Delaware River Basin: Analysis of Potential Flood Mitigation with Existing Reservoirs

Delaware River Basin Interstate Flood Mitigation Task Force

December 15, 2009

U.S. Army Corps of Engineers

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

Why are we here?

- Three top-ten historic floods on the Delaware River in 22 months – September 2004, April 2005 and June 2006
- DRB Interstate Flood Mitigation Task Force recommended development of a flood model
- Model development funded with $500k from Basin States and $285k from USACE, USGS, NWS
- Flood Analysis Model recently finalized
- Discuss on policy implications moving forward

Presentation and Discussion Topics

- Introduction
- Flood Analysis Model Results
- Translating Flood Crest Reductions to Community Impacts
- Water Supply Impacts
- Findings
- Next Steps

Flood Analysis Model
Purpose

- Develop a tool to assess flooding impacts in the basin from:
  - Reservoir Operations
  - Future Development
- Evaluate the effects of different pre-event voids in the 13 existing reservoirs on flooding for the three storm events.

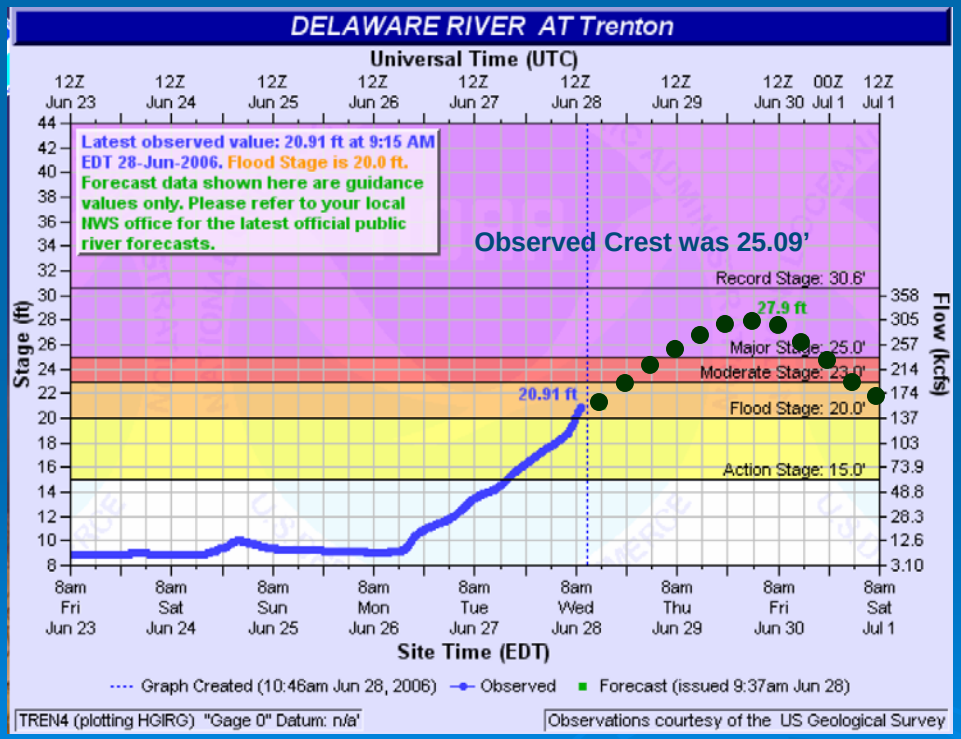
Flood Analysis Model
Design

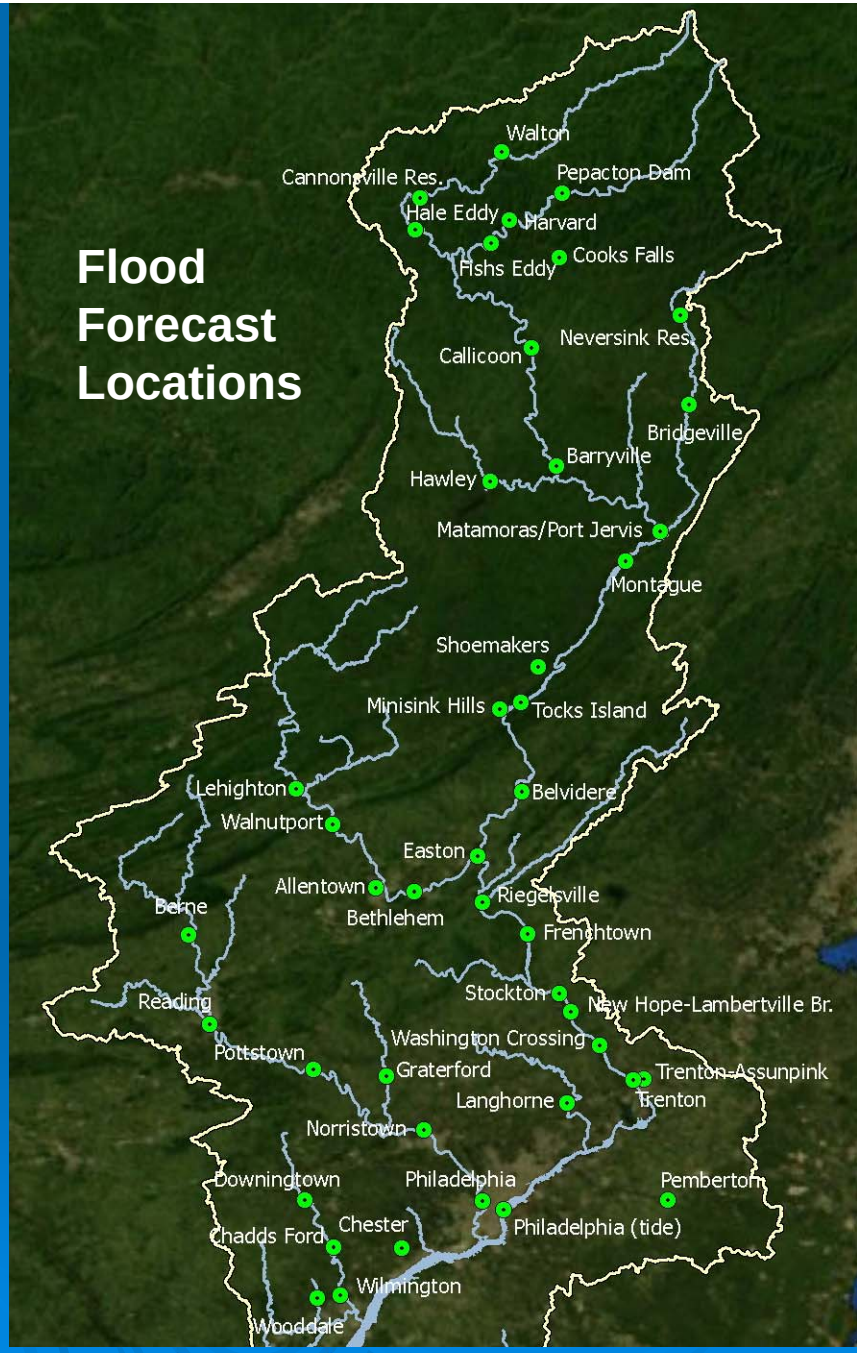
- Separated into three basins
- Gage-derived inflows or simulated rainfall/runoff
- Reservoir operations and river flow routing model HEC-RESSIM
- Graphical User Interface to manage model integration

Project Basins

National Weather Service

Advanced Hydrologic Prediction Service

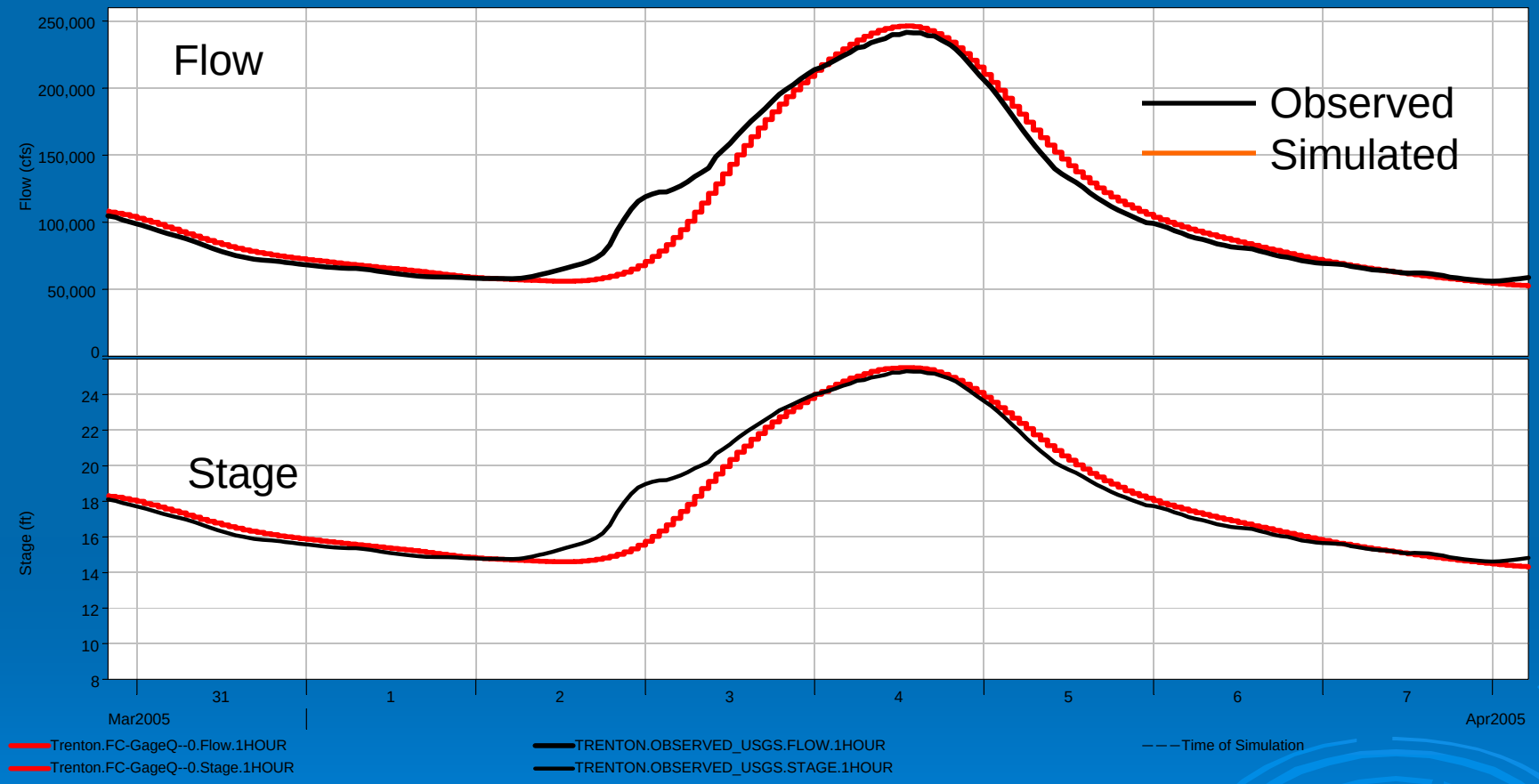




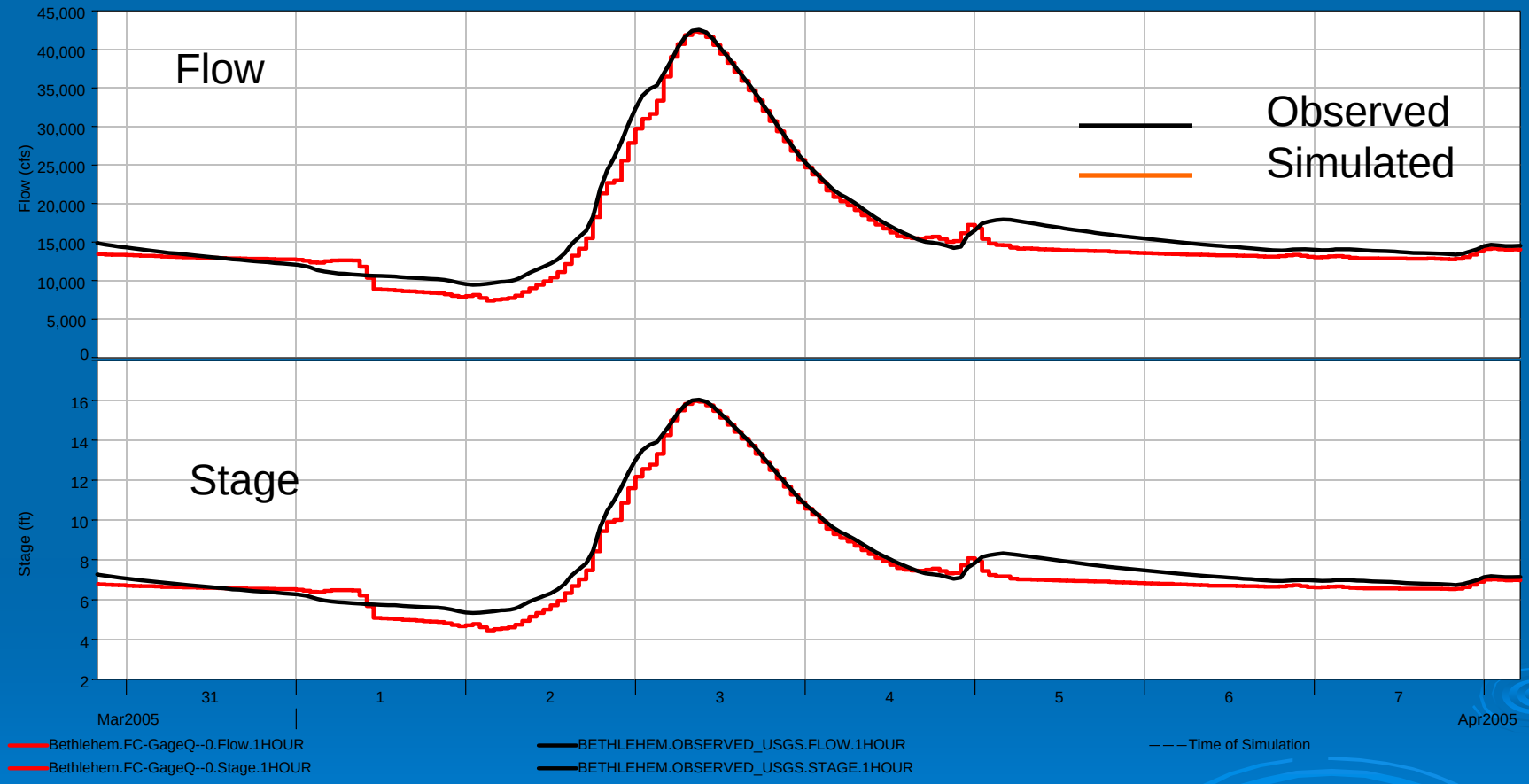
Calibration and Accuracy

- The model was generally able to reproduce the observed peak flows for the three events (+/- 5 percent).
- The model was generally able to reproduce the observed peak stage for the three events by (+/- 0.5 ft).

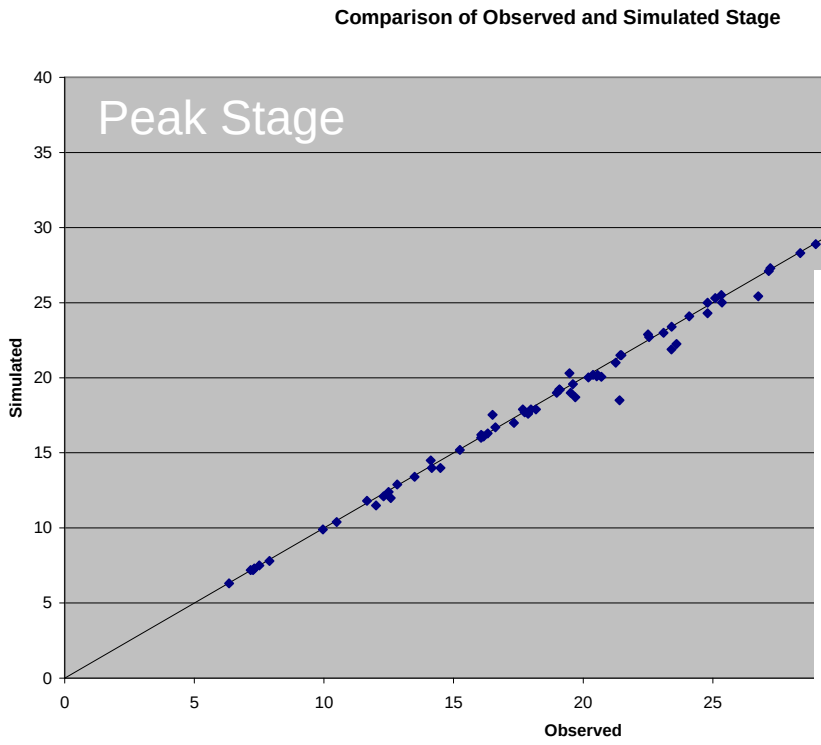
Trenton

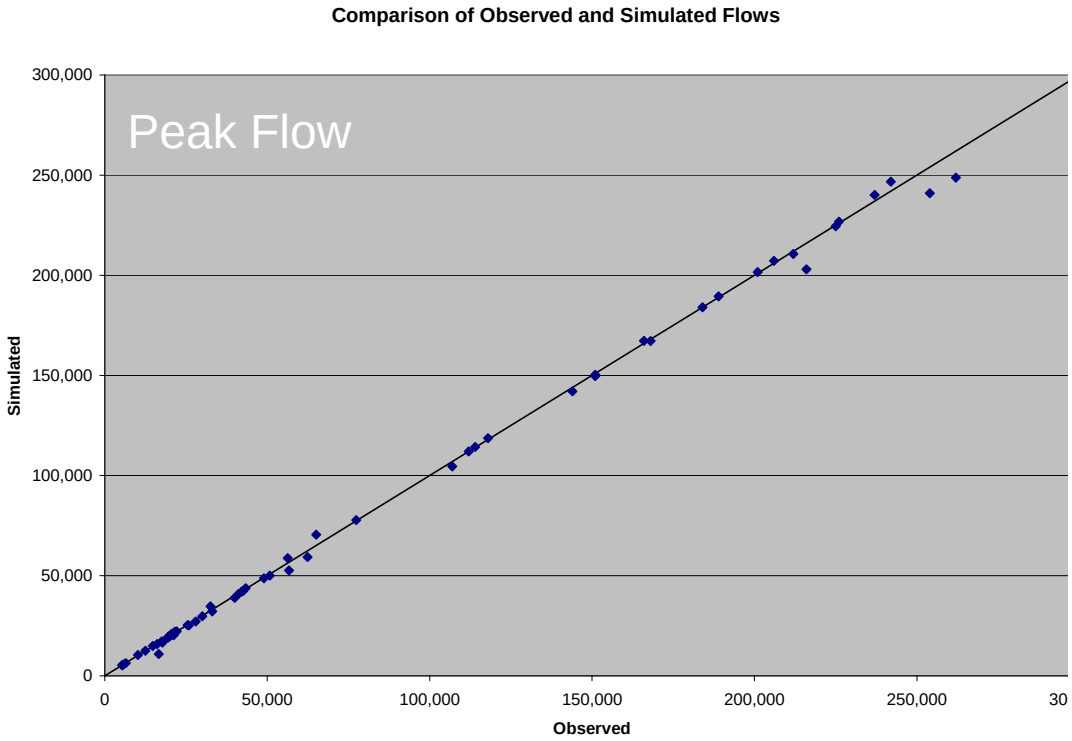

Flow
Observed
Simulated
Flow (cfs)
250,000
200,000
150,000
100,000
50,000
0
Stage
Stage (ft)
24
22
20
18
16
14
12
10
8
31
1
2
3
4
5
6
7
Mar2005
Apr2005
Trenton.FC-GageQ--0.Flow.1HOUR
Trenton.FC-GageQ--0.Stage.1HOUR
TRENTON.OBSERVED_USGS.FLOW.1HOUR
TRENTON.OBSERVED_USGS.STAGE.1HOUR
Time of Simulation

Bethlehem


Flow
Observed
Simulated
Flow (cfs)
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Stage
Stage (ft)
16
14
12
10
8
6
4
2
31
1
2
3
4
5
6
7
Mar2005
Apr2005
Bethlehem.FC-GageQ--0.Flow.1HOUR
Bethlehem.FC-GageQ--0.Stage.1HOUR
BETHLEHEM.OBSERVED_USGS.FLOW.1HOUR
BETHLEHEM.OBSERVED_USGS.STAGE.1HOUR
Time of Simulation

Comparison of Observed and Simulated



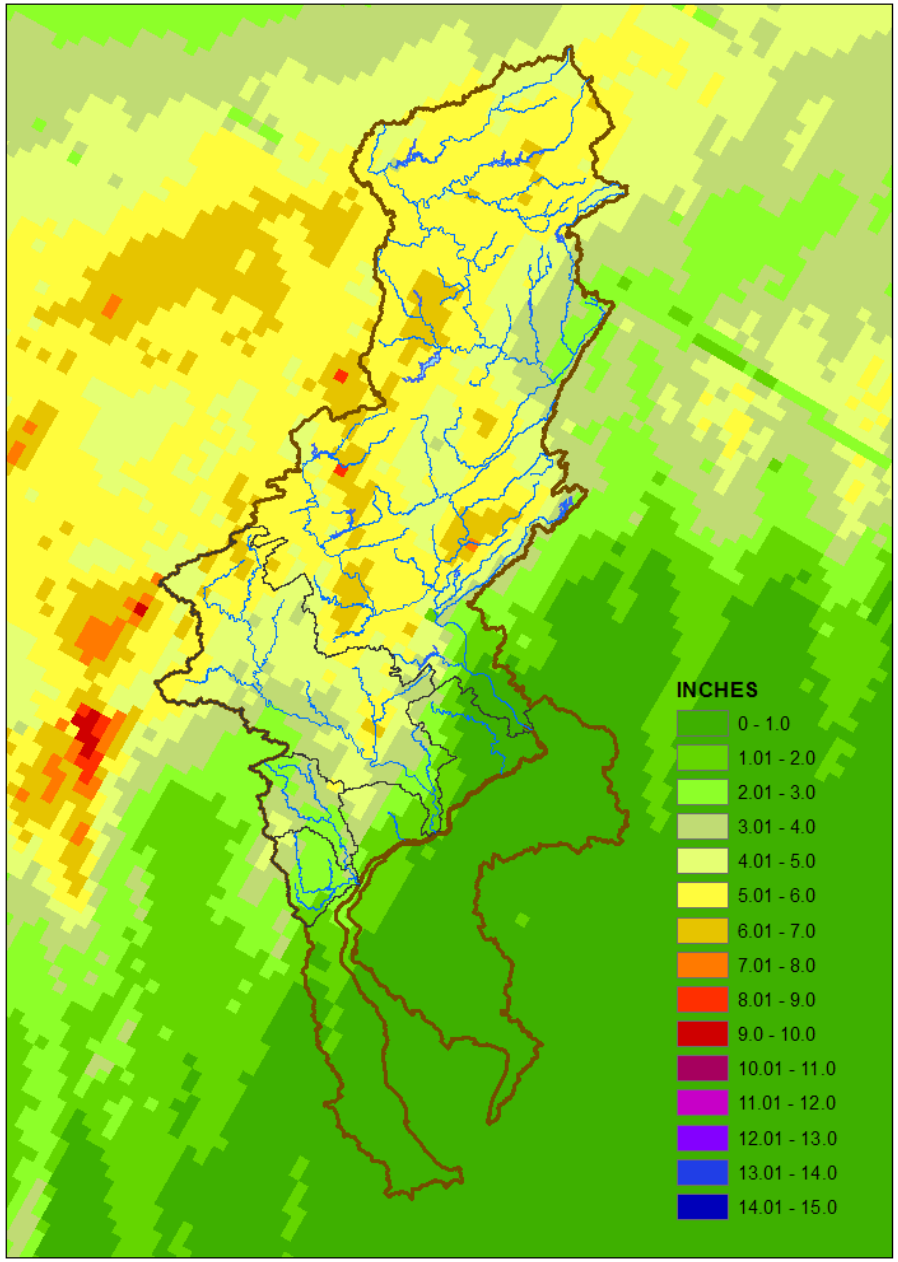


Reservoir Operations Simulations

- Groupings
  - **NYC**: Cannonsville, Pepacton, Neversink
  - **Power/Recreation**: Lake Wallenpaupack, Mongaup (Toronto, Swinging Bridge, Rio), Nockamixon
  - **USACE**: flood risk management reservoirs (voids not evaluated because they did not spill for the 3 events).
- Pre-event conditions
  - Existing (all reservoirs as they were)
  - No Reservoirs (all reservoirs removed from model)
  - Full Reservoirs (NYC-only)
  - 10 Percent Voids (NYC-only)
  - 20 Percent Voids (NYC-only, Power/Recreation-only)
  - 100 Percent Voids (empty reservoirs/no spill: NYC-only)

Twenty Percent Voids

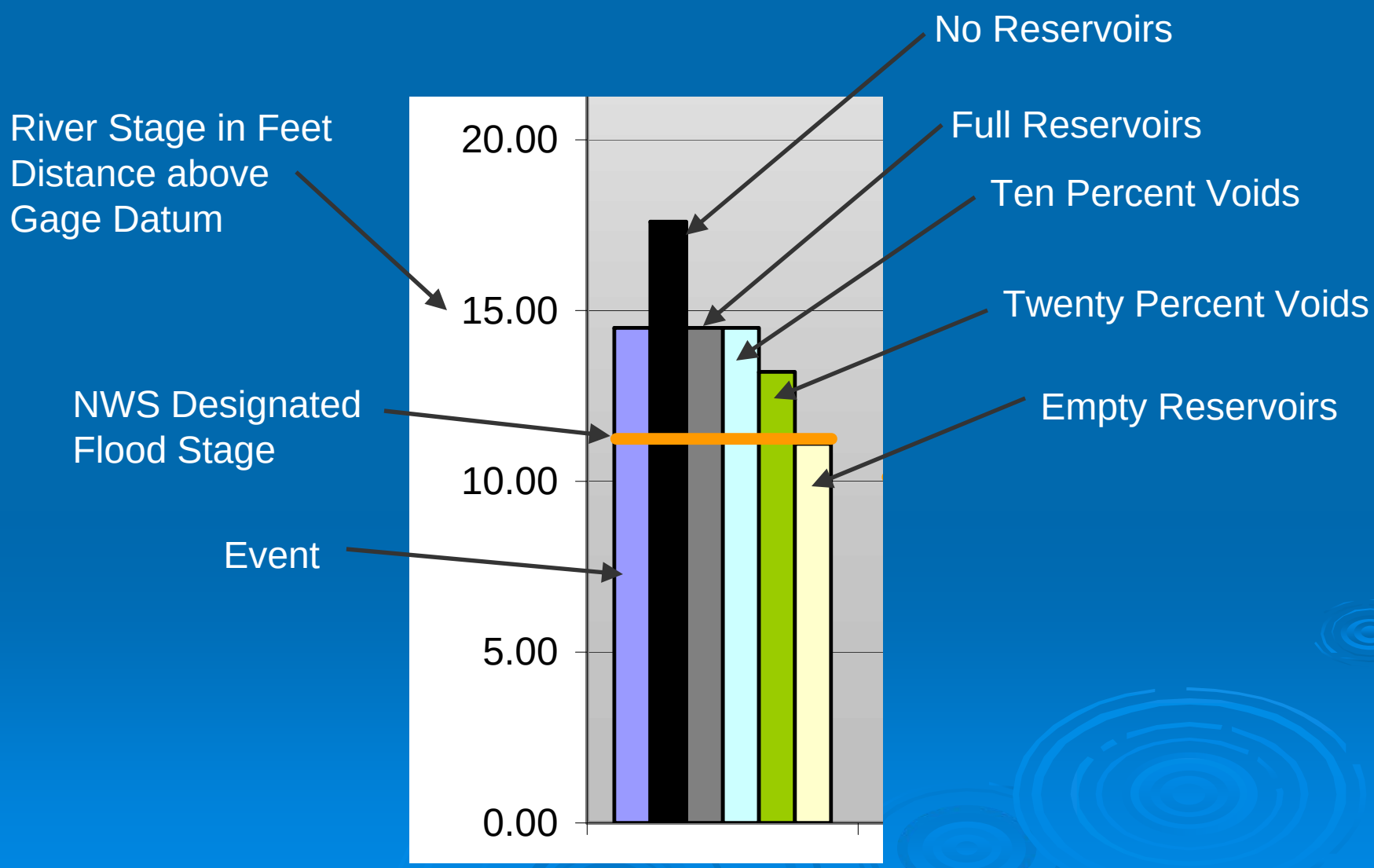
- NYC reservoirs - only
  - Impact varies depending upon location
  - Largest reductions below reservoirs
  - Reductions depend upon storm characteristics and location
- Power/Recreation (Lake Wallenpaupack, Mongaup - Toronto, Swinging Bridge, Rio, Nockamixon)
  - Up to 0.5 foot reduction in stage at Montague
  - Up to 0.2 foot reduction in stage at Trenton



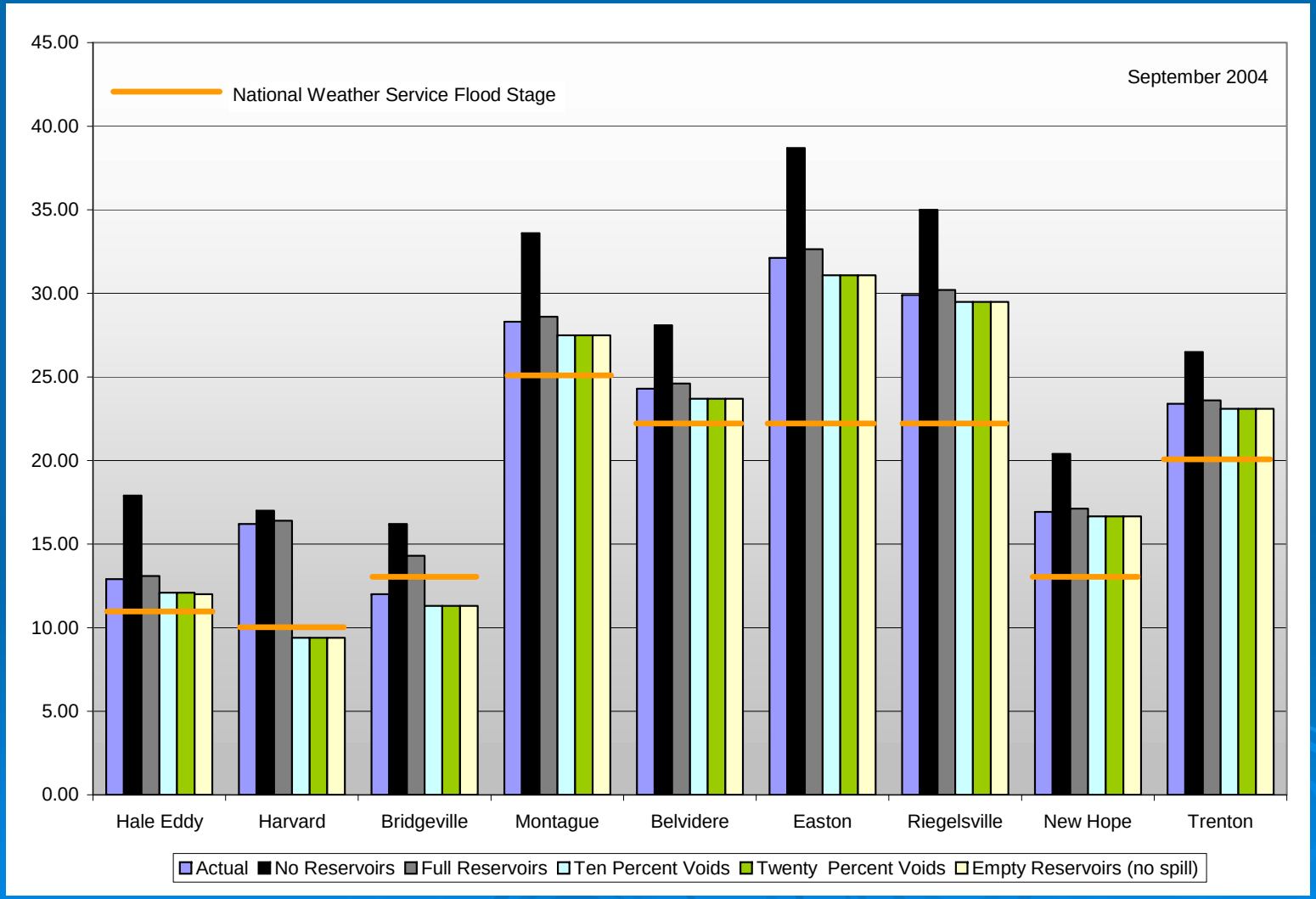
September 17, 2004

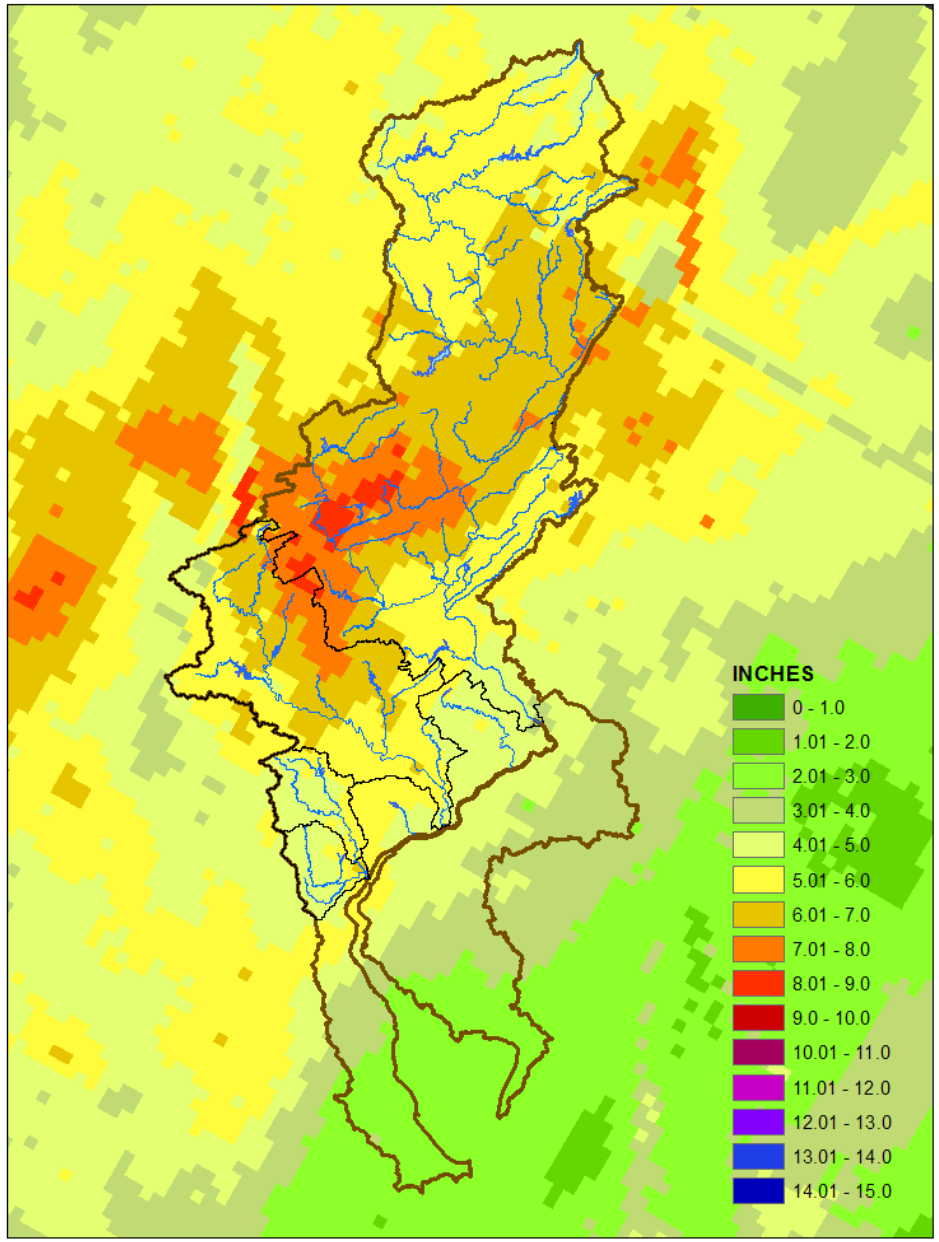
- Remnants of Tropical Storm Ivan interacted with cold front.
- Soils heavily saturated prior to event from Tropical Storm Frances.
- Pre-event flows in the main stem were 298 percent of normal at Montague and 265 percent of normal at Trenton.
- Heavy rain fell in Poconos and Catskills.
- Rainfall rates of three to five inches within a 12-hour period.
- Isolated areas received as much as seven or eight inches.

Results Legend



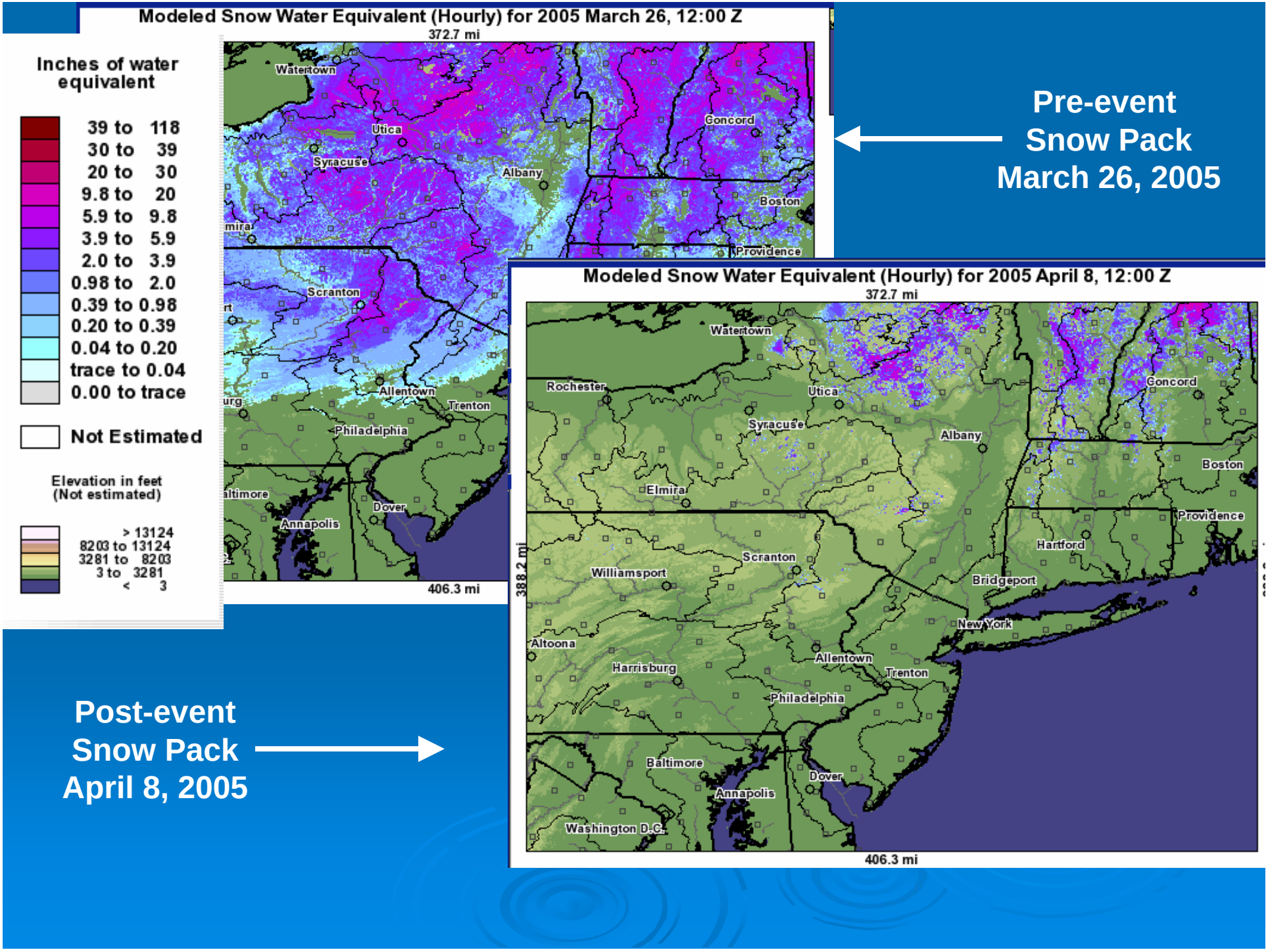
Simulated River Stages
for 2004 Event



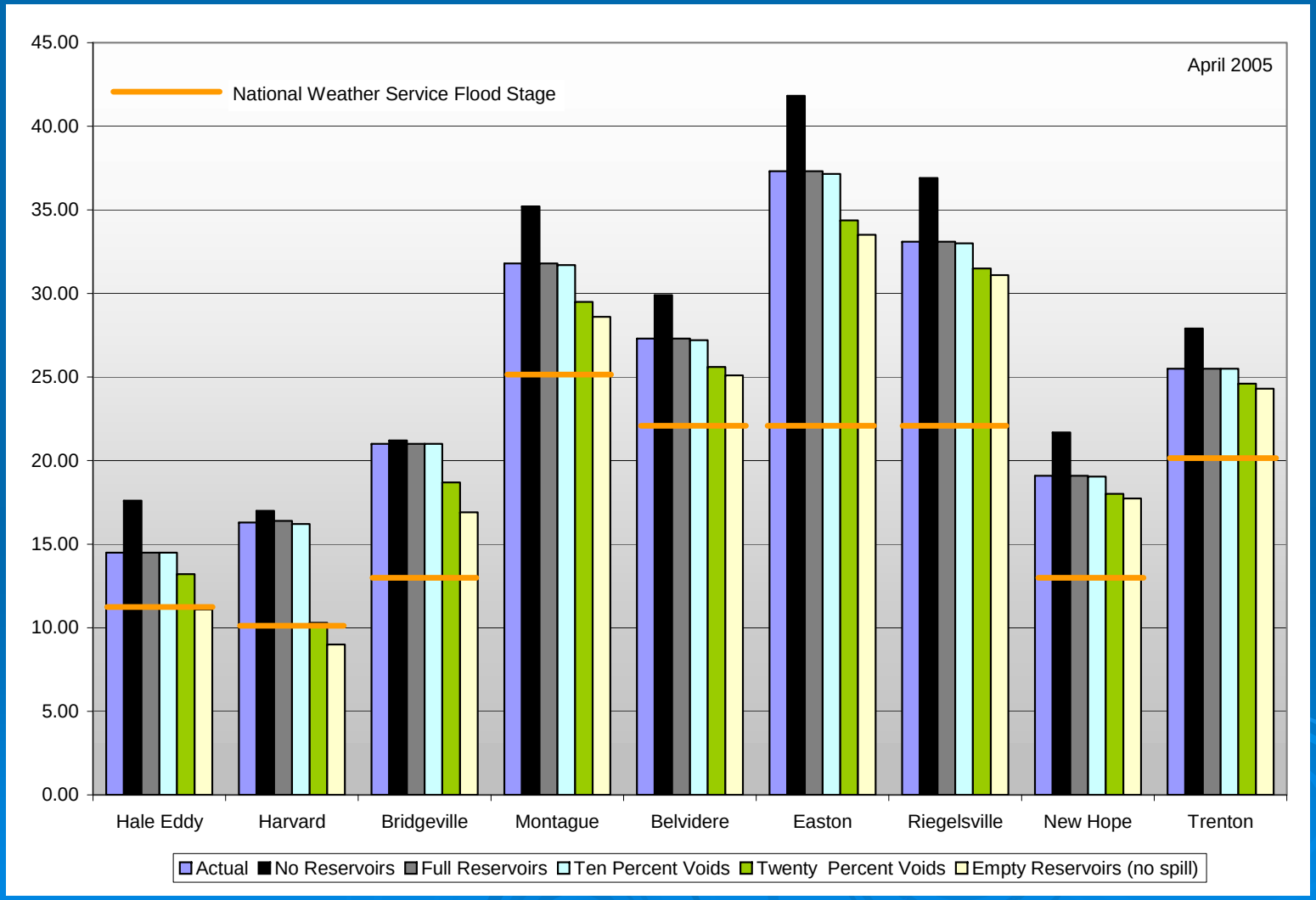


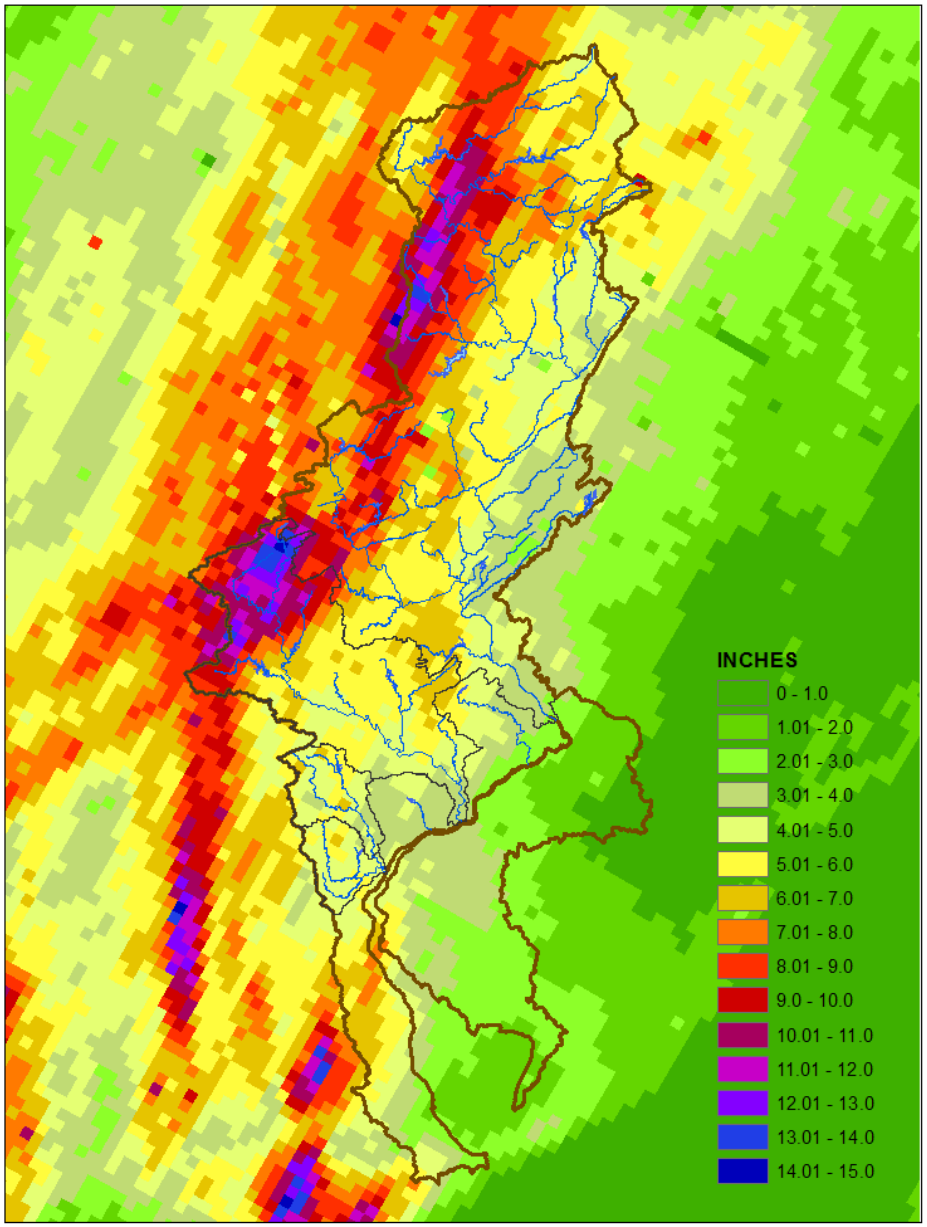
March 28-29 and April 2-3, 2005

- The first event dropped two inches of precipitation.
- Warmer temperatures during and after the first event melted the equivalent of three inches of water stored in the snow pack.
- The second event produced two to five inches of rain throughout the basin and melted the remaining snow pack.
- Prior to the second event, streamflows were high.


Modeled Snow Water Equivalent (Hourly) for 2005 March 26, 12:00 Z
372.7 mi
406.3 mi
Inches of water equivalent
39 to 118
30 to 39
20 to 30
9.8 to 20
5.9 to 9.8
3.9 to 5.9
2.0 to 3.9
0.98 to 2.0
0.39 to 0.98
0.20 to 0.39
0.04 to 0.20
trace to 0.04
0.00 to trace
Not Estimated
Elevation in feet (Not estimated)
> 13124
8203 to 13124
3281 to 8203
3 to 3281
< 3
Watertown
Utica
Syracuse
Albany
Goncord
Boston
Providence
Scranton
Allentown
Trenton
Philadelphia
Annapolis
Dover
Pre-event Snow Pack March 26, 2005
Modeled Snow Water Equivalent (Hourly) for 2005 April 8, 12:00 Z
372.7 mi
388.2 mi
406.3 mi
Watertown
Rochester
Utica
Syracuse
Albany
Goncord
Boston
Providence
Elmira
Hartford
Scranton
Williamsport
Bridgeport
New York
Altoona
Allentown
Harrisburg
Trenton
Philadelphia
Baltimore
Dover
Annapolis
Washington D.C.
Post-event Snow Pack April 8, 2005

Simulated River Stages
for 2005 Event

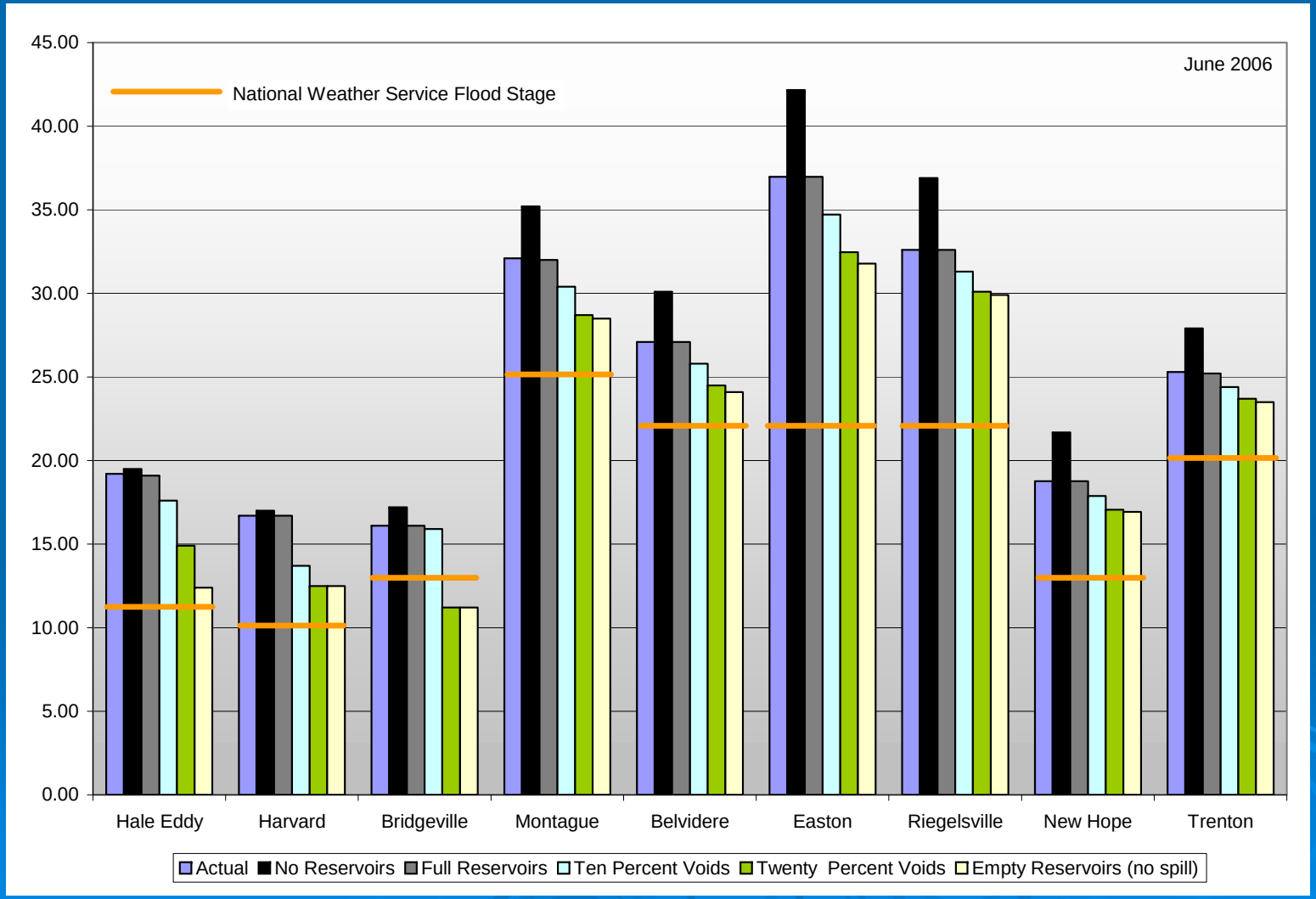




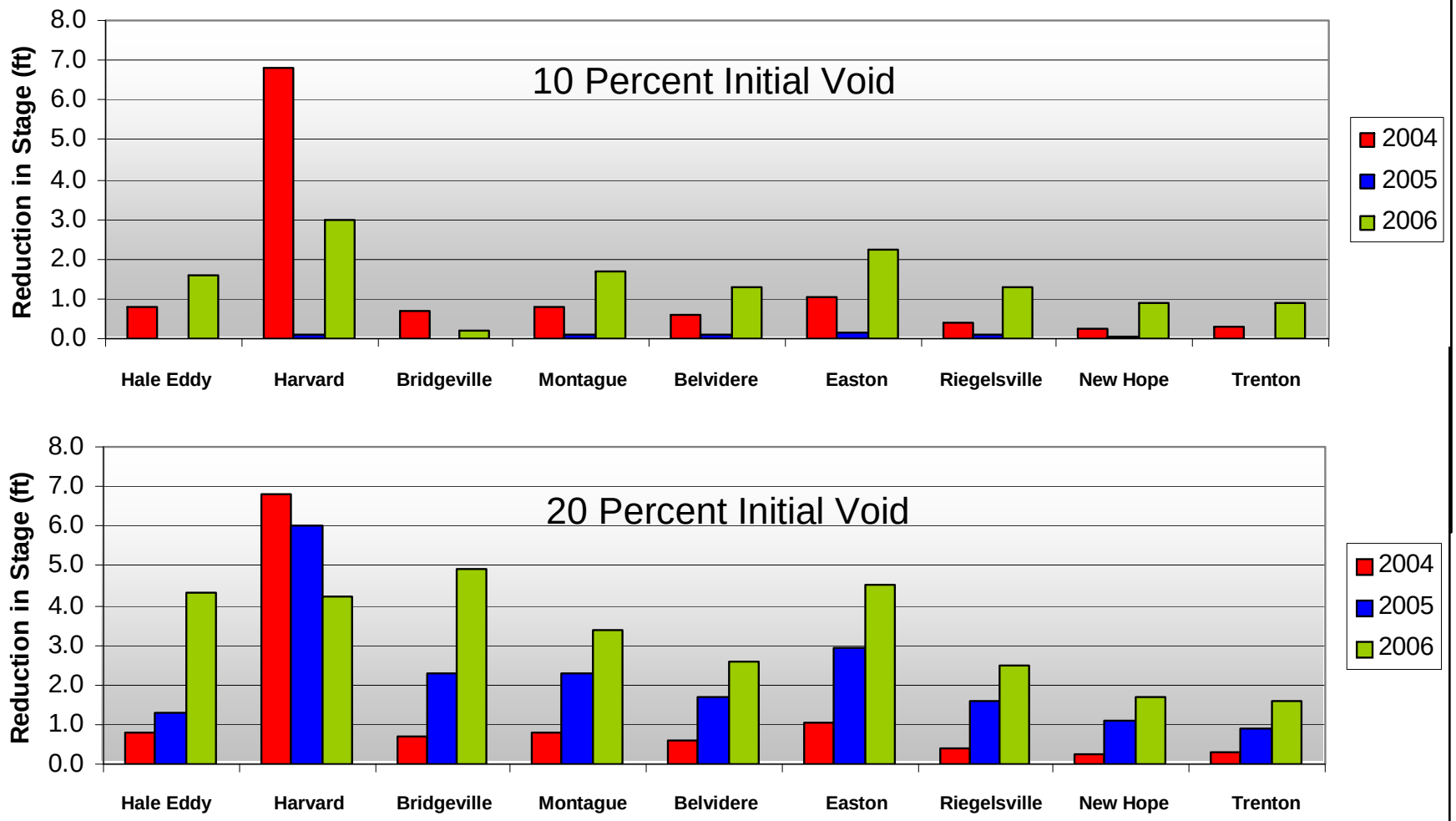
June 24-28, 2006

- Conditions were dry prior to the event.
- Between six and fifteen inches of rain fell in western portion of the upper basin.
- Up to five inches of rain fell in most of the basin except southern NJ and the Philadelphia area.

Simulated River Stages
for 2006 Event



Potential Reduction in River Elevations with Initial Voids in NYC Reservoirs



Translating Flood Crest Reductions into Community Impacts

- How many structures that were flooded by an event would not be flooded under different reservoir conditions?
- Would structures that would still be flooded have the same amount of damage?
- How much damage could be avoided?
- What are the other impacts associated with providing additional mitigation with existing reservoirs?

Other Tools Used to Assess Impacts

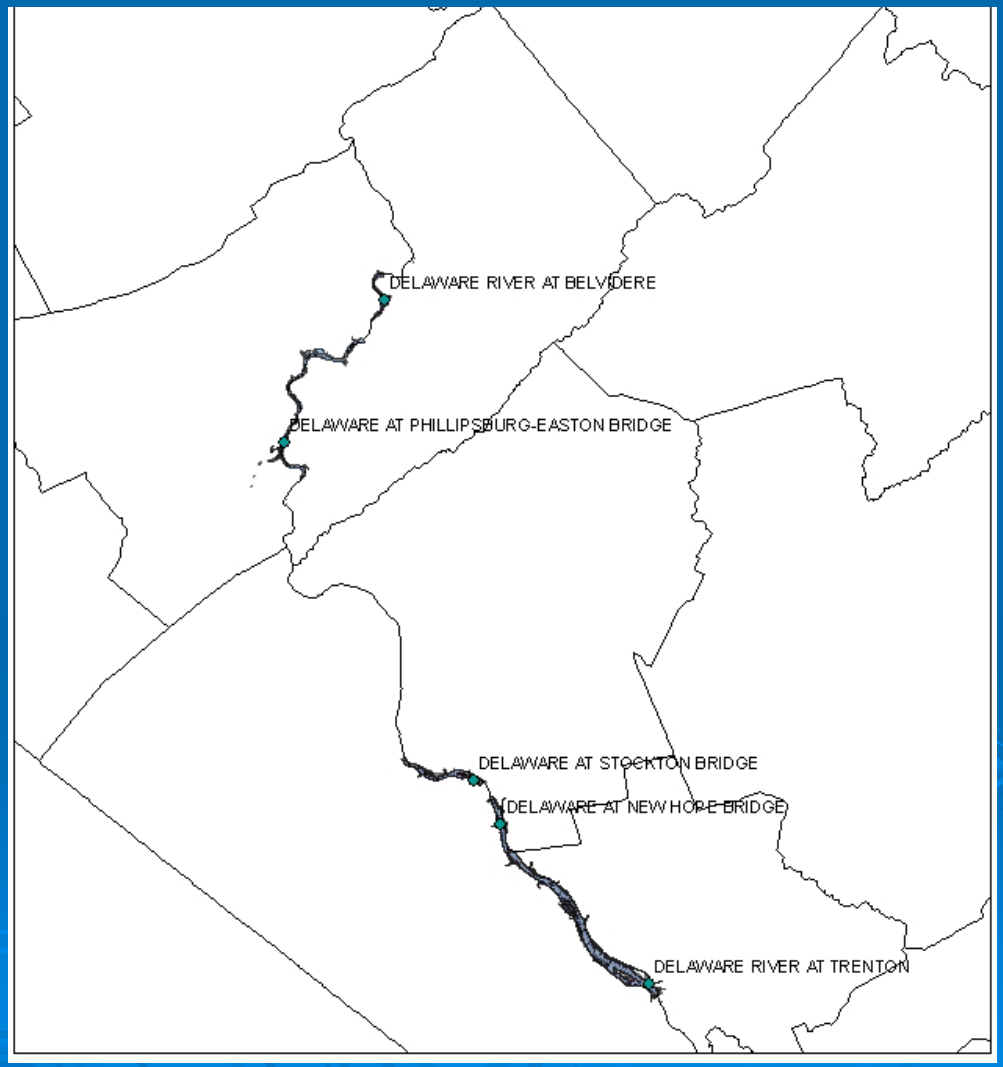
- USACE/NWS Inundation mapping
- USACE Surveys of structures in the floodplain located in high damage areas
- USACE Stage-damage relationships
- Water Supply Planning model (OASIS)

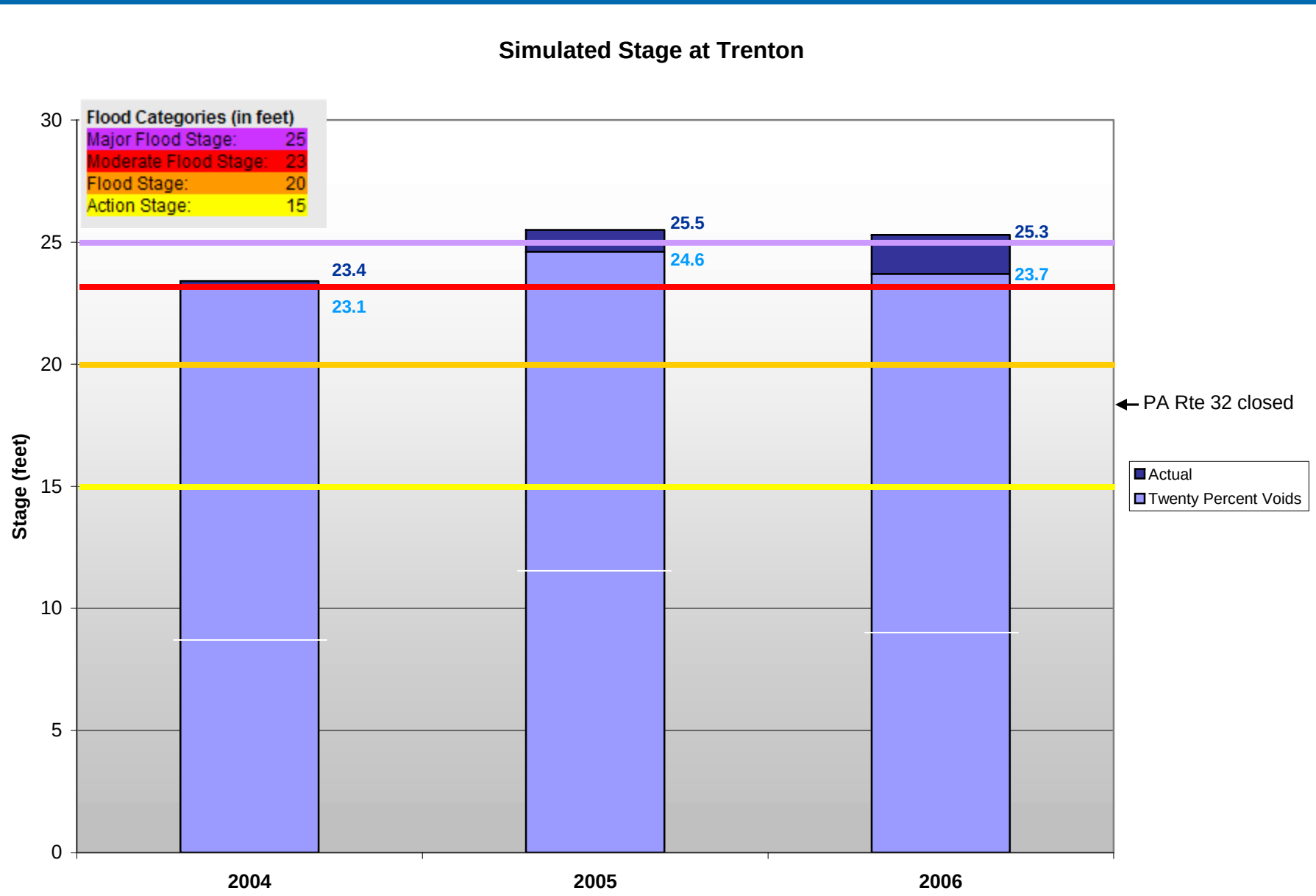
USACE/NWS Inundation Mapping

Limit of USACE/NWS Inundation Layers:

Belvidere/ Lower Mt Bethel
Harmony/ Forks
Phillipsburg/ Easton

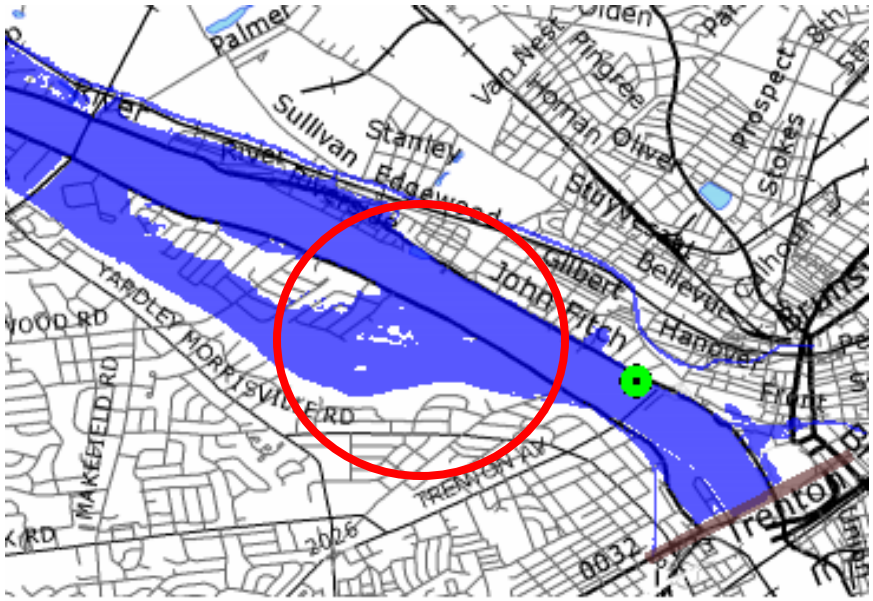
Stockton/ Solebury
Lambertville/ New Hope
Hopewell/ Upper Makefield
Ewing/ Lower Makefield
Trenton/ Yardley



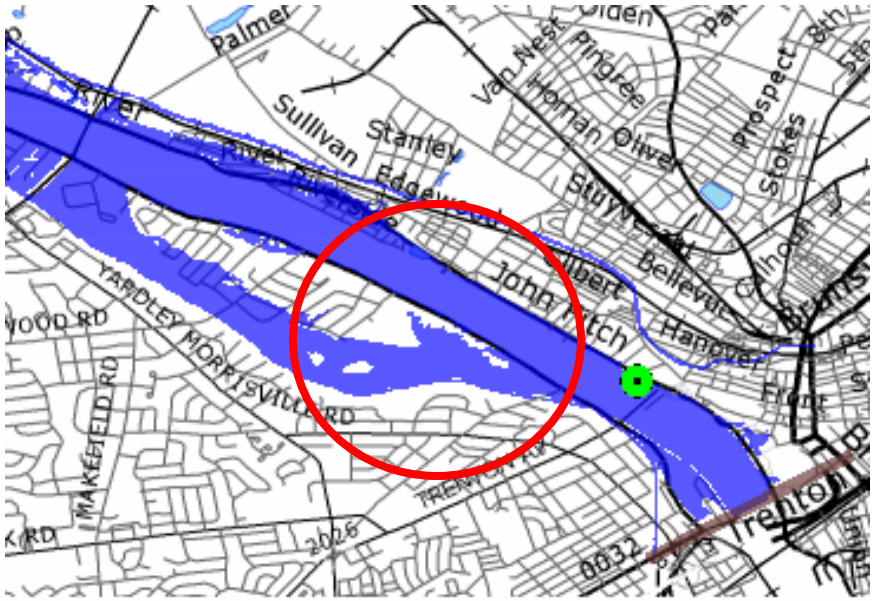

Simulated Stage at Trenton
Flood Categories (in feet)
Major Flood Stage: 25
Moderate Flood Stage: 23
Flood Stage: 20
Action Stage: 15
Stage (feet)
30
25
20
15
10
5
0
23.4
23.1
25.5
24.6
25.3
23.7
2004
2005
2006
PA Rte 32 closed
Actual
Twenty Percent Voids

Differences in Extent of Flooding for June 2006 (existing vs. with 20 percent void – NYC only)

Stage = 25.4 ft*
Simulated Event



Stage = 23.5 ft**
Simulated Event with 20% Void



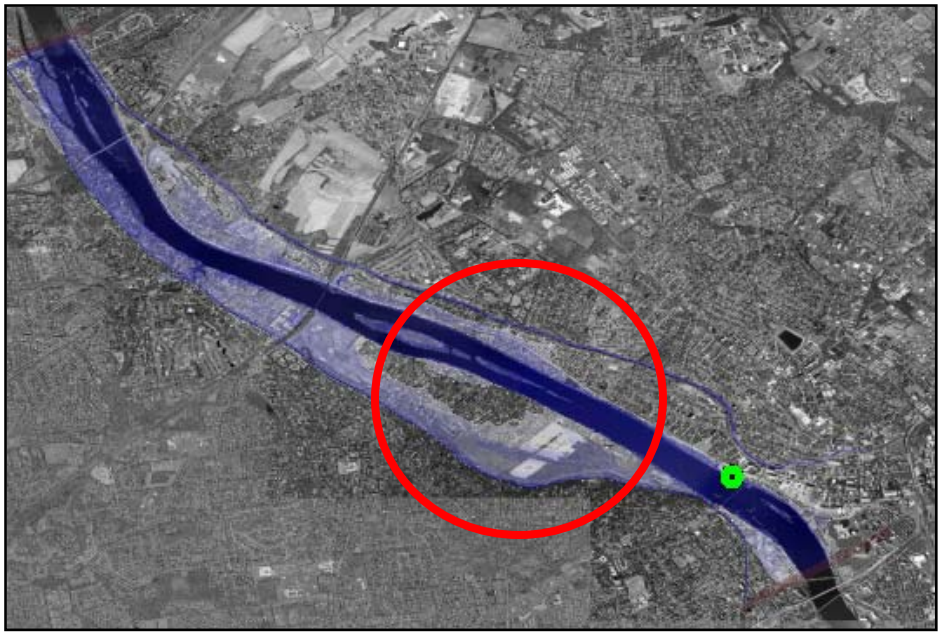
Inundation mapping is preliminary

20 percent void simulations are with all three NYC Reservoirs at 80 percent capacity at the beginning of an event.

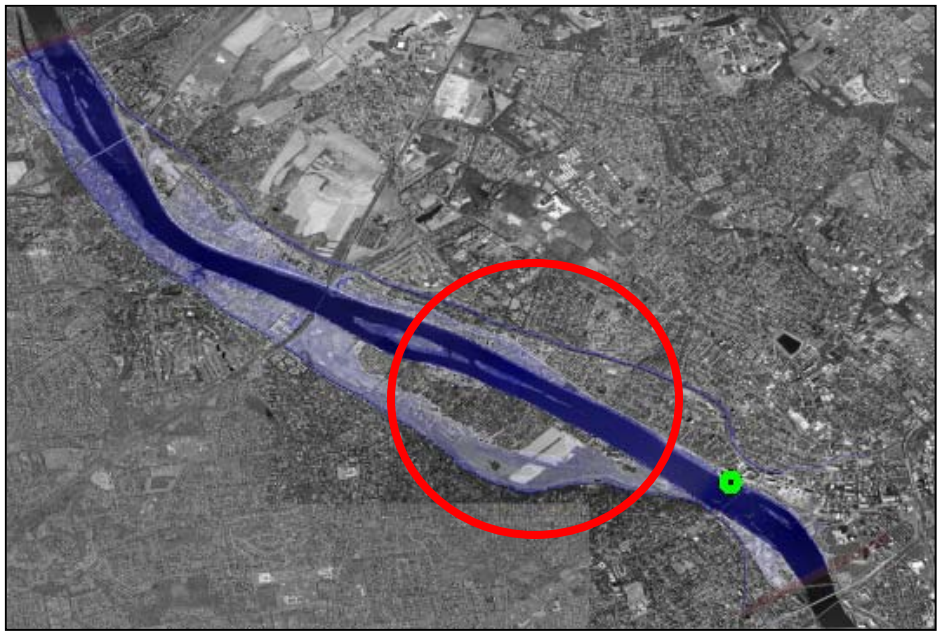
* The simulated stage for the event is 25.3 ft. The closest elevation for which there was inundation mapping was 25.4 ft. ** The simulated stage with a 20 percent void is 23.7 ft. The closest elevation for which there is inundation mapping was 23.5 ft.

Differences in Extent of Flooding for June 2006 (existing vs. with 20 % void)

Stage = 25.4* ft
Simulated Event



Stage = 23.5 ft**
Simulated Event with 20% Void



Preliminary: Inundation mapping is currently being reviewed

20 percent void simulations are with all three NYC Reservoirs at 80 percent capacity at the beginning of an event.

* The simulated stage for the event is 25.3 ft. The closest elevation for which there was inundation mapping was 25.4 ft. ** The simulated stage with a 20 percent void is 23.7 ft. The closest elevation for which there is inundation mapping was 23.5 ft.

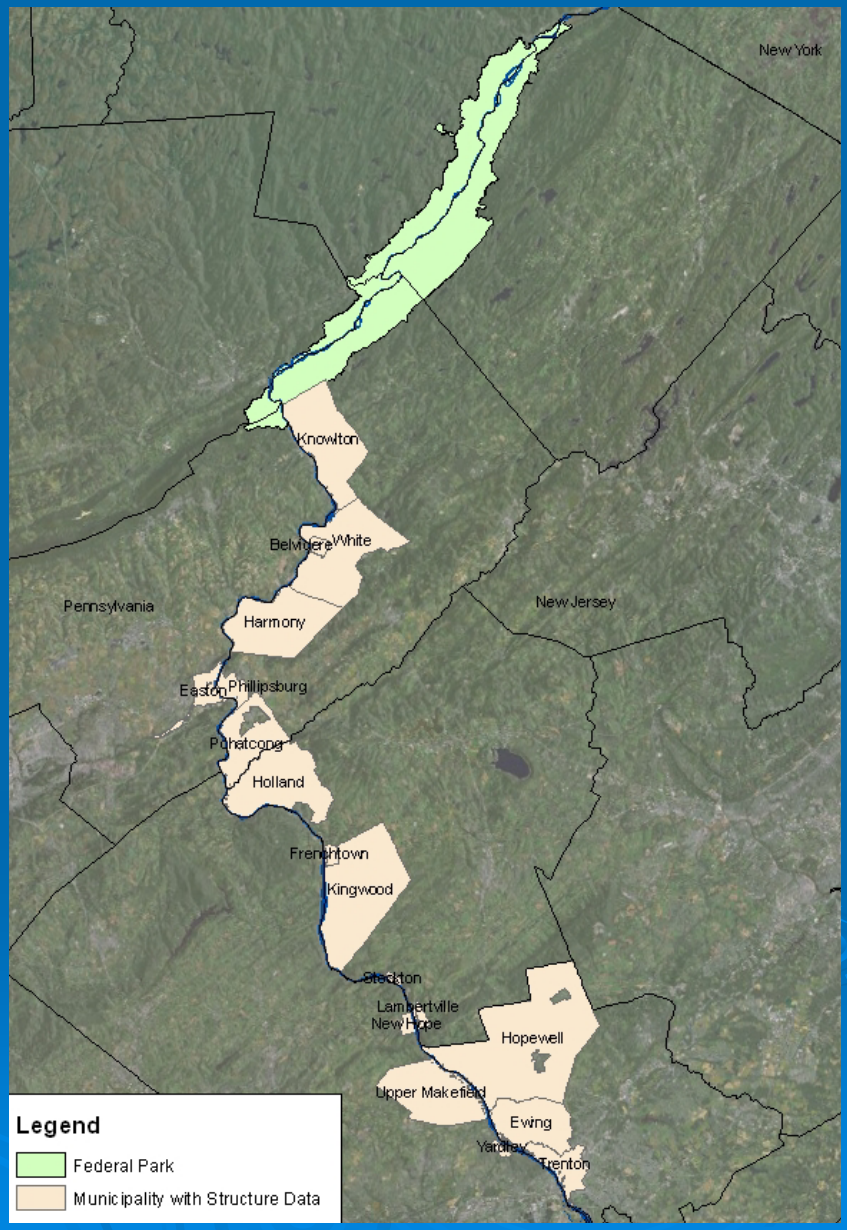
Communities with Surveyed Structures in the Floodplain:

PA: Easton
New Hope
Upper Makefield
Yardley

NJ: Belvidere
Byram
Ewing
Frenchtown
Harmony
Holland
Hopewell
Knowlton
Lambertville
Phillipsburg
Pohatcong
Stockton
Trenton
White

NY: Colchester
Hancock
Livingston Manor
Roscoe

Data collected in for two separate USACE studies;
Multi-jurisdictional Use and Management of Water Resources for the Delaware River Basin and
The Interim Feasibility Study for New Jersey

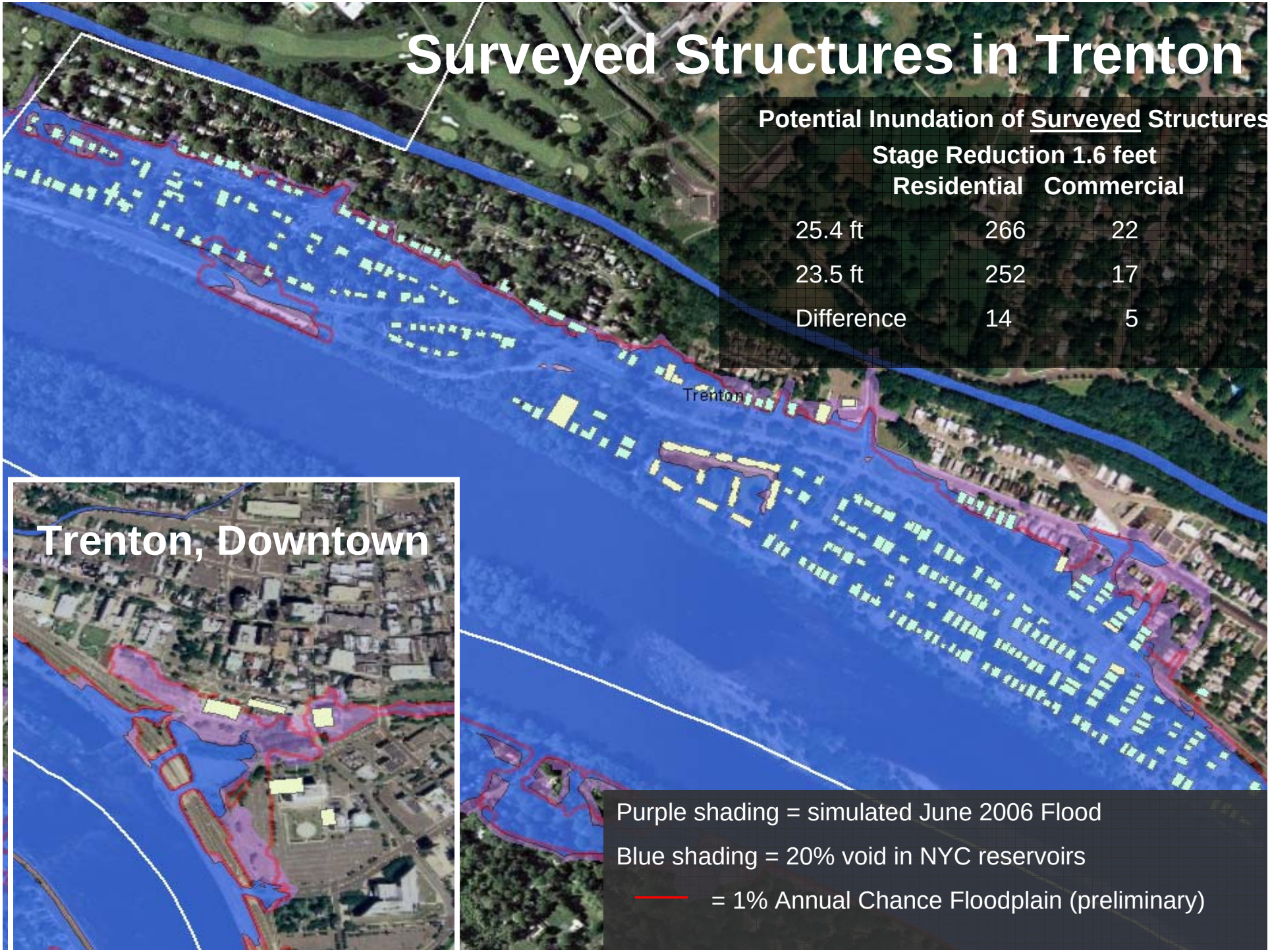


Surveyed Structures in Trenton

Potential Inundation of Surveyed Structures

Stage Reduction 1.6 feet

	Residential	Commercial
25.4 ft	266	22
23.5 ft	252	17
Difference	14	5

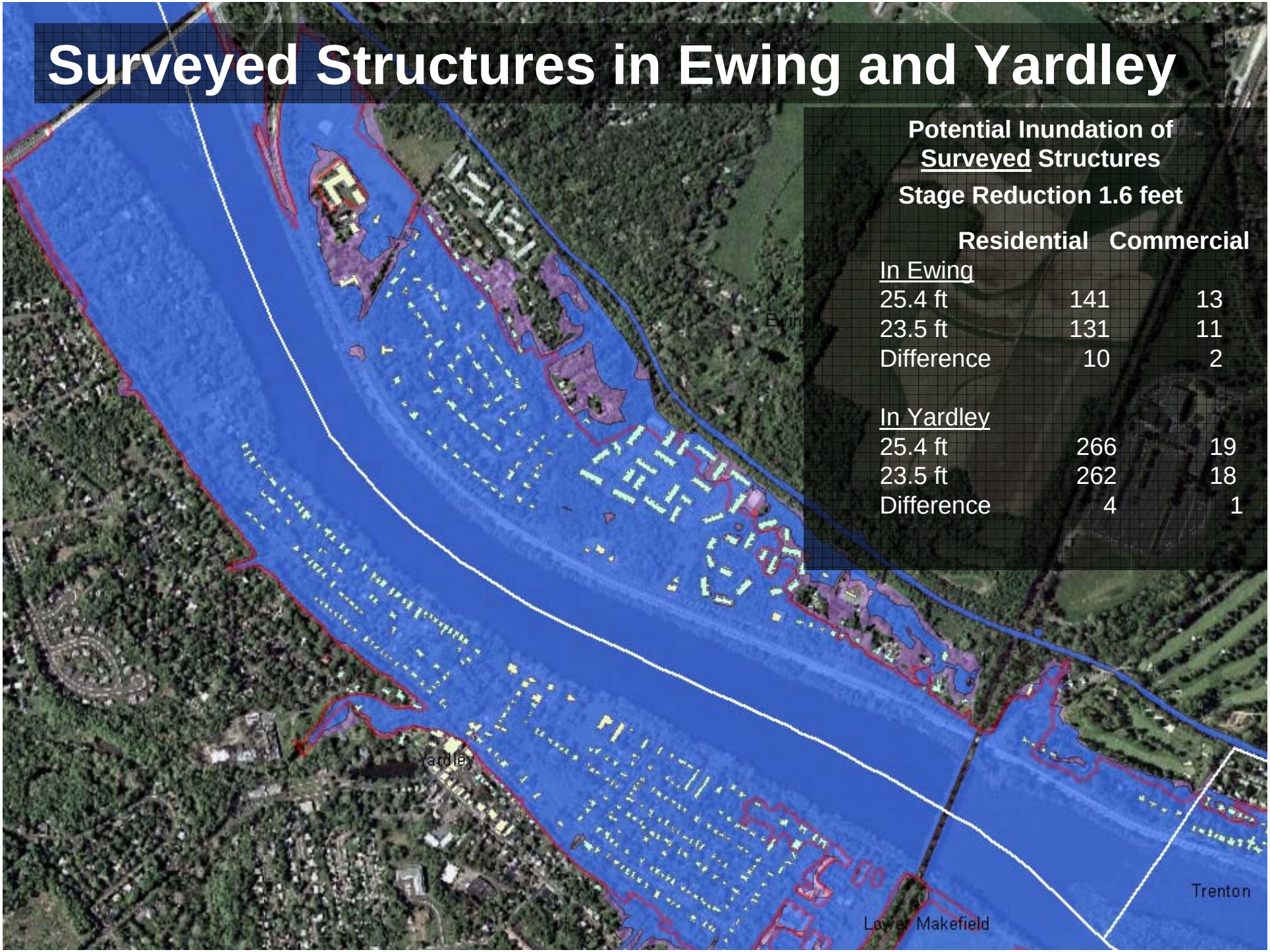


Purple shading = simulated June 2006 Flood

Blue shading = 20% void in NYC reservoirs

= 1% Annual Chance Floodplain (preliminary)

Surveyed Structures in Ewing and Yardley



Potential Inundation of Surveyed Structures

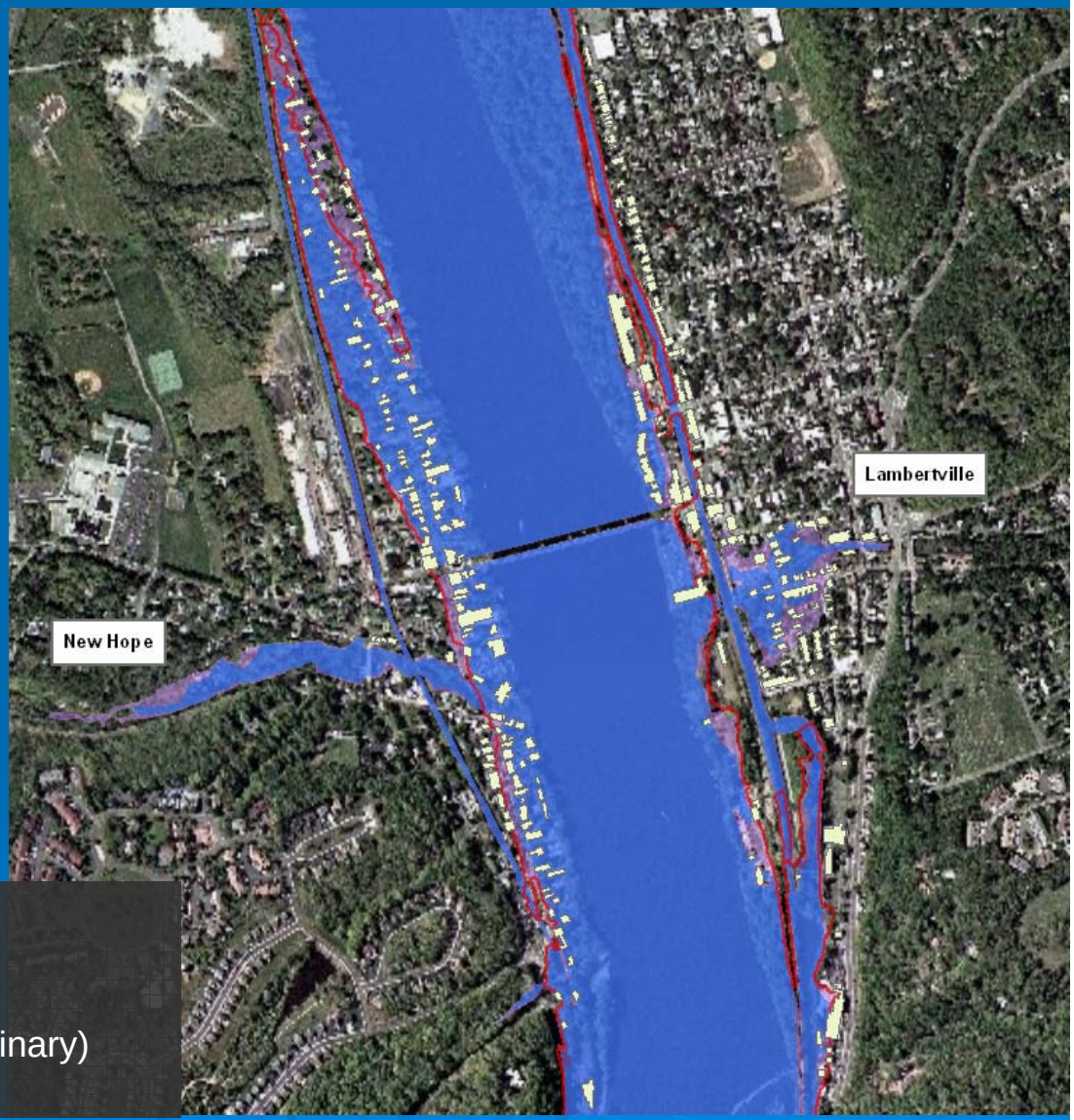
Stage Reduction 1.6 feet

	Residential	Commercial
In Ewing		
25.4 ft	141	13
23.5 ft	131	11
Difference	10	2
In Yardley		
25.4 ft	266	19
23.5 ft	262	18
Difference	4	1

Surveyed Structures in New Hope/Lambertville

Potential Inundation of Surveyed Structures
Stage Reduction 1.7 feet

	Residential	Commercial
In New Hope		
19.4 ft	82	61
17.2 ft	72	58
Difference	10	3
In Lambertville		
19.4 ft	59	30
17.2 ft	25	13
Difference	34	17



Blue shading = simulated June 2006 Flood

Purple shading = 20% void in NYC reservoirs

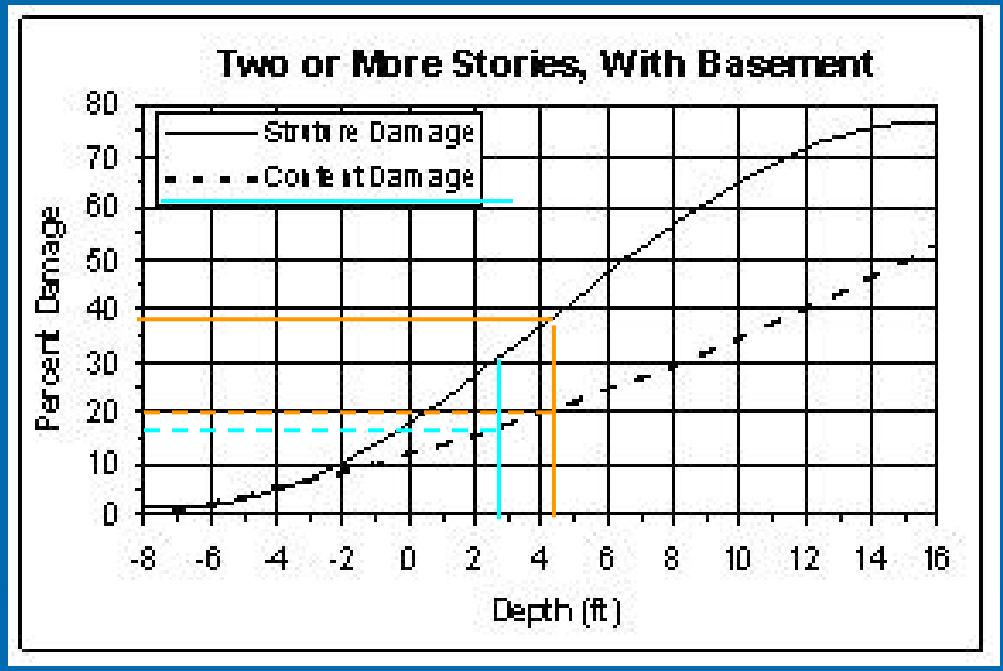
—— = 1% Annual Chance Floodplain (preliminary)

Estimating Damages

Example: 1.7 ft reduction
New Hope – Residential
Single Family
2 Stories with Basement
Zero Damage Elevation = 60.95’
First Floor Elevation = 62.45’

Simulated Elevation of
Flood 2006 = 66.87’
4.42’ above first floor
Structure Damage 38%
Content Damage 21%

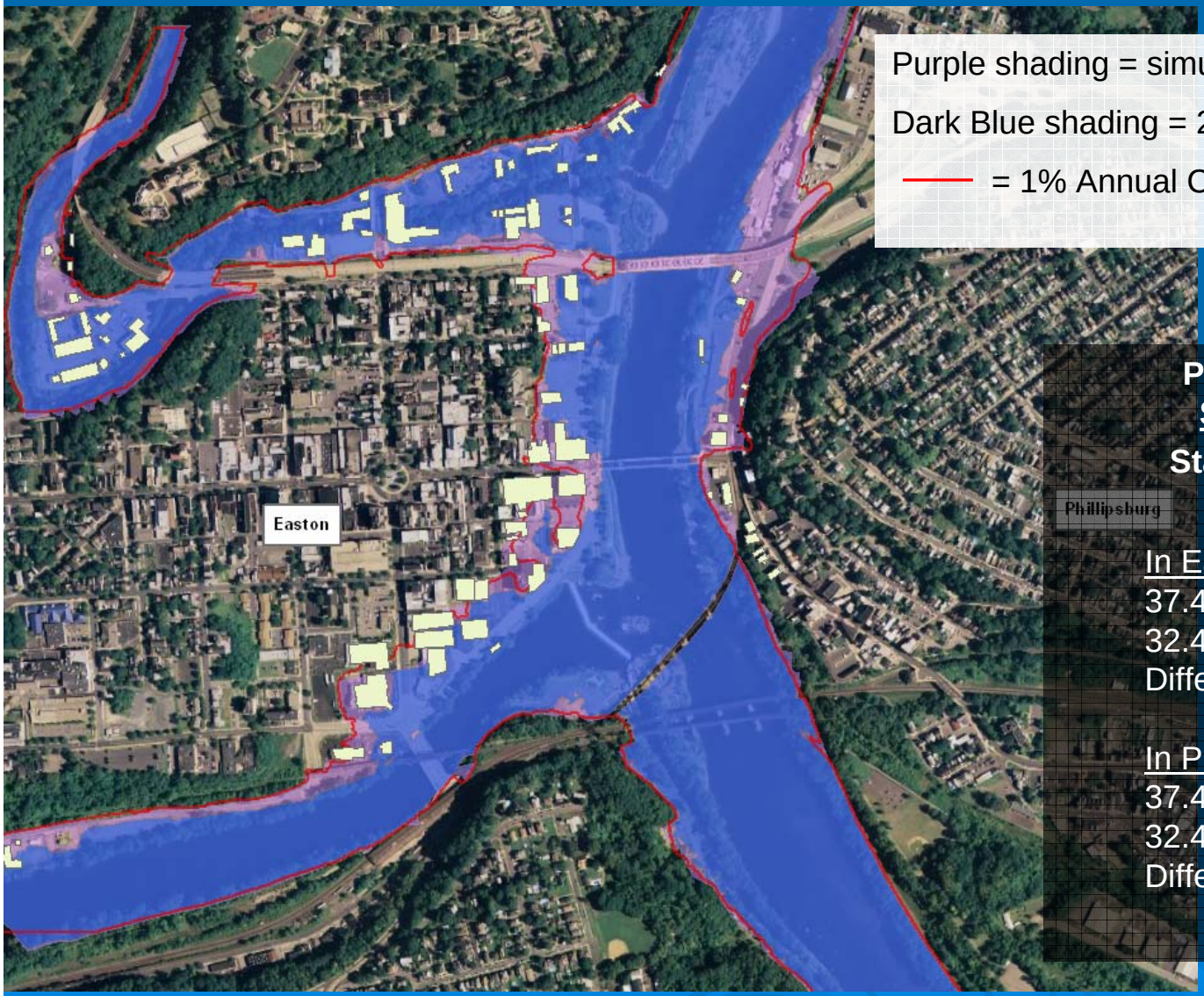
USACE Depth-Damage Curve



Simulated Elevation of Flood 2006 with 20% Voids in NYC reservoirs= 65.17’
2.72’ above first floor. Structure Damage 31% Content Damage 17%

Although the structure is still inundated, the water depth reduced by 1.7 ft. Structural damage may be reduced by 7% and content damage may be reduced by 4%.

Surveyed Structures in Easton, PA



Purple shading = simulated June 2006 Flood

Dark Blue shading = 20% void in NYC reservoirs

—— = 1% Annual Chance Floodplain (preliminary)

Potential Inundation of Surveyed Structures

Stage Reduction 4.5 feet

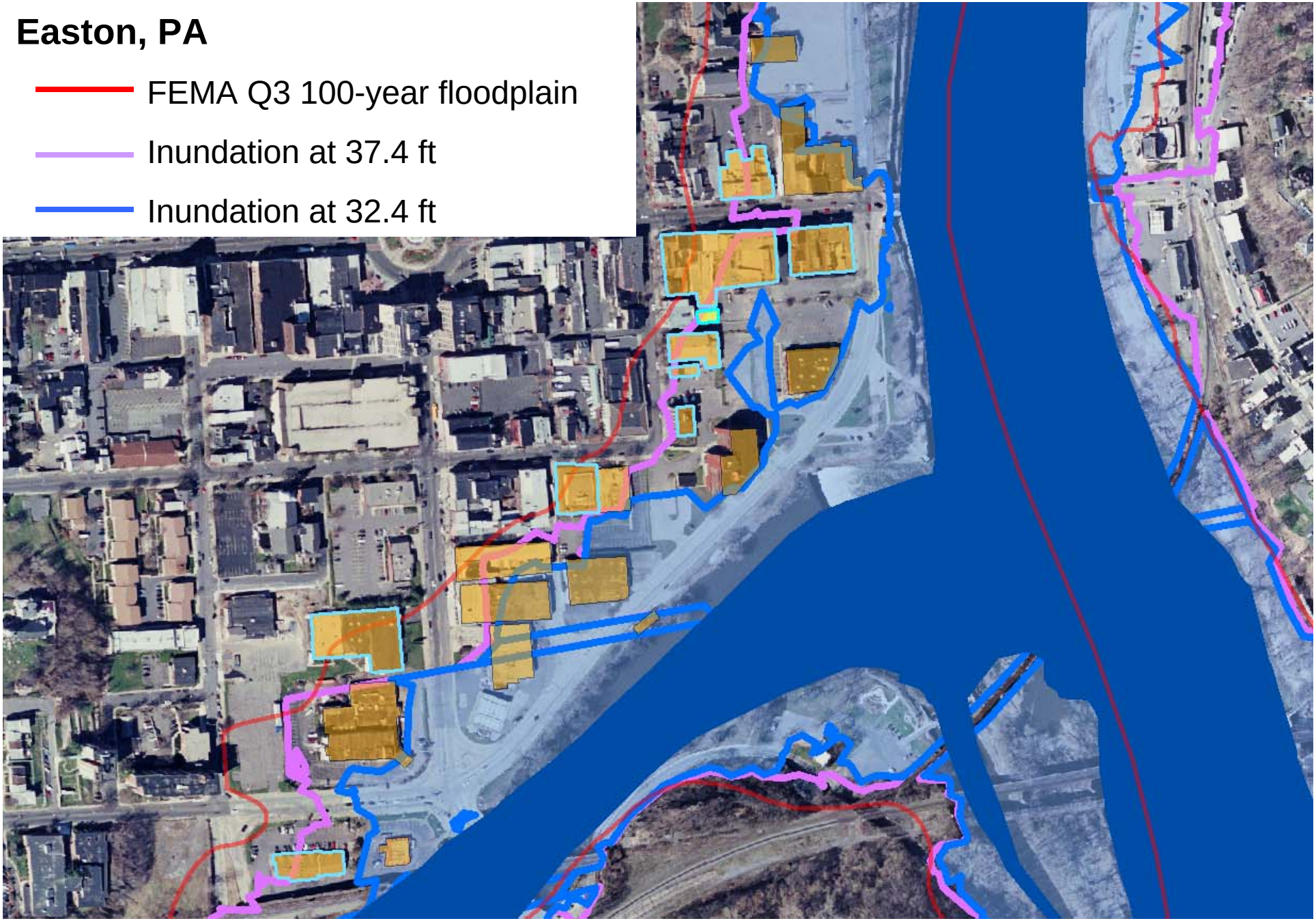
	Residential	Commercial
In Easton		
37.4 ft	8	52
32.4 ft	5	29
Difference	3	23
In Phillipsburg		
37.4 ft	8	9
32.4 ft	0	5
Difference	8	4

Easton, PA

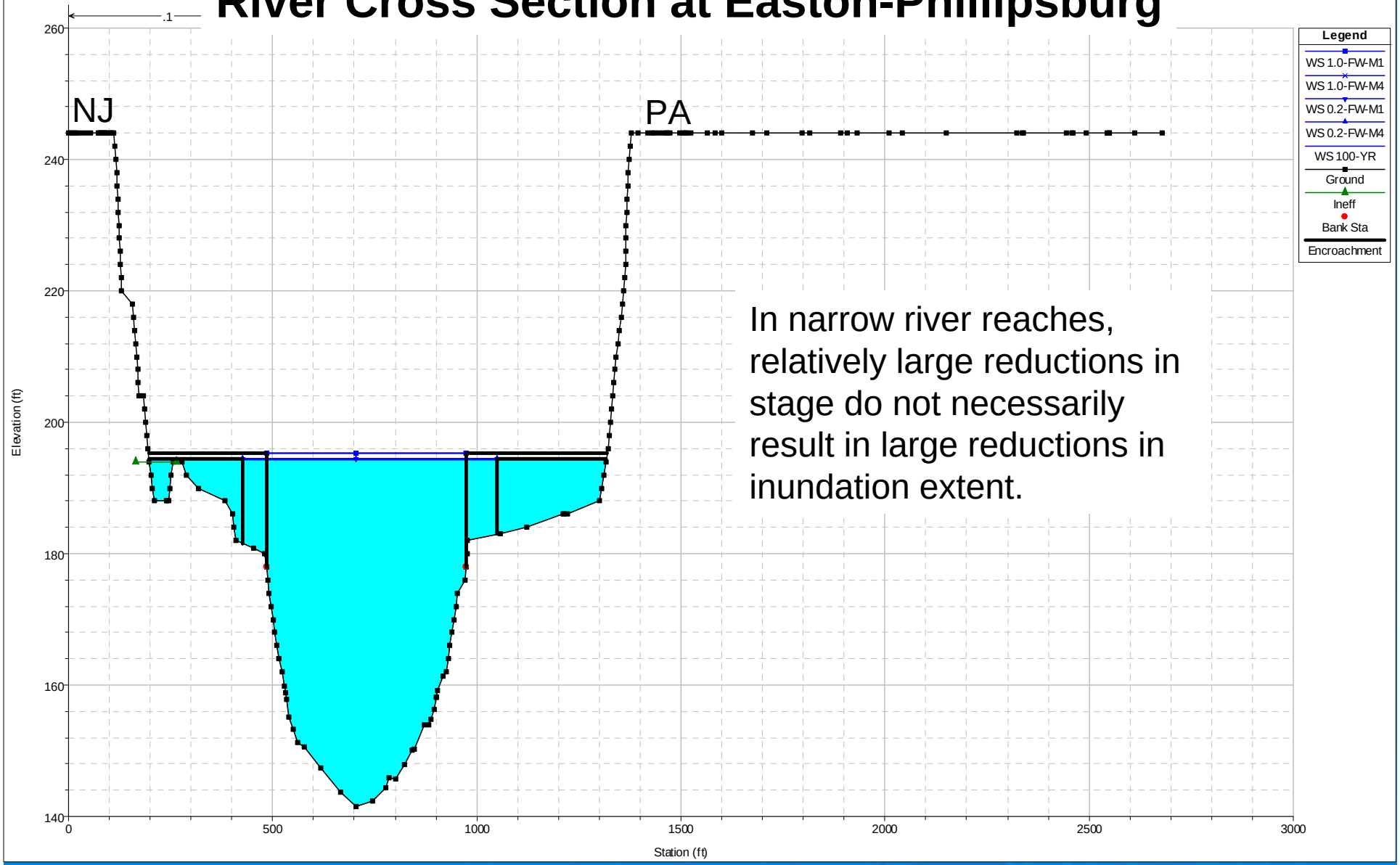
FEMA Q3 100-year floodplain

Inundation at 37.4 ft

Inundation at 32.4 ft



River Cross Section at Easton-Phillipsburg



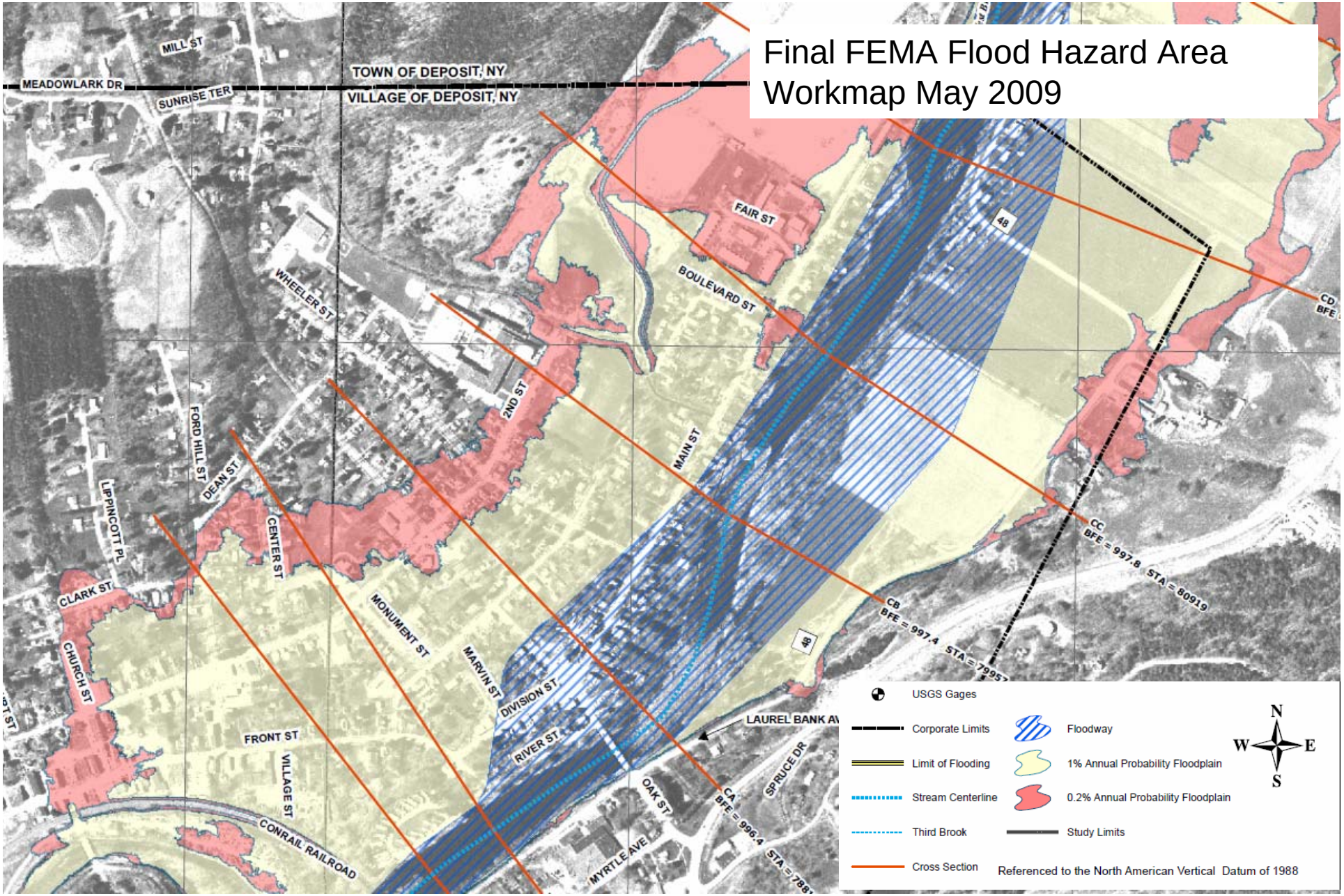
In narrow river reaches, relatively large reductions in stage do not necessarily result in large reductions in inundation extent.

Summary of Inundated Structures

	Residential				Commercial			
Municipality	Total	Inundated w/o voids	Inundated w/ voids	Difference	Total	Inundated w/o voids	Inundated w/ voids	Difference
Yardley, PA	282	266	262	4	35	19	18	1
Trenton, NJ	434	266	252	14	68	22	17	5
Ewing, NJ	156	141	131	10	16	13	11	2
Upper Makefield, PA	309	171	142	29	48	19	13	6
Hopewell, NJ	22	19	17	2	10	7	6	1
New Hope, PA	87	82	72	10	68	61	58	3
Lambertville, NJ	109	59	25	34	63	30	13	17
Stockton, NJ	95	59	22	37	33	15	6	9
Easton, PA	18	8	5	3	80	52	29	23
Phillipsburg, NJ	16	8	0	8	17	9	5	4
Harmony, NJ	143	108	72	36	3	2	2	0
Belvidere, NJ	73	37	7	30	20	11	6	5
Total	1744	1224	1007	217	461	260	184	76

Values represent the largest potential reductions in stage from the June 2006 event with twenty percent voids in the NYC Reservoirs. Structure counts are approximate due to the tolerances associated with the digital elevation mapping (DEM) used to generate the inundation mapping.

Note: As of 11/30/2008, there were 2,210 NFIP classified repetitive and severe repetitive loss properties in the basin.


Final FEMA Flood Hazard Area
Workmap May 2009
TOWN OF DEPOSIT, NY
VILLAGE OF DEPOSIT, NY
MILL ST
MEADOWLARK DR
SUNRISE TER
WHEELER ST
FAIR ST
BOULEVARD ST
48
2ND ST
MAIN ST
FORD HILL ST
DEAN ST
LIPPINCOTT PL
CENTER ST
CLARK ST
MONUMENT ST
MARVIN ST
DIVISION ST
CHURCH ST
FRONT ST
RIVER ST
VILLAGE ST
CONRAIL RAILROAD
OAK ST
SPRUCE DR
MYRTLE AVE
LAUREL BANK AV
CB
BFE = 997.4
STA = 79957
CC
BFE = 997.8
STA = 80919
CA
BFE = 996.4
USGS Gages
Corporate Limits
Limit of Flooding
Stream Centerline
Third Brook
Cross Section
Floodway
1% Annual Probability Floodplain
0.2% Annual Probability Floodplain
Study Limits
Referenced to the North American Vertical Datum of 1988
N
W
E
S

Deposit, NY

Water Management Considerations

- There is a high level of risk for experiencing flooding in the flood hazard area.
- Seven of the ten worst main stem floods reported at Trenton, occurred prior to the reservoirs or in the absence of spills.
- Relying on existing reservoirs for flood mitigation will provide a false sense of security.
- Approximately $237 million dollars in claims have been paid to 2,210 repetitive and severe repetitive loss properties since 1978.

Water Management Considerations

- Approximately 13,150 persons live in the 100-year floodplain of the main stem Delaware River between Hancock, NY and Trenton, NJ.
- Nine million people get their drinking water from the NYC Delaware Reservoirs.
- An additional 2.5 million persons get their drinking water from the main stem of the Delaware River downstream of the Delaware Water Gap.

Impacts to Water Supply

- The OASIS model was used with current demands and drought management protocols.
- The safe yield of the NYC Water Supply would be reduced by 8.8 percent by chasing a 20 percent void.
- Attempting to maintain a year-round, dedicated void results in large increases in drought days
  - 35 percent for a 10 percent void at 600 mgd
  - 99 percent for a 20 percent void at 600 mgd
- Drought days result in the reduction of diversions, flow targets and releases
  - Jeopardizes in and out-of-basin water supply
  - Reduces instream flow for ecological needs
- Additional analyses are needed on impacts to salinity repulsion, other reservoirs and fisheries.

Impacts to Water Supply - Drought Days

	765 MGD				
	FFMP	90 Percent Target	Difference	80 Percent Target	Difference
Drought Days					
Watch	1391	1970	42%	3397	144%
Warning	1857	1986	7%	2761	49%
Drought	2593	3288	27%	3672	42%
Total	5841	7244	24%	9830	68%
	600 MGD				
	FFMP	90 Percent Target	Difference	80 Percent Target	Difference
Drought Days					
Watch	736	885	20%	1912	160%
Warning	858	1502	75%	1916	123%
Drought	1712	2092	22%	2751	61%
Total	3306	4479	35%	6579	99%
Simulation Period: January 1928 through September 2006 (28,763 days)					
FFMP Drought Days (September 27, 2007) = 5841					

At current water supply demand rates, approximately 18 of 78 years would be in drought status

Review of Findings

- Pervasive flooding would still have occurred regardless of the storage condition in the reservoirs before the events.
- Reservoirs did not cause the flooding.
- Alternate reservoir operations could potentially reduce flood crests but amount depends upon storm, proximity and topography.
- Dedicated, year-round voids in NYC reservoirs cannot be maintained.
- Creating dedicated, year-round voids increases drought risk.

The results of the Delaware River Basin Flood Analysis Model and associated studies do not alter the Task Force conclusion of 2007:

No one set of measures will eliminate flooding along the Delaware River, rather the Task Force Members recommended a combination of measures to improve the basin's resiliency—its capacity to prepare for and recover from flooding in the future.

Task Force Recommendations

- Reservoir Operations
- Structural and Non-Structural Measures
- Stormwater Management
- Floodplain Mapping
- Floodplain Regulations
- Flood Warning

Next Steps

- **Reservoir Operations**
  - Continue to pursue spill mitigation
  - Pursue use of NWS AHPS long term probabilistic forecast-based operations
- **Continue Implementing Non-Reservoir Related Task Force Recommendations**
  - Natural, non-structural solutions that do not preclude traditional approaches
  - Flood Warning System Upgrade
  - Education and Outreach

Next Steps - continued

- **Implement New Non-Reservoir Related Measures**
  - Strengthen Floodplain Management
  - Create Riparian Corridor Integrity Trust Fund similar to NJ Blue Acres Fund
  - Develop a Stormwater Retrofit Program similar to the Catskill Watershed Corporation
- **Continue to explore additional storage for multiple purposes**

Questions and Comments

Contact:

Amy L. Shallcross, PE

609-883-9500 x 232

or

William J. Muszynski, PE

609-883-9500 x 221

Delaware River Basin Commission

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