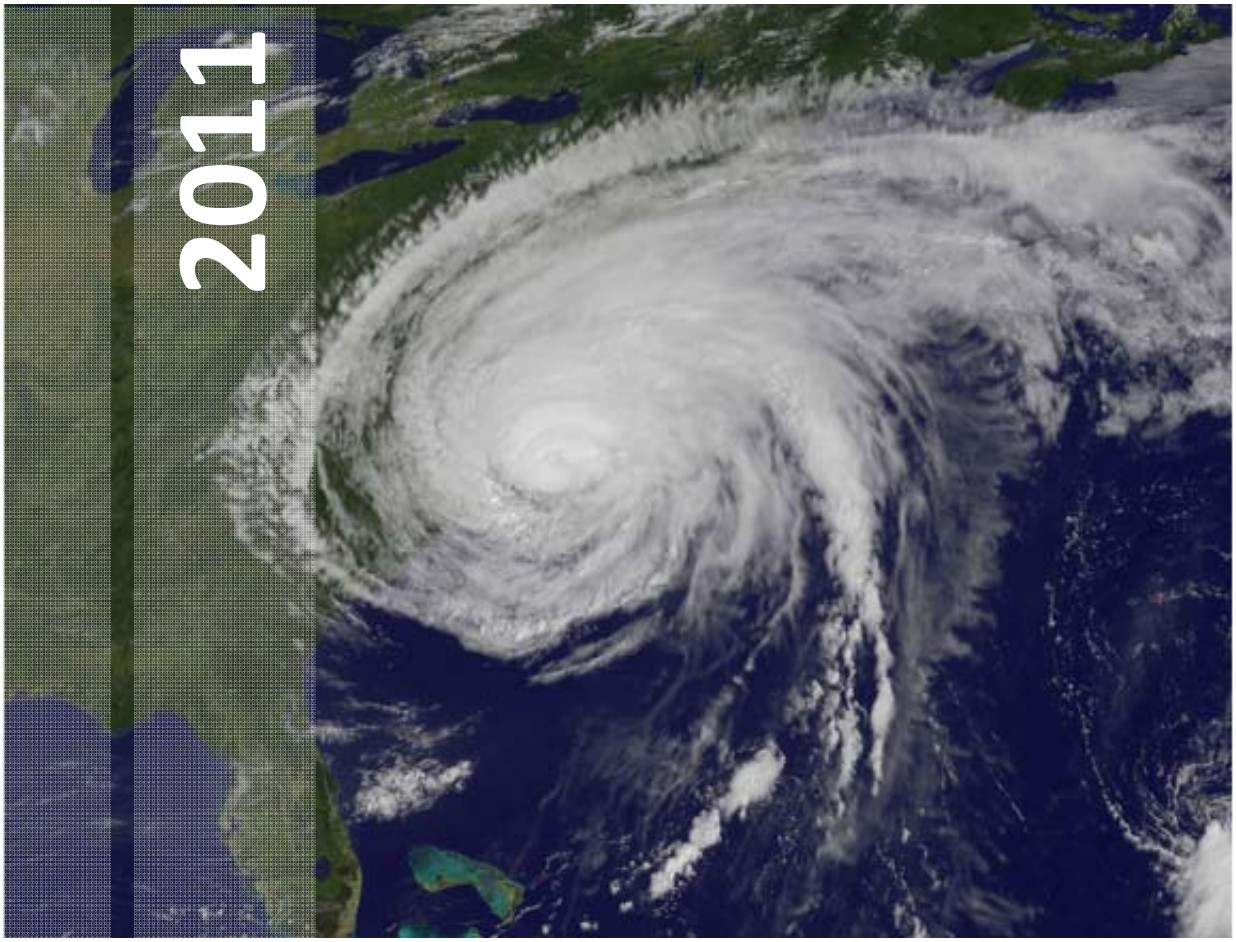
Hydrologic Conditions in the Delaware River Basin



Hurricane Irene on August 27, 2011 at 10:10 a.m. EDT after it made landfall at 8 a.m. in Cape Lookout, North Carolina. Irene's outer bands had already extended into New England. Credit: NASA/NOAA GOES Project.

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Delaware River Basin Commission
DELAWARE · NEW JERSEY
PENNSYLVANIA · NEW YORK
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Hydrologic Conditions in the Delaware River Basin
Annual Report 2011

Hydrologic Highlights of 2011

March Flooding

Heavy rain fell across the Delaware River Basin (DRB) March 6-7, boosting streamflow and saturating the ground. The tail end of the storm brought cold air and produced snow in the northern regions of the basin, suppressing rainfall and runoff amounts in these areas. Minor flooding occurred throughout the DRB.

Shortly after flooding from the first storm subsided, another system impacted the DRB on March 10-13. Conditions were favorable for another flood event: streamflows were high, the ground was saturated, and a portion of the upper basin snowpack had the potential to melt and contribute to runoff. The second storm produced heavy rain and runoff that resulted in widespread flooding along the East and West Branches of the Delaware in the upper DRB and along the main stem Delaware River and its tributaries. Several points along the main stem Delaware from Tocks Island to Trenton, N.J. exceeded flood stage with some locations experiencing moderate flooding. Along the Lehigh River, the Delaware's second largest tributary, major flood stage was reached at Glendon, Pa. while Walnutport, Pa. registered its third highest crest on record. Moderate flooding was experienced along the upper reaches of the Schuylkill River (the Delaware's largest tributary) at Landingville, Pa. and Berne, Pa.

Total rainfall from the March 10-13 event ranged from 2.5 to 5.0 inches along and north of Interstate 78 to between 1.0 and 2.5 inches in other areas of the basin. Combined rainfall amounts from these two events ranged from as little as 2 inches in parts of Delaware and southern New Jersey to between 7 and 8 inches in some regions of the Poconos and northern New Jersey.

Summer Drought

Abnormally dry conditions developed in the basin in June and persisted through late August. Below-normal rainfall during this time resulted in declining streamflow and groundwater levels. On August 5, hydrologic conditions and rainfall deficits prompted the Pennsylvania Department of Environmental Protection (PADEP) to declare a drought watch[1] for 40 counties across Pennsylvania, including nine counties in the DRB. The DRB counties included Berks, Bucks, Chester, Delaware, Lancaster, Lebanon, Montgomery, Philadelphia and Schuylkill.

The drought was brief, however, due to the excessive rainfall produced from Hurricane Irene at the end of August. Improved hydrologic conditions statewide prompted PADEP to lift its drought watch on September 2 for all but four counties in the northwestern and north central regions of Pennsylvania[2]. All counties in the DRB were returned to normal hydrologic status.

Hurricane Irene and Tropical Storm Lee

On August 27-28, Hurricane Irene traveled up the East Coast and delivered widespread rainfall in amounts of 5 to 8 inches, 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 August in Philadelphia, Pa. was

[1] Drought watch is the first and least severe of Pennsylvania's three drought classifications.

[2] PADEP lifted the drought watch for Cameron, Elk, McKean, and Potter counties on October 13, 2011. This was after Hurricane Irene and Tropical Storm Lee erased rainfall deficits and improved streamflow and groundwater levels in these counties.

19.31 inches, which exceeded the all-time maximum monthly accumulation of 13.07 inches for September 1999.

Tropical Storm Lee followed shortly thereafter on September 5-9. 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 rainfall amounts in the range of 7 to 10 inches.

A separate summary report provides additional information about the widespread flooding that occurred after both Irene and Lee.

Coastal Flooding in the Tidal Delaware River

On September 29 and 30, several conditions occurred that produced moderate coastal flooding along portions of the tidal Delaware River in areas north of Philadelphia towards Trenton. Tides were already high in both the Delaware Bay and the tidal Delaware River from a prevailing southerly wind and the September 27 new moon. At the same time, the tidal Delaware River was receiving high flows generated from storms earlier in the week. Many residents and business owners in the impacted areas were not prepared for the sudden flooding. Some of the areas affected by flooding included Bristol Borough in Bucks County, Pa. and Delran Township in Burlington County, N.J.

Historic October Nor'easter

On October 29, 2011, the DRB was impacted by a Nor'easter that produced heavy rain and strong winds along with sleet and rare October snow. For many locations in the basin, the storm began as rain but as temperatures dropped, the rain turned into sleet and snow. Historic October snow accumulations were produced throughout eastern Pennsylvania as well as in northern and western New Jersey. Snow totals of 8 to 16 inches fell across the Poconos, Lehigh Valley, and Berks County in Pennsylvania and into the mountains of northwest New Jersey. North central New Jersey also received significant snow of 8 to 12 inches.

Storm totals were much less in the lower Delaware Valley. In this region, the storm produced a mix of precipitation and snow accumulations of 1 to 3 inches were recorded. Sleet extended as far south as northern Delaware. Moderate to heavy rain fell in central and southern Delaware. Strong 15 to 25 mph winds accompanied the storm, with gusts to 35 mph. Gale force winds and minor flooding were reported along coastal locations in New Jersey and Delaware. The storm caused extensive power outages throughout the DRB and substantial travel delays due to slippery roads and canceled flights.

Precipitation

On average, DRB counties received 150% of their normal precipitation during 2011. Much of this surplus resulted from Hurricane Irene and Tropical Storm Lee during August and September. Annual precipitation totals ranged from 42.4 inches in Sussex Co., Del. to 81.6 inches in Warren Co., N.J. Annual precipitation departures from normal ranged from 1.8 inches below normal in Sussex Co., Del. to 36.8 inches above normal in Warren Co., N.J. Thirty-seven of the 38 reported counties[3] within the DRB ended the year with above-normal precipitation.

[3] This information is based on precipitation data from the National Weather Service Middle Atlantic River Forecast Center for 38 of the 42 counties located either partially or completely in the Delaware River Basin. Data for the remaining four counties is not available. Departures from normal are calculated by DRBC staff.

The observed precipitation above Montague, N.J. for 2011 was 70.39 inches, or 27.13 inches above normal. Similarly, observed precipitation above Trenton was 71.60 inches, or 26.71 inches above normal. Precipitation at Wilmington, Del. was 56.58 inches, or 13.77 inches above normal. Figure 1 presents the annual precipitation by county in the Delaware River Basin and Table 1 presents normal and observed monthly precipitation totals at selected stations in the DRB for 2011.

Streamflow

Monthly mean streamflow observations at selected stations along the Lehigh River, the Schuylkill River, and the main stem of the Delaware River were below normal during January and February 2011. Streamflow recovered after early March storms produced heavy rain, melted snowpack, and caused flooding at numerous locations in the basin.

Observed monthly mean streamflow at the selected stations generally remained normal to above normal throughout the summer months. In the Schuylkill River Basin, where drought was more prevalent and drought watches would be issued for Schuylkill, Berks, Montgomery, and Philadelphia counties, below-normal streamflow was recorded along the Schuylkill River during the month of July. Monthly mean streamflow observations at Pottstown, Pa. and Philadelphia were at 72% and 56% of the monthly mean, respectively.

Tropical storm activity during August and September produced the highest observed monthly mean streamflow of the year. The Delaware River at Montague and Trenton averaged five times the normal August flow and more than ten times the normal September flow. Streamflow at the selected stations remained above the normal monthly flow for the remainder of 2011. Table 2 presents observed monthly mean streamflow at selected stations for 2011 and Figures 2 and 3 present annual hydrographs for 2011 at Montague and Trenton.

Reservoir Storage

Lower Basin

Both Beltzville Reservoir (located on the Pohopoco Creek, a tributary of the Lehigh River) and Blue Marsh Reservoir (located on the Tulpehocken Creek, a tributary of the Schuylkill River) maintained storage in the normal range during 2011. Consequently, the DRBC's lower basin drought operating plan was not implemented. As a result, DRBC did not have to direct releases from lower basin storage during 2011 to meet the Delaware River flow objective of 3,000 cubic feet per second (cfs) at Trenton. Figures 4 and 5 present reservoir elevations for 2011 for Beltzville and Blue Marsh.

Storage in Merrill Creek Reservoir, located near Phillipsburg N.J., is used to replace evaporative losses caused by power generation when the basin is under DRBC-declared drought operations and the equivalent average daily flow target at Trenton, N.J. is below 3,000 cfs. While no releases were made from Merrill Creek Reservoir during 2011 to replace evaporative loss, releases were made during September (362 million gallons [mg]), October (126 mg), and December (100 mg) to lower the reservoir pool due to excessive inflow from precipitation events.

Impacts of Irene and Lee on U.S. Army Corps of Engineers' Lower Basin Reservoirs

Hurricane Irene and Tropical Storm Lee impacted the operations of F.E. Walter, Beltzville, and Blue Marsh reservoirs during late August and early September 2011. The Army Corps of Engineers (ACOE) made extra releases from these reservoirs several days prior to the storm events to create additional storage to capture the high inflows produced by Irene and Lee.

The reservoirs captured and stored the inflow produced by Hurricane Irene. During Tropical Storm Lee, which arrived after Hurricane Irene, storage in Beltzville Reservoir and F.E. Walter Reservoir remained below their

respective spillways. However, inflow to Blue Marsh Reservoir resulted in a spill for only the second time in its history. On September 8, the ACOE issued an emergency declaration after the dam pool level reached the spillway and the release gates were opened fully to allow 5,400 cfs to pass out of the reservoir to reduce the lake's elevation. The dam reached a new record elevation of 309.38 feet on September 9, 2011, surpassing the previous high of 309.19 feet measured in June 2006.

Upper Basin

The three New York City (NYC) Delaware Basin reservoirs -- Cannonsville, Pepacton, and Neversink -- are located in the upper DRB and operated under the Flexible Flow Management Program (FFMP)[4]. Combined storage did not go below the drought watch level during 2011; consequently, DRBC's basinwide drought operating plan was not implemented.

On January 1, 2011, combined storage in the three NYC reservoirs was 239 billion gallons (bg), which is 88% usable capacity and 50 bg above the long-term median usable storage for that date. Combined storage in the reservoirs remained above the long-term median storage except for two short periods when it was below the median in mid-February and early March. March storms produced heavy rainfall and runoff that, in combination with melting snowpack, refilled the reservoirs by the second week in March. The normal refill date for the NYC reservoirs is May 1. Combined storage stayed above the long-term median for the remainder of the year. Figure 6 presents NYC reservoir storage levels for 2011.

The Office of the Delaware River Master briefly directed releases from the NYC reservoirs totaling approximately 0.85 bg from July 24-28, 2011. Such releases are directed when necessary to meet the normal flow target of 1,750 cfs for the Delaware River at Montague, N.J. as required by the 1954 U.S. Supreme Court Decree. By comparison, directed releases totaled 43.7 bg in 2010 and 101 bg during the drought year 2001.

Impacts of Hurricane Irene and Tropical Storm Lee on Upper Basin Reservoirs

In addition to impacting the lower basin reservoirs, Irene and Lee affected the operations of upper basin reservoirs, including the NYC Delaware reservoirs and PPL's Lake Wallenpaupack. Several days in advance of Hurricane Irene, NYC DEP began releases from Neversink and Pepacton reservoirs to create extra storage to capture some storm runoff. Releases began on August 23 and were made at the maximum rates allowed by the FFMP.

On September 12 a few days after Tropical Storm Lee impacted the basin, PPL opened the roller gates of its dam at Lake Wallenpaupack to allow for a controlled release of the lake water that had risen to within two feet of the top of the gates. The last time PPL released water through the gates was June 2006. The spillway gates have only been used for such releases 10 times over the past 86 years of operation.

Groundwater

The average monthly groundwater level in eight reported U.S. Geological Survey (USGS) observation wells in the Pennsylvania portion of the basin was below the long-term average during January and February 2011. Groundwater at that time was still recovering from dry conditions experienced during 2010. Recharged by rainfall and snowmelt, the average monthly level was above the long-term average by March. However, the average groundwater level trended downward during the spring and summer months, decreasing sharply during drier periods in May through late August. The arrival of Hurricane Irene in late August increased levels to much

[4] Beginning in October 2007, the NYC reservoirs were operated in accordance with the FFMP, a temporary operations plan unanimously approved by the parties to the 1954 U.S. Supreme Court Decree (four basin states and NYC).

above the average level by September. The average water level for the eight wells remained above the long-term average through the end of 2011.

The groundwater level in the New Castle Co., Del. coastal plain well began the year within the lower half (25- to 50-percentile) of the normal range[5]. The groundwater level stayed within the normal range until rain from Hurricane Irene and Tropical Storm Lee recharged the well. Groundwater began an upward trend in August. By October, groundwater was above the normal range, where it remained until the end of 2011.

The groundwater level in the Cumberland Co., N.J. coastal plain well began the year within the normal range. Runoff from Hurricane Irene and Tropical Storm Lee caused the groundwater level to rise above the normal range in September, where it remained until the end of the year. Figures 7, 8, and 9 present graphics of groundwater levels throughout the year for the eight USGS network wells in Pennsylvania, the Delaware Geological Survey (DGS) well in New Castle Co., and the USGS well in Cumberland Co.

Salt Front

The *salt front* is defined as the 250 parts-per-million (ppm) isochlor. The seven-day average location of the salt front is used by DRBC as an indicator of salinity intrusion in the Delaware Estuary. The salt front's location fluctuates along the main stem Delaware River as streamflow increases or decreases in response to changing inflows, diluting or concentrating chlorides in the river. Long-term average mid-month locations range from river mile 61 in mid-April (0.5 miles below Pea Patch Island, Del.) to river mile 81 in mid-October (Marcus Hook, Pa.). The farthest recorded upstream location of the salt front, river mile 102, was measured during the 1960's drought of record. The farthest upstream location of the salt front during 2011 was the Delaware-Pennsylvania state line (river mile 78). Figure 10 presents the seven-day average location of the 250-ppm isochlor during 2011.

[5] Water level ranges are defined as: Above Normal (>75-percentile); Normal (25- to 75- percentile flows); Below Normal (<25-percentile).