February 2021

2020 Hydrologic Conditions Report

Technical Report No. 2021-2

Prepared by
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Acknowledgements

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Suggested Citation

DRBC. 2020 Hydrologic Conditions Report. West Trenton, N.J. February 2021.

2020 Main Hydrologic Events Timeline

The following is a brief summary of the major events that impacted hydrologic conditions of the basin.

- **Winter:** The winter of 2019 – 2020 was record breaking for the basin. The Philadelphia region recorded its second lowest snowfall of 0.3 inches total for the season. Little snow fell across the southern half of the basin as well. Figure 1 displays the snowfall accumulation through the end of the season. Although the upper basin received more than of 45 inches of snow in most areas (near normal), snow totals were much lower in southern portions of the basin. Large portions of the lower basin received less than an inch of snow over the entire season.
- **Spring storm**: From April 30 – May 1, a strong low-pressure system made its way across the basin. The largest amount of rain fell along a corridor from the western-central basin through northeast Pennsylvania and into the New York. These areas received greater than 2.5 inches. Figure 2 shows the rainfall amounts from this storm event. Flows in tributaries and the main stem increased as a result of the runoff as shown in Figure 3. Peak flows were two to three times higher than the flow prior to the event. Figure 4 shows the salt front movement of approximately ten miles downstream in response to the event. The three New York City reservoirs were filled and began spilling. Cannonsville spilled approximately 4.5 BG over twelve days. Pepacton spilled approximately 7.5 BG over ten days. Neversink spilled approximately 2.5 BG over five days
- **Tropical Storm Fay:** On July 10, Tropical Storm Fay made landfall east of the basin just north of Atlantic City, NJ, producing heavy rain in the southern half of the basin. Figures 5, 6, and 7 show the precipitation totals from the event, which were mainly concentrated in the southern regions of the basin. Resultant streamflows were three to four times the normal amount. Although the streamflows were high, the salt front only moved downstream by approximately one mile, and flooding did not occur on the main stem. Due to the isolated location of large rainfall amounts, Fay had a limited impact on the hydrologic conditions in the basin.

- **Tropical Storm Isaias:** On August 3 and 4 the remnants of Hurricane Isaias passed over the basin after it was downgraded to a tropical storm. In contrast to Fay, the heavy rain occurred over the central basin and northern basin, with maximum amounts in eastern Pennsylvania of 7.5 inches as shown in Figure 8. The resulting streamflows from Isaias as shown in Figure 9 were the third highest streamflow for the year at Montague, the second highest stream flow for the year at Trenton as well as on the Lehigh River, and the highest flow of the year on the Schuylkill. The Schuylkill river and its tributaries experienced flooding from this event. The Little Lehigh creek at Allentown and the Perkiomen Creek at Graterford, reached their highest levels for the period of record, which was 30 years for the Little Lehigh and 34 years for the Perkiomen. Figure 10 displays some of the gages that experienced flooding as the result of rainfall from Isaias. The gage at Reedy Island was not recording during this time and the data needed to calculate the location of the salt front were not available. Prior to Isaias, the salt front was near RM 69. When data again became available on August 14, 2020 (ten days after Isaias), the salt front was approximately 4 miles downstream.
- **Thermal Releases:** Eight multi-day warm temperature events required thermal releases for a total of 34 days from June 9, 2020 – August 1, 2020. Approximately 2,330 cfs days (approximately 1506 million gallons) of the 2,500 cfs-day thermal mitigation bank were used. Water temperatures at Lordville exceeded 75 ^{O}F on one day in June and seven days in July. The water temperature at Lordville reached a high of 76.3 ^{O}F on both June 22, 2020 and again on July 20, 2020.
- **Dry conditions:** Due to dry conditions in the fall, approximately 19.7 billion gallons of water was released between September 10 and October 30 from the three New York City reservoirs (Cannonsville, Pepacton, and Neversink) to meet the flow objective at Montague[1]. Water was released on one day at the start of the period from Blue Marsh reservoir to meet the Trenton Equivalent Flow Objective (133 million gallons). On October 29, the three upper basin reservoirs were at the lowest combined storage for the year of

[1] Additional releases for other short duration dry periods were also made for a total of 21.4 BG in 2020. See Reservoir Storage and Releases, Upper Basin section.

approximately 163.4 BG, 53.4 BG higher than drought watch. On October 31, 2020, the salt front was at its most upstream location of the year near river mile 76, just north of the mouth of Stoney Creek, DE.

- **Snowstorm and Flood Event:** A winter storm impacted the region on December 16 and 17. Areas in the Pennsylvania regions of the basin received greater than 8 inches of snow, with larger amounts up to 30 inches in the northern regions of the basin, as shown in Figure 13. On December 24, temperatures in the 60s Fahrenheit followed by a period of heavy rain resulted in melting of the snowpack and high river rises. Figure 14 shows precipitation totals across the basin were greater than 1.5 inches in most areas, and higher amounts were observed in eastern Pennsylvania as well as Delaware. Figure 15 shows the resulting streamflows from the combined rainfall, runoff, and snowmelt. The streamflows were the highest of the year for Montague, Trenton, and the Lehigh and the second highest streamflow of the year for the Schuylkill River. Several locations in the basin experienced flooding, including tidal areas and the main stem. Figure 16 shows six gages where flooding occurred during and after this event. The New York City Storage increased from 193.1 to 236.5 BG in just 5 days. Neversink reservoir began to spill on December 25 and continued to spill through the end of the year for a total of 616 MG spilled. The reservoir continued to spill an additional 10 MG on January 1, 2021 before stopping.

Precipitation

Annual total precipitation ranged from 40 inches in the western portion of the basin to 76 inches in southern portion of the basin. Table 1 lists precipitation, departures from normal, and ranks for nine representative locations. Figure 17 presents maps of precipitation amounts and departures from normal (using the 30-year average spanning 1981 – 2010).

Dry conditions occurred in western regions of the basin extending northeast towards New York. Some of these areas received precipitation amounts that were between 10-15 inches below normal. In the southern part of the basin, especially Delaware, annual precipitation was approximately 30 inches above normal. Figure 18 ranks the precipitation at the nine representative stations in the basin from

most to least. In 2020, Callicoon, NY received the most precipitation and Sussex, NJ received the least.

Figure 19 presents the monthly precipitation at each station. August 2020 precipitation was greater than normal due to Tropical Storm Isaias. August precipitation ranked in the top ten wettest for each of the nine representative stations for their respective periods of record, excluding the Sussex, NJ airport (which is located just outside the basin). Reading, PA ranked second, Callicoon, NY ranked third, and both Wilmington, DE and Mount Pocono, PA ranked fourth. In contrast, May was dry for four locations and was the second driest on record for Reading, PA. For other stations, the precipitation for May was normal.

Streamflow

Figure 20 presents the time series of streamflow for 2020 on the left and a comparison of the average monthly flow to normal (long-term median) on the right at four gages in the Delaware River. Two major rainfall events are apparent: Isaias in August and the December 24-25 storm. The low-flow period from late September through the end of October is also apparent. During this time, streamflow at all gages remained at or below the median flow except one precipitation event at the end of September.

The comparison of monthly average flows to normal monthly flows is similar to that of precipitation. In August, average streamflows were 175 percent of normal in the main stem and 200 to 300 percent higher than normal in the tributaries. High flows also occurred in December, ranging from approximately 150 to 200 percent of normal for most gages.

Flooding occurred during both major rainfall events this year. In Berks County near Reading, PA, an intense series of thunderstorms produced approximately six inches of rain, which led to an increase of approximately 7000 cfs in the Schuylkill river two days prior to the impacts from Isaias. During Tropical Storm Isaias, several of the tributaries experienced minor to moderate flooding, as is shown in Figure 10. During the high flows, a barge broke loose and crashed into a bridge over the Schuylkill river. In the last week of December, a combination of melting snow heavy rain led to moderate to major flooding around the basin, including some tidal/main stem locations.

Reservoir Storage and Releases

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 2020. The Delaware River Basin Commission's (DRBC) Lower Basin drought operating plan was not implemented because the requirements (reservoir elevations) were not met.

A release of water from Blue Marsh Reservoir was made on one day at DRBC's request on September 23 to support the Trenton Flow Objective. A total of 55 million gallons were used. No water was needed from the Excess Release Quantity in 2020, a volume of water in the NYC reservoirs reserved for use by the lower basin. Beltzville and Blue Marsh remained near or above their normal pool elevations for most of the year, as shown in Figures 21 and 22. Blue Marsh reservoir has both a summer and a lower winter elevation. The purpose of the lowering the pool is to provide additional flood control storage in the winter and spring.

Releases were not made from Merrill Creek Reservoir during 2020. At the beginning of the year, Merrill Creek had total storage of 15.48 billion gallons. At the end of the year, storage was 15.56 billion gallons. Storage in Merrill Creek Reservoir, located in Phillipsburg, New Jersey, is used to replace evaporative losses caused by power generation when the basin is under DRBC-declared drought operations and the daily flow at Trenton, New Jersey is below 3,000 cfs.

Upper Basin

Releases from the three NYC Delaware River Basin (DRB) Reservoirs were made in accordance with the 2017 Flexible Flow Management Program. The River Master directed releases from the NYC reservoirs to meet the Montague flow objective. The volume of water released for Montague was approximately 21.4 BG, starting on June 23 and lasting until October 27. Releases for thermal mitigation and rapid flow change mitigation totaled 1506 MG and 530 MG, respectively. Thermal mitigation releases were made for eight multi-day events (34 days total) in June, July, and August. Thermal releases are made when the water temperature at

Lordville gage is forecasted to be greater than 75 ^{o}F, in order to protect established cold-water fisheries. Rapid flow change mitigation releases were made for three events in October. Rapid Flow Mitigation Releases are made when the water level is forecasted to decrease too fast for aquatic life to naturally adjust to, so extra water is released to mitigate the rapid decrease.

Figure 23 presents the time-series of combined storage in the New York City Delaware Basin Reservoirs. As of January 1, the combined storage was approximately 237 BG. The storage increased until May 2 when storage was 271.9 BG. During this period, all three reservoirs spilled. The total volume spilled was 14.5 BG. The storage then decreased through October 29, when combined storage was at the minimum value for the year of 163.4 BG, approximately 53 BG above drought watch. The combined storage then increased to 239 BG by the end of the year. The majority of the increase was the result of the rain event on December 24- 25.

Groundwater

Groundwater levels in the twelve indicator wells remained mostly in the normal or above normal range for the year. Most wells experienced a decrease in groundwater levels starting in June and July, following the normal annual trend in groundwater levels. Five wells in the western and northern parts of the basin reached drought watch levels in October before increasing with recharge from a series of storms during November. At years end, levels in 6 wells were at normal levels, with the remaining 6 wells having above normal levels due to the rain event December 24-25. Figures 24-26 demonstrate the time series of groundwater levels at representative wells across the basin.

Salt Front

The salt front is defined as the 250 parts-per-million isochlor (line of constant chlorinity). The seven-day average location of the salt front is used by DRBC as an indicator of salinity intrusion in the Delaware Estuary for reservoir operations. The location of the salt front fluctuates along the main stem Delaware River as streamflow increases or decreases. During higher streamflow, chloride concentrations are diluted by freshwater flowing downstream. During low flows, chlorides become concentrated in the river as the result of saltwater pushing

upstream. Long-term median mid-month locations range from river mile 67 in April (two miles downstream of the Delaware Memorial Bridge) to river mile 76 in September (two miles downstream of the Pennsylvania-Delaware State line).

In 2020, the salt front began the year in the normal range. For the first half of the year, the salt front was within the normal range. In May, the salt front was below Reedy Island (river mile 54)[2]. In June and July, the salt front began to move upstream until August, when it began to move downstream due to the increased flows resulting from precipitation from Tropical Storm Isaias. The salt front then moved upstream in September and October when flows were low. The most upstream location of the seven-day average salt front was near river mile 76 in late-October, then began moving downstream after a high flow event. The salt front fluctuated within the normal range for the remainder of the year, until the rain event on December 24-25 moved the salt front below Reedy Island once more. The time series of daily location and seven-day average location of the salt front is presented in Figure 27.

[2] DRBC does not report the location of the salt front below river mile 54 due to the lack of information needed to determine its location.

Links to Data Sources

Precipitation (rain/snow, departure from normal)

- Applied Climate Information System (ACIS): https://xmacis.rcc-acis.org/
- Advanced Hydrologic Prediction Center (AHPS): https://water.weather.gov/precip/download.php
- National Operational Hydrologic Remote Sensing Center (NOHRSC): https://www.nohrsc.noaa.gov/archived_data/

Streamflow (including statistics)

- United States Geological Survey (USGS) Montague: https://waterdata.usgs.gov/usa/nwis/uv?01438500
- USGS Trenton: https://waterdata.usgs.gov/usa/nwis/uv?01463500
- USGS Schuylkill River at Philadelphia: https://waterdata.usgs.gov/usa/nwis/uv?01474500
- USGS Lehigh River at Bethlehem: https://waterdata.usgs.gov/usa/nwis/uv?01453000
- USGS Schuylkill River at Pottstown: https://nwis.waterdata.usgs.gov/pa/nwis/dv/?site_no=01472000
- USGS Schuylkill River at Norristown: https://nwis.waterdata.usgs.gov/pa/nwis/dv/?site_no=01473500
- USGS Little Lehigh Creek near Allentown: https://waterdata.usgs.gov/nwis/uv?site_no=01451500
- USGS Chester Creek near Chester: https://waterdata.usgs.gov/usa/nwis/uv?site_no=01477000
- USGS Ridley Creek at Media: https://waterdata.usgs.gov/nwis/uv?site_no=01476480
- USGS East Branch Perkiomen at Schwenksville: https://waterdata.usgs.gov/usa/nwis/uv?01472810

Flood Stages

- Schuylkill River at Pottstown: https://water.weather.gov/ahps2/hydrograph.php?gage=ptnp1&wfo=phi
- Schuylkill River at Norristown: https://water.weather.gov/ahps2/hydrograph.php?gage=nrsp1&wfo=phi
- Little Leigh Creek near Allentown: https://water.weather.gov/ahps2/hydrograph.php?gage=allp1&wfo=phi
- Chester Creek near Chester: https://water.weather.gov/ahps2/hydrograph.php?gage=chsp1&wfo=phi
- Ridley Creek at Media: https://waterdata.usgs.gov/nwis/uv?site_no=01476480
- East Branch Perkiomen near Schwenksville: https://water.weather.gov/ahps2/hydrograph.php?gage=swvp1&wfo=phi

Reservoir storage and releases:

- Office of the Delaware River Master (ODRM): https://webapps.usgs.gov/odrm/
- New York City Water Supply Control Center (NYC WSCC): https://www1.nyc.gov/site/dep/water/water-supply.page
- USGS Blue Marsh Lake near Bernville, PA: https://waterdata.usgs.gov/nwis/uv?site_no=01470870
- USGS Beltzville Lake near Parryville, PA: https://waterdata.usgs.gov/nwis/uv?01449790

Specific Conductance:

- USGS Delaware River at Chester: https://waterdata.usgs.gov/nwis/uv?site_no=01477050
- USGS Delaware River at Ben Franklin Bridge at Philadelphia: https://waterdata.usgs.gov/nwis/uv?site_no=01467200
- USGS Delaware River at Reedy Island Jetty: https://waterdata.usgs.gov/nwis/uv?site_no=01482800
- USGS Delaware River at Fort Mifflin at Philadelphia: https://waterdata.usgs.gov/nwis/uv/?site_no=01474703

Groundwater:

- Bucks County, PA Well: https://waterdata.usgs.gov/nwis/uv/?site_no=401157075032001&PARAmeter_cd=
- Delaware County, PA Well: https://waterdata.usgs.gov/nwis/dv/?site_no=395512075293701&agency_cd=
- Wayne County, PA Well: https://waterdata.usgs.gov/nwis/uv/?site_no=414333075153201&PARAmeter_cd=
- Monroe County, PA Well: https://waterdata.usgs.gov/nwis/uv/?site_no=411223075234901&PARAmeter_cd=
- Carbon County, PA Well: https://waterdata.usgs.gov/pa/nwis/uv/?site_no=410123075425401&PARAmeter_cd=
- Schuylkill County, PA Well: https://waterdata.usgs.gov/nwis/uv/?site_no=404708076070701&PARAmeter_cd=
- Lehigh County, PA Well: https://waterdata.usgs.gov/nwis/uv?site_no=403429075392401
- Lebanon County, PA Well: https://waterdata.usgs.gov/nwis/uv/?site_no=402207076180801&PARAmeter_cd=
- Chester County, PA Well: https://waterdata.usgs.gov/pa/nwis/uv/?site_no=395450075485401
- Burlington County, NJ Well: https://waterdata.usgs.gov/nj/nwis/uv/?site_no=395150074284201&PARAmeter_cd=
- Cumberland County, NJ Well: https://waterdata.usgs.gov/nj/nwis/uv/?site_no=392731075092401&PARAmeter_cd=
- New Castle County, DE Well: http://data.dgs.udel.edu/sites/webwatlev/Db24-18.txt

Other:

- Salt Front: https://www.nj.gov/drbc/hydrological/river/salt-front.html
  https://6abc.com/i676-closed-vine-street-expressway-schuylkill-river-barge-hits-676/6354423/

All graphics below were produced by the Delaware River Basin Commission

Tables and Figures

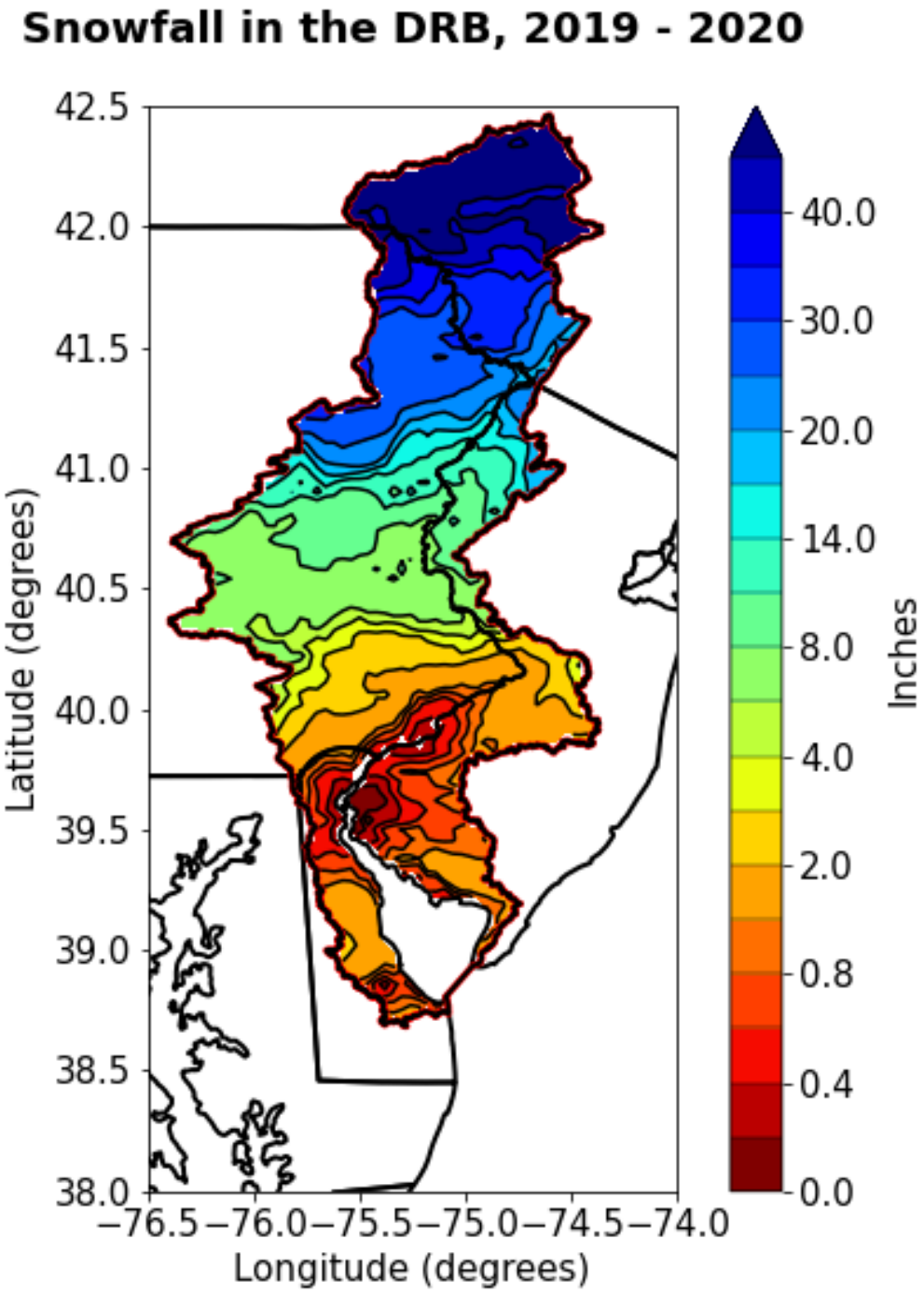

Figure 1: Snowfall for the 2019 – 2020 winter season. While the upper basin received more than 45 inches of snow in parts, areas in the southern half of the basin received less.

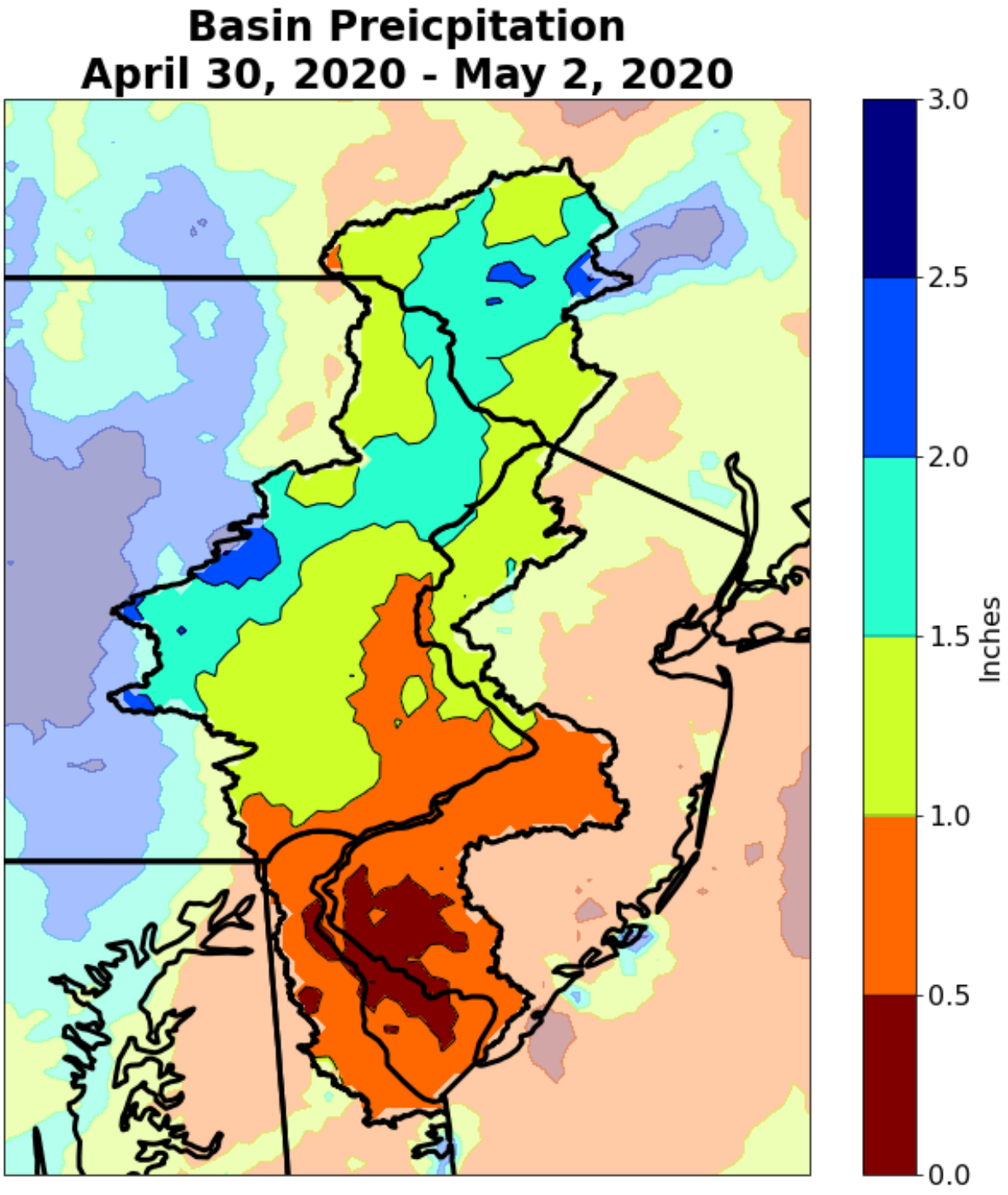

Figure 2: Precipitation totals during the peak streamflow event April 30 – May 2. The most precipitation occurred in areas shaded teal or blue (1.5 inches – 2.5 inches) on the figure.

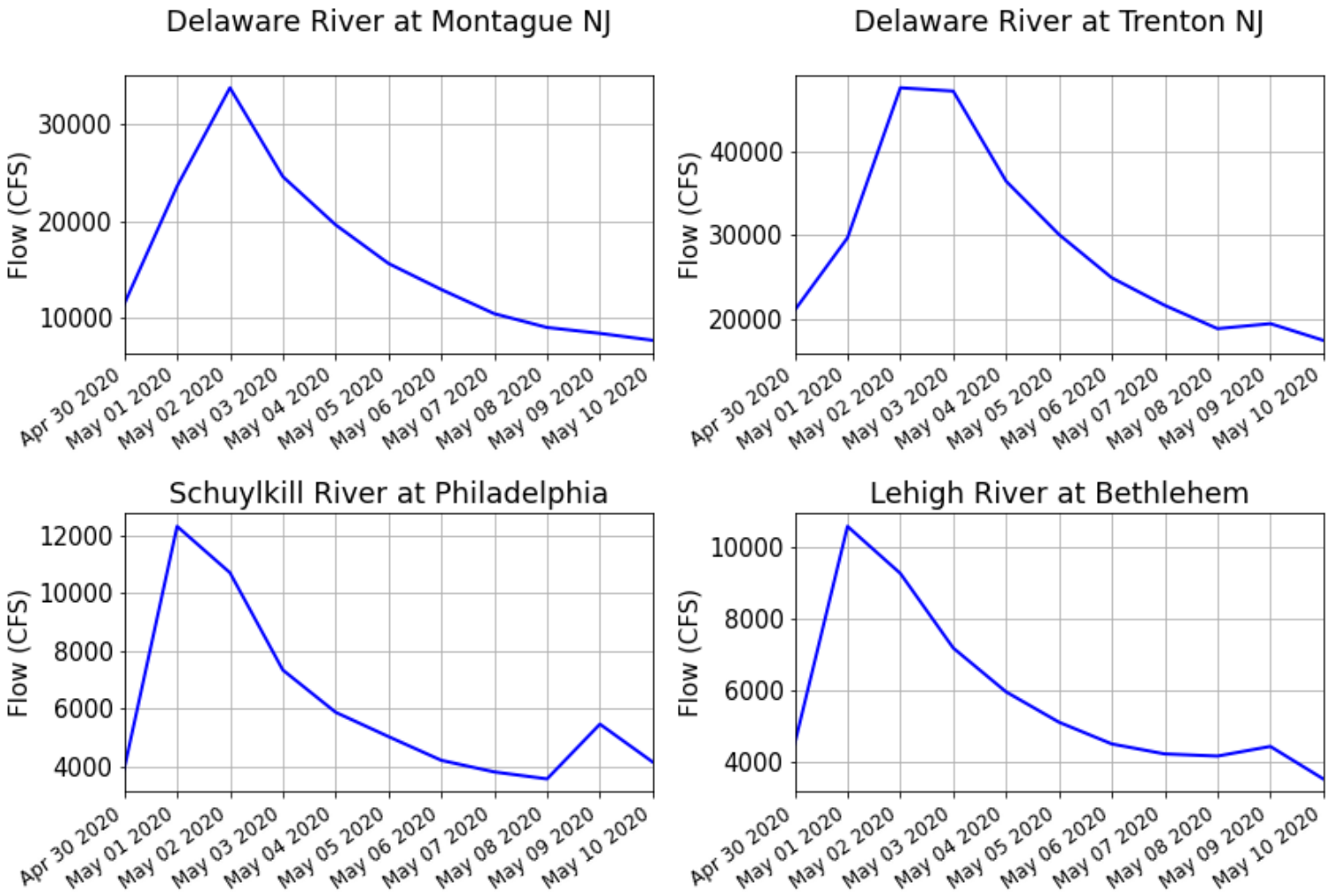

Figure 3: Spring peak flows in response to the rainfall event April 30 – May 2 in Figure 2. Flows in the main stem and tributaries were two to three times the amount before the event and did not return to pre-event levels for eight to ten days, depending on location.

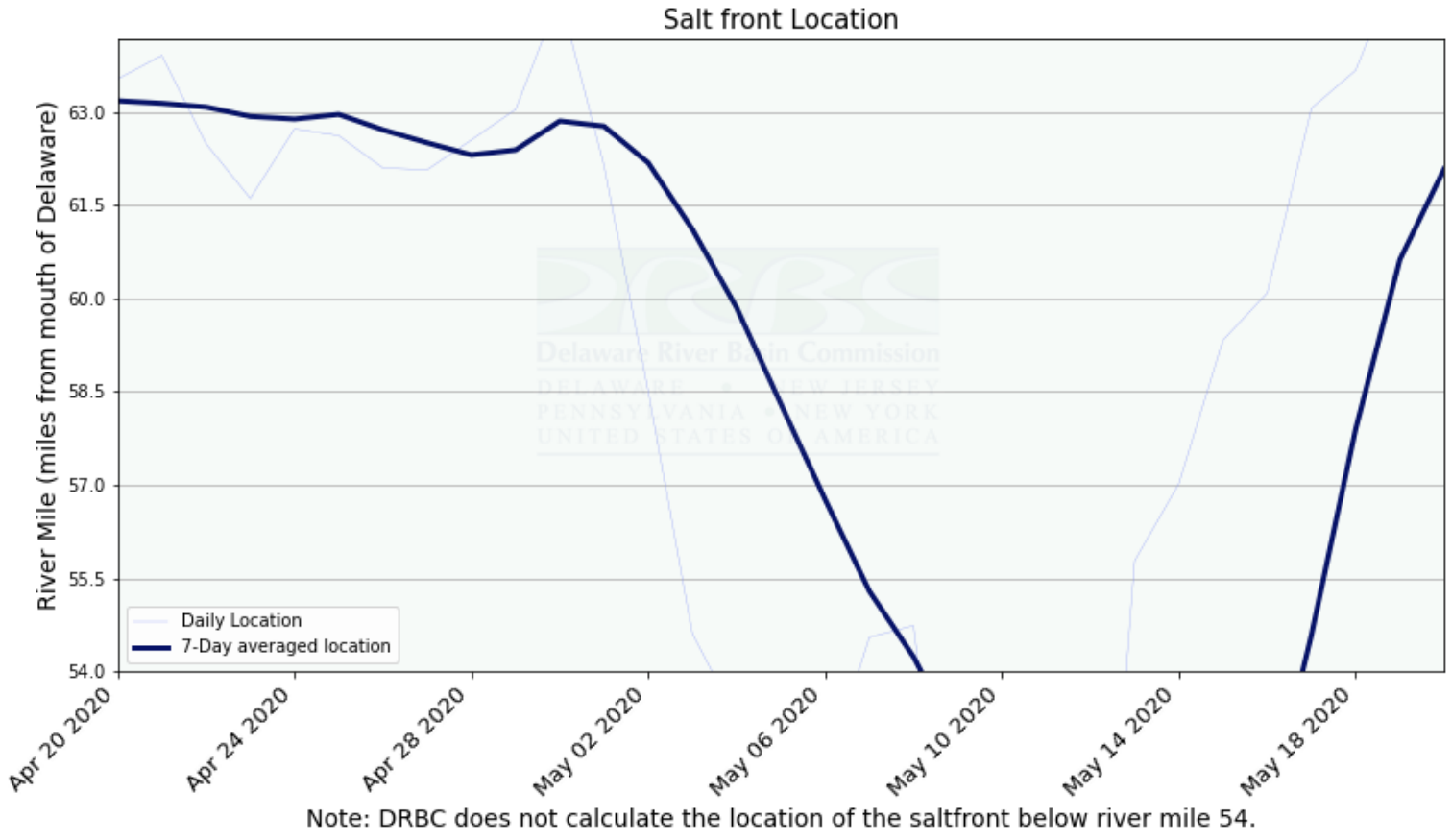

Figure 4: The salt front moved downstream after the high flow event in the spring. The salt front remained below Reedy Island (RM 54) for approximately two weeks before moving upstream again.

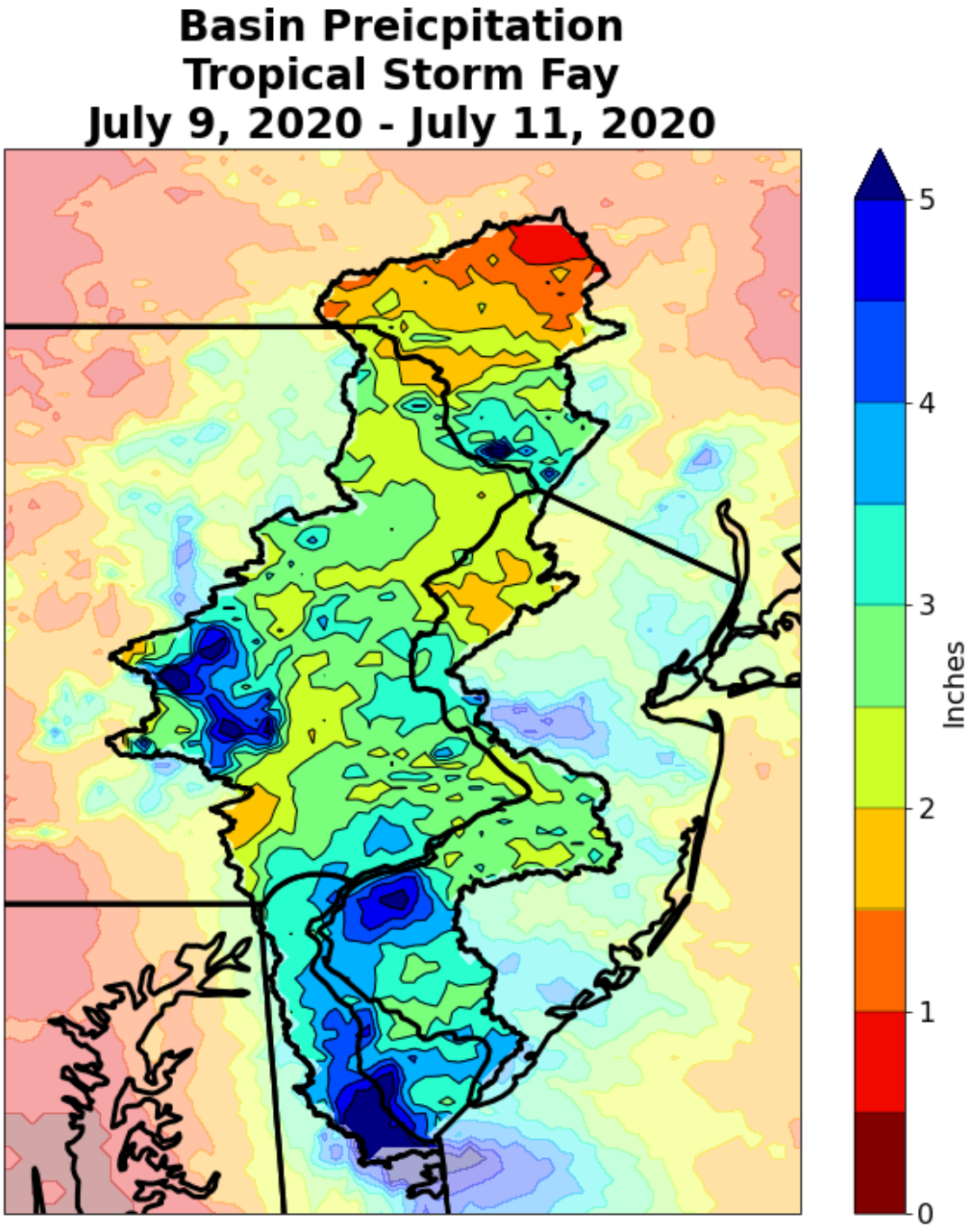

Figure 5: Precipitation Totals from Tropical Storm Fay from July 9 – July 10. The highest amounts were in the southern half of the basin, with some areas receiving greater than five inches of rain.

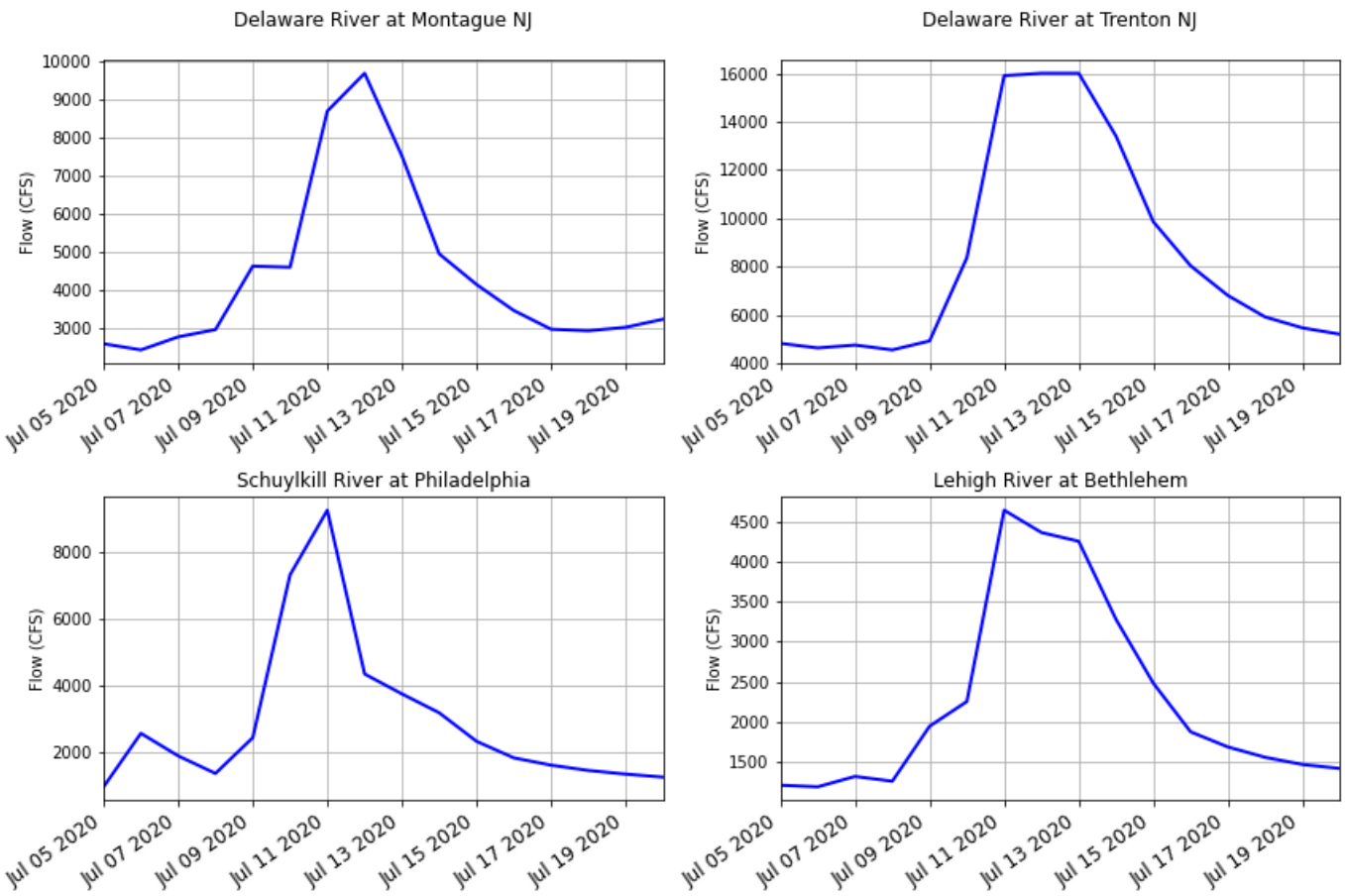

Figure 6: Flow response to Tropical Storm Fay in the basin was three to four times the flow prior to the event. Impacts were more severe in the southern half of the basin where more rain fell. Flows returned to pre-event levels within nine to ten days after the event.

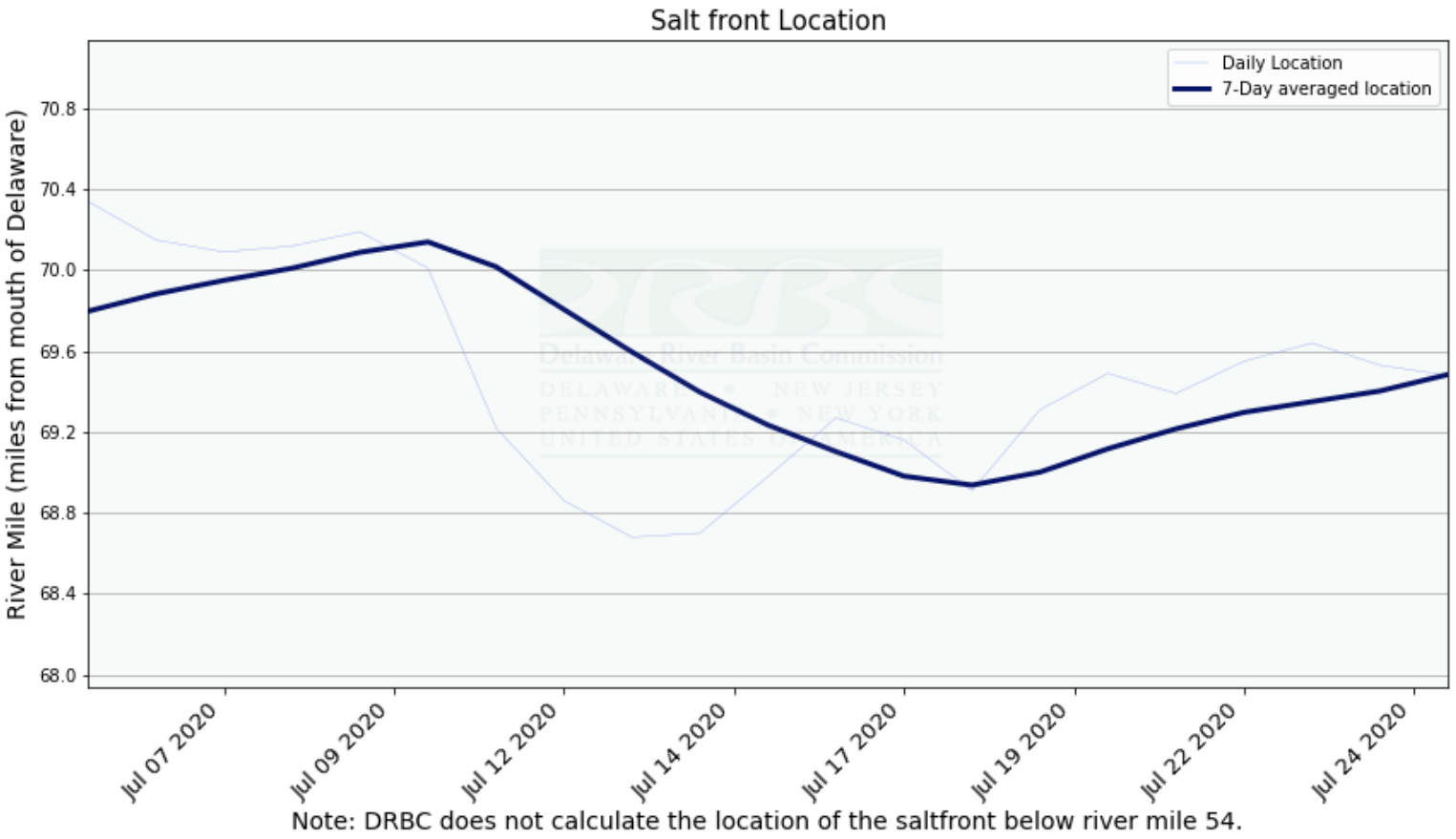

Figure 7: Tropical Storm Fay only moved the salt front by approximately 1 mile. The increase in river flow were not high for enough time to move the salt front further downstream.

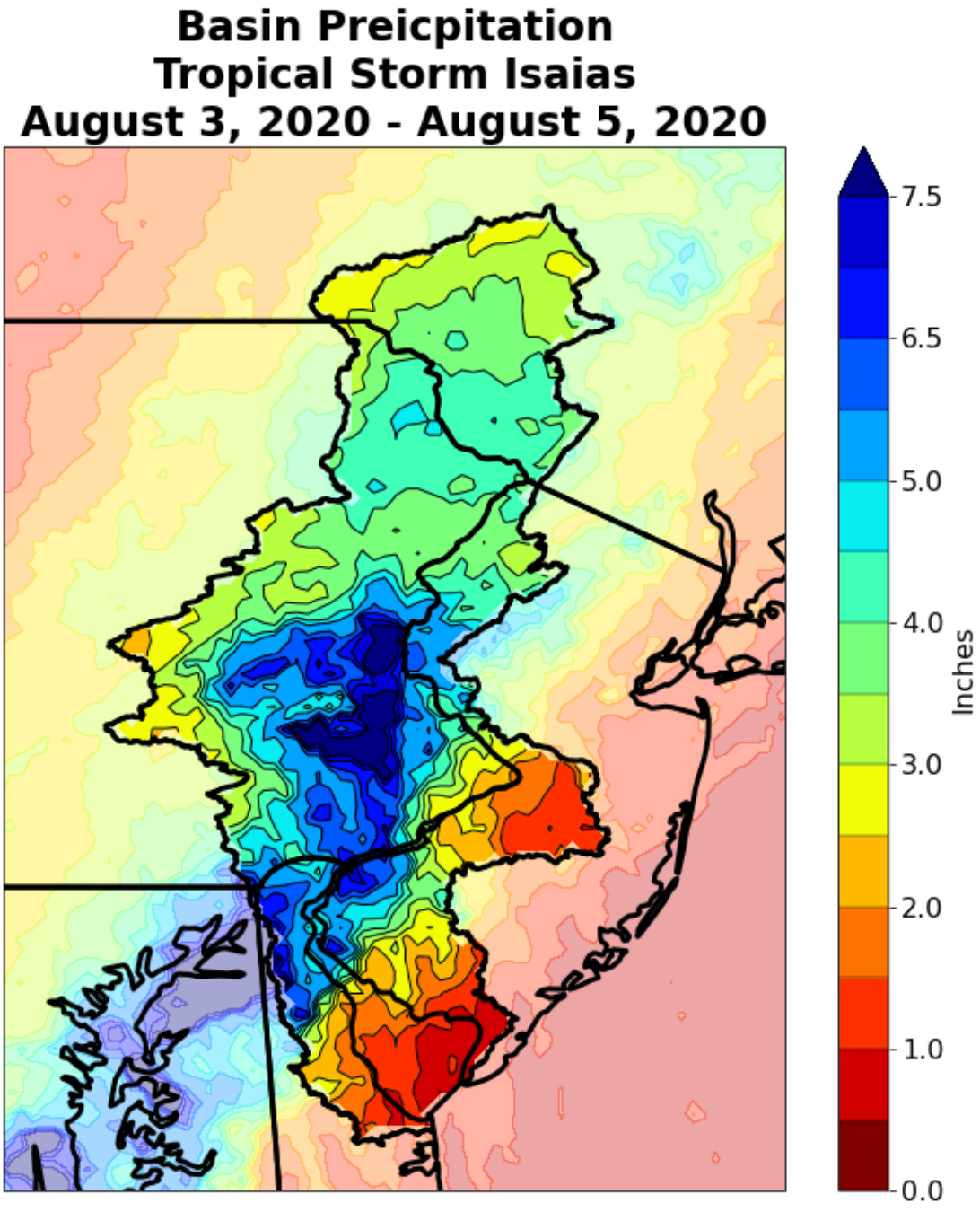

Figure 8: Rainfall totals from Tropical Storm Isaias, August 3 – August 5, 2020. The central and northern regions of basin received heavy rain, with some areas in eastern Pennsylvania receiving greater than 7.5 inches.

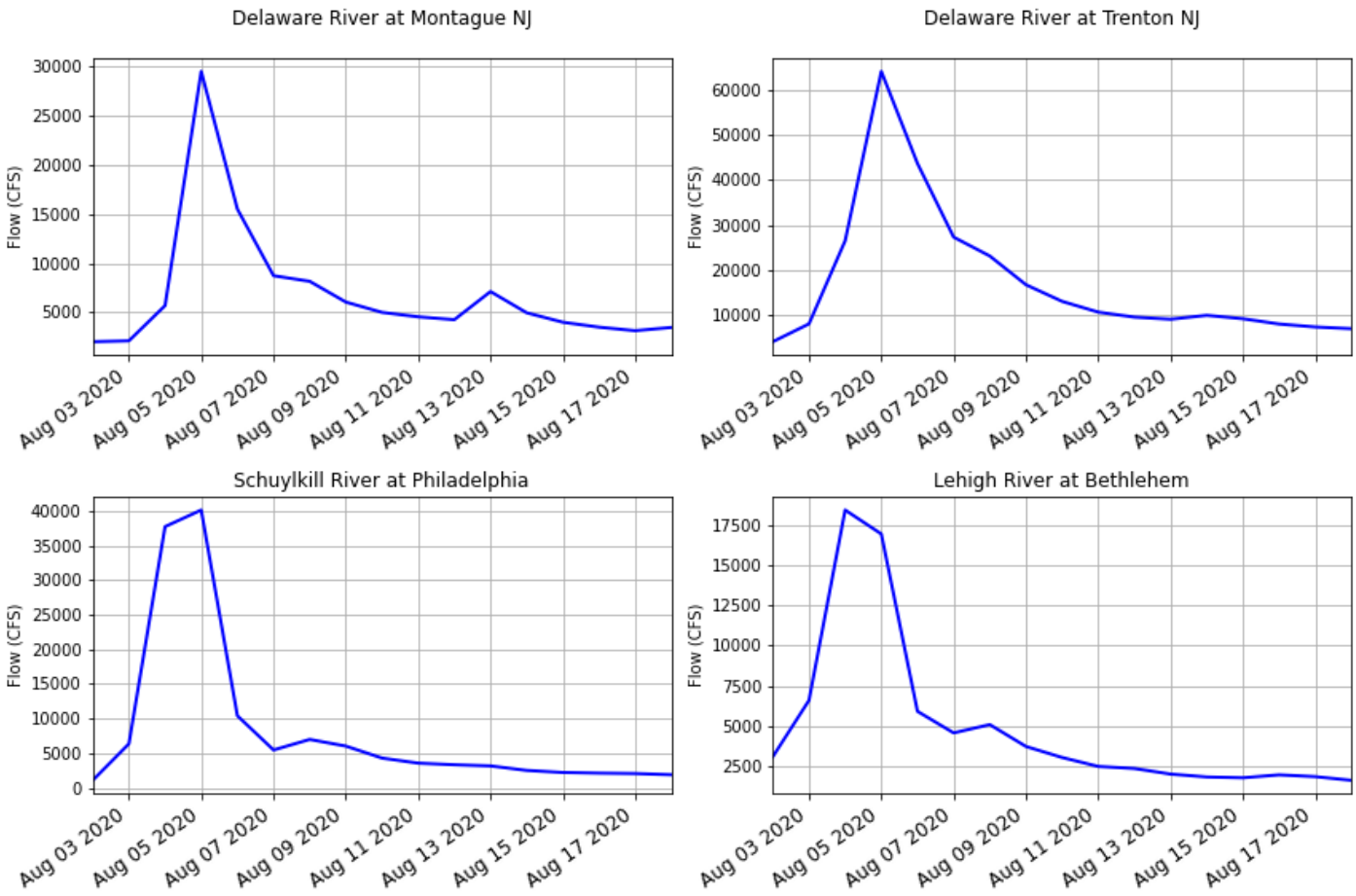

Figure 9: Impact of Tropical Storm Isaias on streamflow. Streamflow in the Schuylkill reached its highest daily discharge of the year due to this event.

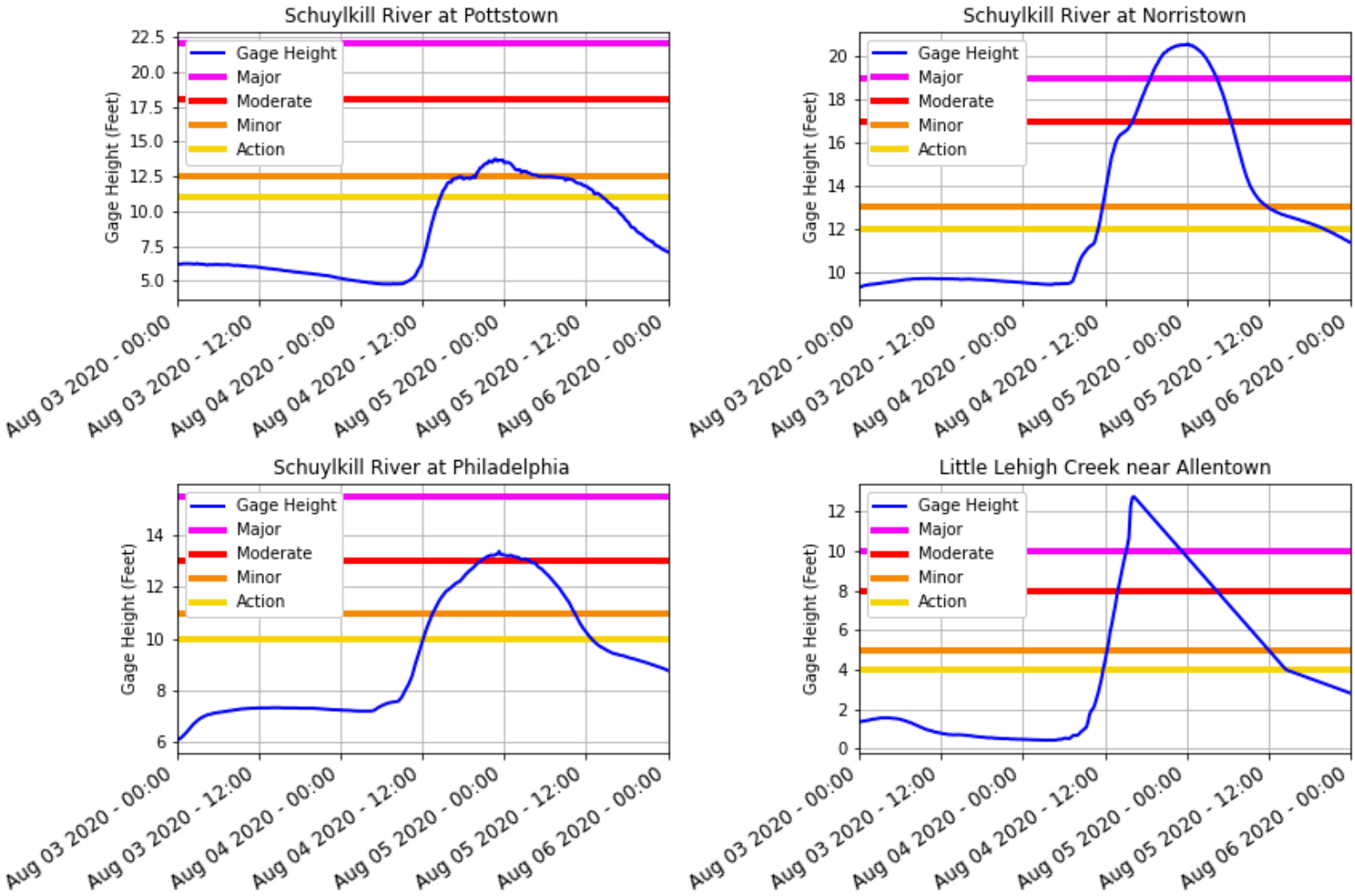

Figure 10: Flooding on the Schuylkill River and the Little Lehigh due to Tropical Storm Isaias. There was widespread moderate flooding and isolated major flooding throughout the basin, including some of the tidal gages.

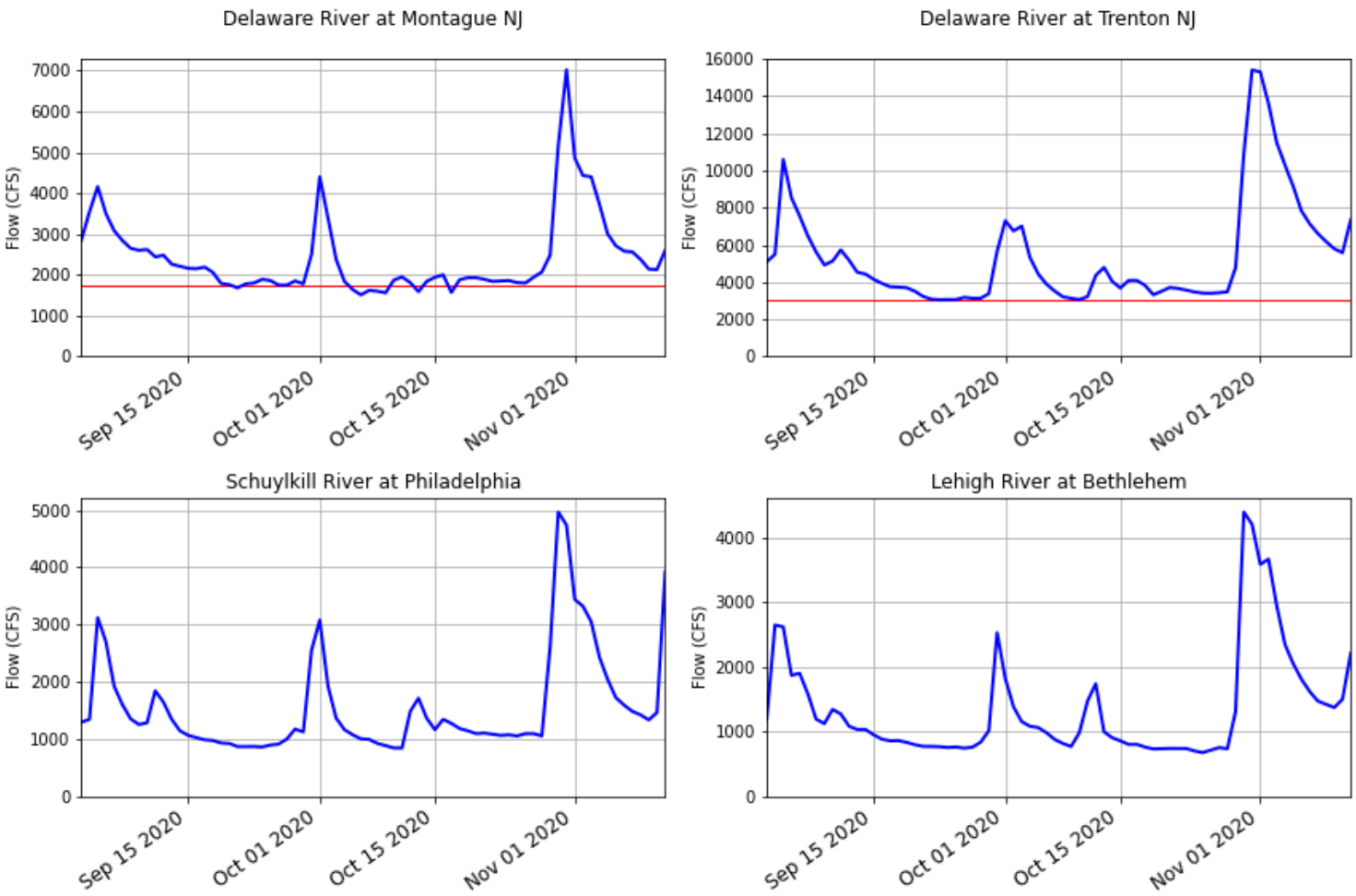

Figure 11: Daily Average flows at four locations during the low flow period September 15 – October 29. Flow objectives are shown at Montague (1750 CFS) and Trenton (3000 CFS).

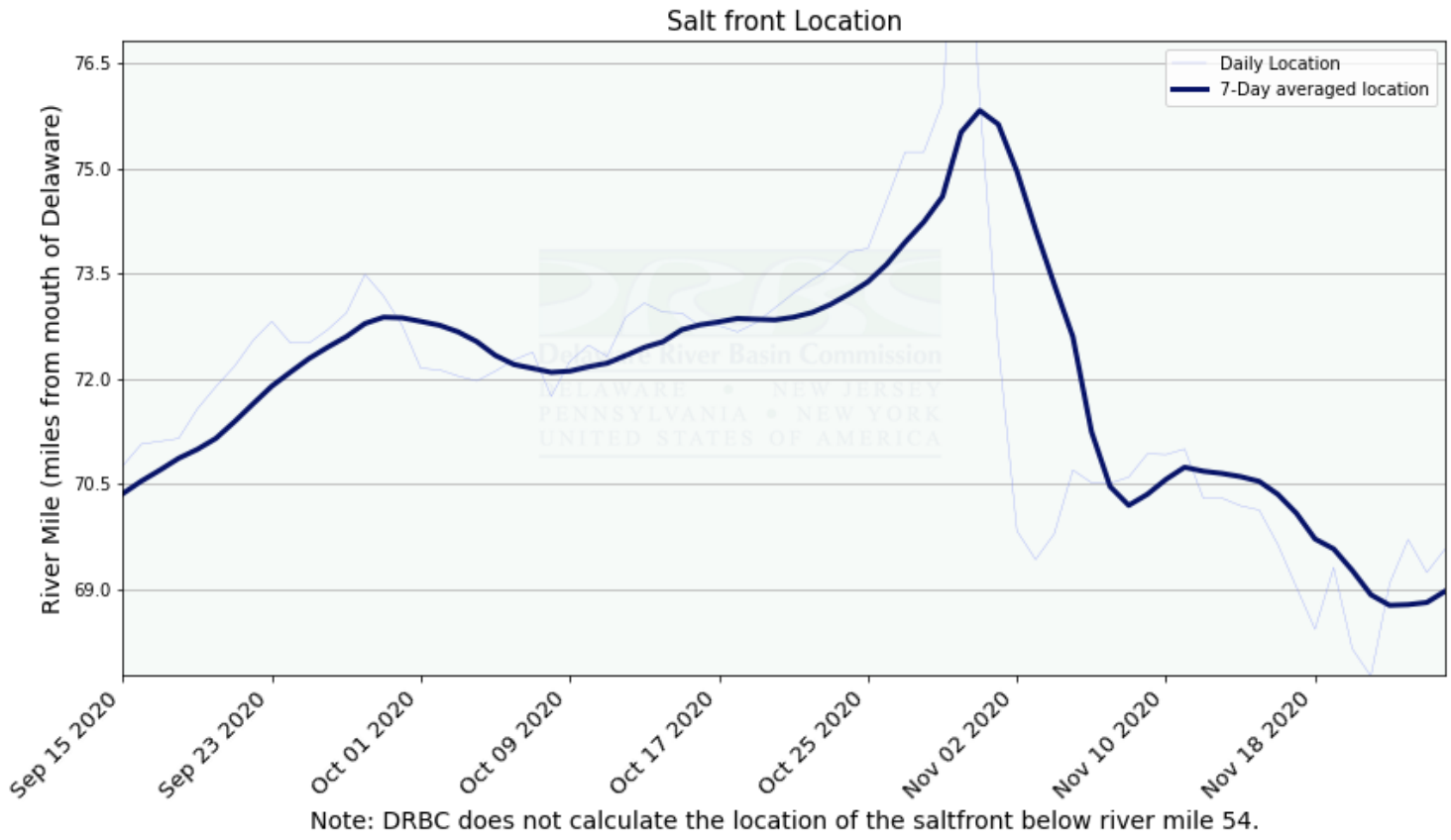

Figure 12: Salt front moved upstream during the low flow period and reached its most upstream location of the year (river mile 76) on October 31, 2020.

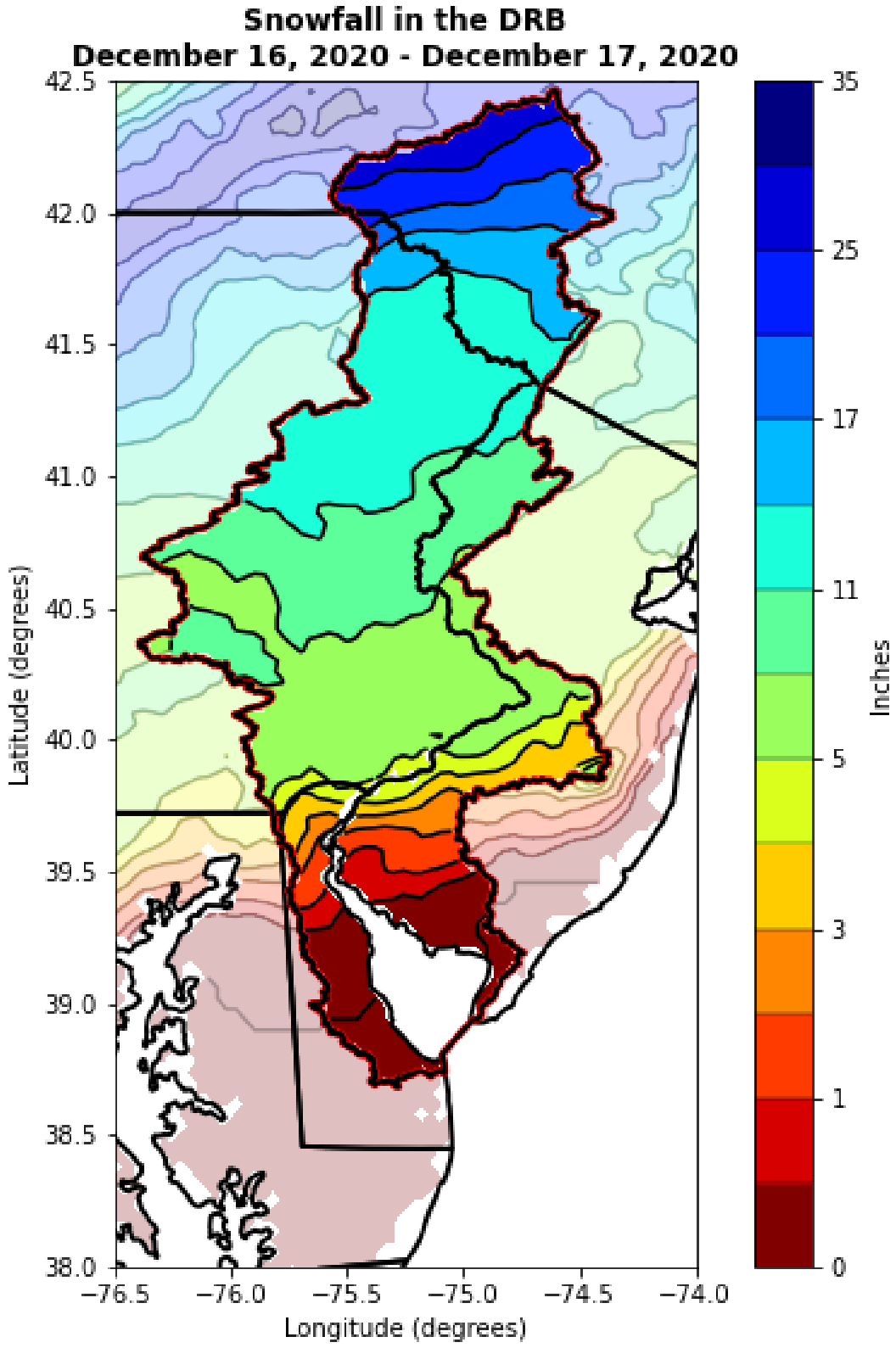

Figure 13: Snowfall totals from the winter storm on December 16 – 17, 2020. The highest amounts were in the northern regions of the basin.

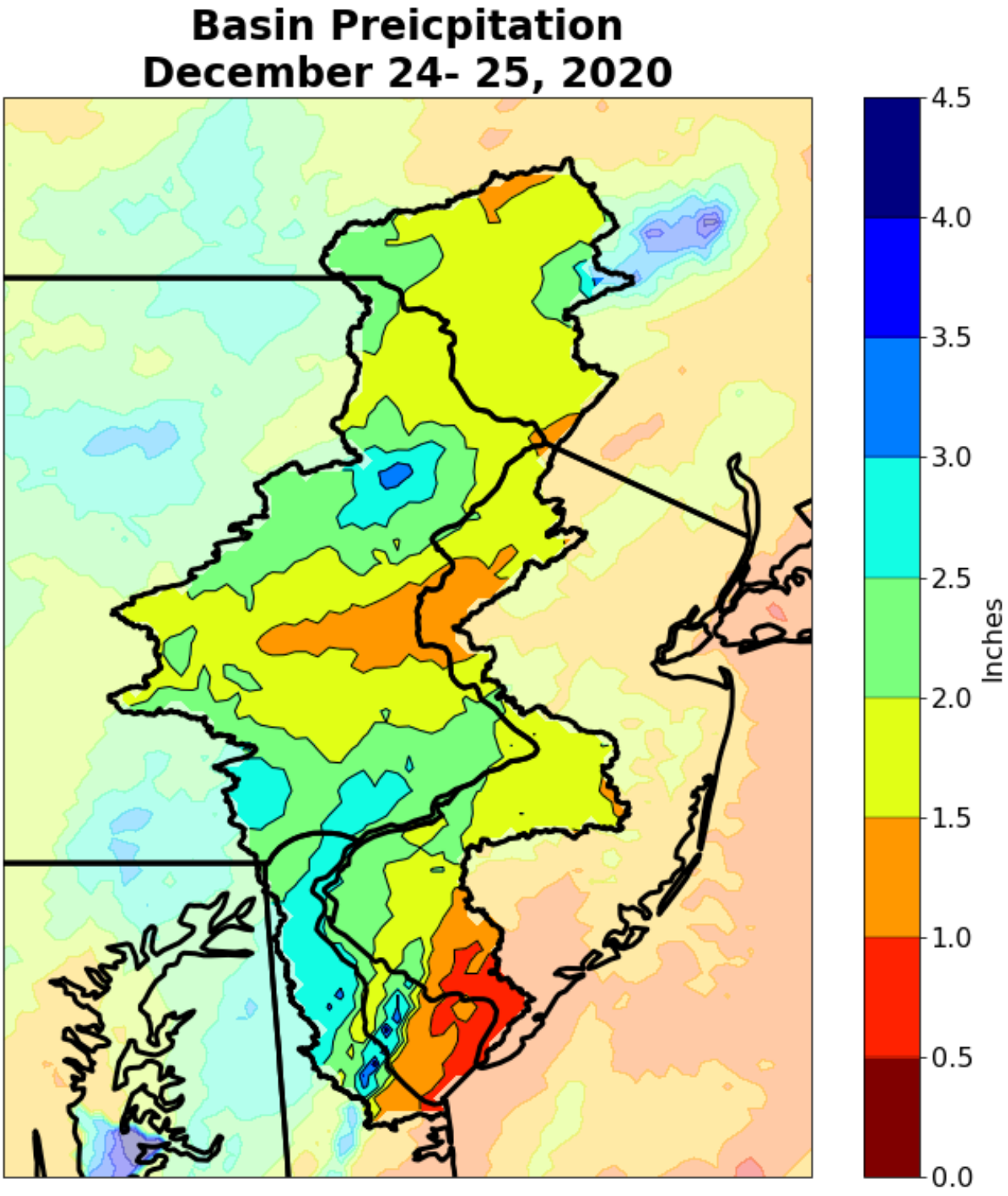

Figure 14: Precipitation (rain and snow water equivalent) was highest in Pennsylvania and Delaware. Most areas received 1.5 inches or more.

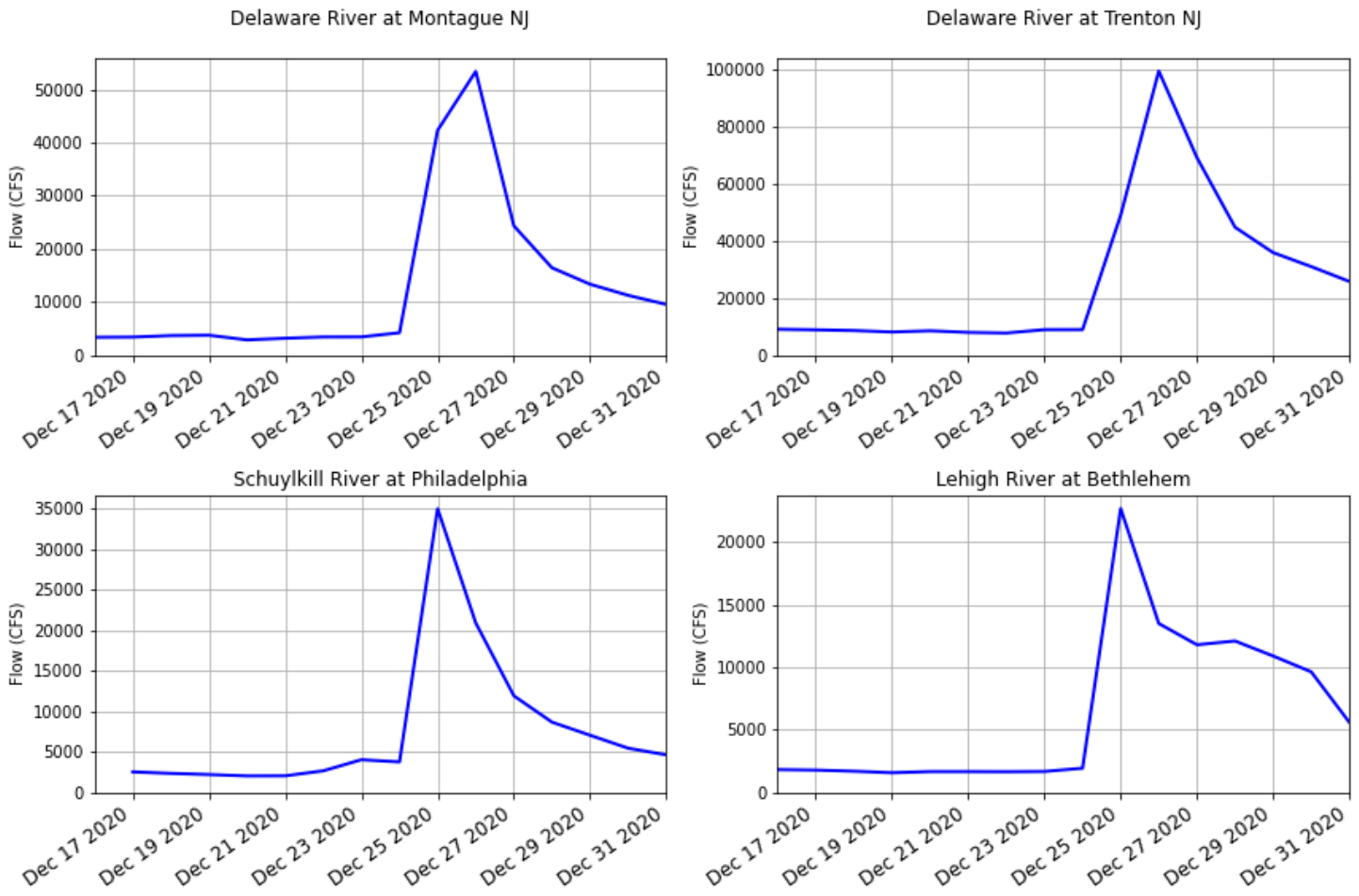

Figure 15: Streamflows increased after the storm due to the combined snowmelt and runoff.

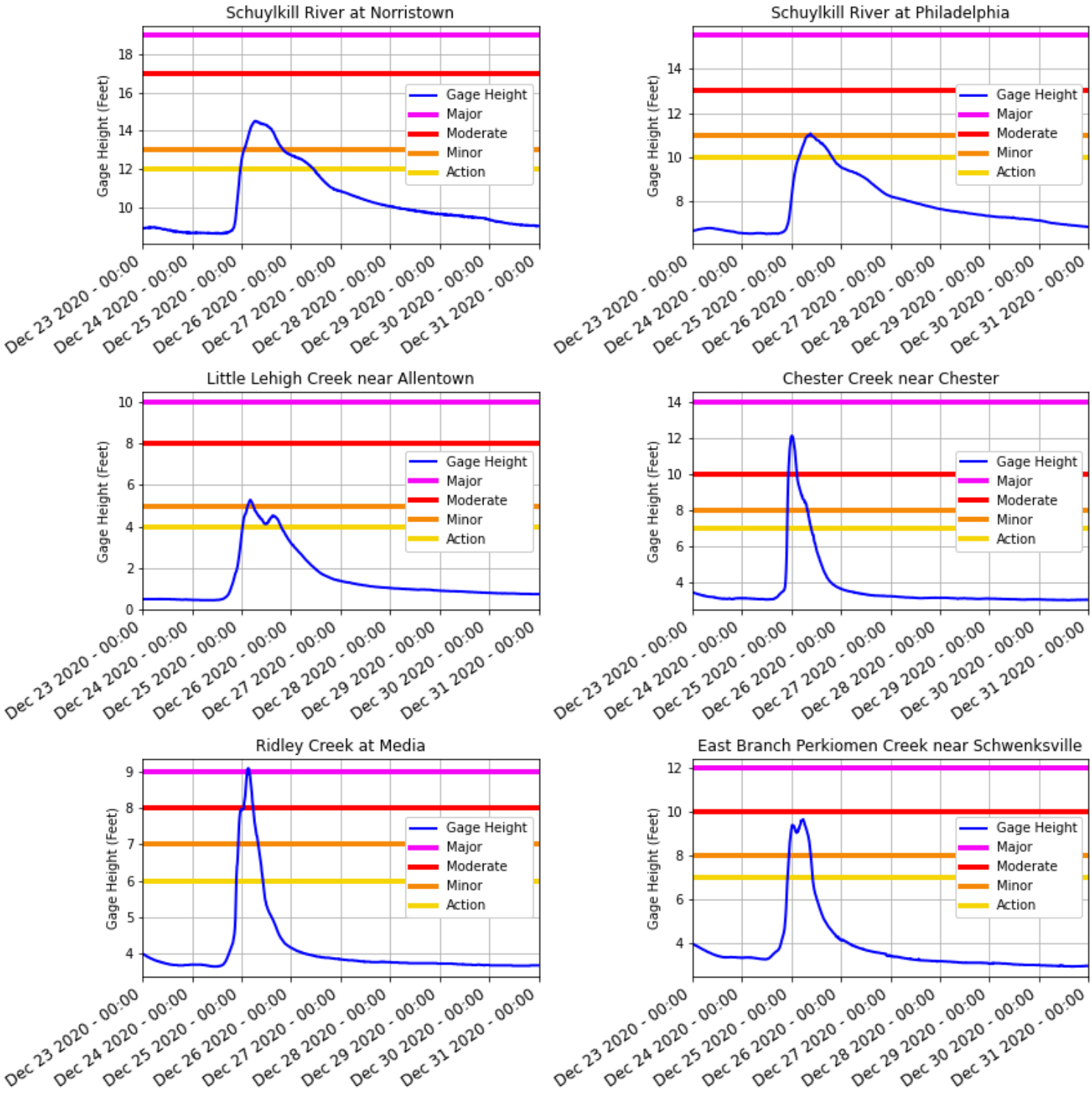

Figure 16: Flooding occurred at many locations due to increased river levels from snowmelt and additional precipitation from the rain event on December 24, 2020.

Station	Number of Years Reporting	2019 Precipitation Total	Normal	Departure	Annual Rank
Reading, PA	25	49.57	43.27	+6.30	6
Callicoon, NY	10	54.18	53.54	+0.64	4
Allentown, PA	81	49.57	45.53	+2.04	23
Trenton, NJ	23	42.57	46.44	-3.87	15
Sussex, NJ	19	32.45	45.28	-12.83	17
Philadelphia, PA	81	49.76	41.53	+8.23	9
Wilmington, DE	72	53.38	43.08	+10.20	6
Mount Pocono, PA	20	41.52	48.78	-7.26	17
Millville, NJ	61	53.18	41.59	+11.59	8

Table 1: Precipitation for representative locations throughout the basin. Upper Basin locations include Callicoon, NY; Mid-Upper Basin locations include: Sussex, NJ (note, not in basin), Mount Pocono, PA; Allentown, PA; Mid-Lower Basin locations include: Trenton, NJ; Reading, PA; Philadelphia, PA; Lower Basin locations include: Wilmington, DE; Millville, NJ.

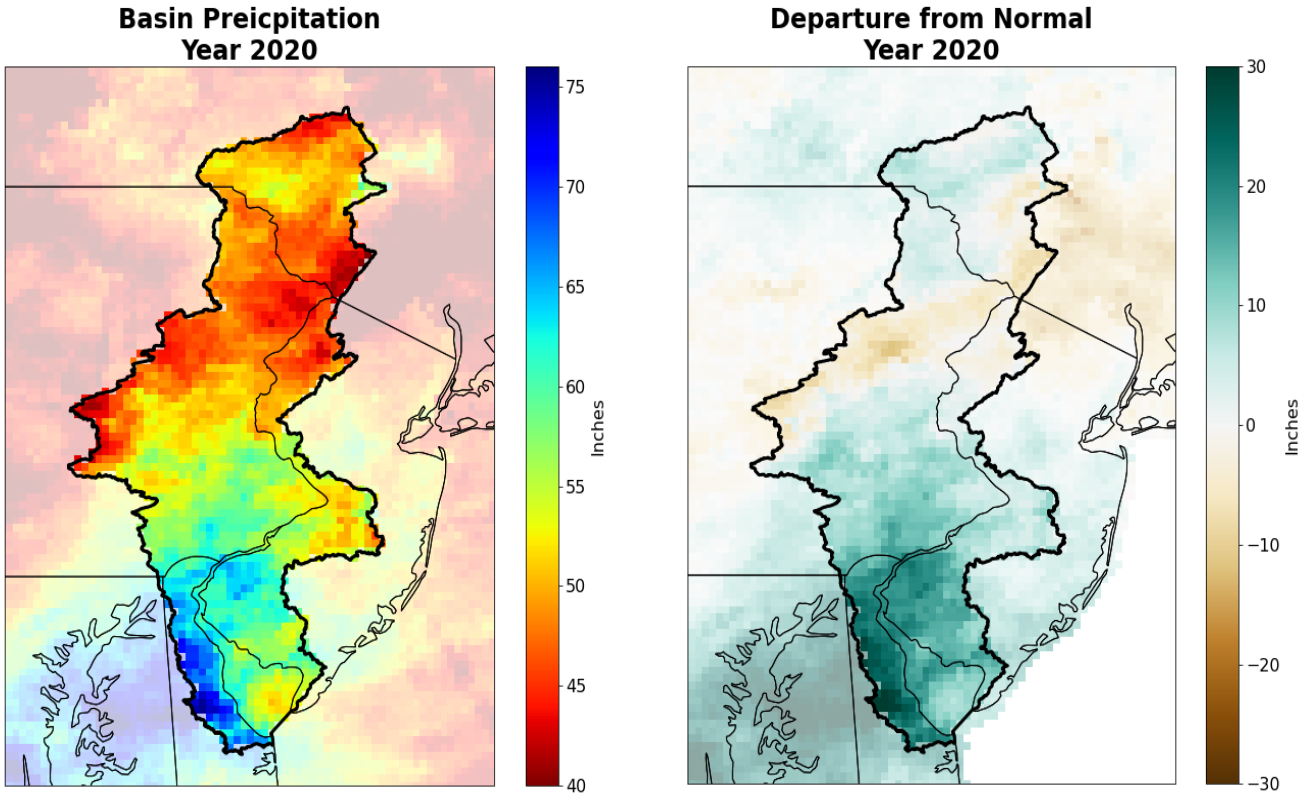

Figure 17: Precipitation for 2020. Delaware had the most precipitation. A drier than normal corridor occurred in the western portion of the basin northeast into NY.

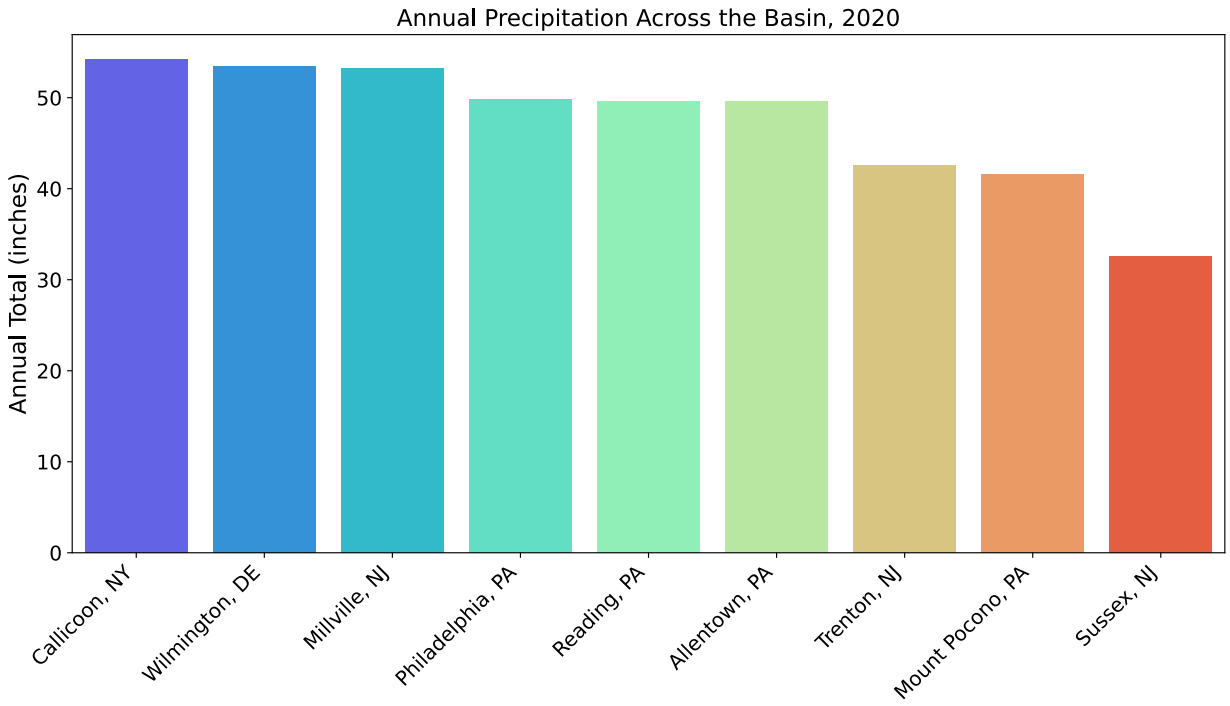

Figure 18: Precipitation from most to least.

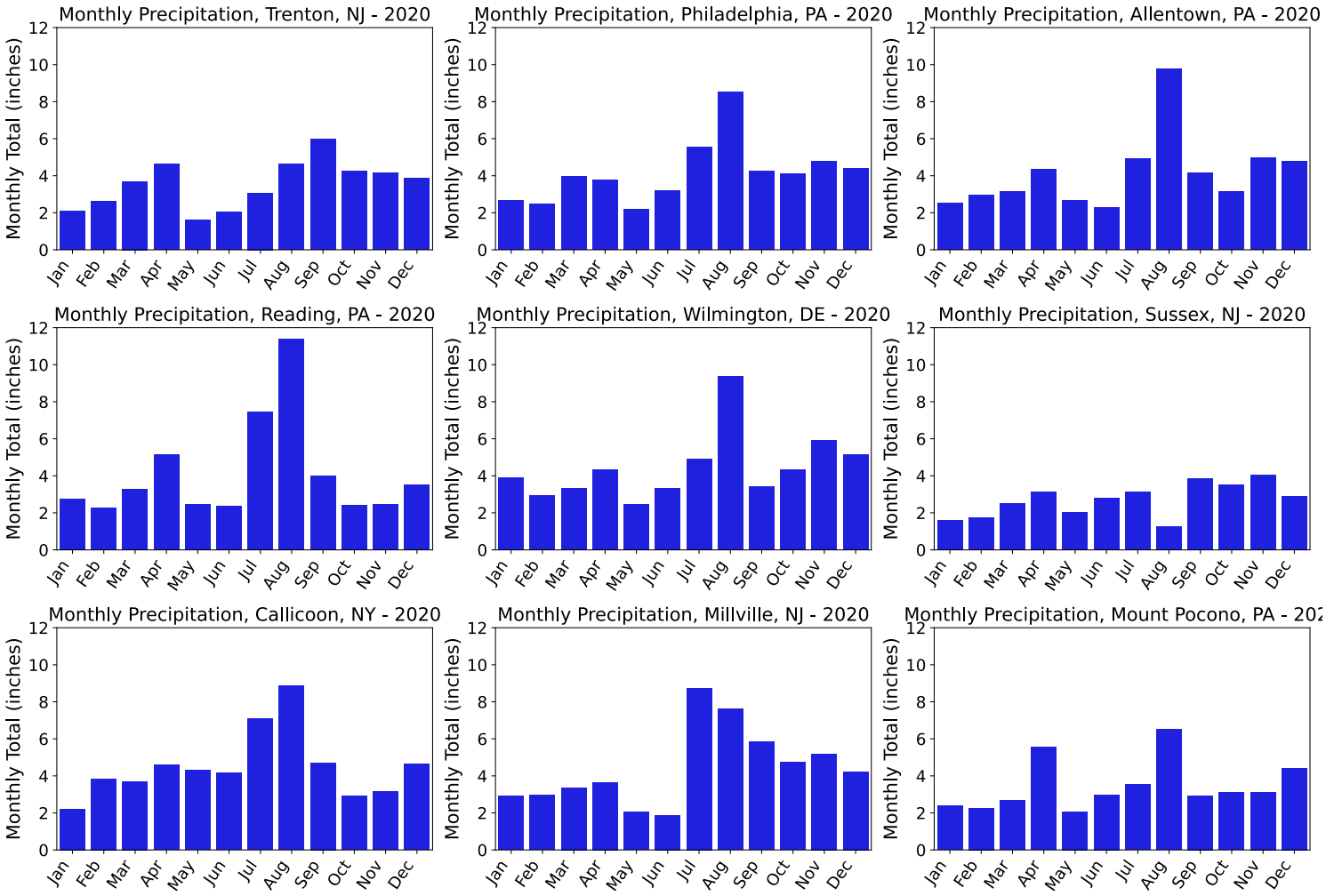

Figure 19: Monthly precipitation at representative stations. Similar patterns include the wet April, and the wet period July - August from Fay and Isaias. Conditions were dry in September and October. Reading, PA received the most rain for the month of August, totaling 11.41 inches

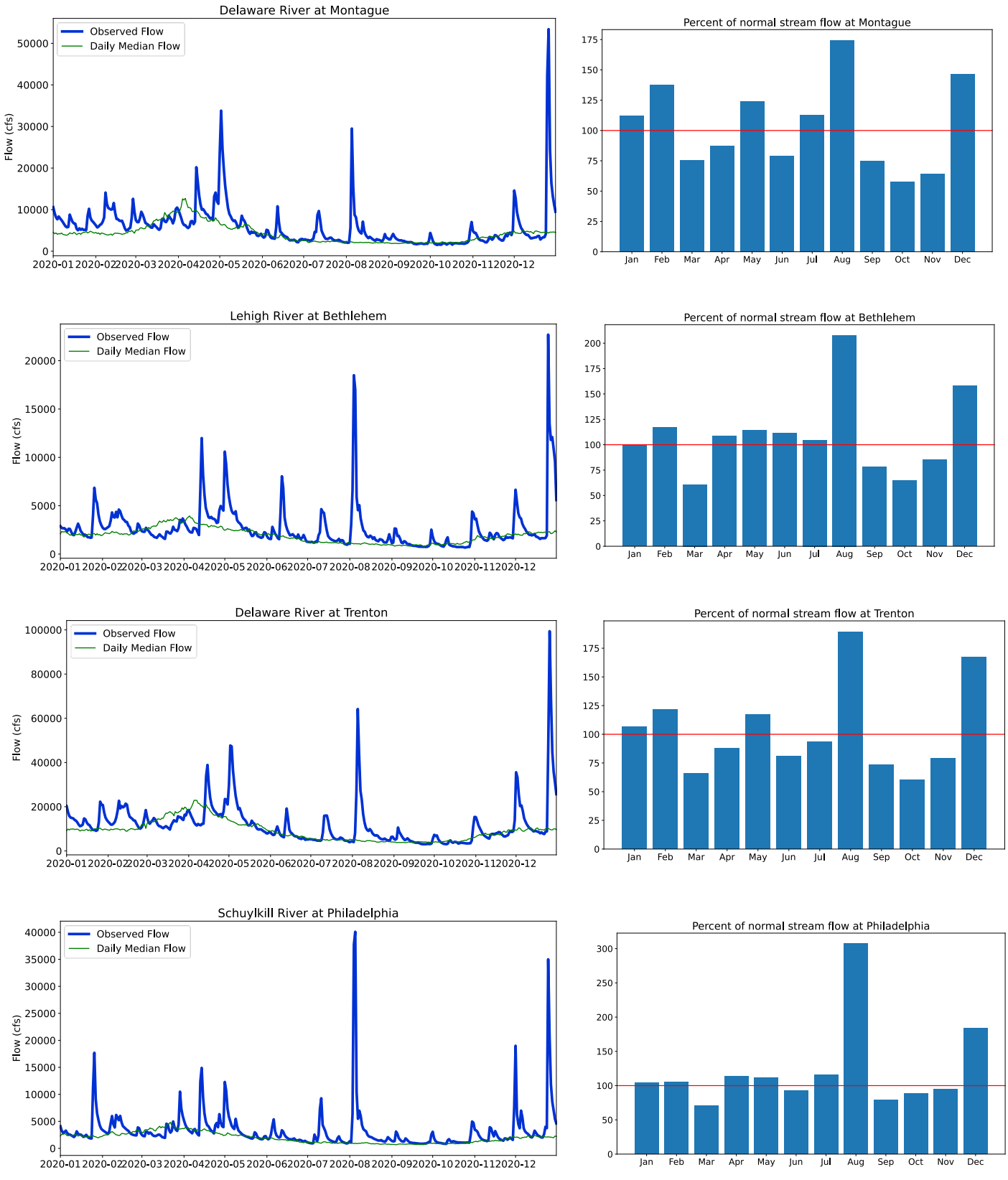

Figure 20: Streamflow at four gages in the Delaware River Basin (right). During October, stream flow was approximately 50 percent of normal for these gages (excluding Philadelphia).

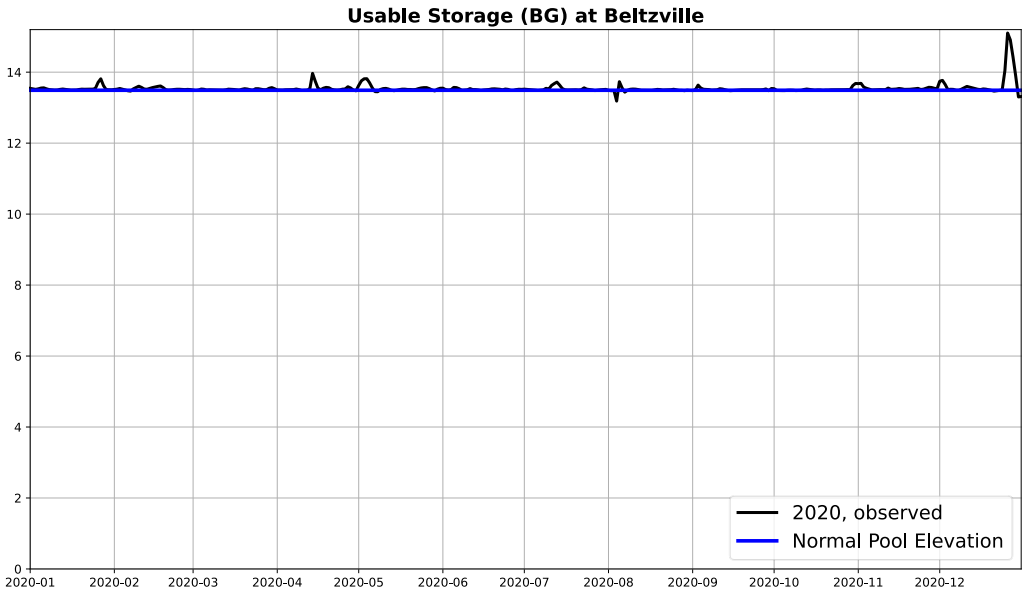

Figure 21: Storage in BG at Beltzville Reservoir Intrusions into the flood control space occurred on several locations with the largest event occurring as the result of the December 24-25 storm event.

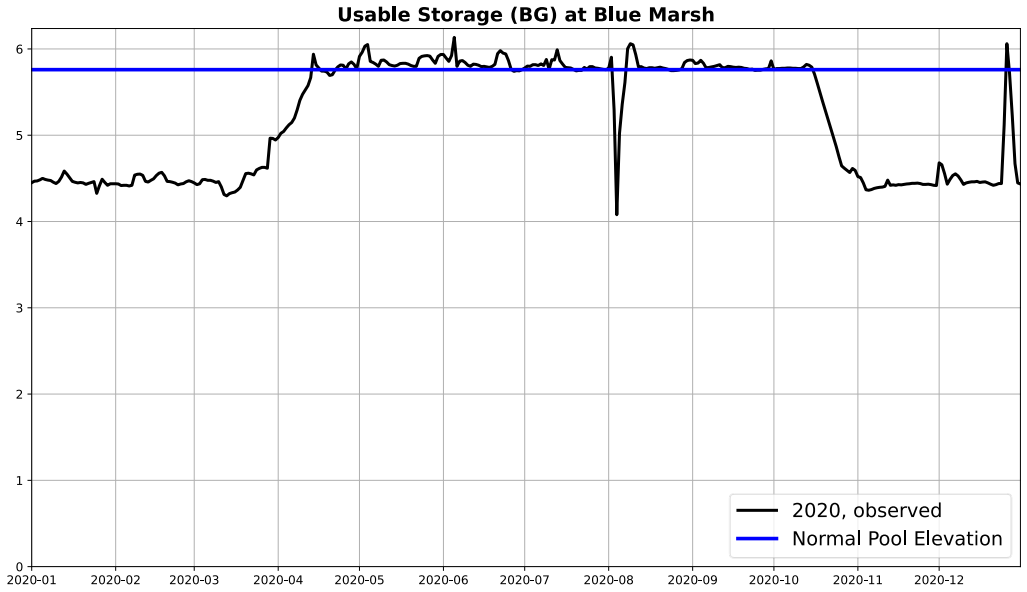

Figure 22: Blue Marsh was maintained at its normal except water was released from the recreation pool to create more space for the anticipated runoff from Tropical Storm Isaias. The inflow refilled the reservoir to its normal pool.

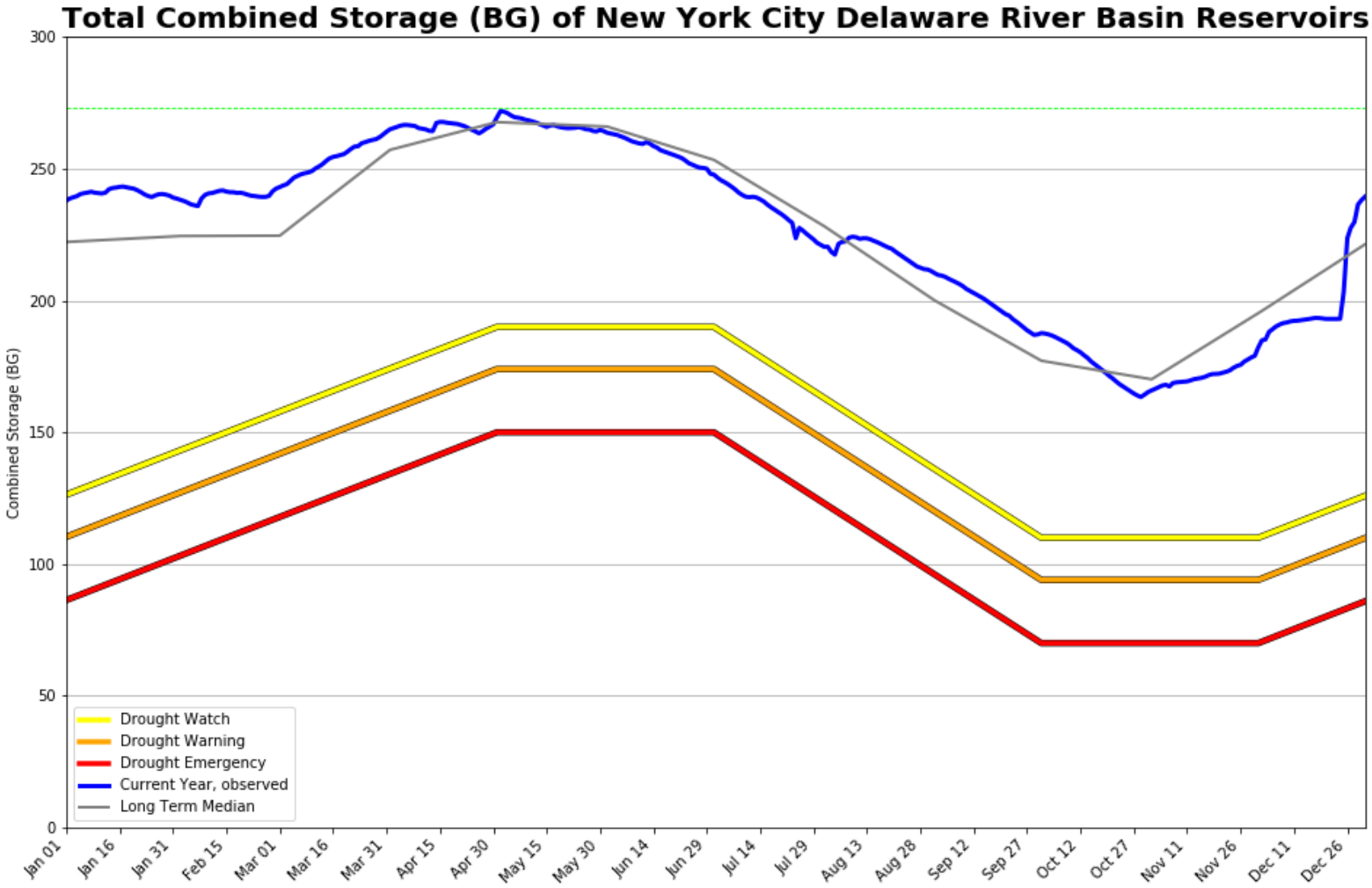

Figure 23: Combined Storage from the NYC DRB reservoirs (Pepacton, Cannonsville, and Neversink). Storage was above the long-term median through the end of April, when the three reservoirs were full. Storage decreased due to habitat releases and withdrawals, and remained below the median, until tropical storm Isaias in August. Storage increased above the median before continuing to decrease through the end of October. On October 28, the level was approximately 53 BG above drought watch. Storage increased until the end of the year. Storage increased approximately 50 BG in response to a major rain and snowmelt event on December 24-25.

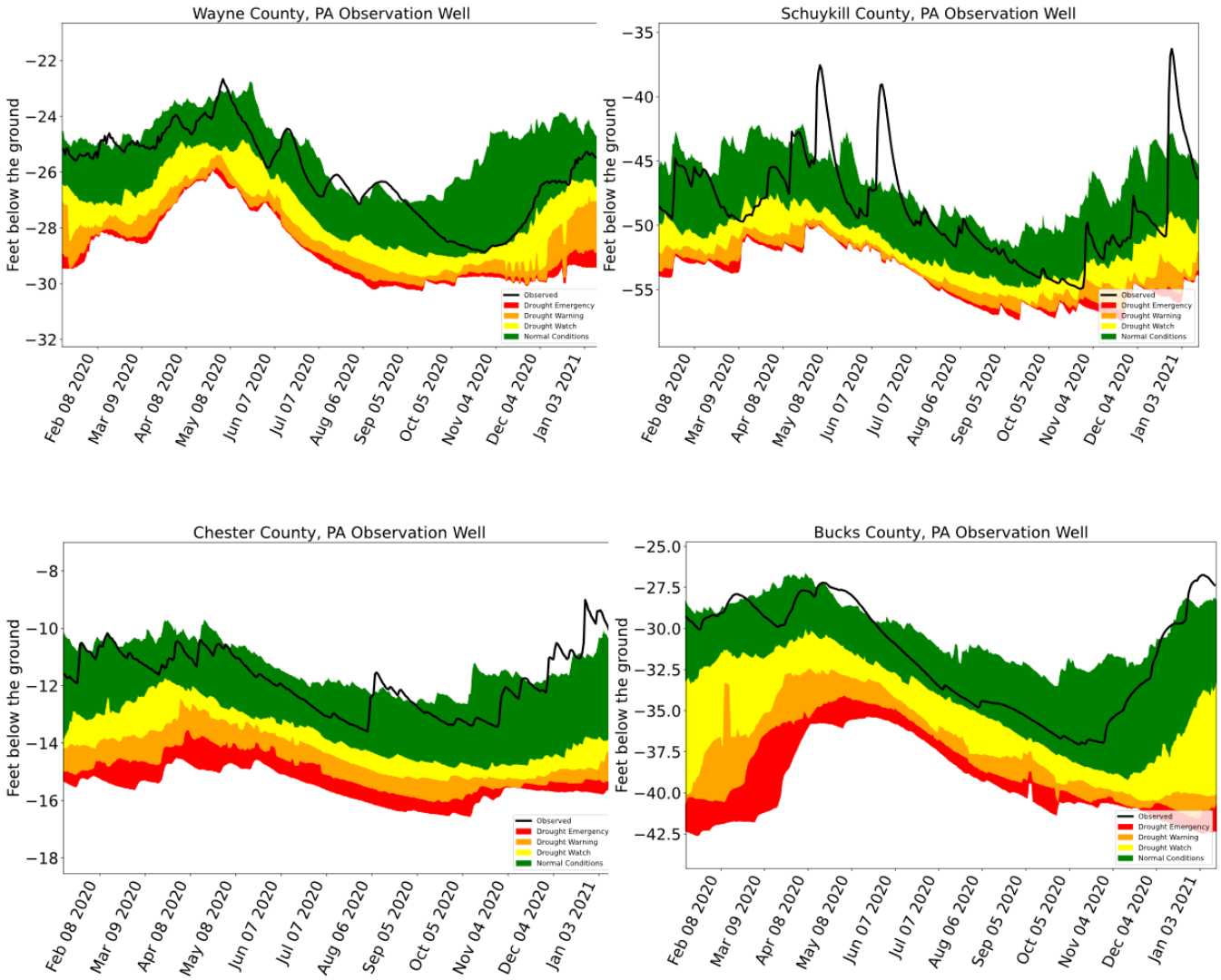

Figure 24: Representative groundwater well levels. Upper basin well – Wayne County, PA. Mid-Upper basin well – Schuylkill County, PA. Mid-Lower basin well – Chester County, PA. Lower basin well – Bucks County, PA. Groundwater levels remained normal for most for the year, with the upper basin and mid-upper basin wells briefly at drought watch levels in the end of October.

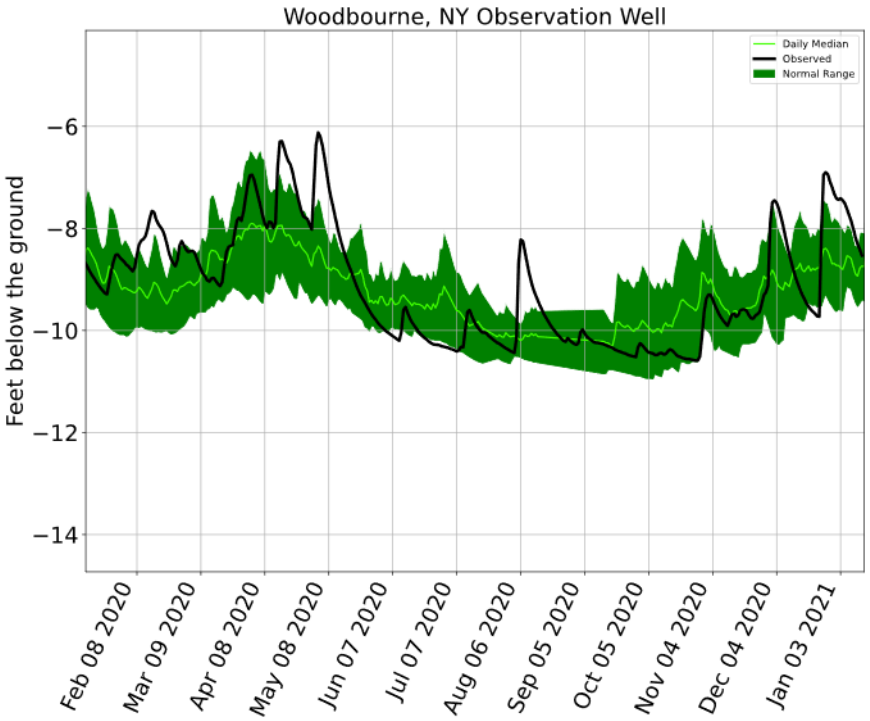

Figure 25: Groundwater levels in Woodbourne, NY were normal or slightly above normal for most of the year.

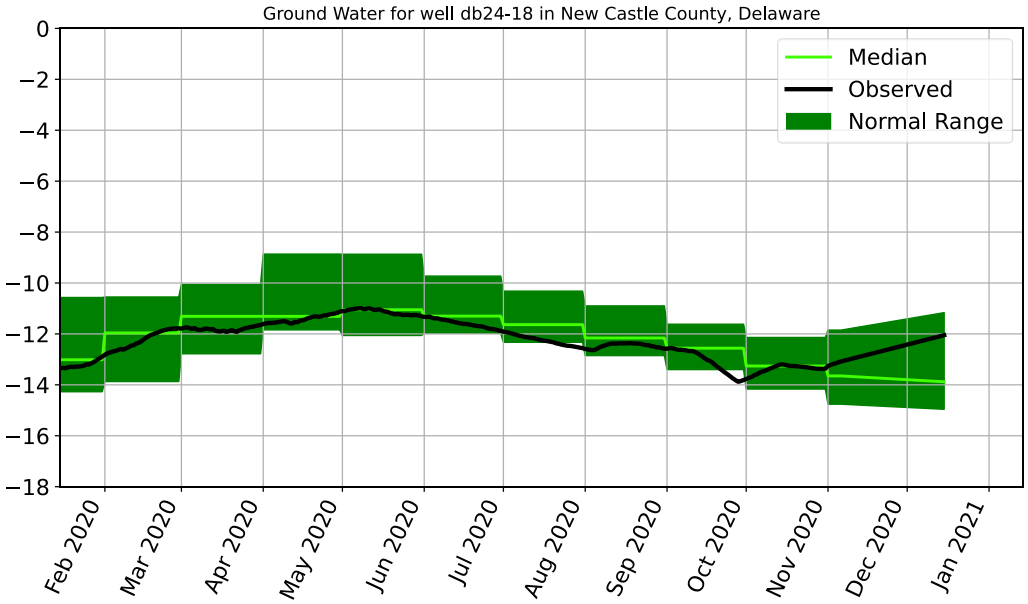

Figure 26: Groundwater levels in New Castle County, DE remained normal, but below the median for most of the year. Data were unavailable for the second half of December 2020.

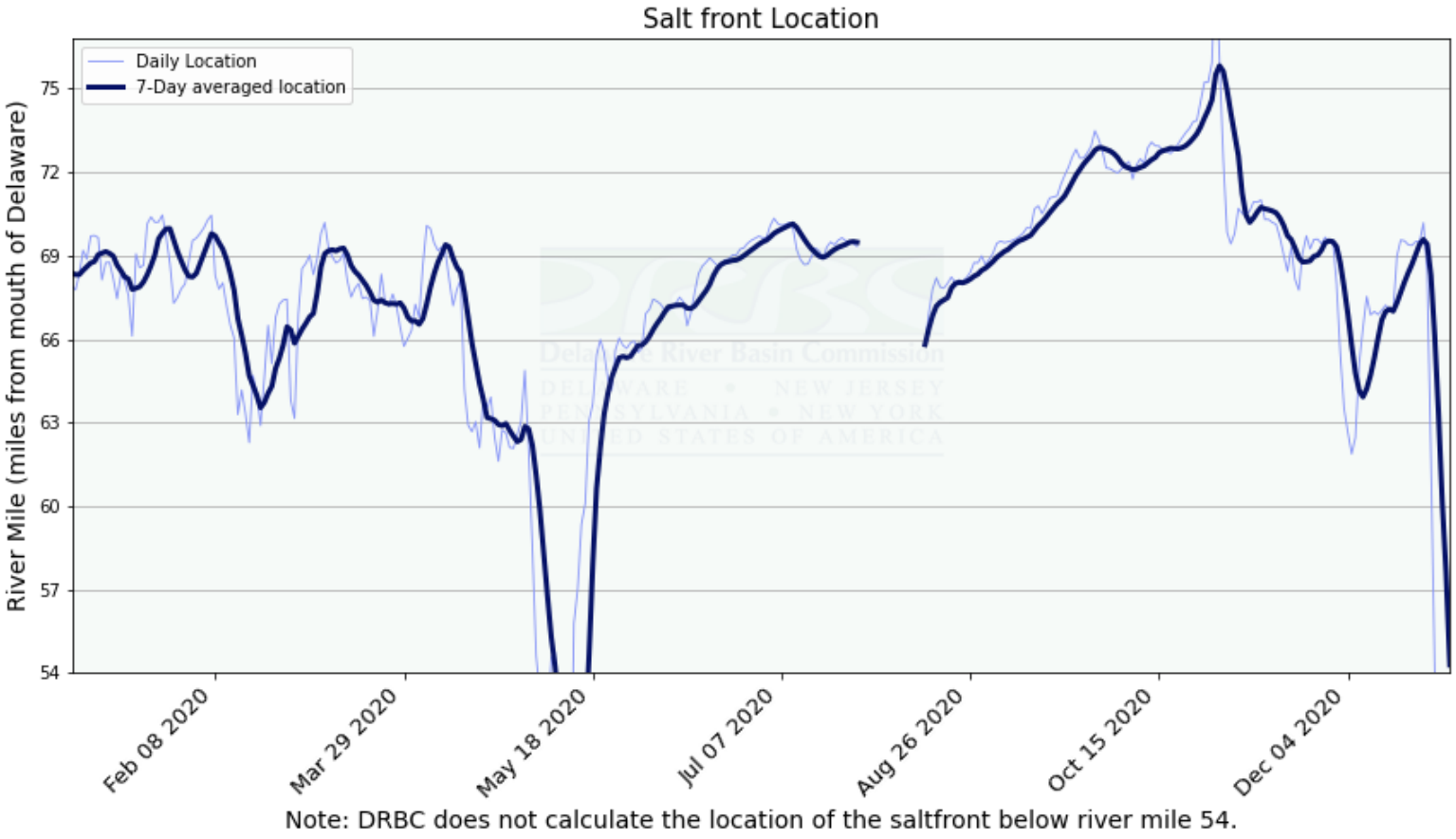

Figure 27: Salt front location time series for 2020. The salt front was in the normal range or below the normal range during the first half of the year. The salt front moved upstream in June and July, before moving downstream in response to increased flows as the result of Tropical Storm Isaias. The salt front then continued upstream until reaching its most upstream location of river mile 76 in late-October. The salt front returned to its normal range in November and December of 2020. The December 24-25 storm event pushed the salt front below Reedy Island.

This report was compiled by DRBC staff in January and February, 2021.