Delaware River Basin Commission
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Steven J. Tambini, P.E.
Executive Director

MEMORANDUM

Flexible Flow Management Program: Performance Report June 1, 2021 – May 31, 2022

The goals of the Flexible Flow Management Program (FFMP)[1] are to manage droughts and maintain flow objectives during periods of low flows. In addition, conservation releases are enhanced to maintain tailwater temperatures, and to minimize spilling of reservoirs through use of the Conditional Seasonal Storage Objective (CSSO). The FFMP evaluation period begins on June 1 and ends on May 31 of the next year. The following is a brief summary of the performance of the FFMP during the release year 2021 – 2022 (June 1, 2021 through May 31, 2022).

In the upper basin, precipitation was above average for six months (July, August, September, October, February, and April) and below average for six months (June, November, December, January, March, and May)[2]. In the lower basin above Trenton, precipitation was above average for 7 months (July, August, September, October, February, April, and May) and below average for 5 months (June, November, December, January, and March)[2].

At the beginning of the release year, storage in the three New York City (NYC) reservoirs (Pepacton, Cannonsville, and Neversink) was near the median value. The storage decreased steadily throughout June 2021 due to below average precipitation in the upper basin[3]. Rainy conditions in July and the remnants of tropical storm Elsa contributed to an increase in storage through the end of the month. The storage decreased through August then remained steady through the beginning of October 2021. During this time, three tropical storms impacted the basin (Tropical Storm Fred, Hurricane Henri, and Hurricane Ida). The tracks of the storm impacts were concentrated in the lower basin and did not significantly impact the storage levels in the NYC reservoirs. In October, the storage began to decrease until the end of the month. A strong Nor'Easter storm system impacted the basin on October 17-19, 2021, which increased the storage levels in the NYC reservoirs. During the winter months November 2021 through February 2022, storage steadily decreased as water was stored in snowpack. At the beginning of February 2022, the storage reached its lowest point of the release year at approximately 213 billion gallons (BG) which is 79.6 percent. During February and March 2022, the storage increased as a direct result of runoff from snowmelt and rain. The reservoirs were full by the middle of March 2022, and remained full or near full through May 2022. The storage then decreased through the end of the release year. For a detailed analysis of the tropical storms and other hydrologic events of 2021, see the Annual

[1] https://webapps.usgs.gov/odrm/documents/ffmp/Appendix_A_FFMP-20180716-Final.pdf
[2] Data Source: Applied Climate Information System - https://www.rcc-acis.org/
[3] Data Source: New York City Department of Environmental Protection – Water Supply Control Center

Hydrologic Conditions Report for the Delaware River Basin, published on the Delaware River Basin Commission (DRBC) website[4].

The flows at Montague[5] and Trenton[6] were above normal[7] for much of the time between July and December. The greater than normal rainfall amounts between July and October, in part due to tropical storms Fred, Henri, and Ida in late summer and a Nor'Easter in late October, resulted in the higher flows. From December through May, the flows were in the normal range, except for a brief period of above normal flow as the result of another Nor'Easter in late April.

In 2021-2022, approximately 2,115 MG of water was used by NYC to meet the flow objective at Montague during a drier period at the end of June, and at the beginning of August[8]. A release was also made at the end of January. This value includes the portion of the conservation releases that was used to meet Montague, but not the amount of conservation release that exceeds what is needed. No water was required from the lower basin reservoirs (Blue Marsh and Beltzville) to meet the flow objective at Trenton.

As defined in the FFMP, the diversion from NYC is limited to 800 million gallons per day (mgd) on a running average beginning on June 1 until May 31 of the previous year. The running average did not exceed 800 mgd during the release year 2021-2022. The average diversion from the NYC reservoirs during the release year 2021-2022 was 464 mgd. In New Jersey, the diversion is limited to 100 mgd as a monthly average. The average diversion for release year 2021-2022 was 96 mgd. The highest monthly average diversion occurred in March and was less than 100 mgd.

Conservation releases are designed to protect the ecology of the stream reaches below the NYC reservoirs. In release year 2021-2022, the required conservation releases based on the FFMP tables were as follows: Cannonsville – 128,909 MG, Pepacton – 66,254 MG, and Neversink – 31,247 MG[3]. All or a portion of the releases on a given day may have been used to meet the Montague Flow Objective. Additional releases were made from the IERQ banks (see next section). The 4G release table was used for all of release year 2021-2022[3].

The Interim Excess Release Quantity (IERQ), 15,468 cfs-days (approximately 10 BG), is available to further protect the ecology of the river by supporting releases for thermal mitigation, rapid flow change mitigation, the Trenton Flow Objective, and the New Jersey Diversion Amelioration. In release year 2021-2022, the rapid flow change mitigation bank was not used. Releases from the thermal bank (769 cfs-days) were made on 13 days for 5 events in June 2021, August 2021, and May 2022. No releases were required from the Trenton Flow Objective bank or New Jersey Diversion Offset Bank.

The summer of 2021 (June – August) was one of the warmest summers on record across the basin[9]. The National Climate Data Center (NCDC), an agency of the National Center for Environmental Information (NCEI), ranks the observed temperature data compared to the long-term historic records for several climate divisions in the US. In the upper basin, the Eastern Plateau region containing much of the upper

[4] https://www.nj.gov/drbc/library/documents/2021Hydrologic-Conditions-Rpt.pdf
[5] USGS 01438500 - https://waterdata.usgs.gov/usa/nwis/uv?01438500
[6] USGS 01463500 - https://waterdata.usgs.gov/usa/nwis/uv?01463500
[7] Normal is defined as the 25th to 75th percentile of flow on a given day
[8] USGS ODRM - https://webapps.usgs.gov/odrm/
[9] NCEI NCDC - https://www.ncdc.noaa.gov/cag/national/rankings

basin was the 15th warmest summer on record. The Hudson valley region was the 7th warmest. For both regions, the records began in 1903. In the lower basin, the Southeastern Piedmont regions in Pennsylvania (containing parts of the Schuylkill and the Lehigh) was the 5th warmest on record. Southern New Jersey was the 6th warmest on record. For the lower basin regions, records began in 1927.

The thermal releases are designed to protect stream reaches below the NYC reservoirs from exceeding 24 degrees C, with a goal of the temperature not exceeding 20 degrees C (FFMP). In release year 2021-2022, the stream reaches at Hale Eddy, Harvard, and Hancock never exceeded 24 degrees C[10]. At Lordville, the maximum temperature exceeded 24 degrees C on 2 days, and the temperature exceeded 24 degrees C at Bridgeville on 2 days. There was a total of five thermal events in release year 2021-2022, defined by consecutive days when releases were made. Releases were made on a total of 13 days during the summer of 2021, and approximately 0.5 BG was used in total for thermal mitigation[8].

To enhance flood mitigation, water is released from the NYC reservoirs based on a Conditional Seasonal Storage Objective (CSSO). Discharge mitigation releases are made from a reservoir when the combined storage is in the L1 zone, and the individual reservoir elevation/storage is above the CSSO. Releases to achieve the CSSO create a high probability of maintaining fifteen percent void spaces in individual reservoirs between November 1 and February 1, and ten percent void spaces in individual reservoirs between approximately September 15 and March 1. Discharge mitigation releases for this release year were 182,380 MG from Cannonsville, 80,557 MG from Pepacton, and 34,954 MG from Neversink and the reservoir elevations were above the CSSO for 179, 249, and 292 days, respectively. Cannonsville reservoir spilled 37,046 MG over 49 days, Pepacton reservoir spilled 35,416 MG over 46 days. Neversink reservoir spilled 14,984 MG over 202 days[3].

As established in the Delaware River Basin Water Code[11], DRBC is responsible for managing salinity intrusion in the Delaware River by maintaining the flow objective at Trenton, N.J. The purpose of the flow objective at Trenton, is to prevent the salt front, an indicator of salinity intrusion, from moving too far upstream. The salt front is a calculated indicator based on the 7-day average location of the 250 mg/L isochlor in the river[12]. The normal range of the salt front is between river mile 67 and 76 (river miles are defined as the along-channel distance from the mouth of the estuary). The DRBC directs releases from reservoirs to meet the flow objective, which impedes the upstream the movement of the salt front to protect drinking water intakes near Philadelphia, PA approximately 110 river miles from the mouth of the bay. In accordance with both the Water Code and the FFMP 2017 agreement, in a drought emergency, the flow objectives depend on the location of the salt front. The increased Montague flow objective provides more water from the upper basin to reduce the amount of water needed from the lower basin reservoirs to meet the Trenton flow objective. During the 2021-2022 release year, a drought emergency did not occur in the basin, and releases were not made for management of the salt front.

The salt front was in or near the normal range from June through late August. After Hurricane Ida in early September, the salt front moved downstream to river mile 54, then returned to the normal range in early October 2021. A Nor'Easter in October caused the salt front to move back downstream, below the normal range. Lower than normal precipitation in November and December along with the typical low winter flows through February resulted in the upstream movement of the salt front. On February 5,

[10] Data Source: USGS Gages (01426500, 01417500, 01427000, 01436690, 01427207)
[11] https://www.nj.gov/drbc/library/documents/watercode.pdf
[12] https://www.nj.gov/drbc/programs/flow/salt-front.html

2022, the salt front was at its most upstream location of the release year, near river mile 72.9. From February through May, the salt front moved downstream due to snowmelt and higher than normal precipitation in March and April along with typical higher spring flows. For a two week period in March, the salt front moved upstream near river mile 68 due to average flows combined with stronger tidal forcing and an offshore meteorological storm event. Flows increased after another Nor'Easter in the first week of April, and the salt front was below river mile 54 by the end of the month[13]. At the end of the release year, the salt front returned to the normal range.

Summary: In release year 2021-2022, precipitation was above average across the basin. The NYC Storage was above the long-term median for the majority of the year, except for in January when water was stored in snowpack. Flows were above normal during the second half of 2021, and normal from December 2021 through the end of March 2022. Flows were above normal during April 2022, and normal to above normal during May 2022. During June and August when flows were low, 2.1 BG was released from the NYC reservoirs to meet the Montague Flow Objective. The NYC Diversion and NJ Diversion did not exceed their respective limits as set in the FFMP. The conservation releases spent 100 percent of the time in Table 4G. Cannonsville was below the CSSO 51 percent of the year, Pepacton was below the CSSO 32 percent of the year, and Neversink was below the CSSO 20 percent of the year. Warm summer air temperature (ranked in the top ten across much of the basin) led to increased water temperatures at the beginning of the release year, and thermal mitigation was used for eleven days during the hot summer months and two days during May 2022. The maximum water temperature exceeded 24 degrees C on two days at Lordville and two days at Bridgeville. The salt front spent all of the release year at or below the normal range, and reached its maximum location near river mile 72.9 on February 5, 2022.

For non-provisional, approved data, contact the Delaware River Basin Commission (salt front), the NYC Department of Environmental Protection (NYCDEP), the Office of the Delaware River Master (ODRM), or the United States Geological Survey (USGS)[14]. This report is available online at: https://www.nj.gov/drbc/programs/flow/FFMP_PerformanceRpts.html

ACKNOWLEDGEMENTS

This report was prepared by the Delaware River Basin Commission staff. Mr. Anthony Preucil and Ms. Amy Shallcross, P.E., Manager of Water Resource Operations, authored this report. Mr. Preucil is a Water Resource Scientist and Ms. Shallcross is the Manager of Water Resource Operations.

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[13] The location of the salt front when below river mile 54 is unavailable due to the lack of data for the calculation.
[14] USGS - https://www.usgs.gov/

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FFMP Implementation Performance

Release Year 2021

June 1, 2021 – May 31, 2022

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Water Resource Scientist

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July 6, 2022

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NOTE

All data used in the analysis are Provisional

Final/approved data are available from:

Delaware River Basin Commission (DRBC)

NYC Department of Environmental Protection (NYCDEP)

Office of the Delaware River Master (ODRM)

United States Geological Survey (USGS)

Methodology for calculations is included for reference on the last slide

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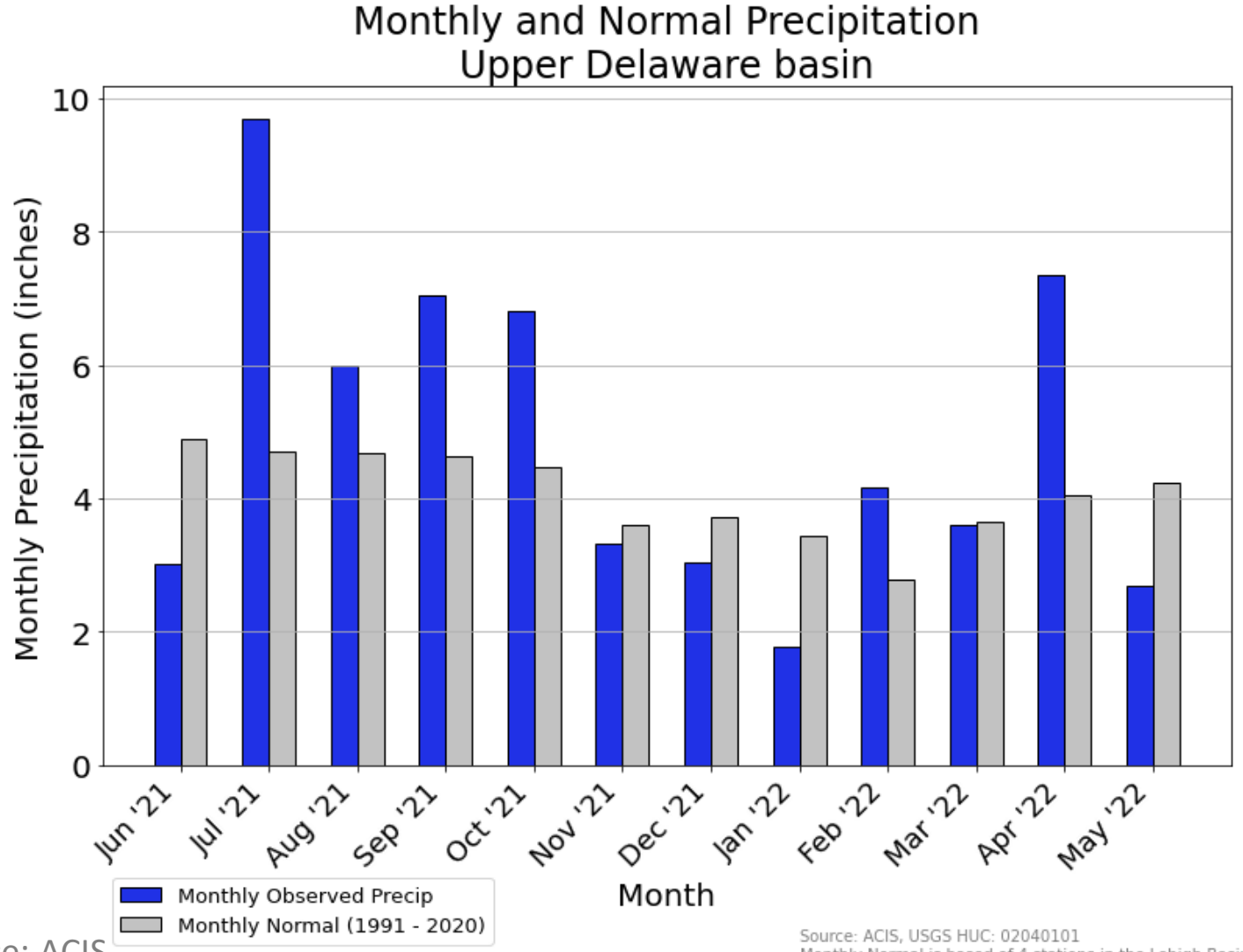
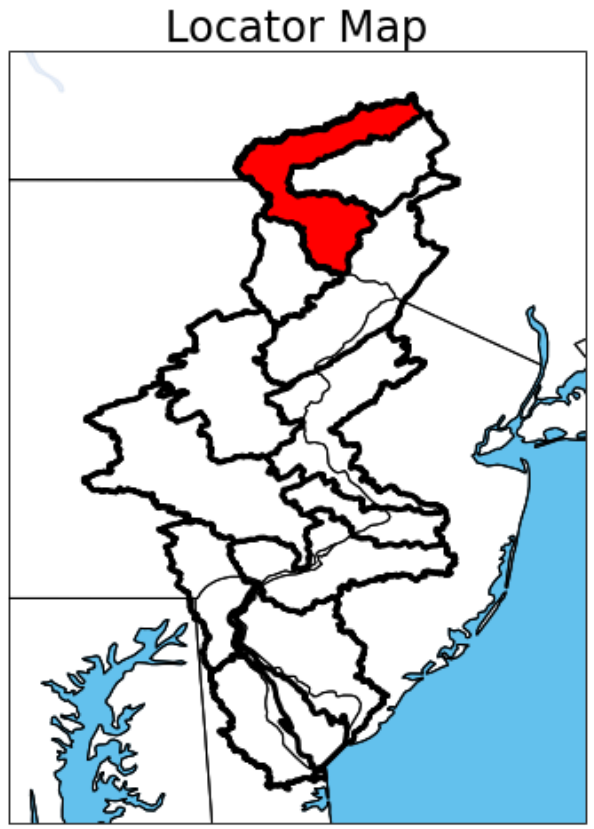
FFMP Performance Goals

* Manage Droughts
* Maintain Flow Objectives
* Provide enhanced conservation releases
* Maintain desirable tailwater temperatures
* Minimize spills using the Conditional Seasonal Storage Objective (CSSO)

Precipitation – Upper Basin





Source: ACIS, USGS HUC: 02040101
Monthly Normal is based of 4 stations in the Lehigh Basin

Data Source: ACIS

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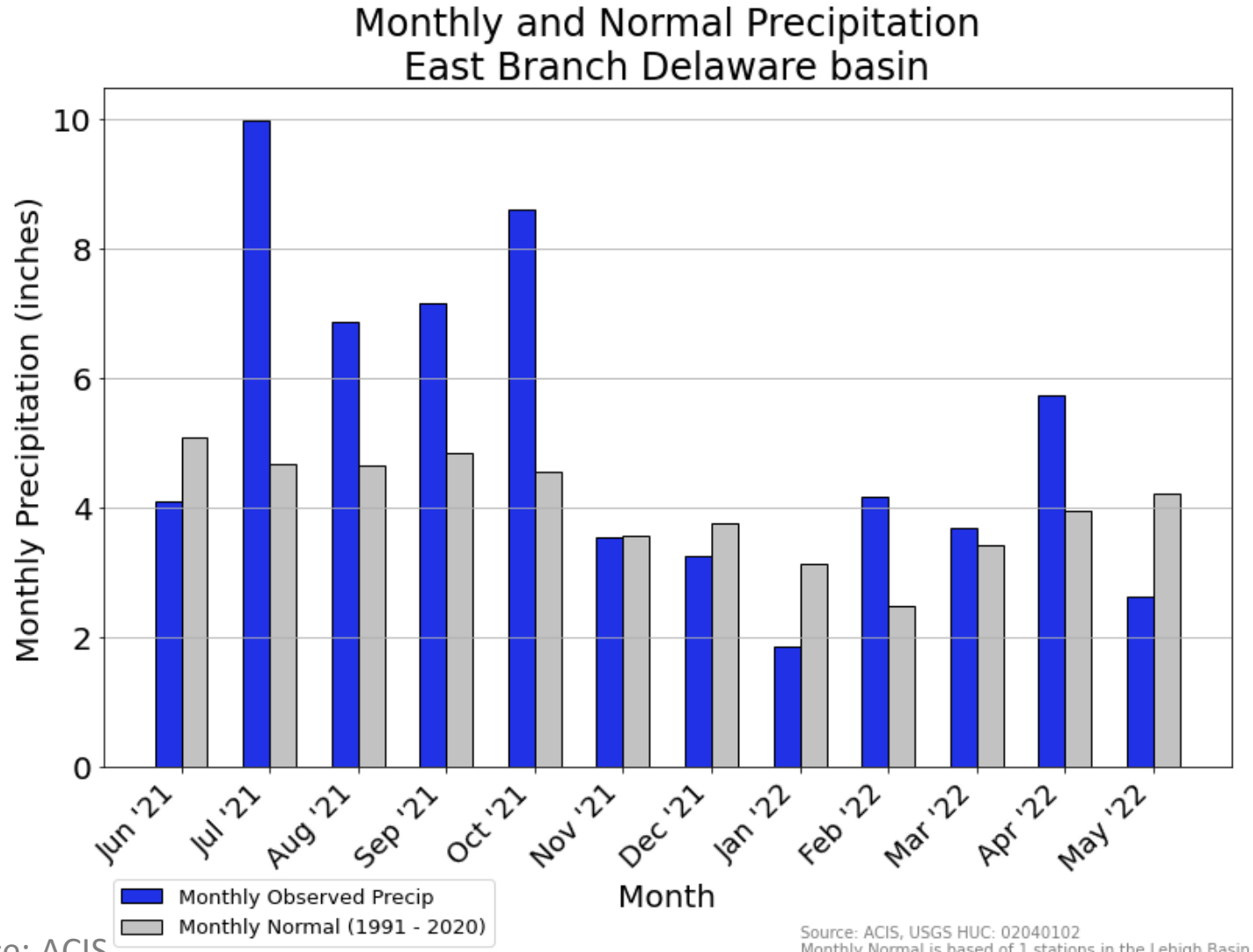
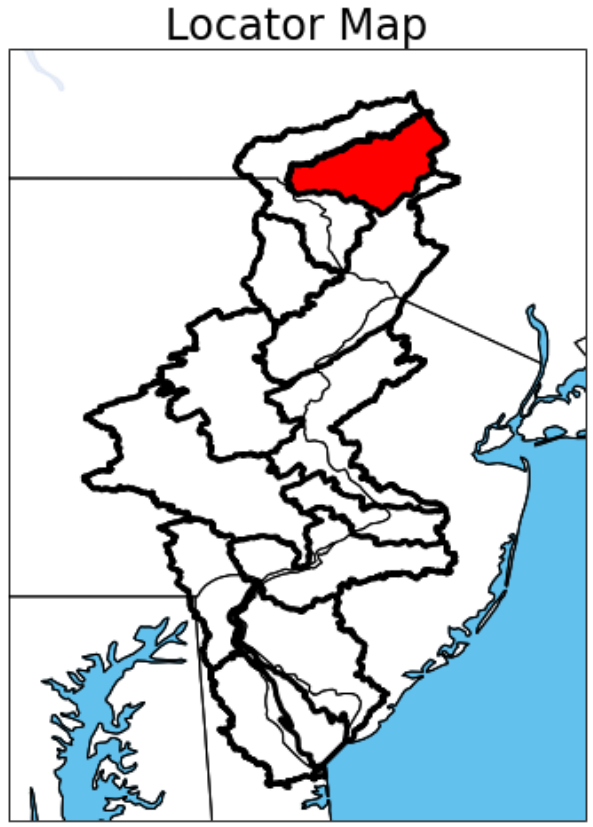
Precipitation – Upper Basin



Source: ACIS, USGS HUC: 02040102
Monthly Normal is based of 1 stations in the Lehigh Basin



Data Source: ACIS

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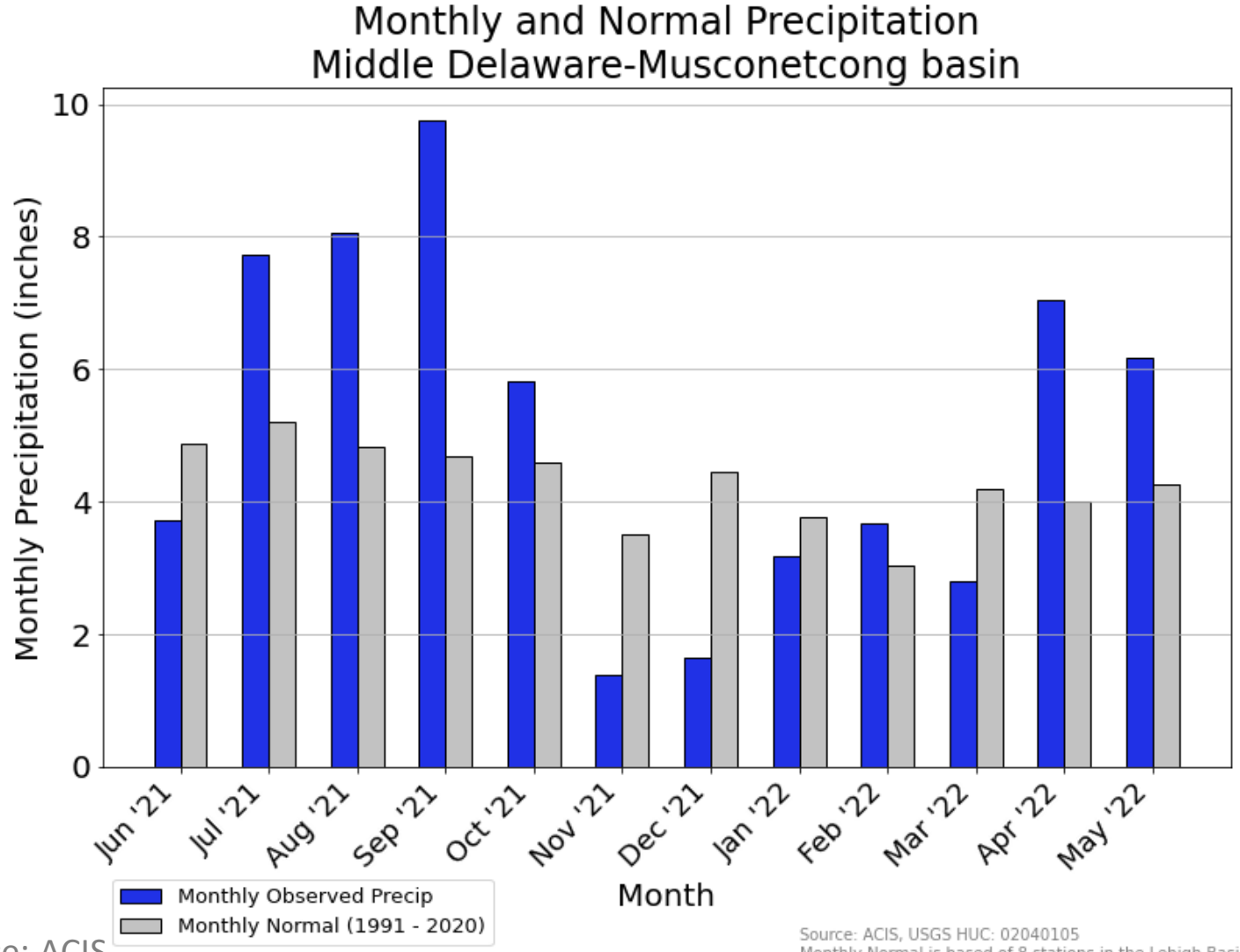
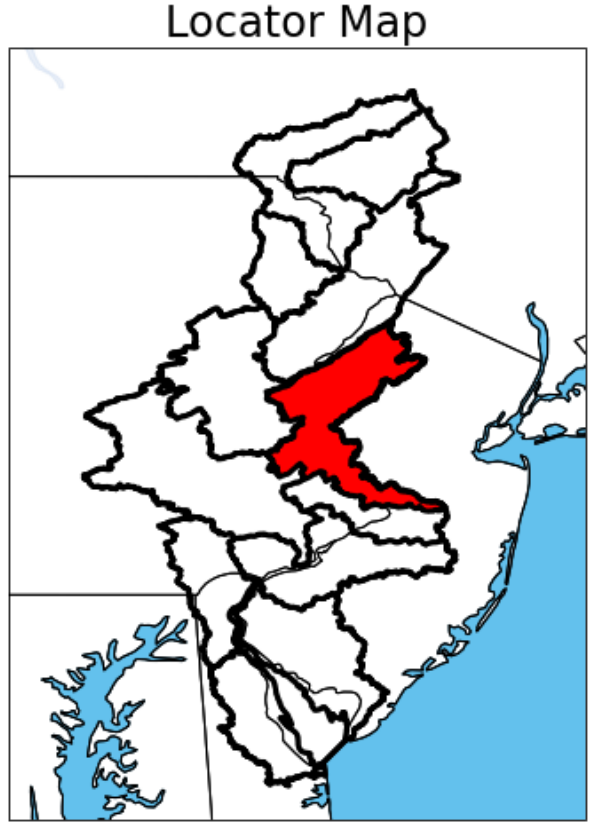
Precipitation – Lower Basin





Source: ACIS, USGS HUC: 02040105
Monthly Normal is based of 8 stations in the Lehigh Basin

Data Source: ACIS

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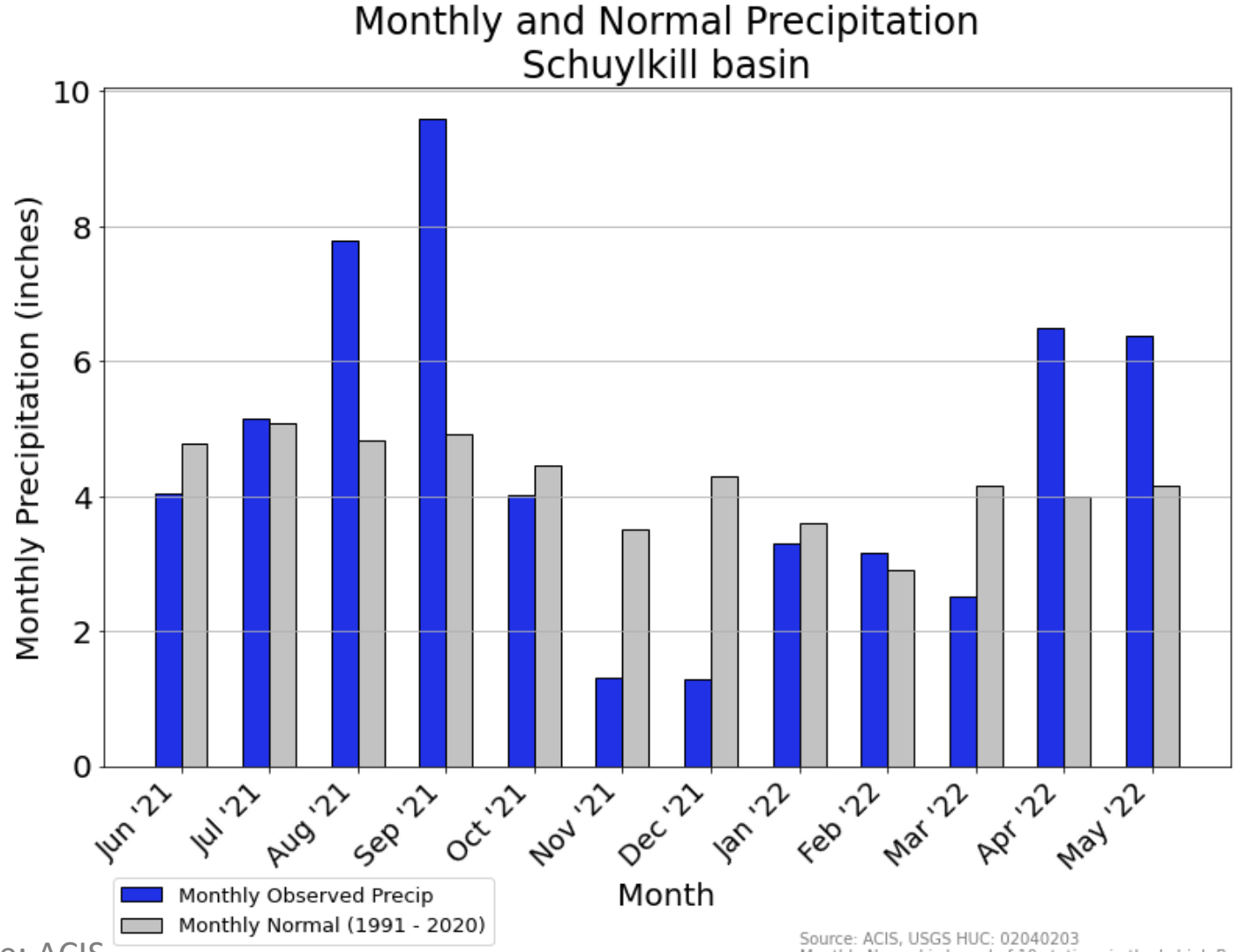
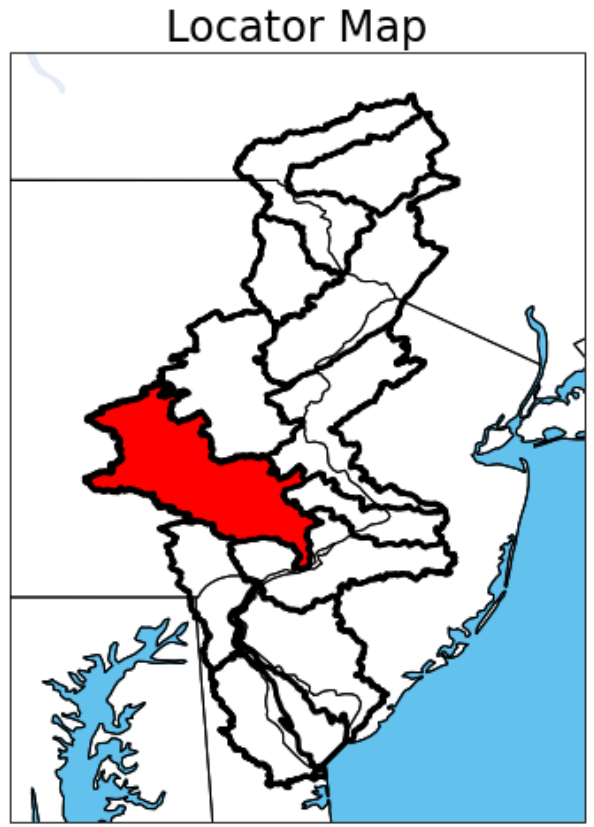
Precipitation – Lower Basin





Source: ACIS, USGS HUC: 02040203
Monthly Normal is based of 19 stations in the Lehigh Basin

Data Source: ACIS

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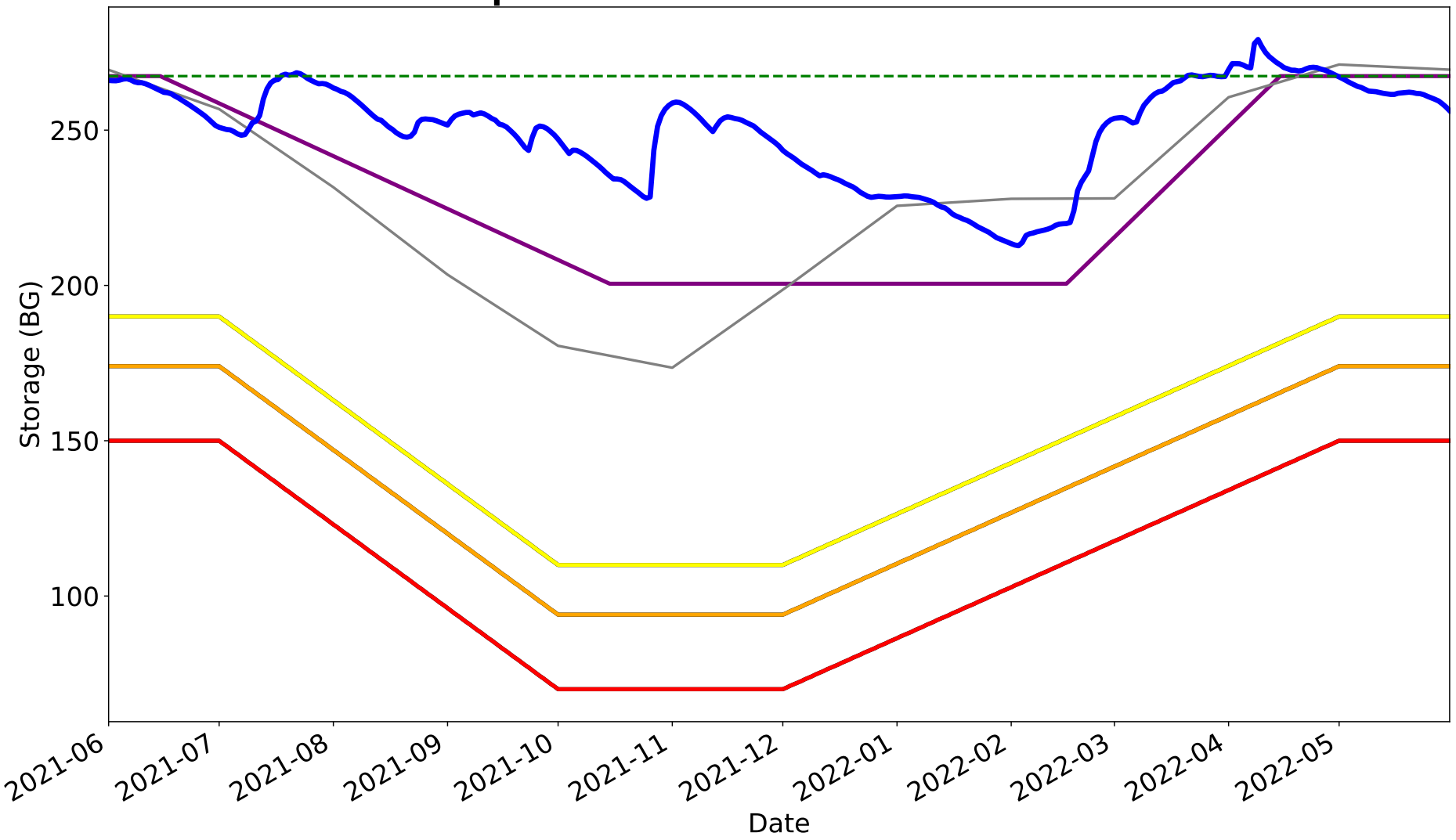
Combined Storage Amount in the NYC Reservoirs
Pepacton + Cannonsville + Neversink



Data Source: NYCDEP

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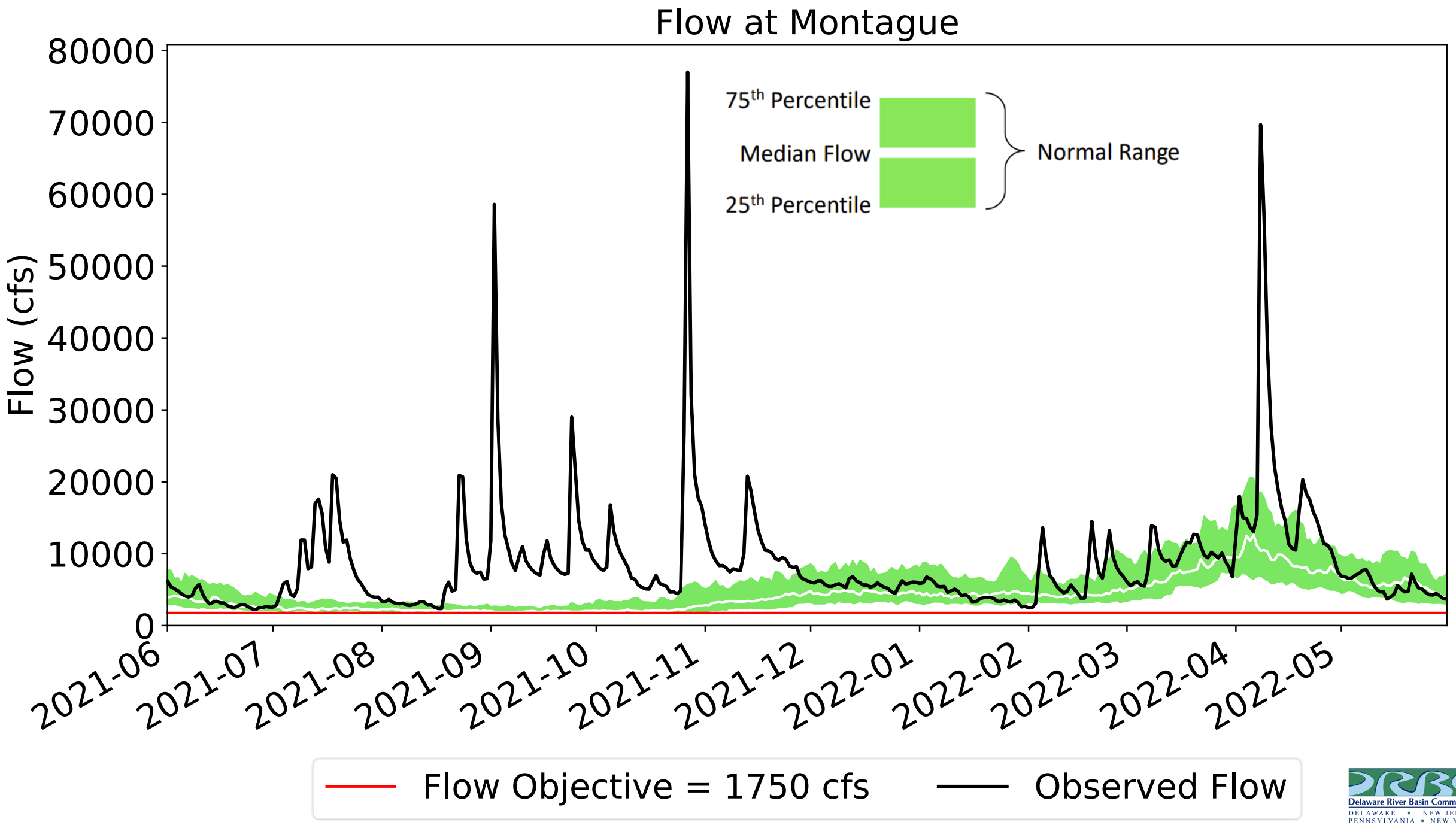
Flow Objectives

Water Released from NYC to Meet Flow Objectives (MG)	
Montague	2,115*
Trenton	0
Total	2,115

Water Released from Lower Basin to Meet Trenton Flow Objectives (MG)	
Beltzville	0
Blue Marsh	0
Total	0

*Includes the portion of the conservation releases needed to meet Montague, but not the amount of the conservation release that exceeds what is needed to meet Montague.

Data Source: ODRM



Data Source: USGS

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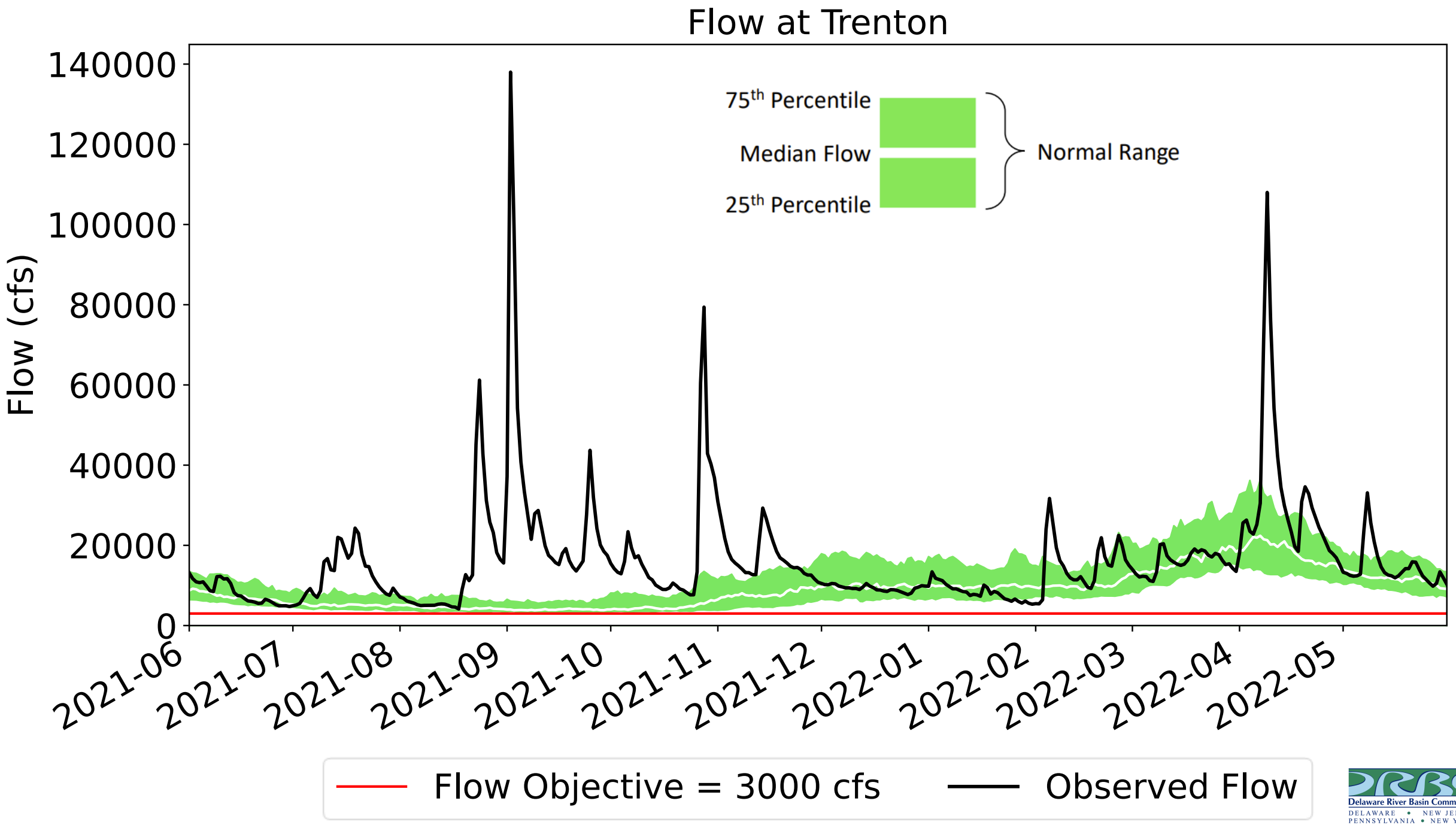

Data Source: USGS

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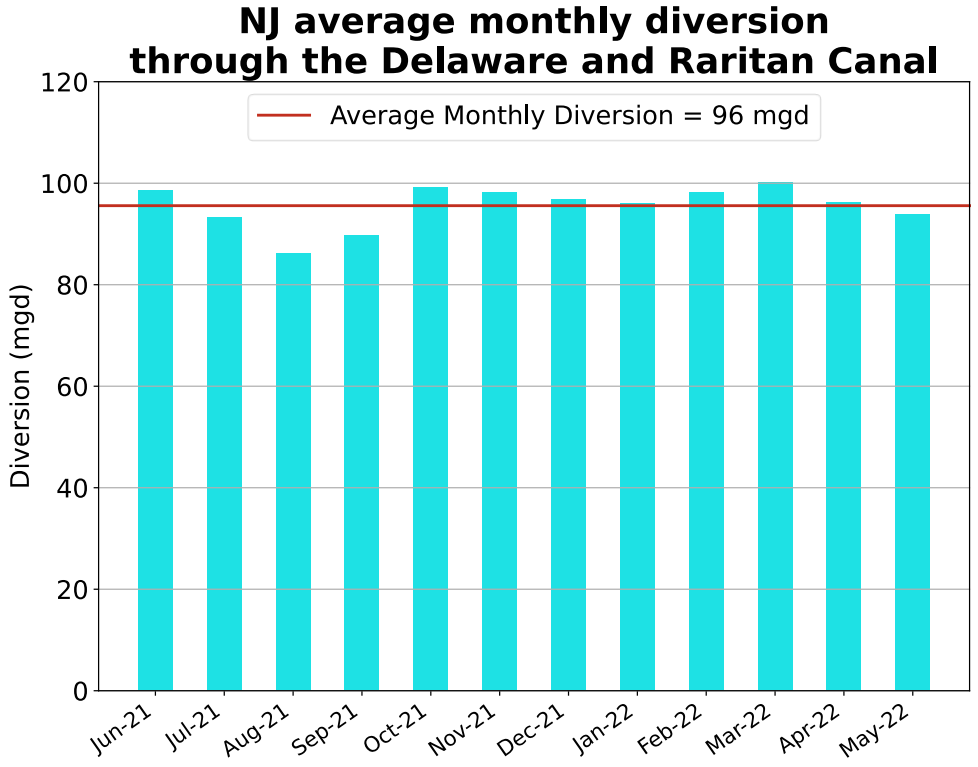
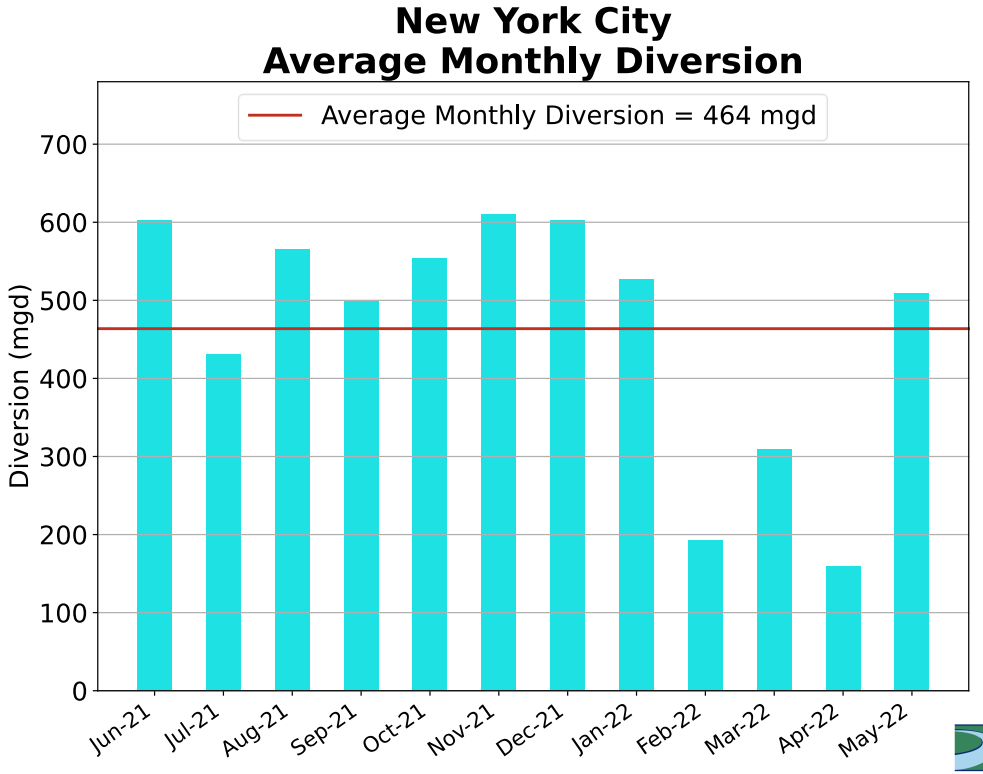
Diversions

Monthly Average Daily Diversion (June 1, 2021 – May 31, 2022)	
New Jersey	New York
96 mgd	464 mgd





Data Source: USGS, NYCDEP

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Conservation Releases

Volume of Conservation Releases (MG)			
	FFMP 2017 Tables Based on Storage (6/1/20 - 5/31/20)	**REV1**	**Multiple of Revision 1**
Cannonsville	128,909	20,665	6.2
Pepacton	66,254	14,562	4.5
Neversink	31,247	8,664	3.6
Values are the conservation releases required by the FFMP Tables Only. All or a portion of the release may have been used to meet the Montague Flow Objective. Additional release volume may have been required for bank use.			

Data Source: NYCDEP

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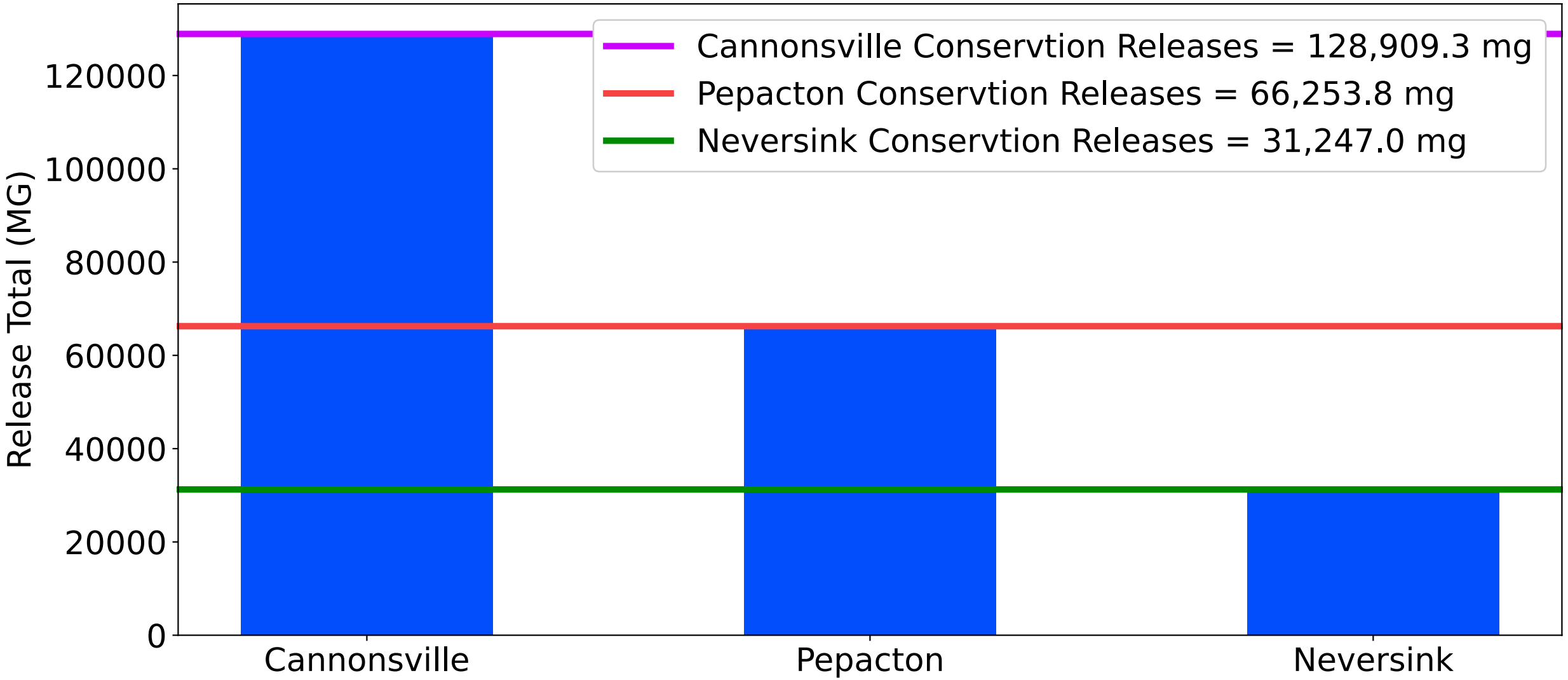
Conservation Releases from NYC Delaware River Basin Reservoirs
FFMP 2021-2022



Data Source: NYCDEP

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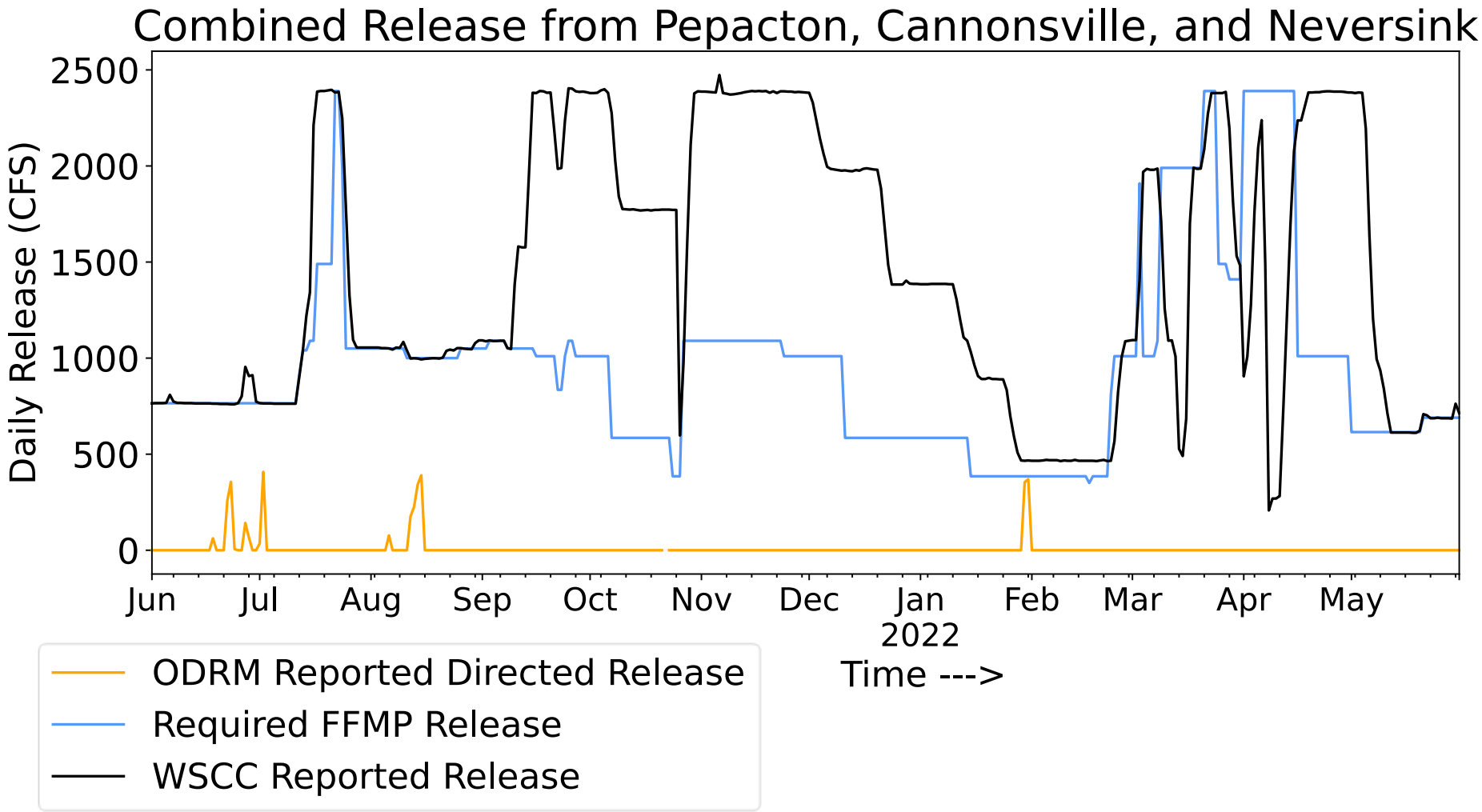
Actual Releases



Data Source: NYCDEP, ODRM, USGS

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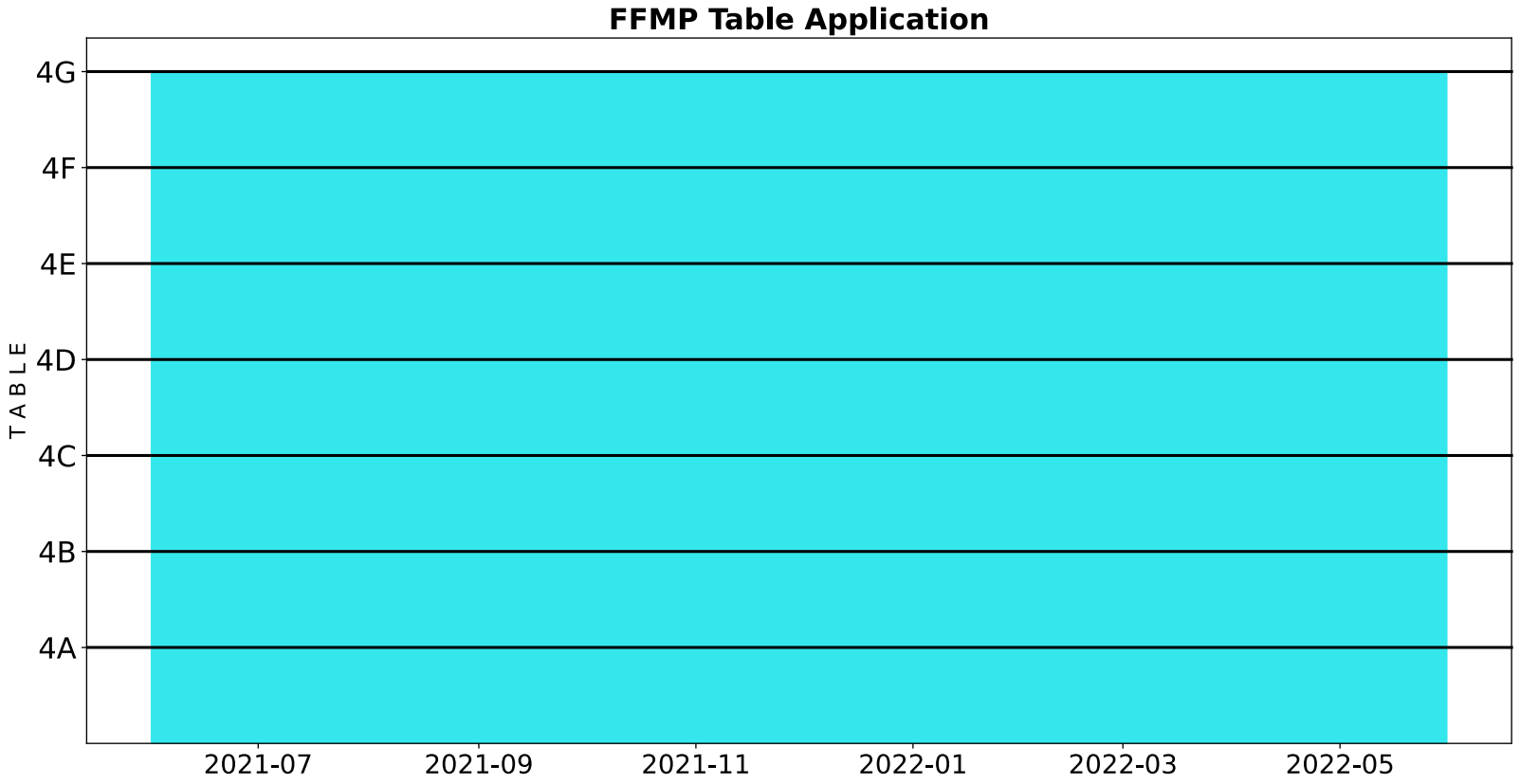
Time in FFMP Release Tables

FFMP TABLE	Number of Days	Percent
4G	365	100.0
4F	0	0
4E	0	0
4D	0	0
4C	0	0
4B	0	0
4A	0	0



Data Source: NYCDEP

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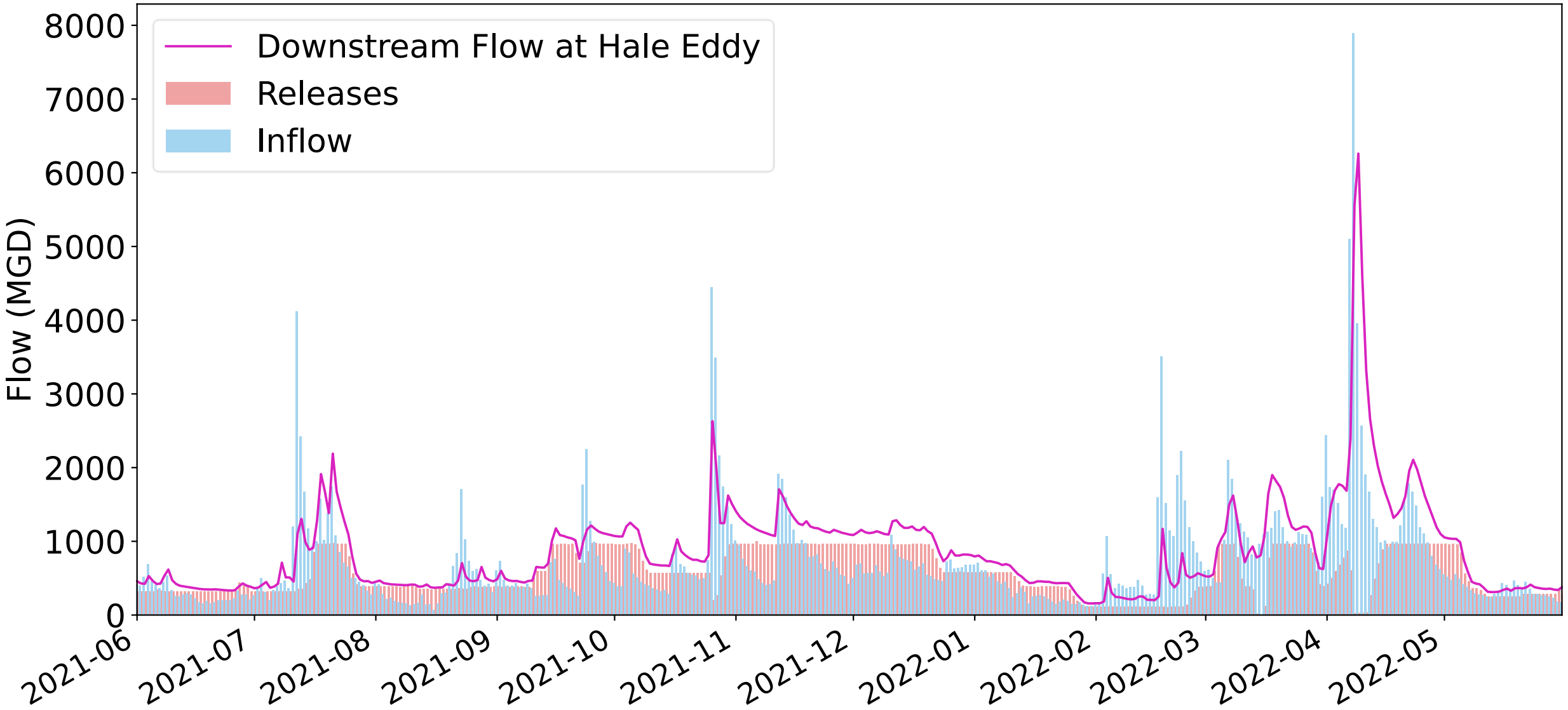
Cannonsville Inflow, Releases, and Downstream Flow



Data Source: USGS

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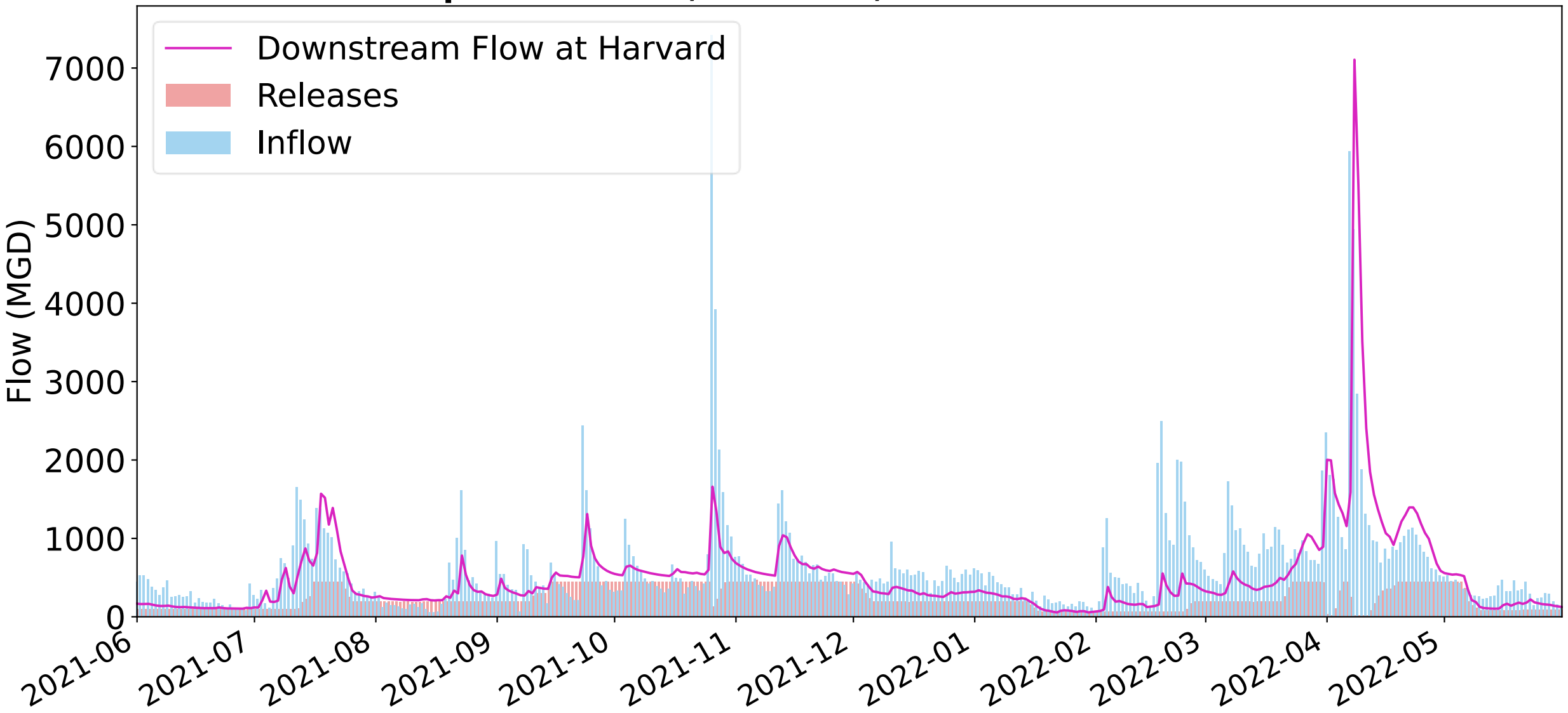
Pepacton Inflow, Releases, and Downstream Flow



Data Source: USGS

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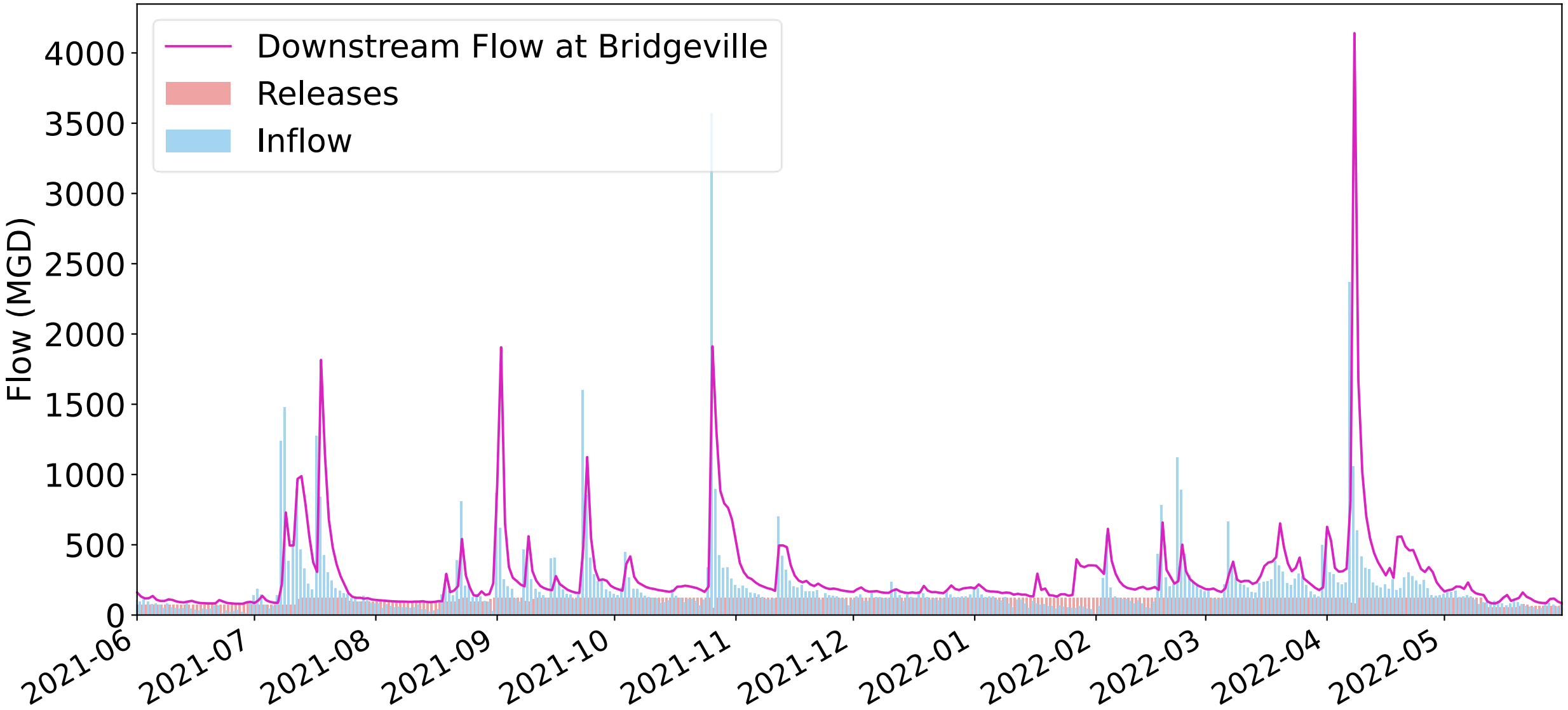
Neversink Inflow, Releases, and Downstream Flow



Data Source: USGS

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Bank Use

FFMP 2017 Bank	Used	Size
NJ Diversion Amelioration Bank	0	of 2,545 cfs-days
Rapid Flow Change Mitigation Bank	0	of 1,000 cfs-days
Thermal Mitigation Bank	769	of 2,500 cfs-days
Trenton Equivalent Flow Objective Bank	0	of 9,423 cfs-days
NJ Diversion Offset Bank	0	cfs-days

Thermal Releases were made on 13 days for 5 events in June 2021, August 2021, and May 2022. No water was needed for rapid flow change mitigation this release year.

Data Source: ODRM

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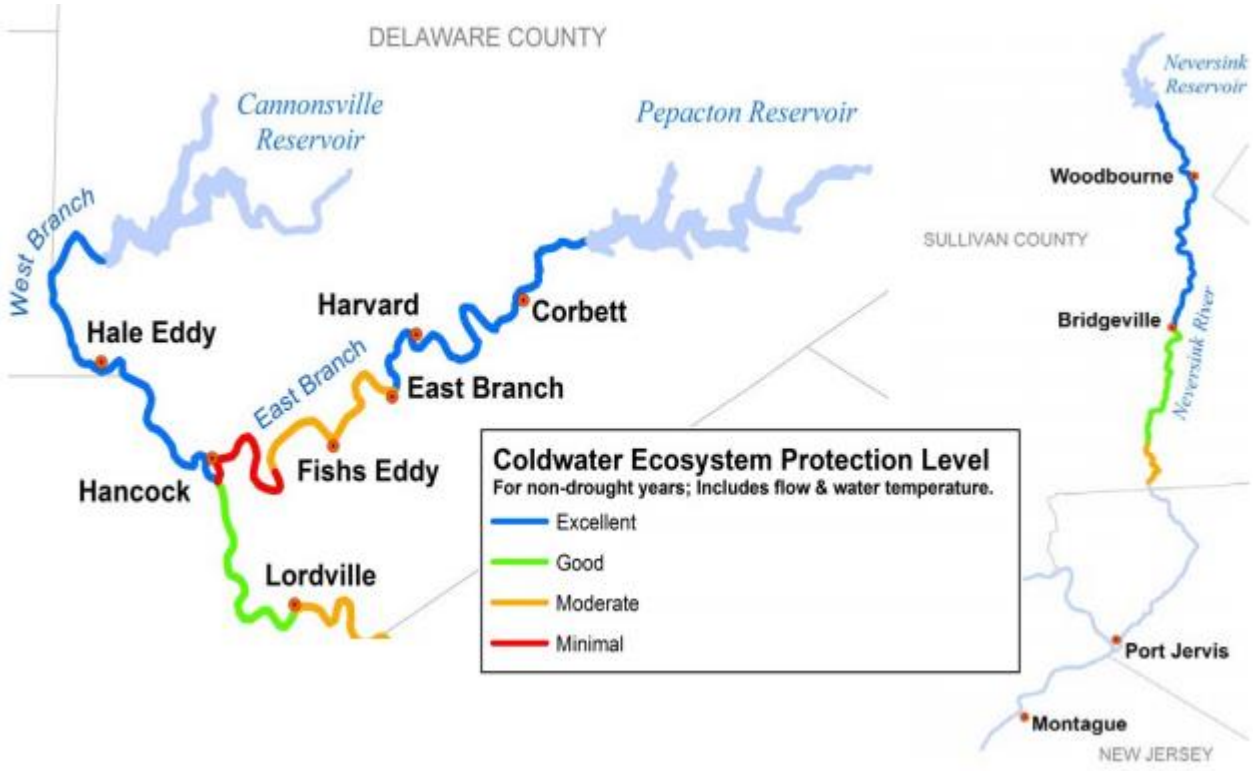
Habitat Protection

(Temperature)



Goals for Excellent Habitat:

- Summer Temperature typical less than 20 ^{0}C
- Rare Exceedances of > 24 ^{0}C

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Temperature

Goals for Excellent Habitat:

* Summer Temperature typical less than 20 ^{0}C
* Rare Exceedances of > 24 ^{0}C

Location	Exceedances of 24^{0}C		Exceedances of 20^{0}C	
	Days the Maximum Temperature was above 24 ^{0}C	Days the Average Temperature was above 24 ^{0}C	Days the Maximum Temperature was above 20 ^{0}C	Days the Average Temperature was above 20 ^{0}C
Hale Eddy	0	0	0	0
Harvard	0	0	6	0
Hancock	0	0	1	0
Lordville	2	0	41	19
Bridgeville	2	0	47	11

Thermal Releases were made on 13 days for 5 events in June 2021, August 2021, and May 2022. Approximately 0.5 BG was used from the bank.

Data Source: USGS

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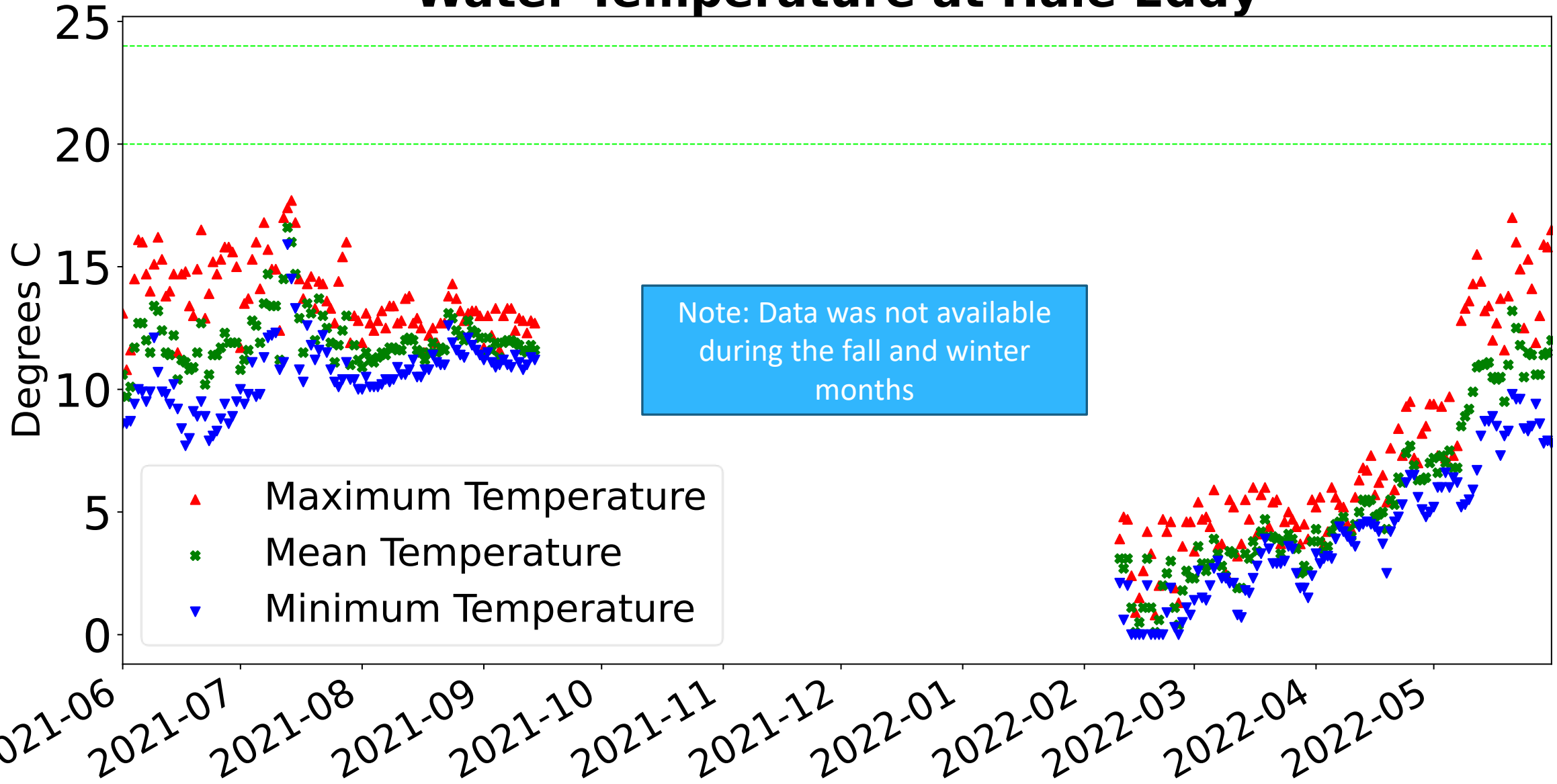
Water Temperature at Hale Eddy



Data Source: USGS

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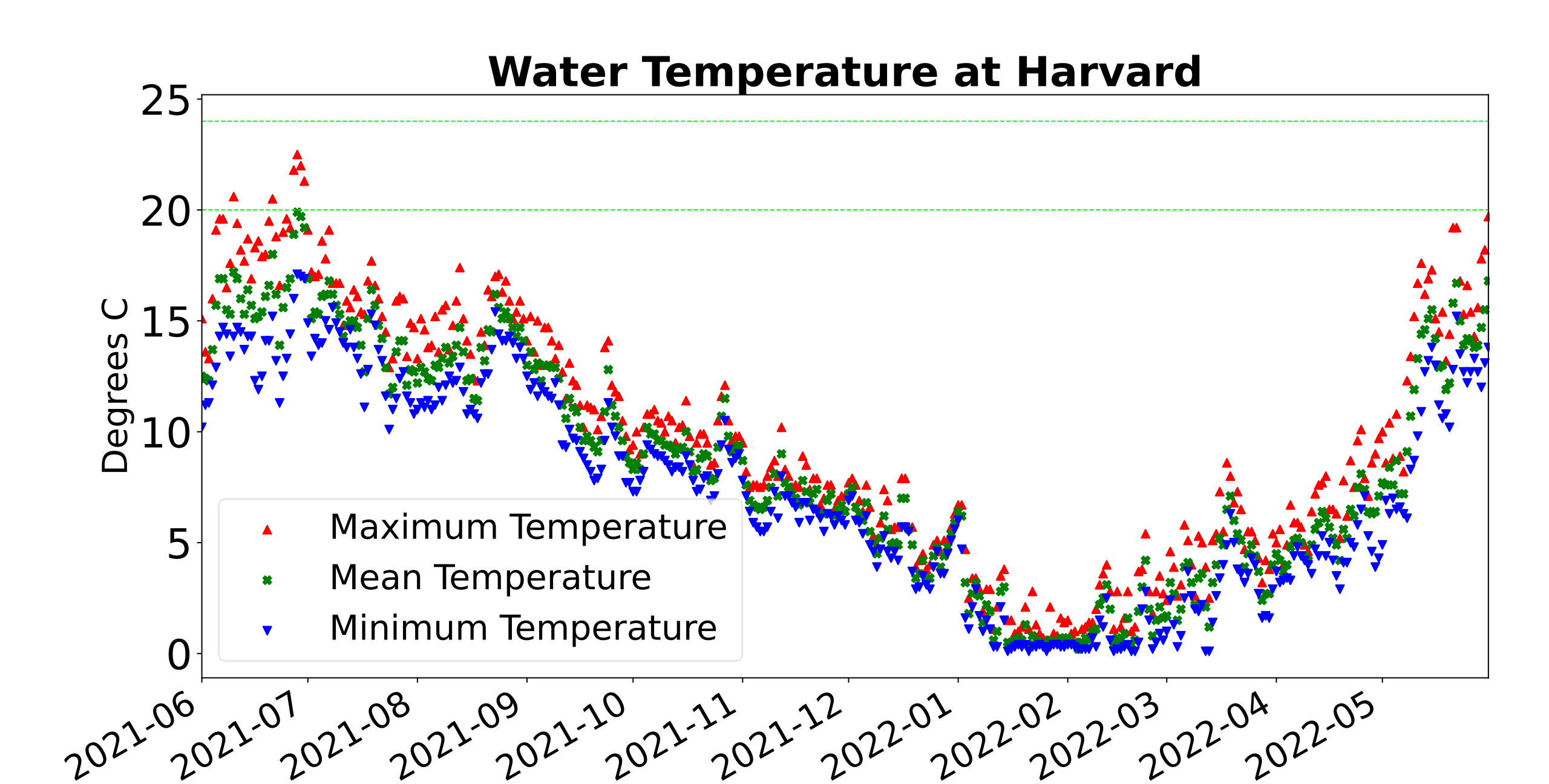

Data Source: USGS

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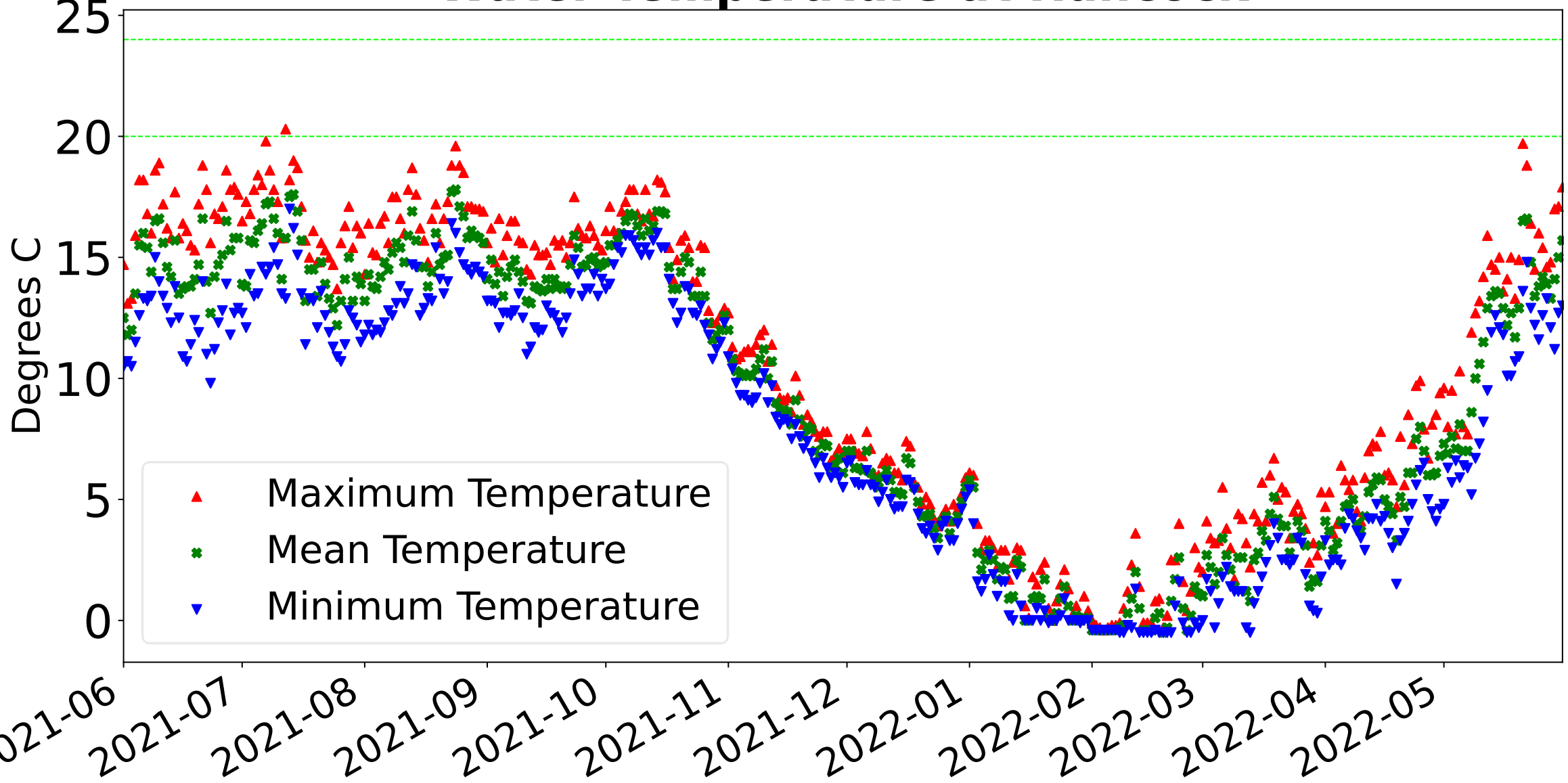
Water Temperature at Hancock



Data Source: USGS

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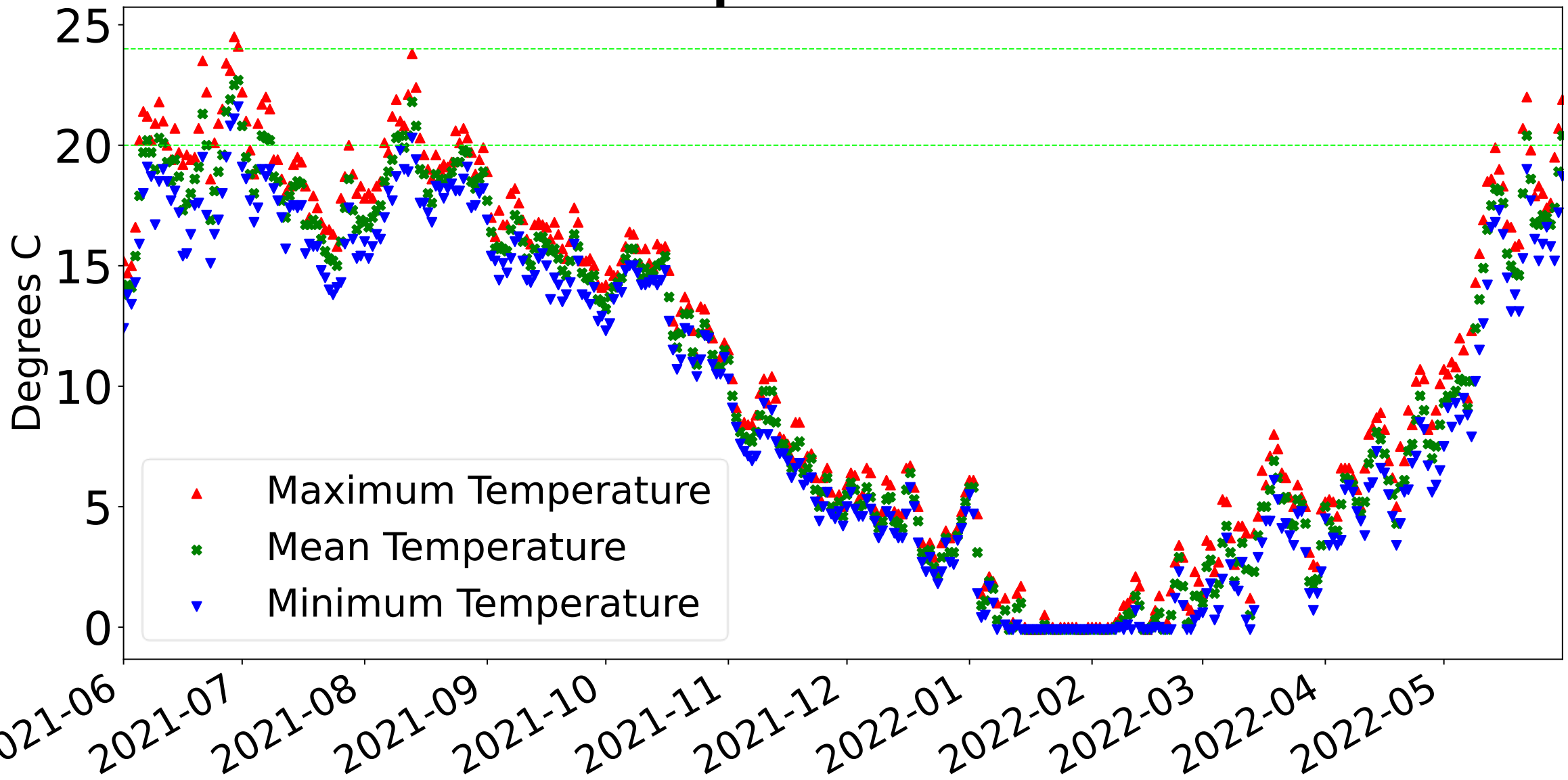
Water Temperature at Lordville



Data Source: USGS

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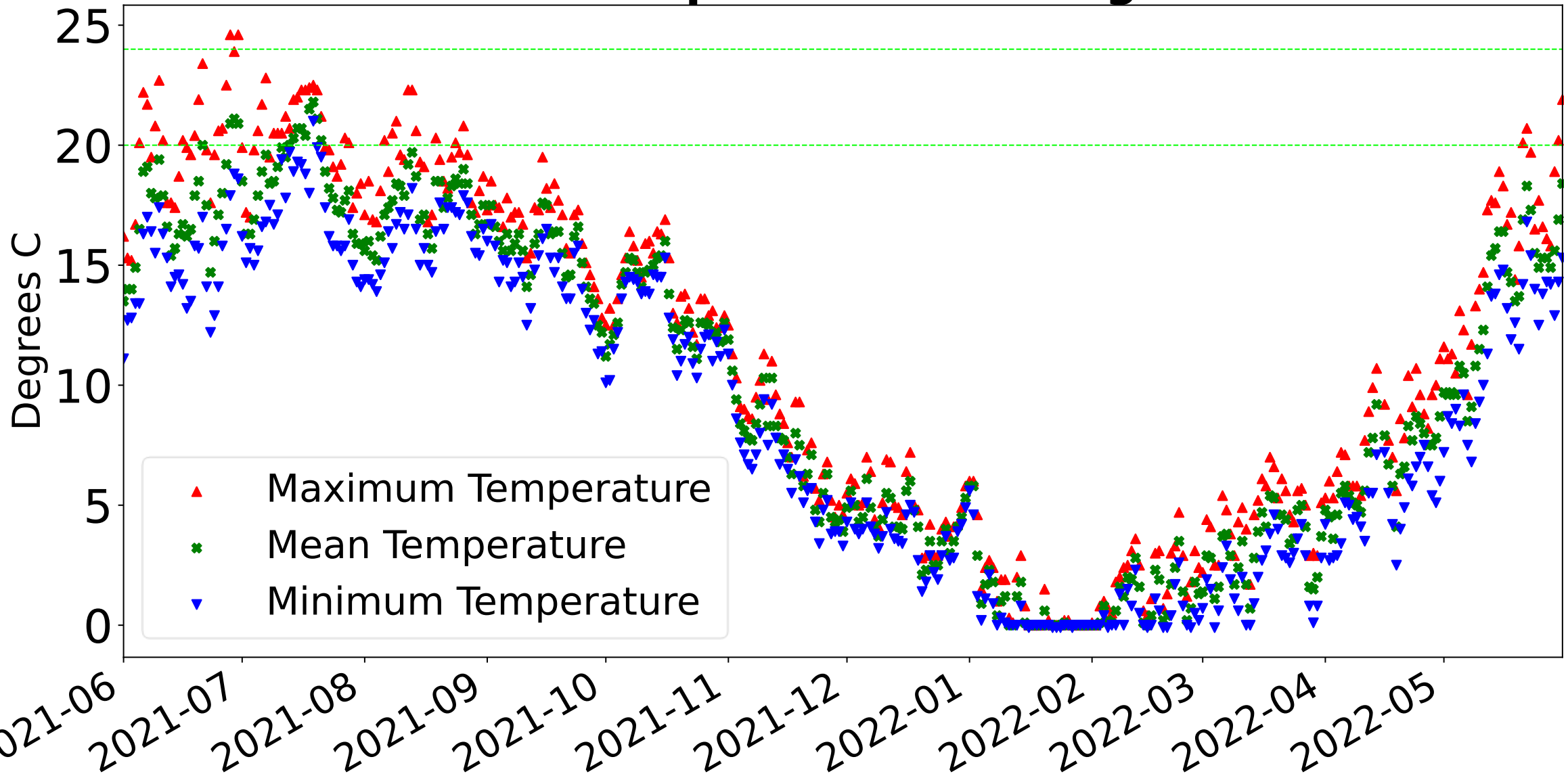
Water Temperature at Bridgeville



Data Source: USGS

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Temperature Rankings – Upper Basin

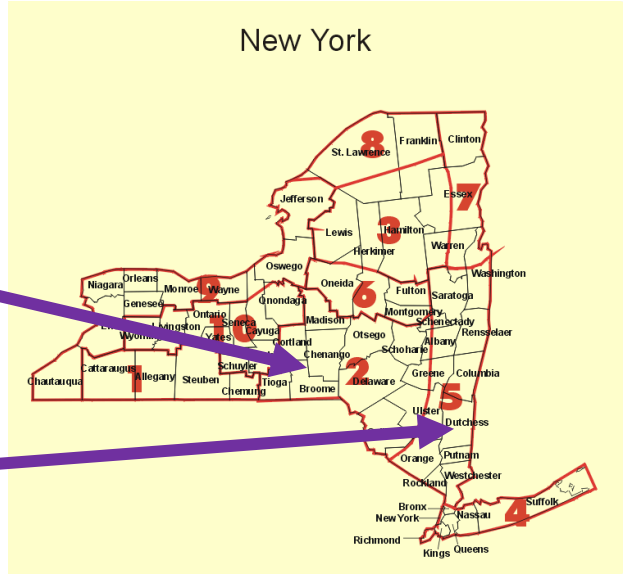
June – August 2021

Record Coolest	Bottom 1/10	Bottom 1/3	Normal	Top 1/3	Top 1/10	Record Warmest

PERIOD	VALUE	1901-2000 MEAN	ANOMALY	RANK (1895-2021)	WARMEST/COOLEST SINCE	RECORD
Jun–Aug 2021 3-Month	67.4°F (19.7°C)	65.4°F (18.6°C)	2.0°F (1.1°C)	113th Coolest	Coolest since: 2019	1903
				15th Warmest	Warmest since: 2020	2005
	Ties: 2012, 2016, 2018					
Jun–Aug 2021 3-Month	71.1°F (21.7°C)	68.3°F (20.2°C)	2.8°F (1.5°C)	121st Coolest	Coolest since: 2019	1903
				7th Warmest	Warmest since: 2020	2005

Region 2

Region 5



Region 2 – Eastern Plateau

Region 5 – Hudson Valley

Data Source: NCDC, NCEI

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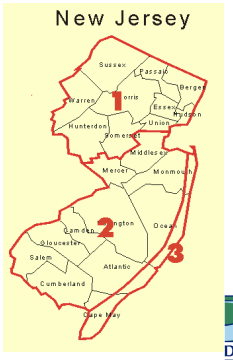
Temperature Rankings – Lower Basin

June – August 2021

Record Coolest	Bottom 1/10	Bottom 1/3	Normal	Top 1/3	Top 1/10	Record Warmest

PERIOD	VALUE	1901-2000 MEAN	ANOMALY	RANK (1895-2021)	WARMEST/COOLEST SINCE	RECORD	
Jun–Aug 2021 3-Month	74.5°F (23.6°C)	71.4°F (21.9°C)	3.1°F (1.7°C)	123rd Coolest	Coolest since: 2019	1927	PA region 2
				5th Warmest	Warmest since: 2020	2010	
	Ties: 2011						
Jun–Aug 2021 3-Month	75.5°F (24.2°C)	72.2°F (22.3°C)	3.3°F (1.9°C)	122nd Coolest	Coolest since: 2019	1927	NJ Region 2
				6th Warmest	Warmest since: 2020	2010	
	Ties: 2019						



PA Region 2 – Southeastern Piedmont
NJ Region 2 - Southern

Data Source: NCDC, NCEI

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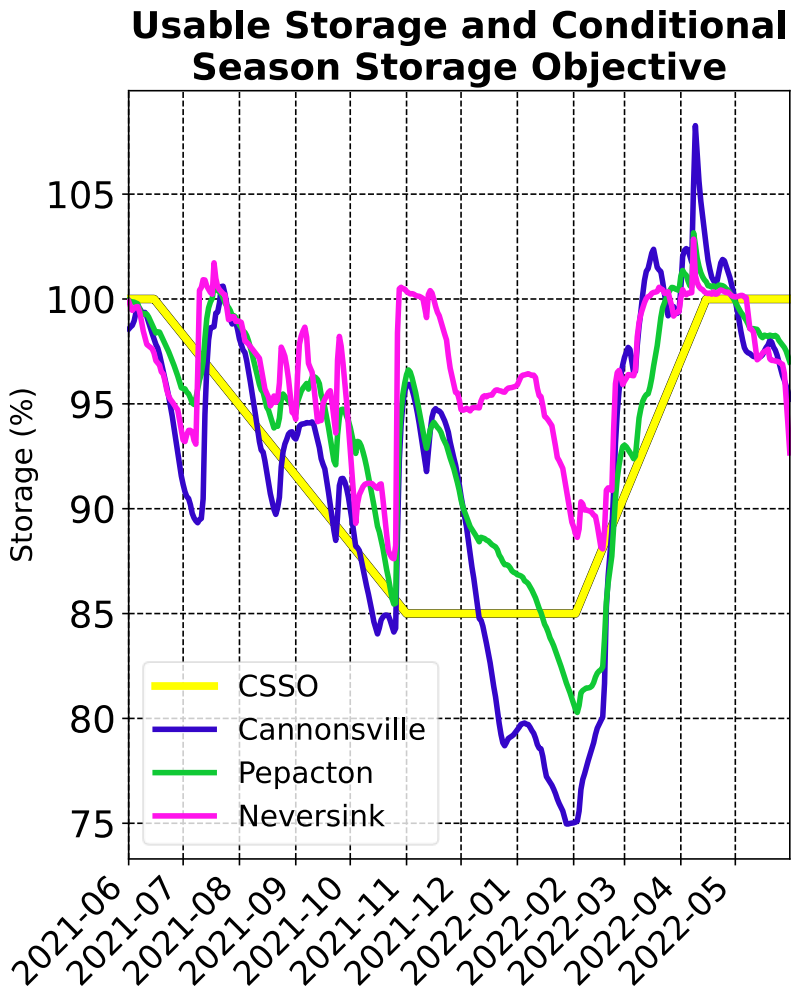
Discharge Spill Mitigation



	Spill Volume (MG)	Days
Cannonsville	37,046	49
Pepacton	35,416	46
Neversink	14,984	202

	All L1 Discharge Mitigation Releases (MG)	Number of days above CSSO (L1-a, L1-b)
Cannonsville	182,380	179
Pepacton	80,557	249
Neversink	34,954	292

Data Source: NYCDEP

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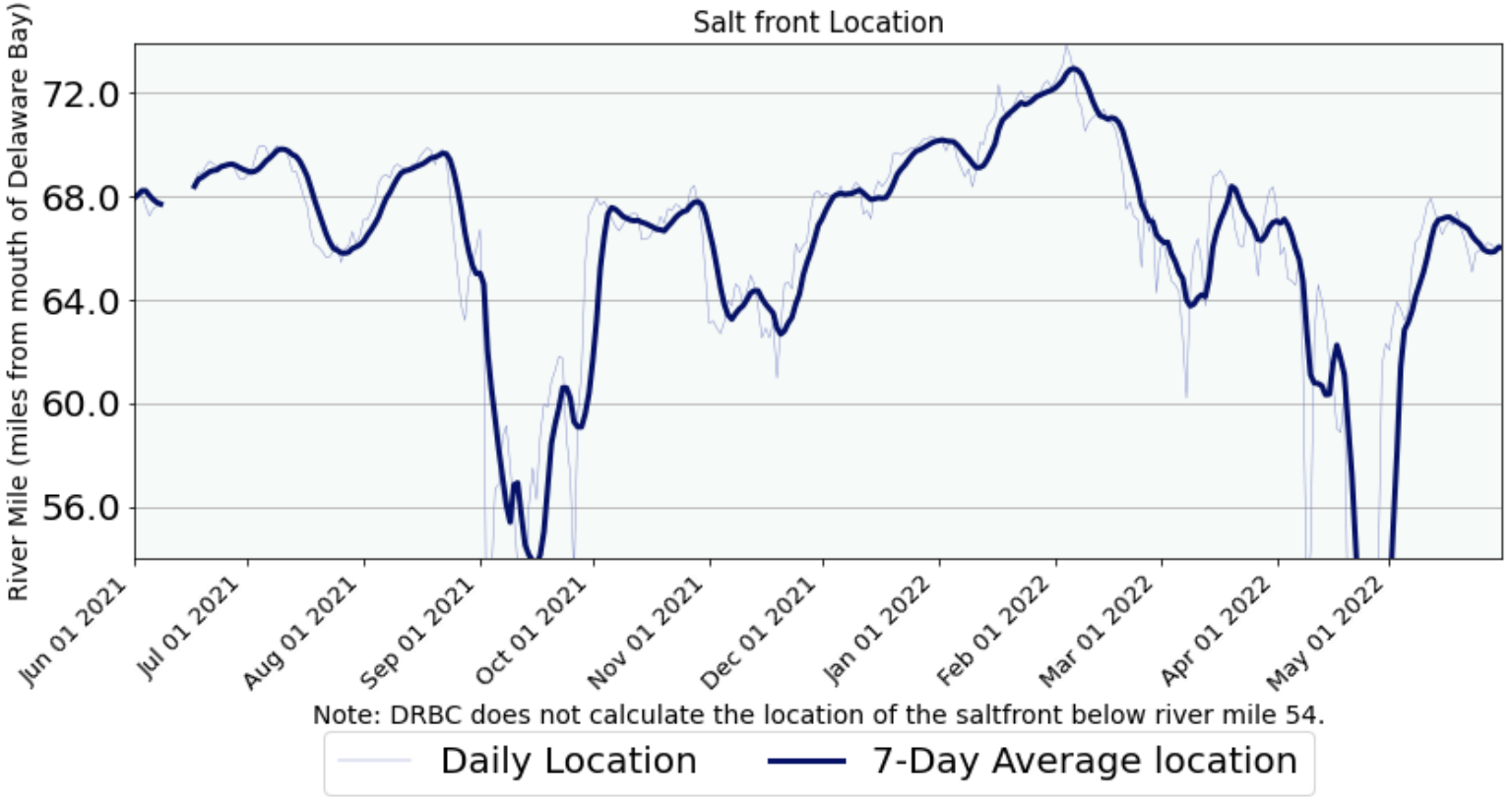
Salinity Management (Water Code)



* DRBC is responsible for making releases to manage the salt front
* Under the FFMP 2017 agreement, NYC makes additional releases **during drought emergency** to provide additional flow from upstream based on the location of the salt front.
* Note: No drought emergency occurred in the past FFMP release year.

Data Source: USGS

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Summary

* Warm water temperatures in June and August of 2021 required use of the thermal mitigation bank on ten separate days.
* Warm water temperatures in May 2022 required use of the thermal mitigation bank on two additional days
* The maximum water temperature exceeded 24 ^{0}C on 2 days at Lordville and 2 days at Bridgeville.
* Dry conditions during June and August required releases of approximately 2.1 BG to meet the Montague Flow Objective.
* The conservation releases were based on Table 4G for 100 percent of the year.
* The three NYC reservoirs were below the CSSO for most of the time between June 2021 and July 2021. From July 2021 until May 2022:
  * Neversink was above the CSSO
  * Pepacton was above the CSSO except between mid-January and end of March
  * Cannonsville was above the CSSO except between beginning of December and end of March
* In May, the reservoirs were below the CSSO.

Methodology

- Slide 9: Amount of water released for flow objectives is calculated by summing the NYC WSCC spreadsheet directed release column for each reservoir. Since directed releases include thermal releases (which is water not released for meeting Montague specifically), this amount of water is removed from the releases for Montague.
- Slide 12: Diversions
  - NJ Diversion is calculated using the daily discharge observations from the USGS Port Mercer gage, 01460440. The averages are of the daily discharge for each month and the average of the daily discharge for the entire year (release year 6/1-5/31).
  - NYC diversion is determined from the WSCC data spreadsheet (column E, daily total). The averages are of the daily discharge for each month and the average of the daily discharge for the entire year (release year 6/1-5/31).
- Slide 13: Conservation release volume: the sum of the conservation released based on the zone (L1, L1-a, L1-b, L1-c, L2) and FFMP Table (4F, 4G). It should be noted that more water may have been released for Montague. For example, if no releases were required for Montague, this is the amount of water that would have been released with minor differences related to transitions among tables and zones.
- Slide 15: Conservation releases, same as slide 13 but displayed as a graph.
- Slide 16: Plot and table of the number of days in each FFMP table from the NYC WSCC end-of-month reports, column AA.
- Slide 20: Bank Use: was obtained from the accumulated Daily River Master Data, dated June 1, 2020.
- Slide 30: CSSO: Discharge Mitigation Releases – volume of water released when a reservoir is in L1. Number of days above CSSO: days when reservoir is in L1-a or L1-b.
- Slide 31: Salinity Management: Documentation on the Salt Front Calculation is available on hydrosnap.drbc.net

A detailed hydrologic conditions report for the calendar year 2021 is available online at https://www.nj.gov/drbc/programs/flow/annual-hydro-reports.html

Presentation Available On DRBC's Website

https://www.nj.gov/drbc/programs/flow/FFMP_PerformanceRpts.html