APPENDIX A: STATE DOT SURVEY QUESTIONNAIRE

The follow letter and questionnaire were sent to all 50 state DOTs. Responses were received from 40 states, and the results are tabulated in Chapter 3.

NCHRP Project 22 – 25: Development of Guidance for the Selection, Use, and Maintenance of Cable Barrier Systems

Background

In 2007, the Texas Transportation Institute (TTI) completed work on NCHRP Project 20-7(210) which included a comprehensive survey of all state agencies to gather detailed information on the selection and use of cable barrier systems in their respective States and on the effectiveness of their field installations. Responses were received from 29 states. This survey provided a snapshot of the extent of use of cable barrier systems and the state-of-the-practice relative to the design, selection, installation, and maintenance through 2005. The National Crash Analysis Center (NCAC) of the George Washington University has been awarded the contract for NCHRP Project 22-25 “Development of Guidance on the Selection, Use, and Maintenance of Cable Barrier Systems” in May 2008.

The enclosed survey is intended to update the information in the earlier TTI survey and to offer those who did not respond to the initial survey an opportunity to provide input based on their knowledge and experiences with cable barrier. Information should be provided only on those cable barrier systems, both generic and proprietary, that have been successfully crash-tested under NCHRP Report 350 (or subsequent) guidelines. Although the primary focus of this study is on cable barriers installed in the median of a divided highway to minimize cross-over crashes, information on recent use of cable as a roadside (non-median) barrier should also be included where appropriate.

The following is a list of questions that will assist us in identifying critical issues related to cable barriers and in developing guidelines for their selection, use, and maintenance. It is not expected that all requested information will be available from all states and for all systems. Please complete the survey with all readily available information. It is important to the success of this project that we gather responses from most states; consequently, we would greatly appreciate your response to the survey even if limited information is available and not all questions are answered. Please list or attach any references used in answering the questions or any additional relevant information (see question 20).

Any questions regarding the survey may be addressed to Dr. Dhafer Marzougui at 703-726-8532. Please send survey responses via e-mail to dmarzoug@ncac.gwu.edu or using the website link at http://www.ncac.gwu.edu/nchrp/survey/. Electronic copies of guidelines, specifications or drawings can also be sent via e-mail or uploaded to the web site address above. Non-electronic information such as State guidelines, specifications or drawings can be mailed to:

Dhafer Marzougui
The National Crash Analysis Center, The George Washington University, VA Campus
20101 Academic Way, Ashburn, VA 20147, USA

Name of Survey Participant: ________________________ Phone: ___________________
E-Mail: _____________________________ State: ____________________
**Survey Questions:**

1. Approximately how many miles of cable barrier are in place or are currently being installed in your state? For each cell, please enter the number of miles in your state (if available), enter “0” if a particular system is not used in your state, leave blank or enter “N/A” if the information is not available.

<table>
<thead>
<tr>
<th>Total (miles)</th>
<th>Miles By Test Level</th>
<th>Miles By Number of Cables</th>
<th>Miles By Placement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TL3 (miles)</td>
<td>TL4 (miles)</td>
<td>Other (miles)</td>
</tr>
<tr>
<td>Brifen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CASS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gibraltar</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nucor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safence</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-Tension</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Please estimate the median slopes that exist in your state for which cable median barriers have been or are planned to be installed to reduce cross median crashes? (Total should add to 100%)

<table>
<thead>
<tr>
<th>Slope</th>
<th>10:1</th>
<th>8:1</th>
<th>6:1</th>
<th>4:1</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent (%)</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

3. Please check the typical median geometry used in conjunction with the different cross slopes used in your state. For each cell, enter “X” for each configuration where a cable barrier is installed. More than one median shape can be checked for each slope. If available, the number of miles can be entered instead.

<table>
<thead>
<tr>
<th>Slope</th>
<th>10:1</th>
<th>8:1</th>
<th>6:1</th>
<th>4:1</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>V-Shape</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat-Bottom</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rounded-Bottom</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Symmetric</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

4. Please estimate the median widths (from one break or hinge point to the other) associated with the different cross slopes used in your state.

<table>
<thead>
<tr>
<th>Slope</th>
<th>10:1</th>
<th>8:1</th>
<th>6:1</th>
<th>4:1</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Width (ft)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Average Width (ft)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Maximum Width (ft)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
5. For the flat-bottom and rounded-bottom median configurations (if used), please specify the typical width of the flat/rounded section.

<table>
<thead>
<tr>
<th>Slope</th>
<th>10:1</th>
<th>8:1</th>
<th>6:1</th>
<th>4:1</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width of flat or rounded section (ft)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. What criteria are used to decide if a barrier is warranted?
   For median application:
   ______________________________________________________________________
   ______________________________________________________________________
   ______________________________________________________________________

   For roadside application:
   ______________________________________________________________________
   ______________________________________________________________________
   ______________________________________________________________________

7. What criteria are generally used to select a cable barrier system over a rigid or semi-flexible system in locations and conditions where any system can be used?
   For median application:
   ______________________________________________________________________
   ______________________________________________________________________
   ______________________________________________________________________

   For roadside application:
   ______________________________________________________________________
   ______________________________________________________________________
   ______________________________________________________________________

8. What criteria, if any, are generally used to select a specific cable barrier system, i.e. Bifren, CASS, Gibraltar, Nucor, Safence, or Generic Low-Tension?
   ____ System specific bid document
   ____ Low-bid open to all NCHRP Report 350 approved systems
   ____ Bid restricted to previously specified vendors
   ____ Other (please specify) _____________________________________________

9. Does your state have specific standards/guidelines for the system design, alignment, construction, and/or maintenance of cable barriers?
   System design (soil testing/properties, end-terminal loads, etc.)  ____ yes  ____ no
   Alignment (lateral placement, adjustment at drainage structure, etc.)  ____ yes  ____ no
   Construction (post foundation, anchor foundation, tolerances, etc.)  ____ yes  ____ no
   Maintenance (re-tensioning, anchor monitoring, re-installation, etc.)  ____ yes  ____ no

10. Approximately, every year, how many reported crashes into cable barriers occur on average in your state?

<table>
<thead>
<tr>
<th>Number of Crashes Per Year</th>
<th>Total (median and roadside)</th>
<th>In median</th>
<th>In roadside</th>
</tr>
</thead>
</table>
11. Approximately how many of these reported cable barrier crashes resulted in vehicular penetration (Penetration is defined as an impact where the vehicle completely passed through the system)?

<table>
<thead>
<tr>
<th>Number of Crashes Per Year</th>
<th>Median &amp; Roadside</th>
<th>In median</th>
<th>In roadside</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Over-ride</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under-ride</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

12. If data is available, please give the number of cable barrier penetrations that have resulted in crashes into opposite-direction traffic?

<table>
<thead>
<tr>
<th>Number of crashes into opposite traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
</tr>
</tbody>
</table>

Who should we follow up with to receive copies of the crash reports?

______________________________________________________________________

13. Based on the penetrations you experienced, is there a factor or factors that most likely contributed to the penetrations (e.g., barrier type, median feature, impact condition, barrier placement, etc.)?

In median:
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

In roadside:
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

14. Are you aware of any crashes into cable barriers by motorcyclists? If so, please summarize the number, circumstances, and severity of such crashes.
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

15. Have you experienced any significant or recurring repair or maintenance concerns? If so, please elaborate by cable barrier type as appropriate.
______________________________________________________________________
______________________________________________________________________

4
16. Please list the most critical issues that you believe need to be addressed in the guidelines for design, selection, installation, and maintenance of cable barriers. List the most critical first.

1-______________________________________________________________________
2-______________________________________________________________________
3-______________________________________________________________________
4-______________________________________________________________________

17. Please answer the following design/construction-related cable barrier questions:

- Do you have typical guidelines for cable barrier placement?____________________________________________________________________
- Is barrier performance better when placed near the shoulder instead of in the median area?____________________________________________________________________
- Do you have requirements for placement near median ditches, drainage inlets and dikes?____________________________________________________________________
- Do you provide soil data during request for procurement?____________________________________________________________________
- Do you require contractor to repair/replace anchors when excess movement of anchor occurs?____________________________________________________________________
- Do you have requirements on the type of ends used on the cables?____________________________________________________________________
- Do you require pull testing of fully fitted splices to determine breaking strength?____________________________________________________________________
- Do you require expected deflection values when anchor-to-anchor length is greater than the crash tested length?____________________________________________________________________
- Do you have inspection requirements?____________________________________________________________________
- Do you have construction tolerance limits?____________________________________________________________________
- What design and placement considerations are complementary with effective maintenance?____________________________________________________________________
- What practices have you found to make maintaining the roadside around where cable barriers are installed easier?____________________________________________________________________

18. Please answer the following maintenance related questions:

- Typically, how often do you inspect cable barrier system? _____ times a year
- Typically, how long after impact is the barrier repaired? _____ days
- Typically, how many posts are replaced per impact? _____
- What is a typical cost of repair per impact? $ _____
- Do you use mow strips? __yes __no; if yes, what is the additional cost? $ _____ per ft
- Do you utilize used parts in repairs? __yes __no; if yes, has this caused problems? __y __n
19. Please indicate (yes/no) if you are aware of any of the following occurring in your state:

- Cable failure during impact _____ yes _____ no
- Failure at end of cable connections (cable extension) _____ yes _____ no
- Failure at connection between cables and end-anchors _____ yes _____ no
- Excess barrier deflection during impact due to horizontal curvature _____ yes _____ no
- Excess barrier deflection due to long anchor-to-anchor segments _____ yes _____ no
- Penetrations/excess deflection due to long post spacing _____ yes _____ no
- Penetration/excess deflection due to cable spacing or number cables _____ yes _____ no
- End-anchor pull-out due to soil condition _____ yes _____ no
- Post foundation pull-out due to soil condition _____ yes _____ no

20. Please list or upload any references used in answering the survey questions or any additional related information:

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
## APPENDIX B: AVAILABLE CABLE BARRIER SYSTEMS

<table>
<thead>
<tr>
<th>System</th>
<th>Acceptance Letter</th>
<th>Test Level</th>
<th>Post</th>
<th>Post Spacing</th>
<th>Post Embedment</th>
<th>Cables</th>
<th>Cable Heights</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generic low-tension</td>
<td>B64, B64 Supp</td>
<td>TL3</td>
<td>Steel S75x8, Steel U-channel, or weakened round timber posts</td>
<td>16 ft</td>
<td>Driven posts with Soil Plate</td>
<td>Three 3/4” Non-pre-stretched</td>
<td>21” 25.5” 30”</td>
</tr>
<tr>
<td>Generic low-tension</td>
<td>B64</td>
<td>TL3</td>
<td>Steel S75x8</td>
<td>16 ft</td>
<td>Driven posts with Soil Plate</td>
<td>Three 3/4” Non-pre-stretched</td>
<td>21” 27” 33”</td>
</tr>
<tr>
<td>Generic low-tension</td>
<td>B161</td>
<td>TL3</td>
<td>Steel S75x8</td>
<td>16 ft (12 ft 8 ft 4ft)</td>
<td>Driven Posts with Soil Plate</td>
<td>Four 3/4” Non-pre-stretched</td>
<td>10” 16” 22” 28”</td>
</tr>
<tr>
<td>Brifen high-tension</td>
<td>B82 A</td>
<td>TL3</td>
<td>S-shaped post (100 mm x 32 mm x 6 mm)</td>
<td>10.5 ft</td>
<td>Driven or Socketed Posts</td>
<td>Four 3/4” Pre or Non-pre-stretched Woven</td>
<td>20” 26.57” 26.57” 28.35”</td>
</tr>
<tr>
<td>Brifen high-tension</td>
<td>B82C1</td>
<td>TL3</td>
<td>S-shaped post (100 mm x 32 mm x 6 mm)</td>
<td>10.5 ft and 7.9 ft</td>
<td>Driven or Socketed Posts</td>
<td>Three 3/4” Pre or Non-pre-stretched Woven</td>
<td>18” 23.5” 28.4”</td>
</tr>
<tr>
<td>Brifen high-tension</td>
<td>B82B B82B1</td>
<td>TL4 TL3</td>
<td>Z-shaped posts, (100 mm x 55 mm x 4.55 mm)</td>
<td>10.5 ft</td>
<td>Driven or Socketed Posts</td>
<td>Four 3/4” Pre or Non-pre-stretched Woven</td>
<td>18.9” 24.8” 30.7” 36.6”</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Code</td>
<td>Type</td>
<td>Dimensions</td>
<td>Height</td>
<td>Mounting Method</td>
<td>Post Type</td>
<td>Notes</td>
</tr>
<tr>
<td>--------------</td>
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</tr>
<tr>
<td>Brifen</td>
<td>B82D</td>
<td>TL4</td>
<td>High-tension</td>
<td>Z-shape (100 mm x 55 mm x 4.55 mm)</td>
<td>21 ft</td>
<td>Driven or Socketed Posts</td>
<td>Four 3/4” Pre or Non-pre-stretched Woven</td>
</tr>
<tr>
<td>Gibraltar</td>
<td>B137</td>
<td>TL3</td>
<td>High-tension</td>
<td>C-channel post (83 mm x 63.5 mm x 3.8 mm)</td>
<td>15 ft</td>
<td>Driven or Socketed Posts On alternate sides of the cables</td>
<td>Three 3/4” Pre or Non-pre-stretched</td>
</tr>
<tr>
<td>Gibraltar</td>
<td>B137A B137B B137C</td>
<td>TL4</td>
<td>High-tension</td>
<td>C-channel post (83 mm x 63.5 mm x 3.8 mm)</td>
<td>14 ft 30 ft 20 ft 10 ft</td>
<td>Driven or Socketed Posts On alternate sides of the cables</td>
<td>Three 3/4” Pre or Non-pre-stretched</td>
</tr>
<tr>
<td>Gibraltar</td>
<td>B137A1</td>
<td>TL4</td>
<td>High-tension</td>
<td>C-channel post (83 mm x 63.5 mm x 3.8 mm)</td>
<td>No test (10 ft -30 ft)</td>
<td>Driven or Socketed Posts On alternate sides of the cables</td>
<td>Four 3/4” Pre or Non-pre-stretched</td>
</tr>
<tr>
<td>Nucor</td>
<td>B96 B96A B183</td>
<td>TL3</td>
<td>High-tension</td>
<td>4 lb/ft U-Post</td>
<td>6.6 ft 12.5 ft 16.7 ft</td>
<td>Driven or Socketed Posts</td>
<td>Three 3/4” Pre or Non-pre-stretched</td>
</tr>
<tr>
<td>Nucor</td>
<td>B167 B183 B184</td>
<td>TL4</td>
<td>High-tension</td>
<td>4 lb/ft U-Post</td>
<td>20 ft</td>
<td>Driven or Socketed Posts</td>
<td>Four 3/4” Pre or Non-pre-stretched</td>
</tr>
<tr>
<td>Safence</td>
<td>B88</td>
<td>TL3</td>
<td>High-tension</td>
<td>Elliptical-Shape Steel Post (4mm thick)</td>
<td>8 ft</td>
<td>Driven Posts</td>
<td>Four 3/4” Pre-stretched</td>
</tr>
<tr>
<td>Model Number</td>
<td>Steel Post Type</td>
<td>Post Height Options</td>
<td>Driving or Socketing Options</td>
<td>Minimum Depth Options</td>
<td></td>
<td></td>
<td></td>
</tr>
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<td></td>
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</tr>
<tr>
<td>B88A/B88B/B88C</td>
<td>I-shape Steel Post (4mm thick) or C-shaped Steel Post (4mm thick)</td>
<td>8 ft, 6.5 ft, 10 ft</td>
<td>Driven or Socketed Posts</td>
<td>Four 3/4” Pre-stretched: 18.9”, 22”, 25.2”, 28.3”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B88D</td>
<td>C-shaped Steel Post (4mm thick)</td>
<td>8 ft, 6.5 ft, 10 ft</td>
<td>Driven or Socketed Posts</td>
<td>Four 3/4” Pre-stretched: 18.9”, 25.2”, 28.3”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B88E</td>
<td>C-shaped Steel Post with Stiffener Plate (4mm thick)</td>
<td>13 ft, 33 ft</td>
<td>Driven or Socketed Posts</td>
<td>Four 3/4” Pre-stretched: 18.9”, 21.2”, 25.2”, 28.3”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B88F (MAS H)</td>
<td>C-shaped Steel Post with Stiffener Plate (4mm thick)</td>
<td>16 ft</td>
<td>Driven or Socketed Posts</td>
<td>Three or Four 3/4” Pre-stretched: 19.7”, 30.9”, 34.6”, 38.4”* Optional</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B119/B119A/B119B/B141E</td>
<td>C-shaped Steel Post</td>
<td>6.5 ft, 10 ft, 16 ft</td>
<td>Driven or Socketed Posts</td>
<td>Three or Four 3/4” Pre or Non-pre-stretched: 21”, 23”, 25.2”, 29.5”* Optional</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B141/B141A/B141B</td>
<td>Weakened I-beam Steel Post (S4x7.7)</td>
<td>20 ft, 30 ft</td>
<td>Driven or Socketed Posts</td>
<td>Three 3/4” Pre or Non-pre-stretched: 21”, 25.2”, 29.5”</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>B141</td>
<td>Weakened I-beam Steel Post (S4x7.7)</td>
<td>20 ft</td>
<td>Driven or Socketed Posts</td>
<td>Three 3/4” Pre or Non-pre-stretched: 21”, 29.5”, 38”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trinity (CASS) high tension</td>
<td>B157</td>
<td>TL4</td>
<td>Weakened I-beam Steel Post (S4x7.7)</td>
<td>20 ft</td>
<td>Driven or Socketed Posts</td>
<td>Four 3/4” Pre or Non-pre-stretched</td>
<td>21” 25.2” 29.5” 38”</td>
</tr>
<tr>
<td>-----------------------------</td>
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<td>------------------</td>
</tr>
<tr>
<td>Trinity (CASS) high tension</td>
<td>B141C</td>
<td>TL3</td>
<td>TL4</td>
<td>Weakened I-beam Steel Post (S4x7.7)</td>
<td>6.67 ft 20 ft</td>
<td>Driven or Socketed Posts</td>
<td>Three or four 3/4” Pre or Non-pre-stretched</td>
</tr>
<tr>
<td>Trinity (CASS) high tension</td>
<td>B141D</td>
<td>TL3</td>
<td>TL4</td>
<td>Steel I-beam S3 x 5.7</td>
<td>10.5ft 21 ft</td>
<td>Driven or Socketed Posts</td>
<td>Four 3/4” Pre-stretched</td>
</tr>
<tr>
<td>Trinity (CASS) high tension</td>
<td>B141F</td>
<td>TL3</td>
<td>TL4</td>
<td>Steel I-beam S3 x 5.7</td>
<td>10.5ft 21 ft</td>
<td>Driven or Socketed Posts</td>
<td>Four 3/4” Pre-stretched</td>
</tr>
</tbody>
</table>
The research considered a wide range of median profiles. The medians varied in shape, slope, and width. The results from the symmetric v-shaped and flat-bottom medians are presented in this appendix. For the v-shaped medians varied in side slopes (4H:1V, 6H:1V, 8H:1V, and 12H:1V) and median widths (5 to 17 m, 16 to 56 ft). Similarly, the flat-bottom medians varied in side slopes (4H:1V, 6H:1V and 8H:1V), depths (0.6 to 1.8 m, 2 to 6 ft), and flat-bottom section widths (1.2 to 12.2 m, 4 to 40 ft).

For each median profile, simulations were performed using five vehicle models (820C, 2000P, 1100C, 2270P, and a mid-size sedan represented by the Ford Crown Victoria), three impact speeds 50, 70 and 100 km/hr (31, 43, and 62 mi/hr), and five approach angles, 5, 10, 15, 20, and 25 degrees.

Underride and override limit plots from the analysis are presented in the following pages. Two plots are included for each median profile. The cable barrier used in the first plot consisted of a generic three-cable barrier system with cable heights set at 533, 647, and 762 mm (21, 25.5, and 30 in) from ground level. This system has one of the narrowest cable spreads. The system used in the second plot consisted of a generic four-cable system with cable heights set at 343, 610, 876, and 1143 mm (13.5, 24, 34.5 and 45 in) from ground level. This system has one of the widest cable spreads.
Symmetric V-Shaped Medians
V-shaped Median - 4H:1V Slope - 16ft Width

Override and Underride Plots
- Green: Maximum Lower Cable Height to Avoid Underrides
- Blue: Minimum Upper Cable Height to Avoid Overrides
- Yellow: Cable Heights: 21" 25.5" 30"

Median Profile
- Lateral placement where the barrier is likely to capture vehicles
- Lateral placement where the barrier may miss some cases

Lateral (ft)
V-shaped Median - 4H:1V Slope - 40ft Width

Override and Underride Plots
- Maximum Lower Cable Height to Avoid Underrides
- Minimum Upper Cable Height to Avoid Overrides
- Cable Heights: 21" 25.5" 30"

Override and Underride Plots
- Maximum Lower Cable Height to Avoid Underrides
- Minimum Upper Cable Height to Avoid Overrides
- Cable Heights: 13.5" 24" 34.5" 45"

Median Profile
- Lateral placement where the barrier is likely to capture vehicles
- Lateral placement where the barrier may miss some cases
V-shaped Median - 6H:1V Slope - 24ft Width

Override and Underride Plots

- Maximum Lower Cable Height to Avoid Underrides
- Minimum Upper Cable Height to Avoid Overrides
- Cable Heights: 21" 25.5" 30"

Median Profile

- Lateral placement where the barrier is likely to capture vehicles
- Lateral placement where the barrier may miss some cases

Vertical (in)

Lateral (ft)
V-shaped Median - 6H:1V Slope - 32ft Width

Override and Underride Plots

- **Maximum Lower Cable Height to Avoid Underrides**
- **Minimum Upper Cable Height to Avoid Overrides**
- **Cable Heights:** 21” 25.5” 30”

**Median Profile**

- Lateral placement where the barrier is likely to capture vehicles
- Lateral placement where the barrier may miss some cases
V-shaped Median - 6H:1V Slope - 40ft Width

Override and Underride Plots
- Maximum Lower Cable Height to Avoid Underrides
- Minimum Upper Cable Height to Avoid Overrides
- Cable Heights: 21" 25.5" 30"

Lateral Profile
- Lateral placement where the barrier is likely to capture vehicles
- Lateral placement where the barrier may miss some cases

Override and Underride Plots
- Maximum Lower Cable Height to Avoid Underrides
- Minimum Upper Cable Height to Avoid Overrides
- Cable Heights: 13.5" 24" 34.5" 45"
V-shaped Median - 6H:1V Slope - 56ft Width

Override and Underride Plots
- Maximum Lower Cable Height to Avoid Underrides
- Minimum Upper Cable Height to Avoid Overrides
- Cable Heights: 21" 25.5" 30"

Override and Underride Plots
- Maximum Lower Cable Height to Avoid Underrides
- Minimum Upper Cable Height to Avoid Overrides
- Cable Heights: 13.5" 24" 34.5" 45"

Median Profile
- Lateral placement where the barrier is likely to capture vehicles
- Lateral placement where the barrier may miss some cases
V-shaped Median - 8H:1V Slope - 40ft Width

Override and Underride Plots
- Maximum Lower Cable Height to Avoid Underrides
- Minimum Upper Cable Height to Avoid Overrides
- Cable Heights: 21" 25.5" 30"

Override and Underride Plots
- Maximum Lower Cable Height to Avoid Underrides
- Minimum Upper Cable Height to Avoid Overrides
- Cable Heights: 13.5" 24" 34.5" 45"

Median Profile
- Lateral placement where the barrier is likely to capture vehicles
- Lateral placement where the barrier may miss some cases
V-shaped Median - 8H:1V Slope - 48ft Width

Override and Underride Plots
- Green: Maximum Lower Cable Height to Avoid Underrides
- Blue: Minimum Upper Cable Height to Avoid Overrides
- Yellow: Cable Heights: 21" 25.5" 30"

Override and Underride Plots
- Green: Maximum Lower Cable Height to Avoid Underrides
- Blue: Minimum Upper Cable Height to Avoid Overrides
- Yellow: Cable Heights: 13.5" 24" 34.5" 45"

Median Profile
- Light green: Lateral placement where the barrier is likely to capture vehicles
- Pink: Lateral placement where the barrier may miss some cases

Lateral (ft)
V-shaped Median - 8H:1V Slope - 56ft Width

Override and Underride Plots
- Maximum Lower Cable Height to Avoid Underrides
- Minimum Upper Cable Height to Avoid Overrides
- Cable Heights: 21" 25.5" 30"

Override and Underride Plots
- Maximum Lower Cable Height to Avoid Underrides
- Minimum Upper Cable Height to Avoid Overrides
- Cable Heights: 13.5" 24" 34.5" 45"

Median Profile
- Lateral placement where the barrier is likely to capture vehicles
- Lateral placement where the barrier may miss some cases
Symmetric Flat-bottom Medians
Flat-bottom Median - 4H:1V Slope - 4ft FB Width - 6ft Depth

Override and Underride Plots
- Maximum Lower Cable Height to Avoid Underrides
- Minimum Upper Cable Height to Avoid Overrides
- Cable Heights: 21" 25.5" 30"

Override and Underride Plots
- Maximum Lower Cable Height to Avoid Underrides
- Minimum Upper Cable Height to Avoid Overrides
- Cable Heights: 13.5" 24" 34.5" 45"

Median Profile
- Lateral placement where the barrier is likely to capture vehicles
- Lateral placement where the barrier may miss some cases

Horizontal Axis: Lateral (ft)
Vertical Axis: Vertical (in)
Flat-bottom Median - 4H:1V Slope - 8ft FB Width - 6ft Depth

Override and Underride Plots

- Maximum Lower Cable Height to Avoid Underrides
- Minimum Upper Cable Height to Avoid Overrides
- Cable Heights: 21" 25.5" 30"

Override and Underride Plots

- Maximum Lower Cable Height to Avoid Underrides
- Minimum Upper Cable Height to Avoid Overrides
- Cable Heights: 13.5" 24" 34.5" 45"

Lateral placement where the barrier is likely to capture vehicles
Lateral placement where the barrier may miss some cases
Flat-bottom Median - 4H:1V Slope - 16ft FB Width - 4ft Depth

Override and Underride Plots
- Maximum Lower Cable Height to Avoid Underrides
- Minimum Upper Cable Height to Avoid Overrides
- Cable Heights: 21" 25.5" 30"

Lateral Profile
- Lateral placement where the barrier is likely to capture vehicles
- Lateral placement where the barrier may miss some cases

Legend:
- Green line represents the maximum lower cable height to avoid underrides.
- Blue line represents the minimum upper cable height to avoid overrides.
- Yellow lines indicate cable heights of 21", 25.5", and 30".
Flat-bottom Median - 4H:1V Slope - 24ft FB Width - 2ft Depth

Override and Underride Plots
- Maximum Lower Cable Height to Avoid Underrides
- Minimum Upper Cable Height to Avoid Overrides
- Cable Heights: 21" 25.5" 30"

Lateral placement where the barrier is likely to capture vehicles
Lateral placement where the barrier may miss some cases
Flat-bottom Median - 4H:1V Slope - 24ft FB Width - 4ft Depth

Override and Underride Plots

- Maximum Lower Cable Height to Avoid Underrides
- Minimum Upper Cable Height to Avoid Overrides
- Cable Heights: 21" 25.5" 30"

Vertical (in) vs. Lateral (ft)

Median Profile

- Lateral placement where the barrier is likely to capture vehicles
- Lateral placement where the barrier may miss some cases
Flat-bottom Median - 4H:1V Slope - 32ft FB Width - 2ft Depth

Override and Underride Plots

- Green: Maximum Lower Cable Height to Avoid Underrides
- Blue: Minimum Upper Cable Height to Avoid Overrides
- Yellow: Cable Heights: 21" 25.5" 30"

Vertical (in)

Lateral (ft)

Median Profile

- Light Green: Lateral placement where the barrier is likely to capture vehicles
- Pink: Lateral placement where the barrier may miss some cases
Flat-bottom Median - 4H:1V Slope - 32ft FB Width - 4ft Depth

Override and Underride Plots

- Maximum Lower Cable Height to Avoid Underrides
- Minimum Upper Cable Height to Avoid Overrides
- Cable Heights: 21" 25.5" 30"

Lateral placement where the barrier is likely to capture vehicles
Lateral placement where the barrier may miss some cases
Flat-bottom Median - 4H:1V Slope - 40ft FB Width - 4ft Depth

Override and Underride Plots

- Maximum Lower Cable Height to Avoid Underrides
- Minimum Upper Cable Height to Avoid Oversides
- Cable Heights: 21" 25.5" 30"

Vertical (in)

Median Profile

Lateral (ft)

Override and Underride Plots

- Maximum Lower Cable Height to Avoid Underrides
- Minimum Upper Cable Height to Avoid Oversides
- Cable Heights: 13.5" 24" 34.5" 45"

Vertical (in)

Median Profile

Lateral (ft)

Legend:
- Light green: Lateral placement where the barrier is likely to capture vehicles
- Pink: Lateral placement where the barrier may miss some cases
Flat-bottom Median - 6H:1V Slope - 8ft FB Width - 2ft Depth

Override and Underride Plots

- Maximum Lower Cable Height to Avoid Underrides
- Minimum Upper Cable Height to Avoid Overrides
- Cable Heights: 21" 25.5" 30"

Median Profile

Vertical (in)

Lateral (ft)

Override and Underride Plots

- Maximum Lower Cable Height to Avoid Underrides
- Minimum Upper Cable Height to Avoid Overrides
- Cable Heights: 13.5" 24" 34.5" 45"

Median Profile

Vertical (in)

Lateral (ft)

Legend:
- Lateral placement where the barrier is likely to capture vehicles
- Lateral placement where the barrier may miss some cases
Flat-bottom Median - 6H:1V Slope - 8ft FB Width - 4ft Depth

Override and Underride Plots
- Maximum Lower Cable Height to Avoid Underrides
- Minimum Upper Cable Height to Avoid Overrides
- Cable Heights: 21" 25.5" 30"

Median Profile
- Lateral placement where the barrier is likely to capture vehicles
- Lateral placement where the barrier may miss some cases

Lateral (ft)
Vertical (in)

Override and Underride Plots
- Maximum Lower Cable Height to Avoid Underrides
- Minimum Upper Cable Height to Avoid Overrides
- Cable Heights: 13.5" 24" 34.5" 45"

Median Profile
- Lateral placement where the barrier is likely to capture vehicles
- Lateral placement where the barrier may miss some cases

Lateral (ft)
Vertical (in)
Flat-bottom Median - 6H:1V Slope - 16ft FB Width - 2ft Depth

Override and Underride Plots

- Maximum Lower Cable Height to Avoid Underrides
- Minimum Upper Cable Height to Avoid Overrides
- Cable Heights: 21" 25.5" 30"

Median Profile

Lateral Placement:
- Lateral placement where the barrier is likely to capture vehicles
- Lateral placement where the barrier may miss some cases
Flat-bottom Median - 6H:1V Slope - 16ft FB Width - 6ft Depth

Override and Underride Plots

- Maximum Lower Cable Height to Avoid Underrides
- Minimum Upper Cable Height to Avoid Overrides
- Cable Heights: 21" 25.5" 30"

Vertical (in)

Median Profile

Lateral (ft)

Override and Underride Plots

- Maximum Lower Cable Height to Avoid Underrides
- Minimum Upper Cable Height to Avoid Overrides
- Cable Heights: 13.5" 24" 34.5" 45"

Vertical (in)

Median Profile

Lateral (ft)

Lateral placement where the barrier is likely to capture vehicles
Lateral placement where the barrier may miss some cases
Flat-bottom Median - 6H:1V Slope - 32ft FB Width - 6ft Depth

Override and Underride Plots

- Maximum Lower Cable Height to Avoid Underrides
- Minimum Upper Cable Height to Avoid Overrides
- Cable Heights: 21” 25.5” 30”

Lateral placement where the barrier is likely to capture vehicles
Lateral placement where the barrier may miss some cases
Flat-bottom Median - 6H:1V Slope - 40ft FB Width - 4ft Depth

Override and Underride Plots

- Maximum Lower Cable Height to Avoid Underrides
- Minimum Upper Cable Height to Avoid Overrides
- Cable Heights: 21" 25.5" 30"

Vertical (in)

Lateral (ft)

Median Profile

- Lateral placement where the barrier is likely to capture vehicles
- Lateral placement where the barrier may miss some cases

Lateral (ft)

Override and Underride Plots

- Maximum Lower Cable Height to Avoid Underrides
- Minimum Upper Cable Height to Avoid Overrides
- Cable Heights: 13.5" 24" 34.5" 45"

Vertical (in)
## APPENDIX D: SUMMARY OF CABLE BARRIER FULL-SCALE CRASH TESTS (FHWA DATABASE)

<table>
<thead>
<tr>
<th>Accept. Barier Letter</th>
<th>Barrier Manufacturer</th>
<th>Cable Heights (mm)</th>
<th># of Cables</th>
<th>Installation Length (m)</th>
<th>Vehicle Speed (km/h)</th>
<th>Tension (kN)</th>
<th>Deflection (m)</th>
<th>Angle (Deg.)</th>
<th>Spacing (m)</th>
<th>Post Deflection (m)</th>
<th>Post Tension (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B22</td>
<td>Briften</td>
<td>4</td>
<td>308, 640, 790, 750</td>
<td>3.20</td>
<td>24.0, 675, 975, 1200</td>
<td>109.0</td>
<td>S-Stepped</td>
<td>0.20</td>
<td>3.60, 620, 760, 890</td>
<td>1.35</td>
<td>Flat</td>
</tr>
<tr>
<td>B22b</td>
<td>Briften</td>
<td>4</td>
<td>308, 640, 790, 750</td>
<td>3.20</td>
<td>24.0, 675, 975, 1200</td>
<td>109.0</td>
<td>S-Stepped</td>
<td>0.20</td>
<td>3.60, 620, 760, 890</td>
<td>1.35</td>
<td>Flat</td>
</tr>
<tr>
<td>B22c</td>
<td>Briften</td>
<td>3</td>
<td>308, 640, 790, 750</td>
<td>3.20</td>
<td>24.0, 675, 975, 1200</td>
<td>109.0</td>
<td>S-Stepped</td>
<td>0.20</td>
<td>3.60, 620, 760, 890</td>
<td>1.35</td>
<td>Flat</td>
</tr>
</tbody>
</table>

### Notes:
- The table provides a summary of cable barrier full-scale crash tests from the FHWA database.
- Columns include Acceptance Barrier Letter, Manufacturer, Cable Heights, # of Cables, Installation Length, Vehicle Speed, Tension, Deflection, Angle, Spacing, Post Deflection, and Post Tension.
- Each row represents a specific cable barrier configuration with its corresponding test results.
<table>
<thead>
<tr>
<th>Accept. Letter</th>
<th>Barrier Manufact.</th>
<th># of Cables</th>
<th>Cable Heights (mm)</th>
<th>Install. Length (m)</th>
<th>Post Shape</th>
<th>Post Spacing (m)</th>
<th>Impact Vehicle</th>
<th>Vehicle Mass (kg)</th>
<th>Speed (km/h)</th>
<th>Angle (deg)</th>
<th>Terrain</th>
<th>Tension (kN)</th>
<th>Defl. (m)</th>
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</thead>
<tbody>
<tr>
<td>B88</td>
<td>Safety</td>
<td>4</td>
<td>480, 630, 780, 930</td>
<td>116.0</td>
<td>Elliptical</td>
<td>2.50</td>
<td>1980 Ford Fiesta</td>
<td>907</td>
<td>102.0</td>
<td>20.0</td>
<td>Flat</td>
<td>14.7</td>
<td>1.10</td>
</tr>
<tr>
<td>B88</td>
<td>Safety</td>
<td>4</td>
<td>480, 630, 780, 930</td>
<td>116.0</td>
<td>Elliptical</td>
<td>2.50</td>
<td>1994 Chevrolet Pick-up</td>
<td>2036</td>
<td>104.0</td>
<td>25.0</td>
<td>Flat</td>
<td>14.7</td>
<td>1.80</td>
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<td>B88a</td>
<td>Safety</td>
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<td>500, 580, 660, 740</td>
<td>71.0</td>
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<td>1979 SAAB 900</td>
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<td>500, 595, 690</td>
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<td>2.50</td>
<td>1988 Volvo FL6111</td>
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<td>3.00</td>
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<td>4.00</td>
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<td>1995 Chevrolet C2500</td>
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<td>500, 765, 975</td>
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<td>1V4H, 8.0 m</td>
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<td>Safety</td>
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<td>500, 755, 975</td>
<td>185.0</td>
<td>C-Shaped</td>
<td>4.90</td>
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<td>1998 Chevrolet 2500</td>
<td>2075</td>
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