

Seminar

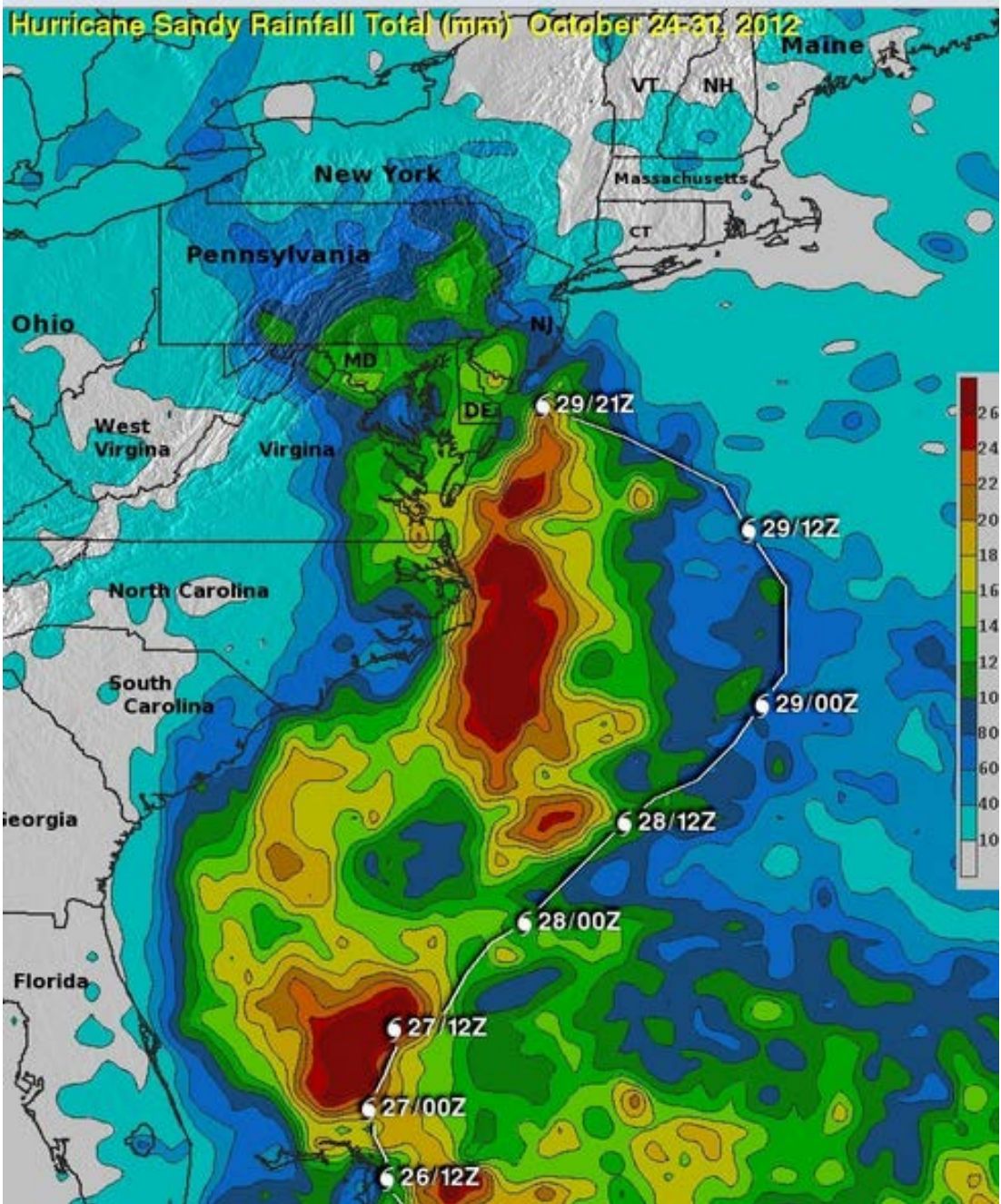
The Delaware Floodplain: Impacts of Severe Storms on Infrastructure in a Low Lying State

October 30, 2017
9:30 am

University of Delaware
Sharp Campus
104 Cannon Lab
Lewes, Del.

Agenda

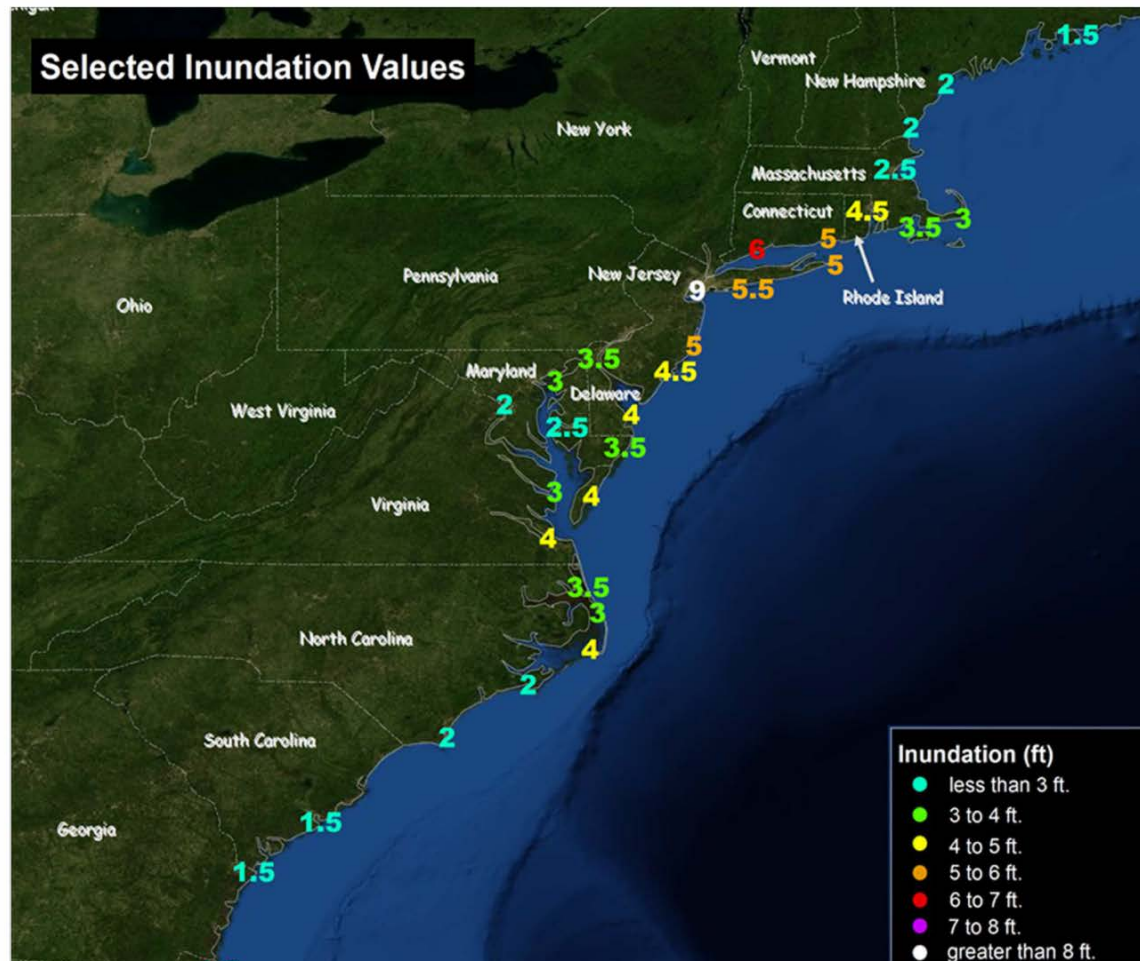
Opening Remarks/Introductions (G. Kauffman, UDWRC)	9:30 am
GIS Mapping/Flood Inundation Analysis (A. Homsey, UDWRC)	9:35 am
Culvert/Bridge Hydraulic Analysis (G. Kauffman, UDWRC)	9:55 am
Web Flood Mapping Interface (D. Racca/E. Best, UD CADSR)	10:15 am
Coastal Inundation Mapping and STREAMSTATS (N. Bates, DGS)	10:35 am
Delaware Coastal Flood Modeling and Issues (M. Powell, J. Hayden, DNREC)	10:55 am
Vulnerability Assessment along SR 1 near Dewey Beach (L. Trout/D. Janiec)	11:15 am
Community Resilience Planning Guide to Transportation (S. Cauffman, NIST)	11:35 am
Storm Surge Risk to DelDOT SR-9 (S. Croope, DelDOT; D. Stander/C. Meenan, RMS)	11:55 am
Delaware Infrastructure Impacts (J. Pappas/B. Urbanek, DelDOT)	12:15 pm
Luncheon	12:35 pm
Discussion	1:00 pm
Adjourn	2:00 pm



NOAA/HPC Provided Selected Rainfall Totals from the Storm:

WASHINGTON DC	
WASHINGTON/NATIONAL	4.11
DELAWARE	
MILFORD	9.55
DOVER AFB	8.46
WILMINGTON ARPT	4.17

NEW JERSEY	
WILDWOOD CREST	11.62
WEST CAPE MAY	9.37
WOODBINE	7.82
ATLANTIC CITY	8.01
ESTELLE HARBOR	6.57
MILLVILLE MUNI ARPT	5.28
NEW YORK	
NIAGARA FALLS INTL ARPT	2.69
JAMESTOWN AIRPORT	2.46



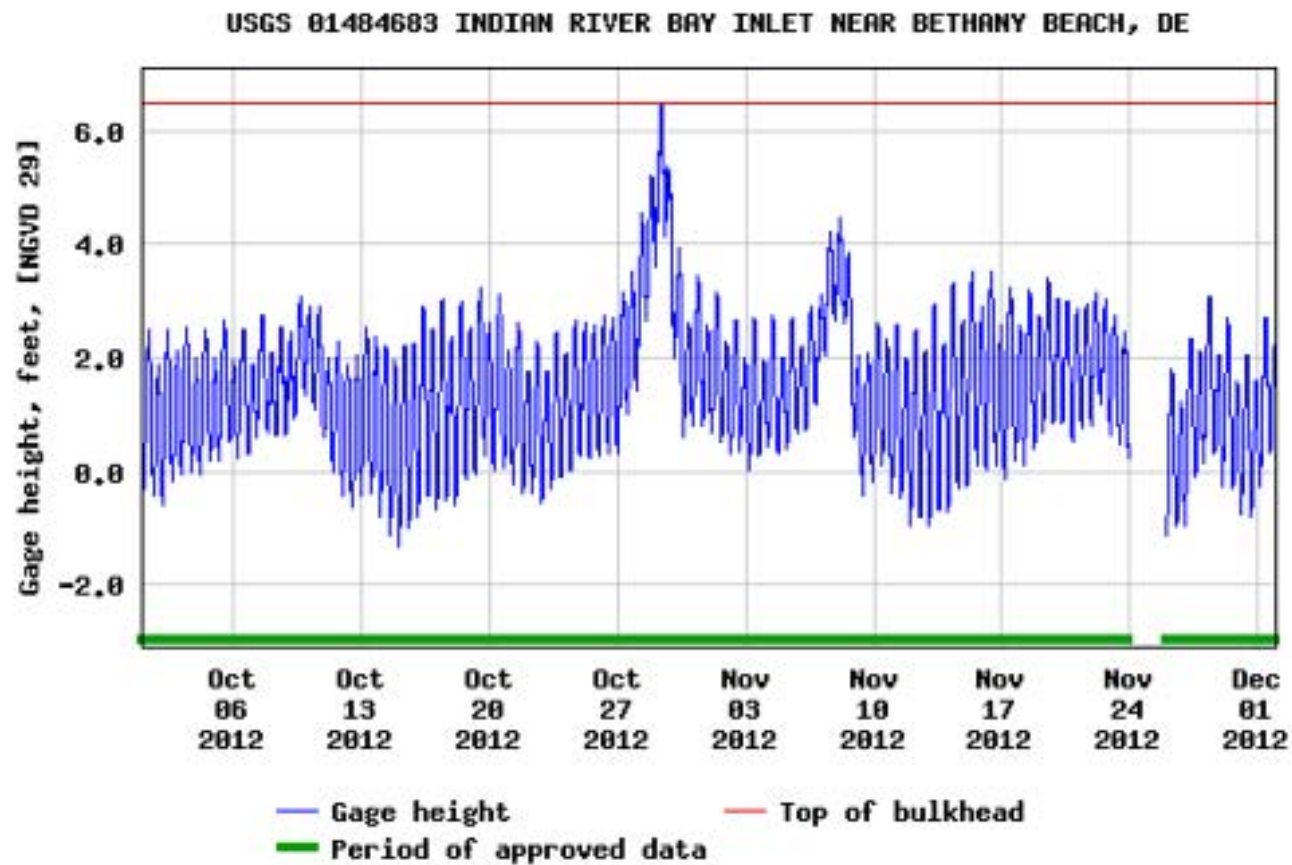


Figure 3.5 Historic peak flood tide at Indian River Bay inlet, Superstorm Sandy October 29, 2012

**Worst Case Effects of Hurricanes, Fluvial Flooding, High Tides,
and Sea Level Rise on DelDOT Assets**

DelDOT Project No. 1739-9

Draft July 14, 2017

Prepared by:

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Prepared for:

Delaware Department of Transportation
Division of Planning
Bay Road
Dover, Delaware

Culvert/Bridge Hydraulic Analysis

October 30, 2017

University of Delaware

Sharp Campus

Lewes, DE

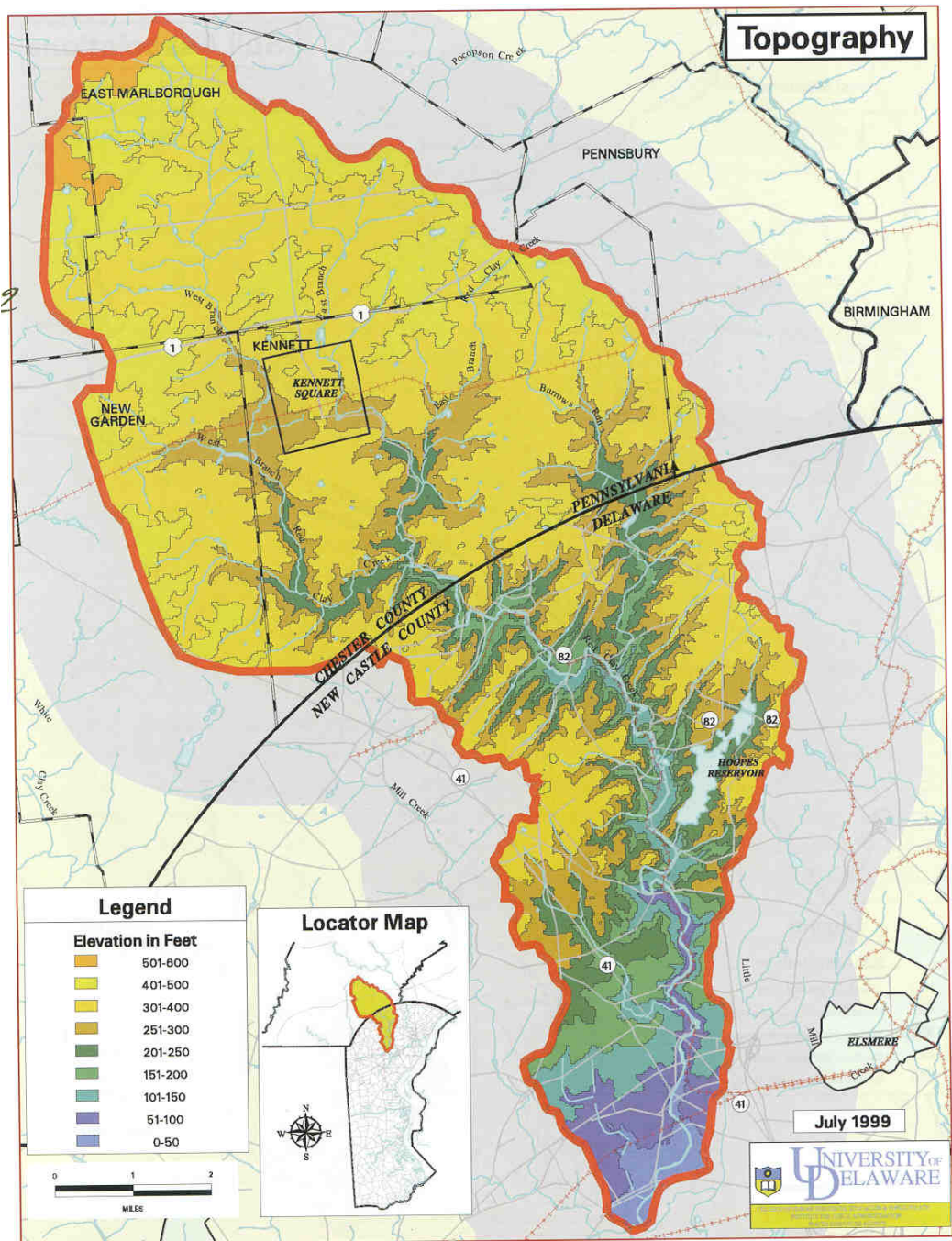
Gerald J. Kauffman, Ph.D., P.E.

University of Delaware

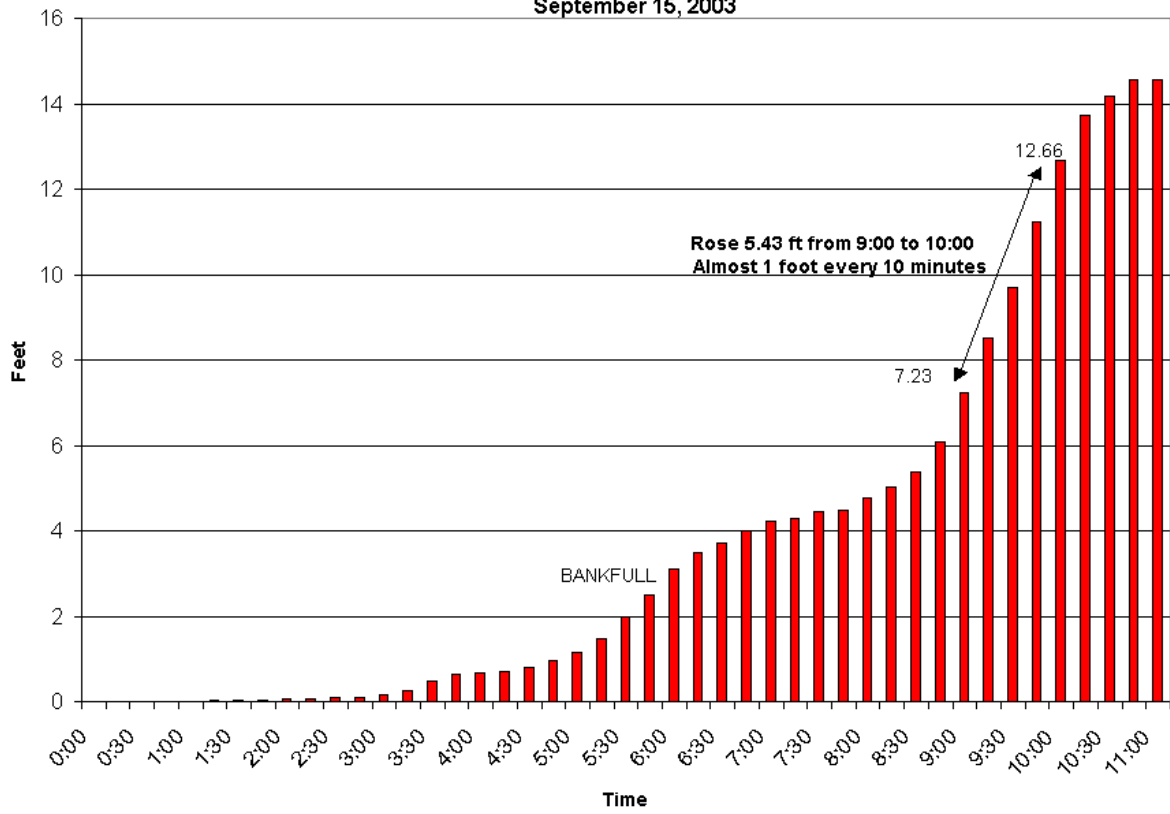
Water Resources Center

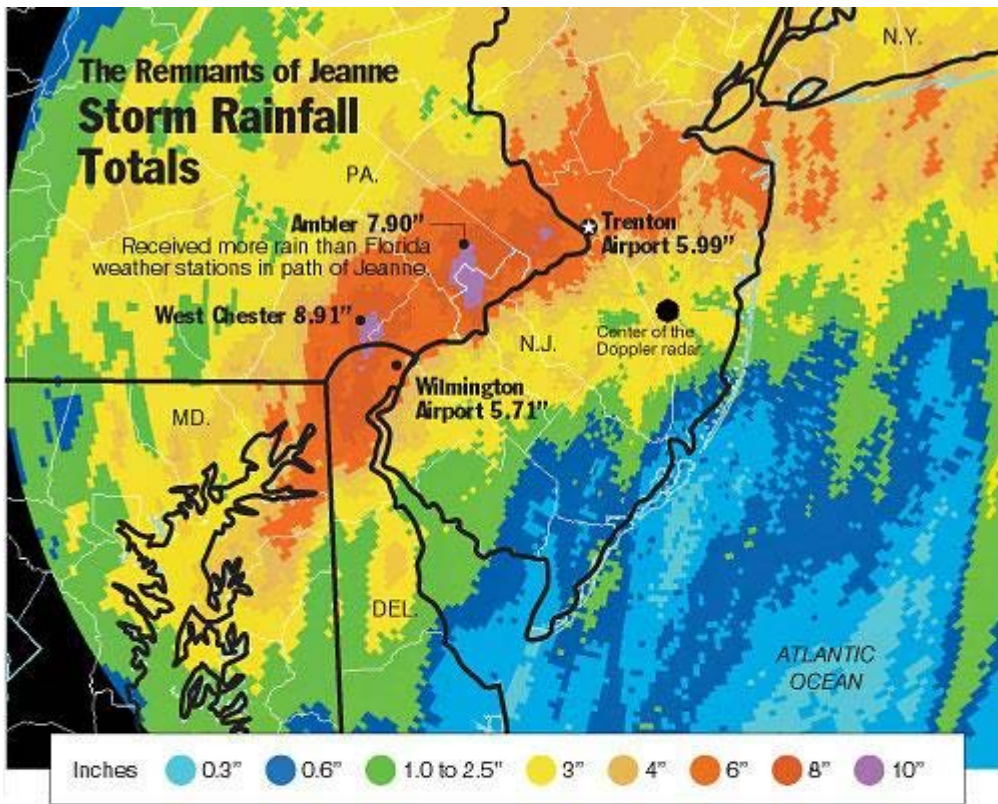
Newark, DE

19716



Red Clay Creek at Wooddale
Cumulative Rate of Rise, 15-Minute Intervals
September 15, 2003



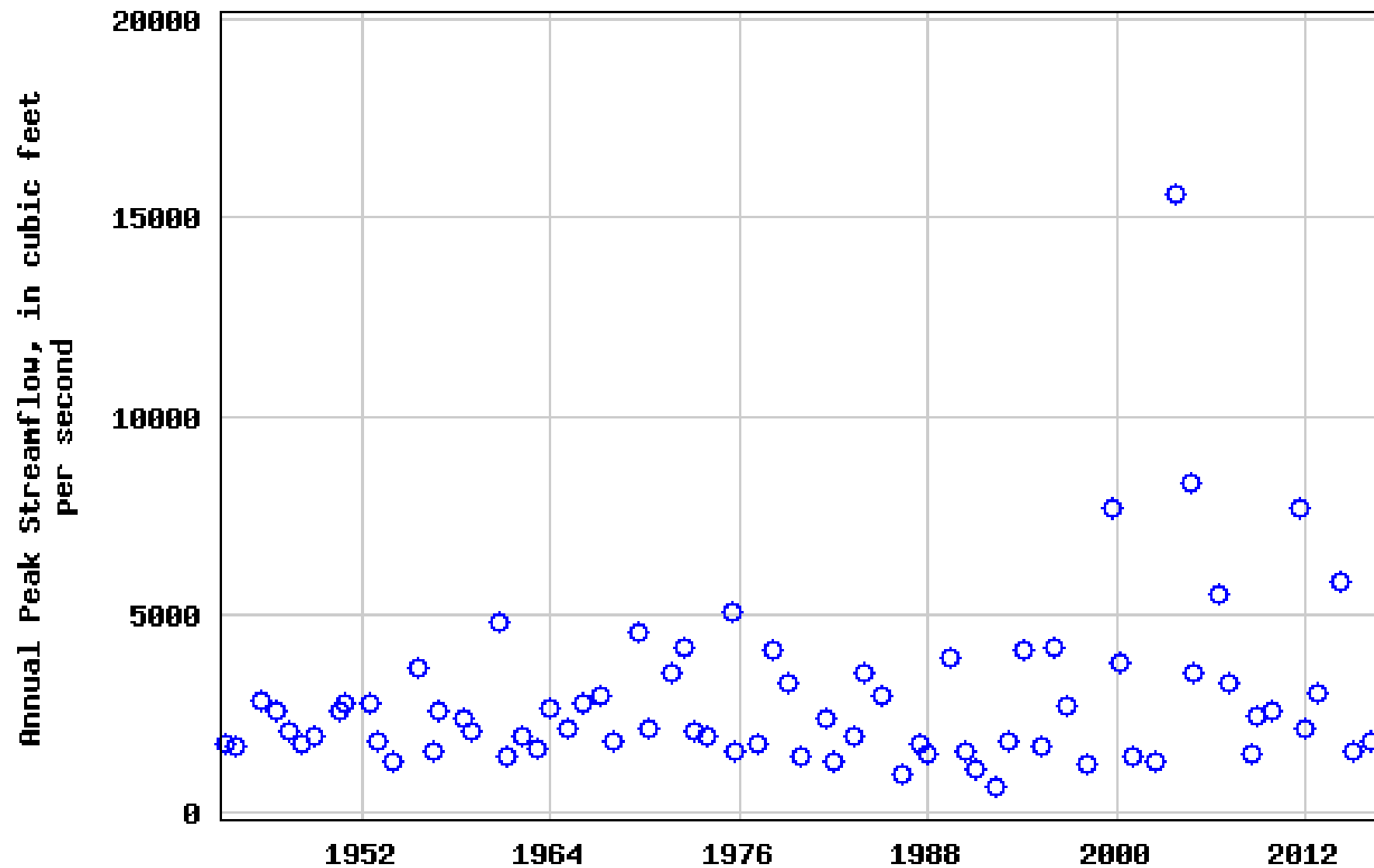


Area	Rainfall	Area	Rainfall
Bucks County		Philadelphia	
Doylestown	5.06	Fairmount Dam	5.98
Neshaminy Falls	6.49	N. Phila. Airport	5.68
		Phila. Airport	3.60
Montgomery County		New Jersey	
Ambler	7.90	Trenton	5.00
King of Prussia	6.15	Trenton Airport	5.99
Wynnewood	6.28	Atlantic City Airport	1.47
Chester County		Absecon	0.90
Downingtown	6.66	Margate	0.56
West Chester	8.91		
Delaware County		Delaware	
Chadds Ford	7.84	Newark	7.44
Havertown	7.00	Wilmington Airport	5.71



Red Clay Creek, Route 4, Stanton
Tropical Storm Jeanne, Sep 28, 2004
DGS

USGS 01480000 RED CLAY CREEK AT WOODDALE, DE



Review of Delaware Floodplain and Drainage Standards Progress Report

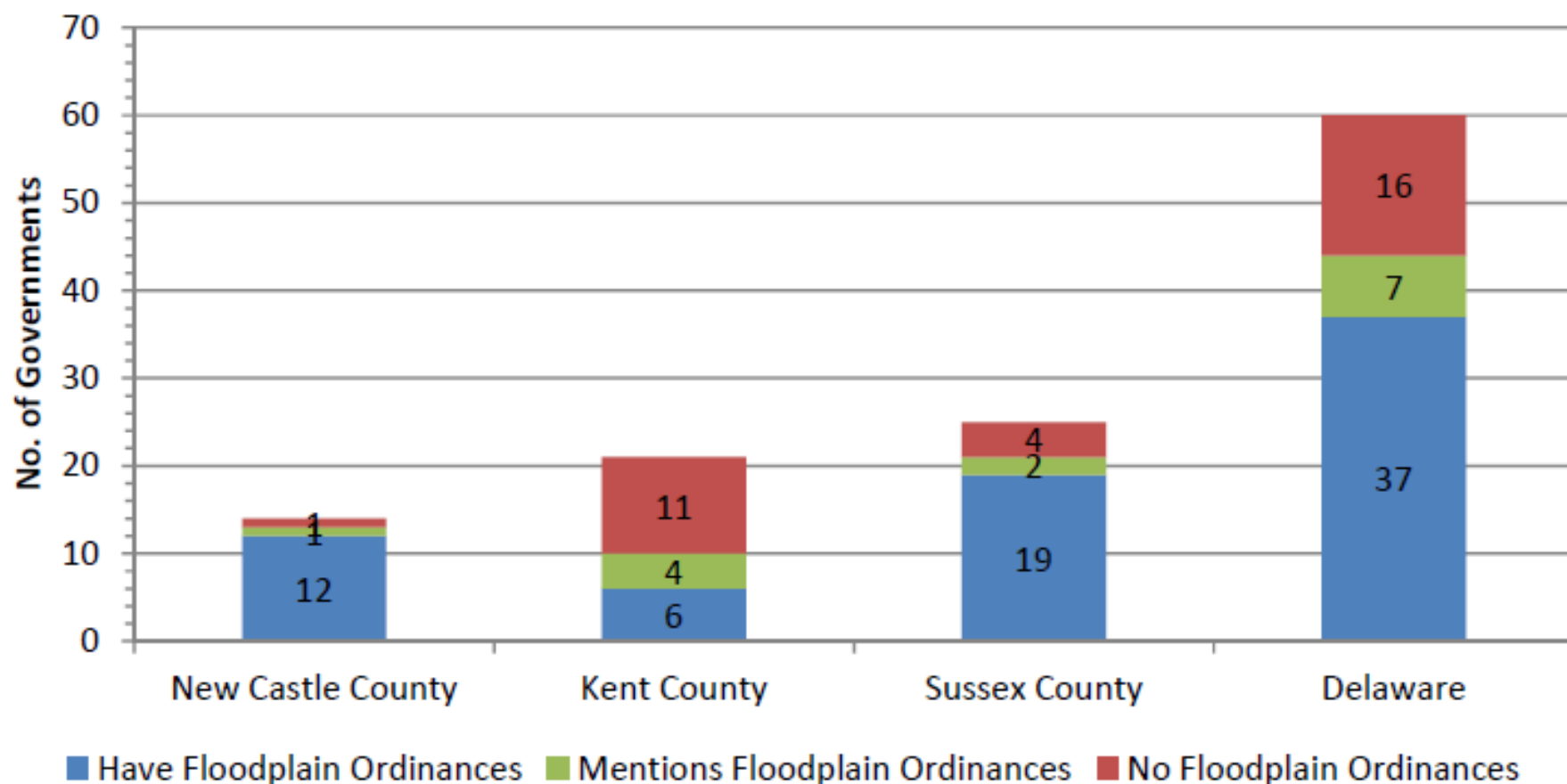
January 14, 2013

Prepared for:
Delaware Department of Natural Resources and Environmental Control
Division of Watershed Stewardship
Dover, Del.

Prepared by:
Catherine Cruz-Ortiz
With contributions by:
Kate Miller and Joe Brown
University of Delaware
Water Resources Agency
Institute for Public Administration
Newark, Del.

Local Governments with Floodplain Ordinances

State of Delaware



Local Governments with Stormwater Ordinances

State of Delaware

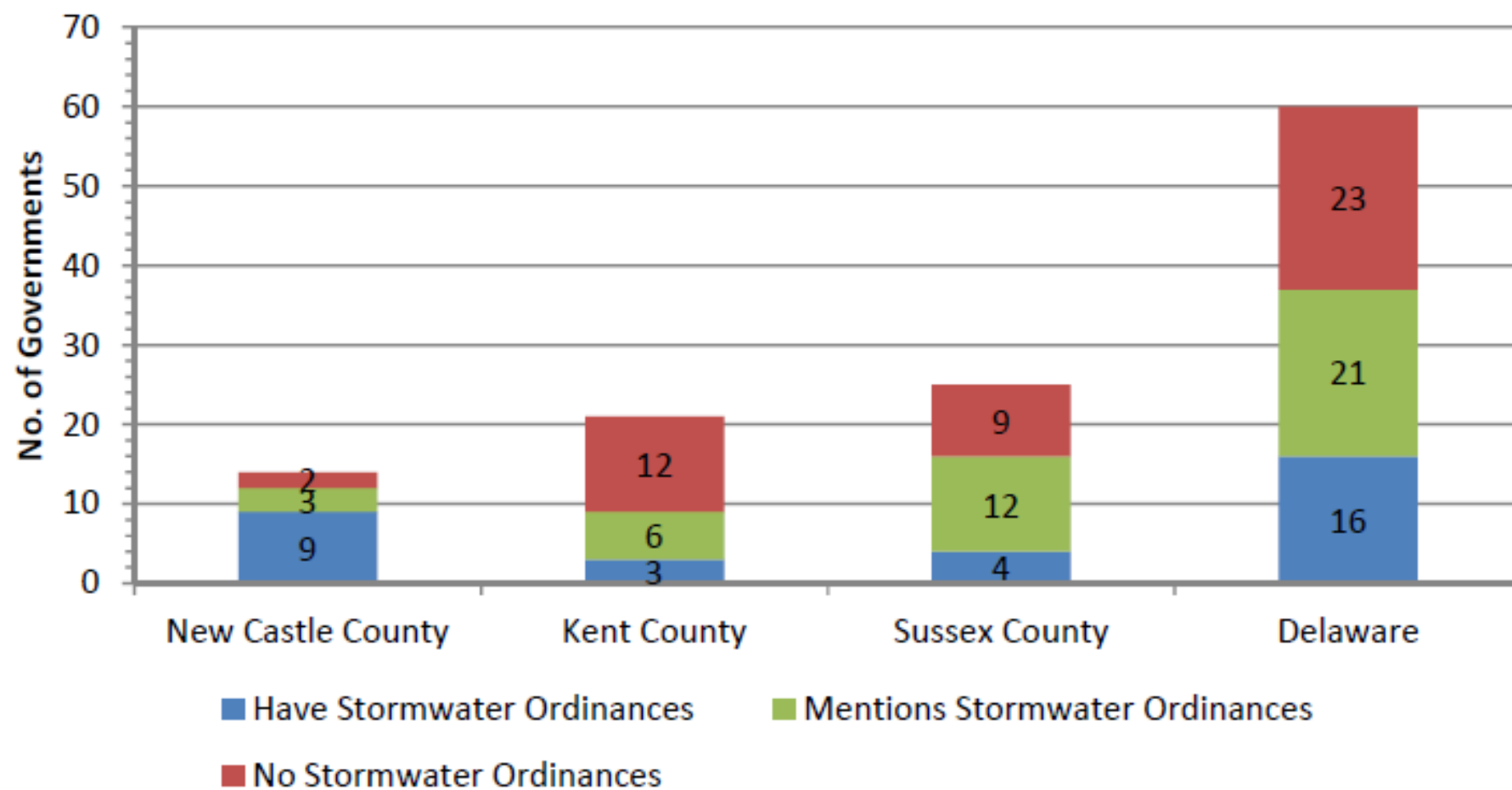


Table 1. Review of floodplain and drainage standards in New Castle County

Government	Floodplain Standards															Drainage Standards						
	1	2	3	4	5	6	7	7a	8	9	10	11	12	13	14	15	1	2	3	4	5	6
New Castle Co.	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y			Y			Y		Y	Y	Y	Y
Arden	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y			Y			Y		Y	Y	Y	Y
Ardencroft	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y			Y			Y		Y	Y	Y	Y
Ardentown	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y			Y			Y		Y	Y	Y	Y
Bellefonte ^A																						
Delaware City					Y	Y				Y	Y											
Elsmere						Y					Y				Y							
Middletown										Y	Y				Y							
New Castle								Y	Y	Y					Y							
Newark ^B																						
Newport										Y	Y				Y						Y	
Odessa ^A																						
Townsend		Y								Y				Y								
Wilmington								Y		Y					Y							
Total	4	5	4	4	5	6	4	2	5	10	8	0	0	5	5	0	4	0	4	4	5	4

A. Bellefonte and Odessa not yet reviewed. B. Newark reviewed by the City with assistance by UDWRA.

Floodplain:

1. Flood study required in unmapped floodplains.
2. Flood study required in Zone A (no BFE) FEMA mapped floodplains.
3. Only FEMA approved and BFE data on record plans and development documents.
4. Use accepted base flood elevations in building permit application documents.
5. Floodplain information included on permitting documentation.
6. Require use of elevation and flood proofing certificates.
7. Require 18 inches of freeboard. 7a. Require one foot of freeboard.
8. Require 18 inches of freeboard for manufactured homes.
9. Shallow fill above BFE will not exempt a structure from floodplain regulations.
10. Hydrostatic vents required.
11. Prohibit below-grade crawl spaces or enclosures.
12. Newly subdivided floodplain shall remain deed restricted open space.
13. Prohibit new non-water dependent structure in floodplains on new lots.
14. Prohibit encroachments that would cause more than 0.1 foot of rise without compensation.
15. Incorporate FEMA technical bulletins in local floodplain regulations.

Table 2. Review of floodplain and drainage standards in Kent County

Government	Floodplain Standards															Drainage Standards						
	1	2	3	4	5	6	7	7a	8	9	10	11	12	13	14	15	1	2	3	4	5	6
Kent County		Y	Y	Y	Y			Y			Y		Y		Y		Y			Y	Y	
Bowers Beach																						
Camden			Y	Y	Y	Y					Y		Y	Y	Y		Y			Y	Y	Y
Cheswold			Y	Y	Y						Y		Y	Y			Y	Y		Y	Y	Y
Clayton																	Y				Y	Y
Dover				Y		Y					Y					Y						
Farmington																						
Felton			Y	Y	Y										Y	Y		Y	Y		Y	Y
Frederica																						
Harrington		Y	Y	Y		Y		Y			Y					Y		Y			Y	Y
Hartly																						
Houston																					Y	
Kenton																						
Leipsic																						
Little Creek																						
Magnolia																						
Milford			Y	Y	Y	Y		Y			Y		Y			Y		Y	Y			
Smyrna					Y													Y		Y		Y
Viola																						
Woodside																						
Wyoming																						
Total	0	2	6	7	6	4	0	3	0	0	6	0	4	3	6	0	7	4	1	4	8	6

Ordinances for Bowers Beach, Farmington, Frederica, Hartly, Kenton, Leipsic, Little Creek, Magnolia, Viola, Woodside, and Wyoming not available for review yet.

Floodplain:

1. Flood study required in unmapped floodplains.
2. Flood study required in Zone A (no BFE) FEMA mapped floodplains.
3. Only FEMA approved and BFE data on record plans and development documents.
4. Use accepted base flood elevations in building permit application documents.
5. Floodplain information included on permitting documentation.
6. Require use of elevation and flood proofing certificates.
7. Require 18 inches of freeboard. 7a. Require one foot of freeboard.
8. Require 18 inches of freeboard for manufactured homes.
9. Shallow fill above BFE will not exempt a structure from floodplain regulations.
10. Hydrostatic vents required.
11. Prohibit below-grade crawl spaces or enclosures.
12. Newly subdivided floodplain shall remain deed restricted open space.
13. Prohibit new non-water dependent structure in floodplains on new lots.
14. Prohibit encroachments that would cause more than 0.1 foot of rise without compensation.
15. Incorporate FEMA technical bulletins in local floodplain regulations.

Drainage:

1. Adequate easements required.
2. Obstruction prohibited.
3. Conveyance systems meet 10-year storm event.
4. Lot grading away from buildings.
5. Topographic plan submittal.
6. As-built submittal.

Table 3. Review of floodplain and drainage standards in Sussex County

Government	Floodplain Standards															Drainage Standards						
	1	2	3	4	5	6	7	7a	8	9	10	11	12	13	14	15	1	2	3	4	5	6
Sussex Co.	Y				Y						Y					Y		Y				Y
Bethany Bch.			Y	Y	Y	Y											Y	Y			Y	Y
Bethel																						
Blades			Y	Y	Y						Y						Y					Y
Bridgeville			Y	Y	Y						Y					Y		Y				Y
Dagsboro			Y	Y	Y												Y				Y	Y
Delmar																						
Dewey Beach			Y	Y	Y				Y		Y										Y	
Ellendale																						
Fenwick Island			Y	Y	Y			Y			Y											
Frankford																						
Georgetown			Y	Y	Y						Y											Y
Greenwood					Y						Y					Y						Y
Henlopen Acres			Y	Y	Y			Y	Y		Y					Y						
Laurel			Y	Y	Y						Y					Y						
Lewes			Y	Y	Y						Y											Y
Millsboro			Y	Y	Y						Y					Y					Y	Y
Millville			Y	Y	Y				Y							Y		Y				Y
Milton			Y	Y	Y			Y	Y	Y		Y				Y					Y	Y
Ocean View			Y	Y													Y				Y	Y
Rehoboth Bch									Y		Y										Y	
Seaford			Y	Y	Y						Y							Y				
Selbyville			Y	Y	Y						Y					Y					Y	
Slaughter Bch																						
S. Bethany			Y	Y	Y						Y						Y				Y	Y
Total	1	0	17	17	18	1	3	4	2	0	16	0	0	0	9	0	8	2	0	6	13	9

Bethel, Delmar, Ellendale, Frankford, and Slaughter Beach ordinances not available for review yet.

Floodplain:

1. Flood study required in unmapped floodplains.
2. Flood study required in Zone A (no BFE) FEMA mapped floodplains.
3. Only FEMA approved and BFE data on record plans and development documents.
4. Use accepted base flood elevations in building permit application documents.
5. Floodplain information included on permitting documentation.
6. Require use of elevation and flood proofing certificates.
7. Require 18 inches of freeboard. 7a. Require one foot of freeboard.
8. Require 18 inches of freeboard for manufactured homes.
9. Shallow fill above BFE will not exempt a structure from floodplain regulations.
10. Hydrostatic vents required.
11. Prohibit below-grade crawl spaces or enclosures.
12. Newly subdivided floodplain shall remain deed restricted open space.
13. Prohibit new non-water dependent structure in floodplains on new lots.
14. Prohibit encroachments that would cause more than 0.1 foot of rise without compensation.
15. Incorporate FEMA technical bulletins in local floodplain regulations.

Drainage:

1. Adequate easements required.
2. Obstruction prohibited.
3. Conveyance systems meet 10-year storm event.
4. Lot grading away from buildings.
5. Topographic plan submittal.
6. As-built submittal.

Functional Classification	Design Frequency (Years)	
	Bridges and Culverts (Over 20-foot clear span) ¹	Bridges under 20 feet, Pipes and Culverts ²
Interstates, Freeways and Expressways	50	50
Principal Arterials and Minor Arterials	50	50
Major Collectors and Minor Collectors	50	50/25 rural collector
Local Roads and Streets and Subdivision Streets	25	25
Evacuation Routes ³		
¹ Rigid frames greater than 20-foot span are considered bridges. ² Greater than 20 square feet. ³ Design of bridges and culverts on evacuation routes should be coordinated with DelDOT's Transportation Management Team Evacuation data. http://www.deldot.gov/information/projects/tmt/evac_map.shtml		

Figure 4.2 DelDOT road design manual bridge design frequency

**Design Criteria – Frequency
(Return Period in Years)**

Functional Classification	Type of Drainage Installation ¹			
	Pipe Culverts	Storm Drains	Roadside Ditches	Median Drains
Interstate, Freeways and Expressways	50	10^2	50	50
Arterials	50	10^2	25	25^2
Collectors	50^3	10^2	25^4	10^2
Local Roads and Streets including Subdivision Streets	25	10^5	10	10^5

Figure 4.1 DelDOT road design manual culvert design frequency

Culverts (Inlet Control)

Example 3.30

Estimate the flow capacity of a 10 ft wide \times 5 ft rise concrete box culvert, under inlet control, with rounded, beveled edges at the entrance. The headwater depth is 6 ft, the tailwater depth is 4 ft, and the length of the culvert is 50 ft.

Solution

Use the inlet control culvert equation, Eq. 3.36.

$$Q = C_d A \sqrt{2gh}$$

$$C_d = 1.0 \quad [\text{for rounded edge entrances}]$$

$$A = (10 \text{ ft})(5 \text{ ft}) = 50 \text{ ft}^2$$

$$h = \text{HW} - \text{TW} = 6 \text{ ft} - 4 \text{ ft} = 2 \text{ ft}$$

$$\begin{aligned} Q &= (1.0)(50 \text{ ft}^2) \sqrt{(2) \left(32.2 \frac{\text{ft}}{\text{sec}^2} \right) (2 \text{ ft})} \\ &= 565 \text{ ft}^3/\text{sec} \end{aligned}$$

Figure 3.27 Culvert Under Inlet Control

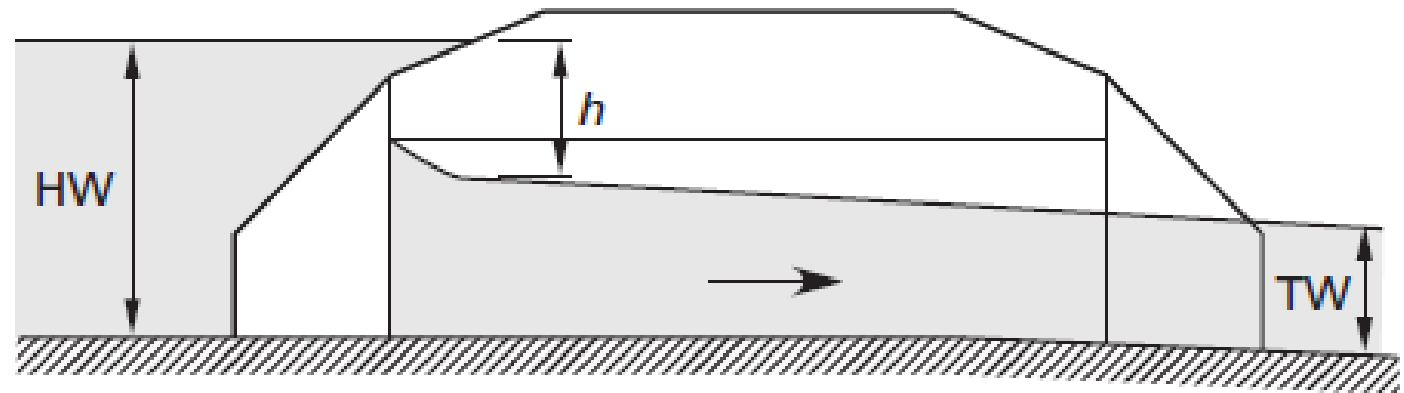
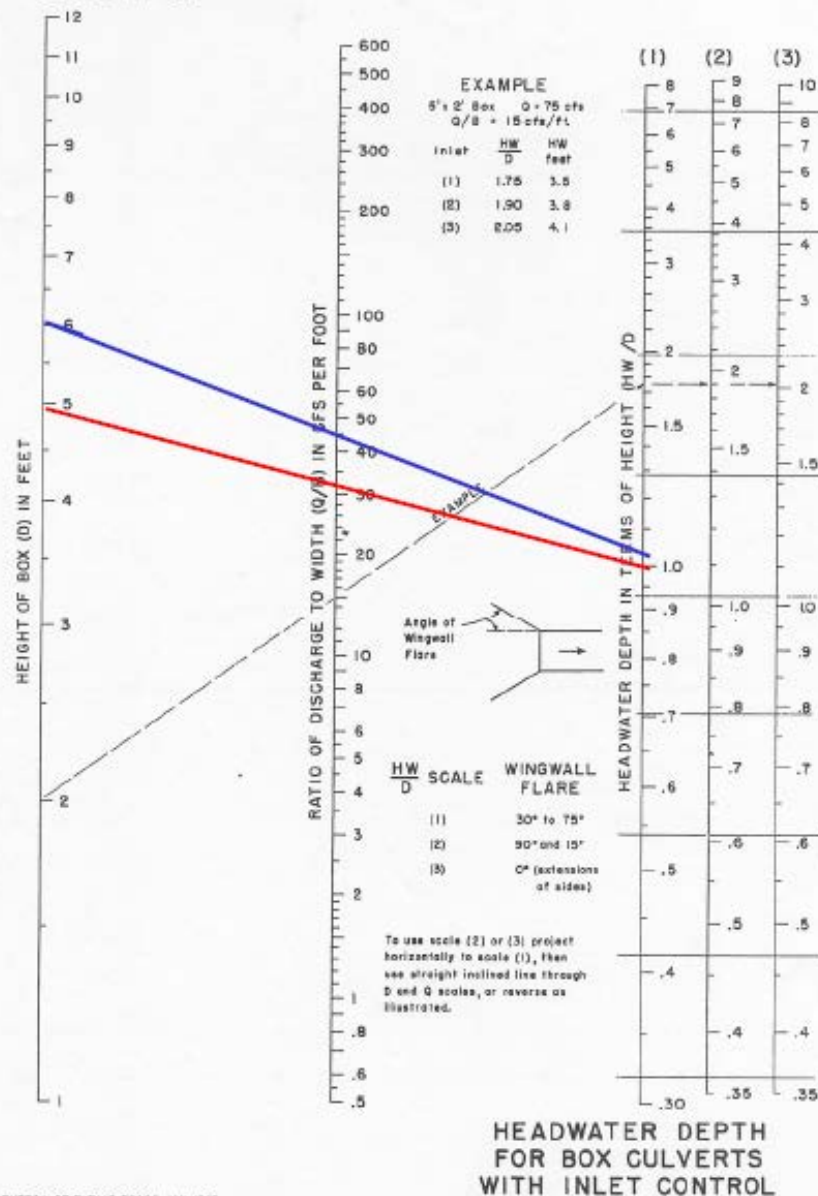
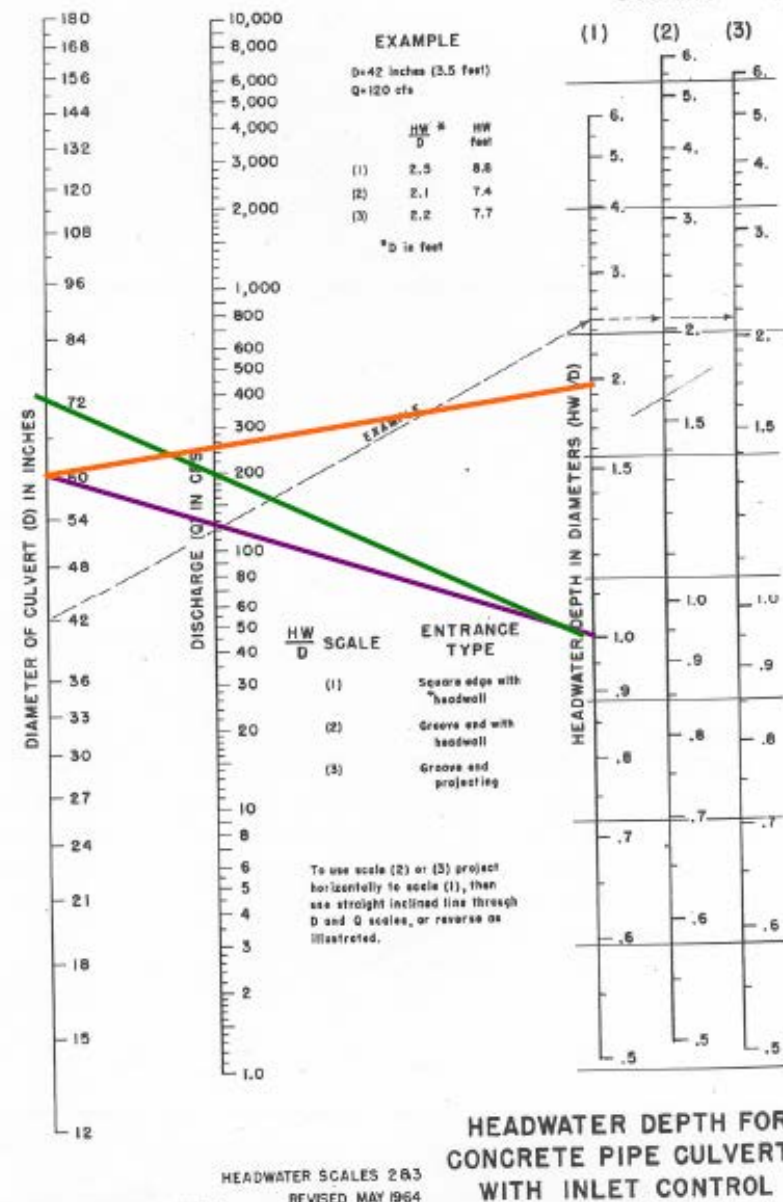


CHART 8



BUREAU OF PUBLIC ROADS JAN. 1963

CHART 1



HEADWATER SCALES 283

REVISED MAY 1964

BUREAU OF PUBLIC ROADS JAN. 1963

Crossing Data - Crossing 1

Crossing Properties

Name: Crossing 1

Parameter	Value	Units
DISCHARGE DATA		
Minimum Flow	0.00	cfs
Design Flow	595.00	cfs
Maximum Flow	795.00	cfs
TAILWATER DATA		
Channel Type	Trapezoidal Channel	
Bottom Width	5.00	ft
Side Slope (H:V)	3.00	:1
Channel Slope	0.0439	ft/ft
Manning's n (channel)	0.0300	
Channel Invert Elevation	90.75	ft
Rating Curve	View...	
ROADWAY DATA		
Roadway Profile Shape	Constant Roadway Elevation	
First Roadway Station	0.00	ft
Crest Length	130.00	ft
Crest Elevation	99.00	ft
Roadway Surface	Paved	
Top Width	43.00	ft

Culvert Properties

Culvert 1

Add Culvert

Duplicate Culvert

Delete Culvert

Parameter	Value	Units
CULVERT DATA		
Name	Culvert 1	
Shape	Concrete Box	
Material	Concrete	
Span	18.00	ft
Rise	6.00	ft
Embedment Depth	0.00	in
Manning's n	0.0130	
Inlet Type	Conventional	
Inlet Edge Condition	1:1 Bevel (45° flare) Wingwall	
Inlet Depression?	No	
SITE DATA		
Site Data Input Option	Culvert Invert Data	
Inlet Station	123.00	ft
Inlet Elevation	91.41	ft
Outlet Station	166.00	ft

Help

Click on any icon for help on a specific topic

Energy Dissipation

Analyze Crossing

OK

Cancel

FHWA HY 8 Culvert Analysis Model

Culvert Summary Table - Culvert 1

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth(ft)	Outlet Control Depth(ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	91.41	0.00	0.0*	0-NF	0.00	0.00	0.00	0.00	0.00	0.00
79.50	79.50	92.66	1.25	0.0*	1-S2n	0.46	0.85	0.54	1.10	8.21	8.68
159.00	159.00	93.39	1.98	0.0*	1-S2n	0.75	1.35	0.91	1.56	9.75	10.50
238.50	238.50	94.00	2.59	0.0*	1-S2n	0.98	1.76	1.22	1.90	10.83	11.70
318.00	318.00	94.56	3.15	0.0*	1-S2n	1.20	2.14	1.52	2.18	11.65	12.61
397.50	397.50	95.11	3.70	0.0*	1-S2n	1.37	2.48	1.79	2.42	12.31	13.38
477.00	477.00	95.63	4.22	0.0*	1-S2n	1.53	2.80	2.05	2.64	12.90	14.02
556.50	556.50	96.12	4.71	0.0*	1-S2n	1.70	3.10	2.31	2.83	13.41	14.59
595.00	595.00	96.36	4.95	0.0*	1-S2n	1.78	3.24	2.42	2.92	13.64	14.85
715.50	715.50	97.08	5.67	0.0*	1-S2n	2.00	3.67	2.78	3.17	14.30	15.57
795.00	795.00	97.56	6.15	0.0*	5-S2n	2.14	3.94	3.01	3.32	14.69	15.99

Display

☐ Crossing Summary Table

☒ Culvert Summary Table

☐ Water Surface Profiles

☐ Improved Inlet Table

☐ Customized Table

Culvert 1

Options...

Geometry

Inlet Elevation: 91.41 ft

Outlet Elevation: 90.75 ft

Culvert Length: 43.01 ft

Culvert Slope: 0.0153

Inlet Crest: 0.00 ft

Inlet Throat: 0.00 ft

Plot

Crossing Rating Curve

Culvert Performance Curve

Selected Water Profile

Water Surface Profile Data

* theoretical depth is impractical. Depth reported is corrected.

Outlet Control: Profiles

Help

Flow Types...

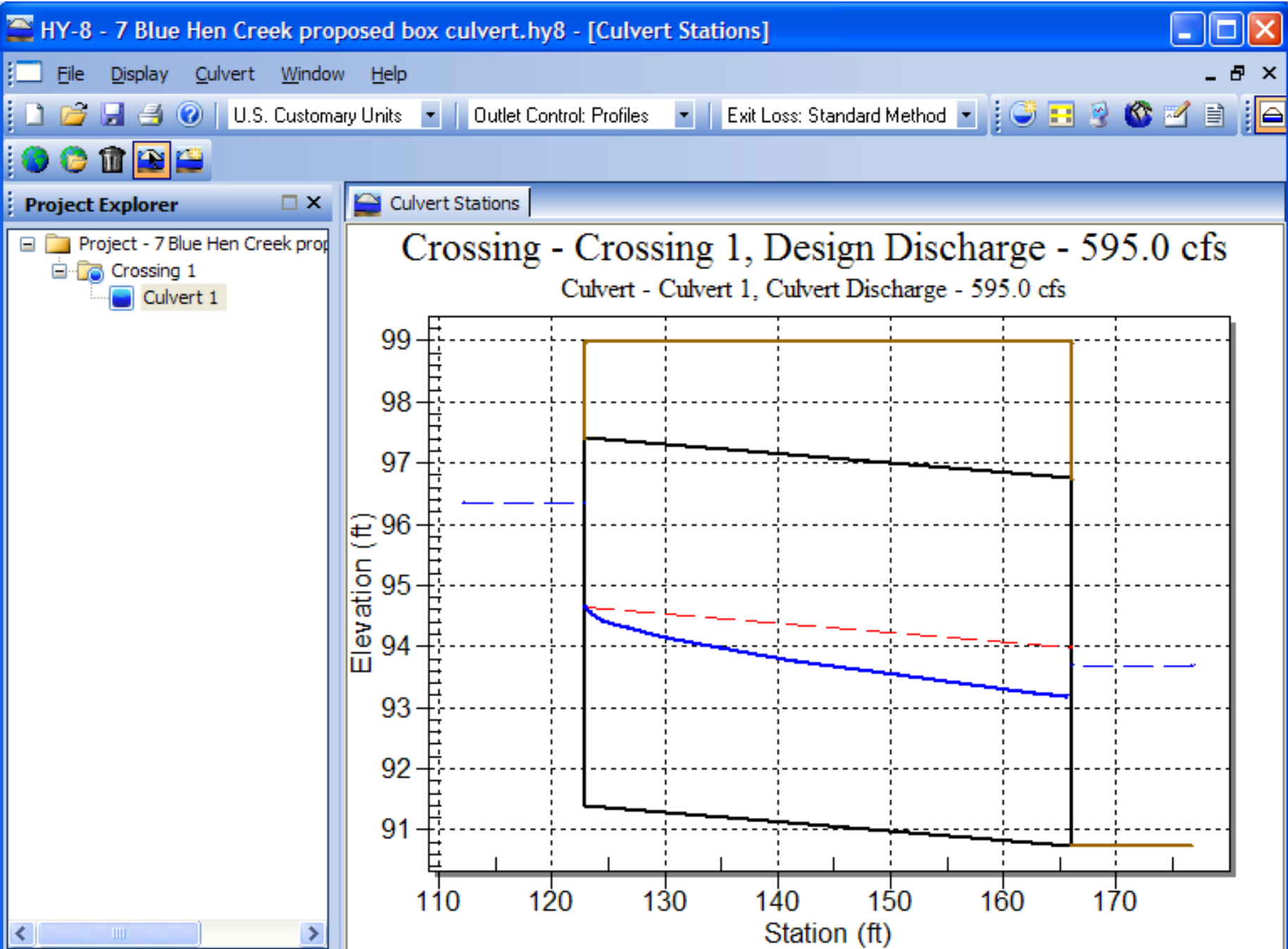
Edit Input Data...

Energy Dissipation...

Export Report

Adobe PDF (*.pdf)

Close



Red Clay Creek Hydraulic Structures

Data compiled from Federal Emergency
Management Agency Flood Insurance
Study, 9 September 1993

Structure	Distance above WCC confluence (ft)	Downstream 100 Year Flood Elevation (ft)	Upstream 100 Year Flood Elevation (ft)	100 Year Flood Elevation Increase (ft)
Amtrak Bridge*	-1,250	15.2	18.3	3.1
SR 4 Eastbound	4,200	22.8	23.5	0.7
SR 4 Westbound	4,430	23.5	23.7	0.2
Kiamensi Road	9,050	27.5	30.5	3.0
Dam #1	9,500	30.5	38.7	8.2
Old Capitol Trail	9,750	41.5	42.7	1.2
Newport Road	11,350	43.5	44.0	0.5
Amtrak Bridge	12,150	50.0	51.3	1.3
Amtrak Bridge	12,550	53.0	53.0	0.0
CSX Transportation	13,370	54.0	54.7	0.7
Dam #2	13,470	54.7	55.2	0.5
SR 41	15,050	58.0	61.2	3.2
Greenbank Road	15,700	61.6	62.5	0.9
Abandoned Bridge	15,850	62.5	63.5	1.0
CSX Transportation	16,050	63.5	64.0	0.5
Dam #3	17,030	65.3	67.7	2.4
CSX Transportation	18,900	73.5	75.0	1.5
Faulkland Road	19,870	76.5	79.0	2.5
CSX Transportation	23,700	89.7	90.2	0.5
Golf Course Bridge	26,300	94.0	94.2	0.2
SR 48 / Lancaster Pike	26,500	94.2	95.5	1.3

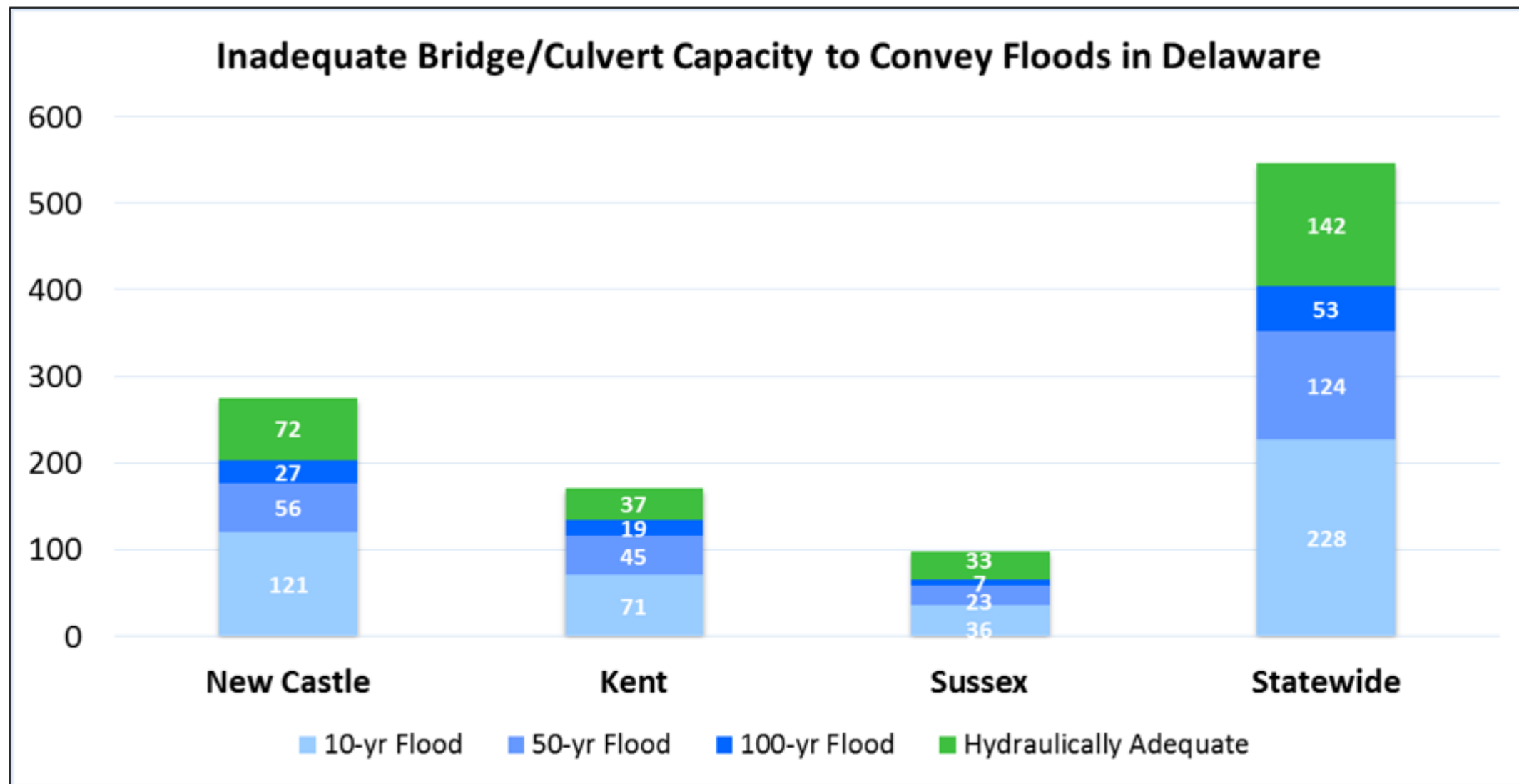


Figure 4.3 Inadequate Bridge/Culvert Capacity to Convey Floods in Delaware

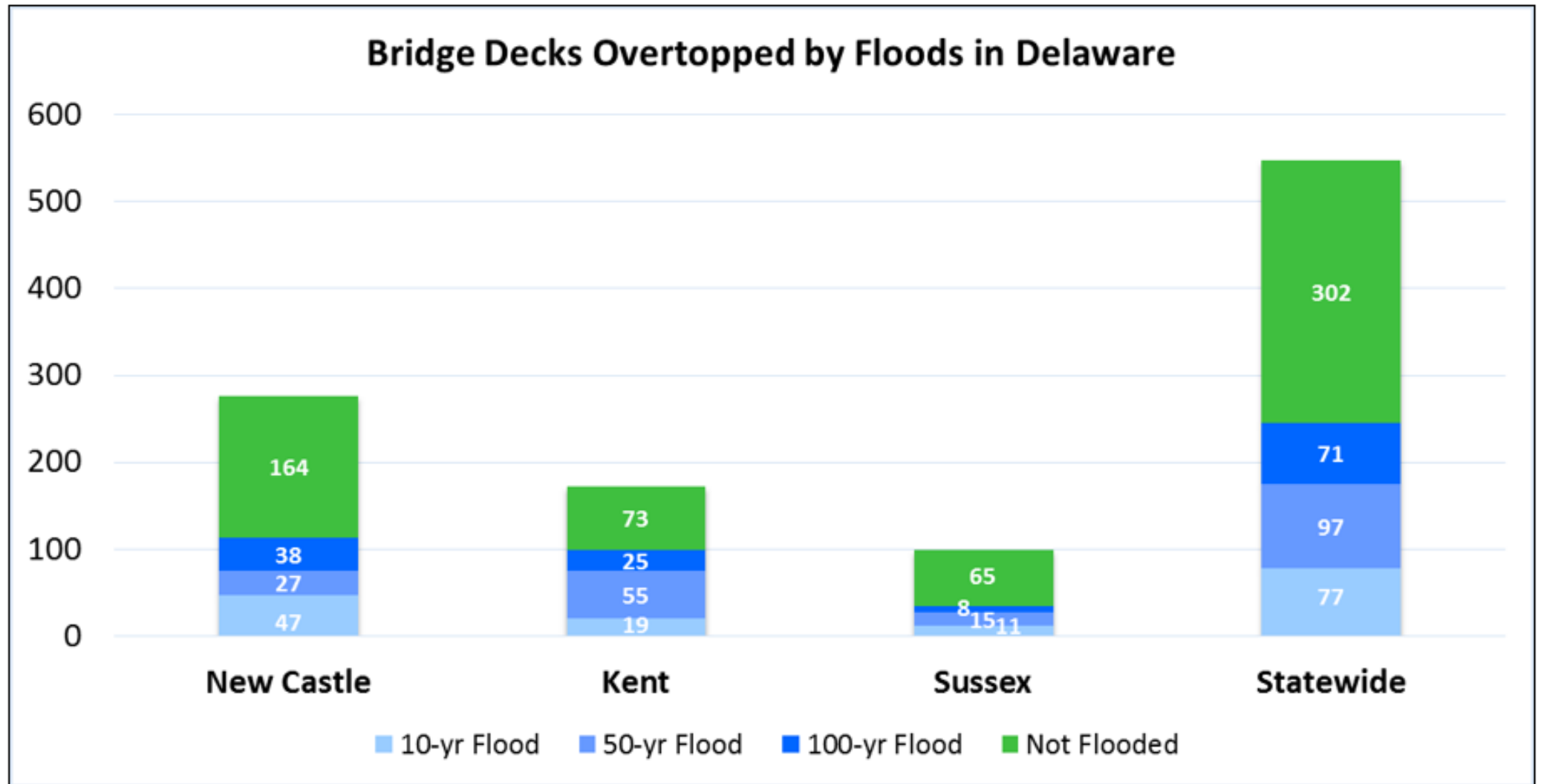


Figure 4.4 Bridge Decks Overtopped by Floods in Delaware

Table 4.2 Bridge hydraulic analysis in New Castle County

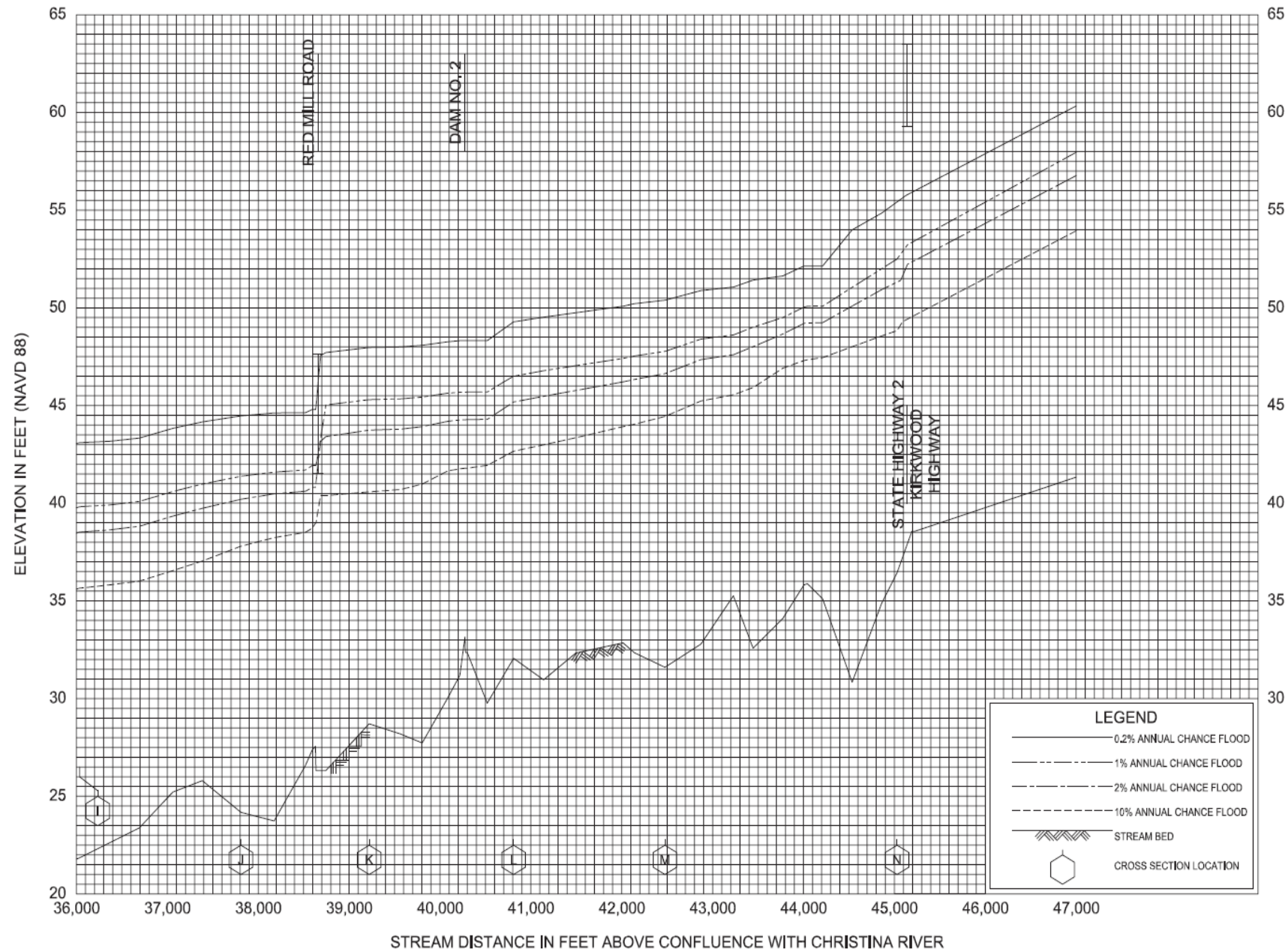
River Name	Road Name	Station (ft.)	Inadequate Bridge capacity to convey:			Bridge deck overtopped by:		
			10-yr Flood	50-yr Flood	100-yr Flood	10-yr Flood	50-yr Flood	100-yr Flood
<u>Appoquinimink River</u>	DuPont Highway	41,000	Y	Y	Y	N	N	Y
<u>Appoquinimink River</u>	State Highway 1	41,850	N	N	N	N	N	N
<u>Appoquinimink River</u>	State Highway 71	62,800	N	N	Y	N	N	N
<u>Appoquinimink River</u>	Railroad	63,950	N	N	N	N	N	N
<u>Appoquinimink River</u>	Wiggins Mill Road	65,350	Y	Y	Y	Y	Y	Y
<u>Appoquinimink River</u>	Grears Corner Road	73,000	Y	Y	Y	Y	Y	Y
<u>Appoquinimink River</u>	State Highway 15	79,450	Y	Y	Y	Y	Y	Y
<u>Appoquinimink Trib. 2</u>	Private Road	1,400	-	-	Y	-	-	Y
<u>Belltown Run</u>	Railroad	6,750	N	Y	Y	N	N	N
<u>Belltown Run</u>	Route 72	7,550	N	Y	Y	N	N	N
<u>Belltown Run</u>	US Highway 40	11,200	Y	Y	Y	N	N	N
<u>Belltown Run</u>	Footbridge	15,050	N	N	N	N	N	N
<u>Belltown Run</u>	Caravel Drive	16,850	N	Y	Y	N	N	N
<u>Belltown Run</u>	Porter Road	20,600	Y	Y	Y	N	N	N
Brandywine Cr LR	Railroad	6,336	N	N	N	N	N	N
Brandywine Cr LR	US Highway 13	7,814	N	N	Y	N	N	N
Brandywine Cr LR	Jessup Street	9,821	N	N	N	N	N	N
Brandywine Cr LR	Market Street	11,299	N	N	N	N	N	N
Brandywine Cr LR	Van Buren Street	14,678	N	N	N	N	N	N
Brandywine Cr LR	Foot Bridge	16,632	N	N	N	N	N	N
Brandywine Cr LR	Private Road	21,014	N	N	N	N	N	N

Table 4.4 Bridge hydraulic analysis in Sussex County

River Name	Road Name	Station (ft)	Inadequate Bridge capacity to convey:			Bridge deck overtopped by:		
			10yr Flood	50yr Flood	100yr Flood	10yr Flood	50yr Flood	100yr Flood
Bark Pond	Conrail	2,300	N	N	N	N	N	N
Bark Pond	County Road 328	2,900	N	N	N	N	N	N
Betts Pond	Conrail	1,250	N	N	N	N	N	N
Betts Pond	State Route 20	2,000	Y	Y	Y	Y	Y	Y
Betts Pond	US Route 13	4,600	N	N	N	N	N	N
Betts Pond	County Route 410	9,950	N	N	N	N	N	N
Shoals Branch	County Road 412	19,200	N	N	N	N	N	N
Shoals Branch	State Route 432	26,350	N	N	N	N	N	N
Bridgeville Branch	Rt. 13 Main Street	7,850	N	Y	Y	N	N	N
Bridgeville Branch	North Cannon Street	9,450	Y	Y	Y	N	N	Y
Bridgeville Branch	Conrail	9,500	N	N	N	N	N	N
Broad Creek	Bethel Bridge	25,150	N	N	N	N	N	N
Broad Creek	Railroad	40,550	N	N	N	N	N	N
Broad Creek	Rt. 28A North Poplar St.	41,225	N	Y	Y	N	N	N
Broad Creek	Alt. 13 N. Central Ave	41,550	N	N	N	N	N	N
Broad Creek	Rt. 486 Delaware Ave	42,200	Y	Y	Y	N	N	N
Broad Creek	Willow Street	42,750	Y	Y	Y	N	N	N
<u>Broadkill River</u>	State Route 5 Union St.	25,200	Y	Y	Y	N	N	N
Bunting's Branch	State Route 54	1,700	N	N	Y	N	N	N

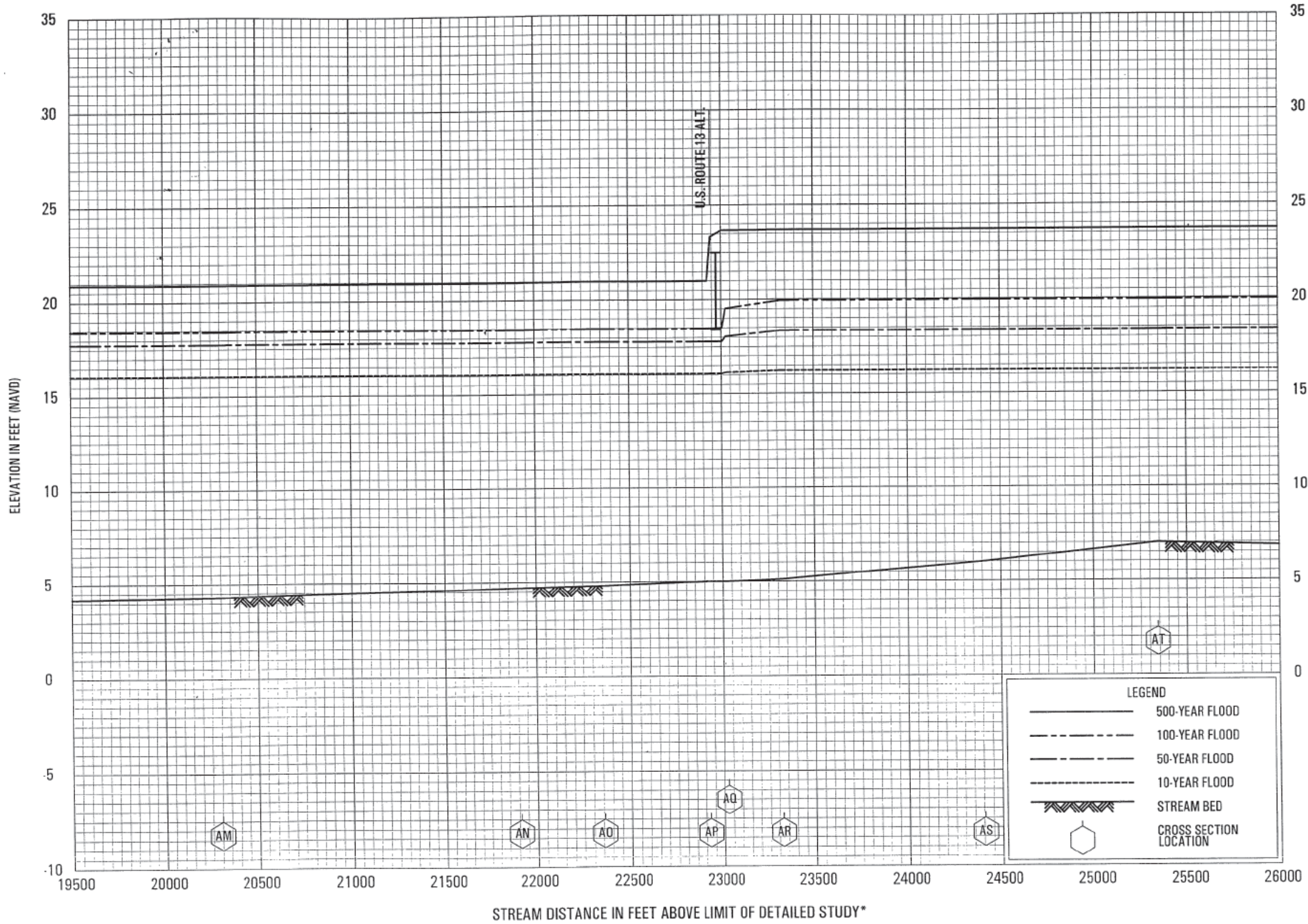
Table 4.3 Bridge hydraulic analysis in Kent County

River Name	Road Name	Station (ft)	Inadequate Bridge capacity to convey:			Bridge deck overtopped by:		
			10yr Flood	50yr Flood	100yr Flood	10yr Flood	50yr Flood	100yr Flood
Andrews Lake	Andrew's Lake Road	-	N	N	N	N	N	N
<u>Beaverdam Ditch</u>	State Route 8	1,350	N	N	Y	N	N	N
<u>Beaverdam Ditch</u>	Strauss Avenue	3,250	N	Y	Y	N	N	N
<u>Beaverdam Ditch</u>	Conrail	4,100	N	Y	Y	N	Y	Y
<u>Beaverdam Ditch</u>	<u>Taraila Road</u>	5,375	N	Y	Y	N	Y	Y
Browns Branch Trib. 1	US Highway 13 NB	4,640	N	Y	Y	N	N	N
Browns Branch Trib. 1	US Highway 13 SB	5,000	N	Y	Y	N	N	N
Browns Branch Trib. 1	Benjamin Street	6,080	Y	Y	Y	N	Y	Y
Browns Branch Trib. 1	Private Road	6,780	N	Y	Y	N	N	N
Browns Branch Trib. 1	Foot Bridge	6,860	N	Y	Y	N	Y	Y
Browns Branch Trib. 1	Del Ave. (Simmons St.)	7,480	N	Y	Y	N	N	Y
<u>Cahoon Branch</u>	Kenton Drive	2,200	Y	Y	Y	N	Y	Y
<u>Cahoon Branch</u>	Chestnut Grove Road	4,550	Y	Y	Y	N	Y	Y
<u>Cahoon Branch</u>	Sharon Hill Road	10,450	Y	Y	Y	N	Y	Y
<u>Cahoon Branch</u>	Rt. 8 (Forrest Avenue)	11,850	Y	Y	Y	N	Y	Y
<u>Cahoon Branch</u>	Rose Valley School Road	18,650	Y	Y	Y	N	Y	Y
<u>Cahoon Branch</u>	Farm Bridge	25,200	Y	Y	Y	Y	Y	Y
<u>Choptank River</u>	Still Road	6,050	N	Y	Y	N	N	N
<u>Choptank River</u>	Mud Mill Road	14,250	N	N	N	N	N	N



FLOOD PROFILES
WHITE CLAY CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY
NEW CASTLE COUNTY, DE
AND INCORPORATED AREAS

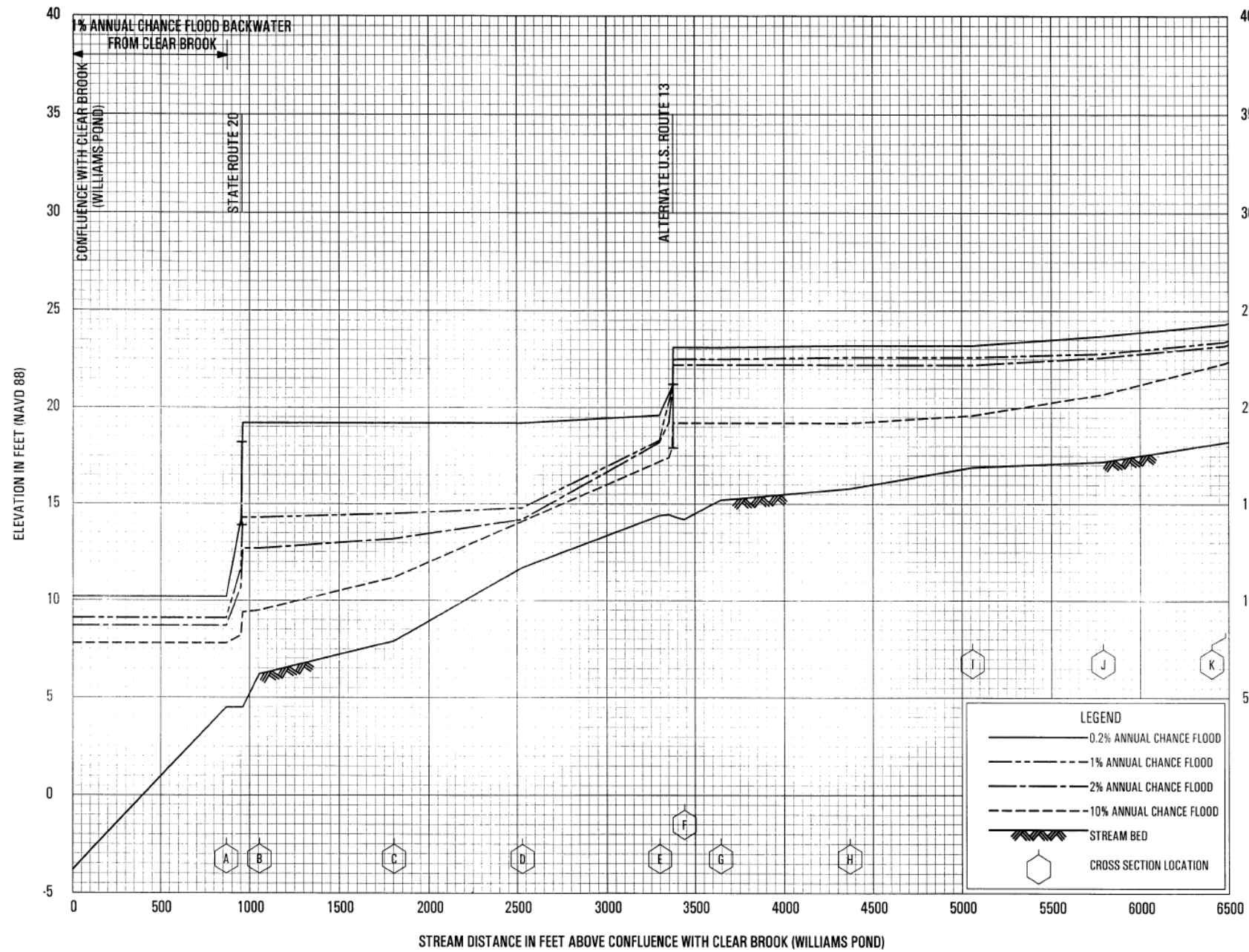


FLOOD PROFILES

ST. JONES RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

KENT COUNTY, DE
AND INCORPORATED AREAS



FEDERAL EMERGENCY MANAGEMENT AGENCY

SUSSEX COUNTY, DE
AND INCORPORATED AREAS

FLOOD PROFILES

HERRING RUN

63P

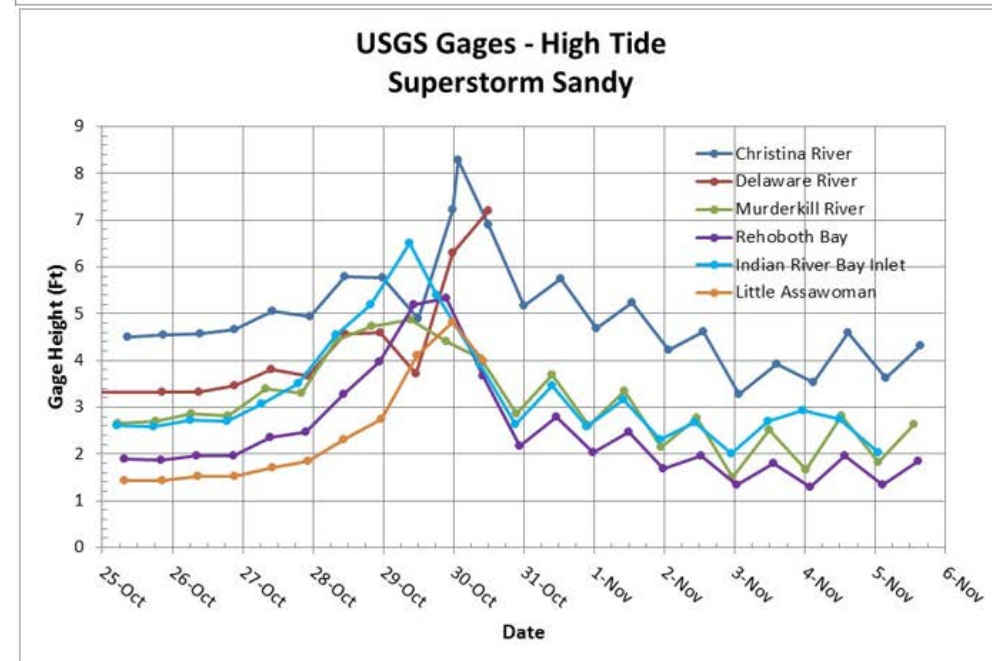
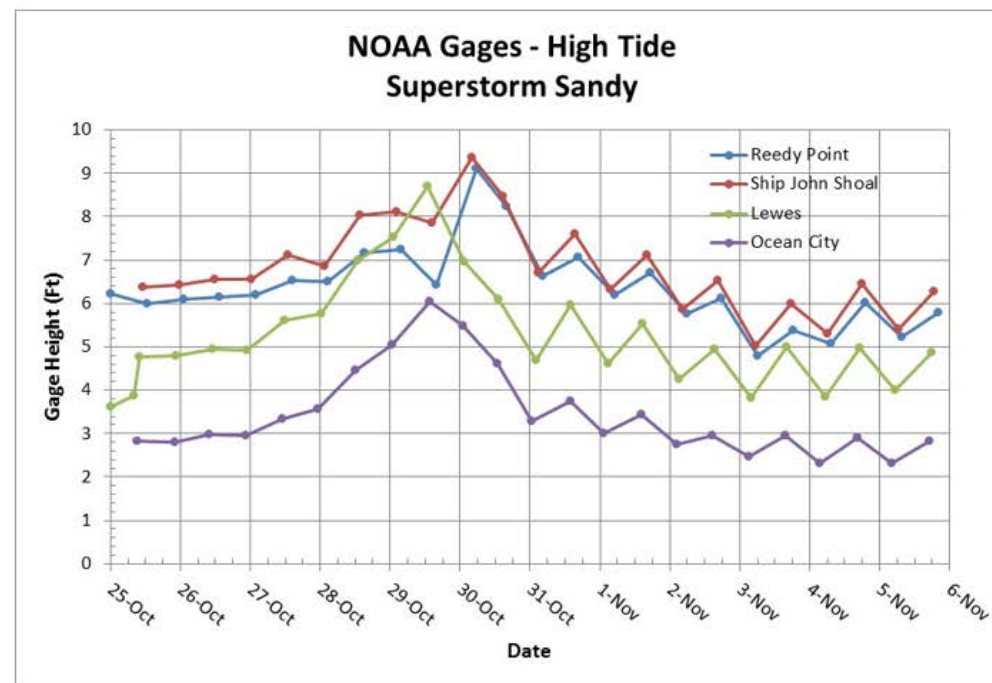


Figure 6.3. High Tide Elevations during Superstorm Sandy (October 2012)

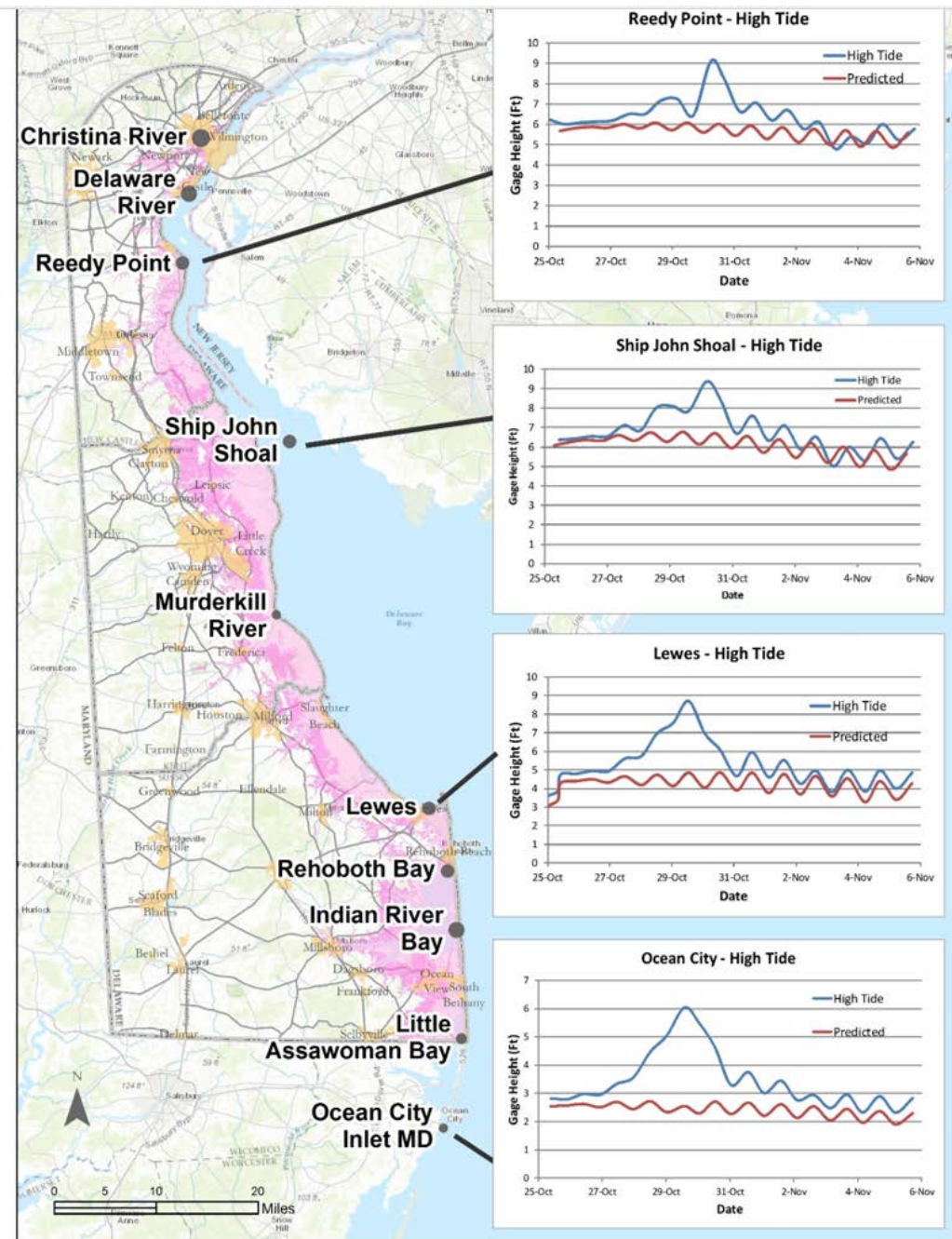
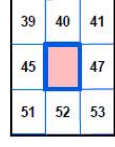
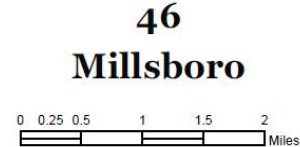
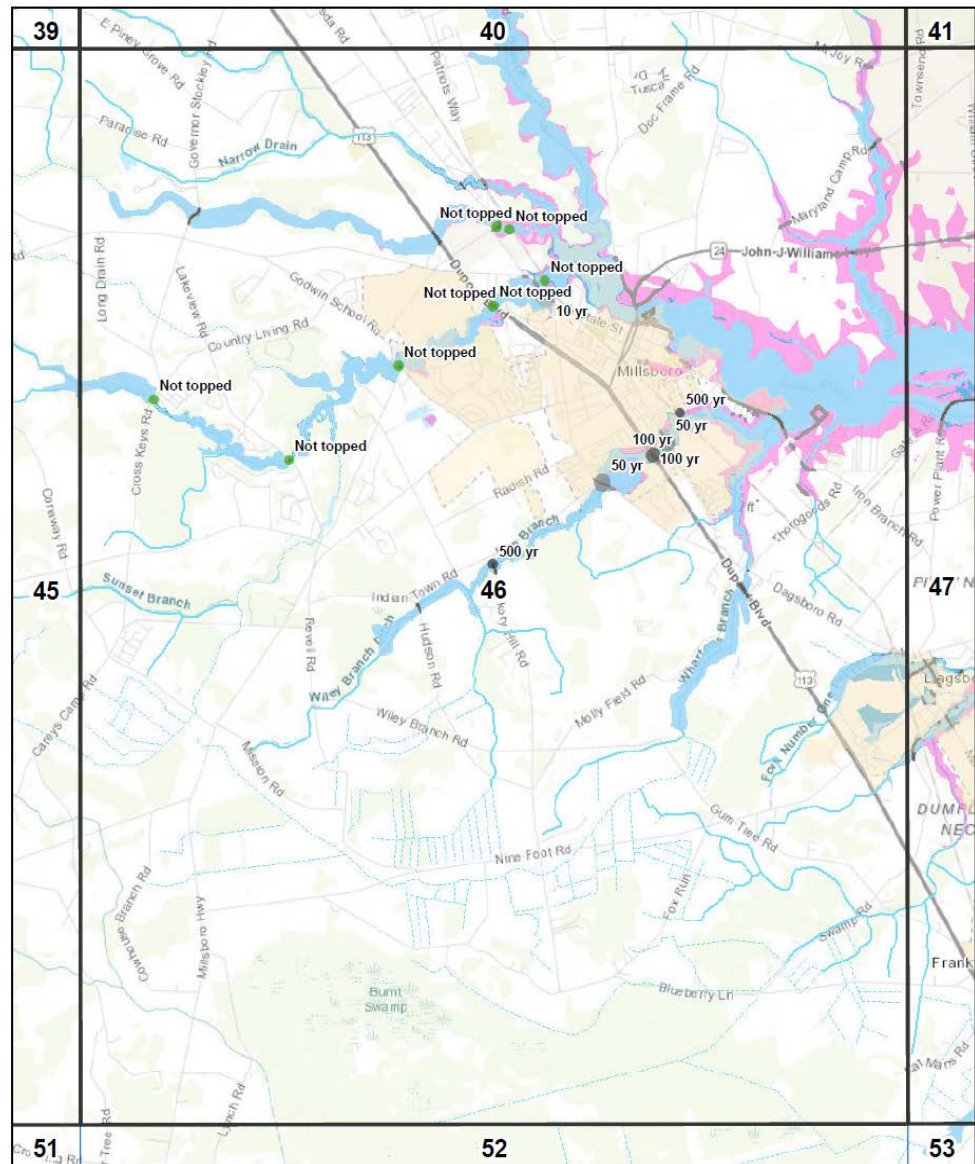
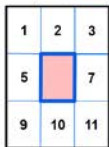
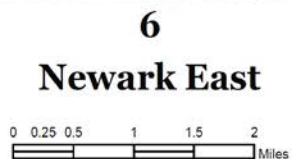
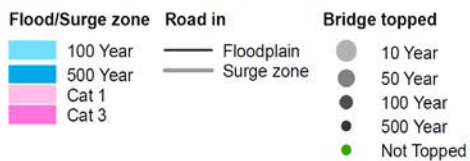
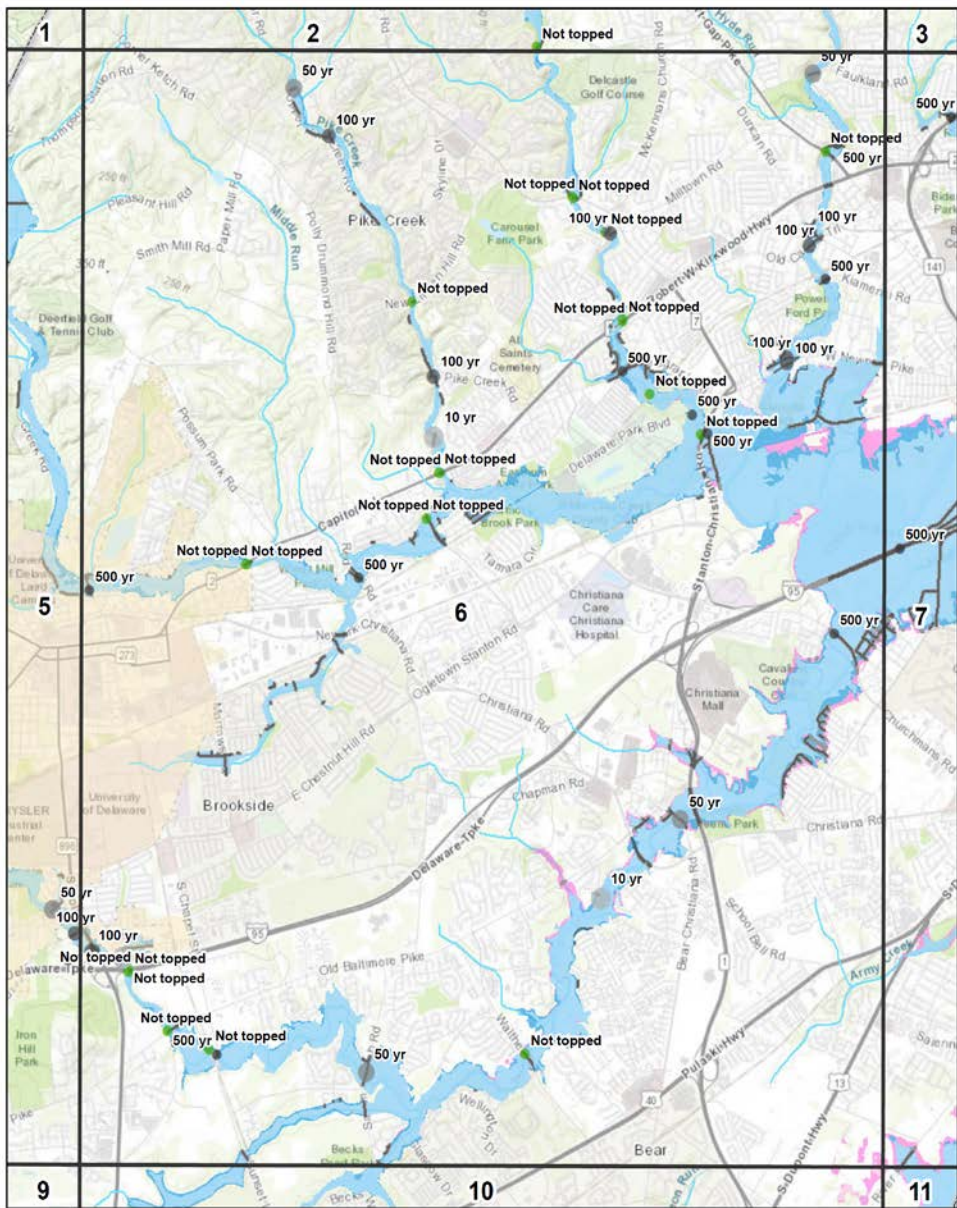
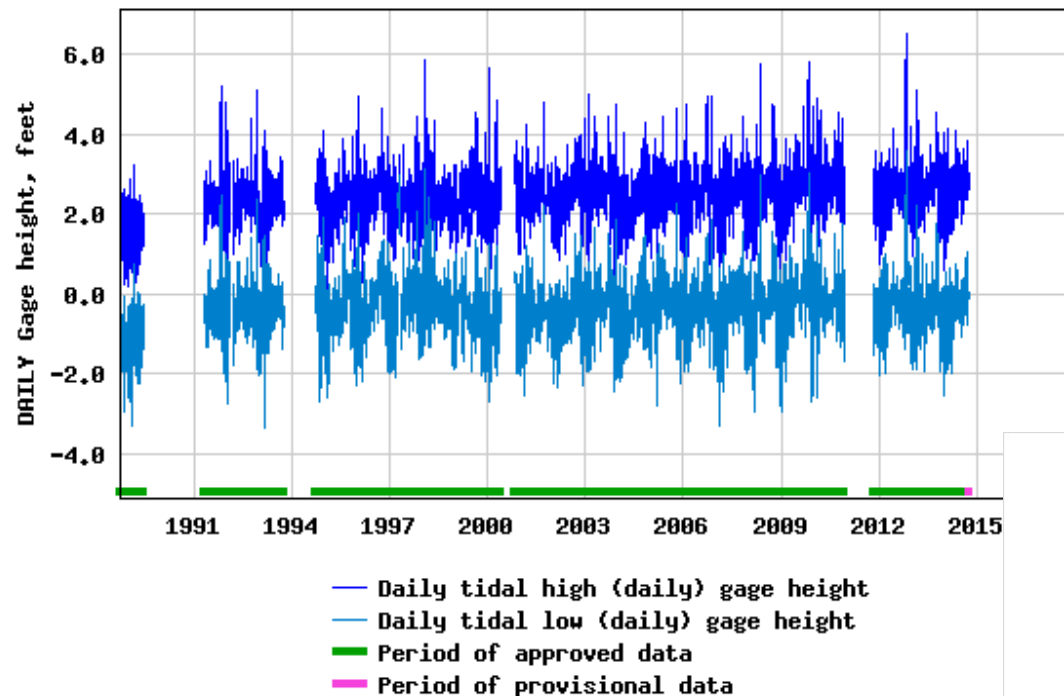


Figure 6.4 Tide levels at NOAA gages, Delaware Bay and River, Superstorm Sandy (October 2012)

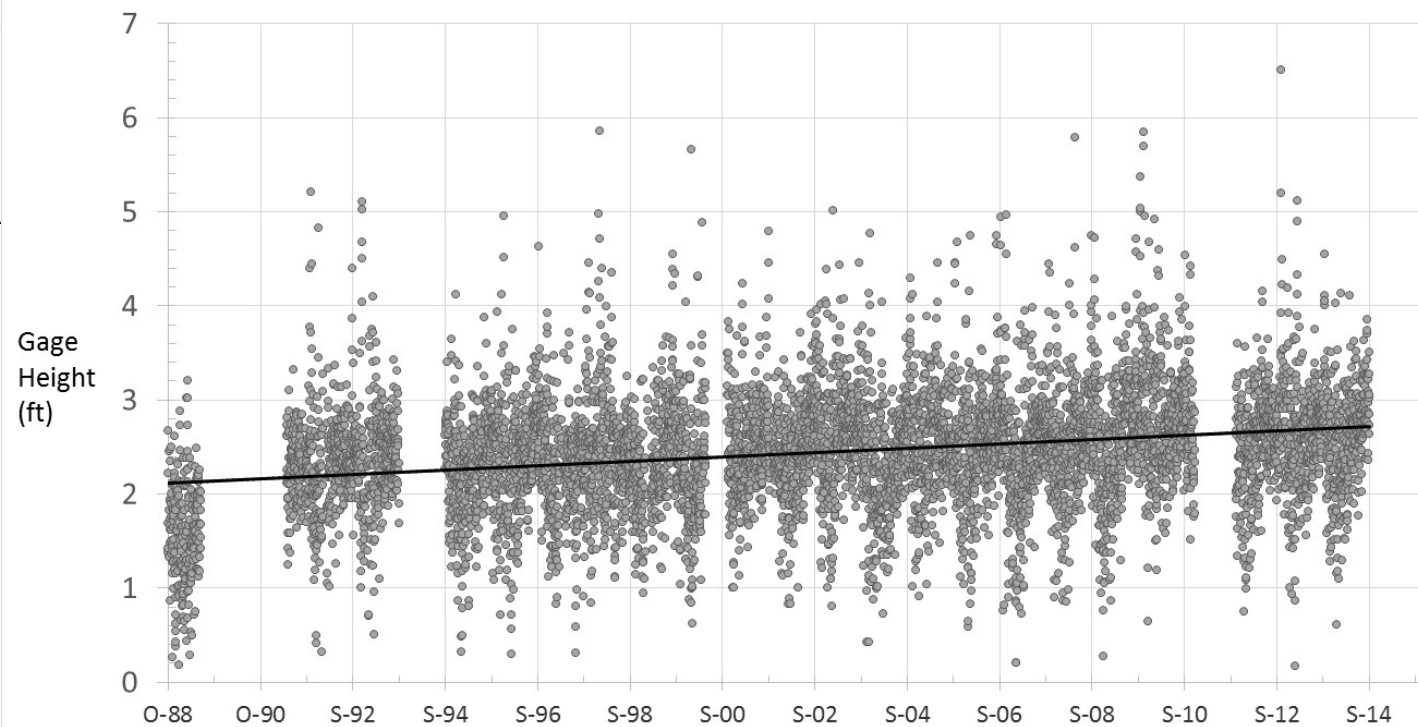




USGS 01484683 INDIAN RIVER BAY INLET NEAR BETHANY BEACH, DE



USGS 01484683 INDIAN RIVER BAY INLET NEAR BETHANY BEACH, DE



10.2. Recommendations

1. Review and revise the DelDOT road design and bridge design manuals to consider strengthening the hydraulic design criteria for bridges and culverts to pass the 100-year frequency flood (instead of the current 50-yr flood specification)
2. Conduct a systematic review of the DelDOT system to enlarge and/or replace bridges and culverts to adequately pass the 100-year flood and raise bridge deck elevations above the 100-year flood elevation with at least 2 feet of freeboard.
3. Conduct a strategic review of the DelDOT highway system to determine the road segments at high risk to flood inundation and program capital funding to raise or flood proof these vulnerable roadway sections.