

**FLOOD SUMMARY – August 28 – September 9, 2011
 Hurricane Irene and Tropical Storm Lee**

Precipitation

August 2011 was the wettest August on record based on data collected since 1872 for Philadelphia. The record rainfall of 12.10 inches for August was broken on August 19, 2011 when the accumulated rainfall for the month reached 12.24 inches. On August 27-28, Hurricane Irene traveled up the east coast delivering widespread rainfall in amounts of 5 to 8 inches of rainfall, with locally higher amounts of up to 12 inches in the State of Delaware. The Pocono and Catskill regions received approximately 3 to 5 inches of rainfall. The total rainfall for the month of August 2011 was 19.31 inches, which exceeded the all-time maximum monthly accumulation of 13.07 inches, which occurred in September 1999.

Tropical Storm Lee followed, shortly thereafter, from September 5th through September 9th. Approximately 5 to 7 inches of precipitation fell over much of the basin, with lesser amounts of 2 to 4 inches recorded in the estuary region of the lower basin. Portions of the Schuylkill watershed and western New Jersey received larger amounts of precipitation in the range of 7 to 10 inches.

Figures 1 and 2 graphically present the Multi-sensor Precipitation Estimates for Hurricane Irene, and Tropical Storm Lee. Table 1 presents the precipitation amounts in various locations in the basin for Hurricane Irene, Tropical Storm Lee and the combined total from August 24, 2011 through September 9, 2011.

Figure 1.

Precipitation Totals from Hurricane Irene

August 24, 2011 8:00 am - August 29, 2011 8:00 am

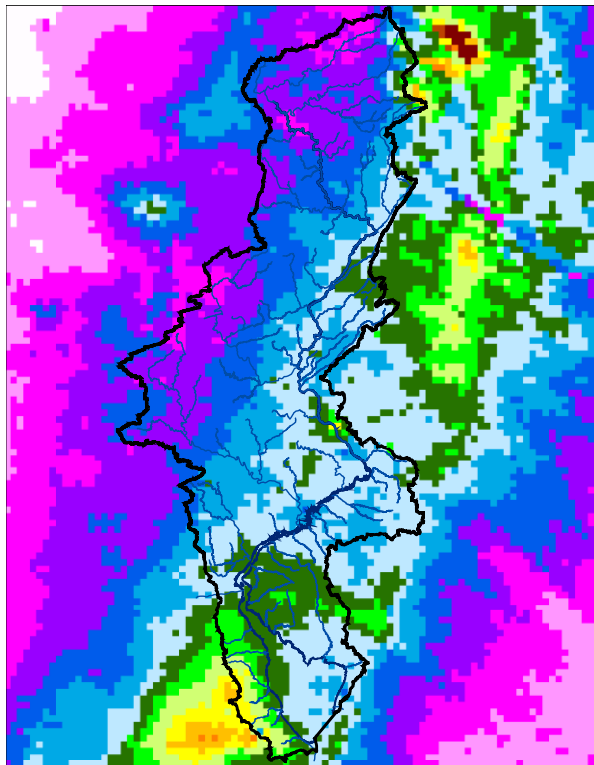
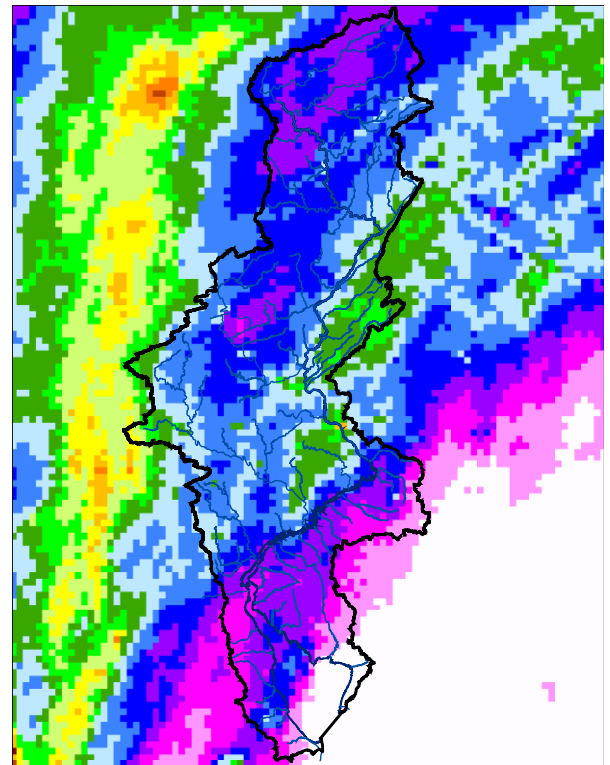


Figure 2.

Precipitation Totals from Tropical Storm Lee

September 5, 2011 8:00 am – September 9, 2011 8:00 am



Provisional data provided by the Mid-Atlantic River Forecast Center.

Flood Stages

The National Weather Service has defined categories of flooding for forecast purposes based on the severity of potential impacts to property and the public. These categories are Action, Flood, Moderate and Major, with more severe flooding occurring in the Moderate and Major categories.¹ As the result of runoff generated by Hurricane Irene, Moderate and Major flooding were observed on the East Branch Delaware and Neversink Rivers, respectively. Other upper basin flood forecast locations were at Action or Flood Stage. On the main stem, most locations achieved Action or Flood stage, except for the Water Gap, where there was Moderate flooding and Montague and Port Jervis, where the river remained below Action Stage. The Lehigh River remained below Action Stage, except at Glendon, which is affected by backwater from the Delaware River, and the Little Lehigh Creek. Many of the lower basin tributaries experienced Major flooding with a few tributaries exceeding their floods of record at some locations. Those included the Assunpink at Trenton, where the Trenton Transit Center flooded, the Christina River at Coochs Bridge, Perkiomen Creek at East Greenville and the Neshaminy Creek at Penns Park. Major and Moderate flooding occurred along the lower Schuylkill River.

High streamflow conditions and runoff from Tropical Storm Lee resulted in Moderate flooding at several locations in the upper basin, primarily on the West and East Branches of the Delaware River. Much of the main stem also experienced Moderate flooding, except Trenton and Barryville, which achieved Flood stage, and New Hope, which just reached Major flood stage. Port Jervis stayed below Action Stage while unlike during Hurricane Irene, Montague reached Action Stage. Smaller lower basin tributaries, such as the Assunpink, Rancocas, Chester Creek and the Red and White Clay Creeks fared better during Tropical Storm Lee than Hurricane Irene, most staying below or barely reaching Action Stage. Only one location on the Brandywine, Chadds Ford, reached Major flood stage. Above Norristown, the Schuylkill River and Perkiomen reached Moderate Flood Stage, while Norristown and Philadelphia reached Flood Stage.

Figures 3 and 4 present the National Weather Service defined flood stage category achieved at the result of Hurricane Irene and Tropical Storm Lee at each of the Advanced Hydrologic Prediction Service flood forecast locations. For comparison purposes, Table 2 also presents a summary of the locations and the Flood Category Stage that was reached for both Hurricane Irene and Tropical Storm Lee. Also included are stages for flood peaks for the three major floods in September 2004, April 2005 and June 2006 as well as the flood of August 1955. Based upon preliminary data for both Hurricane Irene and Tropical Storm Lee, the Delaware River at Trenton achieved its 17th and 9th largest crests on record, respectively. At the Schuylkill River at Philadelphia, the crests achieved were the 7th and 11th largest crests on record, respectively. These ranks account for re-ordering due to the two events.

Reservoir Operations

New York City Reservoirs

Based upon the Flexible Flow Management Program (FFMP) dated June 1, 2011, New York City makes releases from its Delaware Basin Reservoirs to achieve a seasonal conditional storage objective of 90 percent to mitigate spills. Prior to Hurricane Irene, Cannonsville, Pepacton and Neversink were 83.3, 92.0 and 90.7 percent full, respectively. Based upon inflow predictions from the National Weather Service, releases were increased to the maximum level at Pepacton and Neversink several days prior to the arrival of the Hurricane to reduce the reservoirs' storages to 90 percent. During the storm, releases were reduced, as required by the FFMP, when locations downstream reached flood stage. As the result of runoff from Irene, Pepacton and Neversink reservoirs spilled and Cannonsville filled to 98.2 percent. From August 31 through September 5, releases were increased to their maximum rate in accordance with the FFMP and to reduce the

Table 1. Precipitation Amounts (inches) from Hurricane Irene and Tropical Storm Lee

Location (Gage ID)	Hurricane Irene 8/27-8/29	Tropical Storm Lee 9/4-9/11	Total† 8/25-9/11
Cannonsville (NYC*)	3.6	5.27	9.27
Pepacton (NYC*) (PEPN6)	4.54	5.62	10.71
Neversink (NYC*)	4.80	5.19	10.64
Honesdale (HONP1)	4.5	5.61	10.06
Hawley HAWP1/HWYP1)	5.4	4.73	10.57
Belvidere (BELN4)	6.8	8.61	15.42
Bethlehem (BETP1)	7.5	8.67	16.16
Easton/Phillipsburg (ESTN4)	5.9	8.00	13.86
Stockton (STKN4)	12.3	12.04	24.34
Trenton AP (TTN)	6.2	4.74	10.93
Berne (BREPE1)	3.3	6.98	10.25
Reading AP (RDG)	3.2	8.33	11.59
Philadelphia AP (PHL)	6.6	6.34	12.83
Wilmington AP (ILG)	7.6	3.00	10.64
Smyrna, DE (DEKN03)	10.3	2.53	12.83

Data provided by NOAA unless otherwise noted. NOAA data for Irene reported to nearest tenth of an inch. * Provided by NYCDEP, includes 8/27/2011; † Values include rainfall that occurred before and between events. All data are provisional.

¹ For definitions of the NWS Flood Forecast Stage categories, see <http://www.nws.noaa.gov/directives/sym/pd01009050curr.pdf>.

storage prior to precipitation and runoff anticipated with Tropical Storm Lee. On September 6, before the arrival of Tropical Storm Lee, Pepacton and Neversink were still spilling and Cannonsville was 99.4 percent full, despite the maximum releases made between the two storms. Although Neversink continued to spill into October due to additional rainfall, Pepacton and Cannonsville stopped spilling by September 20th.

Figure 3. Highest Flood Stage Reached During Hurricane Irene

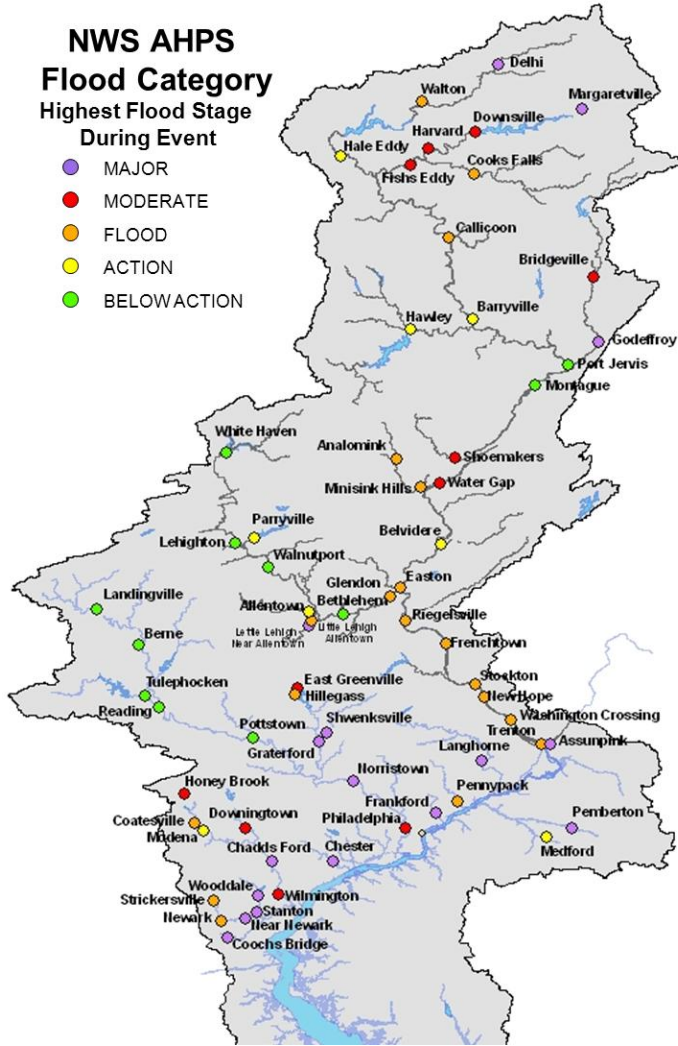
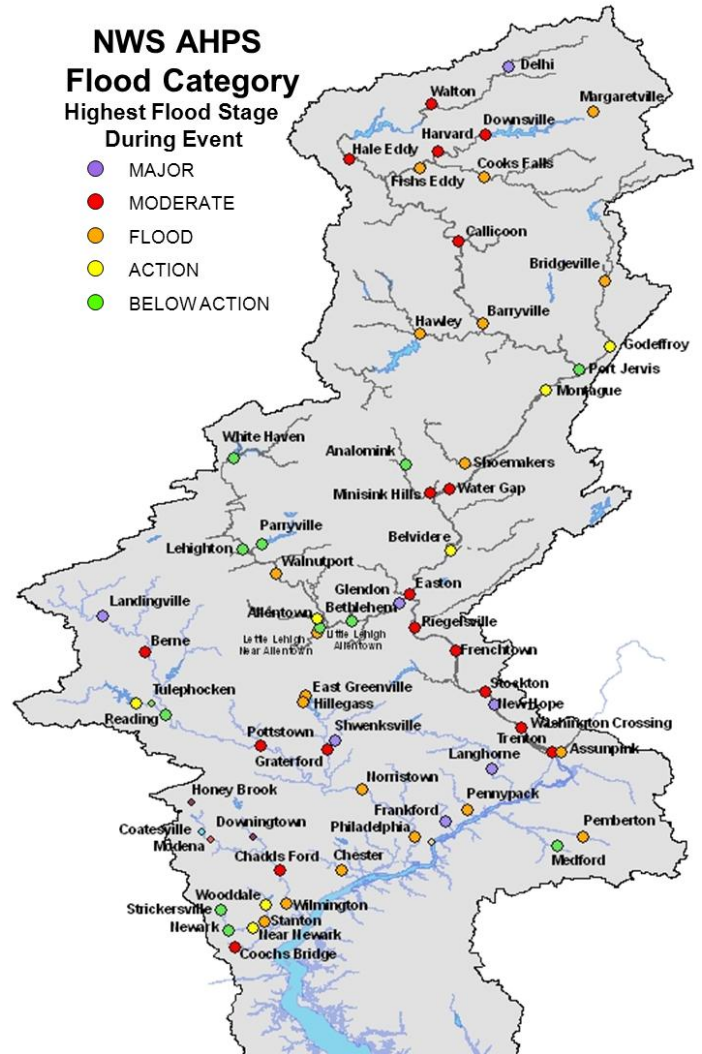


Figure 4. Highest Flood Stage Reached During Tropical Storm Lee



Displayed flood stages represent the maximum stage achieved for each event. The graphics do not represent the flood stage for an instant in time because not all peaks occur at the same time. Graphics prepared by DRBC Staff. The highest flood stages are provisional and subject to revision.

Lake Wallenpaupack

Prior to Hurricane Irene, Lake Wallenpaupack was 53 percent full, which was at its normal operating pool level for August. PP&L generated hydropower at release rates between 1,000 and 1,500 cfs through both Irene and Lee. In doing so, the runoff from both storms was captured and additional releases through the spillway roller gates during the events were not required. After the events, when river levels had receded, PP&L conducted a controlled release from Sept. 12 to 18 to reduce the lake levels by 7 feet, back to their normal operating level. Approximately 8 billion gallons of water was released through the spillway gates and an additional 4 billion gallons was passed through the Wallenpaupack hydroelectric plant, reducing the storage from more than 90 percent to less than 60 percent in accordance with their operating guide curve for September. The controlled release is noteworthy because the spillway gates have only been used for such releases ten times in 86 years of the facility’s operation.

USACE Reservoirsⁱ

The USACE owns and operates two flood control reservoirs in the Lackawaxen basin, two multi-purpose reservoirs in the Lehigh basin and one multi-purpose reservoir in the Schuylkill basin. Prompton and Jadwin are located in the

Lackawaxen basin. Outflows from these reservoirs are uncontrolled, but limited by the design of the outlet works to the non-damaging capacity of the downstream channel. When inflow exceeds the capacity of the outlet works, water is impounded behind the dam. At their fullest, during Irene and Lee, 5.3 and 6.8 percent of Jadwin's and 2.7 and 4.1 percent of Prompton's flood control storages were used, respectively. The Lehigh basin contains FE Walter and Beltzville Reservoirs. Prior to Hurricane Irene, both reservoirs were releasing additional water to return to their normal pool elevations after thunderstorms on August 27th. Runoff from Hurricane Irene filled 32 percent of FE Walter's and 17 percent of Beltzville's flood control storage. Releases were made from FE Walter and Beltzville afterwards to empty their flood control storage to capture runoff from Tropical Storm Lee. Runoff from Tropical Storm Lee filled the flood control storage to 46 percent in FE Walter and 27 percent in Beltzville. In the Schuylkill Basin, in preparation for Hurricane Irene, the USACE made releases to reduce the summer pool at Blue Marsh to create additional flood control storage. Only 5 percent of the summer flood control storage was filled from runoff generated by Hurricane Irene. The reservoir returned to its normal summer pool elevation, just prior to Tropical Storm Lee, as the result of additional releases between the two storm events. Runoff from Tropical Storm Lee filled Blue Marsh reservoir with a peak inflow rate of approximately 8,000 cfs. During the event (on September 8th), the reservoir rose 4 feet in 5 hours and began to spill even though the USACE had begun pre-emptive releases, of up to 5,500 cfs to delay the spill, in accordance with their emergency action plan. As a result of runoff from Tropical Storm Lee, Blue Marsh reached its record pool elevation while spilling.

Table 2. Peak Crests* at Select Flood Forecast Locations

	Irene 8/27-8/29/2011		Lee 9/6-9/9/2011		NWS Flood Category Stages			Reference Flood Crests				
	Crest Time	Crest	Crest Time	Crest	Flood	Moderate	Major	1955	2004	2005	2006	Record
Walton	8/29/2011 3:15	13.7	9/8/11 6:30	14.4	9.5	14	16	12.87	13.05	--	16.85	16.85
Hale Eddy	8/28/2011 16:15	9.97	9/8/11 10:45	14.71	11	13	15	12.67	12.83	14.12	19.10	20.30
Harvard	8/29/2011 10:15	13.31	9/7/11 21:45	14.71	10	12	15	--	16.07	16.32	16.62	16.93
Cooks Falls	8/28/2011 14:30	15.6	9/7/11 20:30	13.64	10	16	18	11.44	17.67	18.98	20.54	20.54
Fishes Eddy	8/28/2011 16:00	16.04	9/8/11 11:45	15.79	13	16	18	15.29	21.40	22.49	21.45	23.60
Callicoon	8/28/2011 22:15	12.9	9/8/11 17:30	14.34	12	13	14.8	--	17.33	17.98	20.37	20.37
Barryville	8/29/2011 2:00	16.78	9/8/11 0:00	18.52	17	22	26	26.40	24.09	24.80	28.97	28.97
Hawley	8/28/2011 11:30	10.39	9/7/11 7:45	11.3	11	12	20	24.80	14.49	15.25	18.19	24.80
Port Jervis	8/29/2011 4:45	14.02	9/8/11 21:15	15.11	18	24	27	23.91	19.52	20.53	21.43	25.50
Bridgeville	8/28/2011 21:00	18.02	9/7/11 13:30	14.05	13	17	19	--	12.58	21.25	16.16	21.25
Godeffroy	8/28/2011 12:15	12.05	9/7/11 15:15	9.92	10	11	12	12.49	8.22	12.40	11.08	12.49
Montague	8/29/2011 7:30	21.94	9/8/11 21:45	23.01	25	28	33	35.15	--	31.69	32.16	35.50
Shoemakers	8/28/2011 10:45	7.35	9/8/11 6:30	6.16	6	7	8	13.95	7.27	7.51	7.31	13.95
Water Gap - Tocks	8/29/2011 12:45	23.2	9/9/11 2:00	24.94	21	23	25	37.40	30.34	33.24	33.87	37.40
Minisink Hills	8/28/2011 11:15	11.4	9/9/11 1:00	12.46	10	12	15	27.00	11.66	20.99	21.34	27.00
Belvidere	8/29/2011 14:30	19.85	9/9/11 3:15	21.55	22	24	25	30.21	24.80	27.24	27.16	30.21
Easton	8/29/2011 17:00	25.2	9/9/11 3:00	29.93	22	26	30	43.70	33.45	37.20	37.09	43.70
Riegelsville	8/29/2011 6:30	24.56	9/9/11 5:15	28.06	22	26	30	38.85	30.95	34.07	33.62	38.85
Frenchtown	8/29/2011 8:15	16.7	9/9/11 7:15	19.02	16	18	20	27.79	20.70	23.60	23.40	27.79
Stockton	8/29/2011 9:30	18.7	9/8/11 6:45	21.76	18	20	24	30.44	22.50	26.79	25.39	30.44
New Hope	8/29/2011 10:45	12.74	9/8/11 7:00	16.14	13	15	16	24.16	16.50	19.60	19.08	24.16
Washington Crossing	8/29/2011 12:00	16.1	9/8/11 8:00	20.4	16	19	22	27.77	20.20	23.10	22.54	27.77
Trenton	8/29/2011 15:30	20.5	9/8/11 9:15	23.11	20	23	25	28.60	23.41	25.33	25.09	30.60
Assunpink	8/29/2011 19:00	15.12	9/8/11 0:00	9.28	8.5	9.5	11	--	--	8.62	--	15.12
Pemberton	8/29/2011 8:15	4.91	9/8/11 14:15	2.37	2.5	3.5	4.2	--	--	--	--	4.91
Langhorne	8/28/2011 11:15	19.6	9/8/11 14:45	18.09	11	13	16	22.84	--	12.87	13.88	22.84
Graterford	8/28/2011 12:00	18.2	9/7/11 5:45	13.93	11	13	16	--	14.80	14.18	13.68	18.26
Berne	8/28/2011 12:00	8.88	9/8/11 12:30	15.45	12	14	16	15.73	15.05	--	18.57	19.00
Reading	8/28/2011 22:30	10.05	9/8/11 18:30	20.4	15.5	18	22	--	16.24	12.84	23.75	31.30
Pottstown	8/28/2011 14:15	10.29	9/9/11 6:30	18.27	12.5	18	22	17.98	14.59	13.41	20.84	29.97
Norristown	8/28/2011 13:45	19.8	9/7/11 10:15	16.06	17	19	22	18.40	16.00	16.06	19.13	25.10
Philadelphia	8/28/2011 14:30	13.6	9/8/11 10:30	12.52	11	13	15.5	--	11.33	11.74	12.49	17.00
Chadds Ford	8/28/2011 13:15	15.23	9/8/11 6:15	11.7	9	11	13	14.64	13.62	--	13.33	17.15
Wilmington	8/28/2011 13:30	18.7	9/8/11 9:15	16.7	16.5	18	19	13.89	--	--	12.46	18.70

*Crests are the observed stage in feet above the local datum used by the U.S. Geological Survey (USGS).

All data are provisional and subject to revision.

ⁱ All quantitative data provided by the USACE, Philadelphia District.