

Horizontal Curve Safety Project

*DeIDOT Winter Workshop
February 19, 2015*



Delaware Department
of Transportation



JOHNSON, MIRMIRAN & THOMPSON
Engineering A Brighter Future®



*Presented By:
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Safety Programs Manager*

Horizontal Curve Safety Project

WHY IS THIS PROJECT IMPORTANT?

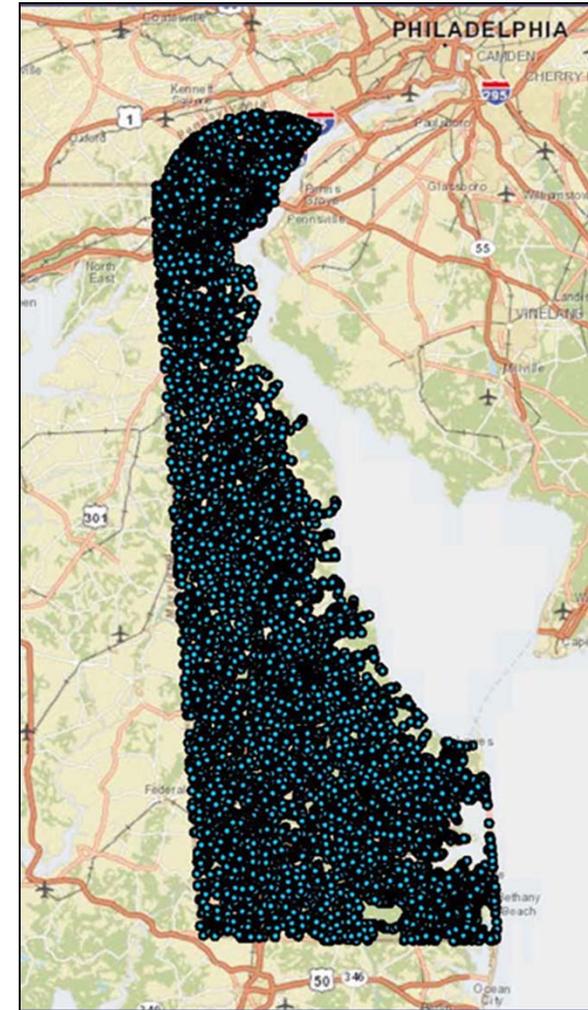
- FHWA's *Toward Zero Deaths* Initiative
- Over representation of fatal crashes
- Low cost countermeasures have proven effective



Horizontal Curve Safety Project

PROJECT SCOPE

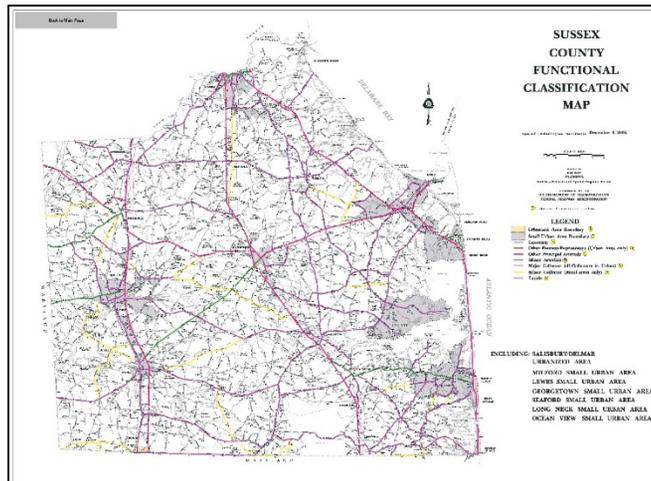
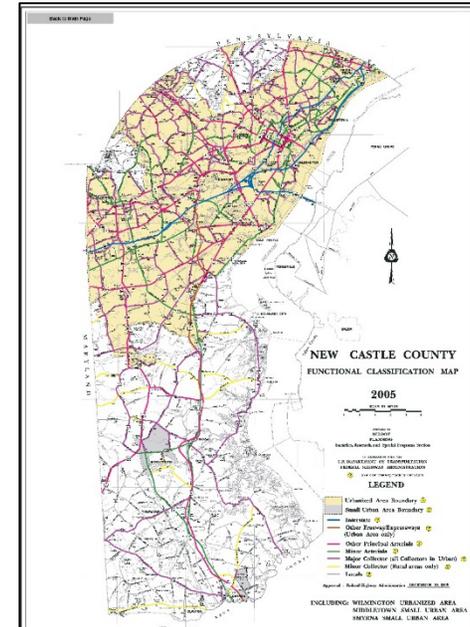
- Arterial and collector roadways > 1,000 AADT
- 3,400 locations Statewide
- Project Completed by December 31, 2019



Horizontal Curve Safety Project

LOCATIONS BY COUNTY

- **New Castle County**
 - **823 Collectors**
 - **740 Arterials**



- **Sussex County**
 - **772 Collectors**
 - **306 Arterials**

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LOCATIONS BY COUNTY

- **Kent County**
 - **429 Collectors**
 - **306 Arterials**
- **Phase 1 – Collectors**
 - **Completed West of US 13 – 279 Locations**
 - **Ongoing East of US 13 – 100 Locations**



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STUDY DETAILS

- Existing sign inventory
- MIRE Data Collection
- Ball-bank indicator study



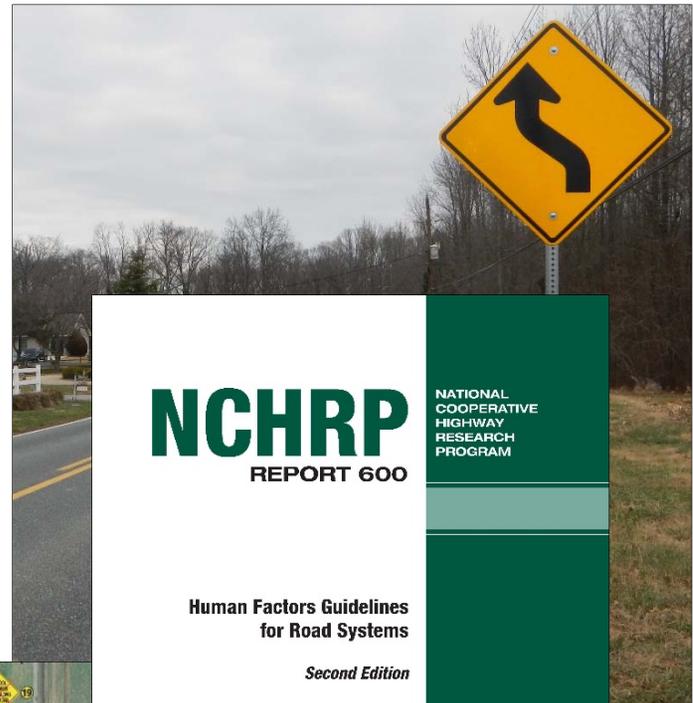
BALL BANK ALLOWABLE READINGS	
SPEED	DEGREES
35 MPH AND HIGHER	12
25 MPH – 30 MPH	14
20 MPH OR LESS	16



Horizontal Curve Safety Project

RECOMMENDATION HIGHLIGHTS

- Curve warning and advisory speed sign provision
- Curve warning sign placement
- Reducing driving task model
- Reducing sign clutter
- Incorporation of DeIDOT Guidance



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RECOMMENDATION HIGHLIGHTS



**Table 2C-5. Horizontal Alignment Sign Selection
(Delaware Revision)**

Type of Horizontal Alignment Sign	Difference Between Approach Speed and Curve Advisory Speed*				
	5 mph	10 mph	15 mph	20 mph	25 mph or more
Turn (W1-1), Curve (W1-2), Reverse Turn (W1-3), Reverse Curve (W1-4), Winding Road (W1-5), and Combination Horizontal Alignment/Intersection (W1-10 series) (see Section 2C.07 to determine which sign to use)	Recommended	Required	Required	Required	Required
Advisory Speed Plaque (W13-1P)	Recommended	Required	Required	Required	Required
Chevrons (W1-8) and/or One Direction Large Arrow (W1-6)	Optional	Recommended	Required	Required	Required
Exit Speed (W13-2) and Ramp Speed (W13-3) on exit ramp	Optional	Optional	Recommended	Required	Required

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CORRIDOR: WEST DENNEYS ROAD (K100)

KENT COUNTY - COLLECTORS > 1,000 ADT



LEGEND:
EXISTING CONDITIONS
PROPOSED CONDITIONS

DATA COLLECTED: 12-13-2019

HORIZONTAL CURVE SIGNING RECOMMENDATIONS

#	SIGN CODE	DESCRIPTION	DISPOSITION / REMARKS	SIZE	NOTES
1	W1-2	HORIZONTAL ALIGNMENT	REMOVE	30"x30"	
2	W13-1P	ADVISORY SPEED	REMOVE	18"x18"	
3	W1-1	HORIZONTAL ALIGNMENT	INSTALL	30"x30"	INSTALL APPROX. 27' EAST OF EXISTING SIGN TO BE REMOVED ON NEW SIGN POST
4	W13-1P	ADVISORY SPEED	INSTALL	18"x18"	
5	W1-8 (L)	CHEVRON ALIGNMENT	INSTALL	24"x18"	INSTALL ON NEW SIGN POST
6	W1-8 (L)	CHEVRON ALIGNMENT	INSTALL	24"x18"	INSTALL BACK TO BACK ON NEW SIGN POST
7	W1-8 (R)	CHEVRON ALIGNMENT	INSTALL	24"x18"	
8	W1-8 (L)	CHEVRON ALIGNMENT	INSTALL	24"x18"	INSTALL BACK TO BACK ON NEW SIGN POST
9	W1-8 (R)	CHEVRON ALIGNMENT	INSTALL	24"x18"	
10	W1-8 (R)	CHEVRON ALIGNMENT	INSTALL	24"x18"	INSTALL APPROX. 25' WEST OF DRIVEWAY ON NEW SIGN POST
11	W5-3	TWO-WAY TRAFFIC	REMOVE	36"x36"	REPLACE EXISTING SIGN WITH PROPOSED SIGN ON EXISTING SIGN POST
12	W5-2	DIVIDED HIGHWAY ENDS	INSTALL	36"x36"	
13	W1-2	HORIZONTAL ALIGNMENT	REMOVE	30"x30"	
14	W13-1P	ADVISORY SPEED	REMOVE	18"x18"	
15	W1-1	HORIZONTAL ALIGNMENT	INSTALL	30"x30"	REPLACE EXISTING SIGNS WITH PROPOSED SIGNS ON EXISTING SIGN POST
16	W13-1P	ADVISORY SPEED	INSTALL	18"x18"	

RECOMMENDATIONS 1 & 2



BALL BANK ALLOWABLE READINGS

SPEED	DEGREES
25 MPH AND HIGHER	12
25 MPH - 20 MPH	14
20 MPH OR LESS	16

CURVE #15 GOVERNING BALL BANK STUDY RESULTS

DIRECTION OF TRAVEL	SPEED (MPH)	MAX READING (DEG)
EAST	30	11
	30	10
	30	10
WEST	30	10
	30	10
	30	10

RECOMMENDATIONS 11 & 12



CURVE & ROADWAY INFORMATION: CURVE #15

PC MILEPOST	5.40 (APPROX.)
PT MILEPOST	5.47 (APPROX.)
DIRECTION	RIGHT
RADIUS	15A = 536' 15B = 315'
DEFLECTION ANGLE	60 DEG
LENGTH	15A = 110' 15B = 280'
CURVE SUPERELEVATION	15A = EB: 2% WB: 5% (C) 15B = EB: 5% WB: 4% (APPROX.)
FEATURE TYPE	COMPOUND
LANE WIDTH	15A = EB: 12' WB: 12' 15B = EB: 12' WB: 12'
SHOULDER WIDTH	15A = EB: 7' WB: 2' 15B = EB: 7' WB: 3'
SURFACE TYPE	BITUMINOUS
SURFACE CONDITION	GOOD
EXISTING LIGHTING?	YES
EXISTING GUARDRAIL?	EB: NO WB: NO
DRIVEWAY W/IN CURVE?	NO
VISUAL TRAP?	EB: NO WB: NO
VISUAL TRAP TYPE:	N/A
FUTURE DEVELOPMENT?	NO
POSTED SPEED LIMIT	40 MPH
EXISTING ADVISORY SPEED	EB: 30 MPH WB: 30 MPH
PROPOSED ADVISORY SPEED	EB: 30 MPH WB: 30 MPH

DATE: 7/20/2018
 DRAWN BY: CHASE
 CHECKED BY: CHASE
 PROJECT: 120060017 - Kent County, Delaware
 COUNTY: Kent
 SHEET NO. 15
 TOTAL SHEETS: 18

DELAWARE
DEPARTMENT OF TRANSPORTATION

ADDENDUMS / REVISIONS

NOT TO SCALE

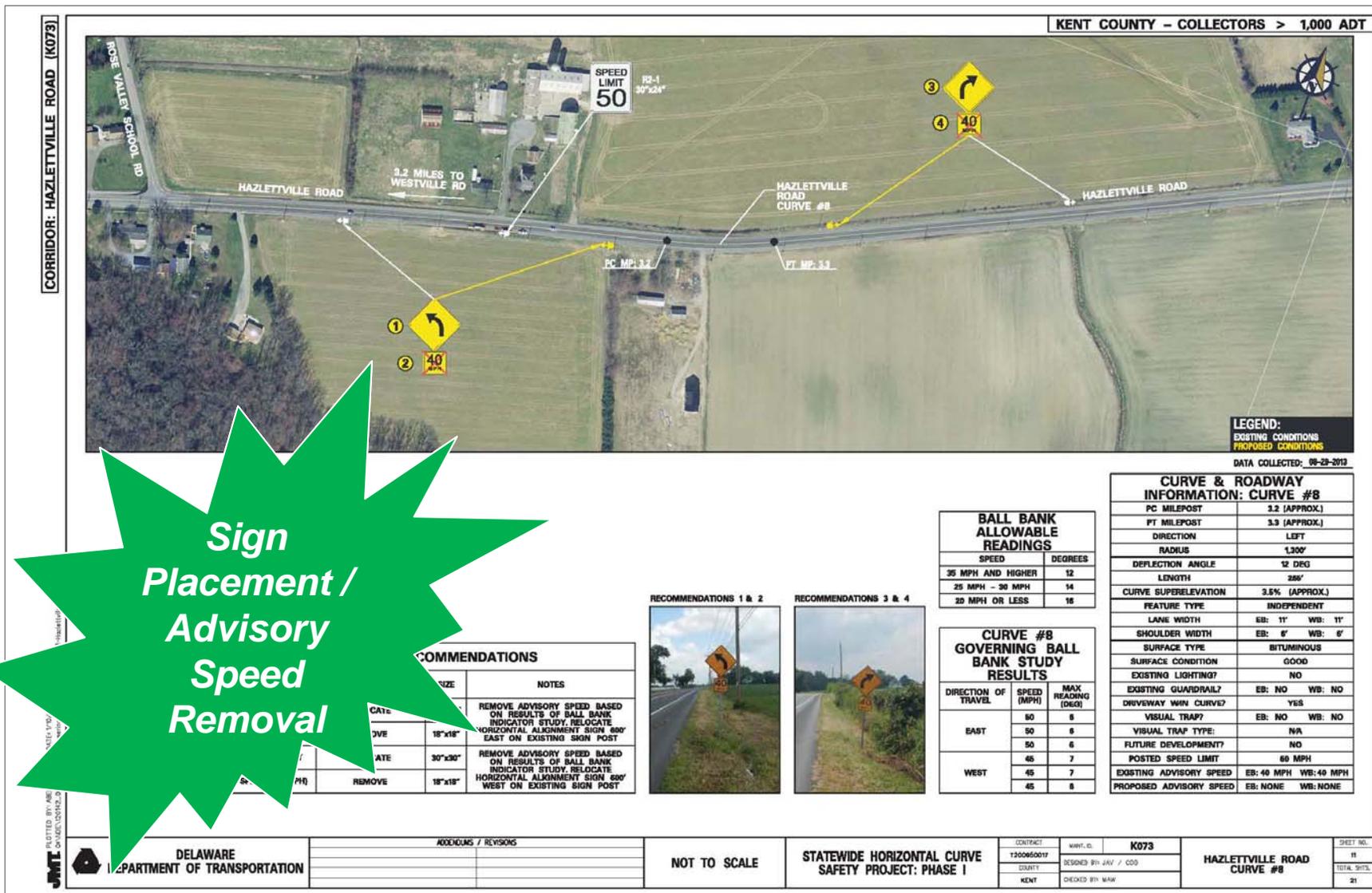
STATEWIDE HORIZONTAL CURVE
SAFETY PROJECT: PHASE I

CONTRACT: 120060017
COUNTY: KENT
SHEET NO.: K100
DESIGNED BY: CHASE
CHECKED BY: MAW

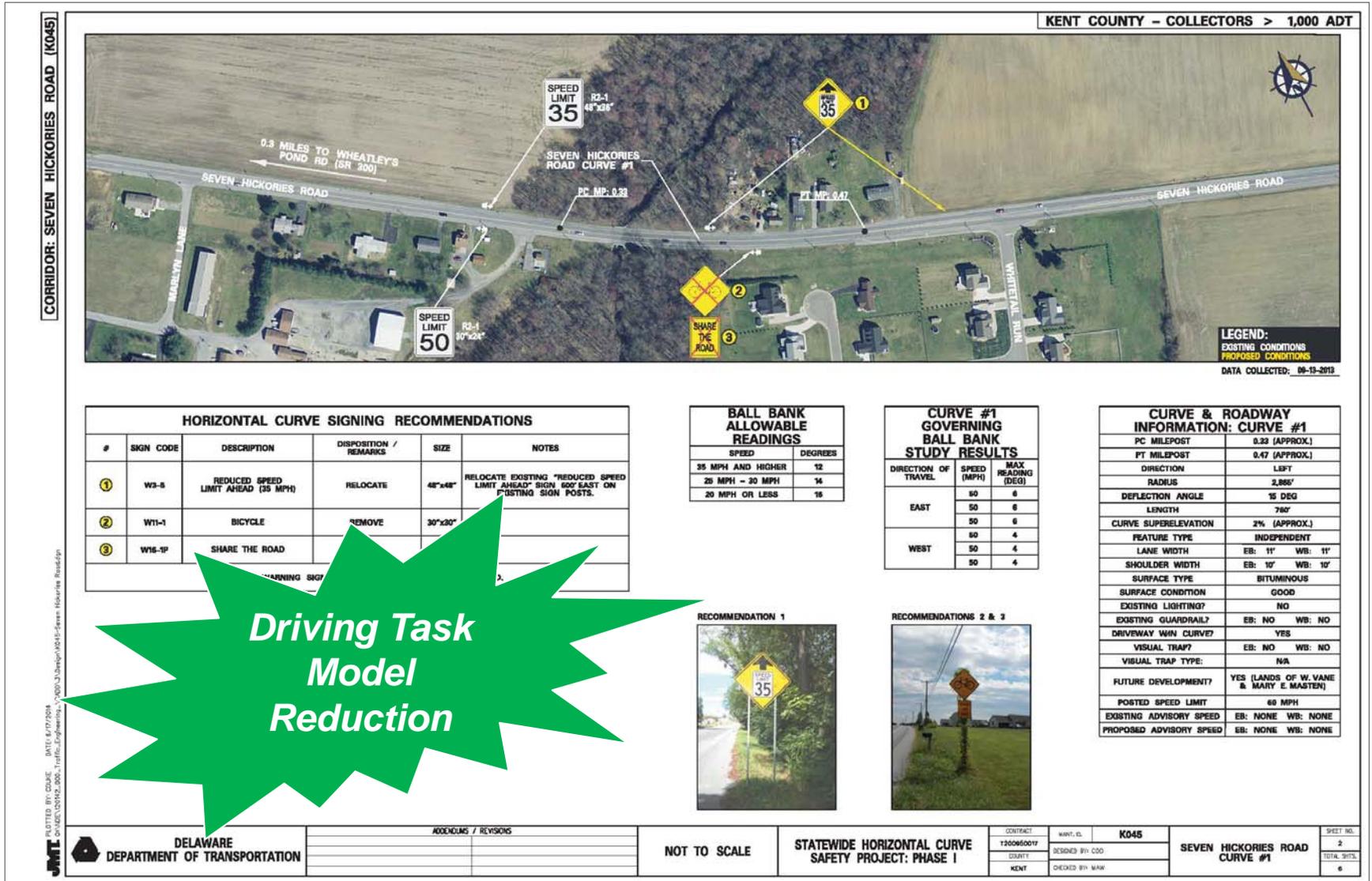
WEST DENNEYS ROAD
CURVE #15

SHEET NO.: 15
TOTAL SHEETS: 18

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Horizontal Curve Safety Project



Horizontal Curve Safety Project

CORRIDOR: BURRITE MILL ROAD (K004)

KENT COUNTY - COLLECTORS > 1,000 ADT



Sign Clutter Reduction

HORIZONTAL CURVE SIGNING RECOMMENDATIONS					
#	SGN CODE	DESCRIPTION	DISPOSITION / REMARKS	SIZE	NOTES
1	W1-2	HORIZONTAL ALIGNMENT	REMOVE	30"x30"	INSTALL APPROX 530' WEST OF INTERSECTION ON NEW SIGN POST
2	W1-10 CUSTOM	COMBINATION HORIZONTAL ALIGNMENT/INTERSECTION	INSTALL	36"x36"	
3	W16-8aP	ADVANCE STREET NAME	INSTALL	18"x30"	
4	W2-2	INTERSECTION WARNING	REMOVE	30"x30"	
5	W16-8aP	ADVANCE STREET NAME	REMOVE	18"x30"	
6	W2-2	INTERSECTION WARNING	REMOVE	30"x30"	
7	W16-8aP	ADVANCE STREET NAME	REMOVE	18"x30"	
8	W1-10 CUSTOM	COMBINATION HORIZONTAL ALIGNMENT/INTERSECTION	INSTALL	36"x36"	
9	W16-8aP	ADVANCE STREET NAME	INSTALL	18"x30"	
10	W1-2	HORIZONTAL ALIGNMENT	REMOVE	30"x30"	

BALL BANK ALLOWABLE READINGS	
SPEED	DEGREES
35 MPH AND HIGHER	12
25 MPH - 30 MPH	14
20 MPH OR LESS	16

CURVE #6 GOVERNING BALL BANK STUDY RESULTS		
DIRECTION OF TRAVEL	SPEED (MPH)	MAX READING (DEG)
EAST	50	7
	50	3
	50	2
WEST	50	5
	50	5
	50	5

CURVE & ROADWAY INFORMATION: CURVE #6	
PC MILEPOST	3.59 (APPROX.)
PT MILEPOST	3.74 (APPROX.)
DIRECTION	RIGHT
RADIUS	1,475'
DEFLECTION ANGLE	30 DEG
LENGTH	775'
CURVE SUPERELEVATION	10% (APPROX.)
FEATURE TYPE	INDEPENDENT
LANE WIDTH	EB: 11' WB: 11'
SHOULDER WIDTH	EB: 8' WB: 0'
SURFACE TYPE	BITUMINOUS
SURFACE CONDITION	GOOD
EXISTING LIGHTING?	NO
EXISTING GUARDRAIL?	EB: NO WB: NO
DRIVEWAY W/IN CURVE?	YES
VISUAL TRAP?	EB: NO WB: NO
VISUAL TRAP TYPE:	N/A
FUTURE DEVELOPMENT?	NO
POSTED SPEED LIMIT	50 MPH
EXISTING ADVISORY SPEED	EB: NONE WB: NONE
PROPOSED ADVISORY SPEED	EB: NONE WB: NONE



DATE: 6/8/2018
 DRAWN BY: JMC
 CHECKED BY: JMC
 PROJECT: STATEWIDE HORIZONTAL CURVE SAFETY PROJECT - PHASE I

	DELAWARE DEPARTMENT OF TRANSPORTATION	ADDITIONS / REVISIONS

NOT TO SCALE

STATEWIDE HORIZONTAL CURVE SAFETY PROJECT: PHASE I

CONTRACT	WWW.NO.	K057
1200650017	DESIGNED BY: COD	
KENT	CHECKED BY: MAW	

BURRITE MILL ROAD CURVE #6

SHEET NO.	7
TOTAL SHEETS	14

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PROJECT STATS

- **62** out of **279** curves had an advisory speed posted
 - **48** were too low or not needed
 - **6** too high
 - **8** were consistent with study results
- **44** out of **279** curves warranted a posted advisory speed
 - **20** did not have an existing posted advisory speed
 - **7** warranted a posted advisory speed ≥ 10 mph below the posted speed limit



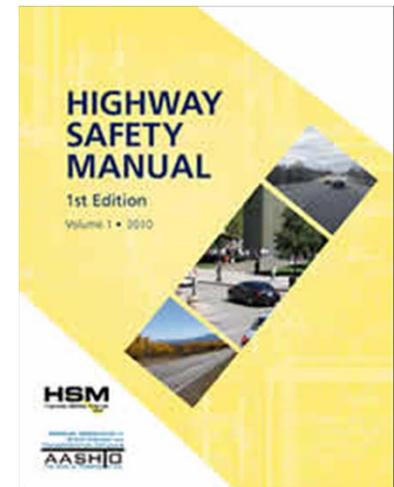
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QUANTITATIVE EFFECT ON SAFETY

- Highway Safety Manual: Predictive Model for Rural Two-Lane, Two-Way Roadway Segments

$$N_{\text{predicted,rs}} = N_{\text{SPF,rs}} * (\text{CMF}_1 * \text{CMF}_2 \dots * \text{CMF}_x) * C$$

- $N_{\text{SPF,rs}} = \text{AADT} * L * 365 * 10^{-6} * e^{(-0.312)}$
- CMFs considered in analysis:
 - Lane width
 - Shoulder width
 - Superelevation variance
 - Horizontal curve length, radius
 - Presence of curve warning/advisory speed signs
 - **CMF = 0.76 (combined)**



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QUANTITATIVE EFFECT ON SAFETY

- **20** locations that warranted a posted advisory speed, but did not currently have one
- $N_{\text{predicted}}$ = crashes / year

Road Name (Maint. #)	Curve #	$N_{\text{predicted}}$ Before	$N_{\text{predicted}}$ After
Millington Rd (K039)	8	0.09	0.07
Dickerson St (K041A)	1	0.19	0.14
Brenford Rd (K042)	1	0.13	0.10
Brenford Rd (K042)	4	0.25	0.19
Sandtown Rd (K056)	3	0.11	0.08
Vernon Rd (K060)	11	0.47	0.36
MLK Blvd (K067)	4	0.64	0.48
Delaware Ave (K081)	1	0.86	0.66
Sunnyside Rd (K090)	1	0.20	0.15
West Denneys Rd (K100)	2	0.10	0.07
West Denneys Rd (K100)	9	0.38	0.29
Lynnbury Woods Rd (K152)	1	0.08	0.06

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QUANTITATIVE EFFECT ON SAFETY

- **20** locations that warranted a posted advisory speed, but did not currently have one
- $N_{\text{predicted}} = \text{crashes / year}$

Road Name (Maint. #)	Curve #	$N_{\text{predicted}}$ Before	$N_{\text{predicted}}$ After
Lynnbury Woods Rd (K152)	2	0.08	0.06
Lockwood Chapel Rd (K171)	2	0.11	0.09
Westville Rd (K206)	1	0.14	0.11
Westville Rd (K206)	6	0.06	0.05
Westville Rd (K206)	8	0.09	0.07
Westville Rd (K206)	18	0.11	0.08
Westville Rd (K206)	21	0.16	0.12
Westville Rd (K206)	23	0.08	0.06
Total / Year	20	4.33	3.29

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QUANTITATIVE EFFECT ON SAFETY

- 1 crash saved per year
- \$400 construction cost to install signs at each curve

Crash Severity Level	% of Total
Fatal + Injury	32.1
PDO	67.9

Collision Type	Societal Crash Costs
Fatal (K)	\$4,008,900
Disabling Injury (A)	\$216,000
Evident Injury (B)	\$79,000
Possible Injury (C)	\$44,900
PDO (O)	\$7,400

Cost : Societal Benefits

1 : 1,050

over 5 year period

Horizontal Curve Safety Project

DELIVERABLES

- Plan Sheet Recommendations
- MIRE Data Spreadsheets
- Quantity Tabulations



TRAFFIC PROJECT COST SUMMARY	
CORRIDOR: WESTVILLE ROAD (K206)	
DESCRIPTION	ENGINEER'S ESTIMATE
TOTAL ROADWAY SIGNING ESTIMATE:	\$5,231.94
TOTAL ROADWAY STRIPING ESTIMATE:	\$88.25
TOTAL ESTIMATE FOR CORRIDOR:	\$5,320.19

MIRE
MODEL INVENTORY OF ROADWAY ELEMENTS
VERSION 1.0

DEPARTMENT OF TRANSPORTATION
OCTOBER 2010
FHWA-SA-10-018

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QUESTIONS?

