PRESENTED BY:
DELAWARE T² CENTER

Manual on Uniform Traffic Control Devices (MUTCD)

Module: Part 3 - Markings
Delaware T² Center

- T² Centers or LTAPs located in all 50 states
- Funded by FHWA and state DOTs
- Mission – promote training, tech transfer, research implementation at local level
- Delaware T² hosted by University of Delaware, part of Delaware Center for Transportation
- Delaware T² funded by FHWA and DelDOT
The Preliminaries

Today’s Instructors:

- Dr. Earl “Rusty” Lee – T² Center Coordinator
- Matheu J. Carter, P.E. – Municipal Engineering Circuit Rider

Restrooms, etc.

Standard Reminders:

- Cell phones, pagers, beepers, walkie-talkies
- Sidebar conversations
More Preliminaries

- Questions – any time
- We’re a small crowd – let’s keep it interactive and informal
- Sharing of thoughts or examples – any time
- These slides will be posted on our website – see link on your notes
The T² Center MUTCD Program

What we cover directly:
- Introduction and Part 1 (General) – the basics
- Part 2 (Signs)
- Part 3 (Markings) – today’s module
- Part 6 (Temporary Traffic Control/Work Zones)

What we incorporate:
- Part 7 (School Areas)
- Part 9 (Bicycle Facilities)
The T² Center MUTCD Program

What we don’t cover:

- Part 4 (Traffic Signals)
- Part 5 (Low-Volume Roads)
- Part 8 (Railroad and Light Rail)

Why?:

- These modules are directed towards municipal gov’ts
- Part 4 – you probably don’t own signals
- Part 5 – their definition of low-volume roads excludes municipal streets
- Part 8 – you probably aren’t responsible for RRs or light rail

However

Go to the DE MUTCD website for training slides on the changes to Parts 2, 3, 4, 6, 7, 8, & 9
Acknowledgements

Primary references:

- Delaware MUTCD
- Federal MUTCD

Who we’ve shamelessly stolen from (with our thanks):

- DelDOT
- DelDOT’s consultants
- FHWA MUTCD website
- Numerous others

Good writers borrow from other writers; Great writers steal from them outright – *Aaron Sorkin*
Introduction

In this module:

- General (colors, dimensions, materials, retroreflectivity)
- Pavement and curb markings
- Delineators
- Colored pavements
- Channelizing devices
- Islands
- Rumble strip markings
Where Are You in the Game?

Show of hands – where do you fit in?
- I can’t spell MUTCD – I’ve never opened it
- I have a passing familiarity – but I’ve always thought it was out of my wheel house
- I paint straight lines very well
- I was at the Intro module (which was fantastic) and am now a developing MUTCD geek
- I’ve read parts of it over time and applied it as I need
- I’m pretty fluent in the MUTCD
- I know the MUTCD – I could teach this course (careful, you’re now our “go to” person)
Where Are You in the Game?

Regardless of where you are now:

- We hope you’ll have a greater command when we’re done
- Don’t imagine this workshop will make you an expert (unless you already are one) – practice will do that
- As we go, share your challenges, experiences, and solutions – let’s all learn from each other

Ok – let’s get into it
• Federal MUTCD published in Dec. 2009

• DE MUTCD committee began meeting in Jan. 2010 to establish DE-specific guidance

• DE MUTCD submitted to Delaware Register for public comment in Spring 2011

• Except as noted, all presentation materials are the Delaware MUTCD June 2011
Where Do I Find the Delaware MUTCD?

**DelDOT Website**

http://deldot.gov/index.shtml
Where Do I Find the Delaware MUTCD?
Where Do I Find the Delaware MUTCD?

New Shortcut to this page

Notice there are other documents here too – complimentary guidance, memoranda, etc.

www.mutcd.deldot.gov
• Paragraphs are numbered

• No more metric

• Definitions relocated to Part 1

• Delaware Revisions in blue with line in margin and "(DE Revision)" at beginning of paragraph

• DE Standard: Reverted to 2003 MUTCD language allowing engineering judgment
  • More on this later

• Standards are bolded

• Guidance is italicized

• Options remain unformatted
How to Read the MUTCD

Throughout the MUTCD, each section will contain one or more of the following in some combination:

- **Standard** — “a statement of required, mandatory, or specifically prohibitive practice regarding a TCD” – these are “SHALLs”

- **Guidance** — “a statement of recommended, but not mandatory, practice in typical situations, with deviations allowed if engineering judgment or engineering study indicates the deviation to be appropriate” – these are “SHOULDs”

- **Option** — “a statement of practice that is a permissive condition and carries no requirement or recommendation” – these are “MAYs”

- **Support** — “an informational statement that does not convey any degree of mandate, recommendation, authorization, prohibition, or enforceable condition”
What’s in Part 3 – Markings?

- 3A – General
- 3B – Pavement and curb markings
- 3C – Roundabout markings
- 3D – Markings for preferential lanes
- 3E – Markings for toll plazas
- 3F – Delineators
- 3G – Colored pavements
- 3H – Channelizing devices for emphasis of pavement marking patterns
- 3I – Islands
- 3J – Rumble strip markings
Functions

- Provide guidance and information to road users
- Convey regulations, guidance, or warnings
- Sometimes supplement other TCDs (signs, signals)

- Other times – act alone

Part 3; Section 3A.01; ¶01
Limitations

- Visibility can be limited
  - By snow
  - By debris
  - By water

- Durability affected by
  - Material characteristics
  - Traffic volumes
  - Weather
  - Location

Photos courtesy 3M™

Day/Dry

Night/Dry

Night/Wet
Markings should be installed prior to opening a road

Shall be retroreflective

Conflicting markings shall be removed or obliterated

“Blackout” tape used to cover conflicting markings only if tape is approximately same color as pavement
RPM lenses were removed to avoid conflict with temporary lane lines.

Conflicting lane lines were obliterated.

Existing neutral area channelizing lines and chevrons were obliterated because Exit 5 is open to traffic.

I-495 southbound approaching I-95 southbound.
“Blackout” tape shall not be used on concrete because it does not match the pavement color.
Maintaining Minimum Retroreflectivity

- Reserved – i.e. no standard yet

- Standard proposed
  - Would be 4 years to implement a maintenance method
  - Would be 6 years to replace markings failing retro levels
  - Would effect “long lines” (e.g., center lines, lane edge lines); not “short line” work (e.g., stop bars, cross walks, words, symbols, arrows, curb markings, parking spaces, shared use path markings, etc.)
  - Would allow several options for inspection/maintenance, very similar to sign retroreflectivity methods

- Bottom line – stay tuned
Maintaining Minimum Retroreflectivity

Coefficient of Retroreflected Luminance

\[ R_L \text{ in } (\text{mcd/m}^2/\text{lux}) \]

Graphic courtesy 3M™

Part 3; Section 3A.03
Maintaining Minimum Retroreflectivity

1. Waterborne paint w/ std 1.5 index glass beads
2. Edge is all weather paint w/dual beads while CL is waterborne paint w/std 1.5 index glass beads
3. Back to waterborne paint w/std 1.5 index glass beads

Video courtesy 3M™
Maintaining Minimum Retroreflectivity

- Snow plow impact

Charts courtesy 3M™

Part 3; Section 3A.03
Maintaining Minimum Retroreflectivity

Conclusions:

- We’ll worry about it when the standards come out?
  - No. While quantitative standards aren’t official as yet, we know the targets and Section 3A.03 says:

  > Standard:

  > 03 Markings that must be visible at night shall be retroreflective unless ambient illumination assures that the markings are adequately visible. All markings on Interstate highways shall be retroreflective.

- If paint wears out in six months, what’s the use?
  - Well, that’s just defeatist thinking
  - Good news is that in the urban municipal environment, there are many areas that have ambient illumination sufficient to satisfy retroreflectivity requirements
  - Raised pavement markers can offset the requirement also
  - But don’t assume that’s the case, do an audit of your streets
  - Don’t wait for the “standards” – 3A.03 already gave you one
Marking Materials

- Includes raised pavement markers (RPMs)
- Delineators should not present horizontal or vertical obstacle to peds

Support:
01 Pavement and curb markings are commonly placed by using paints or thermoplastics; however, other suitable marking materials, including raised pavement markers and colored pavements, are also used. Delineators and channelizing devices are visibly placed in a vertical position similar to signs above the roadway.

01A (DE Revision) DelDOT’s Striping Item Usage Guidelines provides guidance regarding pavement marking materials for various applications along state-maintained roadways.

02 Some marking systems consist of clumps or droplets of material with visible open spaces of bare pavement between the material droplets. These marking systems can function in a manner that is similar to the marking systems that completely cover the pavement surface and are suitable for use as pavement markings if they meet the other pavement marking requirements of the highway agency.

Guidance:
03 The materials used for markings should provide the specified color throughout their useful life.
04 Consideration should be given to selecting pavement marking materials that will minimize tripping or loss of traction for road users, including pedestrians, bicyclists, and motorcyclists.

Part 3; Section 3A.04
Yellow, white, red, blue, and purple markings only

White separates traffic in same direction and delineates right edge of road

Yellow separates traffic in opposite directions and delineates left edge of divided and one-way roads

DE Guidance: Black contrast markings enhance white lane lines and edge lines along all concrete roads
Yellow marking should be white because adjacent lanes are in the same direction.

White markings shall be used to separate traffic in the same direction, not yellow markings.

US 13 Bus. (Walnut St) at A St, Wilmington
Marking Materials

- For conventional roads, Figure 3A-1B
**Section 3A.05 Colors**

Lane lines on all concrete roads should include black contrast markings.

Incorrect – see next slide for correct application.

White-on-black edge lines are no longer the preferred application due to maintenance concerns; follow side-by-side application in Figures 3A-1A and 3A-1B.

Don’t have concrete roads? Applies to bridge decks, also.

SR 1 southbound approaching Exit 119 (N. Smyrna)
Section 3A.05 Colors

Leading black contrast broken lane lines installed along Elkton Rd to enhance the conspicuity of the markings.

Correct

Elkton Rd westbound approaching Casho Mill Rd
Double lines indicate crossing and passing prohibitions

Solid lines discourage or prohibit crossing

Broken lines delineate lane assignments and passing zones

Dotted lines ("skips") inform motorists of changes in lane conditions
The widths and patterns of longitudinal lines shall be as follows:
A. Normal line—4 to 6 inches wide.
B. Wide line—at least twice the width of a normal line.
C. Double line—two parallel lines separated by a discernible space.
D. Broken line—normal line segments separated by gaps.
E. Dotted line—noticeably shorter line segments separated by shorter gaps than used for a broken line. The width of a dotted line extension shall be at least the same as the width of the line it extends.

Guidance:

Broken lines should consist of 10-foot line segments and 30-foot gaps, or dimensions in a similar ratio of line segments to gaps as appropriate for traffic speeds and need for delineation.

Guidance:

(De Revision) A dotted line for line extensions along interstates, freeways, and expressways should consist of 3-foot line segments and 9-foot gaps. A dotted line for line extensions along all other roadways should consist of 2-foot line segments and 6-foot gaps, except at roundabouts. Line extensions used at roundabouts should consist of 2-foot line segments and 2-foot gaps.

- **Wide line** – at least twice normal width
- **Broken lines consist of 10’ lines with 30’ gaps**
- **DE Guidance:**
  - 4” normal and 8” wide lines on conventional roads (5” and 10” on state maintained roads)
  - Double lines have 6” separation
  - 2’ lines with 6’ gaps for dotted lines on conventional roads
Section 3B.01 Yellow Center Line
Pavement Markings and Warrants

The center line markings on two-lane, two-way roadways shall be one of the following as shown in Figure 3B-1:

A. Two-direction passing zone markings consisting of a normal broken yellow line where crossing the center line markings for passing with care is permitted for traffic traveling in either direction;

B. One-direction no-passing zone markings consisting of a double yellow line, one of which is a normal broken yellow line and the other is a normal solid yellow line, where crossing the center line markings for passing with care is permitted for the traffic traveling adjacent to the broken line, but is prohibited for traffic traveling adjacent to the solid line; or

C. Two-direction no-passing zone markings consisting of two normal solid yellow lines where crossing the center line markings for passing is prohibited for traffic traveling in either direction.

A single solid yellow line shall not be used as a center line marking on a two-way roadway.

The center line markings on undivided two-way roadways with four or more lanes for moving motor vehicle traffic always available shall be the two-direction no-passing zone markings consisting of a solid double yellow line as shown in Figure 3B-2.

- Two-lane, two-way roads follow Figure 3B-1
- Single solid yellow center lines prohibited on two-way roads
- Multi-lane roads follow Figure 3B-2
Section 3B.01 Yellow Center Line
Pavement Markings and Warrants

**Correct**

Milltown Rd at Grendon Dr

Two sets of solid double yellow center lines shall form flush medians of the same color regardless of the use of optional chevrons

**Incorrect**

SR 72 south of Old Baltimore Pk
Section 3B.01 Yellow Center Line
Pavement Markings and Warrants

Otts Chapel Rd southbound approaching Old Baltimore Pk

Solid single yellow edge lines surround flush medians of contrasting color

Shall have two sets of solid double yellow center lines preceding leading end of flush median
Section 3B.01 Yellow Center Line
Pavement Markings and Warrants

Old Baltimore Pk at SR 896, west leg of intersection

Edge lines should be “wrapped” around leading end of median; Keep Right sign shall be installed

Solid single yellow edge lines surround raised medians
• DE Standard: Paved roads with traveled way ≥ 19’ and ADT ≥ 500 require center line markings

• DE Guidance: Engineering judgment where traveled way < 19’

• Generally – no centerline within subdivisions
DE Option: Paved roads with traveled way ≥ 19’ and ADT < 500 may be striped with center line, based on study.
Section 3B.02 No-Passing Zone Pavement Markings and Warrants

On roadways with center line markings, no-passing zone markings shall be used at horizontal or vertical curves where the passing sight distance is less than the minimum shown in Table 3B-1 for the 85th-percentile speed or the posted or statutory speed limit. The passing sight distance on a vertical curve is the distance at which an object 3.5 feet above the pavement surface can be seen from a point 3.5 feet above the pavement (see Figure 3B-4). Similarly, the passing sight distance on a horizontal curve is the distance measured along the center line (or right-hand lane line of a three-lane roadway) between two points 3.5 feet above the pavement on a line tangent to the embankment or other obstruction that cuts off the view on the inside of the curve (see Figure 3B-4).

Guidance:
- Where the distance between successive no-passing zones is less than 400 feet, no-passing markings should connect the zones.

Standard:
- Where center line markings are used, no-passing zone markings shall be used on approaches to grade crossings in compliance with Section 8B.27.

### Table 3B-1. Minimum Passing Sight Distances for No-Passing Zone Markings

<table>
<thead>
<tr>
<th>Speed</th>
<th>Minimum Passing Sight Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 mph</td>
<td>450 feet</td>
</tr>
<tr>
<td>30 mph</td>
<td>500 feet</td>
</tr>
<tr>
<td>35 mph</td>
<td>550 feet</td>
</tr>
<tr>
<td>40 mph</td>
<td>600 feet</td>
</tr>
<tr>
<td>45 mph</td>
<td>700 feet</td>
</tr>
<tr>
<td>50 mph</td>
<td>800 feet</td>
</tr>
<tr>
<td>55 mph</td>
<td>900 feet</td>
</tr>
<tr>
<td>60 mph</td>
<td>1,000 feet</td>
</tr>
<tr>
<td>65 mph</td>
<td>1,100 feet</td>
</tr>
<tr>
<td>70 mph</td>
<td>1,200 feet</td>
</tr>
</tbody>
</table>

- **Used where passing sight distance < Table 3B-1**
- **Assumed eye and object heights 3.5’ above road**
- **Continuous no-passing zone if distance between two successive zones < 400’**
- **Required on approaches to rail crossings**
No Passing Zone Warrants

- Vertical curve sight distances must also be checked
**DE Guidance:** No-passing zone $\geq$ Table 3B-1 on approach to intersection and $\geq 200'$ on departure

200' (min.) and 1,000' (min.) no-passing zones should be installed on the departures and approaches, respectively.

**Table 3B.1. Minimum Passing Sight Distances for No-Passing Zone Markings**

<table>
<thead>
<tr>
<th>Speed Limit (mph)</th>
<th>Minimum Passing Sight Distance (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>450</td>
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<tr>
<td>30</td>
<td>500</td>
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<td>35</td>
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<td>55</td>
<td>900</td>
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<tr>
<td>60</td>
<td>1,000</td>
</tr>
<tr>
<td>65</td>
<td>1,100</td>
</tr>
<tr>
<td>70</td>
<td>1,200</td>
</tr>
</tbody>
</table>

**SR 10 Alt. at Berrytown Rd**

- Posted: 50 MPH
- 85th-percentile: 60 MPH
Section 3B.03 Other Yellow Longitudinal Pavement Markings

- Broken (10’ lines; 30’ gaps) and solid yellow lines for two-way left-turn lanes
- Two-way left-turn arrows and Two-Way Left Turn Only signs (R3-9 Series) supplement longitudinal markings
- DE Guidance: 800’ arrow spacing between cross streets
In other words, the number of left turn arrows here is excessive.

Two-way left-turn arrows should be spaced at 800’ intervals between cross streets.

R3-9b sign should be adjacent to two-way left-turn lane pavement markings.

17 two-way left-turn arrows within 1,600’ segment.

SR 300 west of US 13

Middleford Rd west of US 13
Section 3B.04 White Lane Line Pavement Markings and Warrants

**Guidance:**

Lane line markings shall be used on all roadways that are intended to operate with two or more adjacent traffic lanes in the same direction of travel, except as otherwise required for reversible lanes. Lane line markings should also be used at congested locations where the roadway will accommodate more traffic lanes with lane line markings than without the markings.

(DE Revision) Along interstates, freeways, and expressways, the dotted white lane lines that are used for lane drop markings and that are used as a lane line separating through lanes from auxiliary lanes should consist of line segments that are 3 feet in length separated by 9-foot gaps. Along all other roadways, the dotted white lane lines that are used for lane drop markings and that are used as a lane line separating through lanes from auxiliary lanes should consist of line segments that are 2 feet in length separated by 6-foot gaps.

- **Should be used on all roads to separate traffic in same direction**
- **DE Guidance:**
  - 3’ lines with 9’ gaps for dotted lane lines on interstates, freeways, and expressways
  - 2’ lines with 6’ gaps for dotted lane lines on conventional roads

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Old Baltimore Pk eastbound at SR 896

**Solid and dotted (2’ lines; 6’ gaps) lane lines separating left-turn and through/right-turn traffic**

**Solid and broken (10’ lines; 30’ gaps) lane lines separating double left-turn lanes**
Wide (10”) dotted (2’ lines; 6’ gaps) lane lines used at lane drops at intersections on conventional roads

DE Guidance: Begin at first regulatory lane drop sign (R3-7)
Section 3B.04 White Lane Line
Pavement Markings and Warrants

Wide (10”) dotted (2’ lines; 6’ gaps) lane lines shall delineate combination acceleration/deceleration lanes between intersections.

SR 92 westbound between I-95 southbound off-ramp and Peachtree Rd / Society Dr (east)
**DE Guidance:**

- **Taper length:** \( L = WS \) for \( S \geq 45 \text{ MPH} \); \( L = WS^2/60 \) for \( S < 45 \text{ MPH} \)

- **Downstream solid lane line**, equal to 0.5L, separates turn and through lanes

- **Upstream dotted lane line**, equal to 0.5L, separates turn and through lanes

- **Upstream dotted lane line** extends through the taper
DE Guidance:

- Unsignalized approach – broken lane line(s) continues through intersection

- Signalized approach – solid white lane line(s) separates adjacent through lanes; length equal to:
  - $0.5L_L$ if $L_R < L_L < 300'$
  - $0.5L_R$ if $L_L < L_R < 300'$
  - 150' (max.)
Section 3B.04 White Lane Line
Pavement Markings and Warrants

SR 92 westbound at Society Dr (west)

- **Dotted (2’ lines; 6’ gaps)** lane line separates through and right-turn lanes for 0.5L and extends through taper

- **Broken (10’ lines; 30’ gaps)** lane line continues through unsignalized intersection

- **Solid lane line** separates through and right-turn lanes for 0.5L

- **Thru lanes with right turn**

- **Lane arrow placement** should follow Section 3B.20
Solid lane line should be installed to separate adjacent through lanes at signal
Solid lane line, equal to 0.5L, separates through lanes at signalized intersection

Lane arrow placement should follow Section 3B.20

Intersection - correct
DE Guidance – Bypass lanes:
- Dotted (2’ lines; 6’ gaps) and solid lane lines separate traffic in same direction
- Design lengths based on Figure 5-19 in DelDOT Standards and Regulations for Subdivision Streets and State Highway Access
No-passing zones should be installed on approaches to and departures from intersections.

Dotted lane lines delineate approach and departure tapers.

Solid lane line separates through and bypass lanes.

Edge lines shall be installed to delineate right edge of bypass lane.

Extend the edge lines.

SR 30 at SR 26
**Section 3B.06 Edge Line Pavement Markings**

**Standard:**

01. If used, edge line pavement markings shall delineate the right or left edges of a roadway.

02. Except for dotted edge line extensions (see Section 3B.08), edge line markings shall not be continued through intersections or major driveways.

03. If used on the roadways of divided highways or one-way streets, or on any ramp in the direction of travel, left edge line pavement markings shall consist of a normal solid yellow line to delineate the left-hand edge of a roadway or to indicate driving or passing restrictions left of these markings.

04. If used, right edge line pavement markings shall consist of a normal solid white line to delineate the right-hand edge of the roadway.

**Guidance:**

05. Edge line markings should not be broken for minor driveways.

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- **Should continue through minor driveways**
- **Shall not continue through intersections or major driveways**
- **Yellow edge lines used on left side of divided highways and one-way roads**
- **White edge lines delineate right edge of road**

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ADT > 400 considered “high volume” per DelDOT DGM 1-16 Curb Ramps

SR 1 southbound at Tybouts Corner
Section 3B.07 Warrants for Use of Edge Lines

Standard:

01 (DE Revision) Edge line markings shall be placed on paved and surface-treated roadways with the following characteristics:

A. Interstates,
B. Freeways,
C. Expressways, and
D. Roads with a traveled way of 20 feet or more in width and an ADT of 3,000 vehicles per day or greater.

Guidance:

02 (DE Revision) Edge line markings should be placed on paved and surface-treated roadways where an engineering study indicates a need for edge line markings.

03 Edge line markings should not be placed where an engineering study or engineering judgment indicates that providing them is likely to decrease safety.

- **DE Standard:**
  - All paved roads and surface treated streets ≥ 20’ wide with ADT ≥ 3,000

- **Other paved roads based on engineering study or judgment**
Edge lines may be installed based on engineering study or judgment even if center lines are not installed.
Same color as the line they extend

Used at complex intersections and on approaches with multiple turn lanes

Double line should be extended by a single line

Standard:
01 Except as provided in Paragraph 2, pavement markings extended into or continued through an intersection or interchange area shall be the same color and at least the same width as the line markings they extend (see Figure 3B-13).

Option:
02 A normal line may be used to extend a wide line through an intersection.

Guidance:
03 (DE Revision) Where highway design or reduced visibility conditions make it desirable to provide control or to guide vehicles through an intersection or interchange, such as at offset, skewed, complex, or multi-legged intersections, on curved roadways, where multiple turn lanes are used, or where offset left turn lanes might cause driver confusion, dotted line extension markings consisting of 2-foot line segments and 6-foot gaps should be used to extend longitudinal line markings through an intersection or interchange area.

Guidance:
07 Where a double line is extended through an intersection, a single line of equal width to one of the lines of the double line should be used.
Section 3B.08 Extensions Through Intersections or Interchanges

Edge line extension installed for westbound through motorists because of severely offset receiving lane

SR 1 southbound off-ramp at US 13 / Duck Creek Rd
No-passing zone in transition area

Taper length: \( L = WS \) for \( S \geq 45 \text{ MPH} \); \( L = WS^2/60 \) for \( S < 45 \text{ MPH} \)

DE Guidance:
- Figures 3B-14B and 3B-14C for lane reductions beyond intersections
- Dotted lane line begins at first Lane Ends sign and terminates at beginning of taper
- Lane reduction arrows used for all speed limits

Guidance:
- Figures 3B-14A, 3B-14B, and 3B-14C may be adjusted based on engineering judgment at existing locations where space is limited due to site-specific conditions.
- Lane line markings should be discontinued where the transition taper begins.
- Where a lane-reduction transition occurs on a roadway, the lane-reduction arrow markings shown in Drawing F in Figure 3B-24 should be used as shown in Figures 3B-14, 3B-14A, 3B-14B, and 3B-14C.
Section 3B.10 Approach Markings for Obstructions

Standard:

01 Pavement markings shall be used to guide traffic away from fixed obstructions within a paved roadway. Approach markings for bridge supports, refuge islands, median islands, toll plaza islands, and raised channelization islands shall consist of a tapered line or lines extending from the center line or the lane line to a point 1 to 2 feet to the right-hand side, or to both sides, of the approach end of the obstruction (see Figure 3B-15).

Guidance:

03 For roadways having a posted or statutory speed limit of 45 mph or greater, the taper length of the tapered line markings should be computed by the formula \( L = WS \). For roadways where the posted or statutory speed limit is less than 45 mph, the formula \( L = WS^2/60 \) should be used to compute the taper length.

Support:

04 Under both formulas, \( L \) equals the taper length in feet, \( W \) equals the width of the offset distance in feet, and \( S \) equals the 85th-percentile speed or the posted or statutory speed limit, whichever is higher.

Guidance:

05 The minimum taper length should be 100 feet in urban areas and 200 feet in rural areas.

- **Obstructions within paved roads shall be marked**

- **Taper length:**
  - \( L = WS \) for \( S \geq 45 \text{ MPH} \)
  - \( L = WS^2/60 \) for \( S < 45 \text{ MPH} \)
  - \( L \) (min.) urban = 100'
  - \( L \) (min.) rural = 200'
Section 3B.10 Approach Markings for Obstructions

Standard:
07 If traffic is required to pass only to the right of the obstruction, the markings shall consist of a two-direction no-passing zone marking at least twice the length of the diagonal portion as determined by the appropriate taper formula (see Drawing A of Figure 3B-15).

Standard:
09 If traffic can pass either to the right or left of the obstruction, the markings shall consist of two channelizing lines diverging from the lane line, one to each side of the obstruction. In advance of the point of divergence, a wide solid white line or normal solid double white line shall be extended in place of the broken lane line for a distance equal to the length of the diverging lines (see Drawing C of Figure 3B-15).

- Figure 3B-15, Drawings A and B for two-way traffic only passing on right
- Figure 3B-15, Drawing C for traffic in same direction passing on both sides
Standard:
01 The color of raised pavement markers under both daylight and nighttime conditions shall conform to the color of the marking for which they serve as a positioning guide, or for which they supplement or substitute.

- **RPM matches color of line it supplements**
- **DE Standard:** Shall not be used as substitute for pavement markings unless otherwise approved by DelDOT Traffic
- **DE Guidance:**
  - Used on all interstates, freeways, expressways, and principal arterials
  - Considered on two-lane, two-way arterials with posted speed ≥ 45 MPH
  - Installed along other roads based on engineering study
  - Should not be installed on surface treated roads

White RPMs supplement solid, broken, and dotted lane lines at off-ramps

I-95 southbound approaching Exits 5A and 5B
Raised Pavement Markers

01B (DE Revision) Raised pavement markers should be considered for use along conventional roads under the following conditions:

A. Roadways with posted speed limits of 45 miles per hour or greater, with horizontal and/or vertical curves, and areas of low lighting
B. Locations with a history of roadway departure crashes
C. Locations with advisory speed postings
D. Locations where a barrier or parapet is less than 6 feet from the edge of the travel lane

01C (DE Revision) Raised pavement markers should also be installed on other roadways where engineering judgment indicates such a need.

01D (DE Revision) Raised pavement markers should not be installed along surface-treated roadways.
DE Guidance:

- Adjacent to single solid lines
- In line with broken and dotted lane lines
- Between double yellow center lines
- Longitudinally spaced at 80’ intervals along double yellow center lines and broken (10’ lines; 30’ gaps) lane lines
- Longitudinal spacing reduced to 40’ on curves and within “buffer” in advance of curves
Section 3B.15 Transverse Markings

Standard:

01 Transverse markings, which include shoulder markings, word and symbol markings, arrows, stop lines, yield lines, crosswalk lines, speed measurement markings, speed reduction markings, speed hump markings, parking space markings, and others, shall be white unless otherwise provided in this Manual.

Guidance:

02 Because of the low approach angle at which pavement markings are viewed, transverse lines should be proportioned to provide visibility at least equal to that of longitudinal lines.
Stop lines should be installed at all signal approaches

- Primary signal heads ≥ 40’ from stop line

DE Guidance:

- Intersection of two state-maintained roads – stop lines on all stop-controlled approaches
- Entrance along state-maintained road – stop lines on all stop-controlled approaches
- Internal intersections within developments – stop lines typically not installed

Stop lines prohibited on yield-controlled approaches (except rail crossings)

Yield lines prohibited on stop-controlled and signal-controlled approaches
Stop lines shall not be installed for yield-controlled movements, including those defined by Rules of the Road in DE Code.
Stop and Yield Lines

- These sharks teeth have seen much change over the years
- This is how we do it now

Option:
02 Stop lines may be used to indicate the point behind which vehicles are required to stop in compliance with a STOP (R1-1) sign, a Stop Here For Pedestrians (R1-5b or R1-5c) sign, or some other traffic control device that requires vehicles to stop, except YIELD signs that are not associated with passive grade crossings.
03 Yield lines may be used to indicate the point behind which vehicles are required to yield in compliance with a YIELD (R1-2) sign or a Yield Here To Pedestrians (R1-5 or R1-5a) sign.

Standard:
04 Except as provided in Section 8B.28, stop lines shall not be used at locations where drivers are required to yield in compliance with a YIELD (R1-2) sign or a Yield Here To Pedestrians (R1-5 or R1-5a) sign or at locations on uncontrolled approaches where drivers are required by State law to yield to pedestrians.
05 Yield lines shall not be used at locations where drivers are required to stop in compliance with a STOP (R1-1) sign, a Stop Here For Pedestrians (R1-5b or R1-5c) sign, a traffic control signal, or some other traffic control device.
06 Stop lines shall consist of solid white lines extending across approach lanes to indicate the point at which the stop is intended or required to be made.
07 Yield lines (see Figure 3B-16) shall consist of a row of solid white isosceles triangles pointing toward approaching vehicles extending across approach lanes to indicate the point at which the yield is intended or required to be made.

Part 3; Section 3B.16
• Stop lines installed a minimum of 4’ in advance of crosswalks

• At locations without crosswalks, stop and yield lines should be $\geq 4’$ and $< 30’$ from edge of intersecting road
Section 3B.16 Stop and Yield Lines

Yield line installed 20’ to 50’ in advance of midblock crosswalk

Parking prohibition between yield line and crosswalk

R1-5 signs required

DE Guidance: W11-2 assemblies at crosswalk; however, R1-5 signs shall not block W11-2 assemblies
Section 3B.16 Stop and Yield Lines

**W11-2 assemblies; R1-5 signs shall not block W11-2 signs**

Yield line installed about 35’ in advance of uncontrolled midblock crosswalk

Parking prohibition between yield line and crosswalk

Standard R1-5 sign size now 36” x 36”

SR 273 (Main St), Newark
DE Guidance: Yield lines should not be installed in advance of uncontrolled crosswalks at intersections.
Section 3B.16 Stop and Yield Lines

Guidance:
16 (DE Revision) Staggered stop and yield lines are discouraged and should not be used along state-maintained roadways unless approved by DelDOT Traffic.

Support:
17 Staggered stop lines and staggered yield lines can improve the driver’s view of pedestrians, provide better sight distance for turning vehicles, and increase the turning radius for left-turning vehicles.

- **DE Guidance:** Staggered stop lines are generally discouraged
- **DelDOT Traffic:** should be contacted for guidance

Staggered stop lines installed because of skewed approach and to increase storage along northbound Church St between Washington St and SR 1A
Section 3B.17 Do Not Block Intersection Markings

Option:

Do Not Block Intersection markings may be used to mark the edges of an intersection area that is in close proximity to a signalized intersection, railroad crossing, or other nearby traffic control that might cause vehicles to stop within the intersection and impede other traffic entering the intersection. If authorized by law, Do Not Block Intersection markings with appropriate signs may also be used at other locations.

Standard:

If used, Do Not Block Intersection markings (see Figure 3B-18) shall consist of one of the following alternatives:

A. Wide solid white lines that outline the intersection area that vehicles must not block;
B. Wide solid white lines that outline the intersection area that vehicles must not block and a white word message such as DO NOT BLOCK or KEEP CLEAR;
C. Wide solid white lines that outline the intersection area that vehicles must not block and white cross-hatching within the intersection area; or
D. A white word message, such as DO NOT BLOCK or KEEP CLEAR, within the intersection area that vehicles must not block.

Do Not Block Intersection markings shall be accompanied by one or more DO NOT BLOCK INTERSECTION (DRIVEWAY) (CROSSING) (R10-7) signs (see Section 2B.53), one or more DO NOT STOP ON TRACKS (R8-8) signs (see Section 8B.09), or one or more similar signs.

Option D is preferred in DE, where approved by DelDOT Traffic.

- Supplement regulatory signs, where approved for use
Crosswalk Markings

- At intersections, crosswalks exist within the roadway as the extension of sidewalks
- Only at non-intersection locations must you legally establish a crosswalk

44. Crosswalk—(a) that part of a roadway at an intersection included within the connections of the lateral lines of the sidewalks on opposite sides of the highway measured from the curbs or in the absence of curbs, from the edges of the traversable roadway, and in the absence of a sidewalk on one side of the roadway, the part of a roadway included within the extension of the lateral lines of the sidewalk at right angles to the center line; (b) any portion of a roadway at an intersection or elsewhere distinctly indicated as a pedestrian crossing by pavement marking lines on the surface, which might be supplemented by contrasting pavement texture, style, or color.

Support:
01 Crosswalk markings provide guidance for pedestrians who are crossing roadways by defining and delineating paths on approaches to and within signalized intersections, and on approaches to other intersections where traffic stops.
02 In conjunction with signs and other measures, crosswalk markings help to alert road users of a designated pedestrian crossing point across roadways at locations that are not controlled by traffic control signals or STOP or YIELD signs.
03 At non-intersection locations, crosswalk markings legally establish the crosswalk.

Part 3; Section 3B.18
Section 3B.18 Crosswalk Markings

Standard:
04 When crosswalk lines are used, they shall consist of solid white lines that mark the crosswalk. They shall not be less than 6 inches or greater than 24 inches in width.

Guidance:
05 (DE Revision) If 12-inch wide transverse lines are used to mark a temporary crosswalk or patterned pavement crosswalk or along non-state maintained roadways, the crosswalk width should be measured between the two lines (see Figure 3B-19).
05A (DE Revision) Crosswalk markings on roadways with a posted speed limit (or 85th-percentile speed) of 40 mph or greater and at locations with high pedestrian activity should be 10 feet wide. Crosswalk markings on other roadways should be 6 feet wide.
05B (DE Revision) Crosswalk markings on all approaches to an intersection with one or more roadways with a posted speed limit (or 85th-percentile speed) of 40 mph or greater or with high pedestrian activity should be 10 feet wide.

- DE Standard: 24” wide longitudinal ("piano key") markings spaced 24” apart
- DE Guidance: 12” wide transverse lines used to delineate patterned or brick crosswalks (¶15B)
- DE Option: 12” wide transverse lines used for temporary crosswalks (¶15C)

Figure 3B-19. Examples of Crosswalk Markings (Delaware Revision)

Notes:
Transverse crosswalks should be used to delineate patterned and brick crosswalks.
Transverse crosswalks may also be used for temporary crosswalks.
Section 3B.18 Crosswalk Markings

Crosswalks shall consist of solid white lines
Patterned and brick crosswalks should be delineated with 12” wide transverse crosswalk markings, not solely concrete borders.
Uncontrolled crosswalks installed based on engineering studies

Guidelines based on number of lanes, speed limit, ADT, median, etc.

More criteria in NCHRP Report 562 and FHWA Publication HRT-04-100
Crosswalk Markings

Why not a fourth cross walk here?
- An oversight?
- Intentional?

- Here – very deliberate
- Probably high volume east bound turn movement on game day
- Law enforcement present on game day
Crosswalks

Shark’s teeth

Diagonal crossing

High pedestrian volume

Cleveland Avenue/Paper Mill Road

Cleveland Avenue/North College Avenue

Part 3; Section 3B.18
Section 3B.18 Crosswalk Markings

Guidance:
16A (DE Revision) Crosswalk markings accommodating diagonal pedestrian crossings are discouraged and should not be used along state-maintained roadways unless approved by DelDOT Traffic.

- DE Guidance:
  - 6’ crosswalks across roads < 40 MPH (posted or 85th-percentile speed)
  - 10’ crosswalks across roads ≥ 40 MPH
  - 10’ crosswalks in areas with high pedestrian volumes
  - Intersection of high-speed and low-speed roads should have 10’ crosswalks, not varying sizes

SR 41 northbound at Yorklyn Rd

Diagonal crossing discouraged by DelDOT
Crosswalks

Part 3; Section 3B.18

SR 41 at Yorklyn Road
Crosswalks

Incorrect

Correct

But...diagonal alignment still not preferred
Crosswalks must be oriented consistent with curb ramps

Truncated domes (detectable warning surfaces) are required at interface with traffic

Crosswalk markings should be located so that the curb ramps are within the extension of the crosswalk markings.

Support:

Detectable warning surfaces mark boundaries between pedestrian and vehicular ways where there is no raised curb. Detectable warning surfaces are required by 49 CFR, Part 37 and by the Americans with Disabilities Act (ADA) where curb ramps are constructed at the junction of sidewalks and the roadway, for marked and unmarked crosswalks. Detectable warning surfaces contrast visually with adjacent walking surfaces, either light-on-dark, or dark-on-light. The “Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG)” (see Section 1A.11) contains specifications for design and placement of detectable warning surfaces.
Parking Spaces

Section 3B.19 Parking Space Markings

Support:
01 Marking of parking space boundaries encourages more orderly and efficient use of parking spaces where parking turnover is substantial. Parking space markings tend to prevent encroachment into fire hydrant zones, bus stops, loading zones, approaches to intersections, curb ramps, and clearance spaces for islands and other zones where parking is restricted. Examples of parking space markings are shown in Figure 3B-21.

Standard:
02 Parking space markings shall be white.

Option:
03 Blue lines may supplement white parking space markings of each parking space designated for use only by persons with disabilities.

Support:
04 Additional parking space markings for the purpose of designating spaces for use only by persons with disabilities are discussed in Section 3B.20 and illustrated in Figure 3B-22. The design and layout of accessible parking spaces for persons with disabilities is provided in the "Americans with Disabilities Act Accessibility Guidelines (ADAAG)" (see Section 1A.11).

04a (DE Revision) Regulations regarding stopping, standing and parking along state-maintained roadways are provided in §4178, §4179, §4180, and §4183 of Title 21 of the Delaware Code.

Part 3; Section 3B.19
Option:

Word, symbol, and arrow markings, including those contained in the “Standard Highway Signs and Markings” book (see Section 1A.11), may be used as determined by engineering judgment to supplement signs and/or to provide additional emphasis for regulatory, warning, or guidance messages. Among the word, symbol, and arrow markings that may be used are the following:

A. Regulatory:
1. STOP
2. YIELD
3. RIGHT (LEFT) TURN ONLY
4. 25 MPH
5. Lane-use and wrong-way arrows
6. Diamond symbol for HOV lanes
7. Other preferential lane word markings

B. Warning:
1. STOP AHEAD
2. YIELD AHEAD
3. YIELD AHEAD triangle symbol
4. SCHOOL XING
5. SIGNAL AHEAD
6. PED XING
7. SCHOOL
8. R X R
9. BUMP
10. HUMP
11. Lane-reduction arrows

C. Guide:
1. Route numbers (route shield pavement marking symbols and/or words such as I-81, US 40, STATE 135, or ROUTE 10)
2. Cardinal directions (NORTH, SOUTH, EAST, or WEST)
3. TO
4. Destination names or abbreviations thereof

Standard:

Word, symbol, and arrow markings shall be white, except as otherwise provided in this Section.

Guidance:

Letters and numerals should be 6 feet or more in height.

Word and symbol markings should not exceed three lines of information.
STOP word marking installed to reinforce unanticipated stop condition along SR 5

SR 5 at Hollyville Rd / Hollymount Rd
- Multi-line word messages installed in the direction of travel

STOP AHEAD markings are typically installed immediately adjacent to Stop Ahead signs.

STOP installed prior to AHEAD in the direction of travel.

Berrytown Rd approaching SR 10 Alt.
Chapter 7C – Markings

From Part 7
TCDs in School Areas
Guidance: **DRAFT**

01A *(DE Revision)* Pavement word and symbol markings should not extend beyond the centerline, if present, into the opposing direction of travel.

01B *(DE Revision)* When installed in a single lane with a width of 10.5 feet or greater, the SCHOOL word marking should consist of 16 inch wide by 96 inch high letters, separated by 4 inch spaces (see Figure 7C-1).

01C *(DE Revision)* When installed in a single lane with a width less than 10.5 feet, the SCHOOL word marking should consist of 12 inch wide by 72 inch high letters, separated by 3 inch spaces (see Figure 7C-1).

**DE Revision:**

- Markings should not extend beyond centerline into opposing direction
- From the DelDOT MUTCD FAQ’s (May 2009):
Section 7C.03 – Pavement Word, Symbol and Arrow Markings

**INCORRECT**

SCHOOL word marking extends into the departure lane

**CORRECT**

SCHOOL word marking is scaled to fit one lane (although not quite in scale with new guidance in Fig 7C-1)
Curb Markings

- DelDOT would prefer you not paint curbs on state-maintained roads
- If you do, maintenance is yours

Support:
01 Curb markings are most often used to indicate parking regulations or to delineate the curb.

Standard:
02 Where curbs are marked to convey parking regulations in areas where curb markings are frequently obscured by snow and ice accumulation, signs shall be used with the curb markings except as provided in Paragraph 4.

Guidance:
03 Except as provided in Paragraph 4, when curb markings are used without signs to convey parking regulations, a legible word marking regarding the regulation (such as “No Parking” or “No Standing”) should be placed on the curb.

03A (DE Revision) Curb markings should not be used along state-maintained roadways to indicate parking regulations.

Standard:
03B Where curb markings are installed along state-maintained roadways by a local municipality, they shall be maintained by the local municipality.

Part 3; Section 3B.23
• Discourage motorists from driving across certain areas

• **DE Guidance: Used in diverge neutral areas**

• **White “V” shaped markings when separating traffic in same direction**

• **Yellow markings when separating traffic in opposing directions**

• **Yellow markings on left shoulders**

• **White markings on right shoulders**

White chevrons installed to discourage motorists from driving in the shoulder
Guidance:

(De Revision) The chevrons and diagonal lines used for crosshatch markings should be 12 inches wide along all roadways. The longitudinal spacing of the chevrons or diagonal lines should be 50 feet along interstates, expressways, and freeways and 25 feet along all other roadways. The chevrons and diagonal lines should form an angle of approximately 45 degrees with the longitudinal lines that they intersect.

- **DE Guidance:**
  - 12” wide markings
  - Commonly angled at 45 degrees with respect to adjacent travel lane(s)
  - Typically spaced at 25’ along conventional roads
  - Typically spaced at 50’ along interstates, freeways, and expressways

**SR 1A west of Church St**

- Striped flush medians require two sets of double yellow lines
- Flush median delineated with 12” chevrons spaced 25’ at 45 degree angle
• Shall be white and shall comply with Figure 3B-29
• DE Guidance: Option A in Figure 3B-29 is preferred on state-maintained roads
Speed Hump Markings

Part 3; Section 3B.25 & 3B.26
CHAPTER 3D.
MARKINGS FOR PREFERENTIAL LANES

Relocated from 3B

N. College Ave at Cleveland Ave

Improper use of HOV only lane symbol

SR 1 north of Dartmouth Dr
Formerly 3D

CHAPTER 3F. Delineators

SR 300 at Carter Rd

Delineators on left side of two-way roads shall be white, not red

Guardrail reflectors

I-95 southbound off-ramp to SR 273
• Non-retroreflective colored pavement used for aesthetic purposes that does not regulate, warn, or guide traffic is not a traffic control device

Standard:

If colored pavement is used within the traveled way, on flush or raised islands, or on shoulders to regulate, warn, or guide traffic or if retroreflective colored pavement is used, the colored pavement is considered to be a traffic control device and shall be limited to the following colors and applications:

A. Yellow pavement color shall be used only for flush or raised median islands separating traffic flows in opposite directions or for left-hand shoulders of roadways of divided highways or one-way streets or ramps.

B. White pavement color shall be used for flush or raised channelizing islands where traffic passes on both sides in the same general direction or for right-hand shoulders.

Aesthetic crosswalk treatments, not traffic control devices
In addition, FHWA has issued an Interim Approval

- For the optional use of green colored pavement in marked bicycle lanes and in extensions of bicycle lanes through intersections and other traffic conflict areas
- They reviewed available data—consider the experimental green colored pavement to be satisfactorily successful for the bicycle applications that were tested. Positive operational effects have been noted
  - Bicyclists positioning themselves more accurately as they travel across intersections and through conflict areas
  - No notable negative operational effects have been observed
  - The research has also shown that bicyclists and motorists both have a positive impression of the effect of the green colored pavement
    - bicyclists say that they feel safer when the green colored pavement is present
    - motorists say that the green colored pavement gives them an increased awareness that bicyclists might be present and where those bicyclists are likely to be positioned within the traveled way.
Colored Pavements

• Careful – think about
  o Skid resistance
  o Wear resistance
  o Durability
  o UV stable

Part 3; Section 3G

Courtesy Integrated Paving Concepts
Yellow retroreflective bands are required for devices separating traffic in opposing directions.

US 13 northbound at Scott Run (SR 1 “free” ramp):
White retroreflective bands are required for devices separating traffic in the same direction.

US 113 southbound at Arrow Safety Rd:
Channelizing devices shall be either orange or same color as the marking they supplement.
CHAPTER 3J.
RUMBLE STRIP MARKINGS

New chapter

James St bridge, Newport

Transverse rumble strips

Longitudinal center line rumble stripe

US 301 north of Middletown
Bicycle Facilities

- Absence of a marked bike lane does not mean cyclists not permitted to travel on the roadway (§9A.02, ¶03)
- Fluorescent yellow should be used for all bike related warning signs (§9A.08, ¶02)
- Lane width $\leq 14'$ (w/out shoulder) considered too narrow for a bike and a vehicle to travel safely side by side in the same lane (§9B.06, ¶06)
Shared Lane Markings (“Sharrows”)

- Roadways with on-street parking only
  - Reduces “dooring”
  - Assists cyclists with lateral positioning
  - Alerts drivers of likely bike positioning
  - Reduces wrong-way cycling
- Not for:
  - Rural areas
  - Areas without on-street parking
  - Roadways with speeds >35 mph
  - Shoulders or designated bike lanes

Part 9; Section 9C.07

R4-11 can be used in addition or instead
Other Bicycle Facility Markings

- Helmeted cyclist is preferred – it faces traffic lane

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Part 9; Section 9C
Other Bicycle Facility Markings

Part 9; Section 9C
Other Bicycle Facility Markings

Figure 9C-1E. Example of Bicycle Lane Treatment at a Bypass Lane (Delaware Revision)

Figure 9C-1F. Example of Bicycle Lane Treatment at Right In/Out Entrance (Delaware Revision)

Part 9; Section 9C
Other Bicycle Facility Markings

Figure 9C-6. Example of Pavement Markings for Bicycle Lanes on a Two-Way Street (Delaware Revision)

Figure 9C-6A. Example of Pavement Markings for Bicycle Lanes with Bus Pull-off Area and Full-Width Shoulder (Delaware Revision)

Part 9; Section 9C
What is/are in the Other Modules?

- **Introduction and Part 1 (General)**
  - A little bit of “MUTCD 101”
  - A general overview of the “Parts”
  - Details of the MUTCD Introduction and Part 1
  - Some thoughts on regulatory liability and tort implications
  - The meaning of “DelDOT maintained street”
  - Retroreflectivity of signs and markings
What is/are in the Other Modules?

- Part 2 (Signs) – ground based only
  - General (colors, dimensions, mountings, locations, retroreflectivity)
  - Regulatory signs, barricades, and gates
  - Warning signs and object markers
  - Guide signs for conventional roads (as opposed to freeways)
  - General information signs
  - Tourist-oriented directional signs
  - Changeable message signs
  - Emergency management signs
What is/are in the Other Modules?

- **Part 6 (Temporary Traffic Controls)**
  - General and fundamental principals
  - TTC (aka, Work Zone) elements
  - Pedestrian and worker safety
  - Flagger control
  - Work zone devices
  - Types of work zone activities
  - Typical applications/cases
  - Incident management areas
Where Can I Find This Stuff?

- Federal MUTCD: http://mutcd.fhwa.dot.gov/
- Delaware MUTCD: www.mutcd.deldot.gov
- Delaware T² Center: http://www.ce.udel.edu/dct/T2.html
- These slides: http://www.ce.udel.edu/dct/T2TechBriefs.html
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