13b, 401-13c and 401-13d detail Channelizing Island designs for various vehicle combinations.

Channelizing Islands are used at intersections for the following reasons:

1. Separation of conflicts.
2. Control of angle of conflict.
3. Reduction in excessive pavement areas.
4. Indication of proper use of intersection
5. Favor a predominant turning movement.
6. Pedestrian protection. (See MDG Chapter 7.2.6).
7. Protection and storage of vehicles.
8. Location of traffic control devices.

These islands should be placed so that the proper course of travel is immediately obvious and easy for the driver to follow. Care should be given to the design when the island is on or beyond a crest of a vertical curve, or where there is a substantial horizontal curvature on the approach to or through the channelized area.

Properly placed islands are advantageous where through and turning movements are heavy.

401.7.3 - Island Treatments

401.7.3.1 - Curbed Islands

Curbed islands are most often used in urban areas where traffic is moving at relatively low speeds (less than 50 mph. The smallest curbed island that should normally be considered

is 50 sq. ft. in an urban area and 75 sq. ft. if used in a rural area. A 100 sq. ft. island is preferred in either case. Curb Islands are sometimes difficult to see at night, so the intersection should have fixed source lighting.

401.7.3.2 - Painted Islands

Islands delineated by pavement markings are often preferred in rural or lightly developed areas, when approach speeds are relatively high, where there is little pedestrian traffic, where fixed-source lighting is not provided, or where traffic control devices are not located within the island.

401.7.3.3 - Nonpaved Islands

Nonpaved islands are normally used in rural areas. They are generally turf and are depressed for drainage purposes.

401.8 - Designing Roadways to Accommodate Pedestrians

Designing a roadway that successfully meets the needs of both vehicular traffic and pedestrians can be a challenging task. Basic roadway design parameters such as roadway widths, corner turning radii and sight distances affect the ability of that roadway to accommodate pedestrians.

For example, the wider the roadway, the more difficult it is for pedestrians to cross, and the greater the barrier effect of this roadway on the communities through which it passes. Undivided six-lane arterials, with or without parking, are not usually pedestrian friendly, while eight and ten-lane arterials create an even more formidable barrier.

The size of a corner radius can also have a significant effect on the overall operation and safety of an intersection. Large corner turning radii promote higher turning speeds, as well as increasing the pedestrian crossing distance and exposure time. Large curb radii also reduce the space for pedestrians waiting to cross, move pedestrians out of the turning motorists line of sight, and make it harder for the pedestrian to see turning cars. However, in some cases, corners with small turning radii can impact the overall operating efficiency of an arterial intersection, as well as cause the curb to be hit by a turning vehicle.

The designer must keep in mind that, as important as it is for the motorist to see everything adjacent to the roadway, it is of equal importance for the pedestrian, particularly children

and wheelchair users, to be able to view and react to potential conflicts. At no area is this issue more critical than at crosswalk locations. Vehicles parked near crosswalks can create a sight distance problem.

401.8.1 - Curb Radii

At signalized and unsignalized intersections in both urban and suburban locations where there may be pedestrian conflicts the designer should consider the safety and convenience of both the motorist and pedestrian. The radius should be the smallest possible for the circumstances rather than design for the largest possible design vehicle, which often accounts for less than 2 percent of the total users. A large radius can increase the speed of turning motorists and the crossing distance for pedestrians, creating increased exposure risks.

Two distinct radii need to be considered when designing street corners. The first is the radius of the street corner itself, and the second is the effective turning radius of the selected design vehicle. The effective turning radius is the radius needed for a turning vehicle to clear any adjacent parking lanes and/or to align itself with its new travel lane. Using an effective turning radius allows a smaller curb radius than would be required for the motorist to turn from curb lane to curb lane. Parking lanes should end at least 20 ft. in advance of the intersection. Refer to Section 401.9 for guidance on intersection design with design and check vehicles.

401.8.2 - Crossing Distance Considerations

Short crosswalks help pedestrians cross streets. Excessive crossing distances increase the pedestrian exposure time, increase the potential of vehicle-pedestrian conflict, and add to vehicle delay.

Curb extensions reduce the crossing distance and improve the sight distances for both the vehicle and the pedestrian. See MDG Section 4.5.4 for more information.

401.8.3 - Crossing Islands and Medians

Where a wide intersection cannot be designed or timed to accommodate all the pedestrian crossing needs across one leg of the intersection at one time, a median or crossing island (often referred to as a refuge island) should be considered. Medians are raised or

painted longitudinal spaces. Triangular channelization islands adjacent to right turning lanes can also act as crossing islands.

Crossing island width should be a minimum of 8 ft. on roadways with speeds of 50 mph or greater.

See MDG Section 4.5.3 for more information.

401.8.4 - Turning Movements

At both signalized and unsignalized intersections (including roundabouts), steps should be taken to ensure that turning speeds are kept low and that sight distance is not compromised for either the motorist or pedestrian. While performing swept path analyses, the recommended turning speed of the vehicle is 10 mph.

401.9 - Design Vehicles for Intersection Design

Vehicle turning movements affect the operations, safety, and efficiency of an intersection. If intersection geometry restricts vehicle turning maneuvers then capacity can be reduced, the potential for crashes can increase and the potential for the intersection to break down can increase. To circumvent these potential problems the design of the intersection should account for the design and check vehicles and the varying degrees of encroachment (DE).

401.9.1 - Intersection Design Vehicle (IDV)

The Intersection Design Vehicle (IDV) for an intersection turning movement is the largest standard vehicle frequently making the turning maneuver. The Intersection Design Vehicle (IDV) must make the turning maneuver without encroaching into other lanes and without encroaching onto the shoulder or the gutter.

The other lanes in which encroachment is prohibited apply to both the departure leg; as well as, the receiving leg.

401.9.2 - Intersection Check Vehicle (ICV)

The Intersection Check Vehicle (ICV) used for intersection turning movements is typically larger than the Intersection Design Vehicle (IDV) and makes the turning maneuver less frequently. The turning maneuver for the Intersection Check Vehicle (ICV) allows for it to

swing wide and encroach into the adjacent lanes provided there is no significant traffic disruption. The Intersection Check Vehicle should not encroach into opposing travel lanes (except for one scenario, see Figure 401-15a) or leave the roadway (i.e. drive over curbing or leave the paved shoulder).

401.9.3 - Intersection Design Process

The process to analyze the degree of encroachment at an intersection for the Intersection Design Vehicle (IDV) and the Intersection Check Vehicle (ICV) is detailed in Figures 401-15a through 401-15c. Figure 401-15a shows the IDVs and ICVs along with their acceptable Degrees of Encroachment (DE), which is based on the functional classifications of the intersecting roadways. Figure 401-15b details the degrees of encroachment for intersection turning movements. The acceptable degree of encroachment for a particular vehicle varies depending on the roadway type, balancing the operational impacts for turning vehicles with the safety of all other users of the roadway. Figure 401-15c details the effective pavement width as well as an example showing the paths of an IDV and ICV at a collector-to-local intersection. The effective pavement width is the pavement width usable under the permitted degree of encroachments and may include encroachment into adjacent or opposite lanes of traffic, when permitted.

401.10 - Cul-de-Sacs and Turnarounds

A roadway open only at one end should have a dedicated turning area at the closed end. The turning area is typically circular in shape (other shapes are acceptable) and designed with a radius appropriate to accommodate the vehicle types expected to use the turnaround. The cul-de-sac or turnaround should be designed to ensure the design vehicle can make the turn with backing only once. Additional information regarding the design of cul-de-sacs can be found in Section 5.3.2.10 of AASHTO's A Policy on Geometric Design of Highways and Streets (7th Edition).

402 - Two Way Left Turn Lanes (TWLTL)

402.1 - General

Midblock left turns are often a serious problem in urban and suburban areas. They can be a safety problem due to angle crashes with opposing traffic as well as rear end crashes with traffic in the same direction. Midblock left turns also restrict capacity. Two way left turn lanes (TWLTL) have proven to be a safe and cost-effective solution to this problem.

402.2 - TWLTL Justification

TWLTL should be considered whenever actual or potential midblock conflicts occur. This is particularly true when crash data indicates a history of midblock left turn related crashes. Closely spaced driveways, strip commercial development or multiple-unit residential land use along the corridor are other indicators of the possible need for a TWLTL.

Some guidelines which may be used to justify the use of TWLTL are listed below:

1. 10,000 to 20,000 vehicles per day for four lane highways.
2. 5,000 to 12,000 vehicles per day for two lane highways.
3. 70 midblock turns per 1000 ft. during peak hour.
4. Left turn peak hour volume 20 percent or more of total volume.
5. Minimum reasonable length of 1000 ft. or two blocks.

402.3 - TWLTL Design

Widths for TWLTL are preferably the same as through lane widths (See Section 301.1.2). A 10 ft. lane may be used in restricted areas. Care should be taken not to make a TWLTL wider than 14 ft. since this may encourage shared side-by-side use of the lane. TWLTL markings shall be in accordance with the OMUTCD. See Section 301.1.5 for location of the crown point.

402.4 - Reversible Lanes

A reversible lane is a lane on which the direction of traffic flow can be changed to utilize maximum roadway capacity during peak demand periods. Reverse-flow operation on undivided streets generally is justified where 65 percent or more of the traffic moves in one direction during peak periods, where the remaining lanes are adequate for the lighter flow period when there is continuity in the route and width of the street, where there is no median and where left turn and parking can be restricted. Reverse flow operations require special signing and additional control devices. Refer to the federal MUTCD for further guidance. Reverse flow on a divided facility is termed “contra-flow operation.” While the principle of reverse-flow operation is applicable to divided arterials, the arrangement is more difficult than on an undivided roadway.

403 - Roundabouts

403.1 - General

A roundabout is a form of circular intersection in which circulating traffic travels counterclockwise around a central island in which entering traffic must yield to the circulating traffic. The term “modern roundabout” is used in the United States to differentiate modern roundabouts from traffic calming circles and rotaries that have been in use for many years. The term modern roundabout and roundabout are used interchangeably throughout this document.

Modern roundabouts are defined by three basic characteristics shown and described below.

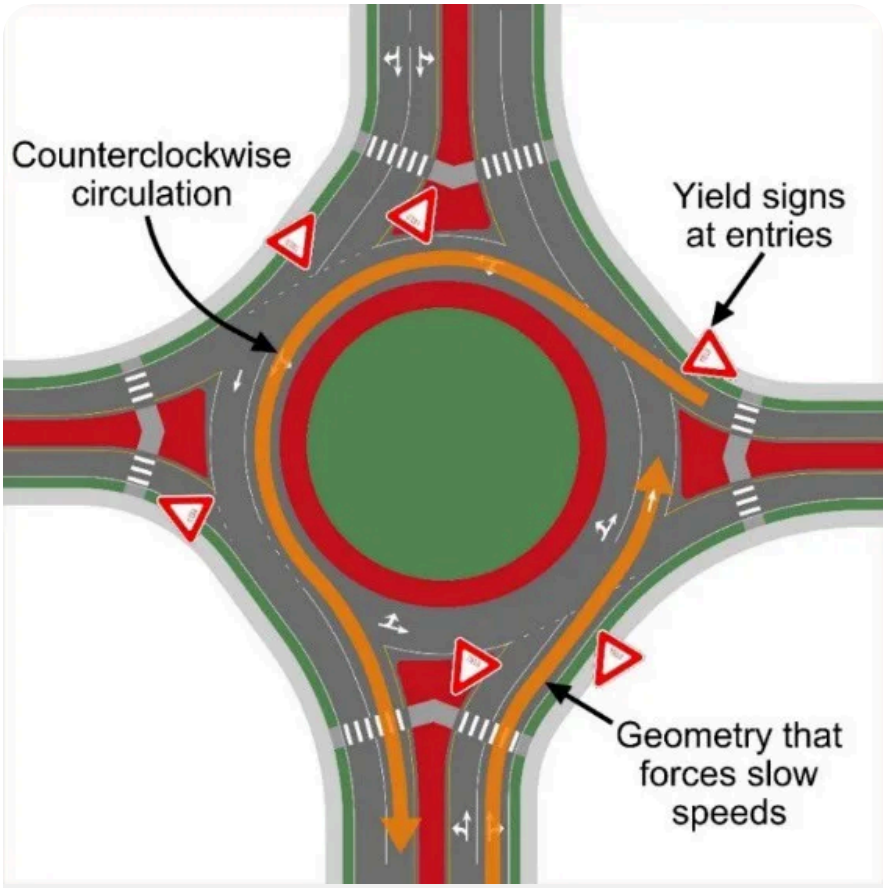


Exhibit 403.1-1: Characteristics of a Roundabout

1. Circular Shape: Roundabouts are generally circular in shape with traffic circulating in a counterclockwise fashion.

2. Yield-at-Entry to Circulating Traffic: Yield-at-entry requires all entering vehicles on the approaches to yield to the circulatory roadway traffic in the roundabout. The

circulating traffic have the right-of-way and all entering vehicles on the approaches must wait for a gap in the circulating flow before entering the circulatory roadway. Yield signs are used as the traffic control on each approach. Modern roundabouts are not designed for high speed or weaving maneuvers, and therefore have smaller diameters (less than 300 ft.) than large traffic circles/rotaries.

3. Slow Speeds for all Vehicles: Modern roundabouts have geometric features that slow all vehicles down, regardless of the posted speed limits on the approaching roadways. Entering traffic is slowed down and deflected to the right by the approach splitter island into an appropriate curved path along the circulating roadway and around the central island of the roundabout.

Generally, roundabouts can process high left turn volumes more efficiently than all-way stop control or traffic signals; as well as, accommodate a wide range of side road volumes.

Roundabouts can improve safety over that of a conventional intersection through the reduction of vehicular speeds through the roundabout (average 15-25 mph), the reduction of crossing conflicts where the paths of opposing vehicles intersect and a lower angle of impact in the event of a crash. Roundabouts are recognized by FHWA as a Proven Safety Countermeasure.

For additional information not detailed in this section, see **NCHRP 1043 Guide for Roundabouts.**

Based on **NCHRP 1043 Guide for Roundabouts,** roundabouts are separated into four basic categories:

1. Mini-Roundabouts
2. Compact Roundabouts
3. Single-Lane Roundabouts
4. Multi-Lane Roundabout

403.2 - Designing Roundabouts for Future Conditions

Once a roundabout has been selected as the intersection control solution consider the potential to phase improvements to reduce excessive capacity in the early years if a multilane roundabout is needed for the design year in an effort to improve safety and driver/public acceptance. Evaluate whether it is best to construct a roundabout based on an interim year traffic that can easily be converted when future traffic volumes dictate the need for expansion and additional capacity. Reducing the number of entry and circulating lanes reduces the number of potential conflicts with multi-lane roundabouts. When considering an interim roundabout condition that may be converted in the future, evaluate the right-of- way and geometric needs for both the interim and multilane configurations. When projected traffic volumes indicate a multilane roundabout is required in the design year, evaluate how long an interim configuration (such as a single-lane roundabout) will operate acceptably using the appropriate capacity methodologies before requiring additional lanes. Consider constructing and operating a roundabout in a single-lane configuration if the single-lane roundabout will provide sufficient capacity for a portion of the project design life until traffic volumes dictate an expansion to a multilane roundabout is warranted.

Expansion from the single-lane to the multilane roundabout can be accomplished in two ways:

Expansion to the Outside – The additional entering, circulating and exiting lanes are constructed to the outside of the single-lane roundabout. This option allows for easier future expansion to the multilane configuration since construction can occur while traffic is maintained on the existing single-lane pavement. Care needs to be exercised to ensure the proper geometric design of the entry and splitter islands allow for good speed reduction and the proper path alignment for the ultimate build-out of the roundabout. It is advisable to initially design the ultimate multilane configuration and remove the outside lanes from the design to form the initial single-lane roundabout. Acquire enough right-of-way to accommodate the future condition. It is preferred that pedestrian and off-street bicycle facilities; as well as, utilities be placed in their permanent location from the start rather than relocated at the time of the full build.

Expansion to the Inside – The additional entering, circulating and exiting lanes are constructed to the inside of the single-lane roundabout. The initial single-lane configuration occupies the same inscribed circle as the ultimate multilane roundabout allowing the designer to set the outer limits of the roundabout during the initial construction. Impacts to

surrounding properties is minimized under this scenario. The single-lane design will provide wider splitter islands and an enlarged central island that occupies the space of the future inside lanes. Future expansion to the multilane roundabout is accomplished by reducing the width of the splitter islands and contracting the diameter of the central island.

403.3 - Operational Analysis

Figure 403-1 is intended to provide rules of thumb for sizing a roundabout. Use capacity analysis software to support all roundabout design configurations. See **Section 401.2.3** and the ODOT Analysis and Traffic Simulation (OATS) manual for additional information on roundabout analysis.

403.4 - Design Principles and Objectives

The geometric design of a roundabout is generally an iterative process looking to balance competing considerations such as safety, operations and costs. Apply the following general design principles to provide a safe and efficient roundabout design:

1. Provide enough deflection with the entry curvature to slow entry speeds; as well as, keep speeds consistent through the roundabout.
2. Ensure adequate capacity, volume balance and lane continuity to achieve acceptable operations is provided through the appropriate number of lanes and the proper lane assignments. Turn lane lengths for the approach lanes of the roundabout must be determined by accommodating the 95th percentile queue lengths as identified by HCS or TransModeler, see Section 401.2.3.
3. Provide smooth channelization that is intuitive and will naturally guide drivers into the intended lanes.
4. Design roundabout elements to allow a WB-62 or larger vehicle (on state-maintained roadways) that will be using intersection to enter, circulate and depart the roundabout efficiently.
5. Design for non-motorized users such as pedestrians and bicyclists.
6. Provide appropriate sight distance and visibility for driver recognition of the roundabout and conflicting users

Since roundabouts are complex and unique designs, the Office of Roadway Engineering (ORE) recommends a Pre-Stage 1 Geometric Review to avoid time consuming revisions. The review will focus on the alignments, truck tracking and performance checks prior to the designer expending extensive detailed design efforts for the Stage 1 submission.

403.4.1 - Speed Management

The most critical objective is to maintain low and consistent speeds through the roundabout. Roundabouts are safest and most effective when the geometry allows the traffic to enter, circulate and exit at slow consistent speeds. Speed management is a combination of managing speeds at the roundabout itself and managing speeds on the approaching roadways.

Since the design of the roundabout requires entering vehicles to negotiate the roundabout at slow speeds, the design speed may vary within the roundabout intersection.
See **Section 403.7.1** for information on Fastest Path Speeds. The roundabout approach design speed range is determined by engineering judgment based on several conditions:

1. The roadway classification for each leg of the roundabout and their respective design speeds (high speed or low speed).
2. The intersection users (pedestrians, bicycles, pedestrian generators, large vehicle generators, etc.
3. The location of the roundabout:
    - Rural or urban.
    - Users familiar or unfamiliar with roundabouts.
4. The type of roundabout: Mini-Roundabout, Single-Lane Roundabout or Multilane Roundabout.
5. Desirable maximum entry design speed:
    - Mini-Roundabout (15 to 20 mph)
    - Single-lane roundabout (20 to 25 mph)

- Multilane roundabout (25 to 30 mph)

6. Design speed consistency:
    - Minimize the relative speeds between consecutive geometric elements.
    - Minimize the relative speeds between conflicting traffic streams.
    - Limit maximum speed differentials to approximately no more than 10 to 15 mph between movements.
7. It is recommended that approach speeds approximately 100 ft. prior to the entrance line (yield line) of the roundabout be limited to approximately 35 mph or less to minimize high-speed rear- end and entering-circulating vehicle crashes. On high-speed rural and urban approaches, it is recommended to use any or some combination of the following techniques to slow down drivers approaching the roundabout:
    - Maximize the Visibility of the Central Island
    - Curbing
    - Splitter Islands
    - Reverse Curves on Approach
        - For superelevation of curves on high-speed approaches to roundabouts use the low-speed urban street criteria L&D Figure 202-9. The design speed for these approach curves is based on its distance from the yield line and the deceleration length determined from AASHTO GDHS (Greenbook), 7th edition, Figure 2-34. If superelevation is not required, provide tangents between reverse curves as follows. Provide a minimum tangent length of 65’ between the broad radius (recommended 45 mph design speed) and moderate radius (recommended 35 mph design speed), and a tangent length of 50’ between the moderate radius and entry radius (recommended 20 to 25 mph design speed).

8. Reverse curves on all low-speed approaches: If tangent for superelevation transition is not required as per L&D Figure 202-9, it is preferred to consider adding some tangent length, 50 feet is preferred, between the reverse curves for smooth transition of pavement cross slopes reversals.

403.4.2 - Lane Arrangements

The operational analysis (See **Section 401.2.3**) will determine the required number of entry lanes to serve each approach into the roundabout. In the case of multilane roundabouts care must be taken to ensure the design provides the appropriate number of circulating and exit lanes to ensure lane continuity is preserved.

403.4.3 - Appropriate Path Alignment

The geometry of the roundabout at the entry will affect the path that vehicles take circulating through and exiting the roundabout. Guided by the lane markings vehicles will continue along their natural trajectory into the circulating roadway based on their speed and orientation. At multilane roundabouts if the entry radius is small there may be a tendency for the vehicle in the outside lane to overlap paths and come into conflict with the vehicle in the inside lane of the circulatory roadway. Overlapping paths presents the potential for inefficient operations due to driver reluctance to use one or more of the entry lanes or sideswipe crashes. Likewise, overly small radii at the exit may result in vehicle path overlap.

Align the entries and exits at multilane roundabouts to position vehicles into their appropriate lanes within the circulatory roadway.

403.4.4 - Design Vehicle

Another important factor determining a roundabout’s layout is the need to accommodate the largest vehicle reasonably anticipated to use the intersection with some frequency. The turning path of this design vehicle controls many of the roundabout’s dimensions.

Because roundabouts are intentionally designed to slow traffic, narrow curb-to-curb widths and tight turning radii are typically used. However, if the widths and turning radii are designed too tight, difficulties for large vehicles may be created. Large trucks and buses often dictate many of the roundabout’s dimensions, particularly for single-lane

roundabouts. Therefore, it is very important to determine the design vehicle at the start of the design and investigative process.

The choice of a design vehicle will vary depending upon the approaching roadway types and the surrounding land use characteristics. Use a WB-62 design vehicle or preferably a WB-67 design vehicle if truck percentages are high on roundabouts at interchanges with interstates, freeways, expressways and at intersections on arterial streets and highways. Smaller design vehicles may be chosen at local street intersections. At a minimum, fire engines, transit vehicles, and single-unit delivery vehicles can be considered in urban areas. In rural environments, school buses or farming equipment may govern design vehicle needs.

Ensure design vehicles can traverse the roundabout without off-tracking over the outside curbing or onto the splitter island curbing. Place vertical and sloped curbing to avoid trailer off-tracking (rear axles passing over curbing). Provide vertical curbing along the central island, the outside perimeter of the roundabout and the splitter islands unless mountable slope curbing is needed for a specific reason.

Confirm guardrail, signs, light poles, pull boxes, and other fixed features are not impacted by the design and check vehicle turning envelope during normal operation.

403.4.4.1 - Design Vehicle Tire Tracking

Since roundabouts are designed to slow traffic, narrow curb-to-curb and tight turning radii are typically used. If these curb-to-curb widths and turning radii are too tight difficulties may occur for larger vehicles. It is very important to select the proper design vehicle, usually a WB-62 or larger vehicle (on state- maintained roadways) and check the vehicle sweep or tracking using CAD-based vehicle turning software. Provide a minimum clearance of 2 ft. between the outside edge of the vehicle’s tire tracking path and the face of curb (with or without gutter). Ensure the truck cab tracks within the circulatory roadway and allow the trailer to use the truck apron as needed. This is not applicable to mini-roundabouts, as the entire truck will typically traverse across the central island.

403.4.4.2 - Design Vehicles at Multilane Roundabouts

Multilane roundabout design vehicles considerations need to consider the swept paths on entry, on exit and in the circulatory roadway.

The design vehicle may operate under one of the two following design situations:

- **Straddle Lanes** – The design vehicle is assumed to use the entire curb-to-curb width for entering, circulating and exiting as needed.
- **Stay-in-lane** – The design vehicle is assumed to stay in lane on entry, while circulating and while exiting. Truck aprons can serve large vehicles in the inside lane, but not on the outside lane.

ODOT-maintained roadways typically have WB-62 vehicles as frequent users, therefore designs using a combination of straddle lane and stay-in-lane techniques are recommended. Where WB-62s are frequent, the swept path analysis should allow the simultaneous passage of a WB-62 and a passenger vehicle through the roundabout. Lane encroachment by the WB-62 is acceptable, although the passenger vehicle swept path should not encroach the truck apron or curbing to avoid the swept path of the WB-62. At locations where trucks are infrequent users, a straddle lane design is acceptable. Locations with significant truck volumes may consider utilizing a design that allows the simultaneous passage of a WB-62 with an SU. Each roundabout design is unique and reviewing what vehicles are expected to use the intersection is important to ensure that a roundabout is designed to the right size.

403.4.4.3 - Agricultural Vehicles at Rural Locations

Various design elements are necessary to better accommodate agricultural vehicles at roundabouts in rural locations.

The swept path for wider equipment such as a farm combine may come into conflict with vertical elements such as light poles and signs. The design for the roundabout shall locate vertical elements such as barrier, light poles and signs a minimum 2’ outside of the swept path of the agricultural vehicles. Signs and poles should be staggered to avoid pinch points. A combine template for AutoTURN (recommended for swept path analyses), as well as other agricultural vehicle templates are available on the *Office of Roadway Engineering's webpage*.

Curbed elements may create issues with lateral clearances. Vertical curb faces may rub against farm equipment tires so a curb with a rolled top (See SCD RD-5.1 Types 3, 3-A, 3-B, or 11) or dropped cross section (See SCD RD-5.1 Types 9 and 10) must be used for the

outside curbing to provide a more gradual transition for the farm equipment. Rolled or dropped curbs with a lower vertical height accommodate the tracking of the farm equipment without increasing the speeds on the fastest path checks. Rolled or dropped curbs may also be used on splitter islands and center islands on a case-by-case basis.

403.4.5 - Sight Distance and Visibility

The visibility of the roundabout as vehicles approach the intersection and the sight distance for viewing vehicles already operating within the roundabout are key components for providing safe roundabout operations. Roundabouts require both the stopping sight distance and the intersection sight distance to be met.

Check the design to verify that stopping sight distance can be provided at every point within the roundabout; as well as, each entering and exiting approach so that a driver can react to objects or conflicting users within the roadway.

Intersection sight distance must be verified for any roundabout design to ensure sufficient distance is available for drivers to perceive and react to conflicting vehicles or pedestrians.

See **Section 403.7.2** for more information on Sight Distance.

403.4.5.1 - Intersection Sight Distance

Intersection Sight Distance is the distance required for a driver without the right-of-way to perceive and react to the presence of conflicting vehicles. The intersection sight distance is measured by sight triangles defining the space a driver needs to be able to identify gaps in circulating traffic and presence of pedestrians at crosswalks.

403.4.6 - Approach Design

The primary safety concern with a high-speed roundabout is to make drivers aware of the approaching roundabout with ample distance to decelerate comfortably to the appropriate speed. Use the following principles to achieve the appropriate speed designs:

- Provide the desirable stopping sight distance at the entry point based on approach operating speeds.

- Align approach roadways and set vertical profiles to make the central island conspicuous.
- Extend splitter islands upstream of the yield line to the point at which entering drivers are expected to begin decelerating from the approach speed to the entry design speed.
- Provide a gentle curve at the approach to the roundabout with each successive curve being smaller. Base the size of the curves on the design speed and expected speed change. While not mandatory for speed reduction, providing curvilinear alignments (chicanes) is an acceptable strategy. Occasionally, they arise naturally as a result of designing for specific entry speeds or other performance objectives.
- Provide tangents between reverse curves to prevent truck rollovers.
- Use landscaping if sight lines are not impacted to create a tunnel effect.
- Provide illumination in transition to the roundabout.
- Use signs and pavement markings to effectively advice drivers of the change in speed and path.

403.5 - Size, Position and Alignment of Approaches

Three decisions are needed in the design of roundabouts to balance the geometric design principles and objectives described in Section 403.4. The design decisions are:

- Size
- Position
- Alignment of the Approach Legs

403.5.1 - Size of the Roundabout (Inscribed Diameter)

The best parameter determining the size of the roundabout is the inscribed circular diameter which is the distance across the circle inscribed by the outer edge of the curb. Ensure the design vehicle has the capability of traversing the roundabout within the circulatory roadway. If this cannot be accomplished without undue impacts to the roundabout performance checks then at a minimum, ensure the truck cab tracks within the

circulatory roadway and allow the trailer to use the truck apron as needed. Due to its nature the mini-roundabout doesn’t need to follow these design vehicle requirements. **Exhibit 403.6-1 Design Elements of a Roundabout** shows the Inscribed Diameter measurement.

Typical Inscribed Circle Diameters:

Roundabout Configuration	Typical AASHTO Design Vehicle	Common ICD Range[a]
Mini-roundabout	SU-30	45 ft to 90 ft (14 m to 27 m)
Compact roundabout	BUS-40 WB-40 WB-62 or WB-67[b]	65 ft to 120 ft (20 m to 37 m)
Single-lane roundabout (non-traversable central island)	BUS-40 WB-40 WB-62 or WB-67	90 ft to 120 ft (27 m to 37 m) 100 ft to 130 ft (30 m to 40 m) 120 ft to 180 ft (37m to 55 m)
Multilane roundabout (2 lanes circulating)[c]	WB-40 WB-62 or WB-67	135 ft to 160 ft (41 m to 49 m) 140 ft to

		180 ft (43 m to 55 m)
Multilane roundabout (3 lanes circulating)[c]	WB-62 or WB-67	190 ft to 240 ft (58 m to 73 m)

[a] Assumes 90-degree angles between entries and no more than four legs. List of possible design vehicles is not comprehensive.

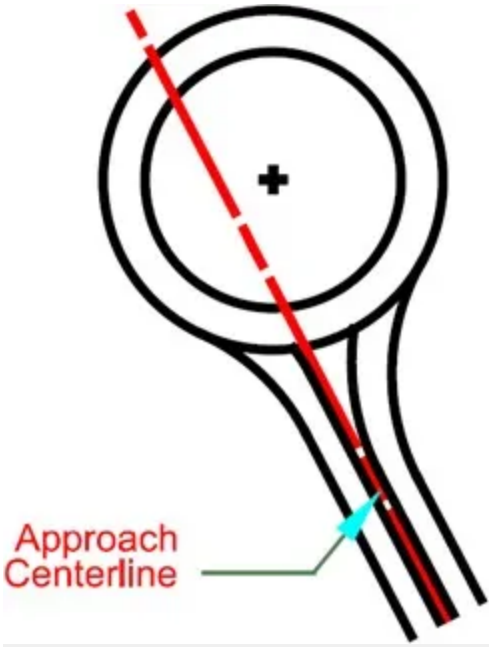
[b] Serving WB-62 or larger vehicles as through movements. Right turning may require other special considerations for approach and splitter island design.

[c] Common ICD ranges depend on whether the design vehicle will straddle or stay in-line. Does not account for special vehicles or OSOWs.

403.5.2 - Position of Approaches

The position is determined by the alignment of the approach leg in relationship to the center of the inscribed circle. The position of the approach alignment for each of the legs has a primary effect on the deflection and speed control. The three positions are:

1. Offset Alignment to the Left of Center
2. Alignment through the Center of the Roundabout
3. Offset Alignment to the Right of Center



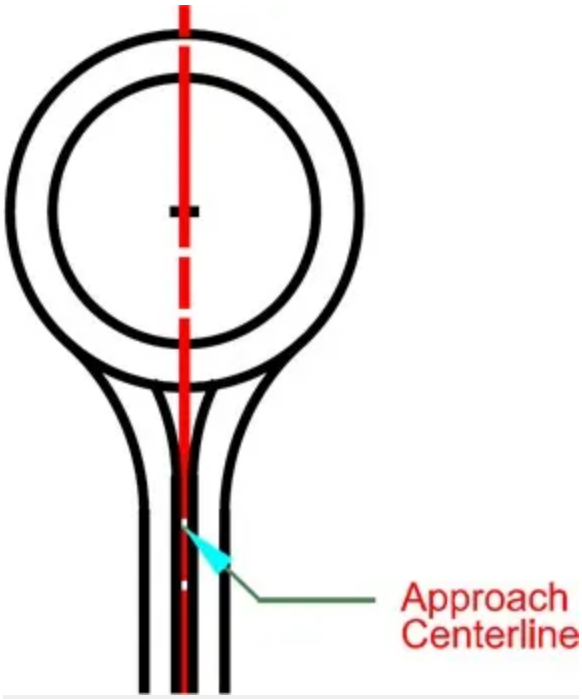
Position 1: Offset Alignment to the Left of Center

Advantages:

- Allows for increased deflection
- Beneficial for accommodating large trucks with small inscribed circle diameter, allows for larger entry radius while maintaining deflection and speed control
- May reduce impacts to the right-side of the roadway

Trade-offs:

- Increased exit radius or tangential exit reduces control of exit speeds and acceleration through crosswalk area
- May create greater impacts to the left side of the roadway



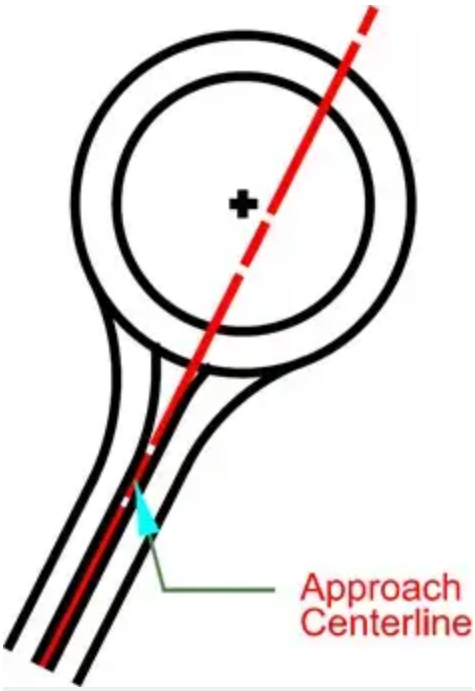
Position 2: Alignment through Center of Roundabout

Advantages:

- Reduces amount of alignment changes along the approach roadway to keep impacts more localized to intersection
- Allows for some exit curvature to encourage drivers to maintain slower speeds through the exit

Trade-offs:

- Increased exit radius reduces control of exit speeds/acceleration through crosswalk area
- May require a slightly larger inscribed circle diameter (compared to offset-left design) to provide the same level of speed control



Position 3: Offset Alignment to the Right of Center

Advantages:

- Could be used for large inscribed circle diameter roundabouts where speed control objectives can still be met
- Although not commonly used, this strategy may be appropriate in some instances (provided that speed objectives are met) to minimize impacts, improve view angles, etc.

Trade-offs:

- Often more difficult to achieve speed control objectives, particularly at small diameter roundabouts
- Increases the amount of exit curvature that must be negotiated

403.5.3 - Alignment Approach Legs

Generally, it is preferable to have the approaches intersect at or near perpendicular. Approach legs intersecting at an angle greater than 105 degrees can result a lack of deflection may result in fast vehicle speeds. Approach legs intersecting at an angle less

than 75 degrees can result in difficulty for the design vehicle to navigate the entry into the roundabout.

403.6 - Design Elements of a Roundabout

This section describes the individual geometric elements comprising a roundabout.

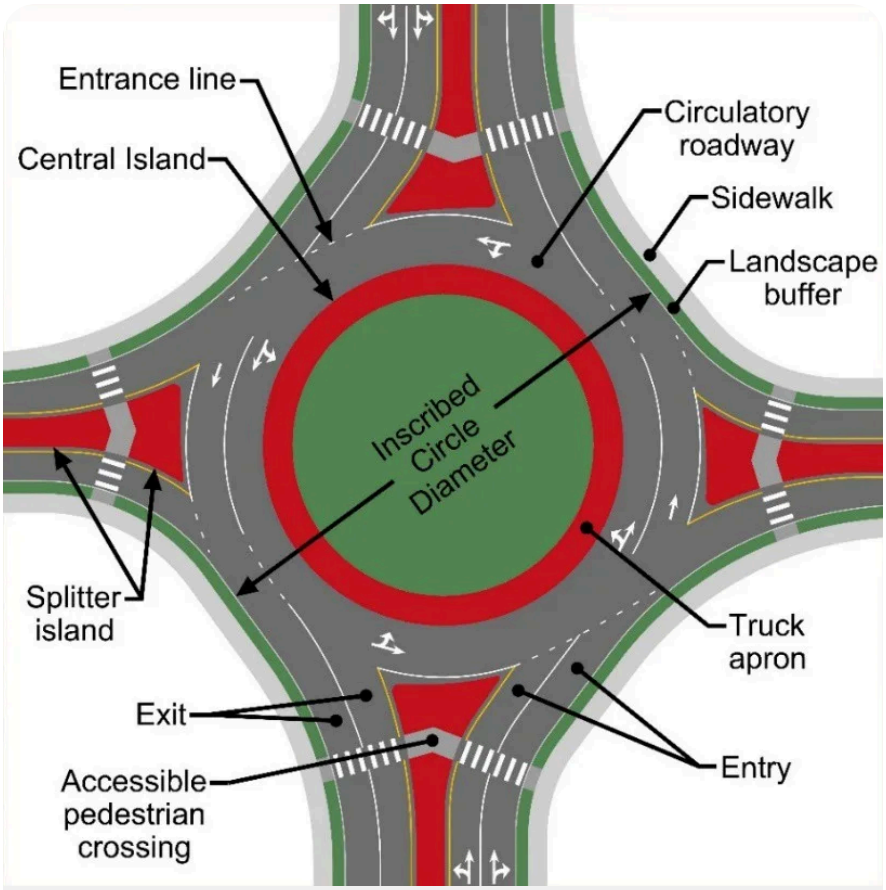


Exhibit 403.6-1: Design Elements of a Roundabout

403.6.1 - Inscribed Diameter (Outside Limits of Circulatory Roadway)

See **Section 403.5.1** and **Exhibit 403.6-1**.

403.6.2 - Circulatory Roadway Width

The required width of the circulatory roadway width is determined from the number of the entering lanes and turning requirements of the design vehicle.

Circulatory Roadway Widths:

- Single Lane: 16 to 20 feet

- Two Lane: 28 to 32 feet

403.6.3 - Central Island

The central island is the area surrounded by the circulatory roadway. Design the central island to be raised or mounded to ensure approaching drivers are aware of the approaching roundabout. The central island is mainly non-traversable, but it does include the truck apron which is traversable. Teardrop shaped islands may be used where certain movements do not exist such as an interchange or where certain turning movements cannot be accommodated.

Central Island Treatment

- Mini-Roundabout: Fully Traversable
- Compact Roundabout: Fully Traversable or Raised (with traversable truck apron).
- Single-Lane Roundabout: Raised (with traversable truck apron).
- Multilane Roundabout: Raised (with traversable truck apron).

403.6.4 - Truck Apron

A truck apron is typically used to provide additional traversable area around the central island to accommodate large vehicles without compromising the deflection for the smaller vehicles. Truck aprons can also be used along the corners of a roundabout (or any intersection). Truck aprons used on the corners of a roundabout reduce the entry width, as well as the fastest path speeds. Accommodating the design vehicle may result in increased pavement areas along the exterior curbing between the entrance to the circulatory roadway and the exit from the circulatory roadway. The use of truck aprons can reduce the fastest path for passenger vehicles while accommodating the design vehicle.

Check truck apron widths with truck turning templates allowing for 2 ft. between the tire path and inside edge of the truck apron. See **NCHRP 1043 Guide for Roundabouts** for additional truck apron details.

Central Island Truck Apron Widths: 3 to 15 feet. For ODOT maintained facilities on the State Highway System (SHS) provide 12 ft. min. Truck apron reveal to circulatory roadway: 2-3 inch maximum.

403.6.5 - Entry and Exit Widths

Ensure the entry and exit widths can accommodate the desired design vehicle and avoid off-tracking over curbing or extend beyond pavement limits.

Preferred Entry and Exit Widths:

- Single Lane: 14 to 18 feet
- Two Lane: 28 to 30 feet

403.6.5.1 - Development of Entry Widths for Multilane Roundabouts

Locations where additional entry capacity is required, Figures 402-2 and 402-3 show acceptable methods of widening the roadway prior to the roundabout.

403.6.5.2 - Exit Width Reduction of Multilane Roundabouts

Locations where additional capacity is required within the roundabout but immediately reduced on the exit leg of the roundabout, the Roundabout Taper Option on Figure 402-2 shows the acceptable method of reducing lanes along the roadway of the exit leg. Lane reductions at the exit could affect lane utilization at entries.

403.6.6 - Gore Striping

An allowable technique to accommodate the design vehicle is to provide gore striping. Gore striping involves placing a striped vane island between the entry lanes to help center the vehicles within the lane and allow a cushion for off-tracking by the design vehicle.

403.6.7 - Right-Turn Bypass Lanes

At locations with a high volume of right-turning traffic, a right-turn bypass lane may allow a single-lane roundabout to continue to function acceptably and avoid the need to upgrade to a multilane roundabout. For additional information, see **NCHRP 1043 Guide for Roundabouts.**

403.6.8 - Cross Slopes

Generally, design the circulating roadway and truck apron to slope away from the central island. This will promote safety by improving the visibility of the central island, lowering the

vehicle speeds in the circulating roadway due to the reverse superelevation and minimizing the breaks in the cross slopes of the entry and exit lanes.

Preferred Cross Slopes:

- Circulatory Roadway: 2% away from the central island.
- Truck Apron: 2% towards the outside.

403.6.9 - Splitter Islands

The purpose of the splitter island is to provide refuge for pedestrians, assist in controlling speeds, guide traffic into the roundabout, physically separate entering and exiting traffic and deter wrong-way movements. Provide at least a length of 50 ft. although 100 ft. is preferable of raised splitter island on all approaches. On high speed roadways, provide an island length of 150 ft. to 200 ft. Also, provide a minimum island width at crosswalks of 6 ft. as a pedestrian refuge.

Except for the splitter island nose at the approach, the splitter island should not be mountable. The approach nose of the splitter island should be ramped as detailed on SCD RM-3.1. Exceptions for mountable splitter islands can be made if accommodating oversize-overweight (OSOW) loads is necessary. Depressions or cuts in the splitter islands are acceptable if alternative access to a driveway is not feasible. Delineation such as flexible posts, signage, or traffic paint at the nose of the splitter island may be appropriate.

403.6.10 - Curbing

Provide curbing on the outside edge of the circulating roadway of the roundabout; as well as, the approach and exit legs. As a minimum, extend the curbing to the beginning of the splitter island on the approach and exit. On designs utilizing reverse curve approaches, extend the curbing to the beginning of the first or “broad radius” curve for both the approach and exit. Use curbs measuring 6 inches in height along the outside edges. Refer to Section 305.2. Outside curbing provides positive guidance, slows entry speeds, and prevents parking within the roundabout. Use curbs with a 3-to-4 inch curb reveal around the truck aprons to prevent a truck from overturning if the trailer tracks over the truck apron.

Curbing does not always require a closed drainage system. Gaps in the curbing can allow for stormwater to drain to ditches, refer to **L&D, Volume 2 Section 1103.2** and **SCD DM-4.1** for more information.

403.6.11 - Lighting

Provide lighting as per Traffic Engineering Manual (TEM) Section 1140-4.6.10 Roundabouts.

403.6.12 - Spirals

Spirals are introduced within the circulatory roadway of the roundabout as a series of lanes gains and lane drops to lead drivers into the appropriate lane for their desired exit. Spirals guide drivers entering the roundabout on the inside lane to shift into the outside lane within the circulatory roadway enabling the driver to exit from the outside lane. The spiral is designed to prevent vehicles from becoming trapped on the inside lane or requiring drivers to make a quick lane change within the circulatory roadway to exit. Spirals can be installed to accommodate heavy left turning movements. Consider spirals where the circulatory roadway has enough width to provide two or more lanes of traffic and where the geometry and traffic volumes are determined to warrant the use of spirals. Circulatory roadway spirals require considerable engineering judgment to design and locate properly, although they are intended to guide drivers, they may be confusing to properly understand and not always intuitive to the driver.

Widen pavement for the spiral along the central island with curb and gutter until a full lane width is developed. A spiral can be developed with the use of pavement markings, but experience shows drivers may ignore those markings which may lead to crashes within the circulatory roadway.

An example of a roundabout spiral is shown in **Exhibit 403.6-2**. This spiral is used to shift the westbound left turn to the outside lane. The spiral is used because the southbound exit is only a single lane exit and the southbound entrance allows dual left turns. To exit without conflict, the westbound left turn needs to be spiraled to the outside lane. Without the spiral, the left turn would be trapped on the inside lane and would do a U-turn or have to crossover lanes.

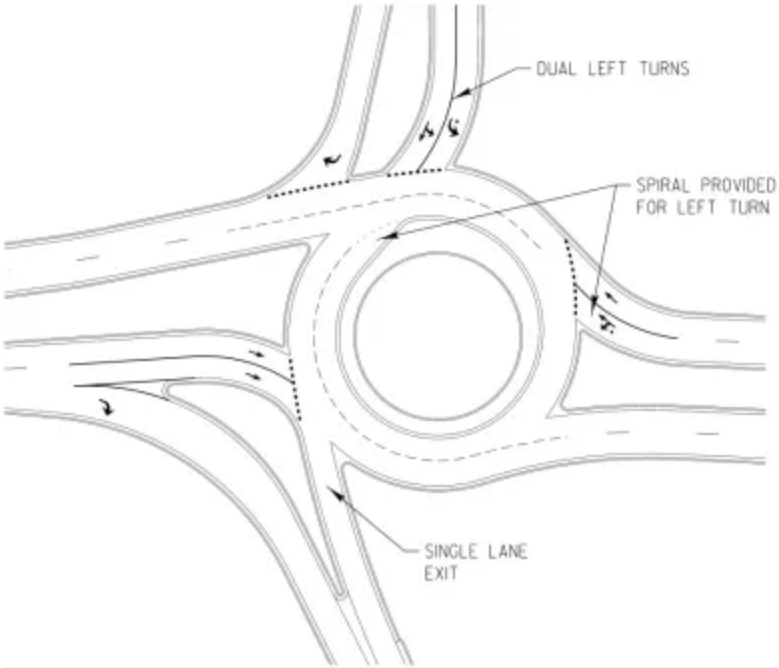


Exhibit 403.6-2: Spiral within a Roundabout

403.7 - Performance Checks

This section describes the individual performance checks vital to good roundabout design. The following performance checks will help the designer and reviewer determine whether the design meets the design principles and objectives described in **Section 403.4**.Submit the roundabout design checklist with the Stage 1 plan submission to aid the reviewer of the roundabout. See Figure 403-2 for the Roundabout Critical Design Parameters Checklist.

403.7.1 - Fastest Path Speeds

The fastest path determines the potential driver speed based on the geometry for a vehicle traversing into, through and exiting the roundabout. It is the smoothest, flattest path possible for a single vehicle in the absence of traffic and any regard for the lane markings. The fastest path must be drawn for all approaches and all movements. The fastest path doesn’t necessarily reflect the vehicle speeds expected through the roundabout, but rather the speeds a vehicle could theoretically attain.

There are five critical path radii to be checked for each approach. The five critical path radii are defined as follows:

- Entry Path Radius (R1) is the minimum radius prior to the entrance line.
- Circulating Path Radius (R2) is minimum radius around the central island.

- Exit Path Radius (R3) is the minimum radius into the exit.
- Left-Turn Path Radius (R4) is the minimum radius on the path of the left-turn movement
- Right-Turn Path Radius (R5) is the minimum radius on the path of the right-turn movement.

See **Exhibit 403.7-1** for a visual representation of the fastest path.

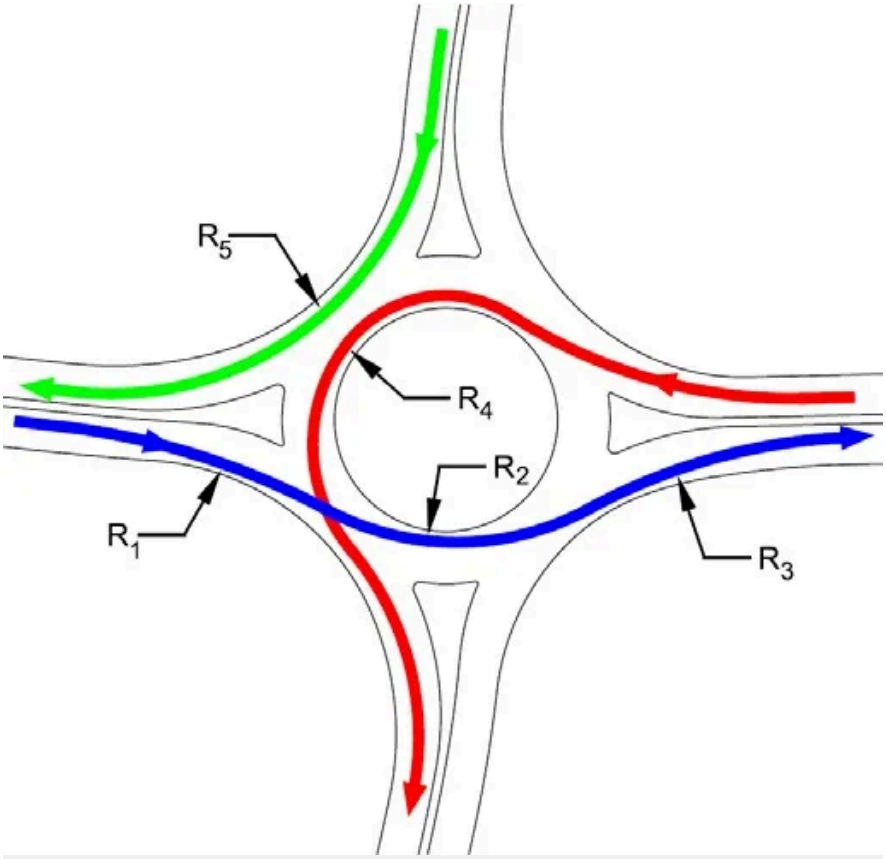


Exhibit 403.7-1: Fastest Path Radii

The performance of the roundabout is chiefly influenced by the Entry Path Radius (R1) due to its ability to control the speed of vehicles entering the roundabout. The recommended maximum theoretical design speeds for the Entry Path Radius (R1) are as follows:

- Mini-Roundabout: 20 mph
- Single Lane: 25 mph
- Multilane: 25 to 30 mph

Use the following parameters in determining the design speeds for the movements within the roundabout (R2, R4, R5):

- Thru Movements (R2): Provide path deflection of the approach vehicle such that the vehicle is required to slow to 15-20 mph within the circulatory roadway. R2, circulatory radius is critical for controlling thru traffic speed.
- Left Turn Movement (R4): Travel speed is controlled by truck apron diameter (typically 10-15 mph).
- Right Turn Movement (R5): Travel speed is a function of the curb radius and splitter islands between adjacent approaches.

Research has shown the Exit Path Radius (R3) may not always be determined by the radius of the curve exiting the circulatory roadway. Exit Path Radius (R3) is the lesser value between the minimum radius curve exiting the circulatory roadway or the speed achieved accelerating from within the circulatory roadway. This speed is derived using the following formula.

$$V_3 = min\begin{Bmatrix} V_{3p} \\ \\ \frac{1}{1.47}\sqrt{(1.47V_2)^2 + 2a_{23}d_{23}} \end{Bmatrix}$$

Exit Path Formula

Where:

- V_3 = exit speed (mph),
- V_{3p} = V3 speed predicted on basis of path radius (mph),
- V_2 = circulatory speed for through vehicles predicted on basis of path radius (mph),
- a_{23} = acceleration between the midpoint of V_2 path and the point of interest along V_3 path (6.9 ft/s^2), and

- d_{23} = distance along the vehicle path between midpoint of V_2 path and point of interest along V_3 path (ft).

Avoid designing strictly for R1/R2/R3 relationship as described in **NCHRP 1043 Guide for Roundabouts** since this can result in a very tight design for trucks to negotiate.

See **Section 403.7.1.1** for guidance on constructing the fastest path.

403.7.1.1 - Construction of Vehicle Fastest Path

The fastest path radii should not be mistaken for the curb radii. The vehicle width is assumed to be 6 ft. and maintain a minimum clearance of 2 ft. offset from a roadway centerline or concrete curb and flush with a painted edge line. The path of the fastest path is drawn with the follow distances:

- 5 ft. from a concrete curb
- 5 ft. from a roadway centerline
- 3 ft. from a painted edge line

Begin the construction of the fastest path at least 165 ft. in advance of the entrance line using the appropriate offsets identified above and the Measure the Entry Path Radius (R1) as the best-fit curve over a distance of at least 65 to 80 ft. near the entrance line.

See **Exhibits 403.7-2 and 403.7-3** for Fastest Path movements.

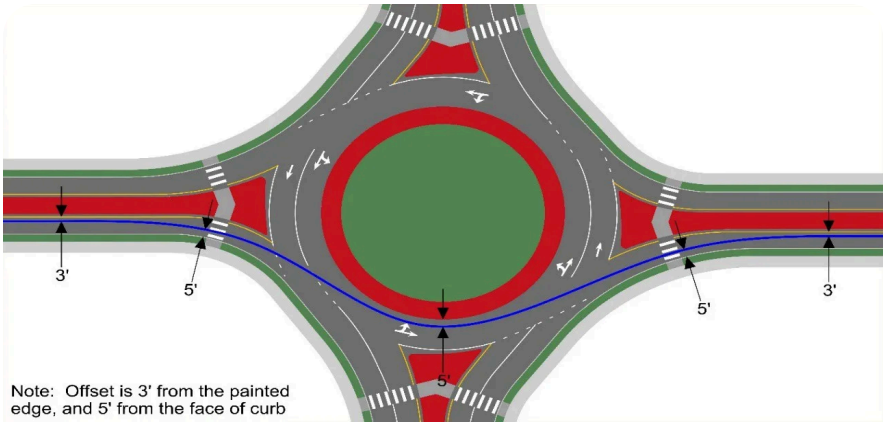


Exhibit 403.7-2: Fastest Path for Through Movements (R1/R2/R3)

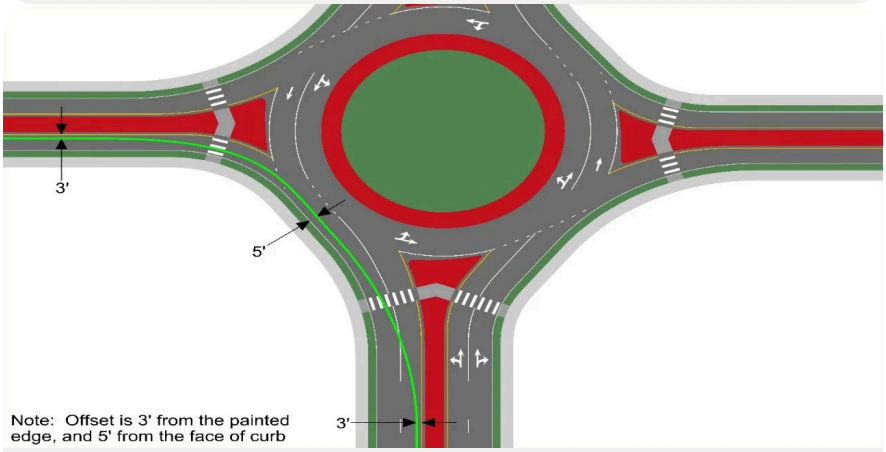


Exhibit 403.7-3: Fastest Path for Right Turn Movements (R5)

See **NCHRP 1043 Guide for Roundabouts** for additional information.

403.7.2 - Sight Distance

The two aspects of sight distance are the stopping sight distance and the intersection sight distance.

403.7.2.1 - Stopping Sight Distance

The stopping sight distance is the distance along a roadway required for a driver to perceive and react to an object in the roadway and brake to a complete stop before reaching the object. Ensure the stopping sight distance can be provided at every point within the roundabout and on each entering and exiting approach. For more information regarding stopping sight distance see Section 201.2 and Figure 201-1.

Perform the following three stopping sight distance checks for the roundabout:

- Sight Distance on the Approach
- Sight Distance in the Circulating Roadway
- Sight Distance to the Crosswalk on Exit

See **Exhibits 403.7-4 - 403.7-6** below:

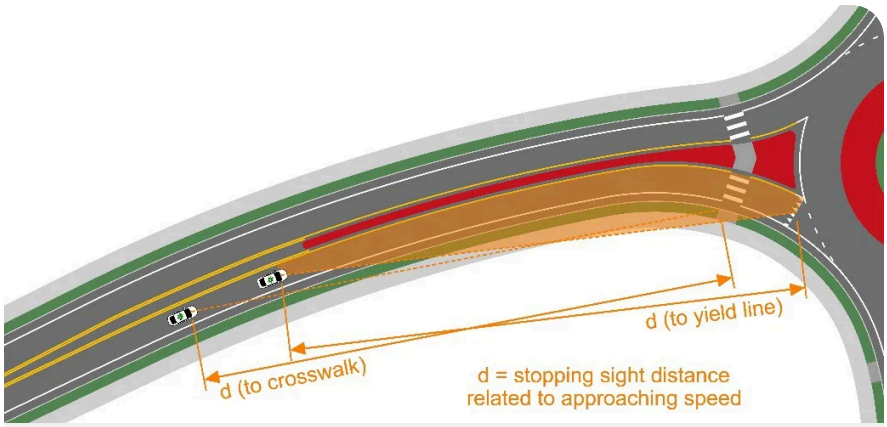


Exhibit 403.7-4 Sight Distance on the Approach

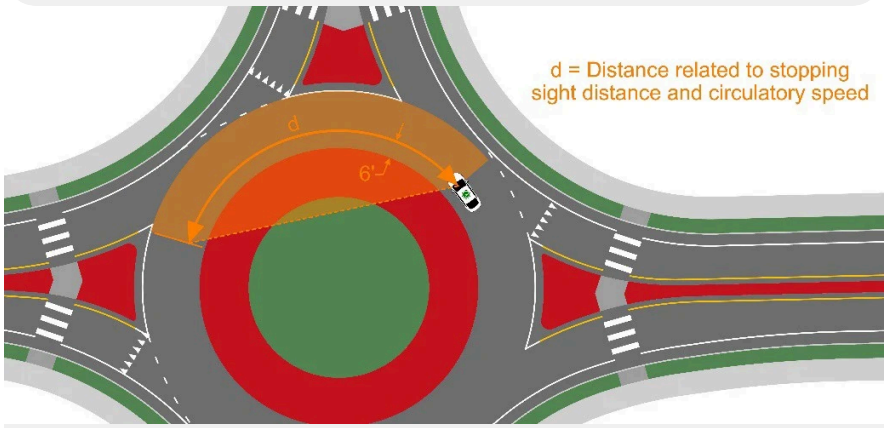


Exhibit 403.7-5: Sight Distance in the Circulating Roadway

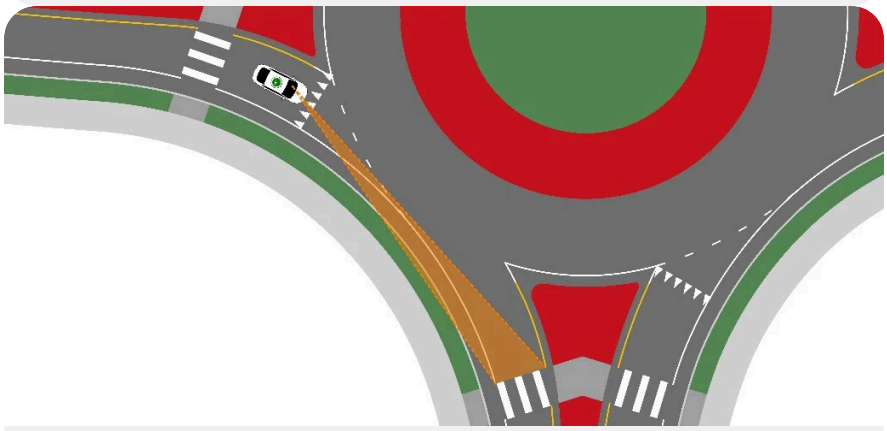


Exhibit 403.7-6: Sight Distance on the Crosswalk on Exit

403.7.2.2 - Intersection Sight Distance

The intersection sight distance is the distance required for a driver without the right-of-way to perceive and react to the presence of conflicting vehicles. The intersection sight distance is determined with the use of sight triangles that allow a driver to see and safely react to conflicting vehicles. For more information regarding intersection sight distance see

Section 201.3 and Figures 201-4 and 201-5. For roundabouts the only location requiring intersection sight distance checks are the entries.

The intersection sight distance is traditionally measured by the determination of a sight triangle. The triangle is bounded by a length of roadway defining a limit away from the intersection on each of the two conflicting approaches and by a line connecting those two limits. These legs are assumed to follow the curvature of the roadway. Measure these distances as the distance along the vehicular path, and not as straight line. Limit the length of the approach leg should to 50 ft. from the entrance line. See **Exhibit 403.7-7**.

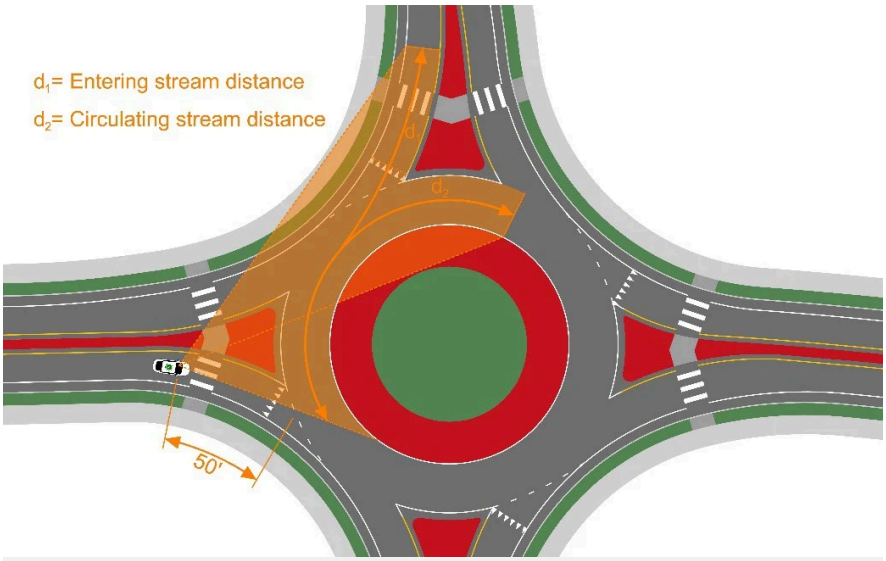


Exhibit 403.7-7: Intersection Sight Distance Checks

404 - Restricted Crossing U-Turns (RCUTS)

404.1 - General

A Restricted Crossing U-turn (RCUT) also referred to as a J-turn intersection, a superstreet intersection or a synchronized street intersection is a reduced conflict intersection that displaces left turn and through movements from the minor intersecting roadway. The minor roadway left turns and through movements are accommodated by providing one-way median openings located on each side of the main intersection and requiring a driver from the minor road to turn right onto the main road (multi-lane divided facility) and make a U-turn maneuver downstream at a one-way median opening. When the left- turn volumes are low the left turn movements from the main road can also be prohibited at the main intersection and accommodated at the one-way median opening. There are three main types of RCUT intersections:

- **Merge or Yield-Controlled:** Merge or Yield-Controlled RCUT intersections allow for a high-speed divided four-lane facility in a rural area to function like a freeway corridor. These are a good alternative when funding for interchanges and overpasses may not be readily available. Longer distances between the intersection and the U-turn crossovers will be needed for the weaving movement.
- **Stop-Controlled:** Stop-Controlled RCUT intersections are a good safety treatment for an isolated intersection on a four-lane divided arterial in a rural area. The stop-controlled RCUT intersection can be upgraded to a signal-controlled intersection as traffic volumes increase.
- **Signal-Controlled:** Signal-Controlled RCUT intersections provide good progression along an urban or suburban corridor. Efficiency is provided due the signals requiring only two phases. Speed and signal spacing do not adversely impact the performance of the RCUT intersection. A signalized RCUT intersection can accommodate pedestrians and adjacent driveways. Capacity limits for the minor street may limit the effectiveness of the RCUT intersection so this option may not be appropriate at the intersection of two high volume arterials. RCUTS may be operated with bidirectional signal progression. Each direction of travel along the major street corridor may be timed to operate independently, allowing for different cycle lengths. In order to implement the bidirectional progression, the signals would need to operate under 2 or 4 separate controllers. See FHWA's Restricted Crossing U-Turn Intersection Informational Guide (Exhibit 8-1 and 8-3) for additional details.

Hybrids of these three types are possible.

The RCUT is a very adaptable intersection which can be used in both a rural and urban setting. The RCUT intersection can be a corridor treatment for arterials and some freeway look-alikes, but they are typically not suitable at the intersection of two arterials.

404.2 - RCUT Advantages and Disadvantages

RCUT intersections have unique features and characteristics regarding multimodal considerations, safety performance, operations geometric design, spatial requirements, constructability and maintenance. This section will provide the advantages and disadvantages of RCUT intersections.

Pedestrians/Bicycles

Advantages:

- Reduces conflicts between vehicles and pedestrians for most crossing movements.
- Creates shorter pedestrian crossing distance for some movements.
- Creates opportunities to install mid-block signalized crossings along an arterial.

Disadvantages:

- Increases conflicts between vehicles and pedestrians for some crossing movements.
- Creates longer pedestrian crossing distances for some movements which could add delay and reduce convenience.
- Requires pedestrians to cross in two stages in some cases which could add delay and reduce convenience.
- Pedestrian wayfinding may require additional signage and/or other features to create appropriate crossings for pedestrians of all abilities.
- Provisions for bicycle facilities may be different from conventional intersections and may result in reduced convenience.

Safety

Advantages:

- Reduces the number of vehicle-vehicle conflict points at the intersection which should reduce the potential for crashes.
- At rural four-lane sites, reduces crashes, injuries and fatalities.
- Potentially reduces high severity turning and angle crashes.
- Less severe crash types compared to a conventional intersection.
- Reduces vehicle-pedestrian conflict points.

Disadvantages:

- Increases sideswipe crashes.
- Introduces weaving movements on the high-speed mainline roadway.
- Increases travel distances which could lead to more crashes related to distance traveled.

Operations

Advantages:

- Creates the possibility for the largest possible progression bands in both directions of the arterial at any speed with any signal spacing.
- Provides potential to reduce overall travel time at signalized sites.
- Provides potential to reduce delay and travel time for arterial through traffic at signalized sites.
- Provides potential for shorter signal cycle lengths.
- Allows larger portion of signal cycle to be allocated to the arterial through movement.
- Reduces delay for the major street movements by using a two phase rather than a four phase traffic signal control.
- Reduces the need for signalization of intersections along rural, high-speed, divided highways.
- Improves minor street travel times if traffic gap times are insufficient at conventional intersections.

Disadvantages:

- Increases travel distance (and potentially travel time) for minor street left turn and through movements.
- Experiences a firm capacity.
- Creates potential for spillback out of the crossover storage lane.

- Minor-street left turn and through traffic must make unusual maneuvers and may require additional guidance.

Access Management

Advantages:

- Allows multiple driveway or side street locations along the RCUT corridor.
- Signals for driveways or side streets may be installed without introducing significant delay for arterial through movement.
- Allows flexibility for crossover locations to accommodate adjacent driveways and side streets.
- Does not require frontage roads.

Disadvantages:

- Does not allow for a driveway or a side street near entrance to U-turn crossover.
- Landowners will not have driveways with direct left turns out of their properties.

Traffic Calming

Advantages:

- Two-way progression provides the opportunity to set any progression speed (even low speed).
- Provides an additional barrier to fast moving minor-street through traffic.

Disadvantage:

- The additional barrier to direct minor-street through traffic may cause separation to a community.

Footprint

Advantages:

- The greater arterial throughput creates the possibility to reduce the basic number of through lanes on the arterial and still achieve similar service levels.

Disadvantages:

- May require additional right-of-way for loons or wider medians.

Maintenance

Advantages:

- Less queuing on the arterial may reduce pavement rutting and wear.

Disadvantages:

- When signalized, there are more signal controllers and cabinets than a comparable conventional intersection.
- There are more signs than a comparable conventional intersection.
- If designed with a larger median, there is more pavement to maintain than a comparable conventional intersection.
- More pavement to maintain in U-turn crossovers and loons.

Aesthetics

Advantages:

- Median and islands provide opportunity for landscaping.

Costs

Advantages:

- A more cost-effective design as compared to a grade separated facility.

Construction

Advantages:

- Fewer construction impacts.
- Project can be implemented quickly reducing inconvenience to the motorist.

Education

Disadvantages:

- Lack of driver familiarity may require investments in public education and outreach.

404.3 - Applications

RCUT intersections can be a great alternative to a conventional intersection under certain conditions. RCUT intersections are most effective at intersections with at least one of the following attributes:

- Intersections where side-street left turn and through volumes are relatively low and the left turn volumes from the major road are high; the ratio of minor road total volume to total intersection volume should be less than or equal to 0.20.
- Areas where median widths are greater than 40 feet; for narrower medians, loons or bulb-outs on the shoulders need to be constructed to allow all vehicles to perform the U-turn movement. Due to the extra-large loons possibly creating driver confusion while negotiating the 180-degree U-turn movement, RCUTs with unsignalized U-turns are not recommended on undivided roadways.
- Intersections with a high number of far-side right-angle crashes.

A table has been provided below for guidance on the feasible demand conditions for an RCUT intersection.

Minor Street Demand (D_{Minor})	Type of RCUT Intersections
D_{Minor} < 5,000 vpd	Consider unsignalized RCUT intersection
5,000 vpd < D_{Minor} < 25,000 vpd	Consider signalized RCUT intersection
D_{Minor} > 25,000 vpd	There are most likely other alternative intersections such as a MUT or DLT intersection that would generally serve the minor street more efficiently.

404.3.1 - Signalized RCUT

On a major road where the progression of the through route needs to be maintained with more green time than a conventional signalized intersection can provide the table below summarizes rules-of-thumb for various percentage of green time allocated to the major/minor road. Note an RCUT intersection may be an appropriate solution based on the analyses of traffic operations and geometric requirements.

Green %

Major Street	Minor Street	Notes
< 60%	≥ 40%	Other intersection designs will likely serve the relatively heavy minor street demand more efficiently.
< 67%	≥ 33%	Minor street demands may be relatively too heavy for an RCUT.
67%	33%	Signalized RCUT is probably appropriate.
75%	25%	Signalized RCUT is probably appropriate.
> 75%	≤ 25%	Minor street demands may be too light for signals to be warranted.

404.4 - Geometric Design

RCUT intersection geometrics create some design principles not present at conventional intersections. These principles include:

- A wide median can make accommodating U-turn movements easier or more straightforward. Bump-outs or loons can be used at narrower medians.
- Positive guidance through design elements and traffic control reduce driver error and promote efficient movements that might otherwise be unexpected.

- U-turn crossovers are large enough to accommodate the design vehicle and allow for more efficient movements through the U-turn by passenger vehicles.
- Corridor-wide access management strategies promote safe and efficient access to properties.
- Stopping sight distance at all points through the intersection and intersection sight distance for all movements is provide at each RCUT intersection junction.

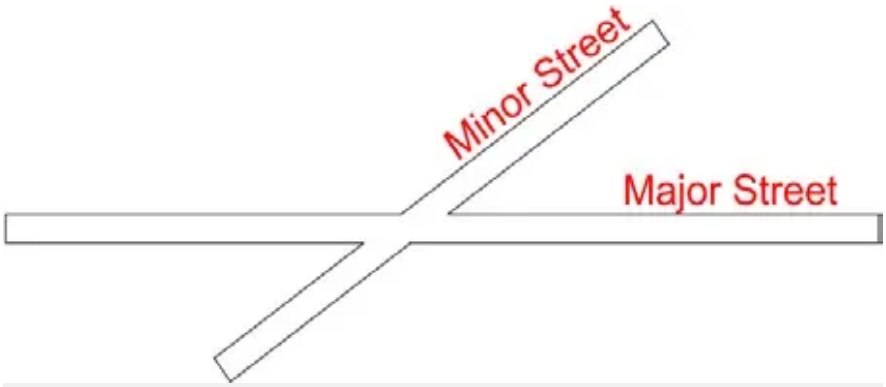
Designing the geometric layout of an RCUT intersection requires considering the relationship between safety, operations and design.

For signal-controlled RCUTs, the main intersection operates as a two-phase signal which may require a shorter cycle length than a conventional signal-controlled intersection. The shorter cycle length may result in shorter traffic queues, and shorter travel distances from the main intersection to the U-turn crossovers.

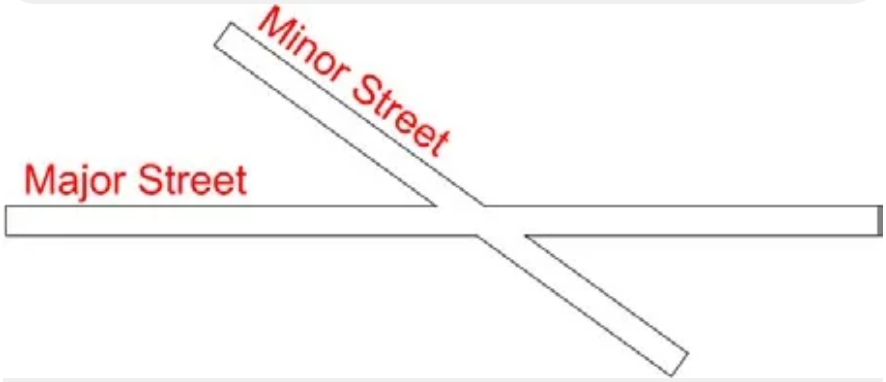
RCUT intersections are very versatile and offer a wide range of possibilities. A list of design possibilities is provided below:

- Major streets can range from four lanes to eight lanes.
- Minor streets can be up to four through lanes wide.
- U-turn crossovers can be one or two lanes wide.
- Left-turn crossovers can range from one to three lanes wide.
- The distance from the main intersection to the U-turn crossover can vary from 600 feet for a stop or signal controlled RCUT intersection to one-half mile for a merge-controlled RCUT intersection.

The orientation of an RCUT intersection angle may influence the ability to convert a conventional intersection into an RCUT intersection. An RCUT intersection at an acute angle (< 90 degrees) between the major street and the minor street can serve the left turns on the major street more efficiently than one at an obtuse angle (> 90 degrees). See the illustration below.



Better Candidate for RCUT Conversion



Less Ideal for RCUT Conversion

404.4.1 - Main Intersections

404.4.1.1 - Left Turns

At a four-legged RCUT, the left-turns are served only on the major street. Base the number of left-turn lanes on operational analyses using the appropriate analysis software per the ODOT Analysis and Traffic Simulation (OATS) manual. Calculate the length of the left-turn lanes per Figures 401-9 and 401-10. Typically, any channelization for the left turn radii should be designed using a 10 to 15 mph design speed.

Main road left-turn movements can be prohibited when volumes are low and they can be accommodated at the downstream one-way median opening. This treatment is referred to as a Thru-Turn and does not preclude constructing a main road left turn in the future.

404.4.1.2 - Minor Street Right Turn Lanes

Since the minor street left turn and through movements are being converted into right turning movements, the design of the right turn lanes must be sufficient to accommodate all traffic from the minor street. Based on the right turning movement volumes perform an operational analysis to determine the number and length of the right turn lanes required.

The minor street approaches need to be designed to prevent wrong-way maneuvers. If the minor street is not a boulevard or a multi-lane divided facility, right-turn channels should be used to minimize wrong way maneuvers. The distance to the U-turn may need to be increased if the right turn is channelized. If multiple right turn lanes are provided, channelization of the lanes may help direct vehicles into the appropriate receiving lanes reducing initial driver confusion and downstream lane changes. A down-side to channelizing the right turn lanes may be the creation of imbalanced lane utilization.

Three options exist for handling the channelizing of the minor street traffic:

- No channelizing island
- A channelizing island (median) separating the traffic turning right from the minor street onto the major street and the traffic turning right from the major street onto the minor street.
- A channelizing island separating minor street right turns that will remain on the major street from the minor street right turns that subsequently makes a U-turn movement on the major street.

The advantages and disadvantages of right turn channelization on the minor street of an RCUT intersection are as follows:

Advantages:

- Drivers are more firmly guided, likely reducing sideswipe conflicts during the turn.
- Shortens pedestrian crossing distances to a pedestrian refuge.
- Reduces paved surface areas.
- Provides the opportunity for a lane addition and a free right turn (merge), reducing delay.

Disadvantages:

- Requires pedestrians to cross more vehicle pathways, with the right turns moving faster and/or more freely.

- Creates the potential for uneven lane utilization on the minor street.
- Drivers on the minor street must select a lane (preposition) earlier.
- Increases right-of-way to accommodate the channelization.

404.4.1.3 - Right Turn (Minor Street to Major Street) without Acceleration Lanes

RCUT intersections with stop signs or signals controlling the minor streets can eliminate weaving movements and thus the need for acceleration lanes by extending the U-turn lane back to the main intersection. By providing pavement markings guiding drivers directly into the U-turn lane drivers can wait for an acceptable gap or a green signal. Extending the U-turn lanes to the main intersection is the preferred design and can shorten the distance between the minor street right turn and the median U- turn crossover.

404.4.1.4 - Right Turn (Minor Street to Major Street) with Acceleration Lanes

RCUT intersections with acceleration lanes join the major road as an add-lane, then merge upstream of the U-turn crossover creating weaving movements. Field observations of RCUTs with acceleration lanes determined vehicles destined for the downstream U-turn tend to use the acceleration lane as little as possible. Vehicles tend to make the lane shifts as soon as an appropriate gap is available. Based on these tendencies the use of acceleration lanes upstream of the U-turn crossover should be discouraged especially at signalized RCUT intersections. If acceleration lanes are constructed the downstream U-turn is typically placed further away from the main intersection as compared to when acceleration lanes are not constructed.

404.4.2 - Median U-turn Crossover

404.4.2.1 - Crossover Spacing

The distance between the main intersection and the U-turn crossover must be designed for both directions of travel on the major street. The distance from the main intersection to the U-turn intersections should be kept as short as operational (queuing/deceleration) and geometrical (location of nearby intersections, drives, bridges, right-of-way constraints and uphill grades etc.) conditions will allow. The U-turn lane can be extended back to the main intersection so the minor road left/thru vehicles destined for the U-turn can enter the U-turn lane as early as possible.

The typical spacing between the main intersection and the U-turn crossings ranges from 400 ft. to 1,000 ft. This distance may vary based on location constraints. The minimum spacing between the main intersection and the U-turn crossing is based on the U-turn lane length, which is determined by Figures 401-9 and 401-10 or the HCS/TransModeler 95th percentile queues, whichever is greater.

404.4.2.2 - Crossover Design

Proper design of U-turns is essential to ensure safe traffic operations. A properly designed U-turn crossover should provide adequate pavement to accommodate a WB-62 without creating conflicts with other vehicles. For crossovers with inadequate median width for the WB-62 to maneuver loons or bulb- outs should be installed to provide adequate turning radii for the tracking of both the front and rear ends of a WB-62. Due to the extra-large loons possibly creating driver confusion while negotiating the 180-degree U-turn movement, RCUTs with unsignalized U-turns are not recommended on undivided roadways.

Four possible U-turn lane destinations exist to account for the truck tracking through the U-turn crossover.

- Inside Lane to Inside Lane
- Inside Lane to Outside Lane
- Inside Lane to Outside Shoulder
- Inside Lane to Loon

Typically, the U-turn crossovers should be designed using a design speed of 15 mph, but 10 mph may be acceptable for narrower median widths.

404.4.2.3 - U-turn Lane Design

U-turn deceleration/queue lengths should be designed to accommodate the 95th percentile queue of U-turning vehicles. See Figures 401-9 and 401-10 for determining the length of the U-turn deceleration/queue length at the approach to the crossover.

Larger vehicles have a larger swept path and may require an additional paved area. For dual U-turn, the U-turn crossover should accommodate one WB-62 and one single unit

truck vehicle. Signage should be provided for the WB-62 to use the rightmost. or outermost U-turn lane. The crossover must be designed so the path of the WB-62 in the rightmost lane and the path of the single unit truck in the leftmost lane provides at least a minimum of 2 ft. between the tire paths of the respective vehicles.

404.5 - Multimodal Considerations

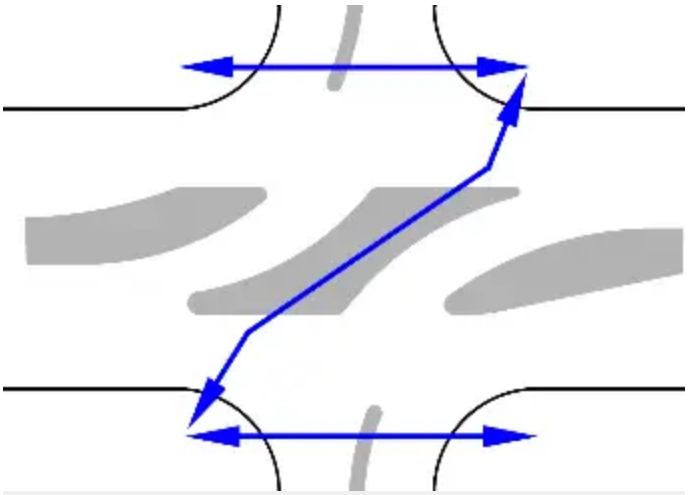
RCUT intersection design should consider all the different transportation modes that will be using the intersection.

Due to their unique geometrics and traffic control features, RCUT intersections can provide both benefits and challenges to non-automobile modes of transportation and these factors need to be considered early in the project development process rather than incorporating them in the later stages of design.

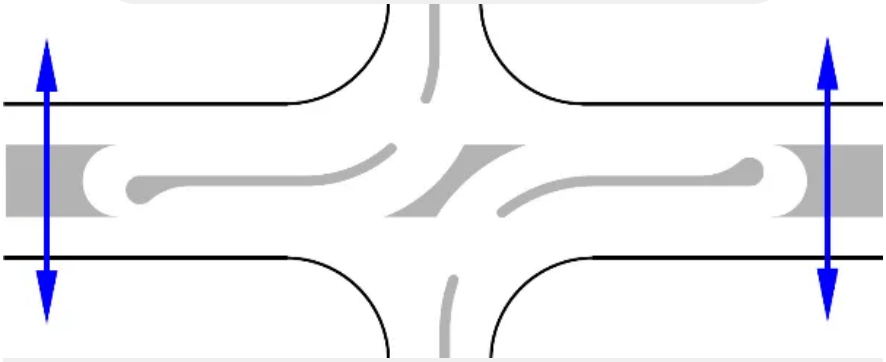
404.5.1 - Pedestrians

Factors such as non-signalized movements, a greater percentage of vehicles making right turning movements and the RCUT intersections wide geometric footprint create challenges to accommodating pedestrians. Pedestrian crossing lengths may be longer than those at conventional intersections, but the shorter traffic signal cycle lengths can help make crossing times comparable to those at conventional intersections.

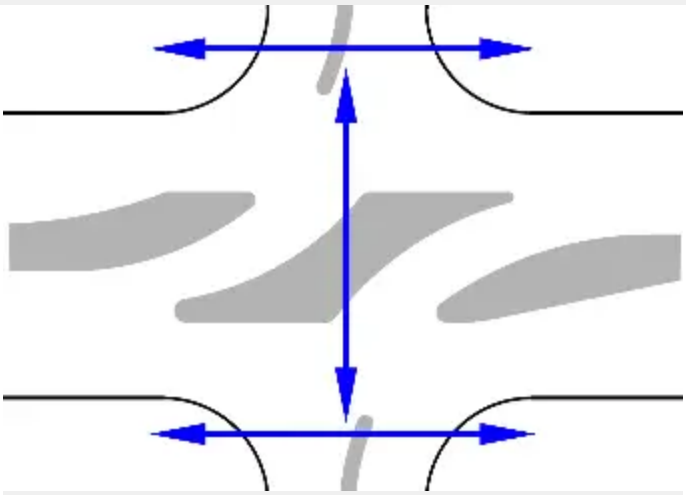
RCUT intersections reduce the number of vehicle-pedestrian conflict points compared to conventional intersections, but they also require pedestrian crossings that differ from conventional intersections. The most common means of serving pedestrians is a “Z” crossing treatment. Other options include a Signalized Mid-Block Crossing and a Median Crossing. Examples of each pedestrian crossing treatment are shown below.



Z Crossing Treatment



Signalized Mid-Block Treatment



Median Crossing Treatment

404.5.2 - Bicycles

Bicycles on the major street navigate an RCUT intersection the same way they navigate a conventional intersection. Minor street left-turning or through bicycles do not have a direct route at an RCUT intersection if they are utilizing the vehicular lanes. There are three primary ways to facilitate minor street left-turn and through bicyclists in an RCUT intersection:

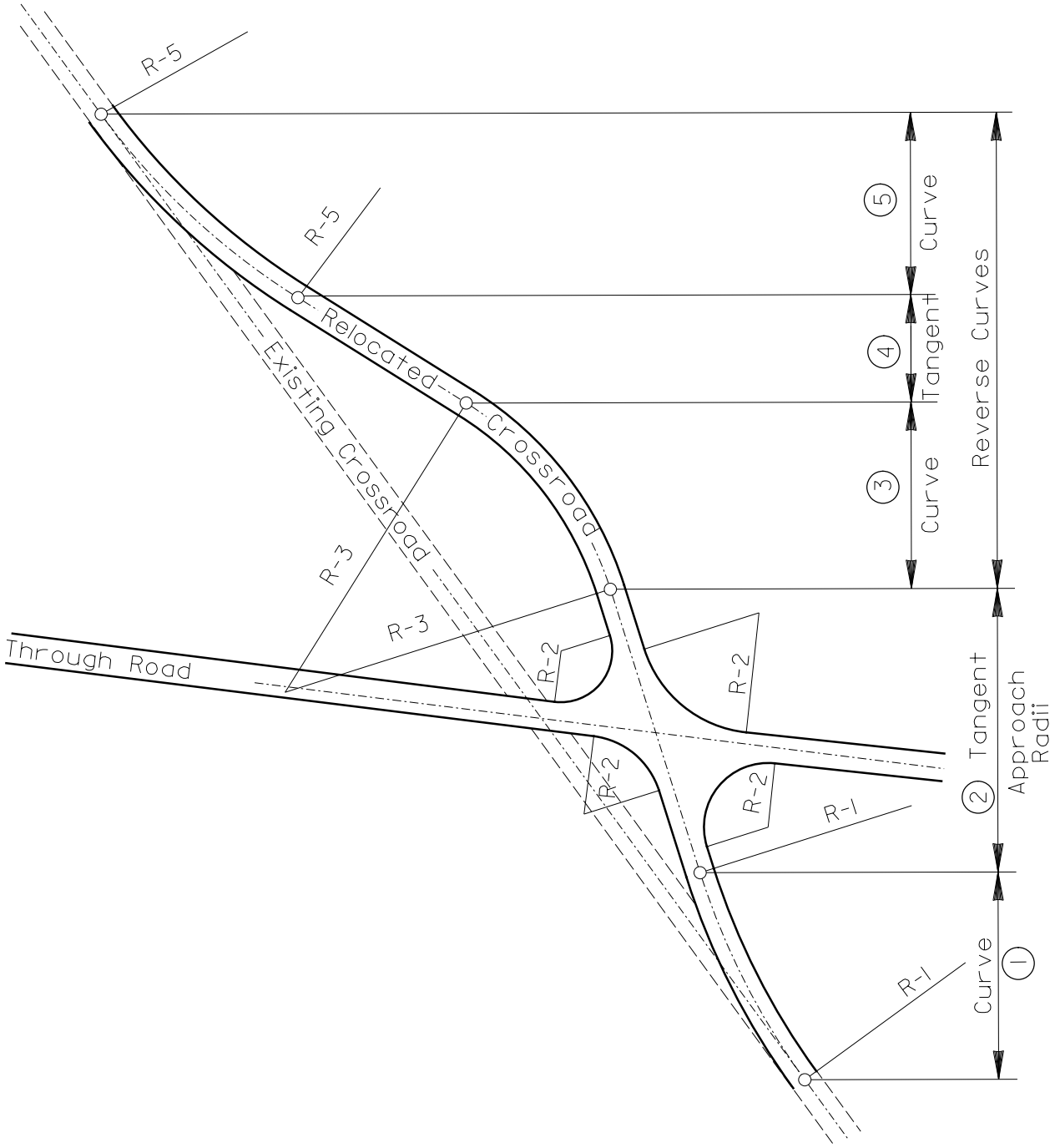
- Use a path matching the pedestrians
- Use a path matching the motor vehicle traffic
- Direct bicycle crossings

The choice of which option will depend on the quality of interaction with motorists, the speed of the major street vehicle traffic, shoulder width or the presence of a bicycle lane, the volume of the major street traffic, the distance to the U-turn crossover and the level of bicyclist experience.

TYPICAL CROSSROAD RELOCATION

401-1

REFERENCE SECTION 401.3



See explanation on adjacent sheet.

October 2004

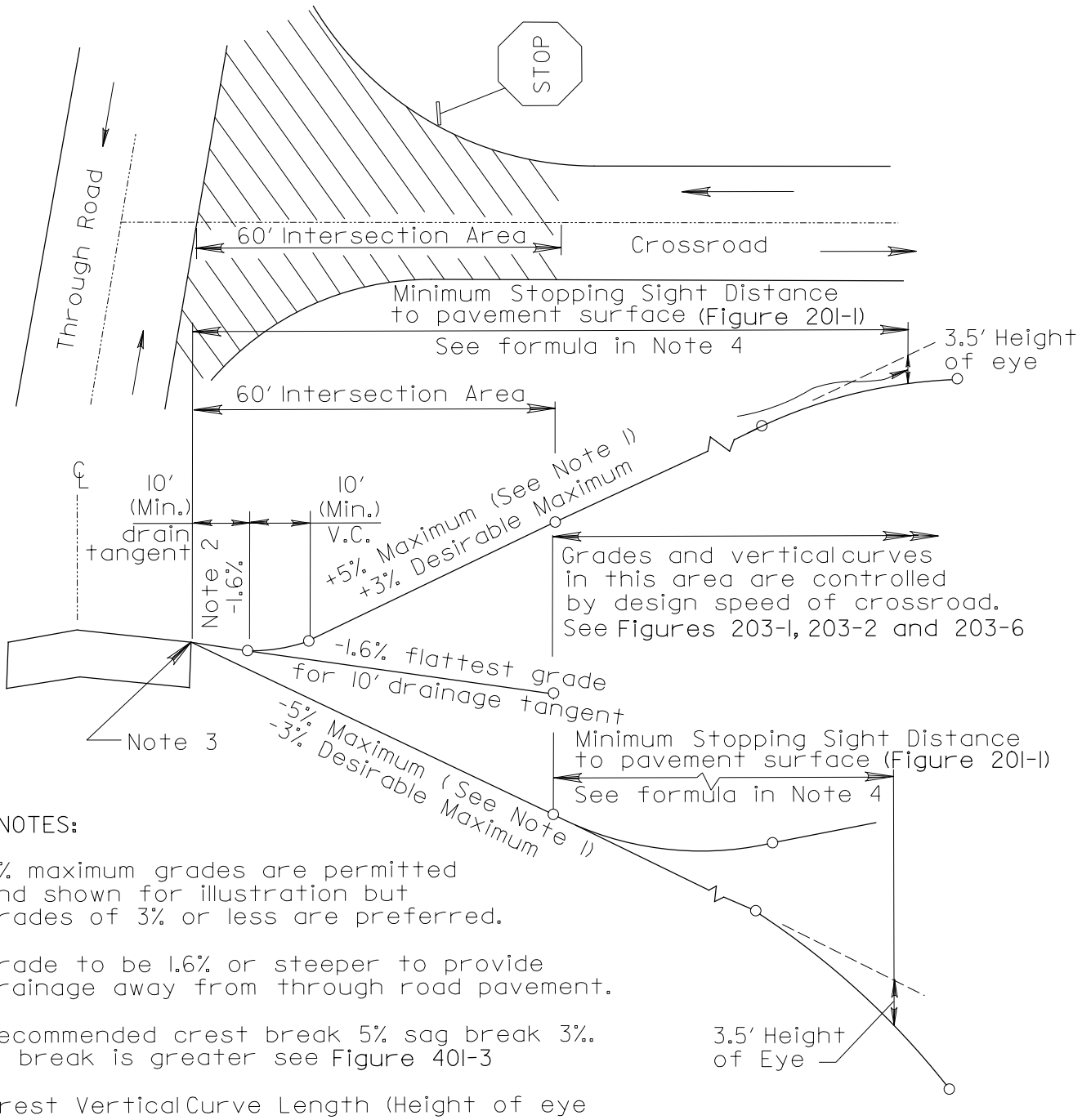
Explanation of Figure 401-1: Typical Crossroad Relocation

1. Curve – This portion of the crossroad can occur by itself at “T” type or three-legged intersections. If possible, the radius of this curve should be commensurate with the design speed of the crossroad. Often, the length of the required profile controls the work length. The horizontal curvature is then chosen so it can be accomplished within this work length. Regardless of the length of the profile adjustment, it is desirable to provide at least a 230 ft. radius for this curve. When a 230 ft. radius incurs high costs, it is permissible to reduce this radius to a minimum of 150 ft.
2. Tangent and Approach Radii – The crossroad in this area should have a tangent alignment. For the condition shown, the alignment between the radius returns is tangent from one side of the road to the other. However, at some intersections with a minor through movement (for example, crossroad intersections of standard diamond ramps) it may be desirable to provide different intersection angles on each side of the through road. For approach radii, see discussion in Section 401.5.
3. Curve – The statements in (1) above also apply to this curve. With the reverse curve condition shown, the radius will often not exceed 250 ft. because flatter curves make the relocation extraordinarily long.
4. Tangent – This tangent should be approximately 150 ft. in length for 30 or 40 mph design speeds on the existing road, and approximately 250 ft. for 50 or 60 mph design speeds. These lengths are generous enough to allow reasonable superelevation transitions between the reverse curves. In general, it is usually not desirable to make this tangent any longer than required. If a longer tangent can be used, the curvature or intersection angle can be improved and these two design items are more important.
5. Curve – This curve should be much flatter than the other two curves. It should be capable of being driven at the normal design speed of the existing crossroad.

CROSSROAD PROFILE -STOP CONDITION- THROUGH ROAD NORMAL CROWN

401-2

REFERENCE SECTIONS
401.4.1 - 401.4.4



NOTES:

1. 5% maximum grades are permitted and shown for illustration but grades of 3% or less are preferred.

2. Grade to be 1.6% or steeper to provide drainage away from through road pavement.

3. Recommended crest break 5% sag break 3%. If break is greater see Figure 401-3

4. Crest Vertical Curve Length (Height of eye 3.5'- height of object 0')

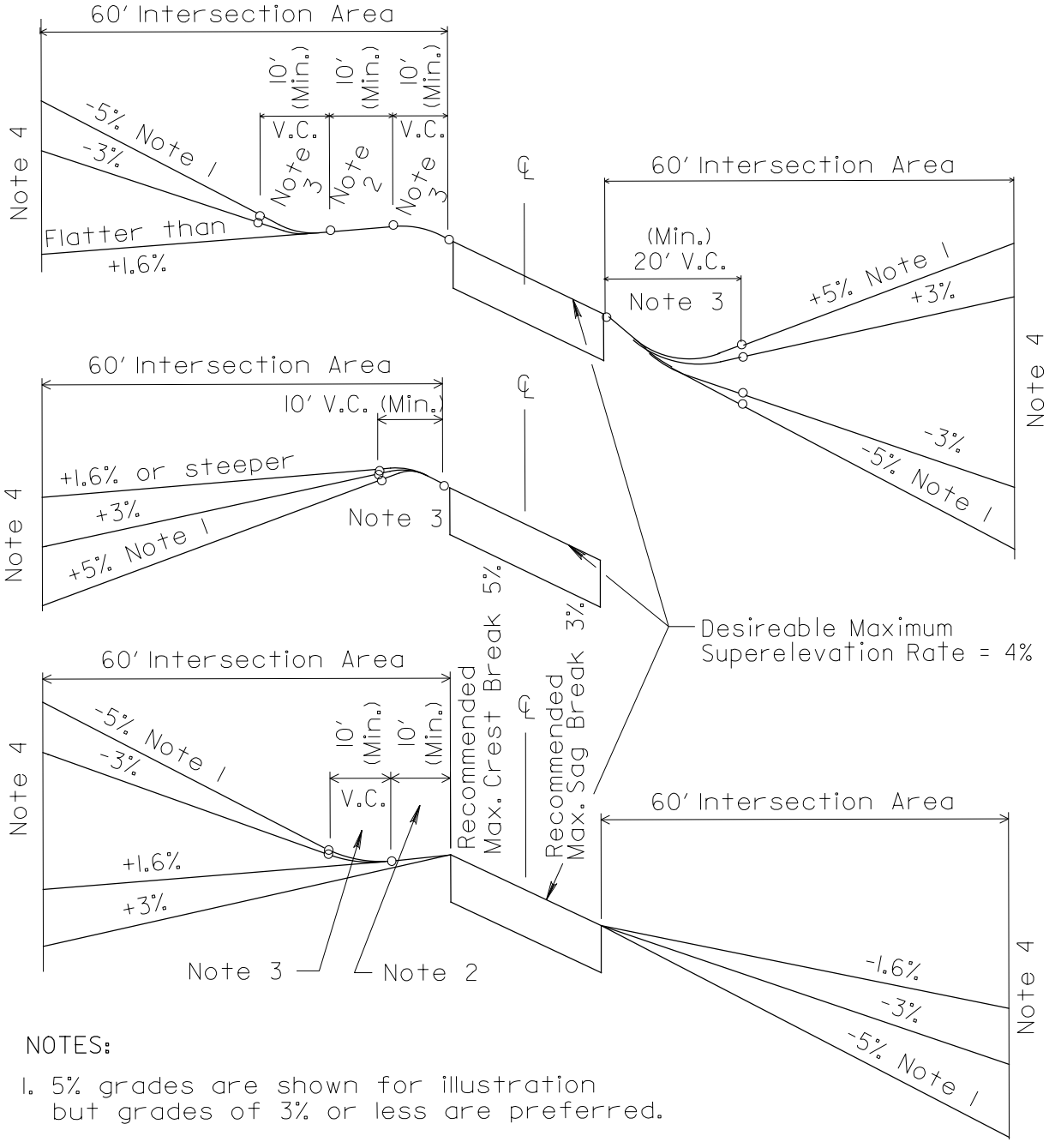
$S<L \quad L = \frac{AS^2}{700}$

$S>L \quad L = 2S - \frac{700}{A}$

CROSSROAD PROFILE -STOP CONDITION- THROUGH ROAD SUPERELEVATED

401-3

REFERENCE SECTION
401.1 & 401.4.3



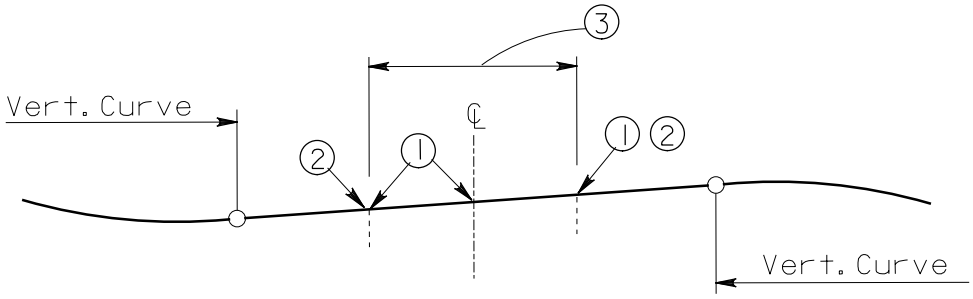
NOTES:

1. 5% grades are shown for illustration but grades of 3% or less are preferred.
2. Grade to be 1.6% or steeper to provide drainage.
3. Crest breaks exceeding 5% shall be rounded using vertical curves having a K of 1 or greater. Sag breaks exceeding 3% shall be rounded using vertical curves having a K of 1.5 or greater.
4. For grade treatment of this area, see Figure 401-2.

CROSSROAD PROFILE SIGNALIZED INTERSECTION

401-4

REFERENCE SECTION 401.4.4

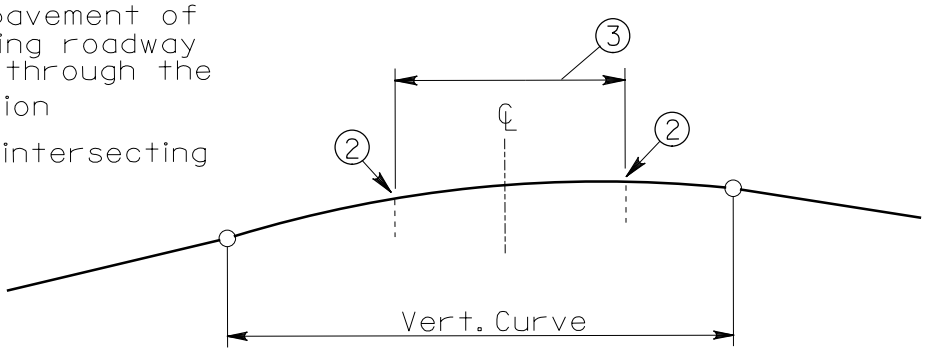


Example A - Crossroad Profile Tangent through Intersection

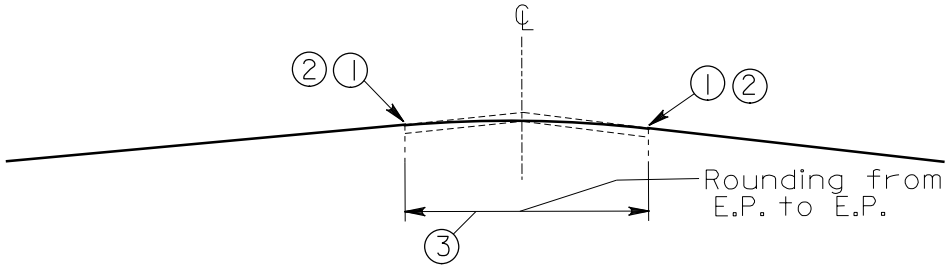
(1) Location of permissable grade break per Figure 203-2

(2) Edge of pavement of intersecting roadway extended through the intersection

(3) Width of intersecting roadway



Example B - Crossroad Profile on Vertical Curve through Intersection



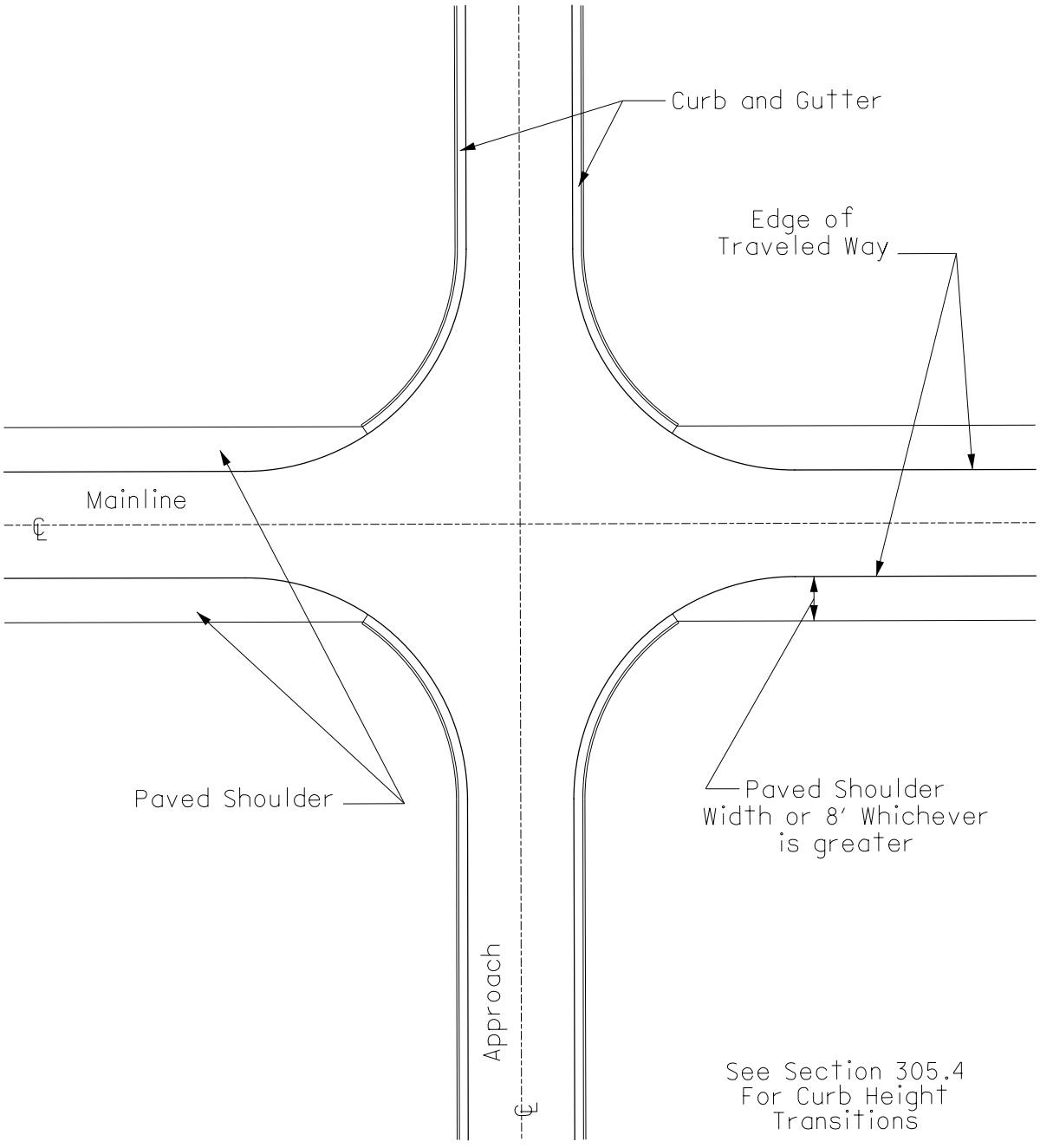
Example C - Crossroad Profile Fitted to a Normal Crown on the Mainline Road

RADIUS RETURNS FOR UNCURBED MAINLINE CURBED APPROACH

401-4a

REFERENCE SECTION
401.5.3 & 305.4

UNCURBED MAINLINE CURBED APPROACH

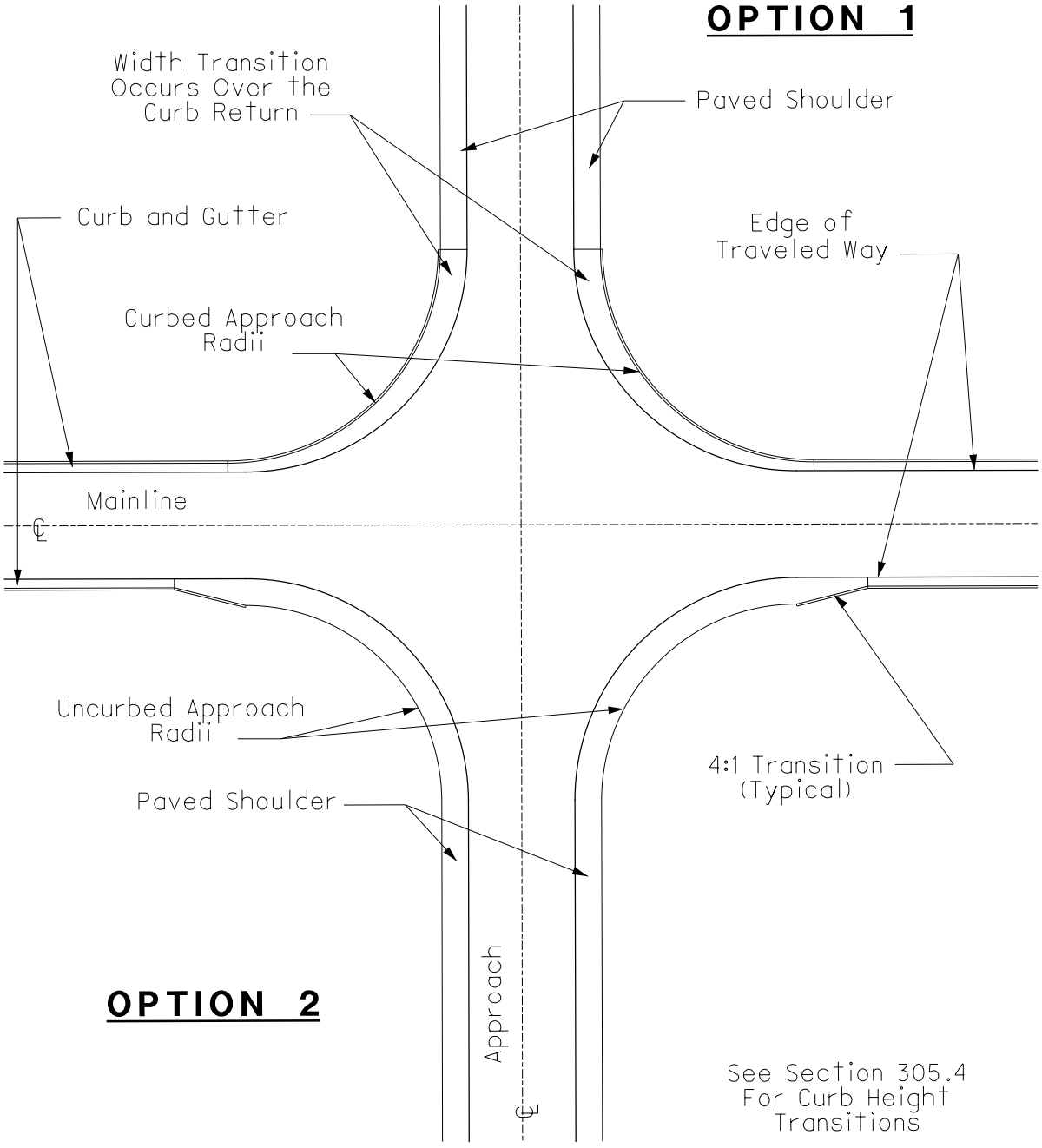


RADIUS RETURNS FOR CURBED MAINLINE UNCURBED APPROACH

401-4b

REFERENCE SECTION
401.5.3 & 305.4

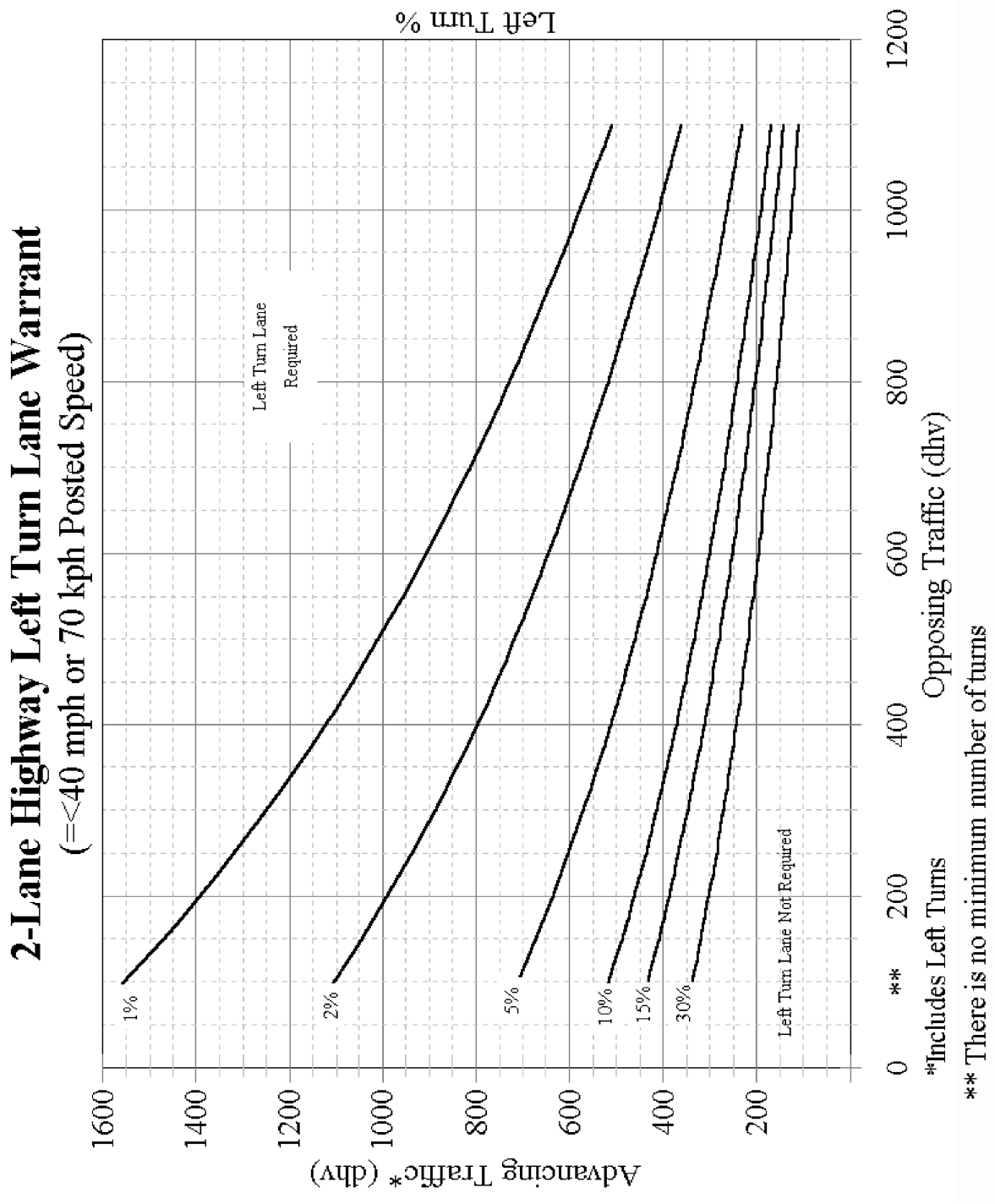
CURBED MAINLINE
UNCURBED APPROACH



2-LANE LEFT TURN LANE WARRANT (LOW SPEED)

401-5a

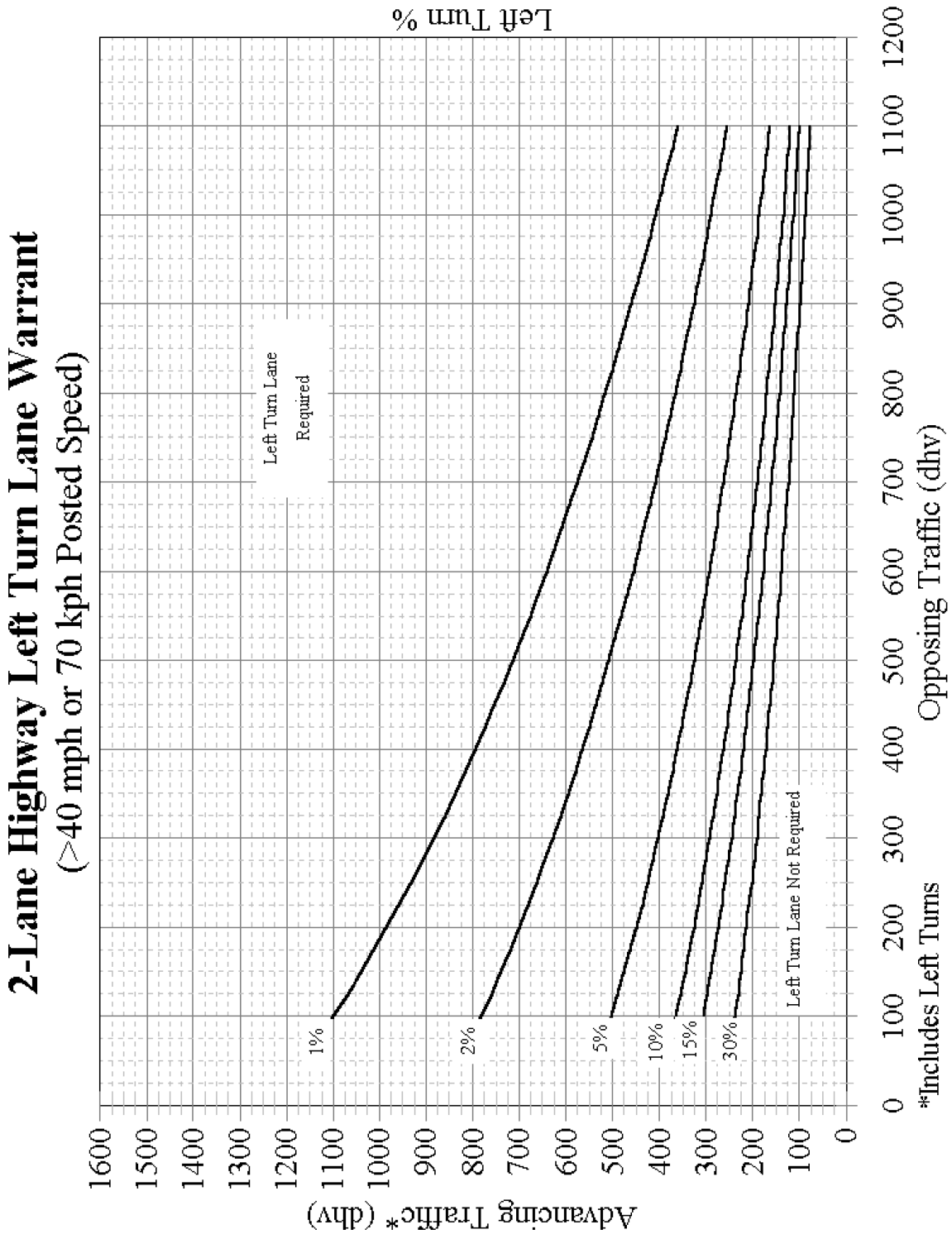
REFERENCE SECTION
401.6.1



2-LANE LEFT TURN LANE WARRANT (HIGH SPEED)

401-5b

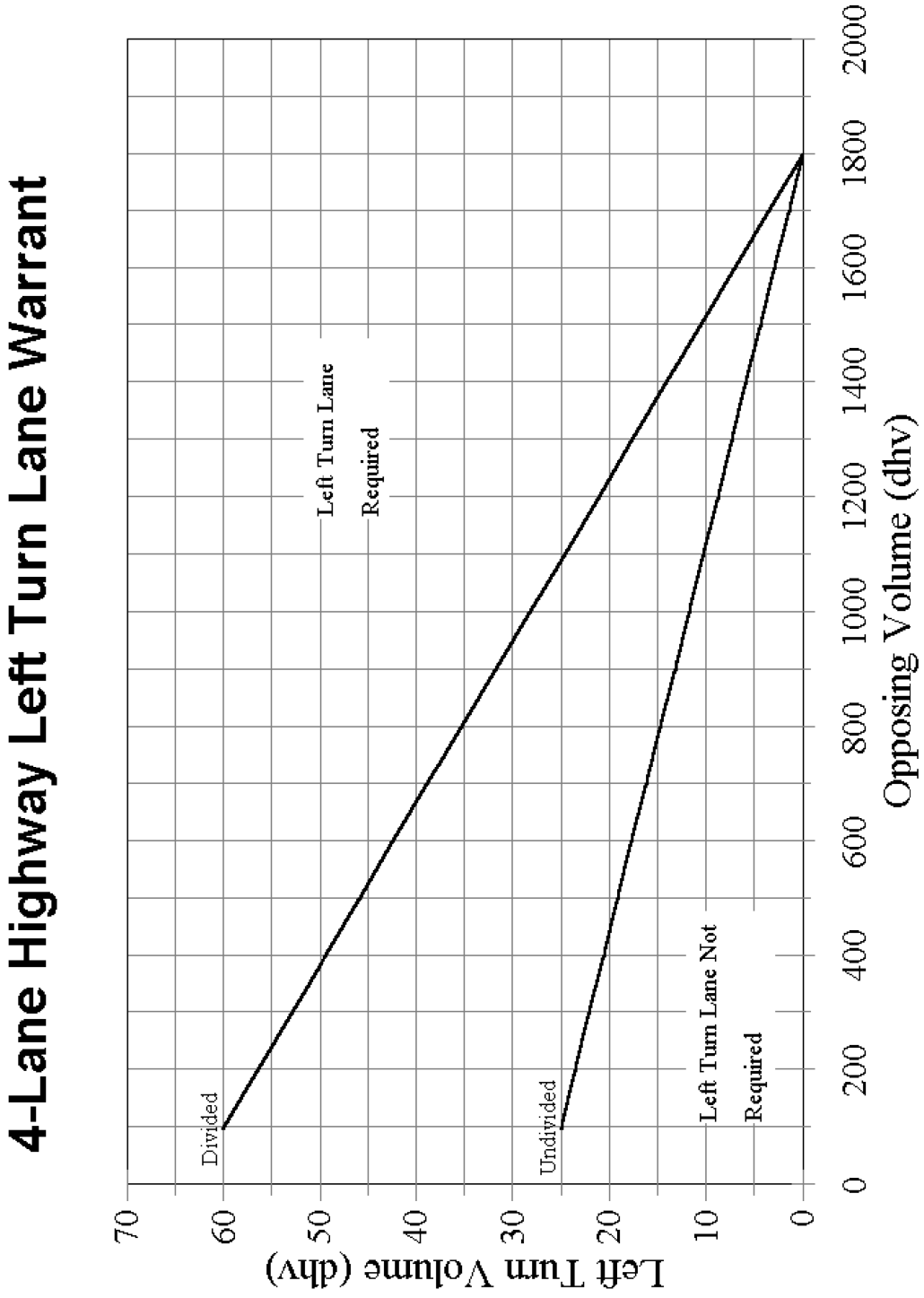
REFERENCE SECTION
401.6.1



4-LANE LEFT TURN LANE WARRANT

401-5c

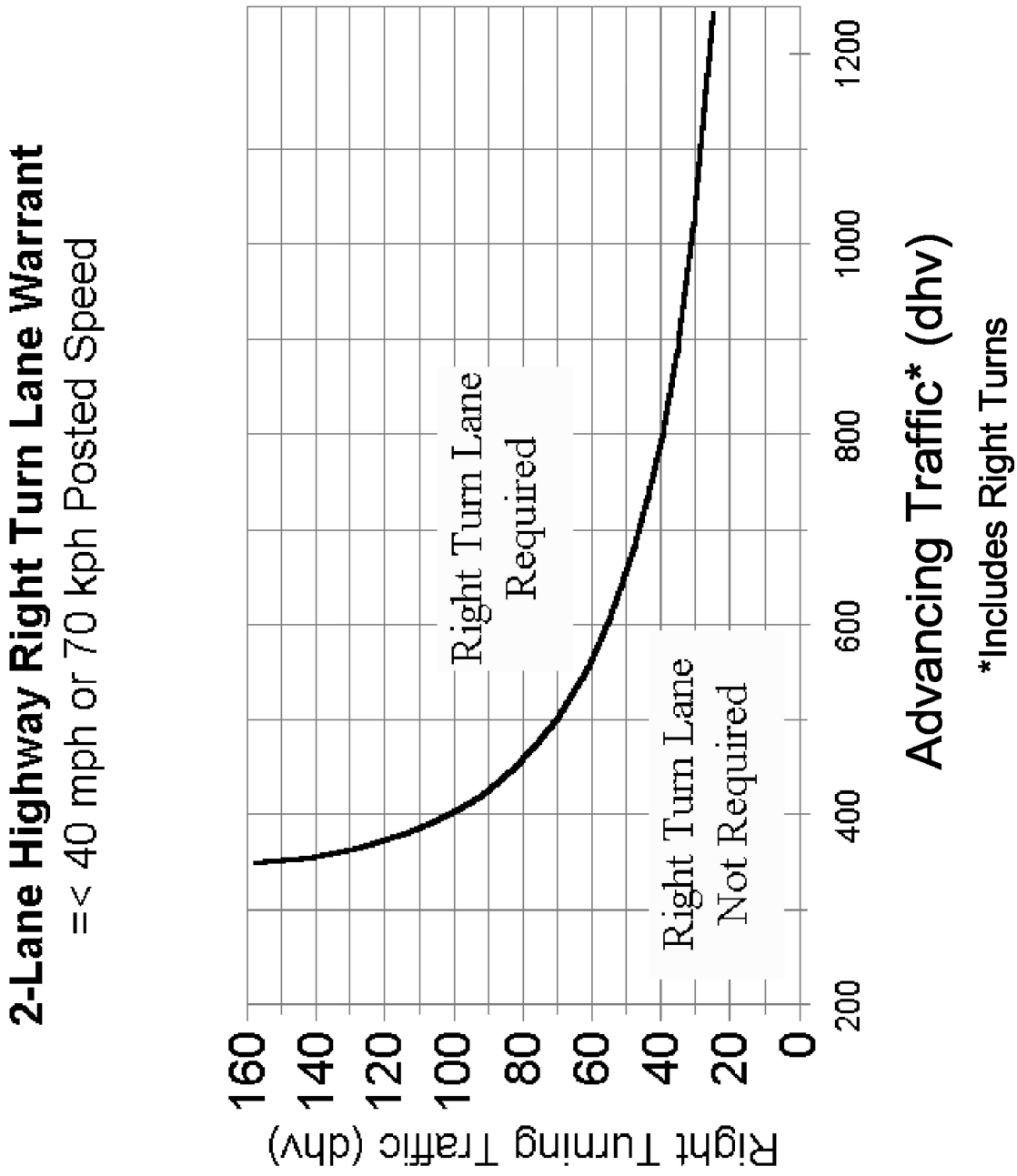
REFERENCE SECTION
401.6.1



2-LANE RIGHT TURN LANE WARRANT (LOW SPEED)

401-6a

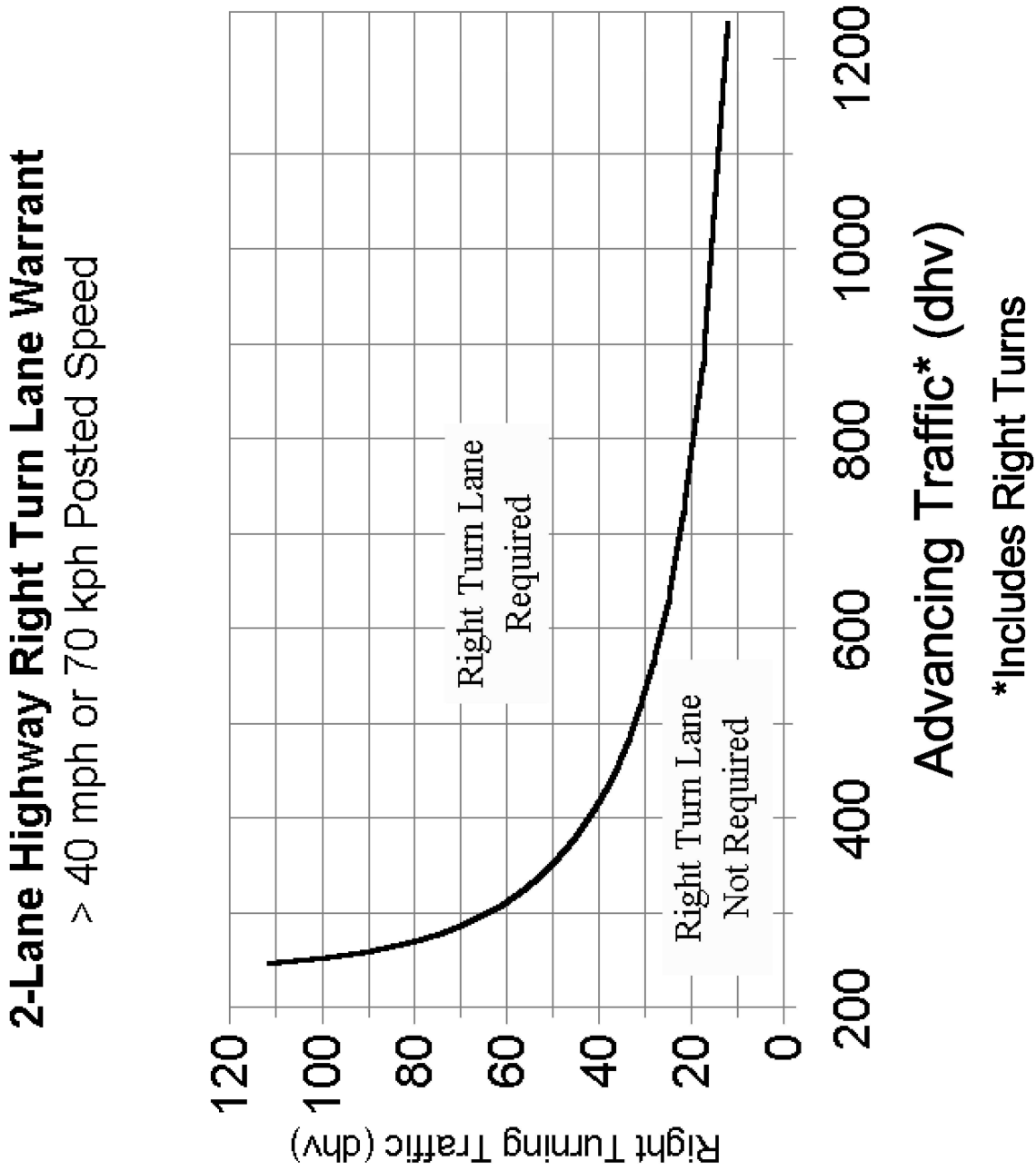
REFERENCE SECTION
401.6.3



2-LANE RIGHT TURN LANE WARRANT (HIGH SPEED)

401-6b

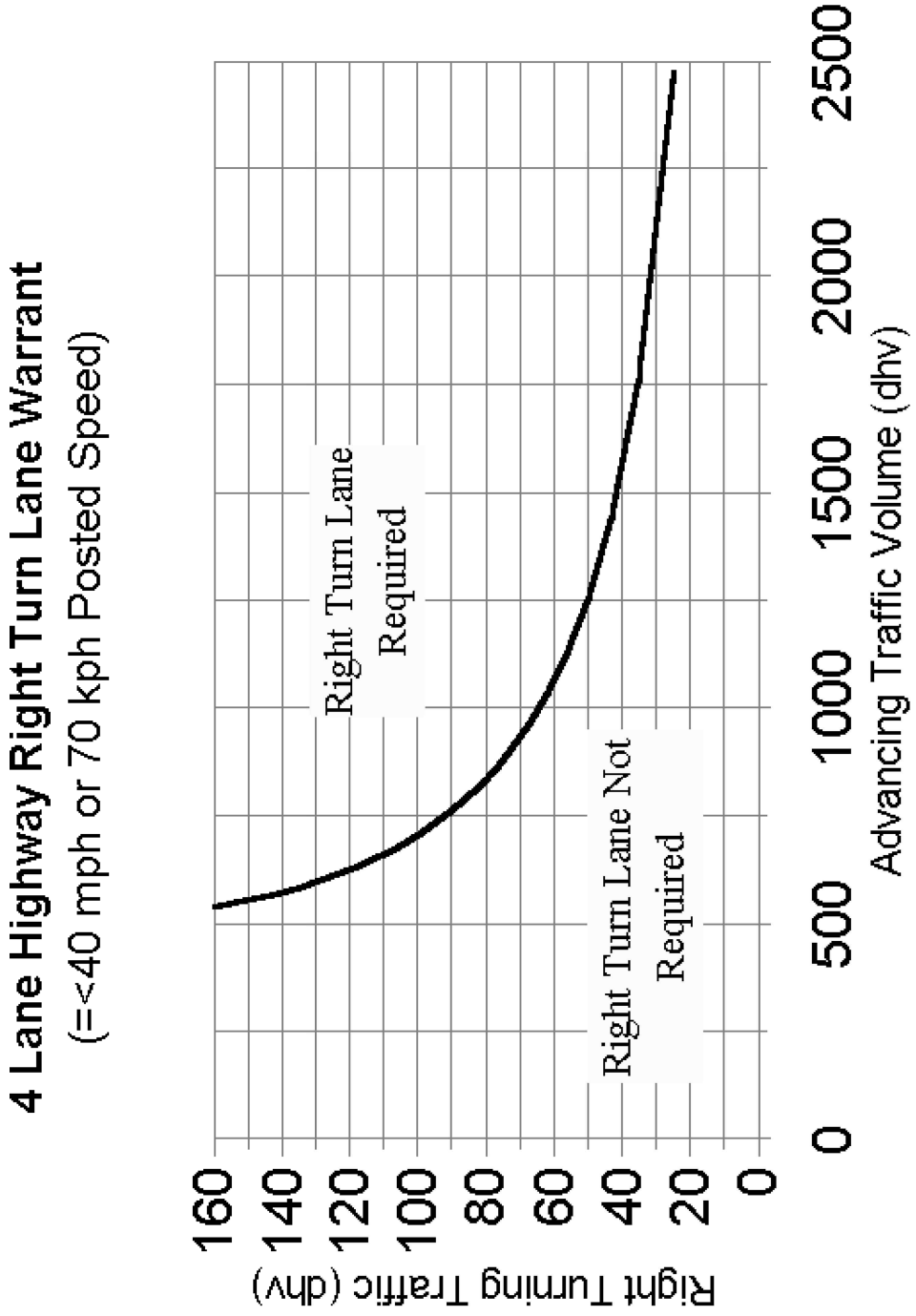
REFERENCE SECTION
401.6.3



4-LANE RIGHT TURN LANE WARRANT (LOW SPEED)

401-6c

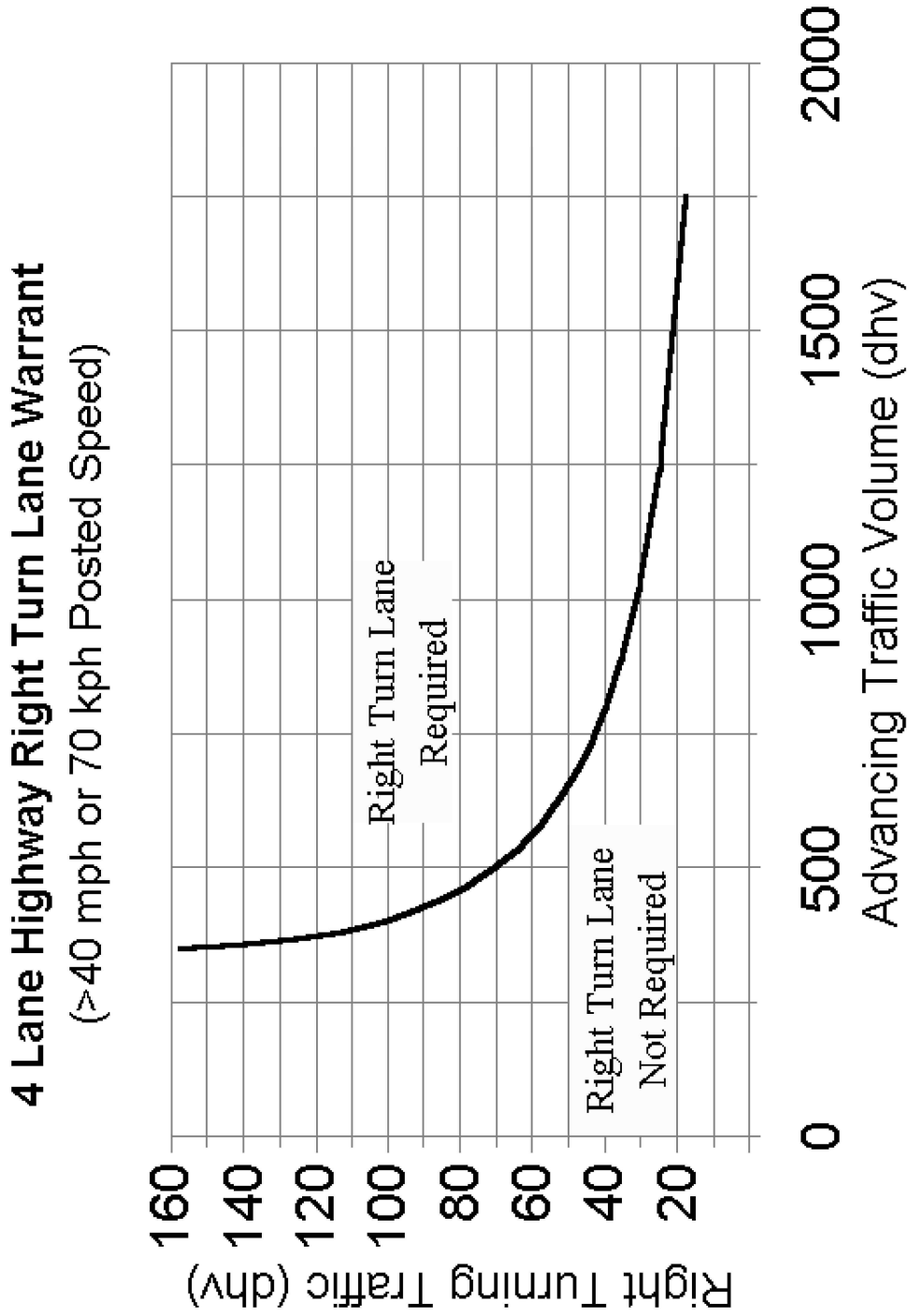
REFERENCE SECTION
401.6.3



4-LANE RIGHT TURN LANE WARRANT (HIGH SPEED)

401-6d

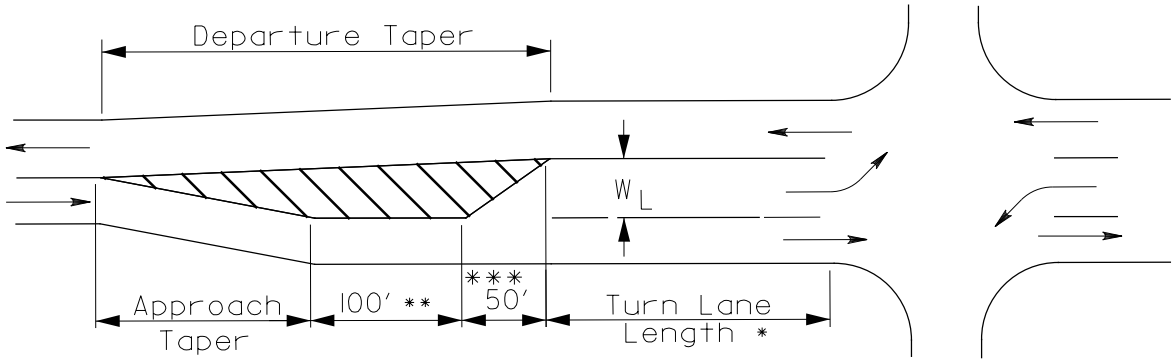
REFERENCE SECTION
401.6.3



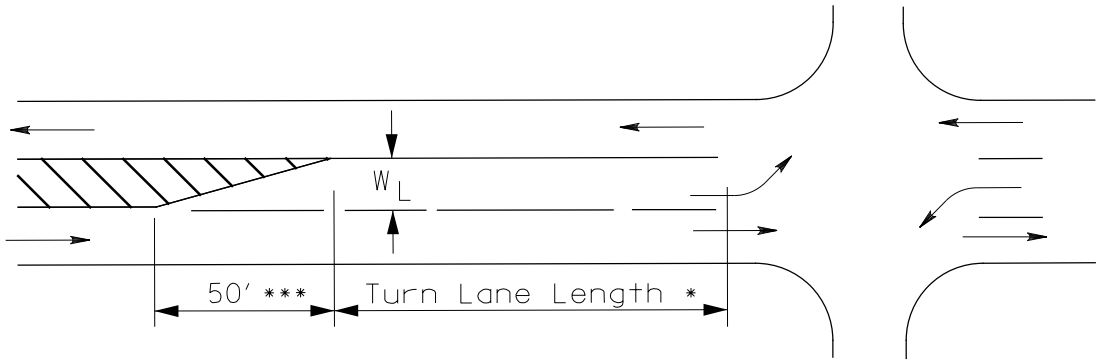
TURNING LANE DESIGN

401-7

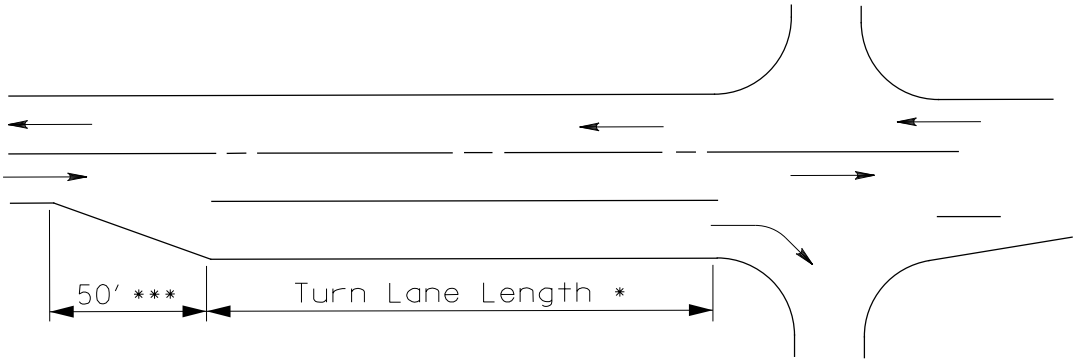
REFERENCE SECTIONS
401.6.1, 401.6.3



LEFT TURN LANE - NO MEDIAN OR MEDIAN WIDTH < W_L



LEFT TURN LANE - MEDIAN WIDTH >= W_L



RIGHT TURN LANE

* Turn Lane Length = Queue + Deceleration
See Figures 401-9 and 401-10 to compute turn lane length.

** May be reduced or eliminated in urban areas if intersection spacing or storage is constraining

*** Diverging taper

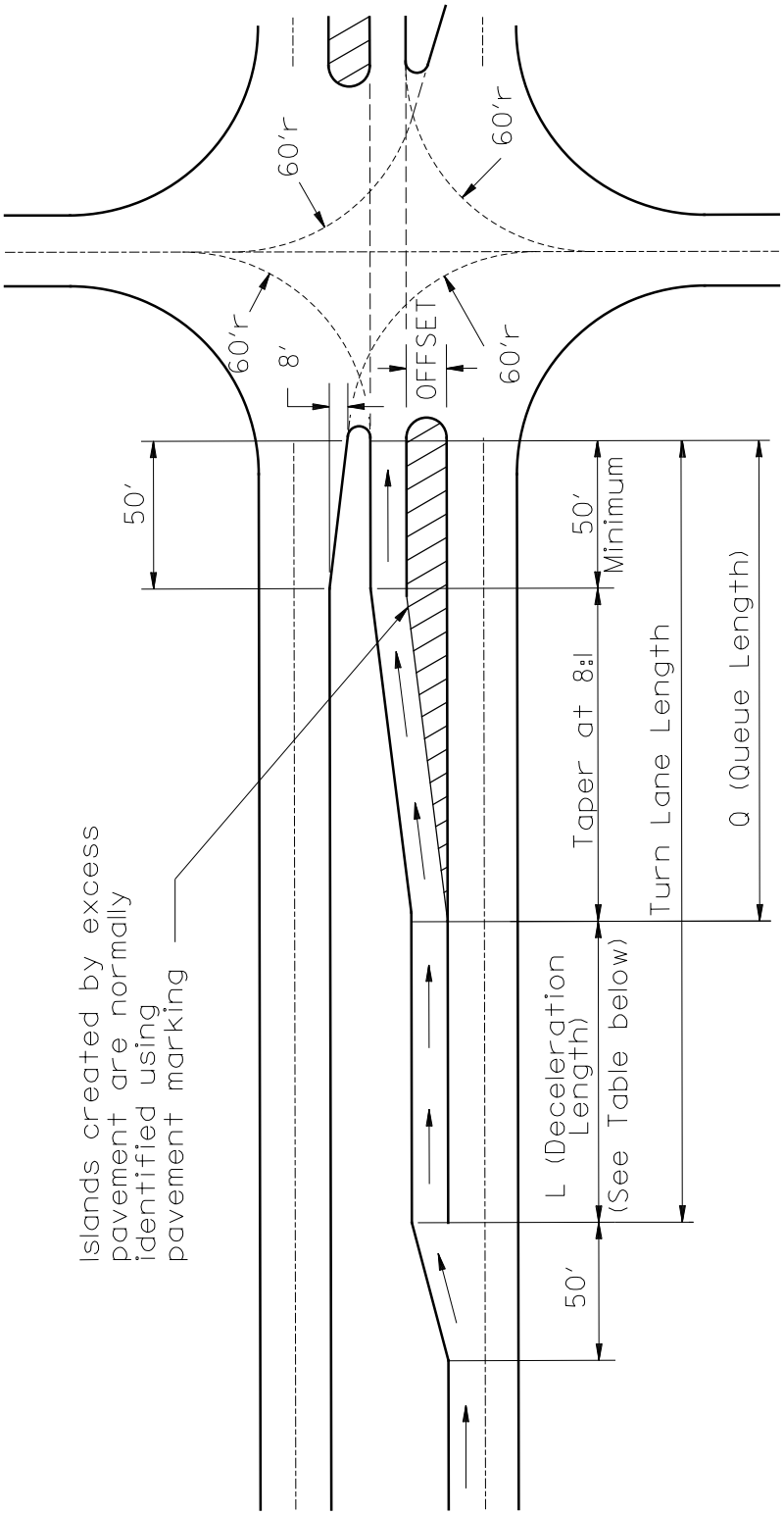
W_L = Turn Lane Width

January 2025

OFFSET LEFT TURN LANE

401-8

REFERENCE SECTIONS
401.6.1, 401.6.3



Compare the minimum queue length [(8 x offset) +50'] to the queue length from Figure 401-10 and use the greater of the two lengths

Design Speed	L
40 mph	75'
45 mph	125'
50 mph	175'
55 mph	250'
60 mph	300'
65 mph	375'

BASIS FOR COMPUTING LENGTH OF TURN LANES

401-9

REFERENCE SECTIONS
401.6.1 & 401.6.3

Type of Traffic Control	Design Speed		
	30-35	40-65	
	Turn Demand Volume		
	All	Low*	High
Signalized	A	B or C**	B or C**
Unsignalized Stopped Crossroad	A	A	A
Unsignalized Through Road	A	B	B or C**

* Low is considered 10% or less of approach traffic volume

** Whichever is greater

CONDITION A	QUEUE ONLY
Length = Queue Length (Figure 401-10)	

CONDITION B	HIGH SPEED DECELERATION ONLY
Design Speed	Length (feet)
40	75
45	125
50	175
55	250
60	300
65	375

CONDITION C	MODERATE SPEED DECELERATION AND QUEUE
Design Speed	Length (feet)
40	75 + Queue Length (Figure 401-10)
45	75 "
50	100 "
55	125 "
60	150 "
65	175 "

For explanation, see Turn Lane Design Example

QUEUE LENGTH AT INTERSECTIONS

401-10

REFERENCE SECTIONS
401.6.1 & 401.6.3

*Average # of Vehicles/Cycle	Queue Length (feet)
1	50
2	100
3	150
4	175
5	200
6	250
7	275
8	325
9	350
10	375
11	400
12	450
13	475
14	500
15	525
16	550
17	600
18	625
19	650
20	675
21	725
22	750
23	775
24	800
25	825
26	875
27	900
28	925
29	950
30	975

*Average # of Vehicles/Cycle	Queue Length (feet)
31	1025
32	1050
33	1075
34	1100
35	1125
36	1150
37	1175
38	1200
39	1225
40	1250
41	1300
42	1325
43	1350
44	1375
45	1400
46	1450
47	1475
48	1500
49	1525
50	1550
51	1600
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54	1675
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57	1775
58	1800
59	1825
60	1850

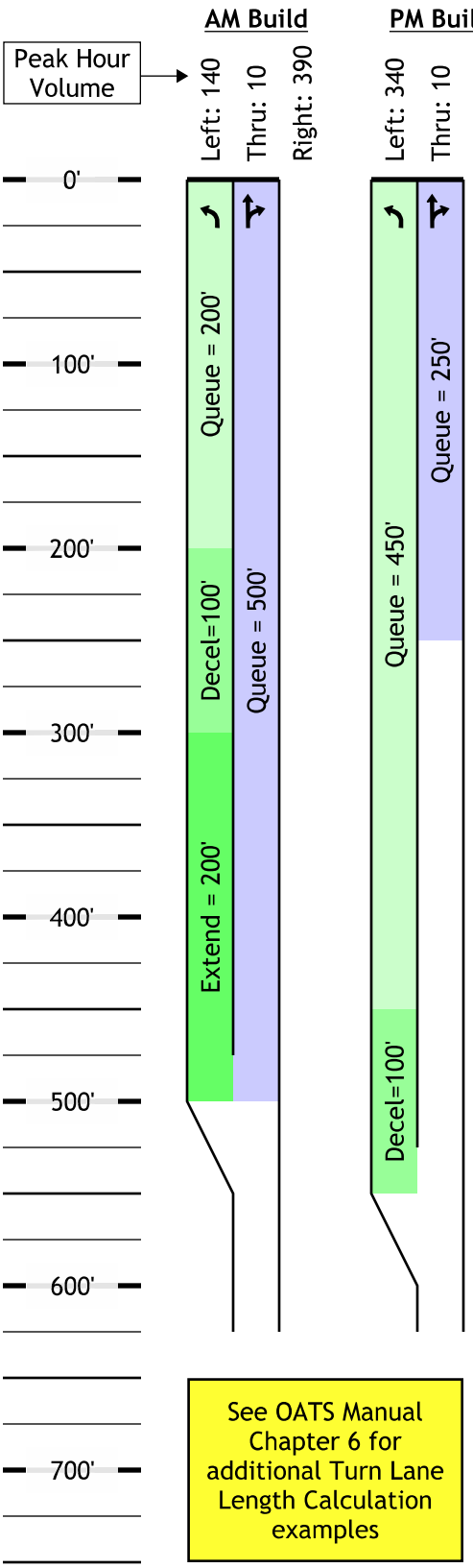
NOTE: ADDITIONAL TURN LANE STORAGE MAY BE REQUIRED WHEN THE AVERAGE VEHICLES PER CYCLE >= 10 AND THE HEAVY VEHICLES ARE >= 10%.

$$\text{* AVERAGE VEHICLES PER CYCLE} = \frac{\text{DHV (TURNING LANE)}}{\text{CYCLES/HOUR}}$$

IF CYCLES ARE UNKNOWN ASSUME:

UNSIGNALIZED OR
2 PHASE = 60 CYCLES/HOUR
3 PHASE = 40 CYCLES/HOUR
4 PHASE = 30 CYCLES/HOUR

Required Turn Lane Length Example Using Figures 401-9 and 401-10



See OATS Manual Chapter 6 for additional Turn Lane Length Calculation examples

Traffic Control: Signalized  Design Speed: 50 mph

Cycle Length(s) = 120s (AM/PM)

Determine Required Turn Lane Length (Queue + Deceleration)

The required turn lane length is being calculated at a signalized intersection with a design speed of 50 mph; therefore, the storage will be based on Figure 401-9 Condition B or Condition C, whichever is greater.

Calculate Required Turn Lane Length for AM Peak Hour

1) Condition B = High speed deceleration only = 175 feet
2) Condition C = Queue Length (see calculations below) + Moderate Speed Deceleration = 200 feet + 100 feet = 300 feet.
3) Determine the left turn queue. Calculate the average number of vehicles per cycle for the turn lane. Round the answer up to the next whole number and determine the queue length per Figure 401-10. This length is shown in figure to the left in green. [(140 veh/hr)*(120 s/cyc)]/3600 s/hr = 4.7 veh/cyc > 5 veh/cyc > 200 feet.
4) Determine thru/adjacent lane queue. Calculate the average number of vehicles per cycle for the thru/adjacent lane. Round the answer up to the next whole number and determine the queue length per Figure 401-10. This length is shown in figure to the left in blue. [(400 veh/hr)*(120 s/cyc)]/3600 s/hr = 13.3 veh/cyc > 14 veh/cyc > 500 feet.
5) Compare the calculated lengths from Step 3 and Step 4. For this example the thru/adjacent lane queue (500 feet) is longer than the required left turn storage (300 feet); therefore, the left turn lane must be extended an additional 200 feet so left turning vehicles can enter the turn lane without being blocked by the thru/adjacent lane.
6) The required turn lane length of the left turn lane for the AM peak hour is **500 feet.**

Calculate Required Turn Lane Length for PM Peak Hour

1) Condition B = High speed deceleration only = 175 feet
2) Required turn lane storage for Condition C = Queue Length (see calculations below) + Moderate Speed Deceleration = 450 feet + 100 feet = 550 feet.
3) Determine the left turn queue. Calculate the average number of vehicles per cycle for the turn lane. Round the answer up to the next whole number and determine the queue length per Figure 401-10. This length is shown in figure to the left in green. [(340 veh/hr)*(120 s/cyc)]/3600 s/hr = 11.3 veh/cyc > 12 veh/cyc > 450 feet.
4) Determine thru/adjacent lane queue. Calculate the average number of vehicles per cycle for the thru/adjacent lane. Round the answer up to the next whole number and determine the queue length per Figure 401-10. This length is shown in figure to the left in blue. [(160 veh/hr)*(120 s/cyc)]/3600 s/hr = 5.3 veh/cyc > 6 veh/cyc > 250 feet.
5) Compare the calculated lengths from Step 3 and Step 4. For this example the thru/adjacent lane queue (250 feet) is shorter than the required left turn storage (550 feet); therefore, the left turn lane does not need to be extended so left turning vehicles can enter the turn lane without being blocked by the thru/adjacent lane.
6) The required turn lane length of the left turn lane for the PM peak hour is **550 feet.**

Determine Required Storage of Turn Lane

1) Per the AM and PM peak hour calculations the required turn lane length for the left turn lane is 500 feet and 550 feet, respectively.
2) The required turn lane length for the left turn lane is **550 feet**.
3) See PM Build figure to the left for the Final Design.

DOUBLE LEFT TURN LANES

401-11

REFERENCE SECTIONS
401.6.2, 401.6.4

INSIDE RADIUS -R-	EXPANDED THROAT WIDTH -W- DESIGN TRAFFIC CONDITION ▼		
	A	B	C
50 ft.	31 ft.	36 ft.	45 ft.
75 ft.	29 ft.	33 ft.	38 ft.
100 ft.	28 ft.	31 ft.	35 ft.
150 ft.	26 ft.	29 ft.	32 ft.
200 ft.	26 ft.	28 ft.	30 ft.

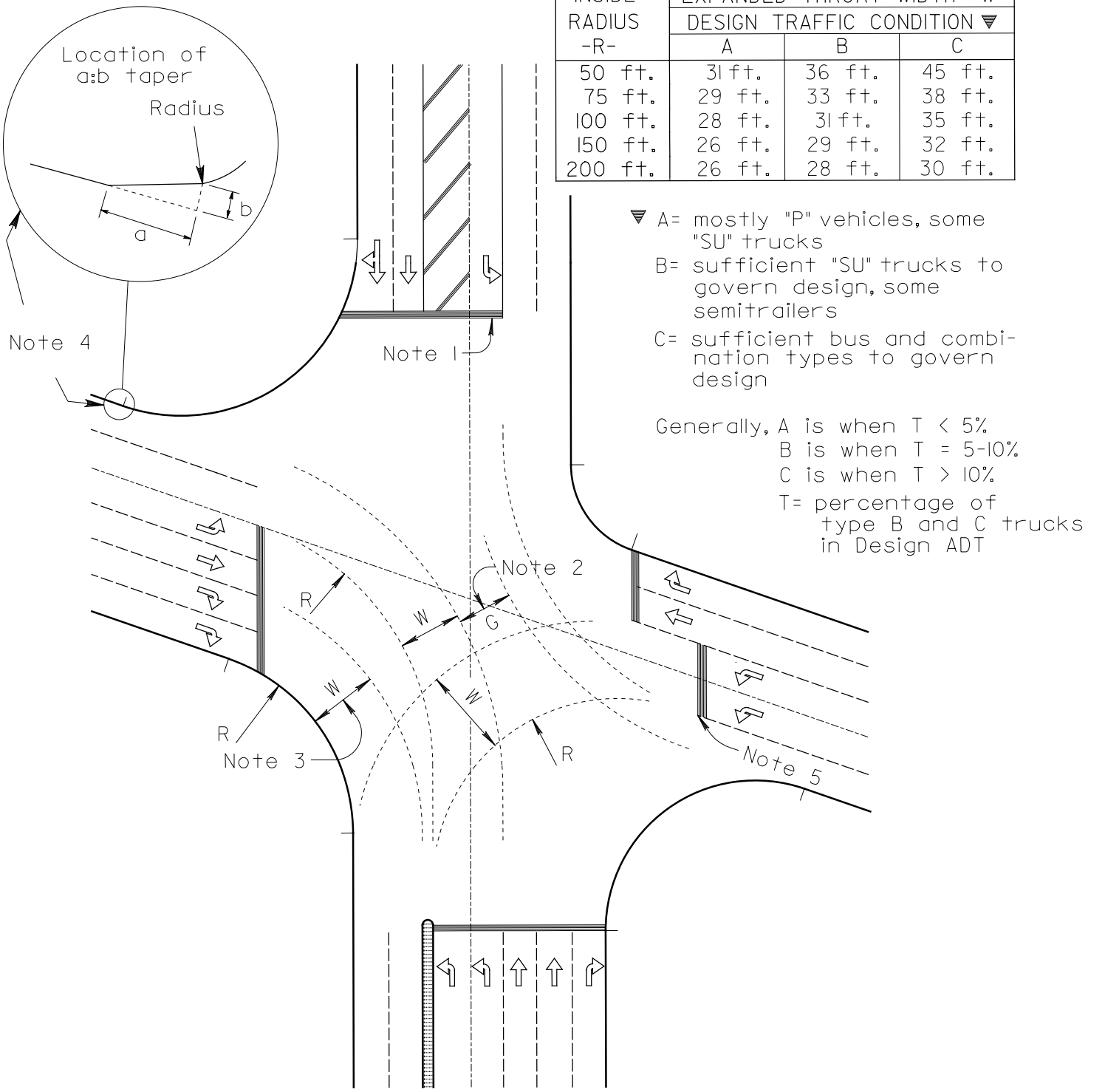
▼ A= mostly "P" vehicles, some "SU" trucks

B= sufficient "SU" trucks to govern design, some semitrailers

C= sufficient bus and combination types to govern design

Generally, A is when T < 5%
B is when T = 5-10%
C is when T > 10%

T= percentage of type B and C trucks in Design ADT



Notes for Figure 401-11 - Double Left Turn Lanes

1. Notice that the single left turn lane at the top of the page has been laterally offset from the through lanes in order to prevent conflicts between opposing turning paths.
2. Opposing turning paths should always be checked to verify that there is no conflict (see dimension “G”). Per AASHTO “Green Book”, page 9-115, dimension “G” should be a minimum of 10’.
3. The double right turn lane design follows the same criteria as the double left turn lane for expanded throat width.
4. The pavement width of the receiving lanes for a double left turn at an intersection needs to be checked to see if design vehicles can complete their turns within the pavement area. This is especially important where the radius returns are curbed. The use of radius templates is one method that can be used to check wheel tracking to see if additional pavement area adjacent to the far return area is needed. If the turning lanes are 12 ft. in width, the following formula is recommended to estimate a need for widening the pavement at the receiving throat:

   $F = (W-24)/2$

   where W is the maximum expanded throat width from the table on Figure 401-11. If the turn lanes are not 12 ft., use truck turning templates.
   Then use the following guidelines:

   If $F < 2.0$, no widening is required.
   If $F = 2.0$ through 3.9, use a 40:4 taper.
   If $F = 4.0$ through 5.9, use a 45:6 taper.
   If $F = 6.0$ through 9.0, use a 50:8 taper.

   See **Figure 503-5** for examples of how these tapers are used at radius returns

5. Stop bar locations may need to be adjusted to the inside radius return of the left turn movements.

DEVELOPMENT OF DUAL LEFT TURN LANES

401-12

REFERENCE SECTION
401.6.2

Design Speed	L_1	L_2
40 mph	125'	75'
45 mph	175'	125'
50 mph	225'	150'
55 mph	300'	175'
60 mph	350'	200'
65 mph	425'	225'

* Use Figure 401-10 to determine queue length. For offset left turn lanes, minimum queue length equals 8 x offset + 50'.

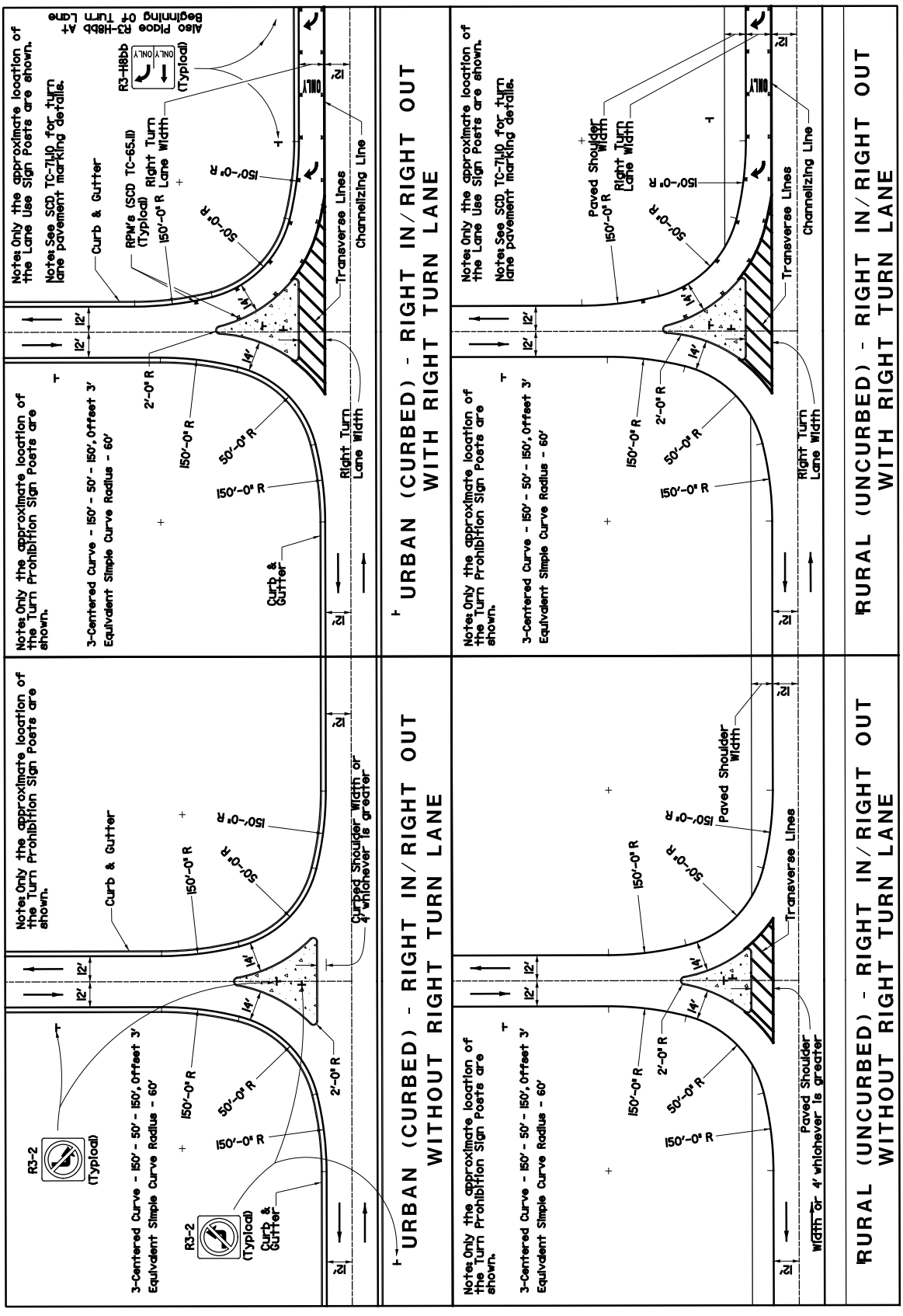
** Taper is used when dual left turn lanes are offset.

△ If opposite approach has one left turn lane, these lanes should line up.

CHANNELIZING ISLANDS
PASSENGER CAR DESIGNS

401-13a

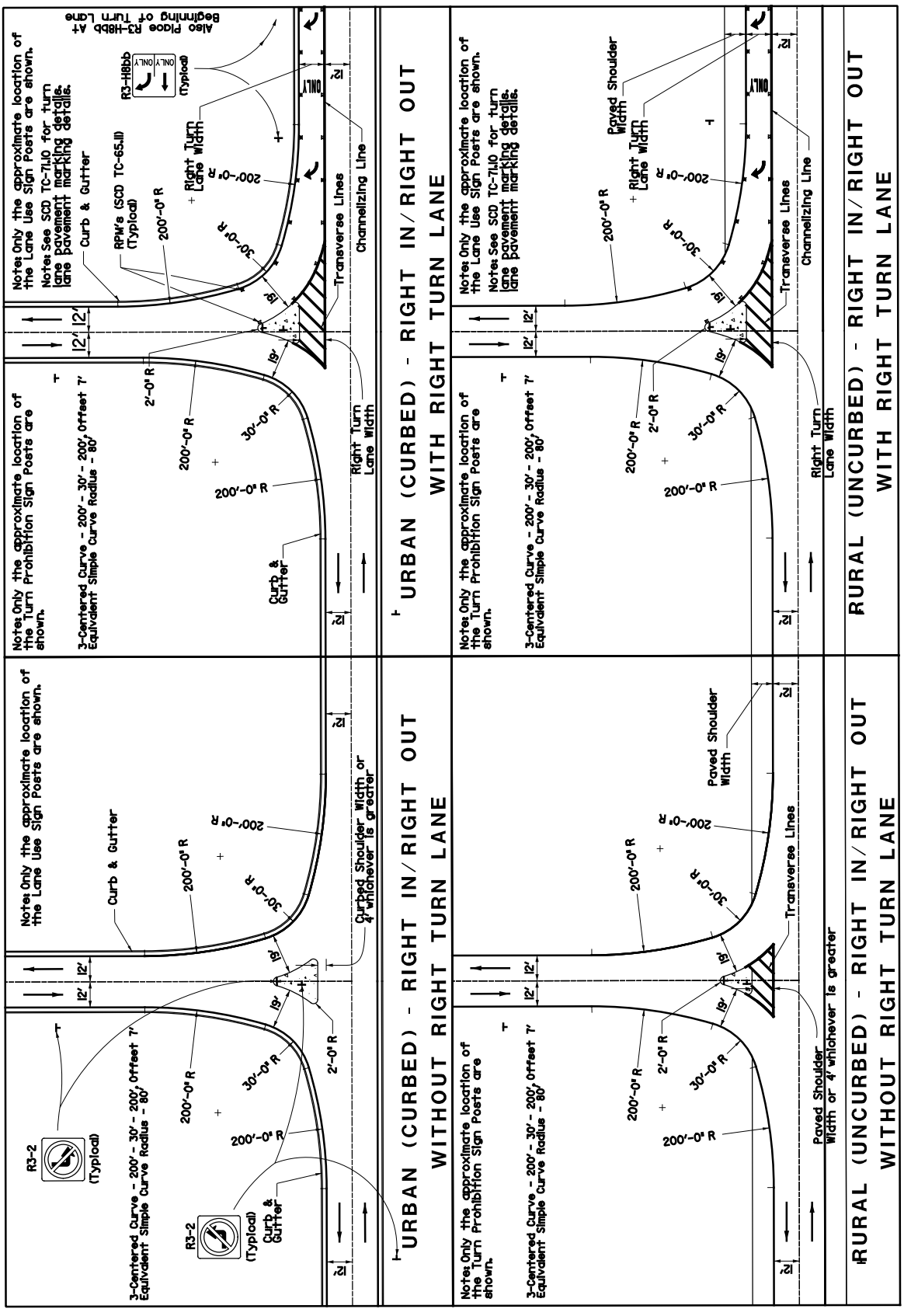
REFERENCE SECTION
401.7.2



CHANNELIZING ISLANDS
SU TRUCK DESIGNS

401-13b

REFERENCE SECTION
401.7.2

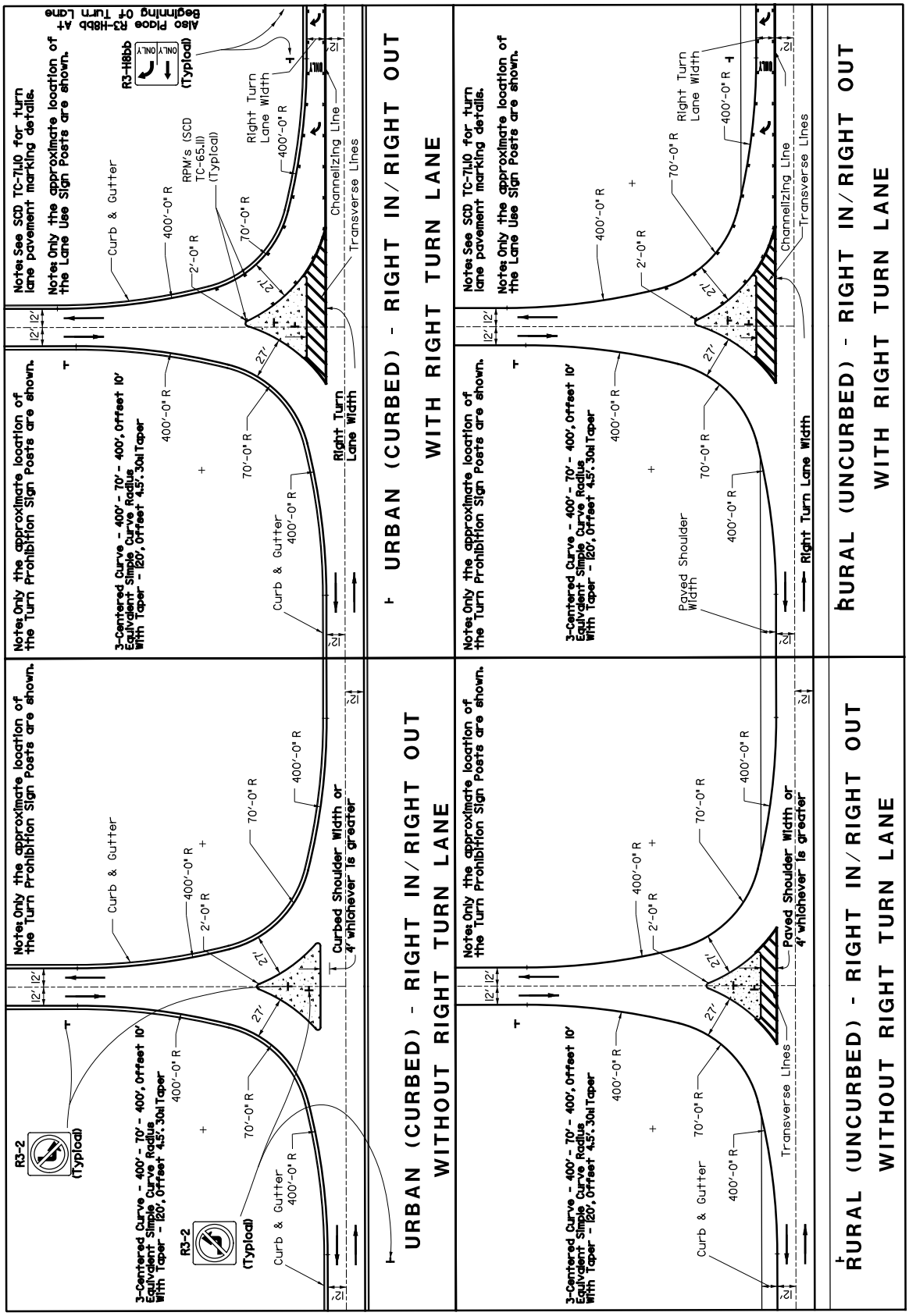


January 2018

CHANNELIZING ISLANDS WB-62 TRUCK DESIGNS

401-13c

REFERENCE SECTION
401.7.2

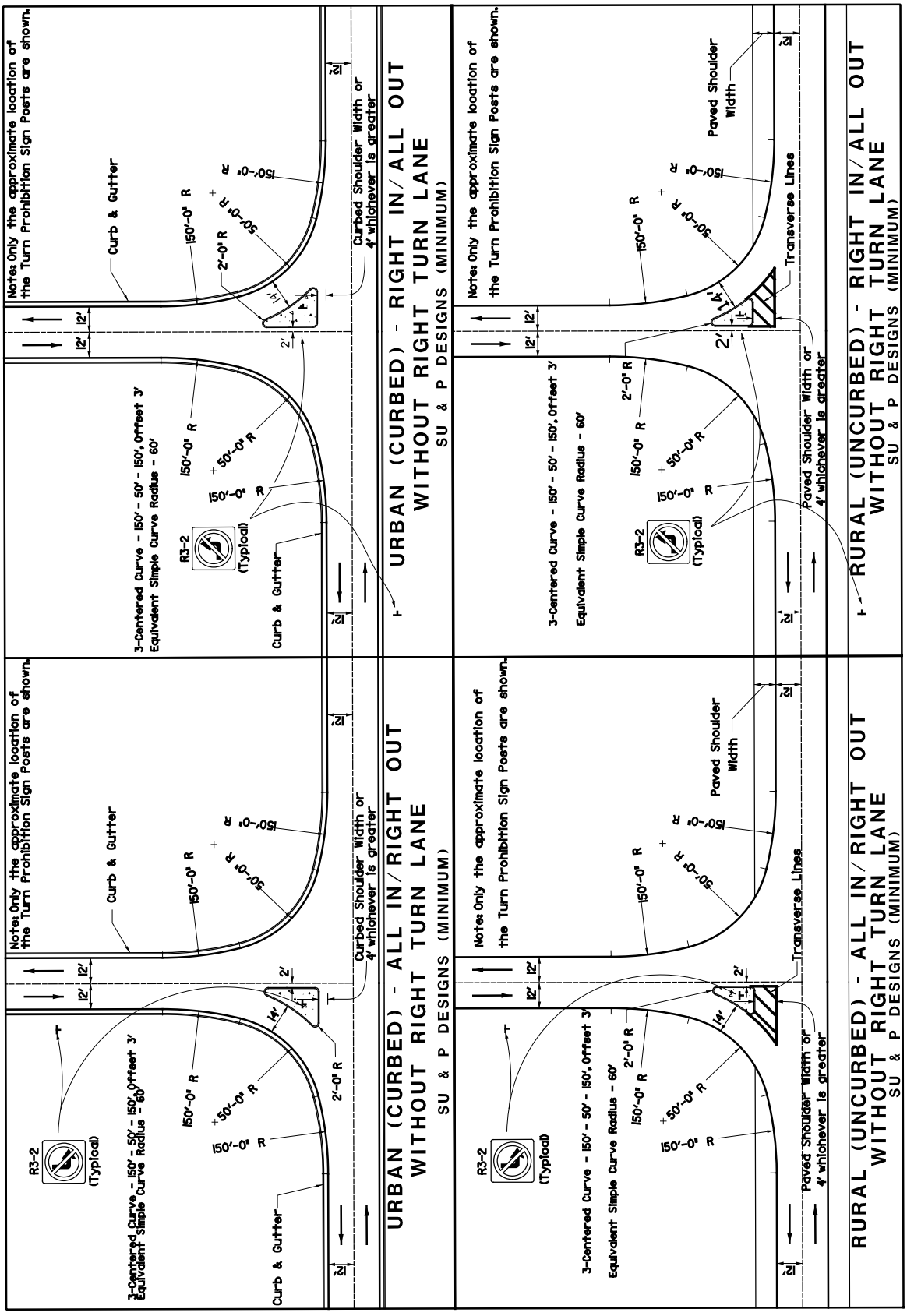


January 2018

CHANNELIZING ISLANDS TYPICAL ISLANDS WITH PERMITTED LEFT TURNS

401-13d

REFERENCE SECTION
401.7.2



TRAFFIC OPERATIONAL ANALYSIS DESIGN SOFTWARE

401-14c

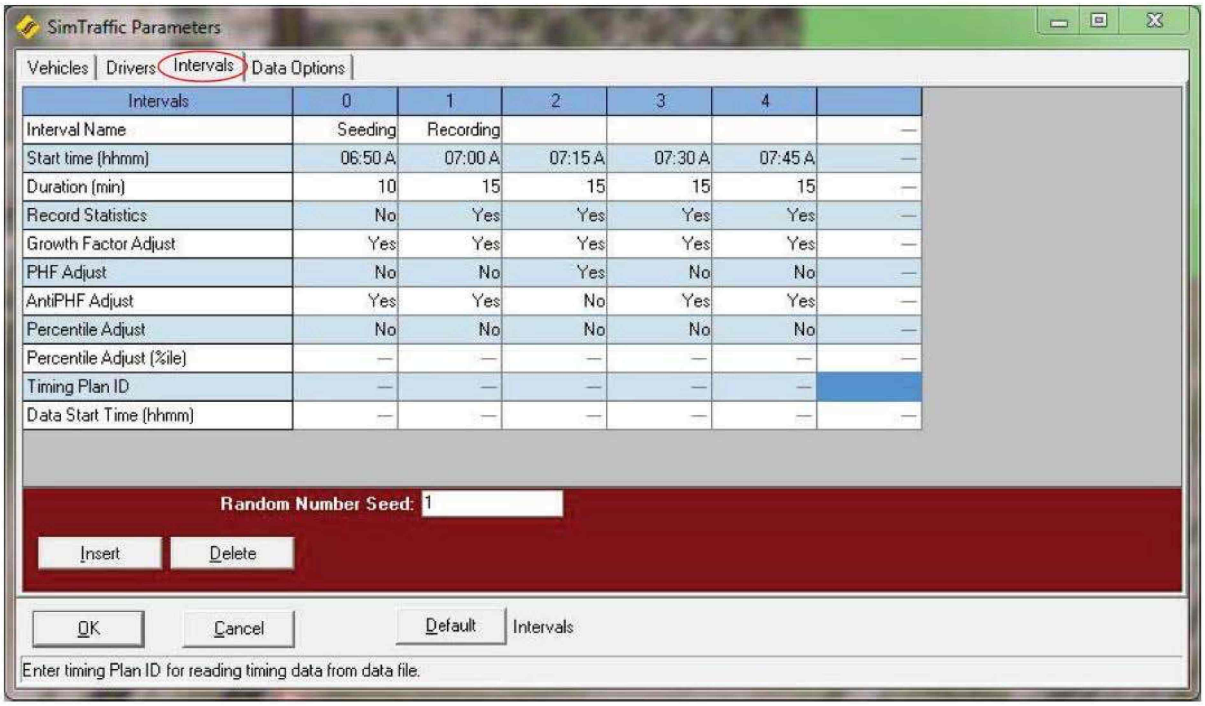
REFERENCE SECTION
401.2

Microsimulation software (SimTraffic/CORSIM/TransModeler)

- Analysis should use a minimum of 10 simulation runs with different number seeds.
- Refer to the FHWA Traffic Analysis Tools Program for additional guidance on using simulation software: http://ops.fhwa.dot.gov/trafficanalysistools/index.htm

Synchro (SimTraffic) - Only to be used if approved by the Office of Roadway Engineering

Below is a screen capture of the minimum parameters, for the peak period, that must be used when running SimTraffic. These are found by selecting "Options" in the menu bar, then "Intervals and Volumes".



INTERSECTION DESIGN AND CHECK VEHICLES

401-15a

REFERENCE SECTIONS
401.9.3

FOR TURN MADE		INTERSECTION DESIGN VEHICLE (DE=A1) [1][2][3]	INTERSECTION CHECK VEHICLE(S) (DE=[XX]) [1][2][3]
FROM (APPROACH)	ONTO (DEPARTURE)		
ARTERIAL COLLECTOR LOCAL	RAMP	WB-62 [4]	
RAMP	ARTERIAL COLLECTOR LOCAL	WB-62 [4]	
ARTERIAL	ARTERIAL COLLECTOR	SU-30	WB-62 [A2]
ARTERIAL	LOCAL	SU-30	WB-40 [A2] [6] WB-62 [B2] [5][7]
COLLECTOR	ARTERIAL COLLECTOR	SU-30	WB-40 [A2] WB-62 [B2] [5][7]
COLLECTOR	LOCAL	SU-30	WB-40 [A2] [6] WB-62 [B3] [5]
LOCAL	ARTERIAL COLLECTOR	SU-30	WB-40 [B2] WB-62 [C2] [5]

NOTES:

1. A smaller Intersection Design/Check Vehicle than shown in the table above may be appropriate at some locations, but must be justified. Conditions that might justify the consideration of a smaller Intersection Design/Check Vehicle include
   - Limited right of way
   - Trucks prohibited on cross streets
   - Current and future traffic counts show a small amount of the Intersection Design/Check Vehicle (<3/day) making the turn(s).
   - Cross street volume is minimal (<400 AADT) and the route is unlikely to be used as a detour route for a nearby higher volume roadway.

(continued on next page)

INTERSECTION DESIGN AND CHECK VEHICLES (CONT.)

401-15a

REFERENCE SECTIONS
401.9.3

NOTES:

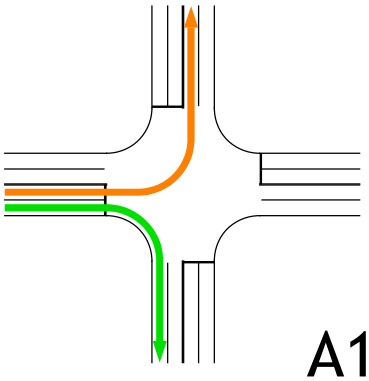
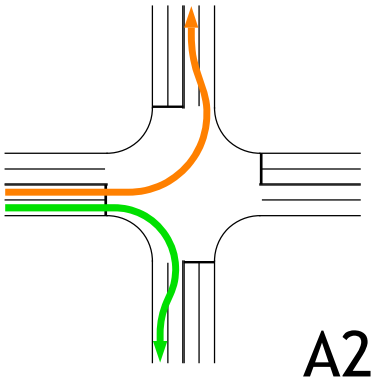
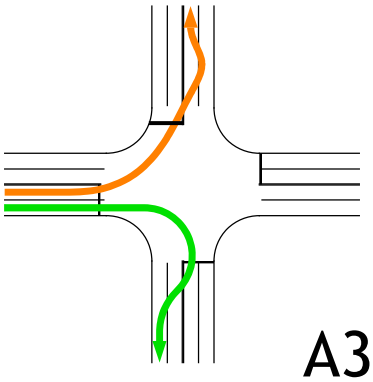
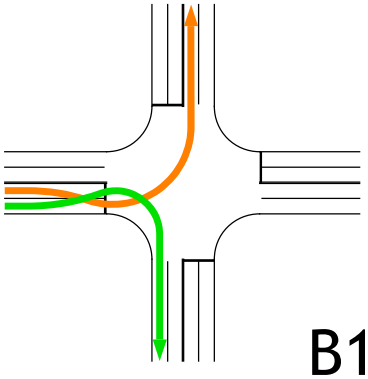
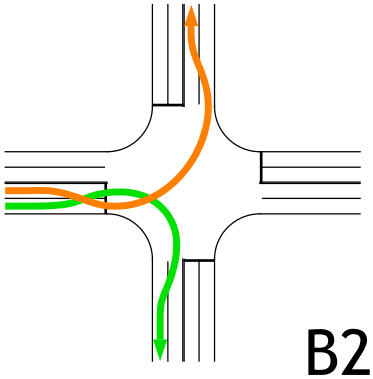
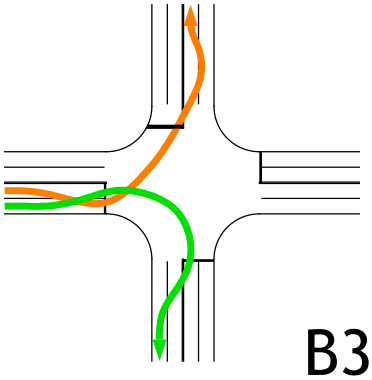
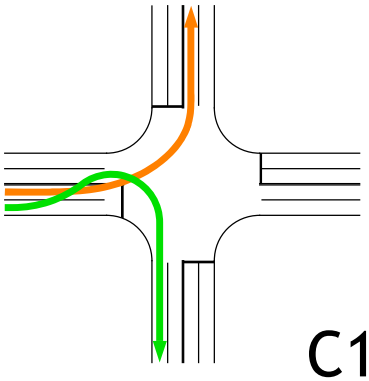
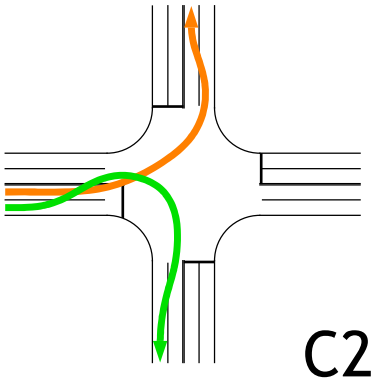
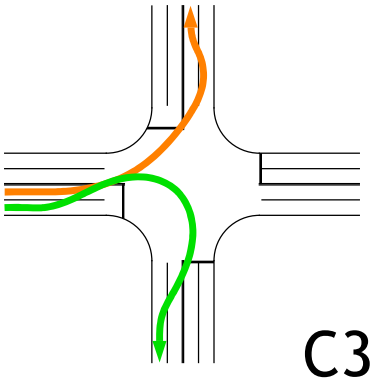
2. A larger Intersection Design/Check Vehicle than shown in the table above may be appropriate at some locations, but must be justified. Conditions that might justify the consideration of a larger Intersection Design/Check Vehicle include
   - Current and future traffic counts show a significant amount of vehicles larger than the Intersection Design/Check Vehicle making the turn(s).
   - The encroachment of even a few larger vehicles will cause significant traffic impacts.
3. If an Intersection Design/Check Vehicle is used that is not shown in the table on the previous page, then the following conditions apply:
   - Use the default Intersection Design Vehicle from the table on the previous page as an Intersection Check Vehicle, and verify that it can make the turn(s) (by encroaching into other traffic lanes if necessary) without significantly impacting traffic. For signalized intersections, if the default Intersection Design Vehicle is a WB-62, verify that the WB-62 can make the turns(s) with a DE=A2.
   - Verify that WB-62 trucks can physically make the turns at an intersection of two routes on the National Network without backing up and without impacting curbs, parked cars, utility poles, mailboxes, traffic control devices, or any other obstructions, regardless of the selected Intersection Design/Check Vehicle or allowable encroachment.
4. At signalized intersections, DE=A2 is acceptable for left turns from a single left turn lane if:
   - Left turns are only allowed during the protected phase
     or
   - There are no opposing vehicles (e.g., on the non-crossing leg of a T-intersection)
5. At signalized intersections, for the WB-62 Intersection Check Vehicle, use a preferred degree of encroachment (DE) = A2, with a minimum DE as shown.
6. A Degree of Encroachment (DE) = A3 may be acceptable for right turns by an Intersection Check Vehicle if there is a right-turn lane on the approach. This allows the right turning vehicle to wait outside of the approach through lane until traffic clears from the opposing lane on the departure leg. Use only if this is an infrequent occurrence and does not cause backups or other traffic impacts.
7. At right-turn lanes with a contiguous bike lane between the turn lane and the through lane, check the swept path of the WB-62 Intersection Check Vehicle to see if it is possible to avoid encroaching into the bike lane without significantly disrupting traffic or going outside of the roadway. Otherwise, consider:
   - accepting infrequent bike lane encroachments but consider adding warning signage that states right turning large trucks swing left before turning (or similar).

   If the bike lane encroachment is freqeuent enough to be potentially dangerous, consider:
   - parking restrictions and/or a larger curb radius
   - mark as a shared bike/right-turn lane instead of a separate bike lane and right-turn lane
   - re-design to reduce or eliminate the conflict

INTERSECTION DEGREES OF ENCROACHMENT

401-15b

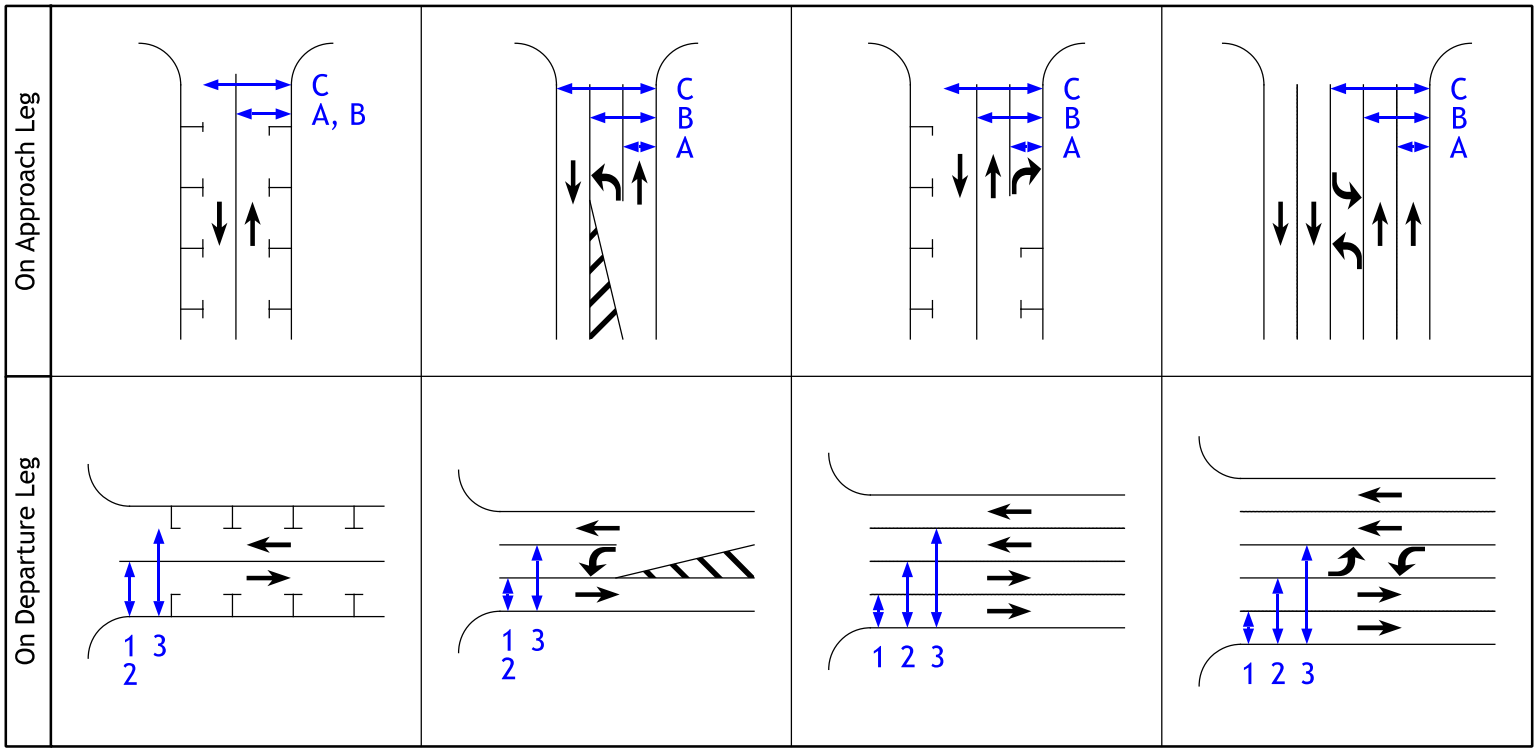
REFERENCE SECTIONS
401.9.3

Approach \ Departure	1 No Encroachment	2 Enroachment into the adjacent lane (same direction)	3 Encroachment into the opposing lane
A No Encroachment	 A1	 A2	 A3
B Enroachment into the adjacent lane (same direction)	 B1	 B2	 B3
C Encroachment into the opposing lane	 C1	 C2	 C3

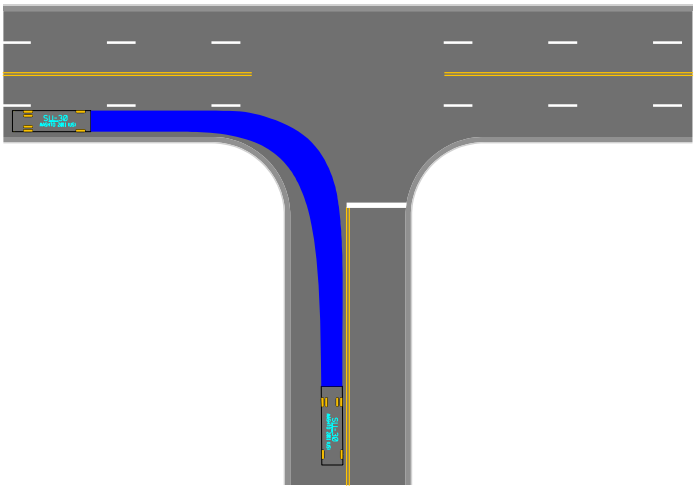
EFFECTIVE PAVEMENT WIDTHS AT INTERSECTIONS

401-15c

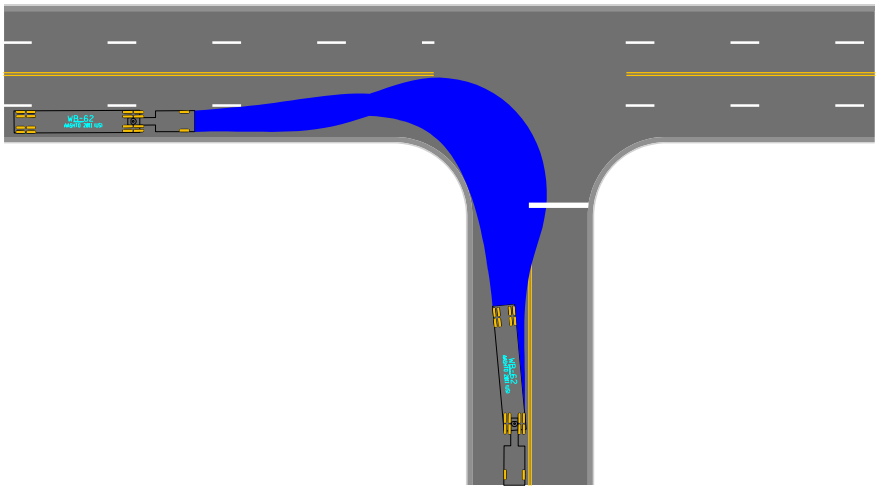
REFERENCE SECTIONS
401.9.3



COLLECTOR TO LOCAL
DESIGN VEHICLE (SU-30)



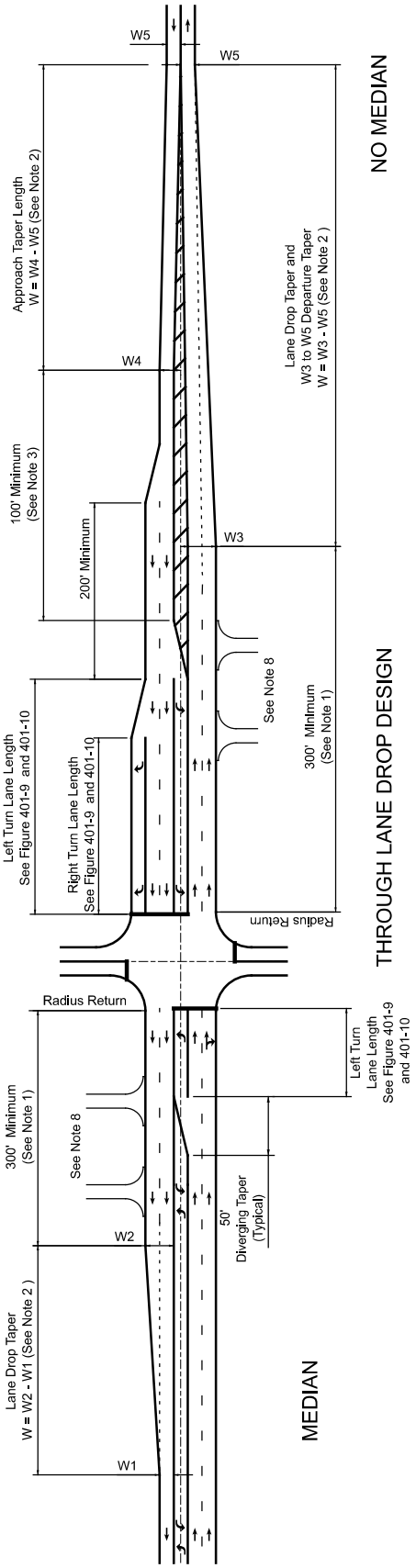
COLLECTOR TO LOCAL
CHECK VEHICLE DE=B3 (WB-62)

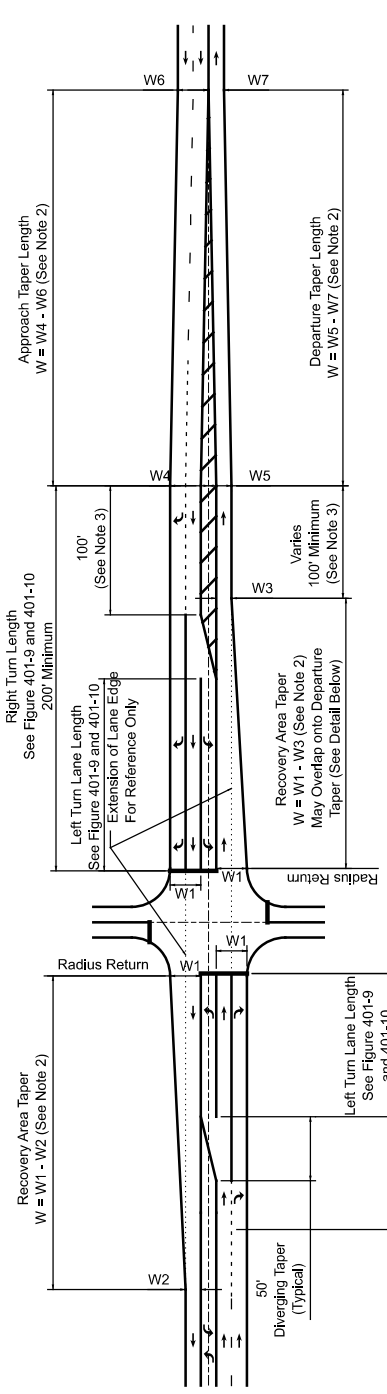


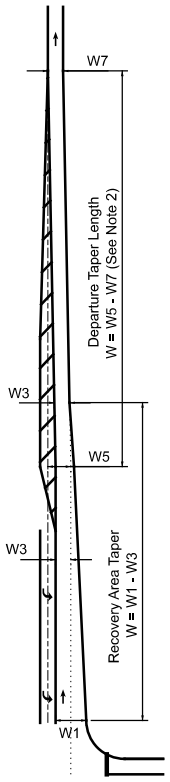
ADD AND DROP LANES AT INTERSECTIONS

402-1

REFERENCE SECTIONS
401.6.5, 401.6.6







Overlap Recovery Area and Departure Taper Detail

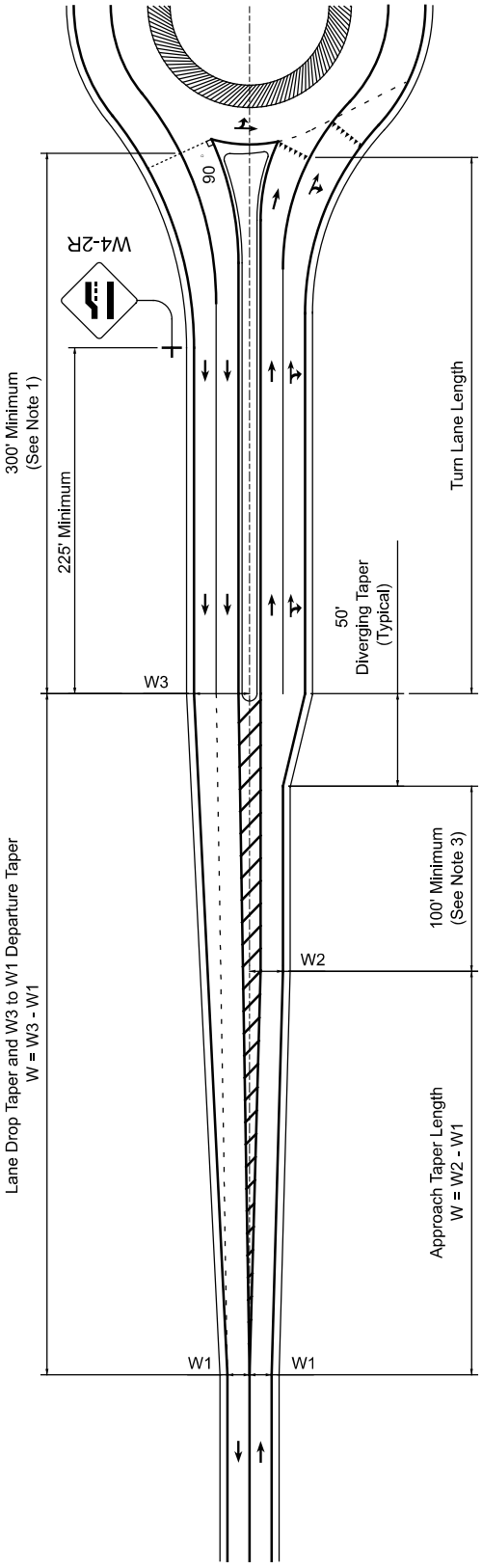
See Note 6 for Relationship of Depature and Approach Taper Layouts

See Figure 402-3 for Notes and Details

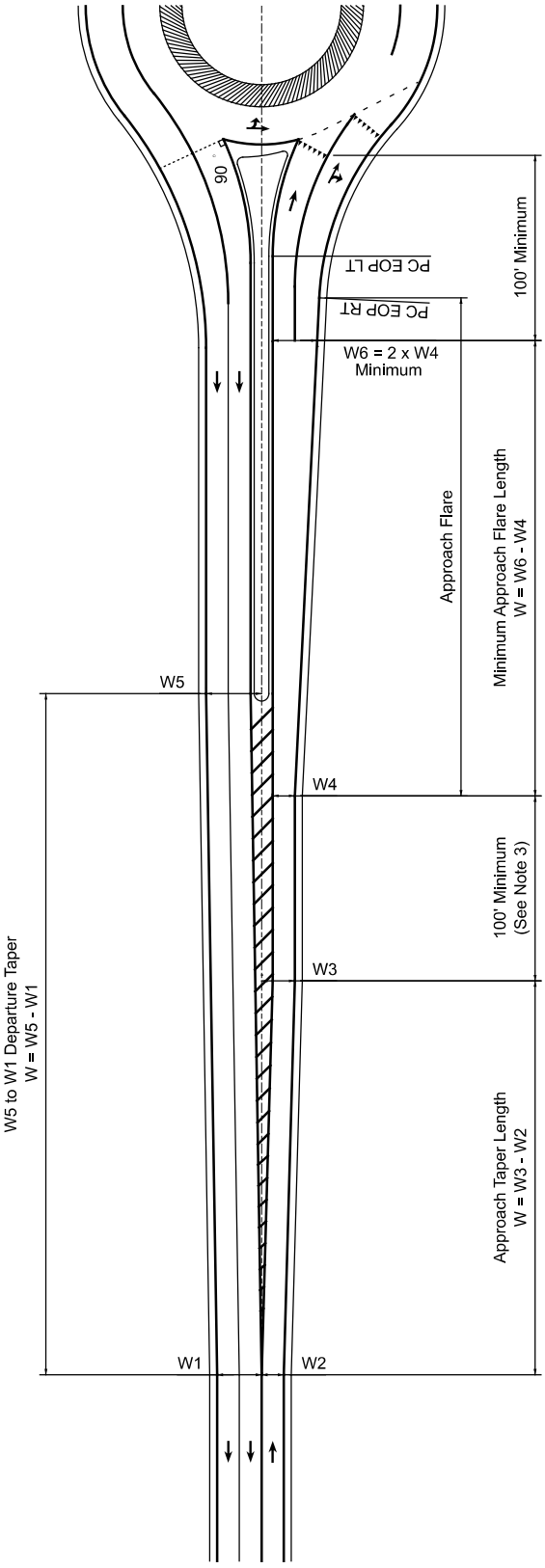
ADD AND DROP LANES AT MULTILANE ROUNDABOUTS

402-2

REFERENCE SECTIONS
403.4



ROUNDABOUT TAPER OPTION



ROUNDABOUT FLARE OPTION

This Option is acceptable for use on Non-State Routes.

See Figure 402-3 for Notes:

See Note 2 for Calculation of Taper Lengths.

See Note 6 for Relationship of Depature and Approach Taper Layouts

ADD AND DROP LANE NOTES AND DETAILS

402-3

REFERENCE SECTIONS
401.6.5 & 403.4

Notes for Figures 402-1 and 402-2 and Other Details

1. This distance should be at least long enough to allow proper advance placement of warning signs for a typical lane reduction, based on OMUTCD guidelines. The lane is then merged at a taper rate as shown in Note 2 below.

2. The taper distance is calculated from:

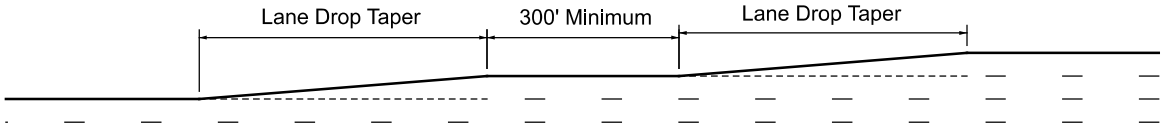
   Design Speed of 50 mph or more:
   $L = WS$

   Design Speed of less than 50 mph:
   $L = WS^2/60$

   Where: L = Taper length in feet
   W = Offset width in feet
   S = Design speed

3. May be reduced or eliminated in urban areas if intersection spacing or storage is constraining.

4. Lane addition and removal on 3-lane or more highways is similar. Dropping of additional lanes shall be based on OMUTCD guidelines or at next intersection as shown on Figure 402-1.



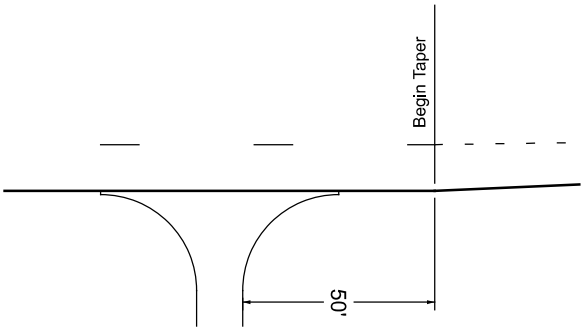
5. Figures are not intended to show pavement striping. Striping is based upon the OMUTCD.

6. For the relationship of departure and approach taper layouts see Figure 401-7.

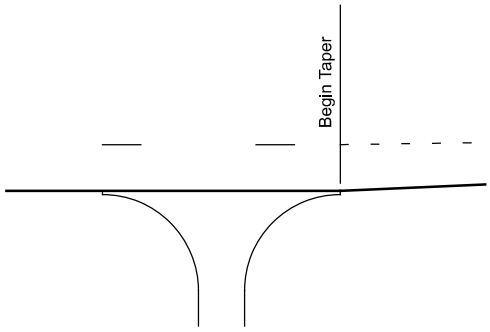
7. In general, it is desirable to place all tapers on tangents or on curves with normal crown superelevation.

8. If driveways are present, distance to beginning of lane drop taper may need to be increased. See details below for drive and taper configurations.

Preferred



Acceptable



ROUNDABOUT SIZING THRESHOLDS

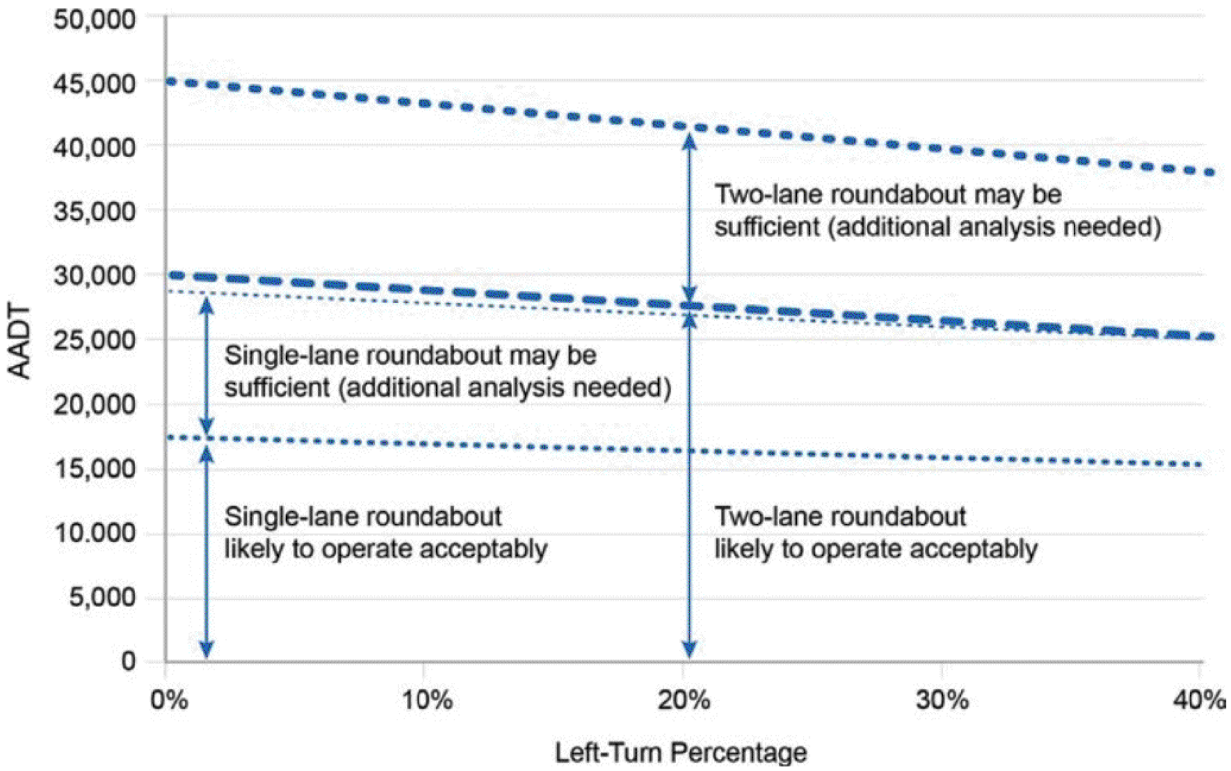
403-1

REFERENCE SECTION
403.3

NHRP Report 1043 - Exhibit 8.6
Planning Level Sizing Guide Using Peak Period Volume Thresholds

Sum of Peak Period Entering and Conflicting Flows (veh/hr)	Type of Roundabout and Number of Lanes
700 or less	Single-lane roundabout with traversable or non-traversable central island is likely sufficient
701 to 900	Single-lane roundabout with non-traversable central island is likely sufficient; single-lane roundabout with traversable central island may be sufficient
901 to 1,300	Single-lane roundabout with non-traversable central island may be sufficient
1,301 to 1,600	Two-lane entry into multilane roundabout is likely sufficient; detailed turning movement analysis recommended
1,601 to 2,300	Two-lane entry into multilane roundabout may be sufficient; detailed turning movement analysis recommended
Greater than 2,300	Three-lane entry into multilane roundabout may be sufficient; detailed turning movement analysis recommended

NHRP Report 1043 - Exhibit 8.2
Planning-Level Daily Intersection Volumes for a Four-Leg Roundabout



ROUNDABOUT CRITICAL DESIGN PARAMETERS

403-2

REFERENCE SECTION
403.7

Roundabout Critical Design Parameters

Project - County Route Section

PID

Design Parameters	Leg 1	Leg 2	Leg 3	Leg 4	Leg 5
Entry Width, FT					
Exit Width, FT					
Circulatory Roadway Width, FT					

Fastest Path Speed	Leg 1	Leg 2	Leg 3	Leg 4	Leg 5
R_1, Radius/Speed, FT/MPH					
R_2, Radius/Speed, FT/MPH					
R_3, Radius/Speed, FT/MPH					
R_4, Radius/Speed, FT/MPH					
R_5, Radius/Speed, FT/MPH					
R_5, Bypass Radius/Speed, FT/MPH					

Minimum Sight Parameters	Leg 1	Leg 2	Leg 3	Leg 4	Leg 5
Approach Design Speed, MPH					
Approach Stopping Sight Distance, FT/MPH					
Circulatory Stopping Sight Distance, FT/MPH					
Exit (Crosswalk) Stopping Sight Distance, FT/MPH					
Intersection Sight Distance, FT/MPH					

General	
Inscribed Circle Diameter, FT	
Design Vehicle(s)	
Truck Apron Width, FT	

Designer:

Signature:

Date:

Link to editable Excel File

500 - Interchange Design

501 - Interchange Design

501.1 - General

An interchange is defined as a system of interconnecting roadways in conjunction with one or more grade separations that provides for the movement of traffic between two or more roadways or highways on different levels. Interchanges are utilized on freeways and expressways where access control is important. They are used on other types of facilities only where crossing and turning traffic cannot be accommodated by a normal at-grade intersection. An Interchange Justification Study may be necessary.

501.2 - Interchange Type

The most commonly used types of interchanges are the diamond, cloverleaf and directional.

In the design of any interchange, consideration should be given to the likelihood of wrong-way travel and to the practical measures that may be taken in the design and traffic control for preventing or discouraging such usage. Signing to prevent wrong-way entry should be in accordance with the OMUTCD.

Wrong-way entry onto freeways and arterial streets are not a frequent occurrence, but it should be given special consideration during design to discourage wrong-way maneuvers. Most wrong-way entrances occur at freeway exit ramps or at intersections at grade along divided arterial streets. Several factors that contribute to wrong-way entrances are related to interchange design. These factors concern the interchange configuration and, more particularly, the crossroad terminal of the exit ramps.

The following countermeasures can be implemented to reduce the occurrence of wrong-way movements:

For Traffic Control Measures see TEM Section 1303-16.

Roadway Geometric Measures

- Increased separation between adjacent entrance and exit ramps.
- Raised medians to prevent selected movements.
- Painted or raised channelizing islands to guide drivers along a desired path and away from prohibited paths.
- Decrease radii of potential entry paths.
- Intersection angles that discourage wrong way turns.

501.2.1 - Diamond Interchanges

The diamond interchange is the most common type where a major facility intersects a minor highway. The design allows free-flow operation on the major highway but creates at-grade intersections on the minor highway with the ramps. Traffic control at the at-grade intersections can be stop, signal or roundabout. The capacity of a diamond interchange is limited by the at-grade intersections on the minor highway. Variations of the diamond interchange include but are not limited to the **Tight Urban Diamond Interchange** (TUDI), the **Single Point Urban Interchange** (SPUI) and the D**iverging Diamond Interchange** (DDI).

501.2.1.1 - Tight Urban Diamond Interchange (TUDI)

The TUDI, a type of compressed diamond interchange, is used in urban and suburban areas where right of way is limited. This interchange design has two closely spaced signalized ramp intersections. Special signal phasing allows queuing of vehicles outside the ramp intersections and eliminates queuing of vehicles between the ramp intersections. Typical designs provide 250 to 400 feet of separation between the signalized intersections.

The key operational aspect of a TUDI is one controller running both intersections implementing the Texas Diamond 4 Phase operation. The single controller that runs both ramps can be coordinated with adjacent intersections, but the two ramp signals are on one controller. The 4 phase sequence is used when queue storage between the ramp intersections is critical as it tends to not store any vehicles between the two ramp intersections.

A TUDI may not need to implement Texas Diamond 4-Phase operation. Geometric constraints may warrant the construction of a TUDI, but operational benefits of the Texas

Diamond Phasing may not be needed and conventional signal phasing can be used.

501.2.1.2 - Single Point Urban Interchange (SPUI)

The SPUI, is another variation of the compressed diamond interchange. It was developed to streamline operations by using a single traffic signal to control traffic movements within the interchange area. The SPUI also requires less right-of-way than a conventional diamond interchange.



I-270 & Sawmill Road SPUI (Source: Google)

A SPUI should be considered:

- In areas with limited right-of-way.
- At locations with heavy left turn volumes both on and off the ramps.
- At locations where a wider structure or intersection can be accommodated.

SPUIs offer the following benefits:

- Construction in a relatively narrow right-of-way, resulting in potentially significant cost reductions.
- Since the SPUI has only one intersection, as opposed to two for a diamond interchange, the operation of the single traffic signal on the crossroad may result in reduced delay through the intersection area when compared to a diamond interchange.
- Improved safety since vehicles only cross paths at one intersection instead of two.

- Right turn movements both on and off the ramps are typically free flow or yield control.
- Only the left turns pass through the signalized intersection. As a result, a major source of traffic conflict is eliminated, increasing overall intersection efficiency and reducing the traffic signal phasing needed from four-phase to three-phase operation.
- The turning angle and curve radii for left-turn movements through the intersection are significantly flatter than at conventional intersections and, therefore, the left turns move at higher speeds. The left turn angle is typically 45 to 60 degrees with a minimum radius of 150 to 200 ft. The above-mentioned operations may result in a higher capacity than a conventional tight diamond interchange.

Limitations/disadvantages of a SPUI include:

- Construction costs of SPUIs tend to be much higher than conventional diamond interchanges due to costs associated with the bridges. Overpass SPUIs need long bridges to span the large intersection below. A two-span structure is not a design option because a center column would conflict with traffic movements. Single-span overpass bridges are typically 220 ft in length, while three-span bridges often exceed 400 ft. The SPUI underpass tends to be wide and often is “butterfly” in shape. Rectangular SPUI structures, while resulting in unused deck area, may provide additional area for maintenance of traffic and simplified construction. Where right-of-way is constrained, SPUIs typically utilize extensive retaining walls, further adding to the cost. However, the higher construction cost of SPUIs is often offset by the reduced right-of-way cost.
- A potential disadvantage of SPUIs is the length and geometry of the path for left-turning vehicles through the intersection. Like typical intersections, left-turning vehicles pass to the left of opposing left-turning vehicles. Due to the size and distance between opposing approaches, the path of left-turning vehicles does not resemble a quarter of a circle found at typical intersections, but rather resembles a quarter of an ellipse. To provide positive guidance for this non-traditional path dashed lane lines should be painted through the intersection.
- A skew angle between the two roadway alignments has an adverse effect on SPUIs because it increases clearance distances and adversely affects sight distance. Severe skew in alignments may also increase the length of the bridge and widen the

distance between the stop bars on the local streets. Extreme care should be exercised in planning SPUIs when the skew angle approaches 30 degrees. It is important to provide visibility between exit ramp traffic and cross street traffic approaching from the left. For left-turn movements from the mainline's ramp to the cross street, provide a clear cornering sight line with no obstructions from bridge abutments, pilasters, signal/light poles, signing, or landscaping.

- It is often cost prohibitive to widen the SPUI in the future. A full build based on future traffic projections may lead to increased construction costs of the structure.

Design considerations of a SPUI include:

- It is desirable that the left-turn curve be a single radius. This will, however, typically result in additional right-of-way, a larger bridge structure, or both. Where it is not practical to provide a single radius and curves are compounded from a larger to a smaller radius, the second curve should be at least half the radius of the first.
- Stopping sight distance should be provided on the left-turn movements equal to or exceeding the design speed for the curve radius involved.
- Additional median width on the cross street can improve intersection operation. The stop bar location on the cross street is dependent on the wheel tracks from the opposing ramp left-turn movement. By widening the median, the stop bar on the cross street can be moved forward, thus reducing the size of the intersection and the distance each vehicle travels through the intersection. The results include greater available green time and less potential driver confusion due to an expansive intersection area.
- Provide a minimum clear distance of 10 ft between opposing left turns within the intersection.
- Pedestrian crossing of the local street at ramp terminals typically adds a signal phase and uses considerable green time, resulting in reduced operational efficiency. Therefore, the overall design should include provision for pedestrian crossings at adjacent intersections instead of at the ramp terminal intersection.
- Right-turn lanes at SPUIs are typically separated from the left-turn lanes, often by a considerable distance. The exit ramp right turn can be a free or controlled movement. The design of free right turns should include an additional lane on the cross street

beginning at the free right-turn lane for at least 300 ft before being merged. Free-flow right turns from the exit ramp to the crossroad may or may not be desirable depending on the traffic operational analysis which includes the downstream intersection(s) of the crossroad. There may be inadequate weaving distance between the exit ramp and the adjacent intersection. Where the right-turn movement is controlled by a stop sign or traffic signal, adequate right-turn storage on the exit ramp should be provided to prevent blockage of vehicles turning left or traveling straight. Free-flow right turns on entrance ramps pose little operational concern, assuming adequate merge length is provided on the entrance ramp. The right-turn lane should extend at least 300 ft beyond the convergence point before beginning the merge.

501.2.1.3 - Diamond Interchange with Roundabouts

Roundabout interchanges utilize roundabouts at either one or both ramp intersections. Additional bridge width is usually not necessary at roundabout interchanges due to the elimination of turn lanes. The benefits and costs associated with this type of interchange also follow those for a single roundabout.

Roundabouts may be a good alternative if the interchange has a high proportion of left turn flows from the off ramps and to the on ramps during peak periods, combined with limited queue storage space on the bridge crossing, off-ramps, or arterial approaches. In such circumstances, roundabouts operating within their capacity are particularly useful in solving these problems when compared with other forms of intersection control.

The raindrop roundabout interchange design exhibits very little queuing between the intersections since these movements are almost unopposed. This allows the approach lanes across the bridge to be minimized. Conversely, drivers do not have to yield when approaching from the connecting roadway between the two roundabouts. If the roundabout is designed poorly, drivers may be traveling faster than they should to negotiate the next roundabout safely; therefore, the relative speeds need to be evaluated.

A potential benefit of roundabout interchanges is that the queue length on the off-ramps may be less than at a signalized intersection.

501.2.1.4 - Diverging Diamond Interchange (DDI)

The Diverging Diamond Interchange (DDI) is a variation of a conventional diamond interchange. The DDI uses directional crossover intersections to shift traffic on the cross street to the left-hand side between the ramp terminals within the interchange. Crossing the through movements to the opposite side replaces left-turn conflicts with same-direction merge/diverge movements and eliminates the need for exclusive left-turn signal phases to and from the ramp terminals. All connections from the ramps to and from the cross street are joined outside of the cross-over intersections, and these connections can be controlled by two-phase signals, have stop or yield control, or be free flowing provided there are no access points downstream creating a weaving situation.

A DDI should be considered:

- At locations where there is limited roadway width for left-turns between ramp intersections and limited right-of-way to expand.
- At locations with heavy left turn volumes both on and off the ramps.
- At locations without adjacent traffic signals/nearby driveways.
- At locations where adjacent traffic signals are present and the adjacent intersections can be modified through retiming or rephasing.

The DDI offers the following benefits:

- Improved safety due to the reduction in the number of conflict points (locations where vehicle paths cross), vehicle-to-vehicle, vehicle-to-pedestrian and vehicle-to-bike.
- By allowing the ramp-terminal intersections to operate with two-phase signal operations, provides flexibility to accommodate a greater volume of traffic and operate with less delay.
- Overall operations of a DDI may be greater compared to a conventional signalized diamond interchange due to shorter cycle lengths, reduced time lost per cycle phase, reduced stops and delay, and shorter queue lengths.
- The DDI also reduces the number and severity of conflict points for both motorized and nonmotorized users. The crossing distances for pedestrians are comparatively shorter, and usually involve traffic approaching from only one direction at a time. The cross-sectional characteristics of a DDI provide multiple options for facilitating

convenient pedestrian and bicycle movements, and the geometry of the crossover intersections have an added benefit of reducing motorized vehicle speeds through the interchange, resulting in a traffic calming effect which may reduce crashes.

- Retrofitting an existing conventional diamond interchange to a DDI may be less costly than options involving widening the crossroad near the interchange (including widening the bridge) and adding additional lanes to the ramps.
- For new interchanges, the operational efficiency of a DDI may allow for a smaller structural footprint since fewer lanes are generally needed to accommodate the traffic demands. In some contexts, the DDI may allow for reduced right-of-way needs and construction costs compared to other interchange forms.
- The large channelizing islands help reduce wrong-way movements onto the exit ramps.
- Accommodates either overpass or underpass designs.
- Provides improved bicycle/pedestrian safety by using one sidewalk through the median; as opposed to, two sidewalks to the outside perimeter of the DDI. The median sidewalk creates fewer ramp crossings and removes left turning vehicle conflicts with bicycles/pedestrians.



I-270 & Roberts Road DDI (District 6)

Limitations/Disadvantages of a DDI include:

- Crossing traffic to the “wrong side” of the road may not meet driver expectations.

- A DDI does not allow free flowing traffic on the crossroad in both directions since the signals cannot be green at both intersections for both directions at the same time.
- The potential operational benefits of the DDI ramp intersections may be overshadowed by poor operational performance of nearby signals on the crossroad. If an adjacent signal is too close and the queue storage length is inadequate, the traffic spillback may inhibit the movement of traffic along the crossroad, and potentially block traffic from the exit ramps.
- The DDI design does not accommodate typical “up and over” exit to entrance movements for oversized vehicles or authorized vehicles during maintenance or emergency situations.
- Crossroads that are heavily skewed to the main facility typically need greater intersection spacing.

None of the items listed above will necessarily preclude the use of a DDI, but are considerations.

Design considerations for a DDI include:

- It may be advantageous to use multiple structures at the grade separation, especially where the skew angle between facilities is significant.
- The spacing between ramp intersections will impact signal design and operations on the crossroad corridor but very tight spacing between ramp intersections may constrain the design of the crossovers and limit queue storage and signal timing options.
- The proximity to a DDI of adjacent signalized intersections along the crossroad may impact the performance of the DDI at a given location. Modifications to adjacent signalized intersections along the crossroad may be necessary to maintain the overall signal progression along the corridor and reduce potential effects of queue spillback.
- Analysis of adjacent intersections needs to be checked to ensure bottlenecks will not occur preventing the DDI from seeing the anticipated design traffic volumes. Oftentimes, the interchange intersections have been the bottleneck in the past and when the DDI’s two-phase signals interact with the adjacent intersections four-phase signals the adjacent intersections are exposed as a bottleneck.

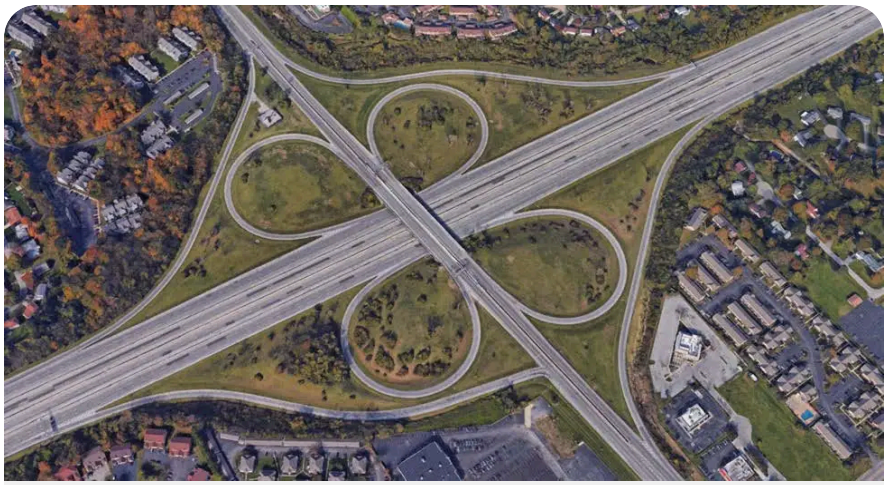
- The through movement queues need to be checked at the crossovers for blockage of the free- flowing left and right turns to and from the ramps. Auxiliary lanes may be needed for the turn lanes if blockage occurs. If an auxiliary lane is needed for the left turning vehicles onto the entrance ramp the auxiliary lane should be developed prior to the upstream crossover since it is undesirable to have lane changing movements in between the crossovers.
- Design speeds for crossover alignments should be in the range of 10 mph minimum to 15 mph maximum below the legal posted speed of the roadway, with a minimum design speed of 25 mph.
- Cross slopes are typically in the range of plus or minus 2 percent.
- Higher approach speeds need to be lowered to the crossover design speeds with advance warning signs and geometric features (reverse curves, etc.).
- A minimum of 100 ft of tangent between the reverse curves through the crossover should be provided in both directions. The tangent helps to maintain the desired vehicle tracking and the curve-tangent- curve sequence promotes driving at the desired target speed. Section 6.4.7.5 of NCHRP 959 provides guidance on determining the crossover tangent length.
- Radii at the exit and entrance ramp movements are like other interchanges and include allowance for the turning path of the design vehicle, sight distance, pedestrians, bicycles and the intersection traffic control type.
- The crossing angle is the acute angle between lanes of opposing traffic within the crossover based on the tangent sections. The greater the crossover angle, the more the crossover will appear like a “normal” intersection of two different cross routes and decrease the likelihood of a driver making a wrong-way movement. However, greater crossing angles generally result in larger footprints. Larger crossing angles in combination with sharp reverse curves can increase the potential for overturning of vehicles with high centers of gravity and excessive driver discomfort through the crossovers. The recommended approach is to attain the largest crossing angle possible that is in balance with the other geometric parameters and site constraints. The crossover angle of a DDI is generally between 40 to 50 degrees. Crossover angles less than 30 degrees may increase the potential for wrong-way movements.

- Lane widths along the crossroad of a DDI typically range from 12 to 15 ft depending on site location and consideration for design vehicles traveling side by side through the crossover area. The wider lane width typically occurs prior to and after the crossover curves. The additional lane width does not need to be continued between the two crossovers.
- The shoulders required by the crossroad should also be provided through the DDI. The outside shoulder will become the inside shoulder between the crossover intersections.
- Sight distance at DDIs is important for both vehicles maneuvering through the crossovers or turning left and right from the ramp terminals onto the cross street, especially when the turning ramp terminal traffic is under yield control.
- Provide left turn lanes on exit ramps with enough curvature to ensure drivers turn into the inside through lanes and not make a wrong way turn.
- Place the left turn on the exit ramps as close to the cross-over as possible to reduce clearance time (all-red) to improve signal efficiency.

The FHWA **Diverging Diamond Interchange Informational Guide** provides additional information on diverging diamond interchanges.

501.2.2 - Cloverleaf Interchange

Cloverleaf designs may be used in lieu of a diamond when a continuous flow design is required where two major facilities intersect. In this case, a full cloverleaf interchange is the minimum design that can be used. The designer should consider collector-distributor roads in conjunction with cloverleaf interchanges to minimize weaving.



I-270 & East Main Street Full Cloverleaf Interchange (Source: Google)

However, full cloverleafs have deficiencies which need to be addressed before being chosen as the interchange type. Principle disadvantages are:

- The inherent weaving maneuver generated and the short weaving length available.
- Large trucks may not be able to operate efficiently on the smaller curve radii on the associated loop ramps.
- Loop ramps are limited in capacity.

When Collector-Distributor roads are not used, a further disadvantage includes weaving on the main line, the double exit on the main line and problems associated with signing for the second exit.

The full cloverleaf weaving maneuver is not objectionable when the left-turning movements are relatively light, but when the sum of traffic volumes on two adjoining loops approaches about 1,000 vehicles per hour, interference occurs, which results in a reduction in the speed of the mainline traffic. When the weaving volume in a section exceeds 1,000 vehicles per hour, the quality of service on the main facility deteriorates, generating a need to transfer the weaving section from the through lanes to a C-D road. For these reasons, full cloverleafs are discouraged.

501.2.2.1 - Partial Cloverleaf Interchange

Partial cloverleaf designs may be used in lieu of a diamond when development or other physical conditions prohibit construction in a quadrant, or where heavy left turns are

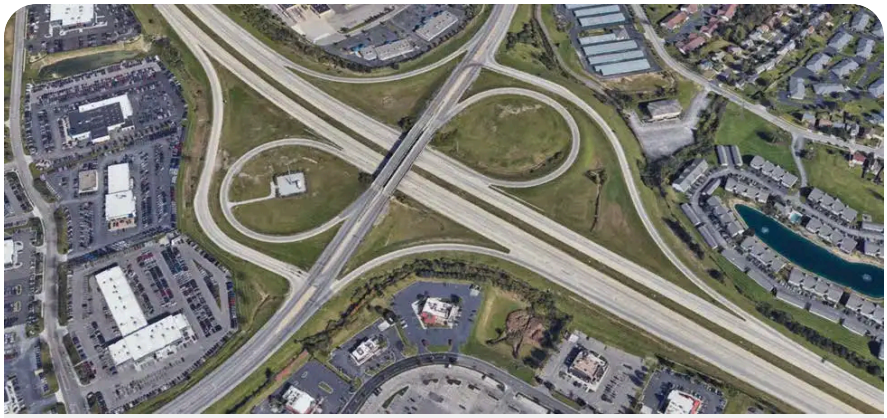
involved. In the design of partial cloverleafs, the site conditions may offer a choice of quadrants to use. However, at an interchange site, topography and culture may be the factors that determine the quadrants in which the ramps and loops can be developed. There is considerable operational advantage in certain arrangements of ramps. These are discussed and summarized below.

Ramps should be arranged so that the entrance and exit turns create the least impediment to the traffic flow on the major highway. The following guidelines should be considered in the arrangement of the ramps at partial cloverleafs:

The ramp arrangement should enable major turning movements to be made by right-turn exits and entrances.

Where through-traffic volume on the major highway is decidedly greater than that on the intersecting minor road, preference should be for an arrangement that places the right turns (either exit or entrance) on the major highway, even though this results in a direct left turn off the crossroad.

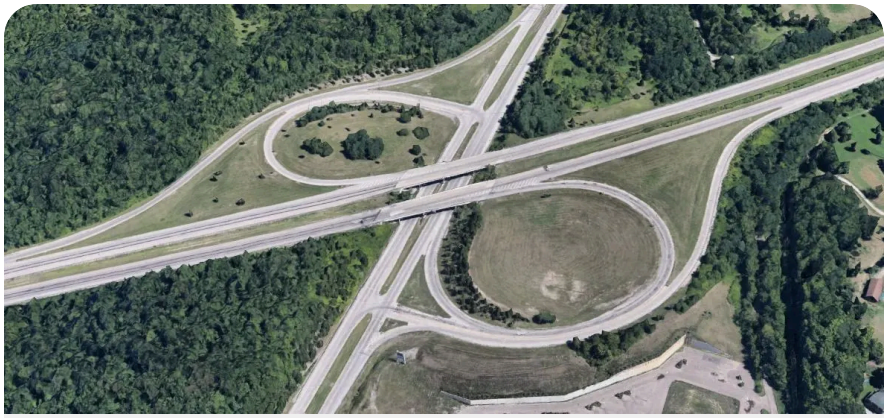
These controls do not always lead to the most direct turning movements. Instead, drivers frequently may need to first turn away from or drive beyond the road that is their intended destination. Such arrangements cannot be avoided if the through-traffic movements, for which the separation is provided, are to be facilitated to the extent practical.



I-270 & Georgesville Road Partial Cloverleaf A Interchange (4 Quadrant ParClo A) (Source: Google)

The ParClo A layout has loop ramps that are in diagonally opposite quadrants and the ramps are on the near side of the structure as drivers approach on the major road.

Preferred for a high volume of left- turns from the crossroad to the mainline. Weaving between the loop ramps is eliminated.



I-71 & SR 48 Partial Cloverleaf B Interchange (2 Quadrant ParClo B) (Source: Google)

The ParClo B layout has loop ramps that are in diagonally opposite quadrants and the ramps are on the far side of the structure as drivers approach on the major road. Preferred for a high volume of left-turns from the mainline to the crossroad. Weaving between the loop ramps is eliminated.

For additional information and types of Partial Cloverleaf Interchanges, see the AASHTO Green Book, Chapter 10.

501.2.3 - Directional Interchanges

Directional interchanges are the highest type and most expensive. They permit vehicles to move from one major freeway to another major freeway at relatively fast and safe speeds.

502 - Interchange Design Considerations

502.1 - Determination of Interchange Configuration

Interchange configurations are covered in two categories, “system interchanges” and “service interchanges.” The term “system interchange” is used to identify interchanges that connect two or more freeways, whereas the term “service interchange” applies to interchanges that connect a freeway to lesser facilities. Generally, interchanges in rural areas are widely spaced and can be designed on an individual basis without any appreciable effect from other interchanges within the system. However, the final configuration of an interchange may be determined by the need for route continuity,

uniformity of exit patterns, single exits in advance of the separation structure, and elimination of weaving on the main facility, signing potential, and availability of right-of-way. Selecting an appropriate interchange configuration in an urban environment involves considerable analysis of prevailing conditions so that the most practical interchange configuration alternatives can be developed. Generally, in urban areas, interchanges are so closely spaced that each interchange may be influenced directly by the preceding or following interchange to the extent that additional traffic lanes may be needed to satisfy capacity, weaving and lane balance. Interchanges should provide for all movements, even when an anticipated turning movement volume is low.

Once several alternates have been prepared for the system design, they can be compared on the following principles: (1) capacity, (2) route continuity, (3) uniformity of exit patterns, (4) single exits in advance of the separation structure, (5) with or without weaving, (6) potential for signing, (7) cost, (8) availability of right-of-way, (9) constructability, and (10) compatibility with the environment.

502.2 - Approaches to the Structure

502.2.1 - Alignment, Profile and Cross Section

Traffic passing through an interchange should be afforded the same degree of utility and safety as that given on the approaching roadways. The design speed, alignment, profile and cross section in the interchange area should be consistent with those on the approaching highways. Four-lane roadways should be divided at interchanges with a non-traversable median to ensure that drivers use the proper ramps for left-turning maneuvers. At-grade left turns preferably should be accommodated within a suitably wide median.

502.2.2 - Sight Distance

Sight distance on the roadways through an interchange should be at a minimum the required stopping sight distance and preferably should be Decision Sight Distance (Figure 201-6), particularly along entrances and exits.

The horizontal sight distance limitations of piers and abutments at curves usually present a more difficult problem than that of vertical limitations. With the minimum radius for a given design speed, the normal lateral clearances at piers and abutments of underpasses does not provide the minimum stopping sight distance. Similarly, on overpasses with the sharpest curvature for the design speed, sight distance deficiencies result from the usual

offset to the bridge railing. Above minimum radii should be used for curvature on roadways through interchanges. If sufficiently flat curvature cannot be used, the clearances to abutments, piers or bridge railing should be increased to obtain the proper sight distance, even though this involves increasing structure spans or widths.

502.3 - Interchange Spacing

Interchanges should be located close enough together to properly discharge and receive traffic from other highways or streets, and far enough apart to permit the free flow and safety of traffic on the main facility. In general, more frequent interchange spacing is permitted in urbanized areas. Minimum spacing is determined by weaving requirements, ability to sign, lengths of speed change lanes, and capacity of the main facility.

Interchanges within urban areas should not be spaced closer than an average of 2 miles, in suburban sections an average of not closer than 4 miles, and in rural sections an average of not closer than 8 miles. In consideration of the varying nature of the highway, street or road systems with which the freeway or expressway must connect, the spacing between individual adjacent interchanges must vary considerably. In urban areas, the minimum distance between adjacent interchanges should not be less than 1 mile, and in rural areas not less than 3 miles. Spacing less than this have a detrimental effect on freeway operations.

502.4 - Uniformity of Interchange Patterns

Since interchange uniformity and route continuity are interrelated concepts, interchanges along a freeway should be reasonably uniform in geometric layout and general appearance to provide the appropriate level of service and maximum safety in conjunction with freeway operations. Except in highly special cases, all entrance and exit ramps should be on the right.

502.5 - Route Continuity

Route continuity is an extension of the principle of operational uniformity coupled with the application of proper lane balance and the principle of maintaining a basic number of lanes. The principle of route continuity simplifies the driving task in that it reduces lane changes, simplifies signing, delineates the through route and reduces the driver’s search for directional signing. Desirably, the through driver should be provided a continuous

through route on which changing lanes is not necessary to continue on the through route. In maintaining route continuity, interchange configuration may not always favor the heavy traffic movement, but rather the through route. In this situation, heavy movements can be designed on flat curves with reasonably direct connections and auxiliary lanes.

502.6 - Signing and Marking

The safety, efficiency and clarity of paths to be followed at interchanges depend largely on their relative spacing, geometric layout and effective signing and marking. The location of and minimum spacing between ramp terminals depends to a large degree on whether or not effective signing can be provided. Signing and marking should conform to the OMUTCD.

502.7 - Basic Number of Lanes

The basic number of lanes is defined as a minimum number of lanes designated and maintained over a significant length of a route, irrespective of changes in traffic volume and lane balance needs. (The basic number of lanes is a constant number of lanes assigned to a route, exclusive of auxiliary lanes, based on capacity needs of the section.)

502.8 - Coordination of Lane Balance and Basic Number of Lanes

Design traffic volumes and a capacity analysis determine the basic number of lanes to be used
on the freeway and the minimum number of lanes on the ramps. The basic number of lanes should be established for a substantial length of freeway and should not be changed through pairs of interchanges, simply because there are substantial volumes of traffic entering or leaving the freeway. There should be continuity in the basic number of lanes. Auxiliary lanes should be provided for variations in traffic demand.

After the basic number of lanes is determined for each roadway, the balance in the number of lanes should be checked on the basis of the following principles:

1. At entrances, the number of lanes beyond the merging of two traffic streams should not be less than the sum of all traffic lanes on the merging roadways minus one, but may be equal to the sum of all traffic lanes on the merging roadways.

2. At exits, the number of approach lanes on the roadway should be equal to the number of lanes on the roadway beyond the exit, plus the number of lanes on the exit, minus one. Exceptions to this principle occur at cloverleaf loop ramp exits that follow a loop ramp entrance and at exits between closely spaced interchanges. In these cases, the auxiliary lane may be dropped in a single-lane exit with the number of lanes on the approach roadway being equal to the number of through lanes beyond the exit plus the lane on the exit.

3. The traveled way of the highway should be reduced by not more than one traffic lane at a time.

502.9 - Auxiliary Lanes

An auxiliary lane is the portion of the roadway adjoining the traveled way for speed change, turning, storage for turning, weaving and other purposes supplementary to through-traffic movement. An auxiliary lane may be provided to comply with the concept of lane balance, to comply with capacity needs or to accommodate speed changes, weaving and maneuvering of entering or exiting traffic.

502.10 - Lane Reductions

The basic number of mainline lanes should not be reduced through a “service interchange”. If a reduction in the basic number of lanes is warranted by a substantial decrease in traffic volume over a significant length of freeway, then it should be reduced between interchanges. The reduction should occur 2,000 to 3,000 ft. from the end of the acceleration taper of the previous interchange to allow for adequate signing. The end of the lane reduction should be tapered at a rate of 70:1. The lane reduction should occur on a tangent section of freeway, preferably within a sag vertical curve, and provide Decision Sight Distance, Figure 201-6, where possible. The lane reduction should also be on the right side of the freeway.

502.11 - Weaving Sections

Weaving sections are highway segments where the pattern of traffic entering and exiting at contiguous points of access results in vehicle paths crossing each other. Weaving sections may occur within an interchange, between closely spaced interchanges or on segments of overlapping routes.

Because weaving sections cause considerable turbulence which results in a reduction in capacity, interchange designs that eliminate weaving or remove it from the mainline by the use of C-D roads are desirable.

The capacity of weaving sections may be seriously restricted unless the weaving section has adequate length, adequate width and lane balance. Refer to the **Highway Capacity Manual** for capacity analysis of weaving sections.

503 - Interchange Ramp Design

503.1 - General

An interchange ramp is a roadway which connects two legs of an interchange. Ramp cross section elements are discussed in Section 303.1. Elements contributing to horizontal and vertical alignments are designed similarly to any roadway (Section 200) once the ramp design speed has been determined.

503.2 - Ramp Design Speed

In order to design horizontal and vertical alignment features, a design speed must be determined for each ramp. Since the driver expects a speed adjustment on a ramp, the design speed may vary within the ramp limits. Figure 503-1 includes three ranges of ramp design speeds which vary with the design speed of the mainline roadway. The ramp design speed range is determined by engineering judgment based on several conditions:

1. The type of roadways at each end of the ramp and their design speeds,
2. The length of the ramp,
3. The terminal conditions at each end, and
4. The type of ramp (diamond, loop or directional).

Design exceptions will be required for speed related design criteria that do not meet the following:

- For directional ramps (roadways) that do not provide the minimum design speed given in **Section 503.2.3**.

- For loop ramps on high-speed roadways that do not provide a minimum design speed of 25 mph (150-ft radius).
- For all other ramps that, at a minimum, do not provide the lower range design speed of Figure 503-1.

503.2.1 - Diamond Ramp Design Speeds

Diamond ramps normally have a high-speed condition at one end and an at-grade intersection with either a stop or slow turn (15 mph) condition at the other. Upper to middle range design speeds in Figure 503-1 are normal near the high-speed facility with middle to lower range design speeds usually used closer to the at-grade intersection.

503.2.2 - Loop Ramp Design Speeds

Loop ramps may have a high speed condition at one end and, either a slow or high speed condition at the other. Loop ramps, because of their short radius, usually have design speeds in the lower range in the middle and slow speed end of the ramp with middle range design speeds occasionally used nearer the high speed terminal. For design speeds, see Figure 503-1. The minimum loop ramp radius is 150 feet (50 m).

503.2.3 - Directional Ramp Design Speeds

Directional ramps (roadways) generally have high speed conditions at both ends. They are normally designed using a design speed falling into the upper range of Figure 503-1. The absolute minimum should be the middle range design speeds. When a directional ramp requires a design exception for horizontal curve radius, selecting a pavement material that will increase the friction on the roadway should be considered.

503.3 - Vertical Alignment

Maximum grades for vertical alignment cannot be as definitely expressed as for the highway, but should preferably not exceed 5 percent. General values of limiting upgrades are shown in **Table 503-1**, but for any one ramp the grades to be used are dependent upon a number of factors. These factors include the following:

1. The flatter the gradient on the ramp relative to the freeway grade, the longer the ramp will be.

2. The steepest grades should occur over the center part of the ramp. Grades at the terminal ends of the ramp should be as flat as possible.
3. Short upgrades of 7 to 8 percent permit good operation without unduly slowing down passenger cars. Short upgrades of as much as 5 percent do not unduly affect trucks and buses.
4. Ramp grades and lengths can be significantly impacted by the angle of intersection between the two highways when the angle is 70 degrees or less. The direction and grade on the two highways may also have a significant impact.
5. Adequate sight distance is more important than a specific gradient control and should be favored in design.

Table 503-1 - Maximum Ramp Upgrades

Ramp Design Speed	25-30 mph	35-40 mph	45 mph and above
Desirable Grade (%)	5	4	3
Maximum Grade (%)	7	6	5

Note: Downgrades may exceed the table values by 2% but not exceed an 8% maximum.

503.4 - Horizontal Alignment

Horizontal alignment will be largely determined by the selected design speed and type of ramp. The horizontal alignment criteria found in Section 202 also applies to ramps. Check that the required horizontal stopping sight distance is provided. Use the allowed skew at the ramp terminal at-grade intersection to minimize curvature.

Depending on the design speed and curvature, curve widening may be required on a two-lane ramp. See **Section 301.1.3** andFigure 301-5c. The WB-62 [WB-19] design vehicle should be used for Interstate ramps.

503.5 - Ramp Terminals

The terminal of a ramp is that portion adjacent to the through traveled way, including speed change lanes, tapers and islands. Ramp terminals, as opposed to diverging roadways, require speed change lanes. Ramp terminals may be the at-grade type, as at the crossroad terminal of diamond or partial cloverleaf interchanges, or the free-flow type where ramp traffic merges with or diverges from high-speed through traffic at flat angles. Terminals are further classified as either single-lane or multi-lane and as either a taper or parallel type.

503.5.1 - General Considerations

While interchanges are custom designed to fit specific site conditions, it is desirable that the overall pattern of exits along the freeway have some degree of uniformity. It is desirable that all interchanges have one point of exit located in advance of the crossroad wherever practical.

Because considerable turbulence occurs throughout weaving sections, interchange designs that eliminate weaving entirely or at least remove it from the mainline are desirable. Weaving sections may be eliminated from the mainline by the incorporation of C-D roadways or grade separating the ramps (braiding).

Interchanges that provide all exit movements before any entrance movements will also eliminate weaving and are highly recommended.

503.5.2 - Left-hand Entrances and Exits

Left-hand entrances and exits are contrary to the concept of driver expectancy when intermixed with right-hand entrances and exits. Therefore, extreme care should be exercised to avoid left-hand entrances and exits in the design of interchanges. Because they are contrary to driver expectancy, special attention should be given to signing and the provision for decision sight distances to alert the driver an unusual condition exists.

503.5.3 - Distance Between Successive Ramp Terminals

In urban areas ramp terminals are often located in close succession. To provide sufficient weaving length and adequate space for signing, a reasonable distance should be provided between successive ramp terminals. Spacing between successive outer ramp terminals is dependent on the classification of the interchanges involved, the function of the ramp pairs (entrance or exit), and weaving potential. Minimum spacing for various ramp combinations are shown in Figure 503-1a.

Where an entrance ramp is followed by an exit ramp, that absolute minimum distance between the successive noses is governed by weaving considerations. This spacing is not applicable to cloverleaf interchanges as the distances between entrance-exit ramps noses is dependent on loop ramp radii and other factors. When the distance between successive noses is less than 1,500 ft. the speed change lanes should be connected to provide an auxiliary lane to improve traffic flow over a relatively short section of the freeway.

503.6 - Single-Lane Ramp Terminals

This discussion is limited to terminals used for single-lane entrance and exit ramps only. See **Section 505** for multi-lane transitions. Ohio's standards currently permit a parallel exit terminal and tapered entrance terminal.

503.6.1 - Terminal Classification

Ohio uses two basic ramp terminal classifications.

High-Speed Terminals (See Figures 503-2a, 503-2b and 503-2c, along with Figures 503-3a, 503-3b and 503-3c) - High-Speed terminals are intended for use on all Interstate highways and on other limited access freeways or expressways having similar design standards and a minimum mainline design speed of 50 mph.

Low-Speed Terminals (See Figures 503-4a and 503-4b) - Low-Speed terminals (mainline design speeds of 45 mph or less) are intended for use on all other limited access expressways or other highways which have little or no access control except through an interchange area. Many of the features of Low-Speed terminals are applicable to a terminal of one ramp with another ramp. Low Speed terminals are also used with Low-Speed C-D Roads.

503.6.2 - Single-Lane Entrance Terminals

503.6.2.1 - High-Speed

The typical single-lane entrance terminal consists of two parts, an acceleration lane and a taper. The acceleration lane allows the entering vehicle to accelerate to the freeway speed and evaluate gaps in the freeway traffic. The taper is provided for the entering vehicle to merge into the chosen gap in freeway traffic. The minimum taper rate is 50:1.

The length of the acceleration lane varies depending on the design speed of the last ramp curve on the entrance ramp and the design speed of the mainline. Figure 503-2aprovides the minimum lengths of acceleration lanes for entrance ramp terminals. When the average grade of the acceleration lane exceeds 3%, the acceleration length obtained from Figure 503-2a should be adjusted by the factor obtained from Figure 503-2b. The acceleration lane length is measured from the last entrance ramp curve point (PT or CS) to the point where the right edge of traveled way of the ramp is 12 feet from the right edge of the through traveled way of the freeway. Figure 503-2c illustrates the typical design of a single-lane entrance ramp terminal.

If the entrance terminal results in an add-lane (no merge), delete the last 600’ of the 50:1 taper of Figure 503-2c. All other entrance terminal dimensions of Figure 503-2c remain the same.

Referring to Figure 503-2c, when the required acceleration length (L from Figure 503-2a, adjusted to grade, Figure 503-2b) is less than the acceleration length provided by the 200 ft. spiral plus 650 ft. of the 50:1 taper, then a parallel acceleration length is not required and the terminal becomes the minimum acceptable design consisting of the 200 ft. spiral and the 1,250 ft. 50:1 taper.

503.6.2.2 - Low-Speed

Figure 503-4a provides the Low-Speed Entrance Terminal designs for mainline design speeds equal to or less than 45 mph.

503.6.3 - Single-Lane Exit Terminals

503.6.3.1 - High-Speed

The typical single-lane exit terminal consists of two parts, a taper for maneuvering out of the through traffic lane and a deceleration lane to slow to the speed of the first curve on the

ramp. All deceleration should occur on the full width deceleration lane and not on the mainline or the taper.

The length of the deceleration lane varies depending on the design speed of the mainline and the design speed of first geometric control on the exit ramp, usually a horizontal curve but could be the stopping sight distance on a vertical curve or the back of an anticipated traffic queue. Figure 503-3a provides the minimum lengths of deceleration lanes for exit ramp terminals. When the average grade of the deceleration lane exceeds 3 percent, the deceleration length obtained from Figure 503-3a should be adjusted by the factor obtained from Figure 503-3b. The deceleration lane length is measured from the point where the taper reaches a width of 12 feet to the first point that governs the design speed of the exit ramp, usually the PC of the first curve. Figure 503-3c illustrates the typical design of a single-lane exit ramp terminal.

The deceleration length is the maximum of either 800 ft. or the deceleration length in Figure 503-3a multiplied by the adjustment factor as a function of grade in Figure 503-3b.

503.6.3.2 - Low-Speed

Figure 503-4b provides the Low-Speed Exit Terminal design for mainline design speeds equal to or less than 45 mph.

503.6.4 - Superelevation at Terminals

Superelevation at ramp terminals should be developed using the following guidelines:

The rate of superelevation at the entrance and exit nose shall be selected on the basis of the design speed of the ramp at the nose.

All transverse changes or breaks in superelevation shall be made at joint lines (See **Standard Construction Drawing BP-6.1**). In the case of asphalt concrete pavement, the superelevation breaks should occur in the same locations as they would in concrete pavement.

For High-Speed terminals, the transverse breaks in superelevation cross-slope shall not exceed a differential of 0.032 at the mainline edge of traveled way or 0.050 at other locations. If a double break occurs on longitudinal joints less than 6 ft. apart, it shall not

exceed a total differential of 0.032, if adjacent to the mainline, or 0.050 elsewhere. On Low-Speed terminals the transverse breaks in superelevation cross-slope shall not exceed a differential of 0.05 to 0.06.

For High-Speed terminals, the rate of rotation of a superelevated ramp pavement or speed change lane pavement shall be in accordance with Section 202.4.

Where possible, the terminal area pavement and shoulder should slope away from the mainline pavement so that a minimum amount of water drains across the mainline pavement.

503.6.5 - Terminals on Crest Vertical Curves

Mainline crest vertical curves in the vicinity of ramp terminals should be designed using decision stopping sight distances. When it is not feasible to provide decision stopping sight distance, at a minimum, 125% SSD (Figure 201-1) should be provided. Where a crest vertical curve occurs on an exit ramp at or near the nose, the crest vertical curve should be designed using the "upper range" design speeds of Figure 503-1.

503.7 - Ramp At-Grade Intersections

Ramp at-grade intersections are designed using much of the same criteria as outlined in Section 401 (the normal design vehicle for Interstate ramps is the WB-62 [WB-19]). However, one of the basic differences is the one-way nature of ramps and the fact that most traffic at ramp intersections is turning. Figure 503-5 shows the design of a typical uncurbed ramp intersection. Curbed returns are normally used in urban areas where space is more restricted.

Intersection Sight Distance, Section 201.3, should be provided at all ramp at-grade intersections.

Exit ramps may require multiple lanes at the crossroad intersection to provide additional storage and capacity. Figure 503-5a illustrates alternate ways to transition from a single lane exit ramp to two lanes. The additional lane is usually provided for the minor movement.

504 - Collector - Distributor (C-D) Roads

504.1 - Use of C-D Roads

The reason for using C-D Roads is to minimize weaving problems and reduce the number of conflict points (merging and diverging) on the mainline. C-D Roads may be used within a single interchange, through two adjacent interchanges, or continuously through several interchanges.

504.2 - Design of C-D Roads

When a C-D Road is provided between interchanges, a minimum of two lanes should be used. Either one or two lanes may be used on C-D Roads within a single interchange. The cross section elements for one and two lane C-D Roads should be in accordance with the one lane and two lane directional roadways shown in Figure 303-1. The design speed of a C-D Road should normally be the same as the mainline design speed but may be reduced by not more than 10 mph unless the reduction results in a design speed of less than 55 mph.

The separation between the mainline and C-D Road pavements should be designed to prevent, or at least discourage, indiscriminate crossovers. As a minimum, the separation should be wide enough to provide normal shoulder widths for both the mainline and C-D Road roadways plus a suitable median. Normally, a standard concrete barrier median is used since C-D Road separation often involves obstructions such as bridge parapets, piers or overhead sign supports. There may be isolated cases where a lesser type median may be used.

504.3 - C-D Road Entrance and Exit Terminals

Figure 504-1 shows both Low-Speed and High-Speed C-D Road entrance terminals. Three exit terminal lane conditions are shown on Figure 504-2. These terminal designs are to be applied to highways using High-Speed exit terminals.

Superelevation at C-D Terminals shall be developed similar to that described in **Section 503.6.4**.

505 - Multi-Lane Ramp & Roadway Terminals and Transitions

When two roadways converge or diverge, the less significant roadway should exit or enter on the right. Left-hand exits or entrances are contrary to driver expectancy and should be

avoided wherever possible.

505.1 - Multi-lane Entrance Ramps and Converging Roadways

505.1.1 - General

Figure 505-1a shows the design to be used for multi-lane entrance ramps and converging roadways. Converging roadways are defined as separate and nearly parallel roadways or ramps which combine into a single continuous roadway or ramp having a greater number of lanes beyond the nose than the number of lanes on either approach roadway. (Single-Lane Entrance Terminals should be used in lieu of Converging Roadway drawings when a speed change lane is required.)

Figure 505-1b shows the specific design to be used for two-lane High-Speed entrance ramps.

High-Speed Converging Roadways should be used when either or both of the Converging Roadways are mainline roadways of an expressway or freeway or if the design speed of converging directional ramps is 50 mph or higher. Low-Speed Converging Roadways should be used at the convergence of directional ramps within an interchange or at the convergence of interchange ramps with non-limited access roads or streets where design speeds are 45 mph or lower.

505.1.2 - Lane Balance and Continuity

In order to avoid inside merges, the number of mainline lanes plus converging lanes approaching the nose must be equal to the resultant number of lanes leaving the nose. To make this possible, it is often necessary to carry additional mainline lanes past the nose for an adequate distance prior to tapering back to the desired number of lanes. These details are shown in Figure 505-1a.

505.1.3 - Inside Merges

When using a taper type of multilane entrance ramp an “inside merge” is created with traffic traveling on both sides of the merging lanes. If either vehicle involved with the merging movement abandons the merge, traffic in the adjacent lanes could prevent the merging vehicles from escaping to the adjacent lanes. By contrast, the parallel type multilane entrance ramp, as shown in Figure 505-1a, allows the merging vehicle to escape

to the right shoulder without any interference. For the above reasons, inside merges are not desirable.

505.1.4 - Preferential Flow

On Figure 505-1a, one roadway in each design is labeled PREFERENTIAL FLOW. This indicates the more important of the two approaching traffic flows. In selecting the preferential flow a designer must consider the effect of traffic volumes, number of lanes, sign route continuity and importance, vehicle speeds and roadway alignment. Lanes carrying the preferential flow are given the higher design treatment. When it is necessary to reduce a number of converging lanes or where an angular change in direction must occur, the design should favor the preferential flow.

505.1.5 - Horizontal Curvature

Horizontal curves of roadways approaching the terminal nose should conform to mainline roadway criteria in the case of mainline roadways and to ramp entrance terminal criteria in the case of ramps.

505.1.6 - Crest Vertical Curves

Crest vertical curves on constant-width roadways approaching the merging nose should be designed to provide sight distance consistent with the design speed of the roadway.

Crest vertical curves from the merging nose forward to a point where pavement convergence ceases and to the converging portion of an approaching roadway where the number of lanes is being reduced in advance of the nose should be designed using the decision stopping sight distance shown in Figure 201-6. (See Figure 505-1a.) When it is not feasible to provide decision stopping sight distance, at a minimum, 125% SSD (Figure 201-1) should be provided.

When design speeds differ on approaching roadways, the higher of the two design speeds shall be used in designing the crest vertical curve beyond the merging nose.

505.1.7 - Superelevation and Joint Location

Reference shall be made to **Section 503.6.4** for superelevation requirements.

Longitudinal joints should be located so they will coincide with and define the lane lines. Reference should be made to **Standard Construction Drawing BP-6.1** for type and location.

505.2 - Multi-lane Exit Ramps and Diverging Roadways

505.2.1 - General

Figure 505-2a shows the general design for multi-lane exit ramps and diverging roadways. A diverging roadway is defined as a single roadway which branches or forks into two separate roadways without the need of a speed change lane.

Figure 505-2b shows the specific designs to be used for a two-lane high-speed exit ramp at a system interchange or the exit from the mainline of a two-lane CD-Road. Type I should normally be used. Type II should only be used when queuing in the optional lane does not extend to the physical gore (long ramps, Parclo B, etc.).

Figure 505-2c shows examples of designs for diverging roadways.

Figure 505-2d shows the specific designs to be used for a two-lane high-speed exit ramp at a service interchange. Type I should normally be used. Type II should only be used when queuing in the optional lane does not extend to the physical gore (long ramps, Parclo B, etc.).

High-Speed Diverging Roadways should be used when either or both the diverging roadways are mainline roadways of an expressway or freeway or at the divergence of high-speed directional ramps within an interchange. Low-Speed Diverging Roadways should be used at the divergence of low-speed directional ramps within an interchange or at the divergence of ramps with non-limited access roads or streets.

505.2.2 - Lane Balance and Continuity

In order to have lane continuity, the number of mainline lanes leaving the diverging nose must be equal to the number of mainline lanes approaching the nose. The total number of lanes leaving the diverging nose (mainline lanes plus diverging lanes) must be one greater than the total number of lanes approaching the nose to obtain lane balance. The purpose for obtaining lane continuity and lane balance is to avoid a drop lane situation. See Figures 505-2a and 505-2b.

It may be necessary to obtain this lane balance by adding additional lanes upstream from the diverging nose. The length of each additional lane should be 2,500 ft. and should be introduced using a 0 to 12 ft. taper with a length of 100 ft. as shown on Figure 505-2b for the approach roadway class and design speed.

There may be conditions off the mainline, such as on Collector-Distributor Roads or within interchanges, where lane balance and continuity is less important. In such cases, the non-mainline roadway design on Figures 505-2a and 505-2b may be used.

505.2.3 - Terminal Design

The design of diverging roadway terminals is determined by the class and the design speed of the approach roadway and is based on the neutral gore length "L" and the nose width "N" (See Figure 505-2a).

Table A on Figure 505-2a lists length "L" and nose width "N" for various design speeds in diverging roadway classes. The "N" dimension should be exact, but the "L" dimensions may vary slightly from the Table A value.

505.2.4 - Horizontal Curvature

Table B on Figure 505-2a lists recommended values for the curve differential between the outer edges of traveled way of diverging roadways. These values apply only when the alignment between the diverging nose and the PC of the diverging curvature is on tangent or simple curvature.

When compounded or spiral curvature is used in the diverging area, it will be necessary to design diverging roadway alignments individually to provide the proper "L" and "N" for the approach roadway Class and design speed.

505.2.5 - Crest Vertical Curves

When a diverging nose is located on a crest vertical curve, this vertical curve shall be designed using the design speed of the approach highway and decision stopping sight distance from Figure 201-6. When it is not feasible to provide decision stopping sight distance, at a minimum, 125% SSD (Figure 201-1) should be provided.

505.2.6 - Superelevation and Joint Location

The superelevation rate will be based on the design speed of the approach roadway. Reference should be made to **Section 503.6.4** for other superelevation requirements.

Longitudinal joints should be located so they will define the lane lines. Reference should be made to **Standard Construction Drawing BP-6.1** for type and location. The joints in the gore area should be located to facilitate superelevation and pavement grading.

505.3 - Four Lane Divided to Two Lane Transition

Figure 505-3 shows a reversed curve design (Types A and B) a tapered design (Type C) and a design for a transition on a curve (Type D). The pavement transition should be located in an area where it can easily be seen. Intersections or drives should be avoided in the transition area. Vertical or horizontal curves should provide decision stopping sight distance.

Reverse curve transitions should normally be used for median widths of 20 ft. or wider.

Taper lengths are calculated as shown in Section 401.6.1.

506 - Service Roads

506.1 - Use of Service Roads

Service roads (frontage roads) are used to enhance capacity on the mainline, control access, serve adjacent properties, or maintain traffic circulation. They permit development of adjacent properties while preserving the through character of the mainline roadway. Service roads may be either one-way or two-way, depending on where they are located and the purpose they are intended to serve.

506.2 - Design of Service Roads

Although the alignment and profile of the mainline may have an influence, service roads are generally designed to meet the specific criteria based on functional classification (usually "local"), traffic volumes, terrain/locale and design speed. Two features, however, are unique to service roads and are further discussed below. They are (1) the separation between the service road and mainline and (2) the design of the crossroad connection.

The further the service road is located from the mainline, the less influence the two facilities will have on each other. A separation width that exceeds the clear zone measurement for each roadway is desirable. However, the separation should be at least wide enough to provide normal shoulder widths on each facility plus accommodate surface drainage and a suitable physical traffic barrier. Glare screen is desirable to screen headlights when the service road is two-way.

At crossroads, the distance between the mainline and service road becomes extremely critical. This distance should be great enough to provide adequate storage on the approaches to both the mainline and service road. The recommended minimum distance between the mainline and service road edges of traveled way is 150 ft. in urban areas and 300 ft. in rural areas. In addition, the designer should check the adequacy of stopping sight distance on the crossroad as well as intersection sight distance at the frontage road.

Since service roads are normally maintained by local governmental agencies, the pavement design should either meet, or exceed, that required by the maintaining agency.

550 - Requests for New or Revised Access Interstate Highways or Other Freeways

550.1 - General

Control of access on the Interstate and other freeway systems is considered critical to providing the highest quality of service in terms of safety and mobility. An access point is any permanent connection (including those metered or closed at times) to the through lanes or shoulders, managed lanes, collector-distributor roads, or ramps on the Interstate System, including “locked gate access”. This section provides guidance for the preparation and processing of access point requests in relation to new and existing interchanges on the Interstate and other freeway systems in accordance with Federal Code 23 U.S.C. 111 and 23 CFR Part 624 dated August 27, 2025.

The documentation required depends on the type of change requested - new or revised.

New Access is the addition of a point of access where none previously existed. This includes the construction of an entirely new interchange such that it will result in additional points of access or additional ramps to existing interchanges. As an example, the

reconstruction of an existing diamond interchange to a full cloverleaf interchange would add four new points of access.

Revised Access is the major revision of an existing interchange such that the number of access points will remain the same but the operation and/or safety of the Interstate/freeway system may be affected. The changing of a cloverleaf interchange to a fully directional interchange, the conversion of a traditional diamond to a diverging diamond interchange, relocating an existing ramp terminal to a new roadway, and adding a collector-distributor system are all considered examples of revised points of access.

New or revised access point requests require the preparation and processing of an Access Point Request Document. Generally, a new access requires an Interchange Justification Study (IJS) or an Interchange Modification Study (IMS). A revised access requires an Interchange Modification Study (IMS) or an Interchange Operations Study (IOS).

550.2 - Interchange Study (Access Point Request Document)

The degree of complexity of the Interchange Study will vary depending on the character of the location (urban or rural) and/or whether the change involves a revised access point, a new access point at an existing interchange, or an entirely new interchange location. To coincide with 23 CFR Part 624, the following is a list of items which must be addressed in the interchange study for a new or revised access on the Interstate/freeway system:

1. The interchange study shall be a standalone report with all relevant information from other previous documents included in the appropriate section of the study.
2. Every IMS/IJS shall include all of the following:

    A. A description and overview of the proposed change in access including a project location map and distances to adjacent interchanges. For requests involving entirely new interchanges, the study should include a discussion of the distance to, and size of, communities to be served by the new interchange. An examination of proper interchange spacing must also be included.

    B. Preliminary design documents demonstrating the geometric viability of the proposed change. This shall include the design criteria, existing geometry overlaid with clearly labeled proposed geometric plan views, lane configuration

schematics, typical sections, proposed right of way lines, interchange spacing, ramp spacing and other design features necessary to evaluate the proposed design. Proposed design must meet or exceed current design standards.

C. Operational analyses evaluating the impact of the proposed change in access on the Interstate/Freeway System and local road network extending to the following area of influence limits at a minimum:

   i. Along the Interstate/Freeway System, and interchanging freeway if applicable, to the adjacent existing or proposed interchange on either side of the proposed change in access, extending further as needed to ensure the limits of the analysis are appropriate to fully understand the impact of the proposed change in access on the Interstate/Freeway System.

   ii. Along each crossroad to the first major intersection on either side of the proposed change in access, extending further as needed to demonstrate the safety and operational impacts that the proposed change in access and other transportation improvements may have on the local road network. Crossroads and other roads shall be included in the analysis to the extent necessary to assure the ability to collect and distribute traffic to and from the interchange with new or revised access points.

   iii. New interchanges must include analysis of the local street system to the extent that local road system improvements can be compared as an alternative to constructing a new interchange.

   iv. Maps and/or diagrams should be provided as needed to clearly describe the location and study limits of the proposal.

   v. In the case of complex changes in access, adjustments to the extent of the operational analysis and the format of the study may be coordinated with the Office of Roadway Engineering.

D. Operational analyses evaluating the impact of the proposed change in access for the area of influence limits shall consider the following:

i. The analyses should demonstrate that the change in access does not have significant adverse impact on the Interchange System traffic operations or the safety for all users of the transportation system in the project's area of influence. The analysis must address design year traffic with and without the new or revised access point (build vs. no-build). Design year traffic must reflect future land use changes and associated trip generations. Traffic projections must be based upon traffic data that is no more than 5 years old and certified as per Section 102.1.

ii. Requests involving new access points or revised access points must use 20-year design traffic projected from the opening day of the interchange. Certified Traffic (High Risk Design Traffic Forecasting Procedure) will be required for all projects involving an IMS or IJS, in accordance with the most current version of the Ohio Traffic Forecasting Manual. Traffic volumes for interchange studies that do not require High Risk Design Traffic (i.e. Certified Traffic), must be reviewed and approved by the District prior to the preparation of traffic analyses. Written documentation of the District's approval of the Low Risk Design Traffic must be included in the interchange study report.

iii. The level-of-service (LOS) of the Interstate/freeway system and the interchange components that are built new or modified should meet the level of service goals in **Figure 301-1**.

iv. All traffic analyses on ODOT projects must be prepared per the OATS Manual.

E. Safety analysis for proposed access modifications must adhere to the following requirements:

i. The safety analysis shall include at least the most recent 3 years of available safety data.

a. If a previous Feasibility or Safety Study exists with safety analysis, but lacks the most recent three years of data, the missing years shall be reanalyzed using AASHTOWare Safety data and the CAM Tool.

b. Compare the new data with the previous studies to note any significant changes in conditions or patterns of crashes.

c. Summarize these changes within the IMS/IJS.

ii. Coordinate with the Highway Safety Program to determine the specific geographic limits of the analysis based on the proposed access change.

iii. Safety analysis of existing conditions must use AASHTOWare Safety data and the CAM Tool to identify crash rates, crash types, crash trends, high-crash locations and other safety concerns. Include discussion of any fatal or serious injury crashes. If there are crashes involving vulnerable road users, they should be discussed as well.

iv. The safety analysis method for the proposed modification must be appropriate for the scope, crash history, and the purpose and need of the project. The analysis shall use ODOT's Safety Analysis Guidelines to assess and compare the anticipated safety impacts of the No-Build alternative and the Build condition (proposed modification) within the IMS. Documentation must be provided based on the analysis method used and document how the proposed modification would impact the identified safety concerns.

v. Safety-based benefit-cost analysis is not necessary for an IMS/IJS.

vi. All safety analysis supporting data shall be included in the appendix.

F. Every IMS/IJS shall include a conceptual signing plan showing the type and location of signs to support the proposed design per 23 CFR 624.11.

G. Assurance that the new or revised access connects to a public road and is part of a configuration that provides for all traffic movements. Less than "full interchanges" for special purpose access for transit vehicles, for HOV's, or into park and ride lots may be considered on a case-by-case basis.

3. For a proposed partial interchange, the IJS/IMS shall meet the following additional requirements.

A. In rare instances where all basic movements are not provided by the proposed design, the report must include a full-interchange option with a comparison of the operational and safety analyses to the partial-interchange option.

B. The report must also include the mitigation proposed to compensate for the missing movements, including wayfinding signage, impacts on local intersections, mitigation of driver expectation leading to wrong-way movements on ramps, and other proposed strategies as necessary.

C. The report must describe whether future provision of a full interchange is precluded by the proposed design.

4. In the case of complex changes in access, adjustments to the extent of the safety and operational analysis and the format of the study may be coordinated with the Office of Roadway Engineering.

The development of an Access Point Request Document should be performed in accordance with the ODOT Project Development Process (PDP). As part of the PDP for all projects that require an IJS/IMS, the relevant PDP submissions (including, but not limited to the Feasibility Study and Alternative Evaluation Report), will include consideration of the following points:

1. Adequate documentation that the existing access points and/or local roads are unable to handle the design year traffic demands while providing the access intended by the proposal, or be improved to do so, if the new or revised access is not provided. If the request involves a new access point, and particularly an interchange at a new location, a comprehensive description of the public need for the access must be included. A justification based on enhanced property values or access to private facilities will not be accepted.

2. Assurance that all reasonable alternatives for design options, location, and transportation system management type improvements (such as ramp metering, mass transit, and HOV facilities) have been assessed and provided for if currently justified, or provisions are included for accommodating such facilities if a future need is identified.

3. The proposal considers and is consistent with local and regional land use and transportation plans. Prior to final approval, all requests for new or revised access must be consistent with the metropolitan and/or statewide transportation plan, as appropriate, the applicable provisions of 23 CFR part 450 and the transportation conformity requirements of 40 CFR parts 51 and 93. The request should include a statement and analysis of compatibility with, and the effect on, the local road network. Letters of support and commitment are required from the State and other sponsoring agencies for any required street or road improvements as well as for the access point.

4. In areas where the potential exists for future multiple interchange additions, all requests for new or revised access are supported by a comprehensive Interstate/freeway network study with recommendations that address all proposed and desired access within the context of a long-term plan.

5. Evidence that the request for the new or revised access generated by new or expanded development demonstrates appropriate coordination between the development and the necessary transportation improvements. A discussion of potential funding sources, if known, should be included.

6. The request for new or revised access contains information relative to the planning requirements and the status of the environmental processing of the proposal.

As part of ODOT's Project Development Process, the Office of Roadway Engineering is required to review all Feasibility Studies and Alternative Evaluation Reports involving an Interchange Study (IJS/IMS/IOS). If the FS and/or AER involves an interchange, the study limits must encompass the applicable interchange study (IJS/IMS/IOS) limits.

The Office of Roadway Engineering will not review any Interchange Study (IJS/IMS/IOS) that:

1. Does not have an approved Purpose & Need (if applicable); or

2. Does not have appropriate study limits required to support the approved Purpose & Need; or

3. Has interchanges that ORE did not review and approve in the Feasibility Study and Alternative Evaluation Report (if applicable)

The Access Point Request Document should only be performed for the preferred alternative, however a discussion of feasible alternatives should also be included in the study. The preferred alternative will comply to all State and FHWA design requirements, including but not limited to: interchange spacing, interchanges to provide for all traffic movements to and from the freeway, not allowing lanes to drop into private facilities, not allowing intersections (driveways or streets) to intersect ramps (except in special cases such as facilities for utilities.

Interchange Modification and Justification Studies (IMS & IJS) are required to reference and describe how each 23 CFR 624 is being met.

All IJS or IMS documents should follow the Report Format/Outline found in the **Traffic Academy Interchange Studies (IJS/IMS/IOS) Course** and the OATS Manual. The Interchange Studies Course can be found on the Office of Roadway Engineering's Interchange Studies page.

A reevaluation of the IJS/IMS may be required by FHWA if the project or a phase of the project has not progressed to construction within 5 years of the approval date of the document.

An IJS/IMS Addendum is required if any of the following condition(s) apply:

1. A Revised-Build condition is proposed that is different than the Build condition (per the approved IJS/IMS) and is not an Interim-Build condition (a phased condition between the No-Build condition and Build condition, per the approved IJS/IMS).

See **Section 550.2.1** for guidance on Interchange Operation Studies if your project does not meet the condition(s) listed above. Contact The Office of Roadway Engineering.

550.2.1 - Interchange Operations Study (IOS)

Some interchange projects do not fall under the definition of warranting an Access Point Request Document (IJS/IMS) per 23 CFR 624 but still require an operational evaluation and approval by the Office of Roadway Engineering. This operational evaluation would be in the form of a report referred to as the Interchange Operations Study, IOS. The IOS is intended to be an abbreviated version of the more comprehensive IMS report, highlighting critical traffic operations that may be affected by the proposed improvement. The IOS will

utilize the same analysis methodology and 20-year design as the IMS, but the IOS will be more limited with respect to the number of analysis points evaluated and the study narrative. For an IOS, Certified Traffic is typically not required. Instead, the Low Risk Design Traffic Forecasting Procedure, per the Ohio Traffic Forecasting Manual, is considered acceptable. Certified Traffic is required when thru lanes on the freeway/crossroad are increased or decreased. In urban areas with significant congestion and oversaturated conditions, coordinate with the Office of Modeling & Forecasting to discuss if Certified Traffic is needed to capture the full demand volumes. An IOS can be applied to an Interstate or non- Interstate. All traffic analyses on ODOT projects must be prepared per the OATS Manual. The following is a list of projects, including, but not limited to, that require an IOS: An IOS may be required if an interim (phased) condition does not match the approved build condition in the IJS/IMS. Contact the Office of Roadway Engineering for further guidance. For mainline capacity additions on a freeway facility or interchange intersection improvements that do not warrant an IOS/IMS/IJS, a 20-year design year traffic analysis is still required to be performed to ensure good engineering design. For such cases, traffic analysis may be documented as part of a Feasibility Study or an AER.

1. Changing lane configurations at a ramp intersection approach, including:
    - Adding/removing a left, thru, or right turn lane along a crossroad
    - Adding/removing turn lanes to the exit ramp
    - Changing lane assignments without altering the number of lanes
        - Example: Changing a 2-lane approach from a (Left/Thru-Right) to (Left-Thru/Right)
    - Implementing a Road Diet (reducing the number of lanes on the crossroad)
    - Moving a continuous right turn to/from the ramp/crossroad to an intersection
    - Converting a right turn at an intersection to/from ramp/crossroad to a slip ramp
2. Changing the exit or entrance ramp terminus point with the freeway mainline by:

- Adding/removing an optional exit lane
- Adding/reducing exit lanes
- Adding/reducing entrance lanes
- Shifting a ramp's location within the same interchange configuration

3. Changing traffic control type at a ramp/crossroad intersection from a signalized/unsignalized condition to a roundabout (only if altering the number of lanes on the approaches)
4. Adding an auxiliary lane between 2 adjacent ramp interchange ramps

The Office of Roadway Engineering has established the Study Area of an IOS for various conditions. This information can be found in the **Traffic Academy, Interchange Studies Course.** Note, that although most projects follow these study limits, the limits can be expanded or reduced with the approval of the Office of Roadway Engineering. For all other interchange or mainline modifications that result in significant operational changes, not covered above or by an Interchange Modification Study, please contact the Office of Roadway Engineering. A reevaluation of the IOS may be required by ODOT if the project or a phase of the project has not progressed to construction within 5 years of the approval date of the document.

550.2.2 - Safety Improvements on Interstate or Other Freeways

Safety improvements eligible for this process are defined as low to medium cost solutions that address an identified "spot" safety problem. The LOS provisions of **Section 550.2** do not apply except that the LOS should not be significantly impacted over the no-build condition in the design year. All other provisions of 550.2 still apply, including the IMS or IOS report to support the analyses. To determine the impacts, the individual operational components must be analyzed and evaluated for acceptance within the context of the overall affected system. Though a single operational component could experience worsened operations, the overall system should improve or essentially remain the same. For a safety improvement to qualify under this section, the following criteria must be met:

1. The project purpose and need is primarily to address "spot" safety problems. The purpose and need may not include operational performance or economic

development objectives.

2. The location has separate independent utility from all other improvements
3. Any potential longer term solution which would provide LOS C would take 5 or more years to implement.
4. No major rehabilitation or reconstruction is planned for 5 or more years. Other work (e.g., routine maintenance or minor rehabilitation) may be done within the 5 year window as long as it does not substantially replace the base pavement and/or reconfigure the facility.
5. The location is a spot location (defined as a ramp, intersection, merge/diverge point, weave, or mainline section not to exceed one mile).
6. The location planning level cost estimate is less than $5 million total (low to medium cost measures) for all phases of project development (i.e. preliminary engineering, detail design, right of way and construction).

550.3 - Holistic Methodology for Operational Analysis

One of the primary objectives of an interchange study is to substantiate that the proposed change does not have a significant adverse impact on the safety or operation of the freeway facility, local street network, or other elements of the transportation system. Per the ODOT Analysis and Traffic Simulation (OATS) manual, HCS or TransModeler must be used to analyze the operational impacts from the proposed changes. Whether an analyst is utilizing the HCS Freeway Facility module or TransModeler, performance measures for each of the individual segments within the facility are computed and these measures can be impacted by the operations of adjacent segments. When a project relieves an operational bottleneck, the improved traffic flow could cause negative impacts on the operations of the downstream segments. If the operations in some of the segments are expected to be made worse, the proposed project may still be approved if it offers overall benefits to the network. All segments should meet the operational goals outlined in Figure 301-1, to the maximum extent feasible. See Section 106 for Safety Analysis requirements.

The most common measure of effectiveness used to assess the performance of freeways and intersections is the level of service (LOS). LOS is determined by the density for freeways and the delay for intersections. LOS results are required as a minimum for all

analyses performed on ODOT projects. Typically, these results will clearly show an overall benefit and are sufficient for determining if a project improves the facility. If it is difficult to determine if the project is an improvement to the overall network based on LOS, additional measures of effectiveness may need to be reported. Some additional measures of effectiveness that can be utilized to determine if the project is an overall improvement could include, but are not limited to: average speed, average travel time, vehicle-miles traveled, and vehicle-hours of travel. The additional measures of effectiveness selected must support the purpose and need of the project. To be useful, they must ultimately provide information that can be used to make investment and management decisions. Analysts should refer to the OATS Manual for additional information on measures of effectiveness.

550.4 - Submission of Interchange Studies

The District must submit all request submissions to the Office of Roadway Engineering (electronic copy). The Office of Roadway Engineering will be responsible for coordination with the Federal Highway Administration for studies involving the Interstate System.

All traffic analysis files must be submitted (see the OATS for submission requirements).

550.5 - Review of Interchange Studies

For Interstates, the Office of Roadway Engineering will review and approve the Access Point Request Document (IJS or IMS), and if acceptable, will forward the request to FHWA for their approval. If the environmental document has not been completed, approval will be conditional on acceptance of the environmental document.

For Access Point Request Documents (IJS or IMS) involving non-Interstate freeways, the Office of Roadway Engineering will review the study and has approval authority.

For Interchange Operations Studies, the Office of Roadway Engineering will review and has approval authority. As a courtesy, all IOS submissions involving the Interstate will be made available electronically to FHWA.

RAMP DESIGN SPEED GUIDE

503-1

REFERENCE SECTIONS
503.2

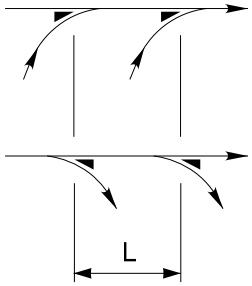
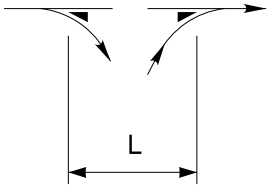
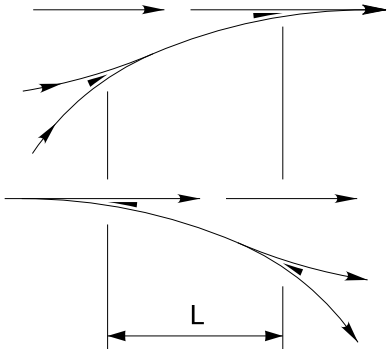
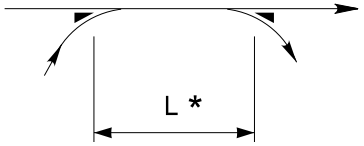
RAMP DESIGN SPEED (mph)	MAINLINE DESIGN SPEED (mph)									
	30	35	40	45	50	55	60	65	70	75
UPPER RANGE	25	30	35	40	45	48	50	55	60	65
MIDDLE RANGE	20	25	30	33	35	40	45	45	50	55
LOWER RANGE	15	18	20	23	25	28	30	30	35	40

Note: Ramp design speeds do not pertain to the ramp terminals.

MINIMUM RAMP TERMINAL SPACING

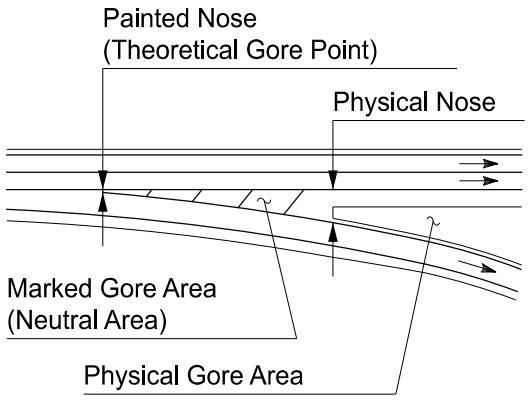
503-1a

REFERENCE SECTIONS 503.5.3

ENTRANCE-ENTRANCE OR EXIT-EXIT		EXIT-ENTRANCE		TURNING ROADWAYS		ENTRANCE-EXIT (WEAVING)			
						 * NOT APPLICABLE TO CLOVERLEAF LOOP RAMPS			
FULL FREEWAY	CDR OR FDR	FULL FREEWAY	CDR OR FDR	SYSTEM INTER-CHANGE	SERVICE INTER-CHANGE	SYSTEM TO SERVICE INTERCHANGE		SERVICE TO SERVICE INTERCHANGE	
						FULL FWY.	CDR OR FDR	FULL FWY.	CDR OR FDR
MINIMUM LENGTHS MEASURED BETWEEN SUCCESSIVE RAMP TERMINALS									
1000 ft	800 ft	500 ft	400 ft	800 ft	600 ft	2000 ft	1600 ft	1600 ft	1000 ft

NOTES: CDR - COLLECTOR DISTRIBUTOR ROAD
FDR - FREEWAY DISTRIBUTOR ROAD

The recommendations are based on operational experience and need for flexibility and adequate signing. They should be checked in accordance with the procedure outlined in the **Highway Capacity Manual (HCM).** Also refer to the HCM for the procedure for measuring the length of the weaving section. The "L" distances noted in the figures above are measured between the painted noses (theoretical gore point). Additionally for EN-EN, a minimum distance of 300 ft. is recommended between the end of the taper for the first entrance ramp and the painted nose for the succeeding entrance ramp (similar for EX-EX except use the physical nose).



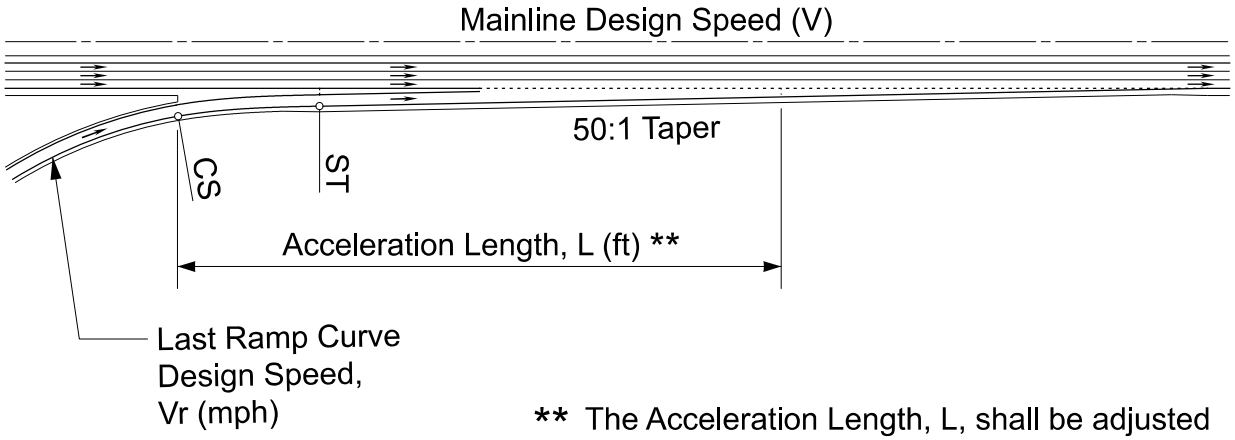
TYPICAL GORE AREA CHARACTERISTICS

MINIMUM ACCELERATION LENGTHS FOR HIGH-SPEED ENTRANCE TERMINALS WITH FLAT GRADES OF 2% OR LESS

503-2a

REFERENCE SECTION
503.6.2

Mainline Design Speed, V (mph)	Acceleration Length, L (ft) for design Speed of Last Ramp Curve, Vr (mph)								
	Stop	15	20	25	30	35	40	45	50
50	720	660	610	550	450	350	130	-	-
55	960	900	810	780	670	550	320	150	-
60	1200	1140	1100	1020	910	800	550	420	180
65	1410	1350	1310	1220	1120	1000	770	600	370
70	1620	1560	1520	1420	1350	1230	1000	820	580
75	1790	1730	1630	1580	1510	1420	1160	1040	780



** The Acceleration Length, L, shall be adjusted for Grade with Figure 503-2b.

HIGH-SPEED ENTRANCE TERMINAL ADJUSTMENT FACTORS AS A FUNCTION OF GRADE

503-2b

REFERENCE SECTION
503.6.2

Mainline Design Speed, V (mph)	Ratio of Length On Grade to Length On Level for Design Speed of Last Ramp Curve, Vr (mph) *							
	20	25	30	35	40	45	50	All Speeds
	3 to 4% upgrade							3 to 4% downgrade
50	1.30	1.35	1.40	1.40	1.40	-	-	0.650
55	1.35	1.40	1.45	1.45	1.45	-	-	0.625
60	1.40	1.45	1.50	1.50	1.50	1.55	1.60	0.600
65	1.45	1.50	1.55	1.55	1.60	1.65	1.70	0.600
70	1.50	1.55	1.60	1.65	1.70	1.75	1.80	0.600
	5 to 6% upgrade							5 to 6% downgrade
50	1.50	1.60	1.70	1.80	1.90	-	-	0.550
55	1.60	1.70	1.80	1.90	2.05	-	-	0.525
60	1.70	1.80	1.90	2.05	2.20	2.35	2.50	0.500
65	1.85	1.95	2.05	2.20	2.40	2.60	2.75	0.500
70	2.00	2.10	2.20	2.40	2.60	2.80	3.00	0.500

No adjustment required for Grades less than 3%.

* Ratio from this table multiplied by acceleration length in Figure 503-2a gives acceleration length on grade.

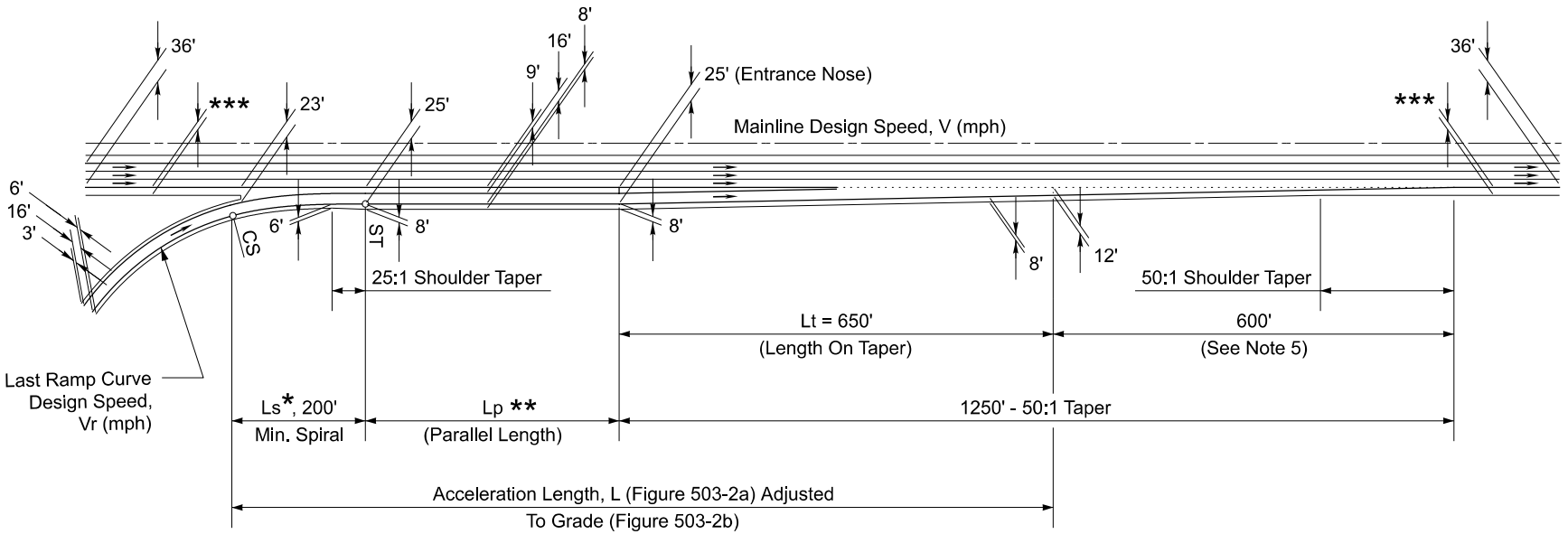
The "grade" in the table is the Average Grade measured over the distance for which the Acceleration Length applies.

For Mainline Design Speeds greater than 70 mph, use 70 mph design speed Adjustment Factors.

HIGH-SPEED SINGLE-LANE ENTRANCE TERMINAL

503-2c

REFERENCE SECTIONS 503.6.2



July 2018

* Length may be increased for Superelevation Transition

** To determine Lp, subtract Ls and Lt from L.

*** Mainline Paved Shoulder Width as required by Figure 301-3 or 301-4.

Notes For Single Lane Entrance Terminals

1. The minimum Acceleration Length, L, shall be Ls + Lt.

2. The 9' to 23' variable width of Treated Shoulder of the Entrance Terminal shall be sloped for 12' as required for mainline design (usually ½in./ft.), except for the last 100' to 200' at the 9' end, which is to be sloped as required for proper terminal grading.

3. Normally Single Lane Ramps will have a Width of 16'. The Width shall be increased to 18' when the Ramp Radius is less than 200'. When an 18' wide ramp is used, the 25' Entrance Terminal Width shall be retained and the 9' width reduced by 2'.

4. If Lp (Parallel Length) is not required (L <= 850'), then the 200' minimum Spiral should be tangent to the 50:1 Taper.

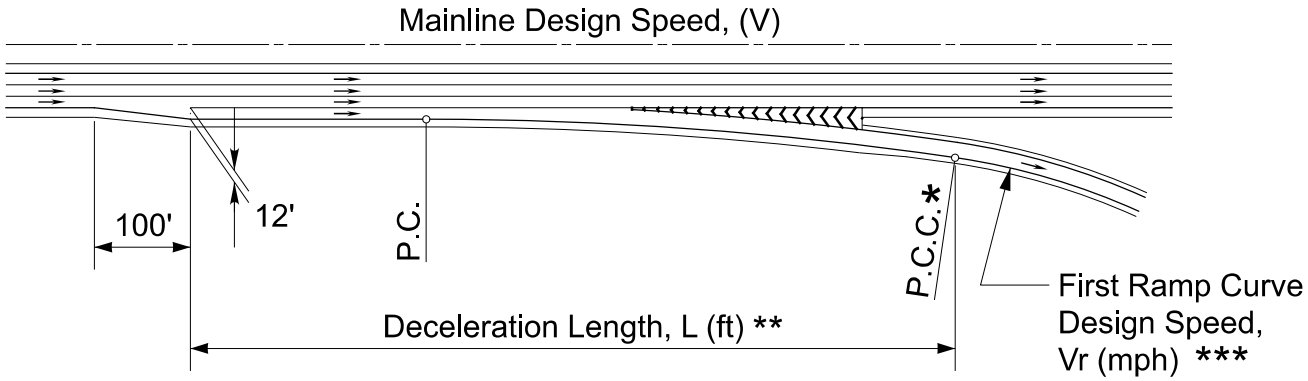
5. If the Entrance Terminal results in an add-lane (no merge), delete the last 600' of the 50:1 Taper.

MINIMUM DECELERATION LENGTHS FOR HIGH-SPEED EXIT TERMINALS WITH FLAT GRADES OF 2% OR LESS

503-3a

REFERENCE SECTION
503.6.3

Mainline Design Speed, V (mph)	Deceleration Length, L (ft) for Design Speed of First Ramp Curve, Vr (mph) ***								
	Stop	15	20	25	30	35	40	45	50
50	435	405	385	355	315	285	225	175	-
55	480	455	440	410	380	350	285	235	-
60	530	500	480	460	430	405	350	300	240
65	570	540	520	500	470	440	390	340	280
70	615	590	570	550	520	490	440	390	340
75	660	635	620	600	575	535	490	440	390



* P.C.C. Or Mid-Point of 200' Spiral

** The minimum Deceleration Length, L, after Adjustment For Grade (Figure 503-3b), shall be 800'

*** Or other Design Speed limiting Geometric Control such as the Stopping Sight Distance for a Vertical Curve or the back of a Traffic Queue.

HIGH-SPEED EXIT TERMINAL ADJUSTMENT FACTORS AS A FUNCTION OF GRADE

503-3b

REFERENCE SECTION
503.6.3

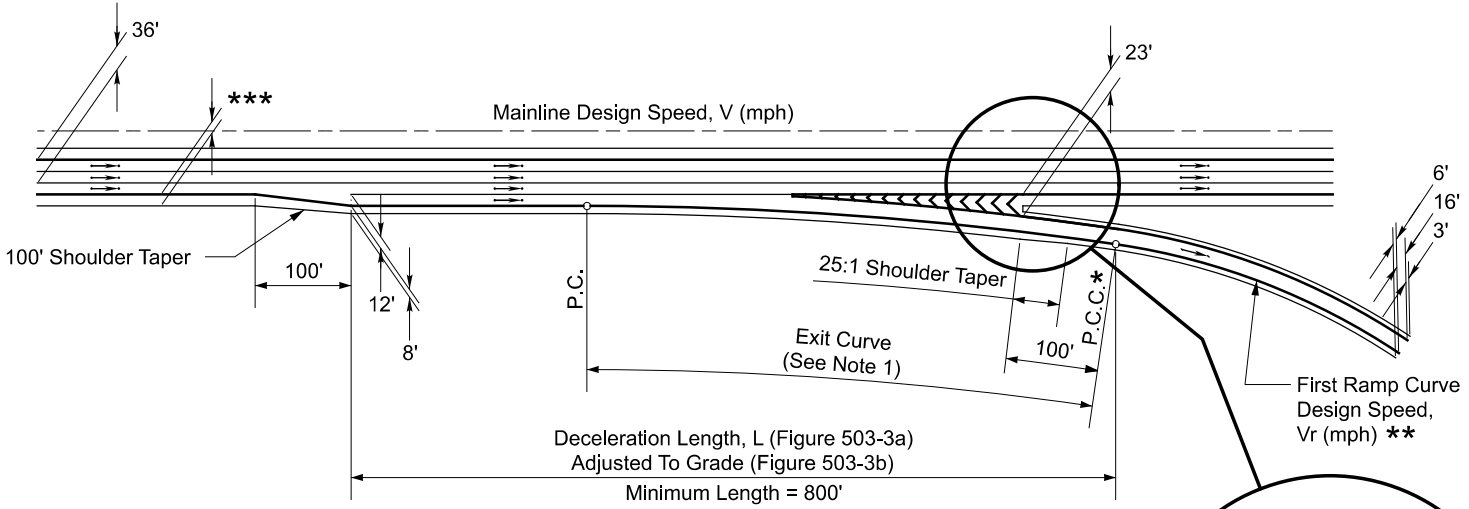
Mainline Design Speed, V (mph)	Ratio of Length On Grade to Length On Level for Design Speed of First Ramp Curve, Vr (mph) *	
	All Speeds	All Speeds
	3 to 4% upgrade	3 to 4% downgrade
All Speeds	0.90	1.20
	5 to 6% upgrade	5 to 6% downgrade
All Speeds	0.80	1.35

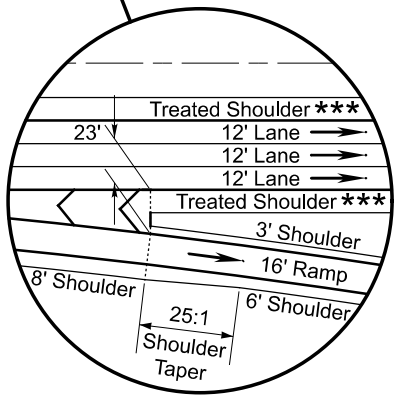
No adjustment required for Grades less than 3%.

* Ratio from this table multiplied by Deceleration Length in Figure 503-3a gives Deceleration Length On Grade.

The "grade" in the table is the Average Grade measured over the distance for which the Deceleration Length applies.

HIGH-SPEED SINGLE-LANE EXIT TERMINAL





GORE DETAIL

EXIT CURVE TABLE		
Mainline Design Speed, V (mph)	Maximum Exit Curvature, Dc	
	Rural	Urban
75	1°- 13'	1°- 22'
70	1°- 24'	1°- 35'
65	1°- 35'	1°- 55'
60	1°- 50'	2°- 15'
55	2°- 10'	2°- 45'
50	2°- 40'	3°- 30'

* P.C.C. Or Mid-Point of 200' Spiral

** Or other Design Speed limiting Geometric Control such as the Stopping Sight Distance for a Vertical Curve or the back of a Traffic Queue.

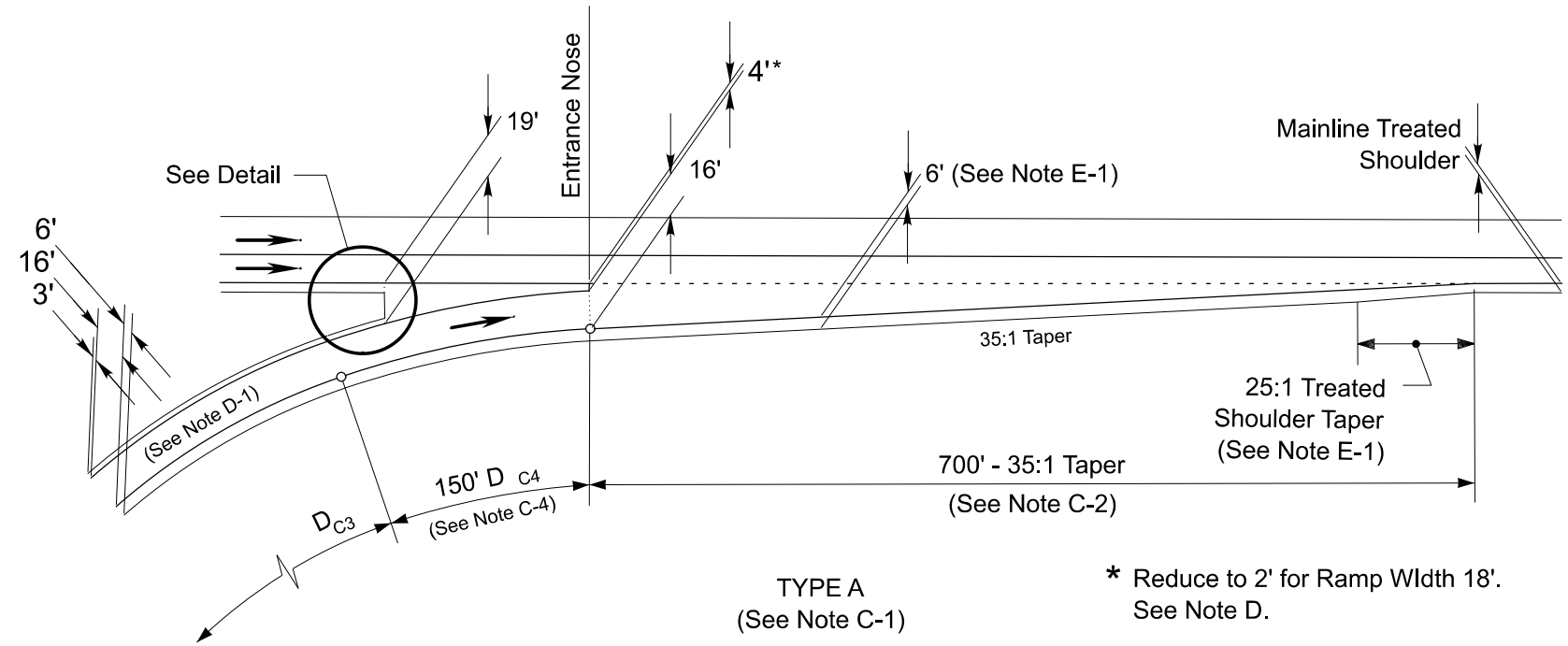
*** Mainline Paved Shoulder Width as required by Figure 301-3 or 301-4.

Notes For High-Speed Single-Lane Exit Terminals

1. The Exit Curve should normally be according to the Exit Curve Table where the mainline is on tangent. Where the mainline is on curving alignment, the maximum differential between the Exit Curve and the mainline curve should normally be the Exit Curve Table value. This differential, however, may vary by as much as one degree in order to avoid a tangent exit alignment. (See Section 503.6.4 for the allowable Transverse Breaks in Superelevation Cross-Sope.)

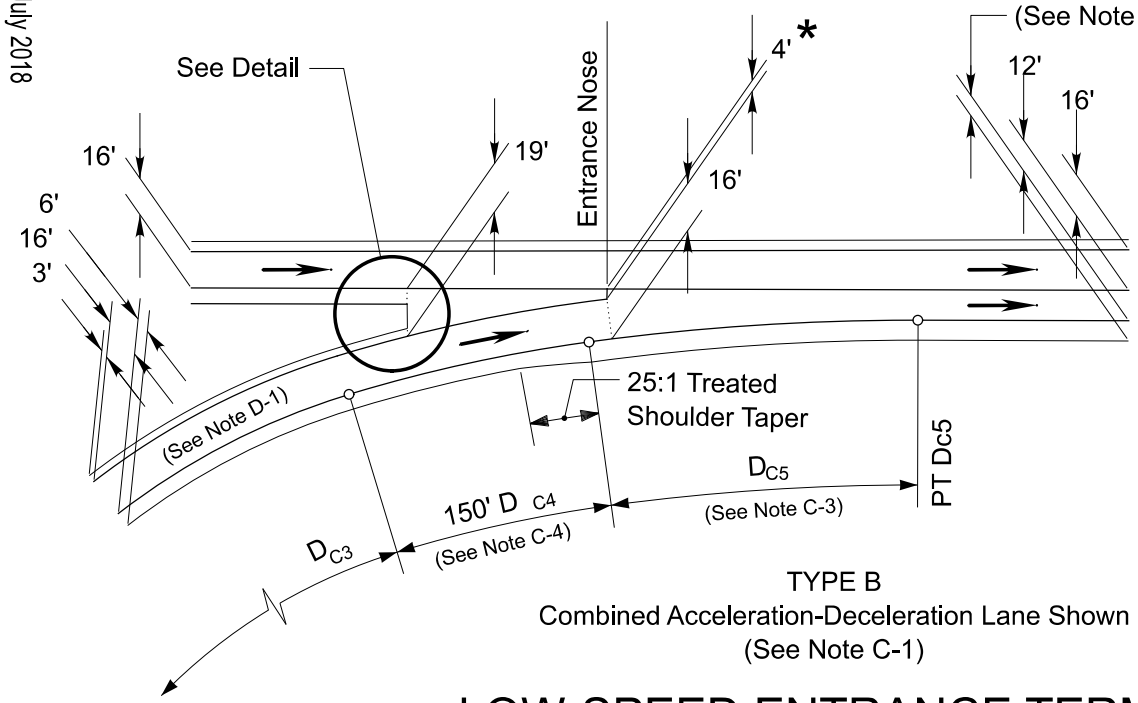
2. When the First Ramp Curve does not exceed 8°, the Exit Curve may be compounded directly with the First Ramp Curve at a PCC 100' beyond the nose. When the First Ramp Curve does exceed 8°, a spiral should be placed between the Exit Curve and the First Ramp Curve and the beginning of the spiral (CS) should be at the nose.

3. Normally Single Lane Ramps will have a Width of 16'. The Width shall be increased to 18' when the Ramp Radius is less than 200'. When an 18' wide ramp is used, the 39' Exit Terminal Width shall be retained and the 23' width reduced by 2'.

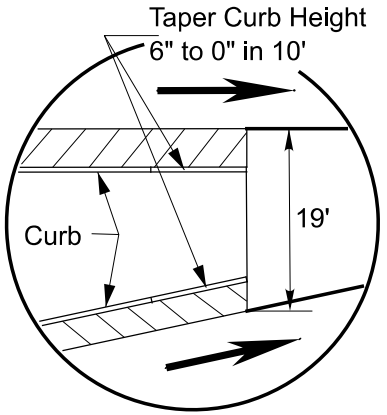


TYPE A
(See Note C-1)

* Reduce to 2' for Ramp WIdth 18'. See Note D.



TYPE B
Combined Acceleration-Deceleration Lane Shown
(See Note C-1)



CURBED ENTRANCE
PAVED SHOULDER DETAIL
(See Note E-2)

LOW-SPEED ENTRANCE TERMINALS

For Notes, see adjacent sheet.

July 2018

LOW-SPEED
ENTRANCE TERMINALS

503-4a

REFERENCE SECTIONS
503.6.2

Notes for Low-Speed Entrance and Exit Terminals

Figues 503-4a and 503-4b.

A. GENERAL

1. Low-Speed Terminals are intended for use on highways which have little or no access control except through an interchange area. Many of the features of Low-Speed Terminals are applicable to a terminal of one ramp with another ramp in a freeway interchange.

B. EXIT TERMINAL

1. The curve differential between the through roadway and exit curve DC1 may vary from a minimum of 4º to the maximum of 8º.
2. Exit Curve D_{c1} may be compounded or spiraled into Ramp Curve DC2. If DC2 is greater than 25º then provide a 150 ft. spiral between DC1 and DC2.

C. ENTRANCE TERMINAL: TYPE A & TYPE B

1. Type A is preferred and shall normally be used. However, when a ramp enters as an added lane or as a combined acceleration-deceleration lane, Type B may be used if its use would result in a substantial savings in cost (i.e. reduced bridge width).
2. The acceleration lane of Type A shall be a uniform 35:1 taper relative to the through edge of traveled way for either tangent or curving alignment.
3. The curve differential between the through roadway and entrance curve DC5 of Type B shall be 4º.
4. The design of the entrance terminal curvature shall be based on the following:

   i. Ramp Curve DC3 of 8º or less

   When the through roadway tangent or a curve to the right, DC4 shall be a 150 ft. long simple curve of a degree such that the differential between it and the through roadway will not exceed 4º. When the through roadway is on a curve to the left, a 150 ft. tangent shall be substituted for DC4.

   ii. Ramp Curve DC3 greater than 8º

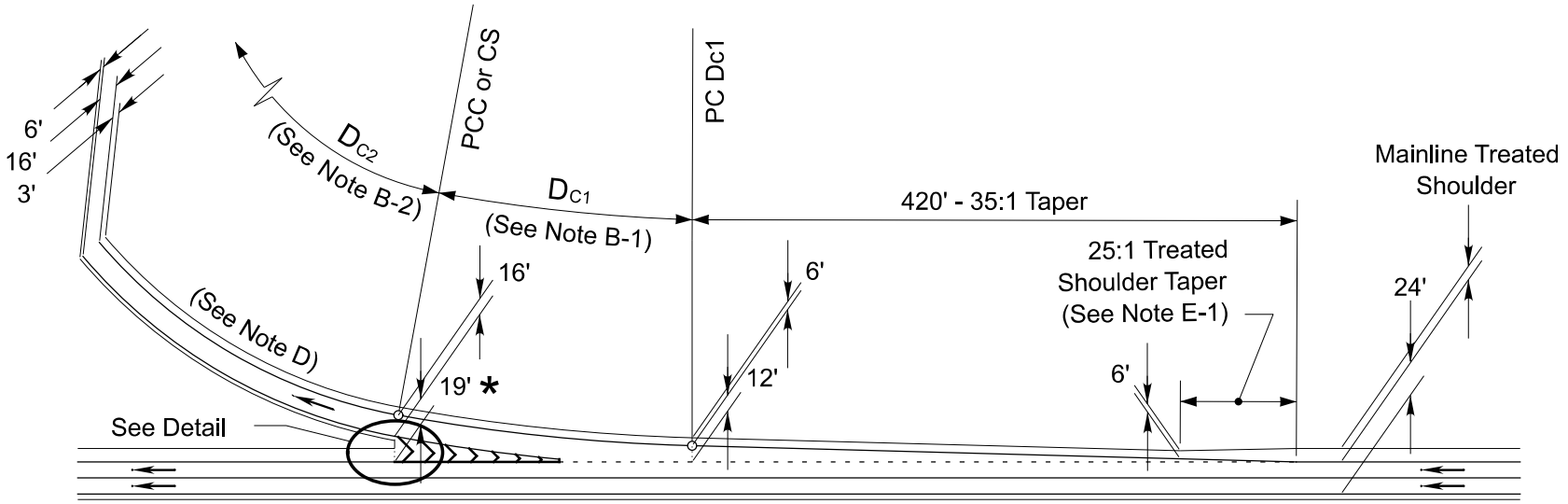
   A 150 ft. spiral may be substituted for D_{c4}.

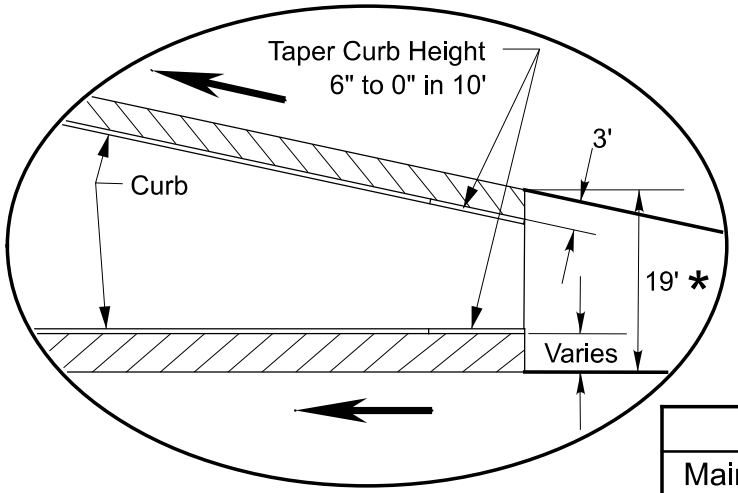
D. RAMP WIDTH

1. Normally single lane ramps will have a width of 16 ft. The width shall be increased to 18 ft. when the ramp radius is less than 200 ft. When an 18 ft. wide ramp is used, the 35 ft. exit and 20 ft. entrance terminal widths shall be retained and the 19 ft. and 4 ft. widths reduced by 2 ft.

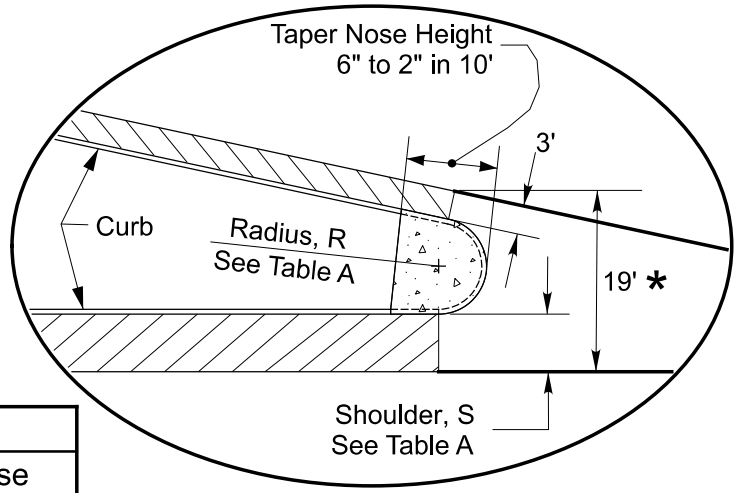
E. TREATED SHOULDER

1. The treated shoulder along the speed change lanes shall be shown on Figure 303-1.
2. If the ramp or through roadway has a curb offset greater than 6 ft. (or 3 ft.), the greater width shall be used at the terminal. Retain the 19 ft. width.
3. The Special Detail drawings shall apply when the through roadway is curbed.





CURBED EXIT PAVED
SHOULDER DETAIL OPTION 1
(See Note E-2)



CURBED EXIT PAVED
SHOULDER DETAIL OPTION 2
(See Note E-2)

TABLE A	
Mainline Shoulder, S (ft)	Nose Radius, R (ft)
10	3
8	4
6	5
4	6
2	7
1	7.5

* Reduce to 2' for Ramp Width 18'.
See Note D.

LOW-SPEED EXIT TERMINAL

For Notes, see adjacent sheet.

July 2018

LOW-SPEED
EXIT TERMINALS

503-4b

REFERENCE SECTIONS
503.6.3

Notes for Low-Speed Entrance and Exit Terminals

Figues 503-4a and 503-4b.

A. GENERAL

1. Low-Speed Terminals are intended for use on highways which have little or no access control except through an interchange area. Many of the features of Low-Speed Terminals are applicable to a terminal of one ramp with another ramp in a freeway interchange.

B. EXIT TERMINAL

1. The curve differential between the through roadway and exit curve DC1 may vary from a minimum of 4º to the maximum of 8º.
2. Exit Curve D_{c1} may be compounded or spiraled into Ramp Curve DC2. If DC2 is greater than 25º then provide a 150 ft. spiral between DC1 and DC2.

C. ENTRANCE TERMINAL: TYPE A & TYPE B

1. Type A is preferred and shall normally be used. However, when a ramp enters as an added lane or as a combined acceleration-deceleration lane, Type B may be used if its use would result in a substantial savings in cost (i.e. reduced bridge width).
2. The acceleration lane of Type A shall be a uniform 35:1 taper relative to the through edge of traveled way for either tangent or curving alignment.
3. The curve differential between the through roadway and entrance curve DC5 of Type B shall be 4º.
4. The design of the entrance terminal curvature shall be based on the following:

   i. Ramp Curve DC3 of 8º or less

   When the through roadway tangent or a curve to the right, DC4 shall be a 150 ft. long simple curve of a degree such that the differential between it and the through roadway will not exceed 4º. When the through roadway is on a curve to the left, a 150 ft. tangent shall be substituted for DC4.

   ii. Ramp Curve DC3 greater than 8º

   A 150 ft. spiral may be substituted for D_{c4}.

D. RAMP WIDTH

1. Normally single lane ramps will have a width of 16 ft. The width shall be increased to 18 ft. when the ramp radius is less than 200 ft. When an 18 ft. wide ramp is used, the 35 ft. exit and 20 ft. entrance terminal widths shall be retained and the 19 ft. and 4 ft. widths reduced by 2 ft.

E. TREATED SHOULDER

1. The treated shoulder along the speed change lanes shall be shown on Figure 303-1.
2. If the ramp or through roadway has a curb offset greater than 6 ft. (or 3 ft.), the greater width shall be used at the terminal. Retain the 19 ft. width.
3. The Special Detail drawings shall apply when the through roadway is curbed.

UNCURBED RAMP INTERSECTION

503-5

REFERENCE SECTIONS
503.7

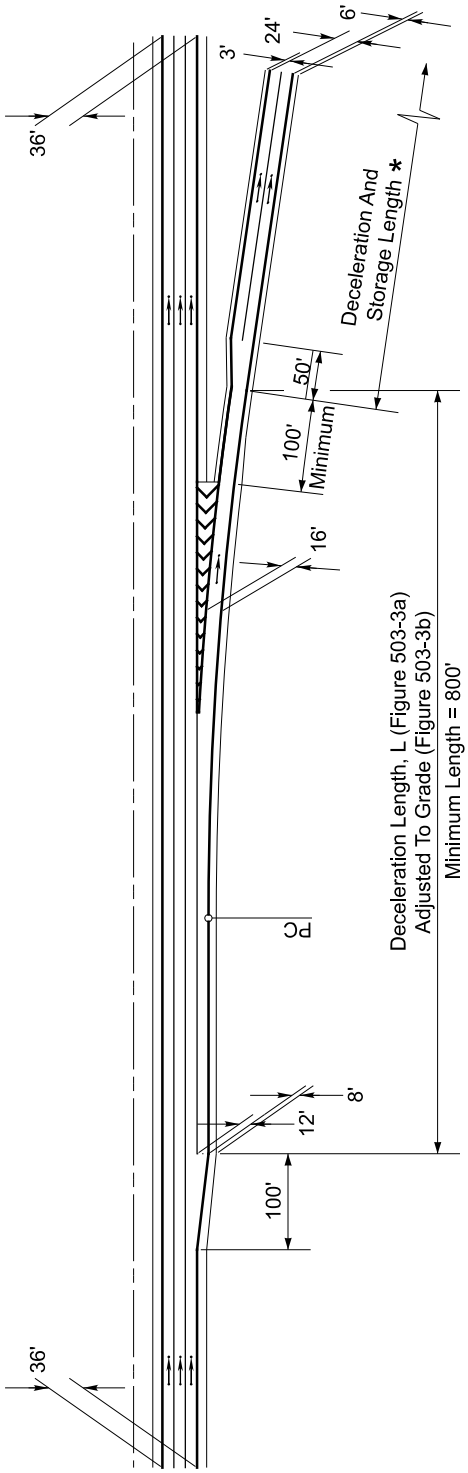
Notes:

1. When the Angle of the Turn into the "ON" Ramp is 100° or greater, reduce the 60' Radius to 50'
2. These points should be at the same centerline station of the crossroad.
3. Where the Ramps intersect a Divided Highway, the Median Opening should be designed to discourage improper turns into the "OFF" Ramps.
4. The 25' Radius and 10:1 Taper may need to be slightly adjusted if the Intersection Angle of the Ramp is less than 90° (verify with turn template software).
5. All of the turn movements at the Intersection are to be analyzed with turning template software and the designated design vehicle.

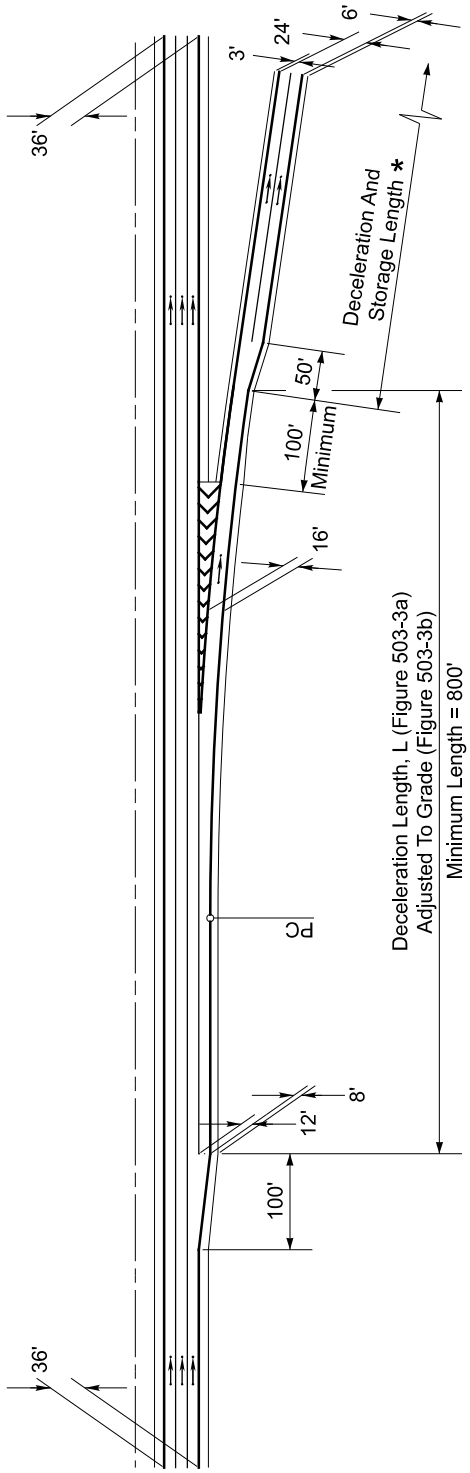
TRANSITION FROM SINGLE-LANE TO TWO-LANE EXIT RAMP

503-5a

REFERENCE SECTIONS
503.7



ALTERNATE A



ALTERNATE B

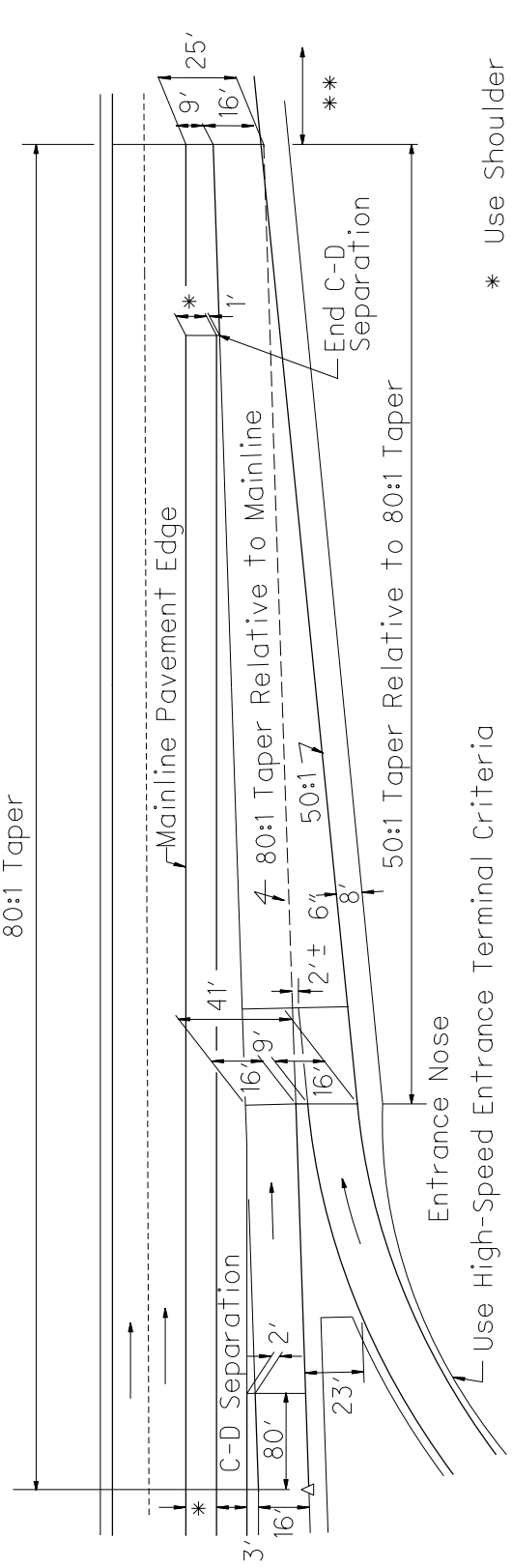
* See Figure 401-9 and 401-10 to compute the length.

Note: The additional lane is usually provided for the minor movement.

COLLECTOR-DISTRIBUTOR ENTRANCE TERMINALS

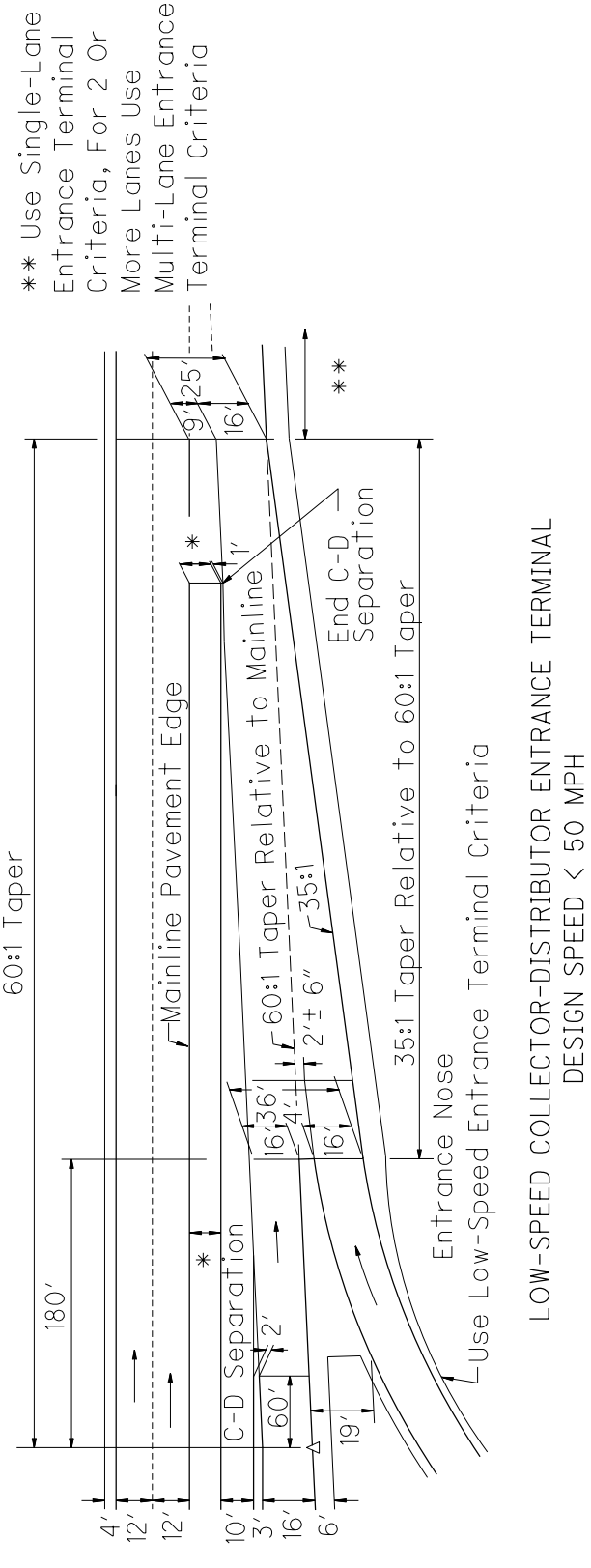
504-1

REFERENCE SECTIONS
504.3



* Use Shoulder Widths from either Figure 301-3 or Figure 301-4.

HIGH-SPEED COLLECTOR-DISTRIBUTOR ENTRANCE TERMINAL
DESIGN SPEED >= 50 MPH



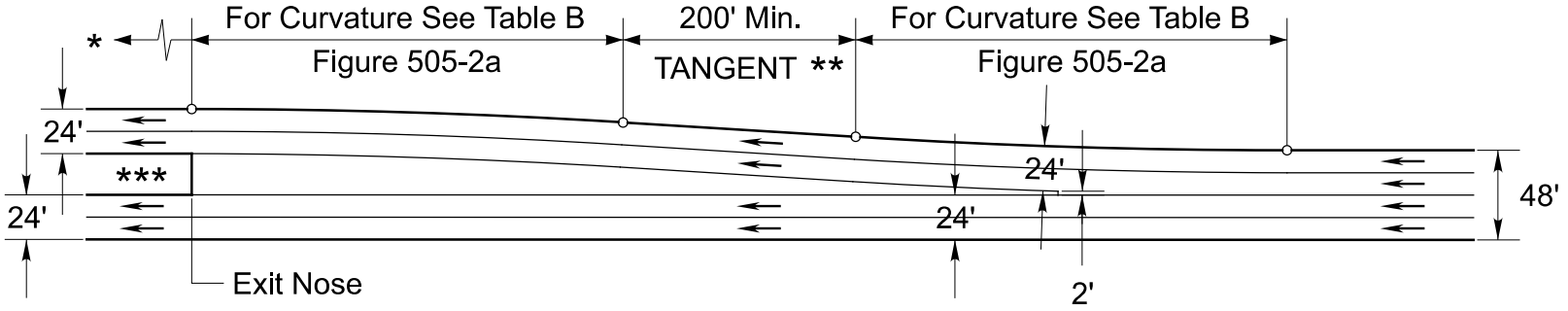
** Use Single-Lane Entrance Terminal Criteria, For 2 Or More Lanes Use Multi-Lane Entrance Terminal Criteria

LOW-SPEED COLLECTOR-DISTRIBUTOR ENTRANCE TERMINAL
DESIGN SPEED < 50 MPH

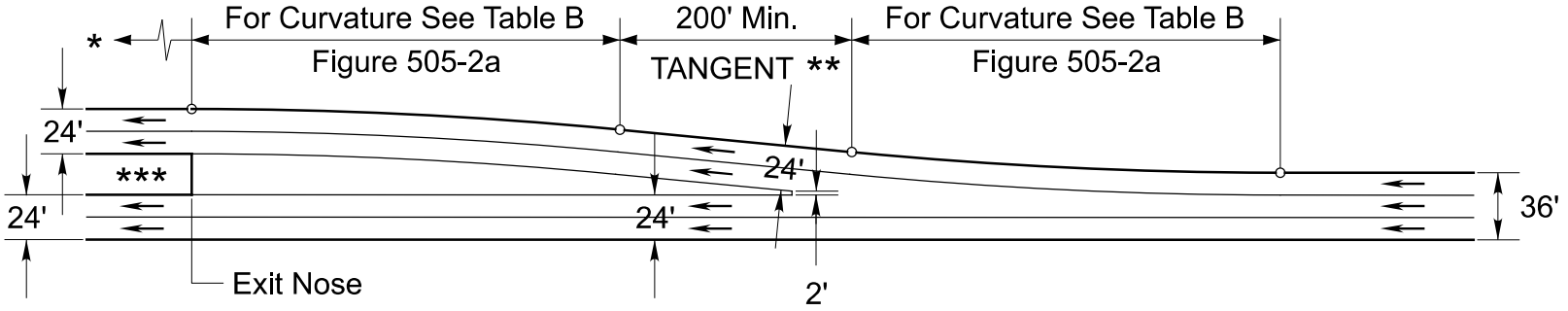
COLLECTOR-DISTRIBUTOR EXIT TERMINALS

504-2

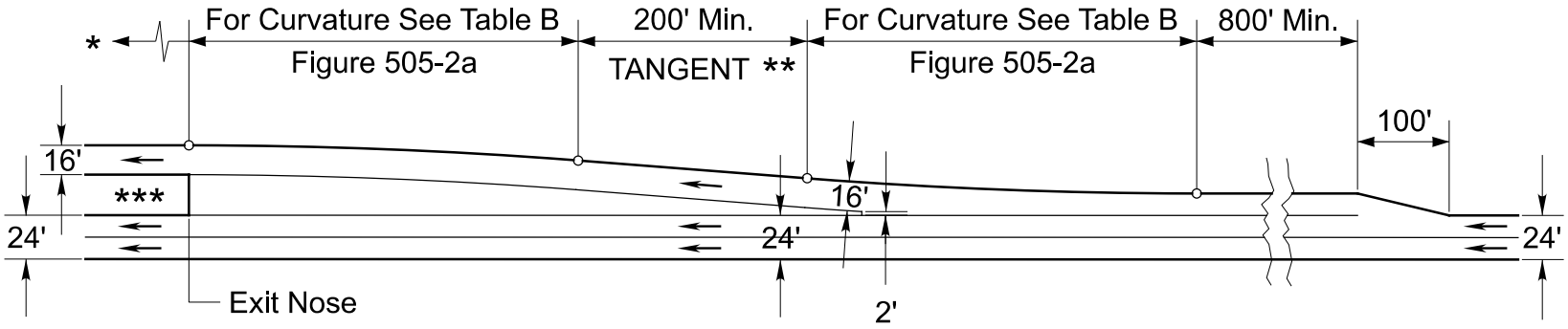
REFERENCE SECTIONS 504.3



2 LANE EXIT FROM 4 LANES



2 LANE EXIT FROM 3 LANES



1 LANE EXIT FROM 2 LANES

* Distance to first ramp exit nose 600' minimum with 1000' desirable especially for two or more lane C-D roads

** Or as required for superelevation transitions

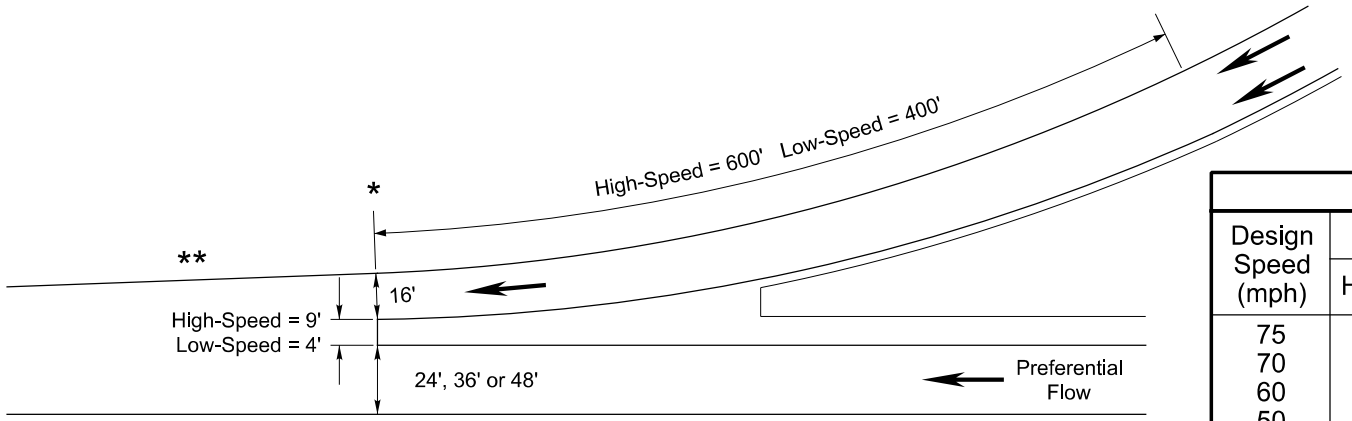
*** Width determined by type of C-D separation chosen

October 2004

MULTI-LANE ENTRANCE RAMPS AND CONVERGING ROADWAYS

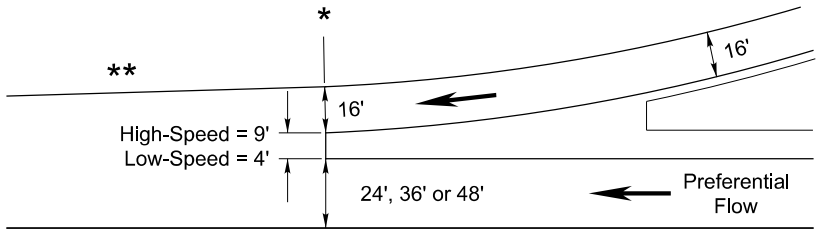
505-1a

REFERENCE SECTIONS 505.1

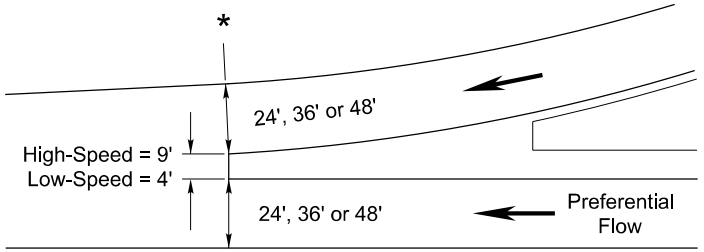


TWO-LANE ROADWAY REDUCED TO SINGLE LANE PRIOR TO ENTRANCE NOSE

TABLE A		
Design Speed (mph)	Taper Rate	
	High-Speed	Low-Speed
75	50:1	--
70	50:1	--
60	50:1	--
50	50:1	--
45	--	35:1
40	--	35:1
30	--	35:1



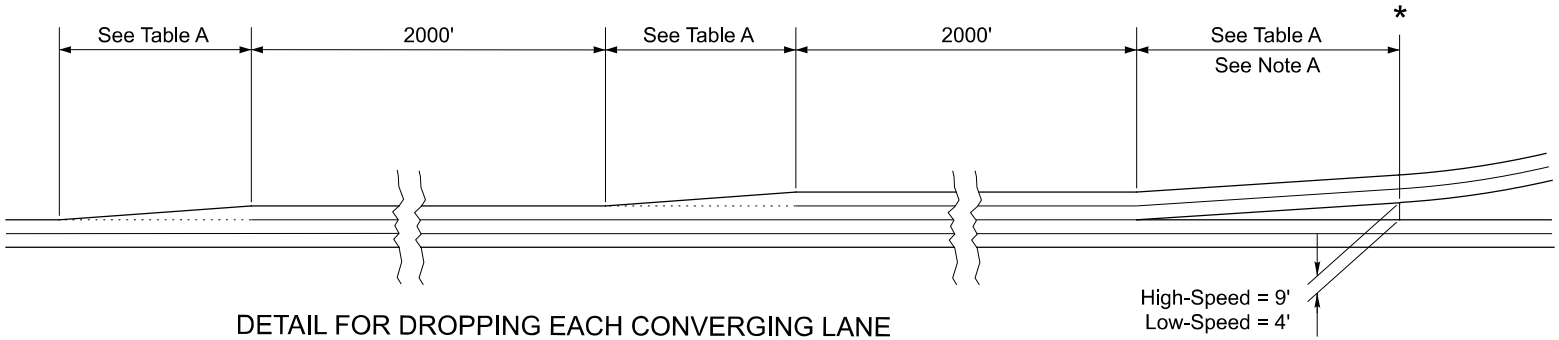
SINGLE LANE CONVERGING WITH MULTI-LANE



MULTI-LANE CONVERGING WITH MULTI-LANE

* Note: the number of lanes leaving the entrance nose must be equal to the total number of lanes (converging plus mainliine) approaching the entrance nose.

** See Figure 503-2c or 503-4a for terminal details.



DETAIL FOR DROPPING EACH CONVERGING LANE

Note A:
Vertical alignment of both the mainline and the ramp should provide Decision Sight Distance, Avoidance Maneuver C or E, as per Figure 201-6.

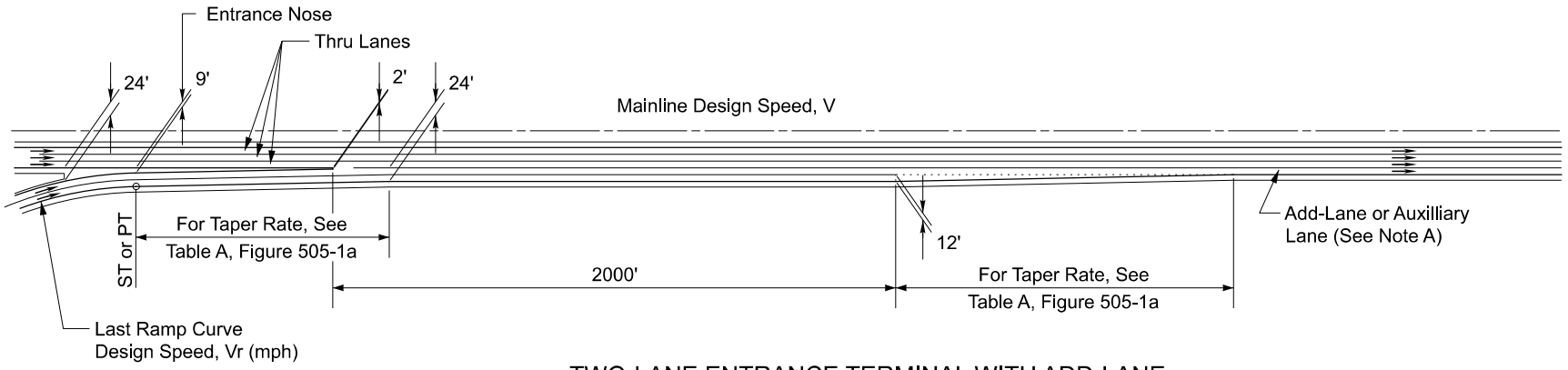
HIGH-SPEED TWO-LANE ENTRANCE TERMINALS

505-1b

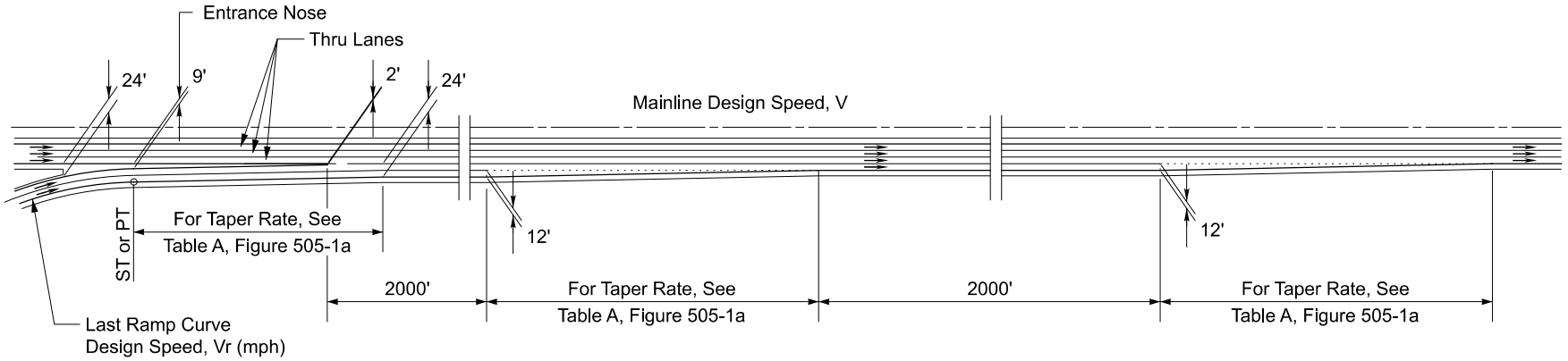
REFERENCE SECTIONS 505.1

Vertical alignment of both the mainline and the ramp should provide Decision Sight Distance, Avoidance Maneuver C or E, as per Figure 201-6.

Note A : Additional lane provided to satisfy lane-balance. The Add-Lane may be a basic lane if needed for capacity or an auxiliary lane and dropped either as shown below or at the next interchange.



TWO-LANE ENTRANCE TERMINAL WITH ADD-LANE

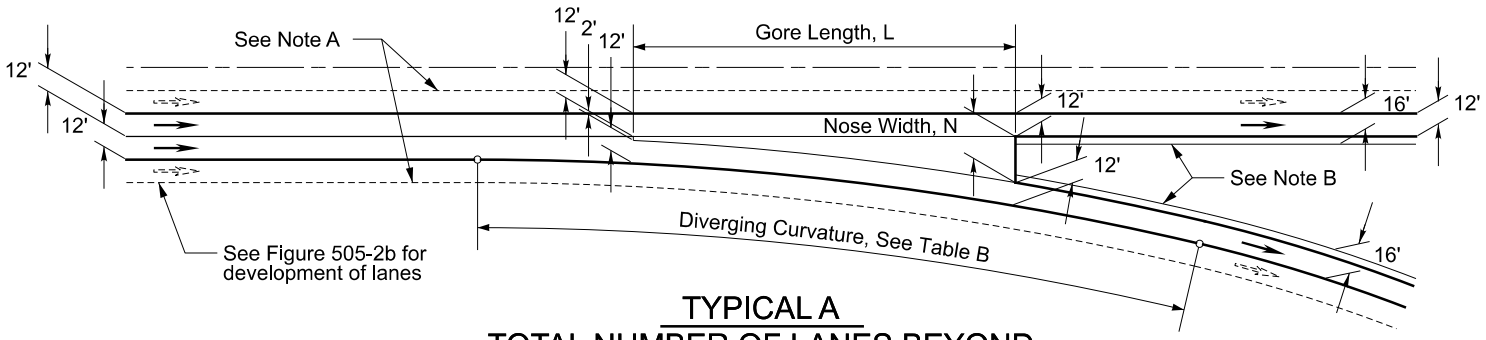


TWO-LANE ENTRANCE TERMINAL WITH DROPPED AUXILLIARY LANE

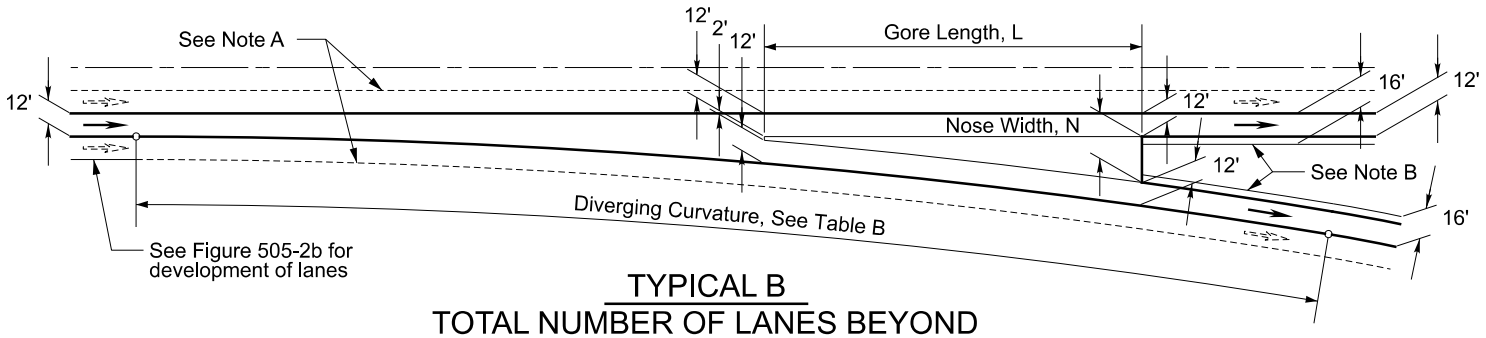
MULTI-LANE EXIT RAMPS AND DIVERGING ROADWAYS

505-2a

REFERENCE SECTIONS
505.2



TYPICAL A
TOTAL NUMBER OF LANES BEYOND THE NOSE EQUALS APPROACH LANES



TYPICAL B
TOTAL NUMBER OF LANES BEYOND THE NOSE EQUALS APPROACH LANES PLUS ONE

TABLE A

Design Speed, "V" (mph)	"L" Gore Length (ft.)			"N" * Nose Width (ft.)		
	High-Speed		Low Speed	High-Speed		Low Speed
	Rural	Urban		Rural	Urban	
75	525	430		32	24	
70	450	370		32	24	
65	400	340		32	24	
60	370	300		32	24	
55	350	280		32	24	
50	320	260		32	24	
45			180			24
40			160			24
35			140			24
30			120			24

* "N" dimension includes 4' of a 16' lane

TABLE B
RECOMMENDED DIVERGING CURVATURE (See Sec. 505.2.4)

Design Speed of Approaching Roadway "V" (mph)	DIVERGING CURVATURE Total Lanes Beyond Diverging Nose Equals					
	Approach Lanes			Approach Lanes +1		
	High-Speed		Low Speed △	High-Speed		Low Speed △
	Rural	Urban		Rural	Urban	
75	0°- 45'	0°- 45'		0°- 25'	0°- 25'	
70	1°- 00'	1°- 00'		0°- 30'	0°- 30'	
65	1°- 15'	1°- 15'		0°- 35'	0°- 35'	
60	1°- 30'	1°- 30'		0°- 40'	0°- 40'	
55	1°- 45'	1°- 45'		0°- 45'	0°- 45'	
50	2°- 00'	2°- 00'		1°- 00'	1°- 00'	
45			4°- 15'			1°- 45'
40			5°- 30'			2°- 15'
35			7°- 00'			2°- 45'
30			10°- 00'			3°- 30'

△ Based on a Design Speed equal to ("V" - 10 mph)

Note A: Any lane combination can be designed from Table A and Typicals A and B by adding one or more lanes to one or both sides of Typical A or adding one or more lanes to both sides of Typical B.

Note B: When a 16 foot lane width is used after the diverging nose, the nose width "N" includes 4 feet of the 16 foot lane width. For two 16 foot lanes, "N" includes 4 feet of each lane.

HIGH-SPEED TWO-LANE EXIT TERMINALS FOR SYSTEM INTERCHANGES

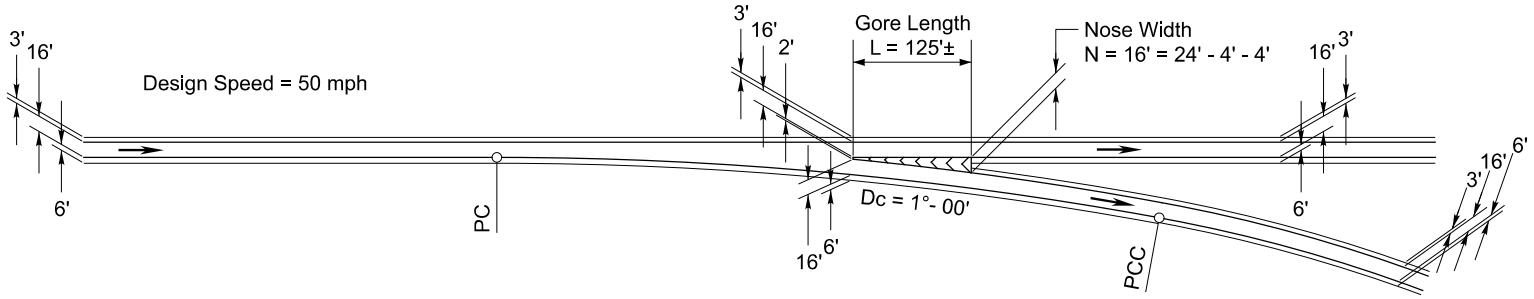
505-2b

REFERENCE SECTION
505.2

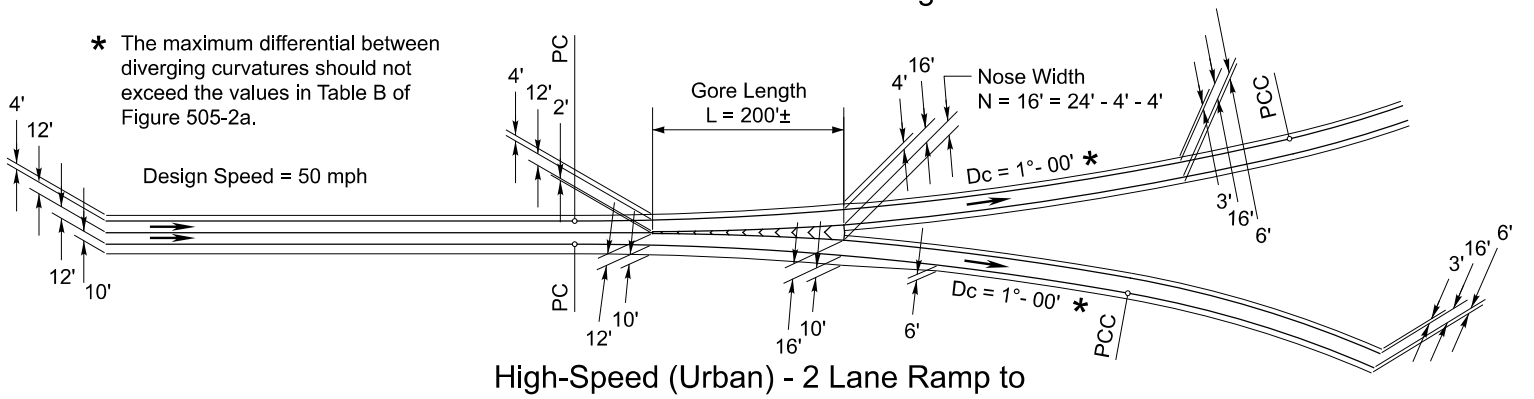
EXAMPLES OF DIVERGING ROADWAYS

505-2c

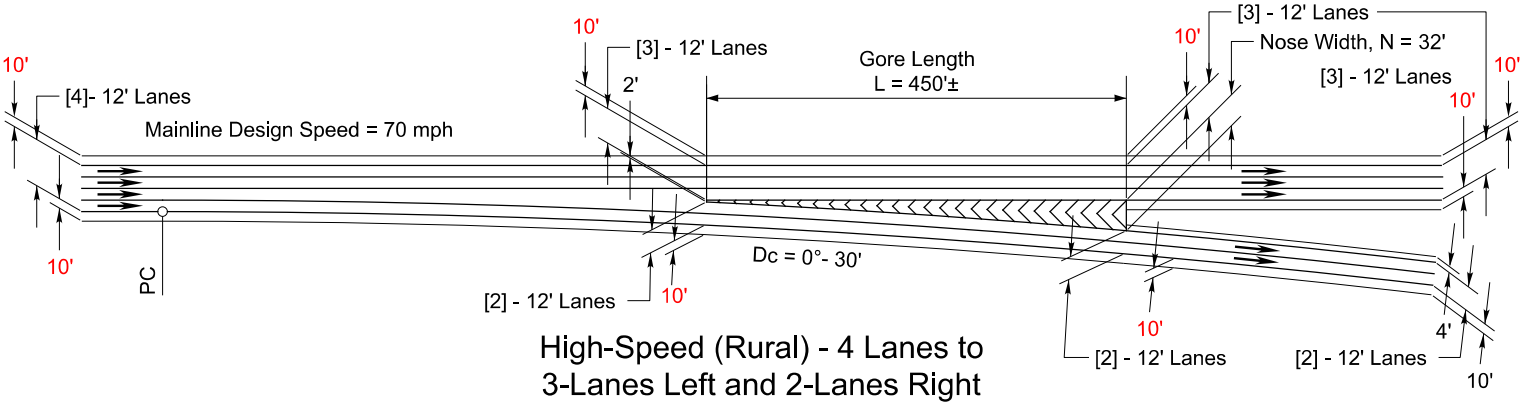
REFERENCE SECTIONS
505.2



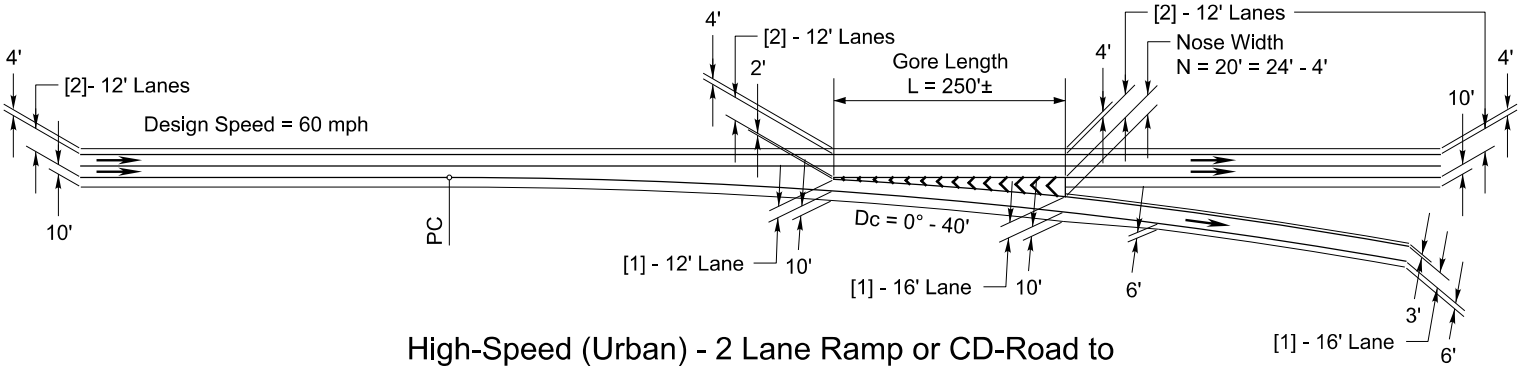
High-Speed (Urban) - 1 Lane Ramp to
1 Lane Left and 1 Lane Right



High-Speed (Urban) - 2 Lane Ramp to
1 Lane Left and 1 Lane Right



High-Speed (Rural) - 4 Lanes to
3-Lanes Left and 2-Lanes Right



High-Speed (Urban) - 2 Lane Ramp or CD-Road to
2 Lanes Left and 1 Lane Right

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HIGH-SPEED TWO-LANE EXIT TERMINALS FOR SERVICE INTERCHANGES

505-2d

REFERENCE SECTION
505.2

TYPE I
TWO-LANE EXIT TERMINAL FOR USE ON ALL FACILITIES
THE TOTAL NUMBER OF LANES BEYOND THE NOSE EQUALS THE NUMBER OF APPROACH LANES

△ Note: The 1500' distance is a minimum. The Length may need to be increased based on the expected queue from traffic analysis.

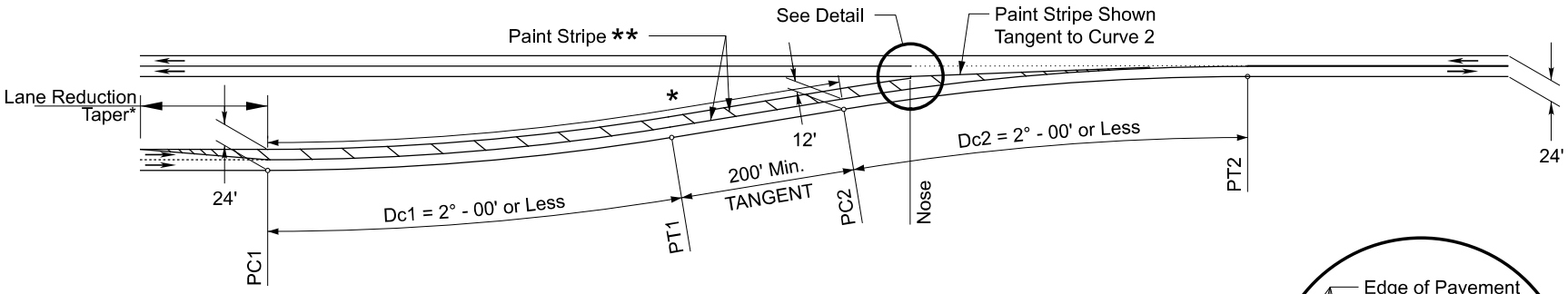
TYPE II
TWO-LANE EXIT TERMINAL LIMITED USE, SEE NOTE *
THE TOTAL NUMBER OF LANES BEYOND THE NOSE EQUALS THE NUMBER OF APPROACH LANES PLUS ONE

* Note: This type of exit terminal is discouraged in congested corridors. Traffic analysis operations must show queuing of ramp vehicles will be contained within the ramp and not extend past the physical nose.

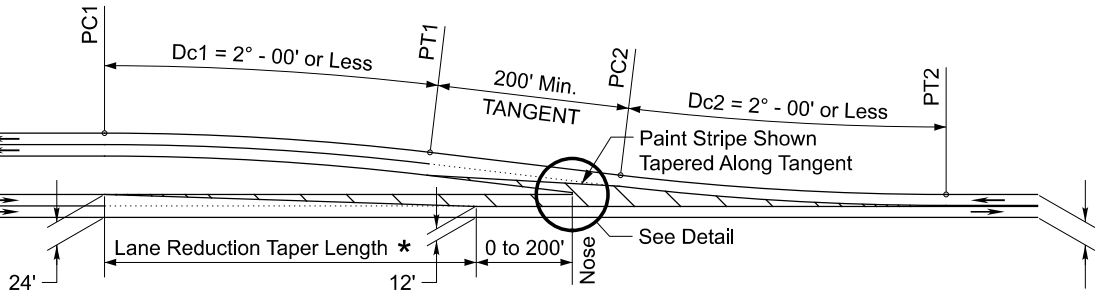
TRANSITIONS
FOUR LANE DIVIDED ROADWAY TO TWO LANE ROADWAY

505-3

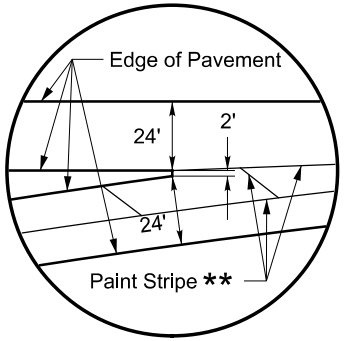
REFERENCE SECTION 505.3



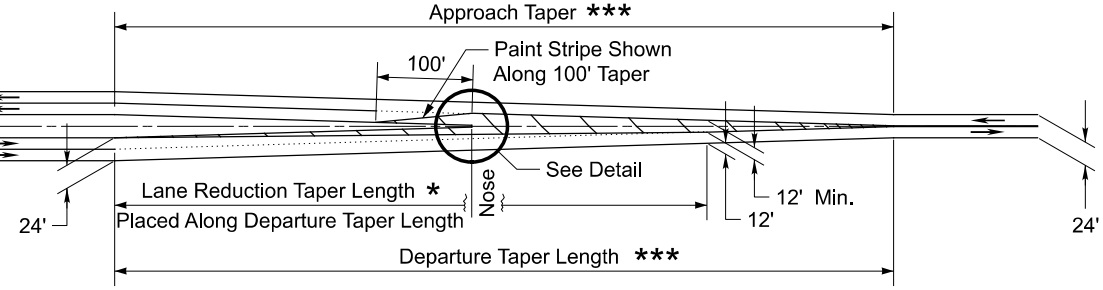
TYPE A - REVERSE CURVE



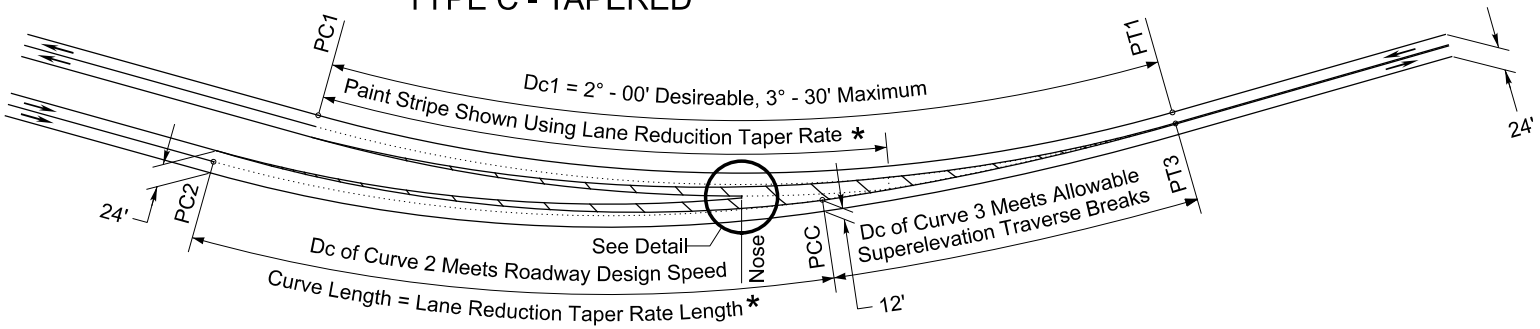
TYPE B - REVERSE CURVE



NOSE DETAIL
Applies to all Types



TYPE C - TAPERED



TYPE D - ON CURVE

Notes:

* See Figure 505-1a Table A for Minimum Lane Reduction Taper Rate.

** Refer to OMUTCD for paint striping details.

*** See Section 401.6.1 to determine Taper Length.

July 2025

600 - Roadside Design

600 - Roadside Design

600.1 - Introduction

This chapter discusses concepts related to roadside safety features which are intended to reduce occurrences of run-off-the-road crashes and reduce the severity of impact when such an incident does occur. The AASHTO Roadside Design Guide contains additional information on roadside design.

Safety devices are themselves fixed objects, and while they may decrease crash severity, they may also increase the total number of impacts. The potential for impacts can be reduced by placing the safety device as close to the hazard being shielded and as far from the traveled lanes as permitted by the following standards. Roadside safety devices are hazards and must result in a less severe crash than the hazard being shielded.

600.2 - Clear Zone

Clear Zone - The unobstructed, traversable area provided beyond the edge of the through traveled way for the recovery of errant vehicles. The clear zone includes shoulders, bike lanes, or auxiliary lanes, except those auxiliary lanes that function like through lanes. Ideally, there should be no obstructions within the clear zone; however, if an obstruction cannot be removed, then engineering judgment must be used to determine how to treat it.

When a warranting feature cannot be removed, the clear zone distances given in Figure 600-1, may be used as minimum values. These widths are based on design speed, traffic volume, and the combination of foreslopes and backslopes on the typical cross section for the roadway. These minimum values should not erroneously be interpreted as permitting or encouraging the construction of potential hazards immediately outside the clear zone at what may be deemed a “safe” distance from the edge of the through traveled lanes.

Rather, the clear zone width should be increased if a site investigation indicates that doing so would significantly lessen the potential for crashes. For example, if an obstruction exists just outside the required clear zone in an otherwise obstruction-free area, it should be considered for removal or protection.

For curves with a history of run-off-the-road crashes and a Degree of Curve of 2°00' or greater, Figure 600-1 also provides a table of adjustment factors based on design speed that should be used to extend the clear zone. In these cases, the designer should ensure that the roadway has proper superelevation before evaluating the curve's effect on the clear zone.

The preferred order of corrective treatment for fixed objects and non-traversable hazards located within the clear zone is as follows:

1. Remove the obstacle.
2. Redesign the obstacle so that it can be safely traversed.
3. Relocate the obstacle to a point where it is less likely to be struck.
4. Reduce the impact severity by using an appropriate breakaway device.
5. Shield the obstacle with a longitudinal traffic barrier designed for redirection or use a crash cushion.
6. Delineate the obstacle if the above alternatives are not appropriate.

The overall intent of roadside design is to strive for a forgiving highway. Designing a project exclusively to meet minimum clear zone values may result in a roadside that is not as safe as it could be. On the other hand, the cost of clearing some roadsides may greatly exceed the associated benefits to the traveling public. The optimum solution lies in the judicious application of engineering judgment coupled with a sincere desire to produce safe roadways.

600.2.1 - Parallel Embankment Slopes & Ditches

Embankment slopes parallel to the roadway fall into the following categories:

Recoverable Slopes – Slopes on which encroaching motorists can generally stop their vehicles or slow down enough to return safely to the roadway. Slopes 4:1 or flatter are considered recoverable.

Non-recoverable Slopes - Slopes which may be safely negotiated but are generally too steep for most motorists to stop their vehicles or to return easily to the roadway. Slopes

steeper than 4:1 up to and including 3:1 are considered traversable but non-recoverable if they are smooth and free of fixed-object hazards. Since a high percentage of encroaching vehicles will reach the toe of these slopes, a clear runout area at the toe is desirable.

Critical Slopes - Slopes steeper than 3:1 on which vehicles are likely to overturn.

Backslopes tend to slow an errant vehicle and are therefore not as critical as foreslopes. They may, under certain conditions, be as steep as 1:1.

Roadside ditches are generally categorized as traversable or non-traversable. Figures 307-10and 307-11 present preferred designs for ditches with gradual and abrupt slope changes, respectively. Ditches that fall within the shaded areas of these figures are considered traversable and are preferred for use within the clear zone. Ditch sections that fall outside the shaded areas are considered non-traversable and should generally be located outside the clear zone. There are certain conditions, however, under which these sections may be considered for use within the clear zone. 3R projects; projects with limited right-of-way or rugged terrain; and low volume or low speed roads (particularly if the channel bottom and backslopes are free of any fixed objects) may utilize non-traversable ditch sections when traversable ditches are impractical.

In determining a clear zone width, only recoverable foreslopes (4:1 or flatter), traversable ditches, and backslopes 3:1 or flatter may be included. The recovery area includes the clear zone width plus any non- recoverable slope (over 4:1 through 3:1). These relationships are shown in Figure 600-2.

Several examples of clear zone calculations are included after the figures.

600.2.2 - Urban Lateral Offsets

Research has found that curb has very little effect on errant vehicles and thus the clear zone should be calculated as if the curb was not present (based on speed and traffic, Figure 600-1).

Clear Zone is intended to provide a recovery area for errant vehicles. While designers should always strive to keep hazards as far away from the through traveled way as possible, it may not always be practical to provide the Clear Zone on transportation facilities in urban areas where right-of-way is often constrained. On urban facilities where

Clear Zone cannot be provided, a minimum lateral offset to fixed objects of 8 feet from the edge of through traveled way for uncurbed roadways is acceptable. On very low speed curbed facilities (35 mph and less), the Operational Offset as described in **Section 600.2.3** is acceptable for design features that are functionally necessary (non-breakaway signs and luminaire supports, utility poles, fire hydrants, bus stops, etc.). Otherwise, low speed curbed facilities, shall utilize a minimum Urban Lateral Offset of 4 feet from face of curb. For higher risk locations such as along the outside of curves, offset to fixed objects should be increased to 6 feet for curbed and 12 feet for uncurbed roadways. Refer to Figures 600-3 and 600-4 for additional guidance. Where bike lanes and full-time parking lanes are used, their width can be included as offset to fixed objects, however the Operational Offset is still required. Roadside lateral offset also applies to medians.

Minimum Urban Lateral Offset Requirement

Posted Speed	Curbed	Without Curb
35 mph or less	Operational offset (See Section 600.2.3) behind curb acceptable for necessary design features. Landscaping and aesthetic features shall be offset per Figures 600-3 and 600-4	8 feet (12 ft. outside curves)
40 to 45 mph	4 feet from face of curb to all fixed objects (6 feet at higher risk locations), refer to Figures 600-3 and 600-4	8 feet (12 ft. outside curves)
50 mph or greater	High Speed - Clear Zone required	High Speed - Clear Zone required

Additional guidance for placement of aesthetic elements (street trees, park benches, trash receptacles etc.) for both curbed and uncurbed urban facilities are provided in the Landscaping Guidelines in the References Section at the end of this Manual.

600.2.3 - Operational Offsets on Urban Streets

A minimum operational offset of 1.5’ (3’ at intersections) is required to be provided from the face of curb to accommodate turning trucks and improve sight distance. The operational offset to any objects accommodates motor vehicles and is necessary to:

- Avoid adverse impacts on vehicle lane position and encroachments into opposing or adjacent lanes
- Improve driveway and horizontal sight distance
- Reduce the travel lane encroachments from occasional parked and disabled vehicles.
- Improve travel lane capacity
- Minimize contact from vehicle mounted intrusions (e.g., large mirrors), car doors, and the overhang of turning trucks.

This operational offset will typically become the controlling criteria where bike lanes or parking lanes meet the previously described lateral clearances. As an exception to fixed object operational offset, traffic barriers should be located in accordance with **Section 602.1.5**.

601 - Warrants

601.1 - Roadside Barrier Warrants

A roadside barrier is a longitudinal barrier used to shield motorists from natural or man-made obstacles located on the roadside within the clear zone where impacts are expected on one side of the barrier only. In addition to shielding the motorist from roadside obstacles, some types of roadside barrier are required where foreslopes are excessive, and occasionally for the protection of others from vehicular traffic.

601.1.1 - Obstacles

Roadside obstacles may be fixed objects or non-traversable terrain. Roadside obstacles located within the clear zone area may or may not require barrier protection. Barriers should be considered in the following circumstances:

1. At bridges, piers and abutments.

2. At culverts, pipes and headwalls depending on traffic volumes, and the culvert's size, location and end treatment. (See **Section 602.6** for additional details.)
3. At non-breakaway sign and light supports.
4. At rough slopes in cut sections.
5. At utility poles that cannot justifiably be relocated.
6. At bodies of water or BMP detention ponds where the normal depth exceeds one foot depending on the location and likelihood of encroachment.
7. At transverse ditches if the likelihood of a head-on impact is high.
8. At retaining walls if the anticipated maximum angle of impact is 15 degrees or where there may be snagging potential. (Estimating an encroaching vehicle's angle of impact is usually done using engineering judgment. In general, higher angles of impact are expected on the outside of curves and at locations where items are flared relative to the roadway.) Barriers are required to protect mechanically stabilized earth (MSE) retaining wall within the clear zone.
9. At unprotected Noise Walls.

Crash experience, either at the site or at a comparable site, will often be the deciding factor with respect to the placement or omission of a barrier. In all cases, the preferred alternative is to keep the entire clear zone free of fixed objects wherever economically feasible.

601.1.2 - Slopes

Embankment height and steepness of foreslopes are the basic factors to be considered in determining the need for barrier slope protection. Figure 601-1 should be used to determine roadside barrier warrants for embankments.

601.1.3 - Protection of Others

Barriers are sometimes required to protect others (schools, residences, businesses, pedestrians, bicyclists, etc.) from vehicular traffic. Barrier criteria for protection of others from errant vehicles are not as defined as in other barrier warrant cases. Such decisions are normally made using crash experience, either at the site or at comparable locations along with engineering judgment.

601.1.4 - Protection on Low Speed Roadways

Barrier protection on city streets and urban type facilities with design speeds less than 50 mph is not normally required. However, on roadways where the design speed is greater than 25 and less than 50 mph, the designer should specify protection at locations where geometric conditions, crash experience or other circumstances indicate that protection should be considered.

601.1.5 - Protection on Low-Volume Collectors and Local Roads (ADT ≤ 2000)

The guidelines presented elsewhere in this section were developed using the AASHTO Roadside Design Guide. Guidelines contained in the 2nd Edition of the AASHTO Guidelines for the Geometric Design of Low-Volume Roads (less than or equal to 2000 ADT) may be used in lieu of those presented here.

On roads with very low traffic volumes, research has found that roadside clear zones provide very little benefit, and that traffic barriers are not generally cost-effective. The low-volume guidelines provide great flexibility to the designer in exercising engineering judgment to decide when it is appropriate to provide improved roadsides. New barrier installations at locations with less than 400 vpd are considered impractical. Where traffic volumes are between 401 and 2000 vpd, new installations of barrier should be based on engineering judgement.

A clear zone of any width should provide some contribution to safety, so when feasible to do so at little or no additional cost, it should be considered for low-volume collectors and local roads.

601.1.6 - Preservation of Safety Grading

Designers should preserve unobstructed areas on roadway designed and constructed with safety grading (**Section 307.2.1**). Typically, safety grading was part of the original construction and is intended to provide a safe recovery area outside of the required clear zone. These unobstructed areas should not be used to locate hazards, such as camera towers, ITS or WIM equipment, BMP detention ponds or aesthetic landscaping. To ensure driver safety and the financial investment made in safety grading the addition of hazards should be located behind existing barriers or as far away from traveled lanes as possible.

601.2 - Median Barrier Warrants

A median barrier is a longitudinal barrier used to separate opposing traffic on divided highways having relatively flat, traversable medians. Figure 601-2 provides barrier warrants for freeways to determine the need for median barriers, based on the width of the median and the volume of traffic on the facility. It may also be used for expressways with full access control. The use of the terms freeway and expressway in this instance apply to the operational characteristics of the highway, not necessarily the functional class designation. The use of median barrier on divided highways that do not have full access control requires engineering judgment and analysis with consideration to such items as right of way constraints, property access needs, sight distance at intersections, barrier end termination, etc.

A median barrier may be high tensioned cable, guardrail, or concrete barrier. If the median is wide enough so that the barrier is outside the clear zone of opposing traffic, then roadside barrier warrants may be used.

601.2.1 - Safety Studies

It is recommended that a safety study be conducted to determine if median barrier protection would be beneficial at locations shown in Figure 601-2 as “evaluate need for barrier” or “barrier optional.” The study may include the following factors: traffic volumes, vehicle classifications, median crossover history, crash incidents, vertical and horizontal alignment relationships and median-terrain configurations.

If barrier is chosen, see **Section 602.2.2** for median barrier design considerations.

601.3 - Criteria for ODOT Maintained & NHS Roadways

Highway safety features, including longitudinal barriers, anchor assemblies, bridge terminal assemblies and impact attenuators installed on the ODOT system and locally maintained National Highway System (NHS) routes must demonstrate satisfactory crashworthy performance and be accepted by the FHWA. The **AASHTO Manual for Assessing Safety Hardware (MASH)** contains the current recommendations for testing and evaluating the crashworthy performance of barriers and has replaced NCHRP Report 350: Recommended Procedures for the Safety Performance Evaluation of Highway Features for the evaluation of new devices. Crashworthiness is currently accepted if either of the following conditions are met:

1. A barrier system has met all of the evaluation criteria listed in MASH (2016) or NCHRP Report 350 for each of the required crash tests, or
2. A barrier system has been evaluated and found acceptable as a result of an in-service performance evaluation.

A given feature must be tested to one of six different test levels (TL) defined in NCHRP Report 350 and MASH. The six test levels correspond to the following crash testing matrix.

Crash Testing Matrix

Test Level	Vehicle	Speed (MASH)
TL-1	Passenger fleet	31 mph
TL-2	Passenger fleet	44 mph
TL-3	Passenger fleet	62 mph
TL-4	Single unit delivery van	56 mph
TL-5	Tractor Trailer	50 mph
TL-6	Tanker Trailer	50 mph

All six levels of testing determine if the barrier is structurally adequate to contain the vehicle type, while TL-1 through TL-3, criteria looks at the vehicle occupant survivability.

In general, all permanent devices installed on the ODOT system and locally maintained NHS routes must meet TL-3 requirements. Exceptions to this would be allowed in low-speed urban situations where a TL-3 protection is not feasible or cost prohibitive; in those locations a TL-2 device may be appropriate. Also, barrier on a retaining wall must meet TL-5 crash criteria on high-speed routes (i.e. Design Speed > 45-mph) with more than two lanes in the same direction. Otherwise, the minimum acceptance requirement shall be TL-3.

Existing roadside devices on ODOT maintained roadways and locally maintained NHS routes meeting NCHRP Report 350 TL-3 may be repaired if the device has sustained minimal damage and does not need to be replaced. Otherwise, roadside devices located on ODOT maintained or NHS roadways that are determined to be damaged beyond repair, must be upgraded to the latest MASH compliant hardware. All permanent roadside devices newly installed on ODOT maintained roadways shall be MASH (2016) TL-3 compliant. Exceptions to using a MASH (2016) device includes:

1. If a MASH (2016) option does not exist, then a NCHRP Report 350 device may be used instead.
2. Connection to bridge railing/parapet with a MASH (2016) device would require replacement/modification of the bridge railing/parapet, and the railing/parapet does not need replaced or is outside of the project scope. Then, a NCHRP Report 350 bridge terminal assembly may be used, but should transition to MGS following the BTA and the run should be terminated with a MASH (2016) compliant end terminal.
3. NCHRP Report 350 devices may be used on non-NHS routes where a site-specific situation exists that substantiates the usage of the device over a MASH alternative.

601.4 - Design Considerations for Large Trucks

Designers should consider the catastrophic nature of crashes involving tractor-tanker trucks and other large vehicles, even though such crashes are relatively rare and occur at generally unpredictable locations. Wherever large vehicles comprise a significant percentage of the traffic volume, crash potential or crash histories should be carefully reviewed to determine if higher performance traffic barriers are warranted and likely to be cost-effective.

Although objective warrants for the use of higher performance barriers do not presently exist, subjective factors most often considered for new construction or safety upgrading to TL-5 or TL-6 devices include:

1. High percentage of heavy vehicles (along major corridors, on hazardous material routes, or near hazardous industries),
2. Adverse geometrics (vehicle conflict points, sharp curvature, long downhill grades, poor sight distance, or adverse pavement surfaces like shoulder wedges or reverse superelevation on shoulders), and
3. Severe consequences associated with the penetration of a large vehicle (buildings or transit facilities underneath a bridge or multi-level interchange, sensitive environmental areas, or at critical bridges and tunnels).

602 - Site Considerations

Standards and guidelines are presented in this section for certain general site conditions; however, a site visit is essential to ensure that all design considerations have been addressed.

602.1 - Roadside Protection

When a roadside obstacle needs to be shielded, the designer should initially consider the most flexible barrier system installed as far from the traveled way as possible. Subsequent systems should be considered in order of increasing strength and decreasing distance from the roadway. In general, the designer should consider options for roadside protection in the following order:

1. Install guardrail and either terminate the end outside the clear zone or bury it into a backslope.
2. Install guardrail and terminate the end with a Type B flared end terminal.
3. Install guardrail and terminate the end with a Type E tangential end terminal.
4. Install concrete barrier according to **Section 603.1.2** and terminate the end according to **Section 603.6**.

602.1.1 - Location/Offset

The normal roadside barrier location, with respect to the edge of traveled lanes, is shown in Figure 301-3 and Figure 301-4. Minimum barrier clearances, measured from the face of the barrier to the face of the obstacle, are shown in Figure 603-2. (See **Section 603.4** for minimum clearances for impact attenuators.) Although variations from these offsets may occur as a result of reduced graded shoulder width, the face of the guardrail, concrete barrier or bridge parapet should not be located closer than 4 feet to the edge of the traveled lane. See **Section 602.1.5** for guidelines concerning the use of curb with guardrail.

602.1.2 - Length of Need on Tangent Alignments

Length of need is the total length of a longitudinal barrier that is needed in advance of an area of concern (warranting feature). The length of need point in a gating end terminal or impact attenuator determines how much of the end treatment can be contributed to the length of need for the barrier.

If it is determined that barrier protection is required to shield a fixed object, Figure 602-1 should be used to determine the length of need. The primary variables are the Runout Length (LR) and the Lateral Extent of the Hazard (LH). The Runout Length is the theoretical distance needed for an errant vehicle leaving the roadway to come to a stop. The Lateral Extent of the Hazard is the distance from the edge of the through traveled way to the far side of the hazard or to the edge of the clear zone if the hazard extends beyond the clear zone. The other three variables are the Tangent Length of barrier (LI,) the Lateral Distance from edge of the through traveled way (L2), and the Flare Rate (a:b).

The formula in Figure 602-1 shown for computing the barrier length of need is appropriate where tangent roadways are involved.

Short runs of barrier should be avoided where economically feasible. Gaps of 300 feet or less between adjacent runs of guardrail should be evaluated for closure. This can be achieved by comparing the estimated cost of the barrier to span the gap versus the cost of the two anchor assemblies.

Sample Calculations for length of need on tangent alignments are included in the **Examples**.

602.1.3 - Length of Need on Curved Alignments

Horizontal curvature of a roadway may have an effect in determining the barrier length of need in roadway design. In general, the length of need for a barrier on the outside of curves with a degree of curvature equal to 2°00' or flatter can be calculated as if the barrier was installed tangentially. However, a vehicle leaving the roadway on the outside of a curve sharper than this will generally follow a tangential runout path.

For those cases involving a horizontal curve sharper than the limiting values given above, rather than using the theoretical LR distance, the tangent line from the curve to the outside edge of the warranting feature (or to the clear zone) should be used to determine the appropriate length of barrier needed (See Figure 602-2.) The guardrail should not be flared in these locations, since the potential impact angles would generally exceed acceptable design limits.

Lengths of need should not be adjusted on the inside of horizontal curves. These locations should be treated as if they were on a tangent and LR should be measured along the length of the curve.

Sample Calculations for length of need on curved alignments are included in the **Examples**.

602.1.4 - Grading for Barriers & End Treatments

To function properly, anchor assemblies and impact attenuators need to be installed with proper grading. The grading is designed to ensure that an impacting vehicle strikes the device at the appropriate height and with all four wheels on the ground. It also helps to reduce the potential for snagging and vehicle rollover during and after impact. Adequate earthwork and excavation should be included in the plans to ensure that all devices have proper grading.

Ideally, the area immediately behind and downstream of all gating terminals should be reasonably traversable and free from fixed objects to the extent practical. A 20 feet by 75 foot area with 10:1 maximum slopes is required. When this is not practical, due to possible impacts to streams, and wetlands, the designer should consider alternatives. Also, there may be situations where existing conditions may preclude the acquisition of additional rights-of-way or easements necessary to build fill slopes that accommodate this grading. In

these situations, it may be advisable to select a terminal that requires less extensive grading (i.e. non-gating or re-directive, see **Section 603.2.1**) or extend a run of guardrail so that the terminal may be placed on more favorable terrain, or buried in the backslope. The designer should attempt to provide a clear area with recoverable slopes (4:1 or flatter) over the same 20 feet by 75 feet area. If a clear runout path is not attainable, this area should be similar in character to the upstream, unshielded roadside area.

In most cases, longitudinal barriers should not be located on slopes steeper than 10:1. Therefore, where a barrier is located outside the graded shoulder, special grading generally will be required to provide slopes that are 10:1 or flatter. Also, 6:1 slopes are of particular concern due to vehicle ramping effects. Barriers installed on 6:1 slopes should be limited to cases where the barrier is located at least 12 feet or more from the edge of the break point for the 6:1 slope to minimize the potential for an errant vehicle to vault over the guardrail. The Buried-in-Backslope Anchor Assembly is one exception that has been designed specifically for 4:1 or flatter slopes. MGS Guardrail may be used with 10:1 approach slopes (See **Section 603.3.1** for additional information.)

602.1.5 - Guardrail with Curbs

Curbs are generally classified as mountable or barrier curbs. Vehicles can, and do, safely traverse mountable curbs. Barrier curbs tend to inhibit vehicles from crossing over them at low speeds, but they are not a substitute for longitudinal barriers.

When guardrail must be used in conjunction with a curb, the location of the guardrail relative to the curb should be carefully considered to minimize unacceptable post impact vehicle trajectories. When a vehicle strikes a curb, the resulting trajectory may cause the vehicle to impact the guardrail too high. In some cases, the vehicle could clear the guardrail altogether.

Type 5 guardrail may be installed in conjunction with 4-inch curb (sloped face) with the face of the rail aligned with the face of the curb; refer to PIS GR-1.1 for details on installation height.

Type MGS guardrail may be installed in conjunction with 6-inch or shorter curb (sloped face) with offsets ranging from 0 inches to 6 feet; refer to the table below for installation height requirements and see SCD MGS-2.1 for additional details. Ensure grading behind the curb is as flat as possible for offsets from 1 to 6 feet where the MGS is installed at a

height of 31” relative to the ground surface. Refer to Figure 307-6 and use a 25:1 (.04) slope or flatter from the back of curb to 1 foot beyond the back of post.

Lateral Offset (Face of Curb to Face of Rail)	MGS Installation Height
≤ 6"	31" relative to roadway surface
1'-6'	31" relative to ground surface
>6'	Not recommended, but may be acceptable for design speeds less than 45 mph

602.1.5.3 - End Treatments and Impact Attenuators in Curbed Sections

None of the approved anchor assemblies or impact attenuators listed in **Sections 603.3 and 603.4** have been designed or tested for use with curbs; consequently, the designer should use the guidelines provided for uncurbed sections in addition to engineering judgment and recommendations from the manufacturer to select end treatments in curbed sections. The current recommendation from product vendors is to ensure curbs are not present (if practical) along the length of the product and for a distance of 50 feet in advance of the product. When terminating or removing curbs in the vicinity of end treatments and impact attenuators remember to taper the curb height from 4 or 6 inches to flush with the pavement over a distance of 10 feet.

602.2 - Median Protection

Two types of shielding are necessary in medians. First, shielding of fixed objects is required if located in the clear zone of either direction of traffic. Second, if the median width

warrants or a safety study shows a history or potential for Cross Median Crashes some type of barrier system may be needed. See **Section 602.2.2**.

602.2.1 - Shielding of Fixed Objects in the Median

When a median hazard requires protection, the treatment depends upon a variety of factors, including design speed, grading, cost, and the available width of the median. Bridge piers are the most common fixed object in the median that requires barrier protection, but there are also other fixed objects such as sign supports and light poles that may require barrier protection. There are multiple methods for shielding objects described in the sections below including installing flared guardrail, tangential guardrail, thrie-beam bullnose guardrail, and concrete barrier.

602.2.1.1 - Tangential and Flared Guardrail

Tangential or flared guardrail is commonly used in the median to shield fixed objects. The backside of MGS guardrail is not crashworthy, and therefore barrier design guardrail must be used if the backside of the MGS installation encroaches into the clear zone of the opposing direction. Refer to Figure 602-1 for MGS flare rates.

602.2.1.3 - Concrete Barrier

Another design for pier protection is to shield center median piers with concrete barrier. This design uses concrete barrier to encase the pier (**SCD RM-4.4**), and then taper the concrete barrier to the end section (**SCD RM-4.6**). Finally install two narrow Type 2 Impact Attenuators, one at each end. This eliminates the need for perhaps hundreds of feet of guardrail. Contact the Office of Roadway Engineering for more information and design details. Proper grading in advance and alongside of the barrier is crucial in ensuring proper performance.

602.2.1.4 - Thrie-Beam Bullnose

ODOT has occasionally utilized a wood-post, thrie-beam bullnose design for median pier protection as shown on the archived **SCD GR-6.3**, which was retired on 07-18-2025 and replaced with **MGS-6.3**. The design from **MGS-6.3** is a non-proprietary, primarily steel-post system and has successfully met MASH 2016 TL-3 criteria. The bullnose design may be a cost-effective solution for shielding hazards in the median when site conditions are conducive for the grading requirements to be met. In addition to shielding fixed objects in

the median, the bullnose can be employed to shield the drop off between twin at-grade bridges. It is critical to ensure correct grading is achievable and that the working width influence area depicted in **MGS-6.3** is hazard-free so that the system can perform as tested and designed. The bullnose assembly may fully enclose the hazard needing protection or may transition to MGS guardrail (or other features) per the transition details from **MGS-6.3**. Existing GR-6.3 installations may continue to be repaired, but all new installations shall follow the current MASH TL-3 design.

See **SCD MGS-6.3** for additional information and details.

602.2.2 - Mitigation of Cross Median Crashes (CMC)

602.2.2.1 - Barrier Selection

If a median barrier is determined to be necessary for shielding of CMC (**Section 601.2**), then the selection of the type of barrier to be used in the median is based on several factors, including the Test Level desired, median cross section, and barrier deflection.

Test Level - A safety study should determine the causes of CMC to determine the type of vehicle involved, and barrier selection should be based on the study. Most flexible and semi-rigid barriers are rated Test Level 3 (TL-3) or Test Level 4 (TL-4). TL-3 products are designed to withstand impacts from the standard fleet vehicles (passenger cars, pickup trucks, etc.); TL-4 products are designed to withstand impacts from the standard fleet and single unit trucks. See **Section 601.4** for further discussion on TL-5 and TL-6 (Large Trucks).

Cross Section Type - Barrier selection also depends on the median configuration, whether or not there is a mounded median, depressed median of 4:1, 6:1, or 10:1 or flatter slopes, the width of the paved shoulder and graded shoulder. Other factors include but are not limited to bifurcation and differential superelevation between the traveled lanes.

Barrier Deflection - The designer also has to be aware of the allowable deflection to appropriately select a median barrier product. On one hand, rigid concrete barriers do not deflect, but may require closed drainage and thus are expensive. High tension cable barrier has large deflections.

602.2.2.2 - Cable Barrier Placement in the Median

Cable barrier should be placed 8 feet up the slope from the bottom of the ditch to avoid drainage hydraulics, poor soil quality, and vehicle under-ride possibilities. If the median slopes are consistent, placement of cable on the slope outside of this zone is allowed, but no more than 4 feet from the graded shoulder/foreslope break point. Another acceptable location for cable placement is at the top slope on one side of the median if the paved shoulder is wide enough to accommodate the required offset from the edge of traveled way. See Section 603.1.1.2 for more information on required offsets. This location places the cable in preferable grading on the near traffic side and at the farthest point away from opposing traffic and allows for a factor of safety of the cable deflection, although this location may result in an increase in nuisance hits. Refer to Figure 602-3 for more information.

Consideration should also be made when ending/beginning cable runs so that staggered placement on either side of the median does not unintentionally leave wide gaps between barrier runs. (Refer to Figures 602-3a, 602-3b, 602-4a and 602-4b.) For more information contact the Standards Engineer in the Office of Roadway Engineering. The maximum post spacing allowed is 18 feet.

602.2.2.3 - Cable Anchor Terminals

Each proprietary cable barrier system must be terminated with approved anchor terminals. The maximum allowable distance between cable anchors is 3000 ft. Most crashworthy designs have breakaway anchors. Breakaway anchors will release the tension in the entire run of cable rendering it ineffective until repaired. If a vehicle is tangled in the cable, tension can be easily dropped out of the system if each run of cable has one set of breakaway anchors. Because of varying system length, the length of need point should be detailed on the plans.

602.2.2.4 - Cable Barrier as the Primary Barrier System

When designing a project utilizing cable barrier, designers should continue to use guardrail or concrete barrier to protect existing fixed objects. Cable barrier should not be used as the primary means of shielding fixed objects in highway medians.

602.3 - Gore Area Protection

Diverging gores are locations where one or more lanes of a road carrying traffic in the same direction diverge away from each other. (Unidirectional traffic exists on both sides of

a gore.) Impact attenuators are typically used to terminate the ends of longitudinal barriers located in diverging gores. (See **Section 603.4** for additional information on impact attenuators.)

602.4 - Protection at Drives and Side Roads

When normal mainline guardrail is interrupted by a side road or drive, the opening should be designed as shown in Figure 603-3.

The introduction of barriers at drives and side roads may have an adverse effect on both horizontal and intersection sight distances. These sight distances should be investigated when barriers are used at these locations. (See **Sections 602.6.2 and 602.7** for additional information.)

602.5 - Protection at Bridges and Fixed Objects

Concrete barrier end protection, utilizing guardrail with bridge terminal assemblies, shall be used at the approach end of bridge parapets, and other similar fixed objects, on all facilities where the design speed is 50 mph or greater. (See **SCD MGS-6.1**)

Pier protection in narrow medians and along the roadside is often accomplished using concrete barrier.

From BDM Section S1.3.4, the columns of single-column and two-column piers shall be considered non- redundant. The columns of cap-and-column piers with three or more columns shall be considered redundant. See BDM Section S3.6.5.1 for protection requirements.

For a low-speed redundant pier, the pier must be located:

1. At least 4-ft from the face of curb or 6-ft along the outside of curves;
2. At least 8-ft from the edge of the through traveled way for uncurbed or 12-ft along the outside of curves

Refer to Figure 603-2 for the appropriate barrier protection when these minimum offset dimensions are not available.

For a low-speed non-redundant pier located within the clear zone defined by Figure 600-1, refer to Figure 603-2 for the appropriate barrier protection.

602.5.1 Guardrail at Bridges & Large Culverts

Figures 602-1 and 602-2 should be used to calculate the barrier length of need at all bridges and large culverts (diameter or span greater than 60").

There are occasionally areas where the calculated lengths of need are impractical. An example would be where a drive or intersection is located too close to a bridge and cannot be relocated. In such cases, the approach guardrail length may be reduced as necessary. In no case shall the minimum treatment be less than shown in Figure 603-4.

On divided highways, guardrail is not required at either of the bridge parapet trailing ends unless it is warranted because of the lack of clear zone distance, the presence of openings between bridges, or where it is required in conjunction with a bridge railing.

602.6 - Protection at Drainage Structures

Adequate drainage is one of the most critical elements in roadway design. A comprehensive drainage design requires consideration of roadside safety as well as hydraulic efficiency.

In general, no part of an unshielded drainage feature within a clear zone graded roadway, excluding curbs, should extend more than 4 inches above the surrounding terrain. (Drainage features that do not comply with this criterion are herein referred to as “protruding.”)

(See the Location and Design Manual, Volume Two for specific drainage requirements.)

602.6.1 - Transverse Drainage

The design of the roadside at transverse conduits typically involves extending the existing conduit and providing clear zone grading or shielding the conduit ends with barrier. A large conduit terminating at the clear zone boundary may still pose a risk to run-off-the-road vehicles. Therefore, when extending the conduit, especially ones with a larger rise, it is preferable to maximize the length of the conduit within the available right-of-way versus terminating the end at the clear zone line. When extending the conduit, it is imperative to

remove or relocate all existing fixed objects (typically trees, utility poles) within the clear zone area to maximize the likelihood of a safe recovery for errant vehicles. There are many cases where extension of the conduit will be more costly than installing guardrail due to limited right-of-way or other site-specific limitations. There are some situations where extension may be preferred if the guardrail installation would not meet standards, such as the length of need would not be met, the barrier offset from the edge of traveled way would be deficient, the installation of a MASH end terminal is infeasible, etc. Overall, since each site poses different constraints that must be considered, engineering judgement and a cost and safety analysis should guide the decision on selecting the appropriate treatment. But in general, the preferred roadside treatment of transverse drainage is as follows:

For conduits with a rise or span greater than 60 inches:

Shield the ends of the exposed pipe per **Section 602.5.1**.

For conduits with a rise or span greater than 36 inches and less than or equal to 60 inches:

1. Extend the exposed pipe ends outside the clear zone when practical. See **Section 307.2.2** for additional information and see **Sample Calculations 600-4**.
2. When the above option is impractical, shield the ends of the exposed pipe per **Section 602.5.1**.

For individual pipes with diameters or spans less than or equal to 36 inches or multiple pipes each with a diameter less than or equal to 30 inches located in areas where clear zone or safety grading is not provided:

Provide standard half-height headwalls (SCD HW 2.1 or HW 2.2) at exposed pipe ends.

For individual pipes with diameters or spans less than or equal to 36 inches or multiple pipes each with a diameter less than or equal to 30 inches located in areas where clear zone or safety grading is provided:

Extend the exposed pipe ends outside the clear zone when practical and provide standard half- height headwalls.

When the above option is impractical, use slope tapered pipe end treatments.

602.6.2 - Intersecting Embankments & Parallel Drainage

Intersecting embankments are slopes that are transverse to the roadway. They are usually created by median crossovers, intersecting roadways and driveways. These slopes are typically struck head-on by vehicles that have left the traveled way.

Median crossovers on Interstates/Freeways shall use a 12:1 slope.

Embankment slopes for side roads should be as flat as practical, and drainage pipes underneath side roads should be located outside of the mainline clear zone where practical. This can typically be accomplished with minor adjustments to the ditch profiles.

For driveways on projects with clear zone or safety grading, the intersecting embankment slopes should be as flat as practical and:

1. All protruding drainage appurtenances should be placed outside the mainline clear zone, when practical. Standard half-height headwalls should be provided on all pipe ends located outside the clear zone.
2. If a protruding drainage appurtenance cannot be located outside the clear zone then it should be placed as far from the roadway as practical and treated similarly to drive pipes on projects without clear zone or safety grading.
3. An enclosed drainage system (storm sewer) may also be considered.

For driveways on projects without clear zone or safety grading, the intersecting embankment slopes should be as flat as practical and:

1. Exposed ends of pipes with diameters or spans less than or equal to 24 inches should be miter cut to conform to the prevailing slope.
2. Exposed ends of pipes with diameters or spans over 24 inches should be designed with standard half-height headwalls.
3. An enclosed drainage system may also be considered.

602.6.3 - Special End Treatments

End treatments that utilize bars or grates designed as safety treatments for exposed pipe ends are commercially available. However, these end treatments reduce hydraulic efficiency and exhibit a high potential for clogging. This type of end treatment should only be used when all other reasonable options have been exhausted.

602.7 - Sight Distance Considerations

The introduction of longitudinal barriers may have an adverse effect on both horizontal and intersection sight distances. The effect on both distances should be investigated at all locations where barriers are used. (See **Sections 201.2.2 and 201.3.2** for additional guidance.)

603 - Roadside Safety Devices

The goal of any highway roadside safety device is simply to assist in providing a forgiving roadside for an errant motorist. The goal is met when the feature does one of the following without causing serious injuries to the occupants of the vehicle or to other motorists, pedestrians or work zone personnel:

1. contains or redirects the vehicle away from the hazard,
2. decelerates the vehicle to a stop over a relatively short distance,
3. readily breaks away, fractures or yields,
4. allows a controlled penetration, or
5. allows the vehicle to safely traverse the feature. (See **Section 601.3** for additional information.)

603.1 - Longitudinal Barriers

Longitudinal barriers function by containing and redirecting impacting vehicles. They are typically classified into three types based on relative strength characteristics: flexible, semi-rigid and rigid.

Deflection characteristics of a longitudinal barrier system determine the minimum clearances between the face of the barrier and the face of the object it shields. Minimum

barrier clearances are listed in Figure 603-2 along with typical applications for the standard types of barrier described in the following sub-sections.

603.1.1 - Flexible Cable Systems

Cable systems are considered flexible systems in that they tend to exhibit large deflections when impacted. Although large deflections can be problematic they produce a relatively soft impact allowing for a gradual deceleration of the vehicle.

603.1.1.1 - Generic Low Tension Cable

Generic low tension cable systems are no longer allowed to be constructed on ODOT's system.

603.1.1.2 - Proprietary High Tension Cable Systems

High-tension cable barriers are proprietary systems installed in the median of divided highways to mitigate cross-median crashes. The systems share a common core design: four standard 3/4-inch galvanized steel cables stretched under substantial tension between crashworthy anchor assemblies. Each system has uniquely designed, lightweight steel posts that are engineered to yield during a crash, allowing the tensioned cables to absorb the impact energy and safely capture or redirect the vehicle. The posts are socketed into concrete foundations, and typically a four-foot-wide concrete or asphalt vegetation control strip is installed along the alignment of the system.

To prevent vehicles from entering the opposing traveled way during an impact, the barrier's minimum offset from the edge of the traveled way must equal or exceed its design deflection. While CMS 610 specifies a maximum allowable deflection of 10 feet, an 'As Per Plan' item can be utilized to restrict this criteria to a lesser value of 8 or 9 feet. Because lateral deflection is limited by decreasing the distance between posts, this tighter deflection limit requires closer post spacing. Consequently, the trade-off for this design modification is a higher life-cycle cost due to the installation and maintenance of the additional posts.

603.1.2 - Semi Rigid Barriers

ODOT's approved semi rigid barriers include: Type 5 and Type MGS guardrail – both strong post w-beam guardrail systems. Other proprietary guardrail systems are not considered equivalent and are not acceptable for use on ODOT jobs.

- Type MGS guardrail is a MASH TL-3 crashworthy system at a 31 inch installation height (+/-1 in.) New guardrail designs should utilize MGS.
- Type 5 guardrail is an NCHRP 350 TL-3 crashworthy system at a 29 inch installation height (+/-1 in.). Still acceptable on the State System, this system should be limited to repair locations of existing rail. **Refer to Plan Insert Sheets (GR series)** and **the July 2012 Version of this Manual** for Type 5 guardrail design standards**.**

The three major components of a strong post barrier are the rail, posts, and blockouts. This ribbon of rail acts to capture impacting vehicles and to dissipate energy up and down the rail length. The tension on the rail from an impact can be transferred a considerable distance. Proper anchoring of the rail at both ends is critical in achieving proper performance.

Guardrail posts are designed to support the rail at the appropriate height and provide lateral support during an impact. For most impacts, the posts are designed to rotate through the soil, rather than bend at or near the ground surface. This rotation helps to contribute considerably to the energy absorbed in the collision and helps to prevent contact between the vehicle and the posts. For this reason, paving around posts is not advisable if the thickness or mass of the pavement would prevent this rotation from occurring. Two inches of asphalt pavement is the maximum allowable thickness for paving under guardrail. Eight inches is the maximum distance that the asphalt can extend beyond the pack of post. See **Sample Plan Note R116** and **SCD MGS-2.1** for additional information. Guardrail posts should never be directly embedded in concrete. But grout leave outs can be provided per **SCD MGS-2.1** when posts must be installed in a section of concrete, or asphalt that extends greater than 8" behind the back of post.

When guardrail is being installed in rocky terrain locations, refer to the details in **SCD MGS-2.1** for special installation guidance.

For guardrail installations to perform properly during an impact, adequate soil support must be provided for the posts in the guardrail run. To ensure this support, longer posts should be specified at locations where the distance behind the post to the slope break point is less than one foot. These locations should be specifically identified in the plans. See **SCD MGS-2.1** for additional details and proper post length.

The use of blockouts increase the overall performance of a guardrail system. Blockouts minimize the potential for a vehicle's wheels to snag on the posts and reduce the likelihood of a vehicle vaulting over the barrier. This is accomplished by maintaining the height of the rail as the barrier deflects and rotates downward during an impact. The standard Type MGS Guardrail uses a 6" wide x 12" deep x 14" long blockout. Crash testing has also been successfully completed on MGS with reduced and eliminated blockouts; see 603.1.2.2 for more information.

603.1.2.1 - Type MGS Guardrail

The Midwest Guardrail System, Type MGS, is Ohio's strong post barrier used for roadside protection where 5 feet of barrier clearance is available. Type MGS guardrail uses w-beam rail with a top rail height of 31 inches to accommodate larger vehicles and the blockouts are 12 inches deep. This guardrail system can be placed on foreslopes as steep as 10:1 and may be flared away from the roadside per Figure 602-1. Flaring MGS guardrail allows for the potential of reducing installation length and positioning the guardrail further from the edge of traveled way, which can decrease construction/maintenance costs and impact frequency. But with a typical flared installation where the guardrail offset decreases in the direction of travel, the effective impact angle is higher than that of a tangent guardrail installation, and the higher impact angle results in an increased impact severity. Another consideration for flared guardrail installations in the median is that the flared alignment could encroach upon the clear zone of the opposing side, which necessitates additional blockouts and w-beam rail (Barrier Design, Type MGS) along with terminating the run with a more expensive Type 1 impact attenuator instead of a Type E or B anchor assembly. Additionally, the 10:1 grading must be perpetuated for a further lateral distance to properly accommodate the flared installation, which increases earthwork costs. These trade-offs along with project and site-specific details must be considered when deciding to flare an MGS guardrail installation. In some cases, flaring MGS guardrail may be necessary to meet the length of need requirement due to the presence of unrelocatable features (e.g., driveway or median U-turn).

(Type MGS guardrail has passed MASH TL-3 testing. See **SCD MGS-2.1** for additional details.

Type MGS guardrail may be constructed with steel, rectangular wood, or round wood posts per **MGS-2.1.** For standard runs of MGS, the selection of the post type is at the discretion of the contractor. Wood post MGS runs shall be grounded where a transmission/sub-

transmission (>69kv) power line passes over them. Wood post MGS runs shall also be grounded where a parallel transmission/sub-transmission (>69kv) power line runs within 50 feet (measured horizontally) of the guardrail alignment. Designers shall include quantity in the plans for Item 625 - Ground Rod at these locations with the assumption that wood posts may be chosen by the contractor. The ground rod(s) should be non-performed in construction if the contractor elects to install steel posts. For grounding details see **SCD MGS-2.1.** A distribution line crossing does not typically necessitate the guardrail to be grounded unless a nuisance current has been reported, or other site-specific conditions indicate grounding the run may be needed.

Half Post and Quarter Post spacing is available for MGS for reduced deflections: 3.5 ft. and 3 ft. respectively. See **SCD MGS-2.1** for additional details. A minimum of 37.5' of half post spacing should be provided with the hazard located in the center of this length. A minimum of 25' of quarter post spacing should be provided with the hazard located in the center of this length. When going from normal post spacing to quarter post spacing, use 25' of half post spacing before reducing further to the quarter post spacing. In constrained situations this transition segment may be reduced to 12.5'. Do not employ quarter or half post spacing for any length of an end terminal.

The Midwest Guardrail System also performed successfully in a crash test with one omitted post. Designers may note in the plans to leave out one guardrail post at a specific location within a standard run of MGS to avoid utilities or other underground conflicts. Fifty feet of guardrail should be available both upstream and downstream of the omitted post to maintain tension and strength in the system. More than one post may be omitted in the same guardrail run if there is adequate spacing of 56.25' between each omitted post; see Figure 31 below. A post may be omitted where curb is present, but the w-beam must be nested per the detail on **SCD MGS-2.1**. A minimum of 12.5' of MGS is required between an omitted post and a Type E, 31.25' of MGS between an omitted post and a Type B, and 75' of MGS between an omitted post and post #1 of a Type T; see Figure 32 below. A minimum of 37.5' of MGS is required between an omitted post and a BTA Type 1.

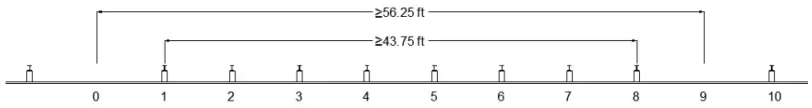


Figure 31 from MwRSF Research Report No. TRP-03-326-16

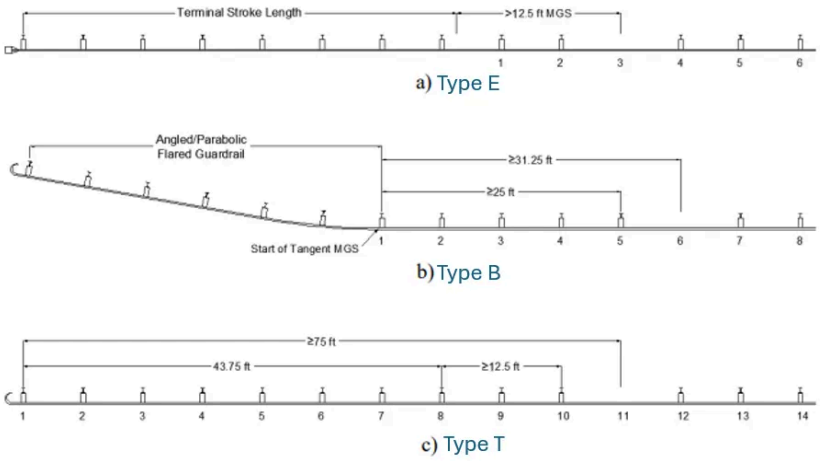


Figure 32 from MwRSF Research Report No. TRP-03-326-16

603.1.2.2 - Non-Blocked Type MGS Guardrail

On 2-lane facilities where the roadside is limited by steep foreslopes, drop-offs, or other site constraints, engineering judgment may be used to consider eliminating the blockout, particularly if this will help improve the overall backfill/embedment of the guardrail posts. It is not recommended to remove the blockout in situations where the available roadside width is not restricted as the blockout improves vehicle stability and reduces the potential for tire snag during impacts. A minimum of 25 feet of standard MGS with blockouts is required in between the non-blocked MGS and any bridge terminal assembly.

Non-blocked MGS may be used in conjunction with long span MGS for the standard posts adjacent to the breakaway CRT posts, but not for the six wood CRT posts. Do not install non-blocked MGS in the following configurations:

1. In conjunction with curb
2. With reduced post spacing
3. With an omitted post within the run
4. Barrier design (with or without rubrail)

See SCD MGS-2.1 for details.

603.1.2.3 - Barrier Design Guardrail

Barrier Design Guardrail is used primarily in bi-directional median applications on any roadway where a minimum barrier clearance of 5 feet can be provided. Barrier Design Guardrail is identical to standard MGS guardrail with the addition of blockouts and rail on the opposite side of the posts. Type MGS Barrier Guardrail requires a minimum cross slope approach of 10:1 on both sides of the barrier. Barrier Design Guardrail is often terminated by attaching to concrete barrier with a Type 1, Barrier Design BTA. Otherwise, a Type 1 Impact Attenuator is used in both bidirectional and unidirectional situations.

See **SCD MGS-2.1** for additional details.

603.1.2.4 - Barrier Design Guardrail with Rub Rail

Barrier Design Guardrail with Rub Rail can be used in bi-directional median situations, similar to standard Barrier Design Guardrail, but when the 10:1 minimum foreslope on the median side cannot be achieved. This design is a double sided MGS guardrail system with a rub rail on the median/ditch side of the system. The purpose of the rub rail is to reduce the potential for underride and snagging for vehicles that have crossed the median ditch and are traveling up the opposing foreslope. A maximum 6:1 foreslope is allowed on the median/rub rail side of the system. The design in **SCD MGS-2.2** replaces the previously retired "Type 5MR" guardrail. Type 5MR guardrail may continue to be repaired, but new installations shall utilize the Barrier Design Guardrail with Rub Rail design per **SCD MGS-2.2.** See **SCD MGS-2.2** for additional details.

603.1.2.5 - Long Span Guardrail

A MASH TL-3 long span guardrail design for spanning up to 25 feet across culverts is shown on **SCD MGS-2.3**. This guardrail system with breakaway posts has a deflection of 8 feet from the face of rail and requires 2 feet of grading (8:1 max) behind the post. When possible consider grading up to the back of headwalls that would otherwise protrude more than 4 inches above the slope break point elevation within that 8 ft. deflection area. Otherwise, the culvert should be extended so that the headwall does not become a hazard in the long span guardrail deflection area.

See Figure 603-7 for design details on minimum guardrail installation lengths prior to various anchor assemblies.

603.1.2.6 - MGS Top-Mounted to Culverts

There are two details provided in **SCD MGS-2.1** for mounting posts to the top of reinforced concrete box culverts or other flat-top (reinforced) concrete structures/conduits. Do not use these details to mount posts to unreinforced concrete. Both designs have met MASH TL-3 criteria and are considered equivalent; Detail #1 is compatible with standard post spacing, and Detail #2 is compatible with half post spacing. Do not use either detail in conjunction with quarter post spacing. Both assemblies are designed to have a minimum of 9" of fill at the post. Each detail has different requirements for the minimum offset from the foreslope wall to the back of post, see **SCD MGS-2.1** for more information.

When applying this standard to existing culverts, coordinate with the District Hydraulic Engineer or appropriate conduit inspection staff to ensure the condition of the existing culvert is adequate to permit installation of the mounted post(s).

If the thickness of the conduit is going to require the bolt-through method, ensure that viable access to within the conduit can be maintained following construction to allow for maintenance staff to inspect and replace hardware.

A detail sheet should be provided in the plan that indicates the station, offset, and total height of each mounted post on the culvert/structure. The detail sheet should include the culvert segments or "sticks" to verify that the proposed post installation(s) maintains 4" of clearance between the center of any attachment anchor and any culvert end (abutting segment or free end). A spreadsheet has been developed to aid designers in determining the post height "H": Culvert Mounted Posts - Height Calculator

603.1.2.7 - Socketed Weak Post - Side Mounted to Headwall

This design uses socketed S3x5.7 posts spaced at half-post spacing (3'-1 1/2") that are attached to the side of a reinforced concrete headwall. This system can be transitioned to standard MGS guardrail at normal post spacing and is typically used to protect box culverts with limited cover. The socketed weak post system with half-post spacing performs similarly to standard MGS guardrail. The primary benefits of the socketed weak post system are that it has a shorter system width and less intensive post-impact maintenance than the two top mounted systems (**Section 603.1.2.6** and **SCD MGS-2.1**). Additionally, the socketed weak post system can be used when the 9" of soil/fill (required with both top mounted systems) cannot be provided in front of the headwall.

See **SCD MGS-2.4** for more details.

603.1.4 - Rigid Concrete Barrier

Concrete barriers are used in locations where barrier deflections cannot be tolerated. Because of its rigidity and shape, it is very effective for small angle impacts and is preferred for use where the chance of impacting it at an angle of 15 degrees or greater is minimal. It also requires less maintenance than steel beam guardrails. Overall impact severities for these barriers are usually greater than the other types of systems.

At locations where a standard barrier cannot be installed, the face of fixed objects within the clear zone should be designed with the concrete barrier shape. Typical locations are along retaining walls and walls that connect pier columns. On upgrading projects where the face of these fixed objects does not have existing protection, the concrete barrier shape should be provided to shield these objects.

Concrete Sealers are not required for concrete barrier.

603.1.4.1 - Single Slope Barrier

ODOT changed its standard concrete barrier shape to that of a single slope, from the New Jersey shape in 2003. Single slope barriers have advantages of better crash test performance for TL-3 vehicles, and the capability of being a TL-5 barrier.

The single slope standard does not require a concrete base outside the end sections, as was required with the previous NJ safety shape. The single slope barrier, however, does need a solid base material (asphalt or aggregate) to support its own weight, and an overlay of material at the toe of the barrier. Single slope barrier does not require horizontal steel rebar except in the end sections and end anchorages. It is used on any roadway in areas where signs, lighting or other unyielding objects are to be mounted on top of the barrier. Concrete barriers are to be terminated with reinforced foundations. Use an End Anchor as shown on **SCD RM-4.3**, unless the barrier end connects to an impact attenuator or guardrail, in which case an End Section as shown on **SCD RM-4.6** should be used in lieu of the End Anchor.

603.1.4.2 - Types B & B1

Single Slope Concrete Barrier, Type B, is 28 inches wide at the base and 42 inches tall. Single Slope Concrete Barrier, Type B1, is 33.75 inches wide at the base and 57 inches

tall. The additional height of the barrier in excess of the Type B serves as the glare screen. Refer to **Section 604** for additional information on glare screens.

The Type B barrier is capable of having multiple pavement overlays placed next to it without having to reset the barrier. The single slope barrier height may be reduced from an original height of 42 inches to 30 inches and remain TL-3 (MASH 2016 criteria).

603.1.4.3 - Type C & C1

Single Slope Concrete Barrier, Types C and C1, are used on any roadway in narrow medians where the difference in elevation on either side of the barrier is less than or equal to 24 inches. The barrier varies in width at the base depending on the height. For Type C, with the height on one side fixed at 42 inches, the other side can vary in height from 42 inches to 66 inches. Type C1 varies from 57 inches to 81 inches on one side while the other side is fixed at a height of 57 inches. Barriers with elevation differences greater than 24 inches are to be individually designed.

603.1.4.4 - Types D & E

Single Slope Concrete Barrier, Type D, is 20 inches wide at the base and 42 inches tall. It has the single slope profile on only one side of the barrier; therefore, it can be used on any roadside where impacts are expected on only one side of the barrier. It is often used for the protection of piers and other fixed obstacles. Two back-to-back Type D barriers should not be used in lieu of a single Type B median barrier as debris collects behind the barrier causing maintenance problems. Nor should Type D barrier be modified to a taller height to accommodate glare screen protection. Separate glare screens attachments should be used. Refer to **Section 604** for additional information on glare screens. See **SCD RM-4.5** for barrier and end anchors details and for use at obstructions. See **SCD RM-4.6** for Type D end sections.

The Type D barrier requires a 5' section of embankment at 20:1 (or 5%) behind the non-traffic side prior to the 2:1 slope break. If the 5' (flat) section of embankment is not achievable, the barrier may need to be transitioned from Type D to Type E barrier**.** The Type E Barrier is a 36" Single Slope Barrier with a foundation and has met MASH TL-4 criteria. There are two foundation designs: the moment slab and grade beam. The moment slab is typically the preferred foundation when used in conjunction with new, concrete pavement or where shallow utilities exist underneath the proposed barrier. The grade

beam foundation is typically preferred with new, asphalt pavement or retrofit installations where the existing pavement is not being disturbed with the project. Contact the Office of Roadway Engineering prior to using the Type E barrier.

See **SCD RM-4.9** for Type E barrier details.

603.1.4.5 - New Jersey Shape

ODOT's previous standard was the NJ safety shape barrier. This barrier type has a 3 inches vertical portion at the base which plays no significant role in the performance of the barrier, but provides an allowance for one future pavement overlay. The NJ shape continues to meet at least TL-3 requirements and can be utilized on very short lengths where existing NJ barrier is present. Plan insert sheets of this design are available on the Office of Roadway Engineering's web page.

603.1.4.6 - Zone of Influence

Designers are encouraged to minimize objects on top of and behind concrete barriers because of truck box yaw into the barrier in an impact. Discrete objects such as lighting standards or sign supports could be snagged by a box truck, or continuous objects like sound wall mounted on top of barrier could be damaged by a truck's cargo box rotation. For single slope and NJ shape barriers, a reasonable area to keep as free of objects as reasonable would be 32 inches behind the top face of the barrier to 80 inches above it. Generally, objects placed in this area would not compromise the crashworthiness of the barrier, but incidental damage to the impacting truck's cargo box or the object itself may occur.

603.1.4.7 - Type N Single Slope Barrier

Noise walls located inside the clear zone are a fixed object requiring barrier protection. Preliminary testing indicates that an 81" tall single slope concrete barrier adjacent to the shoulder can be an effective noise barrier. An 81" single slope barrier as shown in SCD RM-4.8, may be considered at locations under the following conditions:

- Where a noise wall along the shoulder is already planned to include barrier protection.
- Where the roadway is higher than the surrounding residences making a traditional noise wall outside the clear zone infeasible.

- Where clear zone grading does not exist.

603.1.5 - Portable Barrier

Refer to Roadway **SCD RM 4.1,** Roadway **SCD RM 4.2,** Structural **SCD PCB-91,** and the **PCB Design Data Sheet**. All portable concrete barrier used on ODOT's system must be constructed using these drawings, or the shop drawings provided on the Office of Roadway Engineering Approved Products List. All projects shall be designed in accordance with this section, Figure 603-6, RM-4.1, RM-4.2, PCB-91, and the PCBDD. When anchoring PCB to bridge decks, the designer shall list RM-4.2 and PCB-91 in the SCD index on the title sheet of the plans and indicate (via plan note) the number of anchors per segment required if the contractor elects to use PCB-91 instead of the RM-4.2 anchored F-Shape. If the construction completion date is beyond 12/31/2029, do not include PCB-91 (or number of anchors via plan note) in the plans.

Historically, ODOT has used 2 feet as the deflection of unanchored PCB. This dimension more realistically represents the desirable minimum offset distance from a traveled lane to the PCB. With regards to probable deflections, most NCRHP-350 crash tested PCB were displaced laterally between 5 to 6 feet. ODOT's 32" New Jersey Shape Barrier (RM-4.2) design deflected 5.5 feet, but this 2001 crash test was conducted on 244 feet long run of unanchored barrier. It may be assumed that a longer run of barrier would have less deflection as more friction and tension would be available, and that impact angles in tight work zone location are not as severe as the impact of the standard 3-11 test.

2-feet continues to be an appropriate deflection limit criterion between two sets of travel lanes. It is also a valid distance between PCB protecting the traveled lanes and construction equipment or personnel, however, larger deflections are entirely possible. The full deflection offset is required if the barrier is protecting motorists from fixed objects as shown in Figure 603-6.

Design values for portable concrete barrier depend on use, see Figure 603-6:

Drop-off
Where portable barrier is warranted based on SCD MT-101.90, a 2-foot minimum offset is required from the backside toe of the barrier to the drop-off. Where the drop-off is similar to that of a bridge deck, the bridge deck guidance detailed below shall be used.

Fixed Object
When protecting a fixed object, the design offset from the barrier to the fixed object is 5.5 feet minimum from the backside toe of the barrier for 32” PCB and 6.25 feet minimum for 50” PCB. This offset may be reduced for 32" PCB by anchoring the barrier as shown graphically in Figure 603-6 and detailed in RM-4.2. 50" PCB shall not be anchored in concrete or asphalt.

Bridge Deck
The minimum required offset, from the backside toe of an unanchored portable concrete barrier to the edge of a bridge deck, shall be determined by using the PCBDD. The minimum anchored design offset between the edge of the deck and backside toe of the barrier is 1-foot.

Radius
The minimum design radius of a portable concrete barrier is 100 feet.

District approval is required for designs where the minimum design offsets cannot be obtained in the following situations: back side toe of anchored barrier to deck edge or fixed object; back side toe of barrier to drop-off; front side toe of barrier to traveled lane (after applying the applicable guidance described in TEM Section 640-2).

603.1.5.1 - Alternate Portable Barriers

A list of alternate portable barriers approved for use on ODOT maintained roadways can be found on the Office of Roadway Engineering's Approved Products List. The Approved Products list contains both steel and concrete portable barrier options. When an alternate product is proposed to be used in lieu of RM-4.2, the product must be installed per the manufacturer installation guide, shop drawings, and any additional guidance listed on the Office of Roadway Engineering's Approved Product List.

The Portable Barrier Minimum Offset Guide posted on the Approved Products List webpage contains the design offsets for each approved barrier type.

603.2 - Characteristics of Anchor Assemblies & Impact Attenuators

Originally end terminals were designed simply to anchor the ends of guardrail runs. However, over the years safety at the ends has become a major concern. As a result,

guardrail end terminals (anchor assemblies) have taken on additional functions. An anchor assembly can function by:

1. Decelerating a vehicle to a safe stop within a relatively short distance permitting controlled penetration of the vehicle behind the device;
2. Containing and redirecting the vehicle;
3. A combination of the above.

Anchor assemblies must also be capable of developing the full tensile strength of the rail elements.

Impact attenuators (crash cushions) are designed primarily to safely stop a vehicle within a relatively short distance. Some common uses of impact attenuators are at exit gores, on or under bridges where piers require shielding, and at the ends of roadside and median barriers.

Crashworthy anchor assemblies and impact attenuators can be classified as either (1) energy absorbing or not, (2) gating or non-gating and (3) redirective or non-redirective.

603.2.1 - Energy Absorbing

When a vehicle impacts an energy absorbing end terminal, energy from the impact is dissipated in a variety of ways through the deformation of the vehicle's crush zone and also from the barrier itself. An energy absorbing system is designed to expend crash energy by crumbling steel or other material so that most of the energy will be dissipated internally within the barrier system. The advantage of an energy absorbing system is that a vehicle and its occupants can be decelerated to a stop within 30 to 50 feet under designed impact.

603.2.2 - Gating

A non-gating system will bring an impacting vehicle to a controlled stop or redirect it while a gating system will allow a vehicle impacting the system at an angle to pass through the system along the same general path. Gating guardrail end terminals will remove very little of the impacting energy, thus vehicles will pass through the system at close to the

impacting speed. See **Section 602.1.4** for proper grading recommendations with regards to gating end terminals, especially the 20 feet by 75 feet run out area behind and beyond the start of the gating terminal.

The length of need (LON) point in a non-gating system is located at the nose of the system. When using a gating system, the LON point needs to be identified to determine what portion of the system can be used as part of the barrier's LON. See **Sections 602.1.2** and **602.1.3** for additional information on length of need.

603.2.3 - Redirection

A redirective system will redirect an impacting vehicle away from a fixed object when the system is struck at an angle on the side. **A non-redirective system** will allow a vehicle to continue in approximately the same direction until it comes to a stop.

A non-redirective system is designed to contain and capture a vehicle impacting downstream from the nose of the unit. It provides protection in an end-on collision by absorbing the impacting vehicle's kinetic energy; however, it does not control an angle impact and it may allow pocketing or penetration. (Pocketing is said to have occurred if, upon impact, relatively large lateral displacements happen over a relatively short longitudinal distance.) All non-redirective devices are also gating. LON is established at the rear of the device. Sand barrel arrays are typical non-redirective devices.

A redirective, gating system has redirective capabilities over a portion of its length. The LON point varies from system to system. These devices are almost always anchor assemblies.

A redirective, non-gating system is designed to contain and redirect a vehicle impacting downstream from the nose of the unit. Redirection is provided over the entire length of the device; therefore, the LON is established at the nose of the device.

603.2.4 - Proprietary Products

Many of the following devices are proprietary products, which are subject to change at the manufacturer's discretion. The information provided in this manual is accurate and up-to-date at the time of publication and represents the currently approved versions of these products. New products may be introduced and modifications to existing products may

occur, which may or may not be approved by ODOT. Shop drawings of all approved proprietary devices are provided with the standard construction drawings. For additional guidance link to Office of Roadway Engineering's web page on Proprietary Roadside Safety Devices or contact the Roadway Standards Engineer.

Each proprietary end terminal and impact attenuator must be installed according to the manufacturer's recommendations.

603.3 - Anchor Assemblies

There are various anchor assemblies used to safely terminate guardrail runs that are described within this section. It is imperative to label the calculated length of need (LON) point on both the approach & trailing ends of each guardrail run included in the plan, regardless of which anchor assembly has been selected. Certain anchor assembly categories (e.g. Type Es) contain multiple proprietary products with varying system lengths, and the product used is at the discretion of the contractor. Additionally, designating the calculated LON point on the plan enables the contractor/project engineer to confidently and expeditiously make necessary field adjustments, such as shifting the location of the posts to eliminate a conflict with an underground utility, while still meeting or exceeding the required length of need. See **Section 602.1.2** and **602.1.3** for more information on the length of need requirements.

Designers should avoid the placement of two Type E or Type B anchor assemblies in close proximity/parallel to one another. Typically, this situation is encountered in gore areas. The preferred alternative is to connect the individual guardrail runs via the thrie-beam bullnose terminal (**SCD MGS-6.3**) or with an impact attenuator, especially when the offset between assemblies would be <25'.

603.3.1 - Buried-In-Backslope

The buried-in-backslope anchor assembly is a flared, redirective, non-gating, non-proprietary, end terminal. The primary benefits of the buried-in-backslope terminal are that the risk of a head-on impact with the end of the terminal is eliminated and the system offers full protection of the roadside hazard.

The buried-in-backslope assembly ODOT currently uses (SCD MGS-4.5) successfully met MASH 2016 TL-3 criteria (passed tests 3-34 & 3-35). A previous version of the buried-in-

backslope terminal that ODOT used, often referred to as "Type 8" guardrail, contained 8' posts and can be found under the MGS-4.5 SCD dated 01-18-2013. This version was retired on 07-18-2025. Existing Type 8 installations may continue to be repaired, but all new installations shall follow the current MASH TL-3 design.

The buried-in-backslope terminal shall be installed with 4:1 or flatter foreslopes and backslopes as steep as 1:1. A vehicle impacting this terminal close to the buried end may be able to climb flatter backslopes and encroach behind the guardrail. Consequently, where backslopes are flatter than 2:1 a minimum of 75 feet of guardrail must be provided upstream between the warranting feature and the intersection of the guardrail with the ditch flowline. Where backslopes are 2:1 or steeper this provision is not applicable.

This anchor assembly may be used as an approach end treatment for guardrail on any roadway. See **MGS-4.5** for additional details.

603.3.2 - Type B

The Type B anchor assembly is a flared, redirective, end terminal. The overall system length of the Type B varies by device: the length from post #1 to the splice point with standard MGS is 36'-5.5" for the MFLEAT and 34'-4.5" for the 4F-T. To be conservative on the overall footprint of the guardrail installation, the designer should assume a device length of 36'-5.5". The device's length of need for the Type B begins at post #4; therefore, the length from post #4 to the splice point with standard MGS can be applied toward the overall calculated length of need for the guardrail run. This length slightly varies depending on which approved device is installed: the distance is 19'-9.5" for the MFLEAT and 21'-10.5" for the 4F-T. Since the designer cannot predict which device the contractor elects to install, it should be assumed that 19'-9.5" (measured from the final MGS splice) of the Type B device can be applied toward the overall calculated length of need. The length from post #4 to the first post is considered gating. Additionally, the offset from the face of the downstream rail to the face of rail at post #1 varies system to system. The MFLEAT is installed at a tangent flare with an offset of three feet, and the 4F-T is installed at a tangent flare with an offset of four feet.

The Type B may be used as an approach end treatment for guardrail on any roadway. The Type B cannot be used when the back side of the device is in the clear zone of bidirectional traffic. The Type B products require a 75' long by 20' wide recovery area graded at 4:1 immediately behind the 10:1 terminal grading pad detailed on **SCD**

MGS-5.2. Designers should check that this grading is present on existing cross-slopes or otherwise revise the cross-slopes to conform. Where feasible regrade the roadside area to permit installation of a Type B versus installing a tangential (Type E) terminal, assuming the regrading does not trigger right-of-way acquisition on a project that is otherwise wholly contained in the existing right-of-way. See **Roadway Sample Plan Note R112a and R112b** in Appendix B for additional information.

Shop drawings for the approved Type B anchor assemblies can be found under the Roadway Approved Products List on the Office of Roadway Engineering website.

An earlier version of the Type B known as the ELT or MELT depicted on Standard Drawings until 1994 is still found throughout the state highway system. This generic flared end terminal should be systematically replaced with approved Type B terminals meeting MASH criteria.

603.3.3 - Type E

The Type E anchor assembly is a tangent, redirective end terminal. The overall system length of the Type E varies by device: the length from post #1 to the splice point with standard MGS is 46'-10.5" for the MSKT and SGET and 50'-10.5" for the SoftStop. To be conservative on the overall footprint of the guardrail installation, the designer should assume a device length of 50'-10.5". The device's length of need for the Type E begins at post #3; therefore, the length from post #3 to the splice point with standard MGS (34'-4.5") can be applied toward the overall calculated length of need for the guardrail run. The length from post #3 to the first post is considered gating.

The Type E may be used as an approach end treatment for guardrail on any roadway. The Type E cannot be used when the back side of the device is in the clear zone of bidirectional traffic. The Type E products require a 10:1 terminal grading pad immediately behind the terminal detailed on **SCD MGS-5.3**. Although, the 10:1 grading pad may not be achievable in certain scenarios (e.g., a 2-lane facility with limited available right-of-way and the presence of a roadside ditch near the edge of paved shoulder). In these situations, it is still beneficial to install a Type E, and an effort should be made to grade the area behind the anchor assembly in a nature similar to the roadside directly upstream.

The Type E should not be installed over a radius but may be installed with a 25:1 flare over the full length of the terminal, which creates up to a 2-foot maximum offset from the

adjacent (attached) guardrail. The flare rate must be consistent through the entire length of the terminal.

The impact head for any proprietary Type E system shall not be reused if a crash facilitated the extrusion of guardrail, or if an angle crash resulted in physical contact with the impact head (typically crashes that occur at or before post #2).

See **Roadway Sample Plan Note R113a** and **R113b** in Appendix B for additional information.

Shop drawings for the approved Type E anchor assemblies can be found under the Roadway Approved Products List on the Office of Roadway Engineering website

603.3.4 - Type A

The Type A anchor assembly (twisted turned-down end) is a non-proprietary, non-redirective end terminal that does not meet current (MASH 2016) or past (NCHRP-350) crash testing standards. It is 25.0 feet long and may be used in heavily constrained situations as an approach or trailing guardrail end treatment. The Type A anchor assembly shall not be used on NHS routes regardless of maintenance responsibility (ODOT or local). Additionally, the Type A anchor assembly shall not be used on non-NHS routes where a Type B, a Type E, or other crash tested (MASH or NCHRP-350) anchor assembly is feasible. The usage of the Type A anchor assembly is reserved for restricted situations on low-speed, low-volume local or non-NHS roadways, and the decision to install a Type A anchor assembly must be substantiated with documentation included in the project files.

Since the LON point is at the rear of this device, no portion of the Type A can be included within the guardrail length of need. See **Plan Insert Sheets GR-4.1** (used with Type 5 guardrail) or **MGS-4.1** (used with MGS guardrail) for additional details.

603.3.5 - Type T

The Type T anchor assembly is a non-proprietary, non-redirective end terminal that may be used on any roadway in any of the following situations:

1. On trailing ends of guardrail runs outside the clear zone of opposing traffic.

2. In guardrail runs where directional changes are made using a radius of less than 25 feet (see Figures 603-3 and 603-4).

3. On the ends of guardrail runs on drive approaches (see Figure 603-3).

The Type T is 12.5 feet long. Locate the end post of the Type T to be 25’ downstream from the trailing end of the hazard being shielded.

There are two non-proprietary Type T designs included in **SCD MGS-4.2**: the Wood Post System & the Steel Post System. Both designs meet MASH TL-3 criteria and therefore are considered equally crashworthy. Although, some districts and location-specific installations have experienced and are prone to accelerated deterioration of the wood post system due to the breakaway hole through the wood at the ground line, which exposes the post interior to the environment. Additionally, the passenger car crash-test on the steel post system resulted in a lower occupant impact velocity (the wood post system was still in acceptable MASH limits), and the deflection of the steel-post system was notably better (see Figure 134 from the research report below). The contractor is allowed to choose which system from **SCD MGS-4.2** they want to provide, and it is assumed that they will primarily elect to provide the cheaper wood post system. Therefore, if a specific post system is desired, use the As Per Plan item and include a plan note.

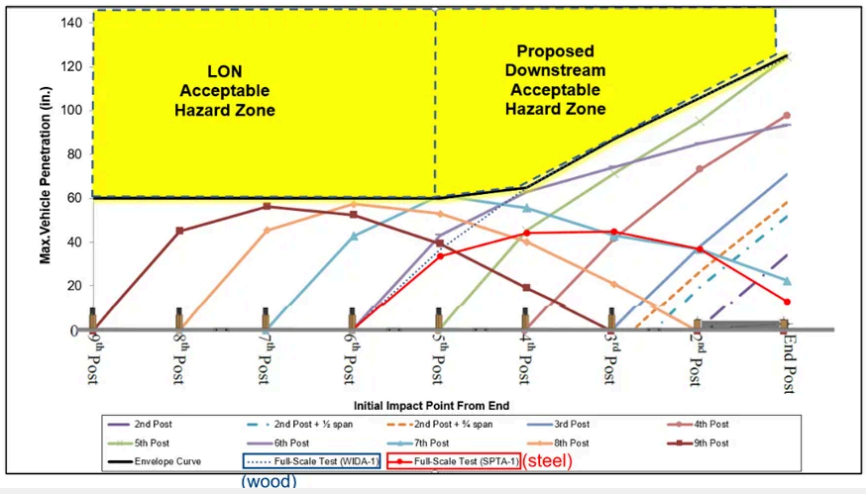


Figure 134: Proposed MGS Placement Guidelines for Shielding Hazards near Trailing-End Anchorage System - Wood-Post and Steel-Post Systems

See **SCD MGS-4.2** for additional details.

603.4 - Impact Attenuators

Impact Attenuators, also known as crash cushions, are generally used to shield motorists from rigid structures like bridge piers and end of concrete barriers. Since impact attenuators can be installed in two sided situations, they are well suited for median or gore applications. Refer to the Office of Roadway Engineering's webpage for links and shop drawings of approved proprietary products.

603.4.1 - Type 1

Type 1 impact attenuators are re-directive, gating, proprietary median guardrail terminal and crash cushion. Type 1's can be installed on any roadway in unidirectional and bidirectional configurations, but they must have at least 10 feet of clearance on both sides of the device. A maximum flare of 20:1 is permissible. Generally Type 1 Impact Attenuators are used in wider medians to safely end barrier design guardrail runs. See **Roadway Sample Plan Note R123** in Appendix B for approved products, specifications, and manufacturer's drawings.

Type 1 impact attenuators are gating systems before the LON of the system, but are re-directive after that point. All systems are sacrificial, meaning they absorb impact kinetic energy by deforming the steel rail elements and/or breaking wood posts. Most of these systems are not reusable after an impact and most be replaced with new parts.

603.4.2 - Type 2

Type 2 impact attenuators are reusable, re-directive, non-gating proprietary systems that can be installed on any roadway in unidirectional and bidirectional configurations. Some of the major components of these crash cushions can be reused after an impact. It is important to note that if any of the components are damaged new parts will need to be installed during the repair in order to make the entire unit crashworthy.

Since the footprint for each product varies the designer should be specific about the available footprint, design speeds, and width of hazard. In some cases when there is a limited footprint available the designer should specify only the appropriate products. If cross slopes are steeper than 8 percent (12:1) or vary by more than 2 percent over the length of the unit, a leveling pad may be used.

Type 2 attenuators are ideal to protect the ends of rigid objects like concrete barrier ends. Some other uses could be for connection to guardrail runs in diverging gores or narrow

medians, as well as temporary work zone locations. See **Roadway Sample Plan Note R124** for approved products, specifications, and manufacturer's drawings. Plan notes are in Appendix B.

603.4.3 - Type 3

Type 3 impact attenuators are low-maintenance/self-restoring crash cushions typically considered for use at locations where high frequencies of impacts is expected. Maintenance is required with these units after impacts to restore full capacity for design impact conditions. These units could be cost-beneficial at locations with high frequency of impacts despite the higher initial costs because of the lower repair costs over the life of the product. These units are typically restored with minimal labor and replacement parts after a design impact.

Type 3 impact attenuators should be specified in lieu of Type 2 impact attenuators when a higher than normal impact frequency would be expected. Specifically at locations that have a history of being impacted more than once per year and at gores of urban systems interchanges as these high ADT weave areas have the highest potential for crash events. Type 3 impact attenuators are cost-effective when considering the benefits of faster and easier repair. Additionally, the safety benefits for maintenance personnel's exposure while repairing frequently damaged units cannot be discounted.

See **Roadway Sample Plan Note R125** in Appendix B for approved products, specifications, and manufacturer's drawings.

603.4.4 - Work Zone Impact Attenuators

All Type 2 and Type 3 impact attenuators are considered acceptable for use in temporary work zones. Additional products specifically listed in this category are approved only for temporary work zones to protect hazards 24" and smaller, and some products can be beneficial in locations where foundations and anchors are not required. Typically considered to be sacrificial units, the impact attenuators that are permitted for work zones only are crashworthy roadside safety devices designed for a single impact, usually protecting the end of temporary barriers. Most of these temporary systems are gating, non-redirective, and absorb impact energy through crushing the product elements. These systems' major components are destroyed in an impact and must be replaced. Refer to

the Traffic Engineering Manual Sections 642-30 and 642-31 for additional design requirements.

603.4.5 - Sand Barrels

Sand barrel arrays are proprietary sand-filled modules of varying sizes arranged in a pattern designed to protect wide hazards. Sand barrel arrays are appropriate in limited situations for the protection of wide hazards when no other product is acceptable. Because each product is different a specific design layout is required for each location based on the design speed and width of the hazard being shielded. All new arrays installed on the NHS must meet MASH Test Level 3. Existing arrays meeting NCHRP Report 350 Test Level 3 criteria may be repaired.

603.5.1 - Type 1

The Bridge Terminal Assembly, Type 1 is commonly used to connect guardrail to a concrete barrier or a concrete bridge parapet. It uses blocked-out, nested, thrie-beam guardrail panels attached to a vertical concrete surface to transition to the guardrail. The addition of a curb under the stiffer thrie-beam transition panel enables the assembly to meet into TL-3 when connecting to the concrete barrier or parapet. Curb is not required when connecting to Twin Steel Tube Bridge Rail **(SCD TST-1-99).**

It is generally installed at the following locations:

1. At the approach end of a rigid object.
2. At the trailing end of a rigid object if it is located within the clear zone of opposing traffic.
3. To connect Type MGS Guardrail to Twin Steel Tube Bridge Rail

Where designs require the upstream guardrail to be used in conjunction with curb for drainage purposes, the section 25 ft. immediately prior to this transition assembly should be without curb. See **SCD MGS-3.1** for additional details.

603.5.2 - Type 1 Barrier Design

The Bridge Terminal Assembly, Type 1: Barrier Design is commonly used to connect barrier design guardrail or a Type 1 Impact Attenuator to a concrete median barrier. It uses

blocked-out, nested, thrie- beam, guardrail panels attached to a vertical face on both sides of the barrier to transition to the guardrail or attenuator. As with the Type 1, the curb and stiffer thrie beam transition panels enables the assembly to meet into TL-3.

See **SCD MGS-3.1** for additional details.

603.5.3 - Type 2

The Bridge Terminal Assembly, Type 2 is commonly used to connect guardrail to the trailing end of a concrete barrier or bridge parapet located outside the clear zone of opposing traffic. It uses standard w- beam guardrail panels attached to a vertical face on the concrete barrier to transition to the guardrail. When used as a trailing end assembly, it can be used on the NHS. See **MGS-3.2** for additional details.

603.5.4 - Previous Types 3 & 4

Refer to the Location & Design Manual dated July 20, 2012 for transitions to Thrie Beam or DBR Bridge Railing (old Types 3 & 4).

603.5.5 - Type TST-2

The Bridge Terminal Assembly, Type TST-2 was developed to connect to Three Steel Tube Bridge Railing (**SCD TST-2-21**) and provide a transition to MGS guardrail. The Type TST-2 BTA shall be used on both the approach and trailing ends of the TST-2-21 run.

For additional details see **SCD MGS-3.3**.

603.6 - Concrete Barrier End Treatment

The end of a concrete barrier may be a hazard if not treated properly. Since a rigid barrier generally does not require end anchorage to develop its strength, the simplest means of providing impact protection for the barrier end may be to terminate the barrier beyond the clear zone. When this approach is used, the flare rate used to offset the barrier should not exceed the flare rates recommended in Figure 602-1. However, when the end of a concrete barrier is located within the clear zone, a terminal is necessary to protect a vehicle's occupants in an end-on impact.

Acceptable end treatments include the following:

1. Transition to guardrail using a bridge terminal assembly and terminate the end of the guardrail run with an anchor assembly.
2. Use an impact attenuator as discussed in **Section 603.4**.
3. Terminate the concrete barrier directly into a cut backslope.
4. Use a tapered end section only: (1) when the barrier is terminated outside the clear zone (See Figure 603-5), or (2) when the barrier is on a non-NHS road with a design speed less than or equal to 40 mph (NCHRP Report 350 TL-2) and space is limited by right-of-way constraints or presence of other roadside features that preclude the use of an approved end treatment.

604 - Glare Screen

Glare screen is used primarily for the shielding of motorists from headlight glare of opposing traffic. It is normally used in the median of divided highways but may be used in other areas where a specific problem exists or is anticipated.

There are locations, other than in the median, where glare screen may be justified. An example would be between a parallel facility and the mainline where geometrics or unusual sources of light cause a glare problem.

604.1 - Median Glare Screen

Glare screens may be provided when concrete barrier is used to separate opposing traffic on interstates and freeways. Median glare screen may also be justified when glare problems are experienced on isolated sharp curves. Median glare screen installation should be as continuous as practical. Gaps of approximately 1 mile or less in length should be avoided.

604.3 - Glare Screen Options

Glare screening may be accomplished in a number of ways. These include, but are not limited to, the following options (shown in order of preference):

1. Use a taller standard barrier. For example use Type B1 in lieu of Type B concrete barrier.

2. On a NJ shape barrier, install a concrete cap to extend the height of existing 32 inch concrete barrier where barrier thickness is adequate.

3. Attach a paddle or intermittent type of glare screen to the top of a 42 inch Single Slope or 32 inch tall NJ shape concrete barrier, or on top of steel beam guardrail. These devices shall be designed using a 20-degree cut-off angle measured relative to the centerline of the barrier. They shall be securely fastened to the barrier using the hardware and procedures specified by the manufacturer. Refer to the Roadway Approved Products List for a list of approved products.

Options 1-3 may only be used in locations where barrier is required.

605 - Rumble Strips

605.1 - Shoulder Rumble Strips

A shoulder rumble strip is a pattern of grooves or depressions made in paved highway shoulders, by milling or grinding, to produce an audible and/or vibratory warning to drivers whose vehicles have drifted off the traveled way.

SCD RD-9.1 contains design details and options for the placement of rumble strips on shoulders. Shoulder rumble strips have proven to be effective in reducing run-off-the-road crashes due to driver inattention, monotony and fatigue. They also may serve as an audible form of roadway edge delineation in adverse weather conditions. Rumble strips are most appropriate for use on higher speed facilities where access is controlled through interchanges or widely-spaced intersections (several miles apart) and are also appropriate for other roadways with a history of run-off-the-road crashes due to driver inattention.

Engineering judgment should be used in determining whether to place rumble strips along roadway sections of variable width or relatively short multilane sections (such as through interchanges) with consideration given to the presence of rumble strips on adjacent sections.

605.1.1 - Locations

Shoulder rumble strips will be installed at the following locations:

1. On new, reconstructed, and resurfaced shoulders of all rural fully access-controlled highways (Interstates and freeways).
2. On sections of any highway with a history of run-off-the-road crashes due to driver inattention, fatigue, or sleep. For this purpose, a threshold rate of 0.25 run-off-the-road crashes per million vehicle miles will be used.

Shoulder rumble strips should be considered at the following locations:

1. On new, reconstructed, or resurfaced shoulders of urban fully access-controlled highways and rural partially access-controlled multilane highways.
2. At certain critical locations, such as: in gore areas, ahead of impact attenuators and next to concrete median barriers.

Shoulder rumble strips may be installed at the following locations:

1. At other locations, where deemed to be a safety enhancement, at the discretion of the **District Deputy Director**. This decision should be based on a review and recommendation by the **District Safety Review Team**.
2. On local roads and streets in Federal-aid projects that are not on the NHS, at the discretion of the responsible local agency. (See **SCD RD-9.1** for additional details on the location of shoulder rumble strips.)

605.1.2 - Freeway Shoulders for Travel

Part-time shoulder use is a Transportation System Management and Operation (TSMO) strategy that allows the use of the left or right shoulders as travel lanes during some, but not all, hours of the day. Rumble strips shall not be installed within any traveled lanes of the roadway, including the part-time shoulder lane. Existing rumble strips located within the part-time shoulder lane must be removed prior to implementation.

605.1.3 - Lateral Clearances for Machinery

The machinery used in the milling process to construct Type 2 rumble strips requires a lateral clearance of at least 34 inches from the outside edge of the pattern to any obstruction (guardrail, a barrier, curbs, etc.).

605.1.4 - Divided Highways

Rumble strips should be installed on both shoulders (right and left) of divided roadways, but individual circumstances may dictate use on only one shoulder.

605.1.5 - Existing Shoulders

Rumble strips should only be installed on existing paved shoulders that are in good condition and have a width of 4.0 feet or greater. Where rumble strips are desired, but existing shoulder widths are less than 4.0 ft and greater than or equal to 2.0 ft, rumble stripes may be considered. Where existing shoulders are resurfaced, the existing rumble strip pattern shall be restored on the new shoulder in accordance with this manual and the Pavement Design Manual.

605.1.6 - Bicycle Considerations

Rumble strips generally should not be used on the shoulders of roadways designated as bicycle routes or having substantial volumes of bicycle traffic, unless the shoulder is wide enough to accommodate the rumble strips and still provide a minimum clear path of 4 feet from the rumble strip to the outside edge of the paved shoulder or 5 feet to adjacent guardrail, curb or other obstacle.

In areas designated as bicycle routes or having substantial volumes of bicycle traffic, the rumble strip pattern should not be continuous but should consist of an alternating pattern of gaps and strips, each 12 feet and 48 feet respectively in length. Also, gaps should be provided in the rumble strip pattern ahead of intersections, crosswalks, driveway openings, and at other locations where bicyclists are likely to cross the shoulder.

In areas designated as bicycle routes or having substantial volumes of bicycle traffic, the use of rumble stripes instead of rumble strips may be more “bicycle friendly” due to the narrower width and reduced depth of the milled surface. See the Traffic Engineering Manual (TEM) Section 1415 for more information.

605.1.7 - Residential Areas

In residential areas, noise generated by rumble strips could be objectionable. Rumble strips installed in these areas may be placed further from the edge of the traveled lane

than shown on **SCD RD-9.1** to reduce the frequency of contact while still providing some degree of warning to drifting drivers.

The distance from the edge of the traveled lane to the rumble strip pattern should not exceed 2.0 feet on the outside shoulder.

605.1.8 - Maintenance of Traffic

Where shoulders are to be used for maintenance of traffic purposes, rumble strips should be positioned to adapt to phased construction sequencing. See **SCD RD-9.1**.

605.2 - Rumble Strips Across Traveled Lanes

Rumble strips in traveled lanes are used to alert drivers of unusual or unexpected traffic conditions or geometrics and to bring the driver's attention to other warning devices. They are not intended for traffic calming and they should only be installed after all other appropriate standard traffic control devices have been utilized and have failed to resolve the problem satisfactorily.

Rumble strips are most effective when they surprise motorists enough to catch their attention. For this reason, they should be used sparingly. (See **Section 605.2.1** for typical locations.)

605.2.1 - Locations

Typical locations for the installation of rumble strips in a traveled lane are at the following:

1. Rural stop approaches with high crash rates.
2. Signalized intersections with high crash rates.
3. Short exit ramp deceleration lanes or hidden intersections.

Other possible locations include:

1. Locations with abrupt changes in horizontal alignment.
2. Intersections with inadequate stopping sight distance caused by vertical or horizontal alignment.

3. Railroad crossings with sight distance restrictions and a history of crashes.

4. Approaches to toll booths and narrow bridges.

5. At the approach to work zones and at other locations within the work zone.

606 - Fence

606.1 - Purpose

Highway fences are a part of the highway facility and are placed within the right-of-way limits of highways having controlled or limited access right-of-way. They act as physical barriers to enforce observance of the acquired access rights. Bikeway fences act as a containment barrier to protect cyclists and pedestrians from certain hazards such as steep drop-offs. The State or other agency responsible for the maintenance of the facility shall assume the responsibility for the maintenance of these fences.

606.2 - Types

It is ODOT's policy to construct only the standard types of fence described below in accordance with the current Standard Construction Drawings and Construction and Material Specifications.

TYPE 47 - Woven wire fence with a 47-inch fabric, steel line posts, and one strand of barbed wire on the top. (See **SCD F-2.1**)

TYPE 47RA - Woven wire fence with 47-inch fabric, wood line posts, and no barbed wire. (See **SCD F-2.1**)

TYPE CLT - Chain link fence with 60-inch fabric but with a tension wire in lieu of the top rail. (See **SCD F-1.1**)

TYPE BR - Wooden bikeway fence with wood line posts. See **SCD F-5.2**

606.3 - Fence on Freeways

606.3.1 - Urban Freeways

Urban freeways shall be continuously fenced. Innerbelts and radials shall use Type CLT. Outerbelts shall use Types CLT or 47 depending upon the adjacent land use.

606.3.2 - Rural Freeways

Rural freeways shall be continuously fenced, usually with Type 47 fence; however, Type CLT may be used in areas where there are schools, subdivisions or other developments.

606.3.3 - Freeway Fence Design Conditions

1. Where chain link fence is located within the design clear zone, such as along the edge of a roadway shoulder, in a median, or between a frontage road and the mainline, a fence with tension wire, Type CLT, shall be used.

2. Type 47RA fence shall be used to fence rest areas where the highway fence is Type 47. It may also be used in other locations where the aesthetics of the area make this type more desirable.

3. Fence installed across a stream or ditch shall be designed using fence terminals or crossings as shown in SCD F-3.3 and F-3.4, respectively.

4. Where a drainage channel is located parallel to the freeway in a channel easement, the fence shall be located on a bench between the main facility and the channel. Maintenance openings shall be provided at 700 feet maximum intervals where the length of fence between a deep channel and the freeway exceeds 1800 feet, unless access can be provided by another means.

5. Fence shall be provided in the median to connect the abutments of all twin bridges on divided highways.

6. All types of fence shall be grounded where a transmission/sub-transmission (>69kv) power line passes over them. Fence shall also be grounded where a parallel transmission/sub-transmission (>69kv) power line runs

   within 50 feet (measured horizontally) of the fence alignment. For grounding details see **SCD F-3.5.**

   A distribution line crossing does not typically necessitate the fence to be grounded unless a nuisance current has been reported, or other site-specific conditions indicate

grounding the run may be needed.

7. In the vicinity of some airports, fencing should be non-metallic since it sometimes interferes with airport traffic control radar. The **Federal Aviation Administration** should be contacted to ascertain if metallic fencing will be a problem.

8. Fence should normally be continued behind a noise wall. Sufficient distance should be provided between the fence and the noise wall to permit normal maintenance operations. If there is no critical maintenance responsibility between the noise wall and the right-of-way or limited access line (generally in "cut" sections) the fence may be terminated at each end of the noise wall.

606.3.4 - Exceptions to Continuous Freeway Fencing

1. Fence shall be terminated with an end post assembly at an existing ½:1 or steeper slope, measured along the fence centerline. However, if the ground approaching the ½:1 slope is too steep to allow proper fence installation, a Type E fence terminal shall be installed at the edge of the slope.

2. Fence shall be terminated in a cut section that exceeds 30 feet in vertical height with a backslope of ½:1 or steeper.

3. Where the fence intersects a crossroad right-of-way line at interchanges, it shall be constructed along the crossroad to the limits of the limited access right-of-way.

606.4 - Fence on Arterials

606.4.1 - Urban Arterials

Fence shall be Type CLT or Type 47 depending upon the adjacent land use. Type CLT should be used where there is any doubt that Type 47 would be adequate to prohibit undesired intrusions.

606.4.2 - Rural Arterials

Fence should normally be Type 47.

606.4.3 - Arterial Fence Design

Fence shall be provided along the limited access right-of-way line on arterials but shall terminate at the end of limited access right-of-way at crossroads or railroads, and at stream banks and driveways. Fence shall be omitted where the highway right-of-way adjoins lateral features which would prevent vehicular access, such as: railroads, streams, deep ditches, swamps, strip mines or other steep slopes. Type CLT and 47RA shall be used on arterials in the same locations as described for freeways in **Section 606.3.3** (1) and (3).

606.5 - Fence on Collectors

Fencing of limited access right-of-way on urban or rural Collectors (or lower classifications) with partial access control will be determined on an individual project basis using arterial requirements as a guide.

606.6 - Lateral Location of Fence

Section 607.06 of the **Construction and Material Specifications** gives line post and fence location as related to the right-of-way line. Normally, woven wire fence should be placed 2.0 feet inside the right- of-way line and chain link 1.0 feet

When viewed at a flat angle, chain link fencing restricts sight distance. This should be considered when placing fence in interchange areas and intersections.

606.7 - Fence Approval

Determination of the type and extent of fencing will be made during the development of the contract plans and will be completed in time for the Stage 3 review.

606.8 - Bridge Vandal Protection Fence

For policy and details of vandal protection fence, see the Bridge Design Manual and **SCD VFP-1-24**, both published by the Office of Structural Engineering.

606.9 - Bikeway Fence

Bikeway fencing is placed along bike paths and shared use paths at a minimum offset of 1 foot (2 foot preferred) to contain users and separate them from various hazards. The

fencing can be terminated by providing a 20' flared end away from the path. See **SCD F-5.2** for more details.

CLEAR ZONE WIDTHS

600-1

REFERENCE SECTIONS
600.2

Design Speed	Design ADT	Foreslope		Backslope		
		6:1 or Flatter	Steeper than 6:1 to 4:1	6:1 or Flatter	Steeper than 6:1 to 4:1	Steeper than 4:1
40 mph or less	<750 750-1500 1501-6000 >6000	8 ft 11 13 15	8 ft 13 15 17	8 ft 11 13 15	8 ft 11 13 15	8 ft 11 13 15
45-50 mph	<750 750-1500 1501-6000 >6000	11 13 17 19	13 18 23 26	11 15 17 21	9 13 15 19	9 11 13 15
55 mph	<750 750-1500 1501-6000 >6000	13 17 21 23	16 22 27 29	11 17 21 23	11 15 17 21	9 11 15 17
60 mph	<750 750-1500 1501-6000 >6000	17 22 28 31*	22 29 36* 40*	15 21 25 27	13 17 21 25	11 13 16 21
65-70 mph	<750 750-1500 1501-6000 >6000	19 25 30 32*	23 32* 38* 42*	15 21 27 28	15 19 23 28	11 14 18 23

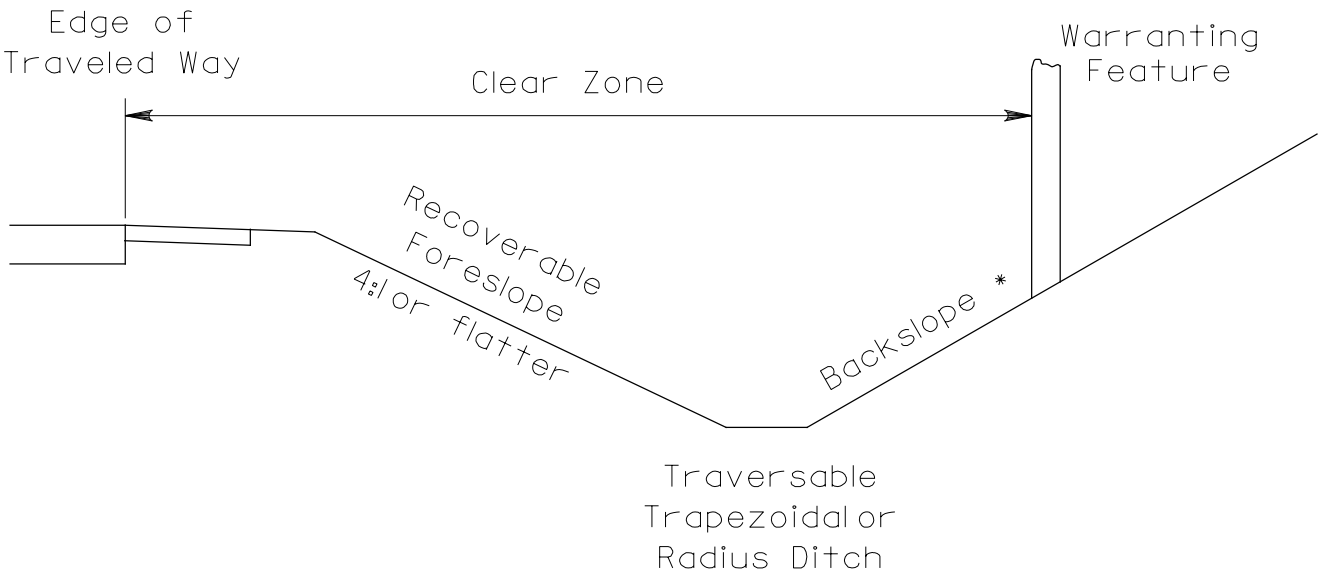
* Use a **maximum clear zone** of 30 feet unless a site-specific investigation or accident history indicates a high potential of continuing accidents. When the potential for continuing accidents is high, the widths in the above chart should be multiplied by the following curve correction factors to extend the clear zone on the outside of curves having a Degree of Curvature of 2 degrees or sharper.

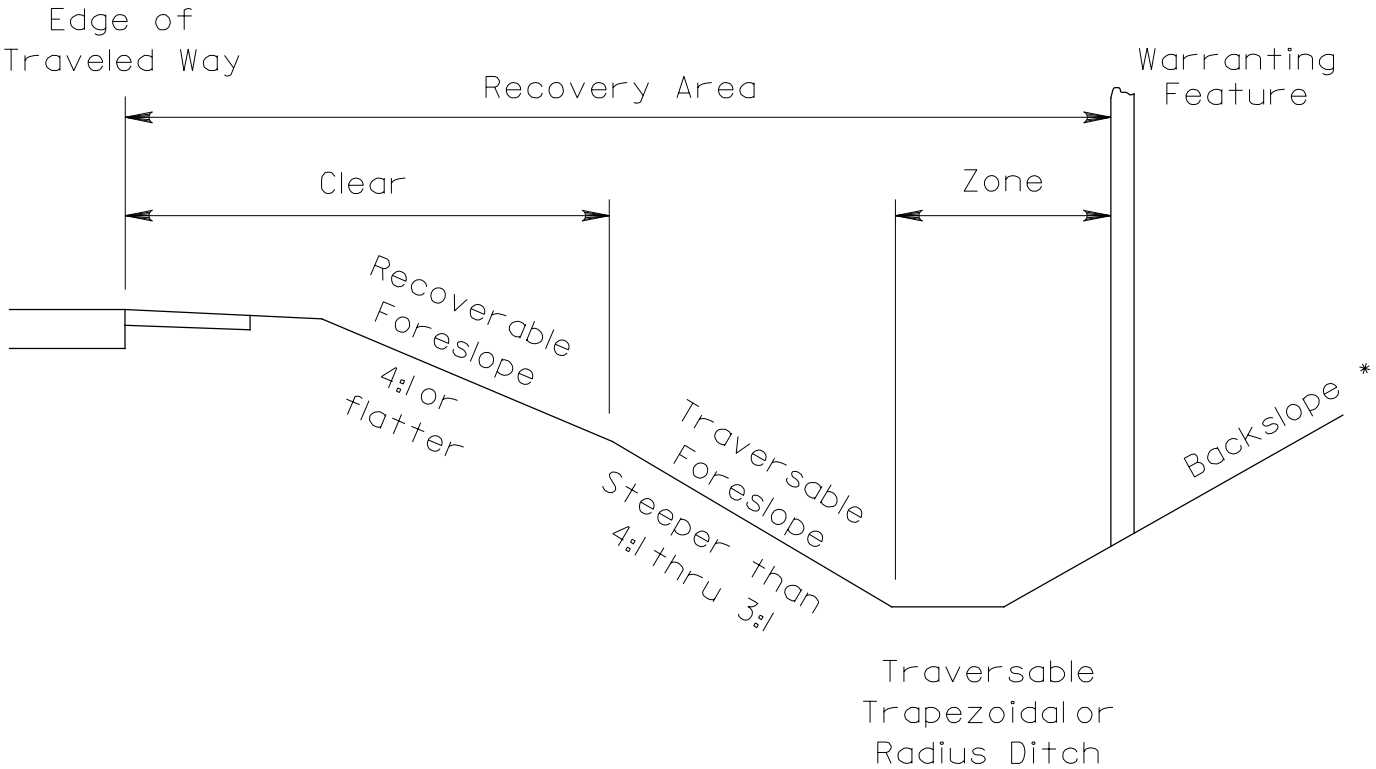
Degree of Curvature	HORIZONTAL CURVE CORRECTION FACTORS Design Speed (mph)						
	40	45	50	55	60	65	70
2.0	1.1	1.1	1.1	1.2	1.2	1.2	1.3
2.5	1.1	1.1	1.2	1.2	1.2	1.3	1.3
3.0	1.1	1.2	1.2	1.2	1.3	1.3	1.4
3.5	1.1	1.2	1.2	1.3	1.3	1.4	1.5
4.0	1.2	1.2	1.2	1.3	1.4	1.4	
4.5	1.2	1.2	1.3	1.3	1.4	1.5	
5.0	1.2	1.2	1.3	1.4	1.5		
6.0	1.2	1.3	1.4	1.4	1.5		
7.0	1.3	1.3	1.4	1.5			
8.0	1.3	1.4	1.5				
9.0	1.3	1.4	1.5				
10.0	1.4	1.5					
15.0	1.5						

CLEAR ZONE MEASUREMENTS

600-2

REFERENCE SECTIONS
600.2.1





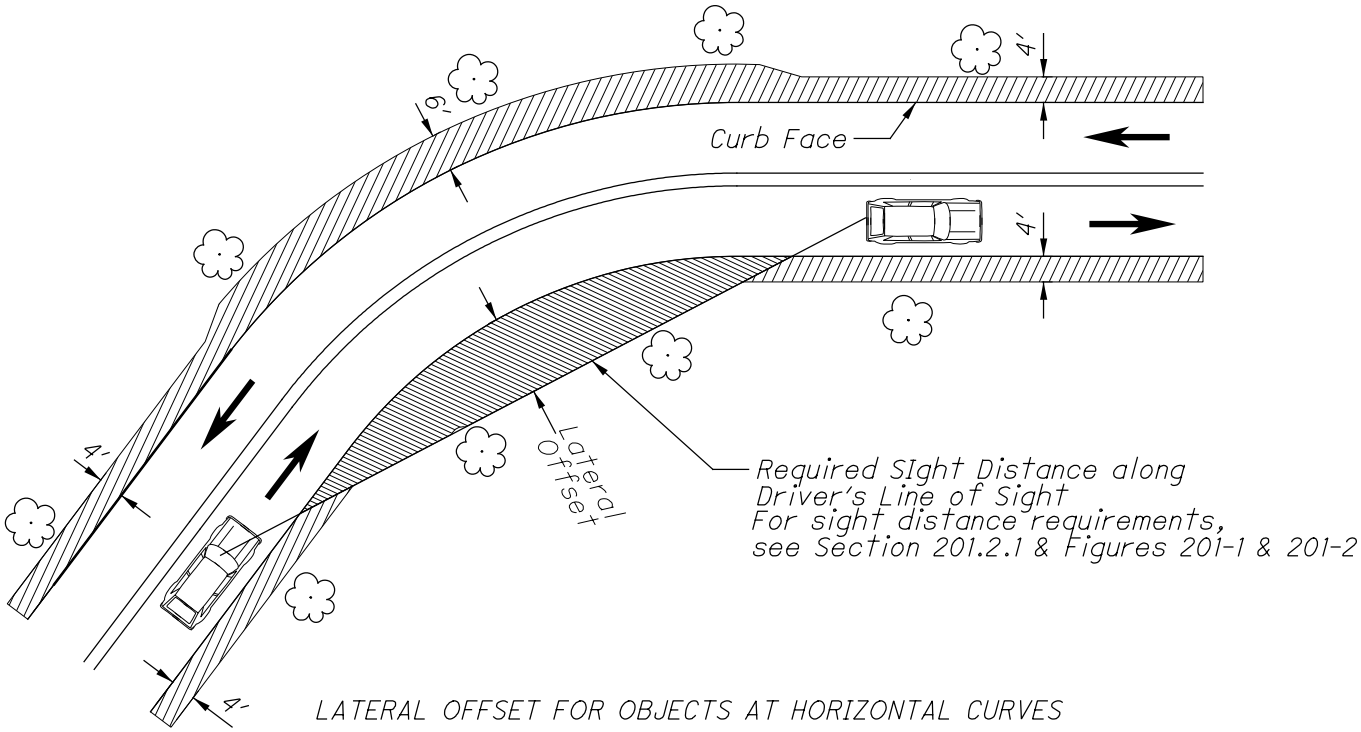
* For acceptable foreslope and backslope combinations that produce traversable trapezoidal and radius ditches, see Figures 307-3 and 307-2 , respectively.

For clear zone widths, see Figure 600-1

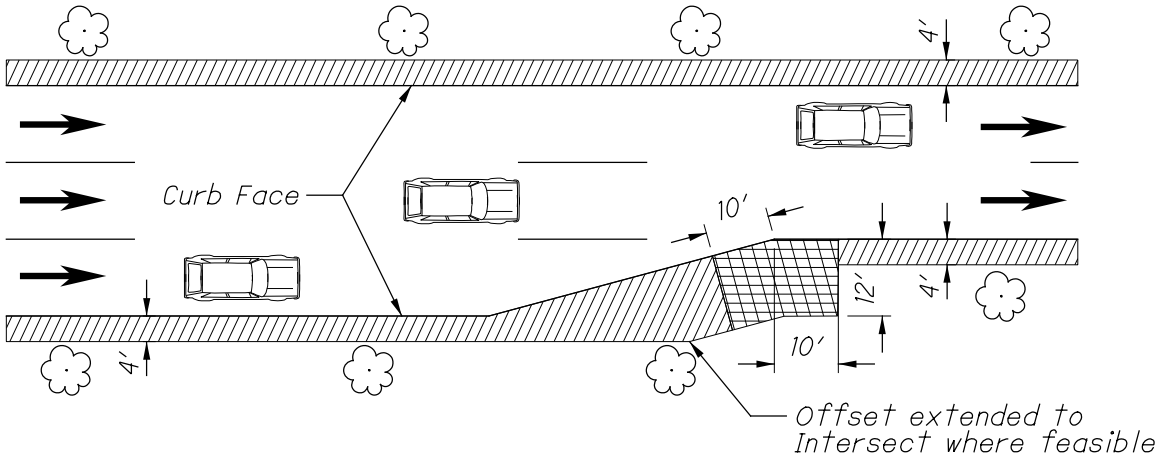
URBAN LATERAL OFFSETS AT HORIZONTAL CURVES AND MERGE POINTS

600-3

REFERENCE SECTION
600.2.2



LATERAL OFFSET FOR OBJECTS AT HORIZONTAL CURVES



LATERAL OFFSET CONFIGURATION APPLIES TO LANE MERGES,
ACCELERATION LANES, AND BUS BAY RETURNS

Std. Recommended Lateral Offset

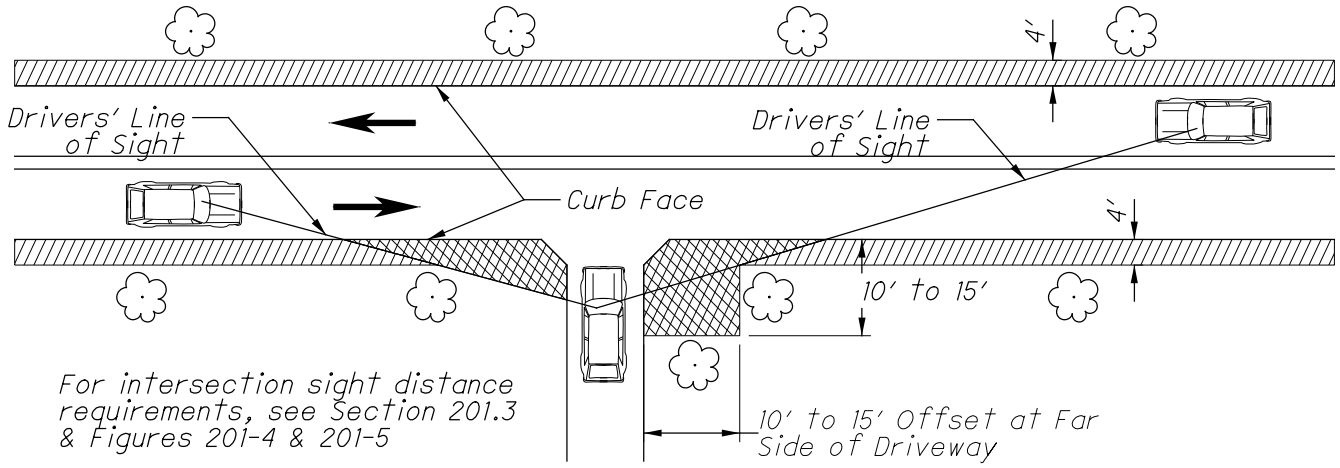
Lateral Offset at Inside of Curve

Lateral Offset at Taper Point

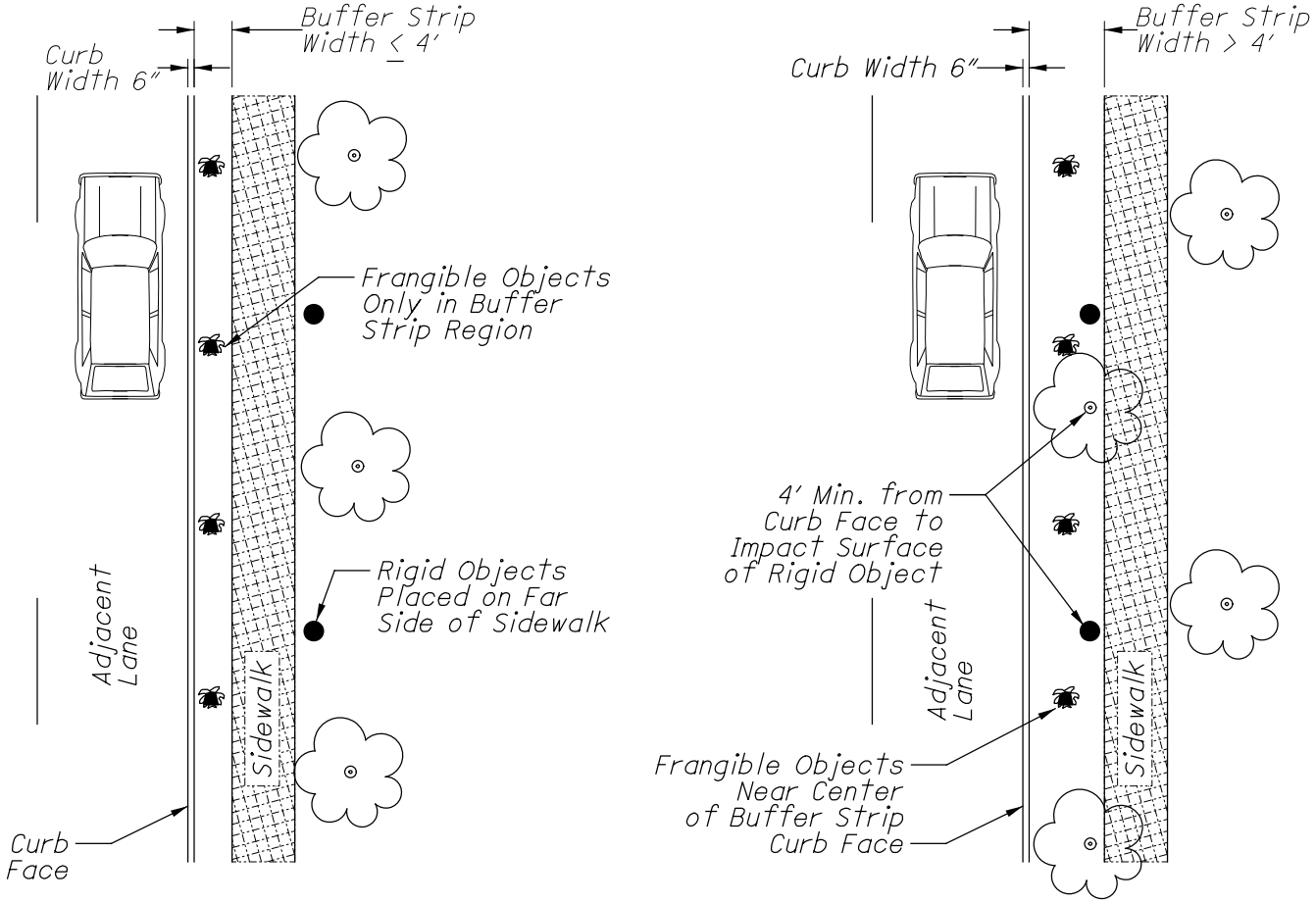
URBAN LATERAL OFFSETS AT DRIVEWAYS AND SIDEWALK BUFFER STRIPS

600-4

REFERENCE SECTION
600.2.2



ROADSIDE LATERAL OFFSETS AT DRIVEWAYS



LANDSCAPE AND RIGID OBJECT PLACEMENT FOR BUFFER STRIPS

Lateral Offset due to Driveway

Std. Recommended Lateral Offset

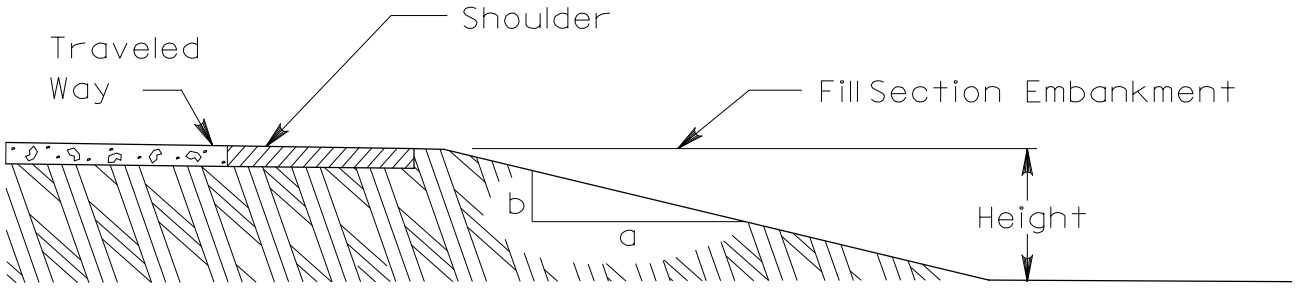
Sidewalk

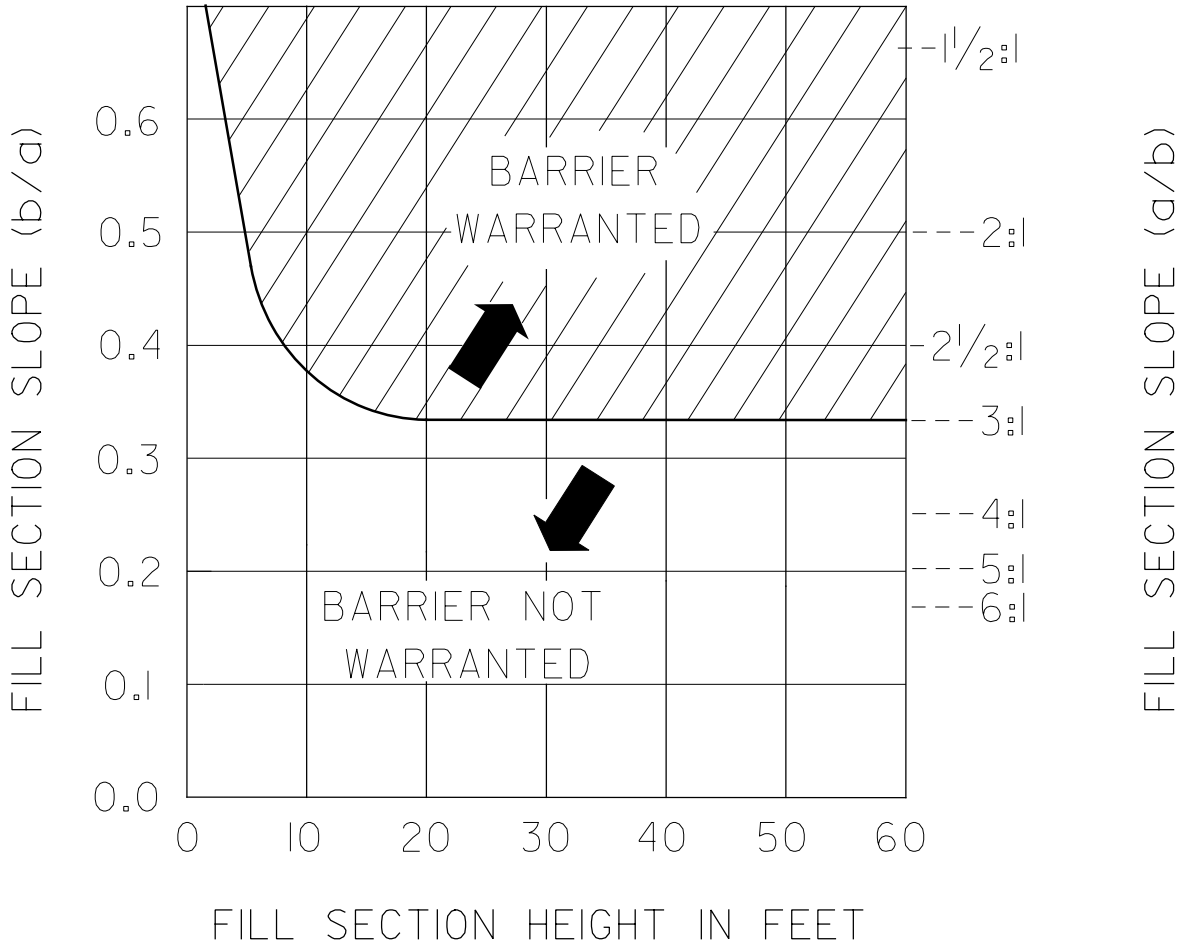
October 2010

BARRIER WARRANTS FOR EMBANKMENTS

601-1

REFERENCE SECTIONS
601.1.2



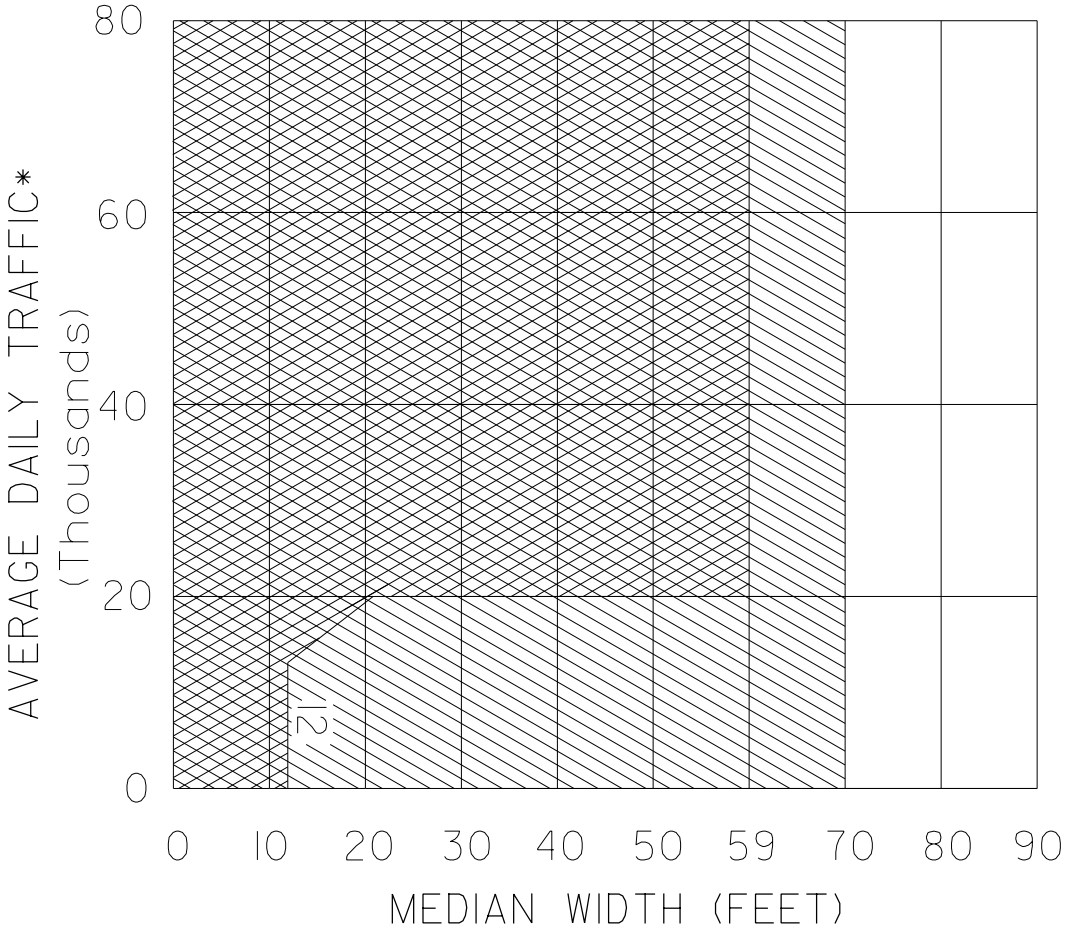


On or below the curve barrier is not warranted for embankment. However, check barrier need for other roadside hazards within the clear zone.

MEDIAN BARRIER WARRANTS

601-2

REFERENCE SECTIONS
601.2



Warrants for median barriers on freeways

* Based on a 5-year projection

BARRIER OPTIONAL

EVALUATE NEED FOR BARRIER

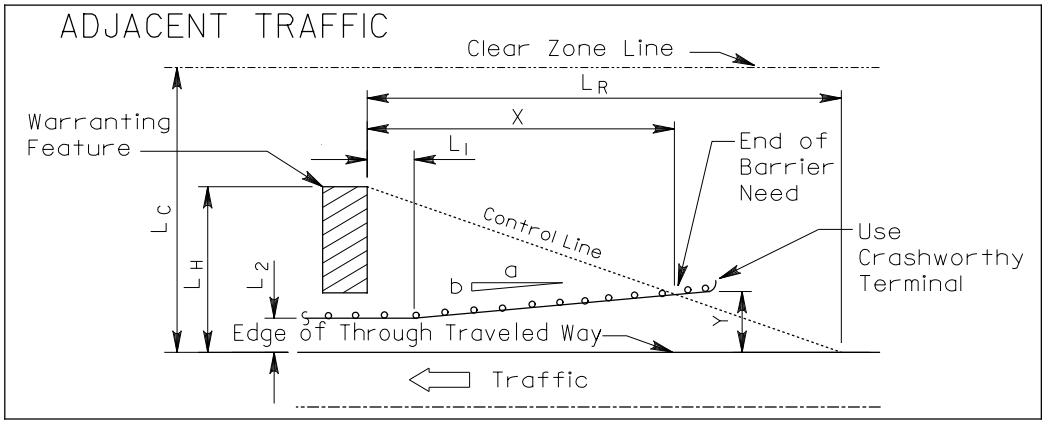
BARRIER NOT NORMALLY CONSIDERED

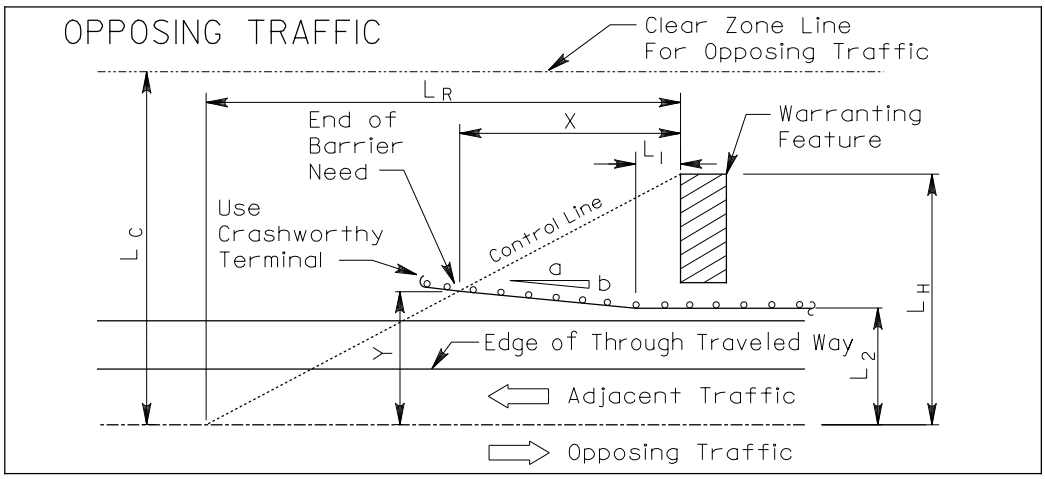
October 2010

BARRIER LENGTH OF NEED (TANGENT ALIGNMENT)

602-1

REFERENCE SECTIONS
602.1.2, 602.5.1, & 603.6



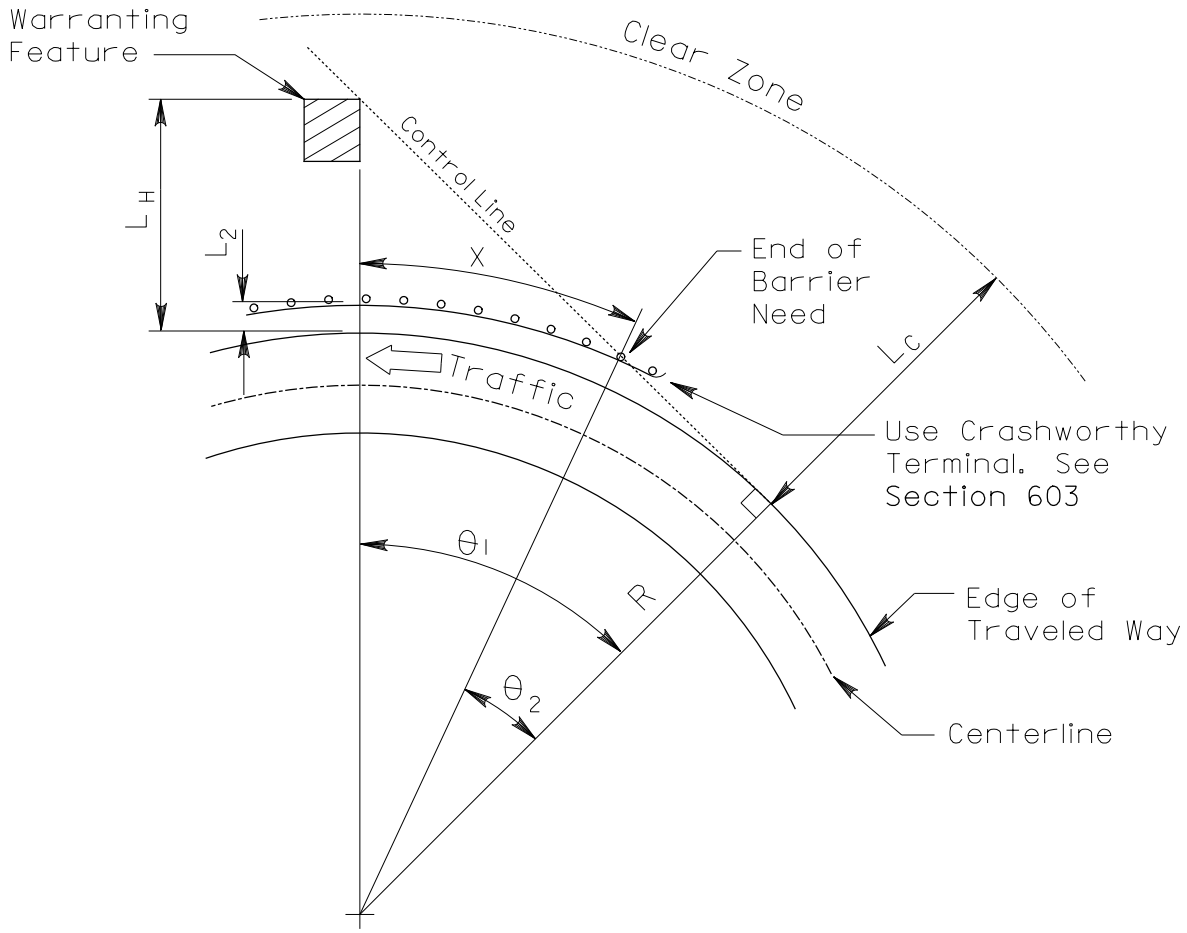


Design Speed (mph)	Flare Rate (a:b)			Runout Length, L_R (ft) Per Design Year ADT				Formulas
	Permanent Concrete Barrier	Standard MGS Guardrail	Cable Barrier	Over 10,000 veh/day	5,000-10,000 veh/day	1,000 5,000 veh/day	Under 1,000 veh/day	
75	20:1	18:1	50:1	415	380	335	290	X = Length of Need L_R = Runout Length L_C = Required Clear Zone L_H = Lateral Offset to Back of Warranting Feature L_2 = Lateral Offset to Face of Barrier (see Figure 301-3) L_1 = Varies (Typically measured to the end of a full panel of guardrail) If $L_H<L_C$: $X = \frac{L_H+(b/a)L_1-L_2}{(b/a)+L_H/L_R}$ $Y = L_H - X(L_H/L_R)$ If $L_H>L_C$: Substitute L_C in the above formulas.
70	20:1	15:1	50:1	360	330	290	250	
65	19:1	15:1	50:1	330	290	250	225	
60	18:1	14:1	50:1	300	250	210	200	
55	16:1	12:1	50:1	265	220	185	175	
50	14:1	11:1	50:1	230	190	160	150	
45	12:1	10:1	50:1	195	160	135	130	
40	10:1	8:1	50:1	160	130	110	100	
35	9:1	8:1	50:1	135	110	95	85	
30	8:1	7:1	50:1	110	90	80	70	

BARRIER LENGTH OF NEED (CURVED ALIGNMENT)

602-2

REFERENCE SECTIONS
602.1.3, 602.5.1, & 603.6

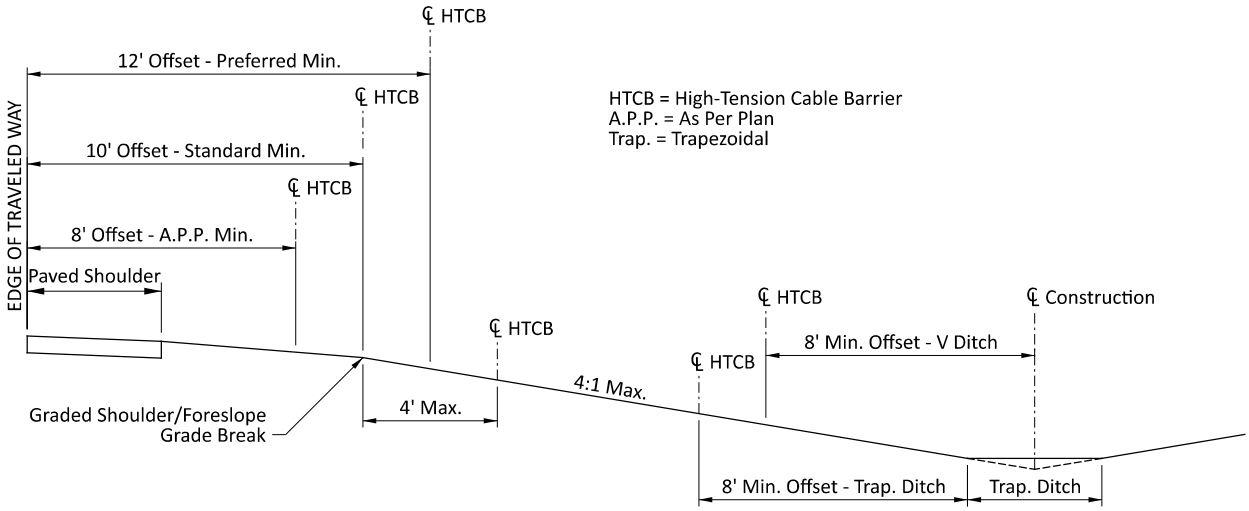


Formulas
X = Length of Need L_C = Required Clear Zone L_H = Lateral Offset to Back of Warranting Feature L_2 = Lateral Offset to Face of Barrier (See Figure 301-3, Guardrail Offset) If $L_H < L_C$: $X = (R+L_2)(\theta_1 - \theta_2)$ radians, where $\theta_1 = \cos^{-1}(R/(R+L_H))$ and $\theta_2 = \cos^{-1}(R/(R+L_2))$ R = 5729.58/Dc, where Dc = decimal degree of curve 1 degree = $\pi/180$ radians If $L_H > L_C$: Substitute L_C in the above formulas

HIGH-TENSION CABLE BARRIER PLACEMENT

602-3

REFERENCE SECTIONS
602.2.2 & 603.1.1

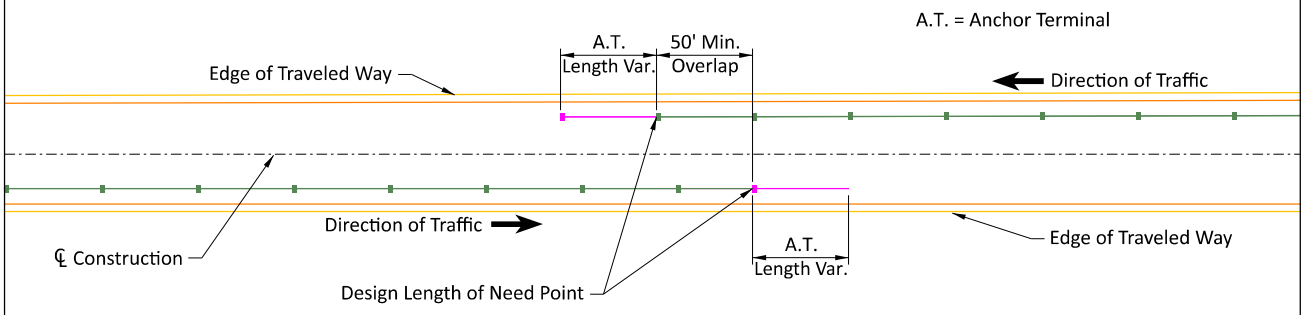


OVERLAPPING RUNS OF HIGH TENSION CABLE BARRIER

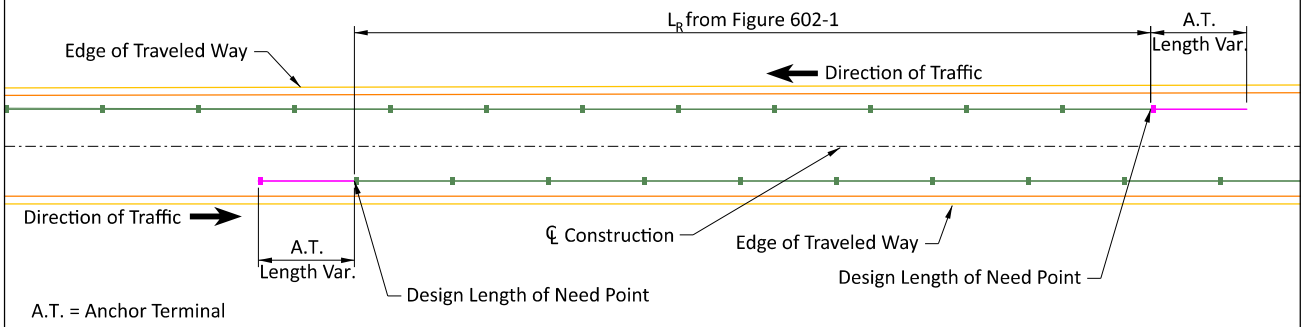
602-4a

REFERENCE SECTIONS
602.2.2 & 603.1.1

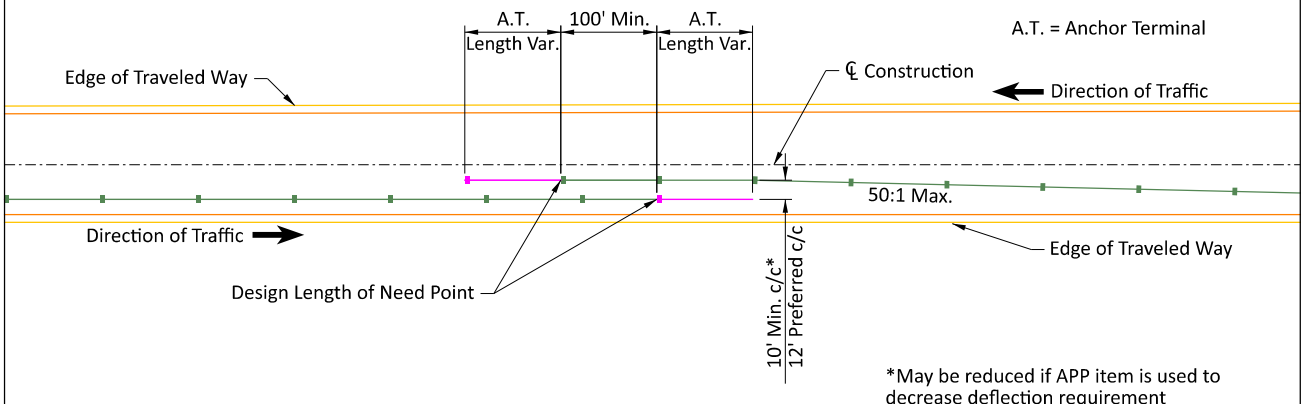
Example #1 Opposite Sides - Preferred



Example #2 Opposite Sides - Preferred



Example #3 Same Side - Not Preferred



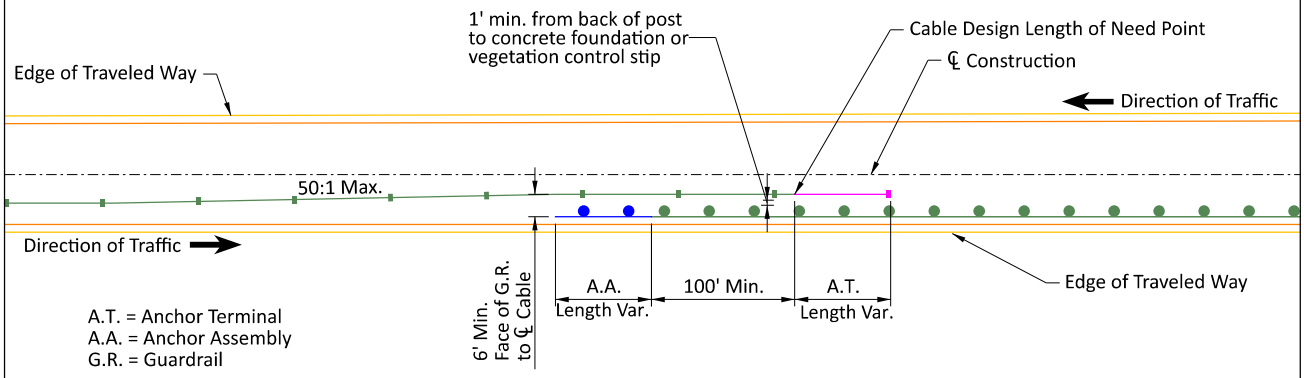
*May be reduced if APP item is used to decrease deflection requirement

OVERLAPPING HIGH TENSION CABLE BARRIER WITH OTHER BARRIER

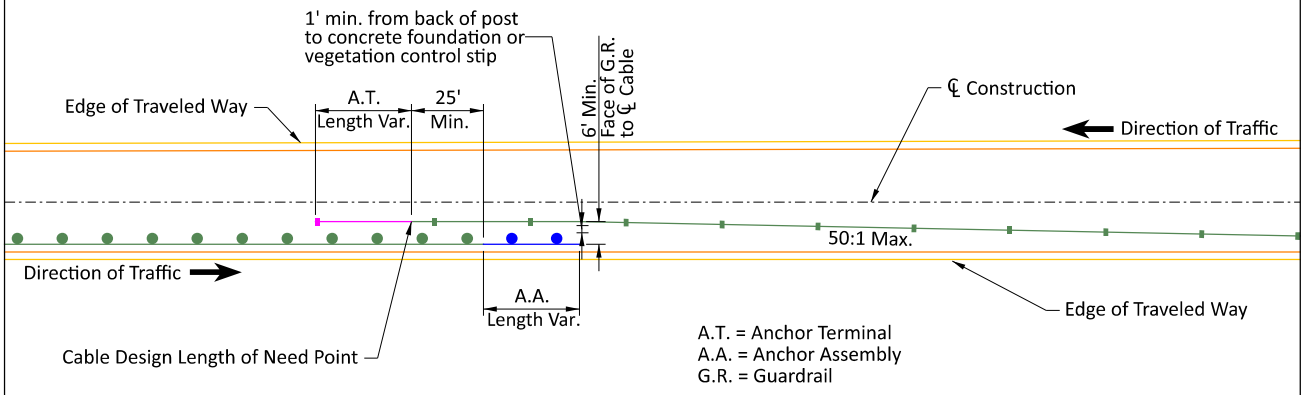
602-4b

REFERENCE SECTIONS
602.2.2 & 603.1.1

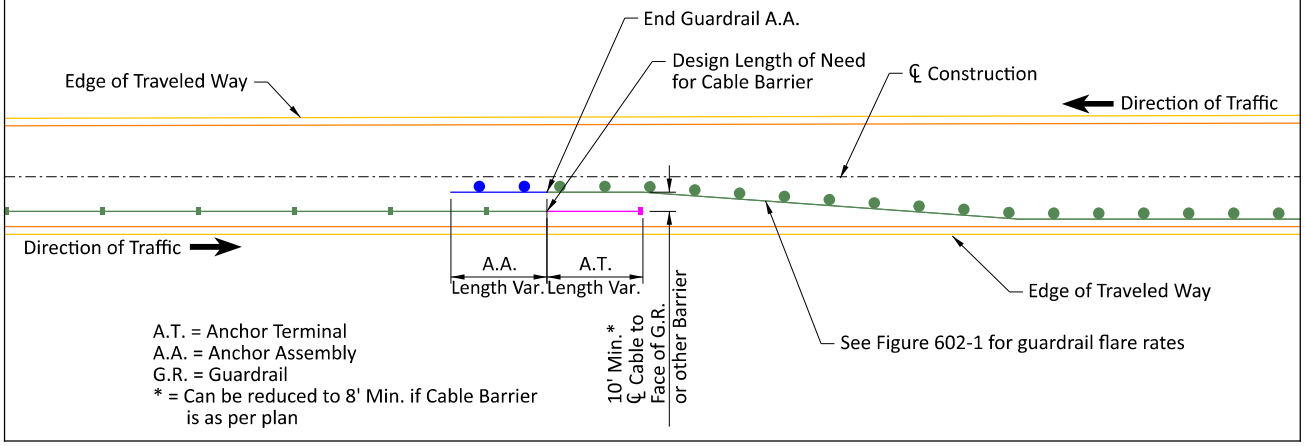
Cable Barrier Behind Guardrail (Leading End)



Cable Barrier Behind Guardrail (Trailing End)



Guardrail/Other Barrier Systems Behind Cable Barrier (Retrofit Only - Not Preferred)

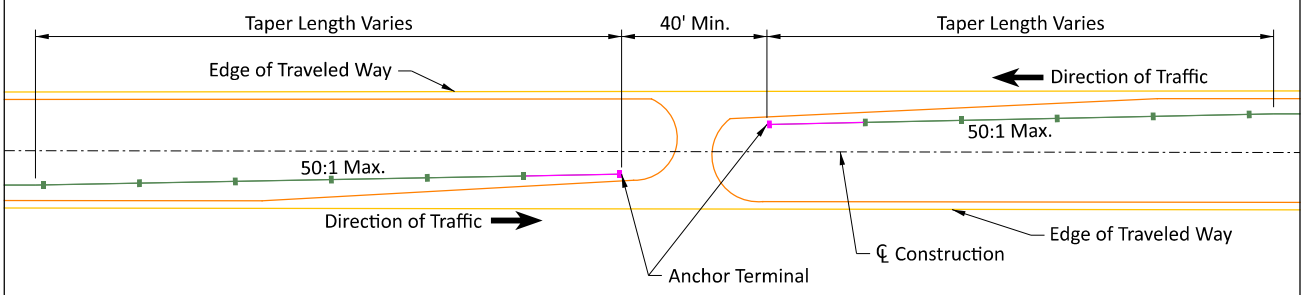


HIGH-TENSION CABLE BARRIER AT TURNAROUNDS

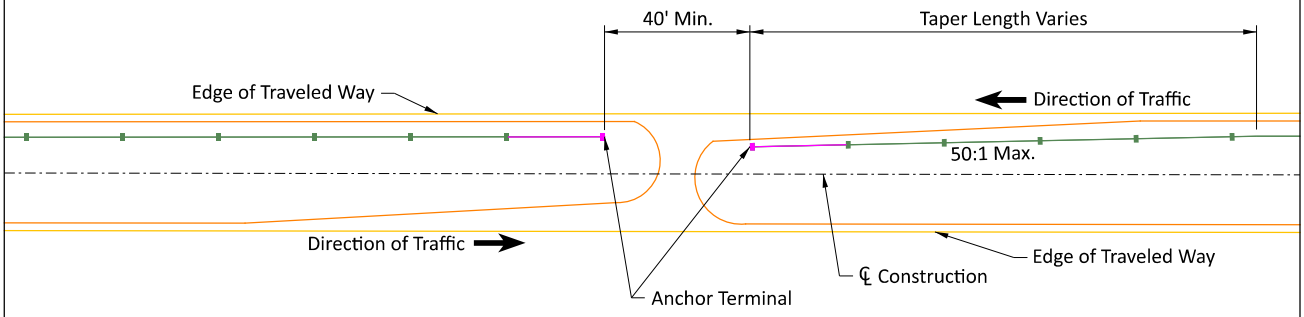
602-4c

REFERENCE SECTIONS
602.2.2 & 603.1.1

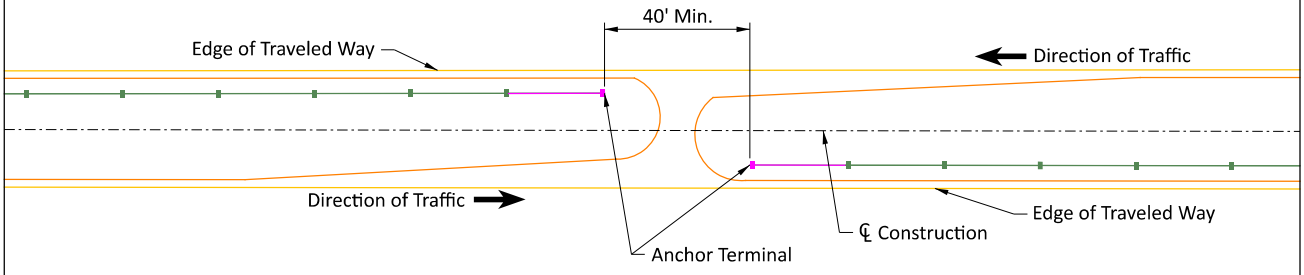
Option A - Preferred



Option B - Acceptable



Option C - Not Preferred



TYPICAL PERMANENT BARRIER USES & WORKING WIDTHS

603-2

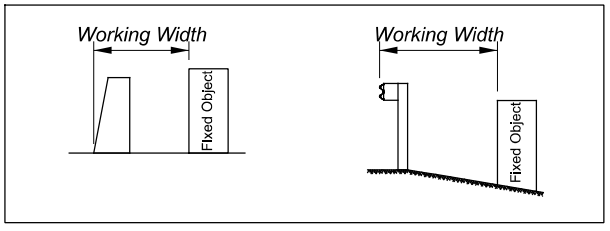
REFERENCE SECTIONS
603.1

	Barrier Type		Standard Drawing	Working Width (see Note 1)	Typical Use & Additional Notes
Steel Beam Guardrail	Type MGS (see Note 3)	Design Speed ≤30mph	MGS-2.1	3'-2"	Roadside protection. 6'-3" Standard Post Spacing (MASH TL-1)
		Design Speed: >30mph and ≤40mph	MGS-2.1	4'-2"	Roadside protection. 6'-3" Standard Post Spacing (MASH TL-2)
		Design Speed >40mph	MGS-2.1	5'	Roadside protection. 6'-3" Standard Post Spacing (MASH TL-3)
	MGS with Half Post Spacing		MGS-2.1	3'-1 ½"	3'-1 ½" Half Post Spacing
	MGS with Quarter Post Spacing		MGS-2.1	3'	1'-6 ¾" Quarter Post Spacing
	MGS Installed in Asphalt		MGS-2.1 (Sheet P.5)	5'	Roadside protection installed directly into 2" of asphalt pavement
	MGS Installed in Vegetation Control Strip (with grout leave outs)		MGS-2.1 (Sheet P.5)		Roadside protection with an asphalt or concrete vegetation control strip, and posts embedded in grout leave outs
	MGS Embedded in Rock		MGS-2.1 (Sheet P.5)	7'	Roadside protection in rocky terrain
	MGS Top Mounted Culvert Detail #1		MGS-2.1 (Sheet P.6)	4'-3"	Roadside protection along box culverts with shallow cover
	MGS Top Mounted Culvert Detail #2		MGS-2.1 (Sheet P.6)		
	MGS Non-Blocked		MGS-2.1 (Sheet P.9)	3'-8"	On 2-lane facilities where the roadside is limited by site constraints
	MGS Barrier Design (Double-Sided MGS)		MGS 2.1 MGS-6.1	5'	Narrow medians where deflections can be tolerated.
	MGS Barrier Design with Rub Rail		MGS-2.2	4'-6"	Narrow medians with steeper than 10:1 slopes on the median/rub rail side
	MGS Long-Span		MGS-2.3	8'*	*When the headwall is flush to grade, the back of the post can be aligned with the near side of the headwall. But if the headwall protrudes above grade, the system should be offset 8' from the fixed object. Used primarily to span culverts that have limited depths of cover.
	Socketed Weak Post Mounting		MGS-2.4	5'	Used primarily on precast structures that have limited depths of cover
Permanent Concrete Barrier (see Note 2)	Type B		RM-4.3	Width of Barrier (28")	Narrow medians
	Type B1		RM-4.3	Width of Barrier (33 3/4")	Narrow medians where additional height is required.
	Type C		RM-4.3	Width of Barrier (Varies 28" to 32 3/8")	Narrow medians where the difference in shoulder elevation is 24 inches or less.
	Type C1		RM-4.3	Width of Barrier (Varies 33 ¾" to 38 1/4")	
	Type D		RM-4.5	Width of Barrier (20")	Roadside protection adjacent to fixed obstacles. Area where impact angles over 15 degrees are unlikely or where maintenance may be difficult/dangerous.
	Type E		RM-4.9	Width of Barrier (14.5")	Where grading requirements behind a Type D wall cannot be met.
	Type N		RM-4.8	Width of Barrier (3.57')	In lieu of a noise wall with Type D barrier placed in front; typically when the roadway elevation is higher than the surrounding residences making a traditional noise wall outside the clear zone infeasible.

NOTES:

1) Working Width - The distance between the traffic face of the barrier before impact and the maximum lateral position of any major part of the system or vehicle after impact. See examples below on how to measure available working width.
2) See Figure 603-6 for minimum design offset values of ODOT (Generic) Portable Concrete Barrier.
3) MASH TL-3 is required on all ODOT maintained routes & locally maintained NHS routes. MASH TL-3 is preferred elsewhere, but in urban low-speed situations TL-2 or TL-1 may be appropriate when the 5' of working width (TL-3) is not achievable due to various constraints.

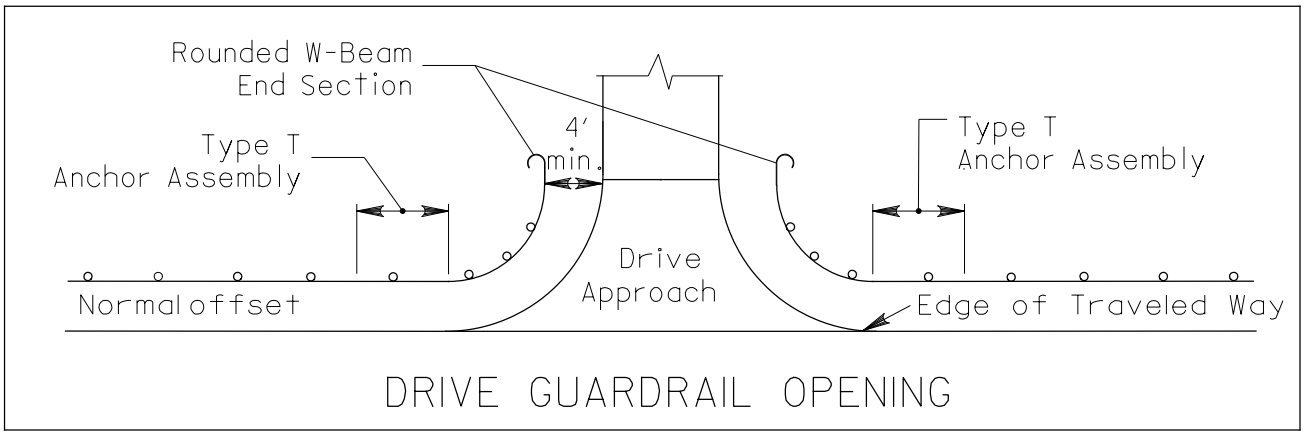
Examples of Working Width Measurement



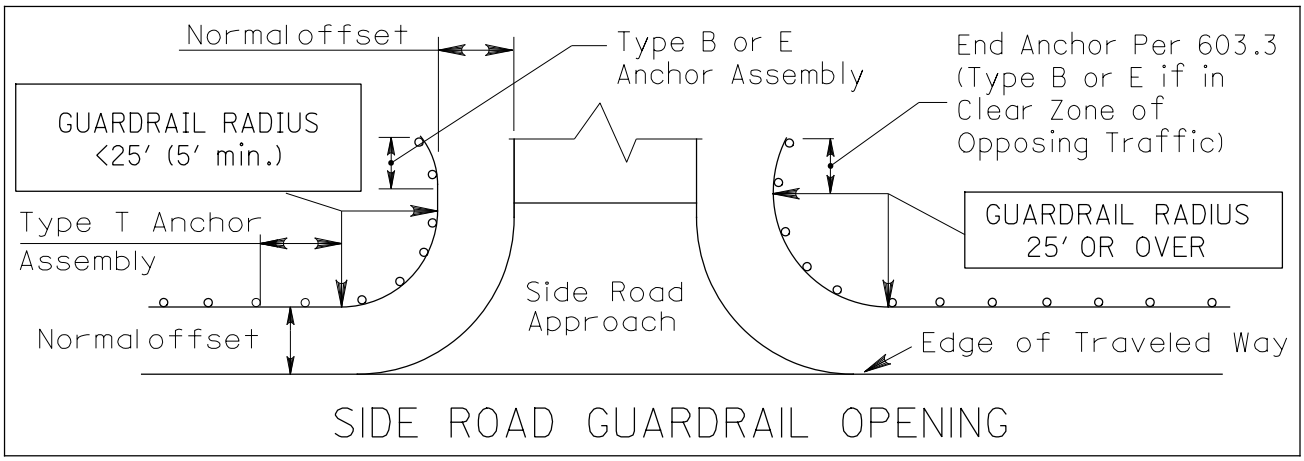
DRIVE AND SIDE ROAD GUARDRAIL OPENINGS

603-3

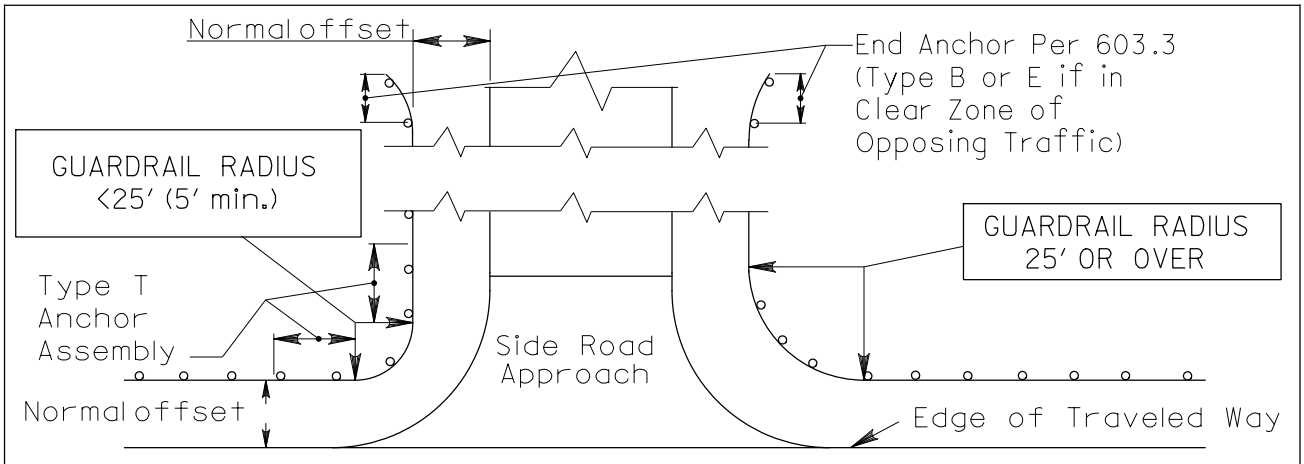
REFERENCE SECTIONS
602.4 & 603.3



DRIVE GUARDRAIL OPENING



SIDE ROAD GUARDRAIL OPENING

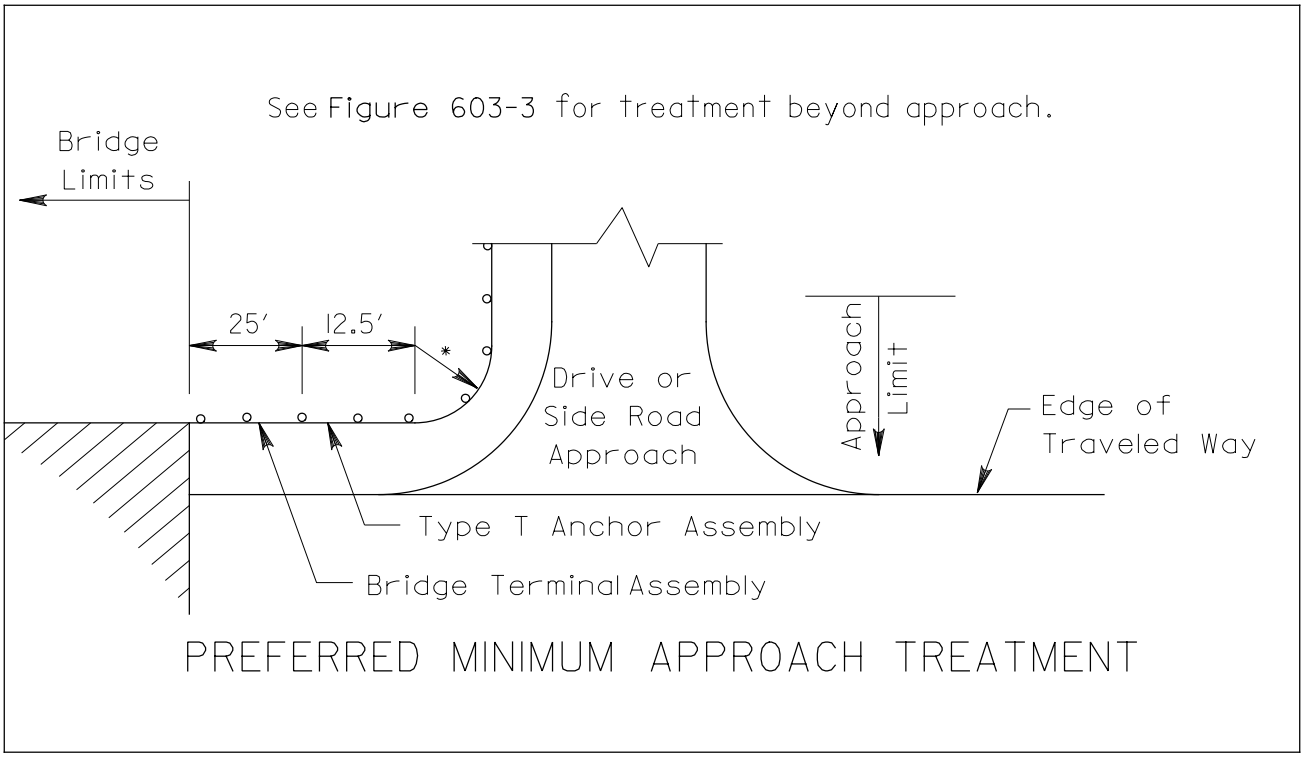


SIDE ROAD GUARDRAIL OPENING WHERE
GUARDRAIL EXTENDS ALONG SIDE ROAD

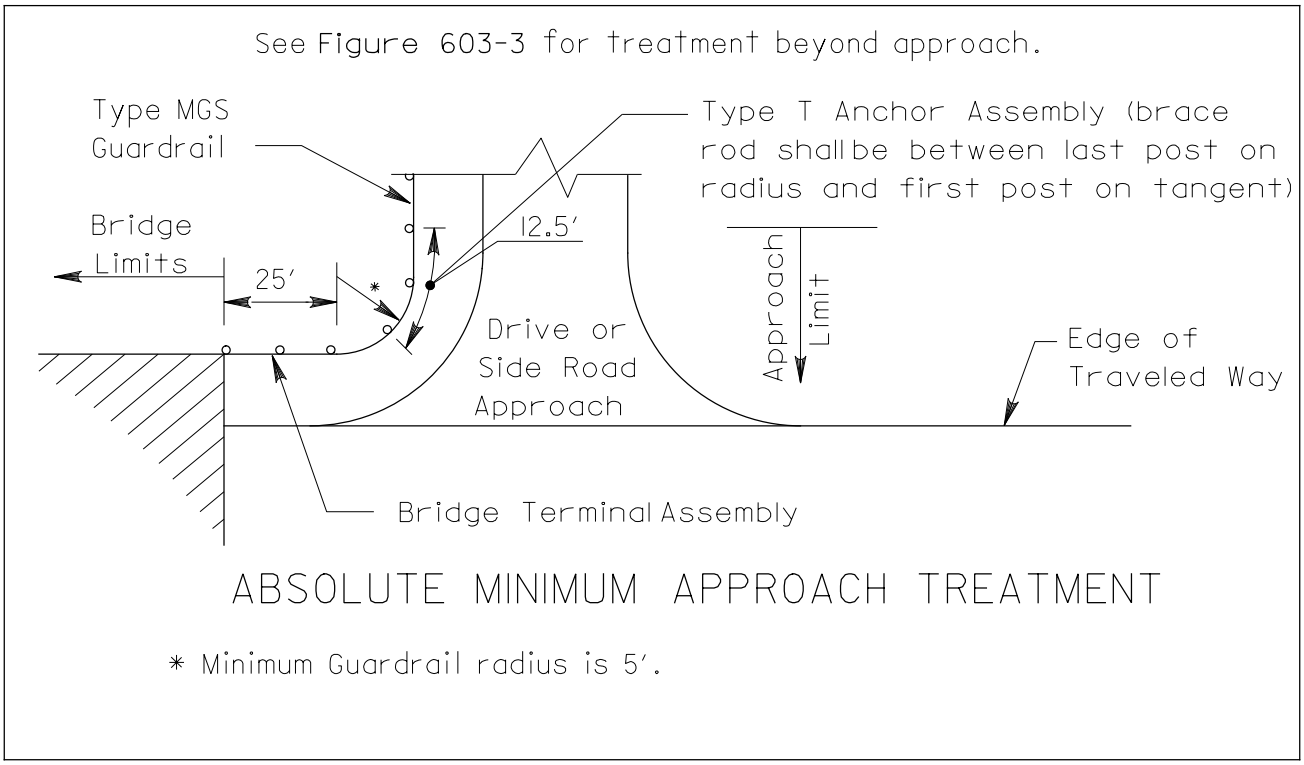
MINIMUM BRIDGE PROTECTION INVOLVING DRIVES OR SIDE ROADS

603-4

REFERENCE SECTIONS
602.5.1 & 603.3.5



PREFERRED MINIMUM APPROACH TREATMENT



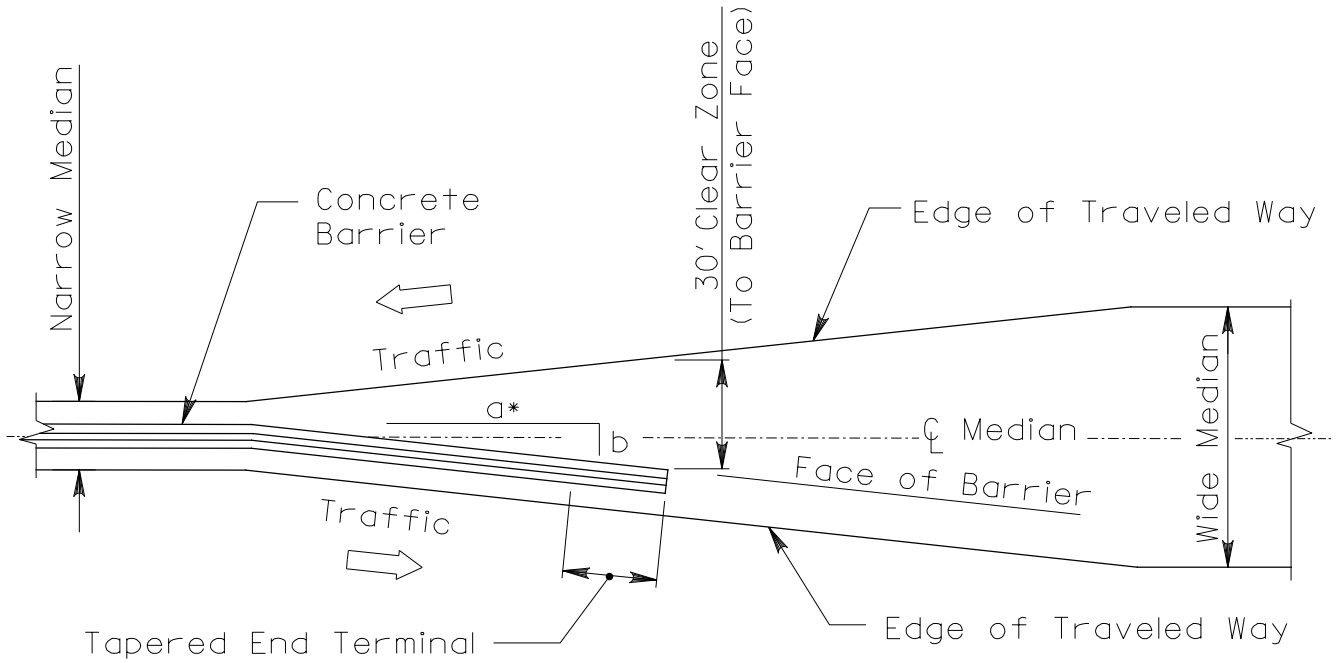
ABSOLUTE MINIMUM APPROACH TREATMENT

* Minimum Guardrail radius is 5′.

CONCRETE BARRIER MEDIAN TRANSITION

603-5

REFERENCE SECTIONS
603.6



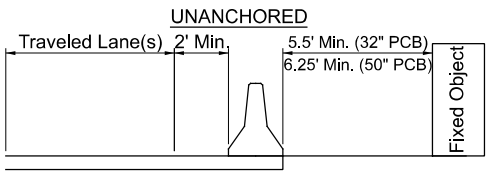
* See Figure 602-1 for barrier flare rates.

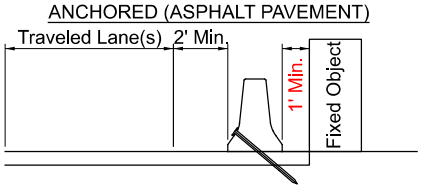
ODOT (GENERIC) PORTABLE BARRIER DESIGN OFFSET DETAILS

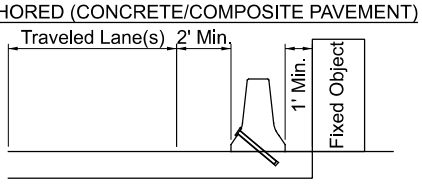
603-6

REFERENCE SECTIONS
603.1.5

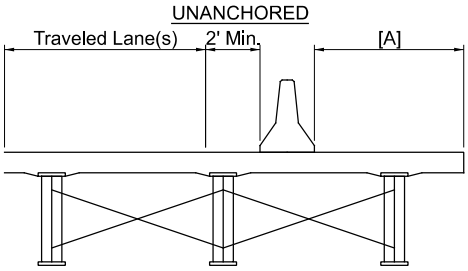
DESIGN OFFSET TO FIXED OBJECT

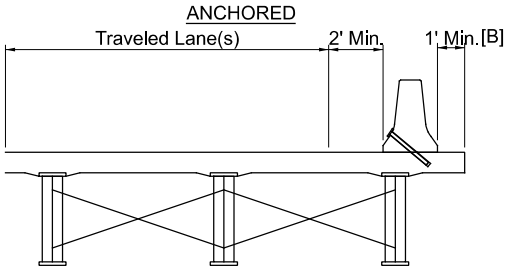






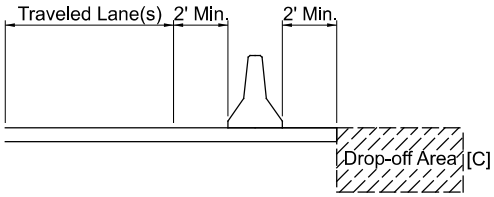
DESIGN OFFSET TO DECK EDGE





DESIGN OFFSET TO DROP-OFF

(See MT-101.90 and TEM Sections 640-6/641-25 for additional information on drop-offs in work zones)



[A] Refer to OSE Design Data Sheet PCBDD for unanchored offset requirements.

[B] Refer to OSE Design Data Sheet PCBDD for PCB-91 anchoring requirements. Refer to RM-4.2 for ODOT F-Shape PCB anchoring requirements.

[C] Refer to OSE Design Data Sheet PCBDD for anchoring determination regarding drop-off depths greater than 24".

	Barrier Type	Anchorage Method	Type of Protection Required	Standard Drawing	Min. Design Offset (see Note 1)	Notes
Portable Concrete Barrier	50" PCB	Unanchored	Fixed Object	RM-4.1	6'-3"	2' min. required from edge of traveled way to barrier toe
		Unanchored	Drop Off ≤ 24" or Work Area		2'-0"	
		Unanchored	Deck Edge or Drop Off > 24"	N/A - 50" PCB shall not be used to protect deck edge or similar drop offs that are > 24"		
		Anchored in Concrete	N/A - 50" PCB shall not be anchored in concrete			
		Anchored in Asphalt	N/A - 50" PCB shall not be anchored in asphalt			
	32" PCB	Unanchored	Fixed Object	RM-4.2 and PCB-91	5'-6"	2' min. required from edge of traveled way to barrier toe
		Unanchored	Drop Off ≤ 24" or Work Area		2'-0"	
		Unanchored	Deck Edge or Drop Off > 24"		Determine using PCBDD Figures 1 & 2- see OSE Design Data Sheets. 2' min. required from edge of traveled way to barrier toe	
		Anchored in Concrete	Any		1'-0"	2' min. required from edge of traveled way to barrier toe
		Anchored in Asphalt	Any		1'-0"	

NOTES:

1) Design Offset - the distance between the hazard and the nearside toe of barrier.

2) Designers shall design portable concrete barrier to the values in this table. The contractor is responsible for ensuring any substitutions from the Approved Products List fulfill the design intent and requirements of the contract documents.

3) District approval is required for designs where the minimum design offsets cannot be obtained in the following situations: back side toe of anchored barrier to deck edge or fixed object; back side toe of barrier to drop-off; and front side toe of barrier to traveled lane (after applying the applicable guidance described in TEM Section 640-2).

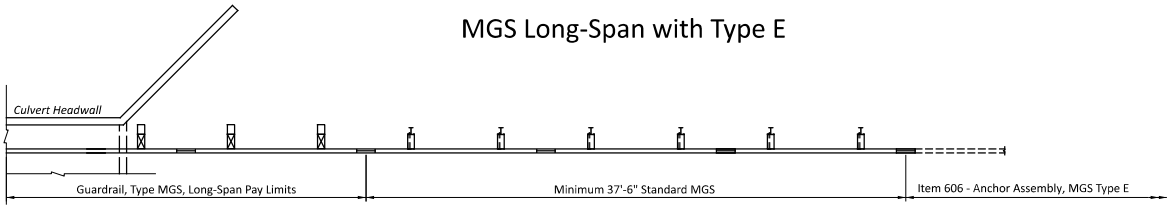
July 2026

LONG SPAN DESIGN DETAILS

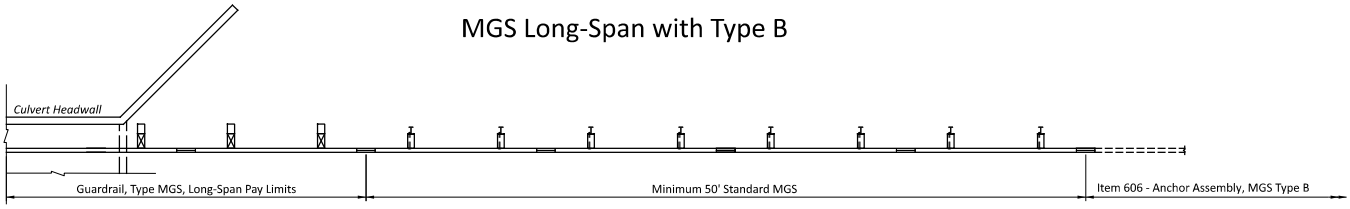
603-7

REFERENCE SECTIONS
603.1.2.5

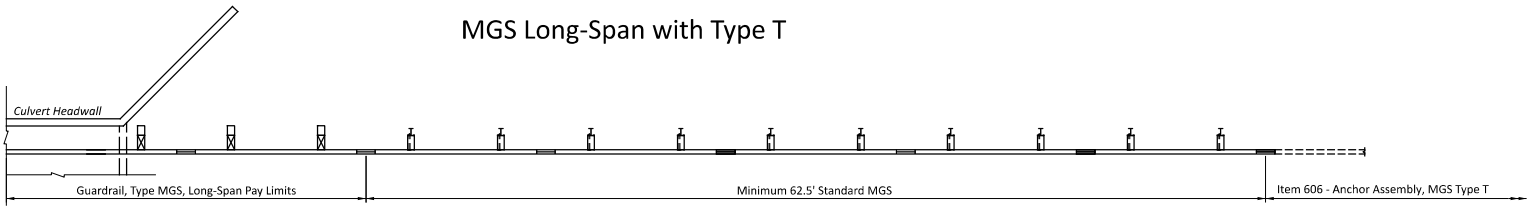
MGS Long-Span with Type E



MGS Long-Span with Type B



MGS Long-Span with Type T



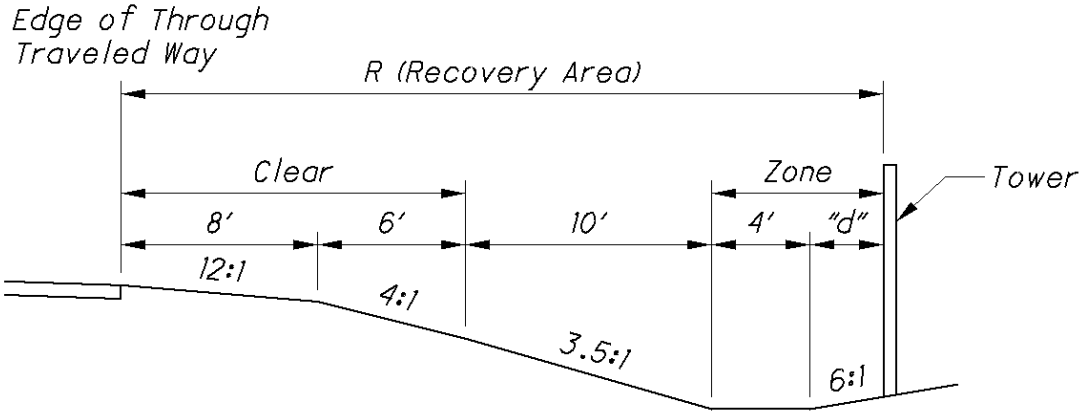
July 2026

SAMPLE CALCULATIONS

Ex. 600-1

Clear Zone Measurement Using Slope Averaging (Traversable Ditch)

Problem 1: Compute the safe distance from the edge of traveled way to locate a tower for lighting. The project has a design speed of 55 mph, a design year traffic volume of 3,400 ADT, and the following cross section in the area where the tower is to be located:



Solution 1: **Step 1** – Check the foreslope from the edge of traveled way to the backslope to determine if all intermediate foreslopes are either recoverable or non-recoverable. (See **Figure 600-2**).

Since the foreslope has intermediate slopes that are recoverable (12:1 & 4:1) and non-recoverable (3.5:1), the clear zone may extend into the backslope if necessary.

Step 2 – Determine the weighted average of the foreslope. For sections flatter than or equal to 10:1, use a 10:1 slope. (The 12:1 shoulder is typically ignored; however, for this example it is included for illustrative purposes.) Decimal results of 0.5 or greater should be rounded up to the next whole numbered slope while decimal results less than 0.5 should be rounded down to the next whole numbered slope.

First, multiply the width of each slope by the rate of the slope to obtain the weighted average rise for the foreslope. Include half of the ditch bottom in the foreslope.

$$8' (1/10) + 6' (1/4) + (0^*) + 4'/2 (1/10) = 2.5'$$

*Since the 3.5:1 foreslope is non-recoverable, it is not included.

SAMPLE CALCULATIONS	
Ex. 600-1	**Clear Zone Measurement Using Slope Averaging (Traversable Ditch)**

(continued)

Next, add the width of each foreslope used above.

8’ + 6’ + 4’/2 = 16’

Then, divide the total recoverable width by the weighted average rise to obtain the weighted average of the foreslopes.

16’/2.5’ = 6.4 (Rounded to 6:1 slope)

Now, use **Figure 600-1** (for 6:1 foreslopes, 55 mph Design Speed and 1,501 < ADT < 6,000) to determine that the required clear zone distance is 21 feet.

Since the required clear zone is 21 feet and only 16 feet of recoverable clear zone exists, additional width must be considered from the backslope.

Step 3 -Determine if the ditch section is traversable.

Using **Figure 307-11**, a ditch with a 3.5:1 foreslope and 6:1 backslope is traversable.

If a non-traversable ditch section had been provided then the designer would have to consider other site conditions to determine whether or not the ditch should be used within the clear zone or if guardrail should be installed. (Ex. 3:1 foreslope)

Step 4 – Determine the clear zone using the back slope.

Determine how much of the backslope should be included in the clear zone.

“d” = 21’ – 8’ – 6’ – 4’ = 3’

Therefore, the clear zone must extend 3 feet into the backslope.

The “Recovery Area” includes the clear zone width plus any intermediate widths where the slopes are traversable, but not recoverable.

SAMPLE CALCULATIONS

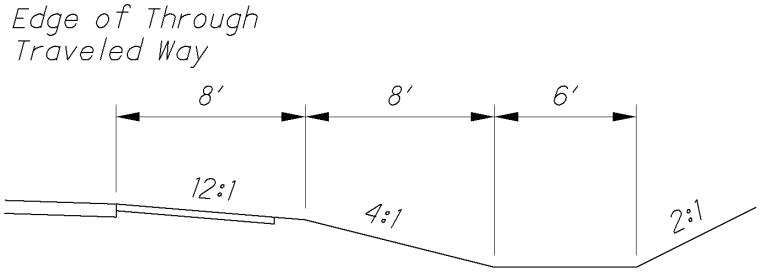
Ex. 600-2

Clear Zone Measurement For a Non-Traversable Ditch

Problem 2: a) Determine the required clear zone distance for the following location on a project with a tangent alignment, a design speed of 55 mph, and a design year traffic volume of 1,700 ADT.

b) Assuming this cross section occurs on the outside of a 2-Degree curve, how would this change the above results?

c) Determine the clear zone distance for a Degree of Curve of 3 degrees.



Solution 2: a) – The required clear zone distance (for foreslopes steeper than 6:1 up to 4:1, 55 mph design speed, and 1,501 ≤ ADT ≤ 6,000) is 27 feet. 19 feet of clear distance is available up to the center of the ditch. A trapezoidal ditch with a 4:1 foreslope, 2:1 backslope, and a width equal to or greater than 4 feet is a non-traversable design (see **Figure 307-11**) and generally should not be located within the clear zone. However, if the probability of encroachment is low, no additional improvement may be needed.

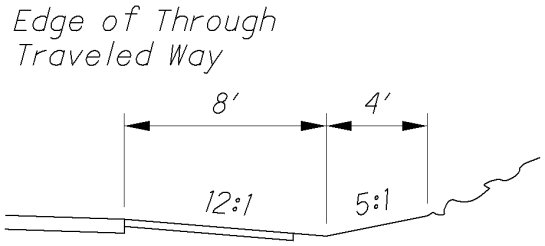
b) – Since this location is on the outside of a curve where the probability of encroachment is high, the designer should consider reshaping the ditch or installing guardrail.

c) – The required clear zone distance determined above for a tangent alignment needs to be increased by a factor of 1.2 for locations on the outside of curves with a curvature of 3 degrees and a design speed of 55 mph. (See **Figure 600-1**). The adjusted clear zone distance is 27(1.23) = 33.2'. Since the adjusted value is greater than 30', use 30'.

Since 19 feet or only 63% of the required clear zone distance exists on the outside of the curve, the designer should consider reshaping the ditch or installing guardrail.

SAMPLE CALCULATIONS	
Ex. 600-3	**Clear Zone Measurement For a Cut Slope**

Problem 3: Determine the required clear zone distance for the following location on a project with a design speed of 45 mph and a design year traffic volume of 1,300 ADT.



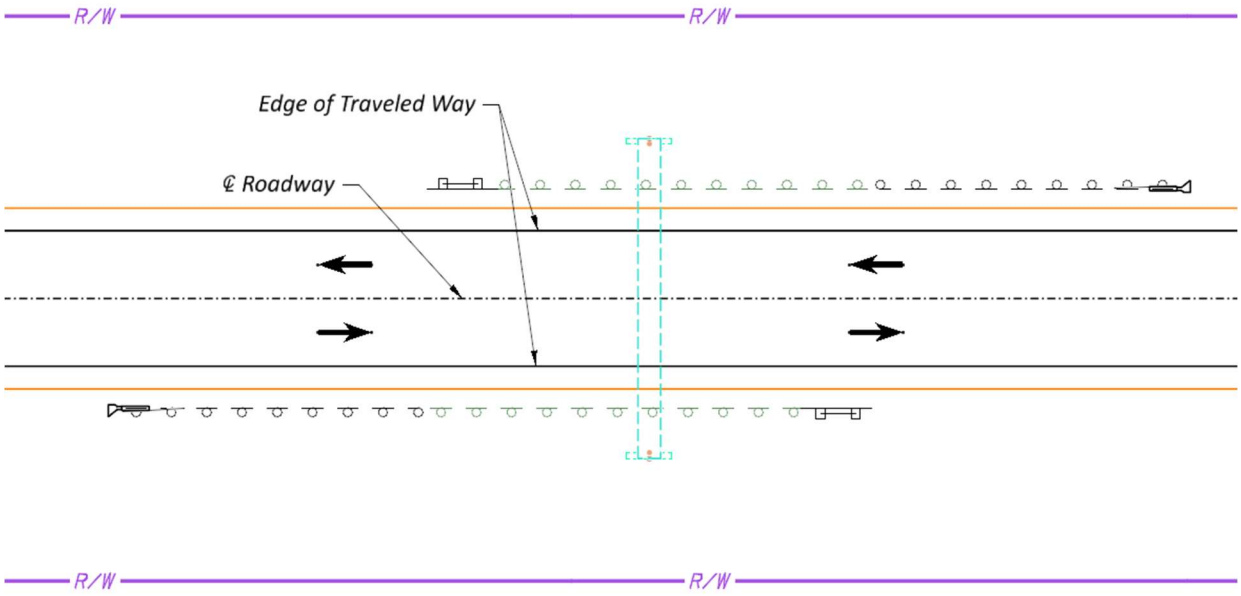
Solution 3: The required clear zone distance (for backslopes steeper than 6:1 up to 4:1, 45 mph design speed and 750 ≤ ADT ≤ 1,500) is 13 feet. (See **Figure 600-1**). The required clear zone is 13 feet but only 12 feet exist. If this section of roadway has a history of accidents with the cut face then guardrail should be installed.

SAMPLE CALCULATIONS

Ex. 600-4

Clear Zone Grading to Eliminate Need for Barrier at a Fixed Object

Problem 4: Determine the required clear zone grading limits and additional pipe length required to extend a 48" culvert within existing right-of-way so that barrier protection can be eliminated. The project conditions are: a rural collector, tangent alignment, 100' of R/W, design speed of 55 mph, and 3200 ADT.



Solution 4: **Step 1** – Determine lateral clear zone grading limits and minimum culvert extension length. Refer to **Figure 600-1**, the clear zone is 21' when a 6:1 or flatter foreslope is provided, and 27' with a foreslope steeper than 6:1 to a maximum of 4:1. For this project a 6:1 foreslope is being used. The distance from the edge of traveled way to the back of headwall will need to meet or exceed the clear zone distance. Therefore, the 48" conduit will be extended so that the back of headwall is at least 21' from the edge of traveled way, and clear zone grading will be provided within that lateral zone.

Note: Although 6:1 is selected for this example, the determination of the foreslope grade will depend on available cover, right-of-way width, and other site & project specific conditions.

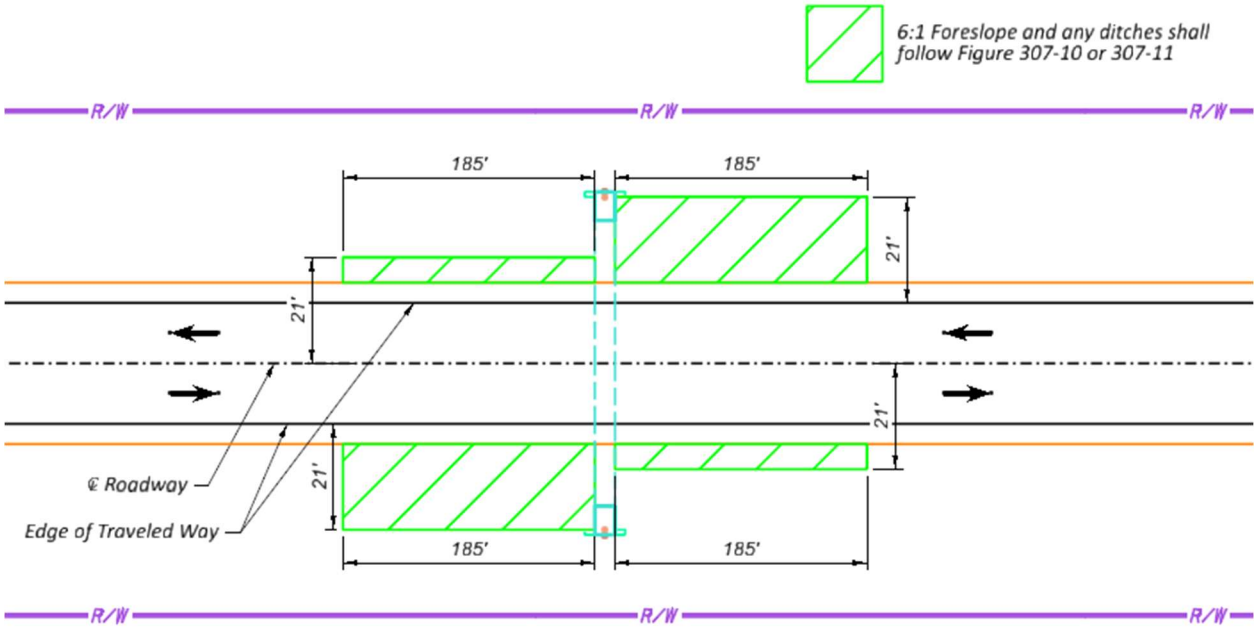
Step 2 – Determine the longitudinal limits of the clear zone grading. Refer to **Section 307.2.2**: clear zone grading is required for the runout length for the warranting feature (the 48" culvert). Refer to **Figure 602-1**, the Runout Length is 185' for a 55 mph roadway with 3200 ADT. Note that the clear zone length is measured from the center line for the Opposing Traffic side.

SAMPLE CALCULATIONS

Ex. 600-4

Clear Zone Grading to Eliminate Need for Barrier at a Fixed Object

(continued)



The foreslope grading shall be a minimum 6:1 for 185' on either side of the culvert and for 21' laterally measured from edge of traveled way. If there are roadside ditches being perpetuated through the hatched area, then they will need to follow **Figure 307-10 or 307-11** for the backslope tie-in.

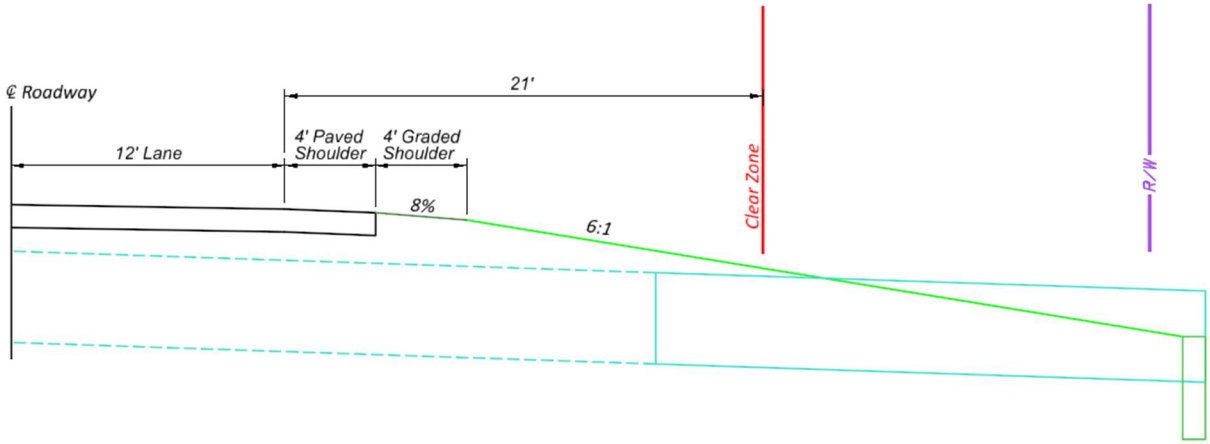
Step 3 – It needs to be confirmed that the extension of the culvert at the applicable grade will intercept the 6:1 foreslope and remain within the right-of-way to ensure the design is in accordance with the project's constraints.

SAMPLE CALCULATIONS

Ex. 600-4

Clear Zone Grading to Eliminate Need for Barrier at a Fixed Object

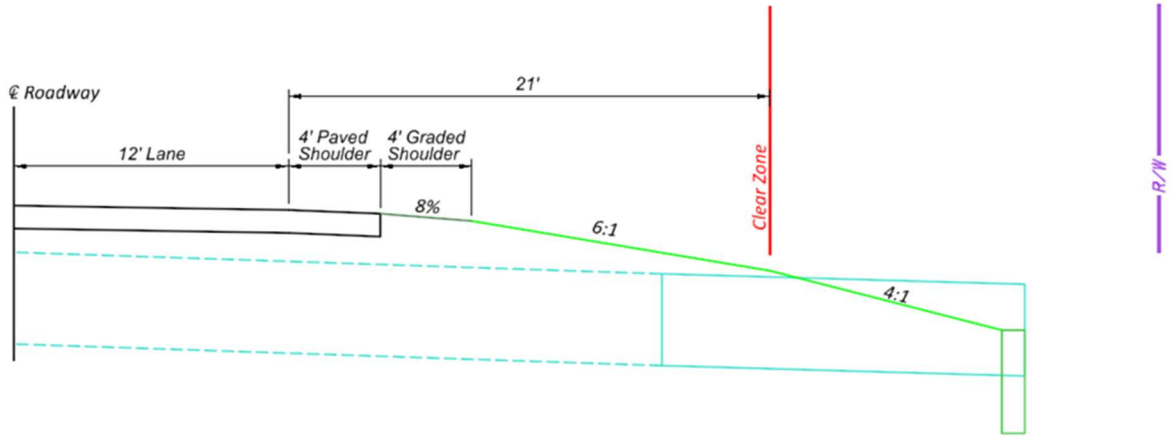
(continued)



It is apparent from the cross section that the culvert extension cannot be completed with a 6:1 foreslope as it would have to be extended outside of the existing right-of-way, which is not an option for this project. Therefore, there are two options to consider before purchasing additional right-of-way:

1. Return to Step 1 and change the foreslope to a value steeper than 6:1 to 4:1 maximum, which would cause the clear zone to increase to 27' (and would affect the graded shoulder width per **Figure 301-3**).
2. Utilize the bottom option on **Figure 307-3** which allows the foreslope grade to have a break at the clear zone boundary to steeper than 4:1 to 3:1 maximum.

Option 2 has been selected for this example:



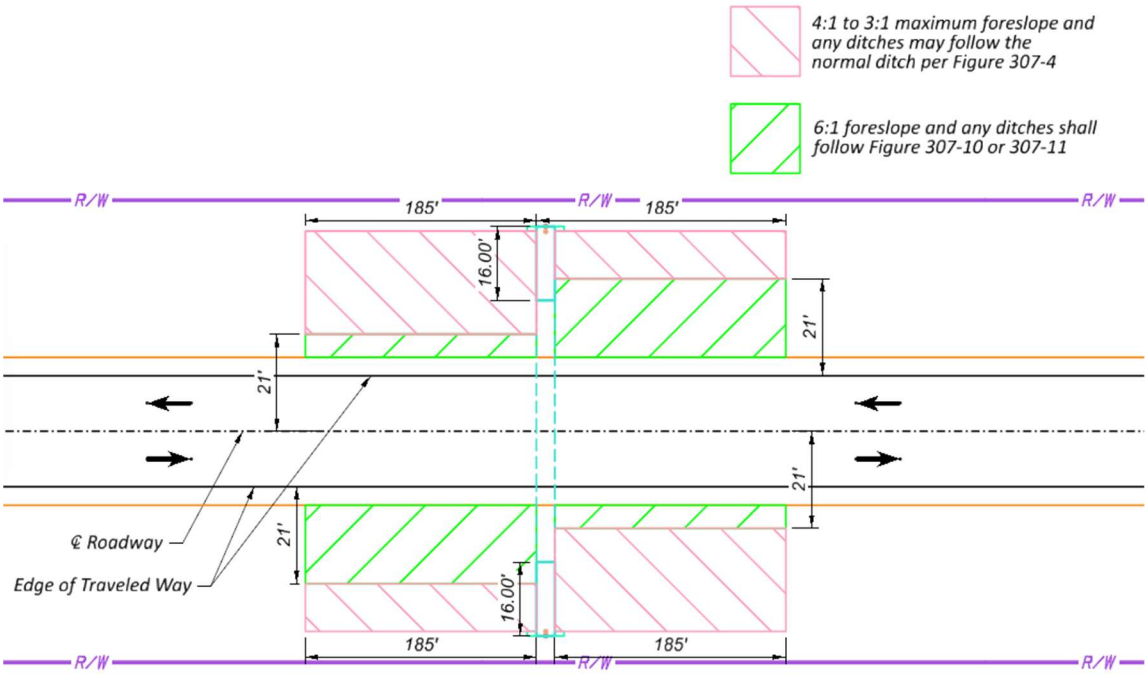
SAMPLE CALCULATIONS

Ex. 600-4

Clear Zone Grading to Eliminate Need for Barrier at a Fixed Object

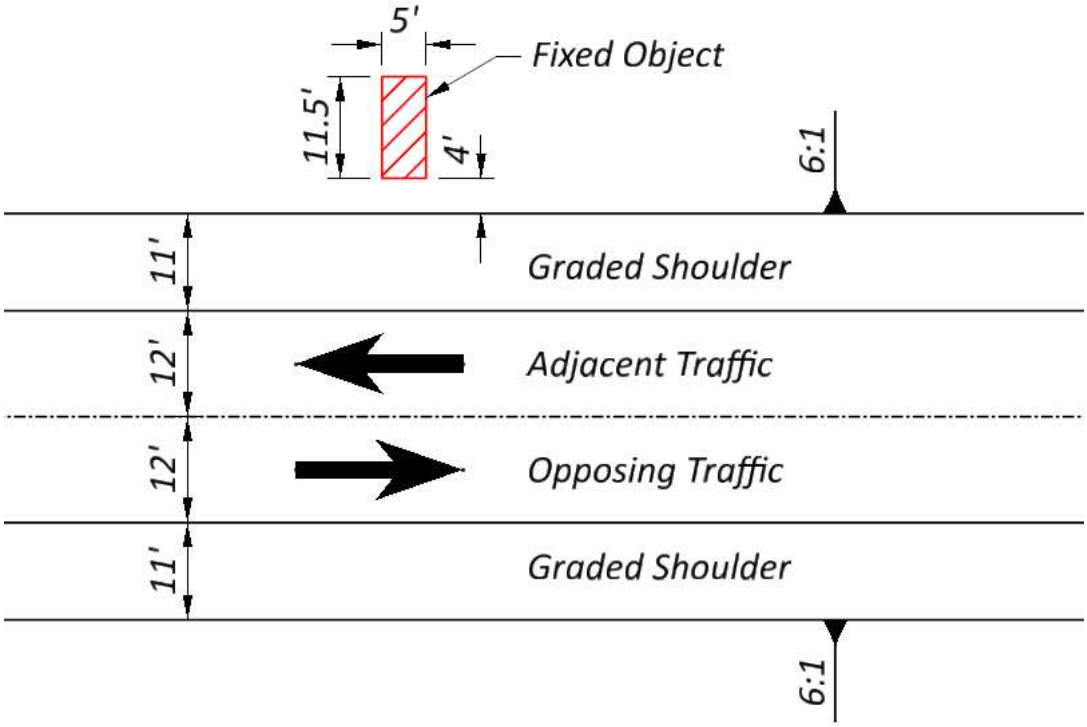
(continued)

Breaking the foreslope at the clear zone boundary to a 4:1 results in the foreslope grade intercepting the top of headwall within the right-of-way. Therefore, a pipe extension of 16’ will meet the project constraints and eliminate the need for barrier when the proper grading is provided. The final step is to update the plan view:



SAMPLE CALCULATIONS	
Ex. 602-1	**Tangent Barrier Design For a 2-Lane Road**

Problem 1: Design barrier if needed to shield the fixed object located on the two-lane rural collector shown below. The project has a design speed of 60 mph, a design year traffic volume of 2,200 ADT, and a 6:1 foreslope. Assume that the object cannot be removed, relocated, or made traversable.



Solution 1: **Step 1** – Determine whether the fixed object is in the clear zone for adjacent traffic. Refer to **Figure 600-1** (for 6:1 or flatter foreslope, 60 mph design speed, and 1,501 ≤ ADT ≤ 6,000) to determine that the required clear zone distance is 28 feet.

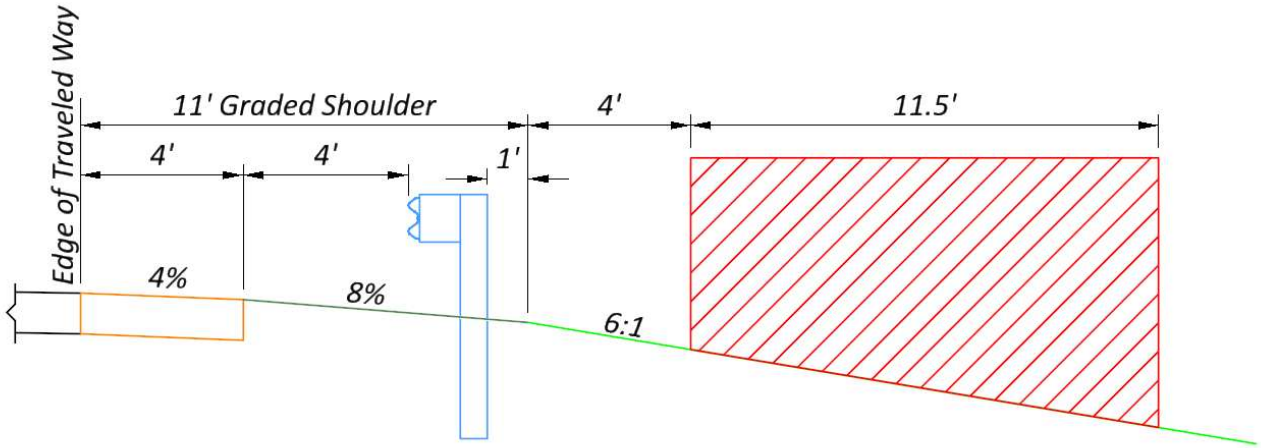
The available clear area for adjacent traffic is 11’ + 4’ = 15’

Since the object cannot be removed, relocated, or made traversable and it is inside the required clear zone, a barrier should be installed to shield it.

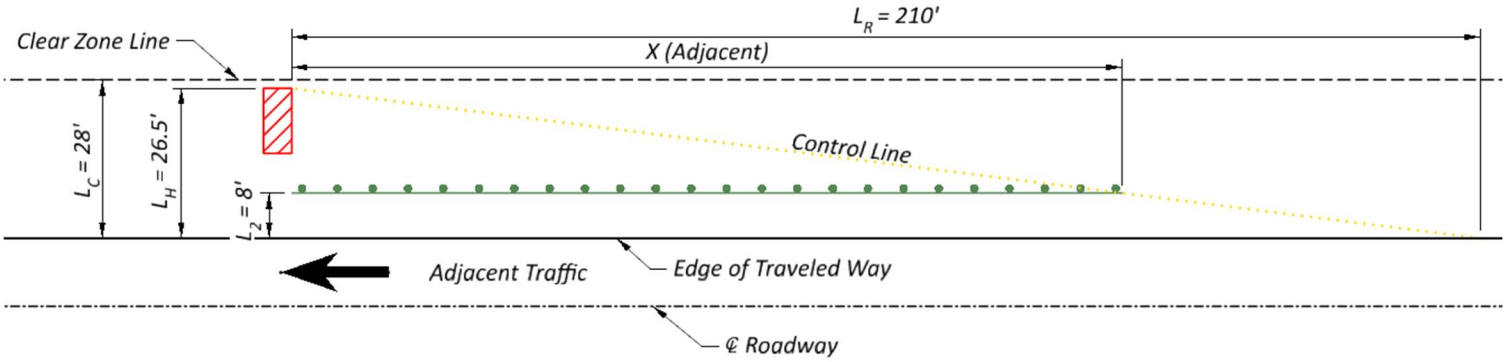
SAMPLE CALCULATIONS	
Ex. 602-1	**Tangent Barrier Design For a 2-Lane Road**

(continued)

Step 2 – Select the type of barrier to be installed. Using **Figure 301-3**, the normal (minimum) barrier offset for a rural collector (Design Year ADT greater than 2,000) is 8 feet away from the edge of traveled way. The available barrier clearance at this location is (11' – 8') + 4' = 7 ft; therefore, use MGS Guardrail which has a minimum barrier clearance of 5 ft. (See **Figure 603-2**).



Step 3 – Calculate the length of need for adjacent traffic. Assume the area along the front of the fixed object cannot be graded to provide 10:1 foreslopes; therefore, the guardrail cannot be installed with a flare.



SAMPLE CALCULATIONS

Ex. 602-1

Tangent Barrier Design For a 2-Lane Road

(continued)

From **Figure 602-1**, L_R = 210 ft. (for design speed = 60 mph and 1,000 ≤ ADT ≤ 5,000). Since the lateral offset to the back of the object (L_H) is less than the required clear zone distance (L_C), use L_H in the LON formula.

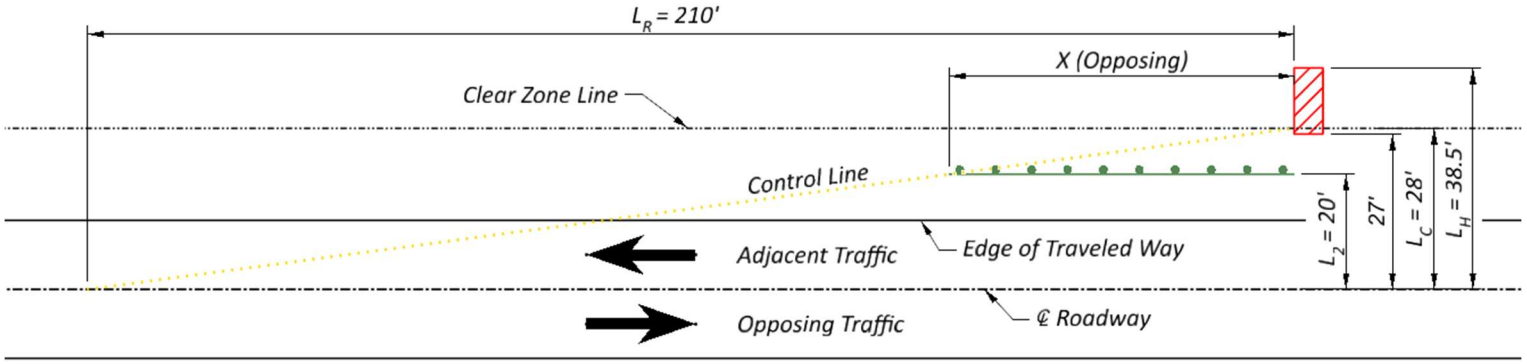
$$X = \frac{L_H + L_1\frac{b}{a} - L_2}{\frac{b}{a} + \frac{L_H}{L_R}}$$

Start measuring the length of the guardrail needed at the edge of the fixed object. Since the guardrail will not be flared, b/a = 0.

$$X_{\text{(adjacent)}} = \frac{26.5 + 0 - 8}{0 + \frac{26.5}{210}} = 146.60 \text{ ft.}$$

Step 4 – Determine whether the fixed object is in the clear zone for opposing traffic. The required clear zone is still 28 feet. The available clear area is 12’ $_{\text{(lane width)}}$ + 15’ = 27 ft. Since the object is in the clear zone, calculate the offset to the back of the object, L_H.

L_H = 12’ + 15’ + 11.5’ = 38.5 ft.



Since $L_H > L_C$, protection only needs to be provided up to the clear zone.

$$X_{\text{(opposing)}} = \frac{L_C + L_1\frac{b}{a} - L_2}{\frac{b}{a} + \frac{L_C}{L_R}} = \frac{28 + 0 - 20}{0 + \frac{28}{210}} = 60.00 \text{ ft.}$$

SAMPLE CALCULATIONS	
Ex. 602-1	**Tangent Barrier Design For a 2-Lane Road**

(continued)

The total length of guardrail required is:

$X_{(adjacent)}$ + width of object + $X_{(opposing)}$ = 146.60’ + 5’ + 60.00’ = 211.60 ft.

The length provided should be a multiple of even 12’-6” panel lengths.

X = 211.60’/12.5’ = 16.93 → Use 17 panels of 17(12.5’) = 212.5 ft.

Note – If the designer had chosen to shield the entire object from opposing traffic instead of providing protection up to the clear zone, then

$$X_{(opposing)} = \frac{L_H + L_1\frac{b}{a} - L_2}{\frac{b}{a} + \frac{L_H}{L_R}} = \frac{38.5 + 0 - 20}{0 + \frac{38.5}{210}} = 100.91 \text{ ft.}$$

The total length of guardrail needed would have been:

146.60’ + 5’ + 100.91’ = 252.51 ft. (or 21 panels)

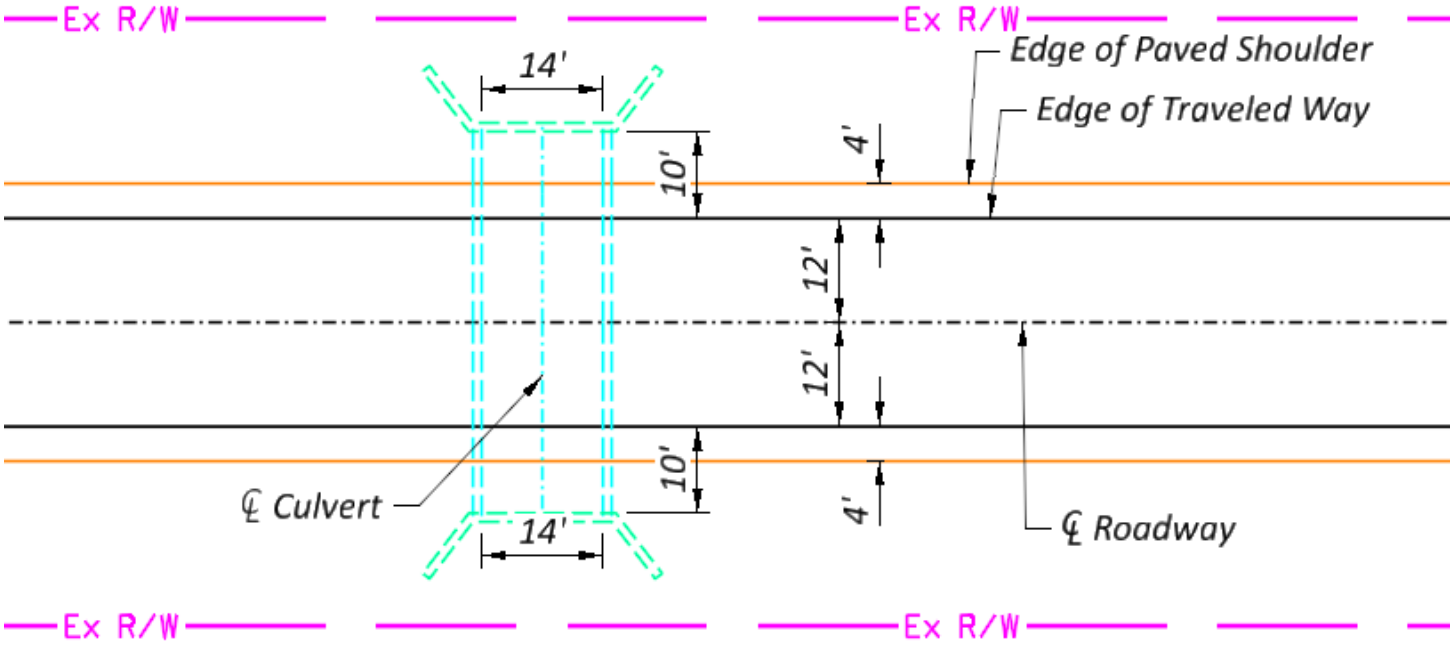
Four additional panels (50 feet) of guardrail would be installed. In some cases, the designer may choose to shield the entire object even though a portion of it is outside the clear zone; however, in some cases it may be uneconomical to do so.

Step 5 – Select Anchor Assemblies. Since the slopes do not allow the guardrail to be flared, MGS Type E anchor assemblies should be installed. With the trailing end of the barrier run within the clear zone of opposing traffic, a MGS Type E anchor assembly should be installed on the trailing end of the guardrail run as well.

SAMPLE CALCULATIONS

Ex. 602-2	Length of Need at a Large Culvert

Problem 2: Design barrier if needed to shield the existing culvert headwalls and drop off located on the two-lane rural collector shown below. This project has a design speed of 55 mph, 4:1 foreslopes, and a design year traffic volume of 4,500 ADT.



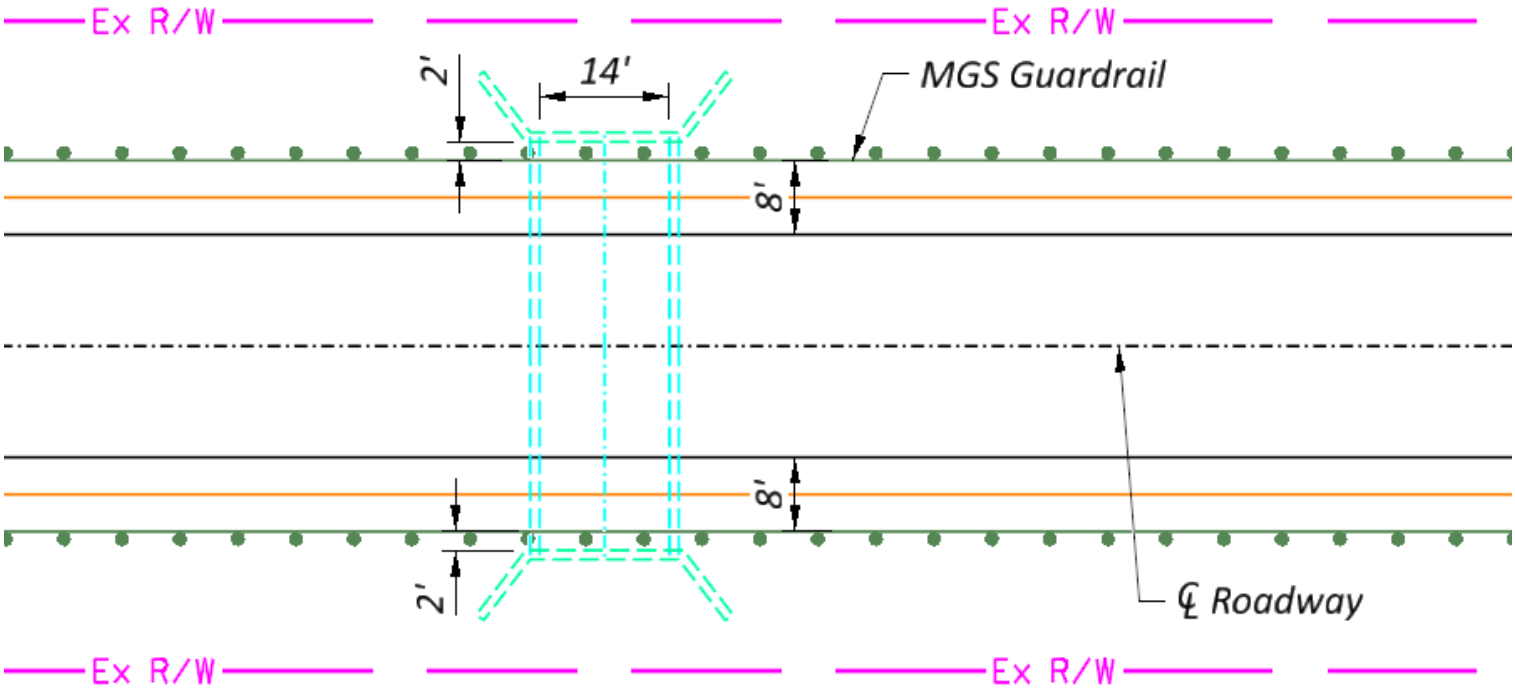
Solution 2: **Step 1** – Determine whether the headwall is in the clear zone for adjacent traffic. Refer to **Figure 600-1** (for foreslopes steeper than 6:1, 55 mph design speed, and 1,510 ≤ ADT ≤ 6,000) to determine that the required clear zone distance is 27 feet measured from the edge of traveled way.

For this situation, it is impractical to extend the culvert outside of the clear zone as it would substantially increase project costs and require the acquisition of right-of-way, which is outside of the scope of the project.

SAMPLE CALCULATIONS	
Ex. 602-2	**Length of Need at a Large Culvert**

(continued)

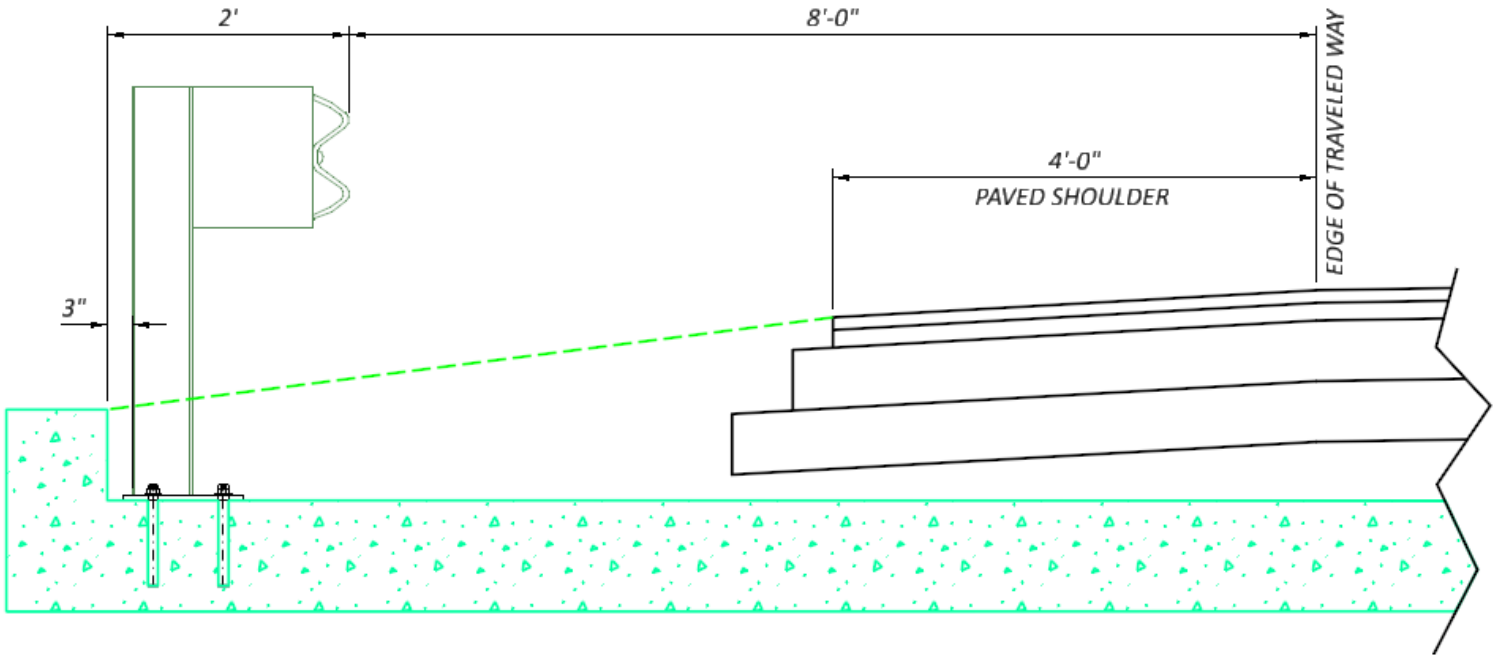
Step 2 – Select the type of barrier to be installed. Using **Figure 301-3**, the normal barrier offset for a rural collector (Design Year ADT greater than 2,000) is 8’ from the edge of traveled way. The available working width at this location for MGS guardrail installed at an 8’ offset from edge of traveled way to face of guardrail would be 2’ measured from the face of guardrail to the culvert headwall.



Refer to **Figure 603-2** for working widths of permanent barrier systems to determine that standard MGS requires 5’ of working width, which is not available in the situation. Furthermore, due to the span of the culvert (14’) the use of standard MGS would be precluded as the required post spacing is 6.25’, which would result in multiple posts conflicting with the existing culvert. Another option to evaluate is the use of the top mounted culvert details from **SCD MGS-2.1**.

SAMPLE CALCULATIONS	
Ex. 602-2	**Length of Need at a Large Culvert**

(continued)



The top mounted culvert details from **SCD MGS-2.1** require either 12” of clearance from the back of post to near face of the headwall wall for half-post spacing or 18” for standard post spacing. When offsetting the barrier 8’ from the edge of traveled way, the offset to the face of the headwall is 3” and therefore mounting a post on top of the culvert is not a viable for this situation.

The other remaining options to evaluate are the use of MGS Long-Span per **SCD MGS-2.3** or Socketed Weak Posts attached to the Headwall per **SCD MGS-2.4**. The previous site visit to the location revealed that the headwalls are not in a suitable condition to have hardware directly attached to them. Therefore, MGS Long-Span will be evaluated, and the requirements for this system are 8:1 grading for 2’ behind the posts, 3 breakaway CRT posts on both sides of the span, and the back of post can be aligned with the near side of the headwall if the top of the headwall is flush to grade.

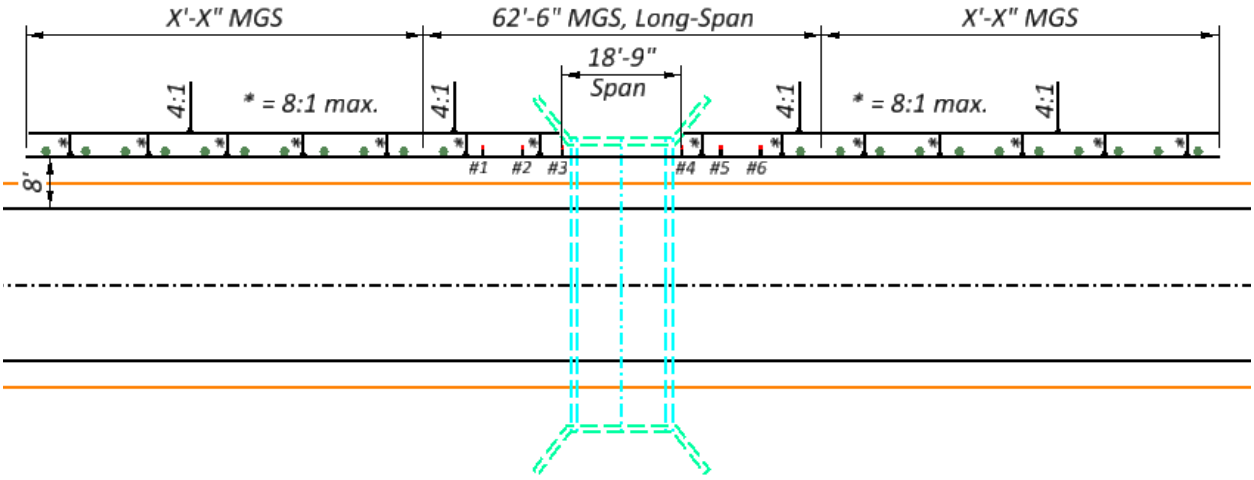
The first step of evaluating the MGS Long-Span is determining the required span length, which can be in 6.25’ increments with a maximum of 25’. Additionally, the adjacent CRT posts (#3 and #4) must maintain an 8” offset to the edge of the box culvert.

SAMPLE CALCULATIONS	
Ex. 602-2	**Length of Need at a Large Culvert**

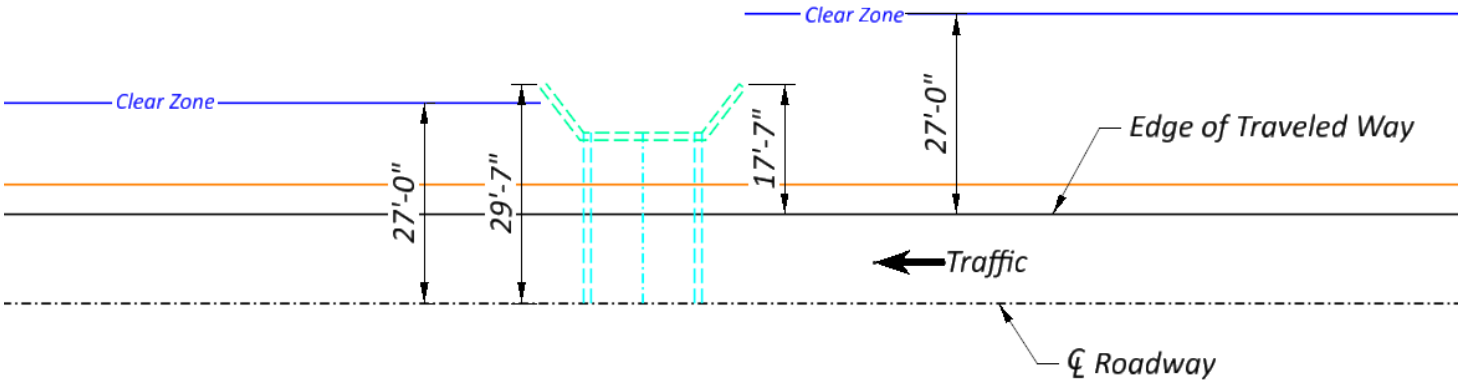
(continued)

14’ span of culvert + 2*(1’ wall thickness) + 2*(8” offset from outer wall) + 2*(3” to center line of CRT post) = 17.83’

An 18’-9” span will be sufficient for this situation.



Step 3 – Check the length of need on both the approach and trailing ends.



The hazard (outer limit of wingwall) on the approaching end is 17.58’ from the edge of traveled way, which is within the limits of the 27’ clear zone, therefore $L_H < L_C$. Refer to **Figure 602-1** (design speed of 60 mph, 1,000-5,000 veh/day) to determine the required runout length of 210’.

(continued)

$$L_H < L_C : X = \frac{L_H + \left({}^{b}/_{a}\right) * L_1 - L_2}{\left({}^{b}/_{a}\right) + {}^{L_H}/_{L_R}}$$

$$X = \frac{17.58 + ({}^{0}/_{0}) * 0 - 8}{({}^{0}/_{0}) + {}^{17.58}/_{210}} = 114.44'$$

The hazard (outer limit of wingwall) on the trailing end is 29.58' from the edge of traveled way (center line of roadway), which is outside of the limits of the 27' clear zone, therefore $L_H > L_C$.

$$L_H > L_C : X = \frac{L_C + ({}^{b}/_{a}) * L_1 - L_2}{({}^{b}/_{a}) + {}^{L_C}/_{L_R}}$$

$$L_2 = 12'(lane) + 8'(offset) = 20'$$

$$X = \frac{27 + ({}^{0}/_{0}) * 0 - 20}{({}^{0}/_{0}) + {}^{27}/_{210}} = 54.44'$$

Step 4 - Next, determine which anchor assembly will be used to terminate the guardrail. It is assumed that a Type E or B anchor assembly may be feasible for this situation, therefore a Type A anchor assembly is not permitted. Since the 75' by 20' recovery area cannot be achieved due to right-of-way constraints, use a Type E end anchor assembly. Per **L&D1 603.3.3**, 34.375' of the Type E can be applied toward the length of need. Additionally, note that per **L&D1 Figure 603-7** 37.5' of standard MGS is required prior to the Type E anchor assembly.

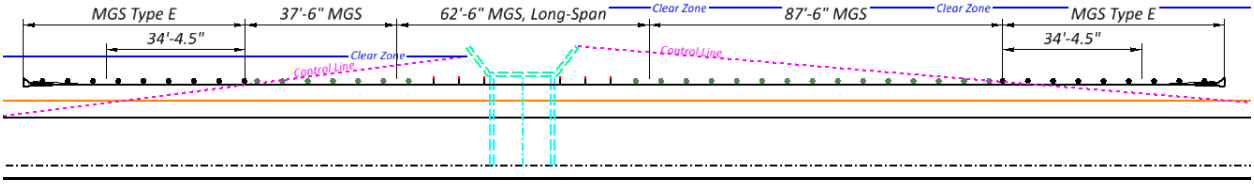
SAMPLE CALCULATIONS	
Ex. 602-2	**Length of Need at a Large Culvert**

(continued)

Re-calculate the length required with the consideration of 34.375’ applying to the length of need when accounting for the Type E:

$$Remaining\ LON\ (approach\ end) = 114.44' - 34.38' = 80.06'$$
$$(round\ up\ to\ 7\ panels) = 87.5'$$

$$Remaining\ LON\ (trailing\ end) = 54.44' - 34.38' = 20.06'$$
$$(round\ up\ to\ 37.5'\ minimum\ per\ \boldsymbol{Figure\ 603-7}) = 37.5'$$

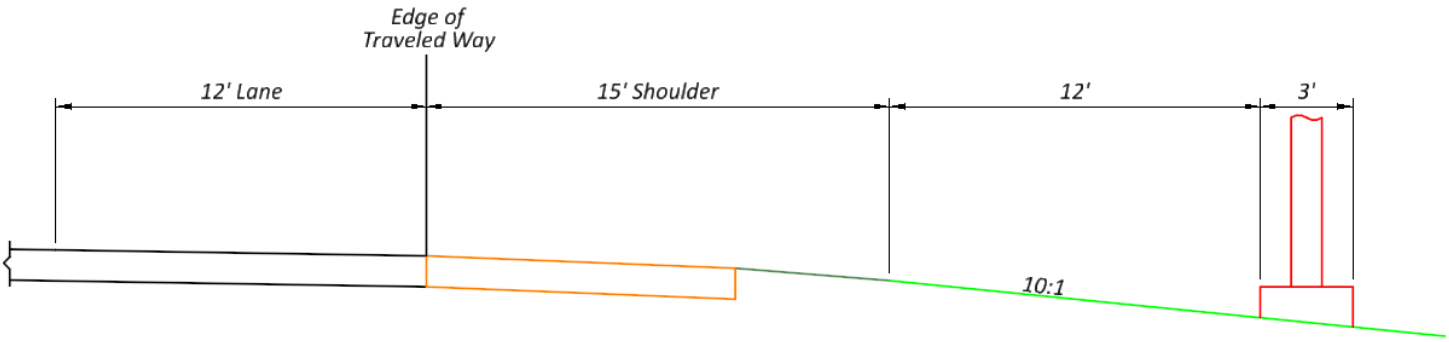


SAMPLE CALCULATIONS

Ex. 602-3

Tangent and Flared Barrier Design For a Divided Highway

Problem 3: Design barrier if needed to shield the 3' diameter footing located on the 4-lane, divided, NHS, urban, interstate reconstruction project shown below. The project has a design speed of 70 mph, a design year traffic volume of 12,000 ADT and a 10:1 foreslope. If barrier is needed, calculate how much should be provided if it is installed a) at the normal (minimum) barrier offset on a tangent, b) at the normal (minimum) barrier offset on a flare, c) as close to the footing as permissible on a tangent and d) as close to the footing as permissible on a flare.



Solution 3: **Step 1** - Determine whether the footing is in the clear zone for adjacent traffic. Refer to **Figure 600-1** (for foreslopes 6:1 or flatter, 70 mph design speed, and ADT > 6,000) to determine that the required clear zone distance is 32 feet measured from the edge of traveled way. However, since this is not a high accident area a maximum clear distance of 30' should be used.

The available clear area for adjacent traffic is 15' + 12' = 27'.

Assuming the footing cannot be relocated outside the clear zone, barrier should be provided.

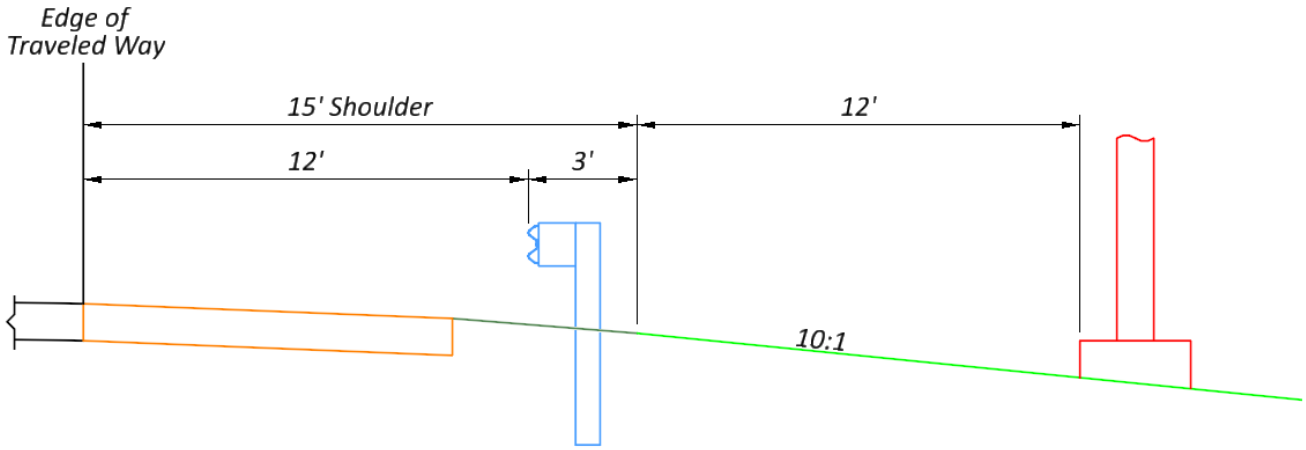
Step 2 - Select the type of barrier to be installed. Using **Figures 301-4** & **301-3**, the normal (minimum) barrier offset for an urban interstate route is 12' from the right edge of traveled way. The available barrier clearance at this location is 3' + 12' = 15'; therefore, use MGS Guardrail, which has a minimum barrier clearance of 5'. (See **Figure 603-2**).

SAMPLE CALCULATIONS

Ex. 602-3

Tangent and Flared Barrier Design For a Divided Highway

(continued)



Step 3 – Calculate the length of need for adjacent traffic. (A calculation for opposing traffic is unnecessary because the concrete median barrier prevents encroachments by opposing vehicles).

From **Figure 602-1**, L_R = 360 ft. (For Design Speed = 70 mph and ADT over 10,000).

a) For tangent guardrail at the normal (minimum) barrier offset, $L_H = L_C$ = 30', L_2 = 12', and b/a = 0.

$$X = \frac{L_H + L_1\frac{b}{a} - L_2}{\frac{b}{a} + \frac{L_H}{L_R}} = \frac{30 + 0 - 12}{0 + \frac{30}{360}} = 216' \rightarrow \text{Use 18 panels}$$

b) For flared guardrail at the normal (minimum) barrier offset, b/a = 1/15. (See **Figure 602-1**). Let L_1 = 12'-6" (one panel length). In this case, this is an arbitrary selection. Site conditions typically control the amount of tangent barrier that should be provided past the warranting feature before a flare is introduced. For instance, where a flared section of MGS Guardrail is attached to a tangent section of MGS Guardrail with Half Post Spacing, it is advisable to extend the tangent MGS Guardrail with Half Post Spacing past the warranting feature such that L_1 is at least equal to 25 feet (two panels) to ensure adequate protection at the edge of the warranting feature.

$$X = \frac{30 + 12.5\left(\frac{1}{15}\right) - 12}{\frac{1}{15} + \frac{30}{360}} = 125.55' \rightarrow \text{Use 11 panels.}$$

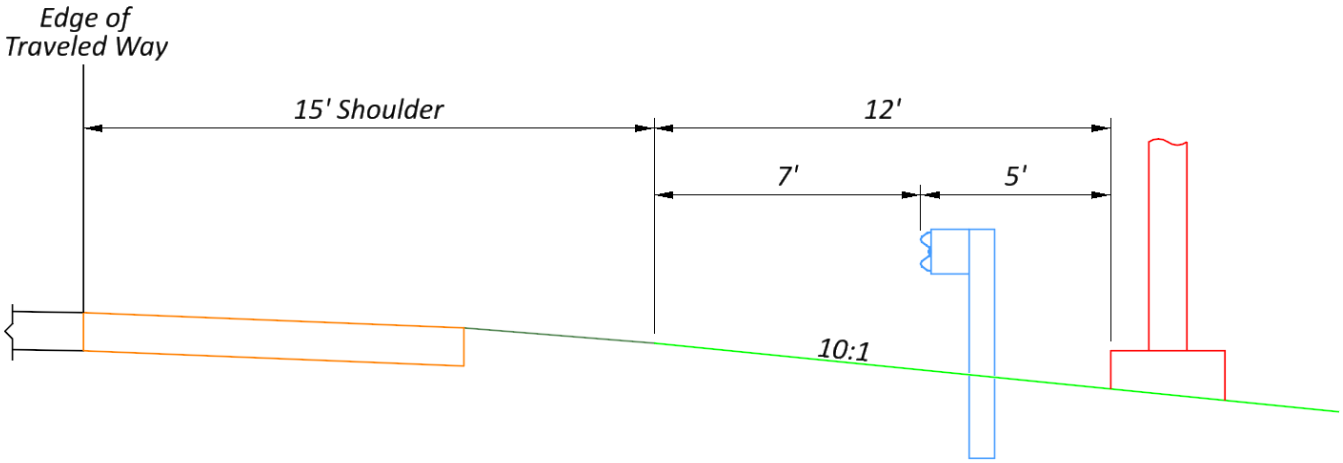
SAMPLE CALCULATIONS	
Ex. 602-3	**Tangent and Flared Barrier Design For a Divided Highway**

(continued)

c) Guardrail can be installed on slope that are 10:1 or flatter. Since MGS Guardrail has a minimum barrier clearance of 5' the guardrail can be placed at this distance in front of the footing.

L_2 = 15' + 12' - 5' = 22'. For tangent guardrail, b/a = 0. L_H is still equal to 30'.

$$X = \frac{30 + 0 - 22}{0 + \frac{30}{360}} = 96' \rightarrow \text{Use 8 panels.}$$



d) For flared guardrail offset at 22':

$$X = \frac{30 + 12.5\left(\frac{1}{15}\right) - 22}{\left(\frac{1}{15}\right) + \frac{30}{360}} = 58.89' \rightarrow \text{Use } 5 \text{ panels.}$$

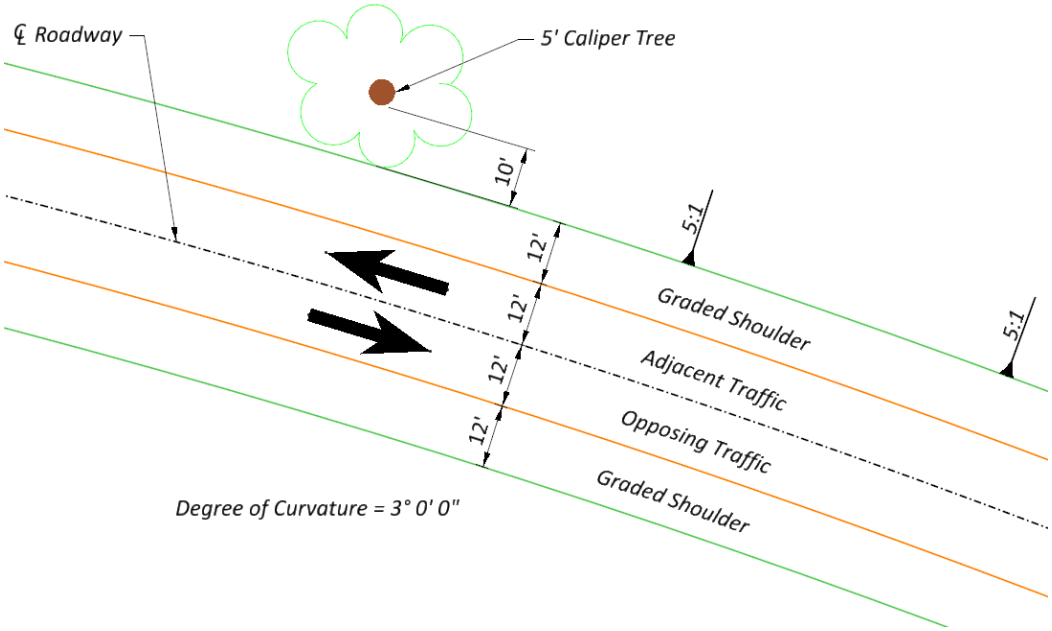
All of these solutions are correct; however, d) is the best solution because it provides the most recovery area with the least amount of barrier.

SAMPLE CALCULATIONS

Ex. 602-4

Barrier on the Outside of a Curve

Problem 4: Calculate the barrier length of need to shield the 200-yr old 5-ft. diameter tree located on the outside of a 3-degree curve as shown below. The HSP project is on a rural arterial and has a design speed of 55 mph, a design year traffic volume of 3,800 ADT, and a 5:1 foreslope. Assume that the HSP project is needed to address run-off-the-road impacts with the tree and assume that the tree cannot be removed.



Solution 4: **Step 1** – Determine whether the tree is in the clear zone for adjacent traffic. From **Figure 600-1** (for foreslopes steeper than 6:1 up to 4:1, 55 mph design speed, and 1,501 ≤ ADT ≤ 6,000) the required clear zone distance is 27 feet measured from the edge of traveled way. Since the tree is on the outside of a 3-degree curve, the clear zone should be widened by using the curve correction factor for 55 mph design speed (1.2) from the chart at the bottom of **Figure 600-1**.

Required Clear Zone = 1.2(27') = 33.4 ft.

Do not reduce this value to 30 ft. since this is a high accident location.

The offset to the face of the tree is 12' + 10' = 22 ft.
This is less than L_C = 33.4 ft.; therefore, install barrier.

SAMPLE CALCULATIONS

Ex. 602-4

Barrier on the Outside of a Curve

(continued)

Step 2 – Select the type of barrier to be installed. Using **Figure 301-3**, the normal (minimum) barrier offset for a rural arterial (Design year ADT greater than 2,000) is 10 feet from the right edge of traveled way. The available barrier clearance at this location is 12 feet; therefore, use MGS Guardrail, which has a minimum barrier clearance of 5 feet (See **Figure 603-2**).

Step 3 – Calculate the length of need for adjacent traffic. The radius for the 3-degree curve is $R_{centerline} = 5729.58/D_C = 5729.58/3.0 = 1909.86'$

The radius at the edge of traveled way is 1909.86' + 12' = 1921.86'.

The lateral offset to the back of the tree is $L_H = 22' + 5' = 27'$.

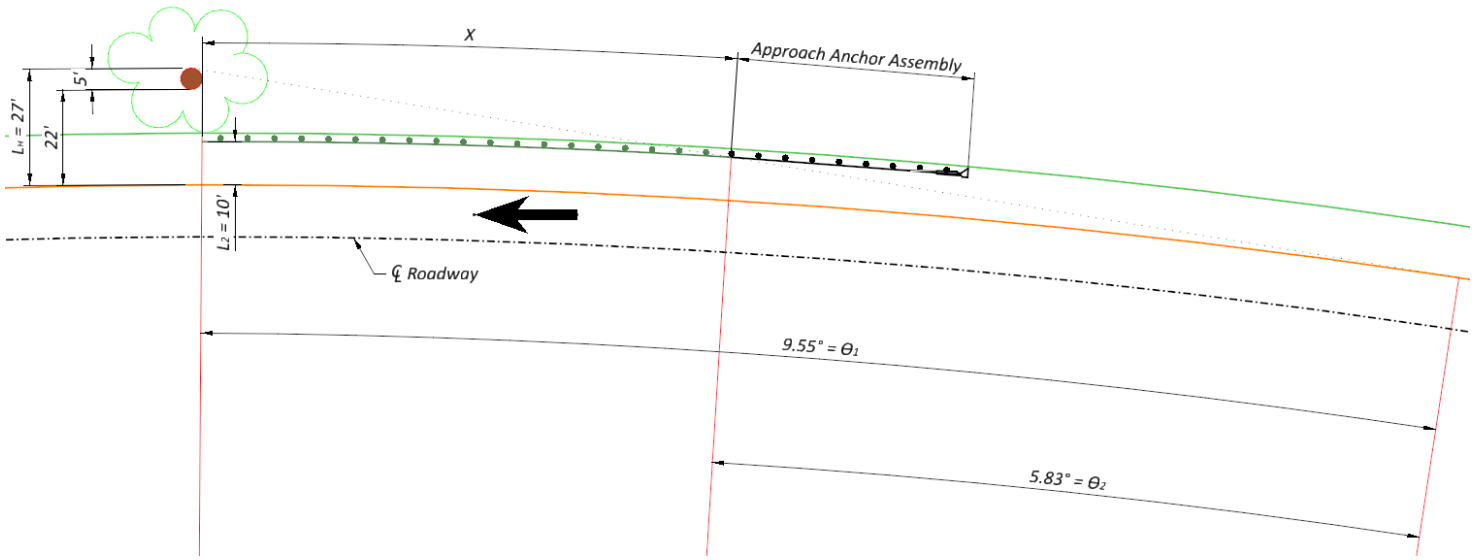
$\theta_1 = \cos^{-1}(R_{adj} / (R_{adj} + L_H)) = \cos^{-1}(1921.86 / (1921.86 + 27)) = 9.5484^0$

$9.5484^0(\pi/180) = 0.1666$ radians

$\theta_2 = \cos^{-1}(R_{adj} / (R_{adj} + L_2)) = \cos^{-1}(1921.86 / (1921.86 + 10)) = 5.8323^0$

$5.8323^0(\pi/180) = 0.1018$ radians

$X = (R_{adj} + L_2)(\theta_1 + \theta_2) = (1921.86 + 10)(0.1666 + 0.1018) = 125.18'$



SAMPLE CALCULATIONS	
Ex. 602-4	**Barrier on the Outside of a Curve**

(continued)

Step 4 – Determine whether the tree is within the clear zone for opposing traffic. The offset to the face of the tree is 12’ + 12’ + 10’ = 34’. Since this is outside the clear zone, guardrail is not needed last the left side of the tree to shield it from opposing traffic. At the trailing end install a Type T Anchor Assembly because it is outside the clear zone for opposing traffic; per **Section 603.3.5,** the end post of the Type T must be located 25’ downstream of the hazard being shielded. Assuming a post will be placed on the far side of the hazard, add 12.5’ to the total (3.125’ from post to splice + 12.5’ + 9.375’ from splice to end post of Type T = 25’)

The total length of guardrail needed is 125.18’ + 5’ (hazard length) + 12.5’ = 142.68’ → Use 12 panels (150’)

On the approach end install a Type E Anchor Assembly due to site grading constraints. Since 34’-4.5” of the Type E can be deducted from the guardrail length of need, decrease the amount of rail specified above at the approach end by this amount. (Use 125’).

Notes – If a point of curvature exists in the vicinity of the runout path, the curve may need to be extended past the PC or OT (into the tangent portion of the roadway) to construct the tangent control line. If this is the case, then the standard runout lengths for tangent roadways should be used to calculate length of need.

700 - Multimodal Considerations

701 - Railroads

701.1 - Background

Ohio is interlaced with a network of railroad systems controlled by a multiplicity of local and state laws and regulations. The complexity of railroad operations and regulations requires that special consideration be given to the location of highways with respect to railroad track, whether it be the intersection of a highway with a railroad, or the location of a highway adjacent to a railroad facility.

701.2 - Crossing At-Grade

701.2.1 - General

Highways that cross railroad tracks on a common grade should be located to provide for a minimum of interference to highway traffic and the least amount of adjustment of railroad facilities.

Crossings at-grade will not be permitted on freeways. The creation of new grade crossings where none now exist should be avoided and will require railroad and Court of Common Pleas approval. (Sec. 957.29 et. seq. ORC).

701.2.2 - Railroad Parallel to Highway

When locating a highway parallel to a railroad track, consideration shall be given to the need for space adjacent to railroad tracks for future industrial development. It is desirable to locate the highway a sufficient distance from the railroad to permit rail service to industrial areas without crossing the highway.

Sufficient distance from a railroad to a parallel highway should be provided along crossroads on which traffic must stop before entering the highway, to permit vehicles to stop clear of the railroad track.

701.3 - Lateral Clearances

The standard gage of railroad tracks is 4 feet 8 ½ inches. Where two or more tracks are parallel, the normal centerline spacing is 14 feet.

701.3.1 - New Construction

Although minimum lateral clearances vary with railroad ownership, clearance from the centerline of the outside track should normally be at least 18 feet. An additional 8 feet of lateral clearance should be provided when a railroad off-track equipment road is located parallel to the tracks.

701.3.2 - Reconstruction

The above clearances should be provided when replacing an existing structure when such additional work can be accomplished at a reasonable cost. A horizontal clearance less than the existing clearance will not be permitted.

701.4 - Vertical Clearance

701.4.1 - New Construction

A minimum of 23 feet between the top of rail and the bottom of an overpassing structure should be provided. This vertical clearance should extend 6 feet on each side of the centerline of the outside tracks. Actual clearance requirements will be determined after the location plan has been submitted.

701.4.2 - Reconstruction

Every attempt should be made to increase the minimum vertical clearance to 23 feet when such additional work can be accomplished at a reasonable cost. A vertical clearance less than the existing clearance will not be permitted.

701.4.3 - Construction Clearances

Construction clearances should also be considered in the design stages since they could be a factor in the location of certain items such as catch basins, headwalls, etc. A minimum of 9 feet of lateral clearance should be maintained at all times from the centerline of the track during construction unless this is not possible because of existing conditions.

702 - Shared Use Paths

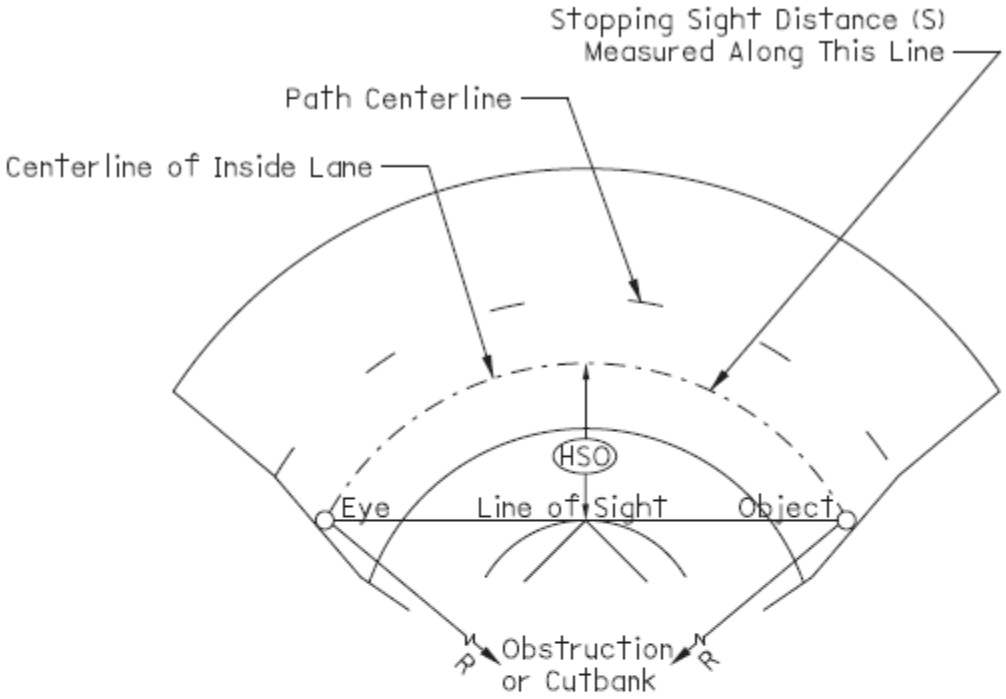
See Multimodal Design Guide Chapter 5 for Shared Use Paths information.

MINIMUM LENGTH OF CREST VERTICAL CURVE BASED ON STOPPING SIGHT DISTANCE	701-3
	REFERENCE SECTION 309.2.7

A	S = Stopping Sight Distance (ft)														
(%)	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300
2												30	70	110	150
3								20	60	100	140	180	220	260	300
4						15	55	95	135	175	215	256	300	348	400
5					20	60	100	140	180	222	269	320	376	436	500
6				10	50	90	130	170	210	267	323	384	451	523	600
7				31	71	111	151	191	231	311	376	448	526	610	700
8			8	48	88	128	168	208	248	356	430	512	601	697	800
9			20	60	100	140	180	220	260	400	484	576	676	784	900
10			30	70	110	150	190	230	270	444	538	640	751	871	1000
11			38	78	118	158	198	238	278	489	592	704	826	958	1100
12		5	45	85	125	165	205	245	533	645	768	768	901	1045	1200
13		11	51	91	131	171	211	251	291	578	699	832	976	1132	1300
14		16	56	96	136	176	216	256	296	622	753	896	1052	1220	1400
15		20	60	100	140	180	220	260	300	667	807	960	1127	1307	1500
16		24	64	104	144	184	224	264	304	711	860	1024	1202	1394	1600
17		27	67	107	147	187	227	267	307	756	914	1088	1277	1481	1700
18		30	70	110	150	190	230	270	310	800	968	1152	1352	1568	1800
19		33	73	113	153	193	233	273	313	844	1022	1216	1427	1655	1900
20		35	75	115	155	195	235	275	315	889	1076	1280	1502	1742	2000
21		37	77	117	157	197	237	277	317	933	1129	1344	1577	1829	2100
22		39	79	119	159	199	239	279	319	978	1183	1408	1652	1916	2200
23		41	81	121	161	201	241	281	321	1022	1237	1472	1728	2004	2300
24	3	43	83	123	163	203	243	283	323	1067	1291	1536	1803	2091	2400
25	4	44	84	124	164	204	244	284	324	1111	1344	1600	1878	2178	2500

Shaded Area Represents S>L
Minimum Length of Vertical Curve = 3'

DIAGRAM ILLUSTRATING COMPONENTS FOR DETERMINING HORIZONTAL SIGHT DISTANCE	701-4
	REFERENCE SECTION 309.2.7



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

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

Where:
- S = Stopping Sight Distance (ft)
- R = Radius of Centerline of Lane (ft)
- HSO = Horizontal Sightline Offset, Distance from Centerline of Lane to Obstruction (ft)

Note:
- Angle is Expressed in Degrees
- Line of Sight is 2.3′ above Centerline of Inside Lane at Point of Obstruction

800 - Access, Right-of-Way Use & Driveways

801 - Access Control

801.1 - Access Control Directives

Access policies for highway right-of-way are as set forth in the following directives:

The State Highway Access Management Manual establishes procedures for processing permit applications, defines permissible uses of right of way for various highway classifications and establishes procedures and standards for access provisions adjacent to major commercial and industrial developments.

It is intended that **Section 800** of this manual supplement the State Highway Access Management Manual with respect to access policies and R/W use permits as well as provide the designer with the criteria necessary to design most types of drives.

801.2 - Access Control Policies

The policy of permitting access on highways is summarized below:

801.2.1 - Interstate Limited Access

Direct access to an Interstate Highway will not be permitted except as outlined in **Sections 801.2.6 and 801.2.7**. All crossroads and railroad grades shall be separated.

801.2.2 - Limited Access

If a highway is now, or is designated to be an ultimate fully limited access freeway and access rights have been acquired:

1. If the highway has no existing private access points, direct private access to such highway will not be permitted.
2. If the highway has existing private access points and the ultimate freeway design has been determined, temporary access improvements may be permitted. However, at the time the improvement is permitted, the method for deleting the temporary access

points must be determined and necessary agreements made with the property owner to facilitate their deletion in the future.

3. If the highway has existing private access points and the ultimate freeway design has not been established, modifications of existing access will not be permitted until the ultimate freeway design has been determined.

4. Provision generally shall be made for future separation of crossroads and railroad grades by purchase of right-of-way as a part of the initial project.

801.2.3 - Controlled Access Highways

Modifications of existing points of access or changes from one location to another within the limits of the applicant's property may be permitted, if such modification or change would be beneficial to both the highway operation and property development. However, new additional points of access will not be permitted. Crossroads and railroads need not be separated unless very high volumes dictate its consideration.

801.2.4 - Non-Limited Access Highways

Access to a non-limited access highway is permissible in accordance with the State Highway Access Management Manual. However, such access is subject to the conditions prescribed by the Director of Transportation under authority granted by Section 5515.01 of the Ohio Revised Code.

801.2.5 - Interchange Controls

No access shall normally be allowed on intersecting highways adjacent to highway interchanges for a minimum of 600 feet at diamond-type interchanges and 1,000 feet at other types of interchanges. This distance applies to each direction along the intersecting highway, measured from the outer-most ramp terminal intersections with the highway. See Figures 801-1 and 801-2 for additional details.

801.2.6 - Locked-Gate Access to Freeways and other Limited Access Highways

Locked-gate access to freeways and other limited access highways is considered an access point and requires documentation of the proposal for approval. Locked-gate access to interstates for purposes other than roadside maintenance requires submission to and approval by FHWA. The Office of Roadway Engineering will evaluate submissions for

freeways and other limited access highways, and will coordinate submissions with FHWA for interstates.

The typical purpose for locked gate access is for emergency access or roadside maintenance from areas outside of the highway right-of-way. Since the gate is intended for a few select users, they should be inconspicuous to the general travelling public with limited improvements. Key consideration in the location and design of locked-gate access are sight distance where vehicles will be entering the freeway and acceleration of the entering vehicles. The proposal document should clearly describe to whom the access is granted, how the access will be secured, and maintenance responsibilities. Locked-gate access for purposes other than roadside maintenance must be sponsored by a public agency.
Locked-gate access to interstate highways for the purpose of roadside maintenance do not require FHWA submission and approval.

801.2.7 - Temporary Construction Access to Limited Access Facilities

Temporary access to the construction site by way of an L/A break must conform to CMS 107.10. The approving authority depends on whether the access is located on the Interstate System and if the access allows construction vehicles access to the travel lanes. Approvals for all temporary construction access through limited access right-of-way will expire at the conclusion of the project construction and the right-of-way must be fully restored, including replacement of all fencing, as applicable.

801.2.7.1 - Temporary Construction Access on the Interstate System

Temporary access to the construction site on the interstate system by way of an L/A break that does not provide access for construction vehicles to the travel lanes must be reviewed and accepted by the District Construction Engineer, District Real Estate Administrator, and District Environmental Coordinator.

Temporary access to the construction site on the interstate system by way of an L/A break that provides access for construction vehicles to the travel lanes must be reviewed and accepted by the District Construction Engineer, District Real Estate Administrator, and District Environmental Coordinator prior to submission to the Office of Roadway Engineering. The Office of Roadway Engineering will review and offer acceptance of the proposed temporary access to and/or from the travel lanes. Upon acceptance by The

Office of Roadway Engineering, the District Real Estate Administrator will coordinate with the FHWA Ohio Division for final approval.

801.2.7.2 - Temporary Construction Access on non-Interstate Limited Access Facilities

Temporary access to the construction site on non-Interstate Limited Access Facilities by way of an L/A break that does not provide access for construction vehicles to the travel lanes must be reviewed and approved by the District Construction Engineer, District Real Estate Administrator, and District Environmental Coordinator.

Temporary access to the construction site on non-Interstate Limited Access Facilities by way of an L/A break that provides access for construction vehicles to the travel lanes must be reviewed and accepted by the District Construction Engineer, District Real Estate Administrator, and District Environmental Coordinator prior to submission to the Office of Roadway Engineering. The Office of Roadway Engineering will review and approve the proposed temporary access to and/or from the travel lanes.

802 - Highway Use Permits

802.1 - General R/W Use Criteria

802.1.1 - Approvals and Agreements

Permission to use highway R/W is required for fencing, storm sewers, sanitary sewers, public utilities, points of access, or other similar types of work. ODOT does not allow non-ODOT agencies to use ODOT right of way for the purpose of locating stormwater Best Management Practices (BMPs). When a request is made to alter, modify or otherwise use highway R/W, Federal and/or State approvals must be obtained and the necessary agreements or permits between the State and applicant must be completed before any work can be initiated.

802.1.2 - Authority

Permits for the use or occupancy of State Highway right-of-way may be granted, upon formal application, by the Director of Transportation. Such permits, when granted, shall be subject to the policies and regulations set forth herein under authority granted by **Section 5515.01 of the Revised Code of Ohio**.

802.1.3 - Application Procedures

The procedure for applying for permits is included in the State Highway Access Management Manual.

802.1.4 - Right-of-Way Use Prohibitions

No parking, servicing of vehicles, erection of lights, signs or other advertising devices will be permitted on highway right-of- way. Similarly, no device or structure will be permitted to overhang highway right- of-way. Provisions should be made in the design of driveways or approaches on rural highways so that a vehicle will not be required to back onto the right-of-way or highway pavement to gain access to the highway.

802.1.5 - Future Highway Improvement Controls

When granting permits, consideration should be given to the extent of future highway improvements. The location and design of driveways or public road approaches should then be governed by the general access criteria (**Section 802.2**) of the future highway facility.

802.1.6 - Drainage Considerations

When any owner or developer of land adjacent to highway R/W proposes to route site drainage into the highway drainage system, see the Location and Design Manual, Volume 2, Section 1001.3 for guidance.

802.2 - General Access Criteria

802.2.1 - Highway Access Considerations

The basic considerations that govern the location and design of highway access shall be to facilitate:

1. The safe and expeditious movement of vehicles on the street or highway.
2. The provision of the best service possible to the private or public facility being served by the drive access.
3. The safe movement of pedestrian traffic.

802.2.2 - Median Openings

Median openings are normally not permitted on divided highways. Exceptions may be for public roads or streets or traffic generators such as large shopping centers or industrial plants, if satisfactorily justified and in the public interest.

If a median opening exists prior to the construction of a drive, the opening may be further modified, including relocation, to accommodate the turning movements of the expected traffic. The design modifications shall, however, be consistent with the overall design of the highway.

802.2.3 - Added Highway Lanes

The construction of an additional lane adjacent to the existing highway lanes to serve as right or left turn lanes may be permitted if benefit to the operation of the through highway will result. The design of any added lane must be consistent with the overall design of the highway and **Section 401.6**.

802.2.4 - Number of Drives Permitted and Their Location

Refer to Section 4.0 of the State Highway Access Management Manual for the acceptable access locations and the number permitted.

802.2.5 - Joint Drives

A jointly owned drive may be permitted upon joint application by both property owners.

802.2.6 - Location of Drive in Relation to Side Property Line

Figure 802-1 shows the controls for locating drives in relation to side property lines.

1. Controls

    A. 90º Control Line - a line at right angles to the centerline of the highway which extends through the intersection of the side property line with the highway right-of-way line.

    B. 4-foot Control - maximum width of driveway approach flare as measured along the 90º control line from the highway edge of traveled way.

2. Curbed Highways - the approach radius may begin at the intersection of the 90º control line with the highway edge of traveled way but may not cross the 90º control.

3. Uncurbed Highways - the approach radius, but not the approach edge extension, may cross the 90º control line within the limits of the 4-foot control.

A permit may be issued for the construction of a driveway which encroaches on the abutting property frontage in excess of the controls set forth above only when written permission from the affected property owner is presented and made a part of the State's record of the permit, and only when such encroachment does not interfere with an existing driveway. It shall be the responsibility of the permit applicant to make all necessary arrangements and agreements with the affected property owners when the relocation of existing driveways is necessary. The expense involved shall be borne by the applicant.

802.2.7 - Location of Drive in Relation to an Intersection

For acceptable locations of driveways near intersections, see Section 4.0 of the State Highway Access Management Manual.

802.2.8 - Drive Sight Distance

Wherever possible, drives should be located in accordance with the intersection sight distance criteria in Section 201.3.

802.2.9 - Drives with Restricted Movements

In some situations, it is desirable to control or prohibit certain movements through the use of median islands or channelizing islands. Median islands divide the ingress and egress movements and are used to prevent cross movements of internal traffic (See **Section 304.3.2, Section 401.7.3 and Section 803.6**). Channelizing islands are used to control and direct turning movements on a driveway approach (See **Section 401.7.2**).

803 - Drive Geometric Design

803.1 - Mailbox Facilities

803.1.1 - Mailbox Supports

Mailbox installations located within the clear zone shall be installed as shown in **SCD RD-4.1** using "breakaway" type supports. Satisfactory supports are as follows:

1. 4-inch by 4-inch square or 4-inch diameter round timber.
2. 1 1/2-inch to 2-inch diameter steel pipe.
3. Any post meeting MASH 2016 TL-3 criteria.

No more than two mailboxes shall be placed on each post. Where guardrail exists, mailboxes and their supports should be located behind the guardrail.

803.1.2 - Mailbox Turnouts

Where the existing or proposed highway shoulder paving is less than 6 feet wide, mailbox turnouts should be provided as shown in **SCD RD-4.1**. Mailbox turnouts should be constructed of the same material used in the drive approach and combined with the drive approach where possible.

803.2 - Rural Residential and Field Drives

Rural residential drives and field drives should normally conform to the Type 1 design shown in **SCD RD-4.1**.

803.2.1 - Drive Intersection Angle

New drives should intersect the highway at an angle between 70º and 90º. However, in some cases, it may be necessary to retain existing drive angles that vary from these desirable angles.

803.2.2 - Drive Widths

If the project involves existing drives, the existing width is normally retained unless it is less than 12 feet. In which case, it should be widened to provide a 12 foot throat width. In the case of new drives, the width should normally be 12 feet. If the new driveway is a combined drive between two properties, the width should normally not exceed 24 feet. Also, a wider field drive may be used if it will keep the farm equipment operator from encroaching on the opposing traffic lane when entering or exiting the highway.

803.2.3 - Drive Radii

The radii of the Type 1 driveway should normally be 25 feet. The radii may be increased on field drives if it is deemed that the larger values will improve driveway operation and reduce the hazard to the motorists and farm equipment operator.

803.2.4 - Curbed Drives

Driveways abutting uncurbed highways may be curbed. However, the curb must have a minimum offset from the mainline edge of traveled way of 8 feet or the treated shoulder width, whichever is greater, to avoid curb obstruction for vehicles, snowplows, etc., using the shoulder and be transitioned in height per Section 305.4.1.

803.3 - Urban Residential Drives

Figures 803-2 and 803-3 show design details for driveways adjacent to curb and sidewalk. Other designs may be used if they are approved for use by the local governmental agencies responsible for maintenance of the project. Residential drives on curbed streets should use a dropped curb as shown in Section B-B on Figure 803-2.

803.4 - Service Station Drives

Section Deleted

803.5 - Commercial Drives

The access requirements of most commercial developments can be served by driveways having standard design characteristics. The exceptions are driveways having high traffic volumes, those being used by large vehicles, or those serving businesses which have traffic patterns unique to the business being conducted.

803.5.1 - Standard Commercial Drives

1. Radii - should be based upon the design vehicle template
2. Width - 35 foot maximum
3. A dropped curb should be used on curbed streets as shown in Section B-B on Figure 803-2.

803.5.2 - Exceptions to Standard Commercial Drives

Where access requirements are such that a non-standard driveway is necessary, the design may approximate the design of signalized commercial or industrial driveways as discussed in **Section 803.6** or public road intersections, **Section 401**.

Specially designed radii and a width greater than 35 feet may be permitted, as necessary, to accommodate the type vehicle using the driveway. (Example: A truck stop may require two one-way driveways or a single drive with width greater than 35 feet and radii as great as 75 feet to facilitate turning movements).

803.6 - Signalized Commercial or Industrial Drives

This section is intended as a guide for the design of driveways to high volume traffic generators such as shopping centers, industrial plants, industrial parks, and other types of developments having similar traffic characteristics. Many of the design features discussed in **Section 401**, Intersections At-Grade, will be applicable. Geometric considerations are listed below:

1. Driveways should intersect the highway at an angle between 70ºand 90º.
2. Each driveway traffic lane should have a minimum width of 10 feet, with 12 feet preferred.
3. Major driveways in shopping centers should be constructed to prevent cross movement of internal traffic within 100 feet of the entrance approach. This may be accomplished by use of a raised divider, 6 inches high, 6 feet wide (min.) and 100 feet long, and/or by use of curbing, sidewalk or other barrier along the drive edges for a length of 100 feet (See Figure 803-9).
4. Driveways designed for traffic signal operation should have curbed radii and should provide a minimum of two lanes for vehicles entering the highway.

804 - Drive Profile Design

804.1 - Drive Profiles (Uncurbed Roadways)

Drive profiles on uncurbed roadways shall slope down and away from the edge of traveled way at the same slope as the graded shoulder. Any vertical curve should be developed

outside the normal graded shoulder width. Vertical curve lengths should be 10 feet to 20 feet, depending on the grade differential. Under normal circumstances, rural drive grades should not exceed 10 percent with 8 percent considered to be the preferred maximum.

804.2 - Drive Profiles (with Curb and Sidewalk)

The design vehicle used to develop the profile criteria of this section is shown on Figure 803-2. The profile criteria shown provides clearance for this vehicle when its springs are completely compressed. If conditions of a particular driveway do not meet the cross-section criteria listed below, a template of the design vehicle can be used to design the driveway profile.

The ramp grade from the gutter to the edge (the ramp cross-slope rate from the gutter to) of the sidewalk is 4-8%. Figure 803-2 shows this condition.

If the cross-section design does not meet the above conditions (has sharper grade breaks), the profile should be designed using a template of the design vehicle.

For tree lawns less than 6 feet wide, Figure 803-3 shows the profile treatment. Clearance for the design vehicle is achieved by depressing the sidewalk 1 inch at the driveway. The sidewalk cross-slope of 1/4 inch per foot is retained. The design may be used directly with curbed highways having cross-section criteria as listed above and the profile conditions of Figure 803-2. For other cross-sections, a template of the design vehicle may be used to design the profile.

Figure 803-3 shows an isometric view and profile for a driveway where only a 3-foot tree lawn is available. This design is shown, not because it is desirable, but because right-of-way width and property development may require this type of design. Whenever feasible, the tree lawn should be 8 feet or wider, as discussed in the Multimodal Design Guide.

Where the total width of tree lawn and sidewalk is less than 7 feet, the minimum 3-foot apron designs are inappropriate, and cannot be used, as they extend curb or sharp flares into the sidewalk area. For this condition, the sidewalk and curb are transitioned to meet the drive profile as shown on the lower portion of Figure 803-3. The profile of the drive meets the 1 inch depressed grade of the sidewalk as shown in the drive profile of Figure 803-3.

The tree lawn and walk design shown in Figures 803-2 and803-3 will keep storm water, flowing at the curb design height or less, from flowing over the sidewalk. If it is necessary to lower the curb and sidewalk more than 1 inch, the drainage condition should be checked thoroughly.

804.3 - Commercial Drive Profiles (Curbed Roadways)

Commercial drive profiles usually use a dropped curb across the approach. However, some commercial drives serving large traffic generators may be designed as at-grade intersections, without dropped curbs, because of their high traffic volumes.

Shown on Figure 804-1 are the grade controls for commercial driveways. The grade should be as flat as possible and still meet drainage requirements. The 20-foot length between grade breaks is appropriate for the low clearance and the long axle spacing of the lowboy commercial design vehicle. Tree lawn profile design should be in accordance with Figures 803-2 and803-3. The grade break at the face of the curb is critical for some commercial vehicles and the cross-section requirements for drives on curbed streets should be used.

805 - Drive Pavement Design

805.1 - Field Drives

Field driveways should be paved with 6 inches of 411 or 304 aggregate. They shall be paved from the edge of traveled way or treated shoulders, to a point where the grade of the new driveway intersects the grade of the existing driveway, or on relocated driveways to where the grade of the new driveway intersects the existing ground.

805.2 - Residential Drives

Residential driveways shall be paved from the edge of new pavement to the point where the grade of the new driveway intersects the grade of the existing driveway, or on relocated driveways to the point where the geometric limits of the new driveway meet the existing driveway.

Residence driveways having an existing hard surface or an existing aggregate surface shall be replaced with a pavement of a similar type, insofar as practicable, using one of the following designs for the portion beyond the flared apron:

Design #1:

- 6" Item 452 - Non-Reinforced Concrete Pavement

Design #2:

- 2" Item 441 - AC Surface Course, Type 1, 449, (Driveways)
- 6" Item 304 - Aggregate Base (or 411 Stabilized Crushed Aggregate)

Design #3:

- 1.25" Item 441 - AC Surface Course, Type 1, 449, (Driveways)
- Item 407 - Tack Coat (see CMS 407.06 for application rate)
- 3.5" Item 301 - Asphalt Concrete Base, PG64-22, (449)

Design #4:

- 8" Item 304 - Aggregate Base (or 411 Stabilized Crushed Aggregate)

Note: Item 441 Asphalt Concrete may be changed to match the asphalt concrete material specified on the adjacent pavement.

In uncurbed areas, the apron pavement design depends on the treated shoulder material as follows:

1. The flared portion of residence driveways adjacent to paved shoulders shall be constructed of the same material and composition as used in the treated shoulder paving.
2. The flared portion of residence driveways adjacent to surface treated aggregate shoulders shall be constructed of the same material as used in the treated shoulder, except it shall be surfaced with 2 inches of 441 Asphalt Concrete, Type 1, 449, (Driveways).
3. The flared portion of residence driveways on projects for which earth shoulders are specified shall be paved with either 6 inches 452 Non-Reinforced Concrete

Pavement, or with 2 inches of 441 Asphalt Concrete, Type 1, 449, (Driveways), on 6 inches of 411 or 304 aggregate.

805.3 - Commercial Drives

Commercial driveways shall be paved from the edge of the new pavement to the point where the grade of the new driveway intersects the grade of the existing driveway, or on relocated driveways to the point where the geometric limits of the new driveway meet the existing driveway.

Commercial driveways having an existing hard surface or aggregate surface shall be replaced with a pavement of a similar type insofar as practical, using one of the following designs for the portion beyond the return or apron:

Additional thicknesses may be provided for the above courses where unusual weights or types of vehicles are expected to use the commercial driveway.

Commercial driveway aprons shall be constructed as previously outlined for residential driveway aprons, except that additional thicknesses should be provided to meet nominal pavement design for commercial driveways.

Design #1:

- 8" Item 452 - Non-Reinforced Concrete Pavement

Design #2:

- 1.25" Item 441 - AC Surface Course, Type 1, 449, (Driveways)
- Item 407 - Tack Coat (see CMS 407.06 for application rate)
- 1.75" Item 441 - AC Intermediate Course, Type 2, 449, (Driveways)
- 8" Item 304 - Aggregate Base (or 411 Stabilized Crushed Aggregate)

Design #3:

- 1.25" Item 441 - AC Surface Course, Type 1, 449, (Driveways)

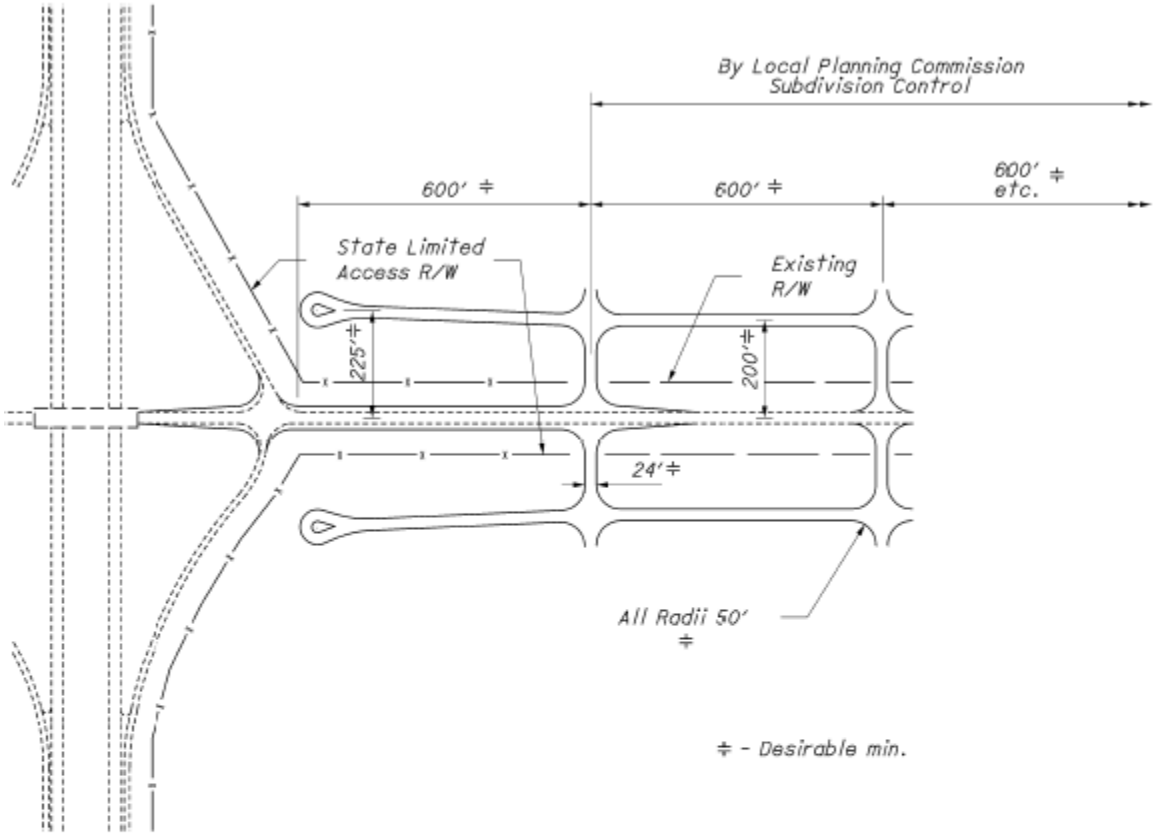
- Item 407 - Tack Coat (see CMS 407.06 for application rate)
- 5" Item 301 - Asphalt Concrete Base, PG64-22, (449)

Note: Item 441 Asphalt Concrete may be changed to match the asphalt concrete material specified on the adjacent pavement.

805.4 - Pavement Treatment of Undisturbed Drives

The preceding treatment of driveways does not apply to resurfacing or widening and resurfacing projects when the existing driveway is not disturbed beyond the edge of proposed pavement. Item 411 or 304 aggregate shall be used to adjust aggregate driveways to meet the new pavement surface for widening and/or resurfacing projects. Asphalt concrete shall be used for adjusting asphalt or concrete driveways to meet the new pavement surface, which adjustment shall be accomplished within a reasonable distance from the edge of the pavement. As a general rule, this can be done within the limits of the roadway shoulders.

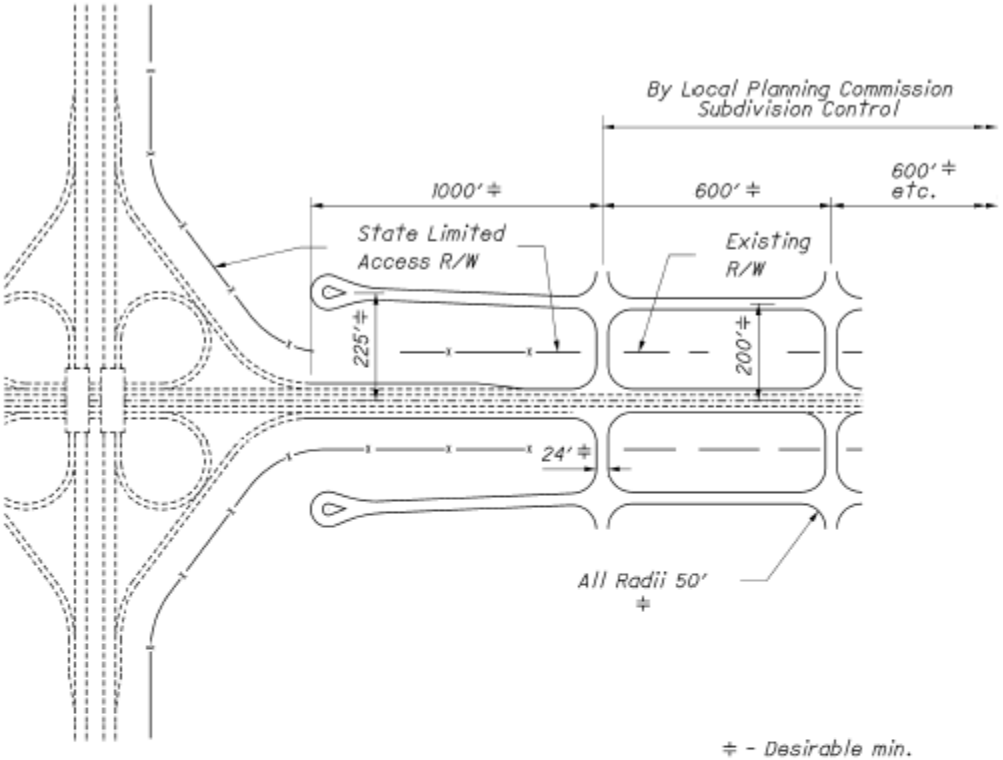
GUIDELINES FOR LIMITATION OF ACCESS AT DIAMOND TYPE INTERCHANGES	801-1
	REFERENCE SECTION 801.2.5



RURAL INTERCHANGES

The control of developments, adjacent to diamond type interchanges on limited access highways can be effectively controlled by county, regional, or city planning commissions, through subdivison controls and building developments, and in addition by local zoning commissions as to zoning regulations. County commissioners or township trustees may exercise similar controls in the absence of planning and zoning commissions.

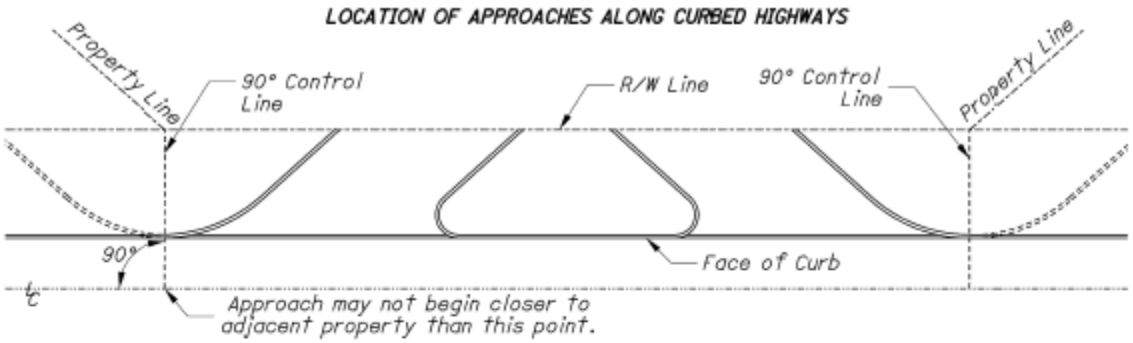
GUIDELINES FOR LIMITATION OF ACCESS AT CLOVERLEAF-TYPE INTERCHANGES	801-2
	REFERENCE SECTION 801.2.5

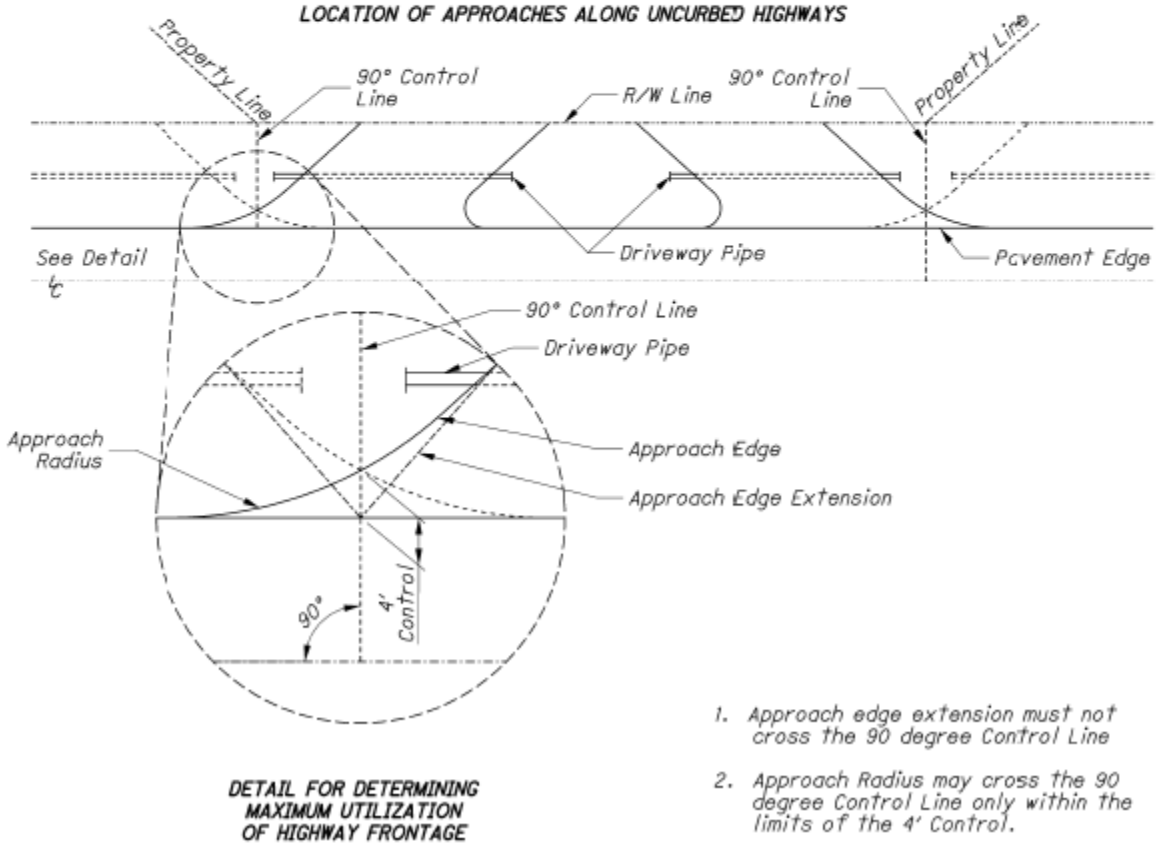


RURAL INTERCHANGES

The control of developments, adjacent to cloverleaf type interchanges on limited access highways can be effectively controlled by county, regional, or city planning commissions, through subdivison controls and building developments, and in addition by local zoning commissions as to zoning regulations. County commissioners or township trustees may exercise similar controls in the absence of planning and zoning commissions.

LOCATION OF DRIVES IN RELATION TO PROPERTY LINES	802-1
	REFERENCE SECTION 801.2.6





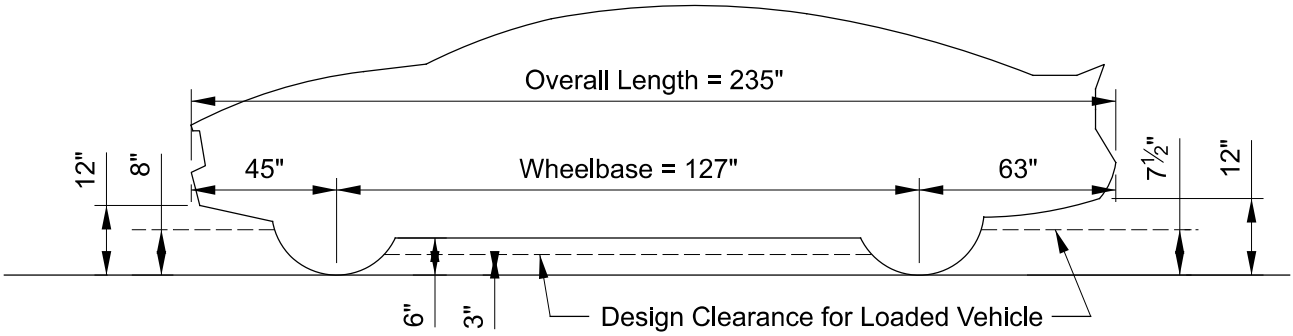
DETAIL FOR DETERMINING MAXIMUM UTILIZATION OF HIGHWAY FRONTAGE

1. Approach edge extension must not cross the 90 degree Control Line
2. Approach Radius may cross the 90 degree Control Line only within the limits of the 4' Control.

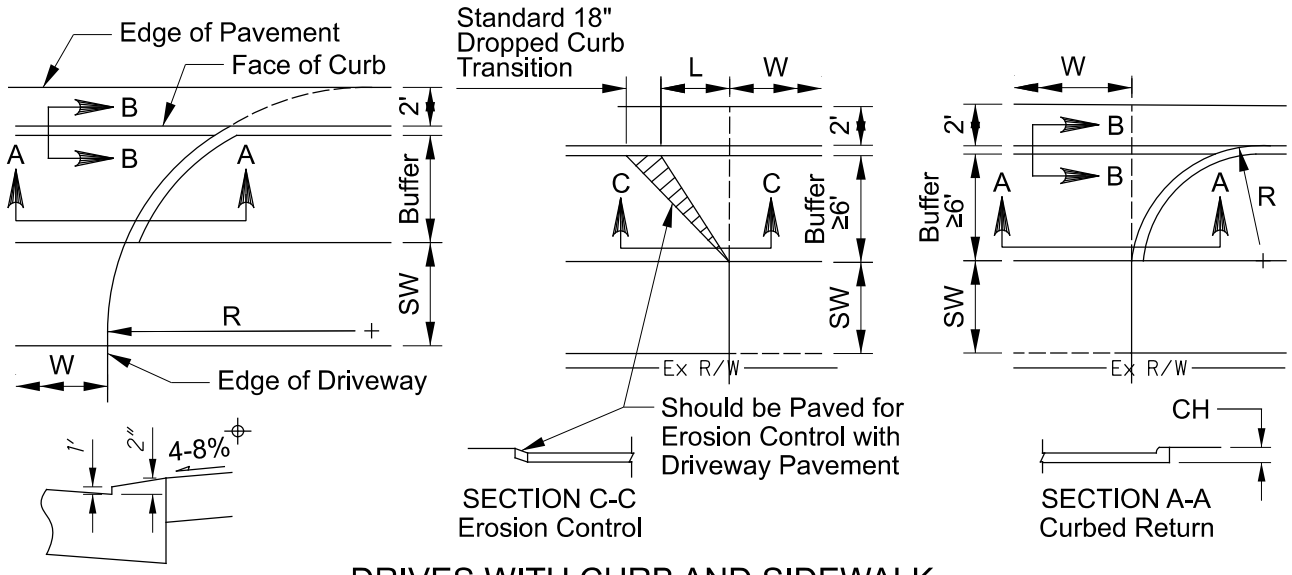
DRIVE (WITH CURB AND SIDEWALK) DETAILS

803-2

REFERENCE SECTION
803.3 & 804.2



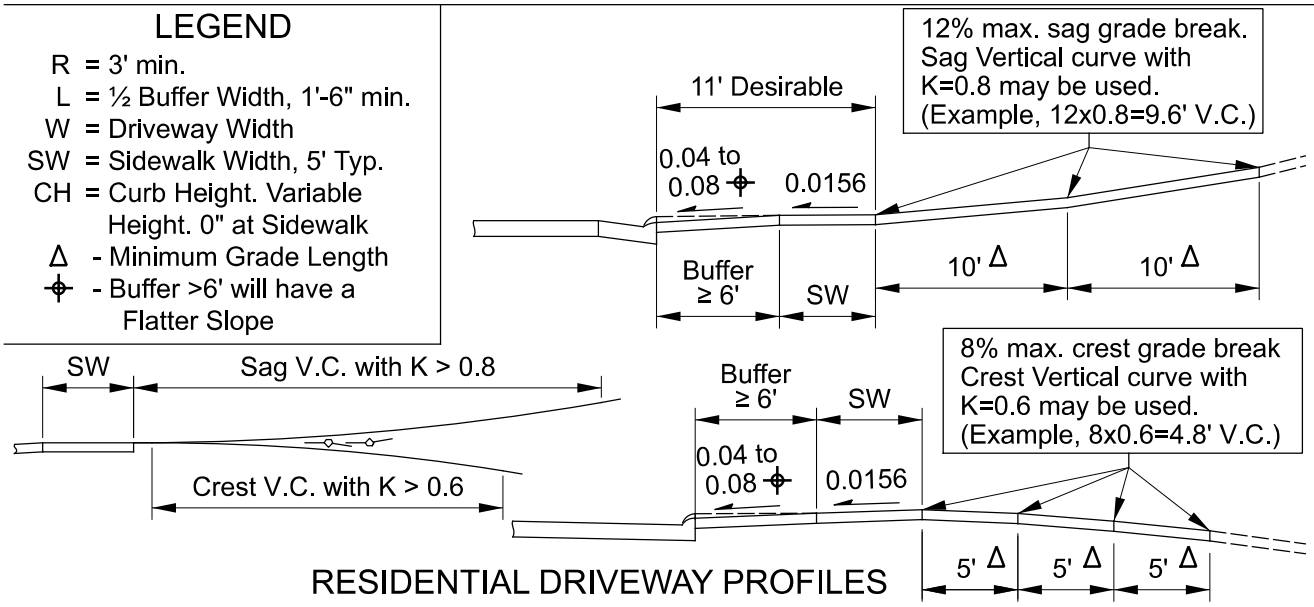
DESIGN VEHICLE



DRIVES WITH CURB AND SIDEWALK
(Plan View of Three Apron Designs)

LEGEND

R = 3' min.
L = ½ Buffer Width, 1'-6" min.
W = Driveway Width
SW = Sidewalk Width, 5' Typ.
CH = Curb Height. Variable Height. 0" at Sidewalk
Δ - Minimum Grade Length
⌖ - Buffer >6' will have a Flatter Slope

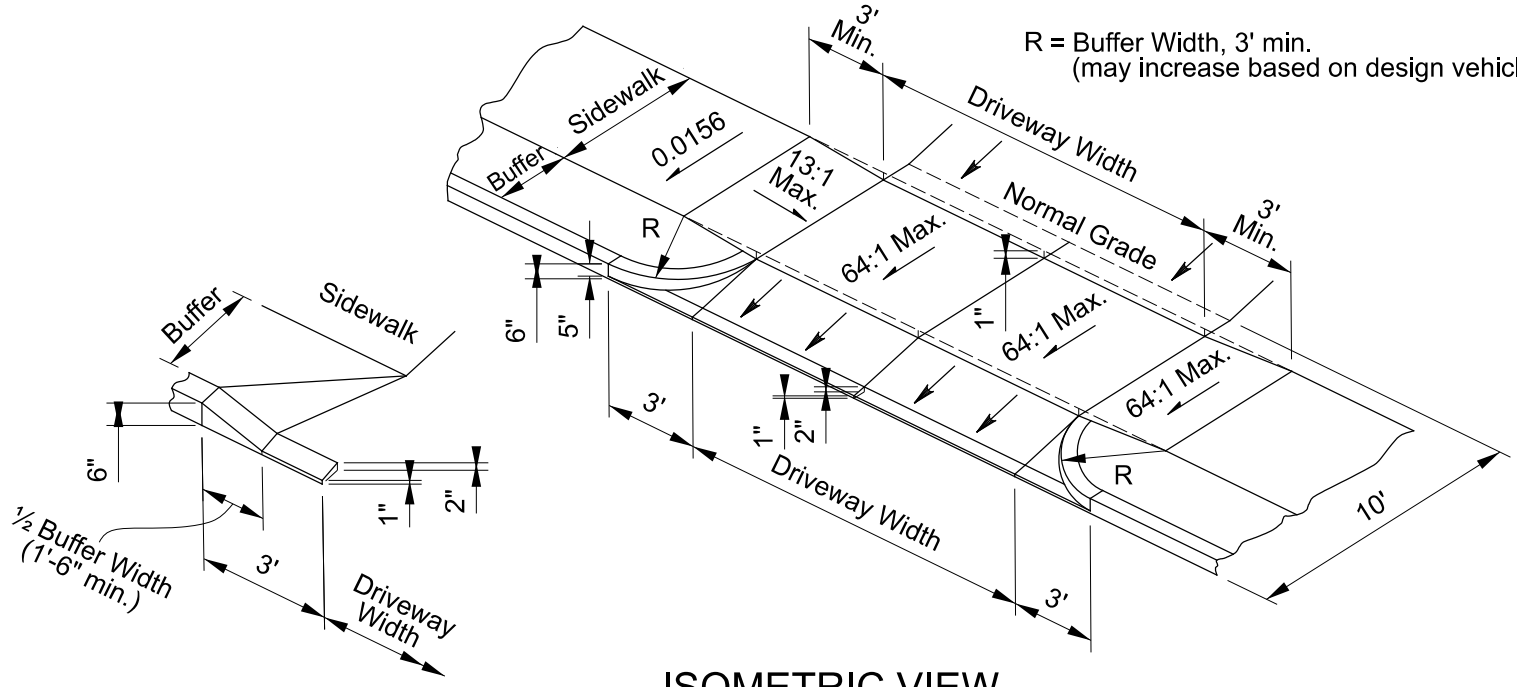


RESIDENTIAL DRIVEWAY PROFILES
6' or Greater Buffer

DRIVE (WITH CURB AND SIDEWALK) DETAILS

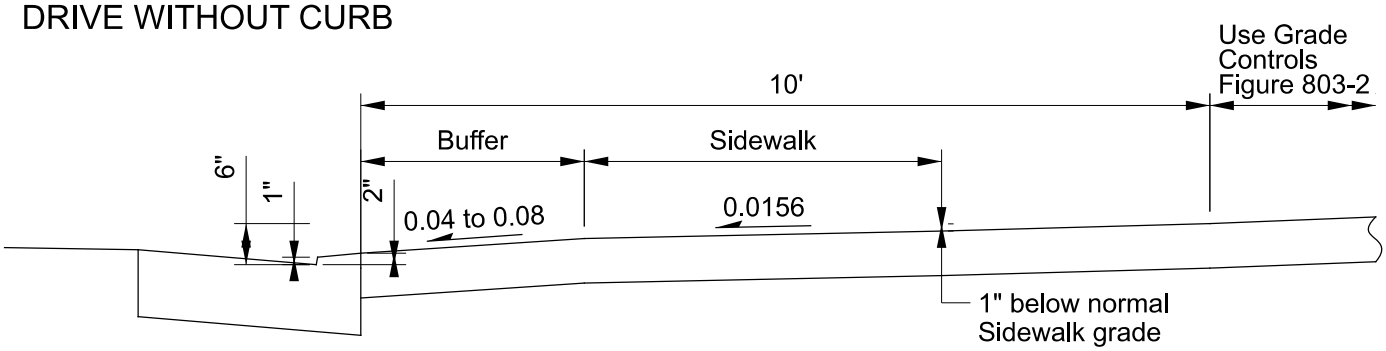
803-3

REFERENCE SECTION
803.3 & 804.2

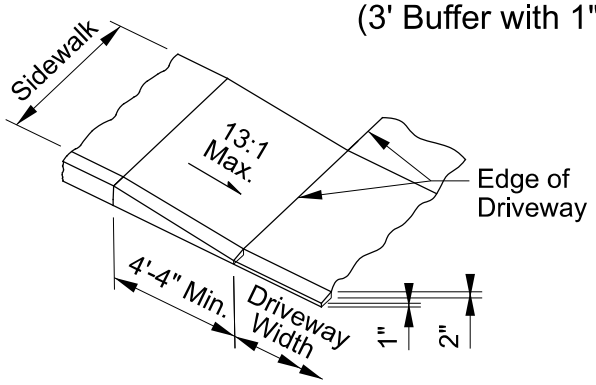


ALTERNATE:
DRIVE WITHOUT CURB

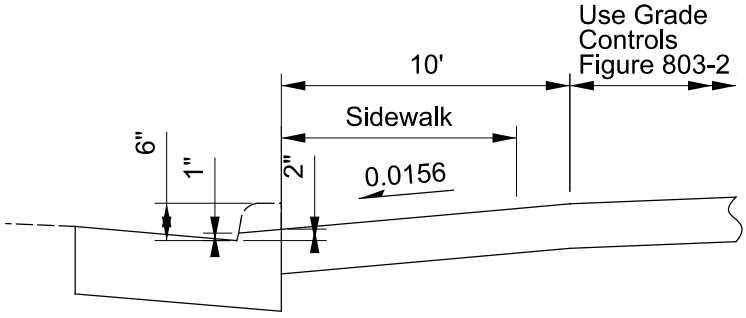
ISOMETRIC VIEW



DRIVEWAY PROFILE
Recommended Minimum Apron Design
(3' Buffer with 1" depressed sidewalk)



ISOMETRIC VIEW
(Sidewalk without any Buffer)

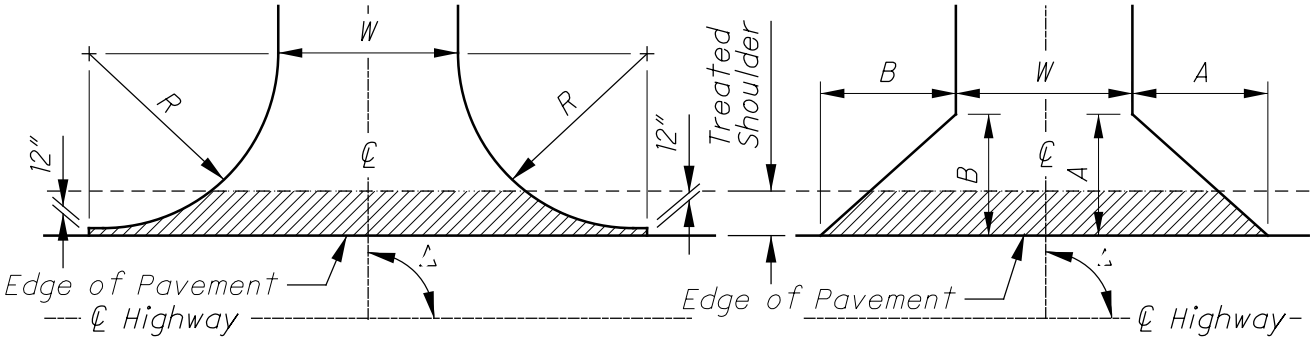


DRIVEWAY PROFILE
(Sidewalk without any Buffer)

COMMERCIAL DRIVE DESIGN DETAILS

803-8

REFERENCE SECTION 803.5



TYPE 1 (STANDARD DRAWING RD-4.1)

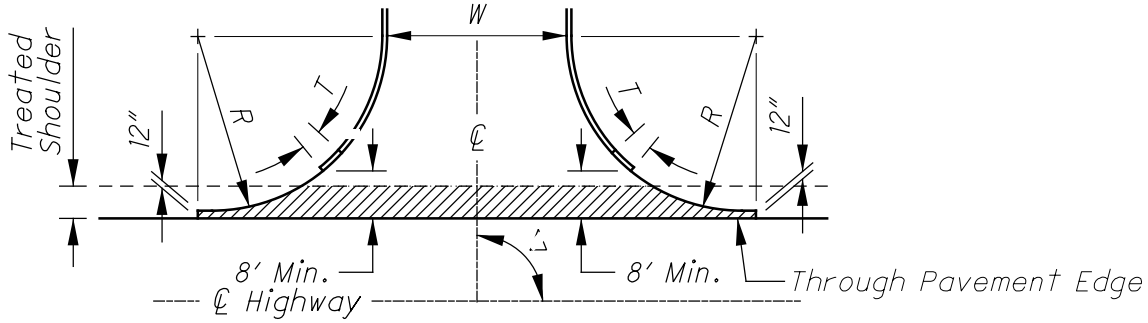
TYPE 2 (STANDARD DRAWING RD-4.1)

UNCURBED DRIVEWAY ALONG UNCURBED HIGHWAY

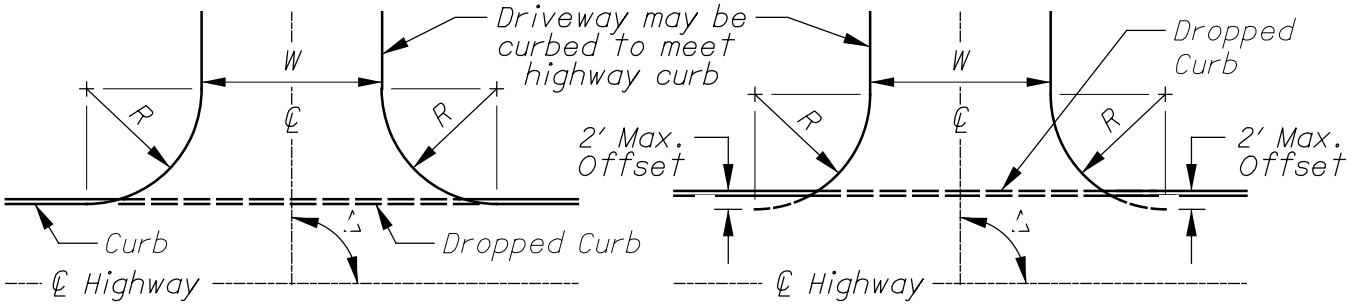
W = 35 ft. Maximum
R = Based on design vehicle turning template.
T = Taper Curb Height from 6 in. to 2 in. in 4 ft.
Δ = 70° to 90° (two-way operation)

Δ	A	B
85° to 90°	20′	20′
75° to 85°	25′	16′
65° to 75°	28′	13′
55° to 65°	33′	12′

Do not replace treated shoulder in this portion of drive flare if shoulder has equal or better pavement buildup.



CURBED DRIVEWAY ALONG UNCURBED HIGHWAY



SEE STANDARD CURB DETAILS STANDARD DRAWING RD-4.1

ALTERNATE DESIGN
To be used when smaller curb opening is required. (or curb and gutter used)

CURBED OR UNCURBED DRIVEWAYS ALONG CURBED HIGHWAY

July 2026

SIGNALIZED COMMERCIAL OR INDUSTRIAL DRIVE DESIGNS

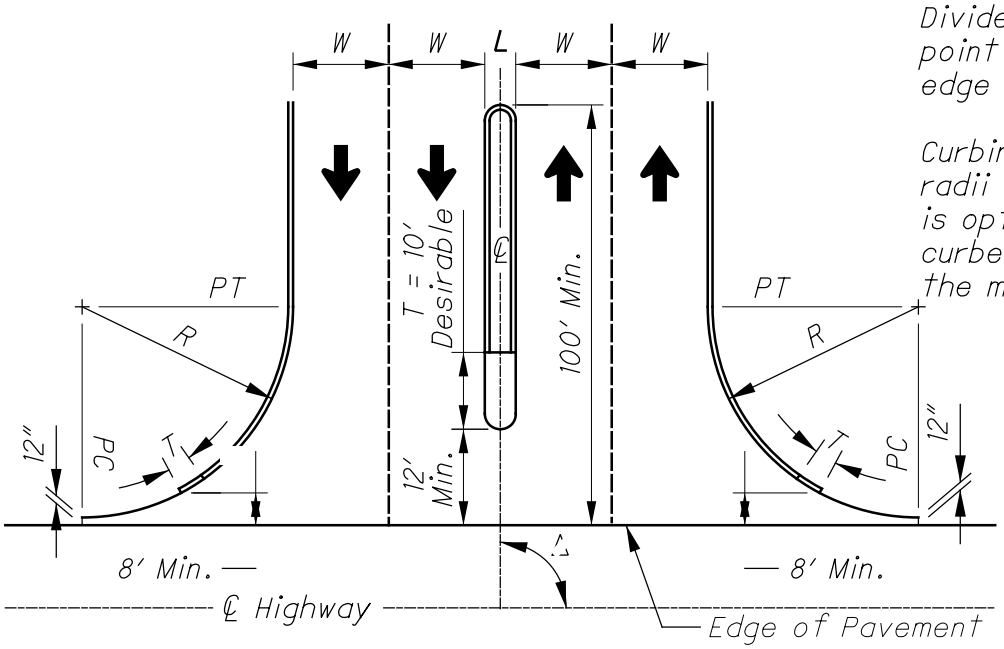
803-9

REFERENCE SECTION
803.6

Note: Number of lanes may vary.

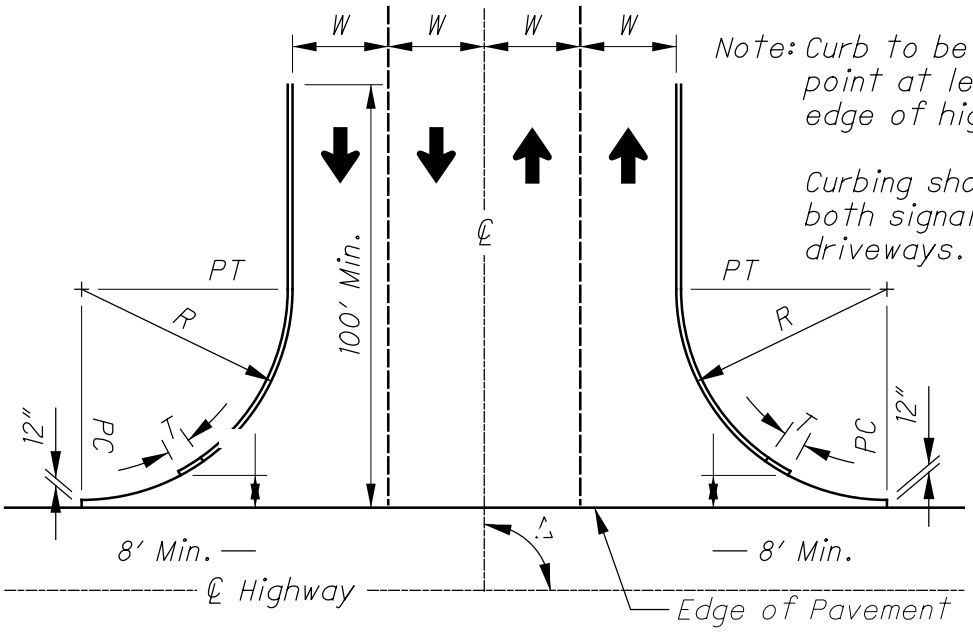
Divider to be extended to a point at least 100′ back from edge of highway pavement.

Curbing shown on approach radii and outer edges of drive is optional. When mainline is curbed, the curb should tie into the mainline curb.



DIVIDED DRIVE

W = Driveway lane width.
R = Determined by design vehicle turning template.
T = Taper Curb Height from 6 in. to 2 in. in 4 ft. or greater.
L = Median Width, 6′ Minimum. (Median must be curbed for 6′ to 15′ widths)
Δ = 70° to 90°



Note: Curb to be extended to a point at least 100′ back from edge of highway pavement.

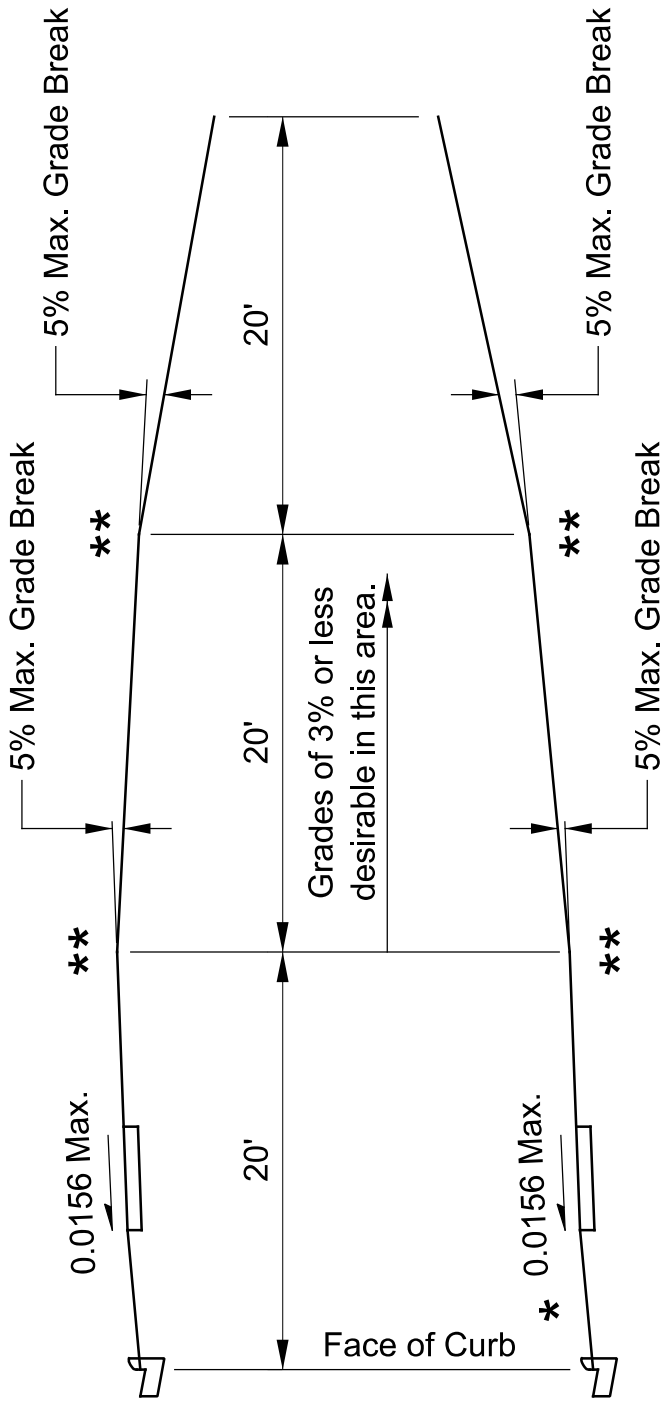
Curbing shown must be used for both signalized and unsignalized driveways.

UNDIVIDED DRIVE

COMMERCIAL DRIVE PROFILE CRITERIA

804-1

REFERENCE SECTION
804.3



* See Fig. 803-2 & 803-3 for Buffer and Sidewalk treatment.

** Although the use of grade breaks is allowable, a 10' rounding is desirable at these locations.

900 - Roadside Safety Landscape Guidelines

901 - Purpose

901.1 - General

These guidelines provide direction for landscaping within highway rights-of-way. The information provided in this guide is primarily safety-related and is intended for use by designers who already possess a good working knowledge of roadside safety design and landscape design. ODOT's Vision is to provide a safe and mobile transportation system. Landscape projects, therefore, shall be designed with the safety of the traveling public and maintenance crews as the top priority. The following guidelines follow the principles offered by AASHTO’s Roadside Design Guide.

901.2 - Background

The basis for this section stems from the fact that trees are a major cause of injuries and fatalities on the nation's highways. While it is desired to increase the amount of aesthetics on the State highway system, and these guidelines try to encourage that end, it cannot be understated: trees are proven killers when placed by the roadside. Single vehicle crashes with trees account for 3,000 fatalities each year nationwide. Trees are not generally a highway element that engineers have control over, except in landscaping projects where the designer can make decisions to reduce the consequences of vehicles leaving the road.

901.3 - Additional Information

This section is written for primarily the roadside safety aspect of landscaping. However, by necessity, this section contains other information for the landscape designer to consider in developing themes, schemes and layouts. But in no way is this information considered to be all inclusive.

902 - General Safety

Trees are potential obstructions by virtue of their size and their location in relation to vehicular traffic. Generally, existing trees with an expected mature size of greater than 4 inches are considered fixed objects. Landscaping elements shall be selected and located to maintain adequate sight distances and clear zone setbacks. These elements shall not interfere with the function of the pavement, shoulders, longitudinal barriers, end

treatments, drainage systems, traffic signs, signals, utilities and other highway structures and appurtenances.

903 - Plan Requirements

903.1 - Preliminary Field Review

All landscape projects should involve a preliminary field review prior to the scoping meeting with the consultant/designer and a district/county designee(s) knowledgeable in landscape design and roadside design/safety. At the preliminary field review, conceptual locations available for planting wildflowers, seedlings, trees, shrubs and other landscaping elements should be identified.

903.2 - Scoping

Experience has shown that proper project scoping is invaluable in heading off later misunderstandings between landscaping proponents and highway engineers. Agreeing in advance of the project to require detailed plans, permissible landscape elements, final field reviews, and maintenance agreements are important to providing a beautiful, yet safe roadside landscaping.

903.3 - Landscape Plan Details

Landscape plan should be concise and easily understood. Plans should be drawn to scale and developed on standard plan and profile sheets. Plans should indicate the following:

- design and legal speeds for the landscaped roadways
- type of adjacent land use (e.g. farmland, commercial, residential, etc.)
- topographic features such as slope limits and slope rates
- contour grading at interchanges is preferred
- locations of all utilities
- location and descriptions of existing landscaped areas
- location of all existing longitudinal barriers, end treatments, impact attenuators,
- curbs and sidewalks

- location and configuration of ditches and other drainage features
- plant lists (including botanical and common names)
- size and spacing of plants as well as area of occupancy at maturity

Although many landscape designers desire to use "conceptual" layouts, it is imperative for the highway engineer to have as much of the above information as possible in a standard format to make informed decisions on the safety merits of the plan. Omission of such information will only lead to delays, and possibly to denial of otherwise acceptable planting arrangements.

903.4 - Permit Applications

Landscaping permit requests shall include landscape plans as described in Section 903.3 and be directed to the District Deputy Director. A Maintenance & Repair permit application (M&R 505) can be obtained from the District Permit Office. The District should consult the ODOT County Manager before issuing the permit to ensure coordination of different projects scheduled in the same area.

903.5 - Final Field Review

After the plans have been accepted and all permits have been approved, the consultant/designer and a district/county designee(s) knowledgeable in landscape design and roadside design/safety should conduct a final field review.

904 - Landscape Design Considerations

904.1 - General

Landscape design can serve several important functions within the highway environment. In addition to making the roadway more aesthetically pleasing, landscaping can also be used to do the following:

- control erosion
- create a living snow fence
- minimize maintenance requirements and costs

- screen undesirable views
- preserve desirable views
- shield headlight glare
- preserve/enhance the natural environment
- reduce unwanted noise, and possibly to serve as a substitute for noise barrier at the request of a local community (see Figure 904-1 Vegetative Screening in lieu of Noise Barrier)

Landscaping projects must be done as a part of a community sponsored comprehensive plan. The plan must be sponsored by the public agency that will also be responsible for maintenance of the landscape features. Landscaping at an interchange should incorporate the entire interchange rather than just individual ramps. Landscaping may be permitted along highway segments if it is sponsored and maintained by a public agency. The goal is to provide a community endorsed, consistent theme along the highway rather than isolated, independent projects. Landscaping that contains advertising or company logos will not be permitted. It is permissible for individual property owners abutting the highway to request a permit to clear, mow, or plant replacement trees along their frontage to improve the visibility from the highway.

It is recommended that the designer choose plants carefully. Highway plantings used in the roadside environment should be hardy for the Planting Zone, salt sprays, and air pollutants (see **Section 906**).

Trees are not to encroach on the sight distances, have trunks greater than 4” mature diameter when planted in certain locations (see **Section 905**), or have canopies that will encroach over the road.

Highway landscaping should result in designs that do not require extensive maintenance. In fact, at the end of the five year maintenance period described in **Section 908.1**, landscaped areas should not require any more maintenance than the natural roadside. Therefore, plant materials noninvasive to the area should be used whenever practical.

904.2 - Landscaping Elements, Fixed Objects, and Community Gateway Monuments

Landscaping elements may consist of natural as well as manmade features, e.g., groundcovers, flowers, trees, and pavers. Many of these features such as most groundcovers and pavers allow a vehicle to safely pass over them and, therefore, do not pose a significant risk to an errant motorist. However, other features may be considered fixed objects and are, therefore, potential safety hazards. In general, a fixed object is any object that cannot be driven over safely by an errant vehicle. This includes but is not limited to the following:

- individual trees with a trunk caliper (diameter) greater than 4 inches at maturity, trunk caliper is measured at 54” up from the ground,
- clusters of smaller caliper trees or shrubs with multiple trunks or groups of small trees planted close together (within 6 feet), where the sum of their calipers at maturity exceeds 4 inches,
- decorative walls,
- rock formations and other free standing objects or fixed objects with a diameter or height greater than 4 inches. Fixed objects shall not be installed within medians or along the roadside within the setback areas specified in Section 905.

Aesthetic fixed objects shall never be placed within the clear zone. In addition to basic clear zone requirements the following shall apply to aesthetic fixed objects:

- Within interchanges shall only be constructed in areas designated for “Tall Plantings and Trees” as shown on Figures 905-2, 905-3 and 905-3a of L&D Volume 1.
- Shall not affect interchange lighting.
- Shall not be constructed at the bottom of a non-traversable slope.
- Shall not be constructed within 50 feet of the edge of the traveled way on safety graded sections.
- The offset of a fixed object to protective barrier shall not be less than the working width of the barrier, see Figure 603-2.
- Guardrail and concrete barriers, while tested to be crashworthy are still fixed objects. Installing protective barriers with the sole purpose of protecting an aesthetic treatment

is not preferred. Other options such as relocating the aesthetic feature or utilizing existing barriers should be exhausted before contemplating the installation of new barrier.

904.2.1 - ODOT Guidelines for Community Gateway Monuments

A Community Gateway Monument is defined as a freestanding structure, decorative sign, retaining wall, etc., that displays the name of a city, village, township, or county. These monuments are a non-integral or nonrequired highway feature. A Community Gateway Monument may display the officially adopted seal, slogan, date of establishment, graphic, or logo that has been associated with the community.

Community Gateway Monuments may be located at or near off-ramp areas of a service interchange exit or along the mainline of non-interstate and non-freeway highways. Community Gateway Monuments located at or near freeway or expressway exits shall not be directed toward the mainline of the major highway but rather are intended to be viewed after drivers have exited the mainline. Community Gateway Monuments must be located outside of the clear zone. Only one Community Gateway Monument will be permitted, per Local Entity, on an ODOT owned route in each direction of the traveled roadway.

Community Gateway Monuments will not be allowed along the mainline of freeways and expressways or at freeway to freeway (major directional) interchanges.

Community Gateway Monuments must be officially authorized by local ordinance or resolution.

Required engineered highway features, such as, but not limited to, noise walls, retaining walls, bridges, bridge abutments, bridge rails, and slope paving, may provide the opportunity for the placement of visual, graphic, or sculptural representations of a community's identity, including its history, resources, or other defining characteristics. Required engineered highway features are not considered Community Gateway Monuments and are not covered within these guidelines. Additional guidance for the above features can be found within the Bridge Design Manual and the Aesthetics Design Guidelines manual.

Permit submissions involving Community Gateway Monuments must include enough detail to demonstrate that all requirements described in these guidelines are met.

Maintenance

A maintenance Agreement for the care and upkeep of a Community Gateway Monument must be established between the Local Entity and the Department.

Community Gateway Monuments shall be kept clean, free of graffiti, and in good repair. The Local Entity shall be required to provide for regularly scheduled maintenance, as described in the maintenance agreement, for its lifespan, including graffiti removal and restoration work to maintain the integrity of the approved project. Maintenance practices shall protect air and water quality as required by law.

The Department may perform maintenance activities in the area of the Community Gateway Monument such as litter pickup and other maintenance that is normally associated with the transportation facility or right-of-way. The Department will not provide maintenance of the Community Gateway Monument itself. Any other maintenance activities anticipated by the Local Entity that are over and above what the Department would normally provide will be documented by the Maintenance Agreement.

Removal

The Local Entity shall remove the Community Gateway Monument which in the opinion of the Department creates safety or operational concern due to deterioration or inadequate maintenance. The Department will notify the Local Entity when it has determined that the Community Gateway Monument needs special attention. In the even the Local Entity fails to maintain, repair, rehabilitate, or remove the Community Gateway Monument in a timely manner, the Department may remove the Community Gateway Monument after 60 days following notification to the Local Entity, and bill the Local Entity for all costs of removal and restoration of the area.

The Department reserves the right to remove the Community Gateway Monument to perform construction, rehabilitation, or other necessary activities affecting the transportation facilities without any obligation, compensation to, or approval of the Local Entity. The Department will strive to notify the Local Entity of its intent to remove the Community Gateway Monument, to allow for timely removal and salvage of the Local Entity if possible.

The Department reserves the right to remove or alter any Community Gateway Monument that presents an immediate safety hazard to the public without delay or advanced notification to the Local Entity.

Guidelines for the Design and Placement of Community Gateway Monuments

Proposed Community Gateway Monuments Shall:

1. Be ground mounted (not above any roadway).
2. Be developed to require low or no maintenance to minimize exposure of workers and others to potential risks.
3. Be appropriate to its proposed setting and community context.
4. Be within the maximum size dimensions of a width of 25 feet, a height of 10 feet and a depth of 10 feet.
5. Be composed of materials that are durable for the projected life span of the project.
6. Be located beyond the clear zone, placed to minimize the likelihood of being struck by an errant vehicle, or in a protected location, and have the site-specific concurrence of the District office. Refer to Location and Design Vol. 1, Figure 905-2, 905-3 and 905-3a for acceptable placement locations at interchanges. Installing or extending protective barriers with the sole purpose of protecting an aesthetic treatment is not permitted.
7. Be located where maintenance can be safely performed.
8. Conform to Ohio Outdoor advertising rules, regulations, laws and all local sign ordinances. View ODOT's website for outdoor advertising control.
9. Be subject to the review and approval of the District in consideration of design and size for appropriate integration on urban or rural highway features.

Proposed Community Gateway Monuments shall not:

1. Be allowed along mainline of a freeway or expressway or within the median areas. Ramp areas and interchange exits areas may be permitted if appropriate conditions

are met and are not within the clear zone. Refer to Location and Design Vol. 1, Figure 905-2, 905-3 and 905-3a for acceptable placement locations at interchanges.

2. Contain religious, political, special interest, private, or commercial messages of any sort including but not limited to symbols, logos, business names, trade names or jingles.
3. Contain any displays of any sort, advertising, decorative banners, non- governmental flags. Official City, County, State of U.S. Flags are permitted in limited numbers (no more than 3 total).
4. Display telephone numbers, street addresses, or internet addresses.
5. Include reflective or glaring surface finishes.
6. Include any underground utilities (electrical, gas, water, etc.).
7. Include illumination that impairs or distracts the vision of transportation system users. All lighting features must be appropriately designed and approved by a licensed electrical engineer. No overhead or underground electrical wiring is permitted within ODOT right-of-way (individual solar powered lighting is permitted).
8. Display blinking or intermittent lights, changeable message signs or any type digital display.
9. Include moving elements (kinetic art) or simulated movement.
10. Neither interfere with official traffic control devices nor interfere with the operational right-of way above the roadway.
11. Be placed within State right-of-way upon trees or painted or drawn upon rocks or other existing natural features.
12. Make use of simulated colors or combinations of colors usually reserved for official traffic control devices described in the Ohio Manual of Uniform Traffic Control Devices.
13. Use garish, fluorescent or otherwise distracting colors.
14. Restrict sight distance per Section 200 in Location and Design Vol.1.

15. Require the removal of trees or other vegetation for visibility, or harm trees during construction. Pruning of tree branches or roots, and removal of shrubs should be avoided, and will be allowed only with approval of the ODOT District Office.
16. Negatively impact existing highway features, including existing signs, or irrigation systems.
17. Protrude or span over travel lanes or roadbed.

904.3 - Bodies of Water

Bodies of water present unique safety concerns. The department recommends the use of longitudinal barriers to protect naturally occurring ponds located within the setback areas. Ponds/pools and other landscape water features shall not be built within highway rights-of-way. This does not preclude the construction of treatment ponds or water retention basins within the right-of-way when mandated in the environmental process.

904.4 - Accessories

In community gateways and downtown business districts many municipalities seek to install street furniture, pavers, bollards, ornamental lighting, planters and other landscaping features to the design. Features within the lateral offset distances described in Figures 904-2 & 904-3 are to be crashworthy, as specified in NCHRP Report 350 or MASH. Amenities located beyond the appropriate offset distances shown in this guideline may be allowed. Any feature placed within ODOT's Right-of -Way is allowed solely at ODOT's discretion. Landscaping plans that include decorative signs must conform to Section 210-3 of the Traffic Engineering Manual.

904.5 - Irrigation Systems

Many lavish plantings will not survive unless maintenance is provided. Some communities protect their investment by installing irrigation systems. Irrigation systems cannot be a hazard to the motorist. Systems cannot have hazardous stub heights (4” diameter max.), exposed pipes or meters in the specified offset distance. Nor should the spray be directed to the roadway, nor is ponding or sheet flow permitted on the traveled way. In all cases, maintenance and repair of irrigation systems will be the responsibility of the project sponsor.

905 - Placement for Safe Roadside Design

905.1 - Roadside Grading

Since operational safety can be affected by the landscape, a continuous length of the highway must be visible to the driver (sight distance) and a lateral run out area (clear zone) must be traversable and free of physical obstructions.

Clear zones provide areas for drivers of errant vehicles to regain control after running off the road. Although minimum setbacks for large trees and other fixed objects are prescribed in the following sections, consideration should be given to providing additional clearance where practical. Setback distances are measured to the face of the fixed object from the traveled edge line of the adjacent roadway. For facilities with curb and gutter, setback distances are measured from the face of curb to the face of the object. Bike lane and parking lane widths may be included in the setback distance. For trees, this measurement shall be taken to the face of the trunk 2 feet above the ground line.

Large trees and shrubs may be planted within the setback limits specified in this section where the likelihood of an impact by an errant vehicle is negligible; for example, on cut slopes above a retaining wall or behind existing longitudinal barrier. See **Section 307** for details on the following types of grading, **Section 600** for clear zone criteria, and Section 201 for details on required sight distances.

905.1.1 - Safety Graded Sections

Trees and large shrubs shall not be planted within 50 feet of the edge of the traveled way on safety graded sections. Low maintenance flowers, ground covers and other plants 18 inches or less in height at maturity may be located within this setback area as long as adequate sight distance is provided. See Figure 307-1 for Safety Grading.

Trees and other plants taller than 18 inches may be located beyond this setback distance with the following restrictions:

- These plants shall not be located within a ditch or on a backslope within 20 feet of the ditch flowline.

905.1.2 - Clear Zone Graded Sections

Trees and large shrubs shall not be planted within 30 feet of the edge of the traveled way on clear zone graded sections. Low maintenance flowers, ground covers and other plants 18 inches or less in height at maturity may be located within this setback area as long as adequate sight distance is provided. See Figure 307-3 for Clear Zone Grading.

Trees and other plants taller than 18 inches may be located beyond this setback distance with the following restrictions:

- These plants shall not be located on foreslopes
- These plants shall not be located within a ditch or on a backslope within 10 feet of the ditch flowline

905.1.3 - Common Graded Sections

Plantings shall be located at least 4 feet behind the ditch line in cut sections and 2 feet outside the shoulder break in fill sections. See Figure 307-4 for Common Grading.

905.1.4 - Barrier Graded Sections

An ideal location for large trees and shrubs is behind existing longitudinal barriers, provided the landscape designer allows for a maintenance access. The lateral offset to these plants shall be 15 feet measured from the face of a w-beam guardrail to allow the barrier to deflect to its design deflection in a crash, but to also allow maintenance vehicles to navigate on the back side of the barrier. Other types of barriers have different deflection limits. Barriers shall not be installed solely to permit the use of large trees or other potentially hazardous landscaping elements along the roadside. See Figure 307-4 for Barrier Grading.

905.1.5 - Gating End Terminals

Advances in the performance of guardrail end terminals and impact attenuators (crash cushions) have dramatically increased the safety of the traveling motorist. Many of these systems are designed to be "gating" (or "non-redirective") in certain types of impacts. Gating terminals function successfully by allowing approaching vehicles to pass through (or "gate") the very end of the end terminal. Impacting vehicles are only slightly impeded by the interaction with the terminal, and possibly still are traveling at a high speed. Thus, no fixed objects are allowed in a runout area that is defined by FHWA to be a

minimum of 20 feet wide behind and perpendicular to the rail and 75 feet long beyond the terminal parallel to the rail. Figure 905-1 shows the permitted landscaping offset needed to protect this runout area behind gating terminals.

If the landscaping designer does not know which treatment is used at the end of a guardrail run, for the purpose of the landscaping plan it will be considered to be gating. All associated runout areas will remain free of fixed objects.

905.2 - Urban Design

The Roadside Grading section generally deals with high speed rural roadways. Municipalities may desire to landscape gateways into their communities, which is often a state highway or an interchange that leads to an arterial. The highway facilities in these gateways are often roadways with lower speeds than found on the rural state system. These roads may be lower speed, divided or not, or curbed or not. Refer to Section 600.2.2 for discussion on Urban Lateral Offsets where Clear Zone cannot be achieved and Figures 600-3, 600-4, 904-2 & 904-3. The following discussion gives highway engineers and landscape designer's additional guidelines for placement of large trees, small trees and foliage in urban areas. Other landscaping features, such as lighting, stones, boulders, bollards, or water ponds, etc. are to meet guidelines listed elsewhere.

Refer to Figure 904-2 for treatment in curb sections. Curbing is considered mountable, a vertical 4-inch curb (or even 6 inches or more) is not going to stop a vehicle. Large trees are considered to be non- frangible and have a final (mature) trunk diameter of 4 inches or greater. The sum of the individual trunk dimensions of multi-stemmed tree are considered as one object over a 6-foot vehicle width. Setbacks in curbed sections are from the front face of the curb unless bike lanes or full-time parking lanes are present. Since urban tree locations have considerably less offset than high speed facilities, vertical clearance becomes an issue. All trees, especially those planted close to a curb will have their canopies clipped by trucks in the lane adjacent to the trees. Plant trees to ensure their mature canopy will not infringe on this area.

905.3 - Highway Design Elements

Certain highway features provide a special opportunity for communities to express themselves through landscaping. Interchanges and intersections are ideal locations, although they do require special attention by designers.

905.3.1 - Interchanges

Interchanges provide an opportunity for establishing and/or preserving attractive landscapes along our highways. Because an interchange often serves as a major focal point, both from the highway and from the cross road, the major components should be coordinated to achieve an overall design that is aesthetically pleasing. Major components of an interchange include: structural design, texture and detailing, railings, lighting, contour grading and plant material.

Generally, a minimum 50-foot setback (from the edge of traveled way) within a loop ramp is considered an appropriate sight distance setback for trees and shrubs with mature heights above 18 inches. Figures 905-2, 905-3, and 905-3a provide details for landscape plantings at cloverleaf, diamond, and diverging diamond interchanges. For interchanges, all plantings shall provide ramp and collector-distributor road sight distances equal to or greater than those required by the design speed criteria in Section 201.

905.3.2 - Intersections

A driver attempting to enter a through road must be able to see traffic at a distance along the intersecting road in order to safely enter the intersection. The required intersection sight distance varies with the speed of the traffic on the main highway. Section 201.3 provides standards for various intersection sight distance conditions. The triangular setback areas shown in Figure 905-4 are based on these principles. No plantings above 18 inches shall be permitted within these setback areas. This figure shows a tangent condition; a graphical solution is required when the through road is curved.

In general, an offset of 50 feet on the inside of a curve with a degree of curvature of 2 degrees or greater should be provided to ensure adequate horizontal sight distances.

905.3.3 - Roundabouts

Landscape elements are vital to the proper operation of a roundabout and needs to be in place when the roundabout is opened to traffic. The purposes of landscape elements in the roundabout are to:

- Make the central island conspicuous to drivers as they approach the roundabout

- Clearly indicate to drivers that they cannot pass straight through the intersection. Restrict the ability to view traffic from across the roundabout through mounding of the earth and plantings. This will lead to slower entering speeds, which increases safety.
- Require motorists to focus toward on-coming traffic from the left
- Help break headlight glare
- Discourage pedestrian traffic through the central island
- Help blind and visually impaired pedestrians locate sidewalks and crosswalks
- Improve and complement the aesthetics of the area

When designing landscaping for a roundabout it is important to:

- Consider maintenance requirements early in the program stages of development
- Develop a formal municipal agreement describing the landscaping and maintenance requirements for roundabouts elements early in the scoping process and prior to design of the facility.
- Maintain adequate sight distances
- Avoid obscuring the view to signs
- Minimize fixed objects such as trees, poles, or guardrail
- Apply the guidance below relative to approach speeds and the permissible use of fixed objects such as trees, poles, non-hazard walls, non-hazard rocks/boulders, or guardrail
- Clear zone and lateral clearance requirements are provided in Section 601.

Typically, a portion of the splitter island is situated within the critical sight triangles, the landscaping in these areas may be constructed with low-growth plants or grass. Grass or low shrubs are also desirable due to their ability to blend well with nearby streetscapes and the fact that they require only limited maintenance. Splitter islands should generally not contain trees, planter boxes, or light poles. Hardscape treatments like a simple patterned concrete or paver surface may be used on splitter islands in lieu of landscaping.

Landscape the central island by mounding the earth and providing plantings. Refer to Figure 905-5 for the general layout of the central island. The truck apron is not included in the clear zone distance. The clear zone for the central island is considered to begin at the inside curb adjacent to the central island landscaping. The combination of the earth mound and plantings in the central island shall provide a visual blocking such that drivers will not be able to see through the roundabout central island. The central island area is considered a low speed environment; however errant vehicles occasionally end up in the central island or crossing the central island.

The approach highway speed is an indicator of the probability of an errant vehicle entering the central island. Therefore, when the posted speed on any approaching leg to the roundabout is greater than 35 mph, hazards and fixed objects such as concrete, stone, or wood walls and trees having a mature diameter greater than 4 inches are prohibited within the central island.

Where the approaching leg to a roundabout has a posted speed of 35 mph or less there may be objects that appear to be hazardous such as walls or rocks, but they are to be constructed with materials and in a manner that is not hazardous to errant vehicles. It is important to minimize the consequences of an errant vehicle that may impact a wall or rocks/boulders. The inner portion of the central island is typically most vulnerable to drivers/vehicles that for some reason leave the roadway and enter the central island at a high impact angle. If in the event that a driver is driving too fast to negotiate a curved approach to a roundabout, or otherwise distracted and/or is not aware of the upcoming roundabout the impact angle entering the central island typically will be much greater than 25 degrees and outside the realm of roadside design. The consequence of hitting a fixed object at an angle greater than 25 degrees is severe.

Minimize the consequence of hitting a wall or boulders by following these guidelines:

1. Do not allow any walls in the central island with cast in-place or reinforced concrete or natural boulders.
2. Construct any walls with light-weight, Styrofoam type, artificial bricks/blocks typically used in landscaping and boulders with chicken wire and stucco. No mortar or reinforcing between the bricks/blocks. Minimize the wall thickness while maintaining stability.

3. If light-weight walls are desired for aesthetic reasons, then construct at a height 20-inch or lower. This will tend to keep flying debris at a lower level as not to penetrate a windshield, or impact other vehicles.

4. Do not allow fill material in back of the light-weight brick/block wall for approximately 2 feet. Then at ground level begin to slope the earth up and away from the non-hazardous wall at a 6:1 slope or flatter.

Design the slope of the central island with a minimum grade of 25:1 and a maximum of 6:1 sloping upward toward the center of the circle. The earth surface in the central island area forms an earth mound that is a minimum of 3.5-feet to a maximum of 6-feet in height, measured from the circulating roadway surface at the curb face. As an absolute minimum, keep the outside 6 feet of the central island free from landscape features to provide a minimum level of roadside safety, snow storage, and unobstructed sight distance. In some situations this central island area may need to maintain a low profile beyond 6-feet to allow over sized vehicle loads to pass over the central island without the axles passing over the central island.

Avoid items in the central island that may be considered an attractive nuisance that may encourage passersby to go to the central island for pictures, or other objects that might distract drivers from the driving task. When reasonable, consider a frost proof water supply (small hand hydrant, not fire hydrant) and electrical supply to the central island. The water supply should be considered for long term use not just to establish plant material.

905.4 - Additional Planting Constraints

Crash Locations - Offset distances greater than the minimum setbacks should be considered at locations with a history of run-off-the-road crashes.

Agriculture - Plants shall not obstruct, shade, or cause harm to crops planted in adjacent farm fields. When wind breaks and living snow fences are proposed adjacent to agricultural use properties, permission to plant should be obtained from the property owner.

Billboards - Plants shall not obstruct the view of billboards. However, naturalized trees blocking billboards should be cut only with permission of the district. This work shall be done by permit using a certified arborist.

Businesses - Trees, shrubs and wildflowers should be planted to blend in with the natural environment.

Canopy Obstruction - Trees and shrubs shall be offset far enough from the edge of the traveled way to prevent damage to vehicle windshields or interference with overhead utilities and signals.

Ditches - No planting other than seeding shall occur within ditches.

Irrigation Systems - Irrigation systems should be designed to minimize overspray onto the traveled way. The systems should be located so that the potential for damage to and from vehicles is prevented.

Scenic Views - Materials should be selected and placed to preserve desirable scenic views along the roadside.

Sight Distance - Proposed plants shall not restrict the horizontal and vertical sight distance of the roadway. Although the minimum setbacks provided in these guidelines were selected to ensure adequate sight distances, this should be field-verified and the setbacks shall be increased where necessary. In cases where an existing facility does not already provide adequate sight distance because of geometric restrictions, no further reduction of the sight distance shall be allowed.

Slopes - Evergreen and deciduous seedlings are the preferred vegetation; mature trees may be used when required for mitigation. Wildflower and native grasses (Construction and Material Specification (CMS) 870, Seed Mixtures Table) may be used with District Deputy Director approval.

Snow Fence - Only evergreens may be planted as living snow fence. Multiple rows shall be staggered. A general rule of thumb is that snow will be deposited on the leeward side of a snow fence over a distance approximately equal to the height of the snow fence. Care should be taken to ensure that the snow fence is planted far enough from the edge of the pavement to prevent snow from being deposited onto the roadway. (Also see Windbreak.)

Windbreak - Use the Ohio Windbreak Guide, published by the Ohio Department of Natural Resources as a source for design and species selection.

906 - Plant Material

Several lists of acceptable plants are available through ODOT Central Office, or certain ODOT District Offices.

906.1 - Native or Non-Invasive Plants

All plant material shall be disease and pest free. A copy of the nursery inspection should be made available upon request.

906.1.1 - Wildflowers

Wildflower sites should be composed of Ohio native perennial forbs and grasses. Other mixtures should be approved by the District Deputy Director, or designated employee. Wildflower areas should be designated as No Mow. See CMS Item 659.09 for available species acceptable for planting on the Right- of-Way.

906.1.2 - Seedlings

Both Deciduous and Evergreen Seedlings should be salt tolerant and planted area should be signed as "No Mow."

Evergreen Seedlings may be used to create living snow fences and screenings. Locations include but are not limited to:

- slopes
- erosion prone areas
- interchanges (see Figures 905-2, 905-3 & 905-3a)

906.1.3 - Trees and Shrubs

Site design should use plant materials in a way that is low maintenance, has multi-seasonal interest and looks natural. Approval of locations should be based on safety, aesthetics and maintenance concerns. Typically trees and shrubs may be planted in the spring and fall. However, for optimum growth, trees shall be planted during the months recommended for the individual species.

906.1.4 - Species

An acceptable list of tree and shrub species is available in the Ohio section of The Roadside Use of Native Plants, FHWA ep-99-014 or the Ohio State University Extension Office's The Native Plants of Ohio (Bulletin 865, 1998), and from the Office of Material's Management. It is preferable that noninvasive species be used. Hybrids and cultivars may be substituted only with permission from the District Deputy Director, or designated employee, when native species are not available.

906.2 - Zones

All trees shall be suitable for growth in Ohio Zone 5a or lower (USDA Hardiness Zones). Trees should be from Ohio growers whenever practical.

906.3 - Emerald Ash Borer Insect

Landscape designers should be aware of the infestation of ash trees throughout Ohio and the efforts of Ohio Department of Agriculture (ODA) to combat this insect, which kill ash trees within three to five years from infestation.

It is recommended to refrain from planting ash trees for the next several years. If a landscaping project is utilizing exiting ash trees in the design, then trees should be monitored for Emerald Ash Borer signs, which can be found at the ODA website. (Some of the signs are "D" shaped exit holes, "S" shaped tunnels beneath the bark, dieback at the tops of the trees, sprouting around the trunk, woodpecker damage, or bark splits.) For more information about the pest, its current status, or ways to assist in early detection, calls the Emerald Ash Borer hotline at 1-888-OHIO-EAB.

907 - Planting

Planting and bracing details are shown on Roadway Standard Construction Drawing LA-1.2.

Planting trees and shrubs too deeply is a persistent problem. To address this problem, the Ohio Nursery and Landscape Association and the ODNR Division of Forestry developed a set of tree planting specifications. This effort, called "Sample Tree Planting Specifications" is included as at the end of this Guideline.

908 - Maintenance

908.1 - General

Unless otherwise specified, all maintenance of all plants shall begin upon installation and be arranged by the project sponsor. Plants shall be maintained by the permit holder for at least five years. The Department should inspect the landscape during this time and require maintenance as needed.

Refer to the CMS 651 thru 673 for detailed roadside installation and maintenance requirements. See M&R 632 for mowing specifications.

Maintenance shall include but not be limited to:

- watering, pruning, mowing, and replacement
- weeding, fertilization, mulching
- removal
- litter pick up
- insect control (by a licensed applicator, when required)
- herbicides (by a licensed applicator)

908.2 - Watering, Pruning, Mowing, and Replacement

Watering - watering of the new plant material is essential for their survivability, and is the responsibility of the project sponsor.

Pruning - All trees and shrubs shall be maintained and only pruned as necessary to retain their natural shape or remove deadwood. For example, water sprouts (suckers) shall be removed from the base of each species as needed.

Mowing - Trees should be spaced sufficiently far apart and shrubs should be grouped and mulched in beds shaped to avoid excessive mower maneuvering and the need for hand trimming.

Replacement - All dead, dying or diseased plants shall be removed and disposed of Construction & Material Specification 105.13. Replacement shall be left up to the project

sponsor.

908.3 - Planting Stakes

Trees planted with support stakes and guy wires shall have all such appurtenances removed no less than 12 months and no more than 18 months after installation.

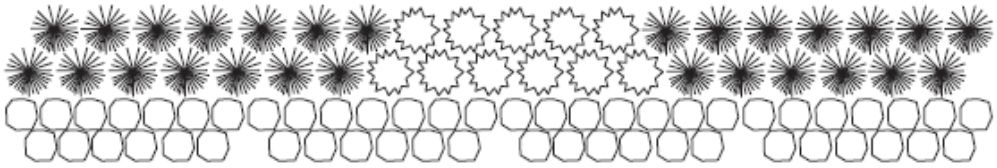
908.4 - Winter Hazards

Landscaping shall not reduce safety for the traveling public or maintenance crews. Trees and shrubs should be placed in locations and trimmed to a size that does not hinder snow and ice removal. Removal or thinning of trees that shade the pavement creating icy spots should be considered. Some sections of the roadside should be kept open to allow sunlight to aid new tree growth.

908.5 - Maintenance of "NO MOW" Areas

Naturalized (No Mow) areas can have a "neat" appearance without the removal of trees or shrubs. These areas within ODOT Right-of-Ways are frequently maintained by municipalities. If a community desires to maintain ODOT's Right-of-Way, an M&R 505 permit is required. Districts offices should also receive a maintenance plan from the community. If maintenance of Right-of-Way areas is done without obtaining the permit, communities can be held liable and be made to perform restitution.

VEGETATIVE SCREENING	904-1
	REFERENCE SECTION 904.1



VEGETATIVE SCREENING IN LIEU OF NOISE BARRIER

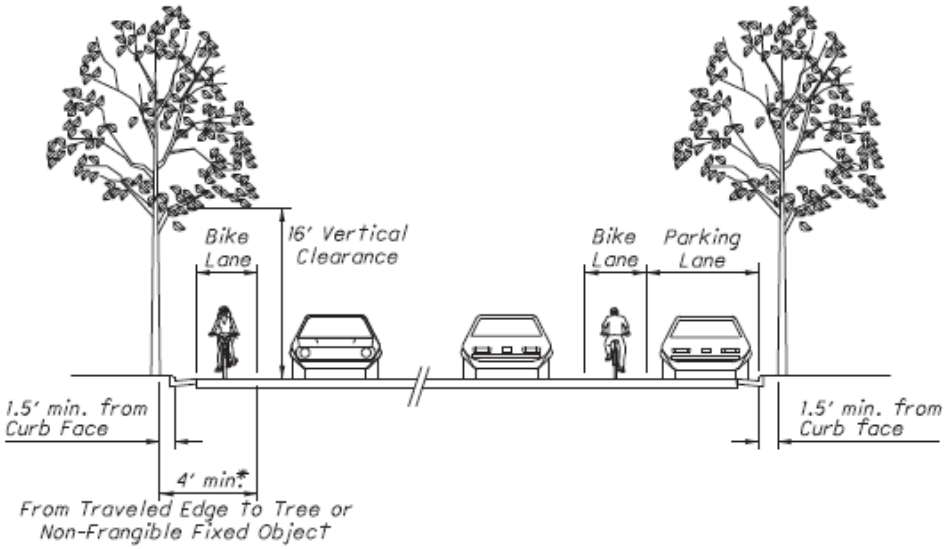
Vegetation in lieu of a noise of a noise barrier is intended to provide psychological relief and is not inteded as a noise abatement measure. The provided drawing is an example. Alternative planting designs may be submitted for approval from the ODOT noise coordinator. All planting must provide 100" opacity year round to height of 6' within 3 years of installation.

Place evergreen trees in an offset pattern with rows 8' apart and 8' on center. Plant trees in single species masses of a at least 15 trees. Plant minimum 5' tall evergreen trees from the following list: Chamaecyparis Thyoides - Atlantic White Cedar, Juniperus Virginiana - Eastern Red Cedar, Picea Abies - Norway Spruce, Picea Pungens - Colorado Spruce, Pinus Nigra - Austrian Pine.

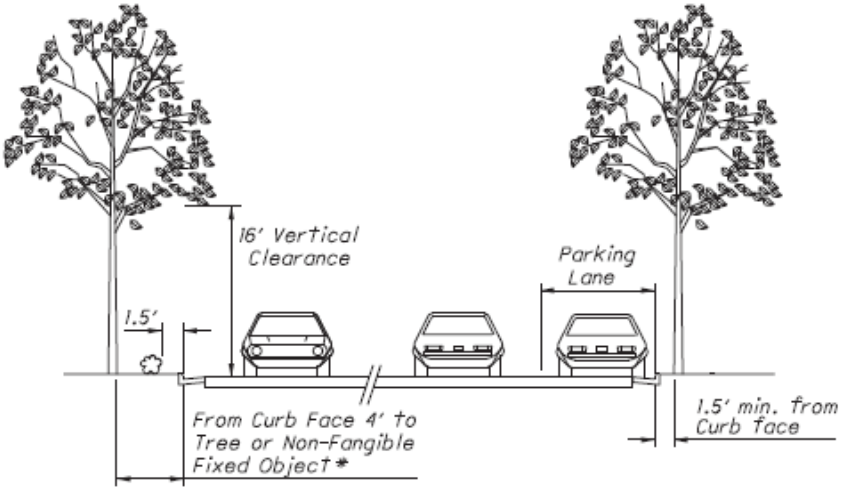
Place shrubs in staggered alternating rows with plants 3' on center. Plant shrubs in single species masses of a minimum 25 plants. Alternate evergreen and deciduous shrub masses. Plant minimum 3' tall shrubs from the following list: Viburnum Prunifolium - Blackhaw Viburnum, Aronia Melanocarpa - Black Chokeberry, Ceanothus Americanus - New Jersey Tea, Juniperus Communis - Common Juniper (Cultivars - "Compressa", "Depressa", "Hills Vaseyi" and others with a similar habit).

July 2014

URBAN LANDSCAPING TYPICAL CURBED SECTION 45 MPH OR LESS	904-2
	REFERENCE SECTION 905.2



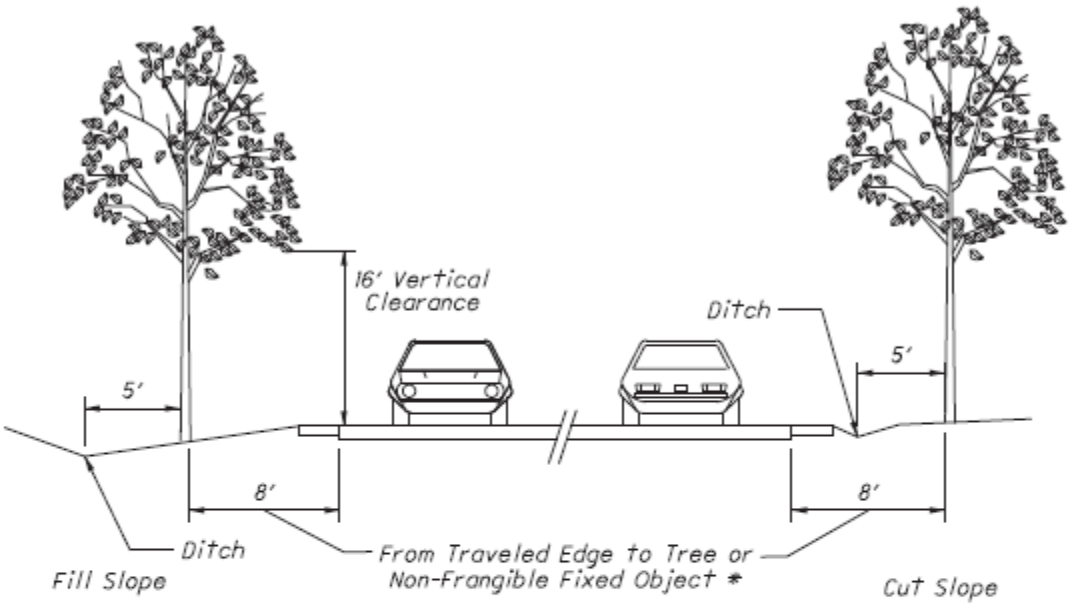
CURBED SECTION
WITH BIKE LANES OR ON STREET PARKING



CURBED SECTION
* 6' min. in High Risk Areas Such as Outside Curves

July 2014

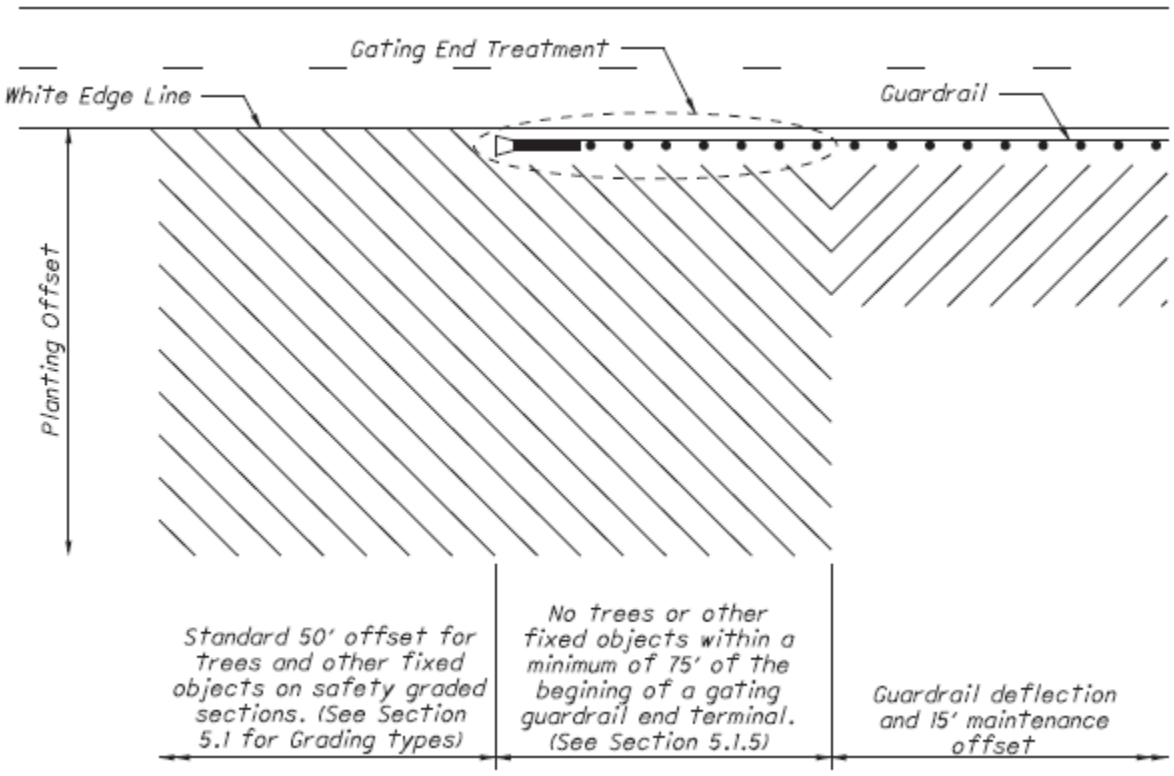
URBAN LANDSCAPE TYPICAL UNCURBED SECTION 45 MPH OR LESS	904-3
	REFERENCE SECTION 905.2



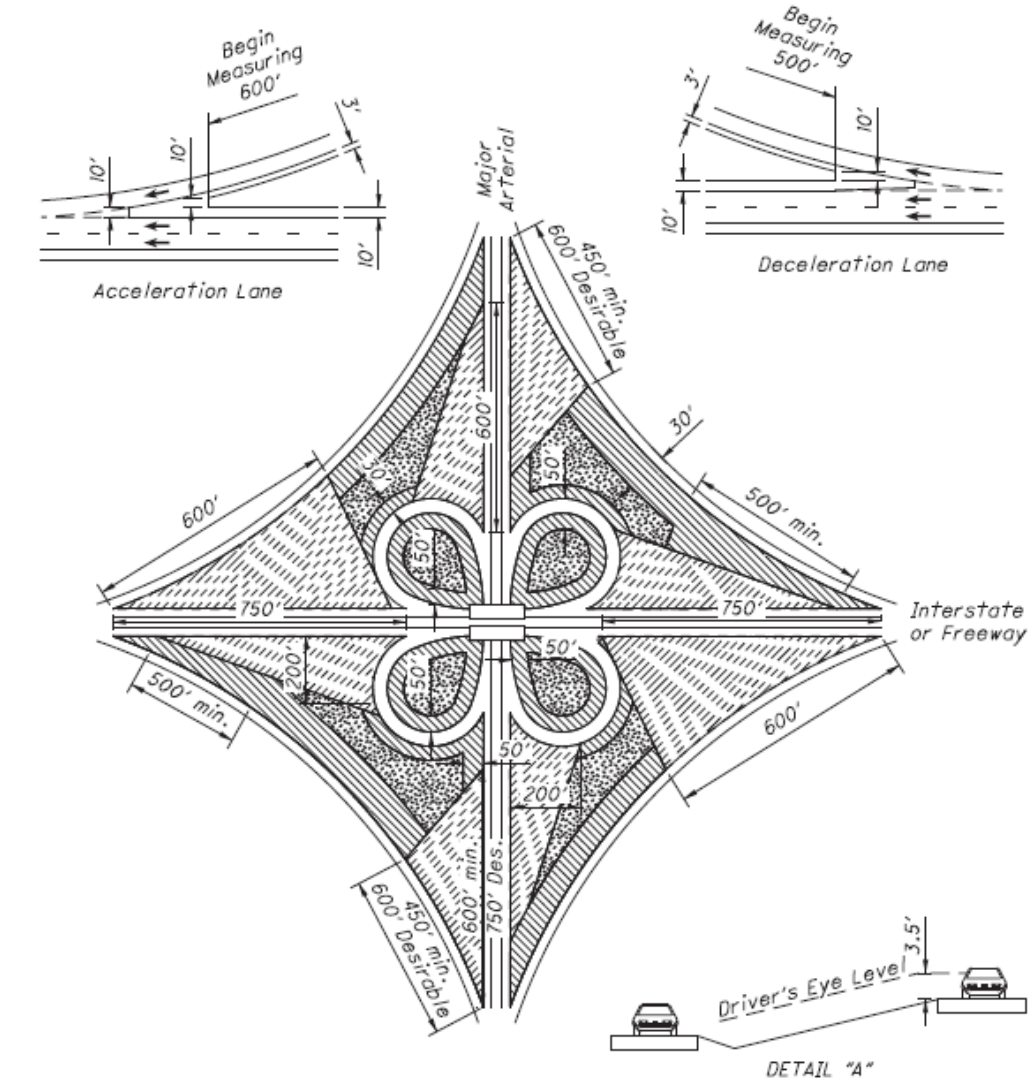
* 12′ min. in high risk areas such as outside of curves

NOTE:
When the widths of the shoulders and ditches do not conform with these typical sections, the 2′ min. distance behind the ditch and 2′ min. distance outside the shoulder break shall govern.

GATING GUARDRAIL END TERMINALS OFFSETS	905-1
	REFERENCE SECTION 905.1.5



GUIDE FOR LANDSCAPE PLANTING AT CLOVERLEAF INTERCHANGES FIGURE 3	905-2
	REFERENCE SECTION 905.3.1 & 906.1.2



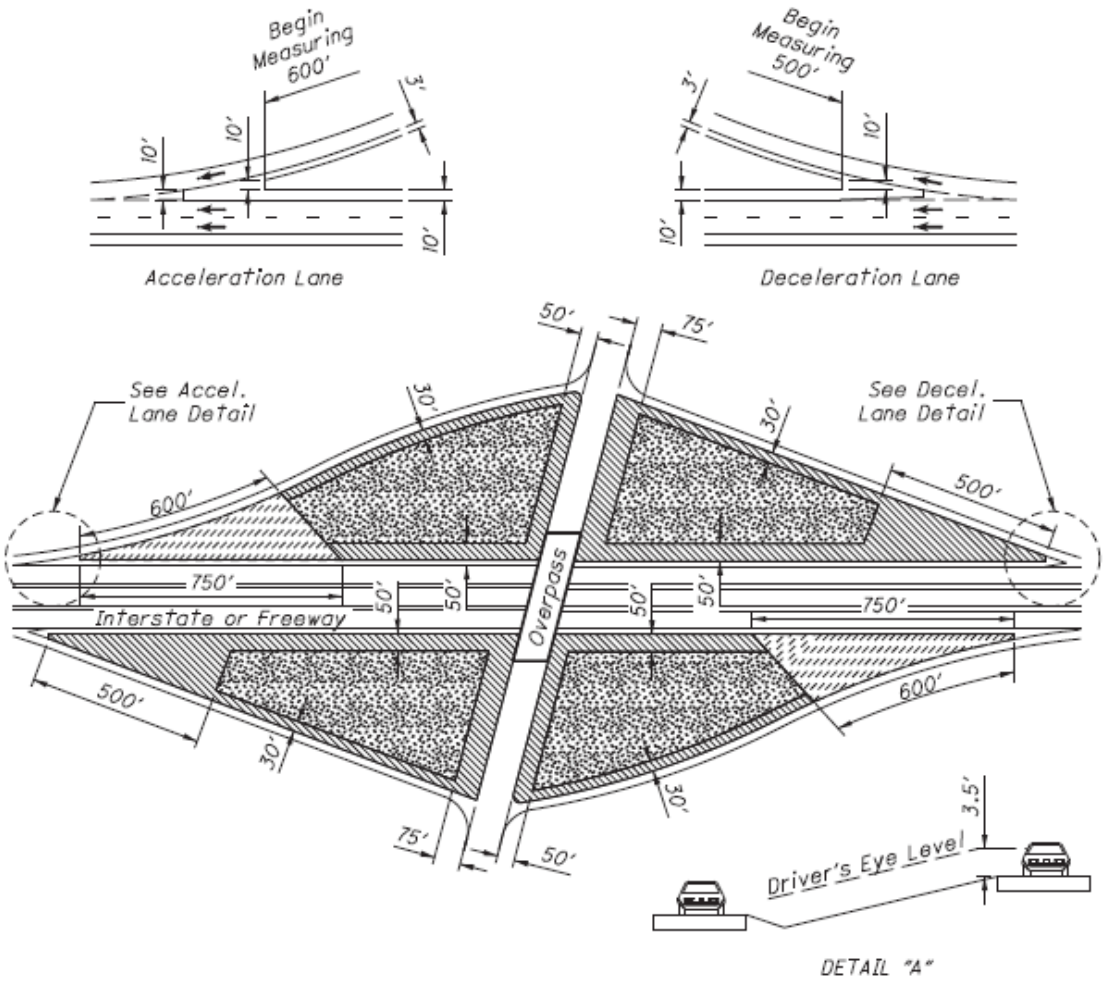
Tall Plantings and Trees Permitted in These Areas Where They Do Not Effect Lighting

Low Plantings Not to Obstruct Driver's View Permitted in These Areas, Except on Shoulders and Ditches

Low Plantings Not to Obstruct Driver's View of the Pavement on Shoulders and Ditches (See Detail A)

July 2014

GUIDE FOR LANDSCAPE PLANTING AT DIAMOND INTERCHANGES FIGURE 4	905-3
	REFERENCE SECTION 905.3.1 & 906.1.2



Tall Plantings and Trees Permitted in These Areas Where They Do Not Effect Lighting

Low Plantings Not to Obstruct Driver's View Permitted in These Areas, Except on Shoulders and Ditches

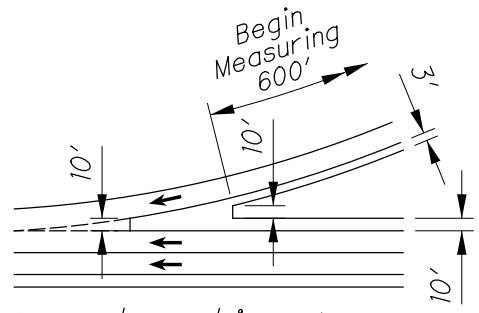
Low Plantings Not to Obstruct Driver's View of the Pavement on Shoulders and Ditches (See Detail A)

July 2014

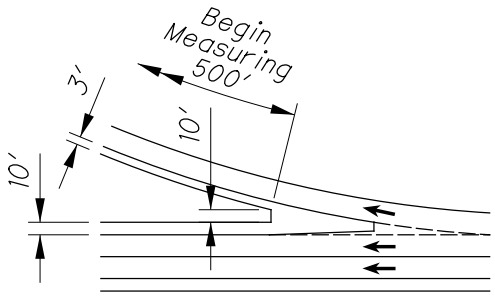
LANDSCAPE PLANTING GUIDE AT DIVERGING DIAMOND INTERCHANGES

905-3a

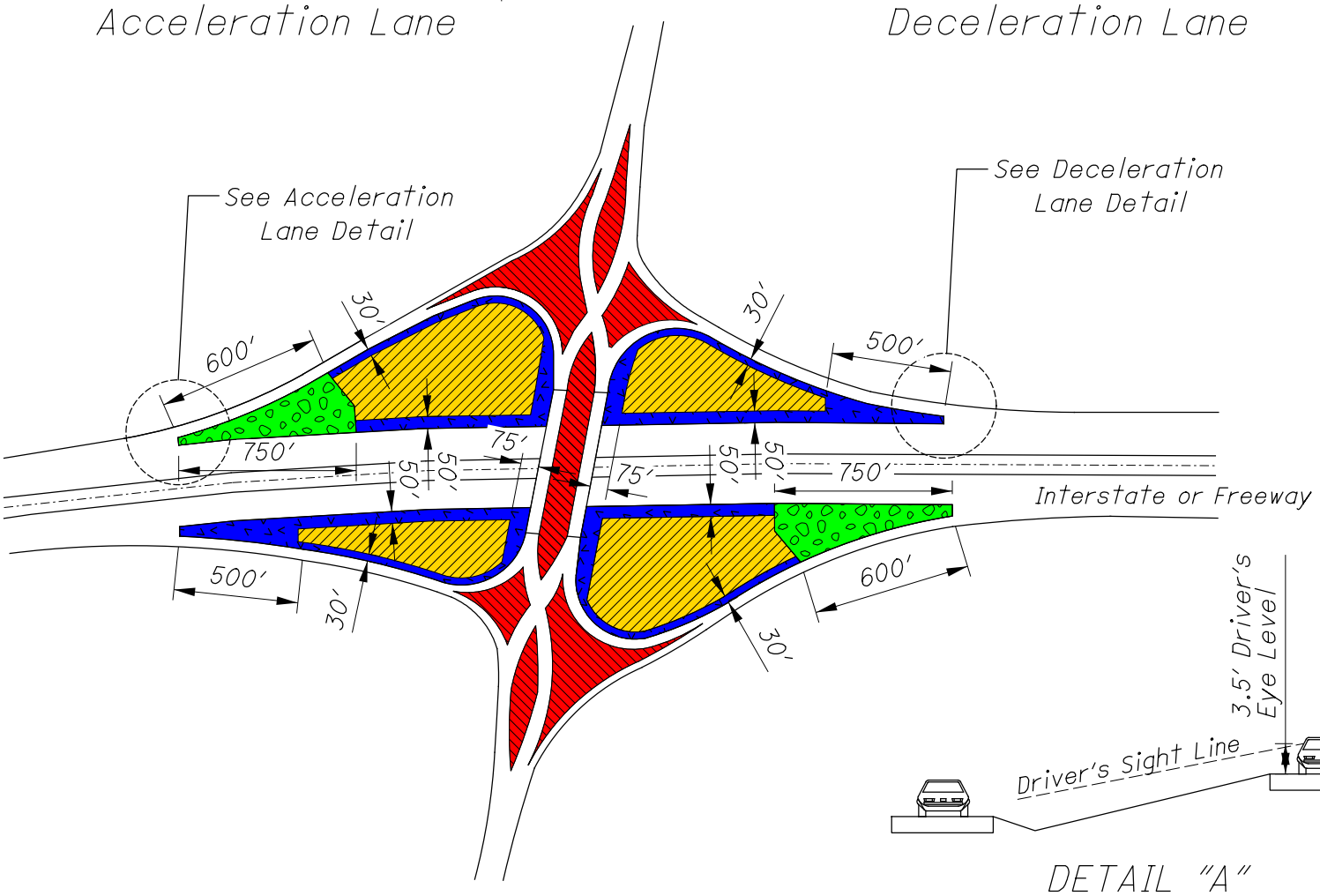
REFERENCE SECTION
905.3.1 & 906.1.2

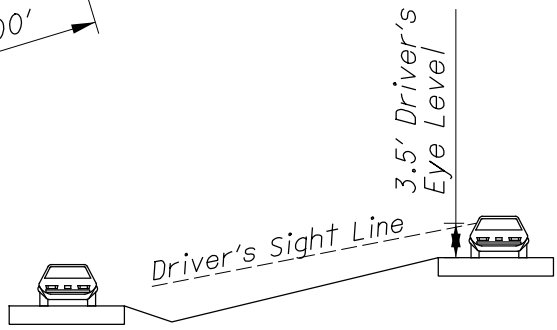


Acceleration Lane



Deceleration Lane





DETAIL "A"

Tall plantings and trees permitted in these areas where they do not effect lighting

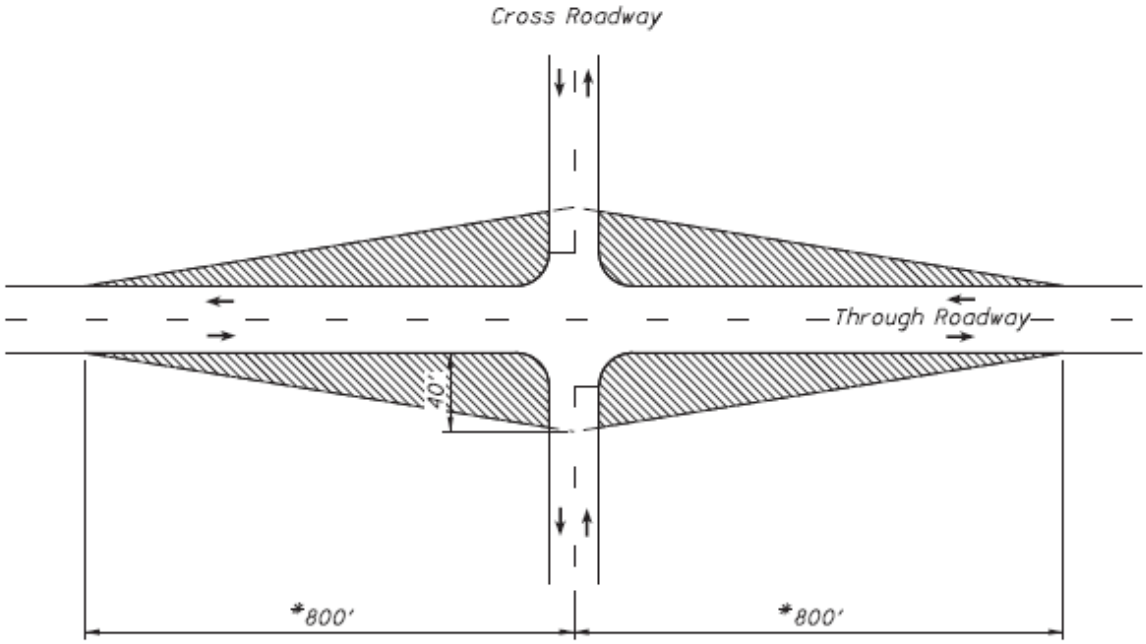
Low plantings not to obstruct driver's view permitted in these areas, except on shoulders and ditches

Low plantings not to obstruct driver's view of the pavement on shoulders and ditches (See Detail A)

No plantings

July 2025

LANDSCAPING SETBACKS AT INTERSECTIONS	905-4
	REFERENCE SECTION 905.3.2



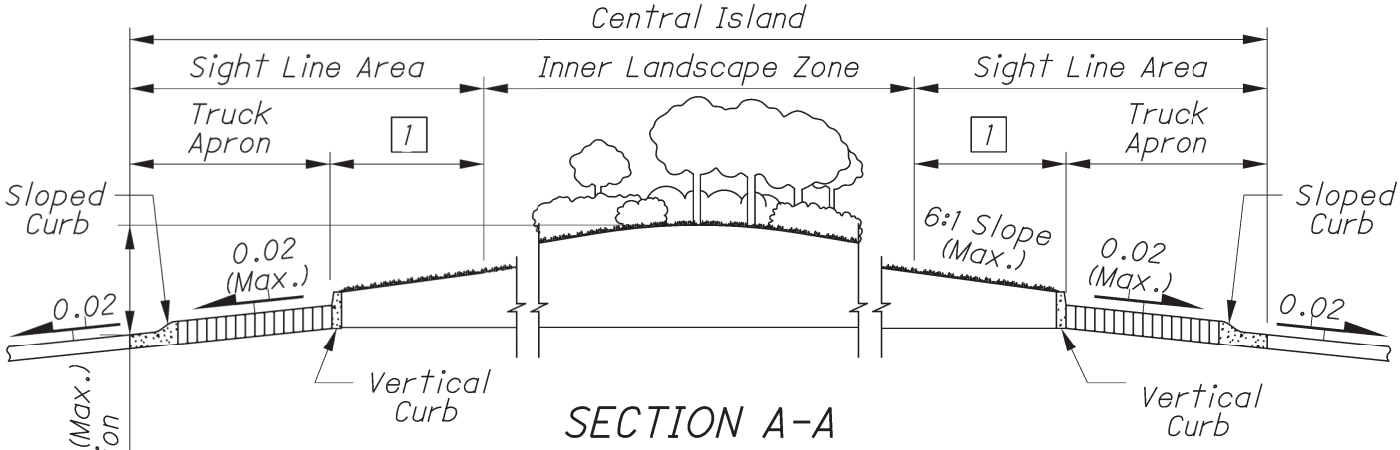
* These distances apply where speeds do not exceed 55 MPH

Low plantings not to obstruct driver's view permitted in these areas, except on shoulders and ditches

ROUNDABOUT CENTRAL ISLAND GRADING AND LANDSCAPING

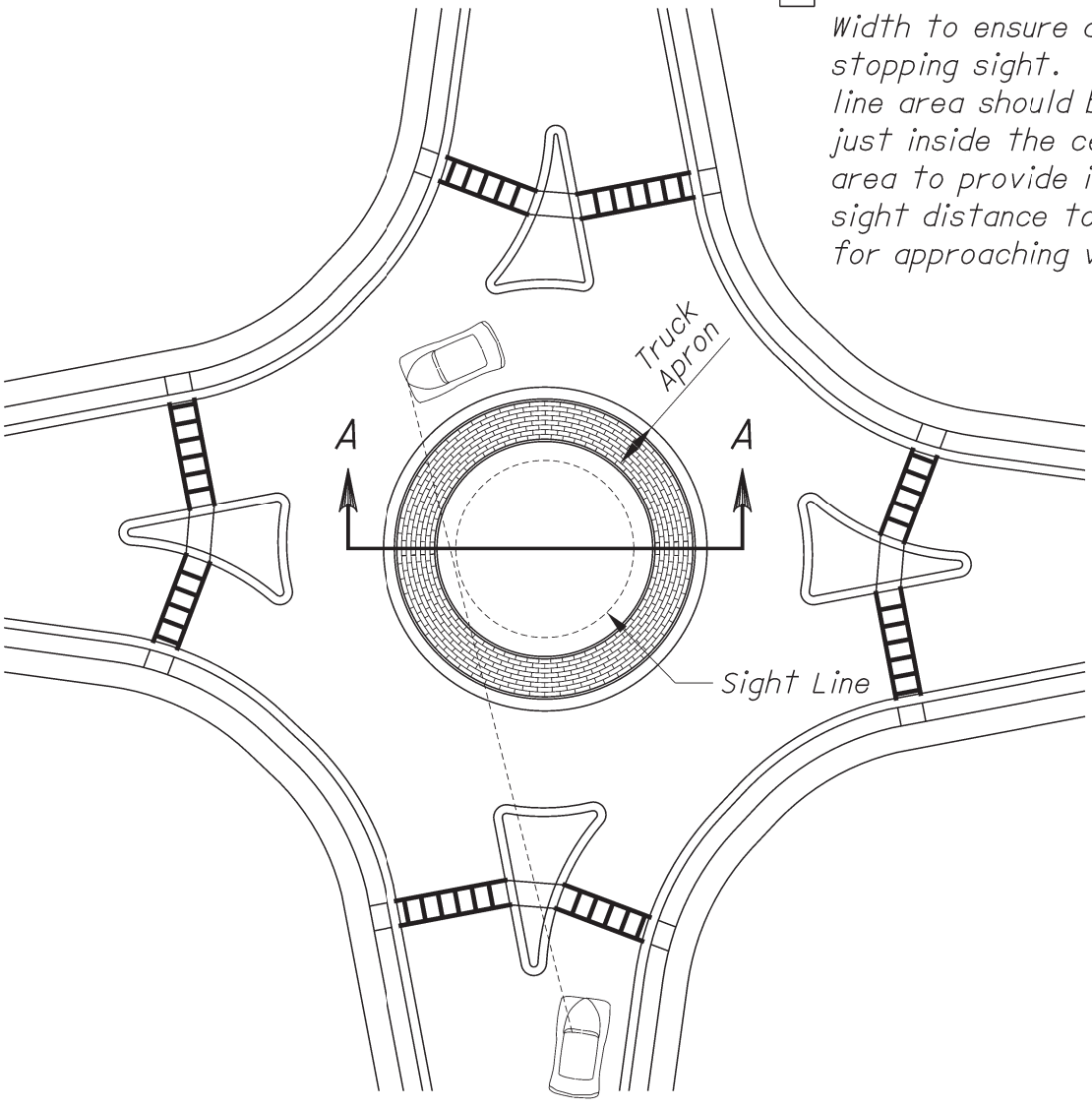
905-5

REFERENCE SECTION
905.3.3



SECTION A-A

1 Perimeter Landscape Zone Width to ensure adequate stopping sight. The sight line area should be 6' - 10' just inside the central island area to provide intersection sight distance to the left for approaching vehicles.



COMMUNITY GATEWAY MONUMENT CHECKLIST	905-6
	REFERENCE SECTION 904.2

District: Community: Location:

Criteria	YES	NO	N/A	Comments
GENERAL				
Has it been officially authorized by local ordinance or resolution?				
Does this only communicate the name of a city, village, township or county?				
Is there only one Community Gateway Monument per route per direction?				
If a seal, slogan, date of establishment, graphic, or logo is present and visible, is it officially related to and adopted by the community?				
If official city, village, township, county, State or U.S. flag(s) is present and visible, are there no more than 3 of any such flag?				
Is it free from religious, political, special interest, private, or commercial messages of any sort including but not limited to symbols, logos, business names, trade names or jingles?				
Is it free from any non-community related displays, advertising, decorative banners, or non-governmental flags?				
Does it conform to Ohio Outdoor advertising rules, regulations, laws and all local sign ordinances? ODOT's website for outdoor advertising control.				
Is it a non-integral or nonrequired highway feature?				
Is it ground mounted?				
Are the natural features (i.e., trees, rocks, etc.) untouched and free from all medium (i.e., paint, carvings, etc.)?				
LOCATION				
Is it located such that it is not placed along the mainline of freeways and expressways or at freeway to freeway (major directional) interchanges?				
Is it located either at or near interchange ramp areas of a service interchange or along the mainline of conventional highways (not a freeways or expressways)?				

If located at or near interchange ramp areas of a service interchange, is it placed in an acceptable location in accordance with Location and Design Vol. 1, Figure 905-3?				
If located at or near interchange ramp areas of a service interchange, is it located such that it is not directed toward the mainline of the major highway but rather toward the drivers that have exited the mainline?				
Is it located beyond the clear zone and placed to minimize the likelihood of being struck by an errant vehicle, or an appropriate distance behind an existing protective barrier?				
Is it located such that it doesn't need to install or extend protective barriers for the sole purpose of protecting it?				
Is it located such that it does not protrude or span over travel lanes or roadbed?				
Is it located such that it does not interfere with or distract from official traffic control devices?				
LOCATION CONTINUED				
Is it located such that it does not interfere with the operational right-of way above the roadway?				
Is it located such that it doesn't restrict sight distance per Chapter 200 in Location and Design Vol. 1?				
Is it located where maintenance can be safely performed?				
Is it located such that construction of the monument does not require any removal, pruning or harming of trees, shrubs or other vegetation for long term visibility or during construction of the monument? (Pruning of tree branches or roots, and removal of shrubs will be allowed only with approval of the ODOT District Office.)				
Is it located such that it does not negatively impact existing highway features, including existing signs, or irrigation systems?				
SIZE				
Is the size appropriate to the proposed setting and community context?				
Does it fit within the maximum size dimensions of a width of 25 feet, a height of 10 feet and a depth of 10 feet?				
MAINTENANCE*				
Does it require low or no maintenance to minimize exposure of workers and others to potential risks?				
It is composed of materials that are durable for the projected life span of the monument?				

(e.g., stone, brick, appropriately treated lumber, etc.)				
UTILITIES				
Is it free from using any underground utilities (e.g., electric, gas, water, fiber, etc.)?				
VISUAL APPEARANCE				
Is the visual appearance appropriate to the proposed setting and community context?				
Is it free from lighting features that impairs or distracts the vision of transportation system users?				
Is it free from blinking or intermittent lights, changeable message signs or any type of digital display?				
Is it free from moving elements (kinetic art) or simulated movement?				
Is it free from reflective or glaring surface finishes?				
Is it free from any type of water features?				
Does it only use colors other than those reserved for official traffic control devices described in the Ohio Manual of Uniform Traffic Control Devices (OMUTCD), to minimize possible confusion with a standard OMUTCD signs?				
Is it free from garish, fluorescent or otherwise distracting colors?				
Is it free from displaying telephone numbers, street addresses, or Internet addresses?				

*Maintenance - Upon approval of the Community Gateway Monument, it is the responsibility of the applicant to establish a Maintenance Agreement between the Local Entity and the Department for the care and upkeep of said Community Gateway Monument.

Community Gateway Monuments shall be kept clean, free of graffiti, and in good repair. The Local Entity shall be required to provide for regularly scheduled maintenance, as described in the maintenance agreement, for its lifespan, including graffiti removal and restoration work to maintain the integrity of the approved project. Maintenance practices shall protect air and water quality as required by law.

The Department may perform maintenance activities around the Community Gateway Monument such as litter pickup and other maintenance that is normally associated with the transportation facility or right-of-way. The Department will not provide maintenance of the Community Gateway Monument itself. Any other maintenance activities anticipated by the Local Entity that are over and above what the Department would normally provide will be documented by Maintenance Agreement.

SAMPLE TREE PLANTING SPECIFICATIONS

Endorsed by
Ohio Nursery and Landscape Association and ODNR Division of Forestry

Purpose: To increase transplanting success by providing municipalities with the most current and acceptable tree planting procedures. This information, prepared in specification format, will enable communities to convey specific requirements to contractors, developers, and/or volunteers. It contains the fundamental elements necessary to ensure transplanting success, and is intended to be a template that can be expanded to address other project issues.

Endorsement: This information is approved and endorsed by the Ohio Nursery and Landscape Association, and the Ohio Department of Natural Resources Division of Forestry.

Assumptions: All plant material complies with American Standard for Nursery Stock ANZI Z60.1. All plant material has been selected based on site conditions and constraints.

Planting Balled and Burlapped Trees:

-If not readily apparent, locate root flare by removing twine, burlap, and excess soil.
-Dig tree hole at least two times wider than the tree ball, with sides sloped to an unexcavated or firm base. Dig hole to a depth so the located root flare, at the first order lateral root, will be at finished grade.
-Lifting only from the bottom of the root ball, position tree on firm pad so that it is straight and top of root flare is level with the surrounding soil.
-Remove all twine from the root ball. If present, remove and discard at least the top one half of the wire basket. Burlap shall be removed from the top to a point halfway down the root ball and discarded.
-With clean, sharp pruning tools, prune off any secondary/adventitious, girdling, and potential girdling roots.
-Backfill planting hole with existing unamended soil, and thoroughly water.
-Mulch the entire planting surface with composted bark applied no less than two inches (2") deep and no more than three inches (3") deep, leaving three inches (3") adjacent to the tree trunk free of mulch.

Planting Containerized or Grow Bag Trees:

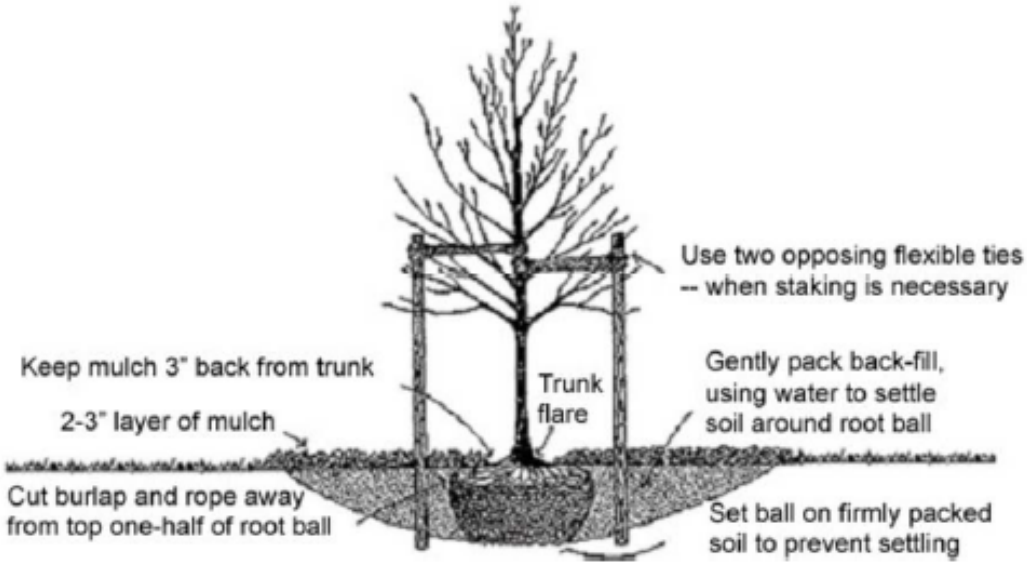
-If not readily apparent, locate root flare by removing excess soil.
-Dig tree hole at least two times wider than the tree ball with sloping sides. Dig hole to a depth so the located root flare, at the first order lateral root, will be at finished grade.
-Create a firm soil mound at the bottom of the planting hole.
-Remove tree from container or grow bag and completely tease apart root system, repositioning any girdling or potentially girdling roots.
-Spread roots over soil mound so that root flare is at finished grade and the tree is straight.
-With clean, sharp pruning tools, prune off any secondary/adventitious, girdling, and potential girdling roots.
-Backfill planting hole with existing unamended soil and thoroughly water.
-Mulch the entire planting surface with composted bark applied no less than two inches (2") deep and no more than three inches (3") deep, leaving three inches (3") adjacent to the tree trunk free of mulch.

Planting Bare Root Trees:

-Dig tree hole at least two times wider than the tree ball with sloping sides. Dig hole to a depth so the located root flare, at the first order lateral root, will be at finished grade.
-Create a firm soil mound at the bottom of the planting hole.
-Spread roots over soil mound so that root flare is at finished grade and the tree is straight.

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-With clean, sharp pruning tools, prune off any secondary/adventitious, girdling, and potential girdling roots.
-Backfill planting hole with existing unamended soil and thoroughly water.
-Mulch the entire planting surface with composted bark applied no less than two inches (2") deep and no more than three inches (3") deep, leaving three inches (3") adjacent to the tree trunk free of mulch.



1000 - Performance Based Project Development

1000 - Introduction

Performance Based Project Development (PBPD) is a planning and design philosophy being promoted by the Federal Highway Administration (FHWA) and State Departments of Transportation. The general premise of PBPD is that proposed improvements should be targeted and right sized based on project specific needs.

This philosophy places less emphasis on strict adherence to standards and more significance on safety and operational performance. PBPD is a design up philosophy that makes the necessary improvements to a facility to address specific performance issues. The goal of PBPD is to fix what is broken and to not unnecessarily spend scarce resources solely for the purpose of meeting published standards when those deficient features (as defined by our manuals) are not causing safety, operational or similar problems.

PBPD is a philosophy that will permeate every aspect of the ODOT project development process. PBPD is used to right size the initial scope of a project and will continue through preliminary engineering as well as into detail design. The goal of PBPD is to right size a project scope and the subsequent engineering decisions through the application of data, analysis and engineering judgement.

It is understood that no one project is more important than the overall system. Consequently, savings obtained from targeted PBPD solutions on specific projects can be reinvested in the overall system.

In ODOT, the basic tenants of PBPD will be:

- Safety will not be compromised;
- In many cases, the minimum standard will be the existing condition;
- A project Purpose & Need should be focused to address specific problems supported by data;
- Design solutions should focus on adherence to the project Purpose & Need;

- Solutions should be an optimized combination of mobility, operations and other modes;
- Designs should be consistent with the context of the corridor;
- Designs should strive to maximize benefit/cost.

PBPD may be applicable to any project and can occur at various phases of the project development process. Planning, Preliminary Engineering, Environmental Engineering and Design can all afford PBPD opportunities. Some projects will, however, obviously have more potential PBPD possibilities than others. Path 1 projects by their very nature will have limited PBPD opportunities. Conversely, more complex projects will generally have more opportunities for meaningful PBPD considerations.

1001 - Application to the PDP

PBPD can happen throughout project development and can be applied to any number of project processes and elements. The key elements to PBPD will be thoughtful application, balanced consideration and documentation. An effort should be made to stay on the existing alignment (vertical and horizontal) to the maximum extent practical when this will allow for the rehabilitation of existing infrastructure (structures, pavements, median barriers, etc.) rather than construct new infrastructure on a different alignment. In all cases, however, the decisions related to PBPD should consider and balance the benefits, disadvantages, costs & impacts.

1001.1 - Planning

PBPD in the Planning phase of a project does not address specific design criteria; rather, it relates to the scope by establishing the Needs of a project. Thoughtful establishment of a project's Needs allows the project to focus on fixing critical elements and save funding by potentially not fixing those elements that aren't deemed to be unacceptably impactful to safety, operations, system conditions, stakeholder concerns or other similar factors.

During the planning phase technical studies will be used to identify those features that are critical and those features that would only be addressed as budget and impacts (benefit/cost) allow. The product of this effort will be the identification of Primary and Secondary Needs that will be incorporated into the project Purpose and Need. Stakeholder involvement can be a useful tool in identifying the context or relative

importance of Primary and Secondary needs as identified through technical studies. Subsequent Preliminary Engineering activities such as the Feasibility Study, AER, IMS, etc. would identify solutions to the Primary and Secondary Needs with a determination if the impacts and cost justify addressing a particular Secondary Need as part of the project.

Primary Needs are those elements of a project that are critical for the project to address in order to satisfy the Purpose and Need. Secondary Needs are essentially elements that may or may not be addressed by the project based upon the cost and impacts they create. The technical studies will be the basis to classify a particular need as being Primary or Secondary. In practical terms, Primary Needs are those that the project must address to the extent feasible. Secondary Needs do not rise to the level of a Primary Need based upon the technical studies (ex. Safety, HCS, HSM, System Conditions, etc.), the context of the project or stakeholder concerns and may ultimately not be addressed by the project depending upon their costs and the impacts they create. A project element may not meet existing standards, policy or guidance and still could be considered a Secondary Need if it is not unduly impacting safety, operations, maintenance or stakeholder concerns.

For example, a common application of this might be a Secondary Need to “Improve Existing Geometrics”. In this example some of the existing geometric elements within the project limits may not meet full L&D Volume 1 standards but the analysis/technical studies performed to craft the P&N shows that these deficient elements are not creating any undue safety or operational problems. In this situation, the project would strive to improve (design up) those geometric features identified as Secondary Needs until the cost and impacts are deemed to be impractical in terms of benefit/cost. The term improve should be noted as the goal is to make improvements to the extent practical, not necessarily to meet full standards if the cost or impacts outweigh the benefits.

During identification of Needs and the subsequent formulation of the Purpose & Need no decision is made about if the project will address a particular Secondary Need. That determination will be made during Preliminary Engineering through the Feasibility Study and AER (if applicable) when sufficient alternative information is available to make a balanced decision. The level of effort to determine if a Secondary Need should be addressed should be as minimal as possible in order to make an informed benefit/cost decision. In addition to determining the cost/impact ramifications of addressing a Secondary Need, the original technical studies (ex. existing crashes and operational performance) may be referred to as a potential information source when making these

decisions. Some decisions will be obvious to a practical person and minimal effort will be required in order to document the decision to not address a Secondary Need.

Establishment of Secondary Needs creates a powerful opportunity in the subsequent Preliminary Engineering phase for PBPD savings in terms of impacts and cost savings.

The following is a non-all-inclusive list of some potential PBPD opportunities for consideration in Planning:

- Addressing secondary needs
- Design Year
- Design Volumes
- Design Speed (Context of Adjacent Corridor)
- Rehab versus replace

1001.2 - Preliminary Engineering

Projects should always address the Purpose & Need to the extent practical and possible. This is especially true of the Primary Needs incorporated into the Purpose & Need document. The Secondary Needs, however, represent a significant opportunity to apply PBPD principals in order to minimize impacts or contain costs.

The Feasibility Study and AER (where applicable) is used to evaluate alternatives to address the Purpose & Need. Included should be an assessment of impacts and costs necessary to address Secondary Needs of the project. PBPD philosophy dictates that the benefits of addressing a Secondary Need is balanced against the impacts and costs in order to make an informed decision. When the benefits outweigh the impacts and costs the Secondary Need should be addressed by the project. In those cases when the impacts and/or costs are deemed to outweigh the benefits the project may opt to not include addressing that particular Secondary Need or to make an improvement that falls short of meeting the standard. This same methodology can be applied to any number of potential project elements identified as Secondary Needs.

It will often not be appropriate for PBPD decisions during Planning and Preliminary Engineering to be made unilaterally at the project level. Some decisions could affect subsequent processes or approvals (ex. a Structure Type Study, IMS or Design Exceptions). It is important for evaluations of PBPD decisions in Planning or Preliminary Engineering to include the appropriate disciplines, process owners and approvers in order to avoid potential back tracking later in the development process. The owners of those subsequent decision points should be involved in the evaluation and acceptance of PBPD decisions during Planning and Preliminary Engineering. For example, an interchange improvement may identify improving one specific movement as being a Primary Need. The Office of Roadway Engineering (ORE) is responsible for the eventual approval of the subsequent IOS/IMS. In this case ORE should be involved in the decision to not address the other movements in order to avoid potential back tracking during evaluation of the IOS/IMS.

The following is a non-all-inclusive list of some potential PBPD opportunities in Preliminary Engineering:

- Operational Performance
    - LOS Criteria
    - 600’ of Access Control along the crossroad for diamond ramps
- Alternatives
    - Facility Type (expressway, freeway, super 2, etc.)
    - Grade separation versus unconventional intersection
- Geometrics
    - Ramp Terminal Spacing
    - Removal of inside merges
    - Removal of left exits or entrance ramps

1001.3 - Design

Design in this context refers to Stage 1, Stage 2 and Stage 3 plans. As such, Design centric PBPD opportunities can occur during Preliminary Engineering, Environmental Engineering or Final Engineering depending on the project path/PDP requirements.

PBPD Design is a “design up” philosophy rather than the traditional approach to make every facet of a facility meet every standard even when those deficient standards (as defined by our manuals) are not causing any operational or safety problems.

PBPD in Design is typically associated with meeting specific geometric design standards and guidelines. The application of PBPD in Design requires a departure from the traditional mentality that meeting design standards is a metric, either formally or informally, to measure the success of a given design. Meeting standards is a worthwhile goal, however, in many instances the cost of meeting all of the design standards can be prohibitively expensive or impactful; sometimes to upgrade substandard geometric features that are not causing undue problems.

Design has formally recognized the concept of PBPD for a very long time through the Design Exception (D.E.) process. Where it is not practical to meet one of the Controlling Criteria due to various impacts and/or costs, a Design Exception is a formal approval process to evaluate and document the decisions (Refer to L&D Volume 1, Section 105). Design Exceptions will continue to be the primary method to document deviations from the Controlling Criteria during Design. Deviation from other Design criteria (non-Controlling Criteria) that do not require Design Exceptions should also be evaluated and documented throughout project development.

It should be noted that application of PBPD in Design can still be beneficial when addressing Primary Needs of the project. The project can still address the Primary Need while reducing impacts and/or costs through the application of Design based PBPD to specific design criteria related to the Primary Need.

Proposed deviations from standards, policies and guidelines must be balanced decisions that considers the potential advantages and disadvantages of the proposal. The decision should be based when appropriate upon a quantitative comparison potentially including historical crashes, predicted crashes (HSM), capacity analysis (HCS), turn and vehicle tracking and similar methodologies. The analytical effort should be commensurate with the

proposal and in all cases should be documented. For proposals requiring deviation from Controlling Criteria, a Design Exception will be required.

The following is a non-all-inclusive list of some potential PBPD opportunities in Design:

- Geometrics
    - Typical/ Cross Section (for both cost/impact avoidance or context)
    - Median width
    - Roadside grading (safety, clear zone, common or barrier)
    - Cross slope corrections
    - Upgrading entrance ramp terminals including additional acceleration length if needed
    - Upgrading exit ramp terminals by providing the standard diverging curvature
    - Providing the minimum ramp design speed

1002 - Evaluation of PBPD Options

1002.1 - General

PBPD decisions should be informed, weighing both the positive and negative impacts (B/C). There is no single process that can be used to evaluate PBPD opportunities. The evaluation methodology and level of effort should be commensurate with the complexity of the situation. When appropriate, decisions should be based on comparative quantification through the use of HCS, HSM, vehicle tracking (for narrow lanes), simulation, technical studies, or similar evaluations.

The level of analysis should be commensurate with the proposal and the facility type. For example, the level of analysis to “squeeze in” an additional interstate lane with resulting narrower lane and shoulder widths would be significantly higher than a proposed spot narrowing of a shoulder underneath an overhead structure.

The historical approach of absolute adherence to standards has primarily been used as a proxy measure of a design's expected safety performance. With the advent of the **Highway Safety Manual (HSM)** and its predictive safety performance methodologies we can now quantify the expected ramifications of many PBPD opportunities.

1002.2 - HSM for Evaluation

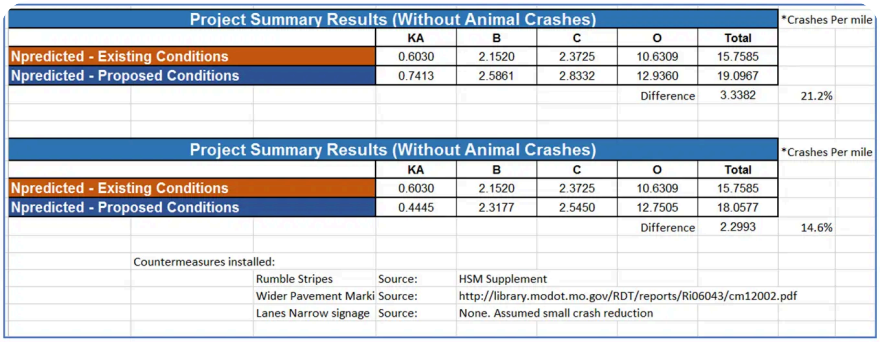
HSM is an analytical tool, which in some cases, can be used to compare the expected crashes between different alternatives. HSM, like other analytical tools, should not normally be the sole basis of making decisions. It can, however, be a factor providing a quantified comparison of potential safety performance in terms of expected crashes.

When appropriate and when the situation does not exceed the capabilities of the software (ECAT) or research data set, HSM can be used to compare expected crashes between alternatives. Safety should always be an important consideration, however, that does not mean an HSM analysis cannot predict an increase in crashes on any proposed alternatives. The question becomes what is the magnitude of the predicted crash increases and what are the associated severities.

For example, it may be perfectly appropriate for a PBPD alternative to accept a modest increase in property damage (PDO) crashes if the offsetting benefits afforded by the alternative are commensurately high.

Below is an example HSM analysis for a pilot PBPD project where:

- KA = Fatalities and Incapacitating Injuries;
- B = Visible Injuries;
- C = Non-Visible Injuries;
- O = Property Damage



Project Summary Results (Without Animal Crashes)						*Crashes Per mile
	KA	B	C	O	Total	
Npredicted - Existing Conditions	0.6030	2.1520	2.3725	10.6309	15.7585	
Npredicted - Proposed Conditions	0.7413	2.5861	2.8332	12.9360	19.0967	
				Difference	3.3382	21.2%

Project Summary Results (Without Animal Crashes)						*Crashes Per mile
	KA	B	C	O	Total	
Npredicted - Existing Conditions	0.6030	2.1520	2.3725	10.6309	15.7585	
Npredicted - Proposed Conditions	0.4445	2.3177	2.5450	12.7505	18.0577	
				Difference	2.2993	14.6%

Countermeasures installed:

Rumble Stripes	Source:	HSM Supplement
Wider Pavement Marki	Source:	http://library.modot.mo.gov/RDT/reports/Ri06043/cm12002.pdf
Lanes Narrow signage	Source:	None. Assumed small crash reduction

Example HSM Analysis

It should be noted that an increase to the expected crashes predicted by HSM may be potentially mitigated with the application of appropriate safety countermeasures. These countermeasures should be factored into the HSM analysis. In the above “Project Summary Results”, the difference between the upper and lower comparisons is the lower has incorporated Safety Countermeasures to reduce the number of predicted crashes.

Refer to the Safety Analysis Guidelines maintained by the Office of Transportation and Economic Development for detailed analysis requirements.

1003 - PBPD Examples

1003.1 - Secondary Needs

Design preference is for ramps to enter/exit from the right hand side due to driver expectation. Converting a left hand ramp to a right hand ramp can be costly or impactful. It might be considered a Secondary Need if the existing left hand ramp is not causing undue safety or operational problems. If the project has interest in potentially retaining a left hand ramp a technical study should be conducted during Planning to determine if the existing left hand ramp is causing undue safety or operational problems. Based upon the results of the technical studies, the project may potentially determine that relocating the ramp to the right side is only a Secondary Need of the project.

The Feasibility Study and/or the AER would determine the actual potential impacts and costs of switching the ramp to the right hand side. A determination about the project addressing this Secondary Need would be made based upon the impacts and costs versus the benefits (B/C).

1003.2 - Design Year/LOS

A PBPD Preliminary Engineering opportunity could be related to the proposed alternatives and Design Year/Level-of-Service (LOS) requirements. For example - an expressway with at-grade signalized intersections is suffering from congestion and congestion related crashes. A Primary Need of the project might be to improve corridor capacity. Note that the Primary Need is not to meet a specified LOS, but to improve capacity. This provides for flexibility in identifying and evaluating alternatives. In these types of situations it would traditionally be common and logical to propose variations of grade separations as the alternatives. The cost of these new interchanges could, however, be prohibitively expensive with little likelihood of funding being available for the foreseeable future.

A PBPD alternative might be to also propose alternative intersection designs such as a Superstreet signalized intersection. The Superstreet operation would not provide the same capacity as a grade separation and it might not potentially meet Design Year LOS criteria, however it does meet the Purpose and Need of the project by improving corridor capacity. It could work acceptably for many years and it would provide significant capacity improvements as compared to the existing (no-build) traditional traffic signals. The Superstreets would also be much less expensive and have the potential to obtain the necessary construction funding. In this case, the Superstreet meets the Primary Need (though not to the extent of a grade separation) by improving corridor capacity but it could potentially fail to meet 20 year LOS criteria. In the context of PBPD, a determination would have to be made if the benefits provided outweigh the costs and impacts of the grade separation.

1003.3 - Bottleneck Projects

Bottlenecks are capacity constraints typically contained in a fairly small geographic area. They can be caused by insufficient capacity due to the number of basic mainline lanes, weaves, merges or other geometric features that cause traffic operational problems.

A potential PBPD solution might be to “squeeze in” an additional lane which may result in less than standard lane widths, shoulder widths or barrier offsets. The Performance of the proposed resulting typical section would be the basis of determining if this type of alternative should be approved, specifically:

1. Capacity analysis can be used to predict the operational benefits;

2. HSM can be used to predict the expected safety performance of the proposed typical section versus the existing (example – expected crash performance related to narrower lanes, shoulders and offsets to barriers versus benefits from reduced congestion);

3. Design vehicle tracking could be investigated to ensure there is not infringement on adjacent lanes;

4. Investigation of hydraulic spread on a reduced shoulder width could be necessary;

5. Others analysis and considerations as the situation and proposal require;

Like all PBPD decisions, the results of the alternative analysis would be the basis of deciding if the benefits of a “squeezed in” lane outweigh the negatives.

1003.4 - Context

PBPD can be applied to establish a project’s design criteria based upon the surrounding context or stakeholder input. An example of this might be a corridor that is winding with narrow lanes and shoulders throughout its length. It may not make sense and may potentially be prohibitively expensive and impactful to improve one section of that roadway to meet full geometric standards. In this case, the project might set geometric goals to improve the geometric design to a practical extent while not attempting to meet full standards. In the end, the corridor will always be a winding road with little likelihood of ever being relatively straight and flat (meeting our standards). Meeting standard in one small section of the corridor, far exceeding the context of the rest of the corridor, might provide relatively little benefit at a relatively large expense. The cost of fully meeting standards would deprive the necessary construction funds from being available to meet other system needs.

It may be practical and appropriate to set design criteria, operational performance requirements and other project level metrics based upon the context of the corridor as well as stakeholder input.

Appendix B: Sample Plan Notes

NOTE: Appendix A & C have been removed.

R112a – ITEM 606 – ANCHOR ASSEMBLY, MGS TYPE B

THIS ITEM SHALL CONSIST OF FURNISHING AND INSTALLING ANY OF THE MASH 2016 TYPE B FLARED END TREATMENTS FOR TYPE MGS GUARDRAIL AS LISTED UNDER "PRODUCTS ACCEPTED FOR NEW INSTALLATIONS" ON THE ROADWAY APPROVED PRODUCTS LIST POSTED ON ROADWAY ENGINEERING'S WEB PAGE. INSTALLATION SHALL BE AT THE LOCATIONS SPECIFIED IN THE PLANS, IN ACCORDANCE WITH THE MANUFACTURER'S SPECIFICATIONS. REFER TO THE POSTED SHOP DRAWINGS FOR THE MOST CURRENT APPROVED PRODUCT MODELS.

REFER TO THE MANUFACTURER'S INSTRUCTIONS REGARDING THE INSTALLATION OF, AND THE GRADING AROUND, THE FOUNDATION TUBES AND GROUND STRUT. THE TOP OF ANY FOUNDATION TUBE SHOULD BE LESS THAN 4 INCHES ABOVE THE GROUND. ON-SITE GRADING IS REQUIRED IF THE TOP OF THE FOUNDATION TUBES OR TOP OF THE GROUND STRUT DOES PROJECT MORE THAN 4 INCHES ABOVE THE GROUND LINE.THE PLACEMENT OF THE FOUNDATION TUBES SHOULD BE AN APPROPRIATE DEPTH BELOW THE LEVEL LINE IN ORDER TO MAINTAIN THE FINISHED GUARDRAIL HEIGHT OF 31 INCHES FROM THE EDGE OF THE SHOULDER.

THE FACE OF THE TYPE B IMPACT HEAD SHALL BE COVERED WITH SOLID FLUORESCENT YELLOW REBOUNDABLE RETROREFLECTIVE SHEETING, PER CMS 730.191.

PAYMENT FOR THE ABOVE WORK SHALL BE MADE AT THE UNIT PRICE BID FOR ITEM 606, ANCHOR ASSEMBLY, MGS TYPE B, EACH, AND SHALL INCLUDE ALL LABOR, TOOLS, EQUIPMENT AND MATERIALS NECESSARY TO CONSTRUCT A COMPLETE AND FUNCTIONAL ANCHOR ASSEMBLY SYSTEM, INCLUDING REFLECTIVE SHEETING AND ALL RELATED HARDWARE, GRADING, EMBANKMENT AND EXCAVATION NOT SEPARATELY SPECIFIED, AS REQUIRED BY THE MANUFACTURER.

Designer Notes:

1. The system length varies with each device but should be assumed to be 36'-5.5". System length is measured from the splice with MGS to post #1 of the Type B.
2. The device's length of need (LON) point is at post number 4; therefore, after calculating the required LON for the guardrail, deduct 19'-9.5" from the calculated length of need for the guardrail. The designer must show the calculated LON point on all guardrail runs in the plans.
3. Pre-approved shop drawings are reviewed and are on the Office of Roadway Engineering’s web page under the Roadway Approved Products List.
4. These end treatments are gating systems.
5. The standard offset for the face of rail at post #1 for the Type B varies from 3’-0” to 4'-0" depending on the device.
6. Use this plan note in conjunction with Type MGS Guardrail.
7. If the intent is to supply a non-MASH 2016 device per one of the exceptions allowed under Section 601.3, then paragraph 1 of the note shall be modified accordingly.

R112b – ITEM 606 – ANCHOR ASSEMBLY REBUILT, MGS TYPE B

THIS ITEM OF WORK CONSISTS OF REBUILDING A PORTION OF A DAMAGED MGS TYPE B ANCHOR ASSEMBLY. THE UNIT BID PRICE FOR EACH ITEM LISTED BELOW SHALL INCLUDE ALL LABOR, MATERIALS AND EQUIPMENT NECESSARY (INCLUDING ALL RELATED HARDWARE NOT SEPARATELY SPECIFIED) TO REMOVE AND REPLACE THE DAMAGED COMPONENT. THE ITEMS LISTED BELOW SHALL BE USED AS DIRECTED BY THE ENGINEER.

- ANCHOR ASSEMBLY, MISC.: MFLEAT IMPACT HEAD
- ANCHOR ASSEMBLY, MISC.: MFLEAT ANCHOR RAIL 12'-6"
- ANCHOR ASSEMBLY, MISC.: MFLEAT SECOND RAIL 10'-5"
- ANCHOR ASSEMBLY, MISC.: MFLEAT THIRD RAIL 13'-6 1/2"
- ANCHOR ASSEMBLY, MISC.: MFLEAT POST #1 TOP

- ANCHOR ASSEMBLY, MISC.: MFLEAT POST #1 BOTTOM
- ANCHOR ASSEMBLY, MISC.: MFLEAT GROUND STRUT
- ANCHOR ASSEMBLY, MISC.: MFLEAT HINGE POST UPPER
- ANCHOR ASSEMBLY, MISC.: MFLEAT HINGE POST LOWER
- ANCHOR ASSEMBLY, MISC.: MFLEAT BCT CABLE ANCHOR ASSEMBLY, BRACKET, AND BEARING PLATE
- ANCHOR ASSEMBLY, MISC.: 6' STEEL POST
- ANCHOR ASSEMBLY, MISC.: 12" BLOCKOUT

Designer Notes:

1. This item should primarily be used on "ding and dent" guardrail maintenance contracts.
2. The item list above may be modified at the discretion of the designer, and it is encouraged to coordinate district specific needs with field personnel who administer the contract.
3. If it is desired to repair NCHRP-350 devices, those items may be added in a similar, individualized fashion.
4. If it is desired to repair Type B devices attached to non-MGS/Type 5 rail, a separate item ANCHOR ASSEMBLY REBUILT, TYPE B should be used with the associated items list.

R113a – ITEM 606 – ANCHOR ASSEMBLY, MGS TYPE E

THIS ITEM SHALL CONSIST OF FURNISHING AND INSTALLING ANY OF THE MASH 2016 TYPE E TANGENTIAL END TREATMENTS FOR TYPE MGS GUARDRAIL AS LISTED UNDER "PRODUCTS ACCEPTED FOR NEW INSTALLATIONS" ON THE ROADWAY APPROVED PRODUCTS LIST POSTED ON ROADWAY ENGINEERING'S WEB PAGE. INSTALLATION SHALL BE AT THE LOCATIONS SPECIFIED IN THE PLANS, IN ACCORDANCE WITH THE MANUFACTURER'S

SPECIFICATIONS. REFER TO THE POSTED SHOP DRAWINGS FOR THE MOST CURRENT APPROVED PRODUCT MODELS.

REFER TO THE MANUFACTURER'S INSTRUCTIONS REGARDING THE INSTALLATION OF, AND THE GRADING AROUND THE FOUNDATION TUBES AND GROUND STRUT. THE TOP OF ANY FOUNDATION TUBE SHOULD BE LESS THAN 4 INCHES ABOVE THE GROUND. ON-SITE GRADING IS REQUIRED IF THE TOP OF THE FOUNDATION TUBES OR TOP OF THE GROUND STRUT DOES PROJECT MORE THAN 4 INCHES ABOVE THE GROUND LINE. THE PLACEMENT OF THE FOUNDATION TUBES SHOULD BE AN APPROPRIATE DEPTH BELOW THE LEVEL LINE IN ORDER TO MAINTAIN THE FINISHED GUARDRAIL HEIGHT OF 31 INCHES FROM THE EDGE OF THE SHOULDER.

THE FACE OF THE TYPE E IMPACT HEAD SHALL BE COVERED WITH SOLID FLUORESCENT YELLOW REBOUNDABLE RETROREFLECTIVE SHEETING, PER CMS 730.191.

WHEN THE FACE OF THE ADJACENT (ATTACHED) GUARDRAIL IS LESS THAN 4' OFFSET FROM THE PROPOSED EDGE LINE, AND PERMITTING SITE CONDITIONS EXIST: THE PROPOSED TYPE E ANCHOR ASSEMBLY SHALL BE INSTALLED AT A CONSISTENT FLARE RATE THROUGH THE FULL LENGTH OF THE SYSTEM. THE FLARE RATE SHALL BE A MAXIMUM OF 25:1 (RESULTING IN A 2' OFFSET). THE INSTALLATION SHALL BE IN ACCORDANCE WITH THE SHOP DRAWINGS, PRODUCT INSTALLATION MANUAL/GUIDANCE, AND AS DIRECTED BY THE ENGINEER.

PAYMENT FOR THE ABOVE WORK SHALL BE MADE AT THE UNIT PRICE BID FOR ITEM 606, ANCHOR ASSEMBLY, MGS TYPE E, EACH, AND SHALL INCLUDE ALL LABOR, TOOLS, EQUIPMENT AND MATERIALS NECESSARY TO CONSTRUCT A COMPLETE AND FUNCTIONAL ANCHOR ASSEMBLY SYSTEM, INCLUDING ALL RELATED TRANSITIONS, REFLECTIVE SHEETING, HARDWARE, GRADING, EMBANKMENT AND EXCAVATION NOT SEPARATELY SPECIFIED, AS REQUIRED BY THE MANUFACTURER.

Designer Notes:

1. The system length varies with each device but should be assumed to be 50'-10.5". System length is measured from the splice with MGS to the first post of the Type E.

2. The device's length of need (LON) point for all systems is at post number 3; therefore, after calculating the required LON for the guardrail, deduct the last 34'-4.5" of the unit (from post #3 to the splice with MGS) from the calculated length of need for the guardrail. The designer must show the calculated LON point on all guardrail runs in the plans.

3. Pre-approved shop drawings are reviewed and are on the Office of Roadway Engineering's web page under the Roadway Approved Products List.

4. These end treatments are gating systems.

5. A Type C delineator should be installed on a flexible post at the head of all Type E units located on the right side of the through roadway in areas that have known snowdrift/piling problems, or per District policy. A Type D delineator should be installed on a flexible post at the head of all Type E units located on the left side of the through roadway. Delineators shall be itemized separately and shall comply with Standard Construction Drawing TC-61.10 and CMS 620.

6. Use this plan note in conjunction with Type MGS Guardrail.

7. If the intent is to supply a non-MASH 2016 device per one of the exceptions allowed under Section 601.3, then paragraph 1 of the note shall be modified accordingly.

R113b – ITEM 606 – ANCHOR ASSEMBLY REBUILT, MGS TYPE E

THIS ITEM OF WORK CONSISTS OF REBUILDING A PORTION OF A DAMAGED MGS TYPE E ANCHOR ASSEMBLY. THE IMPACT HEAD FOR ANY SYSTEM SHALL NOT BE REUSED IF A HEAD-ON CRASH FACILITATED THE EXTRUSION OF GUARDRAIL, OR IF AN ANGLE CRASH RESULTED IN PHSICAL CONTACT WITH THE IMPACT HEAD (TYPICALLY CRASHES THAT OCCUR AT OR BEFORE POST #2).

THE UNIT BID PRICE FOR EACH ITEM LISTED BELOW SHALL INCLUDE ALL LABOR, MATERIALS AND EQUIPMENT NECESSARY (INCLUDING ALL RELATED HARDWARE NOT SEPARATELY SPECIFIED) TO REMOVE AND REPLACE THE DAMAGED COMPONENT. THE ITEMS LISTED BELOW SHALL BE USED AS DIRECTED BY THE ENGINEER.

- ANCHOR ASSEMBLY, MISC.: MSKT IMPACT HEAD

- ANCHOR ASSEMBLY, MISC.: MSKT ANCHOR RAIL 12'-6"
- ANCHOR ASSEMBLY, MISC.: MSKT POST #1 TOP
- ANCHOR ASSEMBLY, MISC.: MSKT POST #1 BOTTOM
- ANCHOR ASSEMBLY, MISC.: MSKT POST #2 TOP
- ANCHOR ASSEMBLY, MISC.: MSKT POST #2 BOTTOM
- ANCHOR ASSEMBLY, MISC.: MSKT BCT CABLE ANCHOR ASSEMBLY, BRACKET, AND BEARING PLATE
- ANCHOR ASSEMBLY, MISC.: MSKT STRUT
- ANCHOR ASSEMBLY, MISC.: SGET IMPACT HEAD
- ANCHOR ASSEMBLY, MISC.: SGET SPECIALIZED GR PANEL
- ANCHOR ASSEMBLY, MISC.: SGET YIELDING POST
- ANCHOR ASSEMBLY, MISC.: SGET STRUT
- ANCHOR ASSEMBLY, MISC.: SGET FOUNDATION TUBE (POST #1)
- ANCHOR ASSEMBLY, MISC.: SGET POST #1 AND PIPE SLEEVE
- ANCHOR ASSEMBLY, MISC.: SGET STRIKE PLATE AND WOOD STRIKE BLOCK
- ANCHOR ASSEMBLY, MISC.: SGET GUARDRAIL GRABBER AND REINFORCEMENT PLATE
- ANCHOR ASSEMBLY, MISC.: SGET BEARING PLATE, 3/4" CABLE
- ANCHOR ASSEMBLY, MISC.: SFST IMPACT HEAD
- ANCHOR ASSEMBLY, MISC.: SFST POST #0
- ANCHOR ASSEMBLY, MISC.: SFST POST #1
- ANCHOR ASSEMBLY, MISC.: SFST POST #2
- ANCHOR ASSEMBLY, MISC.: SFST ANCHOR PADDLE, PLATE WASHER, KEEPER PLATE

- ANCHOR ASSEMBLY, MISC.: SFST ANGLE STRUT
- ANCHOR ASSEMBLY, MISC.: SFST ANCHOR ANGLE
- ANCHOR ASSEMBLY, MISC.: SFST ANCHOR RAIL 12'-6"
- ANCHOR ASSEMBLY, MISC.: 6' STEEL POST
- ANCHOR ASSEMBLY, MISC.: 12" BLOCKOUT
- ANCHOR ASSEMBLY, MISC.: KING BLOCK 4"x7 1/2"x1'-2"
- ANCHOR ASSEMBLY, MISC.: COMPOSITE BLOCKOUT 6"x8"x14"
- ANCHOR ASSEMBLY, MISC.: WOOD BLOCKOUT 6"x8"x14"
- ANCHOR ASSEMBLY, MISC.: W-BEAM MGS 9'-4 1/2"
- ANCHOR ASSEMBLY, MISC.: W-BEAM MGS 12'-6"
- ANCHOR ASSEMBLY, MISC.: W-BEAM MGS 25'-0"

Designer Notes:

1. This item should primarily be used on "ding and dent" guardrail maintenance contracts.
2. The item list above may be modified at the discretion of the designer, and it is encouraged to coordinate district specific needs with field personnel who administer the contract. It may be preferable to combine/consolidate specific items across system types, or in some cases it may be necessary to break components out further to create additional items.
3. If it is desired to repair NCHRP-350 devices, those items may be added in a similar, individualized fashion.
4. If it is desired to repair Type E devices attached to non-MGS/Type 5 rail, a separate item ANCHOR ASSEMBLY REBUILT, TYPE E should be used with the associated items list.

R116 – MGS GUARDRAIL INSTALLED IN ASPHALT

THIS OPERATION SHALL INCLUDE PREPARATION OF THE GRADED SHOULDER USING ITEM 209, LINEAR GRADING, AS PER PLAN AND PAVING UNDER THE GUARDRAIL USING ITEM 441, ASHPALT CONCRETE INTERMEDIATE COURSE, TYPE 1, (449), (UNDER GUARDRAIL).

ITEM 209, LINEAR GRADING, AS PER PLAN SHALL CONSIST OF EXCAVATING TOPSOIL, AND PLACING GRANULAR MATERIAL. ALL COLLECTED DEBRIS AND TOPSOIL, INCLUDING RHIZOMES, ROOTS AND OTHER VEGETATIVE PLANT MATERIAL SHALL BE REMOVED AND DISPOSED OF AS SPECIFIED IN 105.17. THE REMOVED MATERIAL SHALL BE REPLACED WITH COMPACTABLE GRANULAR MATERIAL CONFORMING TO 703.16 PLACED TO GRADE AS DETAILED ON THE TYPICAL SECTION OR AS APPROVED BY THE ENGINEER.

ALL EQUIPMENT, MATERIALS AND LABOR REQUIRED TO PERFORM THE WORK OUTLINED ABOVE SHALL BE INCLUDED FOR PAYMENT UNDER ITEM 209, LINEAR GRADING, AS PER PLAN.

THE GUARDRAIL SHALL BE INSTALLED IN X" OF ITEM 441, ASHPALT CONCRETE INTERMEDIATE COURSE, TYPE 1, (449), (UNDER GUARDRAIL) PER THE DETAIL ON **SCD MGS-2.1** USING ONE OF THE FOLLOWING METHODS:

METHOD A:

1. SET GUARDRAIL POSTS
2. PLACE X" OF ITEM 441

METHOD B:

1. PLACE X" OF ITEM 441
2. DRIVE 6'-0" W6X9 OR W6X8.5 STEEL GUARDRAIL POSTS TO CORRECT DEPTH (31" FROM FINISHED GRADE TO TOP OF W-BEAM)
3. PATCH AROUND POSTS IF ASPHALT WAS DAMAGED DURING POST INSTALLATION. THE MATERIALS USED FOR PATCHING SHALL BE AN ASPHALT CONCRETE APPROVED BY THE ENGINEER. PATCHED AREAS SHALL BE COMPACTED USING EITHER HAND OR MECHANICAL METHODS. FINISHED

SURFACES SHALL BE SMOOTH AND SLOPED TO DRAIN AWAY FROM THE POSTS.

ALL EQUIPMENT, MATERIALS AND LABOR REQUIRED TO PERFORM THE WORK OUTLINED ABOVE, WITH THE EXCEPTION OF SETTING GUARDRAIL POSTS, SHALL BE INCLUDED FOR PAYMENT UNDER ITEM 441, ASPHALT CONCRETE INTERMEDIATE COURSE, TYPE 1, (449), (UNDER GUARDRAIL).

Designer Notes:

1. Quantities for Item 441 should be calculated in Cubic Yards.
2. The asphalt concrete thickness should be shown on the typical sections a

   nd specified in the note (replace "X"). The depth may vary according to project requirements, but shall be a maximum of 2 inches.
3. The area to be paved shall

   not exceed 8" measured from the back of post.
4. The slope shall be the same as the graded shoulder slope.
5. The designer may specify either paving Method A or B, or leave the option to the contractor.
6. Guardrail shall be paid for under Item 606.

R123 – ITEM 606 – IMPACT ATTENUATOR, TYPE 1 (UNIDIRECTIONAL OR BIDIRECTIONAL)

THIS ITEM SHALL CONSIST OF FURNISHING AND INSTALLING ANY OF THE MASH 2016 TYPE 1 IMPACT ATTENUATORS AS LISTED UNDER "PRODUCTS ACCEPTED FOR NEW, PERMANENT INSTALLATIONS" ON THE ROADWAY APPROVED PRODUCTS LIST POSTED ON THE OFFICE OF ROADWAY ENGINEERING'S WEB PAGE (REFER TO THE POSTED SHOP DRAWINGS FOR THE MOST CURRENT APPROVED PRODUCT MODELS). INSTALLATION SHALL BE AT THE LOCATIONS SPECIFIED IN THE PLANS, IN ACCORDANCE WITH THE MANUFACTURER'S SPECIFICATIONS.

PAYMENT FOR THE ABOVE WORK SHALL BE MADE AT THE UNIT PRICE BID FOR ITEM 606, IMPACT ATTENUATOR, TYPE 1(UNIDIRECTIONAL OR BIDIRECTIONAL), EACH, AND SHALL INCLUDE ALL LABOR, TOOLS, EQUIPMENT AND MATERIALS NECESSARY TO CONSTRUCT A COMPLETE AND FUNCTIONAL IMPACT ATTENUATOR SYSTEM, INCLUDING ALL RELATED TRANSITIONS, HARDWARE, REFLECTIVE SHEETING AND GRADING, NOT SEPARATELY SPECIFIED, AS REQUIRED BY THE MANUFACTURER.

Designer Notes:

1. The device's length of need (LON) point for all systems is at post number 3; therefore, after calculating the required LON for the guardrail, deduct the last 18’-9” of the unit (from post #3 to post #6) from the calculated length of need for the guardrail. The designer must show the calculated LON point on all guardrail runs in the plans. Refer to the approved products listed on the Office of Roadway Engineering’s Web Page.
2. The 6’-3” section directly behind the Type 1 shall be parallel to the centerline of the unit. A maximum flare of 3 degrees (20:1) is permissible. A cross slope of no more than 8% (5 degrees) is recommended.
3. Bidirectional should be specified for locations where traffic is expected to be in opposing directions on either side of the barrier. Unidirectional shall be specified when traffic is expected to move in the same direction on both sides of the barrier.
4. All curbs and islands should be removed for optimum impact performance.
5. More information is located in Section 600 of the Location and Design Manual Volume 1.

R124 – ITEM 606 - TYPE 2 (UNIDIRECTIONAL OR BIDIRECTIONAL)

THIS ITEM SHALL CONSIST OF FURNISHING AND INSTALLING ANY OF THE MASH 2016 TYPE 2 IMPACT ATTENUATORS AS LISTED UNDER "PRODUCTS ACCEPTED FOR NEW, PERMANENT INSTALLATIONS" ON THE ROADWAY APPROVED PRODUCTS LIST POSTED ON THE OFFICE OF ROADWAY ENGINEERING’S WEB PAGE (REFER TO THE POSTED SHOP DRAWINGS FOR THE MOST CURRENT

APPROVED PRODUCT MODELS). WHEN BI-DIRECTIONAL DESIGNS ARE SPECIFIED, THE CONTRACTOR SHALL SUPPLY APPROPRIATE TRANSITIONS.

PAYMENT FOR THE ABOVE WORK SHALL BE MADE AT THE UNIT PRICE BID FOR ITEM 606, IMPACT ATTENUATOR, TYPE 2 [(SPEED (IN MPH), HAZARD WIDTH (IN INCHES)), (UNIDIRECTIONAL OR BIDIRECTIONAL)], EACH, AND SHALL INCLUDE ALL LABOR, TOOLS, EQUIPMENT AND MATERIALS NECESSARY TO CONSTRUCT A COMPLETE AND FUNCTIONAL IMPACT ATTENUATOR SYSTEM, INCLUDING ALL RELATED BACKUPS/BACKSTOPS, TRANSITIONS, HARDWARE AND GRADING, NOT SEPARATELY SPECIFIED, AS REQUIRED BY THE MANUFACTURER. INSTALLATION SHALL BE AT THE LOCATIONS SPECIFIED IN THE PLANS, IN ACCORDANCE WITH THE MANUFACTURER'S SPECIFICATIONS.

Designer Notes:

These systems are non-gating and redirective therefore the entire length of the unit can be included as part of the calculated length of need.

The most current approved products and models are updated regularly online, as such, individual products should generally not be listed on the plans.

This note should be used for the protection of Barrier Design Guardrail, concrete median barrier and other fixed objects.

If cross slopes are steeper than 8% (12:1) or if the cross slope varies by more than 2% over the length of the unit, a leveling pad may be used.

Rear fender panels may slide 60 inches rearward upon impact, so ensure the specified width is adequate.

Bidirectional should be specified for locations where traffic is expected to be in opposing directions on either side of the barrier. Unidirectional shall be specified when traffic is expected to move in the same direction on both sides of the barrier.

Each of the Type 2 products have a wide variety of related units (families), typically covering various design speeds (number of bays) and protected widths. The designer

should also identify on the project plans for each unit specified on the plan any contingencies needed to construct a complete device.

They include:

- Design speed (The designer must specify Test level 3 (TL-3) configurations for installations on the NHS)
- Width of hazard
- Available foot print area for the product
- Foundation type (asphalt, concrete, bridge deck)
- Transition type (concrete barrier or guardrail)
- Backup support (A standard concrete backup is detailed on SCD RM-4.6. Otherwise, specify an independent stand-alone anchorage like the product's own concrete backup, or its tension strut backup)
- Any unique characteristics of the site (curb, expansion joints, etc.)

R125 – ITEM 606 - TYPE 3 (UNIDIRECTIONAL OR BIDIRECTIONAL)

THIS ITEM SHALL CONSIST OF FURNISHING AND INSTALLING ANY OF THE MASH 2016 TYPE 3 IMPACT ATTENUATORS AS LISTED UNDER "PRODUCTS ACCEPTED FOR NEW, PERMANENT INSTALLATIONS" ON THE ROADWAY APPROVED PRODUCTS LIST POSTED ON THE OFFICE OF ROADWAY ENGINEERING'S WEB PAGE (REFER TO THE POSTED SHOP DRAWINGS FOR THE MOST CURRENT APPROVED PRODUCT MODELS). WHEN BI-DIRECTIONAL DESIGNS ARE SPECIFIED, THE CONTRACTOR SHALL SUPPLY APPROPRIATE TRANSITIONS.

PAYMENT FOR THE ABOVE WORK SHALL BE MADE AT THE UNIT PRICE BID FOR ITEM 606, IMPACT ATTENUATOR, TYPE 3 [(SPEED (IN MPH), HAZARD WIDTH (IN INCHES)), (UNIDIRECTIONAL OR BIDIRECTIONAL)], EACH, AND SHALL INCLUDE ALL LABOR, TOOLS, EQUIPMENT AND MATERIALS NECESSARY TO CONSTRUCT A COMPLETE AND FUNCTIONAL IMPACT ATTENUATOR SYSTEM, INCLUDING ALL RELATED BACKUPS/BACKSTOPS, TRANSITIONS, HARDWARE AND GRADING, NOT

SEPARATELY SPECIFIED, AS REQUIRED BY THE MANUFACTURER. INSTALLATION SHALL BE AT THE LOCATIONS SPECIFIED IN THE PLANS, IN ACCORDANCE WITH THE MANUFACTURER'S SPECIFICATIONS.

Designer Notes: These systems are non-gating and redirective therefore the entire length of the unit can be included as part of the calculated length of need.

The most current approved products and models are updated regularly online, as such, individual products should generally not be listed on the plans.

This note should be used for the protection of Barrier Design Guardrail, concrete median barrier and other fixed objects.

If cross slopes are steeper than 8% (12:1) or if the cross slope varies by more than 2% over the length of the unit, a leveling pad may be used.

Rear fender panels may slide 60 inches rearward upon impact, so ensure the specified width is adequate.

Bidirectional should be specified for locations where traffic is expected to be in opposing directions on either side of the barrier. Unidirectional shall be specified when traffic is expected to move in the same direction on both sides of the barrier.

Each of the Type 3 products have a wide variety of related units (families), typically covering various design speeds (number of bays) and protected widths. The designer should also identify on the project plans for each unit specified on the plan any contingencies needed to construct a complete device.

They include:

- Design speed (The designer must specify Test level 3 (TL-3) configurations for installations on the NHS)
- Width of hazard & available footprint area for the product
- Foundation type (asphalt, concrete, bridge deck)
- Transition type (concrete barrier or guardrail)

- Backup support (A standard concrete backup is detailed on SCD RM-4.6. Otherwise, specify an independent stand-alone anchorage like the product's own concrete backup, or its tension strut backup)
- Any unique characteristics of the site (curb, expansion joints, etc.)

R128 – ADA WAIVER

AN APPROVED ADA DESIGN WAIVER IS REQUIRED ON THIS PROJECT. THE FOLLOWING FEATURES LISTED BELOW CANNOT FEASIBLY BE CONSTRUCTED TO MEET ADA GUIDELINES.

ADA DESIGN WAIVER

PLAN REFERENCE NO.	ADA RAMP ID	DEVIATING FEATURE
CR-#	RMP#######	XXX
CR-#	RMP#######	XXX

DESIGN NOTES: Use this note when an ADA Waiver signed by the District Design Engineer is required on a project. The waiver verifies that the ADA feature listed cannot be constructed to ADA standards. A waiver is required for each feature that cannot be constructed to ADA standards. Waivers are stored and may be viewed in the ODOT ADA Collector App. Waivers are required regardless of the jurisdiction governing the project. See Multimodal Design Guide for additional information.

R129 – ITEM 610 - CABLE BARRIER, REBUILT

THIS ITEM OF WORK CONSISTS OF REBUILDING PORTIONS OF A DAMAGED CABLE BARRIER SYSTEM. ALL REPAIRS SHALL BE IN ACCORDANCE WITH THE MANUFACTURER'S SPECIFICATIONS. THE UNIT BID PRICE FOR EACH ITEM LISTED BELOW SHALL INCLUDE ALL LABOR, MATERIALS AND EQUIPMENT NECESSARY (INCLUDING ALL RELATED HARDWARE NOT SEPARATELY

SPECIFIED) TO REMOVE AND REPLACE THE DAMAGED COMPONENT. THE ITEMS LISTED BELOW SHALL BE USED AS DIRECTED BY THE ENGINEER.

TERMINAL POSTS ARE POSTS WITHIN THE LIMITS OF THE ANCHOR TERMINAL THAT ARE NOT ANCHOR POSTS AS SHOWN ON SCD RM-8.1.

CABLE BARRIER, ANCHOR POST CONCRETE FOUNDATION, MONOLITHIC INCLUDES THE CONCRETE ANCHOR BLOCK OR PILE FOR SYSTEMS WHERE ALL CABLES TERMINATE AT A SINGLE POST. CABLE BARRIER, ANCHOR POST CONCRETE FOUNDATION, INDIVIDUAL INCLUDES THE CONCRETE ANCHOR BLOCK OR PILE FOR A SINGULAR ANCHOR POST WITHIN A SYSTEM WHERE CABLES TERMINATE AT SEPARATE POSTS.

REPLACEMENT POSTS SHALL BE REINSTALLED AT THE ORIGINAL DESIGN SPACING.

REESTABLISHMENT OF THE PREEXISTING EMBANKMENT AND GRADING AROUND LINE, ANCHOR, AND TERMINAL POST FOUNDATIONS SHALL BE CONSIDERED INCIDENTAL TO THE FOUNDATION REPLACEMENT ITEM.

- ITEM 610 - CABLE BARRIER, LINE POST _ EACH
- ITEM 610 - CABLE BARRIER, LINE POST CONCRETE FOUNDATION _ EACH
- ITEM 610 - CABLE BARRIER, TERMINAL POST _ EACH
- ITEM 610 - CABLE BARRIER, TERMINAL POST CONCRETE FOUNDATION _ EACH
- ITEM 610 - CABLE BARRIER, ANCHOR POST _ EACH
- ITEM 610 - CABLE BARRIER, ANCHOR POST CONCRETE FOUNDATION, MONOLITHIC _ EACH
- ITEM 610 - CABLE BARRIER, ANCHOR POST CONCRETE FOUNDATION, INDIVIDUAL _ EACH
- ITEM 610 - CABLE BARRIER, REPLACEMENT CABLE _ FT
- ITEM 610 - CABLE BARRIER, TURNBUCKLE _ EACH

- ITEM 626 - BARRIER REFLECTOR, TYPE 6 _ EACH

Designer Notes:

1. This item should primarily be used on maintenance contracts to repair existing cable barrier installations.
2. The item list above may be modified at the discretion of the designer, and it is encouraged to coordinate district specific needs with field personnel who administer the contract. Additional specialized items can be added using "Cable Barrier, Misc.:".

R130 – ITEM 610 - CABLE BARRIER, REPAIR TENSIONING

THIS ITEM SHALL INCLUDE ALL EQUIPMENT, MATERIAL, AND LABOR NECESSARY TO RE-TENSION A CABLE WITHIN A CABLE BARRIER RUN ACCORDING TO THE MANUFACTURER'S TEMPERATURE-ADJUSTED TENSION CHART. MEASURE THE TEMPERATURE OF THE CABLE USING AN INFRARED THERMOMETER AND RECORD THE TEMPERATURE IN THE CA-R-2. MEASURE THE TENSION IN THE CABLE WITH A CALIBRATED TENSION METER THAT IS SUPPLIED OR OTHERWISE APPROVED BY THE MANUFACTURER. PERFORM THE TENSION CHECKS AT THREE INDEPENDENT LOCATIONS ALONG THE CABLE: NEAR THE BEGIN ANCHOR TERMINAL, NEAR THE TURNBUCKLE SPLICE, AND NEAR THE END ANCHOR TERMINAL. AT A MINIMUM, TAKE READINGS SPACED AT 150-FOOT INTERVALS. SUBMIT A COMPLETED CA-R-2 TO THE ENGINEER FOR REVIEW AND ACCEPTANCE. THE BID UNIT PRICE SHALL BE PER EACH PER CABLE. THE QUANTITY BELOW SHALL BE USED AS DIRECTED BY THE ENGINEER.

ITEM 610 – CABLE BARRIER, REPAIR TENSIONING _ EACH

Designer Notes:

1. This item should primarily be used on maintenance contracts to restore tensioning in cable barrier systems that have been damaged.

R131 – ITEM 610 - CABLE BARRIER, ANNUAL TENSIONING

THIS ITEM SHALL INCLUDE ALL EQUIPMENT, MATERIAL, AND LABOR NECESSARY TO CHECK AND RE-TENSION ALL CABLES IN A CABLE BARRIER RUN ACCORDING

TO THE MANUFACTURER'S TEMPERATURE-ADJUSTED TENSION CHART. MEASURE THE TEMPERATURE OF EACH CABLE USING AN INFRARED THERMOMETER AND PROVIDE AN AVERAGE TEMPERATURE IN THE CA-R-3. MEASURE THE TENSION IN EACH CABLE WITH A CALIBRATED TENSION METER THAT IS SUPPLIED OR OTHERWISE APPROVED BY THE MANUFACTURER. PERFORM THE TENSION CHECKS AT THREE INDEPENDENT LOCATIONS ALONG THE CABLE BARRIER RUN: NEAR THE BEGIN ANCHOR TERMINAL, NEAR THE TURNBUCKLE SPLICE, AND NEAR THE END ANCHOR TERMINAL. AT A MINIMUM, TAKE READINGS SPACED AT 150-FOOT INTERVALS. A CABLE BARRIER RUN IS DEFINED AS A LENGTH OF CABLES BETWEEN TWO ANCHOR TERMINALS. SUBMIT A COMPLETED CA-R-3 TO THE ENGINEER FOR REVIEW AND ACCEPTANCE.

THE QUANTITIES BELOW SHALL BE USED AS DIRECTED BY THE ENGINEER.

- ITEM 610 – CABLE BARRIER, ANNUAL TENSIONING, THREE CABLE RUN _ EACH
- ITEM 610 – CABLE BARRIER, ANNUAL TENSIONING, FOUR CABLE RUN _ EACH

Designer Notes:

1. This item is to be used on maintenance contracts to check existing cable barrier specifications to ensure proper tensioning has been maintained.
2. Provide a table that includes the county, route, and SLM or STA. of the locations that are to be checked and re tensioned.
3. Include date(s) for each location or a general completion date if there is a desire to have this item completed prior to the final completion date.

References

Reference: Design Designations for Non-Interstate Bridge Replacement/Rehabilitation Projects

The procedures contained in this revised procedural manual are to be used to develop design designations for non-interstate bridge replacement/rehabilitation projects. Such bridge projects may be located on U.S. highways, state routes, county routes, township routes, or local streets. These procedures replace those found in the manual dated November 17, 1993.

Traffic forecasts for bridge projects on the Interstate System must continue to be provided or certified by the Office of Technical Services. For these bridges, the district offices may either forward design designations to Technical Services or request that the Technical Services provide them. Design designations for bridge projects that include more than simple replacement/rehabilitation must also be provided by Technical Services. This would include bridges with major approach work, bridges on new alignments, or bridges that are part of major capacity addition projects.

Bridge projects within a metropolitan planning organization (MPO) area should be coordinated with the MPO. Since a bridge project involving federal funds must be included on the MPO's transportation improvement program (TIP), coordination should take place at the time the project is added to the TIP.

This responsibility was originally delegated to the district offices in November, 1993, based on approval from FHWA in a letter dated September 29, 1993 (see Appendix A). The original version of this manual was designed to provide a cookbook approach to developing design designations for bridge projects for use by the district offices. The changes are intended to make the projections more accurate by giving the district offices more flexibility in developing them.

The major changes in this edition of the manual are as follows:

- The elimination of generalized growth rates by county and their replacement with a statewide continuous range of rates to provide flexibility in the selection of an accurate rate specific to the site and the individual project;

- Changes in the terminology used to refer to the year of construction from “Current Year” to “Opening Year” to eliminate confusing “current” with the current calendar year or with the year of the most recent count data;
- Changing the Design Year to be either 12 or 20 years after the Opening Year, consistent with the draft Pavement Design Manual (paragraph 2.02.1.1);
- Providing a range of values for the selection of the K factor, the calculation of the DHV on the worksheet, and the replacement in the design designation of K with the DHV;
- Three choices for the D factor, depending on whether the bridge is within or outside an MPO’s boundaries and whether the bridge is one-way or two-way;
- Providing a “comments” section on the worksheet for use in documenting the selection of the growth rate, for substituting refined output from the MPO models, for noting more detailed available truck information (the “B” and “C” components), and/or for noting directional imbalances in the ADT such as those found on bridges on routes over freeways between ramp termini;
- Dropping the request for forwarding completed design designations to Technical Services; and
- The update of terms to reflect current terminology in use in the department.

The worksheet, itself, is now larger, the equivalent of two 8 ½ by 11 inch sheets. However, the form can be reproduced as a two-sided 8 ½ by 11 inch form or side by side on an 11 by 17 inch sheet, etc.

Any comments or questions on the use of this manual, including the discovery of any errors or inconsistencies, should be directed to the Office of Technical Services at (614) 644-8195.

Worksheet Instructions

1. A. Enter the PID.
   B. Enter the Count-Route-Log. If the project is not on the State System, enter an appropriate project identifier.

2. A. Enter the Existing ADT. The ADT selected should be the most recent, accurate, seasonally adjusted 24-hour volume available. The most recent ADT may be obtained from the latest Traffic Survey Report (TSR) if the project is on the State System. Other data sources may be used (ODOT data obtained since the last TSR, count data from county engineers, MPOs, consultants, cities, etc.). Partial-day counts may be expanded to 24-hours using average values for the proportion of each hour in the daily total. Expansion tables and season adjustment factors can be obtained from the Office of Technical Services' Traffic Monitoring Section. If the available count data is three (3) years or older, consideration should be given to obtaining a new count.
   B. Enter the 24-hour B&C volume (trucks). If no data is available, leave this box blank.
   C. Enter the Existing Year. This is the year the count was taken. For TSR data, assume this is the year of the report (e.g., for a report published in 1996, assume the data is from 1996) unless the specific ADT is known to come from a count taken in an earlier year.

3. Enter the Opening Year. The Opening Year is the year construction will be completed and the bridge will reopen to traffic.

4. Enter the Design Year. The Design Year is either 12 or 20 years after the Opening Year. This is determined by the scope and intent of the project and is unlikely to be an option available to the user of this manual. Most projects will have a 20-year life; a 12-year design year would occur only when the bridge is part of an overall 12-year pavement rehabilitation project.

5. A. Enter the number of years from the Existing Year to the Opening Year. Enter the difference between the Opening Year and the Existing Year: (3) – (2C).
   B. Enter the number of years from the Existing Year to the Design Year. Enter the difference between the Design Year and the Existing Year: (4) – (2C).

6. Select a growth rate. The growth rate is to be selected from the continuous range of rates shown on the worksheet. The range of rates for each category is subjective, as are the categories, themselves. Judgement must be used in selecting an appropriate rate. If the project lies within an MPO area, manually adjusted output from a travel demand forecasting model provided by the MPO may be used in place of the growth rate. A rate derived from a regression analysis of historical traffic volumes over at least a twelve year period (equivalent to three traffic survey reports – five preferred) may be used as a tool for selecting the growth rate. It is important to

recognize that a high rate derived from a regression analysis, based on only a few data points may not be sustainable when projected 20 or more years into the future. The implicit growth rate based on the Design Year ADT and the Existing Year ADT should be calculated and evaluated against the rates shown. The use of model output in place of the given rates should be noted in “Comments” (Section 15) of the worksheet.

7. Enter the Opening Year Factor. This factor is calculated as follows: [(6) x (5A)] + 1. Multiply the growth rate by the difference between the Opening Year and the Existing Year, then add 1.

8. Enter the Design Year Factor. This factor is calculated as follows: [(6) x (5B)] + 1. Multiply the growth rate by the difference between the Design Year and the Existing Year, then add 1.

9. Enter the Opening Year ADT. The Opening Year ADT is obtained by multiplying the Existing ADT by the Opening Year Factor: (2A) x (7).

10. Enter the Design Year ADT. The Design Year ADT is obtained by multiplying the Existing ADT by the Design Year Factor: (2A) x (8).

11. A. Enter K. The K factor is selected from the chart on the worksheet. The volume groupings shown are subjective. When count data exists, it is possible to estimate K by dividing the peak hour volume by the ADT. However, K is to reflect the 30th highest hour of the year. For a count on a given day, there is no way to know how the peak hour for that day compares to the 30th highest hour, but “true” K would almost always be higher than this estimated K.
    B. Enter the DHV. The DHV (Design Hourly Volume) is obtained by multiplying the projected Design Year ADT by the K Factor: (10) x (11A).

12. Enter the D factor. The D factor is assumed to be .55 for projects outside an MPO’s boundaries and .60 for projects on or within an MPO’s boundaries, except for a one-way bridge, in which case the D factor is always 1.00. The D factor, representing the directional distribution in the design hour, is used to calculate the Directional Design Hourly volume (DDHV). Like the K factor, it can also be estimated from available count data.
    The directional distribution in the ADT is entirely different from D. In the ADT, the directional split is usually close to 50/50. If known to vary significantly from 50/50/,

such as between the ramps on a bridge on a roadway over a freeway, then the directional distribution should be noted in the “Comments” section of the worksheet.

13. Enter the T24 factor. T24 represents the proportion of B&C commercial vehicles in the ADT. T24 is calculated based on the Existing Year data and assumed to apply to the Design Year. Information is seldom available that warrants selecting a T24 value for the Design Year that differs from T24 as calculated from the Existing Year data. T24 is calculated as: (2B)/(2C). If no count data exists, assume T24 = .03 or obtain new count data that provides truck data.

14. Enter the TD factor. TD is the proportion of B&C commercial vehicles in the design hour. If the number of trucks in the peak hour is included in any available count data, an estimate of TD can be calculated directly. However, TD is usually close to 60 percent of the T24 value, which an acceptable approximation for use here. TD is calculated as (13) x .6.

15. The comments section may be used for noting the substitution of MPO model output for volume estimates based on growth rates, the B and C components of the truck traffic, a significant departure from the expected 50/50 split in the daily directional distribution rate, or anything else the use wishes to document.

The Design Designation is summarized at the end of the worksheet from the above information. The design values (D, T24, and TD) are commonly listed as percents rather than decimal proportions. DHV is usually shown on the plans instead of K, although to assess the reasonableness of the DHV, it is usually easier to think in terms of K.

References

1. Pavement Design and Rehabilitation Manual, Draft, Office of Materials Management, transmitted on August 10, 1998.

2. Guidelines for Developing Design Year Traffic on Local Roads and Streets, prepared by the Bureau of Technical Services, December, 1976.

3. Procedures for ODOT District Offices for use in Developing Design Designations for Non-Interstate Bridge Replacement/ Rehabilitation Project, Bureau of Technical Services, November 17, 1993.

4. Traffic Survey Reports prepared by the Bureau/Office of Technical Services, 1975-1998 (some in preparation, older reports exist).

Bridge Project Design Designation Worksheet

1A	Enter the PID:
1B	Enter the County-Ro Log or other identifie
2A	Enter the Existing ADT (Total Vehicles)
2B	Enter 24-hour B&C (commercial) vo if available:
2C	Enter the Existing Ye
3	Enter the Opening Ye
4	Enter the Design Yea
5A	Enter the number of from the Existing Yea the Opening Year: **(3** **(2C) =**
5B	Enter the number of from the Existing Yea the Design Year: **(4)** **(2C) =**
6	Select a growth rate the following range o rates: Stable .0025-.0050 Moderate .0100-.020

	Low .0050-.0100 Hig .0200-.0300
7	Enter the Opening Ye Factor: **[(6) x (5A)] +**
8	Enter the Design Yea Factor: **[(6) x (5B)] +**
9	Enter the Opening Ye ADT: **(2A) x (7) =** Round to nearest 10 vehicles (nearest 10 vehicles if < 1000)
10	Enter the Design Yea ADT: **(2A) x (8) =** Round to nearest 10 vehicles (nearest 10 vehicles if < 1000)
11A	Enter K, selected fro following table of Des Year ADT: < 1000 .12 5001 – 15 .10 1001 - 5000 .11 150(.09

11B	Enter the DHV: **(10) x (11A) =**
12	Enter the D Factor (f DDHV): within an MPO area: outside an MPO area any one-way bridge:
13	Enter the T24 factor proportion of B&C vehicles in ADT): **[(2B)/2A)]** or **.03** if (2 blank
14	Enter the TD factor (proportion of B&C vehicles in the desig hour): **(13) x 0.6**
15 **COMMENTS**	

Design Designation (summarized from above) PID
County-Route-Log
Opening Year ADT =
Design Year ADT =
K =
D =
T24 =
TD =

Reference: Guidelines for Disposal of Waste Material and Construction Debris or the Excavation of Borrow Material

Purpose

This guide provides the criteria to be used when evaluating a project for acceptable locations for the disposal of waste material and construction debris or the excavation of borrow material within highway rights-of-way.

References

1. Ohio Department of Transportation, "Location & Design Manual (LDM), Volume I & III".
2. Ohio Department of Transportation, "Construction and Materials Specifications (CMS)".
3. American Association of State Highway and Transportation Officials (AASHTO), "A Policy on Geometric Design of Highways and Streets, 2018".
4. FHWA Policy, "Recycled Materials Policy", dated February 7, 2002.

Scope

All Districts, Divisions and Offices of the Ohio Department of Transportation (OOOT) involved in the design, construction and maintenance of roadways and all consultants and contractors who provide similar services to ODOT.

Background

The use of ODOT right-of-way for disposal of waste material and construction debris or the excavation of borrow material is now prohibited, unless locations are identified in the plans (see CMS Sections 104.03, 105.16, 105.17 and 107.11). With the increased need to remove and replace the pavements of our Interstate and Freeway System as the pavements approach or exceed their design life, the disposal of the existing pavement, much of it concrete, that cannot be recycled or used as part of the new pavement structure has become a problem. These guidelines have been developed to give designers the criteria that should be used in the evaluation of a project for acceptable waste or borrow areas within the right-of-way of a project.

Definitions

Clear Zone: The desirable unobstructed area along a roadway, outside the edge of pavement, available for the safe recovery of vehicles that have left the traveled way. (Section 600.2, LDM)

Safety Grading: The shaping of the roadside using 6:1 or flatter slopes within the clear zone area and 3:1 or flatter foreslopes and recoverable ditches extending beyond the clear zone. (Figures 307-1 and 307- 2, LDM)

Clear Zone Grading: The shaping of the roadside using 4:1 or flatter foreslopes and traversable ditches within the clear zone area. (Figure 307-3, LDM)

Decision Sight Distance: The distance needed for a driver to detect, recognize and select an appropriate course of action for an unexpected or otherwise difficult-to-perceive condition in the roadway. (Section
201.5 and Figure 201-5, LDM)

Project Evaluation

Waste Disposal Areas

All projects with large amounts of cut and fill or projects with pavement removal, particularly non- recyclable concrete pavement, should be evaluated for acceptable disposal areas within the right-of- way. Acceptable disposal areas would preferably enhance the safety of the roadway and should not provide a less safe highway than now exists. The total width of existing right-of-way should be considered. Examples of roadway safety enhancements would include the use of safety grading where clear zone grading or less now exits, the use of clear zone grading where something less exists and the elimination of barrier. In accordance with Section 307.21 of the LDM, all interstate and interstate look alike roadways should use safety grading. If safety grading now exists, consider the possibility of extending it to the right-of-way line. If clear zone grading now exists, consider the use of safety grading or consider the possibility of extending clear zone grading to the right-of-way line. Existing barrier locations should be evaluated to see if the application of safety grading, or at a minimum clear zone grading, would eliminate the need for barrier. Adjustments to drainage or drainage structures may also be required. Not all acceptable disposal areas will enhance the safety of the roadway. Areas that do not affect the safety of the roadway (areas outside a safety graded or clear zone graded section) and do not affect wetlands or other environmental regulations but are within the right-of-way of the project should also be considered as acceptable disposal areas.

Although interchange infields seem like obvious or ideal areas to dispose of waste material, great care not to restrict sight distances is required.

Exit Ramps - Decision stopping sight distance, Avoidance Maneuver A or B, as per Figure 201-5 of the LDM should be provided for the design speed of the ramp (Figure 404-1 and Section 404.2 of the LDM). Fills may be placed in the infield areas as long as the decision

stopping sight distance is provided and 6:1 or flatter slopes are provided in the gore areas (Section 307.5.3 of the LDM). Fills within the infields of diamond interchanges should not affect the intersection sight distance at the intersection of the crossroad and the exit ramp.

Entrance Ramps - Decision sight distance, Avoidance Maneuver C or E, as per Figure 201-5 of the LDM should be provided for the design speed of the ramp (Figure 404-1 and Section 404.2 of the LDM). The decision sight distance is measured from a point on the ramp where a driver on the ramp has an unobstructed view of vehicles on the mainline to a point on the ramp where the driver no longer has a lane width available on the ramp and must start to merge. This is the distance that the merging ramp driver has to decide where he can safely merge into the mainline traffic. This distance should also be unobstructed for the mainline driver to react to the ramp vehicle by either a lane or speed change.

Loop Ramps - The infields of loop ramps generally should not be filled unless it is to eliminate barrier or provide safety graded slopes. Loop ramps have a higher than average number of run off the road accidents due to the sharp curvature and high speeds. When the infields of these ramps are filled, not only are sight distances decreased but the driver also loses a sense of how sharp the curvature of the ramp is when he cannot see the entire ramp but only a small portion of it. If considered an acceptable fill site, then at a minimum, decision sight distance, Avoidance Maneuver A or B for the exit end of the ramp and Avoidance Maneuver C or E for the entrance end of the ramp, as per Figure 201-5 of the LDM should be provided for the appropriate design speed of the ramp (Figure 404-1 and Section 404.2 of the LDM).

Fill Restrictions - Fill heights greater than 10 feet should be reviewed by the Office of Geotechnical Engineering. Slopes should not exceed 4:1 for ease of maintenance. Fill material and fill construction shall be in accordance with the Construction and Materials Specifications, Item 203.

Borrow Areas

All projects requiring borrow should be evaluated for acceptable borrow areas within the right-of-way. The same criteria used to evaluate the waste disposal areas should be used to evaluate borrow areas within the right-of-way. The safety of the highway should be enhanced, if possible. Consider applying safety grading when something less than safety grading exists or clear zone grading when something less than clear zone grading exists.

The determination as to whether or not to allow the disposal of waste material or the excavation of borrow within the right-of-way of a project should be made as soon as possible in the project development process. Possible waste areas or borrow areas within the project right-of-way should be identified during the field review prior to final scope preparation so that the evaluation of these areas can be included as part of the scope for the project. If during plan development these areas are found to be acceptable as waste areas or borrow areas, then they shall be identified in the construction plan along with their limits. Acceptable locations should be identified on the schematic plan, plan and profile sheets or in a general note (see Location & Design Manual, Volume III, Section 1303.20 and Appendix B, Sample Plan Note G105). If the project has no acceptable waste areas or borrow areas within the project right-of-way, then it shall be stated on the construction plans by plan note, that an evaluation has been completed and no acceptable waste areas or borrow areas exist within the right- of-way of the project. Another consideration should be the impact of the allowed waste area or borrow area on future projects. One should not allow the placement of fill or excavation for borrow in an area that would require its removal or fill in the near future by another project. Environmental regulations, public involvement commitments, erosion control, the effects on utilities and the effects on drainage should also be considered. CMS Section 105.16 addresses erosion control and environmental regulations controlling borrow and waste areas. Coordination with utilities will be required and drainage structures may need extended or adjusted to grade.