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

Delaware River Basin Interstate Flood Mitigation Task Force

December 15, 2009
Why are we here?

- 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

- Delaware R. to Trenton
- Non-Tidal Brandywine/Christina
- Schuylkill R. to Philadelphia
Observed Crest was 25.09’
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

Stage
Bethlehem

Flow

Stage

Observed

Simulated

Time of Simulation
Comparison of Observed and Simulated Stage

Comparison of Observed and Simulated Flows

Peak Stage

Peak Flow
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

River Stage in Feet
Distance above Gage Datum

NWS Designated Flood Stage

Event

0.00
5.00
10.00
15.00
20.00

No Reservoirs
Full Reservoirs
Ten Percent Voids
Twenty Percent Voids
Empty Reservoirs
Simulated River Stages
for 2004 Event

National Weather Service Flood Stage

September 2004

Actual
No Reservoirs
Full Reservoirs
Ten Percent Voids
Twenty Percent Voids
Empty Reservoirs (no spill)
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.
Simulated River Stages for 2005 Event

National Weather Service Flood Stage

April 2005
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

June 2006
Potential Reduction in River Elevations with Initial Voids in NYC Reservoirs

10 Percent Initial Void

20 Percent Initial Void
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
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

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.

Inundation mapping is preliminary
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)
### Potential Inundation of Surveyed Structures

Stage Reduction 1.6 feet

<table>
<thead>
<tr>
<th></th>
<th>Residential</th>
<th>Commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>In Ewing</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25.4 ft</td>
<td>141</td>
<td>13</td>
</tr>
<tr>
<td>23.5 ft</td>
<td>131</td>
<td>11</td>
</tr>
<tr>
<td>Difference</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td><strong>In Yardley</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25.4 ft</td>
<td>266</td>
<td>19</td>
</tr>
<tr>
<td>23.5 ft</td>
<td>262</td>
<td>18</td>
</tr>
<tr>
<td>Difference</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

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Surveyed Structures in Ewing and Yardley
## Surveyed Structures in New Hope/Lambertville

### Potential Inundation of Surveyed Structures

<table>
<thead>
<tr>
<th></th>
<th>Residential</th>
<th>Commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td>In New Hope</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19.4 ft</td>
<td>82</td>
<td>61</td>
</tr>
<tr>
<td>17.2 ft</td>
<td>72</td>
<td>58</td>
</tr>
<tr>
<td>Difference</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>In Lambertville</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19.4 ft</td>
<td>59</td>
<td>30</td>
</tr>
<tr>
<td>17.2 ft</td>
<td>25</td>
<td>13</td>
</tr>
<tr>
<td>Difference</td>
<td>34</td>
<td>17</td>
</tr>
</tbody>
</table>

- Blue shading = simulated June 2006 Flood
- Purple shading = 20% void in NYC reservoirs
- = 1% Annual Chance Floodplain (preliminary)
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%

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

<table>
<thead>
<tr>
<th>In Easton</th>
<th>Residential</th>
<th>Commercial</th>
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<tbody>
<tr>
<td>37.4 ft</td>
<td>8</td>
<td>52</td>
</tr>
<tr>
<td>32.4 ft</td>
<td>5</td>
<td>29</td>
</tr>
<tr>
<td>Difference</td>
<td>3</td>
<td>23</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>In Phillipsburg</th>
<th>Residential</th>
<th>Commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td>37.4 ft</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>32.4 ft</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Difference</td>
<td>8</td>
<td>4</td>
</tr>
</tbody>
</table>
In narrow river reaches, relatively large reductions in stage do not necessarily result in large reductions in inundation extent.
Summary of Inundated Structures

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.

<table>
<thead>
<tr>
<th>Municipality</th>
<th>Residential</th>
<th></th>
<th></th>
<th>Commercial</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Inundated w/o voids</td>
<td>Inundated w/ voids</td>
<td>Difference</td>
<td>Total</td>
<td>Inundated w/o voids</td>
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<tr>
<td>Yardley, PA</td>
<td>282</td>
<td>266</td>
<td>262</td>
<td>4</td>
<td>35</td>
<td>19</td>
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<td>Trenton, NJ</td>
<td>434</td>
<td>266</td>
<td>252</td>
<td>14</td>
<td>68</td>
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<td>141</td>
<td>131</td>
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<td>Upper Makefield, PA</td>
<td>309</td>
<td>171</td>
<td>142</td>
<td>29</td>
<td>48</td>
<td>19</td>
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<tr>
<td>Hopewell, NJ</td>
<td>22</td>
<td>19</td>
<td>17</td>
<td>2</td>
<td>10</td>
<td>7</td>
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<td>New Hope, PA</td>
<td>87</td>
<td>82</td>
<td>72</td>
<td>10</td>
<td>68</td>
<td>61</td>
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<tr>
<td>Lambertville, NJ</td>
<td>109</td>
<td>59</td>
<td>25</td>
<td>34</td>
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<td>Stockton, NJ</td>
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<tr>
<td>Easton, PA</td>
<td>18</td>
<td>8</td>
<td>5</td>
<td>3</td>
<td>80</td>
<td>52</td>
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<tr>
<td>Phillipsburg, NJ</td>
<td>16</td>
<td>8</td>
<td>0</td>
<td>8</td>
<td>17</td>
<td>9</td>
</tr>
<tr>
<td>Harmony, NJ</td>
<td>143</td>
<td>108</td>
<td>72</td>
<td>36</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Belvidere, NJ</td>
<td>73</td>
<td>37</td>
<td>7</td>
<td>30</td>
<td>20</td>
<td>11</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1744</strong></td>
<td><strong>1224</strong></td>
<td><strong>1007</strong></td>
<td><strong>217</strong></td>
<td><strong>461</strong></td>
<td><strong>260</strong></td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th></th>
<th>765 MGD</th>
<th></th>
<th>80 Percent</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>FFMP</td>
<td>90 Percent</td>
<td>Target</td>
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<tr>
<td>Drought Days</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Watch</td>
<td>1391</td>
<td>1970</td>
<td>42%</td>
</tr>
<tr>
<td>Warning</td>
<td>1857</td>
<td>1986</td>
<td>7%</td>
</tr>
<tr>
<td>Drought</td>
<td>2593</td>
<td>3288</td>
<td>27%</td>
</tr>
<tr>
<td>Total</td>
<td>5841</td>
<td>7244</td>
<td>24%</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>600 MGD</td>
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<td></td>
</tr>
<tr>
<td>Drought Days</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Watch</td>
<td>736</td>
<td>885</td>
<td>20%</td>
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<tr>
<td>Warning</td>
<td>858</td>
<td>1502</td>
<td>75%</td>
</tr>
<tr>
<td>Drought</td>
<td>1712</td>
<td>2092</td>
<td>22%</td>
</tr>
<tr>
<td>Total</td>
<td>3306</td>
<td>4479</td>
<td>35%</td>
</tr>
</tbody>
</table>

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

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