The information contained in Chapter Nine: Guardrail and Roadside Barriers, dated October 2012, has been updated to reflect the February 2018 Errata. The errata addresses errors, changes in procedure, changes in NDOT department titles, changes in other Roadway Design Manual chapters and other reference material citations which have occurred since the latest publication of this chapter.

This chapter replaces Chapter Nine: Guardrail and Roadside Barriers, dated July 2006. This chapter also supersedes Nebraska Department of Transportation Policy Letter DES 06-04: “RSAP & Benefit / Cost Analysis” dated June 21, 2006. This chapter was approved by the Nebraska Division of the FHWA for use on the National Highway System and other federal projects on October 16, 2012.

Note: Except as otherwise noted, existing roadside barriers must be reviewed for compliance with the National Cooperative Highway Research Program (NCHPR) Report 350 or the Manual for Assessing Safety Hardware (MASH). Short radius installations (See Section 7.A) shall be in compliance with NCHRP Report 230.

Chapter Nine
Guardrail and Roadside Barriers

The Nebraska Department of Transportation (NDOT) will use the guidance found in the Roadside Design Guide (Ref. 9.1) for the evaluation and design of the roadside geometry, guardrail, and roadside barriers. This chapter includes additional NDOT guidance for new and reconstructed projects (see Chapter Seventeen: Resurfacing, Restoration and Rehabilitation (3R) Projects for barrier guidance on 3R projects).

A roadside barrier is used to shield traffic from steep slopes, cross-median traffic, and other obstacles along the roadside. The barrier is an obstacle itself and should not be used when it presents a greater crash potential than the object or condition being shielded.

Barrier installations at intersections will be checked against the required intersection sight distance (See Chapter Four: Intersections, Section1.C.2). Barrier selection and placement should also take snow drifting into consideration since the barrier may act as snow fence. Check with the District Engineer (DE) on the plan-in-hand field inspection for potential snow drifting areas.

In some locations a roadside barrier may be installed to shield pedestrians and bicyclists from motor vehicle traffic. Whenever significant pedestrian and/or bicycle traffic is anticipated special attention must be paid to the deflection characteristics of the barrier to be provided (see Section 3.D.1).
1. **BARRIER JUSTIFICATION**

The first step is to determine whether a barrier is desirable. This determination will include:

1. Determine the clear-zone distance.
2. Identify the obstacle.
3. Consider your options.
4. Perform a cost effectiveness analysis.

Note: Shielding a non-traversable slope or a fixed obstacle is usually justified only if the slope or fixed obstacle is located within the clear-zone distance, it is impracticable to re-grade the slope due to environmental or right-of-way constraints, the fixed obstacle cannot be economically or practicably removed, relocated, or made breakaway, and the cost effectiveness analysis indicates that shielding may be required.

1.A **Determine the Clear-Zone Distance**

For new and reconstructed projects the clear-zone distance is the roadside area, starting at the edge of the through lane, which is available for the recovery of vehicles leaving the roadway. The clear-zone distance provides an area free of fixed obstacles and may consist of:

- The shoulder and
- A recoverable slope or
- A non-recoverable but traversable slope with a clear runout area.

The minimum required clear-zone width is given in the Nebraska Minimum Design Standards (MDS) (Ref. 9.2) [http://www.roads.nebraska.gov/media/5593/nac-428-rules-regs-nbcs.pdf] as determined by the roadway type, ADT, and design speed.

1.B **Identify the Roadside Condition**

**EXHIBIT 9.1** is a partial list of potential roadside conditions.

1.C **Consider Your Options**

The designer should consider the following options when determining the appropriate treatment for an obstacle:

1. Remove the obstacle.
2. Redesign the obstacle so it can be traversed.
3. Relocate the obstacle to a location where it is less likely to be hit, preferably beyond the clear-zone distance.
4. If the obstacle is a sign support or utility pole that cannot be relocated, use breakaway devices.
5. Shield the obstacle.
6. If no other option is practicable, delineate the obstacle.
1.D Cost Effectiveness Analysis

Barrier installation is based on a cost effectiveness analysis and the premise that shielding should be installed if it will reduce the severity of crashes. The cost effectiveness analysis program used by Roadway Design is the “Roadside Safety Analysis Program” (RSAP). RSAP calculates the benefit to cost ratio, comparing the possible costs of impacting roadside obstacles to the expected benefit of shielding them. The analysis includes, but is not limited to, consideration of the costs of:

- Removing or minimizing the obstacle
- The barrier
- Barrier maintenance
- Crashes involving the barrier
- Crashes involving the roadside obstacle

The Roadway Design Unit Head (Unit Head) or his/her designee should run RSAP on obstacles and on existing unprotected non-traversable fill slopes (steeper than 1:3) within the clear-zone distance for barrier warrants. The length of the vehicle runout path should be included when running the analysis. The NDOT prefers a benefit-cost ratio of 1.0 or greater when shielding roadside obstacles.
<table>
<thead>
<tr>
<th>Roadside Condition</th>
<th>Decision Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foreslopes and Backslopes</td>
<td>Consider the slope and the clear-zone distance. Shielding is not generally required.</td>
</tr>
<tr>
<td>Bridge piers, abutments and end of bridge rail</td>
<td>Consider the clear-zone distance. Shielding is generally required.</td>
</tr>
<tr>
<td>Cross-Median Traffic</td>
<td>Consider the median width, traffic speed, traffic volumes, and percentage of heavy trucks.</td>
</tr>
<tr>
<td>Boulders</td>
<td>Consider the nature of the obstacle and the likelihood of impact.</td>
</tr>
<tr>
<td>Culverts, pipes, headwalls</td>
<td>Crossroad culverts 36 inches or less in diameter with flared end sections, round-equivalent culverts 36 inches or less in width with flared end sections, and multiple-pipe installations of culverts 30 inches or less in diameter with flared end sections may be included within the clear-zone distance without protection. Larger culverts will require either a traversable end section, extension outside of the clear-zone distance, or a cost effectiveness analysis to determine if barrier protection is economically warranted. Driveway culvert pipes parallel to the highway should be placed at the back of the ditch, outside of the clear-zone distance.</td>
</tr>
<tr>
<td>Ditches (parallel)</td>
<td>Consider the foreslope, backslope, and the clear-zone distance. (See FIGURES 3-6 &amp; 3-7 of the Roadside Design Guide, Ref. 9.1).</td>
</tr>
<tr>
<td>Ditches (transverse)</td>
<td>Consider the approach transverse side slope (should be 1:10 or flatter) and the likelihood of impact.</td>
</tr>
<tr>
<td>Embankment / Steep Slopes</td>
<td>Consider the fill height, length of slope, slope geometry, and clear-zone distance. The minimum length of embankment requiring protection should be 100 feet for semi-rigid guardrail (MGS, W-Beam, and Thrie-Beam) and 150 feet for cable guardrail. When fixed obstacles exist on the embankment slope the slope may not be the controlling factor: a cost effectiveness analysis should be based on the severity of the fixed obstacle (e.g. large culverts).</td>
</tr>
<tr>
<td>Retaining walls</td>
<td>Consider the relative smoothness of the wall, anticipated maximum angle of impact, structural integrity of the wall when impacted, and the cost of repairs.</td>
</tr>
<tr>
<td>Sign/luminaire supports</td>
<td>Locate outside of the clear-zone distance whenever possible. Where feasible, all sign/luminaire supports should be a breakaway design, regardless of their distance from the roadway, if there is a reasonable likelihood of their being hit by an errant vehicle. The placement and locations of breakaway supports will also give consideration to the consequence to pedestrians from potential debris resulting from impacts. Shielding is generally required for non-breakaway supports.</td>
</tr>
<tr>
<td>Traffic signal supports</td>
<td>Isolated traffic signals within the clear-zone distance on high-speed rural facilities may warrant shielding with a roadside barrier or a crash cushion.</td>
</tr>
<tr>
<td>Trees</td>
<td>Consider the site-specific circumstances</td>
</tr>
<tr>
<td>Utility poles</td>
<td>Utility poles should be relocated outside of the clear-zone distance whenever possible. If utility poles cannot be relocated, a cost effectiveness analysis will be performed and, if appropriate, the utility poles will be shielded. See Chapter Thirteen: Planning and Project Development, Section 6, for information regarding coordination with utilities.</td>
</tr>
<tr>
<td>Permanent bodies of water</td>
<td>Consider the location and depth of the water and the likelihood of encroachment.</td>
</tr>
</tbody>
</table>

Exhibit 9.1 Barrier Considerations for Roadside Conditions
2. **BARRIER TYPES USED IN NEBRASKA**


<table>
<thead>
<tr>
<th>Barrier</th>
<th>Location</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semi-rigid Guardrail (Midwest Guardrail System (MGS), W-beam, and Thrie-beam)</td>
<td>Used to shield motorists from fixed objects such as bridge piers. Shall not be placed on slopes steeper than 1:6. Semi-rigid systems will be designed with a minimum distance of 1 foot from the back of the post to a non-traversable slope (steeper than 1:3 but less than 1:1.5) when the system utilizes 6 feet long guardrail posts; the guardrail may be installed at the slope break point when 9 feet long posts are used.</td>
<td>Semi-rigid guardrail relies on energy absorption of posts rotating in soil. Posts should be placed to maximize available deflection distance around bridge piers and other point hazards.</td>
</tr>
<tr>
<td>Cable Guardrail (Low-Tension)</td>
<td>Most cost effective method of treating slopes and protecting objects. Can be placed within 4 feet of slope break point when slope is 1:2 or flatter. Should not be placed within 4 feet of a slope between 1:1.5 and 1:2 or within 12 feet of a fixed object. Preferred over semi-rigid guardrail where snow drifting is likely.</td>
<td>Relies on tensile forces in cables and the ability of impacting vehicles to ride down weak posts. Should not be placed on the inside of curves with radii less than 1910 feet unless additional space at 1:6 or flatter slopes, free of obstacles, is provided. Do not place on inside of curve with an R &lt; 716 feet.</td>
</tr>
<tr>
<td>Cable Guardrail (High-Tension)</td>
<td>Used for narrow medians (e.g. Interstate and expressway medians) to guard against cross-over crashes.</td>
<td>The price is approximately twice that of Low-Tension Cable Guardrail. Roadway Design Engineer approval is required for this installation.</td>
</tr>
<tr>
<td>Cable Guardrail Transition to W-Beam Guardrail</td>
<td>Used to transition from cable guardrail to W-Beam guardrail for long runs of guardrail.</td>
<td>Not cost effective if the length of need is less than 350 feet.</td>
</tr>
<tr>
<td>32 inch Concrete Protection Barrier</td>
<td>Used in areas where barrier deflections are intolerable, truck capacity is required, or barrier repair is difficult. Should only be placed adjacent to flat surfaced shoulders or medians.</td>
<td>Barrier will cause the impacting vehicle to lift and may cause a rollover. Rigidity causes somewhat higher injury rate.</td>
</tr>
<tr>
<td>42 inch Concrete Protection Barrier</td>
<td>Used when the ability to contain large trucks is of primary concern. Locations with high volumes and narrow medians or where widening into a median is planned are the most common applications.</td>
<td>Same performance as 32 inch high barrier. Height helps to reduce glare somewhat and holds up a semi-trailer to keep it from tipping over.</td>
</tr>
<tr>
<td>Vertical Concrete Barrier</td>
<td>Used where barrier deflections are intolerable, truck capacity is required, or barrier repair is difficult. Can be built to any height ≥ 32 inches.</td>
<td>Barrier provides high strength and low repair costs without high rollover rates. Rigidity causes somewhat higher injury rate. When initially taller than 32 inches, overlays do not affect performance.</td>
</tr>
<tr>
<td>Bridge Approach Section/Special Bridge Approach Section</td>
<td>Should be used any time semi-rigid guardrail is transitioned to a bridge rail.</td>
<td>End shoe should be lapped with adjacent traffic to minimize snag potential. Posts should be no closer than 2 feet from the hinge point.</td>
</tr>
<tr>
<td>Bullnose Median Barrier</td>
<td>Used in medians of 40 feet or less in width to shield motorists from sign bases, bridge ends, bridge piers, etc.</td>
<td>Requires 66 feet minimum clearance from the tip of the bullnose to the fixed object. The approaching terrain will be graded 1:10 or flatter for 60 feet prior to and under the bullnose.</td>
</tr>
</tbody>
</table>

Note: For additional information see TABLE 5-3 of the Roadside Design Guide (Ref. 9.1).
3. GUARDRAIL DESIGN PROCEDURES - A GRAPHICAL SOLUTION

Once it has been determined that guardrail is appropriate for a given location, its placement, length, type, etc. must be determined. The required length of a guardrail installation is a function of several variables, including:

- Design speed
- Design year ADT
- Runout length
- Lateral extent of the obstacle
- The tangent length of guardrail upstream from the obstacle
- The guardrail’s lateral distance from the edge of the traveled way
- The flare rate for the specific type of guardrail installation

The following steps should be followed in guardrail design:

1. Determine the runout length and the lateral extent of the obstacle.
2. Plot the runout path.
3. Determine the appropriate guardrail flare rate.
4. Select the guardrail components.
5. Graphically locate the guardrail components on the plan.
6. Design the earthwork around the guardrail.
7. Determine the details of surfacing under guardrail.
8. Determine the pay item quantities.

These steps are expanded upon in the following sections.
3.A **Determine Runout Length & Lateral Extent of the Obstacle**

Runout Length: The distance used to graphically determine the required length of a barrier. The runout length is measured from where a vehicle leaves the roadway to the obstacle being shielded as measured along the outside edge of the through travel lane. The runout length may be determined based on the design speed and traffic volume using **EXHIBIT 9.3**.

<table>
<thead>
<tr>
<th>Design Speed (mph)</th>
<th>Runout Length ($L_R$) for Given Traffic Volume (ADT)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Over 10,000 veh/day</td>
</tr>
<tr>
<td>80</td>
<td>470 feet</td>
</tr>
<tr>
<td>70</td>
<td>360 feet</td>
</tr>
<tr>
<td>60</td>
<td>300 feet</td>
</tr>
<tr>
<td>50</td>
<td>230 feet</td>
</tr>
<tr>
<td>40</td>
<td>160 feet</td>
</tr>
<tr>
<td>30</td>
<td>110 feet</td>
</tr>
</tbody>
</table>

**Exhibit 9.3 Runout Length Values**  
(Source: Roadside Design Guide, Ref. 9.1)

Lateral Extent of the Obstacle: The distance from the edge of the traveled way to the far side of a fixed obstacle. If the obstacle extends beyond the clear-zone distance the lateral extent of the obstacle is measured to the outside edge of the clear-zone distance.

The clear-zone distance listed in the MDS (Ref. 9.2) also applies to curved roadway segments in the following cases:

- When the obstacle is located outside a curve with a radius greater than 2950 feet and there is no crash history
- When the obstacle is located inside the curve

When recommended by the Traffic Engineering Division (Traffic Engineering) based on the crash history and the obstacle is located on the outside of a curve with a radius of 2950 feet or less, the clear-zone distance for the tangent roadway may be multiplied by the appropriate curve correction factor to arrive at an adjusted clear-zone distance to be used in plotting the runout path. For additional information see Section 3.1 and TABLE 3-2 of the Roadside Design Guide (Ref. 9.1).

On two-way two-lane roadways guardrail is needed to shield opposing traffic from the obstacle. The same guardrail design procedures are used but for the opposing traffic the lateral extent of the obstacle and the runout length will be measured from the centerline of the two-way roadway (See **EXHIBIT 9.4**).
Exhibit 9.4 Determine the Runout Length & Lateral Extent of Obstacle
3.B Plot the Runout Path

On tangent roadway segments, the runout path runs from the lateral extent of the obstacle to a point on the outside edge of the nearest driving lane which is at the runout length distance from the obstacle as measured along the edge of the lane (See EXHIBIT 9.5). The same procedure should be used on curved roadway segments where the curve radius is greater than 2950 feet and for obstacles on the inside of the curve (See EXHIBIT 9.14).

On curves with a radius of 2950 feet or less, the runout path is plotted tangent to the outside edge of the driving lane so that it intersects the obstacle at the adjusted lateral extent of the obstacle (See Section 3.A and EXHIBIT 9.15).

For MGS, W-beam, and Thrie-beam guardrail installations, the last 12.5 feet of the guardrail end treatment will not be included in the length of need. The runout path must intersect these end treatments at a distance of 12.5 feet or more from the end post (See EXHIBIT 9.7).

For a low-tension cable guardrail installation, the runout path must intersect the guardrail at a distance of 15 feet or more from the end post of the in-line terminal anchorage system when used to shield a fixed object (See below and EXHIBIT 9.16).
Exhibit 9.5  Plot the Runout Path
3.C Determine the Appropriate Flare Rate(s)

Flare is generally incorporated into guardrail installations to place the terminal section at a greater distance from the roadway and to shorten the required length of the barrier. Flare rate is a function of design speed and barrier type.

- A 25:1 flare rate is generally used for a Guardrail End Treatment, Type I (primarily installed on Midwest Guardrail System (MGS) and W-beam guardrail on multi-lane divided roadways)
- A 15:1 flare is used for a Guardrail End Treatment, Type II (generally used on MGS and W-beam guardrail on 2-lane, 2-way roadways).

Parallel installations or flatter flare rates are often used on projects with right-of-way constraints, to reduce environmental impacts, to reduce impacts to utilities, and/or where a limited amount of earthwork is desired. A parallel installation or a flatter flare rate increases the required length of the barrier. The Standard Plans (Ref. 9.3) include guardrail post locations for the various flare rates.

3.D Select the Guardrail Components

Factors influencing guardrail selection include but are not limited to:

- Design speed
- Traffic volume
- The nature of the obstacle
- Roadway geometry
- Median width (consider back-side impacts)
- Allowable deflection distance
- Cost

The following guidelines should be followed:

- Install cable guardrail whenever practicable.
- Design cable guardrail length in multiples of 4 feet, which is the standard post spacing.
- Guardrail, when justified, should be connected to concrete bridge rail with an appropriate transition section (See Section 5). MGS or W-beam guardrail may be used on the off-end of one-way bridges when an obstacle is required to be shielded.
- Design MGS, W-beam, and Thrie-beam guardrail length in multiples of 12.5 feet, which is the standard beam length. MGS, W-beam, or Thrie-beam guardrail may be designed in multiples of 6.25 feet due to site restrictions, if that satisfies the required runout length.
- Use the appropriate terminal sections based on:
  1. Flare rate,
  2. The guardrail system,
  3. The roadway classification,
  4. The design speed, and
  5. District preference.
3.D.1 Deflection Distance

Selection and placement of guardrail is a function of the distance it will deflect upon impact. If the guardrail is shielding a rigid object the distance between the guardrail and the object must be sufficient to avoid a vehicle contacting the object. Guardrail may not function properly in protecting traffic from a rigid object if the guardrail post(s) come in contact with the obstacle. See **EXHIBIT 9.6** for the required guardrail clearances and deflections.

- Low-tension cable guardrail deflects the greatest distance, in testing by as much as 11.5 feet. Low-tension cable guardrail should be designed with a 12 feet minimum deflection.
- High-tension cable guardrail systems have exhibited deflection distances between 7 feet and 9 feet in crash testing but deflections of up to 12 feet have been observed in field conditions.
- Deflection characteristics of semi-rigid systems (MGS, W-beam, or Thrie-beam guardrail) vary depending upon the strength of the post.
- Concrete (rigid) barriers are designed for virtually no deflection and may be used where space is limited between the obstacle and the travel lanes.

See the Roadside Design Guide (Ref. 9.1) for further information.
### MINIMUM REQUIRED GUARDRAIL OFFSET

**FROM BACK OF POST TO A POINT OBSTACLE (e.g. PIER COLUMN) **

<table>
<thead>
<tr>
<th>GUARDRAIL INSTALLATION TYPE</th>
<th>MINIMUM OFFSET *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three Strand Cable Guardrail (Low-Tension)</td>
<td>12' (4' and 16' post spacing)</td>
</tr>
<tr>
<td>Cable Guardrail (High-Tension)</td>
<td>7' to 12', depending on the system</td>
</tr>
<tr>
<td>Midwest Guardrail System (MGS) &amp; W-Beam Guardrail</td>
<td>3'-10&quot; for normal post spacing (6'-3&quot;)</td>
</tr>
<tr>
<td></td>
<td>3'-5&quot; for ½ post spacing (3'-1½&quot;)</td>
</tr>
<tr>
<td></td>
<td>2'-6&quot; for ¼ post spacing (1'-6¾&quot;)</td>
</tr>
<tr>
<td>Thrie Beam Guardrail</td>
<td>2'-3&quot; for normal post spacing (6'-3&quot;)</td>
</tr>
</tbody>
</table>

**FROM BACK OF POST TO A LINEAR OBSTRUCTION (e.g. MSE WALL)**

<table>
<thead>
<tr>
<th>GUARDRAIL INSTALLATION TYPE</th>
<th>MINIMUM OFFSET *</th>
</tr>
</thead>
<tbody>
<tr>
<td>MGS &amp; W-Beam Guardrail</td>
<td>4'-1&quot; for normal post spacing (6'-3&quot;)</td>
</tr>
<tr>
<td></td>
<td>3'-5&quot; for ½ post spacing (3'-1½&quot;)</td>
</tr>
<tr>
<td></td>
<td>2'-6&quot; for ¼ post spacing (1'-6¾&quot;)</td>
</tr>
<tr>
<td>Thrie Beam Guardrail</td>
<td>2'-10&quot; for normal post spacing (6'-3&quot;)</td>
</tr>
</tbody>
</table>

* Based on the dynamic deflections from the NCHRP Report 350 standard strength test for the 4,400 lb pickup truck impacting a barrier at an angle of 25° at a velocity of 60 mph.

** Adjust the posts longitudinally so that they will not be placed directly opposite a point obstacle (e.g. pier column, tree). The minimum offset between the back of the guardrail post and the point obstacle may be found in the table above.

Exhibit 9.6 Minimum Guardrail Offsets When Adjacent to a Fixed Obstacle
3.E Graphically Locate the Guardrail on the Plan

The designer should lay out the guardrail components on the plan (See Exhibit 9.7). For MGS, W-beam, and Thrie-beam installations the components may include the bridge approach section, the appropriate guardrail radius section for the design flare rate, the tangent guardrail section, and the applicable guardrail end treatment(s) (See Section 4). The runout path will intersect the guardrail at a distance of 12.5 feet or greater from the end of the guardrail end treatment.

Cable guardrail installation components are the cable guardrail, the terminal anchorage sections, and the intermediate anchorage sections (if required). The runout path will intersect the low-tension cable guardrail at a distance of 15 feet or greater from the end of the in-line terminal anchorage section (See Exhibit 9.16).

For unique installations (e.g. on a curved roadway where the guardrail is curved in the opposite direction) the designer should provide the station and offset at the ends of the guardrail and at intermediate points as appropriate.

See the Standard Plans (Ref. 9.3) for details of the guardrail components.
EXAMPLE GUARDRAIL DESIGN - 2 LANE, 2 WAY TANGENT ROADWAY
GRAPHICALLY LOCATE THE GUARDRAIL COMPONENTS ON THE PLAN
3.F  **Design the Earthwork Around the Guardrail**

The designer should refer to the *Standard Plans* (Ref. 9.3) for guidance in designing earthwork for guardrail (See [EXHIBIT 9.8](#)). Details of earthwork around the guardrail should be provided on guardrail layout sheets and on the project cross-sections for the benefit of the contractor and inspector. This earthwork will be included in the earthwork quantities.

3.G  **Determine the Details of Surfacing Under the Guardrail**

Surfacing is placed under guardrail as a method to control weeds (See [EXHIBIT 9.9](#)). The designer should consult with the DE or the District Construction Engineer (DCE) during the plan-in-hand field inspection to determine if surfacing under guardrail is desired and the choice of material to be used. Surfacing may be concrete, asphaltic concrete, or millings. When concrete or asphaltic concrete surfacing is used the posts will be blocked out and backfilled with suitable materials (See the *Standard Plans* (Ref. 9.3) and the *Standard Specifications for Highway Construction* (Spec Book) (Ref. 9.4) ([http://dot.nebraska.gov/media/10343/2017-specbook.pdf](http://dot.nebraska.gov/media/10343/2017-specbook.pdf)).

Typical sections of asphalt surfacing under guardrail for non-curbed and curbed conditions are shown in [EXHIBITS 9.10 THROUGH 9.13](#). Designers will submit detailed plans, typical sections, and estimates for all asphalt surfacing under guardrail locations to the Materials and Research Division (M&R) for inclusion in the asphalt quantities; the designer is responsible for calculating concrete surfacing quantities.
Exhibit 9.8  Design the Earthwork Around the Guardrail
Exhibit 9.9 Determine the Details of Surfacing Under the Guardrail
Exhibit 9.10  Surfacing Under Guardrail at Surfaced Shoulder

Exhibit 9.11  Surfacing Under Guardrail with Curb at Surfaced Shoulder
Exhibit 9.12  Surfacing Under Cable Guardrail at Surfaced Shoulder

Exhibit 9.13  Surfacing Under Cable Guardrail with Curb at Surfaced Shoulder
3.H  **Determine the Pay Item Quantities**

Guardrail pay items include, but are not limited to, the following:

- **Remove Guardrail**: Paid for by the linear foot. Used for the removal of both cable and semi-rigid guardrail. The removal length includes the approach and terminal sections for each continuous length of guardrail.
- **Semi-Rigid Guardrail (MGS, W-Beam, and Thrie-Beam)**: Paid for by the linear foot. Measure the semi-rigid guardrail from the bridge approach section to the guardrail end treatment or from the guardrail end treatment to the guardrail end treatment. The semi-rigid guardrail length will include the guardrail radius section, if applicable. This pay item includes the guardrail posts, offset blocks, and hardware required for installation.
- **Cable Guardrail**: Paid for by the linear foot. Measure the cable guardrail from terminal anchorage section to terminal anchorage section (excluding intermediate anchorage sections). The cable guardrail length should be a multiple of 4 feet. This pay item includes the guardrail posts and hardware required for installation.
- **Bridge Approach Sections**: Paid for by each.
- **W-Thrie Beam Transition Section**: Paid for by each. Used to connect MGS or W-Beam guardrail to Thrie-Beam guardrail. This is a separate pay item when it is used separately from a BAS.
- **Cable Guardrail Transition to W-Beam Guardrail**: Paid for by each.
- **Guardrail End Treatments**: Paid for by each. Divided into the pay items Guardrail End Treatment Type I, Guardrail End Treatment Type II, SRT-75 and ET-Plus.
- **End Anchorage Assembly**: Paid for by each.
- **Cable Guardrail Anchorage**: Paid for by each. The designer will also include two anchorage units for each intermediate anchorage, if applicable.
- **Culvert Mounted Guardrail Posts**: Paid for by each. When the designer specifies culvert mounted guardrail posts, the posts are a separate pay item from the semi-rigid guardrail.
- **Crash Cushions and Impact Attenuators**: Paid for by each.
- **Concrete Median Barriers**: Paid for by the linear foot.
- **Bullnose**: Paid for by each. The pay item refers to the entire system from post 10 on the left to post 10 on the right and includes all Thrie-Beam guardrail, posts, cables, blockouts, and hardware necessary to complete the Bullnose installation.
- **Surfacing Under Guardrail**: Paid for by the sq. yd.

For further information see the **Standard Plans** (Ref. 9.3), the **Spec Book** (Ref. 9.4), and Chapter Twelve: **Cost Estimating & Funding**.

Further examples of typical guardrail installations may be found in **EXHIBITS 9.14 THROUGH 9.16**.
Exhibit 9.14  Example W-Beam or Thrie-Beam Guardrail Design:
2-Lane, 2-Way Curved Roadway: R > 2950'
Exhibit 9.15 Example W-Beam or Thrie-Beam Guardrail Design:

2-Lane, 2-Way Curved Roadway: R ≤ 2950'

Example Guardrail Design - 2 Lane, 2 Way Curved Roadway

R ≤ 2950'

1. MIDWEST GUARDRAIL SYSTEM (MGS), PARALLEL TO ROADWAY
2. R = 187.7'
3. MGS
4. GUARDRAIL END TREATMENT TYPE II

--- SEE EXHIBIT 9.6 FOR REQUIRED GUARDRAIL CLEARANCES

--- RUNOUT PATH

--- DEPARTURE ANGLE = 0°

--- CENTERLINE OF ROADWAY

--- DEPARTURE ANGLE = 0°

--- MIN. (TYPICAL) 12'-6" Czar

--- LH = CLEAR ZONE DISTANCE = 30'

--- LR = 290'

--- CZc = 45', (LAT. OBSTACLE CL. x Kc2)
Exhibit 9.16  Example Low-Tension Cable Guardrail Design:
2-Lane, 2-Way Tangent Roadway
4. END TREATMENTS

Guardrail end treatments used in Nebraska may be found in the *Standard Plans* (Ref. 9.3).

4.A Guardrail End Treatment, Type I

A Guardrail End Treatment, Type I is used for design speeds of 65 mph and above for parallel guardrail installations or for installations with a 25:1 taper. This end treatment is used primarily for the Interstate System and on expressways, and may be installed in medians of 40 feet and wider.

4.B Guardrail End Treatment, Type II

A Guardrail End Treatment, Type II is primarily installed on high-speed (≥ 50 mph) two-lane, two-way roadways with a guardrail installation with a 15:1 taper.

4.C Low-Speed Roadways

The ET-Plus and the SRT-75 guardrail end treatments are installed on low-speed (≤ 45 mph) two-lane, two-way roadways with guardrail installations with a 15:1 taper. See the *Standard Plans* (Ref. 9.3) for details. The minimum guardrail installation at a low-speed bridge connection is shown in **EXHIBIT 9.21**.

4.D End Anchorage Assembly

The end anchorage assembly is permitted on the trailing ends of guardrail installations that are not exposed to oncoming traffic and on curved beam guardrail installations (with control releasing terminal posts) terminating on driveways to provide tension to the guardrail system. See the *Standard Plans* (Ref. 9.3) for details.

4.E Bullnose

See Section 6.B.

5. BRIDGE APPROACH SECTIONS

The bridge approach section is a transition section used where semi-rigid guardrail joins to a rigid bridge rail. Transition sections are designed to produce a gradual transition between the deflection capabilities of the two types of rail, reducing the potential of a vehicle pocketing, snagging, or penetrating the rail in the transition area. The bridge approach sections for both high-speed (≥ 50 mph) and low-speed (≤ 45 mph) installations in Nebraska may be found in the *Standard Plans* (Ref. 9.3). For examples of typical guardrail installations at a bridge, see **EXHIBITS 9.17 THROUGH 9.20 AND EXHIBITS 9.23 & 9.24**.
Exhibit 9.17 Example Guardrail Design at a Bridge: 2-Lane, 2-Way Tangent Roadway

GIVEN:
- STATE FUNCTIONAL CLASSIFICATION: MAJOR ARTERIAL (ADT ≥ 4,000 VPD)
- MINIMUM DESIGN SPEED = 50 mph
- POSTED SPEED = 55 mph
- USE 60 mph FOR GUARDRAIL DESIGN
- ADT = 5,200 VPD
- HAZARD SHOWN AT END OF BRIDGE RAIL
- LH = 30' LATERAL OBSTACLE CLEARANCE

EXAMPLE GUARDRAIL DESIGN - 2 LANE TANGENT ROADWAY
Exhibit 9.18 Example Guardrail Design at a Bridge: 2-Lane, 2-Way Curved Roadway; R > 2950'
Exhibit 9.19  Example Guardrail Design at a Bridge:
2-Lane, 2-Way Curved Roadway; $R \leq 2950'$
Exhibit 9.20  Cable Guardrail Transition to Midwest Guardrail System at a Bridge
Exhibit 9.21 Minimum Guardrail Installation for a Low-Speed Bridge Connection
6. MEDIAN BARRIERS

A median barrier is typically placed on the left side of the traffic lanes of a divided highway to redirect vehicles striking from either side of the barrier. The design, height, and lateral placement of the median barrier is critical for proper performance.

6.A Median Barrier Installation Guidelines

1) The NDOT will follow the guidance found in Chapter 6 of the Roadside Design Guide (Ref. 9.1).

2) **EXHIBIT 9.22** presents guidelines for median barrier installations on high-speed controlled access roadways that have relatively flat, unobstructed medians. These criteria may be used in the absence of cross median crash data for a specific site.

3) For median widths between 30 feet and 50 feet, the NDOT will analyze the crash history and determine if median barrier installation is warranted.

![Exhibit 9.22 Guidelines for Median Barriers](image)

**Exhibit 9.22 Guidelines for Median Barriers**

*Source: Roadside Design Guide (Ref. 9.1)*
6.B Median Barrier Systems

Concrete Protection Barrier

The concrete protection barrier (32 inch or 42 inch) should be used in narrow flush medians, depending upon the traffic speed, ADT, and percentage of heavy truck traffic. Both the 32 inch and 42 inch heights provide for a future 3 inch overlay. Concrete median barriers may be precast or cast in place. The barrier ends should be treated with an appropriate terminal section. See the Standard Plans (Ref. 9.3) for details.

Semi-Rigid Guardrail

Guardrail may be installed in the median to deflect vehicles from hitting specific obstacles, such as piers, and at dual bridges on divided highways. The preferred installation at a bridge in a median with a width of 40 feet or greater includes a bridge approach section, MGS or W-beam guardrail, and a guardrail end treatment (See Section 4.A and EXHIBITS 9.23 & 9.24).

Cable Guardrail

Cable guardrail may be installed in medians which are of sufficient width to allow for the greater deflection of the cable, 12 feet for a low-tension installation (See EXHIBIT 9.6). Crash tests on high-tension cable guardrail systems have exhibited deflection distances of between 7 feet and 9 feet (deflections of up to 12 feet have been observed in field conditions), but the price of the system is approximately twice that of the low-tension cable guardrail. The installation of high-tension cable guardrail requires Roadway Design Engineer approval.

Bullnose

The bullnose guardrail installation may be used on multilane divided highways to protect the motorist from hitting sign bases, bridge ends, bridge piers, or other obstacles in the median or gore area (See EXHIBIT 9.25).

When a bullnose installation is used to protect bridge ends in medians of 40 feet or less in width some Districts prefer to connect the bullnose installation from one bridge to the paired parallel bridge; other Districts prefer the away side to be unattached so that maintenance has easy access for mowing behind the bullnose. The designer should contact the DE or DCE to ascertain the preferred installation method (See EXHIBITS 9.26 THROUGH 9.31 for design examples).

Bullnose attenuators are designed so that the front end of vehicles impacting the installation head-on will be wrapped by the guardrail and will decelerate to a stop; side-impacting vehicles will be redirected. The bullnose installation requires 66 feet minimum clearance from the tip of the bullnose to the fixed object. The approaching terrain should be unobstructed and graded 1:10 or flatter for a minimum of 60 feet prior to and under the bullnose for proper performance (See the Standard Plans, Ref. 9.3).
Exhibit 9.23: Example Guardrail Design - 4 Lane Divided Highway: 64 Feet and Wider Median Width

**EXAMPLE GUARDRAIL DESIGN - 4 LANE DIVIDED HIGHWAY**

64' MEDIAN OR WIDER
Exhibit 9.24  Example Guardrail Design – 4 Lane Divided Highway: 40 Feet Median Width
Exhibit 9.25  Example Bullnose Installation for Median Bridge Pier Protection
Exhibit 9.26: Example Bullnose Bridge Connection in a 40 Feet Median

1. THRIE-BEAM BRIDGE APPROACH SECTION
2. R = 187.77'
3. THRIE-BEAM GUARDRAIL
4. # BN12.5'
5. END ANCHORAGE ASSEMBLY
6. BRIDGE APPROACH SECTION
7. R = 312.67'
8. MIDWEST GUARDRAIL SYSTEM
9. GUARDRAIL END TREATMENT TYPE I
   ----- RUNOUT PATH

---

LH +
25:1

7

6

5

4

3

2

1

---

CENTERLINE OF MEDIAN
PARALLEL
POST NO. 1 SHALL BE OUTSIDE OF THE RUNOUT PATH

---

THRIE-BEAM GUARDRAIL MAY BE USED IN MEDIANS OF 40' OR LESS IN WIDTH

* THE THRIE-BEAM GUARDRAIL SHALL EXTEND TO A LINE
TAKEN 25° FROM THE END OF THE CONCRETE BRIDGE RAIL
ON THE OFF-SIDE BRIDGE

MEDIAN INSTALLATION PAY ITEMS
(FOR COMPARISON ONLY)

1. THRIE-BEAM BRIDGE APPROACH SECTION
1. BULLNOSE, 12.5'
1. END ANCHORAGE ASSEMBLY
100' LIN. FT. THRIE-BEAM GUARDRAIL

GIVEN:
STATE FUNCTIONAL CLASSIFICATION: EXPRESSWAY
MINIMUM DESIGN SPEED = 55 mph
(FROM THE NEBRASKA MINIMUM DESIGN STANDARDS)
POSTED SPEED = 65 mph
USE 70 mph FOR GUARDRAIL DESIGN
HAZARD SHOWN AT END OF BRIDGE RAIL
LH = 30' LATERAL OBSTACLE CLEARANCE

4 LANE DIVIDED HIGHWAY
40' MEDIAN
OPTION ONE

12.5' BULLNOSE
15:1 TAPER TRAFFIC SIDE,
PARALLEL OFFSIDE
Exhibit 9.27  Example Bullnose Bridge Connection in a 40 Feet Median:
Parallel Bullnose, Bridges not Connected
Exhibit 9.28   Example Bullnose Bridge Connection in a 40 Feet Median: Tapered Bullnose, Bridges Connected

# BULLNOSE MAY BE USED IN MEDIANS OF 40' OR LESS IN WIDTH

MEDIAN INSTALLATION PAY ITEMS (FOR COMPARISON ONLY)

1 - THRIE-BEAM BRIDGE APPROACH SECTION
1 - SPECIAL THRIE-BEAM END SHOE (SUBSIDIARY)
1 - BULLNOSE, 12.5'
150 LIN. FT. THRIE-BEAM GUARDRAIL

GIVEN:
STATE FUNCTIONAL CLASSIFICATION EXPRESSWAY
MINIMUM DESIGN SPEED = 55 mph
(FROM THE NEBRASKA MINIMUM DESIGN STANDARDS)
POSTED SPEED = 65 mph
USE 70 mph FOR GUARDRAIL DESIGN
HAZARD SHOWN AT END OF BRIDGE RAIL
L H = 30' LATERAL OBSTACLE CLEARANCE

4 LANE DIVIDED HIGHWAY
40' MEDIAN
OPTION THREE
CONNECT PARALLEL BRIDGES

12.5' (BULLNOSE)
15:1 TAPER TRAFFIC SIDE,
7.4:1 TAPER OFFSIDE
Exhibit 9.29  Example Bullnose Bridge Connection in a 40 Feet Median:
Right-Hand-Back Skew, Tapered Bullnose, Bridges Connected
Exhibit 9.30   Example Bullnose Bridge Connection in a 40 Feet Median:
Left-Hand-Back Skew, Tapered Bullnose, Bridges Connected

1. THRIE-BEAM BRIDGE APPROACH SECTION
2. R=187.77'
3. THRIE-BEAM GUARDRAIL
4. # BN12.5'
5. SPECIAL THRIE-BEAM END SHOE
6. BRIDGE APPROACH SECTION
7. R=312.67'
8. MIDWEST GUARDRAIL SYSTEM
9. GUARDRAIL END TREATMENT TYPE I

# BULLNOSE MAY BE USED IN MEDIANS OF 40' OR LESS IN WIDTH

12.5' BULLNOSE
15:1 TAPER TRAFFIC SIDE,
7.4:1 TAPER OFFSIDE

4 LANE DIVIDED HIGHWAY
40' MEDIAN
OPTION FIVE
CONNECT BRIDGES, L.H.B. SKEW

GIVEN:
STATE FUNCTIONAL CLASSIFICATION: EXPRESSWAY
MINIMUM DESIGN SPEED = 55 mph
( FROM THE NEBRASKA MINIMUM DESIGN STANDARDS)
POSTED SPEED = 65 mph
USE 70 mph FOR GUARDRAIL DESIGN
HAZARD SHOWN AT END OF BRIDGE RAIL
LH = 30' LATERAL OBSTACLE CLEARANCE

MEDIAN INSTALLATION PAY ITEMS
(FOR COMPARISON ONLY)
1 - THRIE-BEAM BRIDGE APPROACH SECTION
1 - SPECIAL THRIE-BEAM END SHOE (SUBSIDIARY)
1 - BULLNOSE, 12.5'
145.83 LIN. FT. THRIE-BEAM GUARDRAIL
(PAY LENGTH = 150.00 LIN. FT.)
Exhibit 9.31  Example Bullnose Bridge Connection in a 40 Feet Median:
Do Not Use

4 LANE DIVIDED HIGHWAY
40' MEDIAN

12.5’ BULLNOSE
15:1 TAPER BOTH SIDES
BRIDGES NOT CONNECTED

DO NOT USE

15:1 TAPER ON OFF SIDE DIRECTS VEHICLE INTO END OF CONCRETE BRIDGE RAIL

GIVEN:
STATE FUNCTIONAL CLASSIFICATION: EXPRESSWAY
MINIMUM DESIGN SPEED = 56 mph
(FROM THE NEBRASKA MINIMUM DESIGN STANDARDS)
POSTED SPEED = 65 mph
USE 70 mph FOR GUARDRAIL DESIGN
HAZARD SHOWN AT END OF BRIDGE RAIL
L-H = 30’ LATERAL OBSTACLE CLEARANCE

LR = 360°
7. SPECIAL INSTALLATIONS

7.A Guardrail at Intersections

When a minor road or driveway intersects a main roadway near a bridge it may not be possible to shield the bridge rail end with a standard guardrail installation. If it is not feasible to relocate the intersecting road, a crash cushion or an impact attenuator should be installed to protect the end of the bridge rail. If no other option is available a curved beam guardrail installation may be used with Unit Head approval. An area behind the guardrail, based on the radius of the curved beam, should be free of fixed objects. The standard bridge approach section should be used to transition to a concrete bridge rail. Controlled releasing terminal (CRT) posts are used through the curved section. Low-speed (≤ 45 mph) guardrail end treatments (See Section 4.C) may be used for the terminal on the minor road, an end anchorage assembly may be used for the terminal on driveways, and a guardrail end treatment should be used for the terminal on state highways. See the Standard Plans (Ref. 9.3) for an example of this design and for plans of the guardrail components. Further information may be found in the Roadside Design Guide (Ref. 9.1).

7.B Guardrail Over Low Fill Culverts

The Standard Plans (Ref. 9.3) illustrates the culvert mounted guardrail post details to be used when full embedment of a guardrail post is not possible, such as over low-fill culverts. Designers should graphically lay out the guardrail post location to use the minimum number of special posts.

7.C Guardrail Spans with Posts Eliminated

The Standard Plans (Ref. 9.3) illustrates the MGS design to be used for long spans (up to 25 feet) where guardrail posts are eliminated, such as over low fill culverts or in places where a guardrail post cannot be placed. Note: Posts cannot be eliminated on either a guardrail end treatment or a bridge approach section.

7.D Guardrail and Curbs

If a curb is used in conjunction with a guardrail installation on a high-speed facility (≥ 50 mph), the curb will be either a 3 inch or 4 inch concrete slope curb or a 3 inch asphaltic concrete mountable curb. The desirable curb location will place the back of the curb a minimum distance of 2 feet behind the back of the guardrail post. If curb must be placed in front of a guardrail installation, the back of the curb should be flush with the front face of the guardrail posts.

On low-speed roadways (≤ 45 mph) 6 inch curbs should not be either in front of or for a distance in advance (upstream) of the guardrail end treatment. The minimum curb-free distance should be 25 feet in advance of the first post of the guardrail end treatment. For further information see the Roadside Design Guide (Ref. 9.1), the Standard Plans (Ref. 9.3), and Exhibit 9.32.
Exhibit 9.32  Dropping the Curb in Advance of the Guardrail
8. CRASH CUSHIONS AND IMPACT ATTENUATORS

Crash cushions are designed to decelerate a vehicle to a stop in head-on impacts and to redirect a vehicle away from rigid objects in side impacts. Crash cushions may be used alone or in conjunction with properly designed longitudinal barriers. Crash cushions may also be used in construction and work zones. See the Roadside Design Guide (Ref. 9.1) for further information on crash cushions and impact attenuators.

**EXHIBITS 9.33 & 9.34** and the *Standard Plans* (Ref. 9.3) contain plans and examples of the crash cushions and impact attenuators used by the NDOT.

8.A Inertial Barriers

Inertial barriers are sand-filled barrel modules arranged with increasing amounts of sand in the barrels as they are placed closer to the obstacle. Standard module mass varies from 200 to 2100 lbs. Inertial barriers operate by dissipating the energy of an impacting vehicle, transferring the vehicle’s momentum to the variable weights of sand in the barrels. Inertial barriers may be used to shield a variety of fixed object obstacles and are used primarily for protection of pole and column bases, lighting supports, and other rigid objects on the ground.

Inertial barriers should be set as far from the travel lanes as possible to avoid nuisance hits. The width of the last row of modules should be greater than the shielded object. The individual manufacturers supply design details for barrel layout. See the Roadside Design Guide (Ref. 9.1) for additional information.
Exhibit 9.33 Typical Impact Attenuator Installation at a Bridge Adjacent to an Intersection or Driveway
Exhibit 9.34  Typical Impact Attenuator Installations
9. REFERENCES


