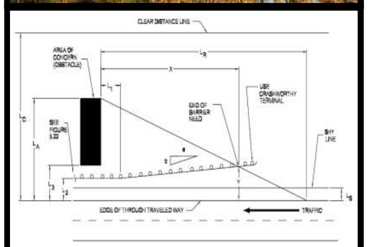


North Carolina Department of Transportation

Highway Safety Barrier Design Training

Instructor: Bill Fitzgerald, PE
KLS Engineering, LLC
(703) 858 1356

March 2 – 3, 2020

THE UNIVERSITY OF NORTH CAROLINA HIGHWAY SAFETY RESEARCH CENTER

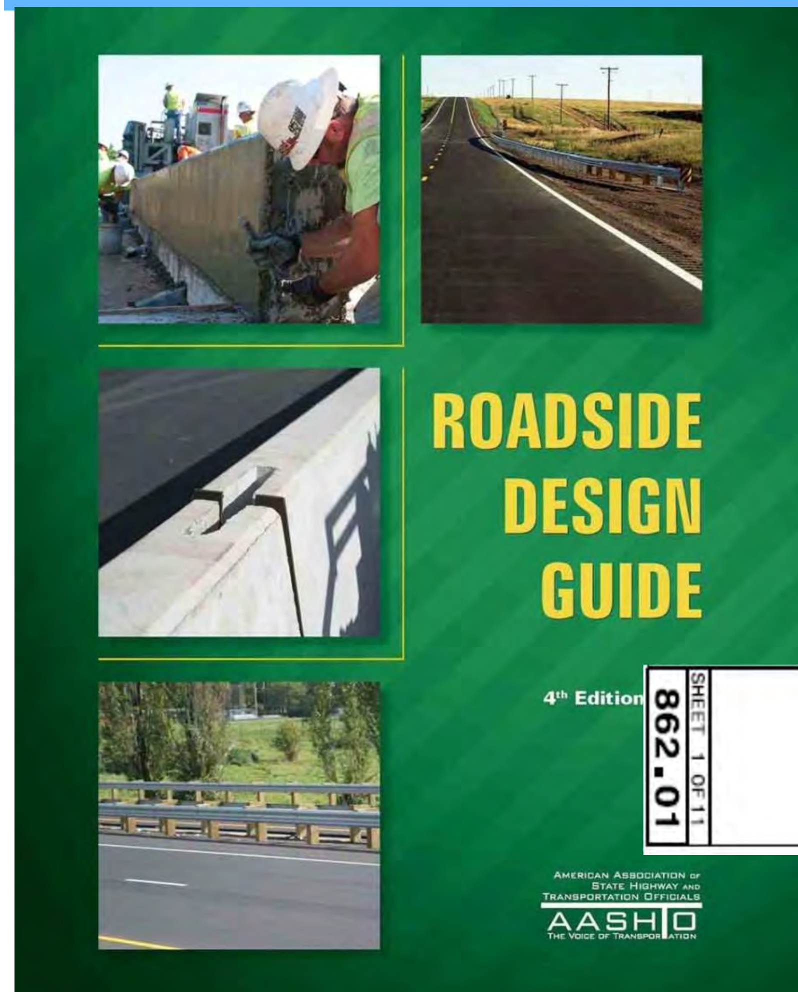
KLS Engineering

STATE OF NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

Ground Rules

- Be on time
- Participate
- Restrict sidebar conversations
- Turn off cellphones

Guidance Presented



ROADWAY DESIGN MANUAL PART 1

CHAPTER THREE

GUARDRAIL, BARRIERS AND ATTENUATORS

GUARDRAIL WARRANTS 3-1

Warrants for guardrail are to be in accordance with the "Roadside Design Guide" and with the guardrail warrant curves included in this Chapter.

In the preliminary design stage, the designer will establish the location and grade of the project so as to eliminate as much guardrail as possible using these warrants.

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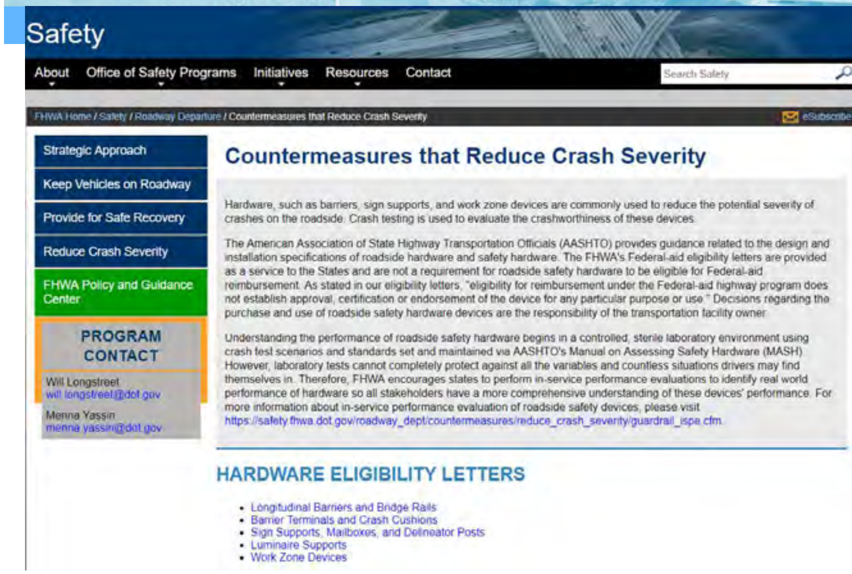
(1) Determine Guardrail Locations
  - (a) Is guardrail warranted in accordance with Figure 1 in this Chapter? If not required, go to (c). If required, go to (b).
  - (b) Is guardrail required in accordance with Figures 4 through 6 of this Chapter? If not required, go to (c).
  - (c) Is guardrail warranted in accordance with Table 2 and 3 in this Chapter? Refer to Sheet 1-4M and 1-4N in Chapter 1 of this manual.

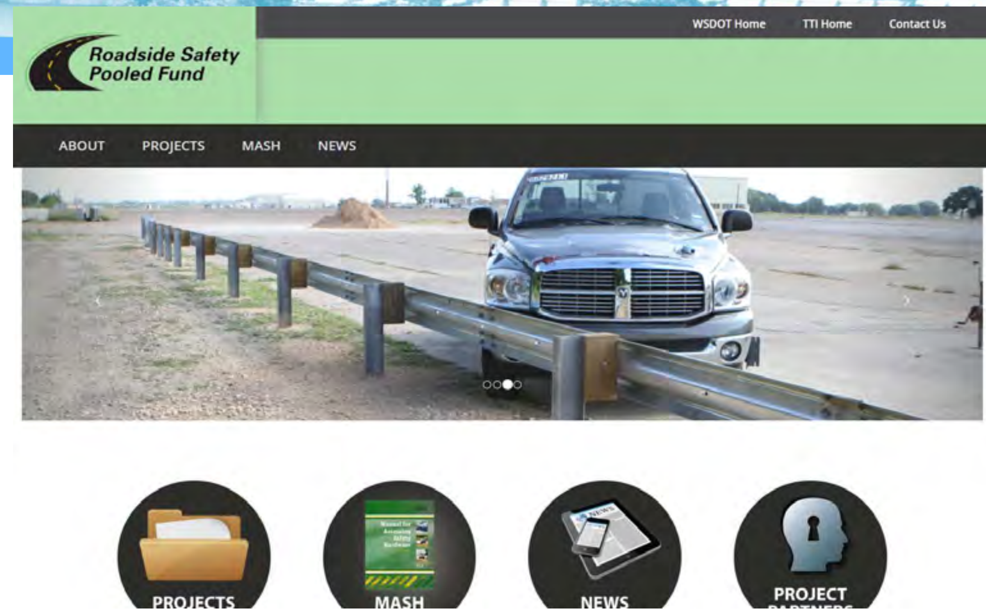
(2) Can Guardrail be eliminated?

862.01	SHEET 1 OF 11	ROADWAY STANDARD DRAWING FOR **GUARDRAIL PLACEMENT**	1-18	STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

862D0 X

Additional Resources

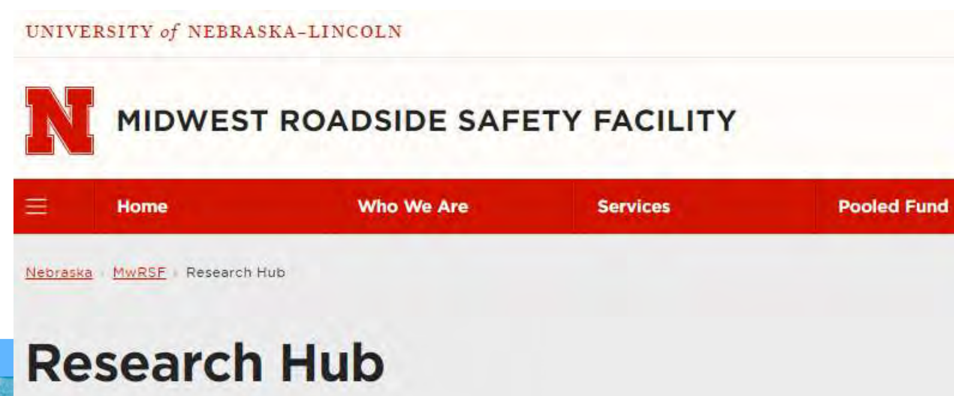




FHWA Eligibility Letters
https://safety.fhwa.dot.gov/roadway_dept/countermeasures/reduce_crash_severity/

TTI Pooled funds, etc.
https://www.roadsidepooledfund.org

https://mwrsf.unl.edu/researchhub →



Objectives of Course

At the end of this module you will be able to:

- Identify when a traffic barrier MAY be the best treatment to use at a specific site.
- Select a barrier that will adequately shield the identified hazard(s).
- Assess the topography of the site to provide for an optimal barrier system installation.

Session 1:
Introduction and Pre-assessment

Session 1 Learning Outcomes

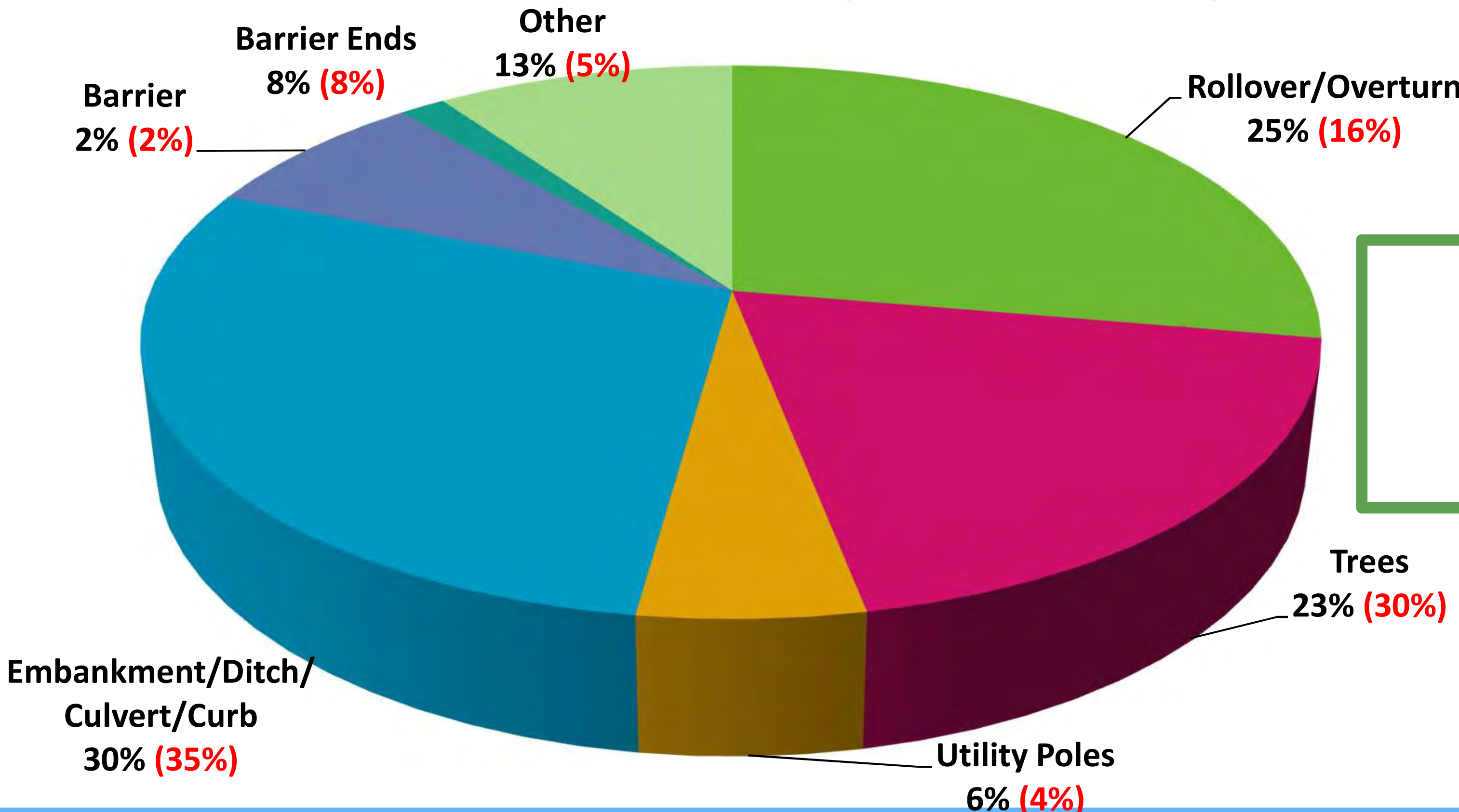
At the end of this session, you will be able to:

- Identify the primary Roadside Safety Concerns in North Carolina.
- Assess your current knowledge of Barrier Design Principles.

National Roadway Departure Fatalities

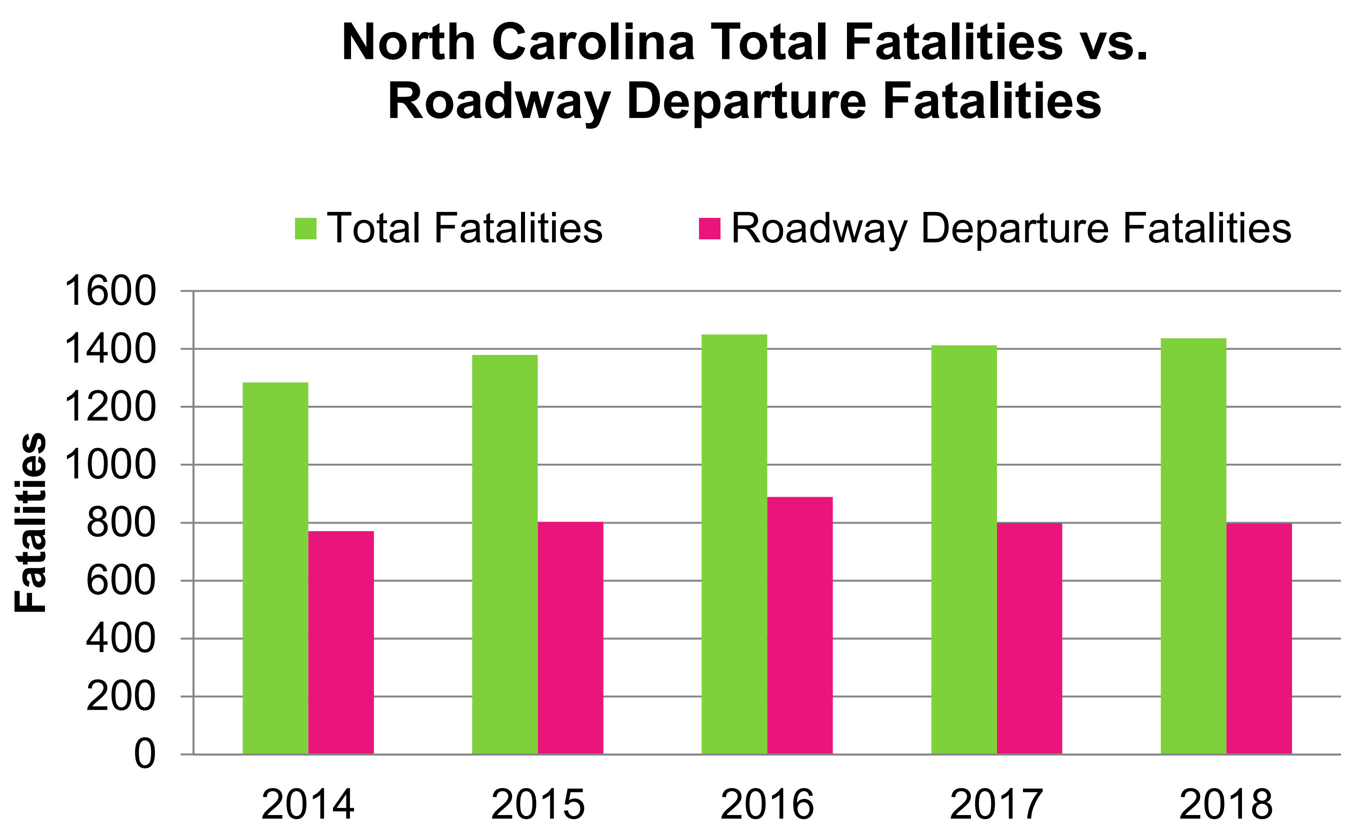
(Single Vehicle Fatal Crashes)

National **(North Carolina)**



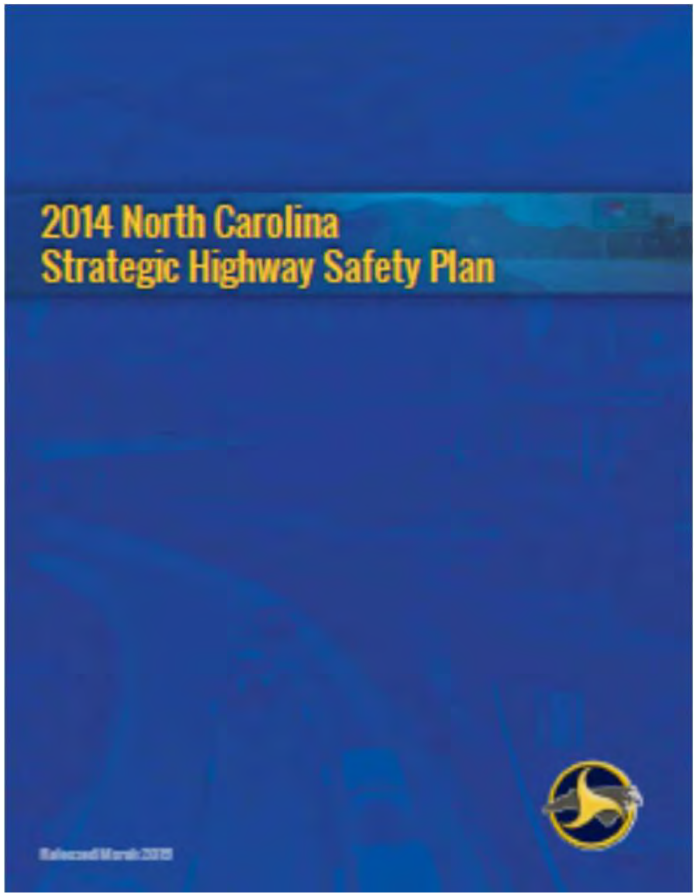
Total US Highway Fatalities 37,143

North Carolina Crash Data Trend



Ref: FARS Data – 2018

North Carolina Strategic Highway Safety Plan



Lane Departure STRATEGIES

1. Keep vehicles on the roadway.
2. Reduce the potential for crashes when vehicles leave the roadway.
3. Reduce the severity of crashes that do occur when vehicles leave the roadway.
4. Support & enhance driver education & awareness programs.

Strategy 3:
Reduce severity of crashes that do occur when vehicles leave the Roadway.

Supporting Actions

- Increase use of median barriers statewide. Cable barriers in particular provide a cost effective means of shielding the median and reducing severity of impacts.
- Shield motorists from trees, poles, or other fixed objects using guardrail or other barrier types.

Real World Crashes

Real World Crashes

Need for Training

Potential consequences of poorly designed barrier systems include:

- Systems may not function as designed.
- Crash severities may be increased.


Driving Off Roads
Prohibited

Need for Training

The next 9 slides show locations where barrier was installed. For each photo, decide at a glance whether you believe it to be:

1. Good example,
2. Bad example, or
3. Cannot decide without more information.

We will discuss these slides in further detail in later applicable sessions, so please record and save your responses.


SHOPPING CENTER
NEXT RIGHT


Childrens Home
NEXT EXIT


EXIT
466


EXIT
265 B

Review Learning Outcomes

- Identify the primary Roadside Safety Concerns in North Carolina.
- Assess your current knowledge of Barrier Design Principles.

Session 2:

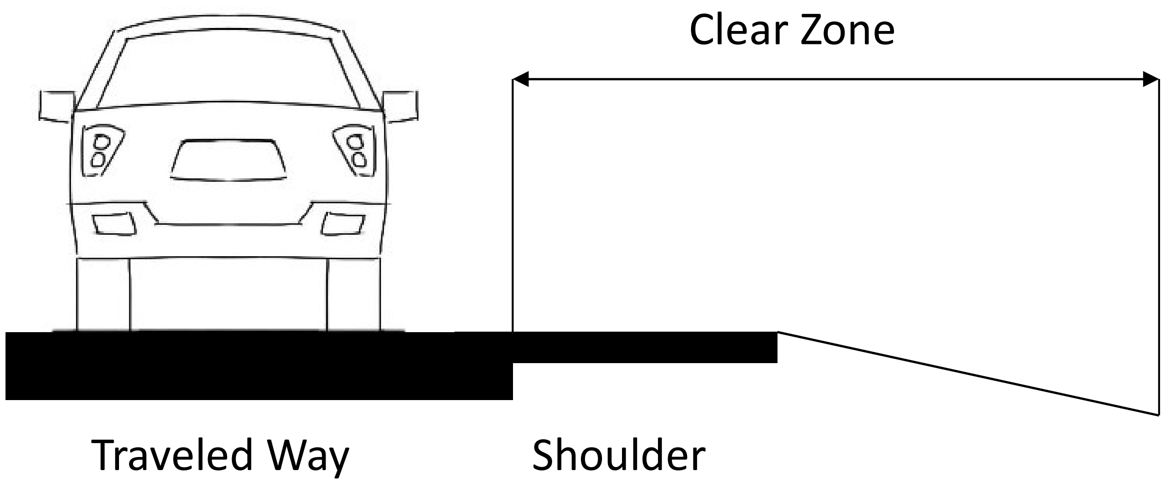
Clear Zone and Guidelines for Barrier Need

Session 2 Learning Outcomes

At the end of this session, you will be able to:

- Understand and apply the clear zone concept
- Identify objects and features that may require shielding

Clear Zone: A Definition



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.

Ref: AASHTO Roadside Design Guide, 4th Edition, Glossary

Clear Zone Principle

Get

MAXIMUM,

COST-EFFECTIVE

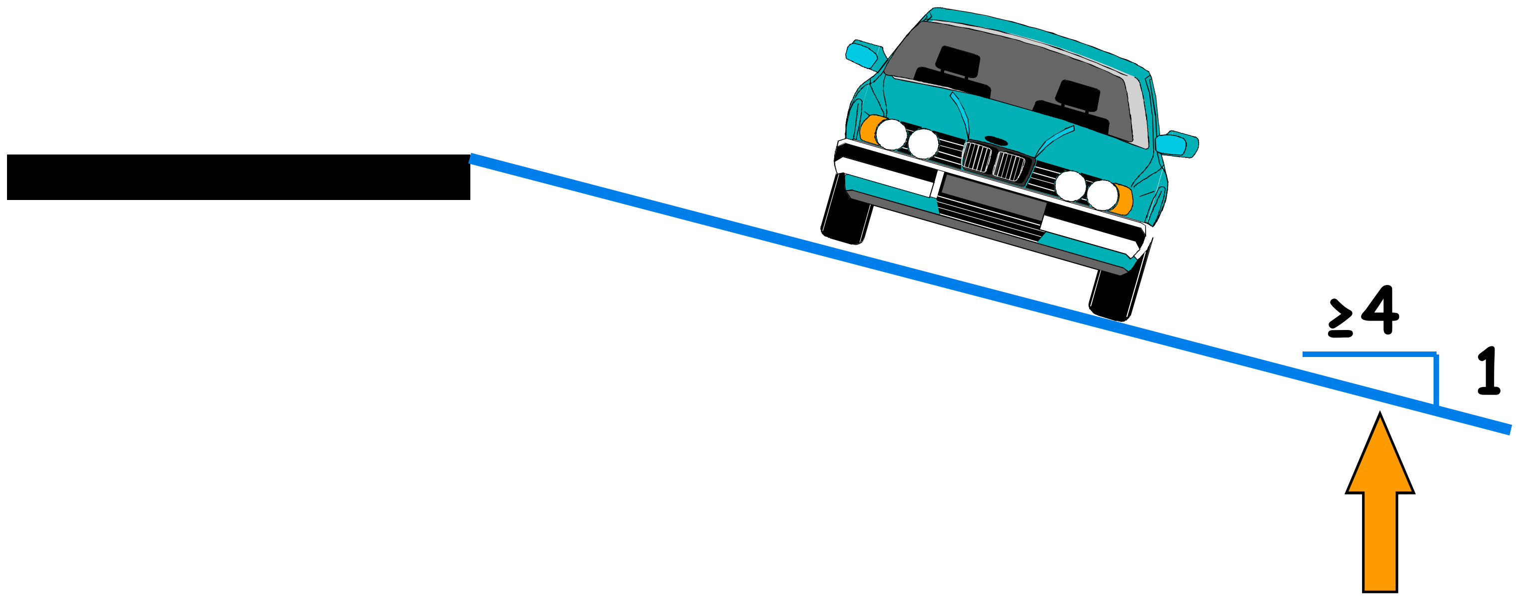
width

As Wide as Practical

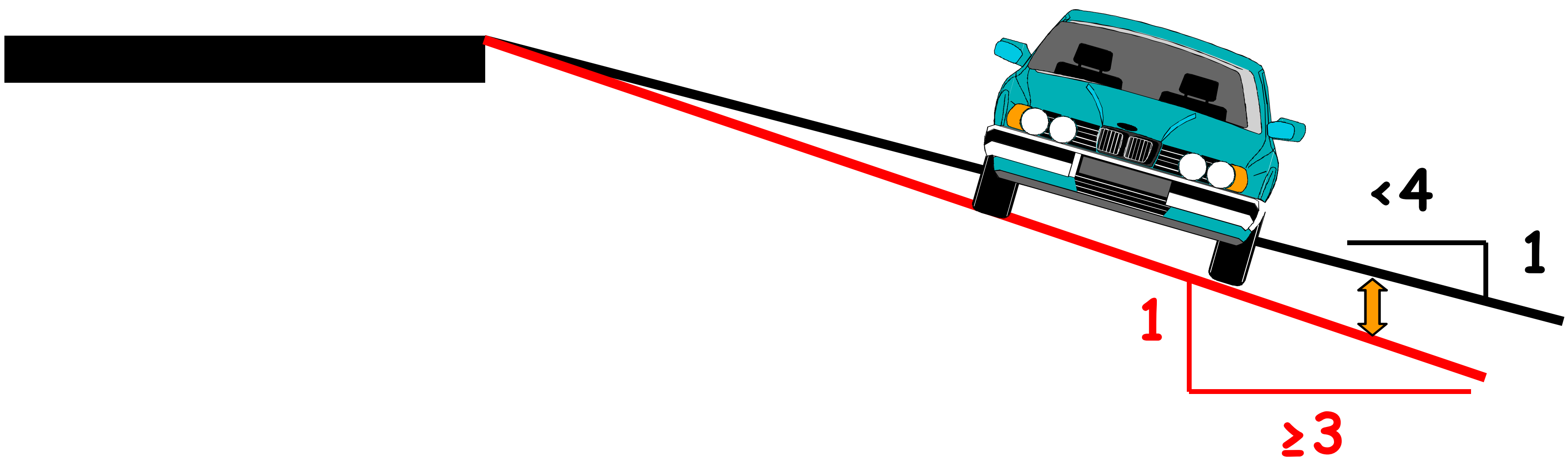
Clear Zone Factors

- Slope Type and Steepness
- Design Speed
- Traffic Volume
- Horizontal Curvature

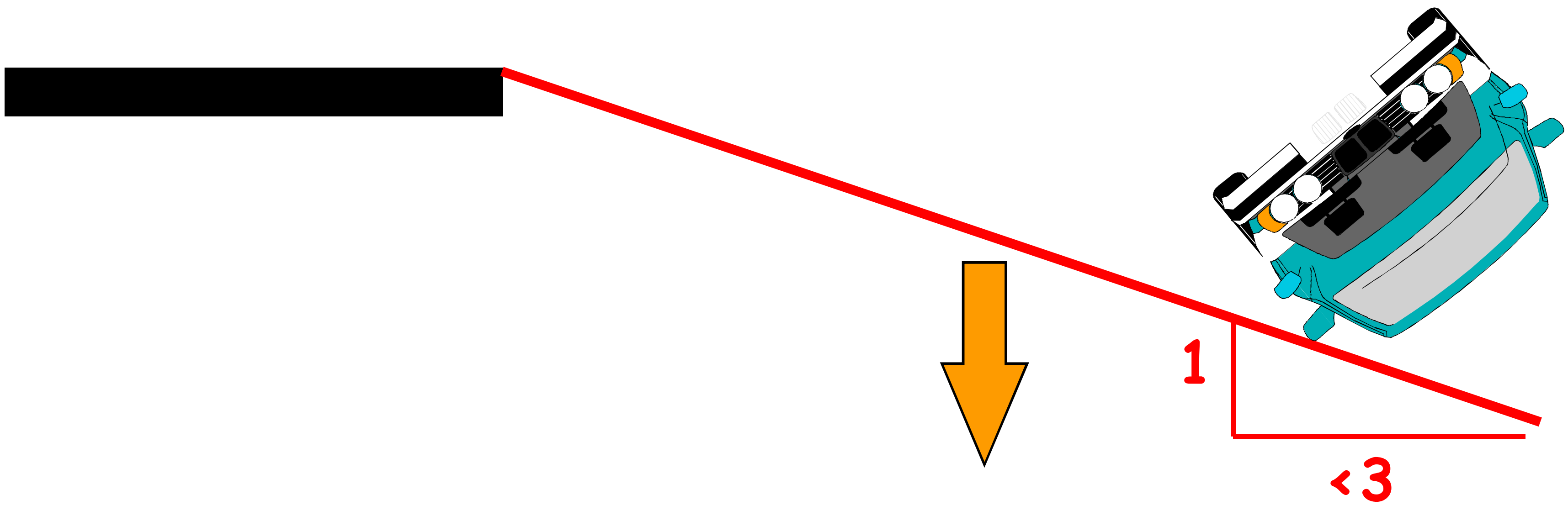
Recoverable



Non-Recoverable (but Traversable)

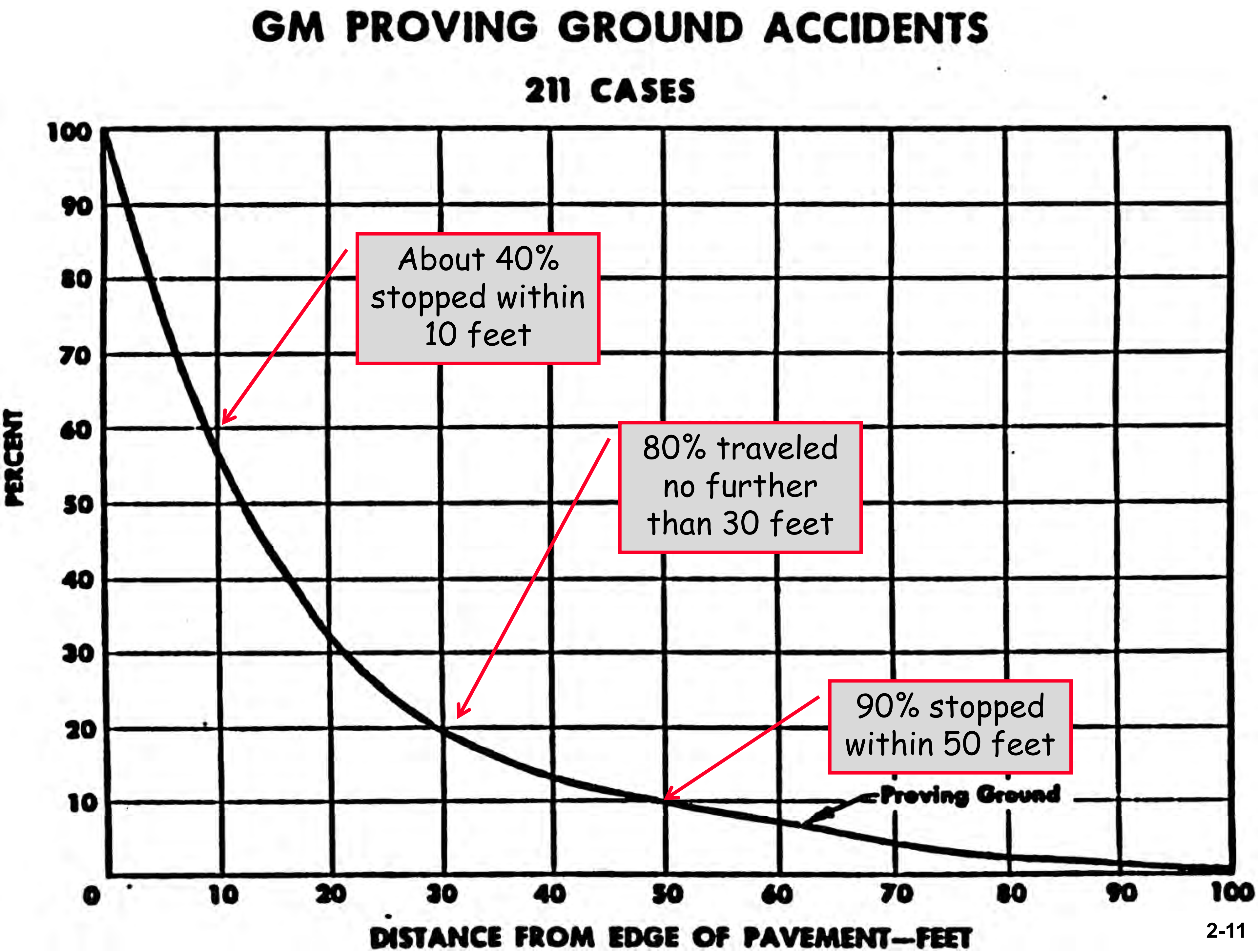


Critical



Clear Zone

THE "MAGIC"
30 FEET


GM PROVING GROUND ACCIDENTS
211 CASES
PERCENT
DISTANCE FROM EDGE OF PAVEMENT—FEET
About 40% stopped within 10 feet
80% traveled no further than 30 feet
90% stopped within 50 feet
Proving Ground
0
10
20
30
40
50
60
70
80
90
100

NCDOT Design Clear Zone Table

Design Speed	Design ADT	Foreslopes			Backslopes		
		1V:6H or flatter	1V:5H to 1V:4H	1V:3H	1V:3H	1V:5H to 1V:4H	1V:6H or flatter
40 mph or less	UNDER 750	7-10	7-10	**	7-10	7-10	7-10
	750-1500	10-12	12-14	**	10-12	10-12	10-12
	1500-6000	12-14	14-16	**	12-14	12-14	12-14
	OVER 6000	14-16	16-18	**	14-16	14-16	14-16
45-50 mph	UNDER 750	10-12	12-14	**	8-10	8-10	10-12
	750-1500	14-16	16-20	**	10-12	12-14	14-16
	1500-6000	16-18	20-26	**	12-14	14-16	16-18
	OVER 6000	20-22	24-28	**	14-16	18-20	20-22
55 mph	UNDER 750	12-14	14-18	**	8-10	10-12	10-12
	750-1500	16-18	20-24	**	10-12	14-16	16-18
	1500-6000	20-22	24-30	**	14-16	16-18	20-22
	OVER 6000	22-24*	26-32*	**	16-18	20-22	22-24
60 mph	UNDER 750	16-18	20-24	**	10-12	12-14	14-16
	750-1500	20-24	26-32*	**	12-14	16-18	20-22
	1500-6000	26-30	32-40*	**	14-18	18-22	24-26
	OVER 6000	30-32*	36-44*	**	20-22	24-26	26-28
65-70 mph	UNDER 750	18-20	20-26	**	10-12	14-16	14-16
	750-1500	24-26	28-36*	**	12-16	18-20	20-22
	1500-6000	28-32*	34-42*	**	16-20	22-24	26-28
	OVER 6000	30-34*	38-46*	**	22-24	26-30	28-30

* Clear zone distances can be limited to 30 feet unless in a high accident rate areas

Ref: Roadway Design Manual, Part I. Clear Zone Distances, 1-4N

Important Distinction

Available Clear Zone = Area Existing for recovery

Design Clear Zone = A selected value used for design to provide recovery area for a majority of errant drivers

Do not compromise available clear zone

Example Clear Zones

Example Clear Zones

Session 2

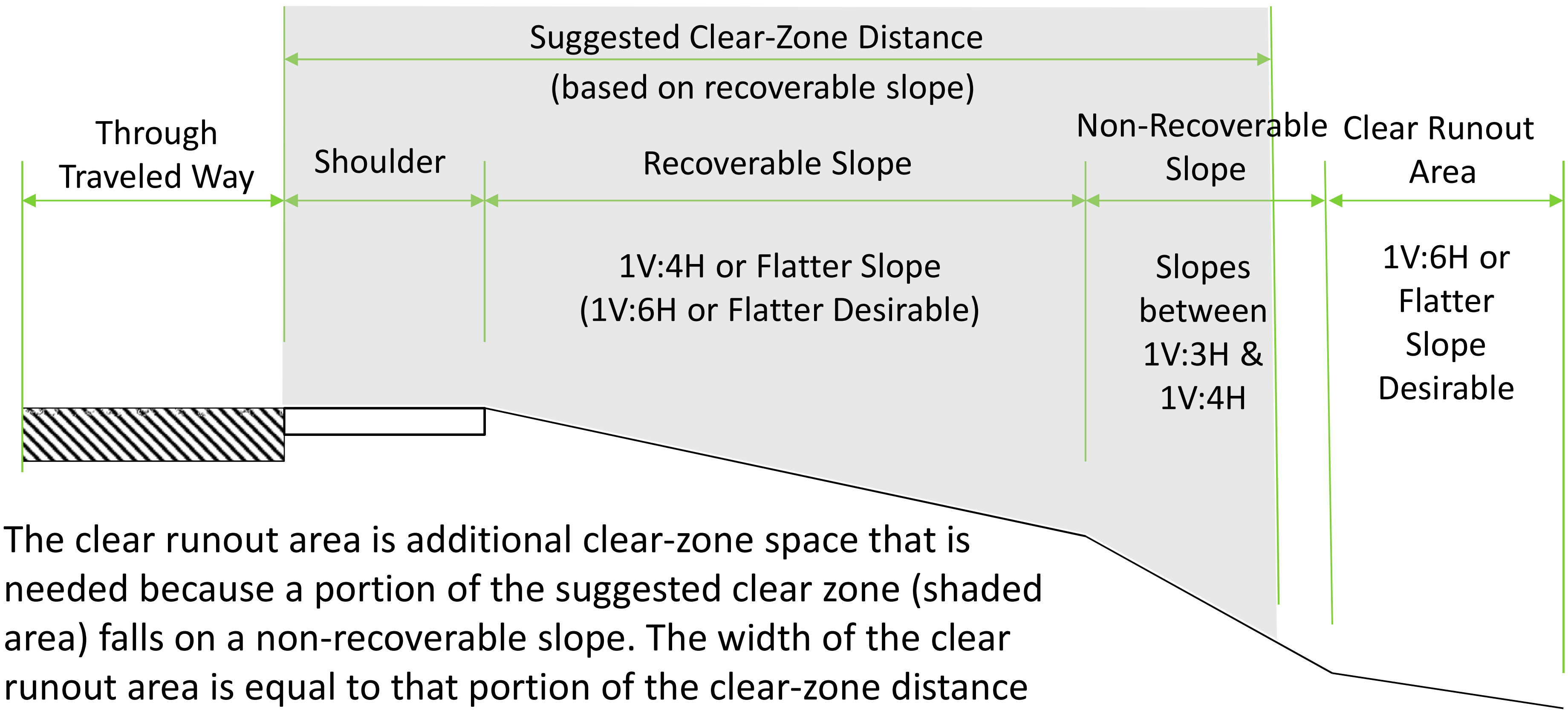
Example Clear Zones

Example Clear Zones

Example Clear Zones

Example Clear Zones

Clear Zone Adjustments for Non-uniform Slopes

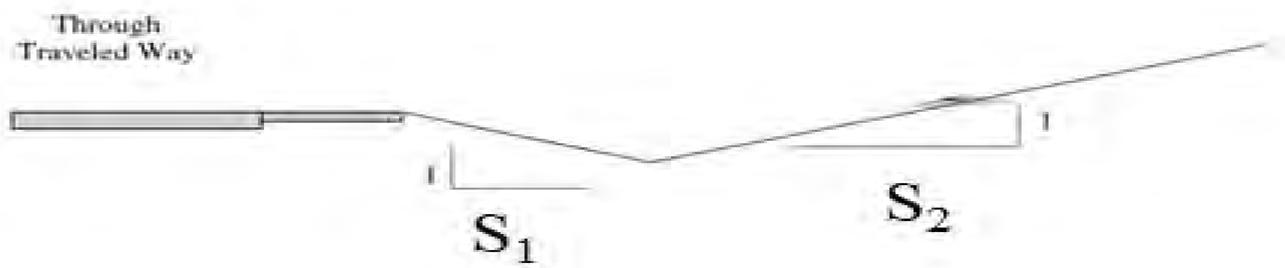


The clear runout area is additional clear-zone space that is needed because a portion of the suggested clear zone (shaded area) falls on a non-recoverable slope. The width of the clear runout area is equal to that portion of the clear-zone distance that is located on the non-recoverable slope – min 10'.

Ref: AASHTO Roadsid

FIGURE 1 SIMILAR 1-4M F-1

Clear Zone with a Ditch

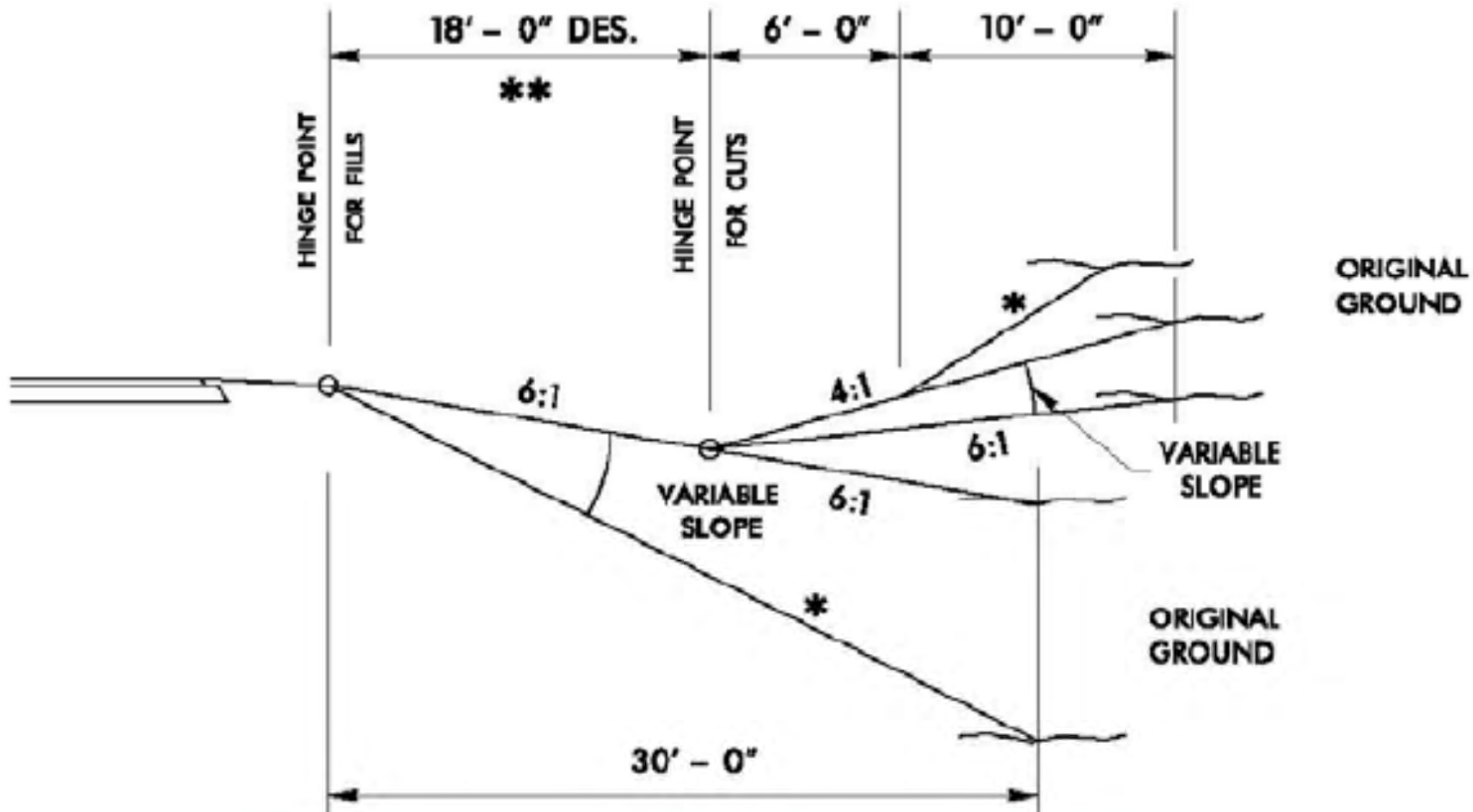


- The combination of S_1 and S_2 needs to fall within the preferred area of Figure 3.6 of the RDG for the clear zone to extend beyond the ditch bottom
- If the combination is outside and S_1 is recoverable, the clear zone stops at the ditch bottom
- If S_1 is not recoverable, the clear zone stops at the top of the S_1 slope

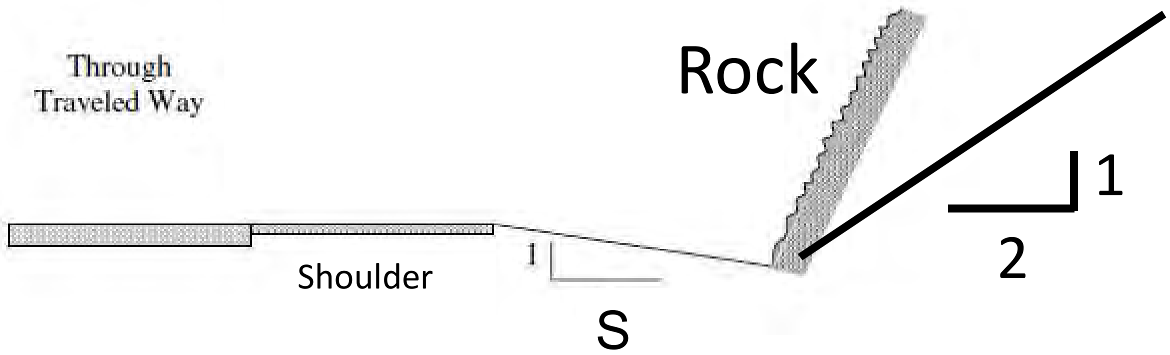
Ref: AASHTO Roadside Design Guide, 4th Edition, Figure 3.6, Pg. 3-9

Clear Zone with a Ditch - NCDOT

(A) INTERSTATES, FREEWAYS, EXPRESSWAYS, OTHER FOUR LANE FACILITIES, ARTERIALS, COLLECTORS AND LOCALS (OVER 4000 ADT DESIGN YEAR TRAFFIC)



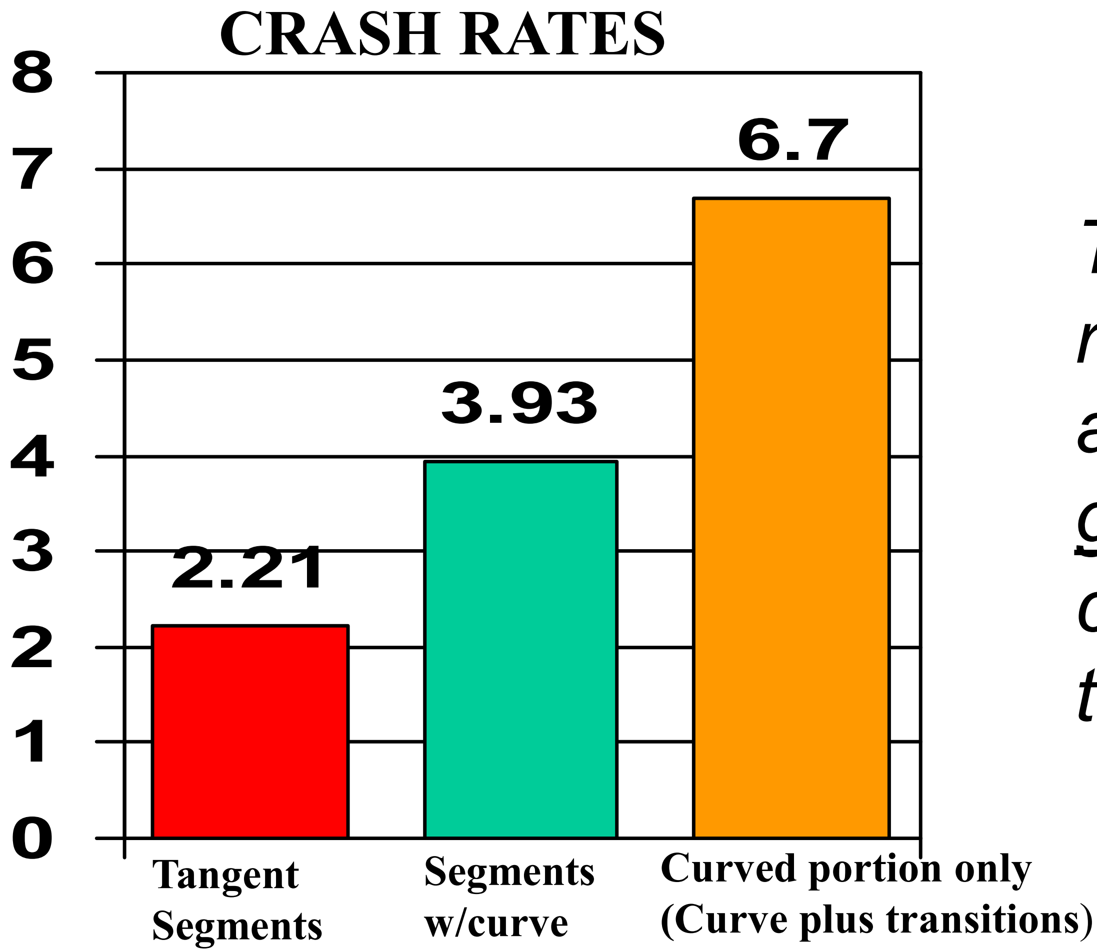
Clear Zone with a steep Cut Slope



S (≥4) Recoverable	Clear Zone extends to the base of the cut. If this distance is less than the design clear zone: • For a **smooth** rock cut – it can be considered a natural barrier. (Note a 2:1 smooth slope is not normally shielded) • For a **jagged** rock cut – it is considered as any other significant obstacle within the design clear zone.
S (<4) Non-Recoverable	Clear Zone ends at the edge of shoulder.

Ref: AASHTO Roadside Design Guide, 4th Edition, Pg.3-24

….Curves Present Particular Safety Problems

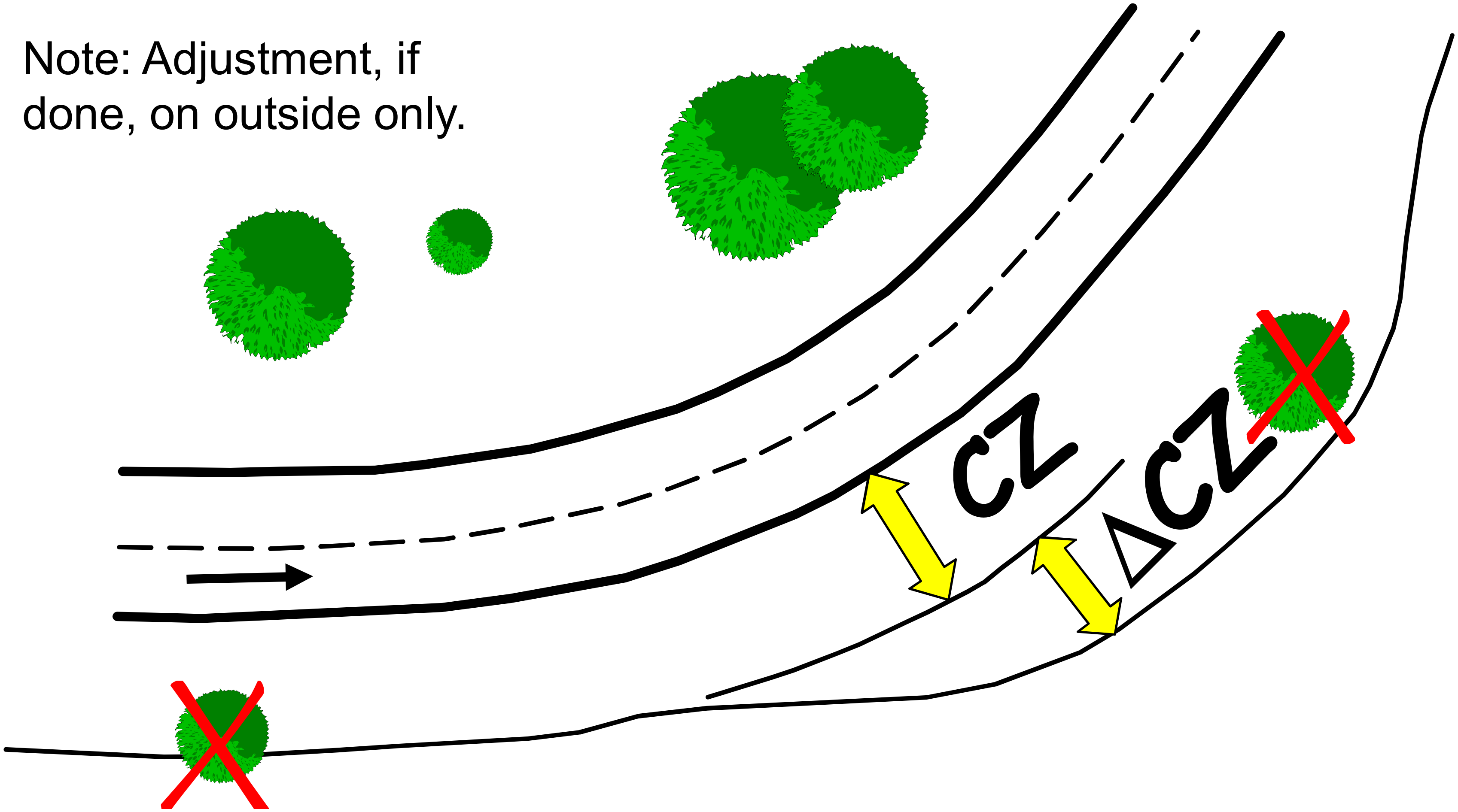


The risk of a reported crash is about <u>three times greater</u> on a curve than on a tangent

Source: Glennon, et al, 1985 study for FHWA

Horizontal Curves - AASHTO

Note: Adjustment, if done, on outside only.



Ref: AASHTO Roadside Design Guide, 4th Edition, Pg. 3-3

Horizontal Curve Adjustments

K_{CZ} (Curve Correction Factor)(U.S. Customary Units)

Radius (ft)	Design Speed (mph)					
	40	45	50	55	65	70
2,950	1.1	1.1	1.1	1.2	1.2	1.2
2,300	1.1	1.1	1.2	1.2	1.2	1.3
1,970	1.1	1.2	1.2	1.2	1.3	1.4
1,640	1.1	1.2	1.2	1.3	1.3	1.4
1,475	1.2	1.2	1.3	1.3	1.4	1.5
1,315	1.2	1.2	1.3	1.3	1.4	-
1,150	1.2	1.2	1.3	1.4	1.5	-
985	1.2	1.3	1.4	1.5	1.5	-
820	1.3	1.3	1.4	1.5	-	-
660	1.3	1.4	1.5	-	-	-
495	1.4	1.5	-	-	-	-
330	1.5	-	-	-	-	-

Ref: AASHTO Roadside Design Guide, 4th Edition, Table 3-2.Pg. 3-4

Horizontal Curves - NCDOT

The Roadside Design Guide states: "The designer **may** choose to modify…". Again, not normally done unless crash history indicates a problem.

Need approval by Roadway Design Unit

Remember - As Wide as Practical

Clear Zone and Curbs

The minimum lateral offset of 1.5 ft should be provided beyond the face of curbs to any vertical objects.

This is called the Lateral Offset and ***<u>should not be construed as an acceptable clear zone distance</u>*.**

Ref: AASHTO Roadside Design Guide, Section 10.2.1.1 Curbs

Clear Zone in an Urban Area

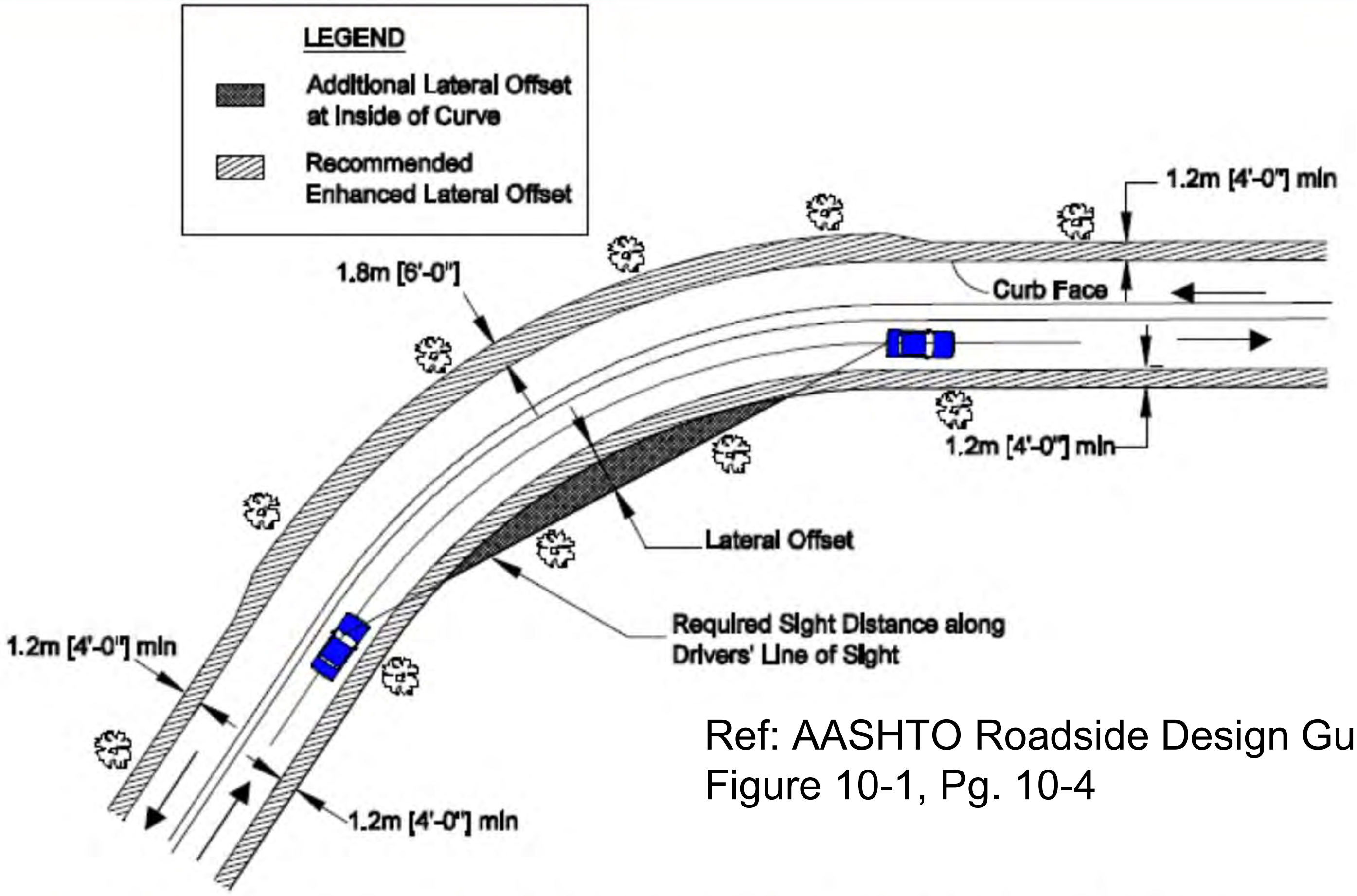


Figure 10-1. Lateral Offset for Objects at Horizontal Curves on Curbed Facilities

Ref: AASHTO Roadside Design Guide, 4th Edition, Figure 10-1, Pg. 10-4

Order of Preference

1. Remove hazard
2. Redesign hazard (make traversable)
3. Relocate hazard (move away from traffic)
4. Reduce Impact Severity (use breakaway design)
5. SHIELD hazard
6. Delineate hazard so motorist can avoid

Ref: AASHTO Roadside Design Guide, 4th Edition – Pg. 1-4

Barriers Must Be Less of a Hazard

AASHTO Barrier Warrants

Obstacle	Guidelines
Bridge piers, abutments, and railing ends	Shielding generally required
Boulders	Judgment decision based on nature of fixed object and likelihood of impact
Culverts, pipes, headwalls	Judgment decision based on size, shape and location of obstacle
Foreslopes and backslopes (smooth)	Shielding not generally required
Foreslopes and backslopes (rough)	Judgment decision based on likelihood of impact
Ditches (parallel)	Refer to Figures 3-6 and 3-7
Ditches (transverse)	Shielding generally required if likelihood of head-on impact is high
Embankment	Judgment decision based on fill height and slope (see Figure 5-1)
Retaining Walls	Judgment decision based on relative smoothness of wall and anticipated maximum angle of impact
Sign/Luminaire supports	Shielding generally required for non-breakaway supports
Traffic signal supports	Isolated traffic signals within clear zone on high-speed rural facilities may warrant shielding
Trees	Judgment decision based on site-specific circumstances
Utility poles	Shielding may be needed on a case by case basis.
Permanent bodies of water	Judgment decision based on location and depth of water and likelihood of encroachment.

Ref: AASHTO Roadside Design Guide, 4th Edition Chapter 5 Table 5-2, Pg. 5-9

NCDOT Guidance

ROADWAY DESIGN MANUAL PART 1

CHAPTER THREE

GUARDRAIL, BARRIERS AND ATTENUATORS

GUARDRAIL WARRANTS 3-1

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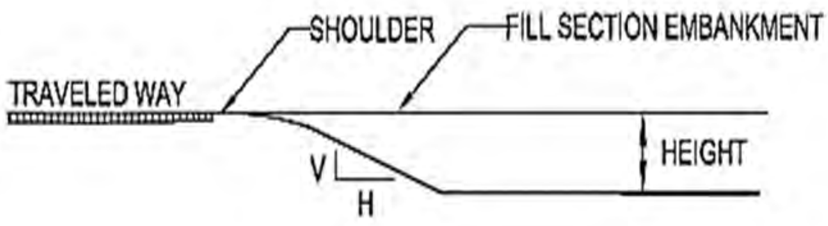
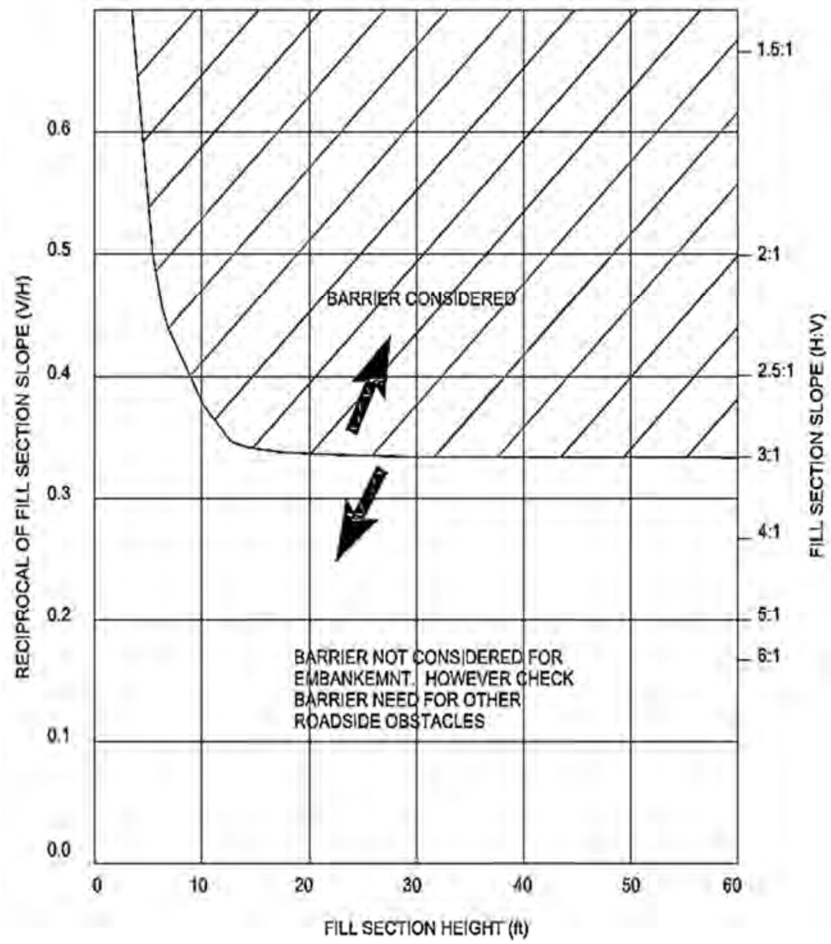
- (b) Is guardrail required in accordance with Figures 4 through 6 of this Chapter? If not required, go to (c).
- (c) Is guardrail warranted in accordance with Table 2 and 3 in this Chapter? Refer to Sheet 1-4M and 1-4N in Chapter 1 of this manual.

(2) Can Guardrail be eliminated?

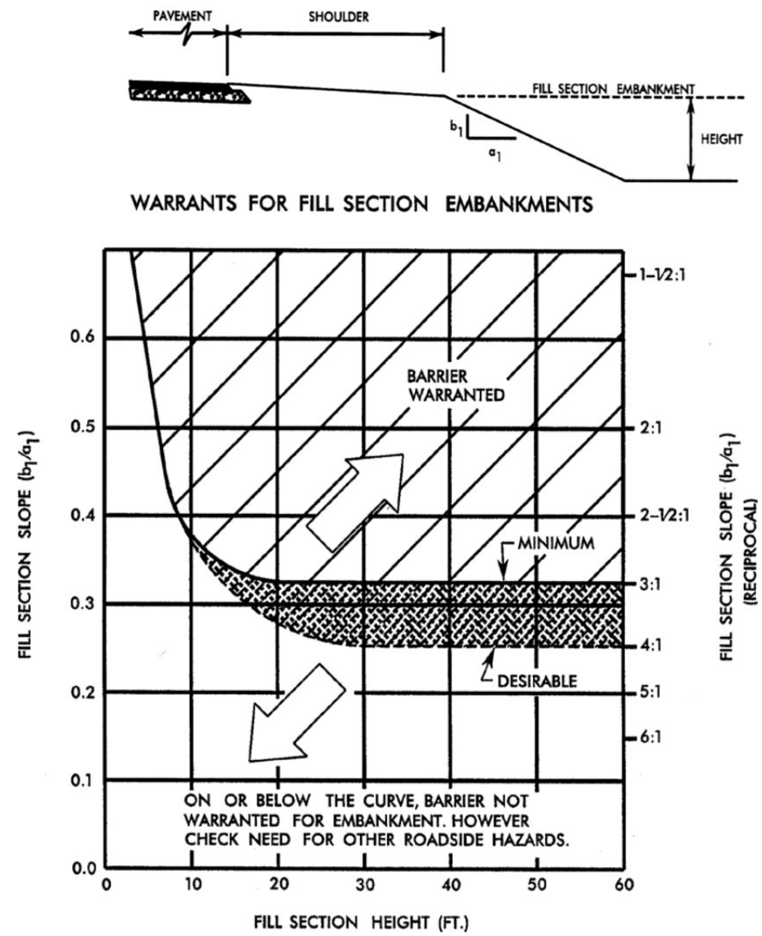
Embankment Guidelines





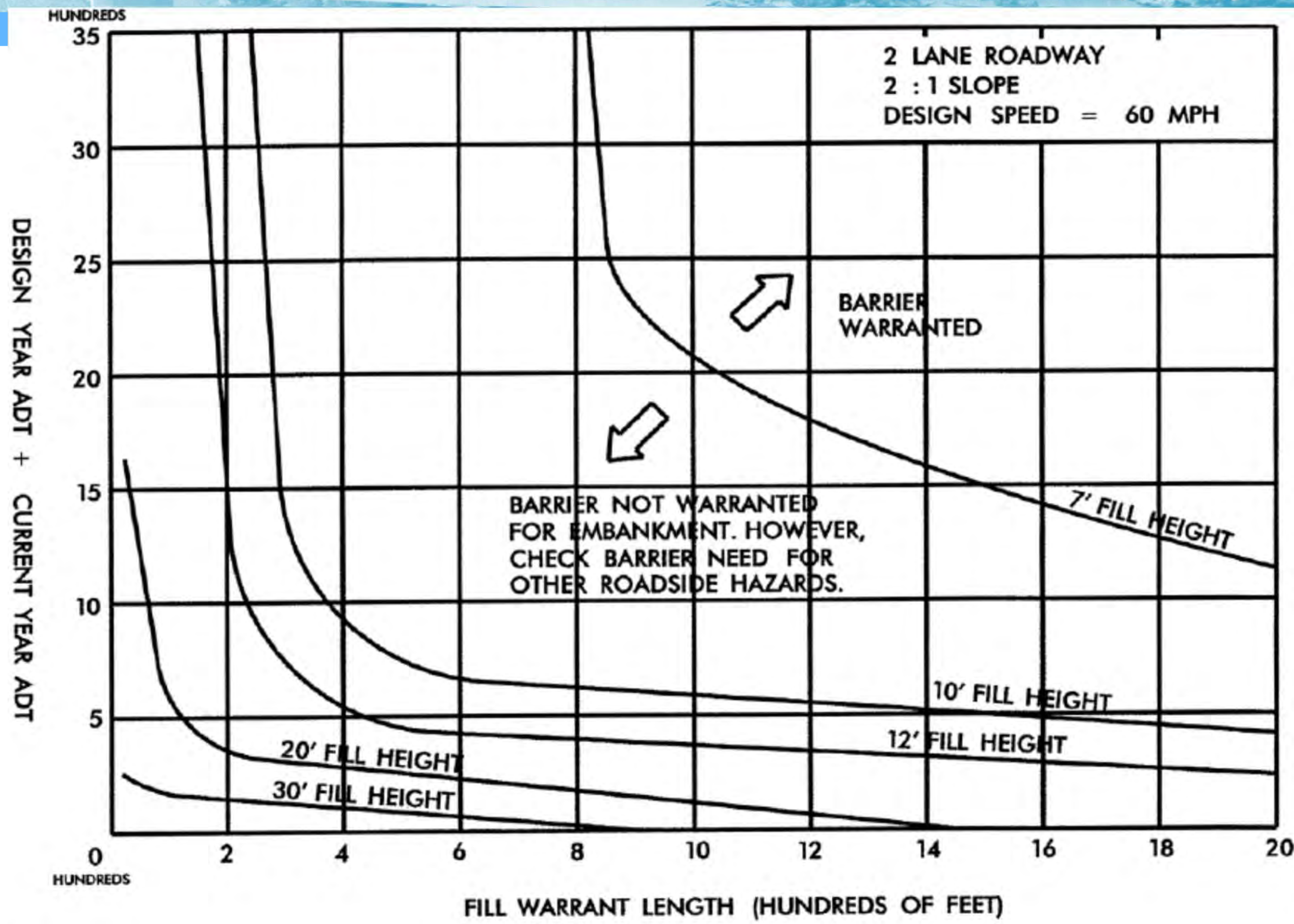
Ref: AASHTO Roadside Design Guide, 4th Edition – Figure 5.1b, Pg. 5-6

NC Embankment Warrants



Ref: NCDOT Roadway Design Manual, Part 1, Chapter 3

Modified Embankment Warrants



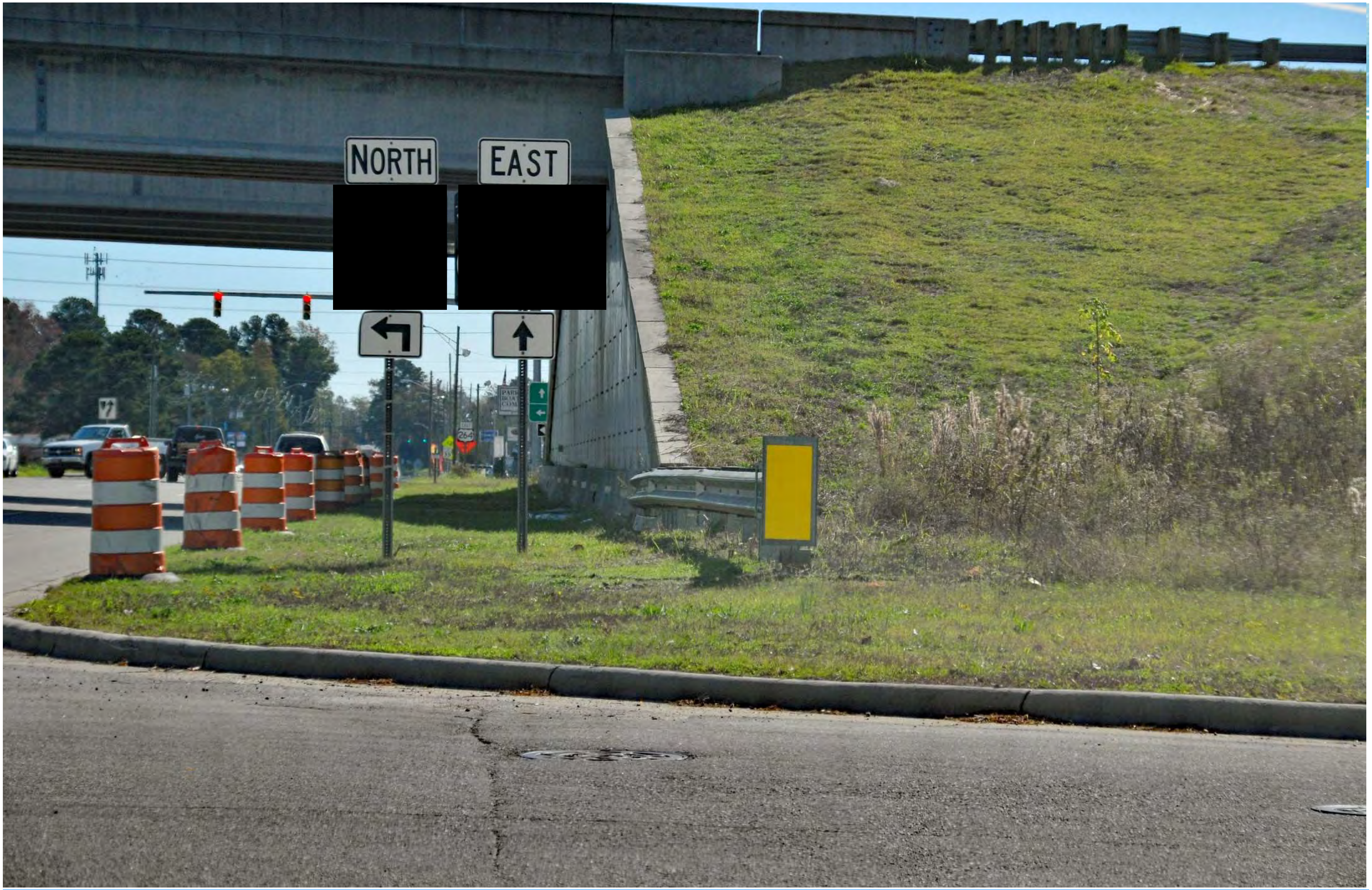
Ref: NCDOT Roadway Design Manual, Part 1, Chapter 3, Figure 5

Is barrier warranted at the locations shown in the next eight photos?

Do not consider effectiveness of existing barrier (if any).


AVAILABLE

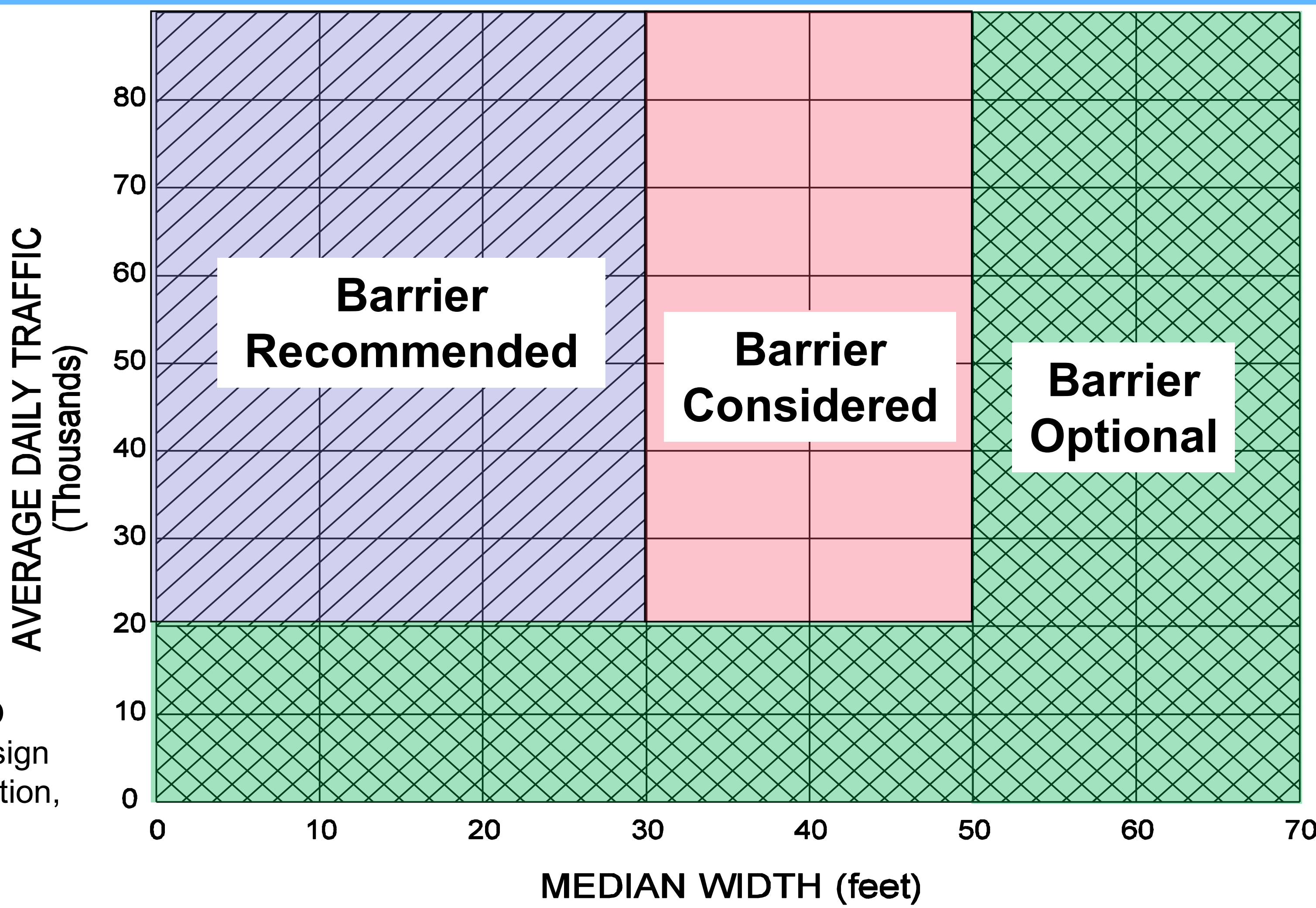

SPEED
LIMIT
45


NORTH
EAST
[redacted]


EXIT 14


Laurel
Fork

Median Width Guidelines - AASHTO



Ref: AASHTO Roadside Design Guide, 4th Edition, Figure 6-1

Median Width Guidelines - NCDOT

ROADWAY DESIGN MANUAL PART 1

GUARDRAIL / GUIDERAIL TREATMENT IN MEDIAN LOCATIONS 3-6

Guidelines for typical Median Guardrail / Guiderail Installations:

Incorporate median guardrail / guiderail on all freeway projects with median widths of 70 feet or less.

Two types of installations will be used: Cable guiderail or steel beam guardrail with 6'- 3" post spacing (semi-rigid guardrail).

Review Learning Outcomes

- Understand and apply the clear zone concept
- Identify objects and features that may require shielding

Session 3:

Testing Requirements and Performance Characteristics of Common Barrier Systems

Session 3 Learning Outcomes

At the end of this session, you will be able to:

- Understand how barriers are tested for crashworthiness
- Identify common barrier systems
- Explain how these barrier systems function
- Define the key components of a transition design

Crash Testing Guidelines

- In 1993, crash testing and evaluation criteria were published as NCHRP Report 350
- In 2009, the Manual for Assessing Safety Hardware (MASH) was published by AASHTO. It was used by FHWA as the testing standard for all new products
- In 2016, an update to MASH was adopted and a timetable for implementation of new installations complying with this edition was signed between FHWA and AASHTO

MASH Implementation Timeline

(AASHTO/FHWA Joint MASH Implementation Agreement Issued January 7, 2016)

11 years

10 years

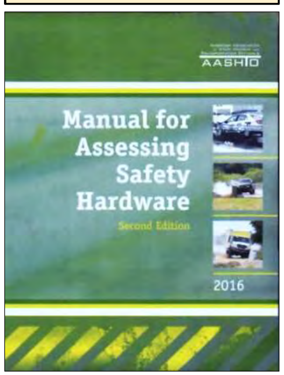
9 ½ years

7 years

2 years

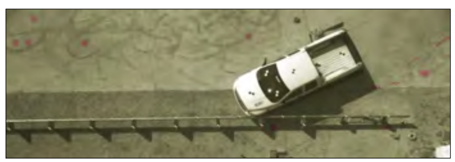
2009 — MASH Published

2016 — MASH 2016 Published



Dec 31, 2017

- **W-Beam Barriers**
- **Cast-in-place Concrete Barriers**



June 30, 2018

W-Beam Terminals
- **Tangent**
- ❖ **Flared**
- ❖ **Median**

Dec 31, 2018

X Crash Cushions
❖ **Cable Barriers**
❖ **Cable Terminals**

December 31, 2019

- **All Other Terminals**
- **Transitions**
- **All Other Barriers/Portable**
- **Bridge Rails**
- **Sign Supports**
- **Other Breakaway Hardware**

❖ **MOVED TO DEC. 31, 2019**

X SOME MOVED TO DEC. 31, 2019

MASH Test Conditions

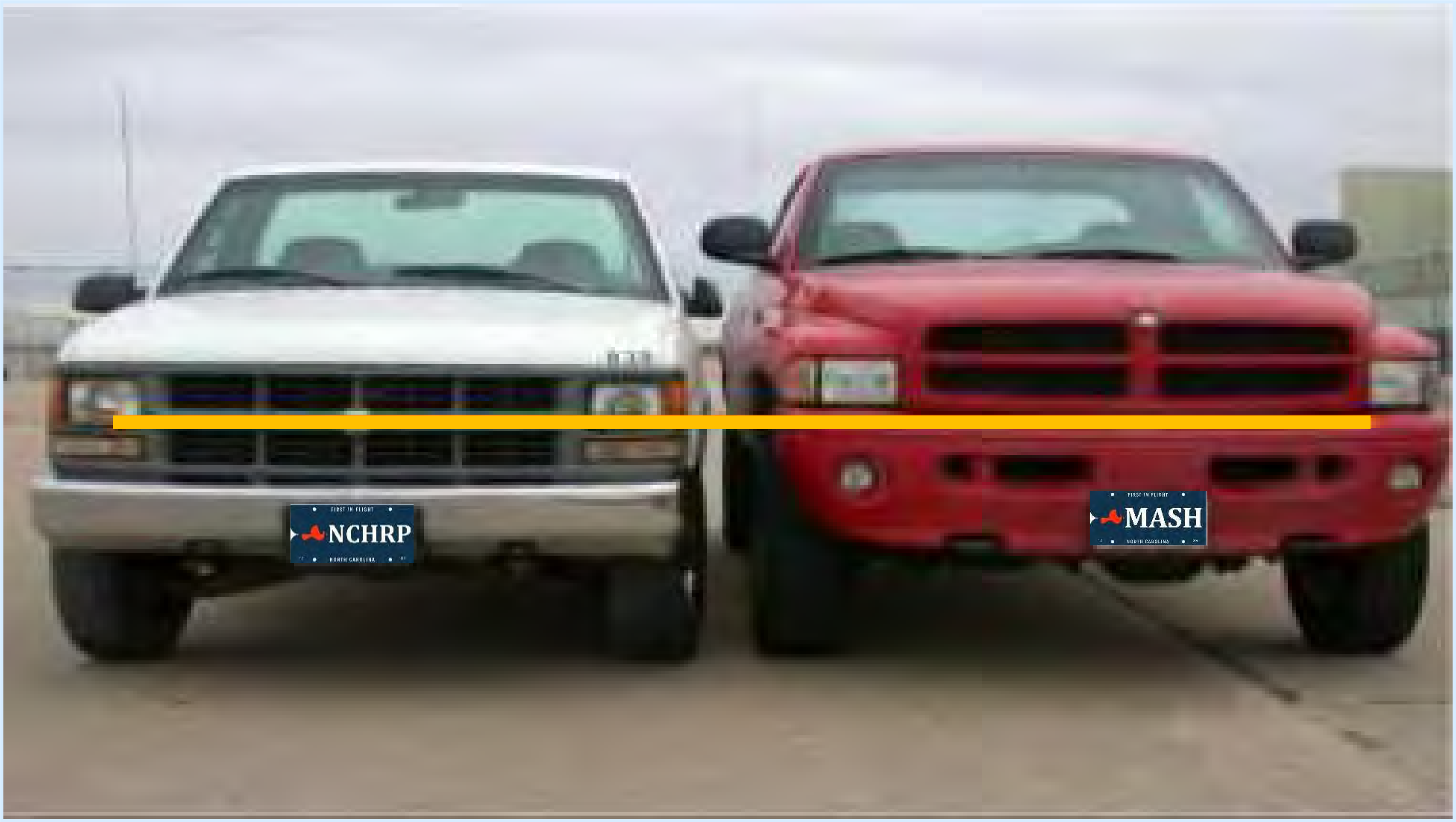
Selection of a performance level is based on speed and traffic mix.

- **TL-1**, **TL-2**, and **TL-3**: crash tests with small car and pickup truck with a 25˚ impact angle at 31, 44, and 62 mph, respectively.

2,420 lbs.
1100C

5,000 lbs.
2270P

NCHRP 350 comparison with MASH Crew Cab Truck

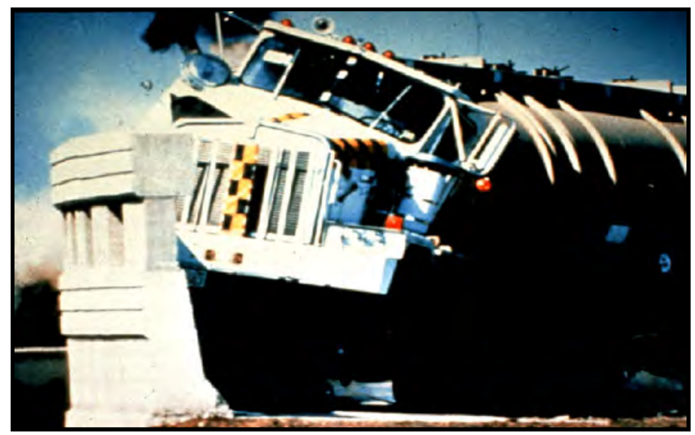


MASH Test Conditions (cont'd)

- **TL- 4**: TL-3 + 15˚ impact angle, 56 mph Single-Unit Truck
- **TL- 5**: TL-3 + 15˚ impact angle, 50 mph Tractor-Van Trailer
- **TL- 6**: TL-3 + 15˚ impact angle, 50 mph Tractor-Tank Trailer

22,000 lbs.

80,000 lbs.



80,000 lbs.

Functional Requirement of Barrier

1. Contain Vehicle
   - No Penetration
   - No Vaulting/Under-riding
2. Redirect Vehicle Smoothly (low exit angle) with no snagging/overturning, and no excessive rotation (75 degree max)
3. Tolerable Occupant Impact Forces
4. Minimum Occupant Compartment Deformation and no Debris Intrusion

Standard Barrier Systems

- Rigid Systems
- Semi-Rigid Systems
- Flexible Systems
- Median Barrier Systems

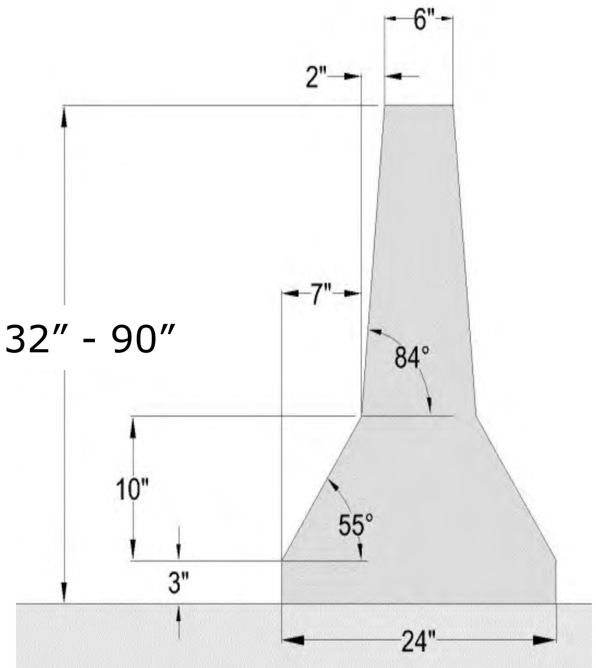
Barrier Systems: Rigid Barriers

Rigid Barrier Systems have little (between 0 to 1 ft.) deflection under the TL-3 pickup impact. They are generally anchored by some acceptable means.

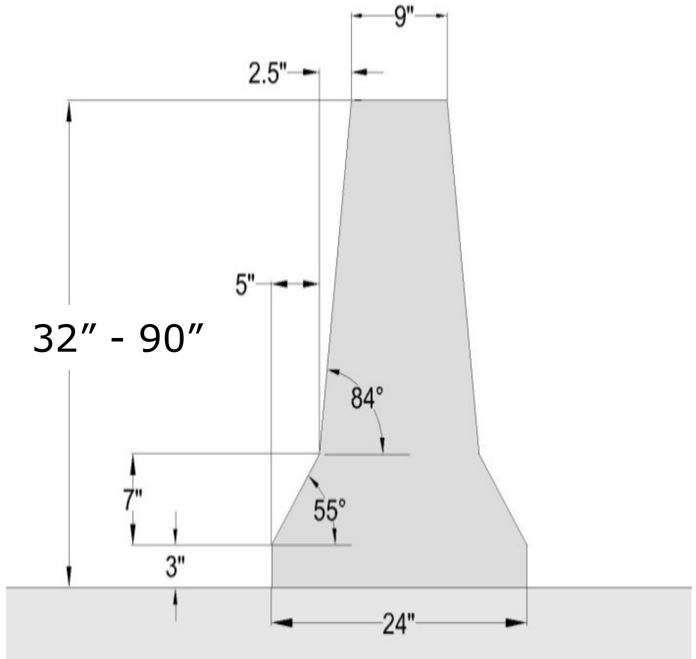
Examples include:

- New Jersey Safety Shape Concrete Barrier
- F-shape Concrete Barrier
- Single or Slope Concrete Barrier
- Vertical Wall

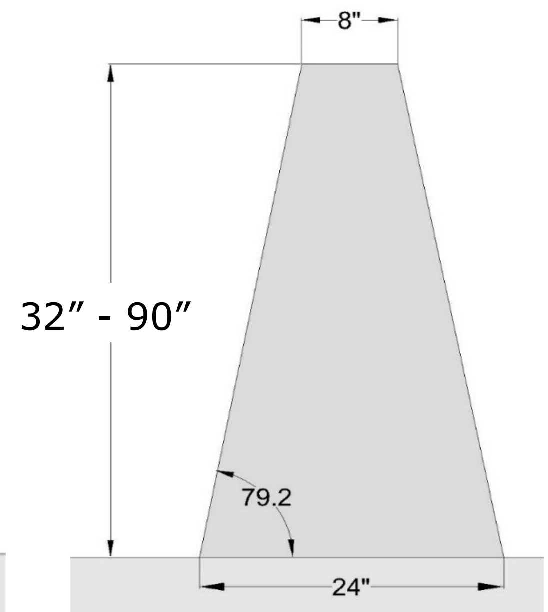
Rigid Barrier



New Jersey Shape

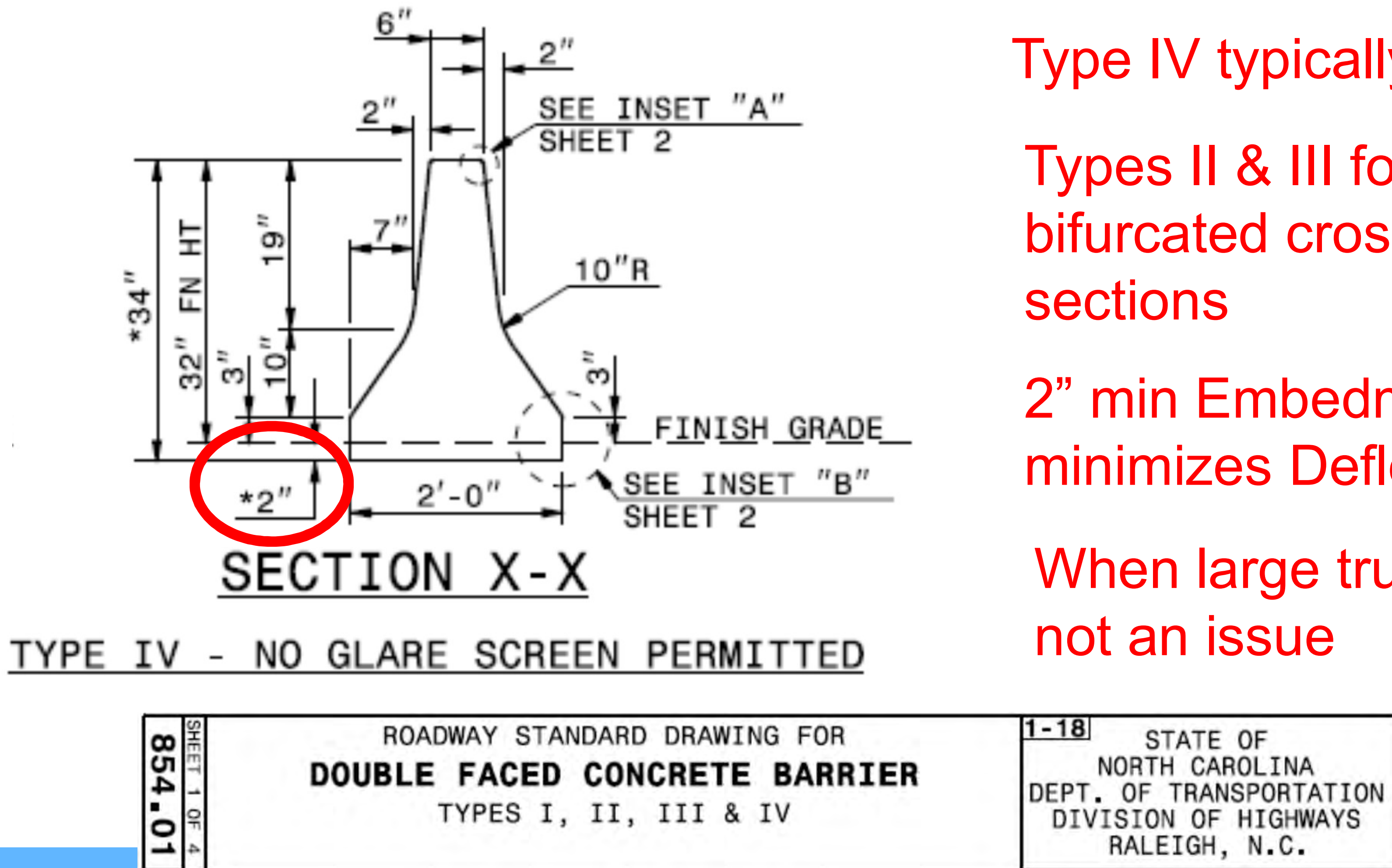


F-Shape



Single Shape

Rigid Barrier – New Jersey Shape



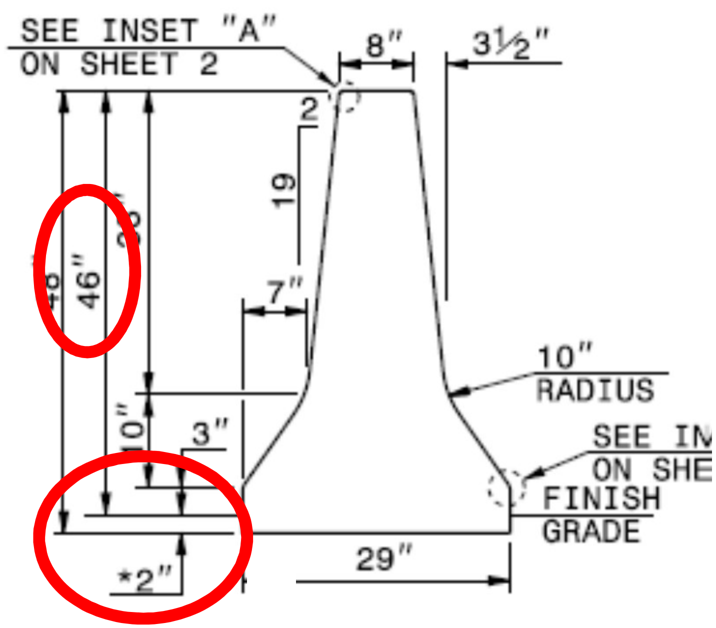
Type IV typically used

Types II & III for bifurcated cross-sections

2" min Embedment minimizes Deflection

When large trucks are not an issue

Rigid Barrier – New Jersey Shape



SECTION X-X

TYPE - T

854.02 SHEET 1 OF 4

ROADWAY STANDARD DRAWING FOR
DOUBLE FACED CONCRETE BARRIER
TYPE T, T1 AND T2

1-18

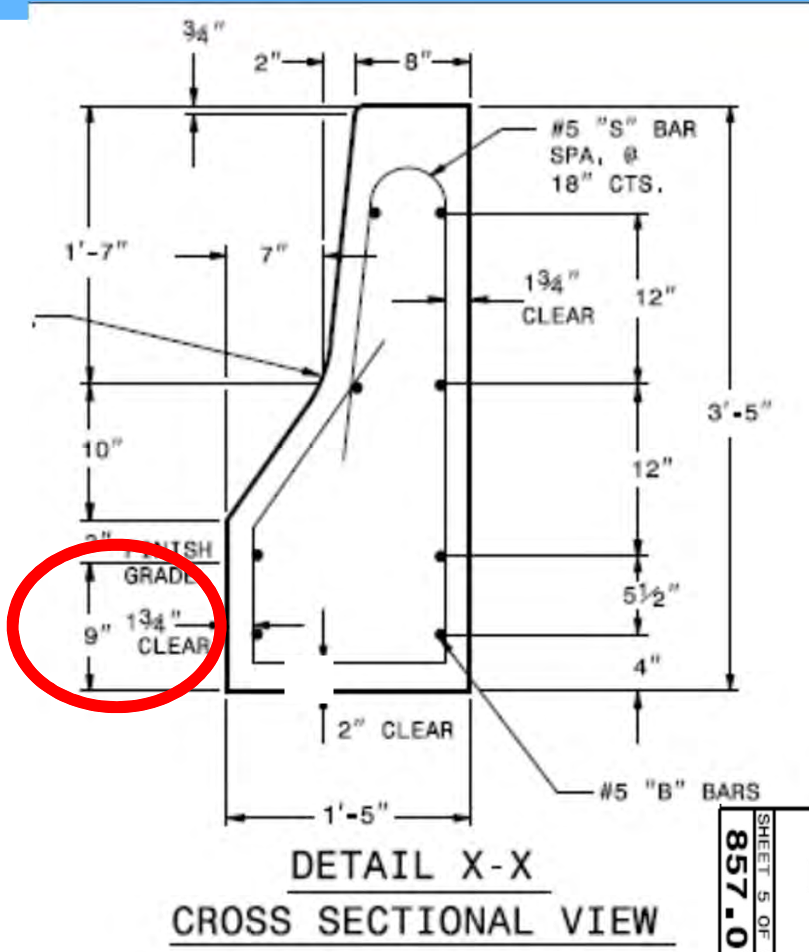
STATE OF
NORTH CAROLINA
DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS
RALEIGH, N.C.

2" min Embedment minimizes Deflection

Considered TL- 5

For use when conditions warrant (typical urban, high truck volume

Rigid Barrier – New Jersey Shape



9” min Provides Fixity

857.01 SHEET 5 OF 8

ROADWAY STANDARD DRAWING FOR
PRECAST REINFORCED CONCRETE BARRIER
41" SINGLE FACED

1-18

STATE OF
NORTH CAROLINA
DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS
RALEIGH, N.C.

MASH Testing of 32" New Jersey Shaped Concrete Barrier

Rigid Barrier

Note – No national criteria for when to use TL-4, 5, or 6

Rigid Barrier: TL-5

Zone of Intrusion

<u>Zone of Intrusion (ZOI)</u> - the region measured above and behind the face of a barrier system where an impacting vehicle or any major part of the system may extend during an impact.

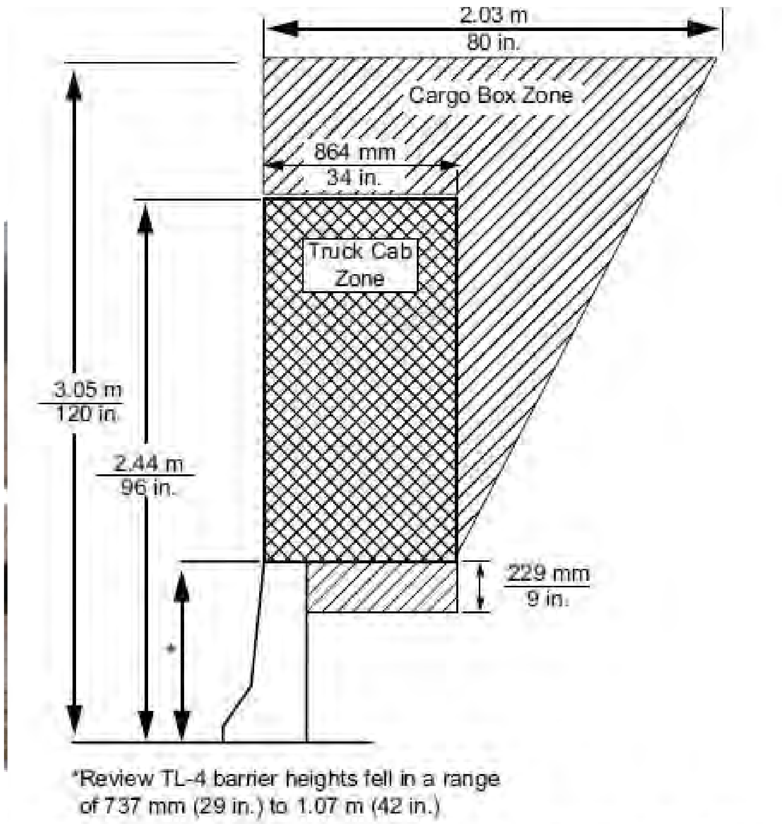


Figure 5-31. Zone of Intrustion for TL-4 Barriers per NCHRP Report 350

AASHTO LRFD Bridge Specification (7th Edition)

3.6.5.1

Where the design choice is to redirect or absorb the collision load, protection shall consist of one of the following:

- An embankment;
- A structurally independent, crashworthy ground-mounted 54.0-in. high barrier, located within 10.0 ft from the component being protected; or
- A 42.0-in. high barrier located at more than 10.0 ft from the component being protected.

Such barrier shall be structurally and geometrically capable of surviving the crash test for Test Level 5, as specified in Section 13.

Barrier Systems: Semi-Rigid

Semi-Rigid Barrier Systems have deflections of a few feet (between 2 to 5 ft.) under the TL-3 pickup impact.

Typically consist of beam and post elements.

TERMINOLOGY: Call new system 31” (shows 2’-1” to bolt on standards)

Barrier Systems: Semi-Rigid

- W-Beam Steel Guardrail – **350 Guardrail (29")**
  - 12" wide W-beam rail section (12-gauge thickness).
  - Posts are spaced at 6'-3" centers, and the nominal rail height is 27" – 30"
  - Rail splice at the post.
  - Steel posts: W6 x 8.5/9.0 x 6'-0" long.
  - Blocks: 6" x 8" wood or plastic.

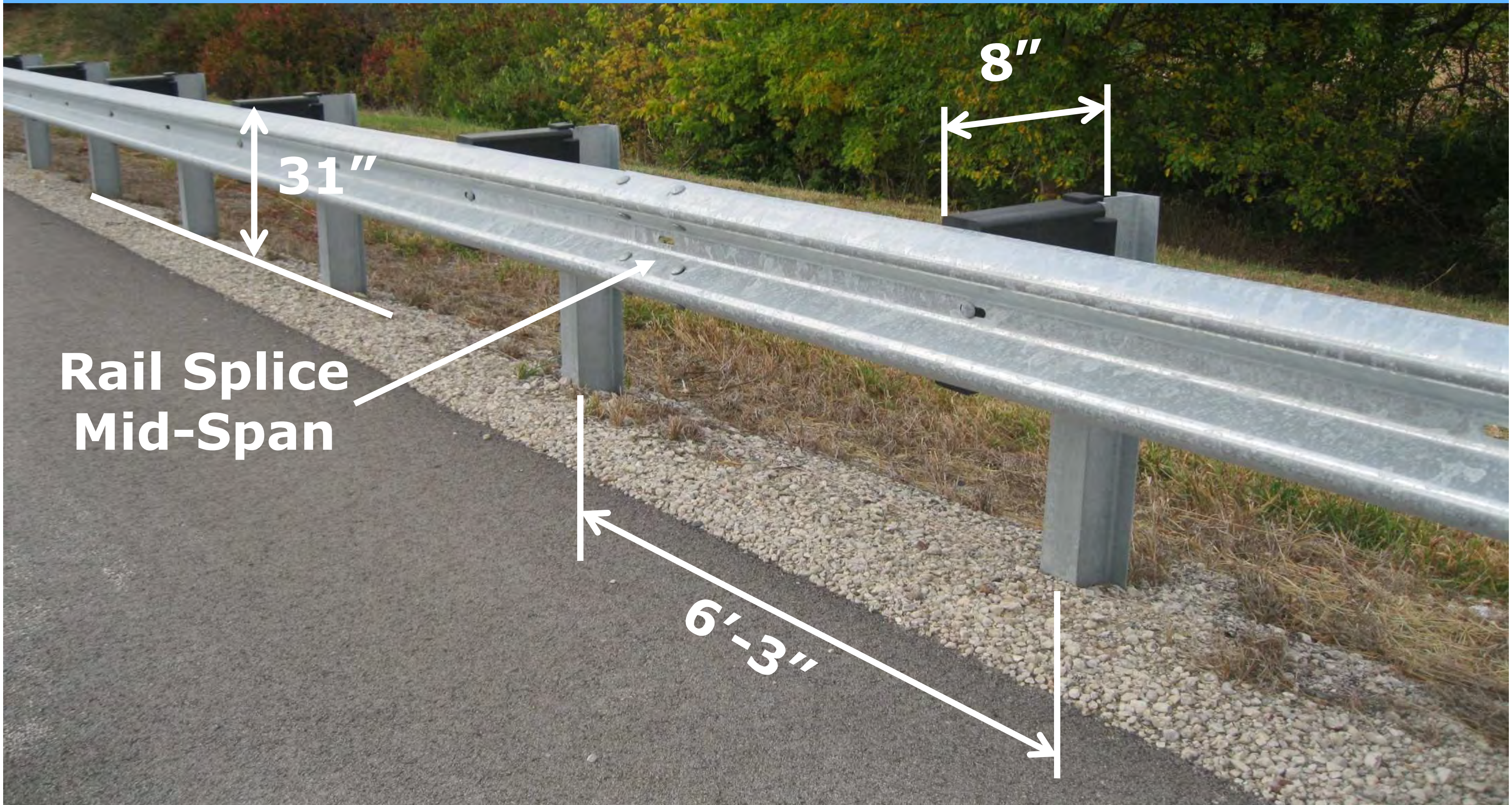
Guardrail with Wood Post & Wood Block-Out 27 5/8” Height

Guardrail with Steel Post & Wood Block-Out 27 5/8" Height

Barrier Systems: Semi-Rigid

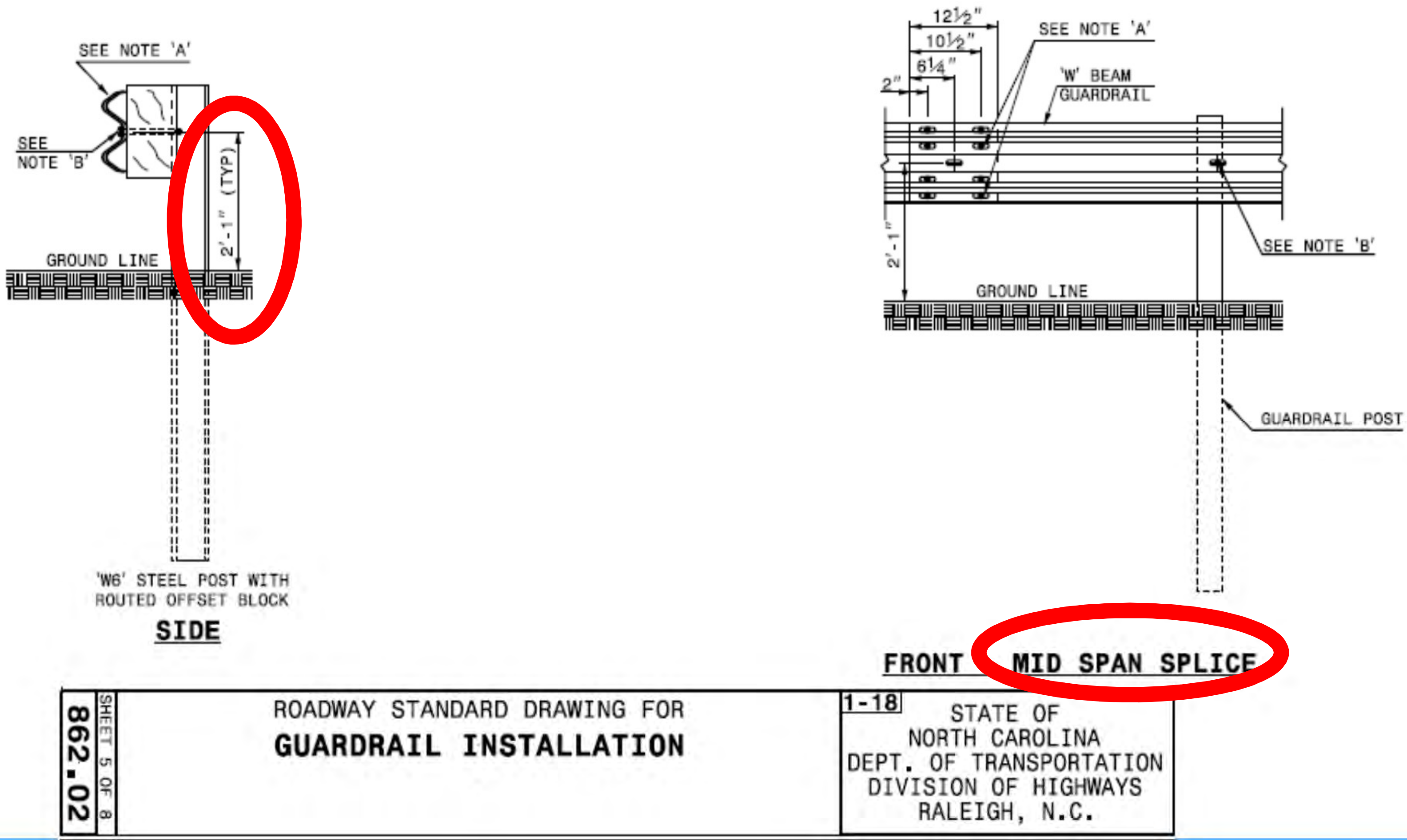
- **31”** (shown in standards as 2’-1”)
  - 31” Height to Top of Rail
  - Rail Splice mid-span.
  - Post spacing 6’-3”
  - Steel posts, W6 x 8.5/9.0 x 6’
  - Offset Block: 8” recycled plastic or composite

31” Guardrail



31” MASH Test 3-11

NCDOT 31" Guardrail



Existing Guardrail Height

Must be ≥ 27” to remain in place within the Transportation Improvement Program (TIP)

Barrier Systems: Flexible Barriers

Flexible Barrier Systems typically have relatively <u>large deflections</u>

Examples of Flexible Barriers include:

- Weak post W-beam
- Low tension cable
- High tension cable

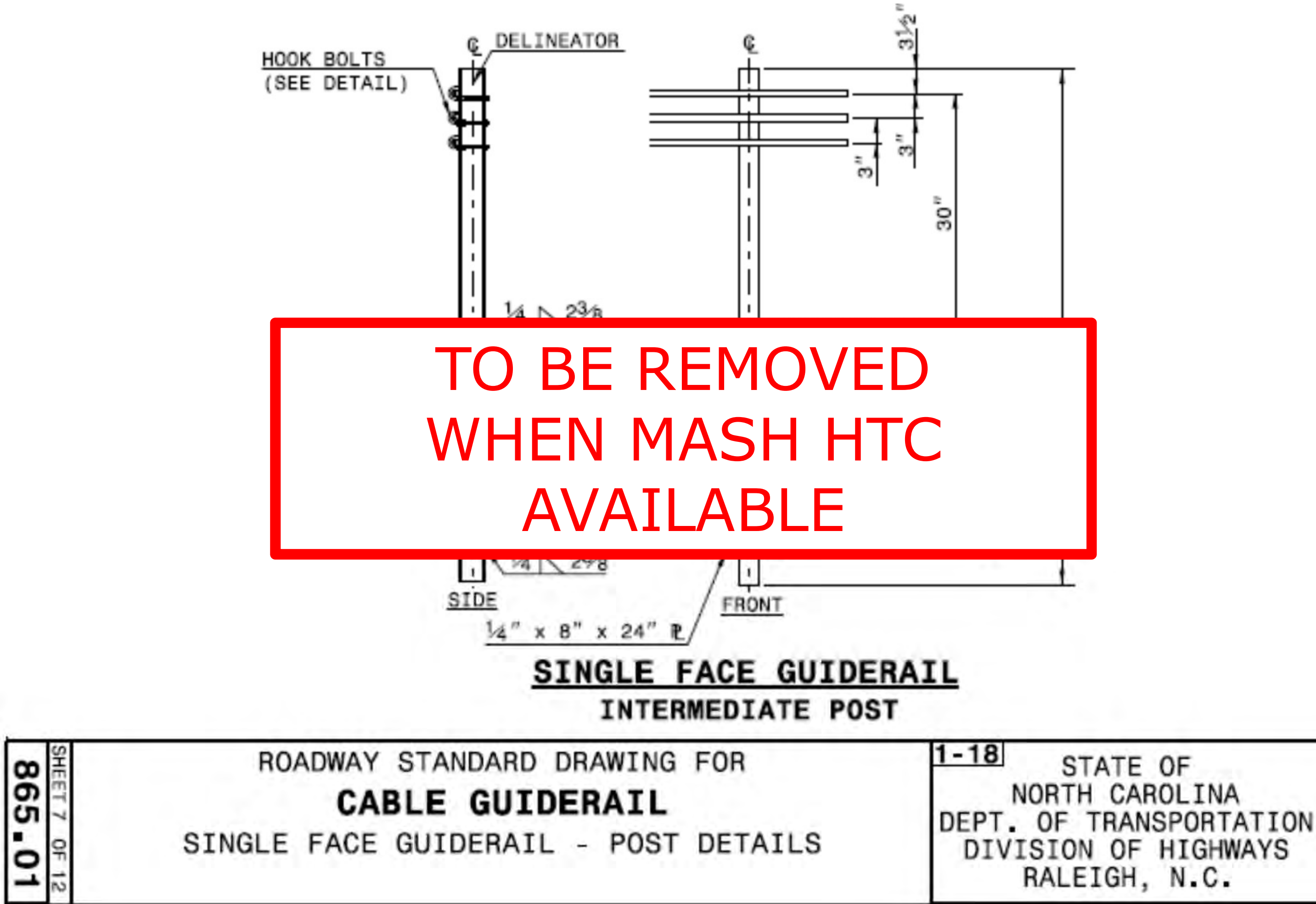
No longer in standards
To be removed from standards when MASH available

Barrier Systems: Flexible Barriers

- Low Tensioned Cable Barrier
  - Generic System
  - 3 cables design (center cable on opposite side of the post for median application).
  - Design deflection of approximately 12 ft.
  - Generic crashworthy terminal.

Cable Guiderail

NCDOT Cable Guiderail



TO BE REMOVED
WHEN MASH HTC
AVAILABLE

Barrier Systems: Flexible Barriers

Advantages of cable systems include:

- Low initial cost
- Lower deceleration forces
- Effective vehicle containment and redirection
- Installation conditions flexibility
- SNOW

Barrier Systems: Flexible Barriers

- High Tensioned Cable (HTC) Barrier
  - Five different proprietary designs available
  - Each requires a unique proprietary terminal
  - Somewhat reduced deflections
  - Generally easier maintenance
  - Can retain effectiveness after most impacts

High-Tension Cable (HTC) Systems

- Brifen ★
- Safence
- CASS (Trinity Steel) ★
- Nucor
- Gibraltar ★

★ = APL

Currently, NO system has passed all MASH 2016 testing

Brifen USA

http://www.brifenusa.com

- Interweaving cables creates a “mini-anchor” at each post due to friction as the tensioned cables weave past each post.
- 3 or 4 cable design available.

Gibraltar

http://www.gibraltartx.com

- Has hairpin type connection to post.
- Posts to cable connection is alternate side-to-side
- 3 or 4-cable design available.

Trinity Industries

(Cable Safety System-CASS)

http://www.highwayguardrail.com

- Post has waved-shape slot located in the web of the upper portion of the post.
- 3 or 4 cable design available.

Four Cable System

Post Foundation and Typical Terminal

HTC On 4:1 Slope

Maximum Offset 4′

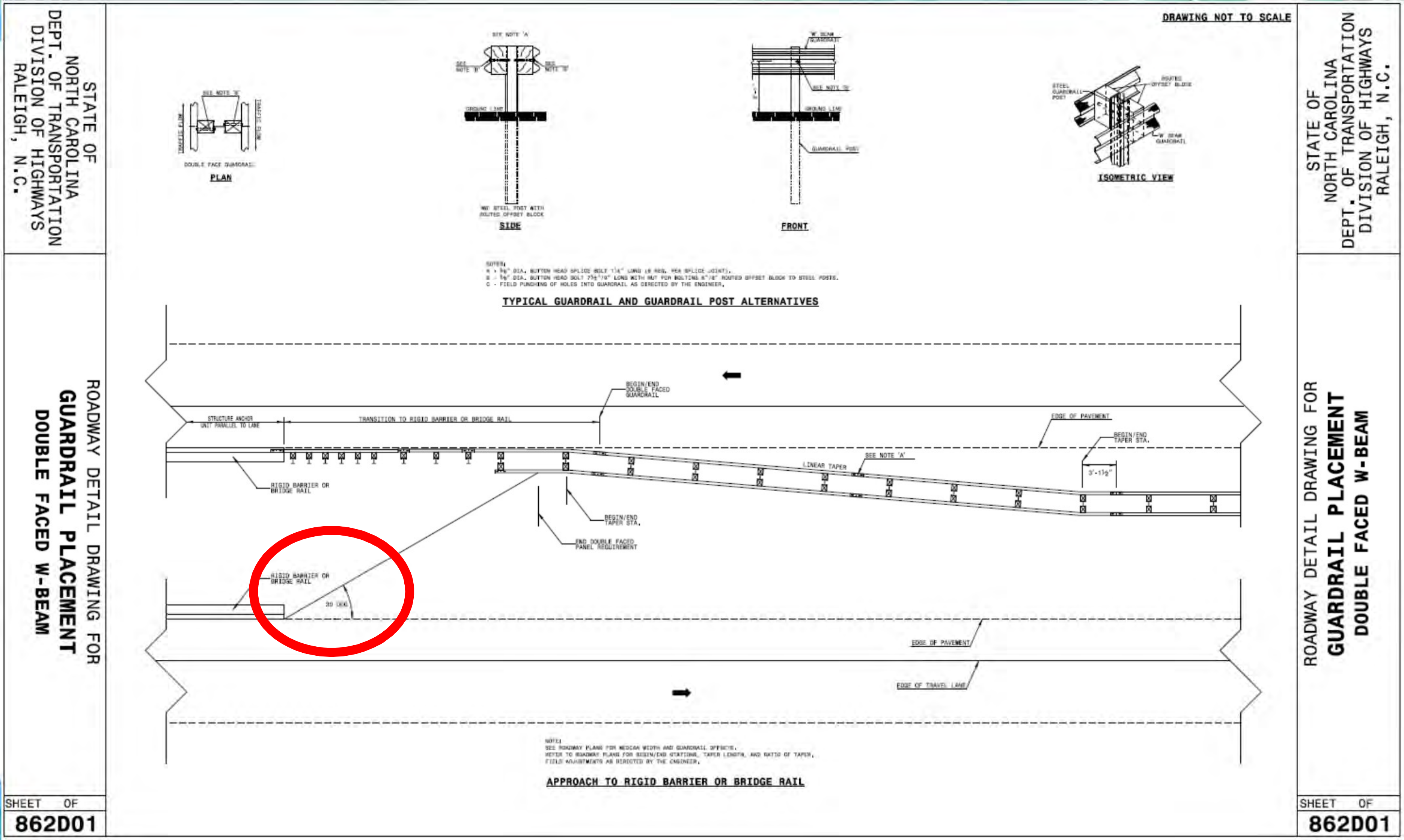
Barriers in the Median

- Used to separate opposing traffic on a divided highway or to separate through traffic from local traffic.
- Many barriers approved for roadside applications can be modified for use in the median.
- Width of the median is an important consideration.
- Also must consider the dynamic deflection of the barrier to avoid intrusion into opposing traffic.
- There are terminals designed specifically to shield the ends of median barriers.

MASH 27" W-Beam Median Barrier Test

MASH 31” Median Barrier Test

MASH 31” Median Barrier



Flexible Median Barriers

Advantage of high tension cable is it may remain effective after impact.

Flexible Median Barriers

Transition Sections

- When a softer (more flexible) barrier precedes a stiffer barrier, a gradual stiffening must occur between the two systems.
- An effective transition must provide the following:
  - Adequate connection (TENSION continuity)
  - Adequate length to gradually increase stiffness.

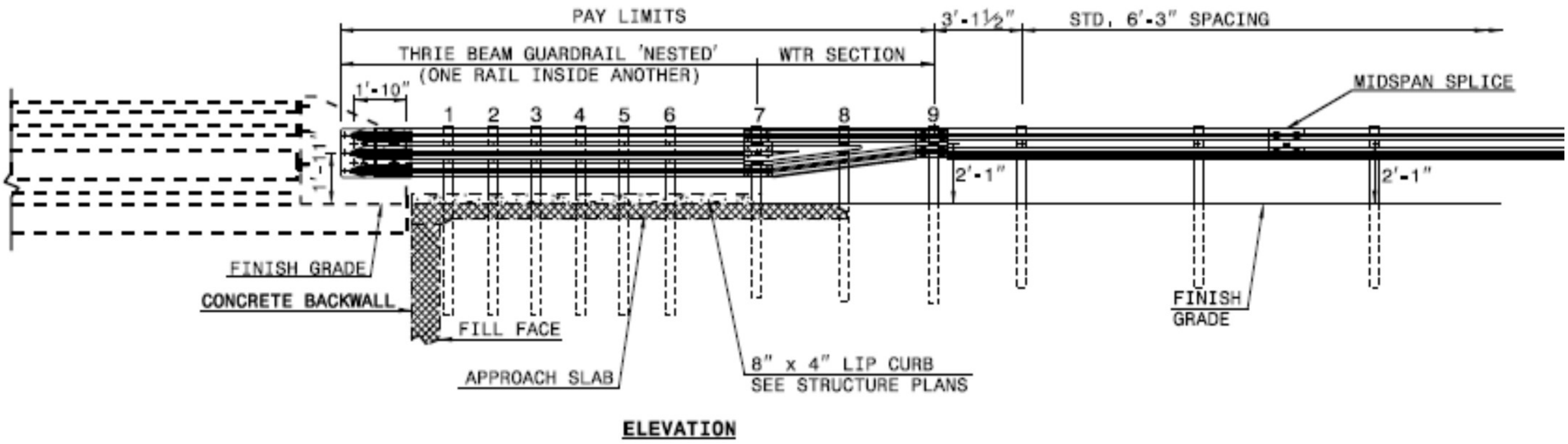
Inadequate Transition

Transition Sections

Successfully crash-tested transitions include the following essential elements (in addition to a structural connection):

- Additional and/or Larger Posts
- Nested rail (w-beam or Thrie-beam)
- Curbs (only as crash-tested transition unit), Rub Rails, and/or Flared Parapet Wall to Prevent Snagging

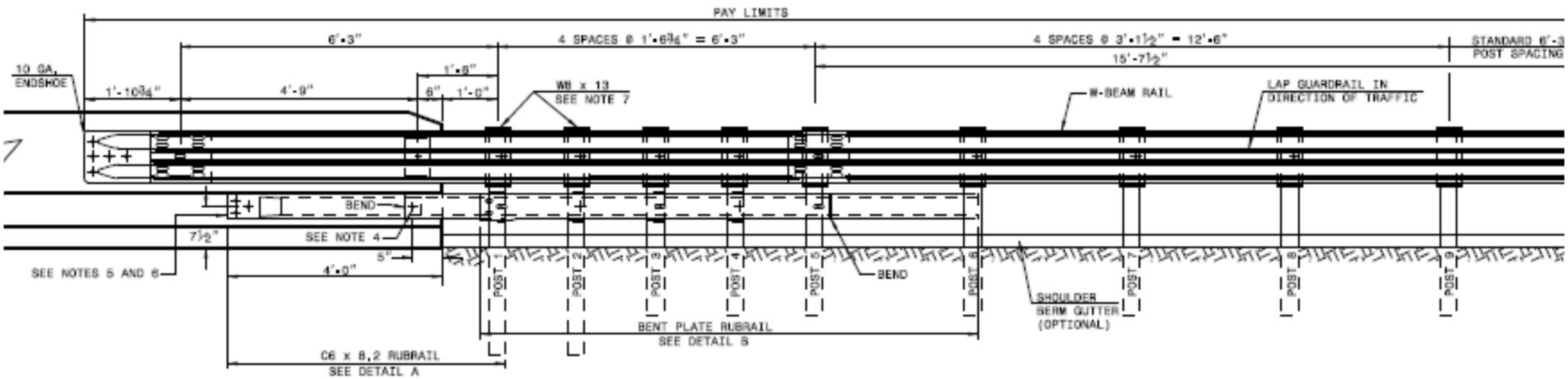
NCDOT Transition – Thrie-beam



862.03	SHEET 1 OF 7	ROADWAY STANDARD DRAWING FOR **STRUCTURE ANCHOR UNITS** GUARDRAIL ANCHOR UNIT, TYPE III FOR ATTACHMENT TO RAIL ON BRIDGE	1-18 STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

NCDOT Transition – Previous Standard

NCDOT Transition – Direct



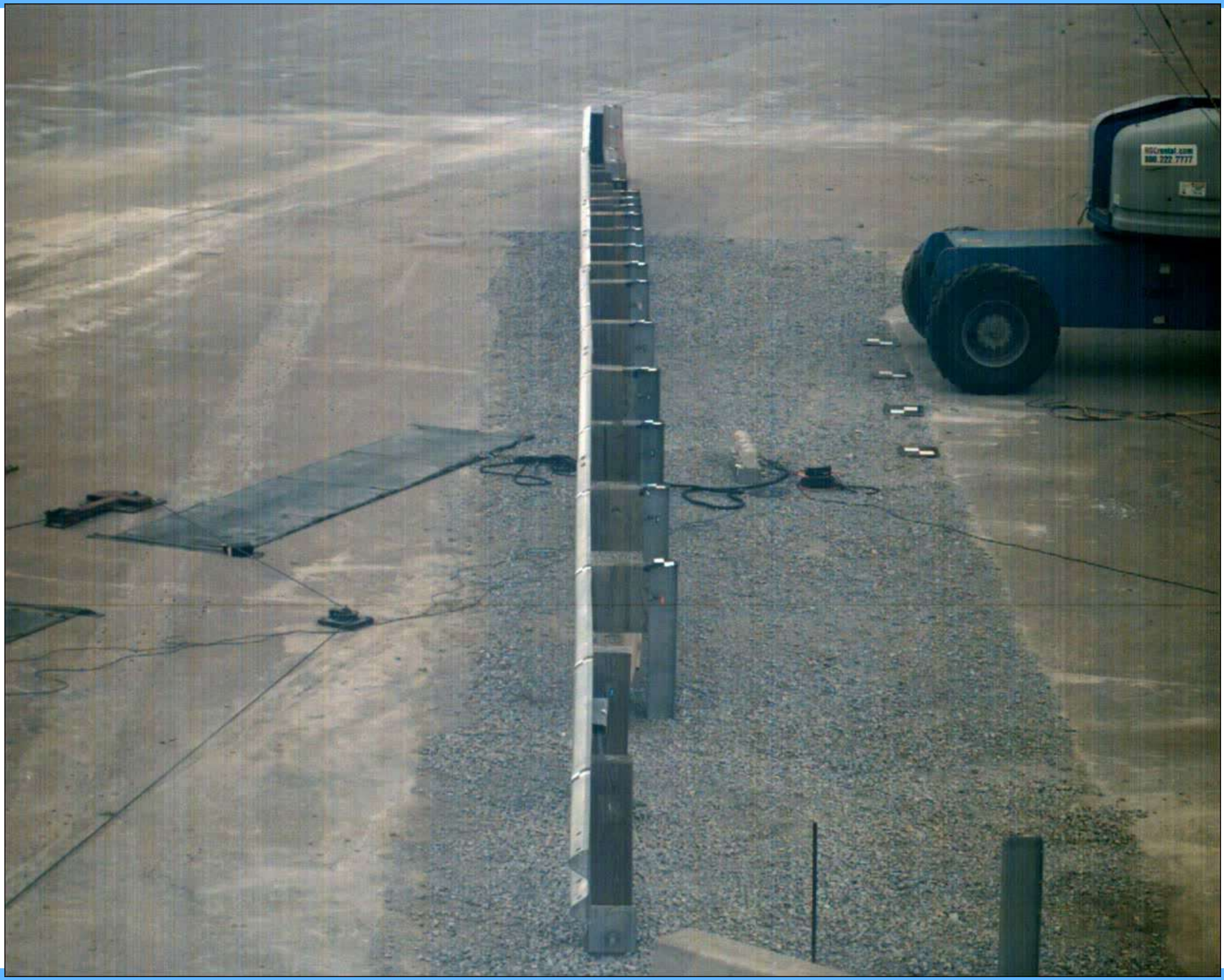
ELEVATION

862.03 SHEET 4 OF 7	ROADWAY STANDARD DRAWING FOR **STRUCTURE ANCHOR UNIT** GUARDRAIL ANCHOR UNIT TYPE B-77 FOR F-SHAPE BARRIER	1-18 STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

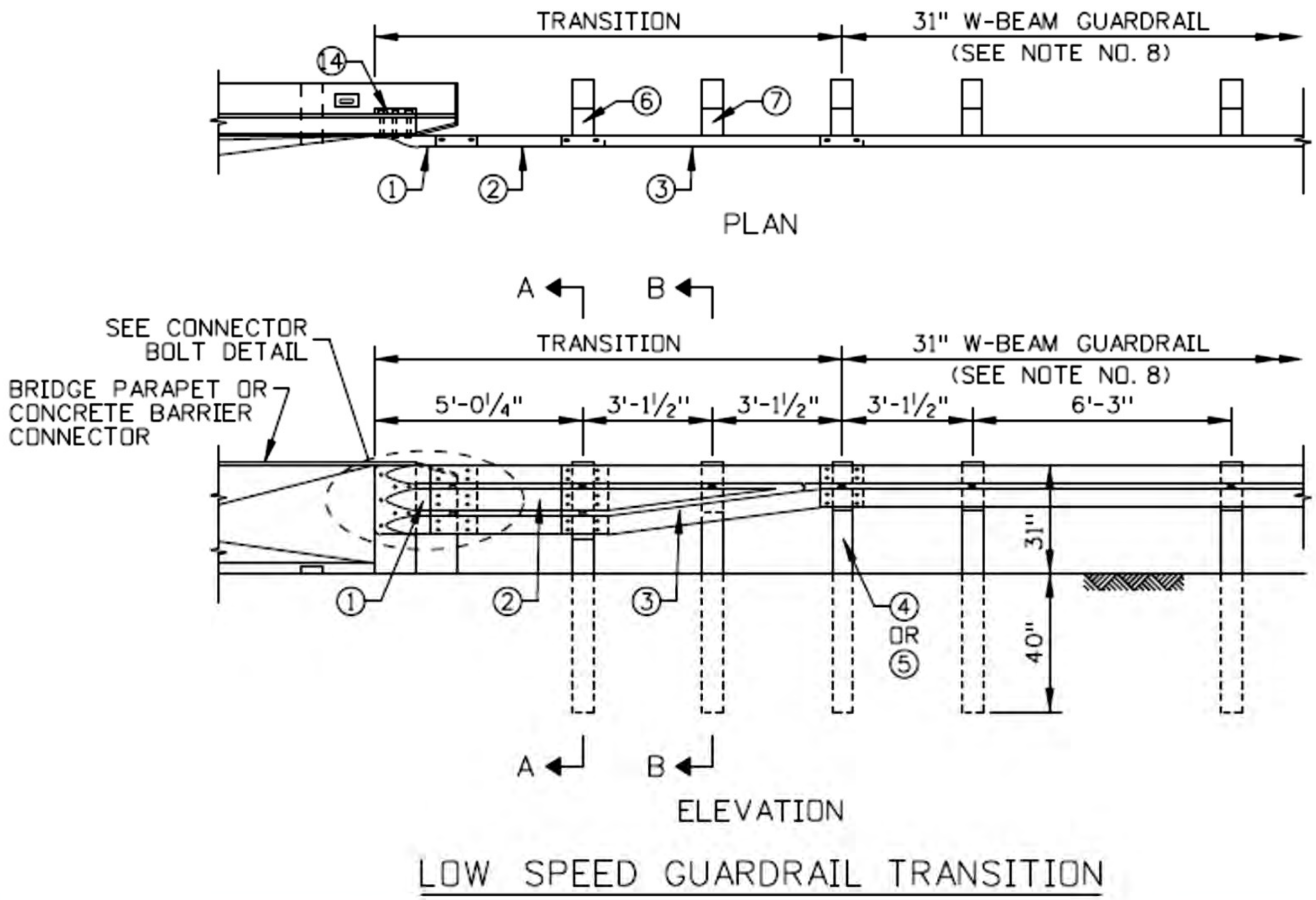
NCDOT Transition – With Curb

NPS Transition

31” Transition



Transition – 31”, TL-2



Connections to Low Parapets or Combination Rails

If the concrete parapet or portion of a combination rail is less than the transition height (31”), a steel plate may be applicable to adjust the height.

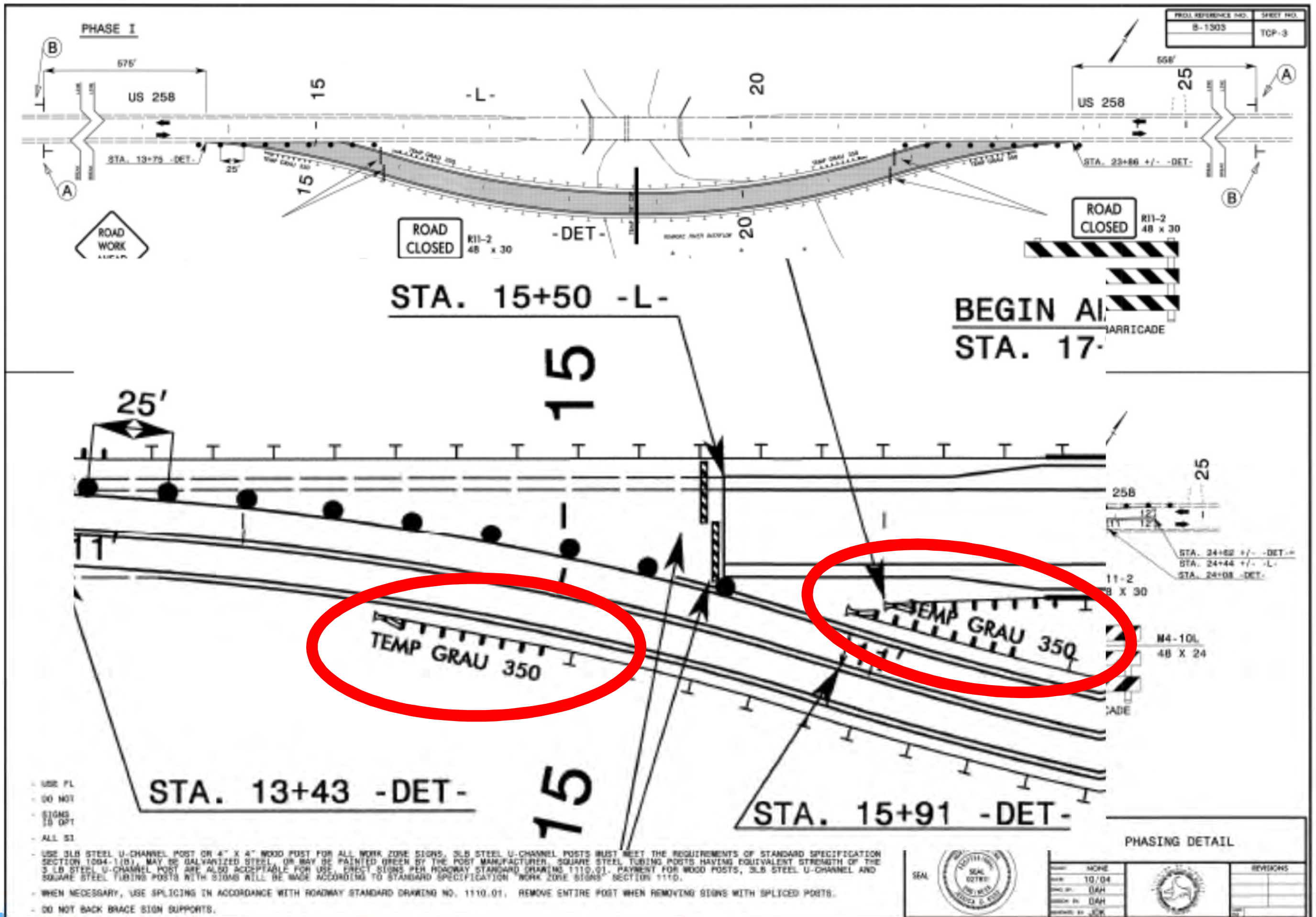
Transition: HTC to Guardrail (Spatial)

HTC or LTC - Cable to W-Beam Transition

Probably not going to be available with MASH

HTC - Cable to W-Beam Transition

Temporary Barrier – Need for Tension



Traffic Management Plan

COMPUTED BY: K.N.WASHINGTON DATE: 05/26/2005
CHECKED BY: T.F. DUNCAN, PE DATE: 06/2/2005

PROJECT NO.	SHEET NO.
B-1303	3-B

Quantity Summary Sheet

STATE OF NORTH CAROLINA
DIVISION OF HIGHWAYS

SUMMARY OF EARTHWORK

Station	Station	Uncl. Excav. CY	Embank. +% CY	Borrow CY	Waste CY
-L-					
13+00.00	17+83.94	74	1,398	1,324	
19+72.06	26+44.63	32	1,332	1,300	
-DET-					
13+00.00	22+50.00		23,877	23,877	
SUBTOTALS:		106	26,607	26,501	
-DET- REMOVAL:		18,445			18,445
PROJECT TOTALS:		18,551	26,607	26,501	18,445
EST. 5% TO REPLACE TOP SOIL OF BORROW PIT				1,325	
EST. SHOULDER MATERIAL			672	672	
GRAND TOTALS:		18,551	27,279	28,498	18,445
SAY:		18,600 CY		28,600 CY	

UNDERCUT EXCAVATION = 500 CY
SELECT GRANULAR MATERIAL = 5000 CY
FABRIC FOR SOIL STABILIZATION = 1500 SY

SUMMARY OF EXISTING ASPHALT PAVEMENT REMOVAL

LINE	Station	Station	LOC LT/RT/CL	AREA SY
-L-	17+40.00	18+14.00	CL	263
-L-	19+20.00	20+20.00	CL	356
-DET-	14+73.08	22+87.55	CL	2,351
			TOTAL:	2,970
			SAY:	3,000 SY

APPROXIMATE QUANTITIES ONLY. UNCLASSIFIED EXCAVATION, FINE GRADING, CLEARING AND GRUBBING, AND REMOVAL OF EXISTING PAVEMENT WILL BE PAID FOR AT THE LUMP SUM PRICE FOR "GRADING".

"N" = DISTANCE FROM EDGE OF LANE TO FACE OF GUARDRAIL.
TOTAL SHOULDER WIDTH = DISTANCE FROM EDGE OF TRAVEL LANE TO SHOULDER BREAK POINT.
FLARE LENGTH = DISTANCE FROM LAST SECTION OF PARALLEL GUARDRAIL TO END OF GUARDRAIL.
W = [illegible] BEGINNING OF TAPER TO END OF GUARDRAIL.
[illegible] GATING IMPACT ATTENUATOR [illegible] 350
NG = NON-GATING IMPACT ATTENUATOR [illegible] 350

GUARDRAIL SUMMARY

LINE	BEG. STA.	END STA.	LOC.	LENGTH: STRAIGHT	LENGTH: TEMP STRAIGHT	LENGTH: DOUBLE FACED	WARRANT POINT: APPR. END	WARRANT POINT: TRAIL. END	"N" DIST FROM E.O.L.	TOTAL SHLDR WIDTH
-L-	13+82.94	17+[illegible]	RT	475.00			13+03.00	17+71.84	10	13
-L-	13+82.94	17+7[illegible]	LT	475.00			17+77.94	13+00.00	10	13
-L-	19+84.06	23+0[illegible]	RT	325.00			19+84.06	23+50.00	10	13
-L-	19+84.06	22+[illegible]	LT	300.00			21+50.00	19+84.06	10	13
-L-	16+00.00		RT						10	13
-L-		21+[illegible]00	RT						10	13
-DET-	14+44.15	[illegible]15	RT		875.00		15+00.00	23+00.00	6	8
-DET-	15+87.50	[illegible]50.00	LT		962.50		20+50.00	17+00.00	6	8
SUBTOTAL:				1,575.0	1,437.5					
[illegible] ANCHORS DEDUCT[illegible]										
GRAU-[illegible]		@	50.00	-200.00						
TYPE III	4	@	18.75	-75.00						
TEMP GRAU	4	@	50.00		-200.00					
ANCHOR TOTALS:				-275.00	-200.00					
GRAND TOTAL:				1,300.00 LF	1,237.50 LF					
SAY:				1,300.00 LF	1,237.50 LF					
ADDITIONAL GUARDRAIL POST:				5 EA						

LINE	FLAIR LENGTH: APPR. END	FLAIR LENGTH: TRAIL. END	W: APPR. END	W: TRAIL. END	ANCHORS	ANCHORS: TYPE III	ANCHORS: GRAU 350	ANCHORS: TEMP GRAU 350			IMP. ATTEN. TYPE 350: EA	G	NG	REMOVE EXISTING GRDRAIL		REMARKS
-L-	50		1			1	1							137.50		GR WARRANTED ALONG ENTIRE RT SIDE BEFORE BR.
-L-		50		1		1	1							137.50		GR WARRANTED ALONG ENTIRE LT SIDE BEFORE BR.
-L-		50		1		1	1							137.50		
-L-	50		1			1	1							137.50		
-L-	50		1					1								REQUESTED BY TRAFFIC CONTROL
-L-		50		1				1								REQUESTED BY TRAFFIC CONTROL
-DET-	50	50	1	1				2								REMOVE -DET- TEMP GR
-DET-	50	50	1	1				2								REMOVE -DET- TEMP GR
SUBTOTAL:						4	4	6								
GRAND TOTAL:						4	4	6						550.00 LF		
SAY:						4	4	6						550.00 LF		

Quantity Summary Sheet – blow-up

LINE	BEG. STA.	END STA.
-L-	13+02.94	17+77.94
-L-	13+02.94	17+77.94
-L-	19+84.06	23+09.06
-L-	19+84.06	22+84.06
-L-	16+00.00	
-L-		21+5[illegible].00
-DET-	14+44.15	23+[illegible]9.15
-DET-	15+87.50	21+50.00
SUBTOTAL:		

W APPR. END	W TRAIL. END	ANCHORS	ANCHORS TYPE III	ANCHORS GRAU 350	ANCHORS TEMP GRAU 350		
1			1	1			
	1		1	1			
	1		1	1			
1			1	1			
1					1		
	1				1		
1	1				2		
1	1				2		
			4	4	6		

Need to re-establish tension in any altered guardrail – include in plan sheets

★ Placement of GRAU (GREU) must abide by standard application criteria (Deflection and LON)

Review Learning Outcomes

- Understand how barriers are tested for crashworthiness
- Identify common barrier systems
- Explain how these barrier systems function
- Define the key components of a transition design

Session 4:

Testing Requirements and Performance Characteristics of End Treatments and Impact Attenuators

Session 4 Learning Outcomes

At the end of this session, you will be able to:

- Understand how end treatments and impact attenuators are tested for crashworthiness
- Identify common end treatments and impact attenuators
- Understand how these systems function
- Choose the appropriate system for a specific site

Guardrail End Treatments

A barrier end treatment must serve two functions:

- Provide the necessary TENSION of the guardrail system for downstream impacts
- Be crashworthy when impacted end-on.

Cable Anchor Terminal – MASH

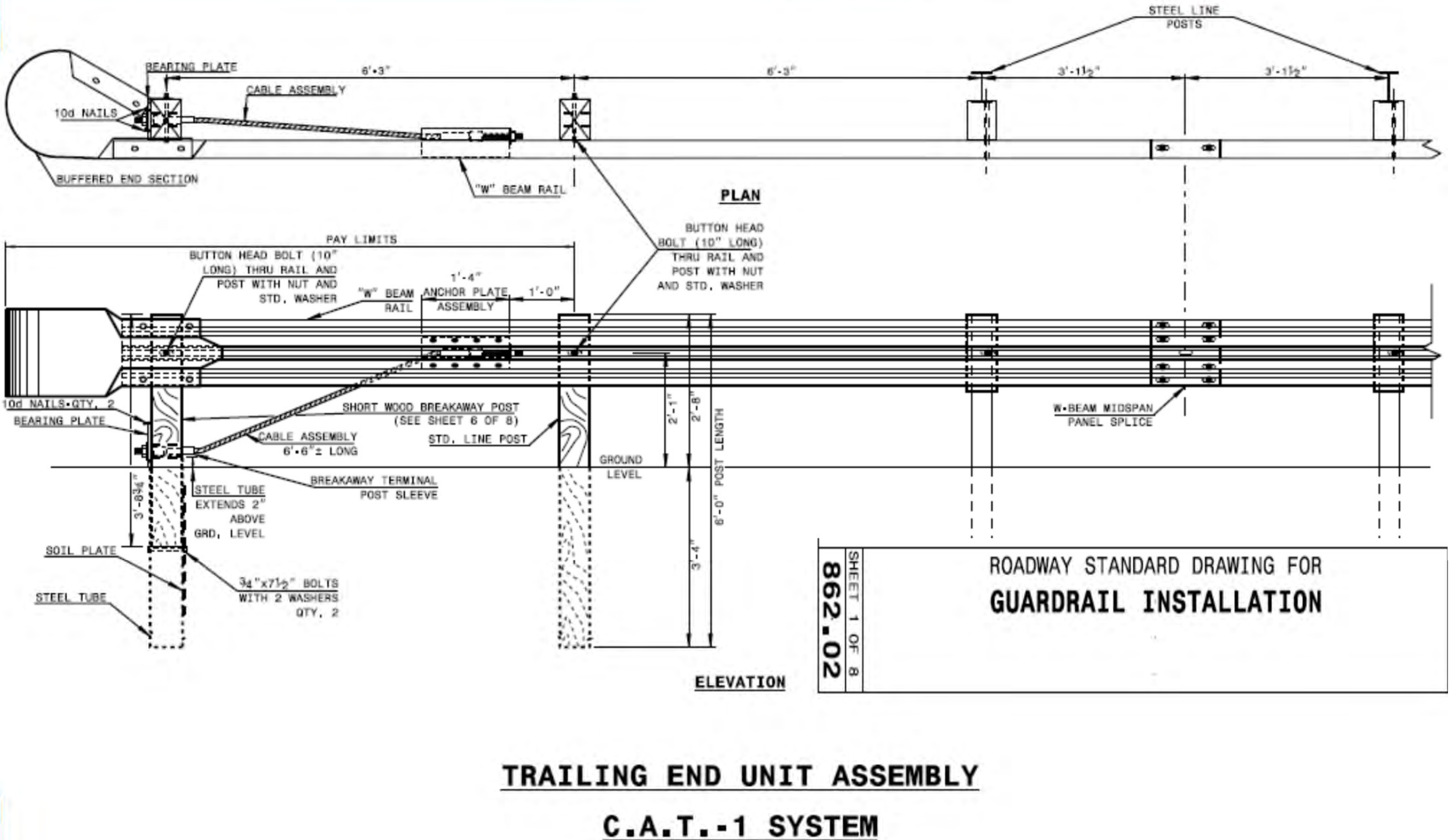
- 2 Design Tested
- Both have a strut between last 2 posts

TxDOT Design
9'- 4 ½ " rail element
Rail ends at last post

MwRSF Design
12'- 6" rail
Rail extends past last post

Cable Anchor Terminal - Tension

NC Cable Anchor – Not tested

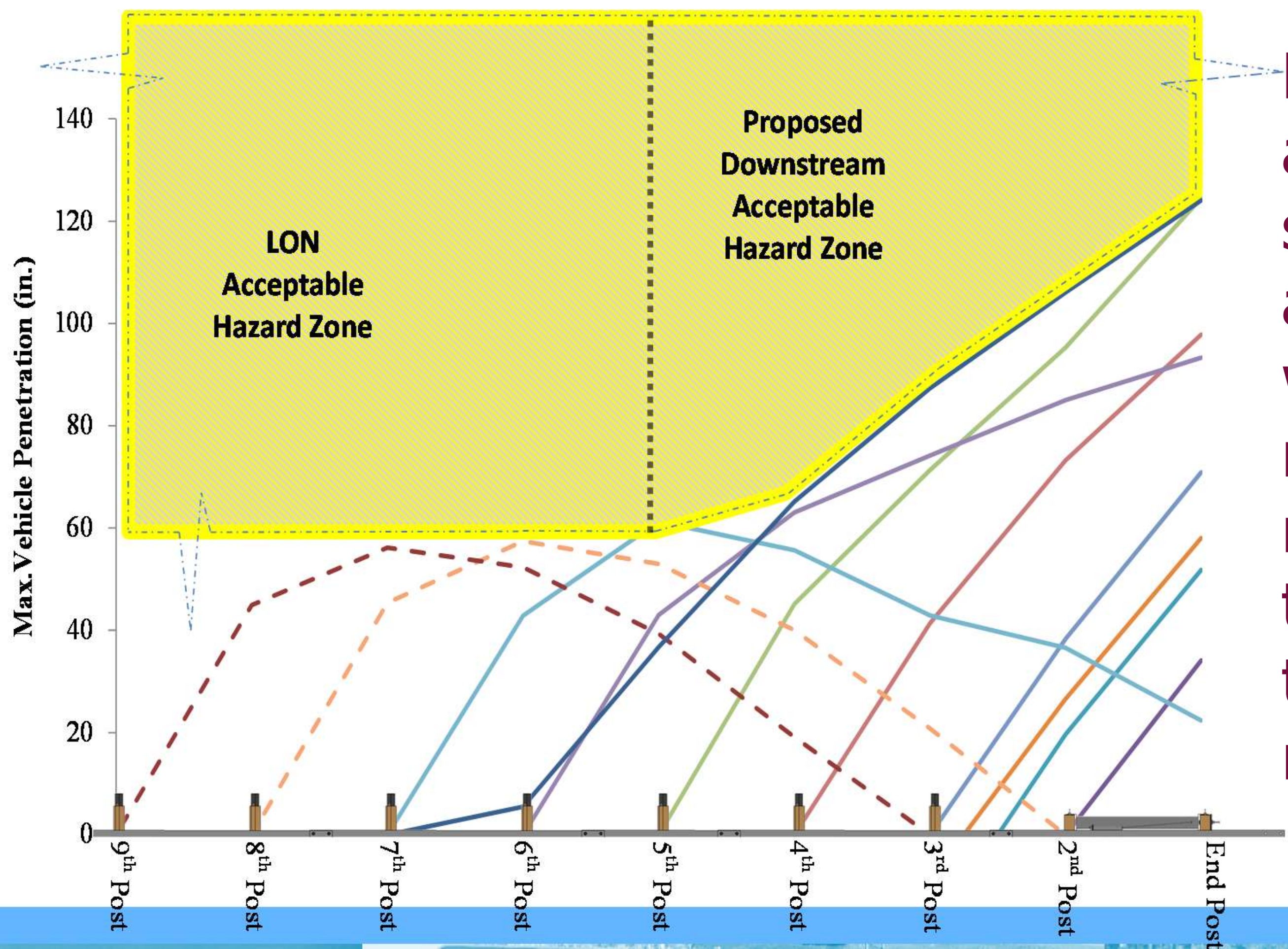


Guardrail Cable Anchor Terminal Test

Impacted at 6th post from the end

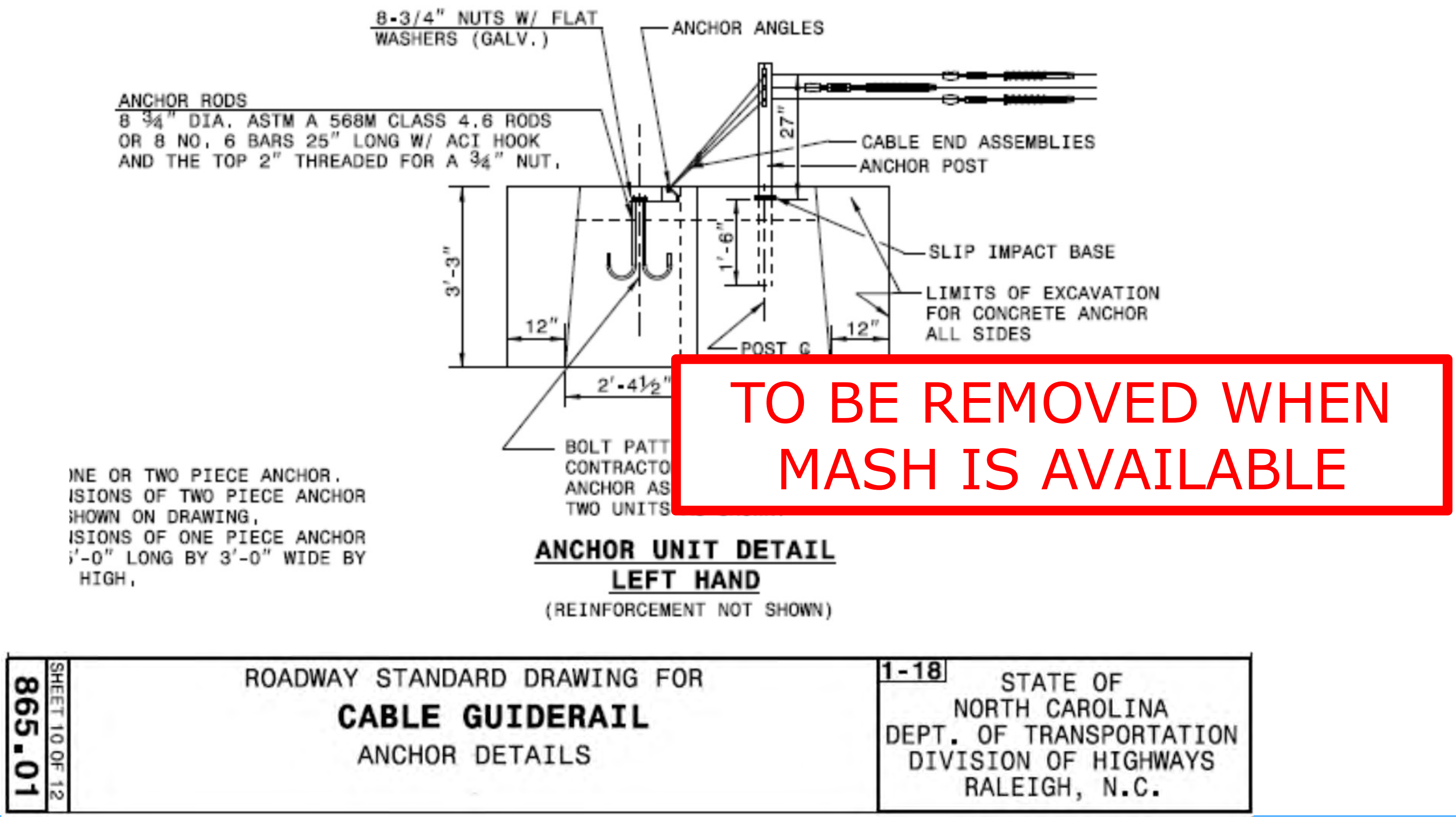
Vehicle deflected up to 10’ behind the barrier

Guardrail Cable Anchor Terminal Test Analysis



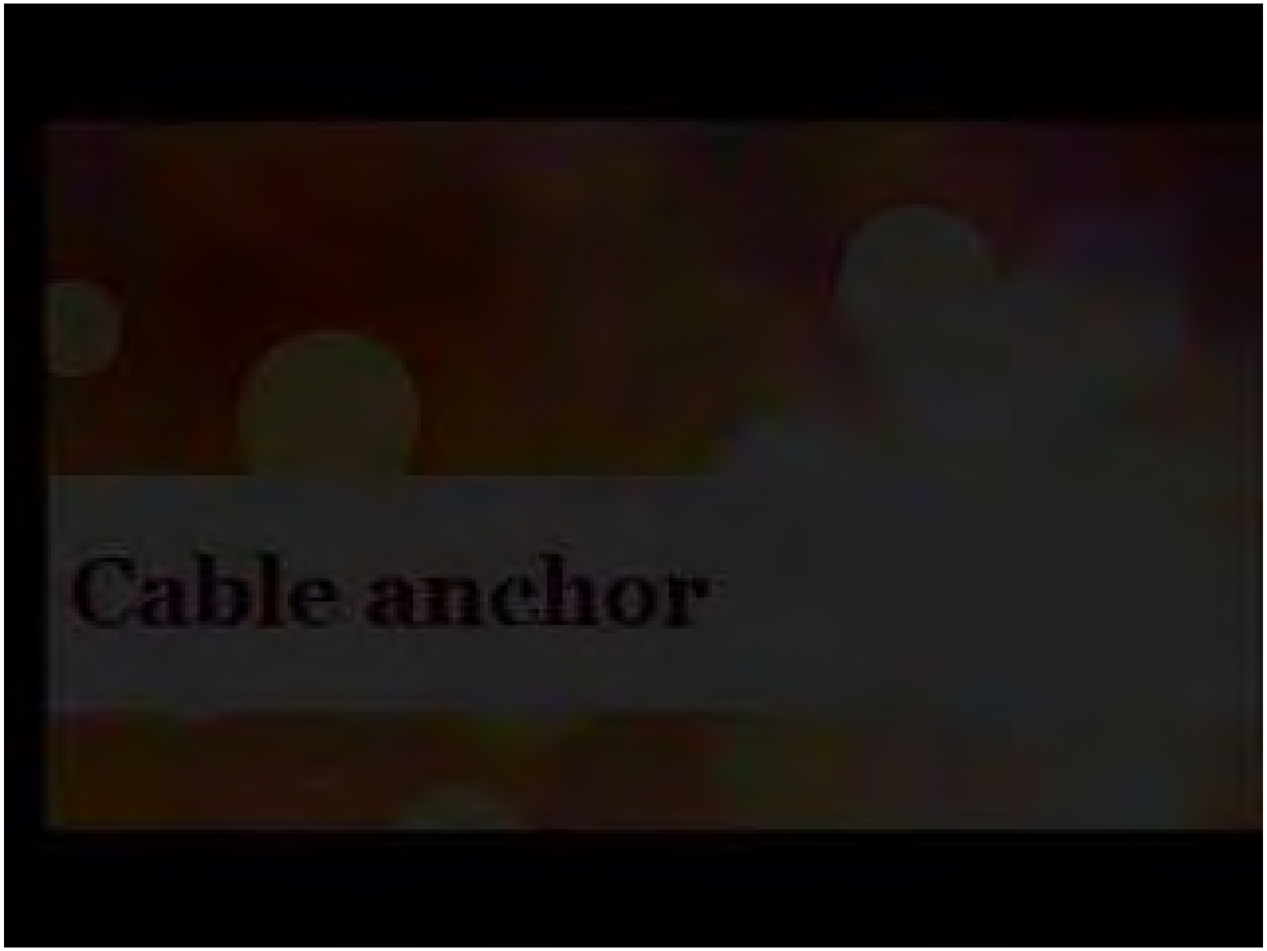
Based on test and simulations, additional working width may be needed from the 6th post to the end of the rail.

Cable Guiderail terminal - LTC



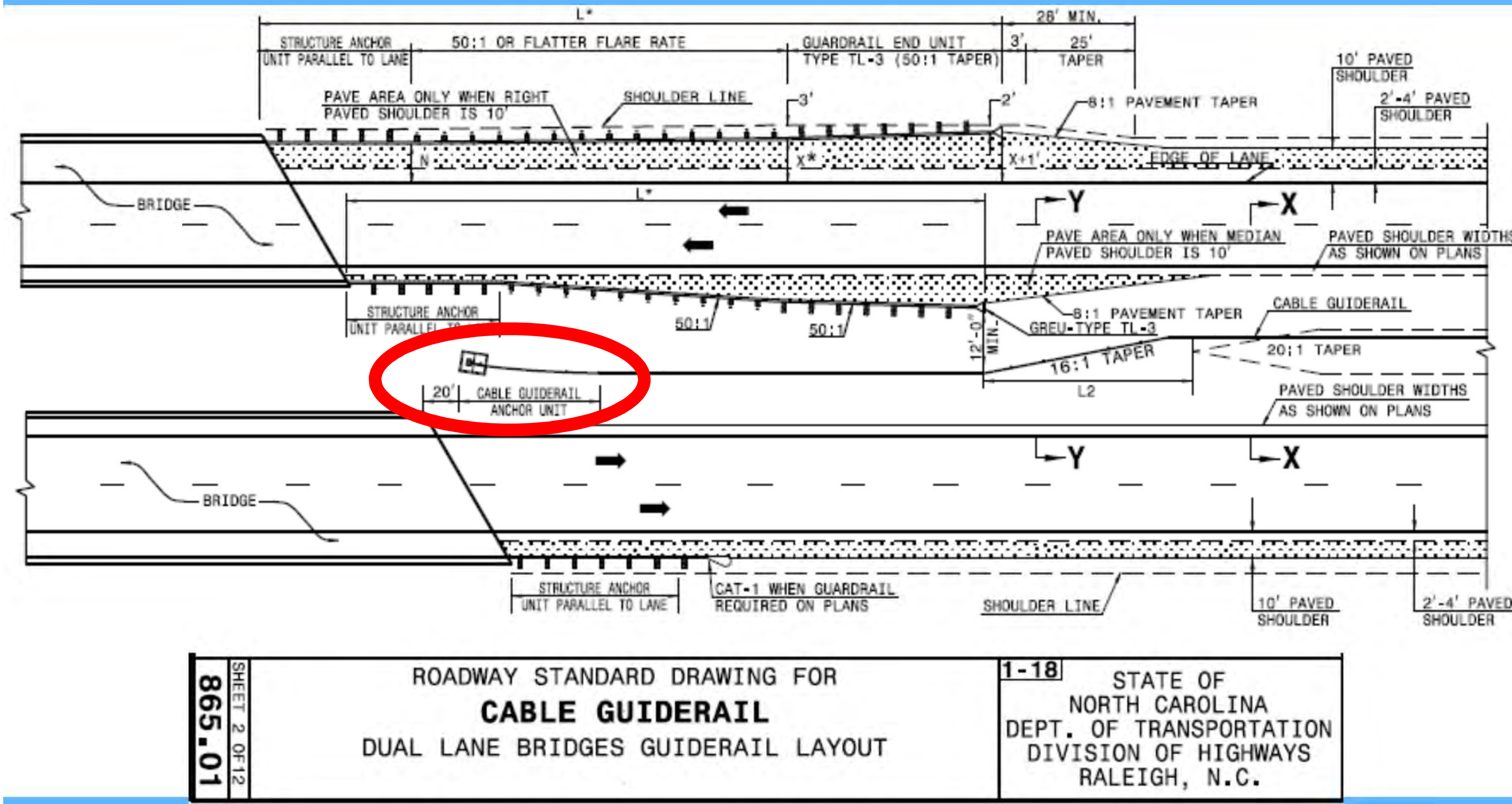
TO BE REMOVED WHEN MASH IS AVAILABLE

Cable Guiderail terminal - HTC



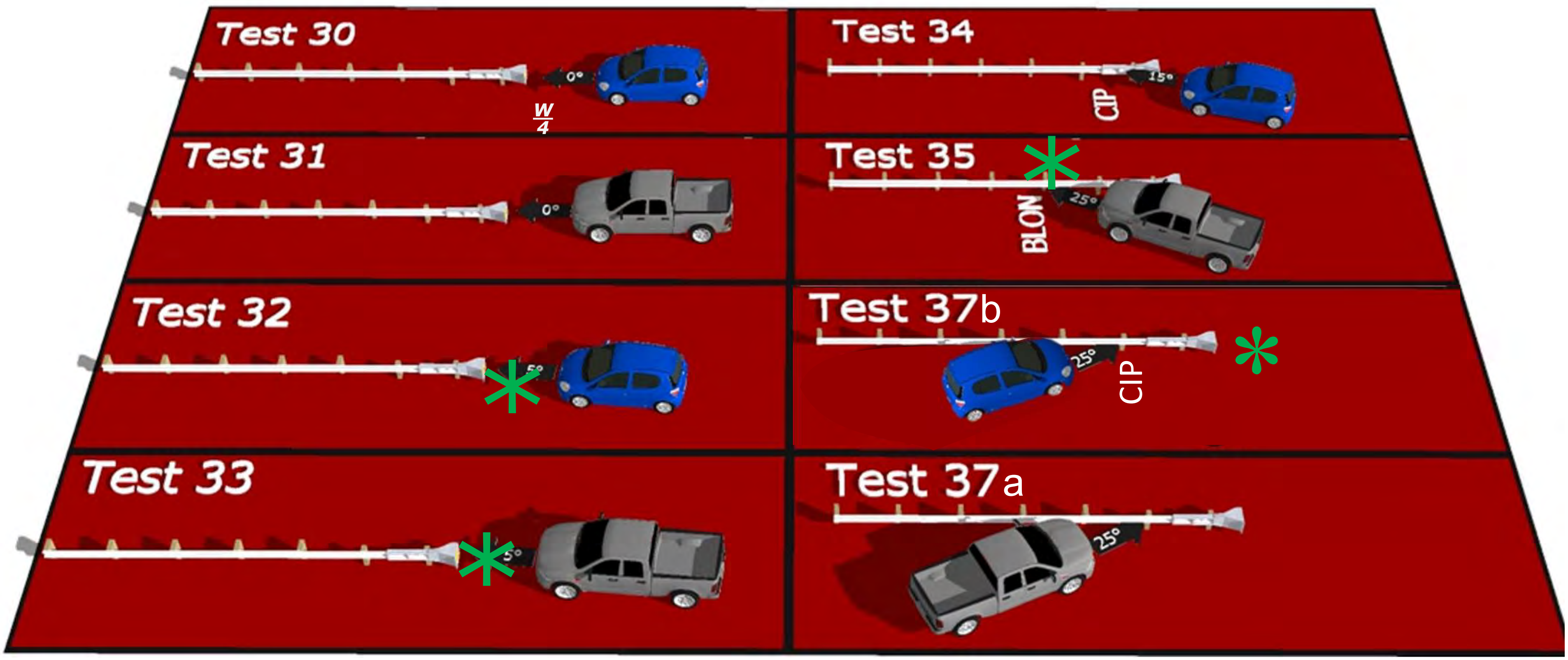
PRE-ASSESSMENT PHOTO

Cable Guiderail Anchor Unit Placement



PRE-ASSESSMENT PHOTO

End Treatment MASH Test Matrix



* Significant Change

* Small Car 1100C (2420 #)
* Pickup Truck 2270P (5000 #)

BLON – Beginning Length of Need

Guardrail End Treatments

Types of End Treatments

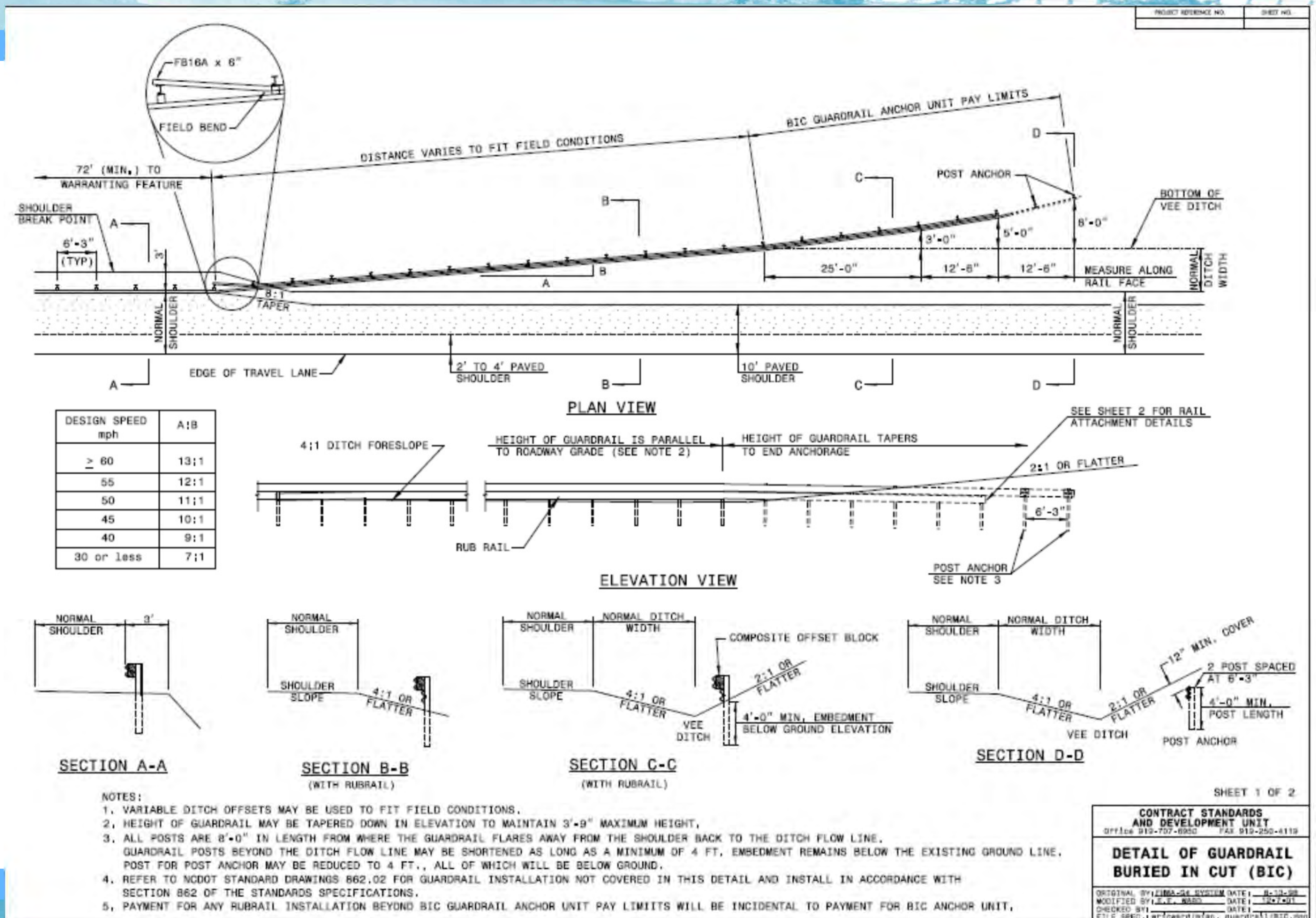
- Buried-in-Cut (Detail, not in Standards)
- Tangent terminals – terminal is parallel to the roadway or has a straight flare with a "slight" offset; all are Energy-absorbing
- Flared terminals – terminal is placed on a flare to the roadway typically 3' or 4'; both non-energy- and energy-absorbing

Buried in Cut End Treatment

- Key design considerations:
  - For slopes steeper than 10:1, keep the height of the w-beam rail constant relative to the roadway grade until the barrier crosses the ditch flow line (but a max height of 47")
  - Use a flare rate, either 13:1 or appropriate for the design speed,
  - Add a w-beam rubrail when the distance between the bottom of the w-beam rail and the ground exceeds ~19",
  - Use an anchor of steel posts capable of developing the full tensile strength of the w-beam rail and buried 1' below ground

MASH
Buried in Cut End Treatment

Buried in Cut (350 – to be Updated)



BIC Looking Across Roadway

Single Rail BIC

BIC Considerations – 10:1 Slope for Single

BIC Considerations - LON

Any concerns with this installation?

PRE-ASSESSMENT PHOTO

End Treatments - Terminology

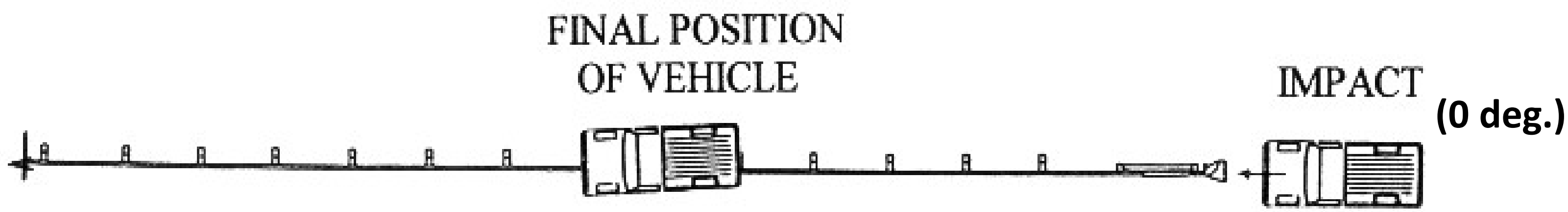
CAT-1 – Cable Anchor Terminal – non-crashworthy device to develop Tension where there is no opportunity for end-on impacts

(AT-1 – Anchor Terminal – no cable)

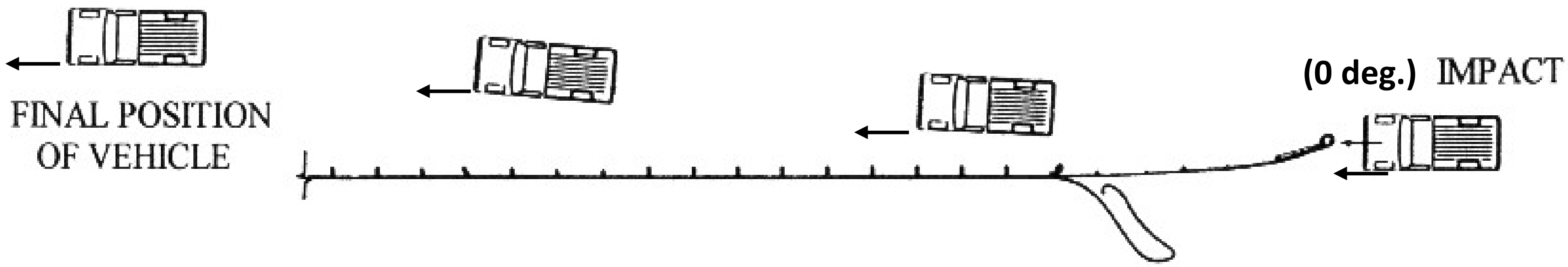
GREA – Guardrail End Anchor – crashworthy Pre-MASH devices

GREU – Guardrail End Unit – crashworthy MASH approved devices

End Treatments



Energy Absorbing Terminal
(vehicle is brought to a controlled stop in a short distance)



Non-Energy Absorbing Terminal
Controlled Buckling Terminal
(vehicle may travel hundreds of feet before stopping)

Flared End Treatments

Historically used, most recently the SRT and FLEAT

Business »

Approved Products List

Product ID (ex. NPYY-xxxx):

Company Name:

Product Name:

Product Group: Guardrail and Delineators (862)(1088)

Product Category: End Treatments

Product Status:

Product ID	Plant ID	Company Name	Product Group	Product Category	Product Name	Model Number	Product Status	Description
NP11-5773		Road Systems, Inc.	Guardrail and Delineators (862) (1088)	End Treatments	MFLEAT		Approved	MASH tested, Guardrail End Terminal
NP18-8095		Lindsay Transportation Solutions	Guardrail and Delineators (862) (1088)	End Treatments	MAX-Tension Median Guardrail Terminal		Approved	Telescoping, tension-based terminal with an energy absorbing coupler that features a cutting tooth design.
NP17-7848	GR44	Lindsay Transportation Solutions	Guardrail and Delineators (862) (1088)	End Treatments	Max-Tension End Treatment		Approved	MASH tested;Telescoping, tension-based guardrail end terminal with an energy absorbing coupler that features a cutting tooth design.

https://apps.ncdot.gov/vendor/approvedproducts/

NCDOT

NORTH CAROLINA

STATE LINE

Flared End Treatment: Energy Absorbing

- **MFLEAT** *MASH Version of FLEAT (MASH 16)*
  - Curls the rail (by kinking) tightly towards the roadway.
  - Steel post system; BLON at 4th Post
  - TL-3 at 39’ 7” straight flared length. 3-ft. offset.
  - Cable-anchored, compression system

BLON – Beginning Length of Need

Ref: FHWA Eligibility Letter CC-143 dated 04/10/19

MASH
MFLEAT

Flared End Treatment: Non-energy-Absorbing

- MASH SRT (Slotted Rail Terminal)
  - W-Beam rails on a straight line and horizontal slots in rail
  - Offset - 4'; 31" Height
  - 37'-6" long, BLON at Post 4
  - Cable-anchored system

Not currently on APL

Ref: FHWA Eligibility Letter CC-140 dated 12/19/17

MASH Test 3-31: SRT

Because of the non-energy absorption, no hazard should exist within 150’ downstream of post #1


NOT GOOD!!!!!

Flared End Treatments on Flared Standard Run

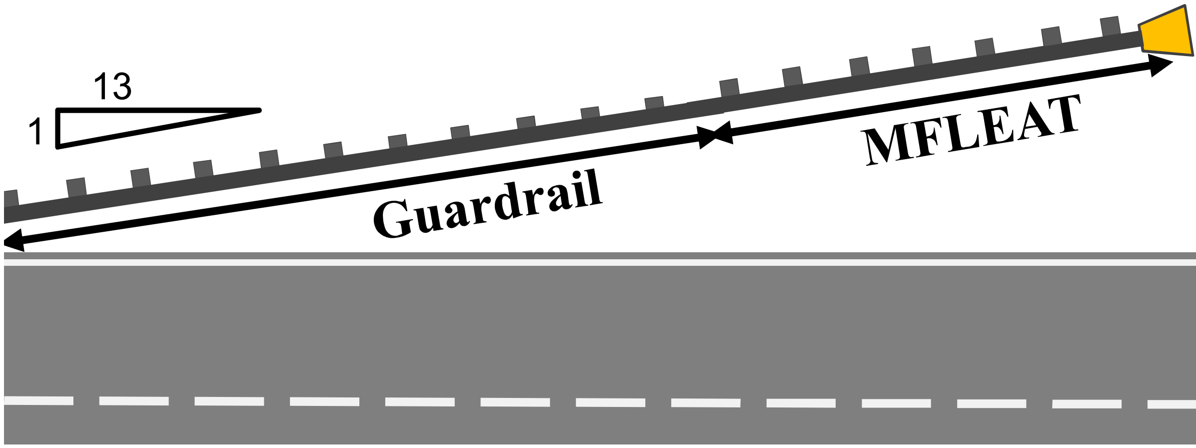
The flare of the end treatment is measured from a line parallel to the ROADWAY:

For Energy Absorbing (MFLEAT) which has a 13:1 flare, there may need to be a "kink" either toward or away from the roadway, depending on the flare of the standard guardrail

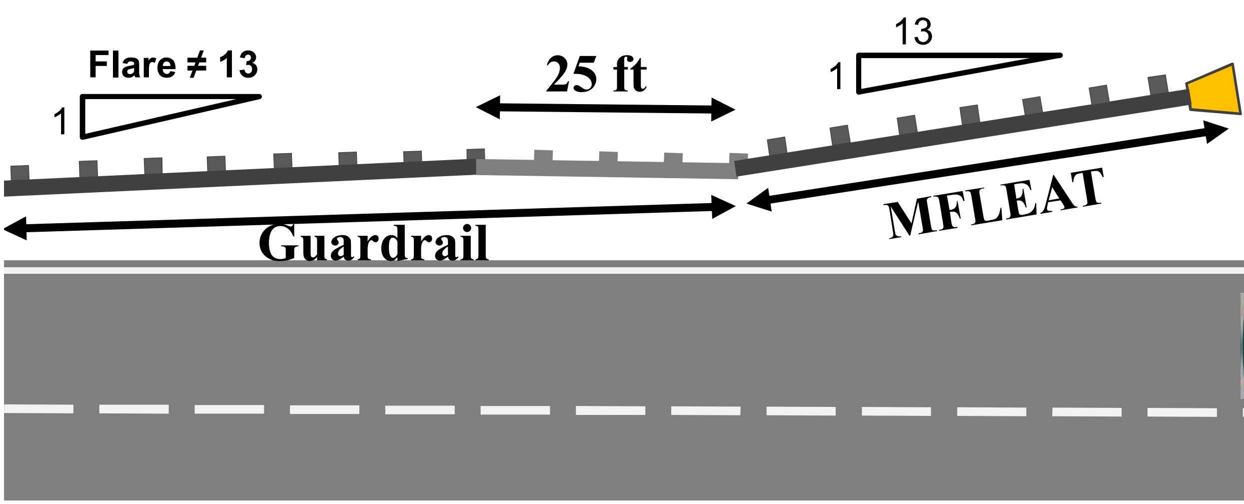
For the SRT MASH, the offsets are measured from a line parallel to the roadway.

NCDOT guidance is to provide 25' of parallel guardrail in advance of any end treatment requiring a kink.

Flared End Treatment on Flared Standard Run MFLEAT - Schematic

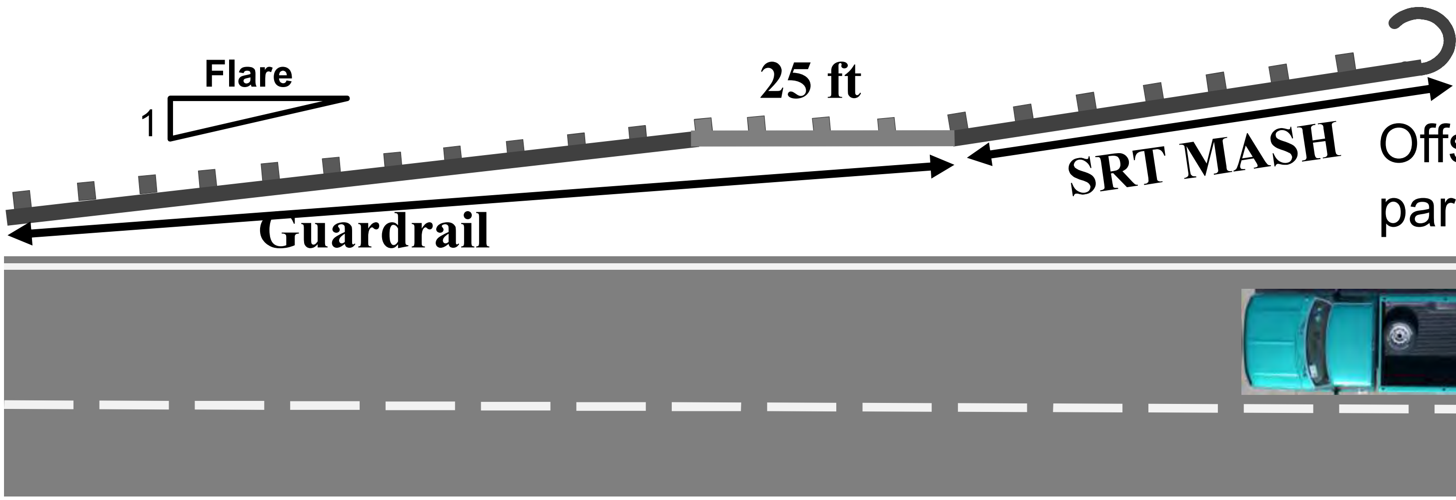


Flare of standard guardrail is 13:1



Flare of standard guardrail is not 13:1

Flared End Treatments on Flared Standard Run SRT MASH - Schematic



Offset measured from parallel to the roadway

Flared End Treatment Selection

- The contractor may choose any system on the Approved Product List meeting the design requirements
  - One is energy absorbing (currently MFLEAT)
  - One could be non-energy absorbing (SRT)

What is **important** is to understand how the system works –a **FLARED** system should only be allowed if criteria have been met (LON and grading)

Tangent End Treatment

NCDOT NORTH CAROLINA DEPARTMENT OF TRANSPORTATION
Connecting people, products, and places safely and efficiently with customer focus, accountability and environmental sensitivity to enhance the economy and vitality of North Carolina.

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Approved Resources
- Product Listing
- Seeds
- Producer/Supplier
- Technician Certification
- Minimum Sampling Guide

Business »

Approved Products List

Product ID (ex. NPYY-xxxx):
Company Name:
Product Name:
Product Group:
Product Category: End Treatments, Type MASH-16
Product Status:

Search Reset

Product ID	Plant ID	Company Name	Product Group	Product Category	Product Name	Model Number	Product Status	Description
NP17-7819		Trinity Highway Products	Guardrail and Delineators (862)(1088)	End Treatments, Type MASH-16	SoftStop Mash End Terminal		Approved	MASH tested;All steel galvanized tangent end terminal for use with 31" W-Beam system.
NP17-7851		Road Systems, Inc.	Guardrail and Delineators (862)(1088)	End Treatments, Type MASH-16	MSKT		Approved	MASH tested;Guardrail End Terminal
NP18-8257		SPIG Industry, LLC	Guardrail and Delineators (862)(1088)	End Treatments, Type MASH-16	SGET		Approved	The SGET (SPIG Gating End Terminal) is a gating guardrail end terminal system in which an impact upon the head causes the head to move down the guardrail and dissipate the energy of the impact. The SGET system also deflects vehicles back onto the roadway

Tangent End Treatment: Energy Absorbing

- **MSKT** *MASH Version of SKT (MASH 16)*
  - Kinks Guardrail when hit head-on or at a shallow angle
  - Steel post system; BLON at 3rd Post
  - TL-3 at 47' long; attachment to 31" Guardrail
  - Cable-anchored system, Compression system

6. PROVIDE A MINIMUM OF 12'-6" OF 31" W-BEAM GUARDRAIL BETWEEN THE GUARDRAIL TERMINAL AND A GUARDRAIL TRANSITION.

MASH MSKT

Tangent End Treatment: Energy Absorbing

- Soft Stop (MASH 16)
  - Impact head slides along panels, crushing them vertically, absorbing the energy of the vehicle in shallow angle impacts – **works in tension**
  - TL-3 at 51’ long; BLON at 16’-6”; 31” only

6. PROVIDE A MINIMUM OF 12'-6" OF 31" W-BEAM GUARDRAIL BETWEEN THE GUARDRAIL TERMINAL AND A GUARDRAIL TRANSITION.

MASH Soft Stop

MASH SGET

Tangent End Treatment: Energy Absorbing

- MAX-Tension (MASH 16)
  - The MAX system utilizes tensioned cables, telescoping panels, and a cutting tooth to absorb the kinetic energy and safely contain or redirect impacting – **works primarily in tension**
  - TL-3 at 50' long; BLON at 9'-4 ½"; 31" only

Also on APL under a different category – End Treatments

6. PROVIDE A MINIMUM OF 12'-6" OF 31" W-BEAM GUARDRAIL BETWEEN THE GUARDRAIL TERMINAL AND A GUARDRAIL TRANSITION.

MASH MAX-Tension

Tangent End Treatments on Flared Standard Run

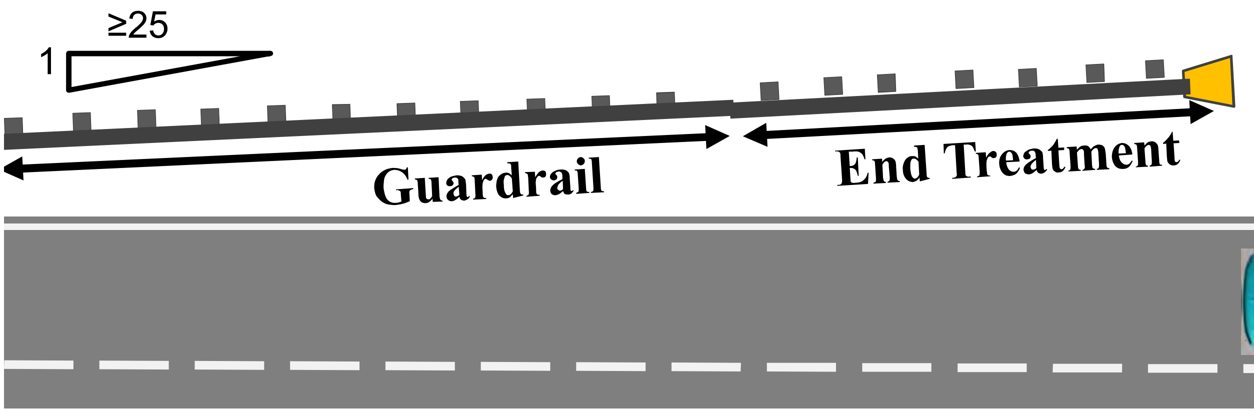
The offset of the end treatment is measured from a line parallel to the ROADWAY:

- If the standard flare is 25:1 or flatter, the end treatment may be placed on the standard flare line extended

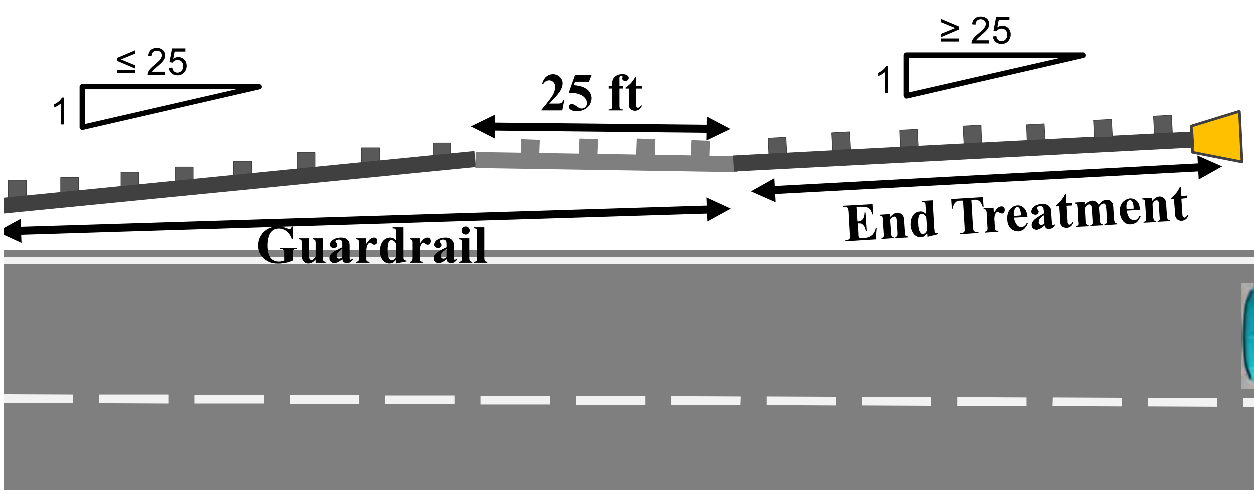
- If the standard flare is sharper than 25:1, a kink in the run must be provided so the end treatment is no sharper than 25:1

NCDOT guidance is to provide 25’ of parallel guardrail in advance of any end treatment requiring a kink.

Tangent End Treatments on Flared Standard Run Schematic



Standard Run Flare of 25:1 or flatter



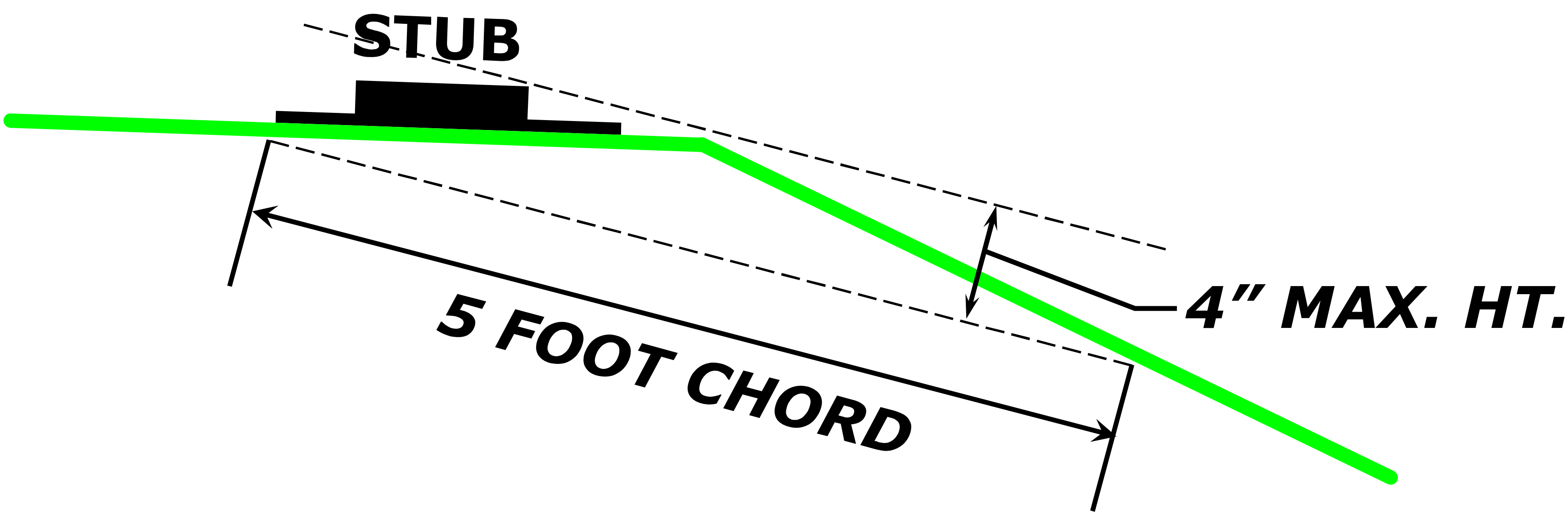
Standard Run Flare is sharper than 25:1

End Treatment Grading

- Special grading requirements for guardrail end treatments:
  - Flat terrain (10:1 or flatter) is required *in* **ADVANCE** *of all end treatments* so that vehicles are relatively stable on approach
  - Flat grading must extend *behind* post 1 (**ADJACENT**) so vehicle is stable at impact ***and*** stub height criteria is satisfied

Ref: FHWA Memorandum, Roadside Safety Hardware, May 26, 2015 with attachment and
Ref: AASHTO Roadside Design Guide, 4th Edition, Section 8.3.3.

Stub Height Criteria



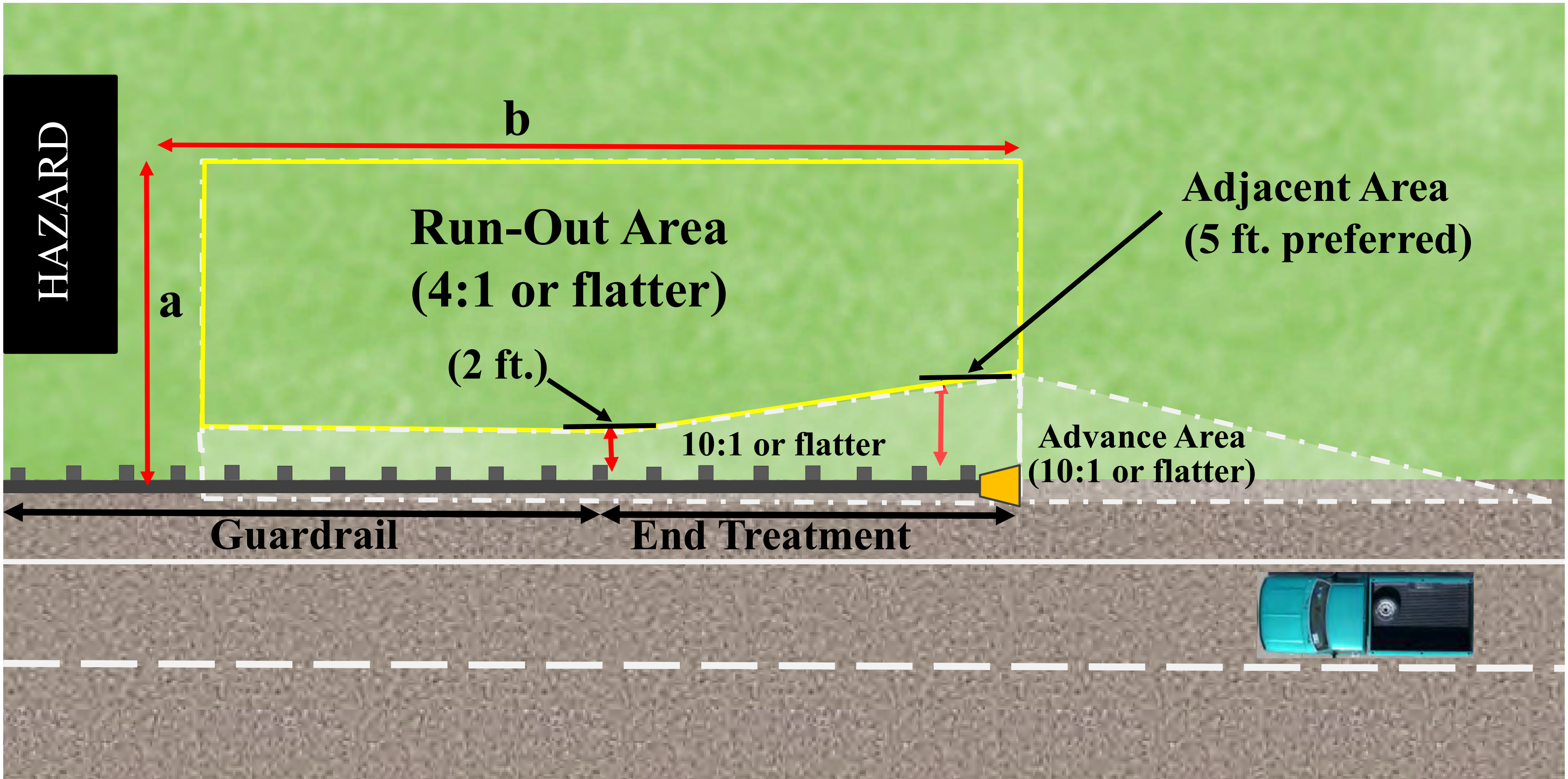
RDG Figure 4.1

Ref: AASHTO Roadside Design Guide, 4th Edition – Figure 4.1

End Treatment Grading Requirements

- **Runout Distance Grading** - refers to the area into which a vehicle may travel after impacting a terminal ahead of its length-of-need point.
  - The lateral runout distance directly behind a terminal ideally should be at least as wide as the roadside clear distance immediately upstream of terminal.
  - The minimum recovery obstacle-free area behind and beyond a terminal should be approximately 75 ft. long.

Ref: AASHTO Roadside Design Guide, 4th Edition, Section 8.3.3.



a – Extend out to clear zone when practical; if not, it should be at least as wide as area upstream of the end treatment.

b – LON Required; when LON cannot be provided due to site conditions, a minimum of 75' from post 1 may be acceptable

Flared End Treatment Grading - AASHTO

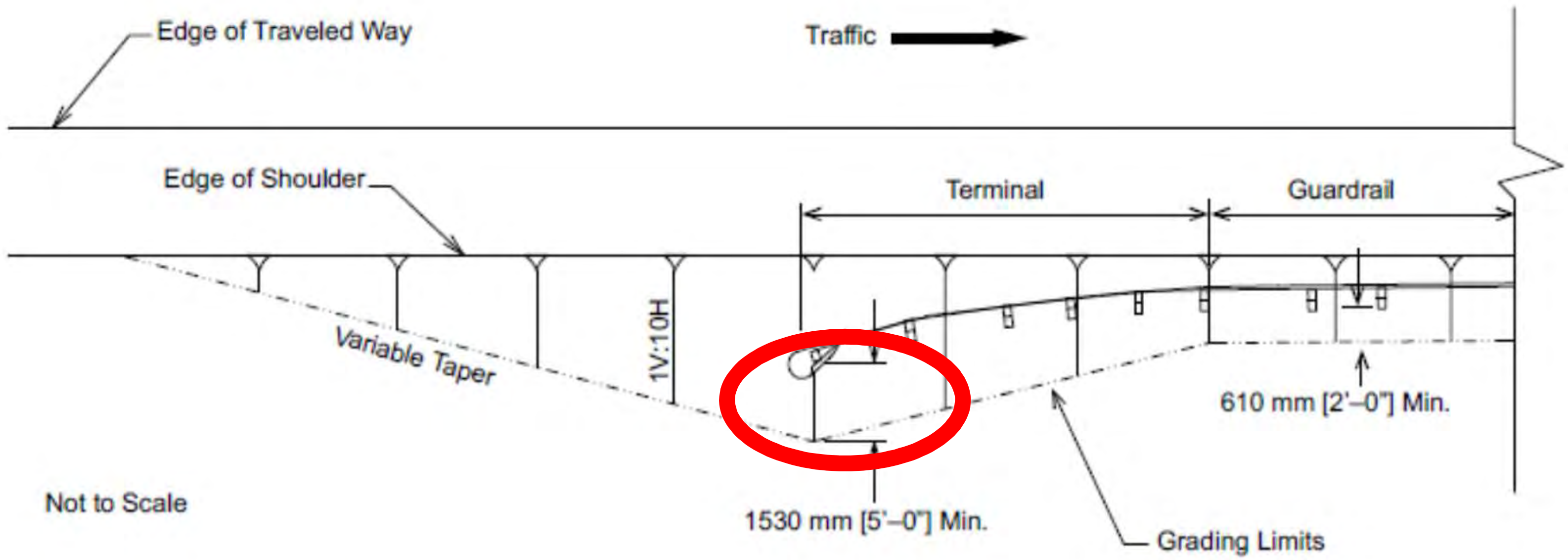
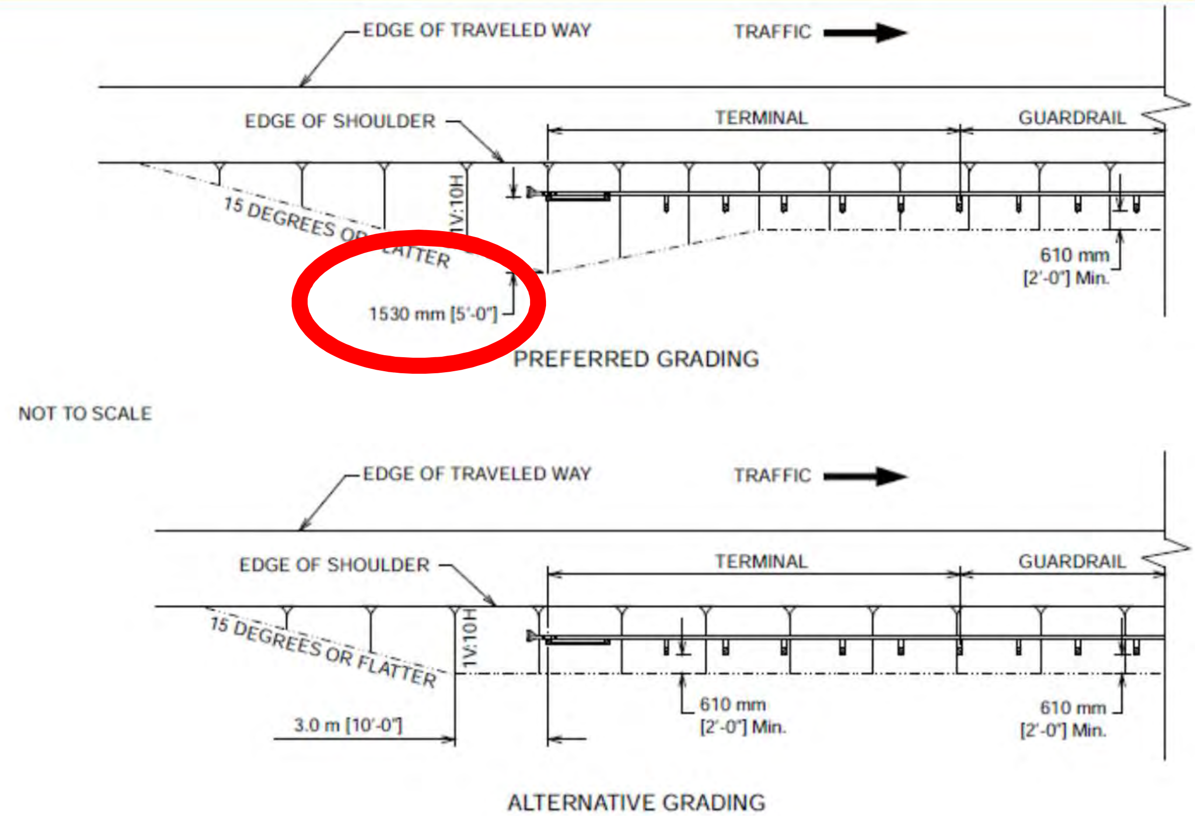


Figure 8-2. Grading for Flared Guardrail Terminal

End Treatments (Anchorages, Terminals, and Crash Cushions) 8-5

Must have this full grading if a flared end treatment is used

Tangent End Treatment Grading - AASHTO

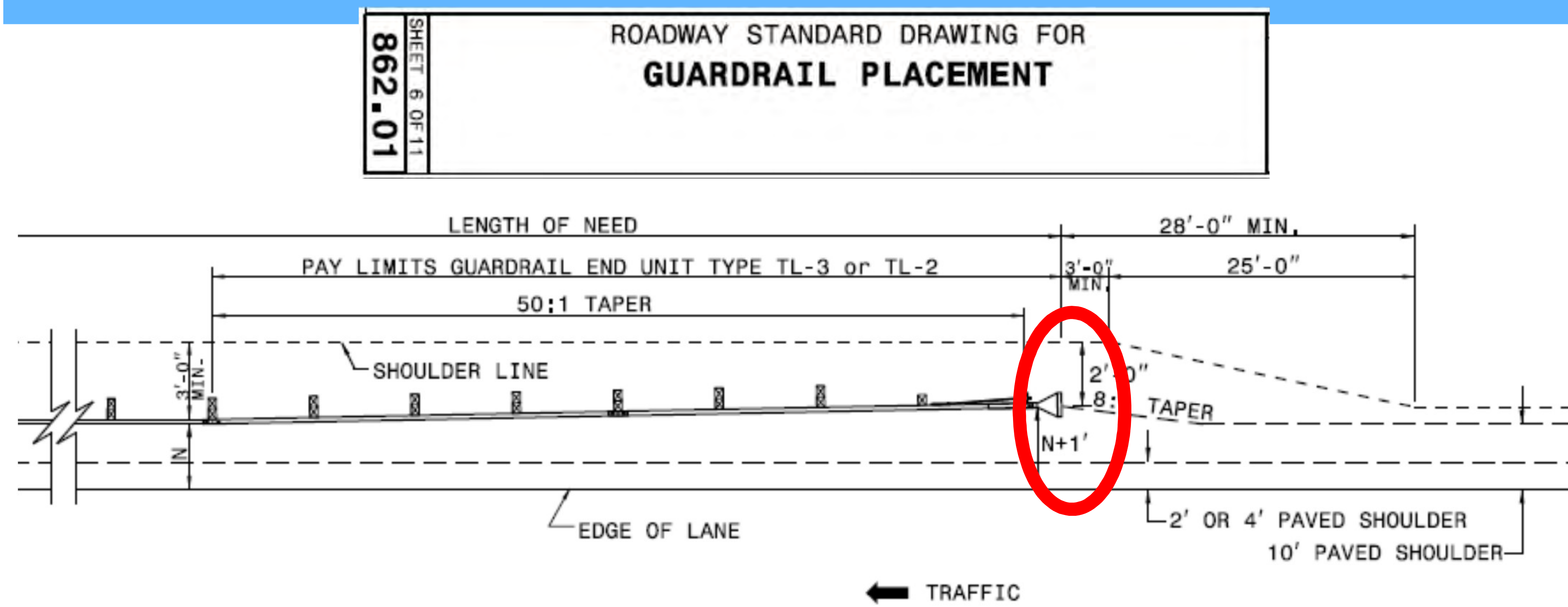


Note: The preferred grading layout should be used when practical. However, if necessary because of site limitations, the alternative grading layout may be used when upgrading an existing terminal.

Figure 8-3. Grading for Tangent Guardrail Terminal

PRE-ASSESSMENT PHOTO

Tangent End Treatment Grading - NCDOT



Need special Borrow bid item for 3R projects

Need Special Provision for Density

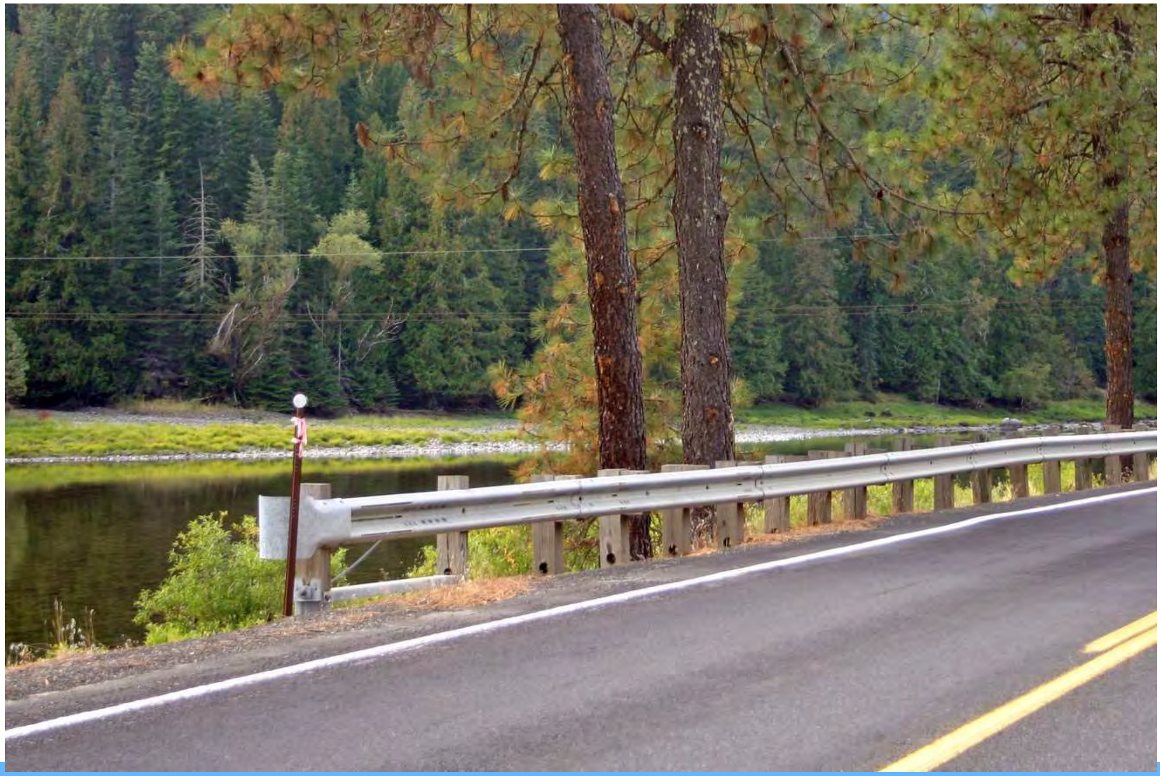
PRE-ASSESSMENT PHOTO

No Stub problem, but could be better

Substandard Grading – DOCUMENT

Thing to Remember about End Treatments

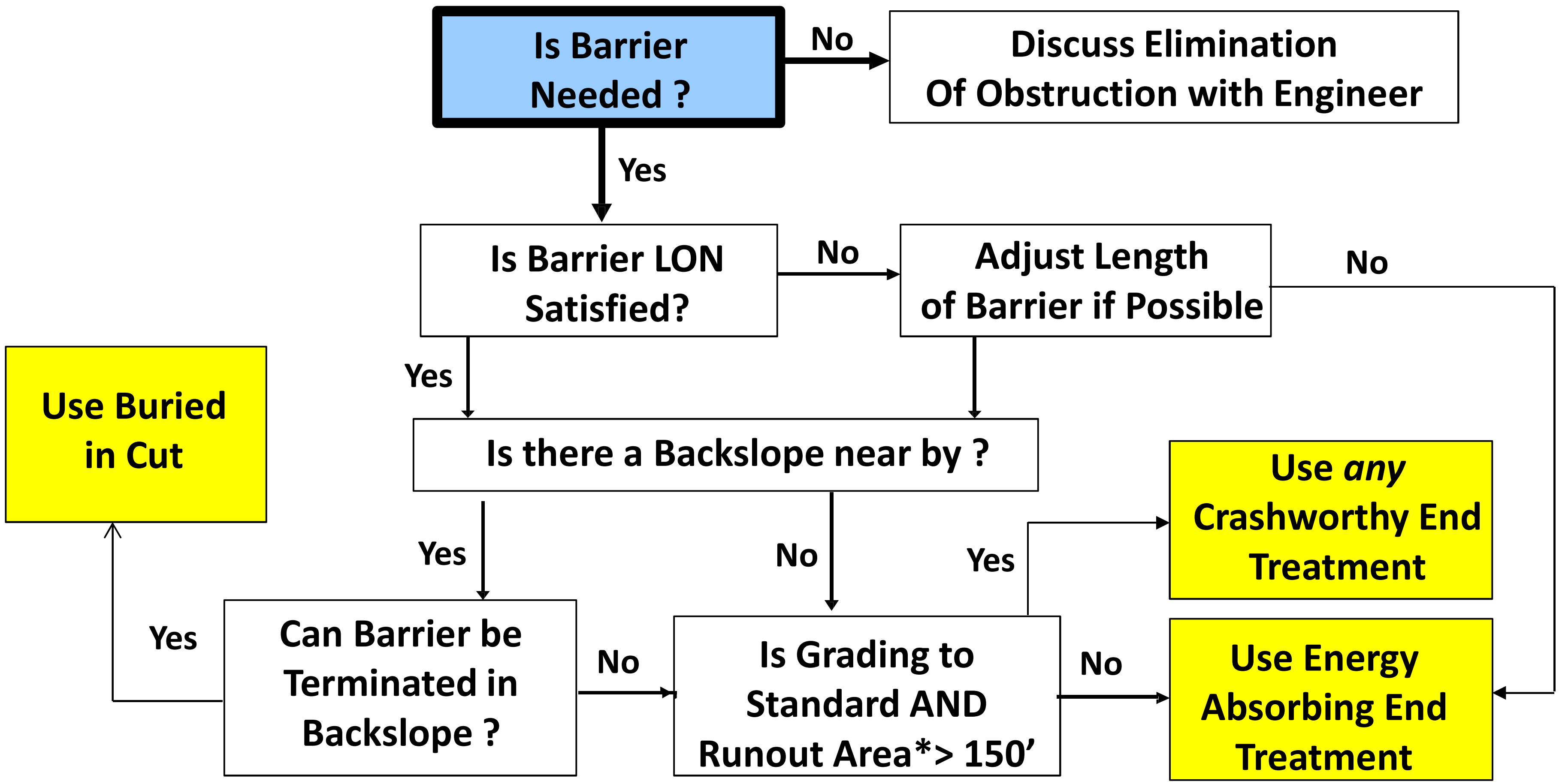
Non-Energy Absorbing End Treatments will not shield objects directly behind and within End Treatment limits



Thing to Remember about End Treatments

Even Energy Absorbing End Treatment will not shield objects directly behind and within End Treatment limits

Suggested FHWA End Treatment Selection Flow Chart



EXISTING END TREATMENTS

Tangent Guardrail End Treatment
Energy Absorbing

- SKT 350 (Sequential Kinking Terminal)(NCHRP 350)
  - Kinks panels when hit head-on or at a shallow angle
  - Wood or Steel post system (many options)
  - TL-3 at 50’ long; BLON at 3^{rd} Post
  - Cable-anchored, Compression system

Ref: FHWA Eligibility Letter CC-88 dated 3/8/05

Tangent Guardrail End Treatment
Energy Absorbing

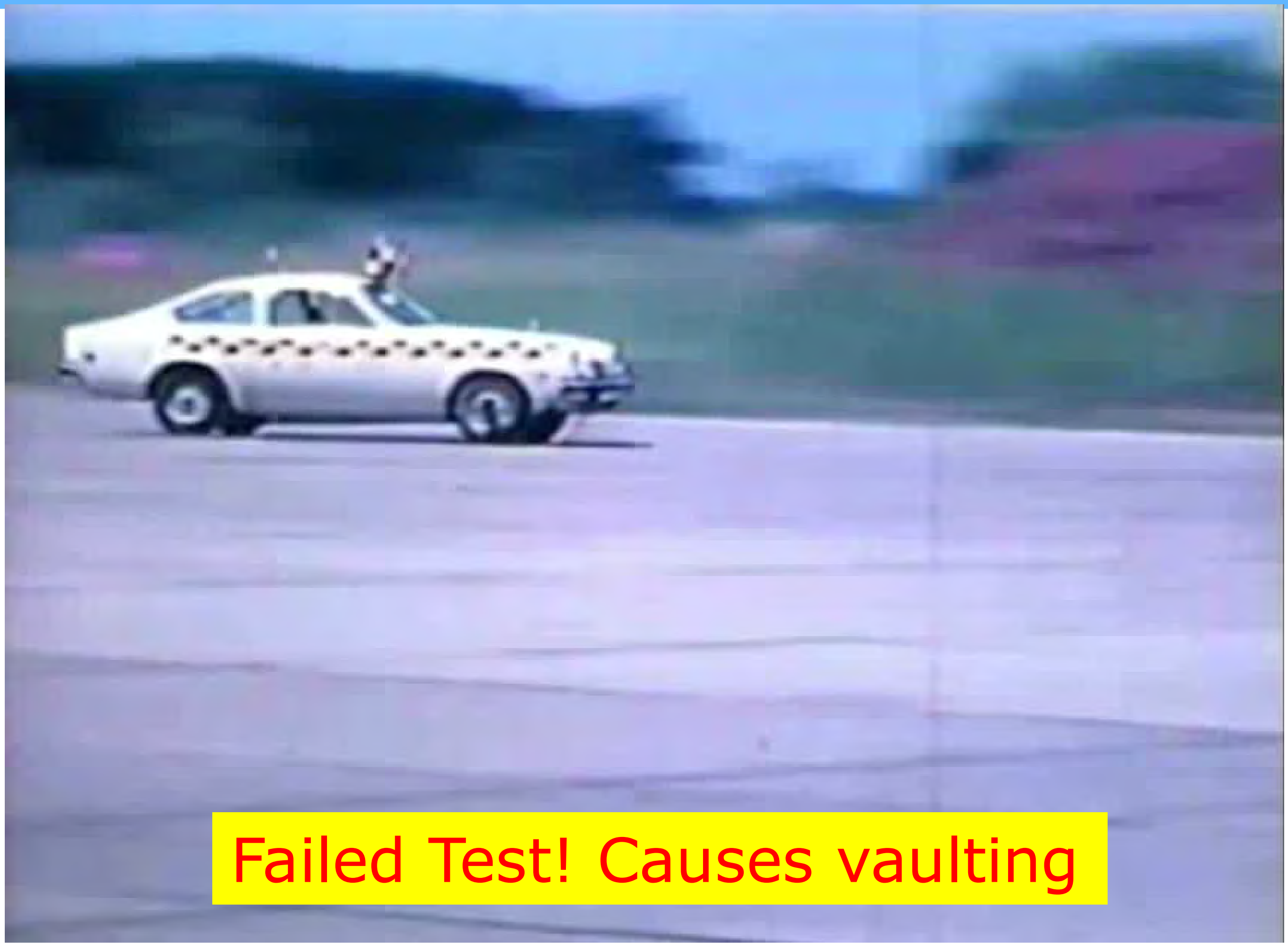
- ET Plus (Guardrail Extruder Terminal)(NCHRP 350)
  - Flattens the rail element when hit head-on
  - Weakened wood or steel posts (several options available)
  - 50' long; attaches to either height w-beam system
  - BLON at 3rd Post
  - Cable-anchored, compression system

Ref: FHWA Eligibility Letter CC-12Q dated 3/15/10

Non-crashworthy End Treatment
Blunt End

Non-crashworthy End Treatment
Turndown

Turndown



Non-crashworthy End Treatment
BCT Terminal

- Breakaway Cable Terminal (BCT) NCHRP 230
  - W-Beam rail with a parabolic curve and 4-ft offset.
  - No impact head or ground strut between the two end posts.
  - Only two breakaway posts.
  - Rail bolted to all posts.

For Identification Only

Non-crashworthy End Treatment
BCT Terminal

Guardrail End Treatments: Non-energy Absorbing – For Identification Only

- MELT – Modified Eccentric Loader Terminal
  - W-Beam rail with an accentuated parabolic curve and 4-ft offset.
  - Strut between the steel tubes foundation of the two end posts.
  - 37'-6" long with 8 breakaway posts; BLON at Post #3.
  - No rail-to-post bolts except at posts 1 and 8 and beyond.

For Identification Only

(NCHRP 350 TL-2)

Guardrail End Treatments: W-Beam Median

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- Seeds
- Producer/Supplier
- Technician Certification
- Minimum Sampling Guide

Business »

Approved Products List

Product ID (ex. NPYY-xxxx):

Company Name:

Product Name:

Product Group:

Product Category: End Treatments

Product Status:

Search Reset

Product ID	Plant ID	Company Name	Product Group	Product Category	Product Name	Model Number	Product Status	Description
NP11-5773		Road Systems, Inc.	Guardrail and Delineators (862) (1088)	End Treatments	MFLEAT		Approved	MASH tested, Guardrail End Terminal
NP17-7848	GR44	Lindsay Transportation Solutions	Guardrail and Delineators (862) (1088)	End Treatments	Max-Tension End Treatment		Approved	MASH tested;Telescoping, tension-based guardrail end terminal with an energy absorbing coupler that features a cutting tooth design.
NP18-8095		Lindsay Transportation Solutions	Guardrail and Delineators (862) (1088)	End Treatments	MAX-Tension Median Guardrail Terminal		Approved	Telescoping, tension-based terminal with an energy absorbing coupler that features a cutting tooth design.

Guardrail End Treatments: W-Beam Median

- MAX-Tension Median (MASH 16)
  - The MAX system utilizes tensioned cables, telescoping panels, and a cutting tooth to absorb the kinetic energy and safely contain or redirect impacting – **works primarily in tension**
  - TL-3 at ~50’ long; BLON at Post 3 (~13’-4”); 31” only

MASH MAX-Tension Median

Impact Attenuator

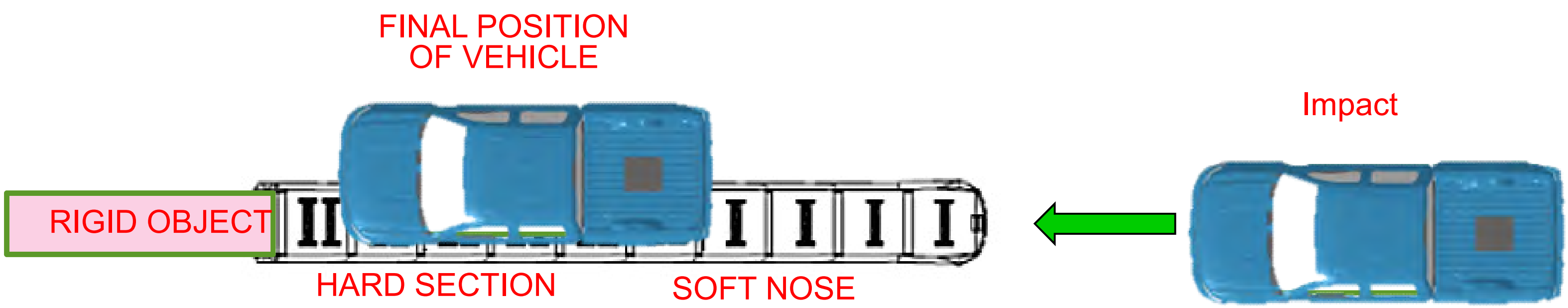
Crash test with blunt end:

Impact Attenuator

Crash test with ramped end:

Impact Attenuator Theory

Soft nose to bring a small car to a controlled stop



Harder back section to bring a pick-up truck to a controlled stop

Impact Attenuator, Sacrificial - Water Filled

- Water-filled Barriers

  <u>Absorb M (MASH)</u> / <u>Sled(MASH)</u> / ACZ 350 / TRITON CET

  - Individual crash cushion designs vary by manufacturer, but they all function in a similar manner.
  - Vehicles impacting the nose at an angle will **not** be redirected.
  - No appreciable re-directive capability under most impact conditions.
  - Typically used in work zones to shield temporary concrete barrier.

Impact Attenuator, Sacrificial - Water Filled

Approved Products List

Product ID (ex. NPYY-xxxx):

Company Name:

Product Name:

Product Group:

Product Category: WZTC - Category III

NP11-5771		Lindsay Transportation Solutions	Work Zone Traffic Control	WZTC - Category III	Absorb 350		Approved for Provisional Use	*Must be approved by Steve Kite (919-814-4937) prior to use on NCDOT project.* The ABSORB 350 is a non-redirective, gating water filled crash cushion that has been successfully tested to NCHRP Report 350 TL-2&3.
NP11-5884		TrafFix Devices, Inc.	Work Zone Traffic Control	WZTC - Category III	SLED	Series 45044	Approved	PE Water Filled Crash Cushion w/Galvanized Steel Cables molded inside.NCHRP-350 for Test Level 1,2or3.Use as end treatment/crash cushion.
NP16-7335		Trinity Highway Products	Work Zone Traffic Control	WZTC - Category III	ACZ-350 Water Filled Crash Cushion	ACZ-350	Approved for Provisional Use	The ACZ-350 is a narrow, non-redirecting TL-2 and TL-3 impact attenuator
NP99-3106	GR10	Energy Absorption Systems, Inc.	Work Zone Traffic Control	WZTC - Category III	Triton Barrier	Triton Barrier	Approved	The Triton Barrier® is a highly portable, water-filled barrier. Performance meets the FHWA NCHRP 350 TL-2 or TL-3 (with TL-3 kit) standard for longitudinal re-directive barrier. The Triton Barrier is certified as its own end treatment.

Impact Attenuator, Sacrificial - Water Filled

Absorb M (MASH)

ACZ-350

Sled (MASH)

TRITON barrier CET

Water Filled

Non-Redirective and Gating

- Individual barrel designs vary in shape by manufacturer, but they all function the same
- Arrays of sand barrels may be designed to shield any shape hazard
- Impacting vehicles will not be redirected.
- Since no re-directive capability, the corner of the hazard must be reasonably shielded.

Impact Attenuator, Sacrificial – Sand Barrel

- Sand Barrels:

Energite

TrafFix Big Sandy (MASH)

Not Normally Used

CrashGard

Sand Barrels – Good Application

Sand-Filled Array

Impact Attenuators, Non-Gating

Non-gating as follows:

- Contains and redirects vehicles impacting along the sides of the device essentially its entire length
- Contains vehicles impacting the nose either head-on or at a 15º angle.
- Approved for TL-2 (350) & TL-3 systems.
- Designed to shield a point hazard; either attached or stand alone.

Impact Attenuators, Non-Gating

Approved Products List

Product ID (ex. NPYY-xxxx):
Company Name:
Product Name:
Product Group:
Product Category: Impact Attenuators, Non-Gating

NP19-8389	Lindsay Transportation Solutions	Guardrail and Delineators (862)(1088)	Impact Attenuators, Non-Gating	Universal TAU-M		Approved	MASH compliant re-directive, non-gating anchored, partially reusable compression-based crash cushion

MASH

NCHRP 350 - Allowed if Conditions Mandate

NP02-1527	Lindsay Transportation Solutions	Guardrail and Delineators (862)(1088)	Impact Attenuators, Non-Gating	Universal TAU-II		Approved	The Universal TAU-II is a redirective, non-gating crash cushion. The system is available in lengths and capacities for both low and high speed applications
NP03-4111	Trinity Highway Products	Guardrail and Delineators (862)(1088)	Impact Attenuators, Non-Gating	WIDE TRACC	N/A	Approved for Provisional Use	the WideTRACC is test level 3 crash cushion and is avaliable in varying lengths and widths. can be configured for any appropriate width application.

Impact Attenuators, Non-Gating

- TAU-M (MASH) and TAU IIR Systems (NCHRP 350)
  - Can be attached directly to a W-beam or Thrie-beam median barrier as well as to a concrete safety shape.
  - Designed to attach to a median barrier.
  - Common set of parts for 36” to 102” widths in 6” increments (350)
  - Consists of Thrie-beam panels, expendable (MASH) or self-restoring (R) (350) absorbing cartridges, steel diaphragms and two cables at the bottom to provide redirection.

Impact Attenuators, Non-Gating - Typical

Impact Attenuators, Life Cycle

Approved Products List

Product ID (ex. NPYY-xxxx):

Company Name:

Product Name:

Product Group:

Product Category: Impact Attenuators, Life Cycle

MASH

NP16-7403	Energy Absorption Systems, Inc.	Guardrail and Delineators (862)(1088)	Impact Attenuators, Life Cycle	Quadguard Elite	N/A	Approved for Provisional Use	**Contact NCDOT Mobility and Safety Field Operations prior to use at 919-773-2800**The QuadGuard Elite System offers the added value of reusable cylinders for applications with above average impact frequency. After a typical design impact, the system is
NP16-7404	Hill and Smith	Guardrail and Delineators (862)(1088)	Impact Attenuators, Life Cycle	Smart Cushion Innovations Crash Cushion	SCI100GM	Approved	Test Level III Crash Attenuator
NP16-7405	Hill and Smith	Guardrail and Delineators (862)(1088)	Impact Attenuators, Life Cycle	Smart Cushion Innovations Crash Cushion	SCI70GM	Approved	Test Level II Crash Attenuator
NP16-7406	TrafFix Devices, Inc.	Guardrail and Delineators (862)(1088)	Impact Attenuators, Life Cycle	Compressor System Crash Cushion	55000 Series	Approved	Low Maintenance, Severe-Duty, Self-Restoring, Re-Directive Impact Attenuator. NCHRP-350 approved as TL-3. Designed for repeated impacts with no need for repair. For use in Uni-directional or Bi-Directional applications up to 96 wide

MASH

Impact Attenuators, Life Cycle

- SCI Smart Cushion (MASH)
  - Variable Reaction Force
  - Re-usable with minimal component replacement
  - Needs repair before next hit

Example – Low Cost

Impact Attenuators, Life Cycle

- QuadGuard Elite (MASH)
  - Uses High Density Polyethylene cylinders to absorb energy
  - Essentially for use in locations where a high number of hits is anticipated.

REF: FHWA Eligibility Letter CC-57E dated 12/18/15

Example - Self Restoring

Very Appropriate Use

Review Learning Outcomes

- Understand how end treatments and impact attenuators are tested for crashworthiness
- Identify common end treatments and impact attenuators
- Understand how these systems function
- Choose the appropriate system for a specific site

Session 5:
Design Principles

Session 5 Learning Outcomes

At the end of this session, you will be able to:

Understand the design principles affecting an optimal barrier installation.

Order of Preference

1. Remove hazard
2. Redesign hazard (make traversable)
3. Relocate hazard (move away from traffic)
4. Reduce Impact Severity (use breakaway design)
5. SHIELD hazard
6. Delineate hazard so motorist can avoid

Ref: AASHTO Roadside Design Guide, 4th Edition – Pg. 1-4

Barriers Must Be Less of a Hazard

Guardrail Placement

Place AS FAR AWAY as Possible

without affecting function

Barrier Design Principles

1. Deflection
2. Slope in Front of Barrier
3. Guardrail and Curb
4. Soil Backing for Fill Locations
5. Flare Rate

Principle 1: Deflection

Adequate room must be left behind the barrier to allow for lateral deflection in an impact.

- If the barrier is shielding a vertical rigid object, the distance between the barrier and the object should be sufficient to avoid the vehicle impacting or snagging on the object.
- Note that, even for rigid barriers with no lateral deflection, large vehicles may roll behind the top of the barrier even if the barrier itself does not deflect.

Deflection Distance

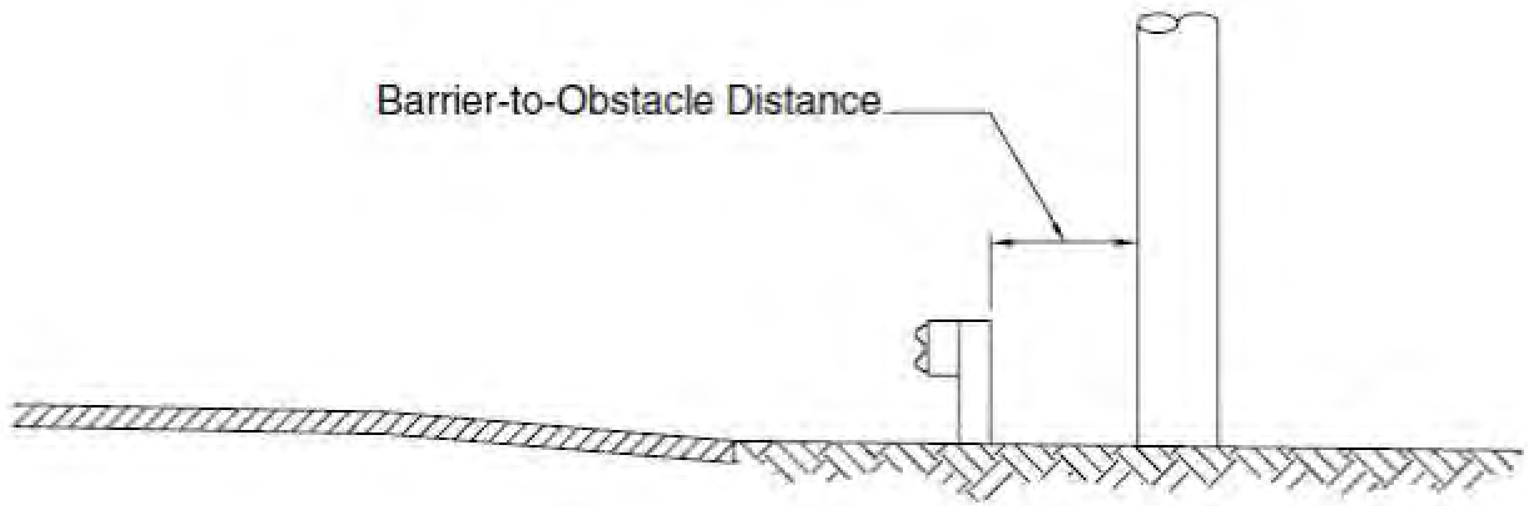
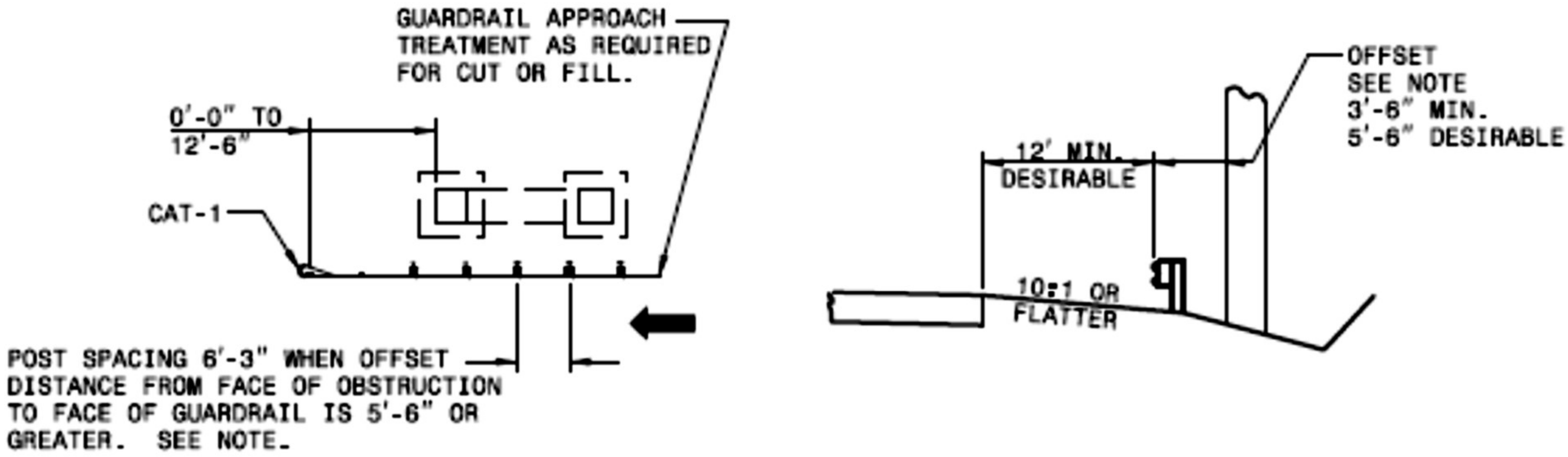


Figure 5-33. Recommended Barrier Placement for Optimum Performance

Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION – Figure 5-33

Deflection

Deflection Distance - NCDOT



NOTE: WHEN OFFSET DISTANCE FROM FACE OF OBSTRUCTION TO FACE OF GUARDRAIL IS BETWEEN 3'-6" AND 5'-6", BEGIN 3'-1½" POST SPACING AT A POINT 25' BEFORE REACHING THE OBSTRUCTION AND CARRY THROUGHOUT ITS LENGTH. IF THE OFFSET IS LESS THAN 3'-6" USE CONCRETE BARRIER.

DETAIL OF RIGHT SIDE GUARDRAIL AT UNDERPASS

Ref: NCDOT Standard Drawing 862.01, Sht 1

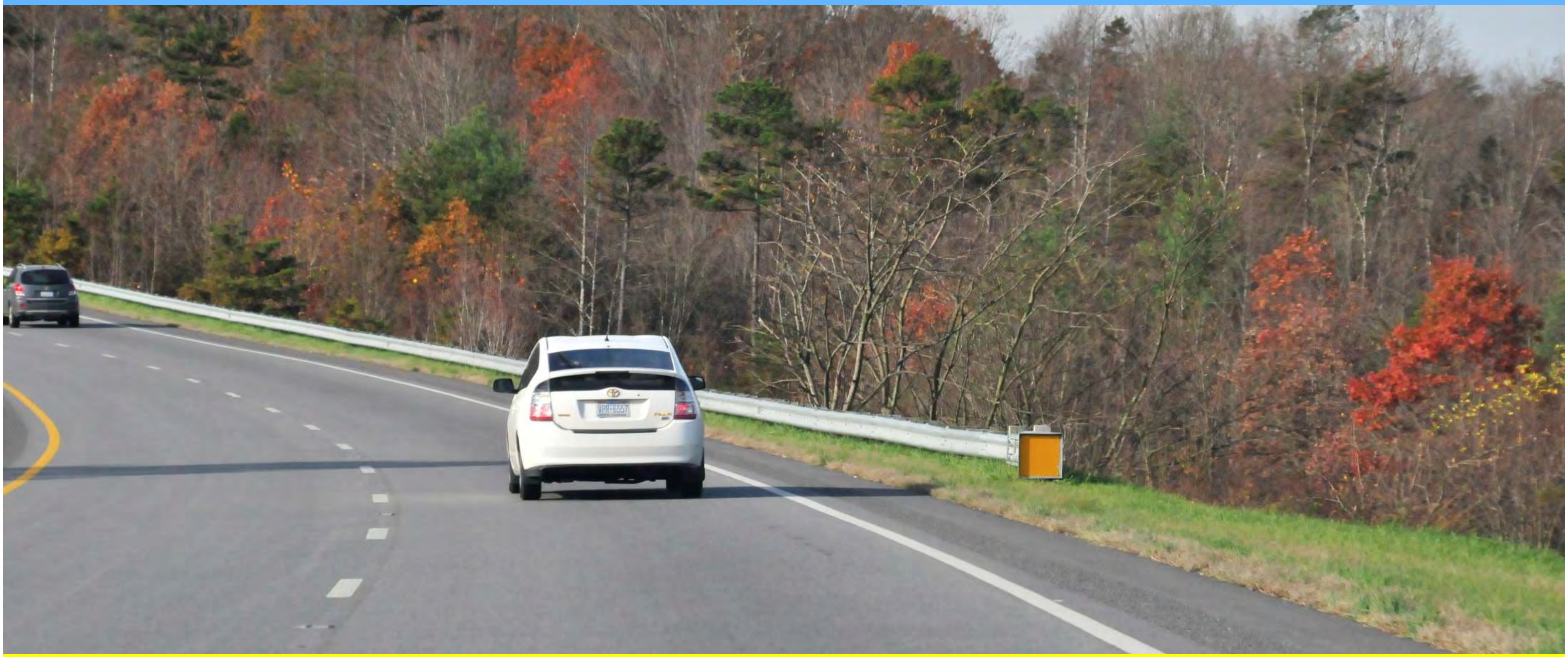
Quarter Post Spacing

Successfully tested to MASH

Deflection distance = 19”; therefore offset from face of rail is 3’

Must start stiffening at 50’ before hard point: 25’ of half post guardrail; 25’ of quarter post guardrail

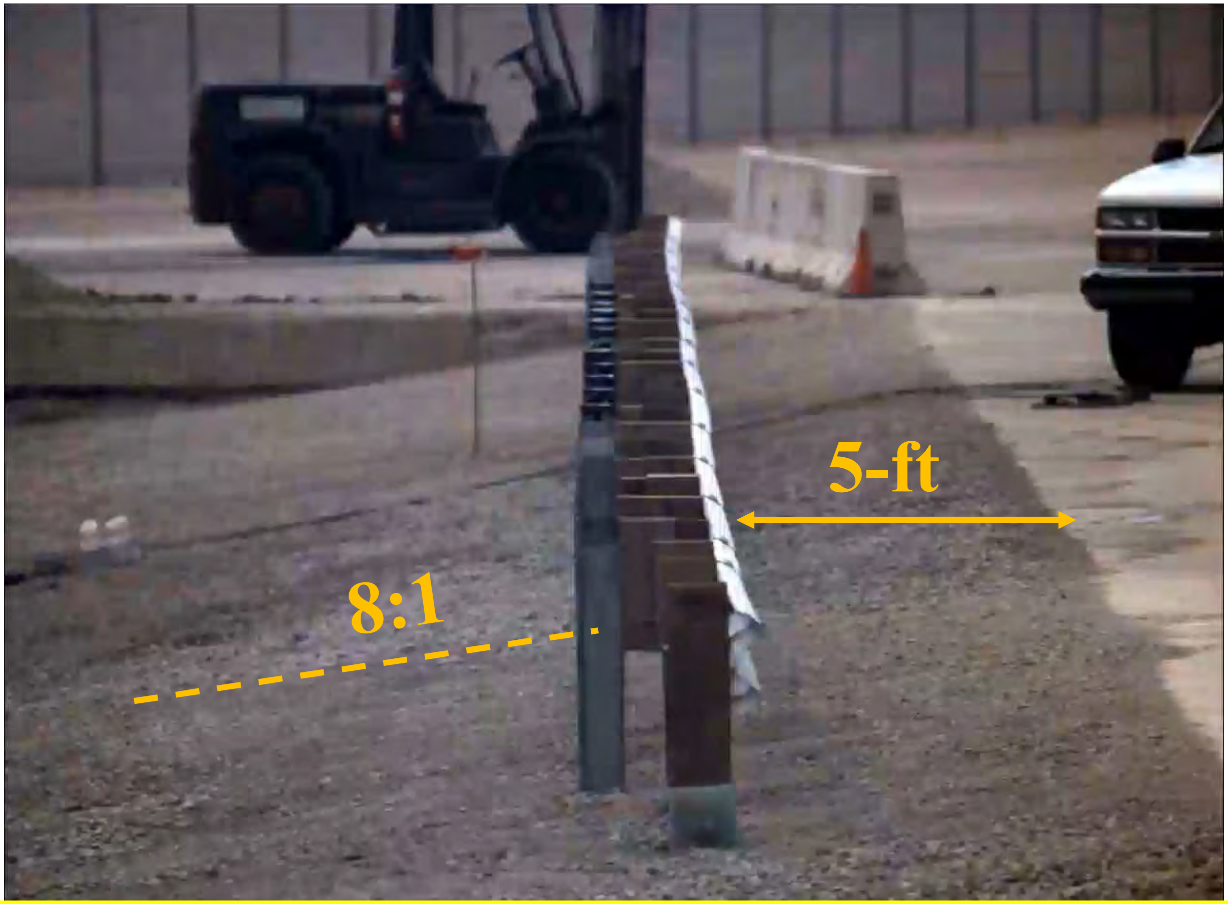
Principle 2: Slope in Front of Barrier



Any barrier may be placed anywhere on a 10H:1V or flatter slope.

Principle 2: Slope in Front of Barrier

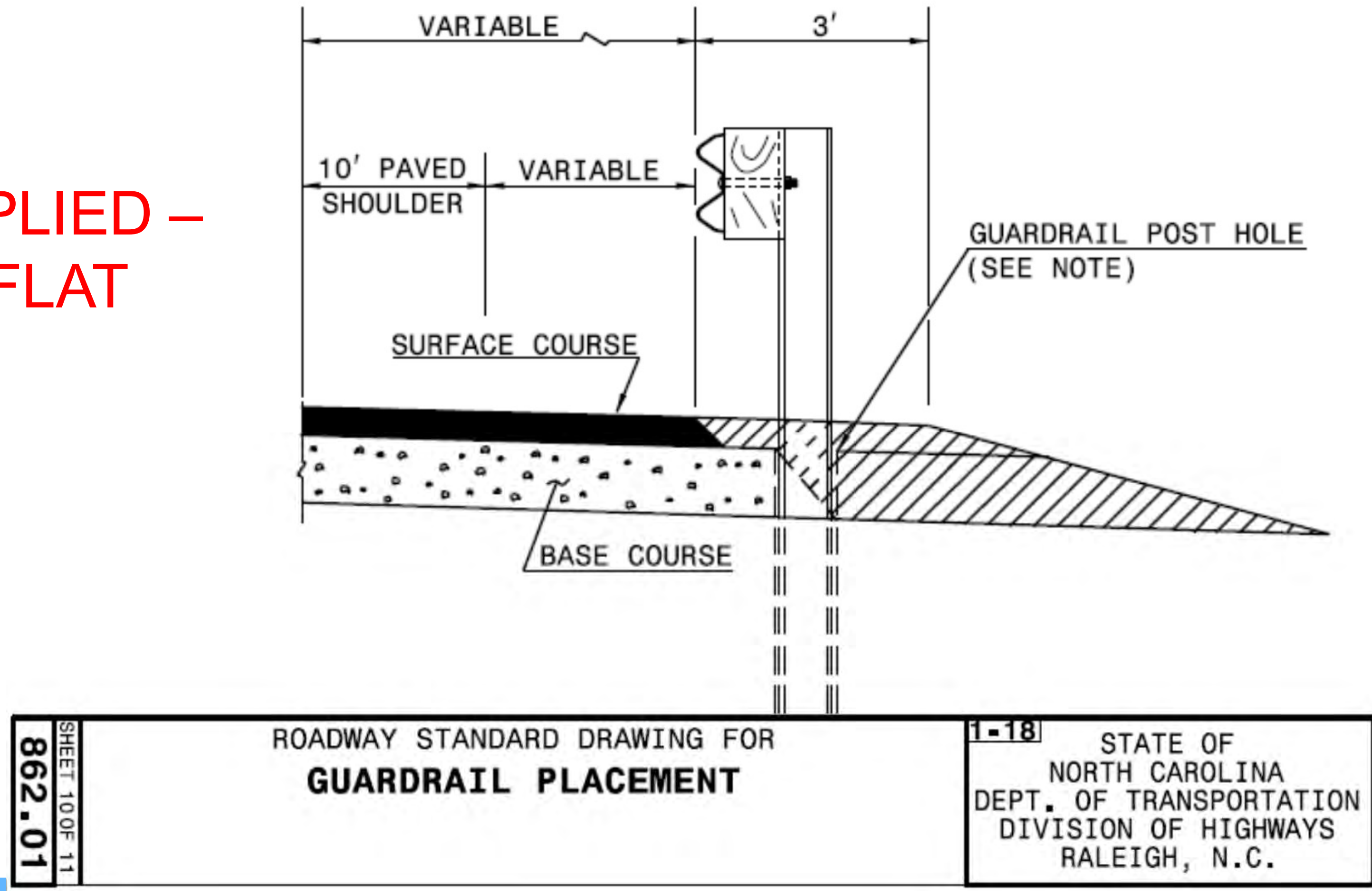
NCHRP 350 TL-3 31" on 8:1 Slope



Vehicle is contained and redirected but shows instability

Slope in Front of Barrier

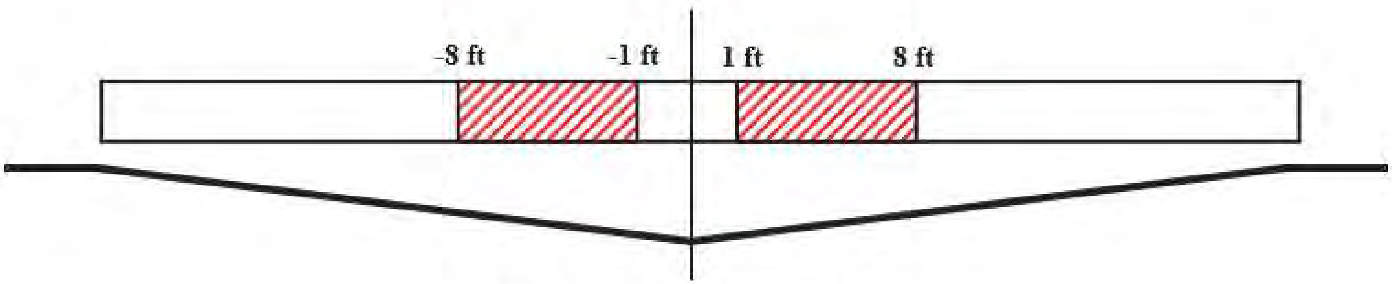
IMPLIED – FLAT



Barrier in Sloped Median - Old System (29”) ONLY -

Slope in Front of Cable Barrier

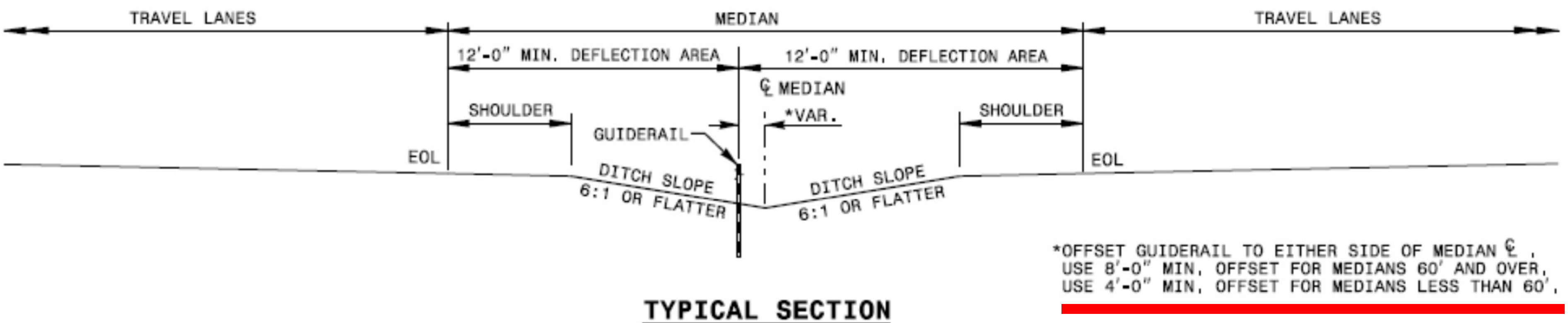
- Cable barrier may be placed anywhere on a 10:1 or flatter slope.
- Cable barrier may be placed on slopes of 6:1, but not in the area from 1 ft. to 8 ft. from the ditch bottom.



(a) Medians shallower than 6H:1V slope (NCHRP Report 711)

Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION – 6.6.1.1, Pg. 6-18

NCDOT Slope/Swale Guidance - LTC



TYPICAL SECTION

(DEFLECTION AREA ON MEDIAN SLOPES)

DOUBLE FACE GUIDERAIL APPLICATION

USE 4'-0" MIN. OFFSET FOR MEDIANS LESS THAN 60'.

Strongly Discouraged

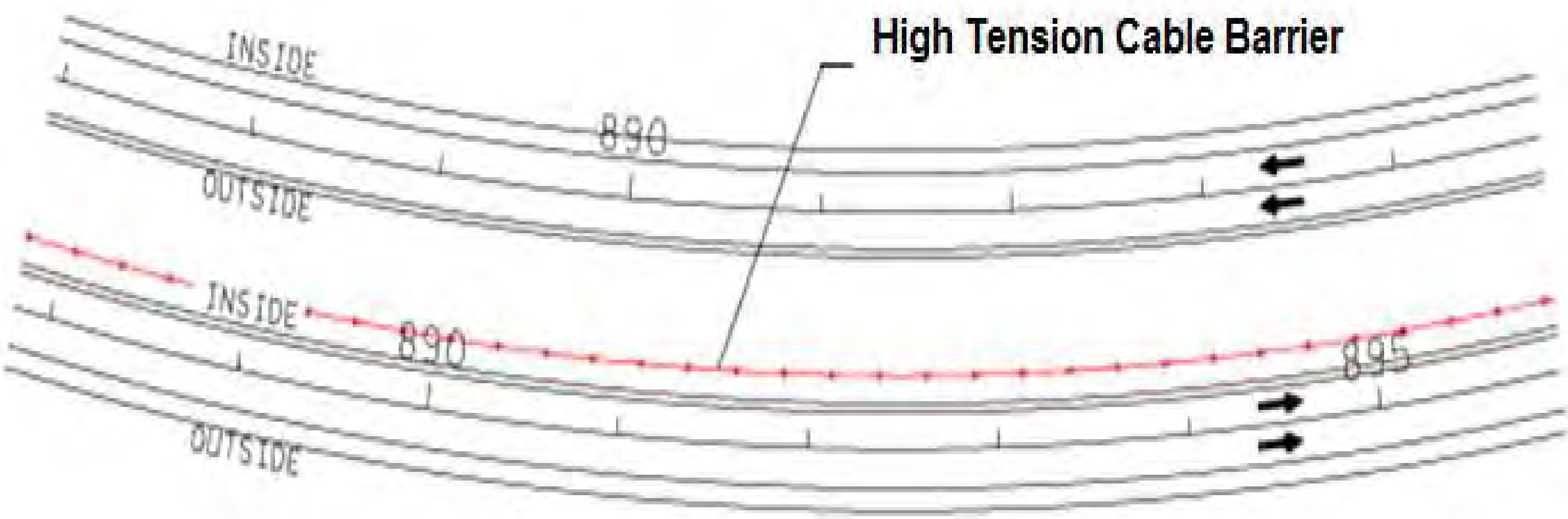
865.01 SHEET 4 OF 12	ROADWAY STANDARD DRAWING FOR **CABLE GUIDERAIL** DESIGN AND PLACEMENT

PRE-ASSESSMENT PHOTO

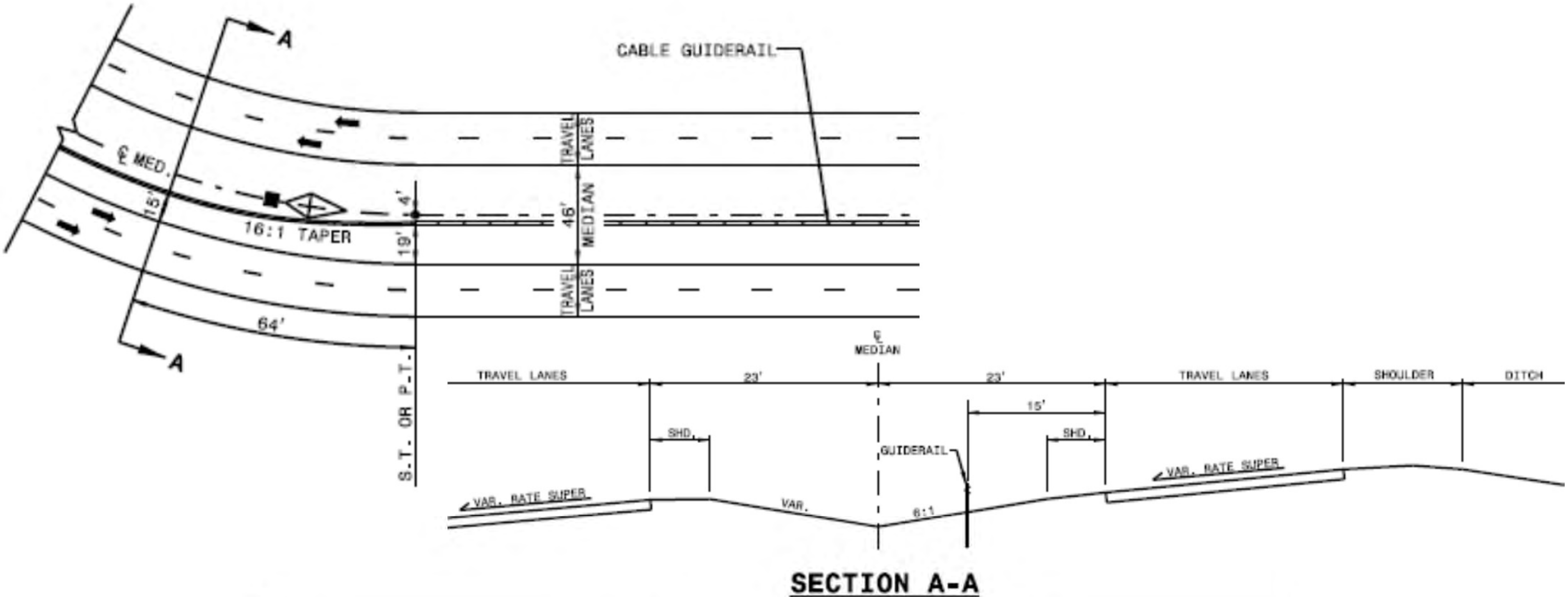
Barrier in Sloped Median

Barrier in a Curved Median

Which Side of the Median Should the Cable Barrier be Placed?



Barrier in a Curved Median



865.01	SHEET 3 OF 12	ROADWAY STANDARD DRAWING FOR **CABLE GUIDERAIL** 46′ MEDIAN GUIDERAIL TRANSITIONS WITH SUPERELEVATION AND/OR FALSE SUMPS

Principle 3: Guardrail and Curbs

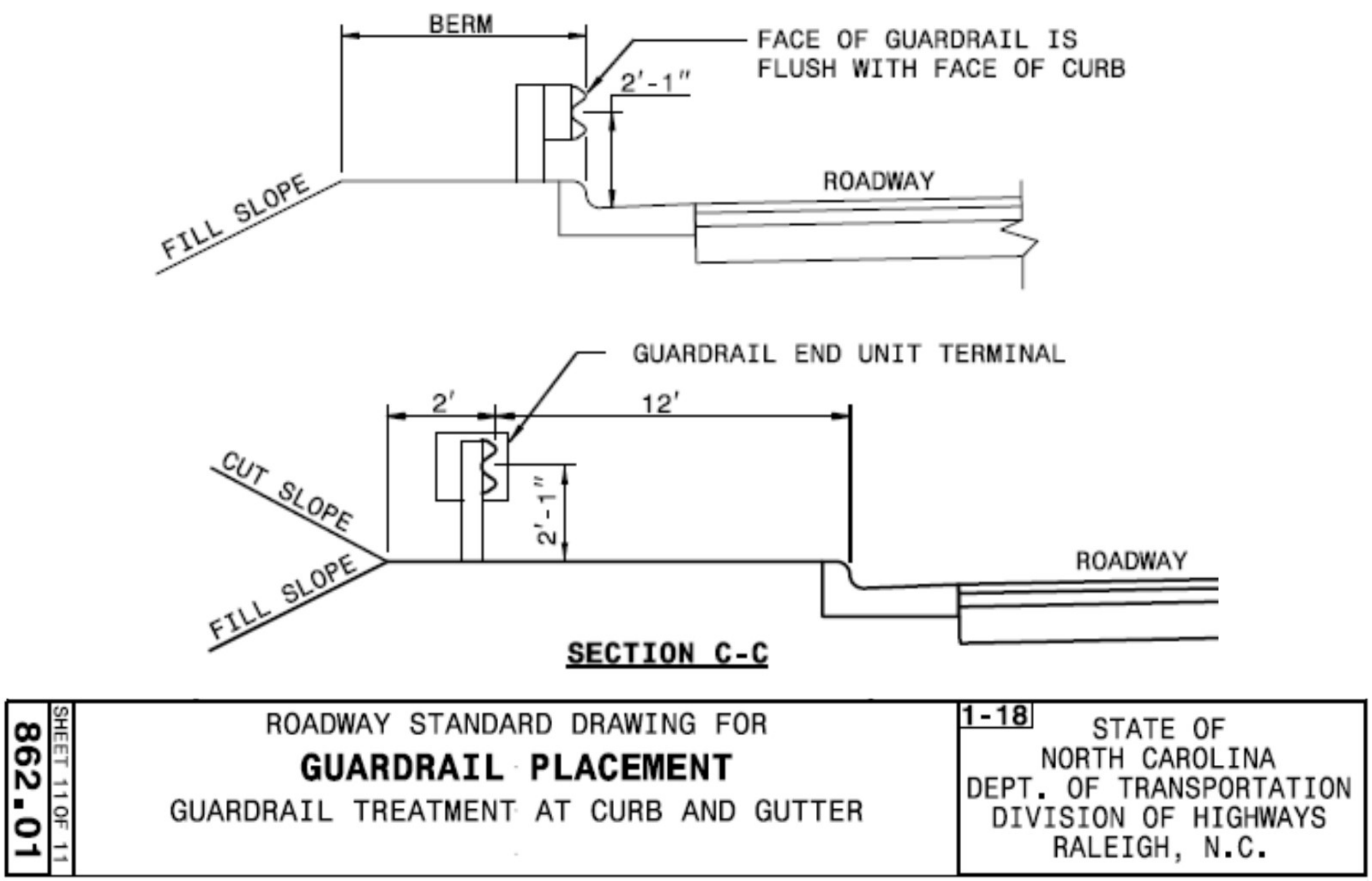
PRE-ASSESSMENT PHOTO

6” Curb not acceptable for old 29” System on HS

Guardrail and Curbs

- Curbs may function to channelize traffic, to control drainage, improve delineation, control access, and reduce erosion.
- Curbs are not adequate to prevent a vehicle from leaving the roadway; they are not a barrier.
- Use of any guardrail/curb combination where high-speed, high-angle impacts are likely should be discouraged.

NCDOT Guardrail and Curbs

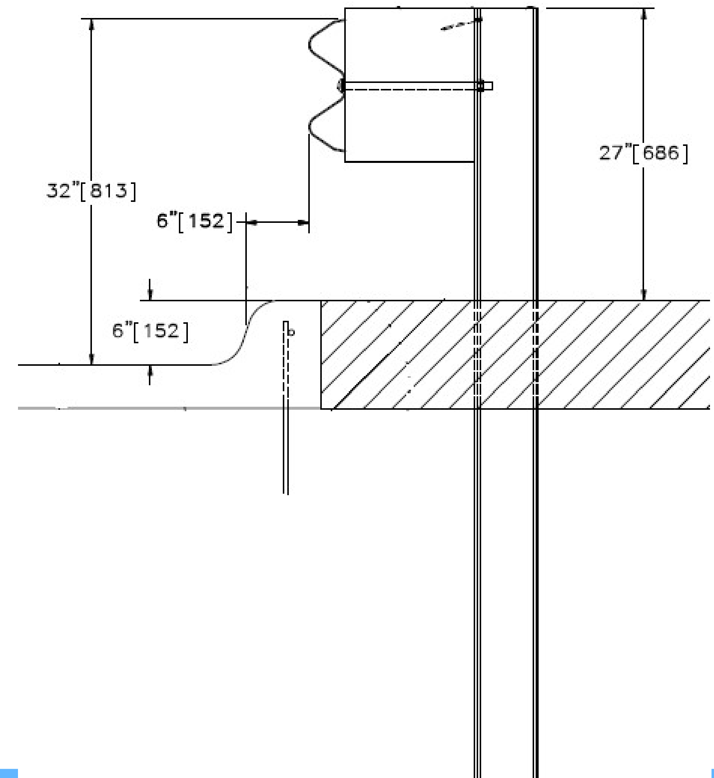


Ref: NCDOT Standard Drawings, 862.01 Sht. 11

Guardrail and Curbs – 29”

31" and Curbs

Successfully tested to MASH placed 6" behind a 6" high curb at TL-3



MASH TL-3 31”
Placed 6” behind 6” high Curb

31" and Curbs

- The 31" was tested with a 6" curb, 8' in front of the rail at MASH TL-3

unsuccessful

End Treatments and Curbs

As stated previously, the GRAU-350 is a tangential end unit. However, these units will be flared over the last 50 feet to provide a 1-foot offset. This minimal flare allows the terminal to be offset so that no component of the unit extends beyond the face of the guardrail. The tangential end unit should not be flared greater than a 50:1 flare rate.

No curb is allowed within the limits of this unit.

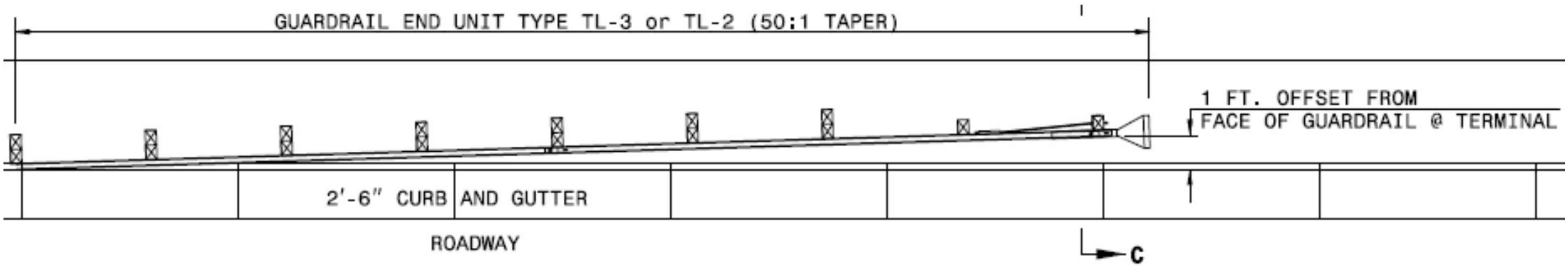
GUARDRAIL ANCHOR UNITS 3-2E

End Treatments and Curbs

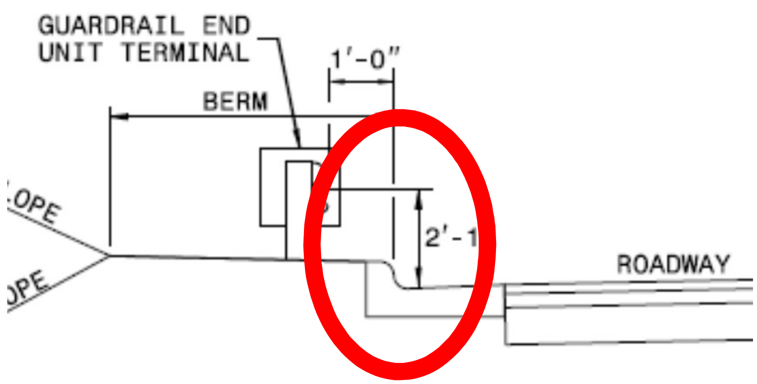
CURRENTLY UNDER STUDY –
DO NOT BURY BEARING PLATE

2” maximum height recommended

End Treatments and Curbs - NCDOT



GUARDRAIL AT FACE OF CURB



SECTION C-C

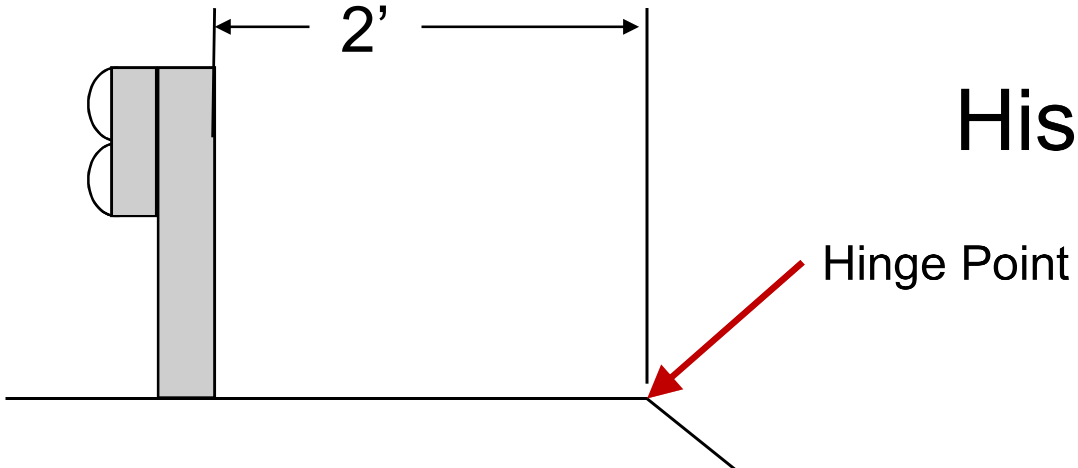
Careful with BCA Terminal Anchor – Don't let Bearing Plate be buried

Ref: NCDOT Standard Drawings, 862.01 Sht. 11

MASH TL-2 31” 6 ft. behind curb

Principle 4: Soil Backing For Fill Locations

Soil Backing Recommendation



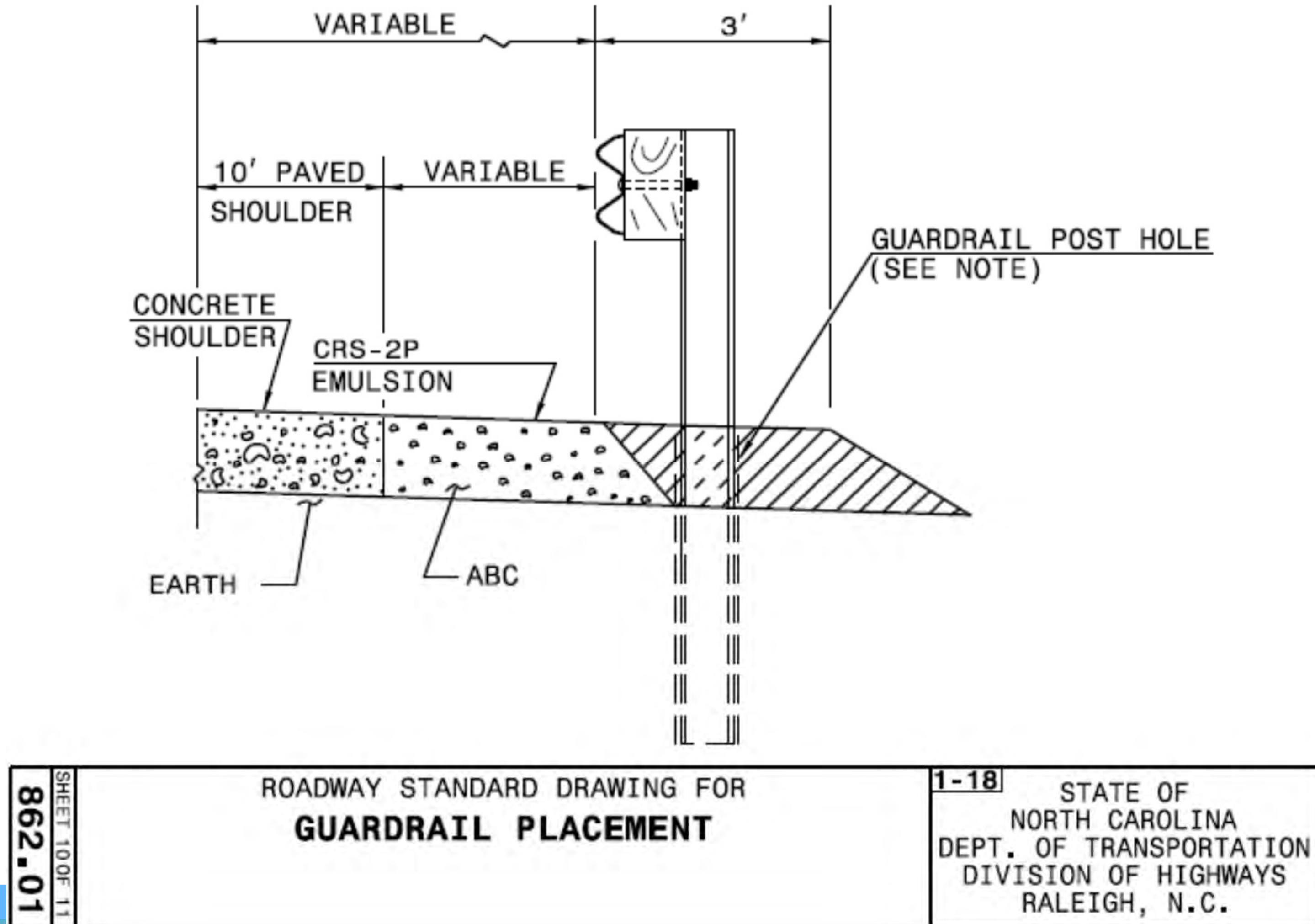
Historical Guidance

1. Slope can be as steep as 2:1 with 2-ft. backing in strong soil with 6 ft. posts.

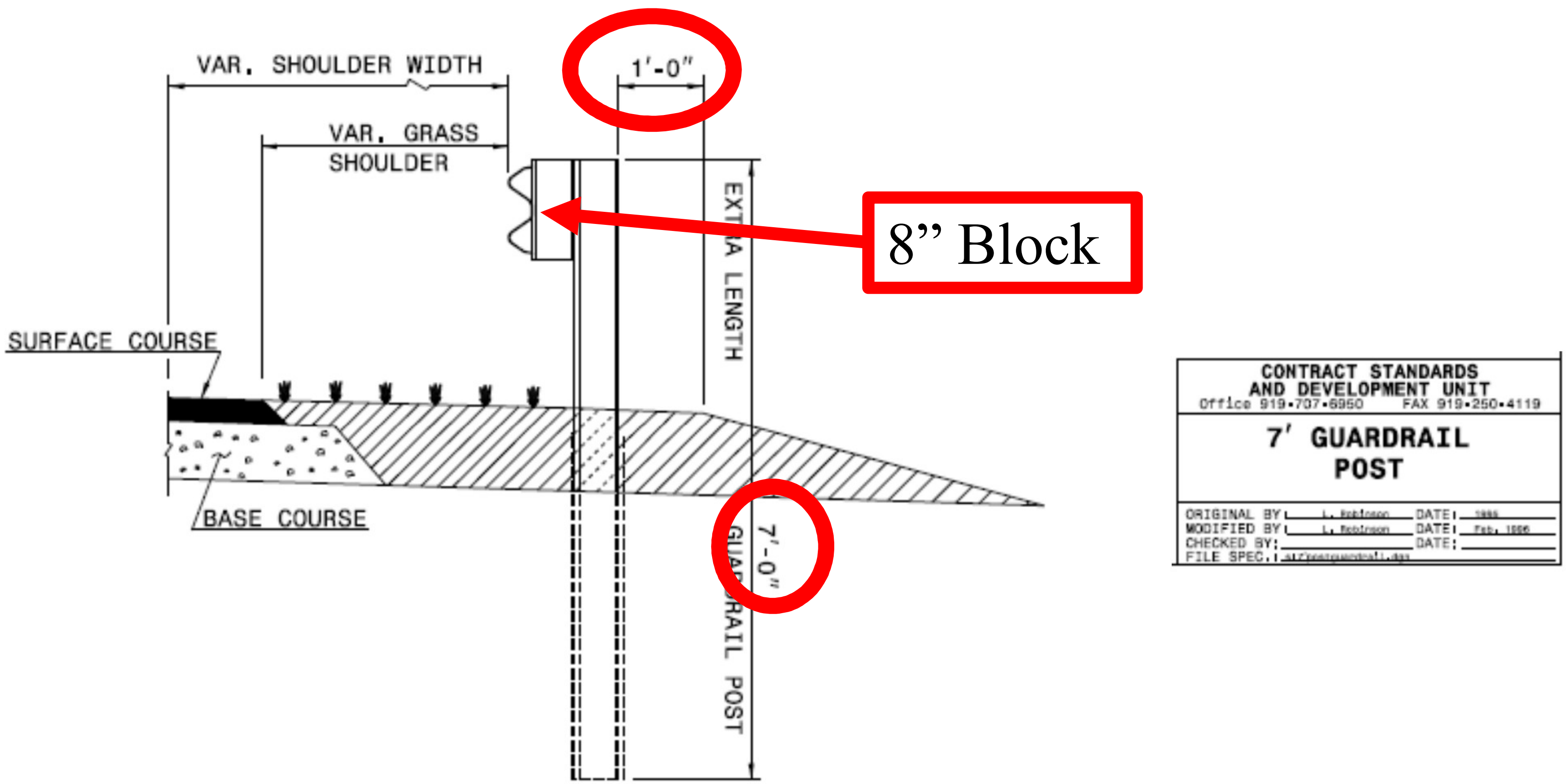
2. Backing can be less than 2 ft. with 2:1 slope in strong soil with 7 ft. posts. NCHRP 350 requires half post spacing – ONLY applies to 29” system

Ref: AASHTO Roadside Design Guide, 4th Edition – Figure 5.33, Pg. 5-41

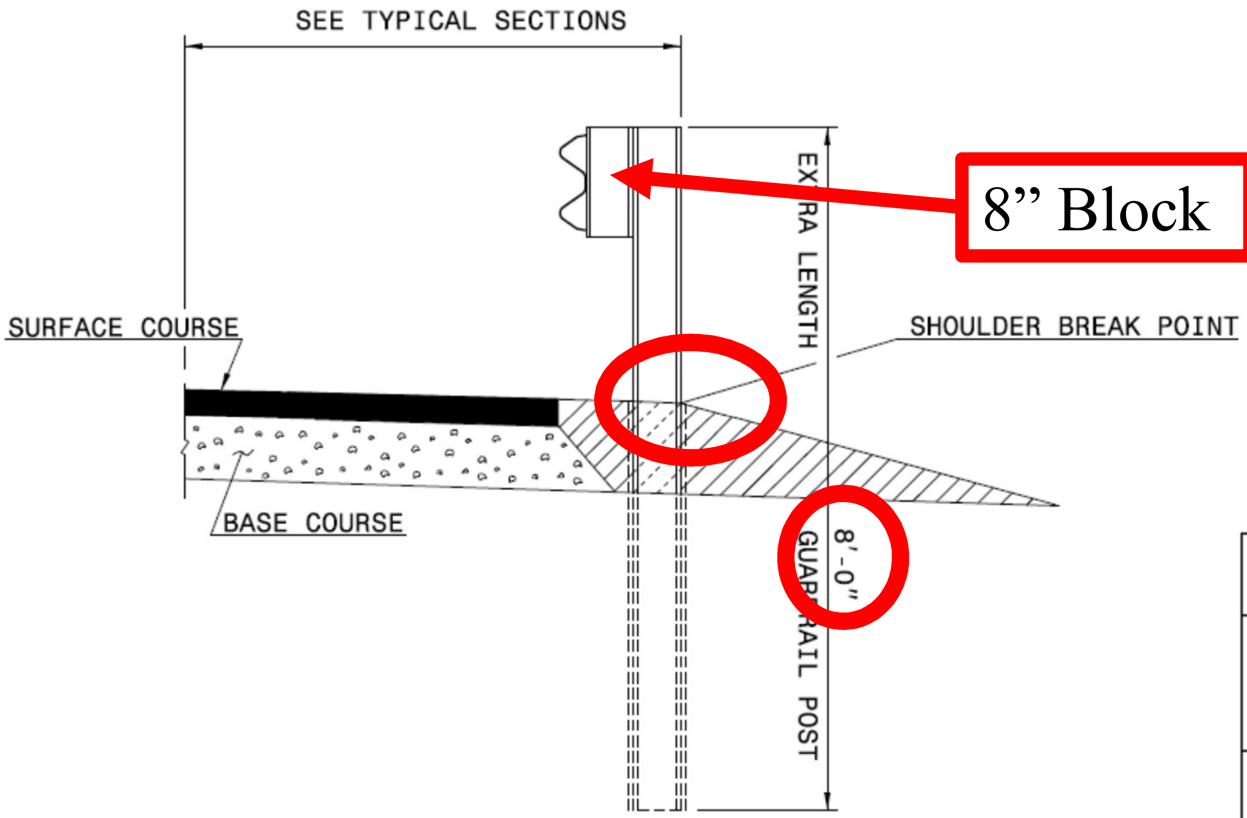
Soil Backing – NCDOT



Soil Backing – NCDOT



Soil Backing – NCDOT



CONTRACT STANDARDS AND DEVELOPMENT UNIT Office 919-707-6950 FAX 919-250-4119
8' GUARDRAIL POST
ORIGINAL BY: L. Robinson DATE: 1995 MODIFIED BY: L. Robinson DATE: Feb. 1996 CHECKED BY: DATE: FILE SPEC.: s17'postguardrail.dgn

31” with Posts on a 2:1 Slope

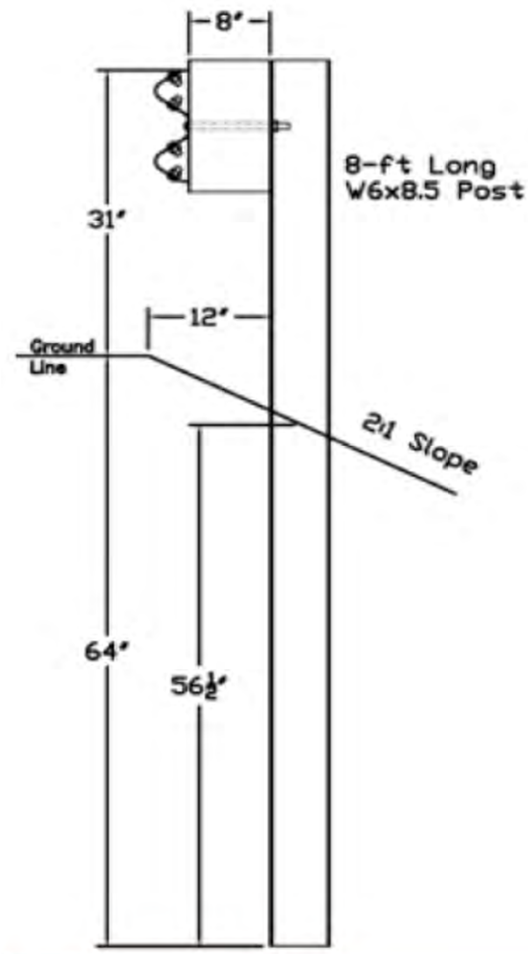
31” with face of rail at slope break point of 2:1 slope

Posts

- 8’ long W6x9 posts tested
- Not recommended with Wood posts at this time
- 6’-3” post spacing

Blocks

- 8” block tested
- Not recommended without blocks at this time



31” with Posts on a 2:1 Slope

MASH Testing of
MGS adjacent to a
2:1 Slope
8" blockout
8' long posts at
6'-3" spacing

Working Width – 55.2”
Eligibility Letter B-261

Roadside High Tension Cable MASH 2009 on a 2:1 Slope

<u>Safence</u>

Located 8" onto the 2:1 Slope

FHWA Letter B- 276

Working Width 7.2 ft.

Principle 5: Flare Rate

Flare Rate

Flared barriers are those that are not parallel to the edge of the traveled way. They are used to:

- Locate end treatments farther from the roadway.
- Lessen driver reaction to a roadside obstacle.
- Reduce total length of rail needed.
- Reduce nuisance hits.
- When tying to a bridge rail from a farther offset (in advance of transition)

Flare Rate

Trade offs and restrictions of flared barriers:

- Flare increases the angle at which the barrier can be hit.
- Flare may increase the angle of redirection after an impact.
- Flared barriers can only be placed on 10:1 or flatter slopes.
- Maximum flare rate varies with design speed
  NCDOT flare rate typically 50:1

Tangent End Treatments on Flared Standard Run - <u>Repeat</u>

The offset of the end treatment is measured from a line parallel to the ROADWAY:

- If the standard flare is 25:1 or flatter, the end treatment may be placed on the standard flare line extended

- If the standard flare is sharper than 25:1, a kink in the run must be provided so the end treatment is no sharper than 25:1

NCDOT guidance is to provide 25’ of parallel guardrail in advance of any end treatment requiring a kink.

Suggested Flare Rates

Table 5-9. Suggested Flare Rates for Barrier Design

Design Speed km/h	Design Speed [mph]	Flare Rate for Barrier Inside Shy Line	Flare Rate for Barrier at or Beyond Shy Line: Rigid Barrier	Flare Rate for Barrier at or Beyond Shy Line: Semi -Rigid Barrier
110	[70]	30:1	20:1	15:1
100	[60]	26:1	18:1	14:1
90	[55]	24:1	16:1	12:1
80	[50]	21:1	14:1	11:1
70	[45]	18:1	12:1	10:1
60	[40]	16:1	10:1	8:1
50	[30]	13:1	8:1	7:1

Notes:
A = Suggested maximum flare rate for rigid barrier system.
B = Suggested maximum flare rate for semi-rigid barrier system.
The MGS has been tested in accordance with NCHRP Report 350 TL-3 at 5:1 flare.
Flatter flare rates for the MGS installations also are acceptable. The MGS should be installed using the flare rates shown or flatter for semi-rigid barriers beyond the shy line when installed in rock formations.

Example of Benefit of Flare

PRE-ASSESSMENT PHOTO

Review Learning Outcomes

Understand the design principles affecting an optimal barrier installation.

Session 6:
Length of Need and Special Considerations

Session 6 Learning Outcomes

At the end of this session, you will be able to:

- Define the Length of Need and apply the design principles for an optimal installation
- Modify guardrail for special situations

Order of Preference

1. Remove hazard
2. Redesign hazard (make traversable)
3. Relocate hazard (move away from traffic)
4. Reduce Impact Severity (use breakaway design)
5. SHIELD hazard
6. Delineate hazard so motorist can avoid

Ref: AASHTO Roadside Design Guide, 4th Edition – Pg. 1-4

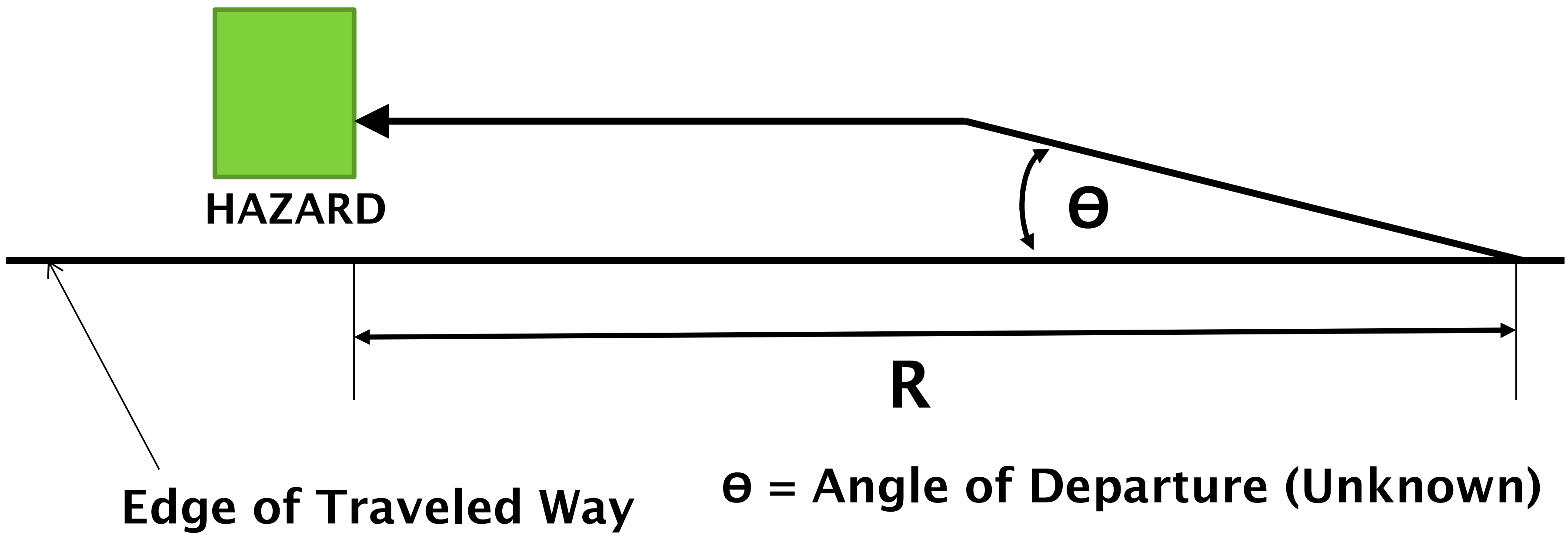
Length of Need (LON) Definition

AASHTO

The length of effective barrier needed IN ADVANCE OF the hazard to intercept and redirect an encroaching vehicle.

Length of Need (LON) Theory

AASHTO



ϴ = Angle of Departure (Unknown)

R = Runout Length

Runout Lengths - NCDOT

Will be replaced with AASHTO RDG values

LR = RUNOUT LENGTH
N = NORMAL SHOULDER WIDTH (WIDTH OF SHOULDER FROM EDGE OF TRAVEL LANE TO FACE OF GUARDRAIL)

DETAIL 3-2A

Runout Lengths - AASHTO

Table 5-10(b). Suggested Runout Lengths for Barrier Design (U.S. Customary Units)

Design Speed (mph)	Runout Length (L_R) Given Traffic Volume (ADT) (ft)			
	Over 10,000	5,000 to 10,000	1,000 to 5,000	Under 1,000
80	470	430	380	330
70	360	330	290	250
60	300	250	210	200
50	230	190	160	150
40	160	130	110	100
30	110	90	80	70

Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION – TABLE 5.10, Pg. 5-50

Length of Need - AASHTO

- Calculating the length of need (X) for straight or nearly straight sections of roadway:
  - For <u>flared</u> guardrail installations:

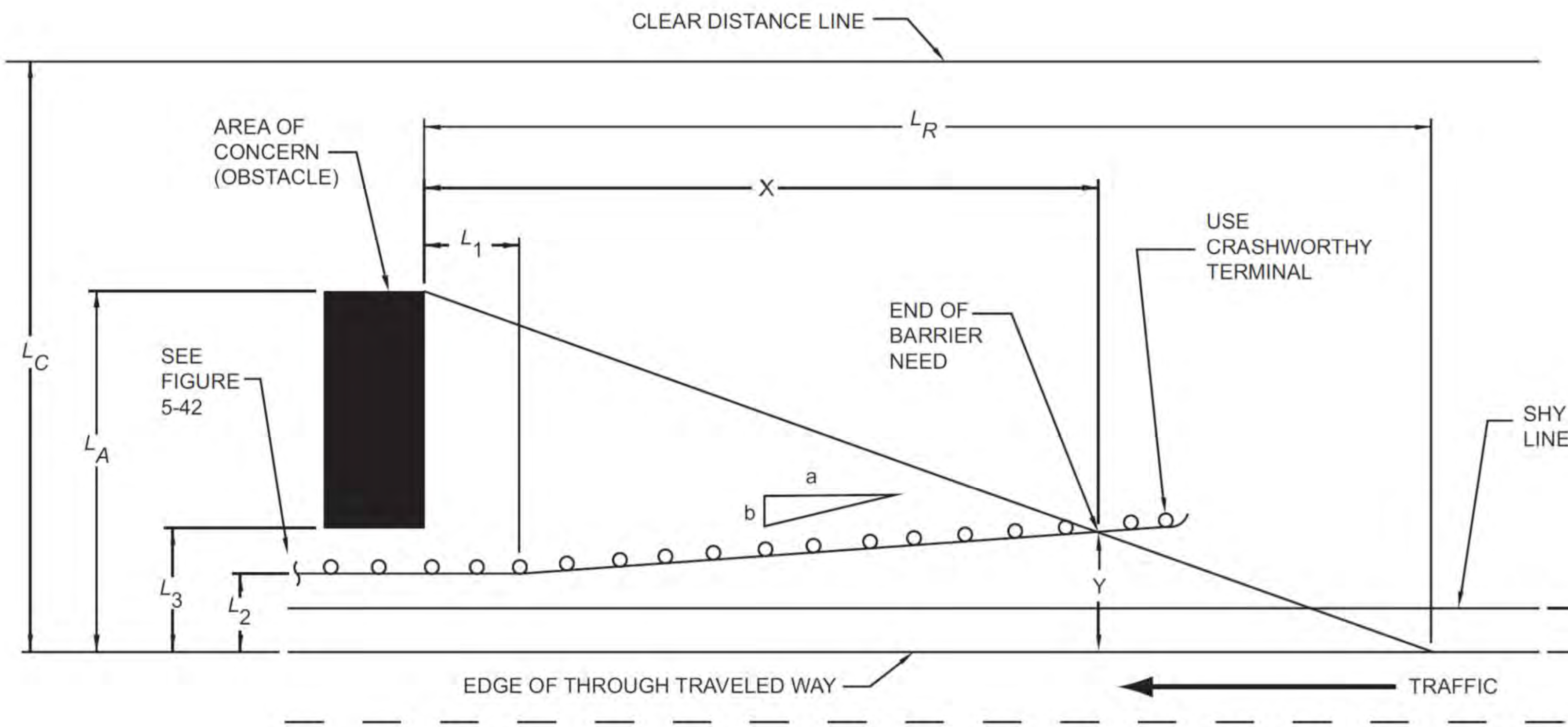
$$X = \frac{L_A + (b/a)(L_1) - L_2}{(b/a) + (L_A/L_R)}$$

  - For <u>parallel</u> guardrail installations:

$$X = \frac{L_A - L_2}{L_A/L_R}$$

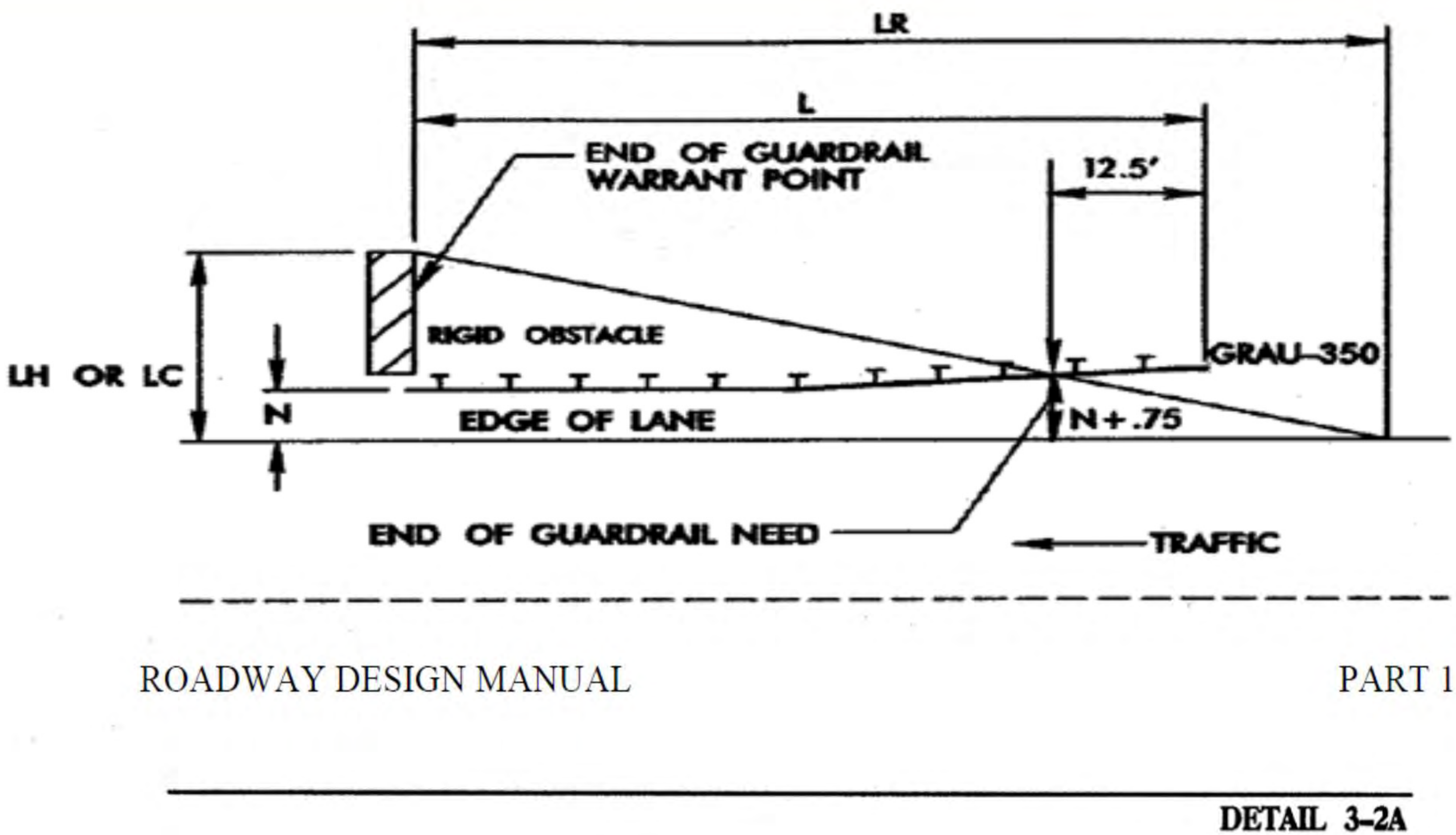
Ref: AASHTO Roadside Design Guide, 4th Edition, Equation 5-1 and 5-2, Pg 5-51

LON Design Procedure for Approach Barrier Layout



Ref: AASHTO Roadside Design Guide, 4th Edition, Figure 5.39, Pg. 5-49

Length of Need – NCDOT



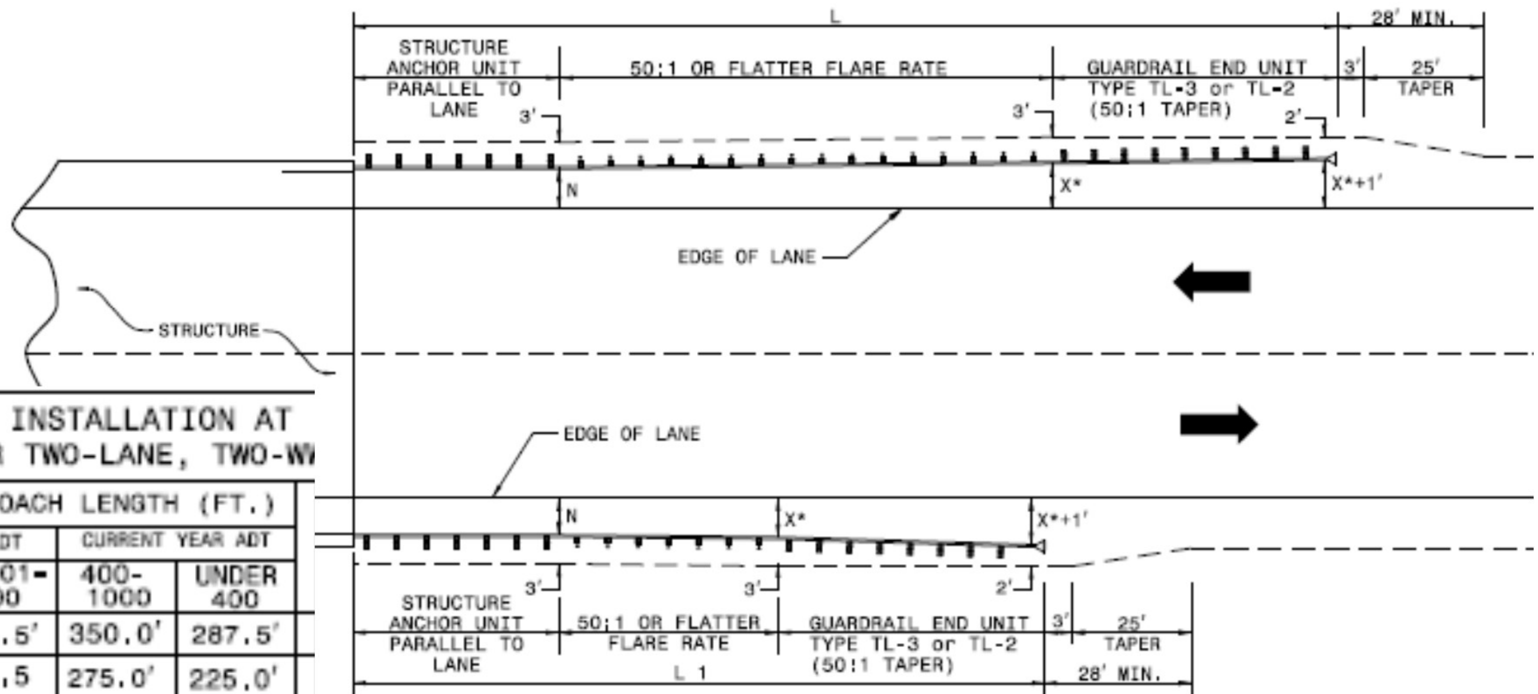
Length of Need – NCDOT

- Calculating the length of need (L) for straight or nearly straight sections of roadway (parallel installation):

$$L = \frac{LH - (N + 0.75)}{LH/LR} \quad \cancel{+ 12.50} \quad + 15'$$

The formulas and details are derived from Chapter 5 in the <u>Roadside Design Guide</u>.

Length of Need for Bridge Approach NCDOT

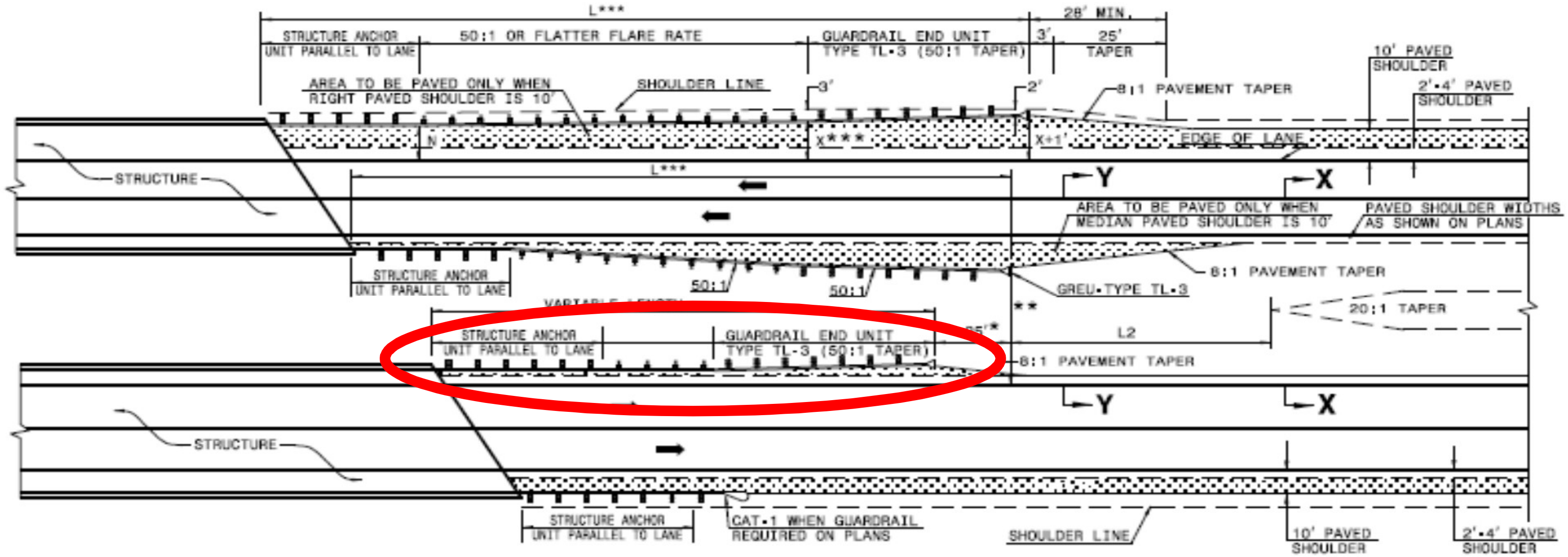


GUARDRAIL INSTALLATION AT
FOR TWO-LANE, TWO-W

DESIGN SPEED (MPH)	"L" APPROACH LENGTH (FT.)			
	DESIGN YEAR ADT		CURRENT YEAR ADT	
	OVER 2000	1001-2000	400-1000	UNDER 400
70	362.5'	362.5'	350.0'	287.5'
60	300.0'	287.5	275.0'	225.0'
50	212.5'	212.5'	200.0'	162.5'
40	175.0'	150.0'	137.5'	112.5'
X *	8'	6'	4'	4'

SHEET 4 OF 11
862.01

Length of Need for Bridge Approach NCDOT – Dual Bridges



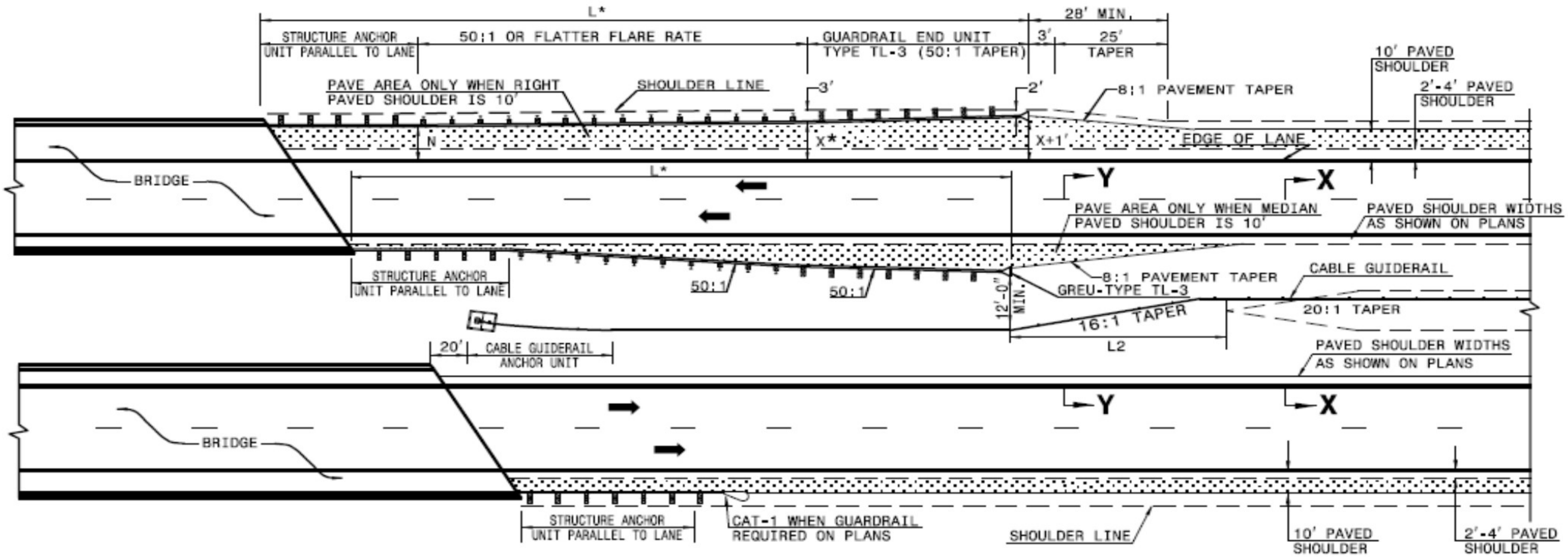
DIMENSIONS FOR LENGTH OF GUARDRAIL APPROACHING DUAL LANE BRIDGES							
MEDIAN WIDTH	-L-***						-L2- DIM.
	70 MPH	60 MPH	50 MPH				
30'	300.0'	250.0'	150.0'				80.0'
36'	300.0'	250.0'	150.0'				60.0'
40' & ABOVE	300.0'	250.0'	150.0'				40.0'

SHEET 3 OF 11

862.01

THE DESIGN LAYOUT FOR LENGTHS SHOWN ON THIS STANDARD ARE MINIMUM DESIGN LENGTHS.

Length of Need for Bridge Approach NCDOT – with Cable Barrier

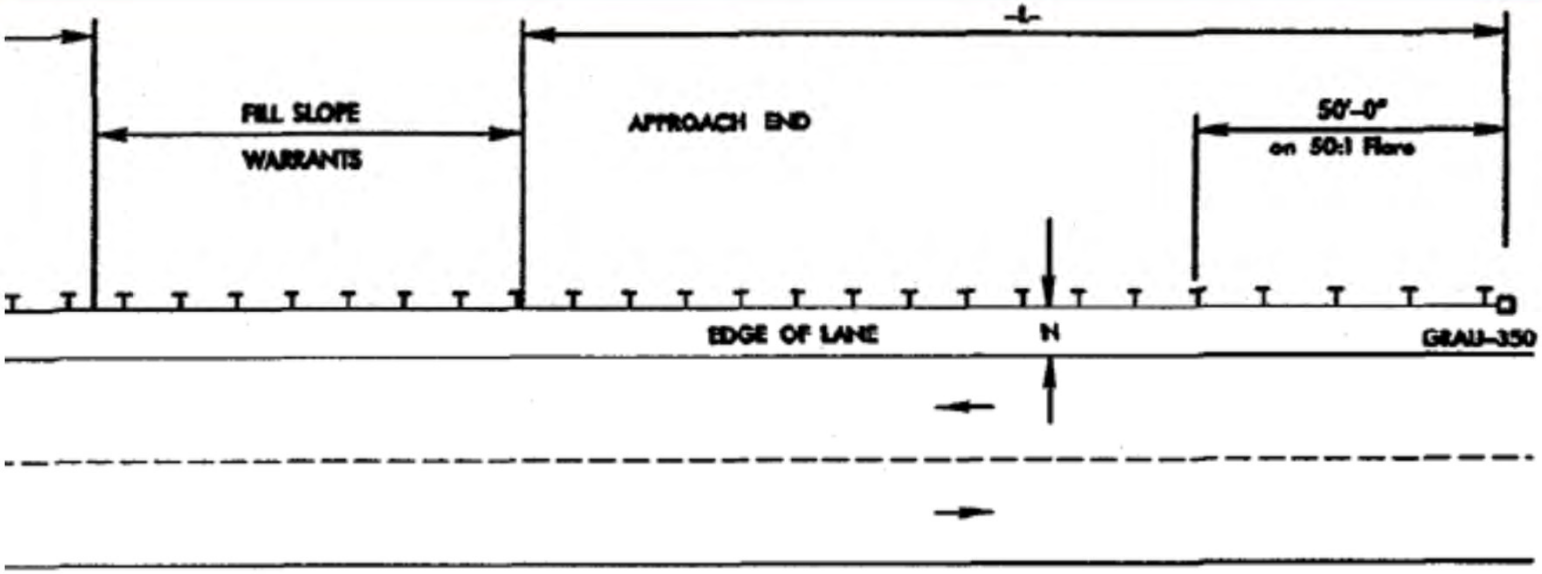


DIMENSIONS FOR LENGTH OF GUARDRAIL APPROACHING DUAL LANE BRIDGES							
MEDIAN WIDTH	-L-*						-L2- DIM.
	70 MPH	60 MPH	50 MPH				
46' & ABOVE	300.0'	250.0'	150.0'				40.0'

SHEET 2 OF 12
865.01

THE DESIGN LAYOUT FOR LENGTHS SHOWN ON THIS STANDARD ARE MINIMUM DESIGN LENGTHS.

Length of Need for Fill Slope NCDOT



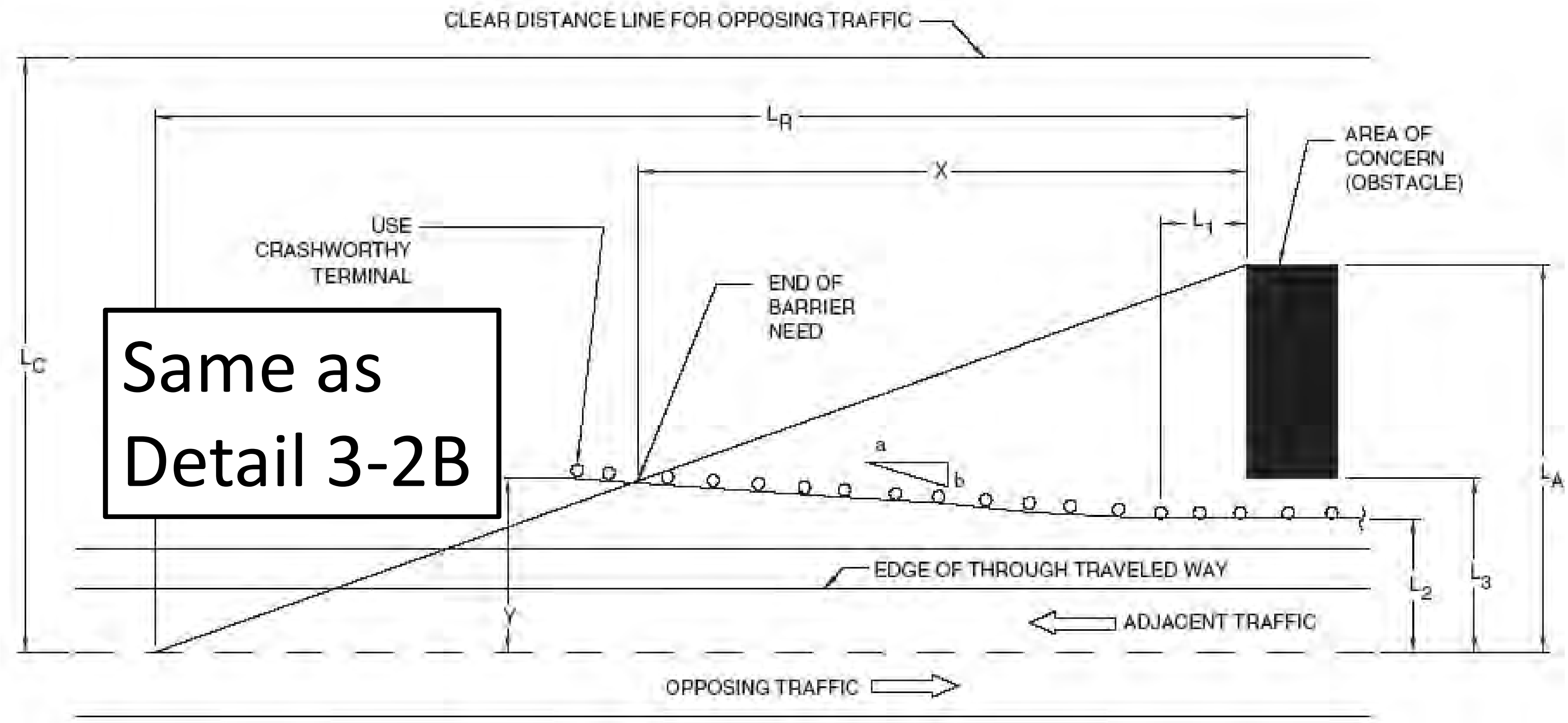
"L" OR LENGTH OF NEED ON THE APPROACH SIDE OF THE GUARDRAIL FOR A FILL SLOPE WARRANT FOR ANY CLASSIFICATION OF ROADWAY

DESIGN SPEED (MPH)	70	60	50	40
*L (FT.)	150'	125'	100'	75'

DETAIL 3 - 2C

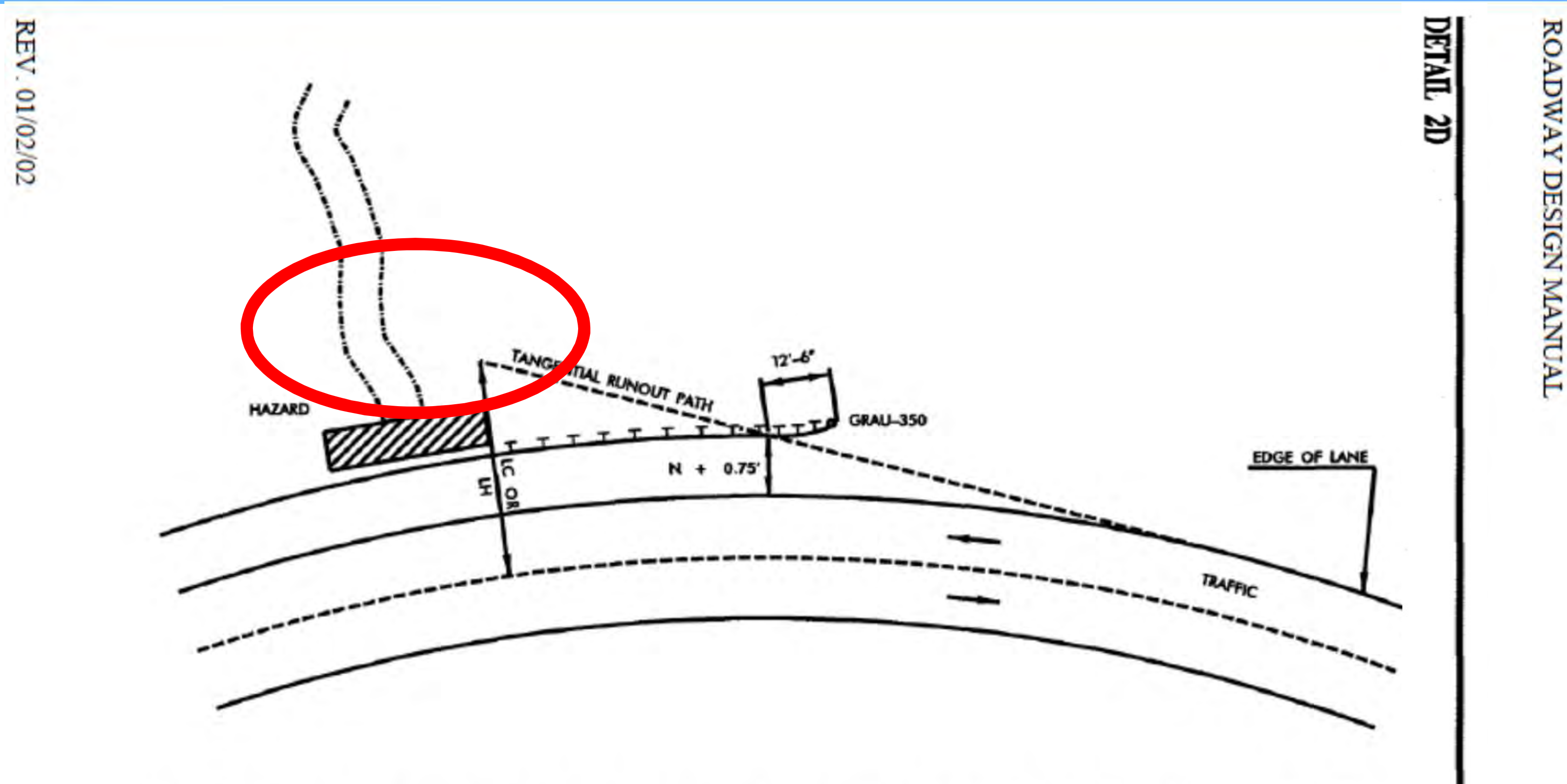
These are quite short compared to AASHTO

LON Design for Opposing Traffic



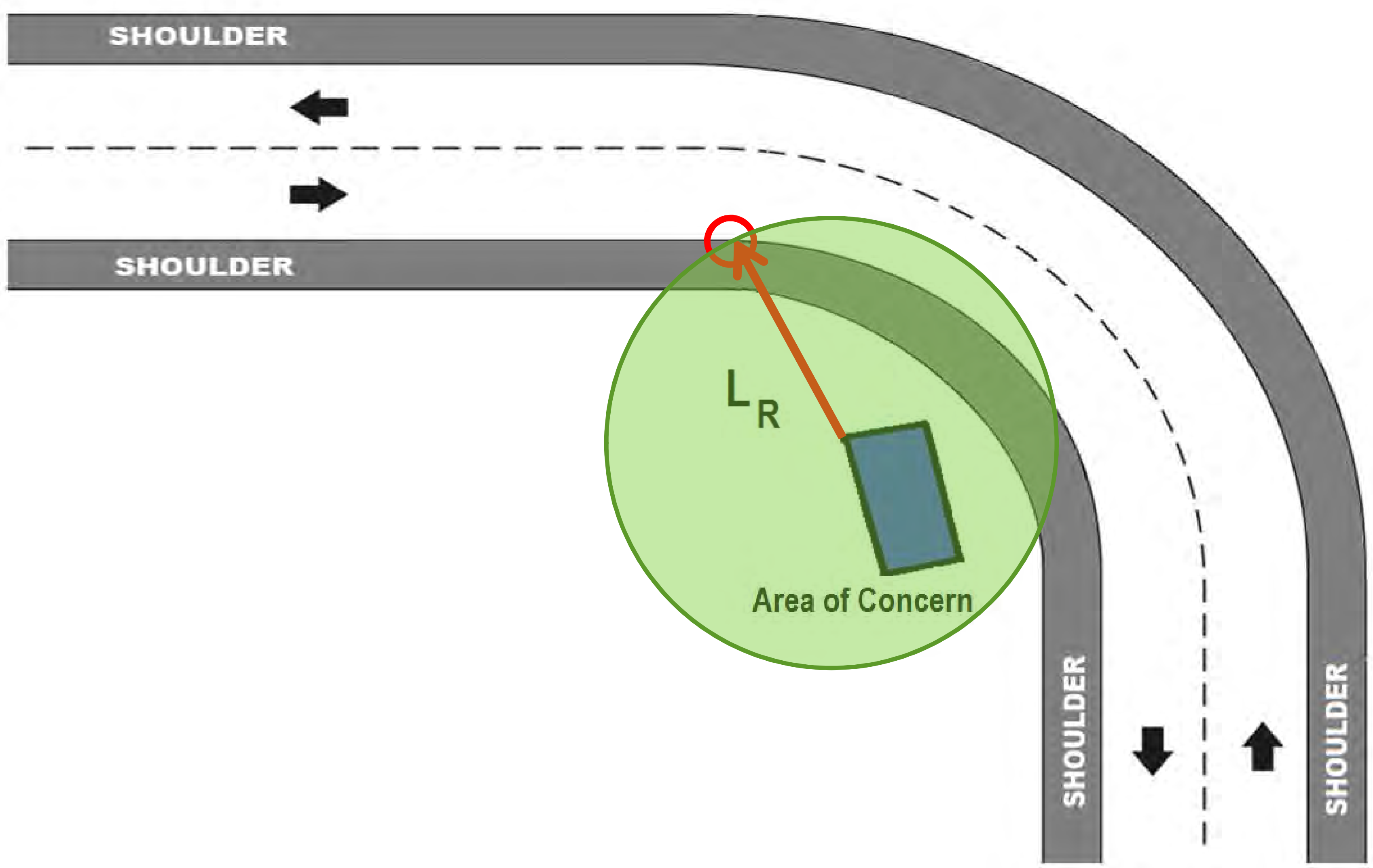
Ref: AASHTO Roadside Design Guide, 4th Edition, Figure 5.42, Pg. 5-54

Length of Need on the Outside of a Horizontal Curve



DETAIL OF GUARDRAIL PLACEMENT ON APPROACH END OF HAZARD LOCATED ON A HORIZONTAL CURVE

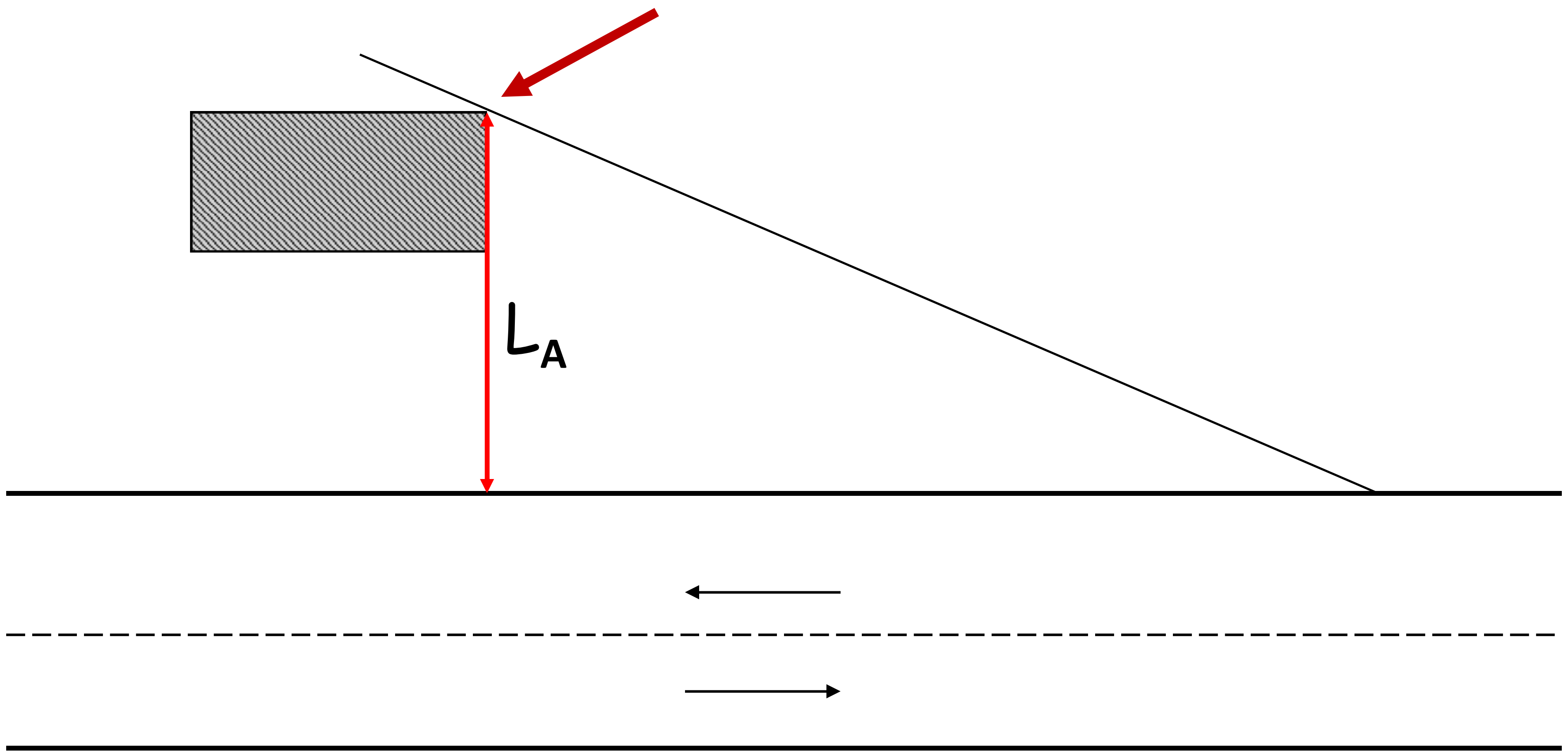
Length of Need on the Inside of a Horizontal Curve



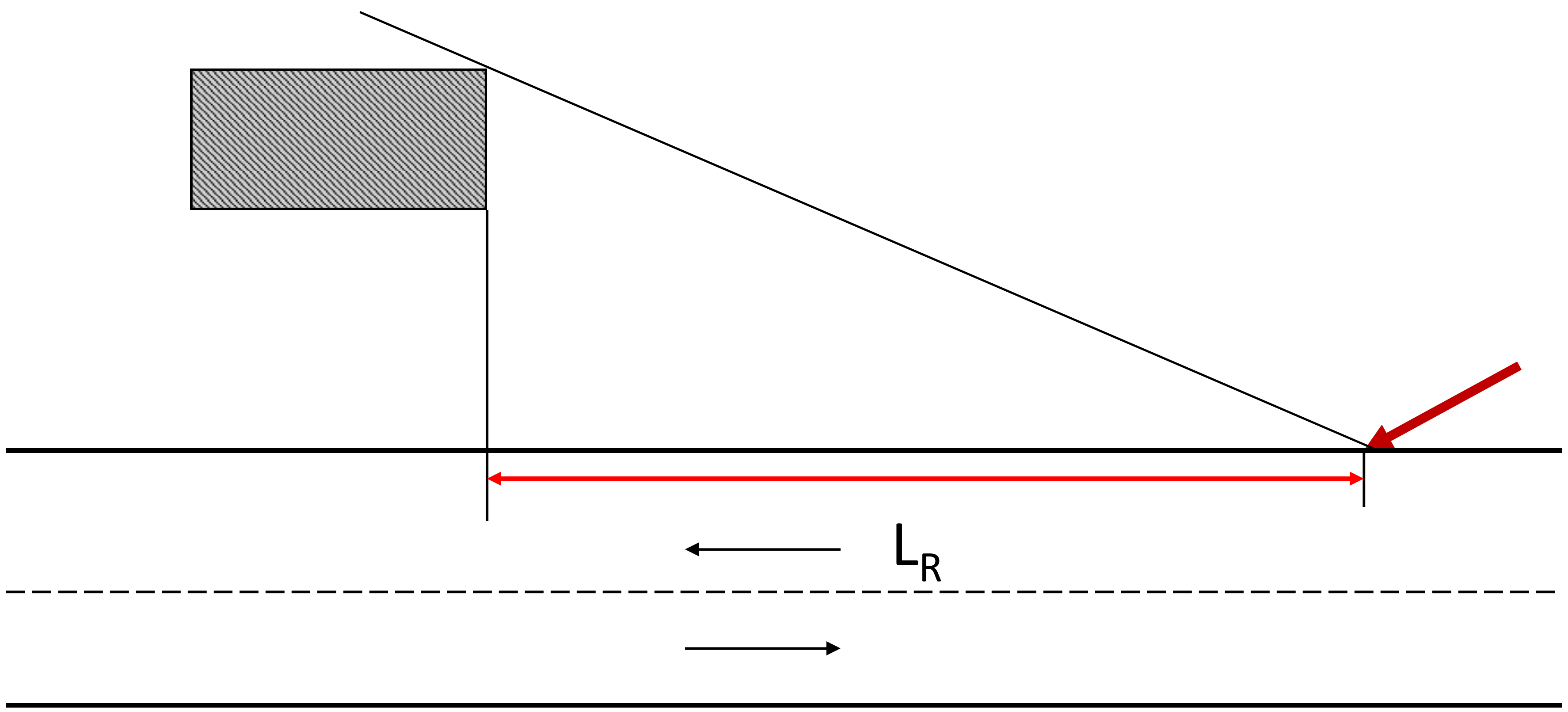
Energy–Absorbing terminal on a curve

Energy-Absorbing terminals must be installed in a straight line over the length of the terminal proper. This may require the barrier to be extended in advance of the curve.

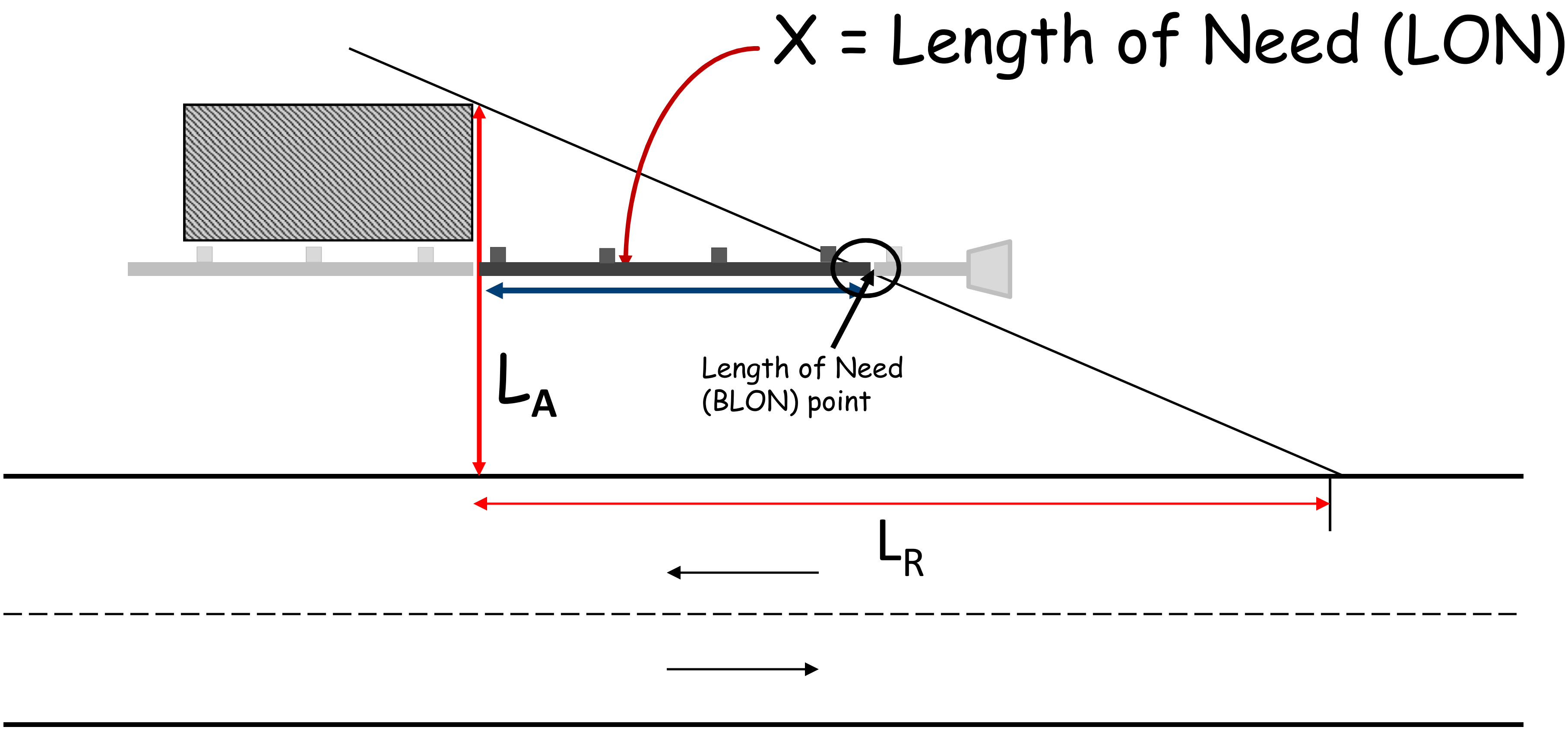
Step 1: Identify the Hazard



Step 2: Define the Point of Departure



Step 3: Intersect the Hypotenuse



Length of Need – Adequate?

Length of Need – Adequate?

Length of Need – Adequate?

Length of Need – Adequate?

Length of Need – Adequate?

PRE-ASSESSMENT PHOTO

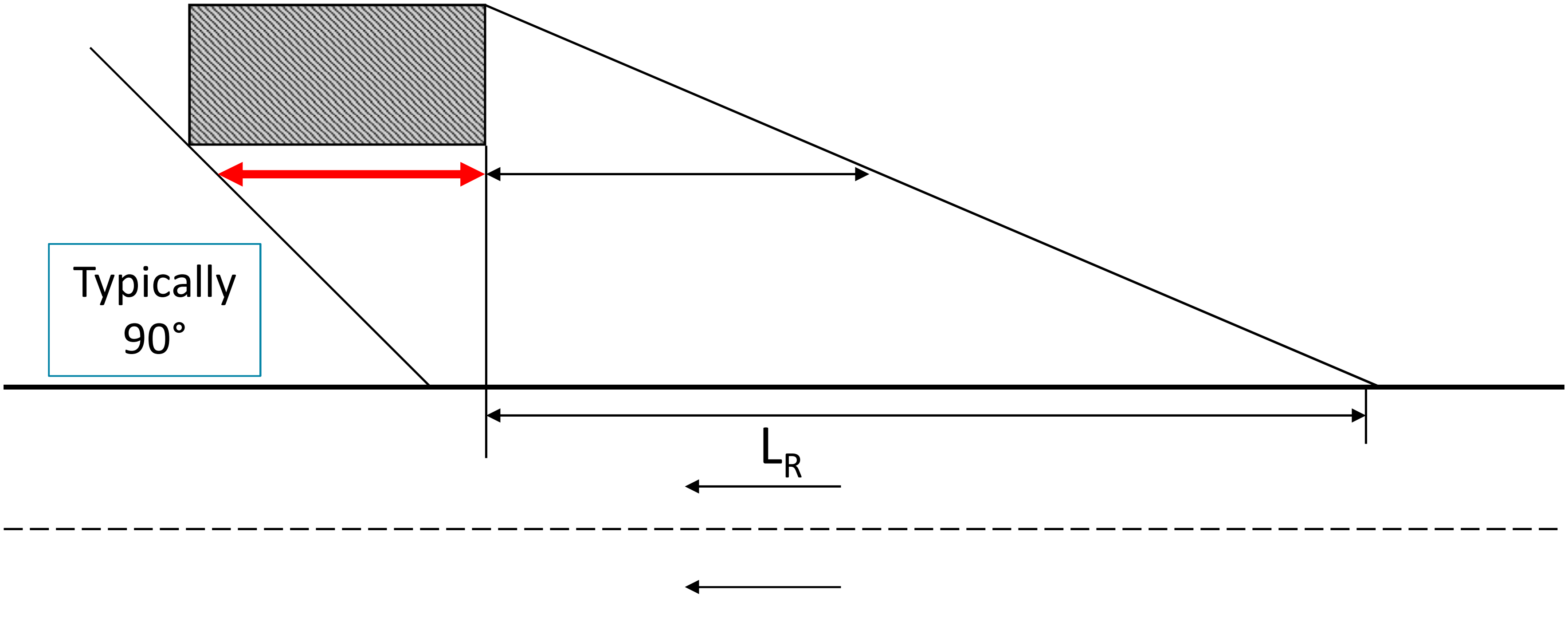
Length of Need – Adequate?

Quick Field Check of LON

1. Stand on roadway edgeline opposite the upstream edge of the hazard.
2. Pace upstream along edgeline appropriate runout length (based on speed of roadway and traffic volume).
3. Turn and look at far lateral edge of hazard.
4. If planned (or existing) guardrail run intercepts this line of sight, it satisfies basic design length of need.
5. Check for ALL hazards that should be shielded in this area
6. Check for better terminal location by extending barrier a short distance (especially on curves!!!)

Downstream Termination One Direction Traffic

An anchor (CAT-1) plus some length of rail (?) must be ADDED at the end



Guardrail Placement

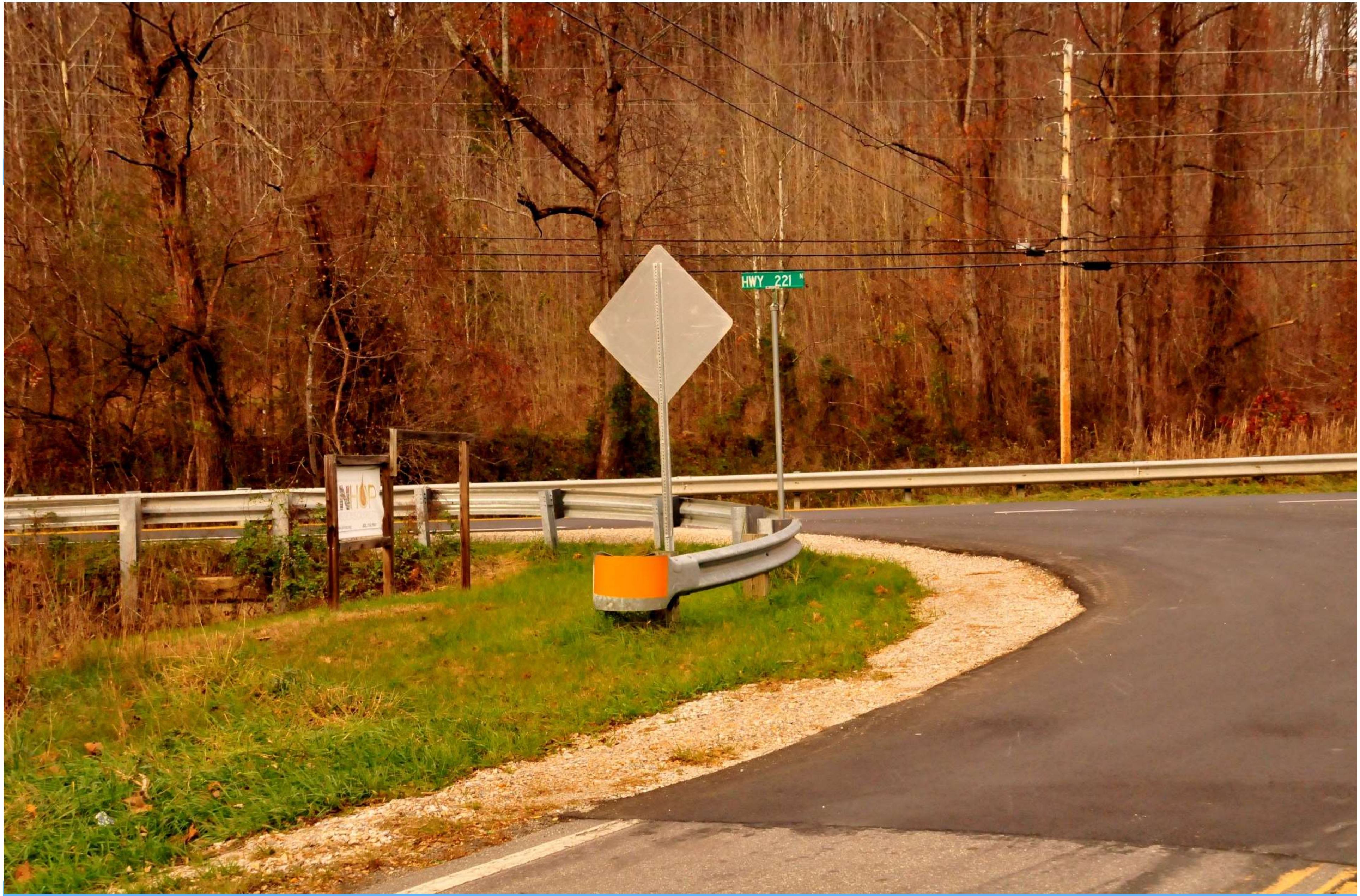
Place as far from traffic as practical

(without affecting performance)

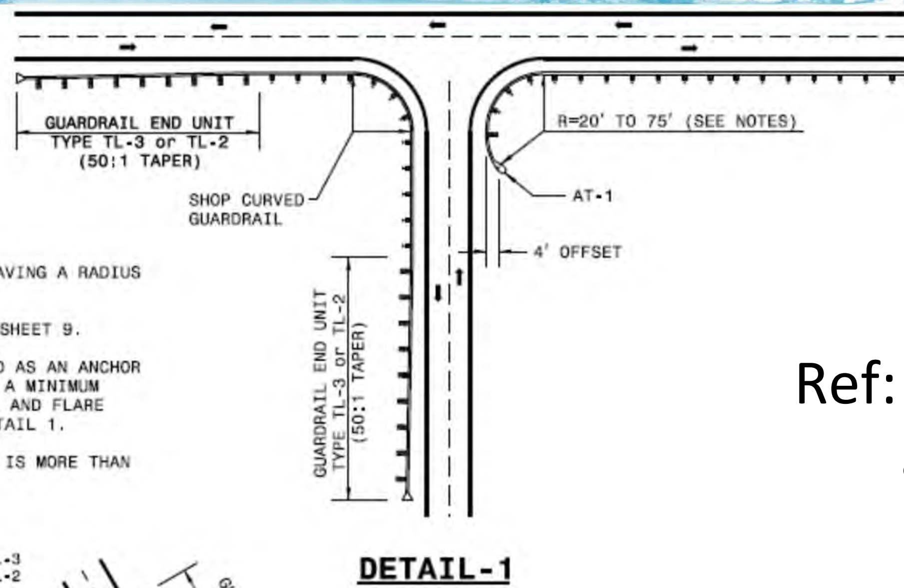
Guardrail Placement in Special Situations

- Turnout Conflict (Side Access)
- Long Span (Omitted Post{s})
- Gaps between runs of barrier
- Extra Blocks
- Leaveouts (Blockouts) for Posts in Structural Pavement
- Guardrail Post in Rock

Guardrail Placement at Intersections


HWY 221 N

Guardrail Placement at Intersections



NOTES:

SHOP CURVED GUARDRAIL IS DEFINED AS HAVING A RADIUS OF 150' OR LESS.

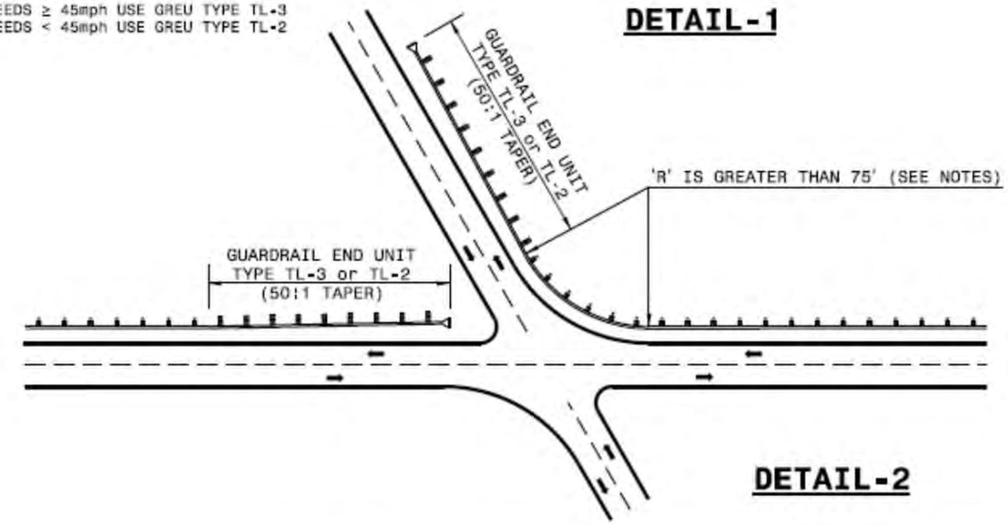
WHEN RADIUS IS LESS THAN 20' REFER TO SHEET 9.

WHENEVER SHOP CURVED GUARDRAIL IS USED AS AN ANCHOR AND THE RADIUS IS FROM 20' TO 75', USE A MINIMUM LENGTH OF 50' OF SHOP CURVED GUARDRAIL AND FLARE WITH AN AT-1 ANCHOR UNIT. REFER TO DETAIL 1.

WHENEVER SHOP CURVED GUARDRAIL RADIUS IS MORE THAN 75', REFER TO DETAIL 2.

MAINTAIN CLEAR SIGHT DISTANCE.

FOR POSTED SPEEDS ≥ 45mph USE GREU TYPE TL-3
FOR POSTED SPEEDS < 45mph USE GREU TYPE TL-2

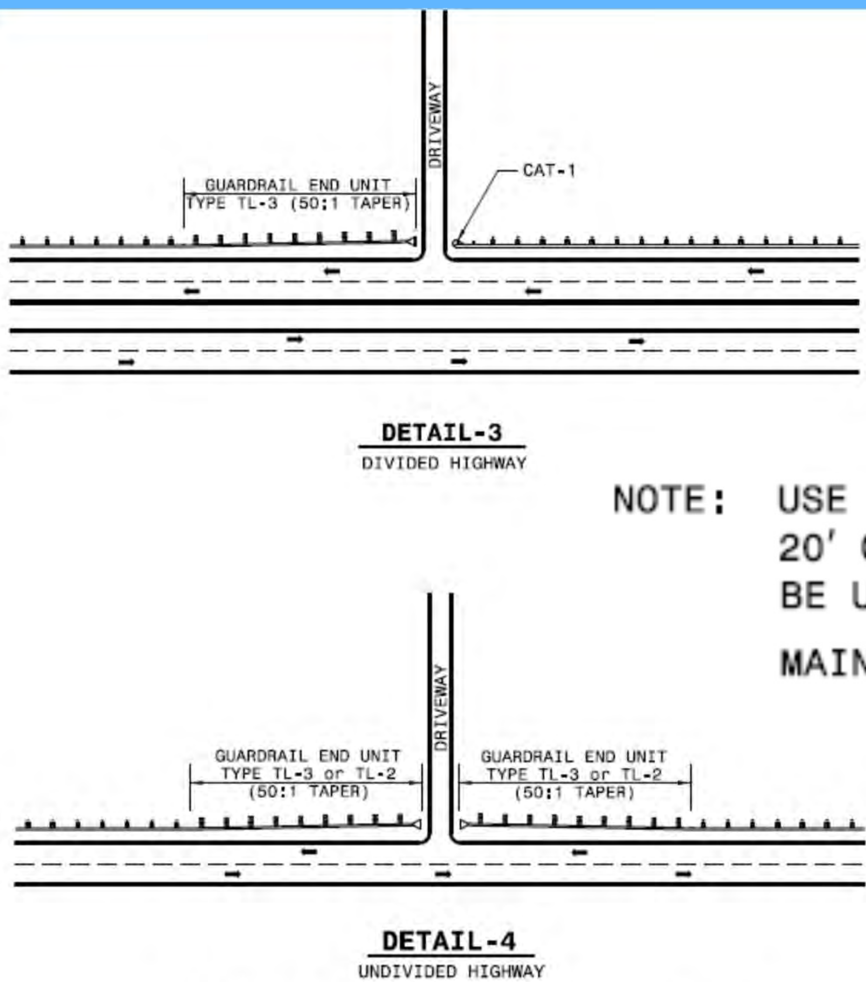


GUARDRAIL TREATMENT AT INTERSECTIONS

Ref: NCDOT Standard 862.01, Sht 8

PRE-ASSESSMENT PHOTO

Guardrail Placement at Driveways



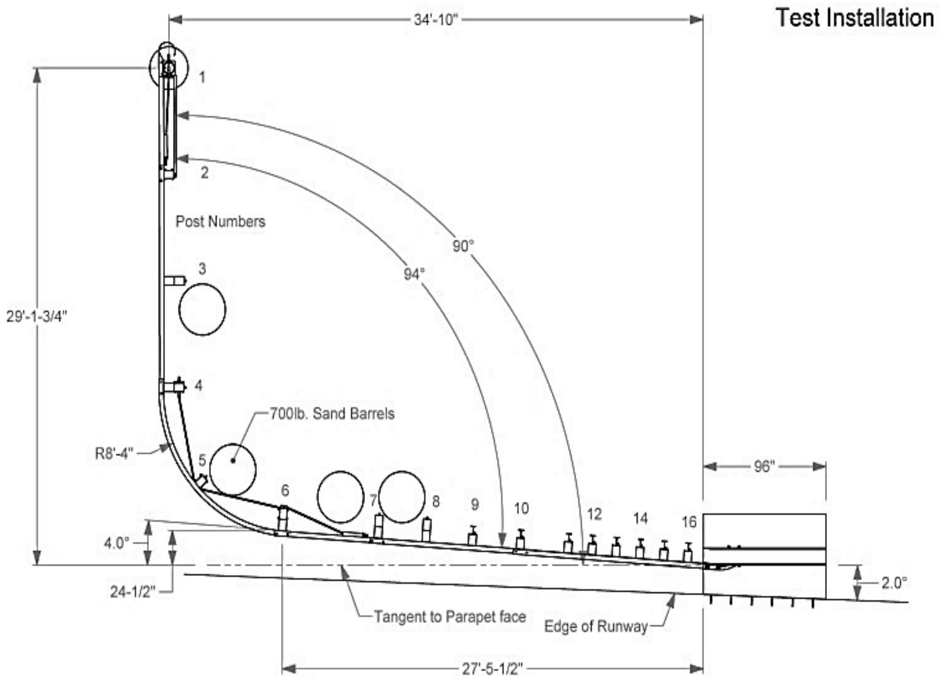
NOTE: USE DETAIL 3 & 4 WHENEVER 20′ OR LARGER RADIUS CANNOT BE UTILIZED.

MAINTAIN CLEAR SIGHT DISTANCE.

GUARDRAIL TREATMENT AT DRIVEWAYS

Ref: NCDOT Standard 862.01, Sht 9

TxDOT MASH TL-3 Short Radius



On-going Research by Pool Fund – No Eligibility Letter

TxDOT MASH TL-3 Short Radius

NCDOT Investigating further developments

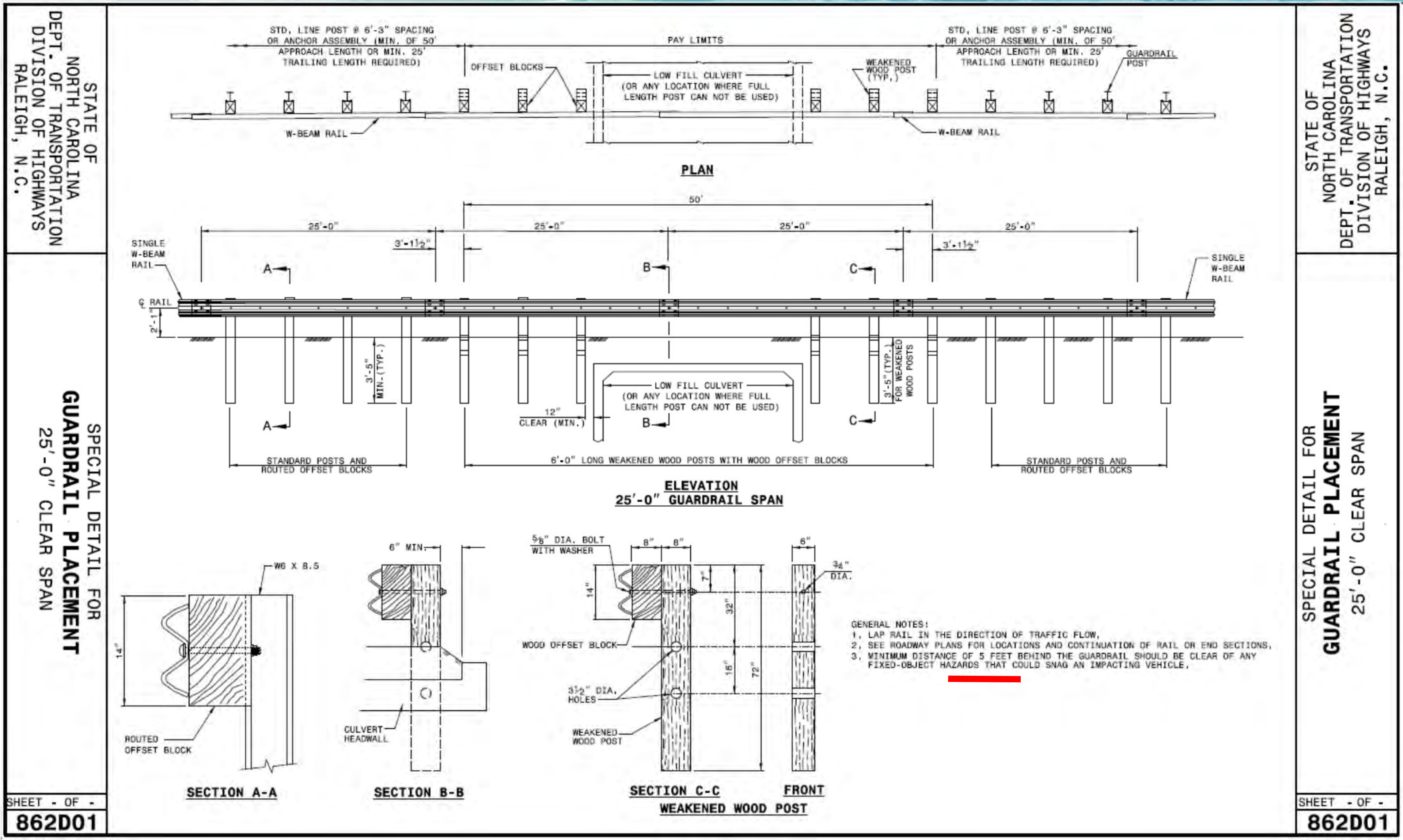
MASH TL-3 Short Radius - NCHRP

Omitting posts – old 29” guardrail

31” – Omitting 3 posts

Working Width – 94”
Eligibility Letter B-189

31" – Omitting 3 posts



Openings in Barriers

Check with maintenance, ROW, etc

Openings in Barriers - NCDOT

ROADWAY DESIGN MANUAL PART 1

DETERMINING GUARDRAIL LENGTHS OF NEED 3-2

NOTE: A space of less than 300' should not be left between guardrail installations. If less than 300' remains between installations, the guardrail should be extended through the area.

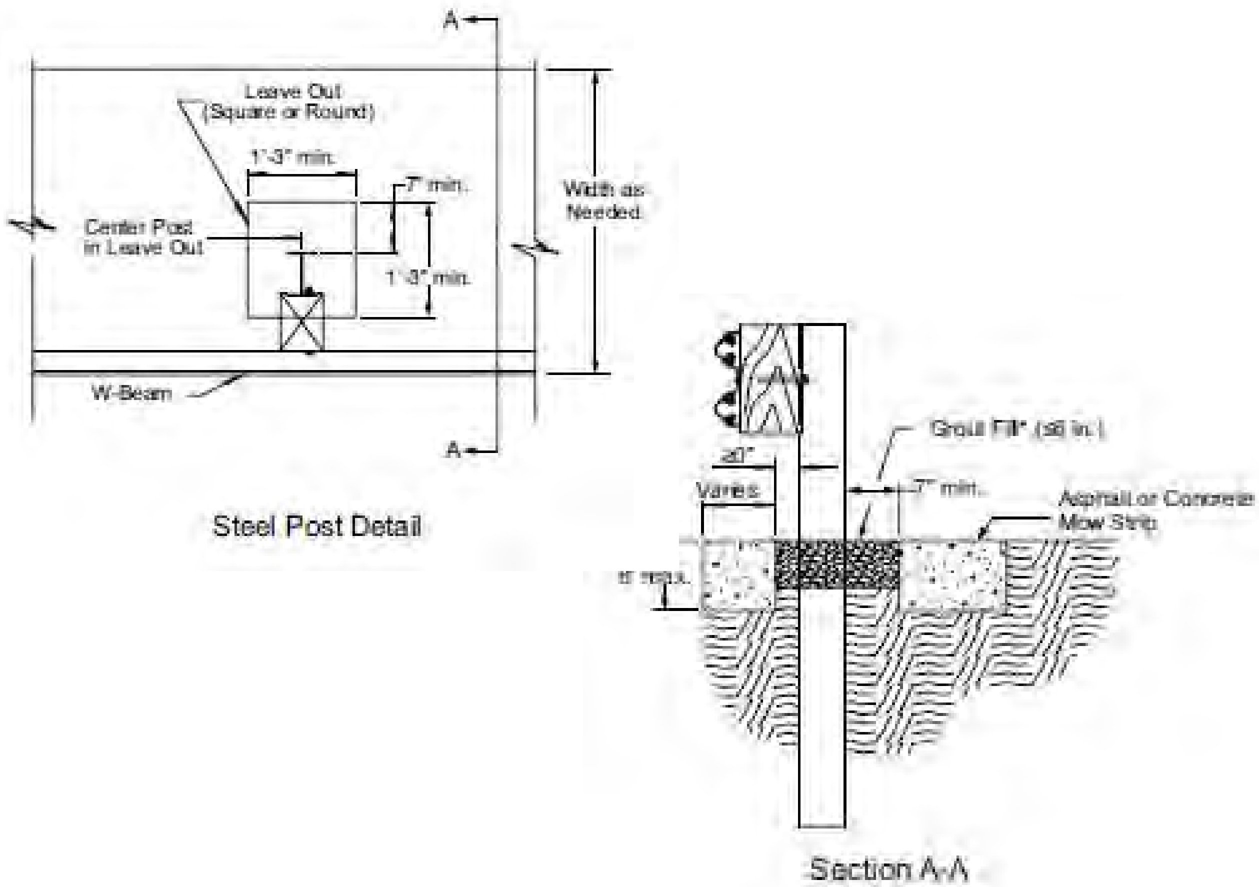
Again, be sure there are no conditions that would preclude closure

Extra Blocks – National Guidance

- Two block-outs (up to 16" deep) may be used at any time, for any number of posts.
- Three block-outs may be used at one or two posts in a section of guardrail.

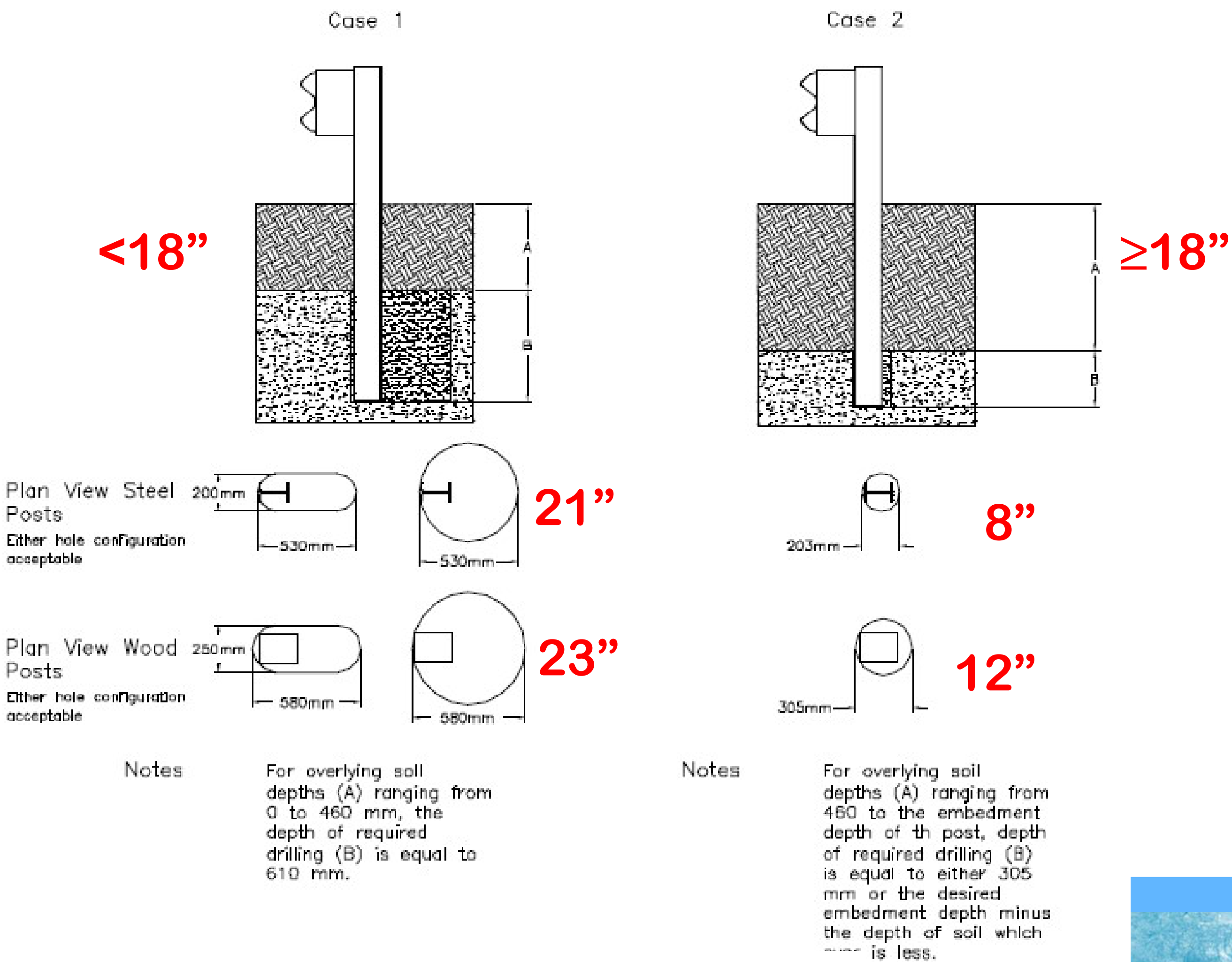
Ref: AASHTO Roadside Design Guide – 3rd Edition, Section 5.4.1.6

Leaveouts in Structural Pavement



Ref: AASHTO Roadside Design Guide – 4th Edition, Figure 5-52

Guardrail Posts in Rock AASHTO



Eligibility Letter B-64B

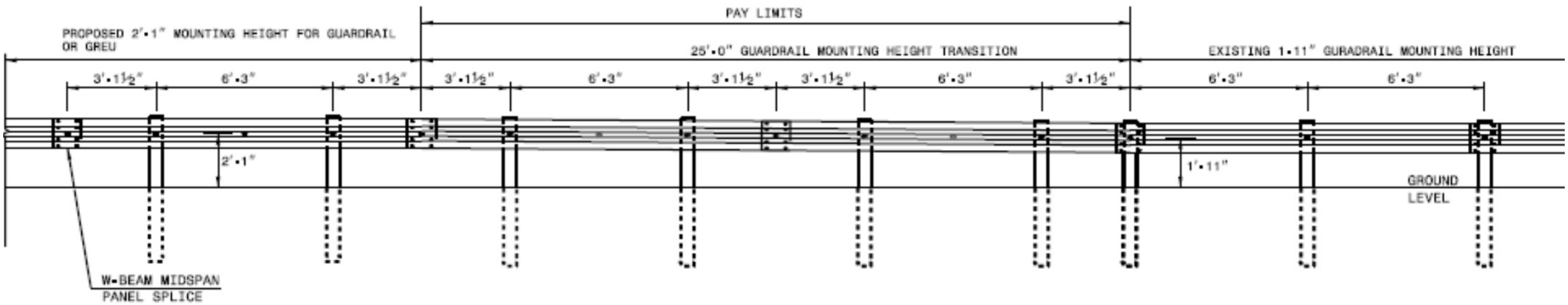
Guardrail Posts in Rock - NCDOT

SECTION 862
GUARDRAIL

862-3 CONSTRUCTION METHODS

Where rock interferes with the proper installation of the post, excavate a shaft in the rock at least 9 inches wide, parallel to the roadway, by 23 inches long, perpendicular to the roadway and 24 inches deep. Place the post against the roadside edge of the shaft and fill in behind the post with Class VI select material, up to the top elevation of the rock. Fill the remainder of

Height Transition – 31" to/from Old Guardrail



ELEVATION VIEW

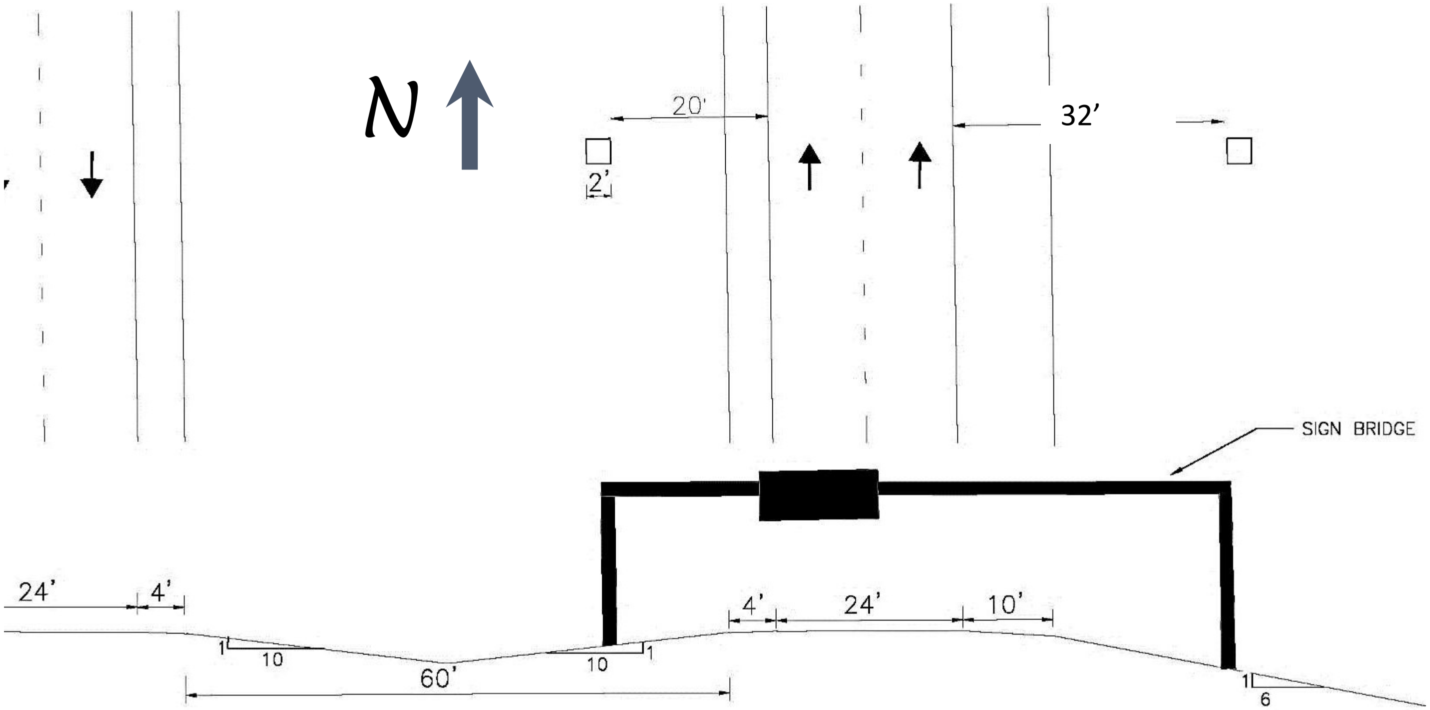
TRANSITION FROM OR 1′-11″ TO 2′-1″ W-BEAM GUARDRAIL MOUNTING HEIGHT

862.02 SHEET 4 OF 8

ROADWAY STANDARD DRAWING FOR
GUARDRAIL INSTALLATION

1-18
STATE OF
NORTH CAROLINA
DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS
RALEIGH, N.C.

Example – LON



Design speed: 70 mph

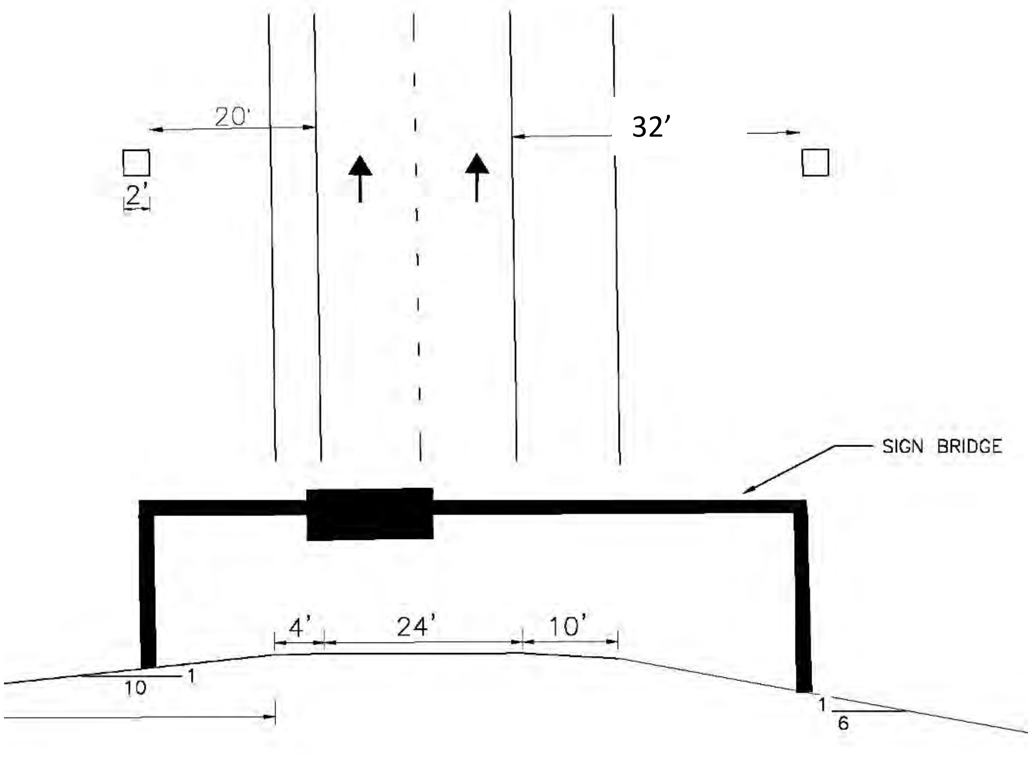
ADT: 53,000

Side slope:

10:1 Left, 6:1 Right

DETERMINE TREATMENTS FOR NB TRAFFIC

Example – LON



Determine Design Clear Zone

The Clear Zone is a look up value from NCDOT Design Manual

Design speed: 70 mph

ADT: 53,000

Side slope: 10:1 or 6:1

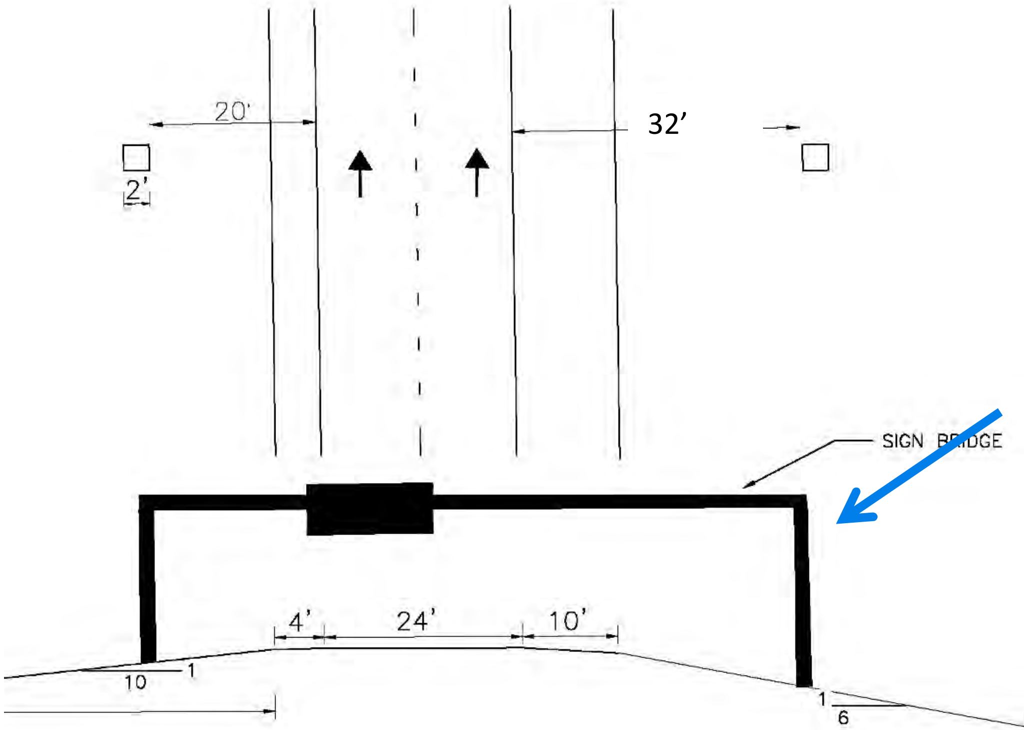
Design Clear Zone Distance – Fill

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

Design Speed 70 mph
AADT = 53,000

LC = 32 ft.

Example – LON

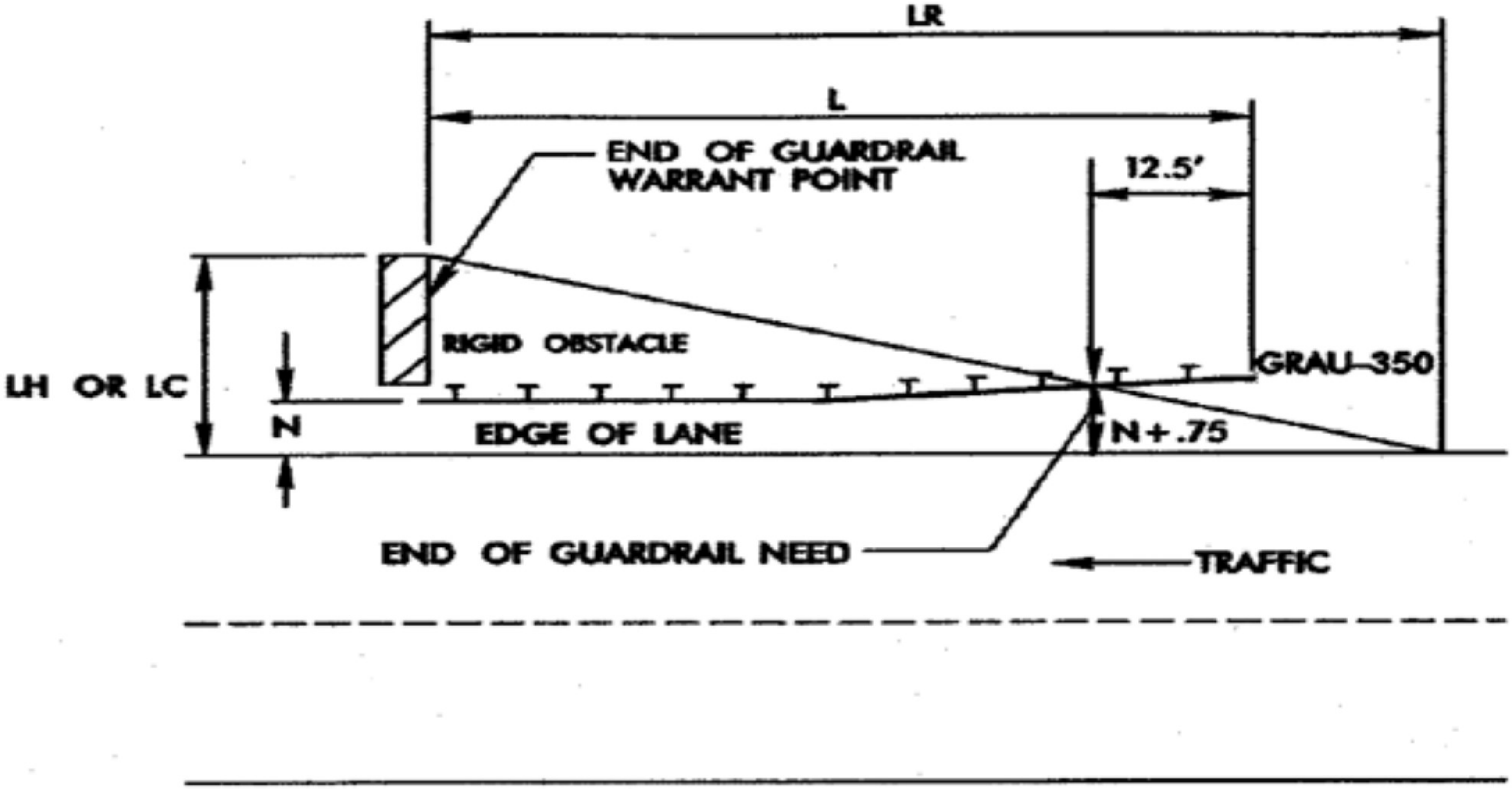


Identify ALL the hazards

NOT SHIELDED

Sign supports – both sides

Calculating the Length of Need (L)

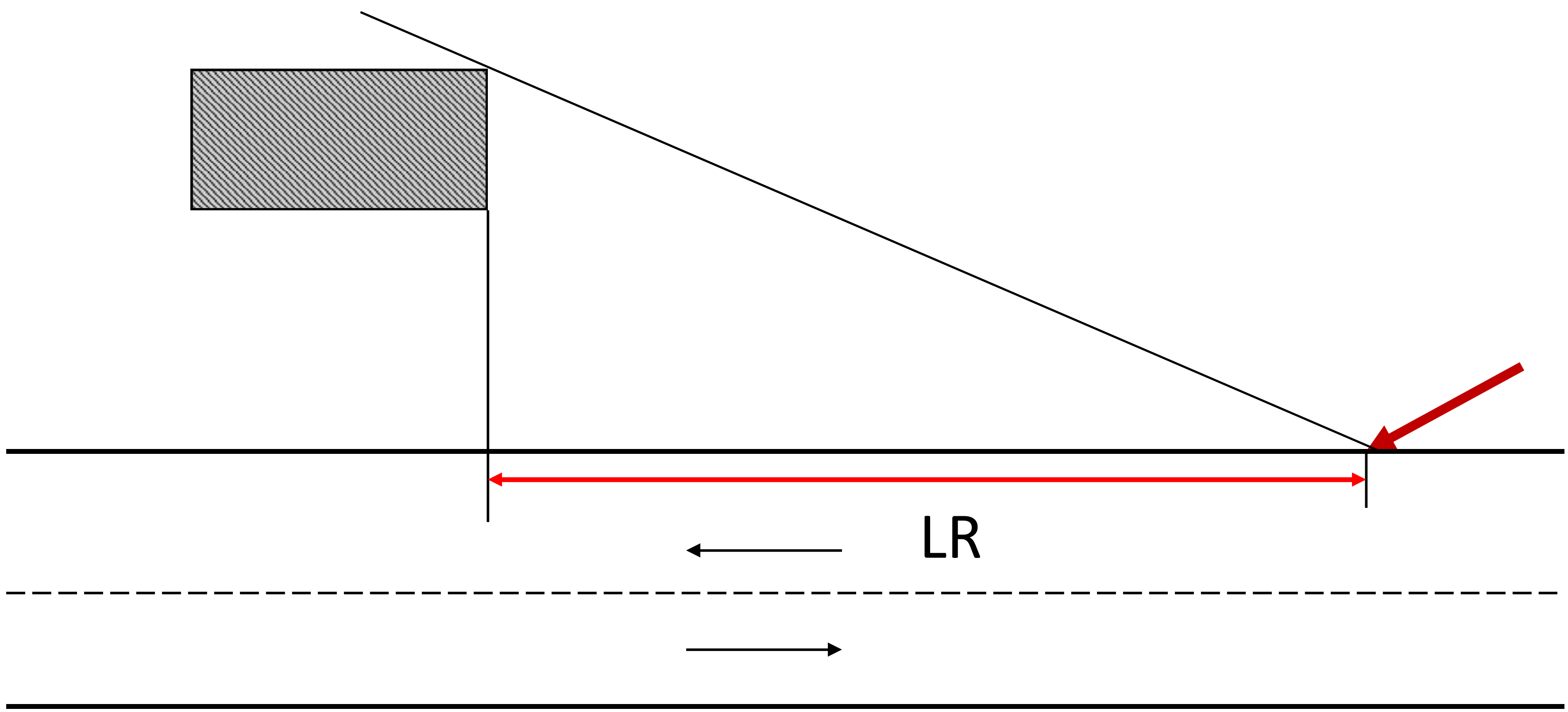


Length of Need – NCDOT

- Calculating the length of need (L) for straight or nearly straight sections of roadway for parallel installation:

$$L = \frac{LH - (N + 0.75)}{LH/LR} + 15$$

Step 2: Define the Point of Departure



Look up LR:

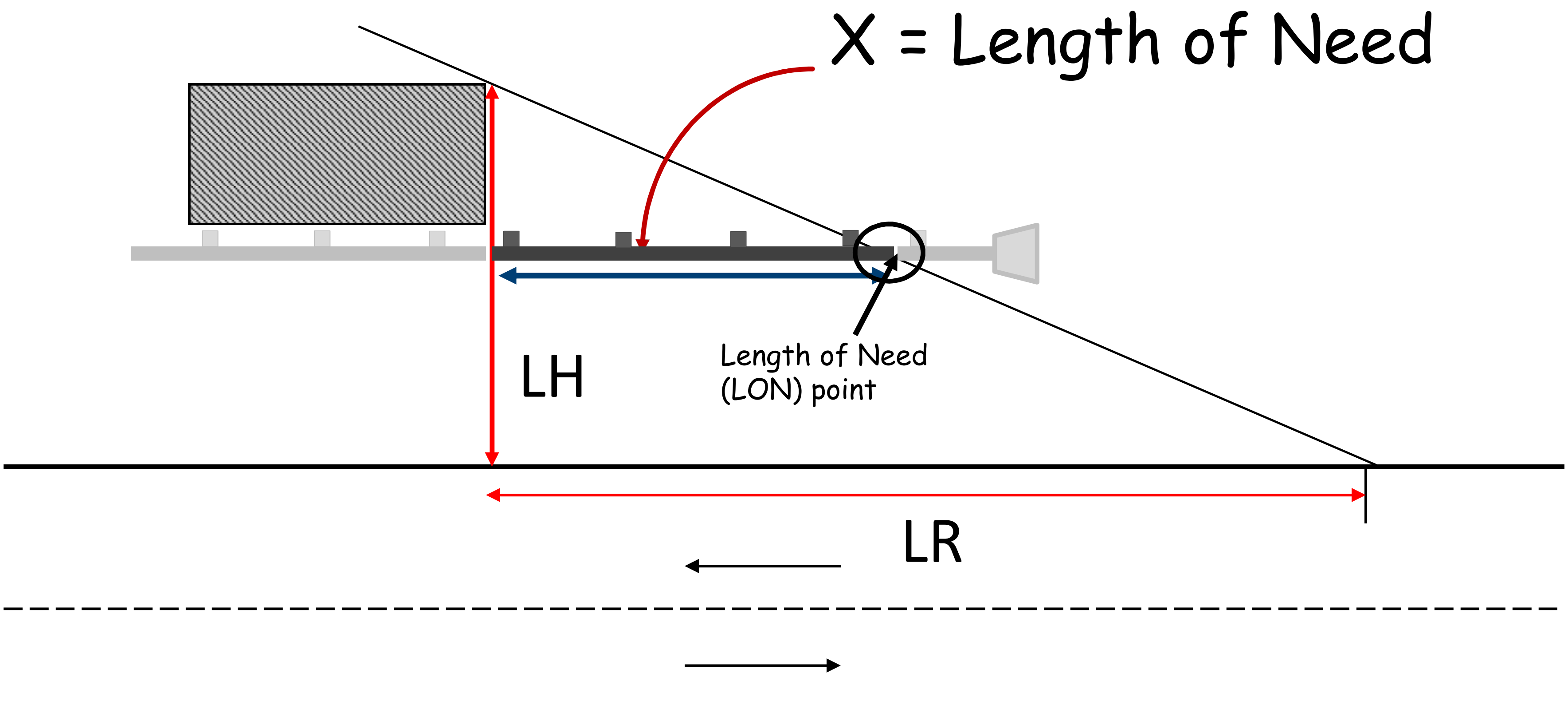
Design Speed 70 mph
AADT = 53,000

Design Speed (mph)	Runout Length (L_R) Given Traffic Volume (ADT) (ft)			
	Over 10,000	5,000 to 10,000	1,000 to 5,000	Under 1,000
80	470	430	380	330
70	360	330	290	250
60	300	250	210	200
50	230	190	160	150
40	160		110	100
30	110	90	80	70

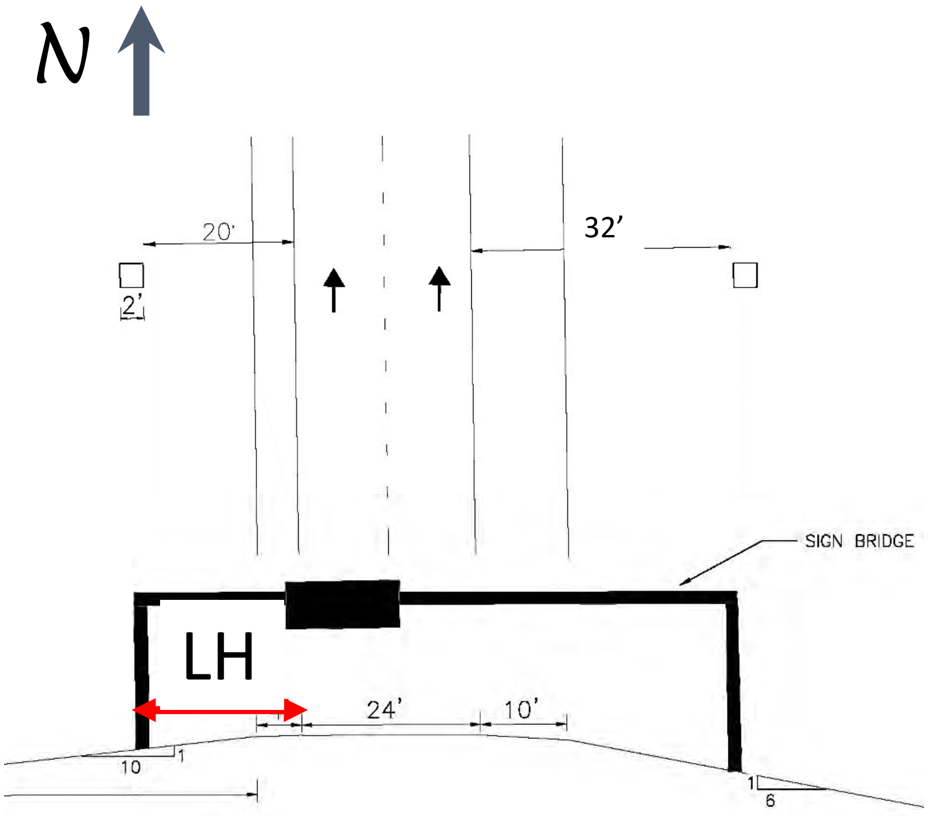
LR = 360 ft.

AASHTO Runout Lengths – LR

Step 3: Intersect the Hypotenuse



Example – LON

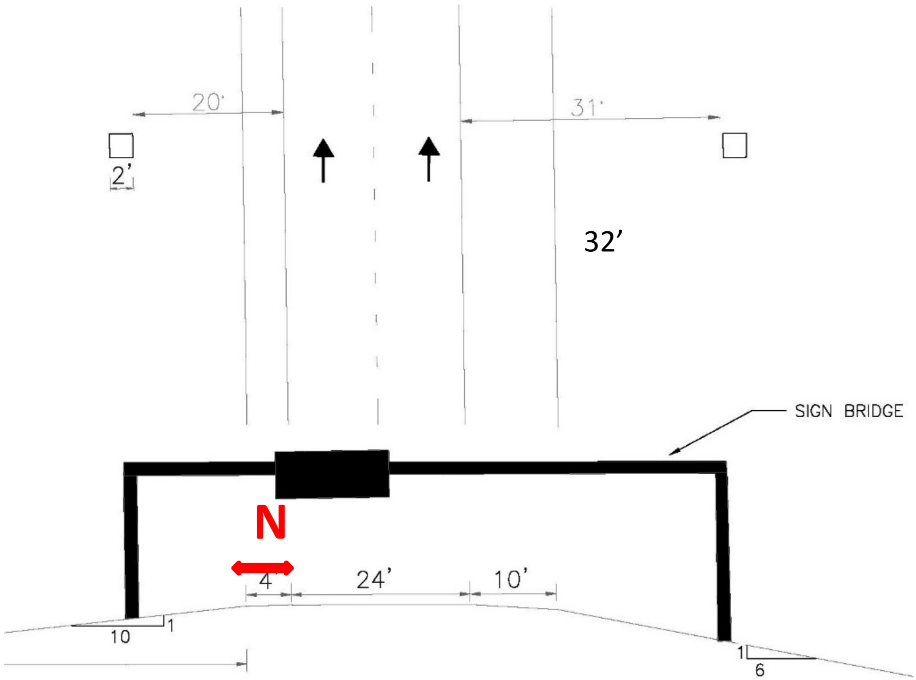


Determine LH – distance to the backside of hazard

For the back of the sign support:

LH = 20 + 2 = 22'

Find N



N – Guardrail offset from edge of travel lane.

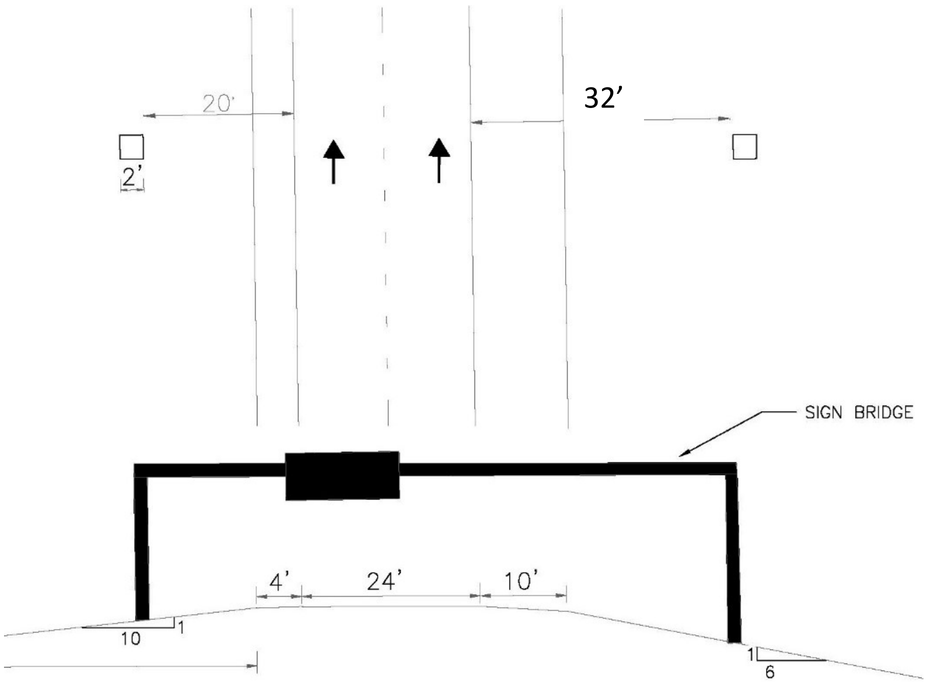
N = 6 ft.

N = The distance from the edge of the travel lane to the face of the guardrail.

N = Minimum shoulder width for locals and collectors.

N = Usable shoulder width plus 2' for arterials, interstates and freeways.

Calculate LON – Determine Bid Item



LH = 22 ft   N = 6 ft   LR = 360

Using the formula L =

$$L = \frac{LH - (N + 0.75)}{LH/LR} + 15$$

$$= \frac{22 - (6 + .75)}{22/360} + 15$$

$$= 249.6 + 15 = 265 \text{ ft.}$$

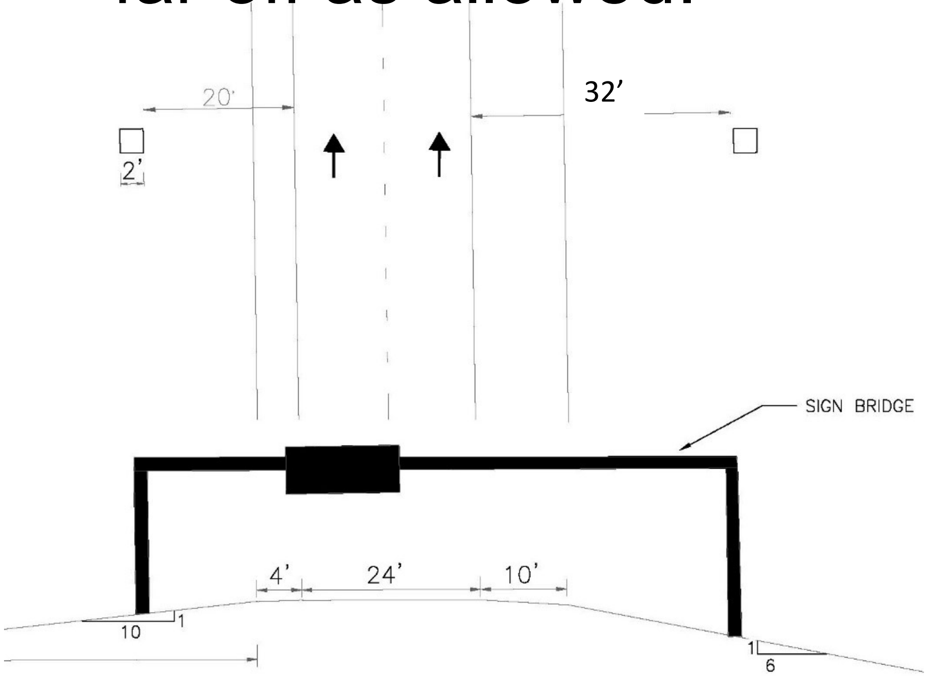
Need Terminal: GREU (50' length of unit))

Therefore 265 – 50 = 215 LF of standard barrier is required; add 2' for length of hazard; add 25' for CAT-1 effectiveness; convert to panel lengths by dividing by 12.5, rounding up to whole number, and multiplying by 12.5

A CAT-1 must be added

Calculate LON – Additional Offset

If guardrail is placed as far off as allowed:



LH = 22 ft   N = (20'-5.5') =14.5'   LR = 360'

Using the formula L =

$$L = \frac{LH - (N + 0.75)}{LH/LR} + 15$$

$$= \frac{22 - (14.5+.75)}{22/360} + 15$$

$$= 110.5 + 15 = 126 \text{ ft.}$$

A CAT-1 must be added

BIG savings by offsetting the barrier: 126' VS 265'

Review Learning Outcomes

- Define the Length of Need and apply the design principles for an optimal installation
- Modify guardrail for special situations