

GUARDRAIL REPORT

Plat of Tolt River Terrace 3660 Tolt Avenue Carnation, WA 98014

City File No. TBD

Prepared for: MainVue WA, LLC 121 3rd Avenue Kirkland, WA 98033

December 3, 2021 Revised: June 14, 2023

Our Job No. 18057



APPENDICES

Appendix A – Relevant Pages from the Tolt River Terrace Civil Plans

Appendix B – Relevant Pages from the WSDOT Design Manual

Appendix C – Impact Attenuator Selection

Overview

The Plat of Tolt River Terrace project is a proposed residential development consisting of 84 single-family homes and 56 units mixed between duplex and townhomes located on a 33.8-acre site. The site contains three existing tax parcels: 212507-9035, 212507-9062, and 212507-9063. The site is located within a portion of the northeast quarter, the northwest quarter, the southeast quarter, and the southwest quarter of the northeast quarter of Section 21, Township 25 North, Range 7 East, Willamette Meridian. Specifically, the site is located at 3660 Tolt Avenue in the City of Carnation, Washington. The project will clear, grade, and construct roads, utility extensions, features, and eventually single-family and multi-family residences on the lots.

The site is polygonal in shape and is located to the immediate north of the Tolt River. The western edge of the site is Tolt Avenue, with the Tolt River Trail and Snoqualmie Valley Trail bordering the eastern edge. Immediately north of the site is Tolt Middle School. In the existing condition, the sites two most western parcels have been cleared and developed into an industrial storage yard. The eastern most parcel has also been largely cleared and was being used as an industrial maintenance and fabrication yard for concrete structures with two existing gantry cranes and a large warehouse with it's associated out buildings.

There are fourteen Tracts on site, named A through N. There are two tracts that have alleys that are adjacent to retaining walls that match to existing grade.

On the east side of Tolt Avenue, a pedestrian bridge is proposed over the existing pond to construct a sidewalk along the frontage road.

Tolt Avenue Pedestrian Bridge

As part of the frontage road requirements, a pedestrian bridge will be constructed over the existing pond to connect the 12' sidewalk. The existing pond currently serves as a detention pond but will be abandoned following construction. The pedestrian bridge will span an existing 60" culvert that discharges to the west side of Tolt Avenue. There is approximately an 8' elevation difference between the top of the pedestrian bridge and the bottom of the pond. Retaining walls will be constructed in both the north and south ends of the bridge. The north wall will be a rockery retaining wall adjacent to the bridge for the sidewalk to be graded to the existing grade. The south wall will be a lock and load retaining wall since fill will be used in this area to construct the 12' sidewalk adjacent to the detention pond. Please refer to Sheets 5, 6, 46, 49 and 50 in Appendix A for further detail on site limitations, retaining walls and the proposed pedestrian bridge.

Guardrail Requirements

The proposed non-traffic rated pedestrian bridge is located within the 10' clear zone of Tolt Avenue, guardrail placement will be required according to the WSDOT Standards. The sections below have been provided to show compliance with the required standards.

Guardrail Configuration and Location

The Beam Guardrail Type 31 system was chosen due to the posted speed of 30 mph of Tolt Ave and 2023 average daily demand (ADT). The ADT was calculated by transpogroup based off collected weekday PM hour counts in 2018, then compared to the WSDOT 2018 ADT volumes in the vicinity of the project. Resulting in approximately a 9 to 1 factor producing an ADT of 12,000 north and 12,600 south of the project site.

When placing vertical curb in front of a guard rail the face of rail shall be flush to the flowline. An acceptable option is to place up to a 6-inch-high extruded curb at a maximum 6-inch offset in front of the rail face at any posted speed per section WSDOT 1610.04(4). Standard guard rail post spacing of 6'-3" on center will be used for the length of system except in proximity of the existing 60-inch culvert. Where the existing steel posts will be used between station 104+23.55 to 104+48.67 and Type 31 guardrail face will be installed.

A guardrail anchor is required at the end of a run of guardrail to develop tensile strength throughout its length. In addition, when the end of the guardrail is within the Design Clear Zone (DCZ) and subject to head-on impacts, a crash-tested guardrail terminal is required. The north bound lane guardrail is within the DCZ of 10-feet requiring impact attenuator. The Impact Attenuator Selection Template prepared by WSDOT was used to select SCI70GM system, see Appendix C for more details. The south bound lane DCZ of 10-feet does not intersect the proposed guardrail system. Per 1610.074(7)(a) Case 2-31 A crash-tested terminal required at both ends of guardrail system. Therefore, a SCI70GM system will be used at the north end of rail.

Length of Need

As described in the WSDOT Design Manual, the length of need refers to the total length of barrier needed to shield a fixed feature. As part of the length of need, an additional length of guardrail that extends from the end of the fixed feature needs to be provided. The WSDOT length of need equations are shown below and in Appendix B of this report.

L1 = Length of barrier parallel to roadway from adjacent-side fixed feature to beginning of barrier flare. This is used if a portion of the barrier cannot be flared (such as a bridge rail and the transition)

L2 = Distance from adjacent edge of traveled way to portion of barrier parallel to roadway

L4 = Length of barrier parallel to roadway from opposite-side fixed feature to beginning of barrier flare

L5 = Distance from centerline of roadway to portion of barrier parallel to roadway. Note: If the fixed feature is outside the Design Clear Zone when measured from the centerline, it may only be necessary to provide a crash-tested end treatment for the barrier

LH1 = Distance from outside edge of traveled way to back side of adjacent-side fixed feature

Note: If a fixed feature extends past the Design Clear Zone, the Design Clear Zone can be used as LH1. (10-feet @ 30 MPH Posted Speed)

LH2 = Distance from centerline of roadway to back side of opposite-side fixed feature. Note: If a fixed feature extends past the Design Clear Zone, the Design Clear Zone can be used as LH2

LR = Runout length, measured parallel to roadway

X1 = Length of need for barrier to shield an adjacent-side fixed feature

X2 = Length of need for barrier to shield an opposite-side fixed feature

F = Flare rate value

Y = Offset distance needed at the beginning of the length of need

Different end treatments need different offsets:

No offset is needed for the non-flared terminals or impact attenuator systems. Use Y = 0

Adjacent-Side Fixed Feature – Barrier Flare Begins Before Fixed Feature

X1 =
$$\frac{\binom{LH1 + \frac{L1}{F} - (L2 + Y)}{\binom{1}{F} + \binom{LH1}{LR}}}{\binom{LH1}{LR}} = 80.7 \text{ feet}$$
LH1 = 18.5 feet

L1=70.2 feet

$$L2 = 1.5$$
 feet

F = 9

Y = 0 feet

LR = 110 feet (30 mph posted speed, over 10,000 ADT, See Appendix B)

Opposite-Side Fixed Feature Barrier Parallel to Roadway

$$X2 = \frac{LH2 - (L5 + Y)}{(LH2/LR)} = \underline{44.5 \text{ feet }} (75.0' \text{ min per exhibit 1610-4})$$

$$LH2 = 21 \text{ feet}$$

$$L5 = 12.5 \text{ feet}$$

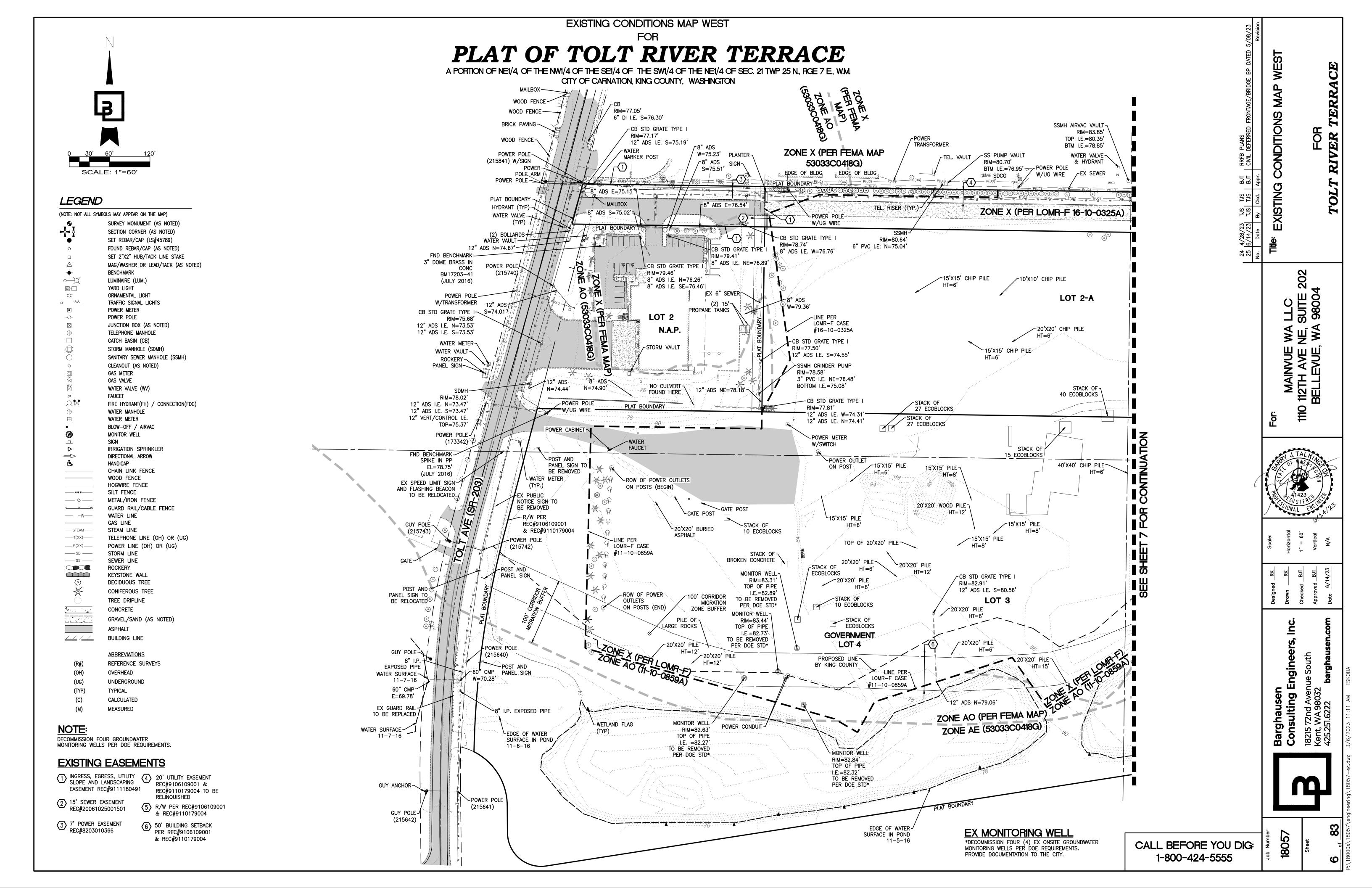
LR = 110 feet (30 mph posted speed, over 10,000 ADT, See Appendix B)

Y = 0 feet

As shown in the equations above, the additional length of guardrail required adjacent to the traveled way is 80.7 feet (+ 3 feet for gating) making the required length of 83.7 feet to account for the SCI70GM attenuator system. To minimize the south length of need (X_1) and avoid a 6' gap for the temporary ADA ramp a 9:1 flare will be utilized for the last 13.8-feet of the run.

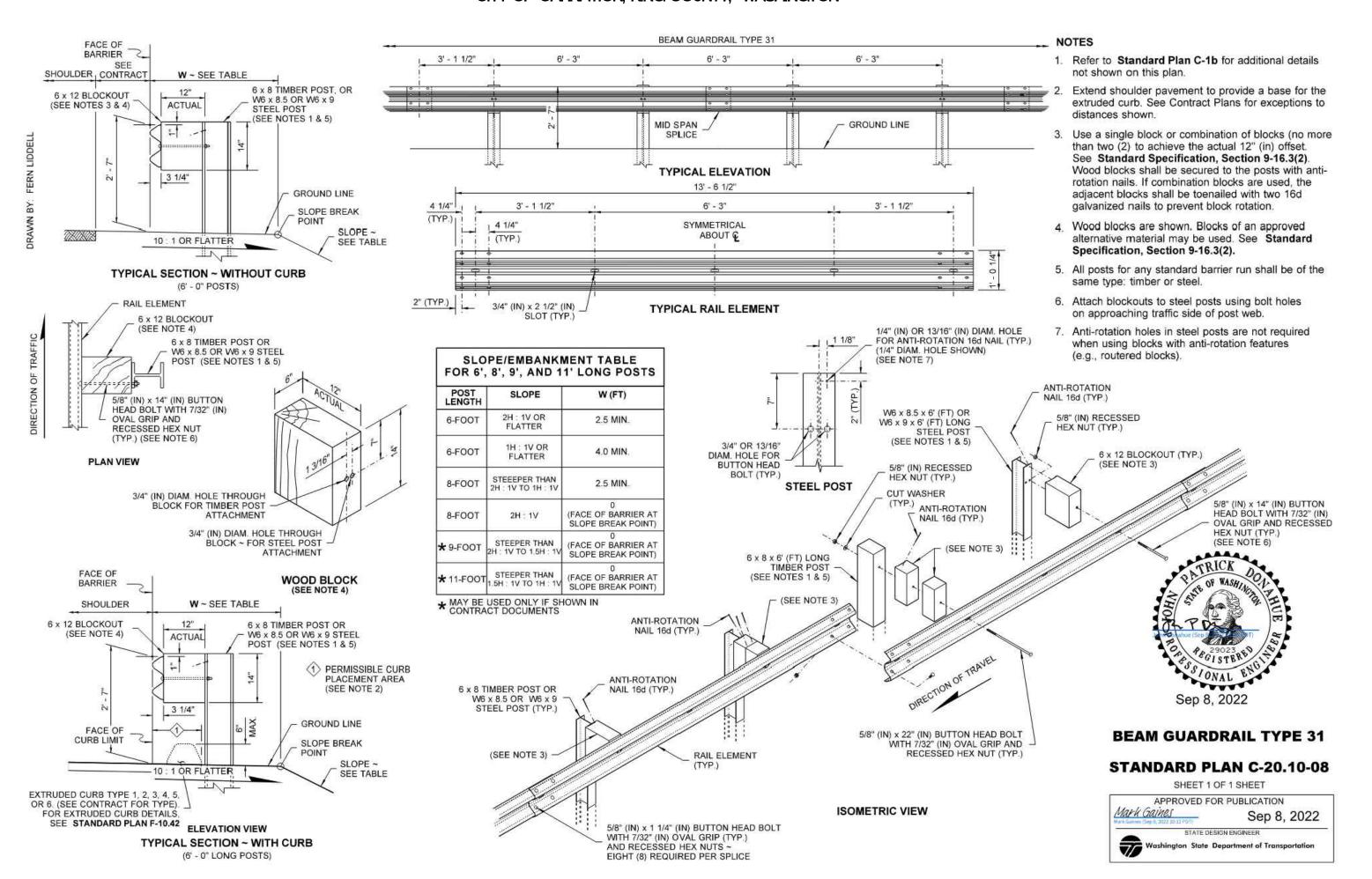
See Appendix C for attenuator selection details. The length of guardrail required opposite of the traveled way is 44.5-feet and was increased to 75-feet to account for the minimum run length per Exhibit 1610-4 and includes the gating requirement for the SCI70GM attenuator system. See Appendix A and B for more information.

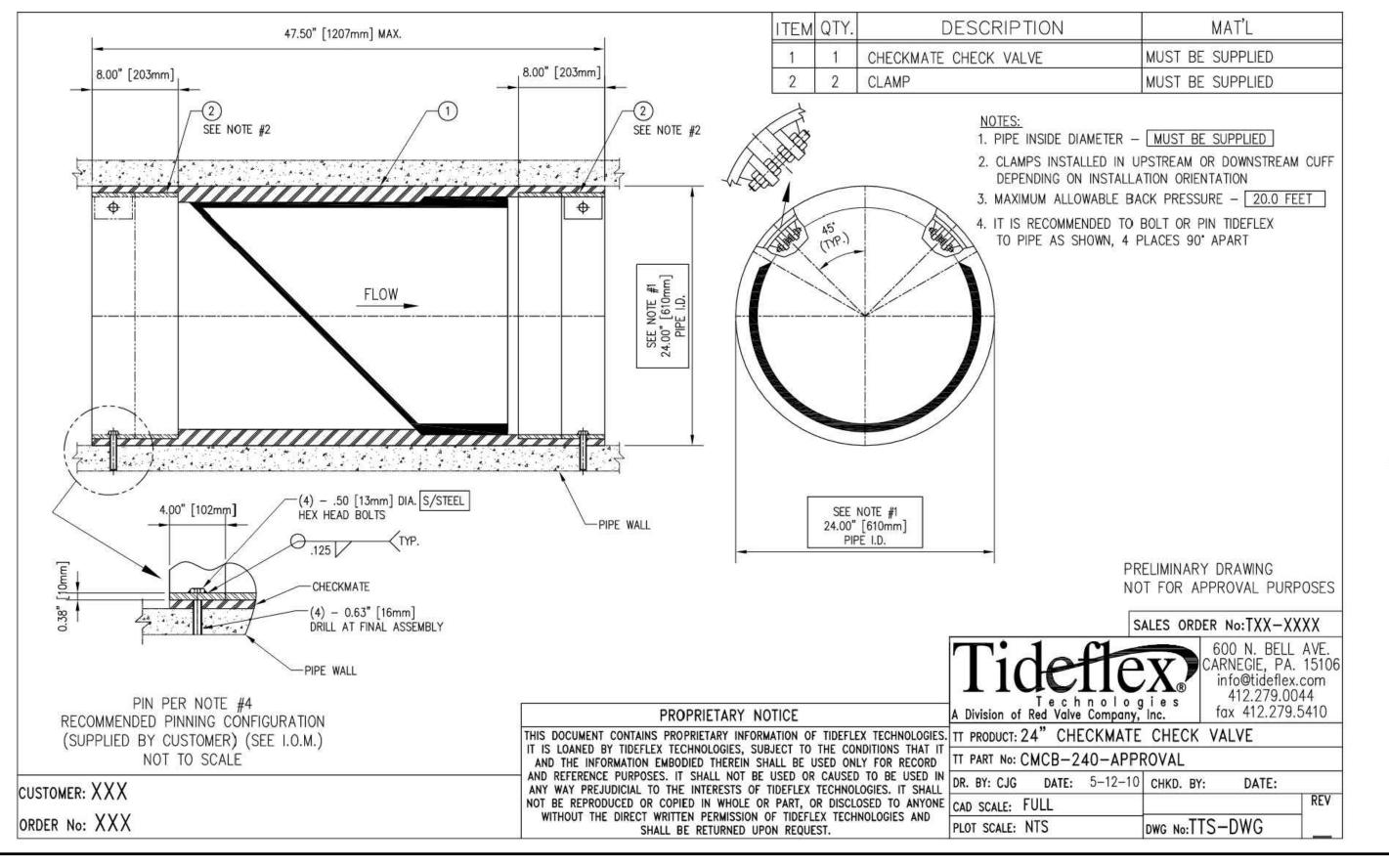
Appendix A

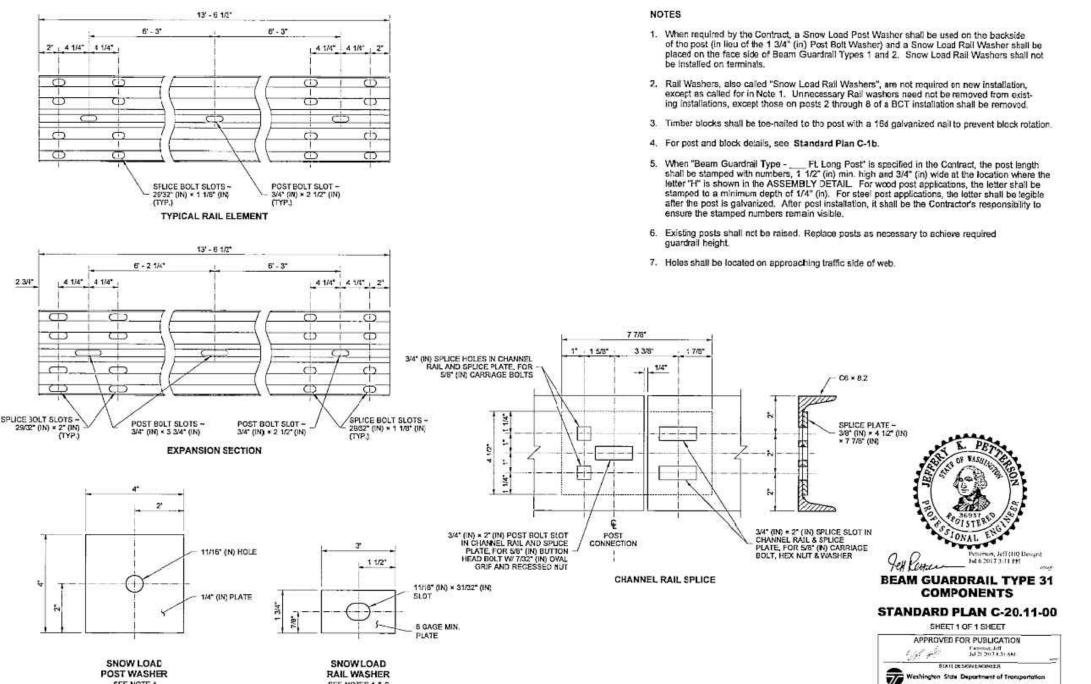


PLAT OF TOLT RIVER TERRACE

A PORTION OF NE1/4, OF THE NW1/4 OF THE SE1/4 OF THE SW1/4 OF THE NE1/4 OF SEC. 21 TWP 25 N., ROE 7 E., W.M. CITY OF CARNATION, KING COUNTY, WASHINGTON







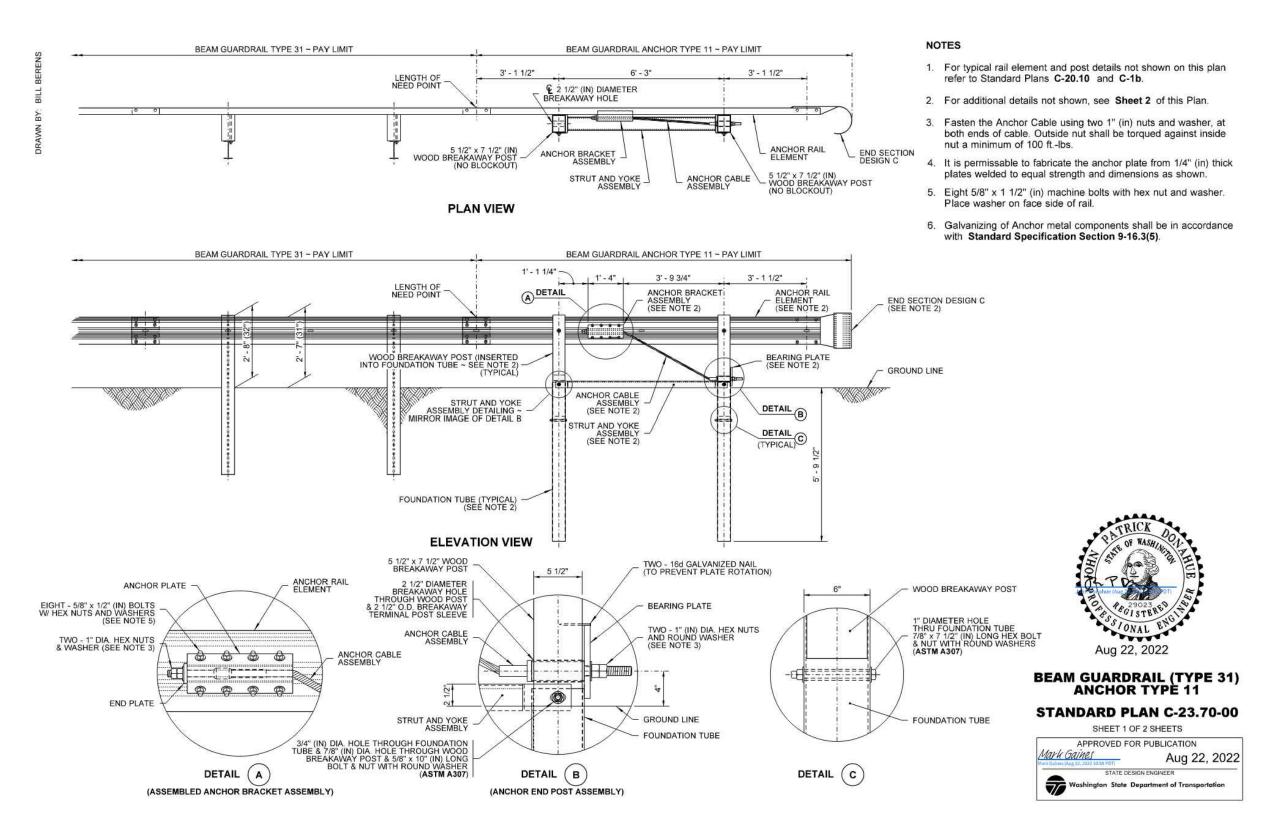
CALL BEFORE YOU DIG: 1-800-424-5555

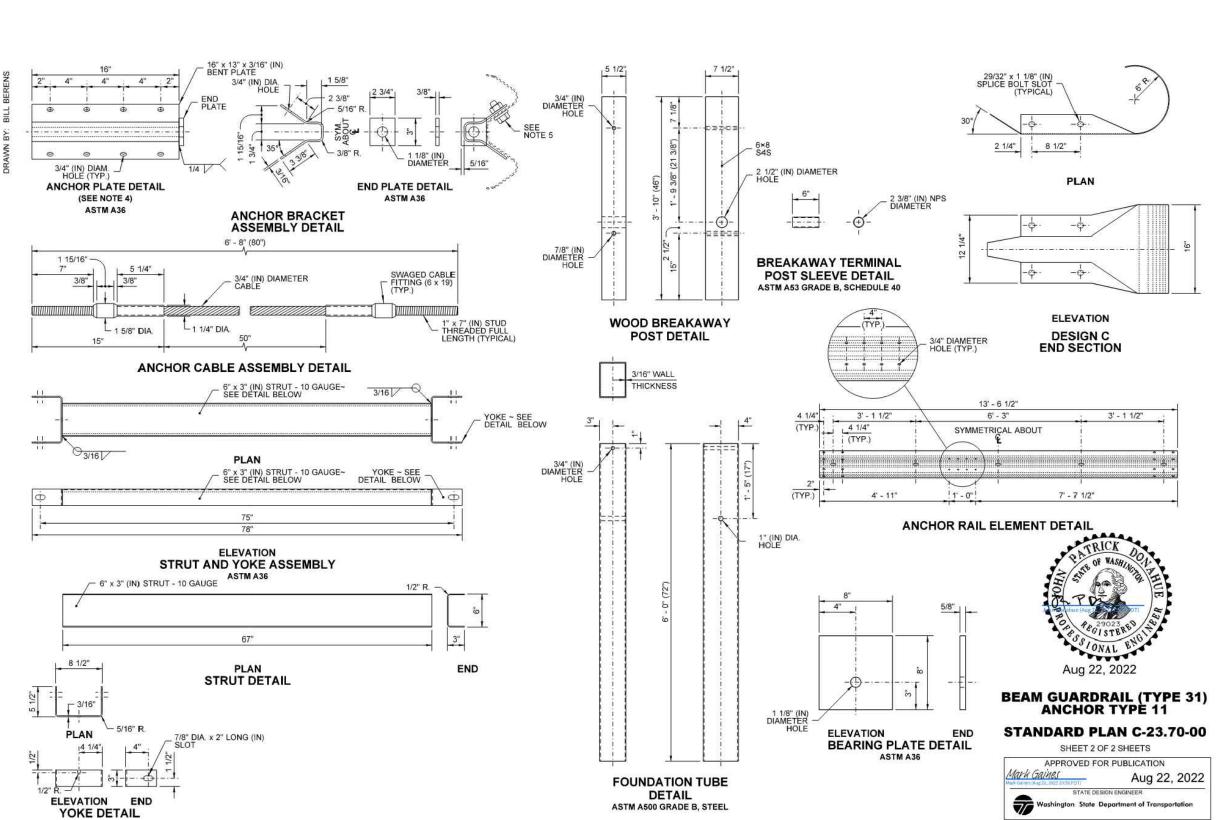
Barghausen Consulting

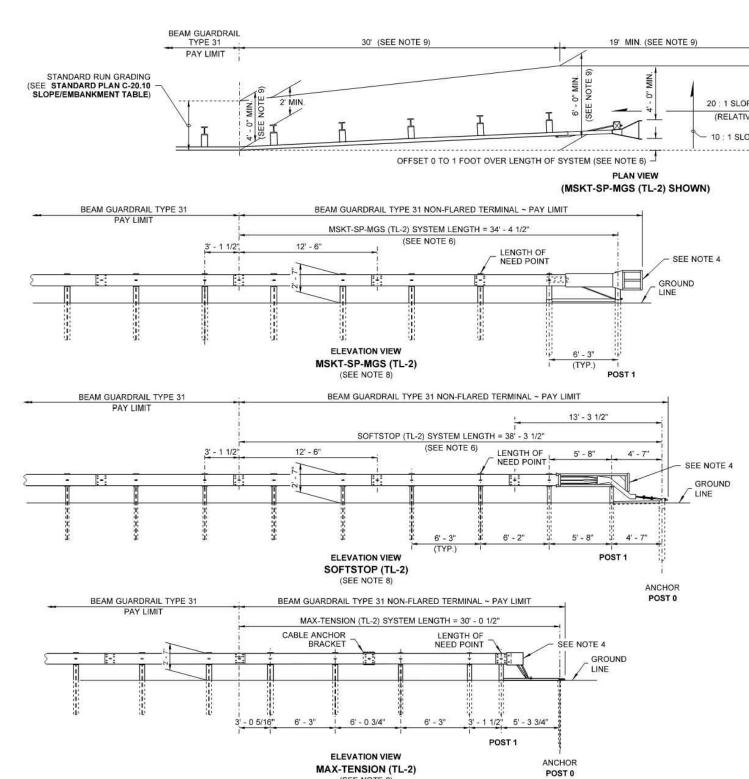


PLAT OF TOLT RIVER TERRACE

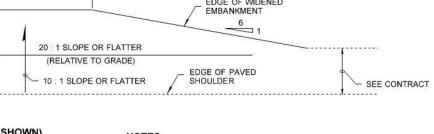
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MAX-TENSION (TL-2)



1. The Implementation of the Manual for Assessment of Safety Hardware (MASH) criteria may result in the acceptance of guardrail terminal systems currently not shown on this plan. Non-Flared terminals shall be selected from the WSDOT Qualified Products List (QPL) or approved through the WSDOT Request for Approval of Materials (RAM) process.

2. This terminal is MASH compliant at Test Level Two (TL-2) and may be used in applications with posted speed of 45 mph or less. 3. An MSKT-SP-MGS (TL-2) as manufactured by Road Systems, Inc, SOFTSTOP (TL-2) as manufactured by Trinity Highway Products, LLC, or MAX-TENSION (TL-2) as manufactured by Lindsay Transportation Solutions, shall be installed according to manufacturer's recommendations

4. A reflectorized object marker shall be installed according to manufacturer's

5. Snow load rail washers shall not be installed within the terminal limits.

6. Provide an offset between 0 to 1 foot so that the impact head does not encroach onto the paved shoulder. The offset is provided over the length of the terminal system from the center of the last post splice to either: 1) The face of the impact head at its leading edge (MSKT-SP-MGS), or (2) The center of anchor Post 0 (Softstop or Max-Tension). Provide the maximum offset where practicable.

7. For terminal details, see WSDOT approved manufacturer's drawings.

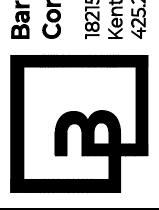
8. These terminals are supplied with steel posts only. They can be used with beam guardrail Type 31 runs, composed of steel or wood

guardrail posts. shown on this plan will satisfy the installation requirements of all 3 quardrail terminal systems shown on this plan.

BEAM GUARDRAIL TYPE 31 NON-FLARED TERMINAL (POSTED SPEED 45 MPH AND BELOW) STANDARD PLAN C-22.45-06 SHEET 1 OF 1 SHEET

APPROVED FOR PUBLICATION Mark Gaines Sep 8, 2022 Sep 8, 2022 Washington State Department of Transportation

Barghausen Consulting Enginee



Appendix B

Enter Values for Equations found in Chapter 1610 of the Design Manual and field conditions encountered.

LH1=	10.0
LH2=	21.0
L1=	70.2
L2=	1.5
L4=	

Adjacent-Side Hazard Barrier Parallel to Roadway

$$X1 = \frac{LH1 - (L2 + Y)}{(1/F) + (LH1/LR)}$$

$$X1 = \frac{10 - (1.5 + 0)}{(1/9) + (10/110)}$$

Adjacent-Side Hazard Barrier Flare Begins at Hazard

$$X1 = \frac{(LH1+L1/F) - (L2+Y)}{(1/F)+(LH1/LR)}$$

$$X1 = \frac{(10+70.17/9) - (1.5+0)}{(1/9)+(10/110)}$$

$$X1 = \frac{16.3}{0.2}$$

Adjacent-Side Hazard
Barrier Flare Begins Before Hazard

80.7

X1=

X2=	LH2 -(L5+Y) (LH2/LR)
X2= —	21-(12.5+0) (21/110)
X2= —	8.5 0.2
X2=	44.5

Opposite-Side Hazard
Barrier Parallel to Roadway

$$X2 = \frac{LH2 - (L5 + Y)}{(1/F) + (LH2/LR)}$$

$$X2 = \frac{21 - (12.5 + 0)}{(1/9) + (21/110)}$$

Opposite-Side Hazard Barrier Flare Begins at Hazard

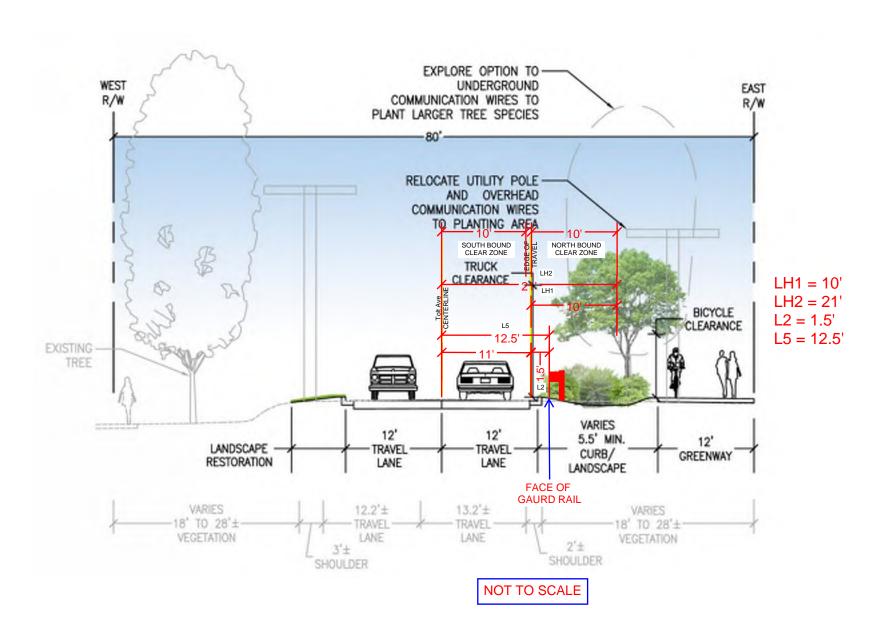
$$X2 = \frac{(LH2+L4/F) - (L5+Y)}{(1/F)+(LH2/LR)}$$

$$X2 = \frac{(21+/9)-(12.5+0)}{(1/9)+(21/110)}$$

Opposite-Side Hazard
Barrier Flare Begins Before Hazard

South Greenway Section (1 of 6)

Tolt Avenue Section 2 - Tolt-MacDonald Park South Entrance to Fire Station



Chapter 1610

Traffic Barriers

1610.01 Introduction 1610.02 Barrier Impacts 1610.03 General Barrier Design

1610.03 General Barrier Design 1610.04 Beam Guardrail

1610.05 High-Tension Cable Barrier

1610.06 Concrete Barrier 1610.07 Bridge Traffic Barriers 1610.08 Other Barriers

1610.09 References

Exhibit 1610-1 Concrete Barrier Placement Guidance: Assessing Impacts to

Wildlife

Exhibit 1610-2 Traffic Barrier Locations on Slopes Exhibit 1610-3 Longitudinal Barrier Deflection

Exhibit 1610-4 Barrier Standard Run Minimum/Maximum Lengths (New

Exhibit)

Exhibit 1610-5 Longitudinal Barrier Flare Rates

Exhibit 1610-6 Barrier Length of Need on Tangent Sections

Exhibit 1610-7 Barrier Length of Need

Exhibit 1610-8 Barrier Length of Need on Curves

Exhibit 1610-9 Beam Guardrail Trailing End Placement for Divided Highways

Exhibit 1610-10 Beam Guardrail Post Installation

Exhibit 1610-11 Guardrail Connections
Exhibit 1610-12 Transitions and Connections
Exhibit 1610-13 Median Cable Barrier Placement
Exhibit 1610-14 Roadside Cable Barrier Placement

Exhibit 1610-15 Cable Barrier Placement: Overlap on Divided Highways

Exhibit 1610-16 Cable Barrier Placement: Cable Barrier Termination/Overlap

with Beam Guardrail

Exhibit 1610-17 Concrete Barrier Shapes

Exhibit 1610-18 Type 7 Bridge Rail Upgrade Criteria Exhibit 1610-19 Thrie Beam Rail Retrofit Criteria

Chapter Organization: Sections 1610.01 and 1610.02 (Introduction and Barrier Impacts) present information to consider when deciding whether or not to install a barrier. Section 1610.03 (General Barrier Design) contains guidance common to ALL barrier types; such as deflection distance, minimum/maximum system lengths, length of need, and sight distance. The remaining sections, 1610.04 through 1610.08, present design information organized by specific barrier type (beam guardrail, cable barrier, concrete barrier, bridge traffic barrier, and other barriers).

Refer to the Glossary of Terms for many of the terms used in this chapter.

Refer to Chapter 300 and Section 1610.01(1) for design documentation requirements.

1610.01 Introduction

WSDOT uses traffic barriers to reduce the overall severity of crashes. Consideration is given as to whether a barrier is preferable to the recovery area it may replace. In some cases, installation of a traffic barrier may result in more crashes as it's an object that can be struck. Barriers are designed so that such encounters might be less severe and not lead to secondary or tertiary crashes. However, traffic barriers are not guaranteed to redirect an impacting vehicle without resulting injury to its occupants or triggering additional crashes. Barrier performance is affected by the characteristics of the vehicles that collide with them. Different vehicles will react differently given the characteristics and dynamics of the crash. Therefore, vehicles will be decelerated and redirected differently given the size, weight and direction of force imparted from the vehicle to the barrier.

Barriers are not placed with the assumption that the system will restrain or redirect all vehicles in all conditions. It is recognized that the designer cannot design a system that will address every potential crash situation. Instead, barriers are placed with the assumption that, under typical crash conditions, they might decrease the potential for excessive vehicular deceleration or excessive vehicle redirection when compared to the location without the barrier.

Traffic barriers do not prevent crashes or injuries from occurring. They often lower the potential severity for crash outcomes. Consequently, barriers should not be used unless a reduced crash severity potential is likely. No matter how well a barrier system is designed, optimal performance is dependent on drivers' proper maintenance and operation of their vehicles and the proper use of passenger restraint systems. Site constraints play a major role in decisions regarding barrier selection and placement.

Depending on the location, these constraints may include environmental considerations, topographic challenges, restricted right-of-way, geologic concerns, or conflicts with other infrastructure.

Barrier systems and vehicle fleets continue to evolve. The choice of a barrier is based on the characteristics of today's vehicle fleet and testing criteria, not on speculative assumptions of future vehicle designs. This continuum of change does not allow engineers to predict the future with any degree of certainty. Consequently, engineering decisions need to be made based on the most reliable and current information.

Engineers are constantly striving to develop more effective design features to improve highway safety. However, economics, asset management and maintenance needs, and feasibility do not permit the deployment of new designs as soon as they become available on the market or are invented by a manufacturer. Further, most new designs only make marginal changes to systems and do not imply that old designs are unsafe or need modification.

Solutions may consider crash frequency and severity. As discussed previously, performance of the system relies on the interaction of the vehicle, driver, and system design at any given location. Additionally, the ability to safely access, maintain and operate over time is incorporated into the final barrier decision.

When barriers are crash-tested, it is impossible to replicate the innumerable variations in highway conditions under which the barrier applications occur. Therefore, barriers are crash-tested under standardized conditions. These standard conditions were previously documented in National Cooperative Highway Research Program (NCHRP) Reports 230 and 350. These guidelines have been updated and are now presented in the AASHTO publication, *Manual for Assessing Safety Hardware* (MASH).

Roadside safety hardware (barriers, devices, etc.) are accepted for use by WSDOT following a review of its performance with respect to a crash testing standard. Documented evidence of performance includes, but is not limited to, crash testing results, a comparison to similar crash tested designs, or an engineering analysis of the system and/or its components. Following a successful review, the device is then considered "compliant" with the applicable standard (eg MASH-compliant).

The latest roadside safety hardware standard (MASH) is being implemented by WSDOT product category. Implementation takes place as designs and products are reviewed by WSDOT, determined to be MASH-compliant, and accepted for use. Following acceptance, implementation is documented through modifications to the corresponding standard specification(s), standard plan(s), and/or are accepted to the Qualified Products List (in the case of proprietary hardware). The policy on work zone devices is described in Chapter 1010.

To learn more about MASH <u>implementation at WSDOT</u> see the following website: Roadside safety | WSDOT (wa.gov)

1610.01(1) Documentation

Document barrier location decisions, including any site constraints encountered that influenced those decisions. A decision to install barrier using criteria outside the guidance provided in this chapter requires a Design Analysis, unless otherwise directed by the ASDE.

1610.02 Barrier Impacts

Engineering judgment is required in determining the appropriate placement of barrier systems, therefore consider the location of the system and the possible impacts the barrier may have to other highway objectives.

1610.02(1) Assessing Impacts to Stormwater and Wetlands

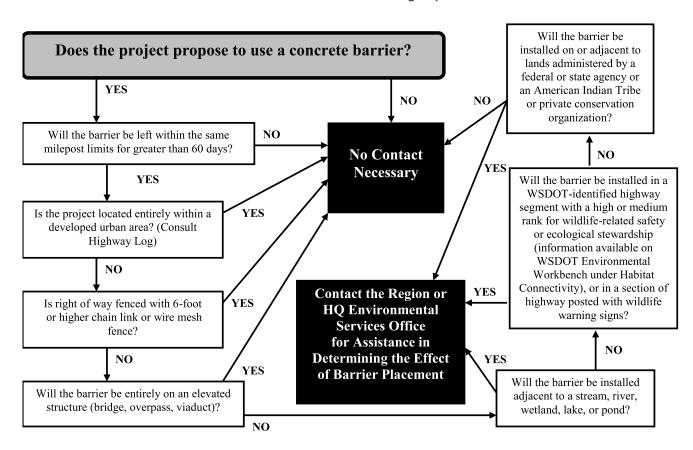
The presence of stormwater facilities or wetlands influence the choice and use of barrier systems. For example, the placement of concrete barrier may increase the amount of impervious surface, which could then result in retrofit or reconstruction of the existing retention/detention systems and environmental impact requirements and studies. Assess whether concrete barrier or beam guardrail placement will cause the need for an evaluation by the HQ Environmental Services Office. Conduct this evaluation early in the project's development process to allow adequate time for discussion of options.

1610.02(2) Assessing Impacts to Wildlife

The placement of concrete barriers in locations where wildlife frequently cross the highway can influence wildlife-vehicle crash potential. When wildlife encounters physical barriers that are difficult to see beyond or cross, such as concrete barriers, they often stop or move parallel to those barriers, increasing their time on the highway and their exposure.

Traffic-related wildlife mortality may play a role in the decline of some species listed under the Endangered Species Act. To address wildlife concerns, see Exhibit 1610-1 to assess whether barrier placement needs to have an evaluation by the HQ Environmental Services Office to determine its effect on wildlife. Conduct this evaluation early in the project development process to allow adequate time for discussion of options.

Exhibit 1610-1 Concrete Barrier Placement Guidance: Assessing Impacts to Wildlife



1610.03 General Barrier Design

Apply the policy and guidance in this chapter when directed to do so in Exhibit 1105-1, and following an examination of the potential alternative mitigation measures described in Section 1600.01.

Chapter 1120 identifies those elements and features to be evaluated and potentially addressed during the course of <u>many Preservation projects (see Exhibit 1105-1)</u>.

Once the use of a barrier has been selected as the mitigation measure for a condition, select a particular barrier type by considering the barrier system's deflection characteristics, cost, maintainability and impacts to traffic flow during repair. Barriers are categorized as flexible, semi-rigid, or rigid depending on their deflection characteristics (see Exhibit 1610-3). Barrier types include:

- Beam Guardrail
- Cable Barrier
- Concrete Barrier
- Bridge Traffic Barrier
- Other Barriers

1610.03(1) New Roadside Safety Hardware

Since non-rigid systems typically sustain more damage during an impact, consider the amount of traffic exposure maintenance crews might incur with the more frequent need for repairs.

The costs for procuring and maintaining the barrier system are important factors when considering what system to install. Considerations may include:

- Consultation with the Area Maintenance Superintendent to identify needs or recommendations.
- Drainage, alignment, and drifting snow or sand are considerations that can influence the selection of barrier type. Beam guardrail and concrete barrier can contribute to snow drifts. Consider long-term maintenance costs associated with snow removal at locations prone to snow drifting. Cable barrier is not an obstruction to drifting snow.
- Analysis of potential reduction of sight distance due to barrier selection and placement.
- Additional widening and earthwork requirements. With some systems, such as concrete barrier and beam guardrail, the need for additional shoulder widening or slope flattening is common. Selection of these types of barriers may require substantial environmental permitting or roadway reconstruction.
 Permits issued under the SEPA and NEPA processes may lead to the use of a barrier design, such as cable barrier, which has fewer potential environmental impacts and costs.
- For concrete barrier systems:
 - Lower maintenance costs than for other barrier types.
 - Deterioration due to weather and vehicle impacts is less than most other barrier systems.
 - Unanchored precast concrete barrier can usually be realigned or repaired after a vehicle impact. However, heavy equipment may be necessary to reposition or replace barrier segments. Therefore, in medians, consider the shoulder width and the traffic volume when determining the acceptability of unanchored precast concrete barrier versus rigid concrete barrier. See Exhibit 1610-3 for deflection area requirements.

1610.03(2) Existing Roadside Safety Hardware (New Section)

When directed in Exhibit 1105-1 to apply the policy and guidance in this chapter, evaluate the need to upgrade existing roadside safety hardware to a MASH-compliant product or design. Consider the standard to which the existing barrier or device was originally designed and tested: MASH, NCHRP 350, and pre-NCHRP 350. The decision to replace existing hardware that is not MASH-compliant is based on the project type as follows:

- All projects directed to use this chapter in Exhibit 1105-1 are required to replace pre-NCHRP 350 hardware, except for breakaway cable (guardrail) terminals, which have their own independent replacement program.
- In addition, all Improvement projects directed to use this chapter in Exhibit 1105-1 may leave in place existing NCHRP 350 compliant hardware that is still in serviceable condition, or alternatively may relocate it within the project limits. Note that NHCRP 350 hardware found to be in serviceable condition that is temporarily moved as part of work zone activity may also be reinstalled in its original location without the need to upgrade.
- See Section 1610.04(5) for additional evaluation instructions for beam guardrail terminals.

See Chapter 1120 for policy on addressing existing roadside safety hardware in Preservation projects.

When leaving existing barrier in place per the direction above, confirm that the configuration and layout (height, length, offset, etc.) are according to the original standard, and correct if necessary.

Note that as the process for determining whether roadside safety hardware is in serviceable condition is still in development, consult with your ASDE for more information and for the latest guidance on documenting the decision to replace or not replace NCHRP 350 hardware on a project.

1610.03(3) Barrier Placement

Proper installation of a barrier system is required for the system to perform similar to the crash tests that resulted in its acceptance for use on our highways. Maximize the distance between the barrier and the travelled way.

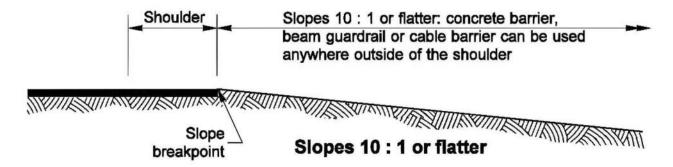
See Chapter 1239 for minimum lateral clearance requirements.

1610.03(3)(a) Placement on a Slope

Slopes may affect barrier placement. Considerations for barrier placement on a slope include:

- For slopes that are 10:1 or flatter, concrete barrier, beam guardrail or cable barrier can be installed anywhere beyond the edge of shoulder. See Exhibit 1610-2.
- For additional placement guidance see Section 1610.05(1) for cable barrier, see Section 1610.04(2) for beam guardrail, and see Section 1610.06 for concrete barrier.

Exhibit 1610-2 Traffic Barrier Locations on Slopes



1610.03(3)(b) Placement in Median Locations

The following barrier types may be used in medians in new installations:

- Cast in place double-sided, single-slope, concrete barrier
- Precast double-sided single-slope concrete barrier
- Pinned F-shape double-sided concrete barrier
- Unpinned F-shape double-sided concrete barrier
- Type 31 w-beam guardrail
- Double-sided Type 31 w-beam guardrail
- High-tension cable barrier

Select the appropriate barrier type using the following criteria:

- Contact HQ Design when retrofitting non-freeways with median barrier (regardless of median width).
- Address the design deflection characteristics of the barrier to avoid placement of barrier where the design deflection extends into oncoming traffic.
- Barrier may be provided under certain conditions as separation between a freeway mainline and collector-distributor road (see Chapter 1360).
- When W-beam barrier is placed in a median as a countermeasure for cross-median crashes, design the barrier to be struck from either direction of travel. For example, the installation of beam guardrail might be double-sided (Type 31-DS).
- Narrow medians provide little space for any maintenance activities, including repair or repositioning of
 the barrier. Installing barriers in medians that provide less than 8 feet from the edge of the traveled way
 to the face of the barrier will likely require temporarily closing the adjacent lane during maintenance
 activities. This will impact the travelling public and impact maintenance staff, and maintenance staff
 should be consulted. See Chapter 301 Design and Maintenance Coordination.
- Use single slope high performance concrete barrier (HP barrier) on freeways with medians 22-feet wide and less.
- Any barrier type listed above may be used on freeways with medians greater than 22-feet wide.
- In general, cable barrier is recommended with medians that are 30 feet or wider. However, cable barrier may be appropriate for narrower medians if adequate deflection distance exists.

• In wider medians, the selection and placement of barrier might depend on the slopes in the median. At locations where the median slopes are relatively flat (10H:1V or flatter), unrestrained precast concrete barrier, beam guardrail, and cable barrier can be used depending on the available deflection distance. At these locations, position the barrier as close to the center of the median as possible so that the recovery distance can be maximized for both directions. There may be a need to offset the barrier from the flow line to avoid impacts to the drainage flow.

• At locations where the roadways are on independent alignments and there is a difference in elevation between the roadways, the slope from the upper roadway might be steeper than 6H:1V. In these locations, position the median barrier along the upper roadway and provide deflection and offset distance as discussed previously. Barrier is generally not needed along the lower roadway except where there are fixed features in the median.

For additional placement guidance see Section 1610.05(1) for cable barrier, see Section 1610.04(2) for beam guardrail, and see Section 1610.06 for concrete barrier.

1610.03(4) Sight Distance

When selecting and placing a barrier system, consider the possible impact the barrier type and height may have on sight distance. In some cases, barriers may restrict the sight distances of road users entering the roadway, such as from road approaches, intersections, and other locations. In these cases, the barrier may need to be adjusted to meet the sight distance requirements at these locations.

1610.03(5) Barrier Deflections

Expect all barriers, except for certain types of rigid barriers (such as concrete bridge rails, barrier integral to retaining walls, or embedded cast-in-place barriers), to deflect when hit by an errant vehicle. The amount of deflection is primarily dependent on the stiffness of the system. However, vehicle speed, angle of impact, and weight of the vehicle also affect the amount of barrier deflection.

For roadside or wide median installations of flexible and semi-rigid roadside barriers (high tension cable barrier and beam guardrail), the deflection distance is designed to prevent the impacting vehicle from striking the object being shielded. For unrestrained rigid systems (unanchored precast concrete barrier), the deflection distance is designed to help prevent the barrier from being knocked over the side of a drop-off or steep fill slope (2H:1V or steeper).

For narrower median installations, design systems so that the anticipated deflection will not enter the lane of opposing traffic. When evaluating new barrier installations, consider whether impacts would require significant traffic closures to accomplish maintenance. Rigid embedded barrier systems are used when no barrier deflection is necessary or desired (areas such as narrow medians, at the edge of bridge decks, or other vertical drop-off areas). Runs of rigid embedded concrete barrier can be precast, cast in place, or extruded with appropriate footings.

In locations where deflection distance is limited, precast concrete barrier can be anchored. Some movement can be expected for rigid anchored barrier systems and repairs may be more expensive (anchoring pins may damage the asphalt or concrete surface that the barrier is placed upon during a vehicle collision).

Use of an anchored precast concrete barrier and other deflecting barrier systems placed on top of a retaining wall at less than the deflection distances provided in Exhibit 1610-3 requires approval from the HQ Design Office. See Section 1610.06 for more information on concrete barrier.

Exhibit 1610-3 provides barrier deflection design values when selecting standard runs of longitudinal barrier. This exhibit does not provide deflection values for specialty barrier systems or installations (for example long span guardrail systems (Std. Plan C-20.40), box culvert guardrail systems (Std. Plan C-20.41 or C-20.43), Type 31 guardrail installed on a flare, the ends of Type 31 guardrail runs when terminated with an anchor (Std. Plan C-20.14 or C-20.18), etc.). Refer to related Standard Plans showing specialty barrier systems or installation placement cases for additional details about deflections and dimensions that are useful in design, or contact HQ Design for specialty barrier systems or installations deflections. The deflection values for cable and beam guardrail are minimum distances measured between the face of the barrier to the fixed feature. The deflection values for concrete barrier are minimum distances measured from the back edge of the barrier to the fixed feature, drop-off, or slope break.

Exhibit 1610-3 Longitudinal Barrier Deflection

Barrier Type	System Type	Deflection Distance		
High-tension cable barrier	Flexible	6 ft to 10 ft typical [1] (measured from face of barrier to object)		
Beam guardrail, Types 1, 1a, 2, and 10	Semi-rigid	3 ft [3] (measured from face of barrier to object)		
Beam guardrail, two-sided Types 3, and 4	Semi-rigid	4 ft (measured from nearest face of barrier to object)		
Beam guardrail Type 31 (including two-sided and omitted post)	Semi-rigid	5 ft (measured from face of barrier to object)		
Permanent precast concrete barrier, unanchored	Rigid Unrestrained	6 ft (measured from back of barrier to object, slope break point, or drop-off)		
Permanent precast concrete barrier, unanchored (When placed in front of a 2:1 or flatter fill slope on right hand shoulders and not shielding any fixed objects. Contact HQ Design before using this deflection condition for barrier placed in medians)	Rigid Unrestrained	3 ft (measured from back of barrier to slope break point)		
Permanent precast concrete barrier, anchored	Rigid Anchored	2 ft (measured from back of barrier to object, slope break point, or drop-off)		
Temporary precast concrete barrier, unanchored [4]	Rigid Unrestrained	3 ft [2] (measured from back of barrier to object, slope break point, or drop-off)		
Temporary precast concrete barrier, anchored [4]	Rigid Anchored	1 ft [2] [5] (measured from back of barrier to object, slope break point, or drop-off)		
Cast in place or precast concrete barrier, embedded	Rigid Embedded	No deflection [6]		

Notes:

This exhibit provides deflection values for standard runs of barrier. It does not provide deflection values for specialty <u>barrier</u> systems or installations (e.g. long span guardrail systems(Std. Plan C-20.40), box culvert guardrail systems (Std. Plan C-20.41 or C-20.43), Type 31 barrier installed on a flare, <u>the ends of Type 31 guardrail runs when terminated with an anchor (Std. Plan C-20.14 or C-20.18), etc.). Refer to related Standard Plans of specialty barrier systems or installation placement cases showing additional details about deflections and dimensions that are useful in design.</u>

- [1] See Section 1610.05(2)
- [2] When used as temporary bridge rail, anchor all barrier when the back of barrier is located within 3 feet of a drop-off.
- [3] Place any new objects a minimum of 5 feet from the face of existing beam guardrail type 1.
- [4] Steel barrier is also available for temporary applications. See Chapter 1010 for more information.
- [5] When anchoring temporary precast concrete barrier on bridges or other drop-offs, see applicable Standard Plans for anchorage details, lateral offsets, and deflection distances.
- [6] When placed in front of a fill slope or on top of an MSE wall, provide a minimum distance of 2-feet of widening with a 10:1 or flatter slope from the back of barrier to the slope break point.

1610.03(6) Minimum/Maximum Barrier System Lengths (New Section)

At times, the barrier Length of Need (LON) formulas may calculate barrier run lengths that are quite short in order to shield an object or feature. Regardless of the calculated barrier Length of Need, barrier runs require a minimum installed length in order to retain their ability to contain and redirect an impacting vehicle.

In addition, a maximum allowable run length is required for longer runs of high-tension cable barrier. Longer runs of high-tension cable barrier can be more difficult to maintain.

Exhibit 1610-4 gives the required minimum and maximum lengths for standard runs of barriers currently used by WSDOT:

Exhibit 1610-4 Barrier Standard Run Minimum/Maximum Lengths (New Exhibit)

Barrier Type	Minimum Run Length	Maximum Run Length	
High-Tension Cable Barrier	<u>No Minimum</u>	<u>10,000-feet *</u>	
Beam Guardrail Type 31	<u>75-feet *</u>	<u>No Maximum</u>	
Permanent precast concrete barrier, unanchored	<u>200-feet</u>	<u>No Maximum</u>	
Permanent precast concrete barrier, anchored	<u>100-feet</u>	No Maximum	
Temporary precast concrete barrier, unanchored	<u>200-feet</u>	No Maximum	
Temporary precast concrete barrier, anchored	<u>100-feet</u>	<u>No Maximum</u>	
Cast in place concrete barrier, embedded	<u>40-feet</u>	<u>No Maximum</u>	
Precast concrete barrier, embedded	<u>80-feet</u>	<u>No Maximum</u>	

^{*} Minimum/maximum barrier run lengths includes the terminal and anchors of the High-Tension Cable Barrier and Beam Guardrail systems.

1610.03(7) Flare Rate

A roadside barrier is considered flared when it is not parallel to the edge of the traveled way.

Flare the ends of longitudinal barriers where site constraints allow (see Section 1610.01). The four functions of a flare are to:

- Maximize the distance between the barrier (and its terminal) and the travelled way.
- Reduce the length of need.
- Redirect an errant vehicle.
- Minimize a driver's reaction to the introduction of an object near the traveled way.

Keeping flare rates as flat as site constraints allow preserves the barrier's redirectional performance and minimizes the angle of impact. It has also been shown that an object (or barrier) close to the traveled way might cause a driver to shift laterally, slow down, or both. The flare reduces this reaction by gradually introducing the barrier so the driver does not perceive the barrier as an object to be avoided. The flare rates in Exhibit 1610-5 are intended to satisfy the four functions listed above. Flares that are more gradual may be used. Flare rates are offset parallel to the edge of the traveled way. Transition sections are not flared.

Situations exist where hardware installations may have barrier flare rates different than shown in Exhibit 1610-5. If a *Standard Plan* for a barrier installation shows a different flare rate than is shown in Exhibit 1610-5, use the flare rate shown on the Standard Plan (see Std. plan C-2c and C-4f for bullnose terminals, and Std. Plan C-22.16 for buried terminals).

Exhibit 1610-5 Longitudinal Barrier Flare Rates

Po	osted Speed (mph)	Rigid & Rigid Anchored System	Unrestrained Rigid System	Semi-rigid
	65–70 20:1		18:1	15:1
60		18:1	16:1	14:1
55		16:1	14:1	12:1
	50	14:1	12:1	11:1
	45	12:1	11:1	10:1
40 or below 11:1		11:1	10:1	9:1

1610.03(8) Length of Need

Length of need refers to the total length of longitudinal barrier needed to shield a fixed feature. See length of need calculation spreadsheet.

In many cases, there may be a portion of the traffic barrier installation that is not redirective in capability. For instance, if a run of concrete barrier is terminated with an impact attenuator, there will likely be a section of the impact attenuator that is not redirective (see Chapter 1620 for more information). Therefore, in most cases, the Length of Need does not equal (i.e., it is shorter than) the actual physical length of the traffic barrier installation required to achieve that length of need.

Length of need is dependent on the location and geometrics of the object, direction(s) of traffic, posted speed, motor vehicle traffic volume, and type and location of traffic barrier.

When designing a barrier for a fill slope (see Chapter 1600), the length of need begins at the point where the need for barrier is recommended. For fixed objects and water, Exhibit 1610-6 shows design parameters for determining the needed length of a barrier for both adjacent and opposing traffic on relatively straight sections of highway.

When barrier is to be installed on the outside of a horizontal curve, the length of need can be determined graphically as shown in Exhibit 1610-8. For installations on the inside of a curve, determine the length of need as though it were straight. Also, consider the flare rate, barrier deflection, and barrier end treatment to be used.

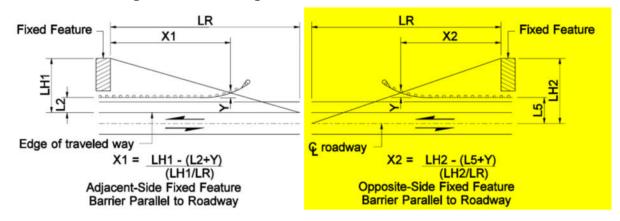
When beam guardrail is placed in a median, consider the potential for impact from opposing traffic when conducting a length of need analysis. When guardrail is placed on either side of objects in the median, consider whether the trailing end of each run of guardrail will shield the leading end of the opposing guardrail. Shield the leading end when it is within the Design Clear Zone of opposing traffic (see Exhibit 1610-9). This is also a consideration when objects are placed in the outer separations between the main line and collector-distributors.

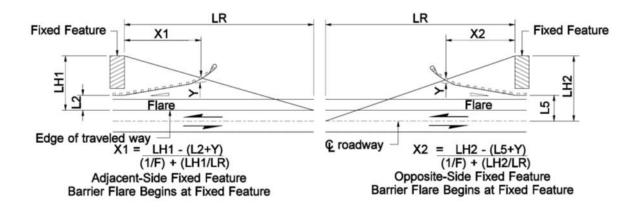
Before the actual length of need is determined, establish the lateral distance between the proposed barrier installation and the object shielded. Provide a distance that is greater than or equal to the anticipated deflection of the longitudinal barrier. (See Exhibit 1610-3 for barrier deflections.) Place the barrier as far from the edge of the traveled way as possible while maintaining the deflection distance.

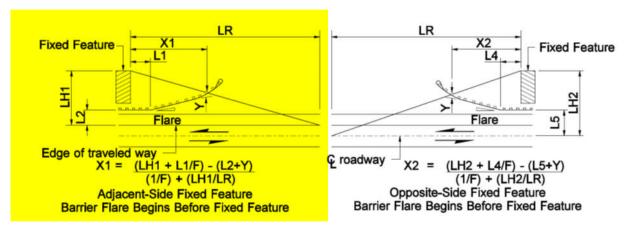
If the end of the length of need is within 300 feet of another barrier run (either existing or proposed), it is recommended that the barriers be connected to form a continuous run except where the gap involves a buried terminal and cut slope. In these cases and where practicable, extend barrier runs beyond the length of need to a backslope and provide a buried terminal (see Section 1610.06(3) for concrete barrier buried terminal, and Section 1610.04(5) and Standard Plan C-22.16 for beam guardrail buried terminal).

Where access is needed behind a barrier (e.g. maintenance access, utility objects, road approaches, etc.) and an alternative approach to providing access is not practicable, provide a gap in the barrier that meets the access need using a configuration where the termination of the downstream run is situated behind the upstream run, or is otherwise outside the Design Clear Zone. Where this overlapping configuration is not practicable, provide a minimum size gap in the guardrail run to meet the access need and evaluate the need for barrier terminals on the upstream and downstream runs.

Exhibit 1610-6 Barrier Length of Need on Tangent Sections







Note:

For supporting length of need equation factors, see Exhibit 1610-7.

See length of need calculation spreadsheet.

Exhibit 1610-7 Barrier Length of Need

	Design Parameters						
Posted	ADT				Barrier Type		
Speed (mph)	Over 10,000	5,000 to 10,000	1,000 to 4,999	Under 1,000	Rigid & Rigid Anchored Barrier	Rigid Unrestrained Barrier	Semi-rigid Barrier
	LR (ft)	LR (ft)	LR (ft)	LR (ft)	F	F	F
70	360	330	290	250	20	18	15
65	330	290	250	225	20	18	15
60	300	250	210	200	18	16	14
55	265	220	185	175	16	14	12
50	230	190	160	150	14	12	11
45	195	160	135	125	12	11	10
40	160	130	110	100	11	10	9
35	135	110	95	85	11	10	9
30	110	90	80	70	11	10	9
25	110	90	80	70	11	10	9

L1 = Length of barrier parallel to roadway from adjacent-side fixed feature to beginning of barrier flare. This is used if a portion of the barrier cannot be flared (such as a bridge rail and the transition).

L2 = Distance from adjacent edge of traveled way to portion of barrier parallel to roadway.

L4 = Length of barrier parallel to roadway from opposite-side fixed feature to beginning of barrier flare.

L5 = Distance from centerline of roadway to portion of barrier parallel to roadway. Note: If the fixed feature is outside the Design Clear Zone when measured from the centerline, it may only be necessary to provide a crashtested <u>terminal</u> for the barrier (see Section 1610.04(7)(a) Beam Guardrail Placement Cases).

LH1 = Distance from outside edge of traveled way to back side of adjacent-side fixed feature.

Note: If a fixed feature extends past the Design Clear Zone, the Design Clear Zone can be used as LH1.

LH2 = Distance from centerline of roadway to back side of opposite-side fixed feature. Note: If a fixed feature extends past the Design Clear Zone, the Design Clear Zone can be used as LH2.

LR = Runout length, measured parallel to roadway.

X1 = Length of need for barrier to shield an adjacent-side fixed feature.

X2 = Length of need for barrier to shield an opposite-side fixed feature.

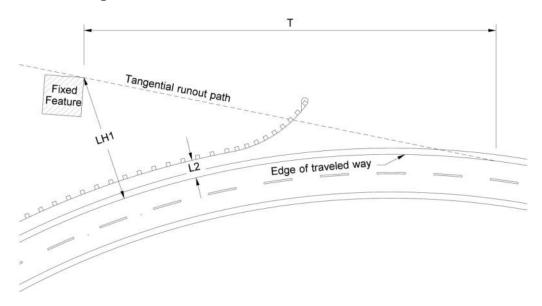
F = Flare rate value.

Y = Offset distance needed at the beginning of the length of need.

Different end treatments need different offsets:

- For the SRT 350 and FLEAT 350, use Y = 1.8 feet.
- For evaluating existing BCTs, use Y = 1.8 feet.
- For the FLEAT TL-2, use Y = 0.8 feet.
- No offset is needed for the non-flared terminals or impact attenuator systems. Use Y = 0.

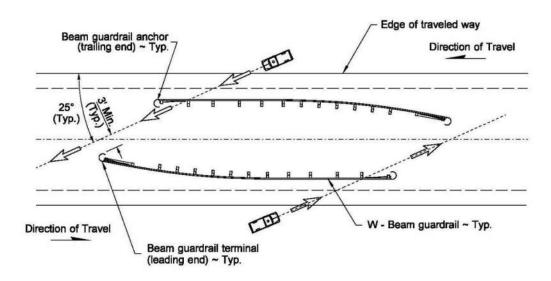
Exhibit 1610-8 Barrier Length of Need on Curves



Notes:

- This is a graphical method for determining the length of need for barrier on the outside of a curve.
- On a scale drawing, draw a tangent from the curve to the back of the fixed feature. Compare T to LR from Exhibit 1610-7 and use the shorter value.
- If using LR, follow Exhibit 1610-6 and Exhibit 1610-7.
- If using T, draw the intersecting barrier run to scale and measure the length of need.

Exhibit 1610-9 Beam Guardrail Trailing End Placement for Divided Highways



1610.03(9) Barrier Delineation

Refer to Chapter 1030 for barrier delineation requirements.

1610.04 Beam Guardrail

Strong post W-beam guardrail and thrie beam guardrail are semi-rigid barriers used predominantly on roadsides. They have limited application as median barrier. A strong-post W-beam (commonly referred to as W-Beam) guardrail system is the most common type of guardrail system used. The design uses wood or steel posts, rail, and blockouts to support the rail away from the post. The system resists a vehicle impact through a combination of the tensile and flexural stiffness of the rail and the bending or shearing resistance of the post.

Installed incorrectly, strong post W-beam guardrail can cause vehicle snagging or spearing. This can be avoided by lapping the rail splices in the direction of traffic (as shown in the *Standard Plans*), by using crash-tested end treatments, and by blocking the rail away from the posts.

Beam guardrail systems are shown in the Standard Plans.

1610.04(1) Beam Guardrail Systems

1610.04(1)(a) Type 31 Beam Guardrail

Use Type 31 guardrail for new installations. The Type 31 system uses many of the same components as the old WSDOT Type 1 system. The main differences are that the blockouts extend 12 inches from the posts, the rail height is 31 inches from the ground to the top of the rail, the deflection requirements are 2 feet greater, and the rail elements are spliced between posts.

Type 31 guardrail offers tolerance for future HMA overlays. The system allows a 3-inch tolerance from 31 inches to 28 inches without adjustment of the rail element.

Type 31 guardrail is available double-sided, which can be used in medians.

1610.04(1)(b) (Old) Type 1 Beam Guardrail

Previous WSDOT standard practice was to install W-beam guardrail at a rail height of 27 to 28 inches, and is referred to as "Type 1" guardrail. WSDOT is phasing out the use of Type 1 guardrail. Do not use Type 1 guardrail for new installations, except when the Type 1 guardrail weak post system is the best choice at an intersection due to site constraints (see Section 1610.04(7)(a)). Place new objects a minimum of 5 feet behind the face of existing beam guardrail type 1. For more information on (Old) Beam Guardrail Type 1, see: https://wsdot.wa.gov/engineering-standards/design-topics/roadside-safety.

Existing runs of Type 1 guardrail are acceptable to leave in place. If an existing run of Type 1 guardrail requires extending, use the Beam Guardrail Type 31 to Beam Guardrail Type 1 Adaptor shown in the *Standard Plans*, and complete the guardrail extension using Type 31 guardrail.

1610.04(1)(c) Other Guardrail Types

W-beam guardrail Type 2 and Type 3 have a height of 30 inches and utilize a rubrail. A rubrail is a structural steel channel added below the W-beam rail and is used in these specific designs to reduce vehicle snagging on the post. Existing runs of Type 2 or Type 3 guardrail are acceptable to leave in place. If the existing run of Type 2 or 3 requires extending contact WSDOT Design Office to identify appropriate extension methods.

Type 4 guardrail is a double-sided version of the Type 1 guardrail system. For new installation, use the Type 31 double-sided w-beam guardrail instead of Type 4 guardrail. Existing runs of Type 4 guardrail are acceptable to leave in place. If the existing run of Type 4 requires extending contact WSDOT Design Office to identify appropriate extension methods to transition to the Type 31 double-sided system.

Type 10 and Type 11 are thrie-beam guardrail systems. Existing runs of Type 10 or 11 guardrail are acceptable to leave in place. If an existing run of Type 10 or Type 11 guardrail requires extending, contact the WSDOT Design Office to discuss options.

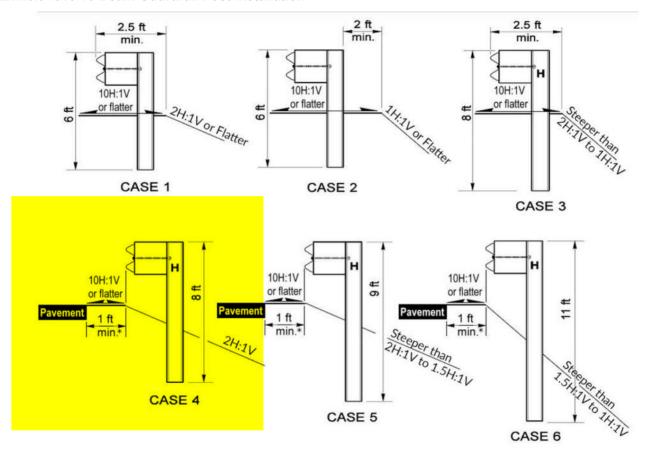
Weak post W-beam guardrail (Type 20) and thrie beam guardrail (Type 21) are flexible barrier systems primarily used in conjunction with a Service Level 1 bridge rail system for bridges with timber decks. These systems use weak steel posts. For information on Type 20 and Type 21 guardrail see: https://wsdot.wa.gov/engineering-standards/design-topics/roadside-safety

1610.04(2) Beam Guardrail Placement

There a number of considerations regarding guardrail placement. These include:

- During the project development processes, consult with maintenance staff to help identify guardrail runs that may need to be modified.
- When existing Type 1 guardrail is replaced by Type 31 guardrail along existing shoulders with a width greater than 4 feet (5 feet for bicycles), the shoulder width may be reduced by 4 inches to accommodate the 12-inch blockout. A Design Analysis is not required for the reduced shoulder width. If the remaining shoulder width is 4 feet or less, see Chapter 1030 for barrier delineation guidance.
- Keep the slope of the area between the edge of the shoulder and the face of the guardrail 10H:1V or flatter.
- Type 31 or Type 1 beam guardrail can be placed anywhere outside of the shoulder on fill slopes 10:1 or flatter.
- Type 1 beam guardrail can be placed on fill slopes between 6H:1V and 10H:1V at the slope break point of the shoulder or at least 12 feet from the slope breakpoint. This placement case does not apply to Type 31 beam guardrail.
- Do not place Type 31 or Type 1 beam guardrail with standard length posts on a fill slope steeper than 6H:1V. See Exhibit 1610-10 for allowable placement exceptions on fill slopes steeper than 6H:1V using long post beam guardrail.
- On the high side of superelevated sections, place beam guardrail at the edge of shoulder prior to the slope breakpoint.
- For W-beam guardrail installed at or near the shoulder, 2 feet of widening behind the barrier is generally provided from the back of the post to the slope breakpoint of a fill slope (see Exhibit 1610-10, Case 2). If the slope is 2H:1V or flatter, this distance can be 2.5 feet measured from the face of the guardrail rather than the back of the post (see Exhibit 1610-10, Case 1).
- On projects where no roadway widening is proposed and site constraints prevent providing the 2-foot shoulder widening behind the barrier, long post installations are available as shown in Exhibit 1610-10, Cases 3, 4, 5, and 6. When installing guardrail where the roadway is to be widened or along new alignments, the use of Cases 5 and 6 requires a Design Analysis.

Exhibit 1610-10 Beam Guardrail Post Installation



*Provide 1-foot minimum of unpaved shoulder from edge of pavement to slope breakpoint in new construction and shoulder widening to preserve the edge of pavement and side slopes from erosion (See Exhibit 1239-4).

Notes:

- Use Cases 1 and 3 when 2.5-foot or greater shoulder widening exists or will be constructed from face of guardrail to the slope breakpoint. The use of Case 3 is not allowed on slopes steeper than 1H:1V.
- Use Case 2 when 4.0-foot or greater shoulder widening exists or will be constructed from face of the guardrail to the slope breakpoint.
- Use Cases 4, 5, and 6 when less than a 2.5-foot shoulder widening exists or will be constructed from face of guardrail to the slope breakpoint (see Section 1610.04(2)). The use of Case 4 is not allowed on slopes flatter than 2H:1V. The use of Case 6 is not allowed on slopes steeper than 1H:1V.
- Cases shown do not apply to terminals, transition sections, or anchors. Install terminals, transition sections, and anchors per <u>applicable Design Manual requirements and</u> Standard Plans.
- Cases shown only apply to standard guardrail run installations that are placed parallel to the roadway. Apply Case 2 when installing guardrail on a flare (see Section 1610.03(7)) or on a radius (see Section 1610.04(7)(a)).
- See Exhibit 1239-4 for shoulder widening/grading details associated with guardrail.

1610.04(3) W-Beam Barrier Height

See Chapter 1120 when evaluating guardrail system height on Preservation (P1, P2, P3) projects.

For other projects requiring evaluation of guardrail (see Section 1105.02(1)), evaluate the guardrail system height as follows:

- For existing Type 1 guardrail with heights falling outside the range from 26.5 inches to 31 inches, adjust or replace the rail to a minimum height of 28 inches up to a maximum height of 30 inches, or replace the run with 31-inch-high Type 31 beam guardrail.
- For existing Type 31 guardrail runs with heights falling outside the range of 28 to 32 inches, adjust or replace the rail to a height of 31 inches, or replace the run with a new run of 31-inch-high Type 31 beam guardrail.

For Type 1 and Type 31 standard run W-beam guardrail, the blockout and rail element may be raised up to 4 inches by field drilling a new hole in the guardrail post. Verify that the condition of the posts and blockouts are suitable for raising in this manner. If not, the post or block will need to be replaced. See the *Standard Plans*.

If Type 1 Alternative W-beam guardrail is present, the blockout and rail element may be raised after each overlay by using the pre-drilled holes in the guardrail posts.

See Section 1610.04(5) for information on adjusting the height of guardrail terminals.

1610.04(4) Additional Guidance

Additional guidance related to w-beam guardrail:

- Crossroad and driveway locations cause gaps in the guardrail creating situations requiring special consideration. The preferred solutions are either to eliminate the need for the barrier, or realign the crossroad or driveway to accommodate the necessary guardrail run length. Alternatively, an intersection design guardrail system can be installed at the intersection. See Section 1610.04(7)(a) for more information. At these locations, a barrier flare might be needed to provide sight distance.
- Snowload post and rail washers are not used in new guardrail installations or guardrail terminal installations. Snowload post and rail washers installed on existing guardrail installations may remain in place except when the rail element is removed from post for any reason. If this occurs, remove and discard the snowload post and rail washers before reassembling the guardrail components.
- In most cases, the use of curb in conjunction with beam guardrail is discouraged. When a curb is needed place the curb as follows:
 - For Type 1 W-beam guardrail, a 3-inch high curb is preferred and it is placed flush with the face of rail or placed behind the face of the rail. The 3-inch high curb can be used for any posted speed. If necessary, a 4-inch high extruded curb is placed flush with the face of rail or placed behind the face of the rail and can be used for any posted speed. Finally, a 6-inch high extruded curb is placed flush with the face of rail or placed behind the face of the rail and can be used where the posted speed is 50 mph or below. When replacing extruded curb at locations where the posted speed is above 50 mph, use 3-inch high or 4-inch high curb. (See the Standard Plans for extruded curb designs.)
 - o For Type 31 W-beam guardrail, a 3-inch, 4-inch, or 6-inch curb is placed flush with the face of rail or placed behind the face of the rail and can be used for any posted speed. Use the shortest height curb possible. An acceptable option is to place up to a 6-inch-high extruded curb at a maximum 6 inch offset in front of the rail face at any posted speed. Contact the WSDOT Design Office for more information.

- For Type 31 W-beam guardrail placed behind curb and sidewalk, guardrail shall be placed 4-to 12-feet behind a 3-inch, 4-inch, or 6-inch curb and sidewalk for posted speeds of 45 mph or below. Use the shortest height curb possible. Contact HQ Design when placing Type 31 guardrail behind curb and sidewalk in areas with posted speeds greater than 45 mph.
- Guardrail posts should be able to rotate when the rail is impacted. When installing strong post W-beam guardrail posts in a rigid surface such as asphalt or concrete pavement, use leave-outs. Leave-outs are areas around the post that has no rigid material, which allows the post to rotate. Contact the WSDOT Design Office for more information.
- For (Old) Guardrail Types 1, 2, 3, and 4, it is acceptable to use blockouts that extend the rail element from the post for a distance not to exceed 16 inches.
- Where it is not feasible to install a post on a Type 31 system (i.e. utility or drainage conflict), one post may be omitted every 56.25 feet (9th post), except that an omitted post must be a minimum of 75 feet from an anchorage post, a minimum of 35 feet from the beginning of a thrie beam transition, and a minimum of 35 feet from the point where a terminal system joins the standard run.
 - Do not omit posts in guardrail runs with posts placed less than 2 feet from the slope break point. Guardrail runs with omitted posts must have at least 2 feet of 10:1 or flatter embankment behind them as shown in DM Exhibit 1610-11 Case 2.
 - O Do not omit posts where curb is in front of the guardrail.
 - Oconsult HQ Design for acceptable conditions to omit single posts in guardrail runs with 12' 6'', 18' 9'', or 25' 0'' span systems (see Std. Plan C-20.40) placed within the run.
 - List all the locations of omitted posts in the project plans to ensure that posts are omitted following the conditions described in this section.
- In locations where shallow fill depth prevents the installation of standard length guardrail posts (i.e. box culverts, drainage), guardrail can be spanned over the location or be attached to the top of the structure (see standard plans). When a barrier design requires the guardrail posts to be attached to the top of a structure, either: (1) Notify the structure designer from HQ Bridge about the guardrail post attachment requirement, or (2) Follow the design requirements for a structure with attached guardrail posts provided in Chapter 8 of the Bridge Design Manual. Other shallow fill designs are available. Contact HQ Design for more information about these alternative designs.

1610.04(5) Terminals and Anchors

A guardrail anchor is required at the end of a run of guardrail to develop tensile strength throughout its length. In addition, when the end of the guardrail is within the Design Clear Zone and subject to head-on impacts, a crash-tested guardrail terminal is required (see the *Standard Plans*).

See Chapter 1120 for guidance regarding the evaluation of terminals on Preservation projects (P1, P2, and P3). For projects that require the evaluation of terminals (see Section 1105.02(1)), evaluate the terminals as follows:

- Replace guardrail terminals that do not have a crash-tested design with MASH compliant crash-tested guardrail terminals. Common features of systems that do not meet current crash-tested designs include:
 - No cable anchor.
 - A cable anchored into concrete in front of the first post.
 - Second post not breakaway (CRT).
 - Design A end section (see Beam Guardrail End Sections plan sheet in the Traffic Barrier (TB) section of the Plan Sheet Library).

Design C end sections may be left in place if the terminal is otherwise a crash-tested design
 —see the Standard Plan C-7 for end section details.

- Buried guardrail terminals that slope down such that the guardrail height is reduced to less than 28 inches (measured in relation to a 10H:1V line extended from the breakpoint at edge of shoulder).
- When the height of a terminal or anchor, as measured from the ground to the top of the rail element,
 will be affected by the project, adjust the terminal or anchor based upon the following criteria:
 - o If the height of the terminal or anchor adjoining Types 1, 2, 3, or 4 guardrail will be reduced by the project to be less than 26.5 inches or increased to greater than 30 inches, adjust the height of the terminal to a minimum of 28 inches and a maximum of 30 inches. A terminal height of 30 inches is desirable to accommodate future overlays.
 - If the height of the terminal or anchor adjoining Type 31 guardrail will be reduced by the project to be less than 28 inches or increased to greater than 32 inches, adjust the height to 31 inches.
 - When adjusting terminals that are equipped with CRT posts, the top-drilled holes in the posts need to remain at the surface of the ground.
 - When adjusting the height of a terminal or anchor, adjust it by raising the posts of the terminal or anchor and tamping the ground around the posts to prevent settlement of the raised posts. Note: do not raise the blockouts or rail of the terminal or anchor by drilling new holes in the terminal posts.

One terminal that was used extensively on Washington's highways was the Breakaway Cable Terminal (BCT). This system used a parabolic flare similar to the Slotted Rail Terminal (SRT) and a Type 1 anchor (Type 1 anchor posts are wood set in a steel tube or a concrete foundation). For guidance regarding BCT's and other terminals on Preservation projects see Chapter 1120. For non-Preservation projects, replace BCTs with a currently approved terminal using the following guidance:

- Verify length of need, and adjust the terminal location as required.
- Replace adjacent transition sections that are not compliant with Section 1610.04(6).
- Transition from Type 1 to Type 31 using the adaptor (Standard Plan C-25.80) where required.
- Raise or replace the entire run if engineering judgement indicates that it is prudent for that situation.
- Use the grading criteria shown on the terminal standard plans (C-22.40 or C-22.45). When using existing grading, check to see that it complies with the grading criteria shown on the current terminal standard plans.
- Remove curbs from in front of terminals if hydraulically acceptable.

Information regarding (Old) Type 1 beam guardrail terminals can be found at: https://wsdot.wa.gov/engineering-standards/design-topics/roadside-safety

1610.04(5)(a) Buried Terminal for Type 31 Beam Guardrail

A Buried Terminal (BT) is designed to terminate the guardrail by burying the end in a backslope. The BT is the preferred terminal because it eliminates the exposed end of the guardrail.

For new BT installations, use the Buried Terminal Type 2. Previously, another BT option (the Buried Terminal Type 1) was an available choice. For existing installations, it is acceptable to leave this option in service as long as height requirements and other design criteria is met. See Beam Guardrail Type 1 – Buried Terminal Type 2 plan sheet in the Traffic Barrier (TB) section of the WSDOT Plan Sheet Library.

The BT uses a Type 2 anchor to develop the tensile strength in the guardrail. The backslope needed to install a BT is to be 3H:1V or steeper and at least 4 feet in height above the roadway.

The entire BT can be used within the length of need for backslopes of 1H:1V or steeper if the barrier remains at full height in relation to the roadway shoulder to the point where the barrier enters the backslope.

For backslopes between 1H:1V and 3H:1V, design the length of need beginning at the point where the W-beam remains at full height in relation to the roadway shoulder—usually beginning at the point where the barrier crosses the ditch line. If the backslope is flatter than 1H:1V, provide a minimum 20-foot-wide by 75-foot-long clear area that is free of fixed features behind the barrier and between the beginning length of need point at the terminal end to the mitigated object to be protected.

Flare the guardrail to the foreslope/backslope intersection using a flare rate that meets the criteria in Section 1610.03(7). Provide a 4H:1V or flatter foreslope into the face of the guardrail and maintain the full guardrail height to the foreslope/backslope intersection in relation to a 10H:1V line extending from edge of shoulder breakpoint. (See the *Standard Plans* for details.)

1610.04(5)(b) Non-flared Terminals for Type 31 Beam Guardrail

Install a non-flared terminal when a buried terminal cannot be installed as described in Section 1610.04(5)(a). WSDOT does not use flared terminals on Type 31 guardrail systems. Non-flared terminals typically use w-beam guardrail, proprietary hardware, and an impact head mounted at the leading end. These systems also include an anchor to provide tensile strength for the guardrail. Non-flared terminals absorb energy during head-on impacts by processing the rail through the impact head in varying ways depending on the manufacturer's own proprietary approach. Although these terminal systems are called non-flared, all manufacturers allow for an offset to move the impact head away from traffic.

Select non-flared terminals based on the posted speed: those restricted to locations 45 mph or below (TL-2, Standard Plan C-22.45), and those that can be installed at any posted speed (TL-3, Standard Plan C-22.40). Where practicable, provide an offset of up to one-foot over the length of the terminal (TL-2, Standard Plan C-22.45) or up to two feet over the length of the terminal (TL-3, Standard Plan C-22.40) to increase the clearance between the impact head and traffic to reduce the potential of incidental hits.

Include or confirm that embankment widening is provided as part of the terminal design and installation. Where practicable, install non-flared terminals on tangent sections of roadway. Contact HQ Design for options to install non-flared terminals on horizontal curves. Do not install snowload rail or post washers within the limits of the terminals. Do not install terminals behind or coincident with curbs.

Refer to Standard Plans C-22.40 or C-22.45 for additional details about terminal layout and dimensions that are useful in design including:

- Terminal lengths and pay limits
- Embankment widening dimensions
- Location of the Length of Need point on the terminal as it varies by manufacturer

The roadside safety website provides information on availability or acceptance of different terminal systems including approved shop drawings. (see https://wsdot.wa.gov/engineering-standards/design-topics/roadside-safety)

Chapter 1610 Traffic Barriers

1610.04(5)(c) Terminal Evolution Considerations

Some currently approved terminals have been in service for a number of years. During this time, there have been minor design changes. However, these minor changes have not changed the devices' approval status. Previous designs for these terminals may remain in place.

Note: If questions arise concerning the current approval status of a device, contact the HQ Design Office for clarification when replacement is being considered.

1610.04(5)(d) Anchors

A guardrail anchor is needed at the end of a run of guardrail to develop tensile strength throughout its length.

- Use the Type 11 anchor to develop the tensile strength of the guardrail on the end of Type 31 guardrail runs where a crash-tested terminal is not needed.
- A Type 2 anchor is used with the buried terminal.

For information on anchor types used in runs of (Old) Beam Guardrail Type 1, see: https://wsdot.wa.gov/engineering-standards/design-topics/roadside-safety.

1610.04(6) Transitions and Connections

When there is an abrupt change from one barrier type to a more rigid barrier type, a vehicle hitting the more flexible barrier may be caught in the deflected barrier pocket and directed into the more rigid barrier. This is commonly referred to as "pocketing." A transition stiffens the more flexible barrier by decreasing the post spacing, increasing the post size, and using stiffer beam elements to reduce the possibility of pocketing.

When connecting beam guardrail to a more rigid barrier or a structure use the transitions and connections that are shown in Exhibit 1610-11 and Exhibit 1610-12 and detailed in the *Standard Plans*. Verify the length of need (see Section 1610.03(8)) when designing transitions, particularly transitions between beam guardrail or end terminals to bridge structures.

Type 21 transitions can be used on highways with all posted speeds to connect w-beam guardrail to single slope, safety shape or vertical concrete barriers.

Type 22 and Type 23 transitions are used to connect w-beam guardrail to thrie beam on bridges.

Type 24 transitions can be used on highways with a posted speed of 45 mph or less to connect w-beam guardrail to single slope, safety shape or vertical concrete barriers.

When connecting a Type 21 or Type 24 Transition to an existing vertical faced bridge rail with a low parapet, a special connection plate may be required. Coordinate with the WSDOT Bridge and Structures Office (BSO). The transition pay item includes the connection.

Install transitions on 10:1 or flatter slopes with the 10:1 or flatter slope extending a minimum of 2 feet behind the guardrail transition post similar to what is shown in DM Exhibit 1610-10 Placement Case 2.

For information regarding transitions used with (Old) Type 1 guardrail see: https://wsdot.wa.gov/engineering-standards/design-topics/roadside-safety

Appendix C

	IMPACT ATTENUATOR SELECTION TEMPLATE (Form Date 9/24/21)										
	Project:	:					Tolt River Terrace Subdivision				
	Location:						Tolt Ave in Carnation WA				
	NCHRP 350 or MASH 16 Compliant:	MAS	SH								
	By (Name):	Trer	nton Skod	a, PE				Date:			11/17/2021
IMPA	CT ATTENUATOR SYSTEM NAME:					£		£	- d		
Click o	on the name below for a description of the system's purpose,		350	Temporary		Width	Object	Length	Distance Beyond Length of Need (See DM Exhibit 1620 1)		Reason impact attenuator eliminated (SQ1, SQ2, etc.)
parts,	and function, as well as transition needs, foundation, and slope	Je	₹P.	od	(3)	e v	8	n Lk	ngt oit 1	(8)	nua 12, c
requir	ements for the attenuator.	tenance	훙	e	ph)	tsid	pə	ten	Le chik	o.	SQ ff
		_ ⊆	or NCHRP		Speed (mph) ⁽³⁾	Outside et)	Shielded t)	System	ond 1.E.	Category	.t a. 21,
	the "Impact Attenuator Selection Template" is updated on a periodic basis. As	Mai	.6 or N	t (P), h (B)	bes	ite (fee	.c. Shi	ıte	eyo DIV		pac (So
	t, there may be MASH compliant impact attenuators accepted onto the	3	201 ant	nent Both	Spe	<u>ב</u> ב	num Sk (feet)	im (e B	Cost	in ted
	QPL that are not shown on this selection template. <u>Always check the</u> QPL to ensure that all MASH compliant impact attenuators accepted onto	2	H 2	mar or E	eq	proxima	ii ti	eet	anc d (S) E	ina
	are considered for the project.	Ė	MASH 2016 Compliant ^{(s}	Permanent ((T), or Both	Posted	Approximate of System (fe	Maximu Width (f	Approximate ⁽⁷⁾ (feet)	ista leer)	nitial	Reason impact eliminated (SQ
		لتا)	_		ATTENUATORS	2	4 5	Ξžπ	_=_	<u>~ 0</u>
Quad	uard Elite(8-Bay) - 24"/30"/36"/69"/90" widths	LM		B	> 60	2.5/3.0 /3.5/.6.3/8.0	2.0/2.5/3.0 /5.8/7.5 ⁽¹⁰⁾	27.1	3.3	С	Posted Speed
	uard Elite (5-Bay) - 24"/30"/36"/69"/90" widths	LM		В	< 45	2.5/3.0 /3.5/6.3/8.0	2.0/2.5/3.0 /5.8 ⁽¹⁰⁾ /7.5 ⁽¹⁰⁾	18	3.3	С	Not MASH
	uard Elite M10 (8-Bay) - 24" width	LM		В	> 60	2.5	2.0	26.2	2.2	С	Posted Speed
	uard Elite M10 Wide (8-Bay) - 69" width	LM		В	≥ 60	6.3	5.8	26.2	2.2	D	Posted Speed
REACT	350 (9-Bay)	LM	350	В	<u>></u> 60	4.0	3.0	30.5	4.3	D	Not MASH
REACT	350 (6-Bay)	LM	350	В	<u><</u> 55	4.0	3.0	20	4.3	D	Posted Speed
REACT	350 (4-Bay)	LM	350	В	<u>< 45</u>	4.0	3.0 ⁽¹⁰⁾	15.5	4.3	D	Posted Speed
REACT	350 Wide TL-3 (60"/96"/120" widths)	LM	350	В	<u>></u> 60	5.2/8.2/10.2	5.0/8.0 ⁽¹⁰⁾ /10.0 ⁽¹⁰⁾	32.8/36.8/36.8	4.3	D	Not MASH
REACT	350 Wide TL-2 (60"/96" widths)	LM	350	В	<u><</u> 45	5.2/8.2/10.2	5.0 ⁽¹⁰⁾ /8.0 ⁽¹⁰⁾ /10.0 ⁽¹⁰⁾	21	4.3	D	Posted Speed
SCI100		LM		В	<u>></u> 60	3.1	2.0/2.5/3.0	21.5/24.4/25.9	3	С	Posted Speed
	GM with Variable Width Wide Transition (37" to 54" widths)	LM		В	<u>></u> 60	3.3-3.4/3.5-4.0/4.1-4.7	3.1-3.2/3.3-3.8/3.9-4.5	29.1/31.1/33.1	3	С	Posted Speed
	GM with Variable Width Wide Transition (55" to 78" widths)	LM		В	<u>></u> 60	4.8-5.4/5.5-6.1/6.2-6.7	4.6-5.2/5.3-5.9/6.0-6.5	35.0/37.0/39.0	3	С	Posted Speed
	GM with Variable Width Wide Transition (79" to 103" widths)	LM		В	<u>></u> 60	6.8-7.4/7.5-8.0/8.1-8.8	6.6-7.2/7.3-7.8/7.9-8.6	40.9/42.9/44.8	3	С	Posted Speed
	GM with Variable Width Wide Transition (104" to 127" widths)	LM		В	<u>></u> 60	8.9-9.4/9.5-10.0/10.1-10.8	8.7-9.2/9.3-9.8/9.9-10.6	46.8/48.7/50.7	3	С	Posted Speed
SC1706		LM		В	< 45	3.1	2.0/2.5/3.0	13.5/15.4/16.9	3	С	Option 1
	M with Variable Width Wide Transition (37" to 54" widths)	LM		В	<u>> 60</u>	3.3-3.4/3.5-4.0/4.1-4.7	3.1-3.2/3.3-3.8/3.9-4.5	21.1/23.1/25.1	3	С	Posted Speed
	M with Variable Width Wide Transition (55" to 78" widths) M with Variable Width Wide Transition (79" to 103" widths)	LM		B B	≥ 60 ≥ 60	4.8-5.4/5.5-6.1/6.2-6.7 6.8-7.4/7.5-8.0/8.1-8.8	4.6-5.2/5.3-5.9/6.0-6.5 6.6-7.2/7.3-7.8/7.9-8.6	27.0/29.0/31.0 32.9/34.9/36.8	3	C C	Posted Speed Posted Speed
	M with Variable Width Wide Transition (104" to 127" widths)	LM		В	> 60	8.9-9.4/9.5-10.0/10.1-10.8	8.7-9.2/9.3-9.8/9.9-10.6	38.8/40.7/42.7	3	С	Posted Speed
CAT 35		LIVI	350	P	> 60	2.5	2.0	31.3	18.8	A	Posted Speed
	rend 350 (4)	${}^{+}$	350	P	> 60	1.3	2.0 ⁽¹⁰⁾	20	10.5	A	Posted Speed
	(8-Bay, 30" width)	T	350	P	> 60	2.9	2.5	25.4	3.0	D	Posted Speed
	(8-Bay, 42"/48"/54"/60" widths)		350	P	<u>></u> 60	4.4/4.9/5.4/5.9	3.9/4.4/4.9/5.4	27.1	3.0	D	Posted Speed
	(7-Bay, 66"/72"/78"/84"/90"/96" widths)		350	Р	<u>≥</u> 60	6.4/6.9/7.4/7.9/8.4/8.9	$5.9^{(10)}/6.4^{(10)}/6.9^{(10)}/7.4^{(10)}/7.9^{(10)}/8.4^{(10)}$	24.2	3.0	D	Posted Speed
al Tau II	(7-Bay, 30" width)		350	Р	<u><</u> 55	2.9	2.5 ⁽¹⁰⁾	22.7	3.0	С	Not MASH
<u>H</u>	(7-Bay, 42"/48"/54"/60" widths)		350	Р	<u><</u> 55	4.4/4.9/5.4/5.9	$3.9^{(10)}/4.4^{(10)}/4.9^{(10)}/5.4^{(10)}$	24.2	3.0	D	Not MASH
rsa	(5-Bay, 72"/78"/84"/90"/96" widths)	$oldsymbol{oldsymbol{oldsymbol{\square}}}$	350	Р	<u><</u> 55	6.9/7.4/7.9/8.4/8.9	$6.4^{(10)}/6.9^{(10)}/7.4^{(10)}/7.9^{(10)}/8.4^{(10)}$	18.6	3.0	D	Not MASH
Univers	(5-Bay, 30" width)	₩'	350	Р	<u><</u> 50	2.9	2.5 ⁽¹⁰⁾	16.9	3.0	С	Not MASH
ᅴ	(5-Bay, 42"/48"/54"/60" widths)	₩	350	Р	<u><</u> 50	4.4/4.9/5.4/5.9	$3.9^{(10)}/4.4^{(10)}/4.9^{(10)}/5.4^{(10)}$	18.6	3.0	D	Not MASH
	(4-Bay, 66"/ 72"/78"/84"/90"/96" widths)	₩'	350	Р	<u><</u> 50	6.4/6.9/7.4/7.9/8.4/8.9	5.9 ⁽¹⁰⁾ /6.4 ⁽¹⁰⁾ /6.9 ⁽¹⁰⁾ /7.4 ⁽¹⁰⁾ /7.9 ⁽¹⁰⁾ /8.4 ⁽¹⁰⁾	16	3.0	D	Not MASH
	(4-Bay, 30" width)	╨	350	P	<u>< 45</u>	2.9	2.5	14.5	3.0	С	Not MASH
	(4-Bay, 42"/48"/54"/60" widths)	$+\!-\!\!\!\!-$	350	Р	< 45	4.4/4.9/5.4/5.9	3.9 ⁽¹⁰⁾ /4.4 ⁽¹⁰⁾ /4.9 ⁽¹⁰⁾ /5.4 ⁽¹⁰⁾	16	3.0	С	Not MASH
	(8-Bay, 30" width)	$+\!-\!\!\!\!-$	350	Р	≥ 60	2.9	2.5	25.4	3.0	D	Posted Speed
	(8-Bay, 36"/42"/48"/54"/60" widths)	$+\!-\!\!\!\!-$	350	Р	≥ 60	3.8/4.4/4.9/5.4/5.9	3.3/4.4/4.9/5.4	27.1	3.0	D	Posted Speed
~1	(7-Bay, 66"/72"/78"/84"/90"/96" widths)	$+\!-\!\!\!\!-$	350	P P	≥ 60	6.4/6.9/7.4/7.9/8.4/8.9 2.9	$\frac{5.9^{(10)}/6.4^{(10)}/6.9^{(10)}/7.4^{(10)}/7.9^{(10)}/8.4^{(10)}}{2.5^{(10)}}$	24.2 22.7	3.0	D	Posted Speed Not MASH
<u> </u>	(7-Bay, 30" width) (7-Bay, 36"/42"/48"/54"/60" widths)	\vdash	350 350	P	< 55 < 55	3.8/4.4/4.9/5.4/5.9	3.3 ⁽¹⁰⁾ /3.9 ⁽¹⁰⁾ /4.4 ⁽¹⁰⁾ /4.9 ⁽¹⁰⁾ /5.4 ⁽¹⁰⁾	24.2	3.0	C D	Not MASH
'sal Tau-II-R	(6-Bay, 66"/72" widths)	+	350	P	< 55 < 55	6.4/6.9	5.9 ⁽¹⁰⁾ /6.4 ⁽¹⁰⁾	19.9/19.0	3.0	D	Not MASH
. Jes	(5-Bay, 78"/84"/90"/96" widths)	+	350	P	< 55	6.9/7.4/7.9/8.4/8.9	$6.4^{(10)}/6.9^{(10)}/7.4^{(10)}/7.9^{(10)}/8.4^{(10)}$	18.6	3.0	D	Not MASH
Ver	(5-Bay, 76 764 750 750 widths)	\vdash	350	P	< 50	2.9	2.5 ⁽¹⁰⁾	16.9	3.0	С	Not MASH
= =	(3 Sur, 30 William)	ш	330		<u>\</u> 30	2.3	1 2.3	10.3	5.0	·	Page 1 of

							(10) (10) (10) (10)				_
기	(5-Bay, 36"/42"/48"/54"/60" widths)		350	Р	<u><</u> 50	-3.8/4.4/4.9/5.4/5.9	$_{rs}$ 3.3 ⁽¹⁰⁾ /3.9 ⁽¹⁰⁾ /4.4 ⁽¹⁰⁾ /4.9 ⁽¹⁰⁾ /5.4 ⁽¹⁰⁾	18.6	3.0	D	Not MASH
	(4-Bay, 66"/ 72"/78"/84"/90"/96" widths)		350	Р	<u><</u> 50	6.4/6.9/7.4/7.9/8.4/8.9	$5.9^{(10)}/6.4^{(10)}/6.9^{(10)}/7.4^{(10)}/7.9^{(10)}/8.4^{(10)}$	16	3.0	D	Not MASH
	(4-Bay, 30" width)		350	Р	<u><</u> 45	2.9	2.5	14.5	3.0	С	Not MASH
	(4-Bay, 36"/42"/48"/54"/60" widths)		350	Р	<u><</u> 45	3.8/4.4/4.9/5.4/5.9	$3.3^{(10)}/3.9^{(10)}/4.4^{(10)}/4.9^{(10)}/5.4^{(10)}$	16	3.0	С	Not MASH
TAU-N	1 TL-3 (7-Bay) - 30" width	N	MASH	В	<u>></u> 60	2.9	2.5	22.8	2.5	С	Posted Speed
TAU-N	1 TL-2 (4-Bay) - 30" width	N	MASH	В	<u><</u> 45	2.9	2.5	14.2	2.5	С	Option 2 - Not LM
ard	(6-Bay, 24"/30"/36"/90"/120" widths)		350	В	<u>></u> 60	2.5/3.0 /3.5/8.0/10.5	$2.0/2.5^{(10)}/3.0^{(10)}/7.5^{(10)}/10^{(10)}$	22.1	3.3	С	Posted Speed
96	(5-Bay, 24"/30"/36"/90" widths)		350	В	<u><</u> 55	2.5/3.0 /3.5/8.0	$2.0^{(10)}/2.5^{(10)}/3.0^{(10)}/7.5^{(10)}$	19.1	3.3	С	Posted Speed
ad	(4-Bay, 24"/30"/36"/69"/90" widths)		350	В	<u><</u> 50	2.5/3.0 /3.5/6.3/8.0	$2.0^{(10)}/2.5^{(10)}/3.0^{(10)}/7.5^{(10)}$	16.1	3.3	С	Posted Speed
쥥	(3-Bay, 24"/30"/36"/69"/90" widths)		350	В	<u><</u> 45	2.5/3.0 /3.5/6.3/8.0	$2.0/2.5^{(10)}/3.0^{(10)}/5.7^{(10)}/7.5^{(10)}$	13.1	3.3	В	Not MASH
= p	(5-Bay, 24"/30"/36"/90" widths)		350	В	<u>></u> 60	2.5/3.0 /3.5/8.0	$2.0^{(10)}/2.5^{(10)}/3.0^{(10)}/7.5^{(10)}$	19.1	3.3	С	Posted Speed
nar	(4-Bay, 24"/30"/36"/69"/90" widths)		350	В	<u><</u> 55	2.5/3.0 /3.5/6.3/8.0	$2.0^{(10)}/2.5^{(10)}/3.0^{(10)}/5.8^{(10)}/7.5^{(10)}$	16.1	3.3	С	Posted Speed
adG	(3-Bay, 24"/30"/36"/69"/90" widths)		350	В	<u><</u> 50	2.5/3.0 /3.5/.6.3/8.0	$2.0^{(10)}/2.5^{(10)}/3.0^{(10)}/5.8^{(10)}/7.5^{(10)}$	13.1	3.3	В	Posted Speed
ηO	(2-Bay, 24"/30"/36" widths)		350	В	<u><</u> 45	2.5/3.0 /3.5	$2.0^{(10)}/2.5^{(10)}/3.0^{(10)}$	10	3.3	В	Not MASH
Quad	Guard M10 TL-3 - 24" width	N	MASH	В	<u>></u> 60	2.5	2.0	22.1	3.3	D	Posted Speed
Quad	Guard M10 TL-2 - 24" width	N	MASH	В	<u><</u> 45	2.5	2.0	13.1	3.3	D	Option 3 - Not LM and Cost
HEAR			350	В	<u>></u> 60	3.0	2.0	26	5.0	D	Posted Speed
Comp	ressor		350	В	<u>></u> 60	4.1	3.0 ⁽¹⁰⁾	21.3	3.0	D	Posted Speed
X-TEN	<u>uator</u>		350	В	≥ 60	3.0	2.0	24.8	5.5	Α	Posted Speed

IMPACT ATTENUATOR SYSTEM NAME: Click on the name below for a description of the system's purpose, parts, and function, as well as transition needs, foundation, and slope requirements for the attenuator. Note: The "Impact Attenuator Selection Template" is updated on a periodic basis. As a result, there may be MASH compliant impact attenuators accepted onto the WSDOT QPL that are not shown on this selection template. Always check the WSDOT QPL to ensure that all MASH compliant impact attenuators accepted onto the QPL are considered for the project.	LM - Low Maintenance	MASH 2016 or NCHRP 350 Compliant ^{(9) (11)}	Permanent (P), Temporary (T), or Both (B)	Posted Speed (mph) ⁽³⁾	Approximate Outside Width of System (feet)	Maximum Shielded Object Width (feet)	Approximate System Length ⁽⁷⁾ (feet)	Distance Beyond Length of Need (See DM Exhibit 1620- 1)	Initial Cost Category ⁽⁸⁾	Reason impact attenuator eliminated (SQ1, SQ2, etc.)
ABSORB 350 TL-3 (5)		350	EIVIPU	> 60	2.0	2.0	32.0	N/A (2)	В	Temporary
ABSORB 350 TL-2		350	T	< 45	2.0	2.0	19.3	N/A (2)	В	Temporary
ABSORB-M TL-3 (5)		MASH	Т	> 60	2.0	2.0	30.0	N/A (2)	A	Temporary
ABSORB-M TL-2		MASH	T	< 45	2.0	2.0	14.6	N/A (2)	A	Temporary
ADIEM 350		350	T	< 45	2.7	2.0	30.0	14.1	В	Temporary
(6-Bay, 24"/30"/36" widths)		350	Т	<u>></u> 60	2.5/3.0 /3.5	2.0/2.5/3.0	22.1	3.3	D	Temporary
(6-Bay, 24"/30"/36" widths) (5-Bay, 24"/30"/36" widths) (4-Bay, 24"/30"/36" widths) (3-Bay, 24"/30"/36" widths)		350	T	<u><</u> 55	2.5/3.0 /3.5	2.0/2.5/3.0	19.1	3.3	D	Temporary
(4-Bay, 24"/30"/36" widths)		350	Т	<u><</u> 50	2.5/3.0 /3.5	2.0/2.5/3.0	16.1	3.3	С	Temporary
(3-Bay, 24"/30"/36" widths)		350	Т	< 45	2.5/3.0 /3.5	2.0/2.5/3.0	13.1	3.3	С	Temporary
N-E-A-T		350	Т	< 45	1.9	2.0	10.0	N/A (2)	В	Temporary
TRACC		350	T ⁽⁶⁾	<u>></u> 60	2.6	2.0	21.3	8.0	В	Temporary
ShorTRACC		350	T ⁽⁶⁾	< 45	2.6	2.0	14.3	8.0	В	Temporary
Triton CET TL-3 (5)		350	Т	<u>></u> 60	1.8	2.0	40.0	N/A (2)	Α	Temporary
Triton CET TL-2		350	Т	<u>< 45</u>	1.8	2.0	40.0	N/A (2)	Α	Temporary
QUEST TL-3 (24"/30"/36" widths)		350	Т	<u>></u> 60	3.0/3.5/4.0	2.0/2.5/3.0	28.0	3.5	В	Temporary
QUEST TL-2 (24"/30"/36" widths)		350	T	<u><</u> 45	3.0/3.5/4.0	2.0/2.5/3.0	22.0	3.5	В	Temporary
ACZ-350 TL-3 (5)		350	T	<u>></u> 60	1.7	2.0	31.6	N/A (2)	Α	Temporary
ACZ-350 TL-2		350	Т	<u><</u> 45	1.7	2.0	18.4	N/A (2)	Α	Temporary
<u>SLED TL-3 (5)</u>		350	Т	<u>></u> 60	2.0	2.0	26.0	N/A (2)	В	Temporary
SLED TL-2		350	T	<u><</u> 45	2.0	2.0	19.0	N/A (2)	В	Temporary

NOTES

- [1] Generally for use with double-sided beam guardrail
- [2] The ABSORB 350, ABSORB-M, N-E-A-T, Triton CET, ACZ 350, and SLED may only be used beyond the barrier length of need. The entire attenuator system is gating and does not redirect vehicles impacting the side of the attenuator.
- [3] It is acceptable to use an attenuator rated for a higher posted speed on a roadway with a lower posted speed. For example: an attenuator rated for > 60 mph may be used on a roadway with posted speed of 50 mph (see DM 1620.03).
- [4] See manufacturer's requirements for slope and clear area behind the device.
- [5] This attenuator does not provide redirection for vehicles striking the side of the system. Test Level 3 version on high-speed facilities should be limited to locations where the likelihood of side impacts is low.
- [6] May be considered for permanent installations with concurrence of the Area Maintenance Superintendent.
- [7] The given dimension is the approximate system length. The effective length may vary depending on such factors as the physical design and type of anchorage used. To verify the total length needed, refer to the manufacturer's specifications and drawings.
 - Cost Category: A (\$5,000 to \$10,000); B (\$10,000 to \$15,000); C (\$15,000 to \$25,000); D (\$25,000 to \$50,000).
- [8] These are rough initial cost estimates of the base impact attenuator unit only. Impact attenuator transitions, other custom parts, installation costs, foundation construction costs, and overhead & profit costs are not included in these price estimates. Verify actual costs through manufacturers/suppliers. Some products are priced very close to the margin between cost categories.
- [9] For Impact Attenuators Check QPL Standard Specification 8-17.1

	NCHRP 350 compliant attenuators are allowed with approval [See DM 1620.03(2)] where:	Table 1 - List of Attenuato	NCHRP 350 compliant attenuators are allowed with approval [See DM 1620.03(2)] where:
	Posted Speed Limit - Greater than 45 mph	Tuble 1 List of Attendate	Posted Speed Limit - 45 mph or less
	Shielded object width is 2.0-feet or less and the required attenuator system length is less than 21.5-feet		Shielded object width is 2.0-feet or less and the required attenuator system length is less than 13.1-feet
	Shielded object width is 2.1- to 2.5-feet and the required attenuator system length is less than 22.8-feet		Shielded object width is 2.1- to 2.5-feet and the required attenuator system length is less than 14.2-feet
	Shielded object width is 2.6- to 3.0-feet and the required attenuator system length is less than 25.9-feet		Shielded object width is 2.6- to 3.0-feet and the required attenuator system length is less than 16.9-feet
	Shielded object width is 3.1- to 5.8-feet and the required attenuator system length is less than 26.2-feet		Shielded object width is 3.1- to 3.2-feet and the required attenuator system length is less than 21.1-feet
	Shielded object width is 5.9-feet and the required attenuator system length is less than 37.0-feet		Shielded object width is 3.3- to 3.8-feet and the required attenuator system length is less than 23.1-feet
	Shielded object width is 6.0- to 6.5-feet and the required attenuator system length is less than 39.0-feet		Shielded object width is 3.9- to 4.5-feet and the required attenuator system length is less than 25.1-feet
[10]	Shielded object width is 6.6- to 7.2-feet and the required attenuator system length is less than 40.9-feet		Shielded object width is 4.6- to 5.2-feet and the required attenuator system length is less than 27.0-feet
	Shielded object width is 7.3- to 7.8-feet and the required attenuator system length is less than 42.9-feet		Shielded object width is 5.3- to 5.9-feet and the required attenuator system length is less than 29.0-feet
	Shielded object width is 7.9- to 8.6-feet and the required attenuator system length is less than 44.8-feet		Shielded object width is 6.0- to 6.5-feet and the required attenuator system length is less than 31.0-feet
	Shielded object width is 8.7- to 9.2-feet and the required attenuator system length is less than 46.8-feet		Shielded object width is 6.6- to 7.2-feet and the required attenuator system length is less than 32.9-feet
	Shielded object width is 9.3- to 9.8-feet and the required attenuator system length is less than 48.7-feet		Shielded object width is 7.3- to 7.8-feet and the required attenuator system length is less than 34.9-feet
	Shielded object width is 9.9- to 10.6-feet and the required attenuator system length is less than 50.7-fee	t	Shielded object width is 7.9- to 8.6-feet and the required attenuator system length is less than 36.8-feet
			Shielded object width is 8.7- to 9.2-feet and the required attenuator system length is less than 38.8-feet
			Shielded object width is 9.3- to 9.8-feet and the required attenuator system length is less than 40.7-feet
			

[11] MASH or NCHRP 350 compliant attenuators are allowed in temporary applications. See Std. Spec. 8-17.3 and Std. Spec. 1-10.2(3)

IMPACT ATTENUATOR SELECTION QUESTIONS

Note: The impact attenuator selection questions shown below are common selection criteria requiring evaluation. There may be other attenuator selection criteria needing evaluation not shown. See DM 1620.03 (1), and 1620.03 (2) for comprehensive guidance concerning impact attenuator selection. Use the space provided in SQ13 "Other Impact Attenuator Selection Considerations" section to evaluate and document any attenuator selection criteria not addressed in the given selection questions.

ID	Selection Questions (SQ)	Selection Question Answers	Instructions
SQ1	Is the impact attenuator permanent or temporary?	Permanent	Eliminate and highlight in red all attenuators not meeting answer #1 criteria for attenuator type
SQ2	Is a Low-Maintenance Category impact attenuator needed at the location? (See DM 1620.03(1) for guidance)	n/a	If a Low-Maintenance attenuator is needed, eliminate and highlight in red all attenuators not considered Low-Maintenance.
SQ3	What is the posted speed limit of the roadway where the impact attenuator is located?	30	Eliminate and highlight in red all attenuators whose rated speed is less than the speed shown in answer #3
SQ4	What is the width of the object being shielded?	0	Eliminate and highlight in red all attenuators whose maximum shielded object width is less than the width shown in answer #4
SQ5	What is the available length and width of area to place the attenuator?	3'	Eliminate and highlight in red all attenuators whose system length and width is greater than the length and width shown in answer #5
SQ6	What type of surface is the attenuator being placed on? (i.e. concrete pavement, asphalt pavement, concrete foundation, compacted soil, other)	compacted soil	Eliminate and highlight in red all attenuators which cannot be placed on the surface shown in answer #6 (see manufacturer's online installation guide and/or contact the manufacturer)
SQ7	If a foundation is being constructed for the attenuator because the existing roadway surface is not suitable for use of the attenuator foundation, what is the available length, width, and depth of the area for the attenuator foundation construction?	n/a	Eliminate and highlight in red all attenuators whose foundation length, width, and depth requirements are greater than the dimenstion shown in answer #7. (see manufacturer's online installation guide and/or contact the manufacturer)
SQ8	What are the longitudinal slope and cross slope that the impact attenuator is being placed upon? What are the slope(s) adjacent/advance to the attenuator?	3 to 1	Eliminate and highlight in red all attenuators which require cross and longitudinal slopes flatter than the slopes shown in answer #8 (see manufacturer's online installation guide and/or contact the manufacturer)
SQ9	What type of barrier or object is the impact attenuator connecting to? (i.e. Type F or Single-Slope concrete barrier, Type 31 beam guardrail or thrie beam, back-up structure, bridge pier, other)	Type 31 Beam guardrail	Eliminate and highlight in red all attenuators or attenuator transitions that cannot be connected to the barrier or object shown in answer #9. (see manufacturer's online installation guide and/or contact the manufacturer)
	Is there curb placed between the impact attenuator and traffic? (directly in front-of or in advance-of the attenuator)	Yes, 6 inch curb. Direcly infront	Eliminate and highlight in red all attenuators which: (A) Do not allow curb to be placed in front-of or adjacent to the attenuator
SQ10	If there is curb, what is the height of the curb? (See DM 1620.02 for guidance on impact attenuators and curbs)		OR (B) Allow curb but the curb on the project is taller than the maximum curb height allowed for the attenuator (see manufacturer's installation guide, and/or contact the manufacturer)

SQ14 project	Total if asing an iternal 350 compliant permanent attenuator instead of a firebrick compliant permanent attenuator, see Diff 1020/05(2) for necessary approvaising						
Are the project	ist the attenuators to be included as Contractor options at this location. Note: If using an NCHRP 350 compliant permanent attenuator instead of a MASH compliant permanent attenuator, see DM 1620.03(2) for necessary approvals.)						
Are the	ATTENUATORS ACCEPTABLE FOR USE AT PROJECT LOCATION						
SQ13	nere any MASH impact attenuators listed on the WSDOT QPL that are not shown on the "Impact of location. If the attenuator(s) cannot be used, please note which Selection Question (SQ1 - SQ1		•				
	impact attenuator selection considerations (Document any other impact attenuator selection cr						
installi	SQ1 through SQ12 have been answered, consider whether maintenance has concerns about ling any of the remaining impact attenuators on the project and how those concerns might be essed. (See DM 1620.02 for guidance on consulting with maintenance)		Consider the concerns raised by maintenance about the remaining attenuators and determine if those concerns result in a fatal flaw that cannot be addressed. Eliminate and highlight in red all attenuators with maintenance concerns. (Provide documentation on this sheet in "answer section" or attached to sheet when eliminating an attenuator due to maintenance concerns)				
Does t powde SQ11	the impact attenuator need an aesthetic treatment? (i.e. reactive coloring agent such as Natina, er coating, other See DM 1610.08(2))		If an aesthetic treatment is needed, eliminate and highlight in red all attenuators which do not allow aesthetic treatments to be applied to their surfaces (see manufacturer's online installation guide and/or contact the manufacturer)				

Smart Cushion Innovations SCI100GM / SCI70GM

- 1. **Purpose:** The SCI100GM and SCI70GM are end treatments for concrete barrier, beam guardrail, and fixed objects up to 36-inches (3-feet) wide. In addition, Variable Width Wide Transitions are available for use with the SCI 100 GM or SCI 70 GM to shield objects up to 127-inches (10.5-feet) wide.
- 2. **Description:** The system for both models consists of a front sled assembly, telescoping steel side panels mounted to collapsing steel frames, a shock arresting cylinder, and a steel cable routed around sheave assemblies. It is mounted on a base with a series of tubular steel side frame assemblies.
- 3. **Function:** During a head-on impact, the system telescopes backwards and dissipates impact energy with a combination of friction between the steel cable and sheaves as well as variable resistance from the shock arresting cylinder. During a side impact, a vehicle is redirected by the steel side panels. It is anticipated that this system will not need many replacement parts or extensive repairs following typical head-on or side impacts.
- 4. **Foundation:** The system is installed on a concrete foundation (see manufacturer's installation information for details).
- 5. **Slope:** Longitudinal and cross slopes at the installation site must be 10H:1V or flatter.
- 6. Transitions: A transition section is not needed for concrete barrier and fixed objects exposed to traffic from only one direction. A custom transition section per manufacturer's specifications is needed for connection to a concrete barrier or fixed object exposed to bidirectional traffic. If used as an end treatment for beam guardrail, the system must be connected to a transition section. (See Chapter 1610 and the Standard Plans for the type of transition section required.) Connection of the transition section to the attenuator must be per the manufacturer's specifications using custom connection pieces (included in the cost of the attenuator).
- 7. Manufacturer/Supplier: Hill and Smith, Inc. / Work Area Protection Corp.



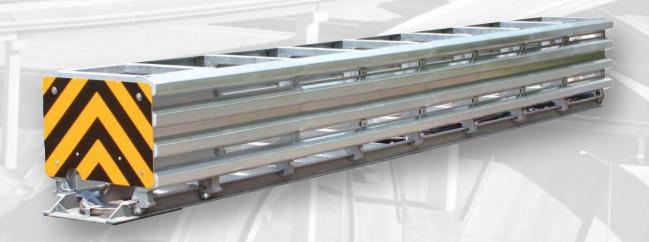
SCI100GM - Permanent and Work Zone Installations



SCI70GM AND SCI100GM DESIGN, INSTALLATION AND MAINTENANCE MANUAL

The World's Only Speed-Dependent Crash Attenuator





SMART CUSHION®

MASH 2016 | NCHRP 350 Compliant

Hill & Smith Inc.

987 Buckeye Park Road • Columbus, OH 43207 Phone: 614 340.6294 • Fax: 614.340.6296 Web:www.hillandsmith.com

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Officet Congreta Block	т

1

OVERVIEW

Product

The SMART CUSHION® impact attenuators are manufactured by Hill and Smith, Inc. The Test Level 3 model is NCHRP 350/MASH approved by the FHWA. The Test Level 2 is NCHRP 350 approved and has passed the MASH capacity test #2-31. Based on that test, it is MASH approved in many states. They and are fully redirective, non-gating, and bi-directional. SMART CUSHION® impact act attenuators are used to help protect motorists from hazards in both permanent and temporary work zone locations. They can be attached to most types of median and roadside barriers.

The SMART CUSHION® attenuators use a patented system for stopping vehicles. The system is speed dependent and stops small and large vehicles by automatically regulating the stopping force exerted on a vehicle. Essentially, the system provides the necessary forces based on the speed of the vehicle automatically compensating for the mass of the vehicle.

The SMART CUSHION® attenuators are slightly tapered from front to rear. This allows the side panel sections to collapse over the next section without stress or damage. During collapse, the parts move freely past each other and do not become wedged during the impact.

Wide temperature variations and temperature extremes do not affect the performance of SMART CUSHION® impact attenuators.

Maintenance

SMART CUSHION® impact attenuators are low-maintenance units. A trained, two-person maintenance crew can return most impacted SMART CUSHION® attenuators to full service within 30 minutes. This short repair time reduces the maintenance workers' exposure to traffic and minimizes traffic congestion. Side impacts rarely require a repair which eliminates worker exposure, repair costs and traffic delays/exposure.

Crash Performance

The SMART CUSHION® broke new ground during NCHRP Report 350 crash testing. In the high-speed test, 100 kilometers per hour (63 miles per hour), the small vehicle's deceleration rate was significantly lower than any previously recorded value (-9.8 G's as compared to previous low of -13.4 G's). This means less impact forces on the vehicle's occupants and a reduced risk of injury due to a much lower impact severity.

The NCHRP 350 Test Level 3 Smart Cushion performed and passed ALL MASH tests to exact MASH standards with no modifications. The NCHRP Test Level 2 Smart Cushion also performed and passed the pickup capacity test #2-32 with no modifications. These tests were performed by an accredited independent testing facility. As with the NCHRP 350 tests, MASH frontal impacts only needed two shear bolts to reset the unit back to full operation status.



SPECIFICATIONS

Description

The SMART CUSHION® is a re-directive, non-gating crash attenuator that consists of a base, supporting frames, a sled, side panels, a wire rope cable, sheaves, and a shock-arresting cylinder. The base is anchored to the mounting surface and provides support for the frames that are mounted on it. The support frames hold the side panels that provide a flat outer redirective surface for side impacts. The sled provides redirective support for side impacts and deceleration force for frontal impacts. The SMART CUSHION® telescopes rearward upon frontal impact and can be reset with minimal repair parts.

System Dimensions & Weight

	SCI 70 GM	SCI 100 GM
Width	24 inch (610 mm)	24 inch (610 mm)
Length	13 ½ feet (4115 mm)	21 ½ feet (6550 mm)
Height	33 inch (840 mm)	33 inch (840 mm)
Weight	2465 lbs. (1120 kg)	3450 lbs. (1570 kg)
Test Level	MASH / NCHRP 350 Level 2	MASH / NCHRP 350 Level 3

DESIGN CRITERIA

General

SMART CUSHION® impact attenuators comply with MASH and NCHRP Report 350. They are designed for temporary work zone and permanent applications.

Foundations

Foundations must be a flat surface with longitudinal and cross slopes of 10:1 (horizontal: vertical) or less. SMART CUSHION® impact attenuators should not be located over drainage basins or expansion joints. Portland cement concrete foundation pads are preferred for permanent installations; asphaltic concrete foundation pads are appropriate for temporary work zone installations. The following table describes the foundations that may be used. See Appendices for drawings.

Foundations

Pad Material and Thickness	Anchor Embedment
6 inch (150 mm) reinforced PCC ¹	5 ½ inch (140 mm)
8 inch (205 mm) non-reinforced PCC	5 ½ inch (140 mm)
3 inch (75 mm) AC ^{2,3} over 3 inch (75 mm) non-reinforced PCC	16 ½ inch (420 mm)
6 inch (150 mm) AC over 6" compacted subgrade ³	16 ½ inch (420 mm)
8 inch (205 mm) AC ³	16 ½ inch (420 mm)

Notes: 1. Portland cement concrete

2. Asphaltic concrete

3. Minimum compaction: 95% of optimal



Concrete compressive strength shall be 4000 psi (28 MPa) at 28 days.

Foundation lengths may vary when using wide transitions.

Support Structure

SMART CUSHION® impact attenuators are self-supporting and do not require an additional support structure.

Location

The SMART CUSHION® impact attenuator's location determines its position and transition requirements.

- 1. <u>Approach Zone</u> SMART CUSHION® impact attenuators should not be placed directly behind raised curbs that exceed 4 inches in height. The longitudinal and cross slopes in front of the device should not exceed 10:1 (horizontal: vertical).
- 2. <u>Barrier Width</u> SMART CUSHION® impact attenuators are 24 inch (610 mm) wide at the rear. Barriers 24 inch (610 mm) wide, or less, can be shielded without using a transition if there is no reverse direction traffic. Barriers that are wider than 24 inch (610 mm) and/or have reverse direction traffic require a transition, available from Hill and Smith, Inc.
- 3. Barrier Height SMART CUSHION® impact attenuators are approximately 33 3/8 inch (848 mm) high.
- 4. <u>Barrier Shape</u> SMART CUSHION® transitions allow for connection to many barrier shapes.

Transition Design

SMART CUSHION® impact attenuators can be attached to many different barrier shapes. The attenuators are designed for direct attachment to 24 in wide barriers and Jersey/F-Shape barriers. **The SMART CUSHION® side panels must have an unobstructed travel zone for 30" behind the attenuator to allow a full collapse.** SMART CUSHION® transitions provide this travel zone in front of wide hazards.

See appendices for SMART CUSHION® transition drawings. Additional transitions are available for other frequently used applications. Contact us for drawings and details.



Transitions

Necessary Locations (see Figure 1 – Necessary Locations):

- There is reverse direction traffic within the clear zone.
- The barrier intrudes into the side panels' travel zone.

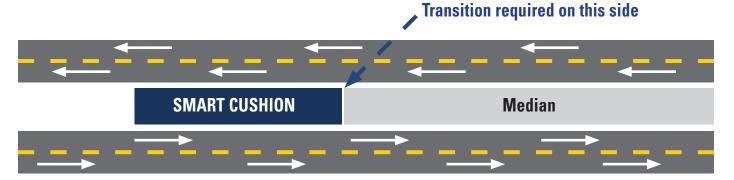


Figure 1 – Necessary Locations

Examples are median applications with bidirectional traffic, two lane roads with crossover potential, etc.

Unnecessary Locations (see Figure 2 – Unnecessary Locations):

- No reverse direction traffic within the clear zone.
- The barrier does not intrude into the side panels' travel zone.

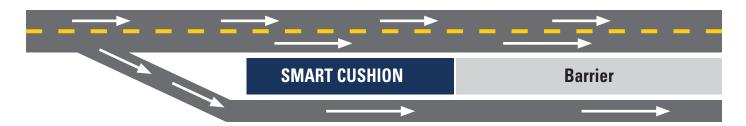


Figure 2 – Unnecessary Locations

Examples are traffic splits, shoulder applications with no crossover potential, one-way roads, etc.

<u>Determining Side of Transition</u>

The transition's side is determined by standing at the front of the attenuator looking rearward toward the barrier to choose between left and right.



INSTALLATION

Installation and Performance Statements

Proper performance within MASH/NCHRP 350 design limits depends on correct installation of the SMART CUSHION® on an approved foundation. Any SMART CUSHION® not installed according to the drawings and the requirements of this installation manual may present an unsafe condition and should be reinstalled accordingly.

Impacts with vehicles whose size or mass are outside of those tested according to MASH/NCHRP 350 or with vehicles traveling at speeds greater than those tested according to MASH/NCHRP 350 will not necessarily produce results within the test criteria. The crash cushion is in conformance with all requirements of MASH Test Level 3, MASH Test Level 2 test #2-31 and NCHRP 350 Test Levels 2 & 3.

Safety

<u>All</u> work during installation, repair and inspection of the SMART CUSHION® should be performed according to federal, state and local laws.

Equipment List

See Appendix B

Site Preparation

Check to make sure there are no drains, expansion joints, or buried conduit, cables or utility lines in the footprint space where the attenuator will be placed. Remove any curbs >4 inch or obstacles in front of or beside where the attenuator will be installed for a minimum distance of 12 feet from any edge of the attenuator. Be sure to set up proper traffic control before beginning any installation or repair work at the site.

Foundations – (reference Appendices E and E2)

New foundations should be installed according to Appendix E – Foundation Drawing. Concrete cure strength should reach 4,000 psi minimum before use. The surface of the foundation must be cleaned of all debris, dirt, mud, sand, etc., as the crash cushion must sit on a flat plane, although longitudinal and/or cross slope of up to 10:1 (horizontal:vertical) is allowed.

Any of the following foundations will meet the minimum requirements:

- 6 inch reinforced concrete pad
- 8 inch non-reinforced concrete pad
- 3 inch asphalt over 3 inch of concrete
- 6 inch asphalt over 6 inch of compacted sub base
- 8 inch asphalt

Note: Concrete should be 28 MPa or 4000 psi minimum at full cure. The slope should not exceed 10:1.



Installing the SMART CUSHION® on an existing foundation may result in anchor bolt locations corresponding to rebar positions in the foundation. When rebar is encountered, rebar bits should be used as concrete bits may bend around the rebar and continue to drill at an angle while the anchors will not bend.

Prior to installing the SMART CUSHION® on an existing foundation, the concrete must be thoroughly inspected for slope, signs of cracking, surface wear, shifting from original position, undercut of earth below or to the sides supporting the foundation, settling, and any other signs of age or deterioration which may make the foundation unusable. If any of these signs are evident, the foundation should be removed and a new one must be installed according to requirements stated. If prior bolt patterns are present, use proper engineering calculations to assure adequate strength in the new holes.

Placement of the SMART CUSHION®

Measure the correct distance and offset of the SMART CUSHION® according to the type of object being shielded and the type of transition being used. The dimensions shown on the transition drawings may be used as a guide for this. System drawings are also available.

The crash cushion is shipped in one piece, fully assembled. Use a choked four-point attachment on panel support frames 3 & 4 behind the sled for the Test Level 3 unit. **Do not lift using the side panels only!** The lift points on the Test Level 2 unit are the 1st and 2nd frames behind the sled. Lift the SMART CUSHION® off the transporting vehicle with a boom or forklift of sufficient capacity and place it in the position marked on the foundation.

Once in place, double-check the measurements to be sure of the proper location of the SMART CUSHION®.

Warning: On a full collapse, the last set of side panels will telescope 30 inches beyond the last terminal brace at the rear of the crash cushion. All objects that may interfere with this motion can affect the performance of and cause undue damage to the crash cushion.

Anchor Installation

Embedment Requirements are as follows:

- 1. 6 inch reinforced concrete pad anchor embedment of 5 ½ inch / torque value of 170 N-m (125 ft-lbs)
- 2. 8 inch non-reinforced concrete pad anchor embedment of 5 ½ inch / torque value of 170 N-m (125 ft-lbs)
- 3. 3 inch asphalt over 3 inch of concrete anchor embedment of 16 ½ inch / torque value of less than N-m (10 ft-lbs)
- 4. 6 inch asphalt over 6 in of compacted sub base anchor embedment of 16 ½ inch / torque value of less than 14 N-m (10 ft-lbs.)
- 5. 8 inch asphalt anchor embedment of 16 ½ inch and a torque value of less than 14 N-m (10 ft-lbs)



Using the holes in the base as a template, drill 7/8 inch diameter holes to the proper depth as previously defined. If the SMART CUSHION® is being installed on an existing foundation and the drills are hitting rebar, use a core drill or rebar cutter to ensure that straight, vertical holes are made at each location. Take care that the holes do not break out the bottom of the foundation as this may result in loss of epoxy during anchor placement.

Once the holes are drilled, clean the hole of all debris using suitable means. To ensure epoxy adhesion, **concrete holes MUST be cleaned with a bottle brush to remove embedded dust,** and a final check conducted that all holes are clean of debris. Inject the epoxy into each hole at an angle to avoid air entrapment. Use a sufficient amount of epoxy so that the hole will be filled when the bolt is inserted. Screw the nut on the anchor bolt flush with the end, put the washer on the stud, and immediately insert the anchor stud all the way to the bottom while turning the anchor. This method assures the anchor bolts are vertically plumb and the threads are coated with epoxy. **Bolts should not project more than ½ inch above the nut after final torque is completed.**

There is a quantity of 48 anchors for the SCI 100 GM, TL-3 attenuator.

There is a quantity of 34 anchors for the SCI 70 GM, TL-2 attenuator.

The epoxy should be ready for bolt tightening after 30 minutes at 80 degrees F (27 degrees C). See the container label for other temperatures and bolt up times. Allow the epoxy to cure. Torque the anchor nuts to 170 N-m (125 ft-lbs). Substitute epoxy must match our specifications. Asphalt anchors are longer and should have a torque value of 14 N-m (10 ft-lbs). The SCI uses Redhead A7+ Epoxy. Concrete TL2 and TL3 units require 3 and 4 tubes of epoxy, respectively while Asphalt TL2 and TL3 units require 9 and 12 tubes of epoxy, respectively.

Delineator Panel Attachment

Installation of the front delineation plate will be determined by the location of the attenuator and state regulations. A delineation plate is shipped with a yellow powder coat background and no striping. It is attached with four bolts. Applying the striping to the plate is easier while it is removed from the attenuator. Examples of the delineation plate are as follows:



Left Shoulder



Chevron for Median



Right Shoulder

<u>Transition Installation</u>

Transitions may be required. Any use of a SMART CUSHION® with a possible reverse direction impact will require a the transition drawings for details of the required anchor locations. For horizontal stud installation in concrete use mechanical anchors. Transition drawings and parts explosions are in the appendices. System drawings are available for additional details such as foundation lengths. Transition Concrete Drop-in anchors only expose the head of the anchor to reduce snag potential. For guardrail transition connections <30" behind the attenuator, you must use guardrail bolt heads (not nuts) to provide unobstructed side panel travel.



Final Inspection

After the anchor bolts have been tightened to the proper torque value, check that the SMART CUSHION® is not distorted in any way as might happen if the unit is secured to a foundation which is not a flat plane. Check that the front section is pulled out to within 1 inch of the front stop bolts and that no part of the unit has been damaged by shipping and handling. Verify that all assembly bolts are tight and have not come loose during shipping or installation. Finally, check that no tools or other equipment have been left within the SMART CUSHION® structure.

Resetting SMART CUSHION® after Impact

In the event of any impact, the crash cushion will require a full evaluation to determine the necessary repairs to return it to service. To do this, proceed as follows:

<u>Site Preparation - Do not begin work until the area is declared</u> safe and accessible.

Re-Extension and Inspection after Frontal Impact

- Remove the front delineator panel and attach pulling means to the bottom brace of the front sled.
- 2. Use wire/bungee cord on the bottom brace at the front of the sled to hold the spelter socket up in the air while pulling out or it will catch on the base frame cross braces. (See Fig. 1)
- Remove the front cable bracket that is located on the front sheave at the front of the attenuator. (See Fig. 2)
- 4. Attach a ½" Grade 100 chain to the bottom brace of the front sled.
- 5. Pull the sled forward one to two feet to give you slack on the cable.
- 6. If necessary, use the cable release tool to break cable loose from the sheave at the front of the attenuator if the zinc coating has attached the cable to the sheave. (See Fig. 3)



Fig. 1

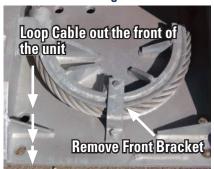


Fig. 2



Fig. 3



- 7. Pull out in two foot increments while helping the cable feed out of the front of the unit. (See Fig. 4)
- 8. Pull the sled out the rest of the way in **short smooth increments** so you can help feed the cable out the front of the attenuator. This will give you a cable loop in front of the attenuator. When you are past the last cross brace, you will need to remove the strap or wire to allow the cable to follow the path down into the front sheave. The sled must be fully extended to replace the shear bolts. The sled should be no more than 1 inch from the stop bolts in the front.



Fig. 4

- **During any pullout, do not stand within the snap radius of the chain in case of failure**.
- 9. During frame pullout, inspect the front part of the cable from the spelter socket, as it will be partially obscured after extension of the mobile frames and sheaves. **See the cable inspection procedure.**
- 10. Remove the front and rear sheave cover plates at each end of the cylinder by removing the two hex bolts that hold them down. Perform steps 11 and 12 when you have access to them. Access may be restricted until the unit if fully pulled out.
- 11. Remove the anti-rotation pins, which are the two outer pins, inserted through the holes in the sheaves from both the front and back sheaves. This will be easily done with the anti-rotation pin removal tool. Caution: <u>Do not</u> remove the center pin. The rear sheave pins are longer than the front sheave pins and cannot be intermixed so leave them by their locations. (See Fig. 5)

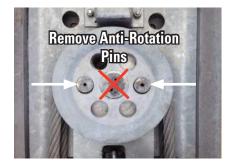


Fig. 5

12. Remove shear bolt remnants in the holes on both sides of the mobile sheaves. These are grade 8 bolts so they can be difficult to remove without a 90 degree pry bar with a claw to pry out. (See Fig. 6)



13. Attach a pulling means to the shackle on the mobile sheave assembly. (See Fig. 6)

Fig. 6

14. Slowly pull out the mobile sheaves. **Do not stand inside the cable loop or be in the pulling strap danger zone.**



- 15. Finish pulling out the mobile sheaves until you can see through the shear bolt holes **but do not put in the shear bolts yet.**
- 16. If the cable passes inspection, release any tension on your pulling means and reinstall the anti-rotation pins in the front and back sheave assemblies and reinstall the cover plates for those sheaves using marine grade anti-seize on the bolt threads. The sheaves may be aligned by inserting a pry bar into the sheave holes. Work your way from the bottom up.
- 17. Re-tension your chain and replace the two ¼ inch **Grade 8** shear bolts in the front corners of the mobile sheaves.
- 18. Inspect the cylinder, anchor bolts and side panels according to the subsequent procedures listed.

Side Impact Inspection and Repair

- 1. Inspect and replace any damaged side panels.
- 2. Inspect and replace any damaged side keeper bolts on all panels. There are three styles of side keeper bolts. The winged style is for the panel connected to the sled and bolts through the first frame behind the sled. The center side keepers have a ½ inch shoulder while the last side keeper, which is bolted to the terminal frame, has a ¼ inch shoulder.
- 3. Inspect and repair any damaged side guides.

Cable Inspection Procedure

The cable should be visually inspected for damage. The most common sign of rope deterioration is broken wires. The wire must be clean to perform a visual inspection. The visual inspection should include looking for broken wire strands, localized wear or crowns. A sharp awl or marlin spike can be used to separate wires to check if internal damage is present, indicated by loose wires or crowns. If internal inspection shows any damage to any core wires, remove the unit from service. If there are more than six random broken wires in one rope lay or three broken wires in one strand in one rope lay, remove the unit from service. A rope lay is the length along the rope in which one strand makes a complete revolution around the rope. (See Fig. 7)

Understanding a Rope Lay

One Rope Lay

STRAND NUMBER

6 5 4 3 2 1 6

Understanding a Rope Lay

Length of Rope Lays

Fig. 7

Inspect the spelter socket for broken wires, damaged eyes or other fatigue. Any signs of broken wires at the spelter socket will require the unit to be removed from service.

Cable damage is the indication of an over-design impact. You should replace the attenuator if the cable does not pass inspection. This is a clear sign that an over design impact occurred and other parts could possibly be compromised.



Cylinder Inspection

The cylinder should be inspected for:

- Dented or swollen tube jacket
- Visible cracks in any welds and fluid leakage from the welds
- Piston rod surface damage, bending or fluid leakage in seal area

If any of these inspections are suspect, remove the unit from service. Current models have PTFE seals with an unlimited static life.

Anchor Bolt Inspection

Loose or damaged anchor bolts should be extracted and reinstalled.

Side Panel Inspection

Side Panels are designed to nest and collapse with minimal or no damage upon frontal impact. The side keepers sustain a shock upon impact. These side keepers should be replaced if there are any signs of fatigue, bending or other visible damage. Inspect the side panels for any bending or torn metal. If damage is found, any side panel is removable by removing four bolts. The side keepers used to hold the large front sled panels are different than the side keepers on the center panels. Also, the side keeper used on the last terminal brace, which is the rearmost support, has a shorter collar (¼ inch vs. ½ inch), as it does not have a panel overlap. These shoulders must seat into the outer overlapping panel and pin the inside panel to the frames using a torque value of 270 N-m (200 ft-lbs). Be careful to fully insert the collar into the panel slot so you do not pin the edge of the outside panel as it will restrict free sliding of that panel.

Side Guide Inspection

At the bottom of each support frame, there are two guides to stabilize and guide collapse of the attenuator. Inspect each side guide for damage. The torque value for the side guides is 920 N-m (680 ft-lb). These side guides are stronger than the rail, so visually inspect the rail for crowns. Any crowning of the rail can be straightened using a large maul to flatten it back to its' original position.

Final Inspection

After the resetting of the SMART CUSHION® is complete, verify by visual inspection that all assembly bolts are tight and show no sign of damage. Finally, check that no tools and other equipment or debris have been left within the SMART CUSHION® structure. Verify that no other damage unrelated to the most recent impact has occurred and that no significant corrosion or other deterioration has taken place.



Non-Repairable Impacts

There can be instances where the impact is outside the scope of the SMART CUSHION® design. This may render the SMART CUSHION® unsafe to reuse and it should be replaced.

Periodic Maintenance

Maintenance is site dependent. Small amounts of debris and trash will not affect the performance of the SMART CUSHION®. Accumulations of dirt/mud can impede the collapse of any system. We suggest an annual clean-out of the system in the fall of the year. If sites are in locations prone to heavy rain/mud runoff, a bi-annual cleaning may be required.





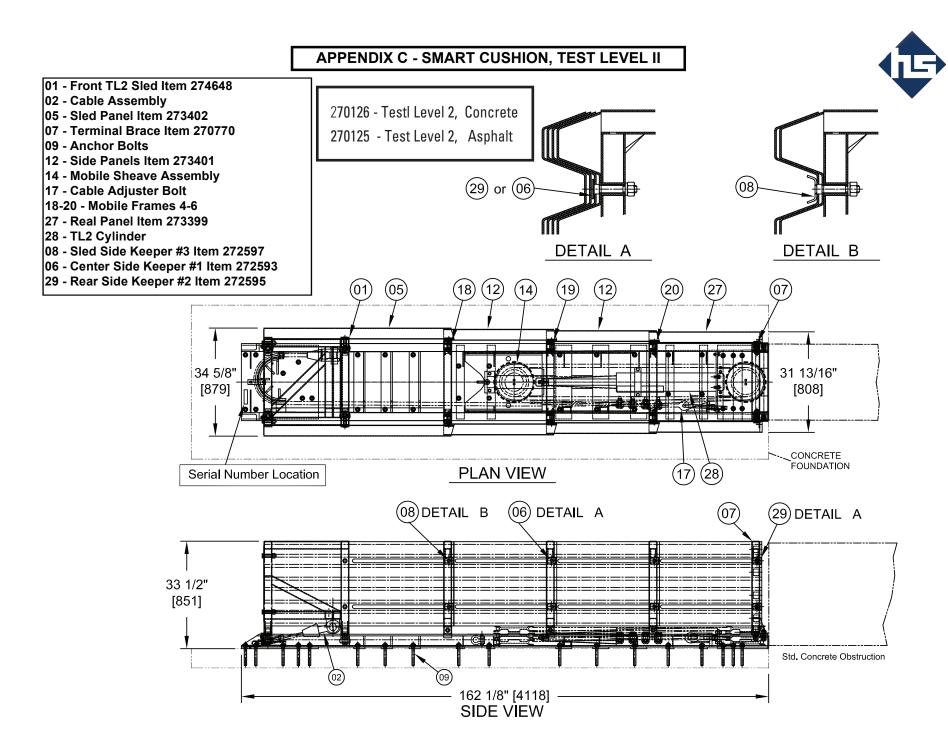
Prod No.	Description	Unit of Measure
270128	Attenuator 24" wide w/Concrete Anchors TL3	
270127	Attenuator 24" wide w/Asphalt Anchors TL3	
270126	Attenuator 24" wide w/Concrete Anchors TL2	
270125	Attenuator 24" wide w/Asphalt Anchors TL2	
270667	Bolt Concrete Anchor 3/4" X 7" TL3 (Included in P/N 270128)	KIT/48 pcs.
270663	Bolt Asphalt Anchor 3/4" x 18" TL3 (Included in P/N 270127)	KIT/48 pcs.
270666	Bolt Concrete Anchor 3/4" X 7" TL2 (Included in P/N 270126)	KIT/34 pcs.
270664	Bolt Asphalt Anchor 3/4" x 18" TL2 (Included in P/N 270125)	KIT/34 pcs.
271242	Epoxy 28 oz. Cartridge and Nozzle	EACH
273113	Nozzle Epoxy Mixing	EACH
272612	Epoxy Kit for TL3 Concrete Attenuator	EACH
272610	Epoxy Kit for TL3 Asphalt Attenuator	EACH
272611	Epoxy Kit for TL2 Concrete Attenuator	EACH
272609	Epoxy Kit for TL2 Asphalt Attenuator	EACH
270683	Bolt Shear	EACH
270770	Brace Terminal	EACH
272527	Keeper Side #3 (Sled Panels) TL2 & TL3	EACH
272593	Keeper Side #1 (Side Panels) TL2 & TL3	EACH
272595	Keeper Side #2 (Rear Panels) TL2 & TL3	EACH
273378	Panel Delineator (Painted Yellow) TL3	EACH
273386	Panel Delineator (Painted Black) TL3	EACH
273381	Panel Delineator Diamond Grade Chevron 6 inch stripes TL3	EACH
273383	Panel Delineator Diamond Grade Left 6 inch stripes TL3	EACH
273389	Panel Delineator Diamond Grade Right 6 inch stripes TL3	EACH
273380	Panel Delineator (Painted Yellow) TL2	EACH
273385	Panel Delineator (Painted Black) TL2	EACH
273382	Panel Delineator Diamond Grade Chevron 6 inch stripes TL2	EACH
233928	Panel Delineator Diamond Grade Left 6 inch stripes TL2	EACH
273388	Panel Delineator Diamond Grade Right 6 inch stripes TL2	EACH
273401	Panel Side TL2 & TL3	EACH
273402	Panel Sled	EACH
273399	Panel Rear	EACH
274649	Sled (with guide rollers) 24" TL3	EACH
274648	Sled (with guide rollers) 24" TL2	EACH
271946	Dispenser Epoxy	EACH
270707	Boot Cylinder TL3	EACH
233937	Boot Cylinder TL2	EACH
272621	Reset Parts Kit TL3	EACH
272620	Reset Parts Kit TL2	EACH
273994	Tool Anti Rotation Pin Removal	EACH
270069	Anchor Drop In	EACH
275224	Cable Release Tool	EACH
238247	Shear Bolt Removal Tool	EACH
270952	Hole Brush-Nylon	EACH
264383	Drop-in Anchor Setting Tool	EACH
262004	SCI Debris Hood Assembly- DH3	EACH
262006	Fiberglass Stay Kit for Debris Hood - DH3	KIT

APPENDIX B - EQUIPMENT LIST

The following tools and equipment will be required to install and repair the Crash Cushion:

- > Standard roadside work area safety equipment
- Personal safety equipment (gloves, latex gloves for epoxy, eye/face protection, etc.)
- Means of safely unloading 3500 lbs.
- Compressed air source/vacuum
- ➤ 1 inch nylon bottle brush (Part # 270952)
- Safety goggles
- Four lifting slings or four-point sling
- ▶ Bosch rotary hammer drill 13 ½ amp #11263EVS Model 0 611 263 739 or equal
- > % inch X 22 inch concrete drill bit for concrete installations or % inch X 28 inch drill bit for asphalt installations
- ➤ Relton rebar eater bit #RB-14 7/8 inch rebar cutter bit or equal
- ➤ 1 inch X 12 inch concrete drill bit for drop-in anchors on transitions
- Punch or setting tool for drop in anchors (Part # 264383)
- > 1/2 inch electric drill for rebar bit and bottle brush (cordless will work for bottle brush)
- ➤ Epoxy dispenser for 28 oz. dual cartridge system. A spare is recommended in case of malfunction. (Part # 271946)
- Socket wrench and breaker bar
- > Torque wrench (225 ft-lb capacity) with 3 ft extension
- Measuring and layout equipment (tape measure, chalk line, markers, etc.)
- Combination wrenches, deep sockets (Including 7/16 inch 5% inch, 1 ¼ inch, 1 ½ inch, 1 5% inch) and 3+ inch extension
- > 5 foot wedge and round-ended pry bar
- ➤ Loctite #34395 marine grade anti-seize
- ➤ Suitable pulling means Chain 20′ x ½″ Grade 100
- Misc. small tools (hammers, pliers, screw drivers, vise grips, etc.)
- ➤ Bear claw pry bar to remove ¼ inch shear bolt remnants (Part # 238247)
- > Anti-rotation pin removal tool (Part # 273994)
- > Cable release tool (Part # 275224)
- > Piece of wire or bungee cord to hold up spelter socket during pullout

This list is adequate for general installation and repair. Depending on site conditions, additional tools and equipment may be required.

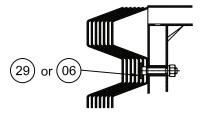


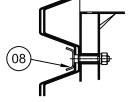
APPENDIX D - SMART CUSHION, TEST LEVEL III



- 01 Front TL3 Sled Item 274649
- 02 Cable Assembly
- 05 Sled Panel Item 273402
- 07 Terminal Brace Item 270770
- 09 Anchor Bolts
- 12 Side Panels Item 273401
- 14 Mobile Sheave Assembly
- 17 Cable Adjuster Bolt
- 18-23 Mobile Frames 1-6
- 26 TL3 Cylinder
- 27 Real Panel Item 273399
- 08 Sled Side Keeper #3 Item 272597
- 06 Center Side Keeper #1 Item 272593
- 29 Rear Side Keeper #2 Item 272595

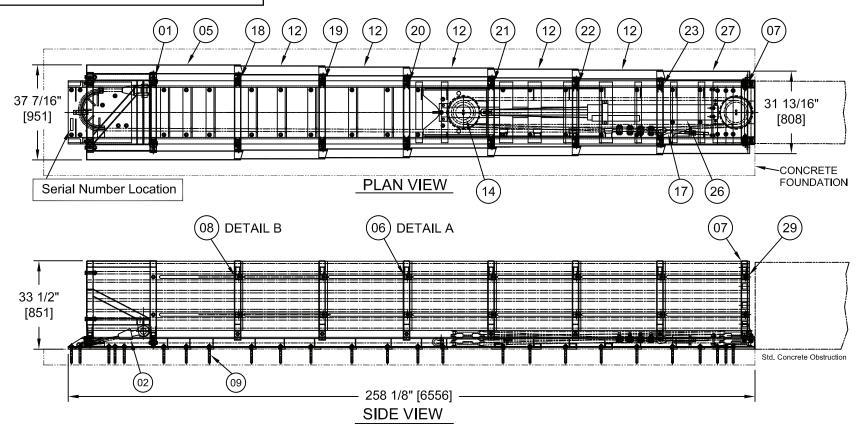
270128 - Testl Level 3, Concrete 270127 - Test Level 3, Asphalt





DETAIL A

DETAIL B



APPENDIX E - TEST LEVEL II FOUNDATION



Cross Slope at Top Surface not to Exceed 1 in 10 Foundation must be a Level Plane

* * * * * Wide Hazards and Transitions may require the foundation to be longer. See Transition Drawings.

SPECIFICATIONS

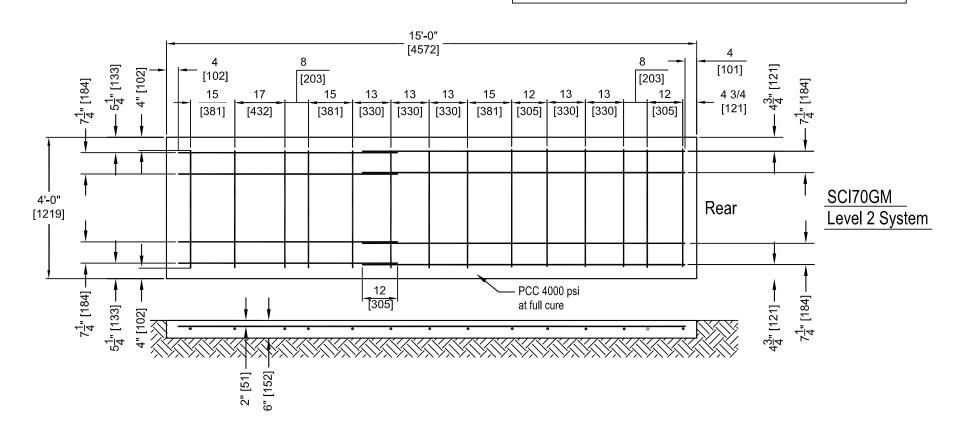
All reinforcing steel - straight #4 ASTM-A36

Embedment requirements:

- 6" reinforced concrete pad with anchor embedment of 5 1/2"
- 8" non-reinforced concrete pad with anchor embedment of 5 1/2"
- 3" asphalt over 3" concrete with anchor embedment of 16 1/2"
- 6" asphalt over 6" of compacted subbase with anchor embedment of 16 1/2"
- 8" asphalt with anchor embedment of 16 1/2"

The contractor shall furnish a certification for material installed to the following requirements:

- 6" reinforced concrete (PCC) sampling per ASTM C31-84, testing per ASTM C39-84
- 8" non-reinforced concrete (PCC) sampling per ASTM C31-84, testing per ASTM 39-84
- 3" asphalt over 3" concrete Type SP 12.5 Level C or higher
- 6" asphalt over 6" of compacted subbase same as above
- 8" asphalt (AC) Type SP 12.5 Traffic Level C or higher



APPENDIX E(2) - TEST LEVEL III FOUNDATION



Cross Slope at Top Surface not to Exceed 1 in 10 Foundation must be a Level Plane

* * * * * Wide Hazards and Transitions may require the foundation to be longer. See Transition Drawings.

SPECIFICATIONS

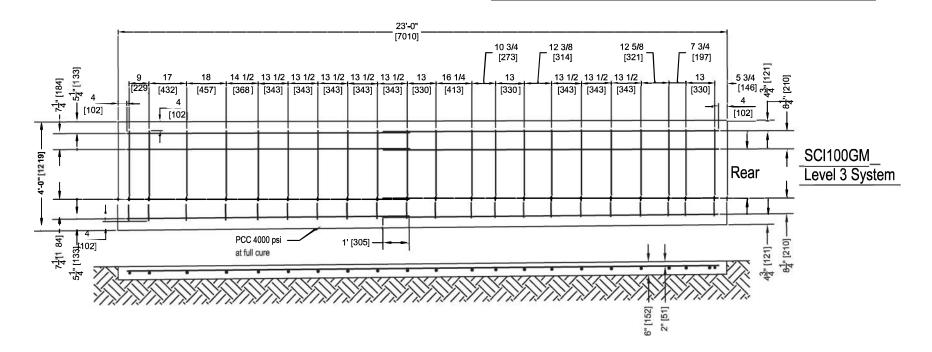
All reinforcing steel - straight #4 ASTM-A36

Embedment requirements:

- 6" reinforced concrete pad with anchor embedment of 5 1/2"
- 8" non-reinforced concrete pad with anchor embedment of 5 1/2"
- 3" asphalt over 3" concrete with anchor embedment of 16 1/2"
- 6" asphalt over 6" of compacted subbase with anchor embedment of 16 1/2"
- 8" asphalt with anchor embedment of 16 1/2"

The contractor shall furnish a certification for material installed to the following requirements:

- 6" reinforced concrete (PCC) sampling per ASTM C31-84, testing per ASTM C39-84
- 8" non-reinforced concrete (PCC) sampling per ASTM C31-84, testing per ASTM 39-84
- 3" asphalt over 3" concrete Type SP 12.5 Level C or higher
- 6" asphalt over 6" of compacted subbase same as above
- 8" asphalt (AC) Type SP 12.5 Traffic Level C or higher

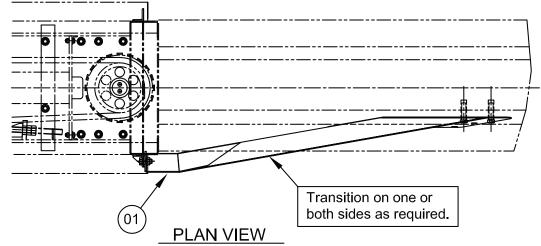


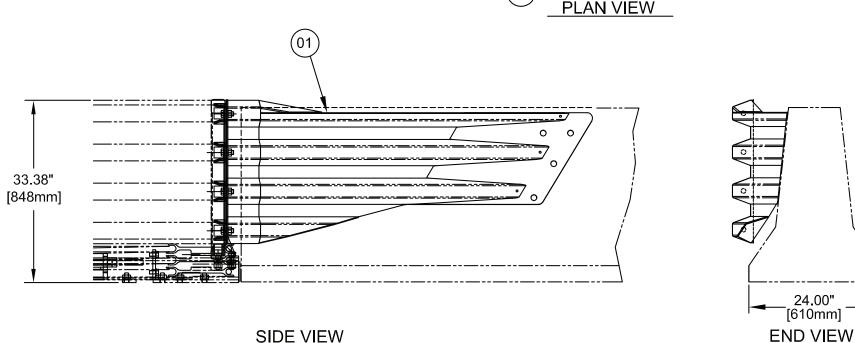
APPENDIX F - NCHRP 350 TRANSITION, JERSEY/F SHAPE BARRIER



Parts List:

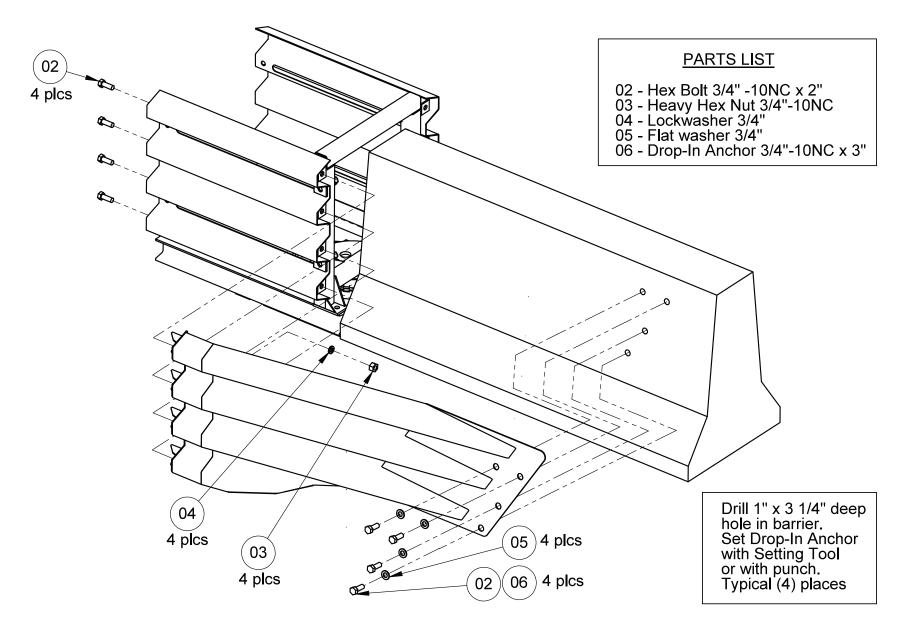
- 01 Transition Jersey Barrier Right #275297 (shown)
- 01 Transition Jersey Barrier Left #275294 (not shown)





APPENDIX F(2) - NCHRP 350 TRANSITION, JERSEY/F SHAPE BARRIER

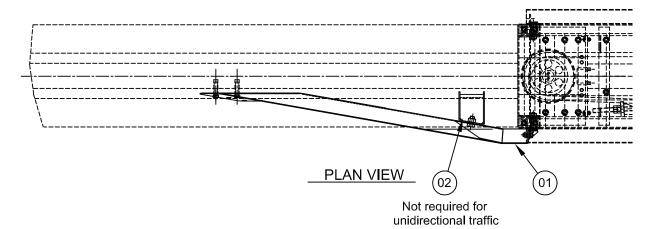


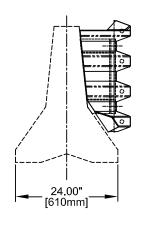


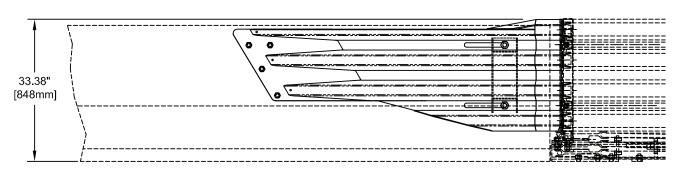




Parts List:	Jersey/K-Rail
01 - Transition Panel MASH Left (shown)	#268891
01 - Transition Panel MASH Right (not shown)	#268892
02 - Support Bracket MASH Left (shown)	#268893
02 - Support Bracket MASH Right (not shown)	#268894



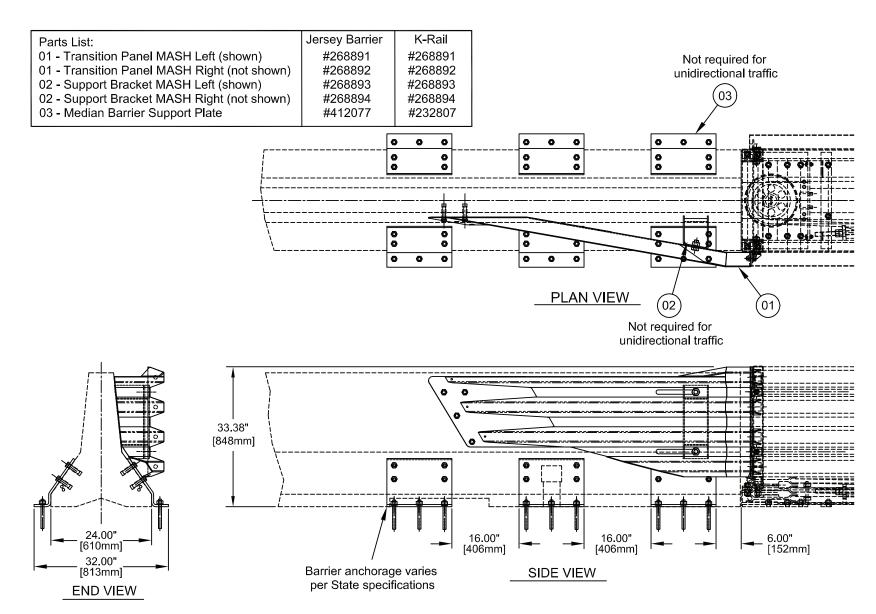




END VIEW SIDE VIEW

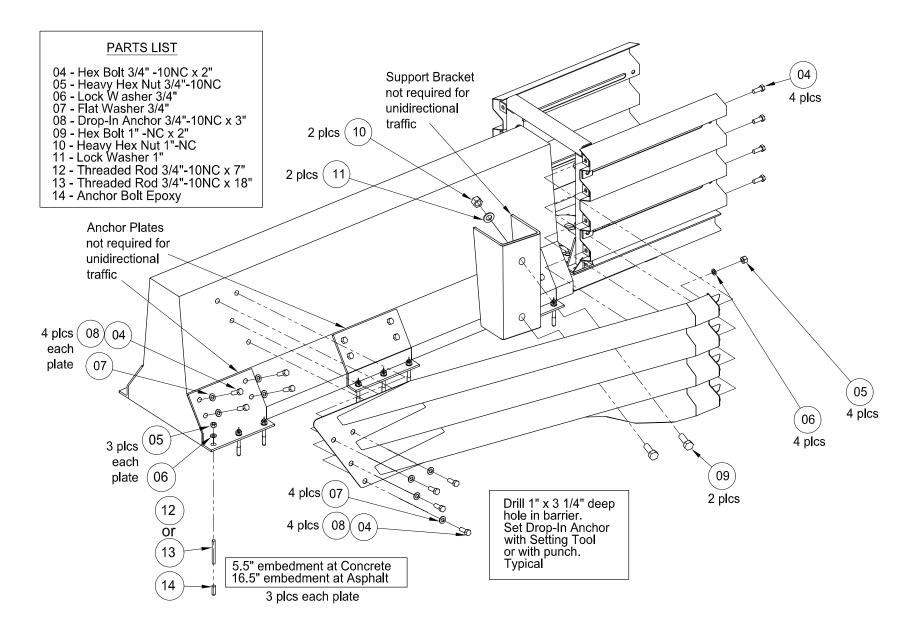
APPENDIX G(2) - MASH TRANSITION, JERSEY/F SHAPE BARRIER TEMPORARY





APPENDIX G(3) - MASH TRANSITION, JERSEY/F SHAPE BARRIER PERM. & TEMP



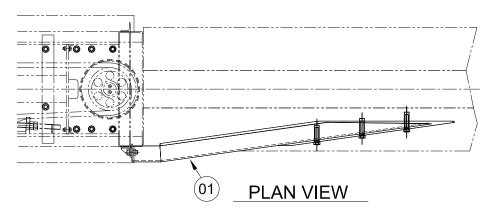


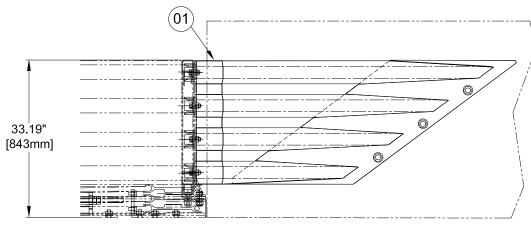
APPENDIX H - TRANSITION, MEDIAN BARRIER - SINGLE SLOPE 24"- 26.75" (610 - 679mm) Base



Parts List:

- 01 Transition Single Slope Median Barrier Right #275299 (shown) 01 Transition Single Slope Median Barrier Left #275302 (not shown)

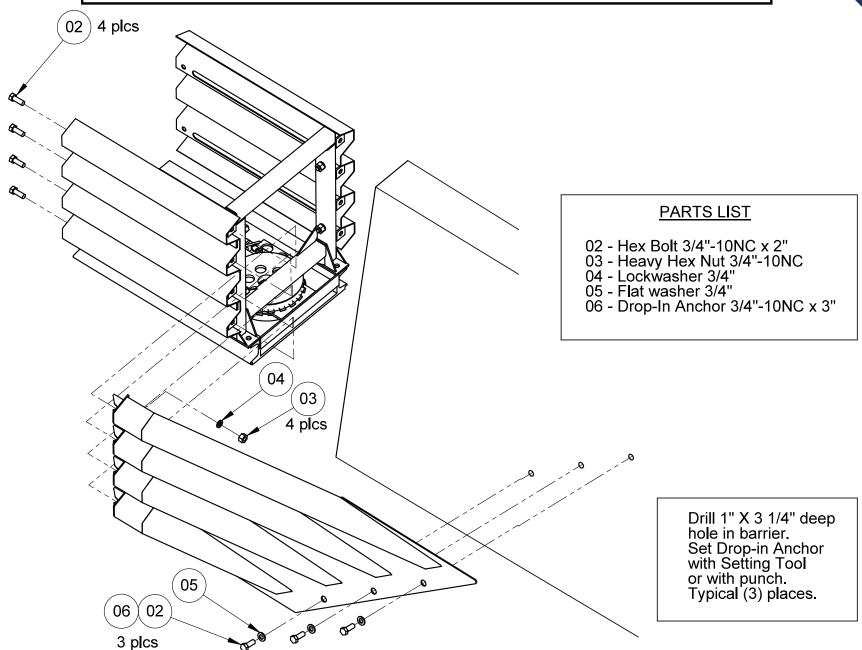




SIDE VIEW

APPENDIX H(2) - TRANSITION, MEDIAN BARRIER - SINGLE SLOPE 24"- 26.75" (610 - 679mm) Base





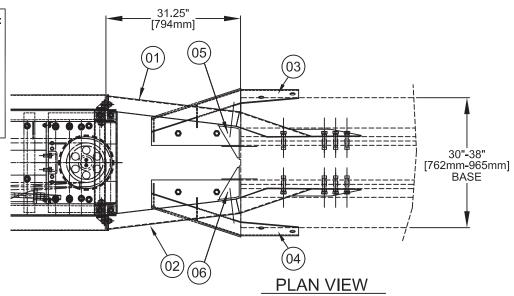
APPENDIX I - TRANSITION, JERSEY/F SHAPE, VARIABLE WIDTH BASE

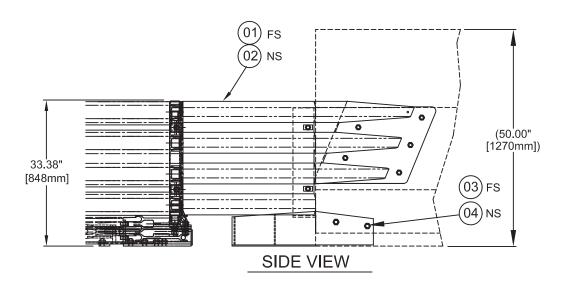


Parts List for Double Sided Median Barrier 30"-38" Base: Two-Sided Full Assembly #239542 (with rub rail), #239545 (without rub rail)

- 01 Transition Left #275272
- 02 Transition Right #275273
- 03 Transition Rub Rail Left #275270
- 04 Transition Rub Rail Right #275271
- 05 Transition Support Bracket Right #239471
- 06 Transition Support Bracket Left #239472

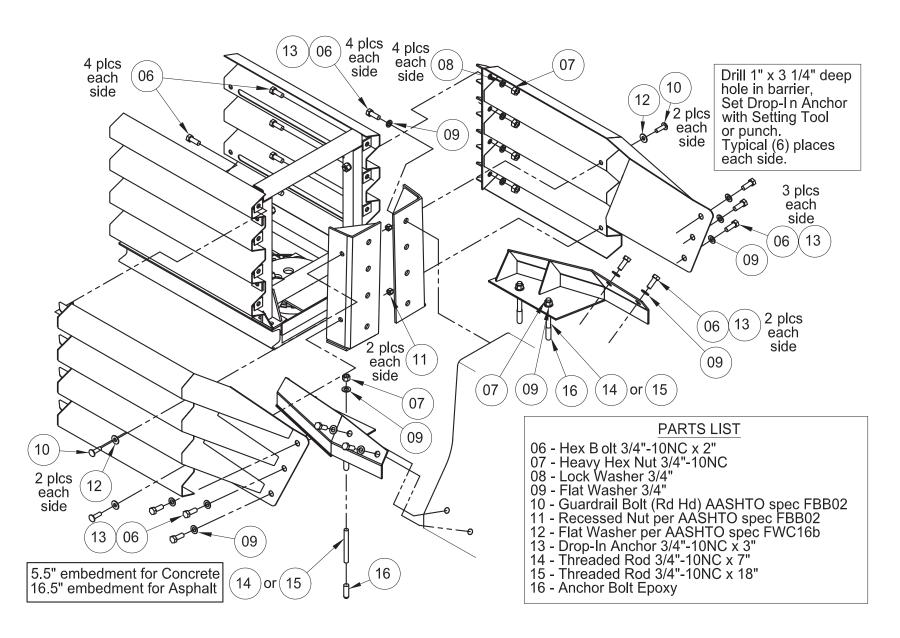
For use with barriers with base widths of 30"-38" Rub rails only required for base widths > 34"





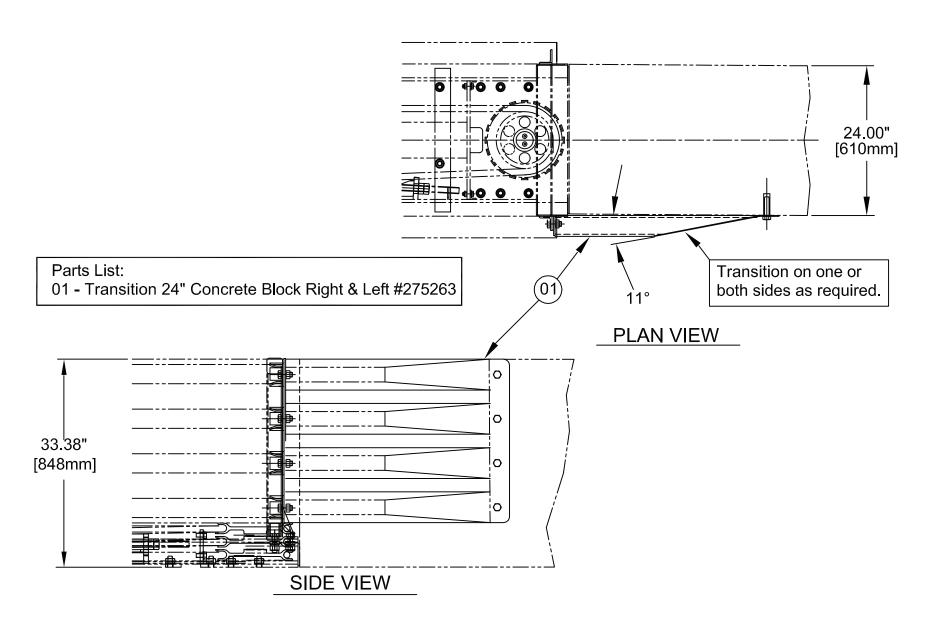
APPENDIX I(2) - TRANSITION, JERSEY/F SHAPE, VARIABLE WIDTH BASE





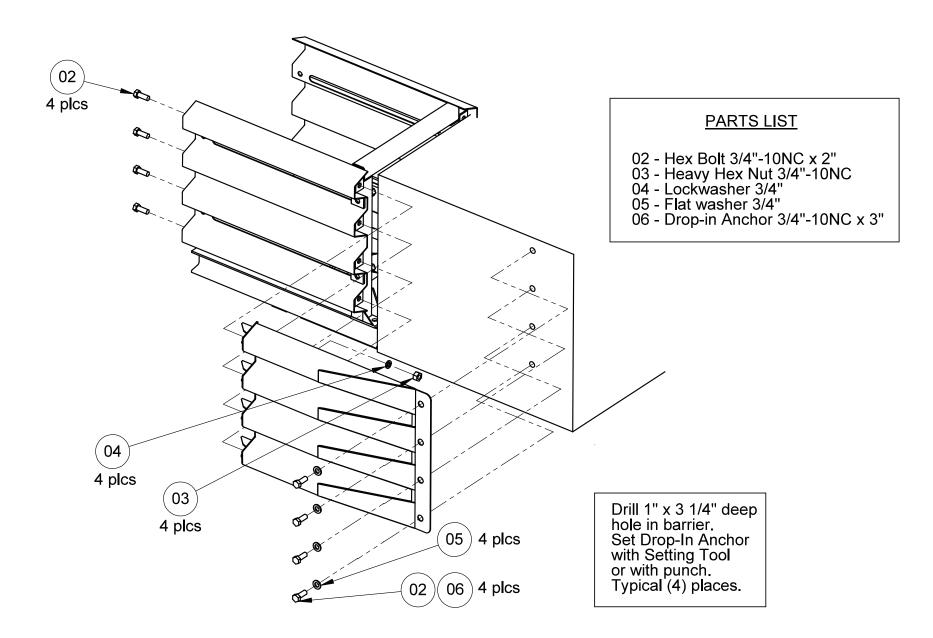
APPENDIX J - TRANSITION, CONCRETE BLOCK, 24 INCH (610mm)





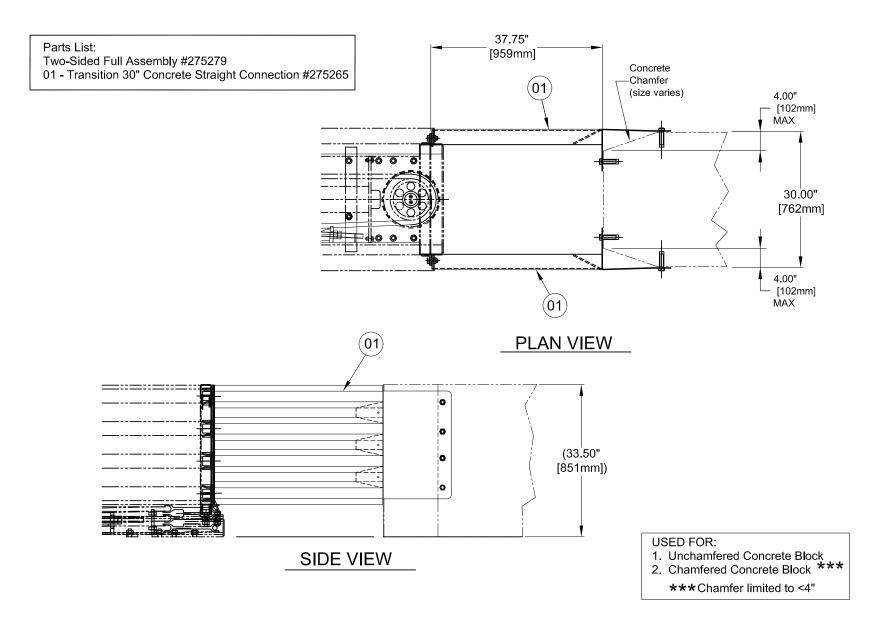
APPENDIX J(2) - TRANSITION, CONCRETE BLOCK, 24 INCH (610mm)





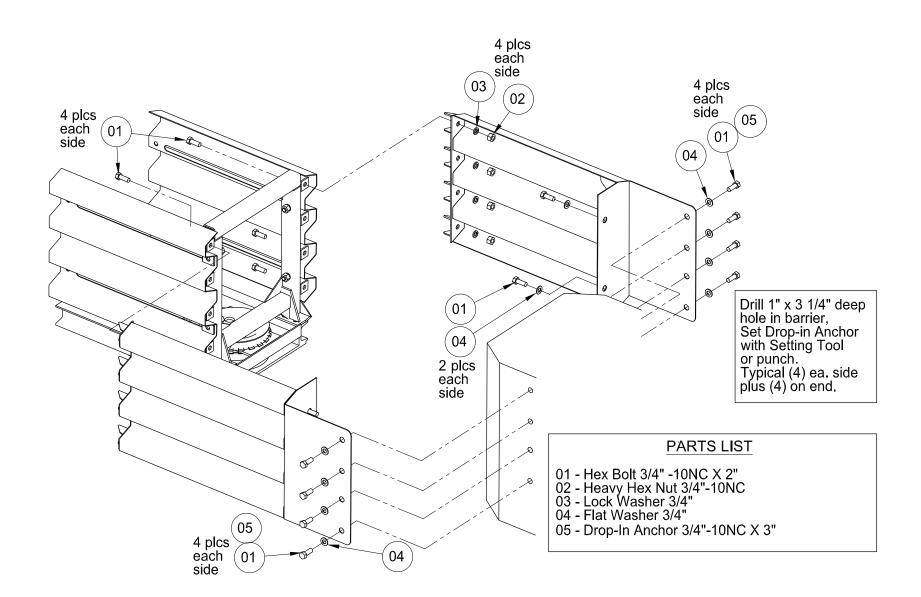
APPENDIX K - TRANSITION, CONCRETE BLOCK, 30 INCH (762mm)





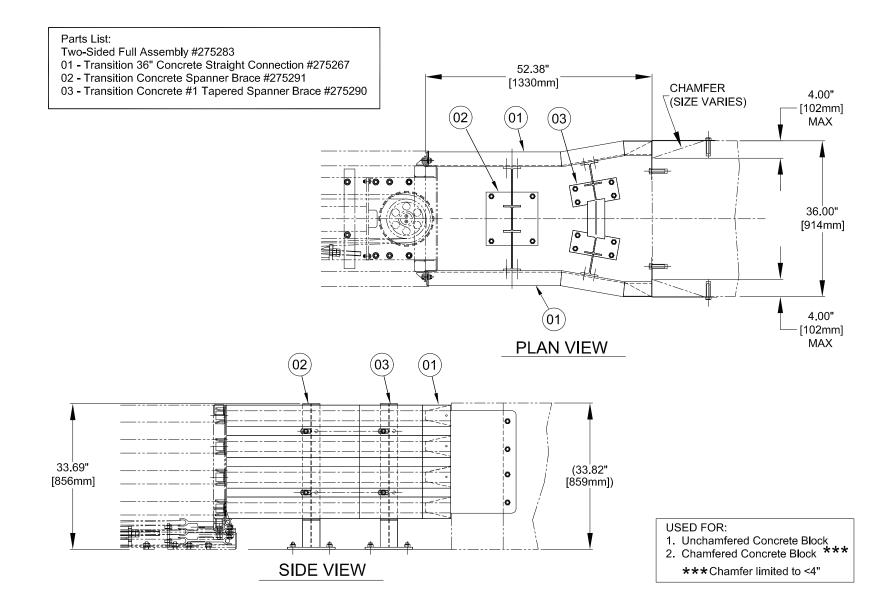
APPENDIX K(2) - TRANSITION, CONCRETE BLOCK, 30 INCH (762mm)





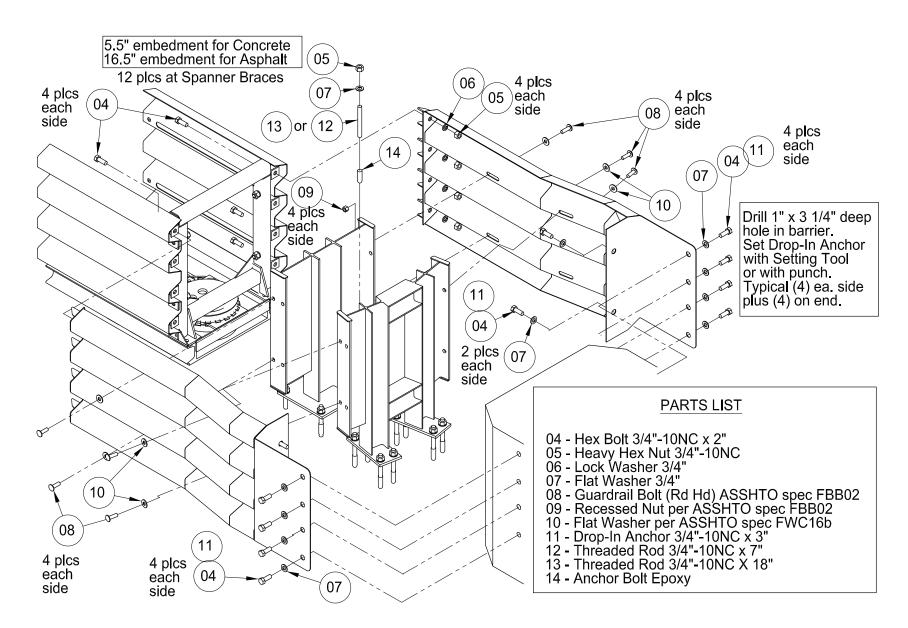
APPENDIX L - MASH TRANSITION, CONCRETE BLOCK, 36 INCH (915mm)







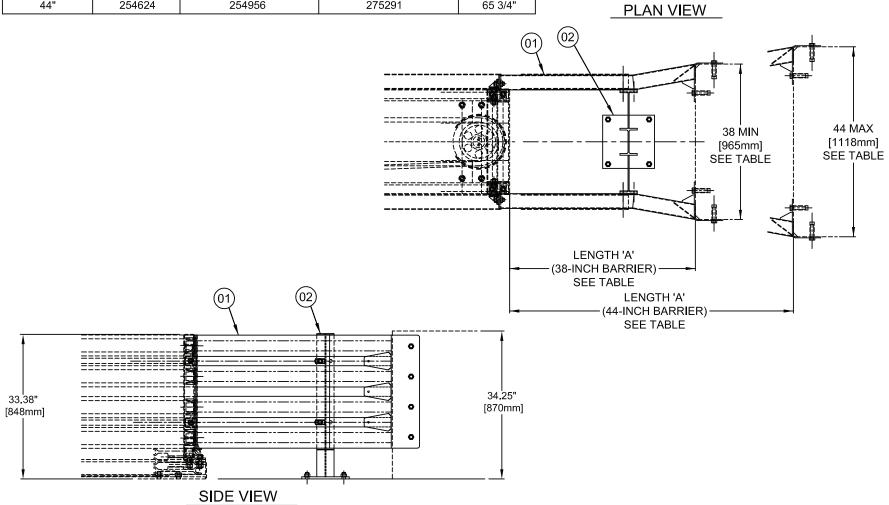
APPENDIX L(2) - MASH TRANSITION, CONCRETE BLOCK, 36 INCH (915mm)



APPENDIX M - TRANSITION, CONCRETE BLOCK, 38-44 INCH (965-1118mm)

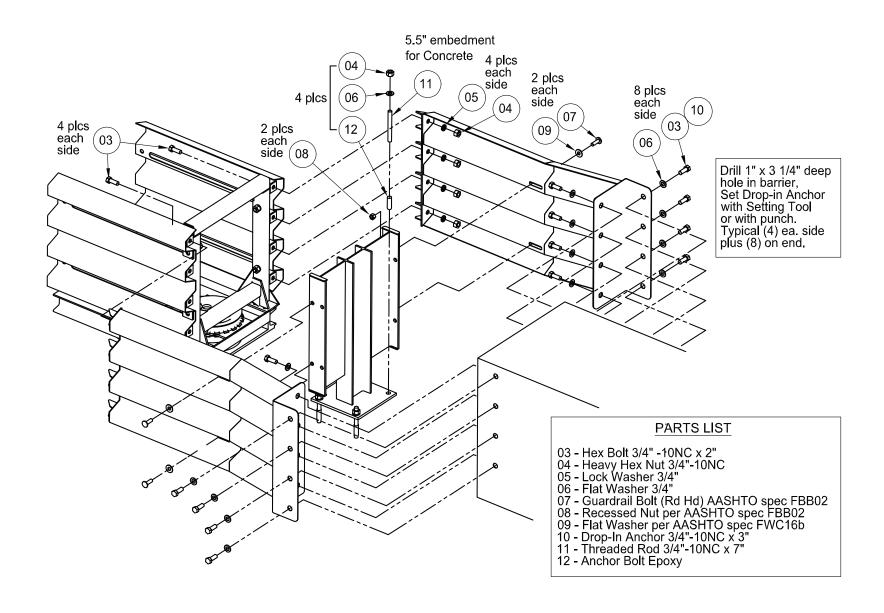


BARRIER WIDTH	ASSEMBLY PART NO	PANEL ET-06-38 PART NO (ITEM 01)	STEEL POST ET-06-22 PART NO (ITEM 2)	LENGTH 'A'
	JDE	JDE	JDE	
38"	254621	254953	275291	48 1/2"
40"	254622	254954	275291	54 1/4"
42"	254623	254955	275291	60"
44"	254624	254956	275291	65 3/4"



APPENDIX M(2) - TRANSITION, CONCRETE BLOCK, 38-44 INCH (965-1118mm)



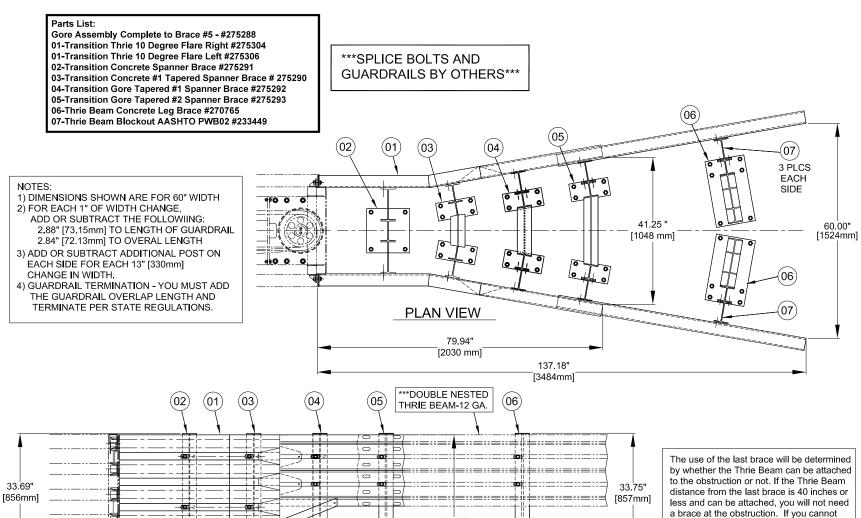


APPENDIX N - TRANSITION, THRIE BEAM WIDE TAPER



attach to the obstruction, you may need a

brace and drill holes in the Thrie Beam at the furthest rearward location.



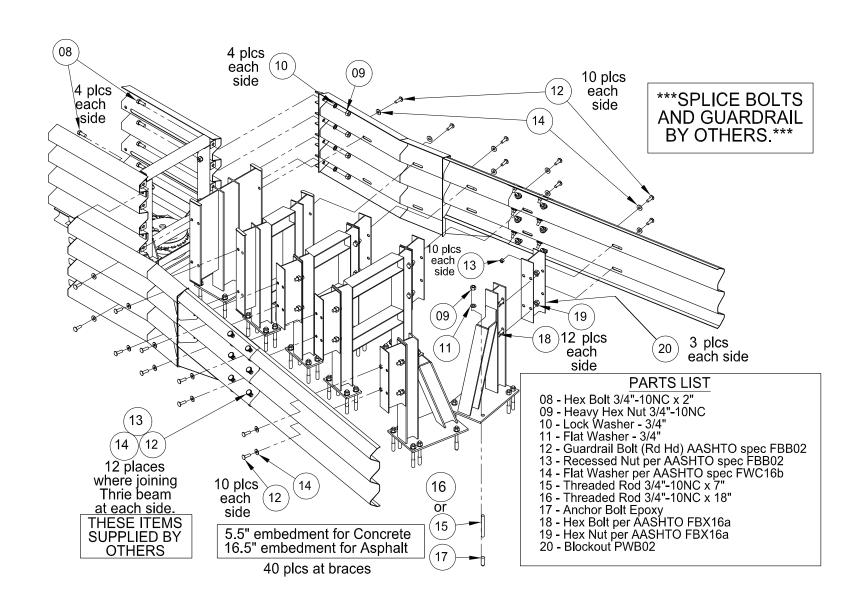
33.25"

[846mm]

SIDE VIEW

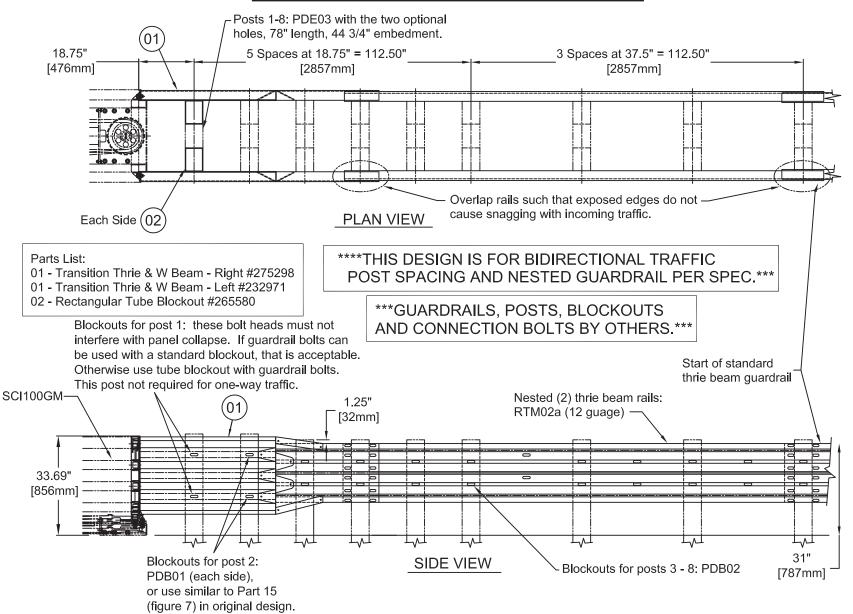
APPENDIX N(2) - TRANSITION, THRIE BEAM WIDE TAPER





APPENDIX O - TRANSITION TO THRIE BEAM **FOR USE WITH BIDIRECTIONAL TRAFFIC**



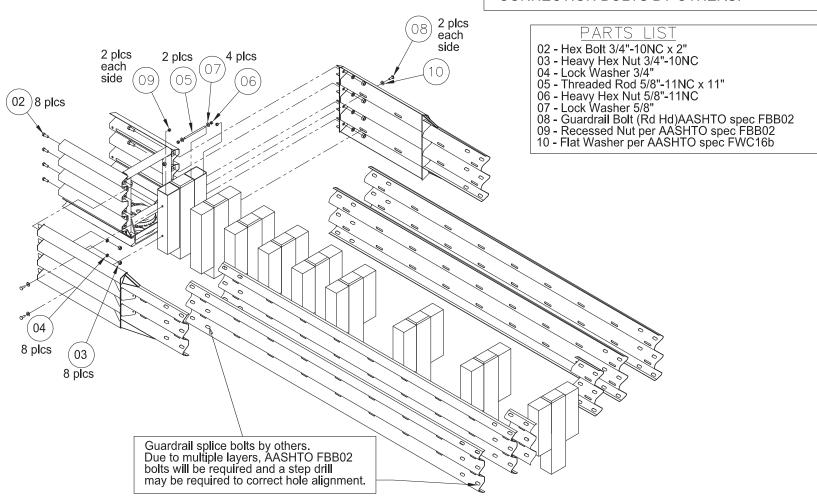


APPENDIX O(2) - TRANSITION TO THRIE BEAM ** FOR USE WITH BIDIRECTIONAL TRAFFIC**



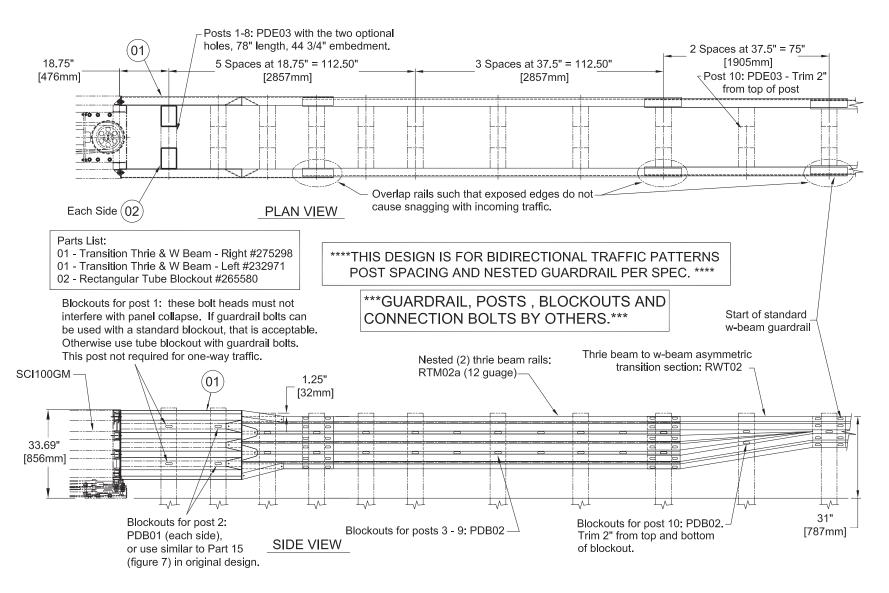
***THIS DESIGN IS FOR BIDIRECTIONAL TRAFFIC. POST SPACING AND NESTED GUARDRAIL PER SPEC.

GUARDRAILS, POSTS, BLOCKOUTS AND CONNECTION BOLTS BY OTHERS.



APPENDIX P - TRANSITION TO W BEAM **FOR USE WITH BIDIRECTIONAL TRAFFIC**

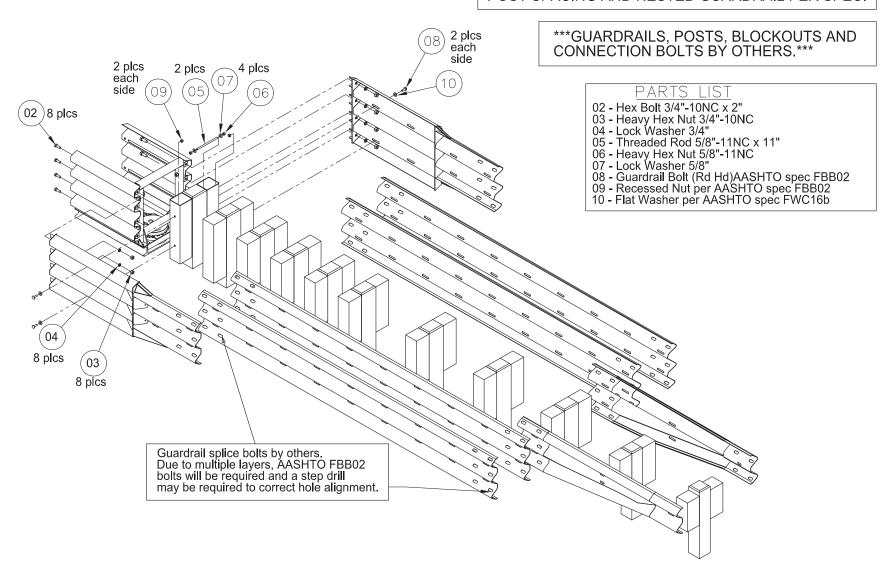




APPENDIX P(2) - TRANSITION TO W BEAM ** FOR USE WITH BIDIRECTIONAL TRAFFIC**

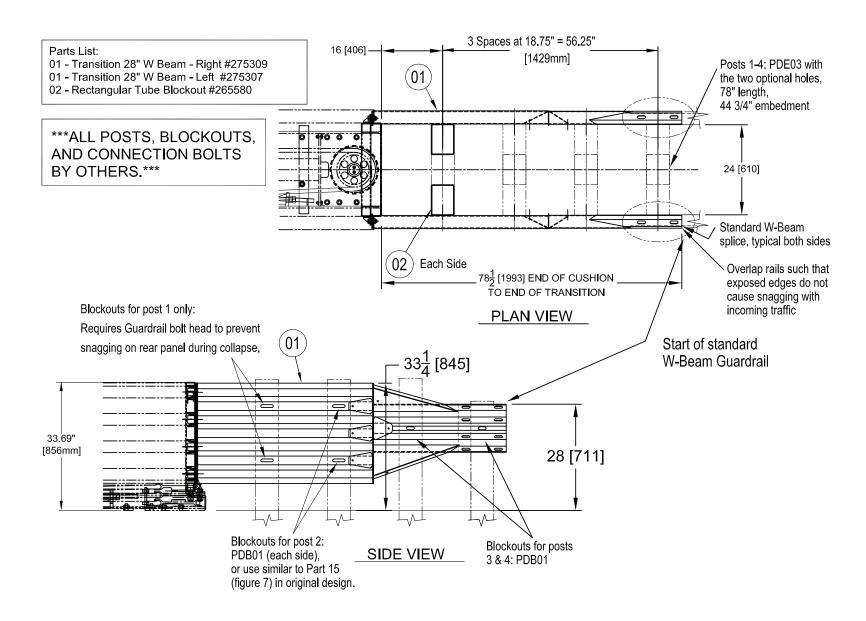


***THIS DESIGN IS FOR BIDIRECTIONAL TRAFFIC.
POST SPACING AND NESTED GUARDRAIL PER SPEC.



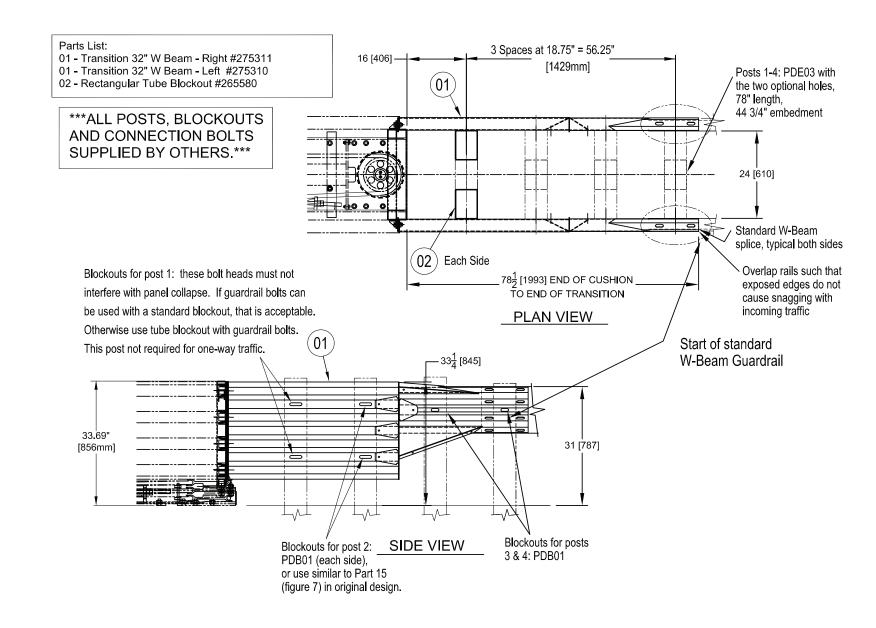
APPENDIX Q - TRANSITION, W BEAM 28" HIGH **Unidirectional Traffic Only**





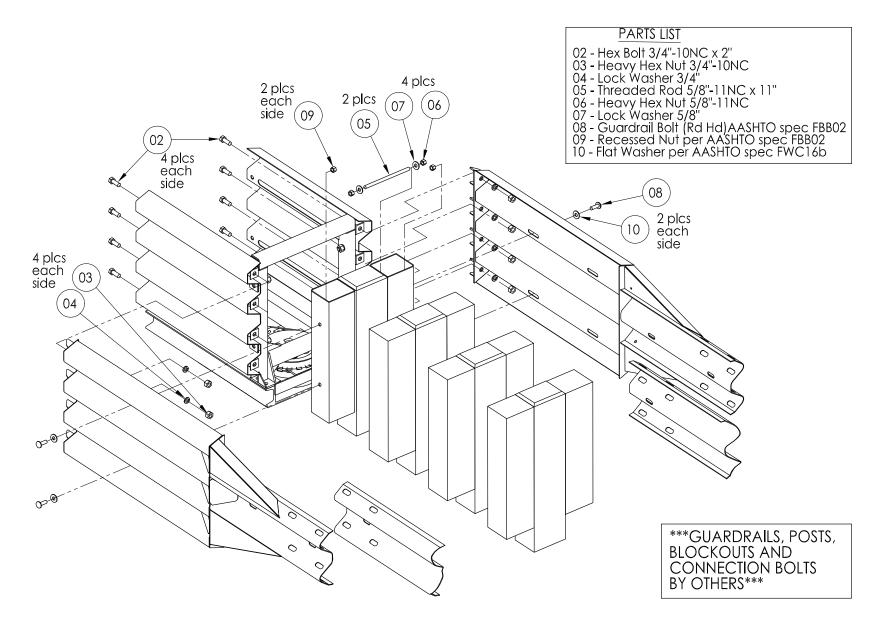


APPENDIX R - TRANSITION, W BEAM 31" HIGH ** Unidirectional Traffic Only



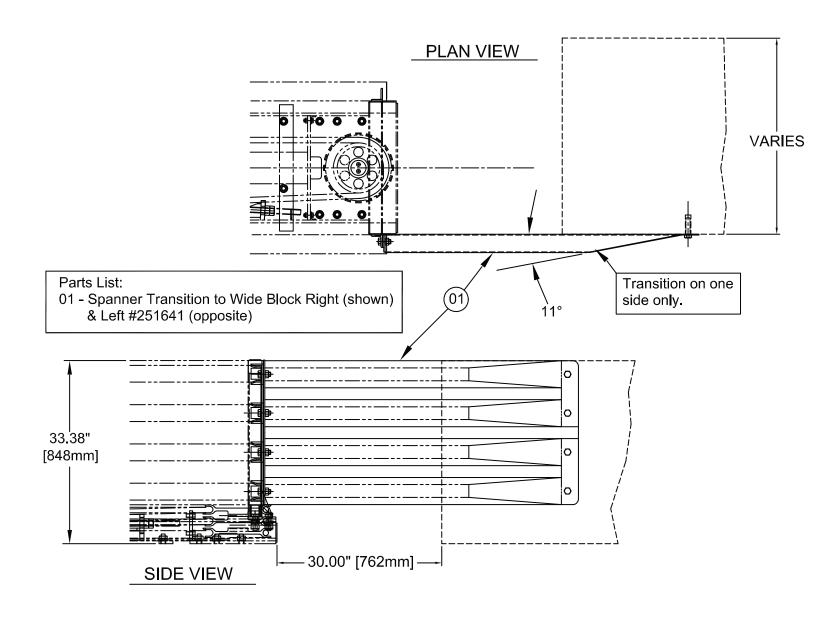
APPENDIX Q(2) & R(2) - TRANSITION, W BEAM 28" & 31" HIGH





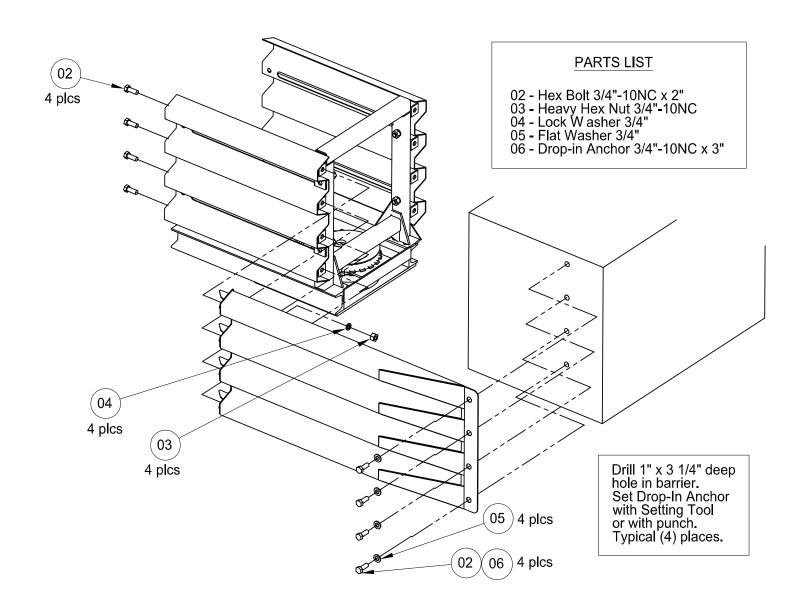






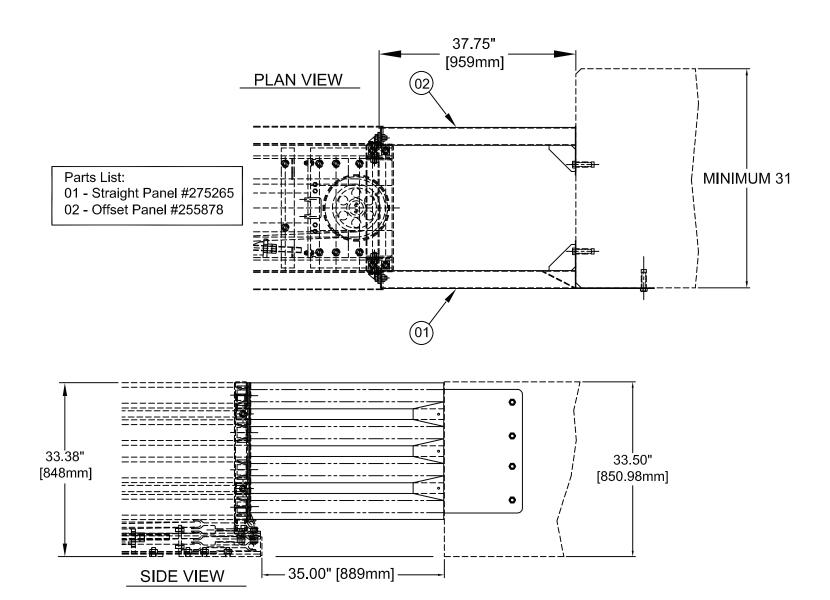
APPENDIX S(2) - TRANSITION, SPANNER FOR CONCRETE BLOCK





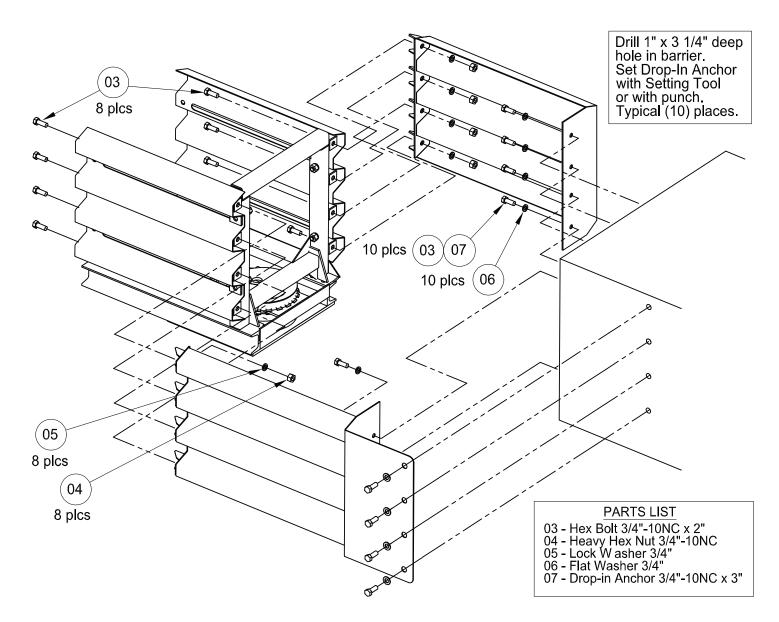


APPENDIX T - TRANSITION, OFFSET CONCRETE BLOCK



APPENDIX T(2) - TRANSITION, OFFSET CONCRETE BLOCK







SCI70/100GM CRASH CUSHION COMMERCIAL 1-YEAR WARRANTY

Hill and Smith, Inc. warrants this product to be free from defects in material and workmanship under normal use and service for a period of one (1) year beginning on the date of installation. Hill and Smith Inc. will repair or replace without charge to the original customer any defective component. This is the sole and exclusive remedy.

This warranty is contingent upon proper use of the System and does not cover Systems that have been modified (including the addition of parts) without the approval of Hill and Smith Inc. or which are in need of repair due to damage from external cause, including accident, collision, improper handling, improper transporting, failure to properly maintain the System as recommended by Hill and Smith Inc. abuse, misuse or which have been damaged by outside parties not employed by Hill and Smith Inc., whether in installation or otherwise.

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THE BUYER AGREES TO INSPECT THE PRODUCT ON RECEIPT AS FULLY AS THE BUYER DESIRES AND TO NOTIFY HSI PRODUCTS INC. OF ANY REVEALED DEFECT.

