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

MEMORANDUM

Flexible Flow Management Plan: Performance Report
Release Year 2022 – 2023

The goals of the Flexible Flow Management Program (FFMP) 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 following is a brief summary of the performance of the FFMP during the release year 2022 – 2023 (June 1, 2022 through May 31, 2023).

In the upper basin above Montague, precipitation was above average for six months of the year (June, September, November, December, January, and March) and below average for six months (July, August, October, February, April, and May). In the lower basin above Trenton, precipitation was above average for four months (October, December, January, and April) and below average for eight months (June, July, August, September, November, February, March, and May). In the lower basin along the Schuylkill River, precipitation was above average for three months (October, December, and January) and below average for nine months (June, July, August, September, November, February, March, April, and May). For all areas of the basin, precipitation for September was near or above normal due to precipitation from the remnants of Hurricane Ian. More detail about Hurricane Ian is available in the Annual Hydrologic Conditions Report for 2022 on DRBC's website[1].

The combined storage in the New York City reservoirs is used to define drought levels for the basinwide drought management plan, adopted in the Delaware River Basin Water Code (18 CFR 410 Part 410) and incorporated in the FFMP. During the release year, the combined storage was not less than the drought watch line and the drought management plan was not implemented. At the beginning of the release year, the combined storage in the three New York City (NYC) reservoirs (Pepacton, Cannonsville, and Neversink) was below the median value. The storage decreased steadily throughout June, July, and August 2022 due to higher diversion, typical in the summer, and below average precipitation in the upper basin. The storage remained steady following a rainy period in September, and after remnants of Hurricane Ian impacted the basin during October 2022. With more consistent rainfall after the beginning of October, the combined storage remained relatively constant between 170 BG and 175 BG through November. During the winter months December 2022 through February 2023, storage steadily increased as a mild winter caused most precipitation to fall as rain and fill the reservoirs. The combined storage in the reservoirs was nearly 100 percent by April 2023. The reservoirs remained full or near full through the beginning of May 2023. Then, the combined storage began to decrease because May was a dry month, and the demand was higher than typical for the end of the release season.

[1] https://www.nj.gov/drbc/library/documents/2022Hydrologic-Conditions-Rpt.pdf

The FFMP established four banks of water from the NYC reservoir storage used for specific purposes from the Interim Excess Release Quantity. The Interim Excess Release Quantity (IERQ) with a total of 10 BG (15,468 cfs-days) is provided to further protect the ecology of the river by supporting releases for Thermal mitigation (1.6 BG or 2,500 cfs-days), Rapid Flow Change Mitigation (0.6 BG or 1,000 cfs-days), the Trenton Equivalent Flow Objective (6.1 BG or 9,423 cfs-days), and the New Jersey Diversion Amelioration (1.6 BG or 2,545 cfs-days). Another bank of water, called the New Jersey Diversion Offset Bank is accumulated during the summer season and amounted to 1.3 BG (2,075 cfs-days) during the release year, but was not needed. Use of the banks are described below.

The flows at Montague and Trenton were mostly within the normal range (defined as the 25th to 75th percentile of flow on a given day throughout the release year. Exceptions occurred for large rainfall events such as the remnants of Hurricane Ian, a Nor'Easter in late December, and another Nor'Easter in late April and consistently rainy months such as June 2022. In 2022-2023, approximately 21,448 MG of water was used by NYC to meet the flow objective at Montague during a dry period from the end of July through the end of August. Releases were also made in November 2022, February 2023, and May 2023. The total number of days releases occurred on was 51 days. All or part of the conservation release is considered as part of the release made to meet the Montague Flow Objective. If the amount of water needed to meet Montague is less than the conservation release, only the amount needed for Montague is used to calculate the total. The Rapid Flow Change Bank is used when the amount of water needed for Montague decreases drastically, to reduce the rate gradually. The rapid flow change mitigation bank was used on one day in August, totaling 14 cfs-days. Water from the Trenton Flow Objective Bank (released from the NYC reservoirs) was use on 5 days to meet the Flow Objective at Trenton in the release year 2022-2023. From August 15 to August 19 and one additional day on September 1, the amount of used was approximately 550 MG. Releases for the Trenton Flow Objective were also required from the lower basin reservoirs. The combined amount released from Blue Marsh and Beltzville Reservoirs was 1,540 MG.

Diversions from the Delaware Basin by New York City are limited to a maximum running average of 800 mgd, calculated beginning on June 1st. New York City's running average diversion for the release year ending on May 31, 2023 was 500 mgd, with the highest monthly average diversions occurring in July and August. Diversions by the State of New Jersey may not exceed a monthly average of 100 mgd, with a maximum daily amount of 120 mgd. The average diversion for the state of New Jersey during the 2022-2023 release year was 93 mgd, with the highest average monthly diversion occurring in July.

Conservation releases are designed to protect the ecology of the stream reaches (also called tailwaters) below the NYC reservoirs. The required conservation releases based on the FFMP tables were as follows: Cannonsville – 104,190 MG, Pepacton – 43,476 MG, and Neversink – 23,482 MG. Additional releases may have been needed for bank use (see next section). During the release year, the Tables 4G, 4F, and 4E were used for 82, 9, and 9 percent of the time respectively.

The Thermal releases are designed to provide additional water to reduce temperatures in stream reaches from below the NYC reservoirs for the protection of the cold-water fishery. The goal is for the average daily temperature not to exceed 20 degrees C and a maximum daily temperature less than 24 degrees C. The summer of 2022 was one of the warmest summers on record across the basin, resulting in high water temperatures. 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 division in the US. In the upper basin, the Eastern Plateau region, which contains much of the upper basin, experienced the 23rd warmest summer on record. The Hudson valley region experienced the 4th warmest. For both regions, the records began in 1903. In the lower basin, the Southeastern Piedmont region in Pennsylvania (containing parts of the Schuylkill and Lehigh), experienced the 6th warmest on record, and southern New Jersey experienced the 3rd warmest on record. For both the lower basin regions, records began in 1927.

During the summer of 2002, the water temperatures at Hale Eddy on West Branch below Cannonsville reservoir, and Harvard and Hancock on the East Branch below Pepacton reservoir never exceeded 24 degrees C. At Lordville on the main stem of the Delaware River below the confluence of the east and west branches, the maximum temperature exceeded 24 degrees C on two days. The temperature exceeded 24 degrees C at Bridgeville on the Neversink River below Neversink reservoir on three days. There were nine thermal events in 2022-2023, defined by consecutive days when releases were made. Releases were made on a total of 26 days during the summer of 2022, and approximately 1.1 BG was used in total for thermal mitigation.

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 the release year were 48,100 MG from Cannonsville, 28,844 MG from Pepacton, and 11,866 MG from Neversink. The reservoir elevations were above the CSSO for 104, 118, and 110 days, respectively. Cannonsville reservoir spilled 27,770 MG over 40 days, Pepacton reservoir spilled 10,652 MG over 25 days. Neversink reservoir spilled 3,611 MG over 19 days.

As established in the Delaware River Basin Water Code, 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. 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 release year, a drought emergency did not occur in the basin, and releases were not made for management of the salt front.

At the beginning of the release year, the salt front was near the normal range. A dry summer resulted in the upstream movement of the salt front from June through August. The salt front reached its most upstream location on September 8, 2022, near river mile 79.5, near Marcus Hook, PA. The salt front moved downstream due to increases in flow during the fall and winter and remained in the normal range until the end of April. A late April Nor'Easter storm system brought rain to the basin, resulting in

higher flows, and the salt front moved downstream below the normal range, but returned to the normal range by the end of May.

Summary: For the 2022-2023 release year, precipitation was dry during the summer and near normal for the remainder of the year. A few large precipitation events occurred including two Nor'Easters and rainfall from the remnants of Hurricane Ian. Combined storage in the NYC was influenced by the precipitation pattern and decreased during the dry summer. The combined storage remained steady or increased for the remainder of the release year. During July and August when flows were low, 20.4 BG was released from the NYC reservoirs to meet the Montague Flow Objective. The total releases for Montague including releases made during November 2022, February 2023, and May 2023 were 21.5 BG. The conservation releases spent 82 percent of the time in Table 4G. Warm air temperature in the basin led to increased water temperatures at the beginning of the release year, and thermal mitigation was used for 26 days during the hot summer months. The maximum water temperature exceeded 24 degrees C on two days at Lordville and three days at Bridgeville. Cannonsville was below the CSSO 72 percent of the year, Pepacton was below the CSSO 68 percent of the year, and Neversink was below the CSSO 70 percent of the year. The salt front spent a period in August above the normal range, reaching its most upstream location near river mile 79.5 in early September. The salt front remained near or below the normal range for the remainder of the release year.

REFERENCES

United States Geological Survey (including Office of the Delaware River Master)
Applied Climate Information System
New York City Department of Environmental Protection – Water Supply Control Center
National Centers for Environmental Information – National Climate Data Center
Delaware River Basin Commission

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).

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.

SUGGESTED CITATION

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FFMP Implementation Performance

Release Year 2022

June 1, 2022 – May 31, 2023

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July 2023

Delaware River Basin Commission

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NOTE

All data used in the analysis are Provisional

Final/approved data are available from:

NYC Department of Environmental Protection (NYCDEP)

Office of the Delaware River Master (ODRM)

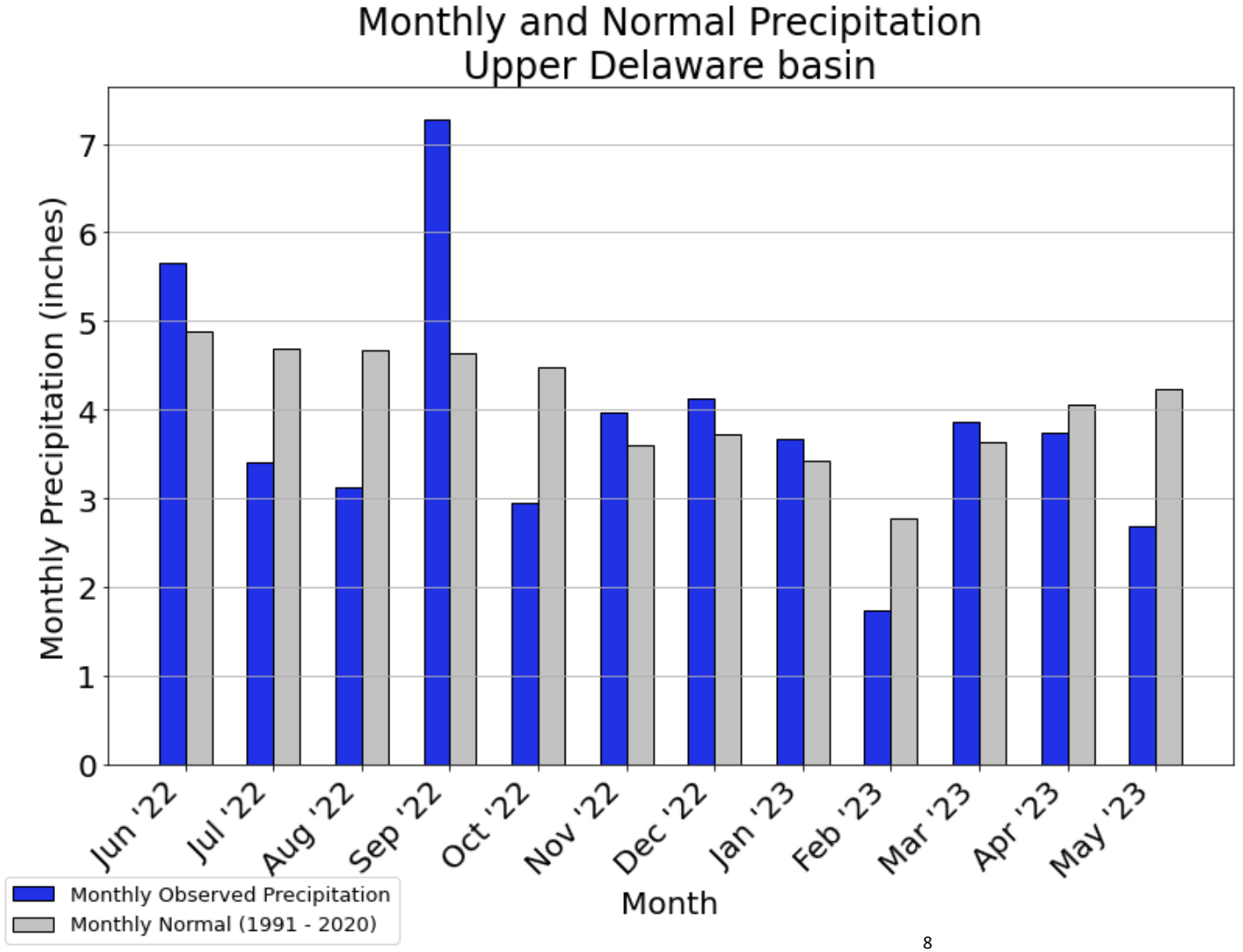
United States Geological Survey (USGS)

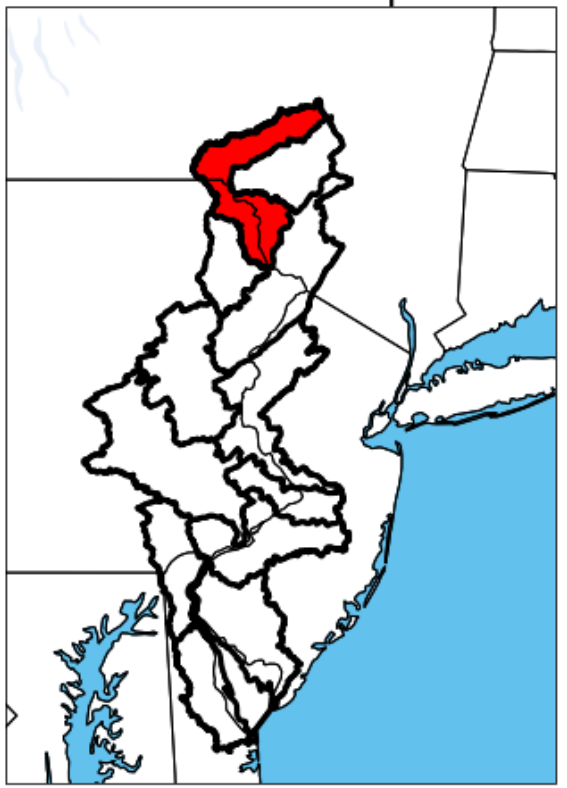
Methodology for calculations is included for reference on the last slide

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

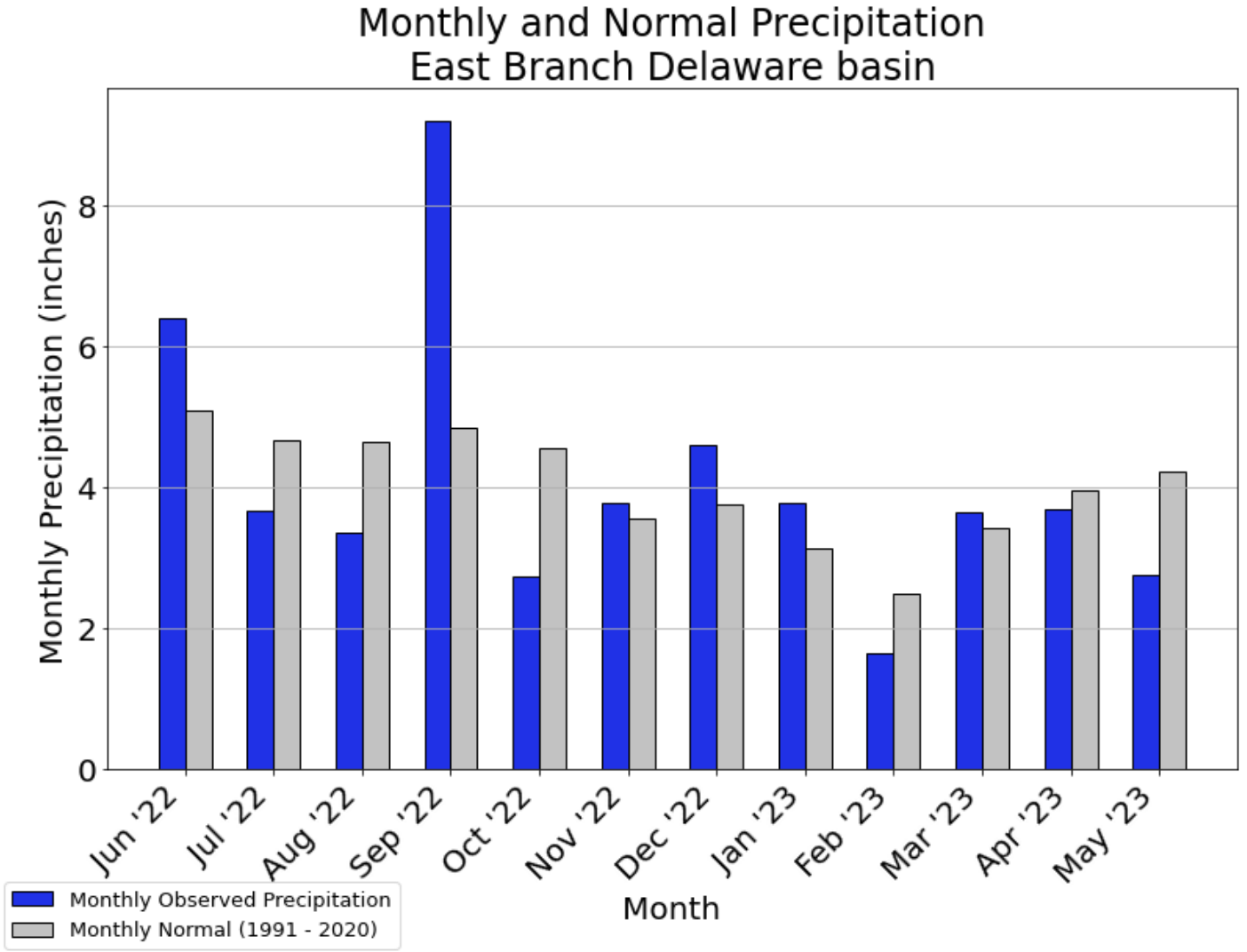


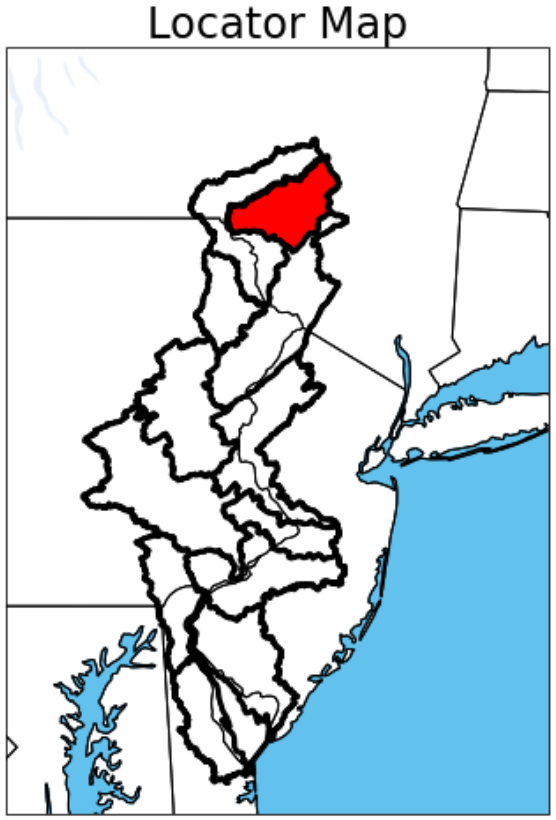


Source: ACIS, USGS HUC: 02040101
Monthly Normal is based of 4 stations in the Upper Delaware basin

Data Source: ACIS

Precipitation – Upper Basin

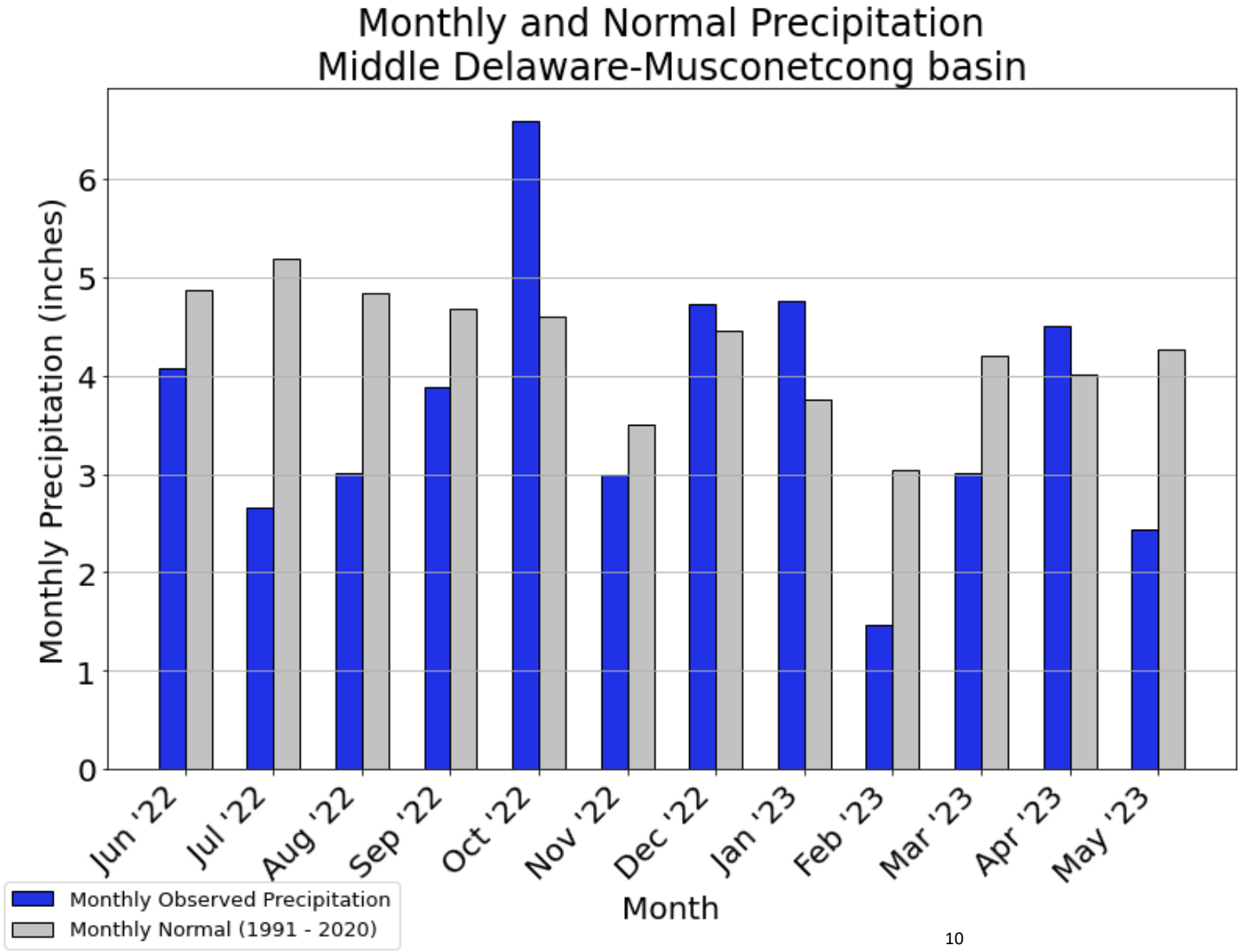


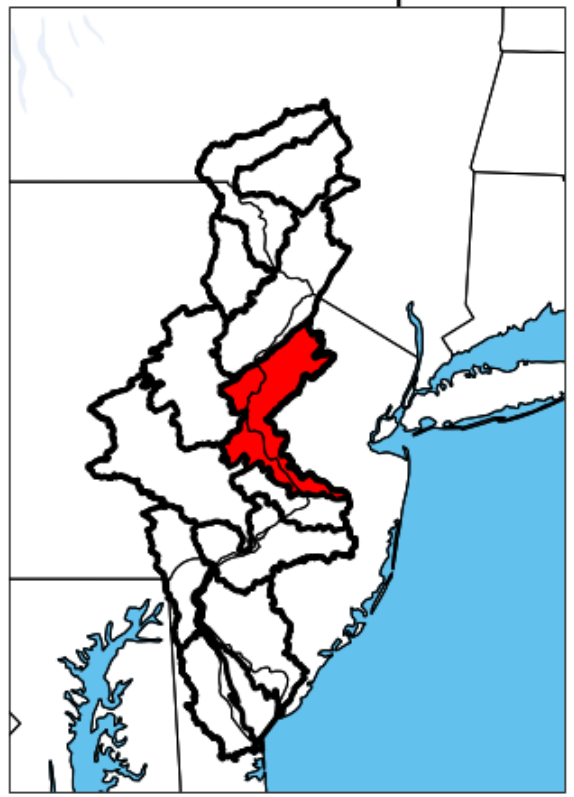


Source: ACIS, USGS HUC: 02040102
Monthly Normal is based of 1 stations in the East Branch Delaware basin

Data Source: ACIS

Precipitation – Lower Basin

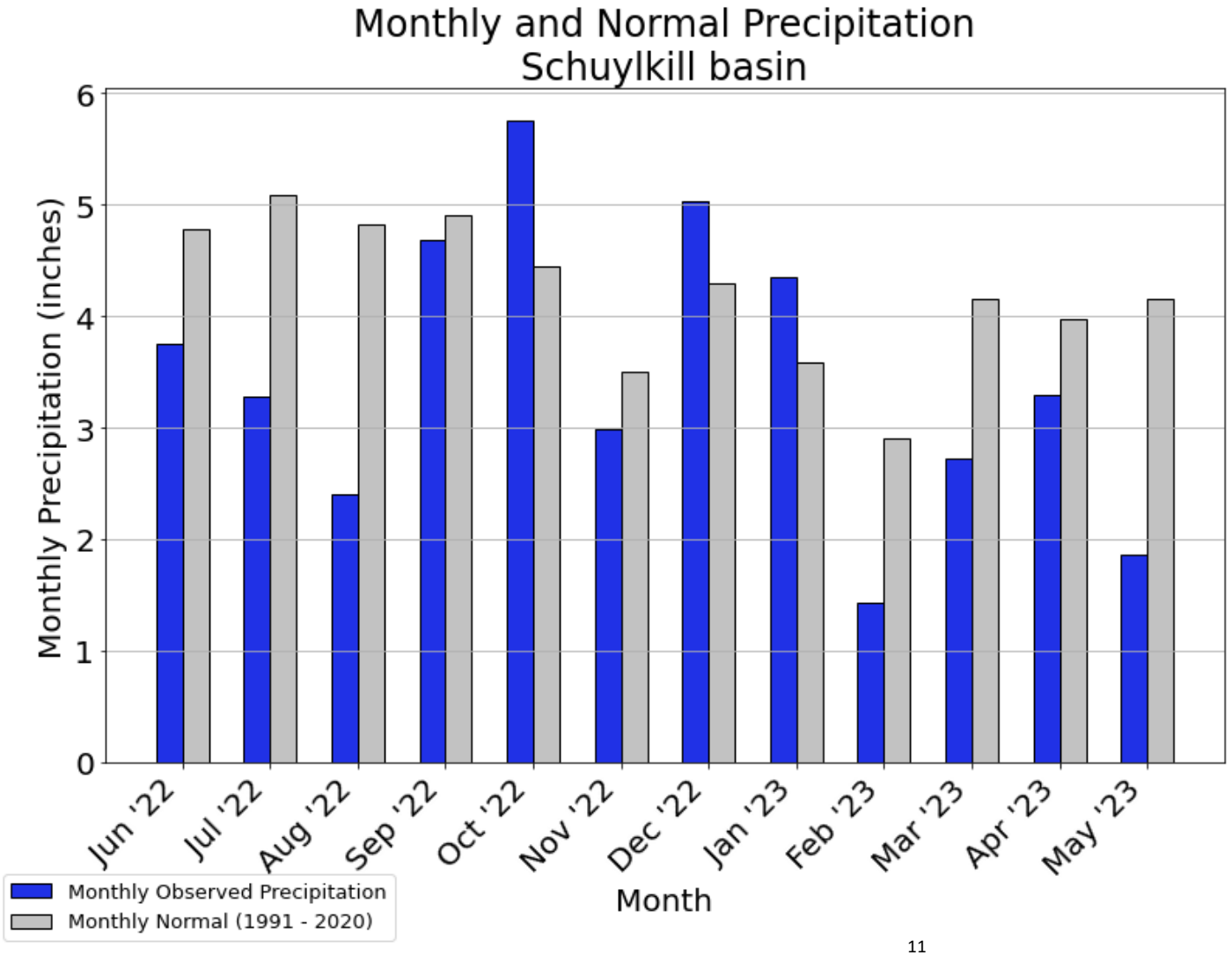


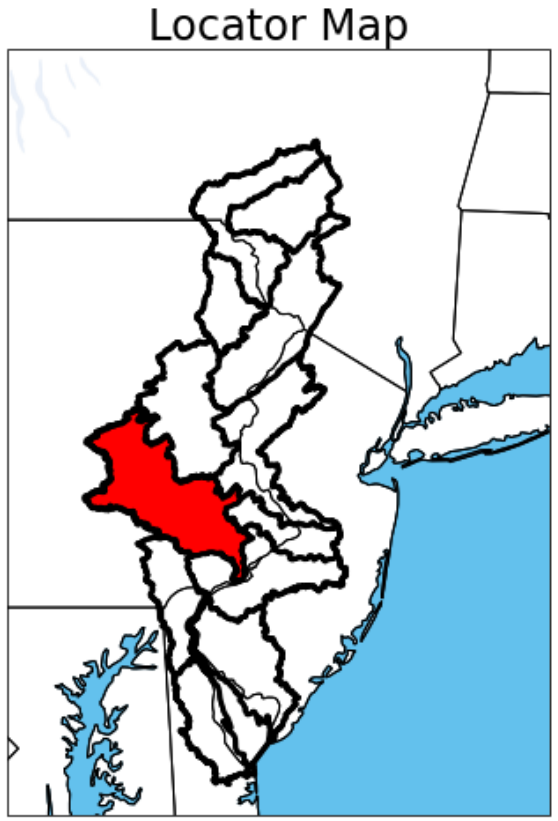


Source: ACIS, USGS HUC: 02040105
Monthly Normal is based of 8 stations in the Middle Delaware-Musconetcong basin

Data Source: ACIS

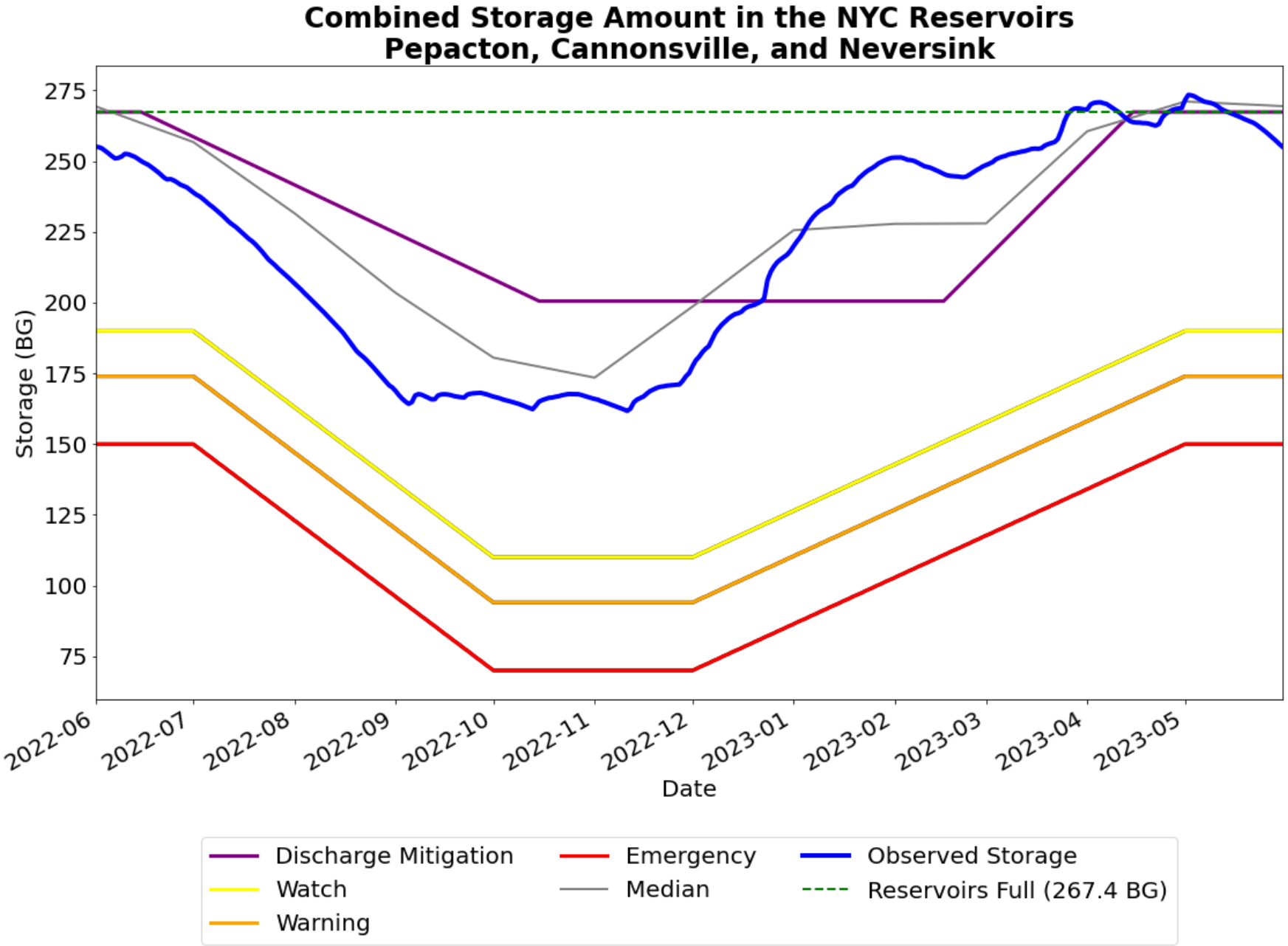
Precipitation – Lower Basin





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

Data Source: ACIS



Data Source: NYCDEP

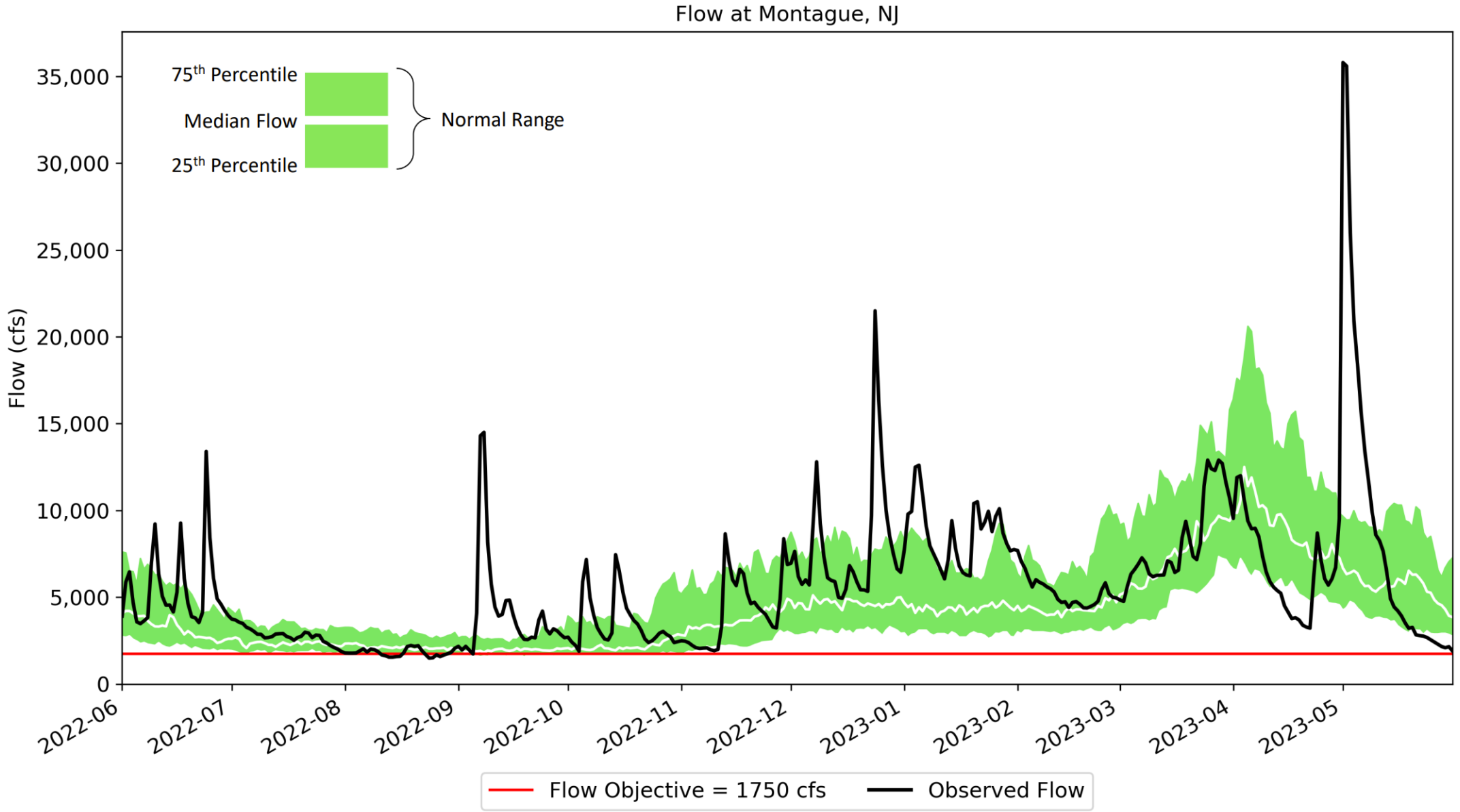
Flow Objectives

Water Released from NYC to Meet Flow Objectives (MG)	
Montague	21,448*
Trenton	550
Total	21,968

Water Released from Lower Basin to Meet Trenton Flow Objectives (MG)	
Beltzville	990
Blue Marsh	550
Total	1,540

*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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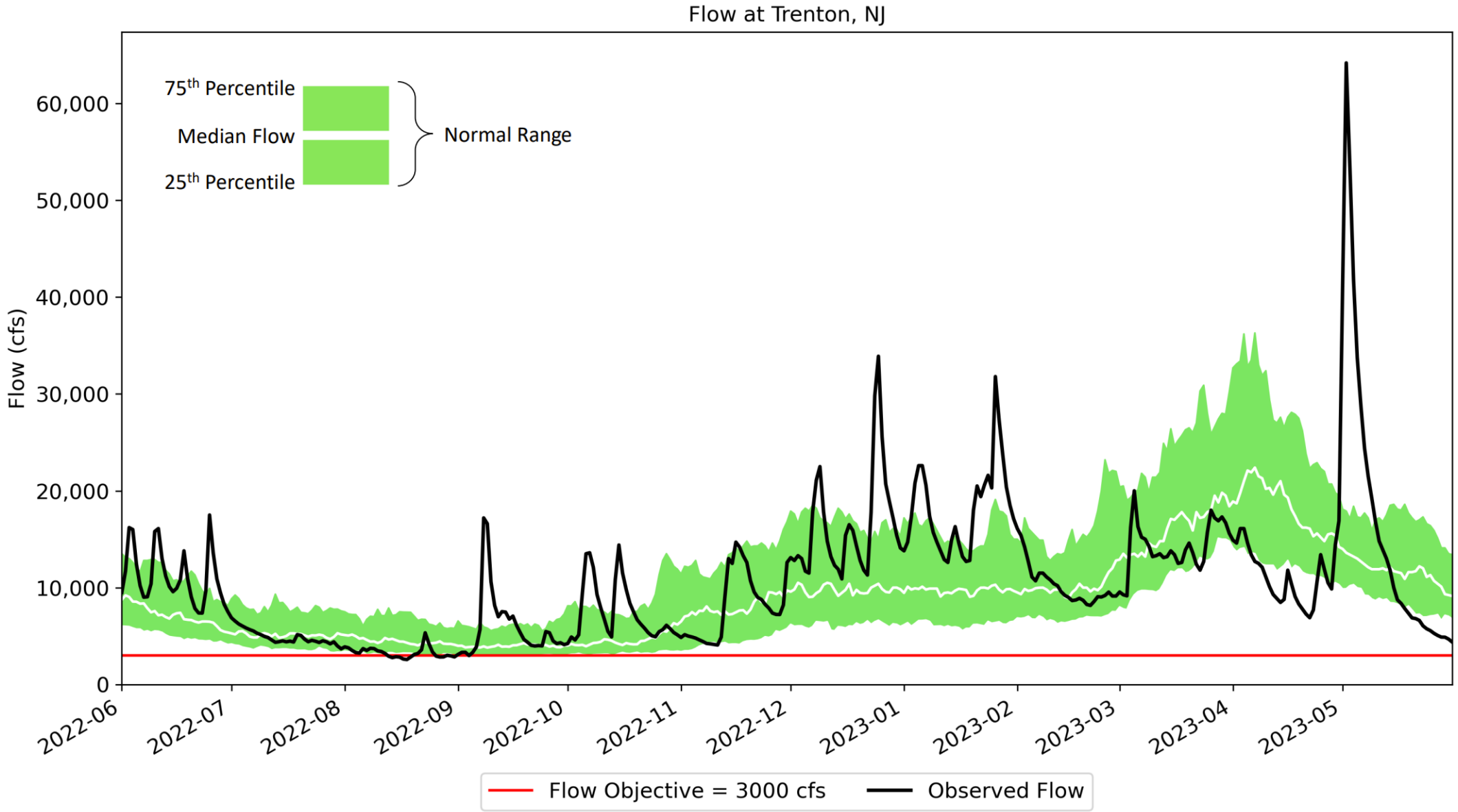
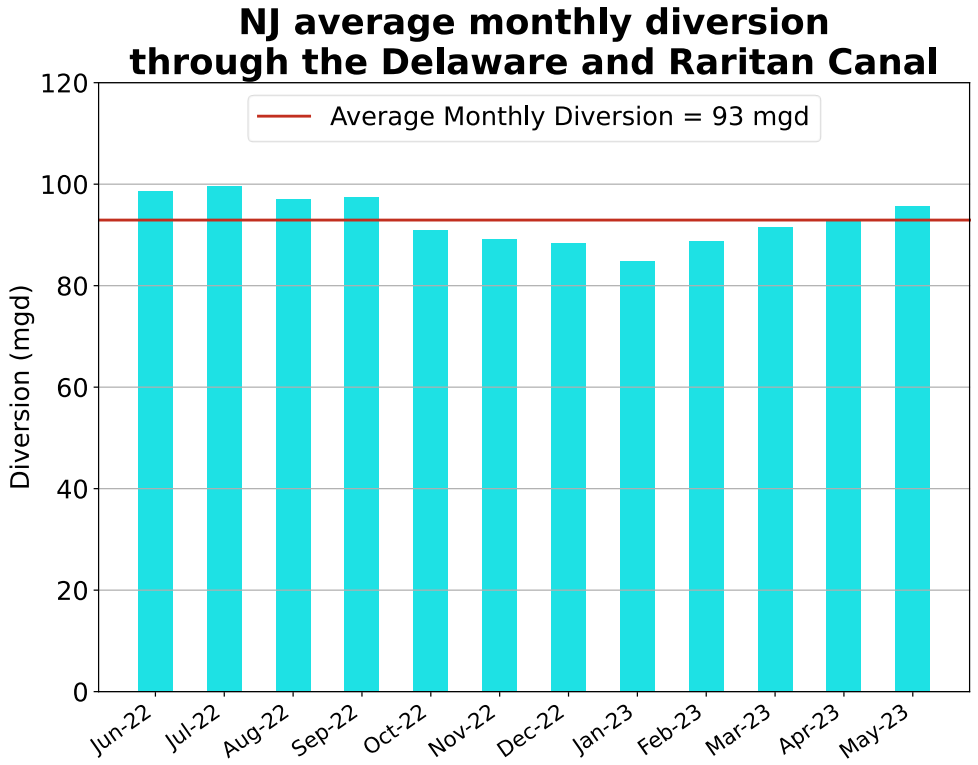
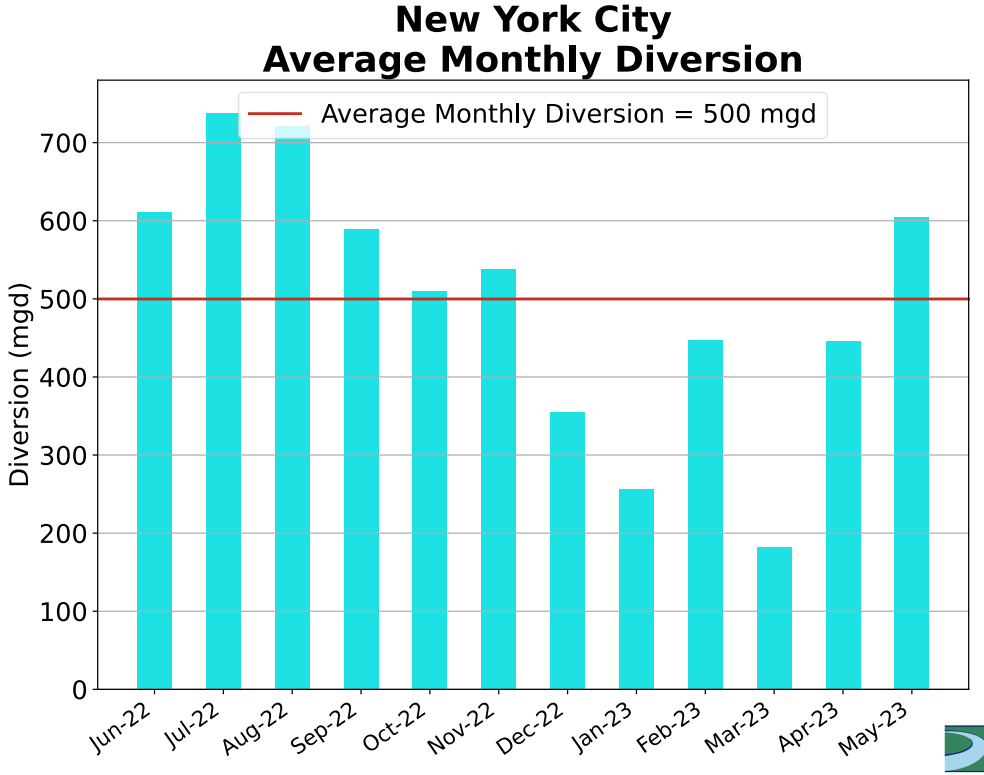


Data Source: USGS

Diversions

Monthly Average Daily Diversion (June 1, 2022 – May 31, 2023)	
New Jersey	New York
93 mgd	500 mgd





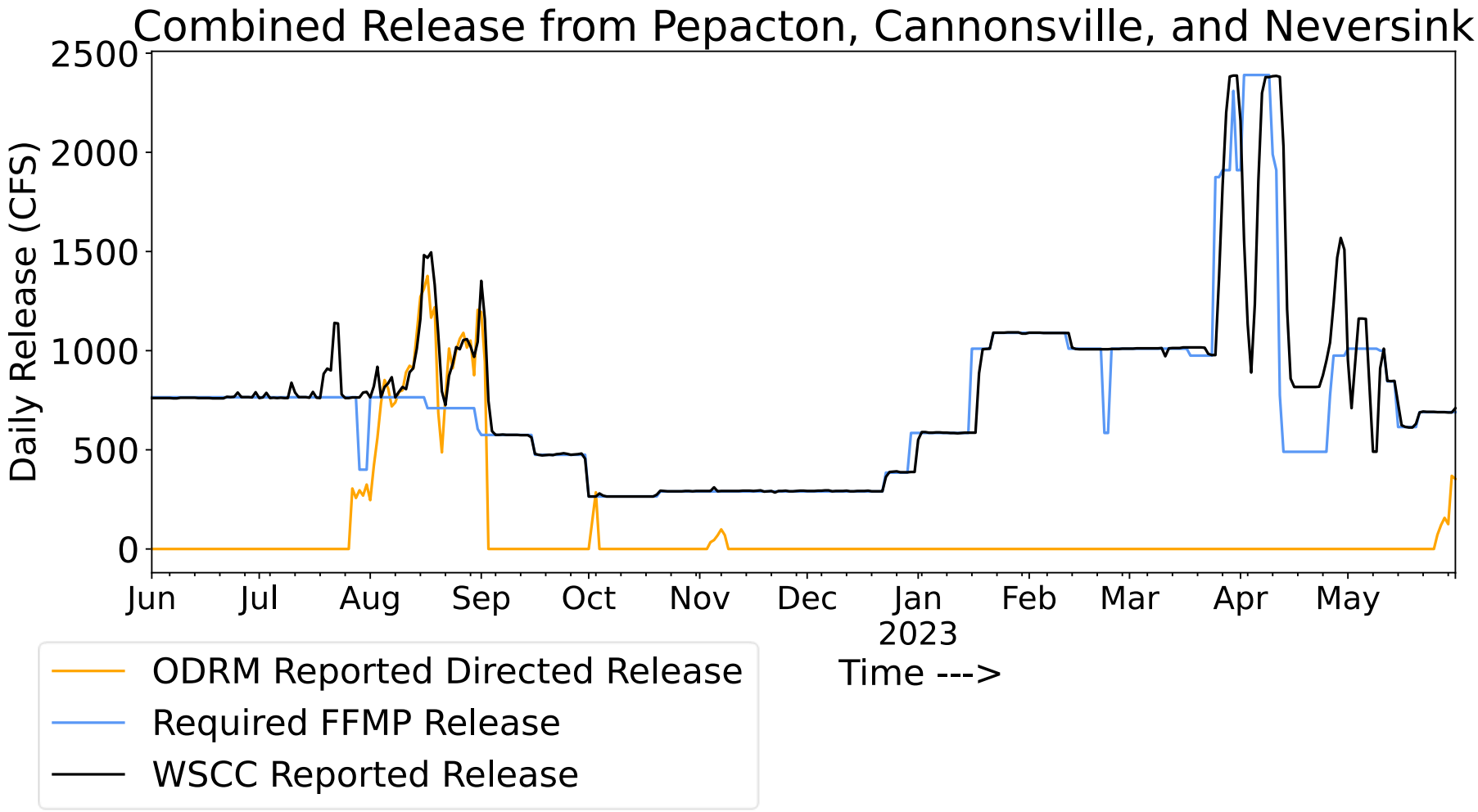
Data Source: USGS, NYCDEP

Conservation Releases

Volume of Conservation Releases (MG)			
	FFMP 2017 Tables Based on Storage (6/1/22 - 5/31/23)	**REV1**	**Multiple of Revision 1**
Cannonsville	104,190	20,665	5.0
Pepacton	43,476	14,562	3.0
Neversink	23,482	8,664	2.7
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, D-77-20 CP (Revision)

Actual Releases



Data Source: NYCDEP, ODRM, USGS

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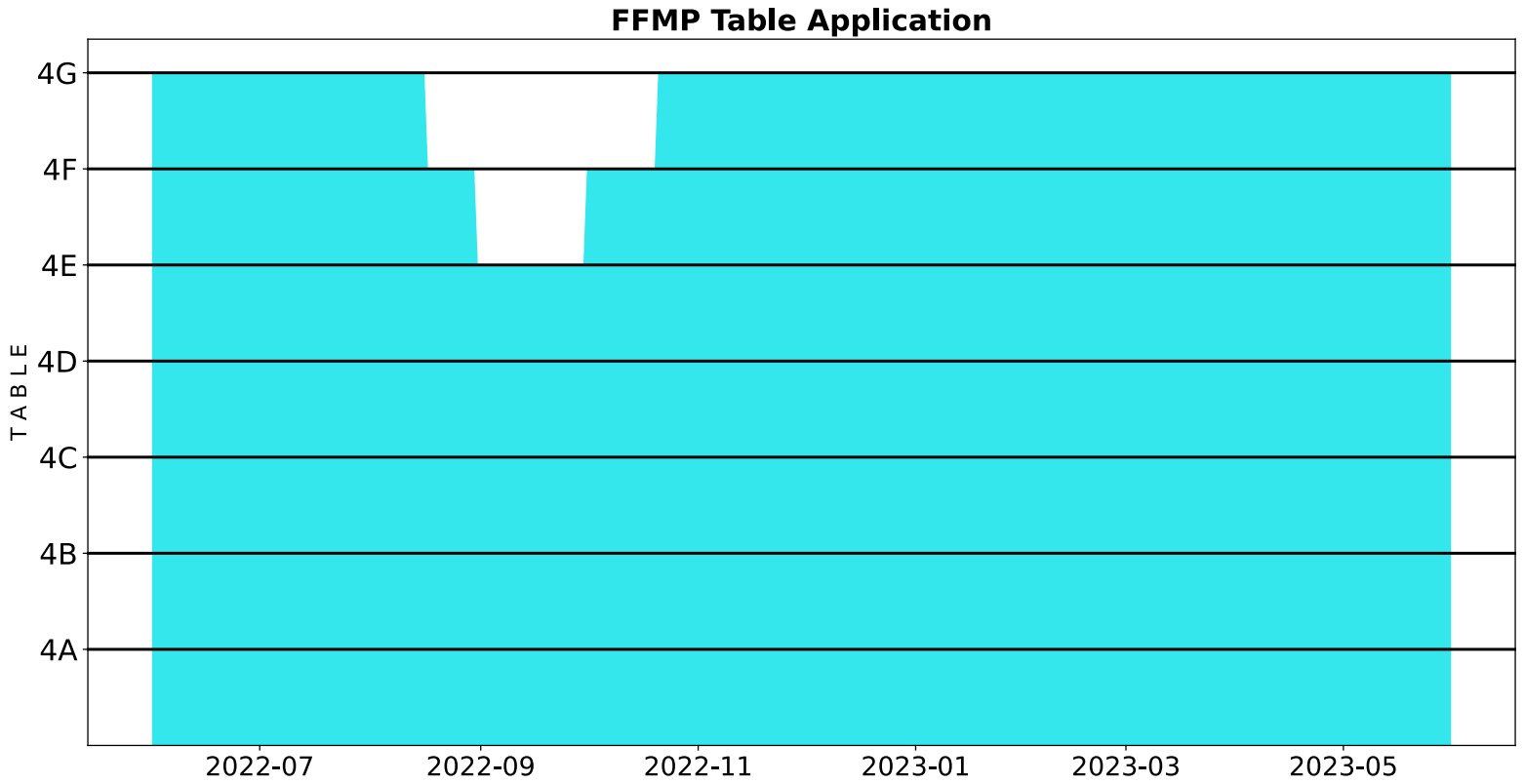
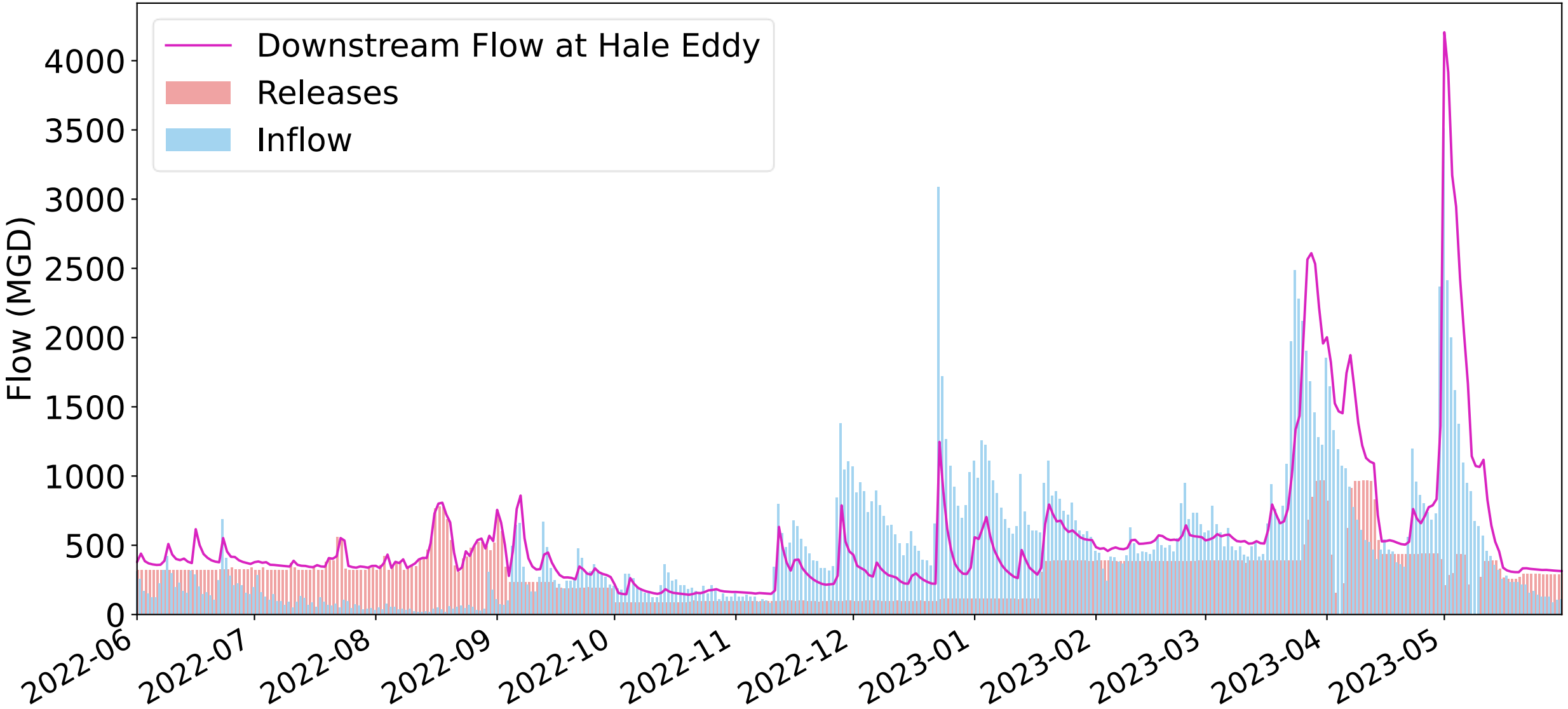
Time in FFMP Release Tables

FFMP TABLE	Number of Days	Percent (%)
4G	300	82.2
4F	34	9.3
4E	31	8.5
4D	0	0
4C	0	0
4B	0	0
4A	0	0



Data Source: NYCDEP

Cannonsville Inflow, Releases, and Downstream Flow



Data Source: USGS

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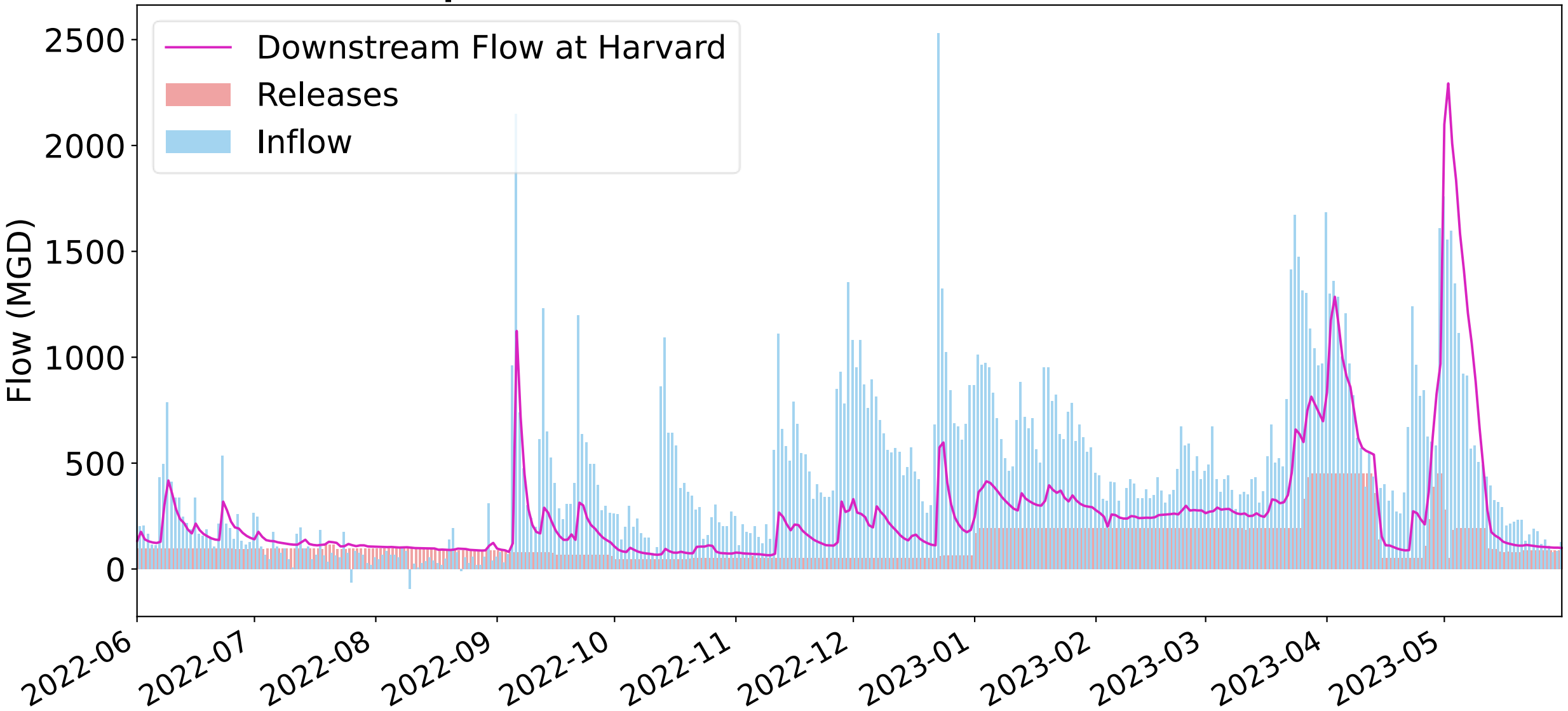
Pepacton Inflow, Releases, and Downstream Flow



Data Source: USGS

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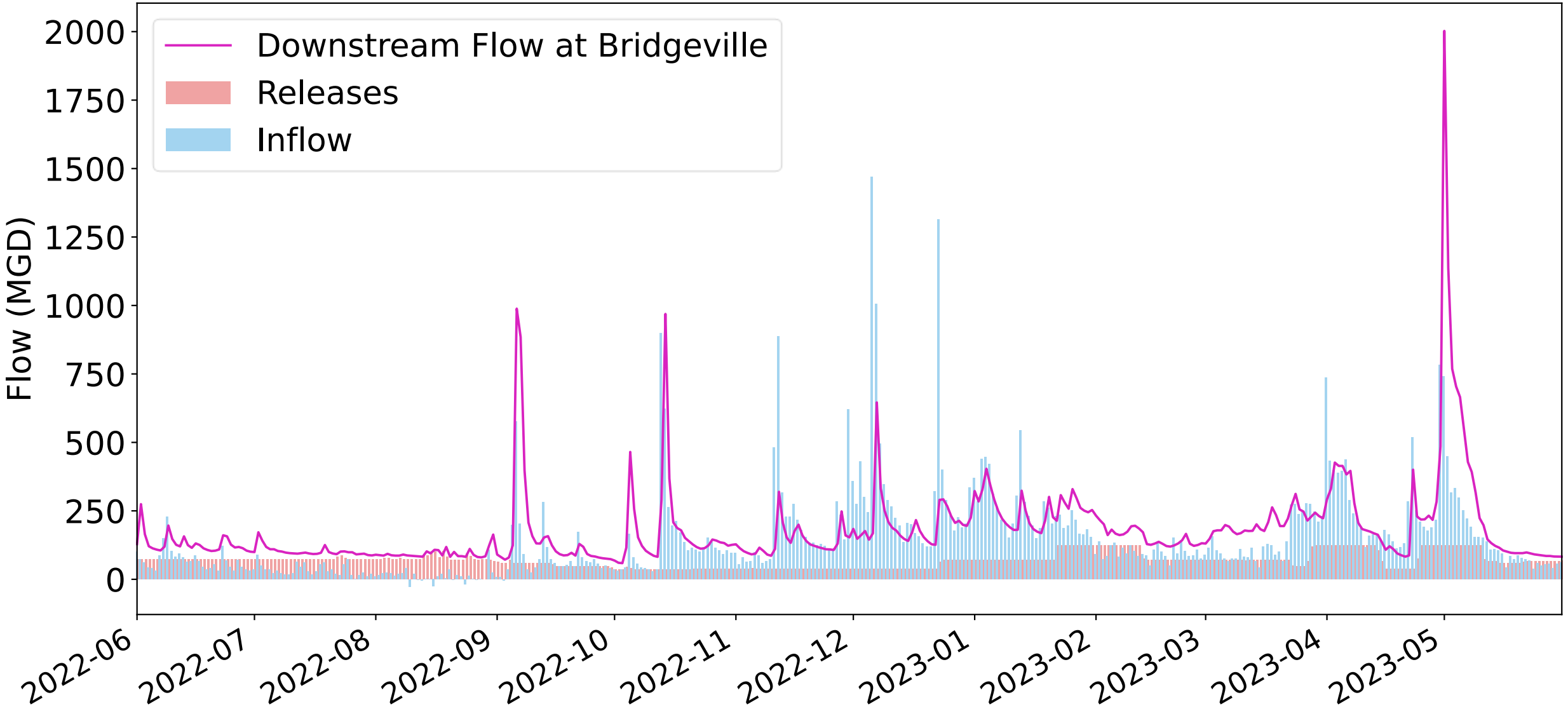
Neversink Inflow, Releases, and Downstream Flow



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	14	of 1,000 cfs-days
Thermal Mitigation Bank	1,754	of 2,500 cfs-days
Trenton Equivalent Flow Objective Bank	850	of 9,423 cfs-days
NJ Diversion Offset Bank*	0	cfs-days

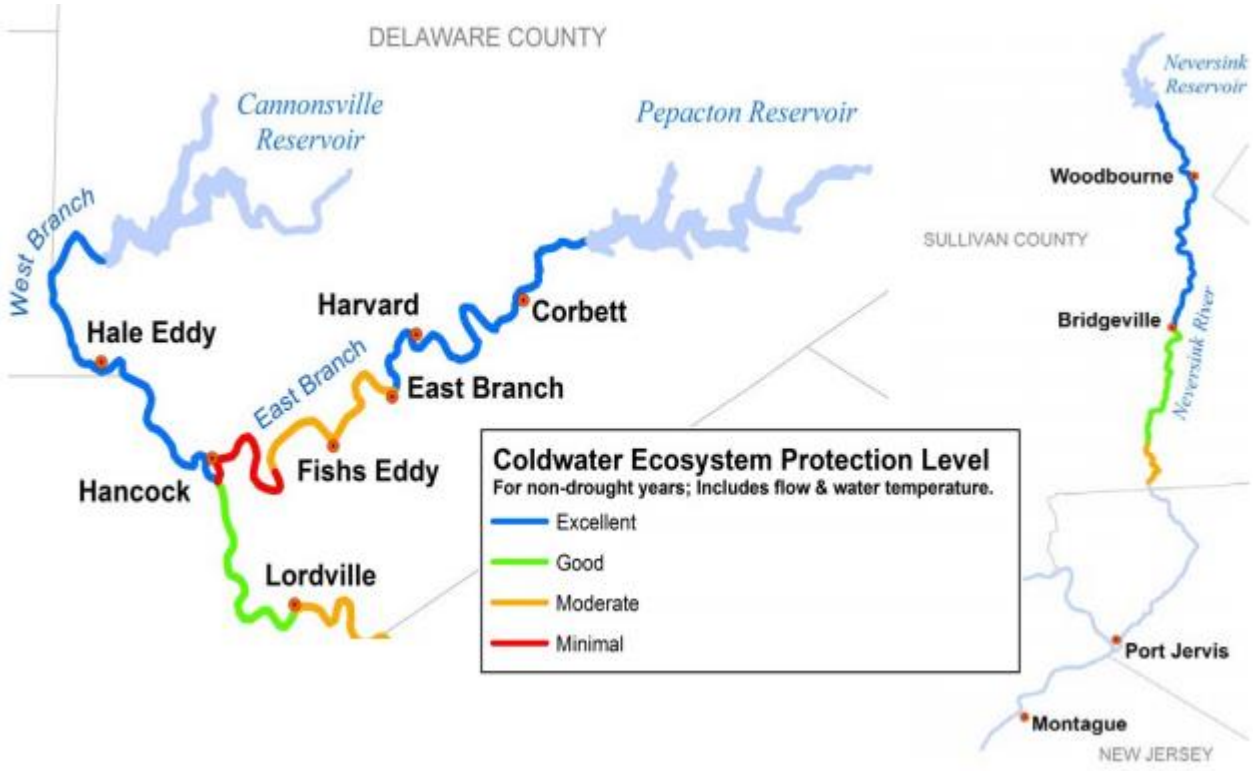
Thermal Releases were made on 26 days for 9 events in June 2022, July 2022, and August 2022. A rapid flow change mitigation release was needed on August 20, 2022.

*The NJ Diversion Offset Bank accumulated 2,075 cfs-days

Data Source: ODRM

Habitat Protection

(Temperature)



Goals for Excellent Habitat:

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

Temperature

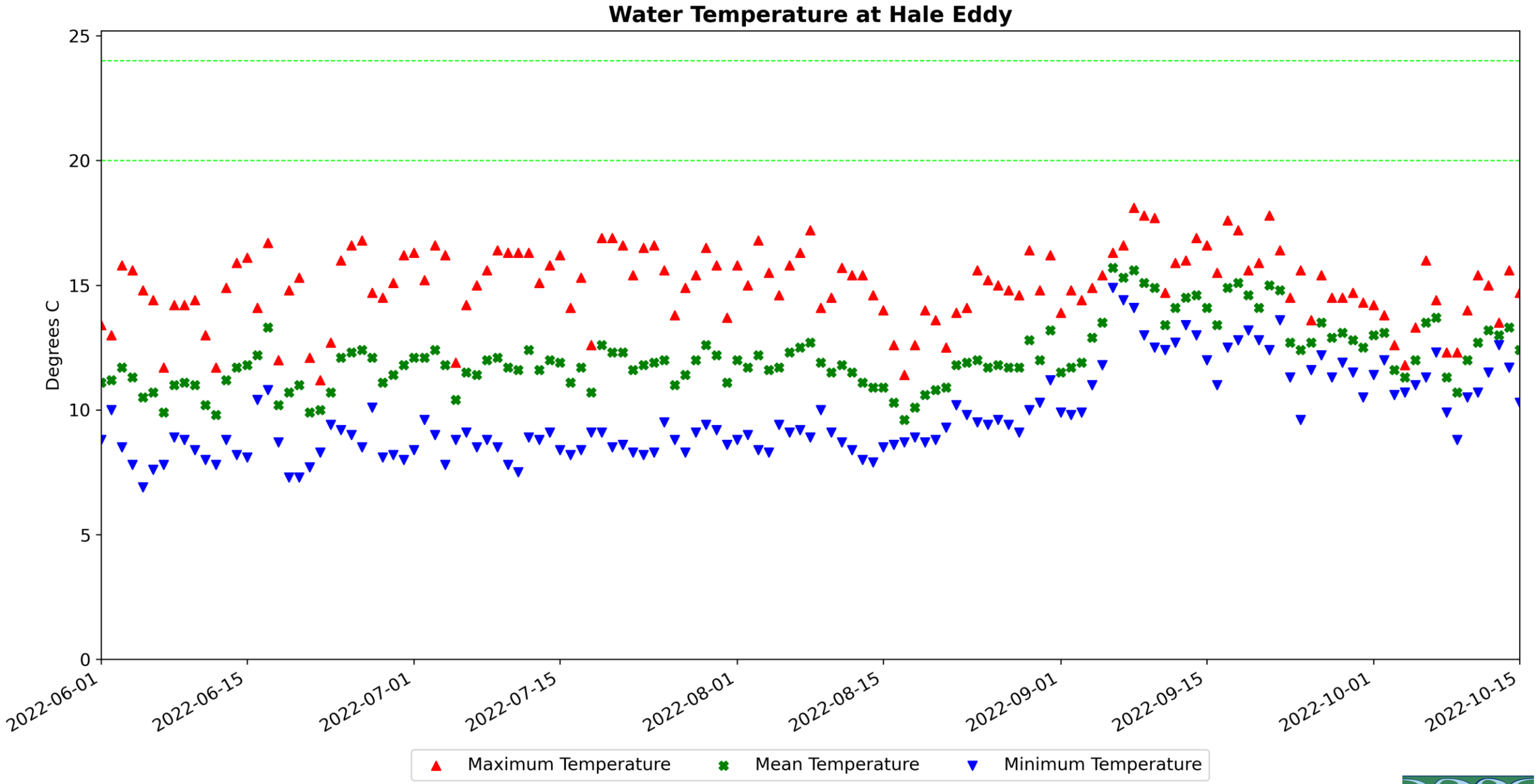
Goals for Excellent Habitat:

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

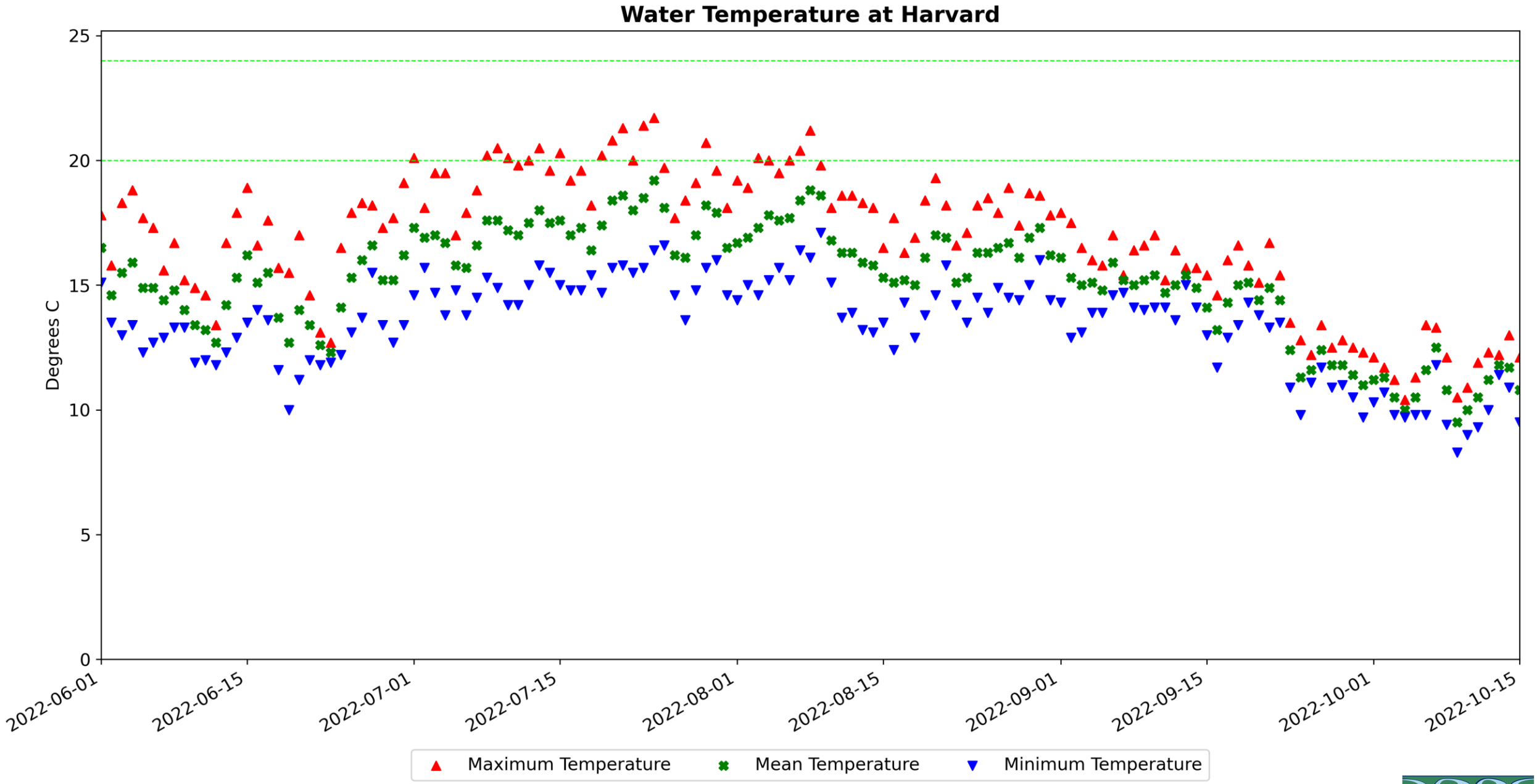
Location	Exceedances of 24^{0}C		Exceedances of 20^{0}C	
	Days the Maximum Temperature was above 24 ^{0}C	Days the Average Temperature was above 24 ^{0}C	Days the Maximum Temperature was above 20 ^{0}C	Days the Average Temperature was above 20 ^{0}C
Hale Eddy	0	0	0	0
Harvard	0	0	15	0
Hancock	0	0	0	0
Lordville	2	0	67	37
Bridgeville	3	0	70	11

Thermal Releases were made on 26 days for 9 events in June 2022, July 2022, and August 2022. Approximately 1.1 BG was used from the bank.

Data Source: USGS



Data Source: USGS



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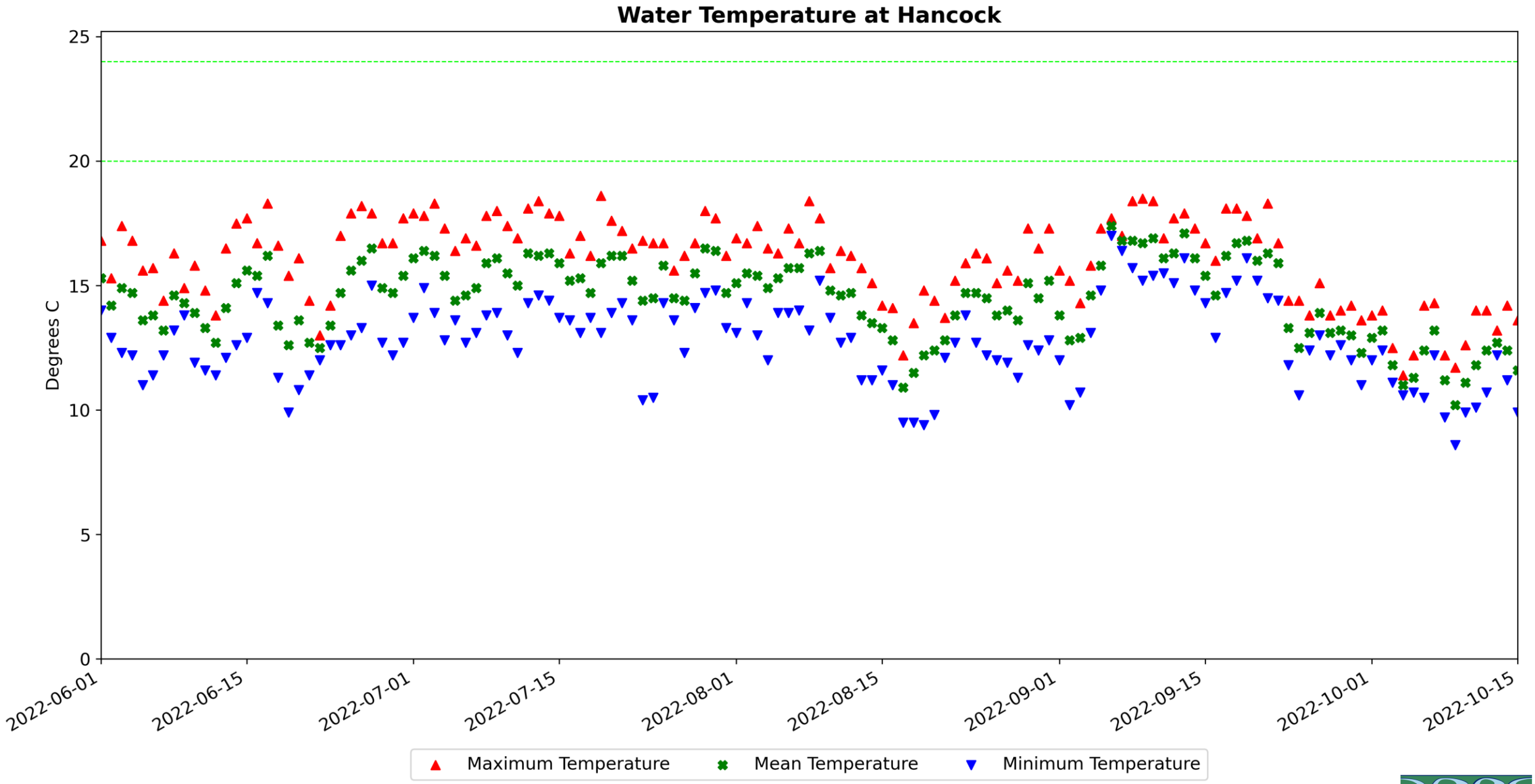

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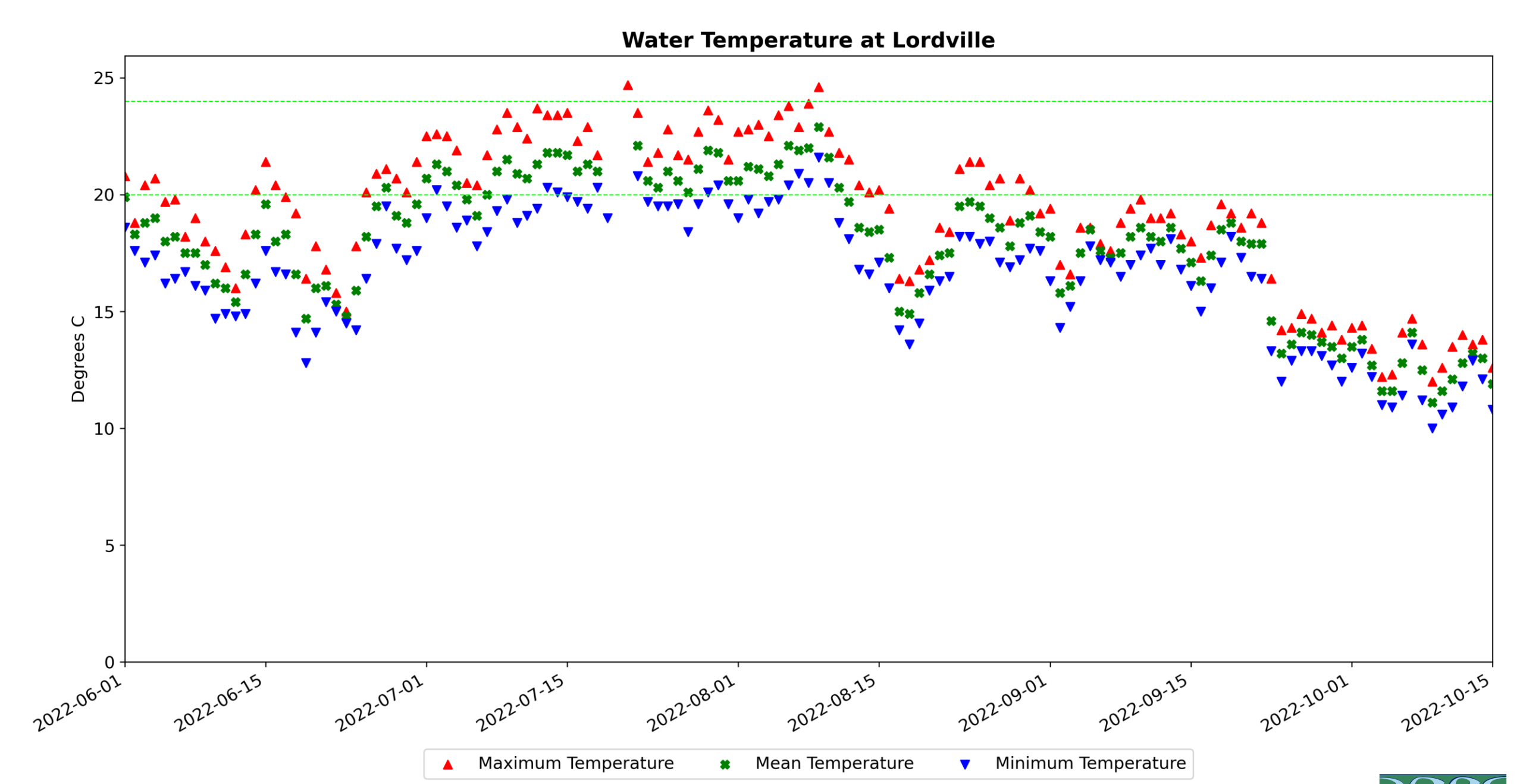
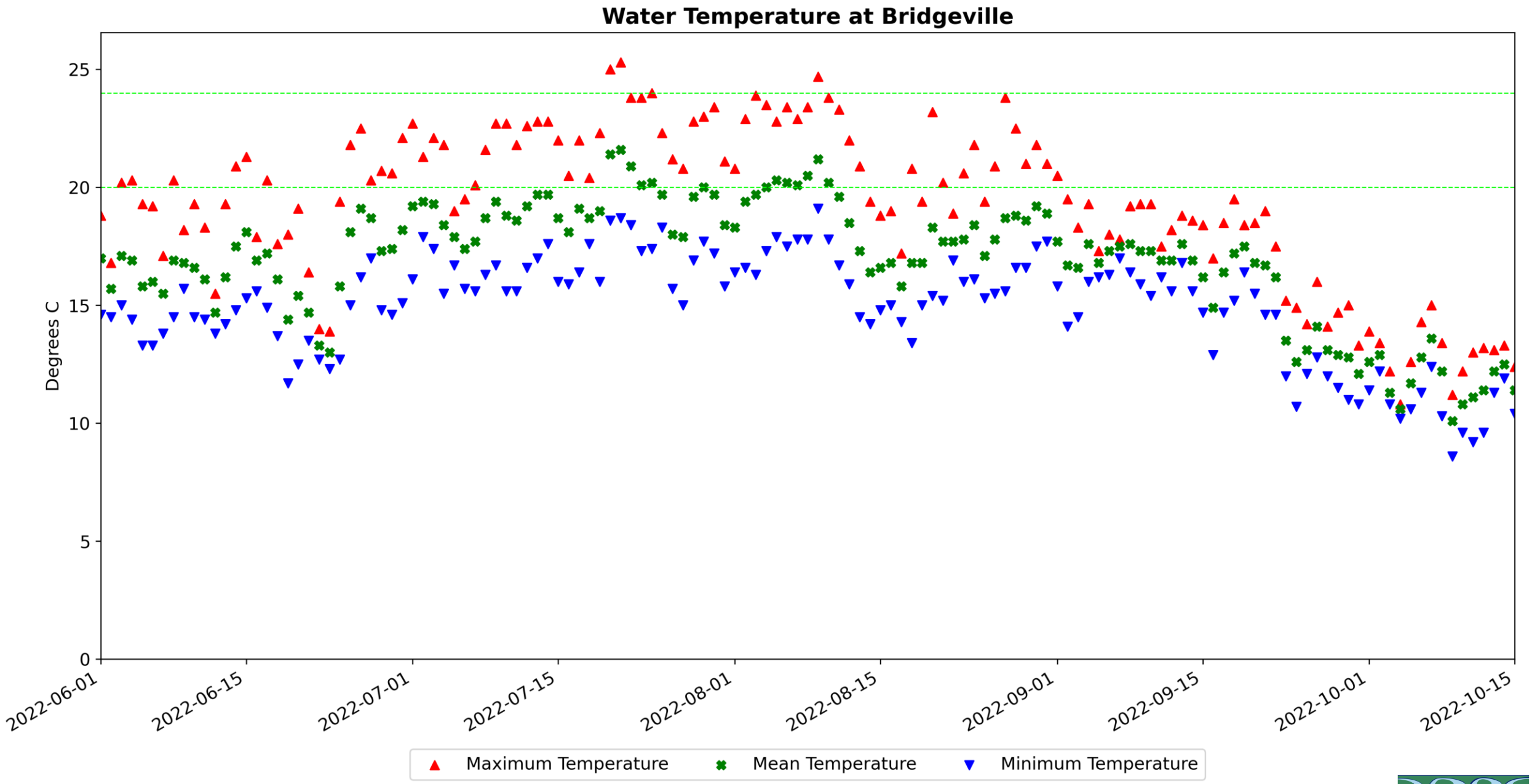


Data Source: USGS



Data Source: USGS

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Temperature Rankings

June - August

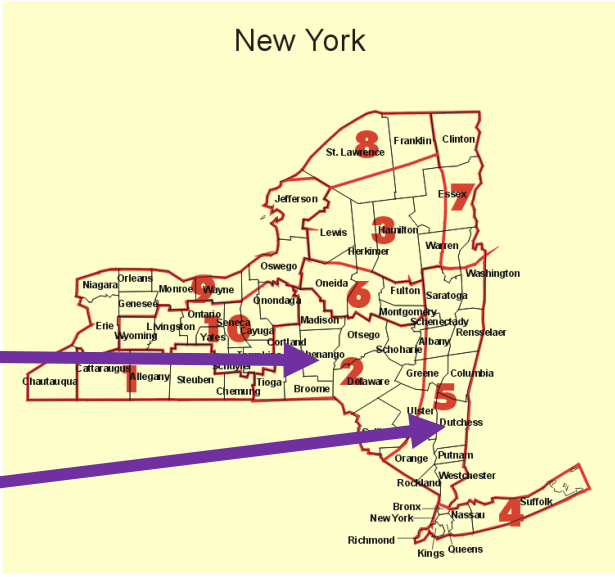
Upper Basin

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

Period	Value	1901-2000 Mean	Anomaly	Rank (1895-2022)	Warmest/Coolest Since		Record
Jun–Aug 2022	67.0°F	65.4°F	1.6°F	106th Coolest	Coolest since:	2019	1903
3-Month	(19.4°C)	(18.6°C)	(0.8°C)	23rd Warmest	Warmest since:	2021	2005
Jun–Aug 2022	71.5°F	68.3°F	3.2°F	125th Coolest	Coolest since:	2021	1903
3-Month	(21.9°C)	(20.2°C)	(1.7°C)	4th Warmest	Warmest since:	2020	2005

Region 2

Region 5



Data Source: NCDC, NCEI

Temperature Rankings

June - August

Lower Basin

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

Location	Period	Value	1901-2000 Mean	Anomaly	Rank (1895-2022)	Warmest/Coolest Since		Record
PA region 3	Jun–Aug 2022 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
					6th Warmest	Warmest since:	2021	2010
NJ region 2	Jun–Aug 2022 3-Month	76.0°F (24.4°C)	72.3°F (22.4°C)	3.7°F (2.0°C)	126th Coolest	Coolest since:	2021	1927
					3rd Warmest	Warmest since:	2020	2010

Data Source: NCDC, NCEI

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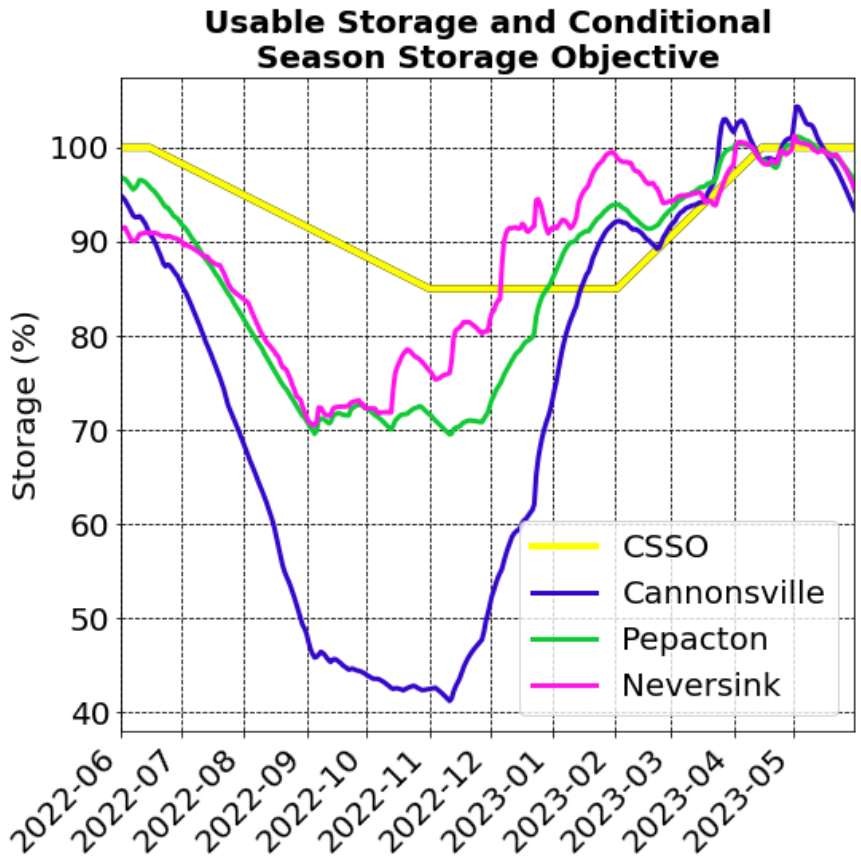
Discharge Spill Mitigation

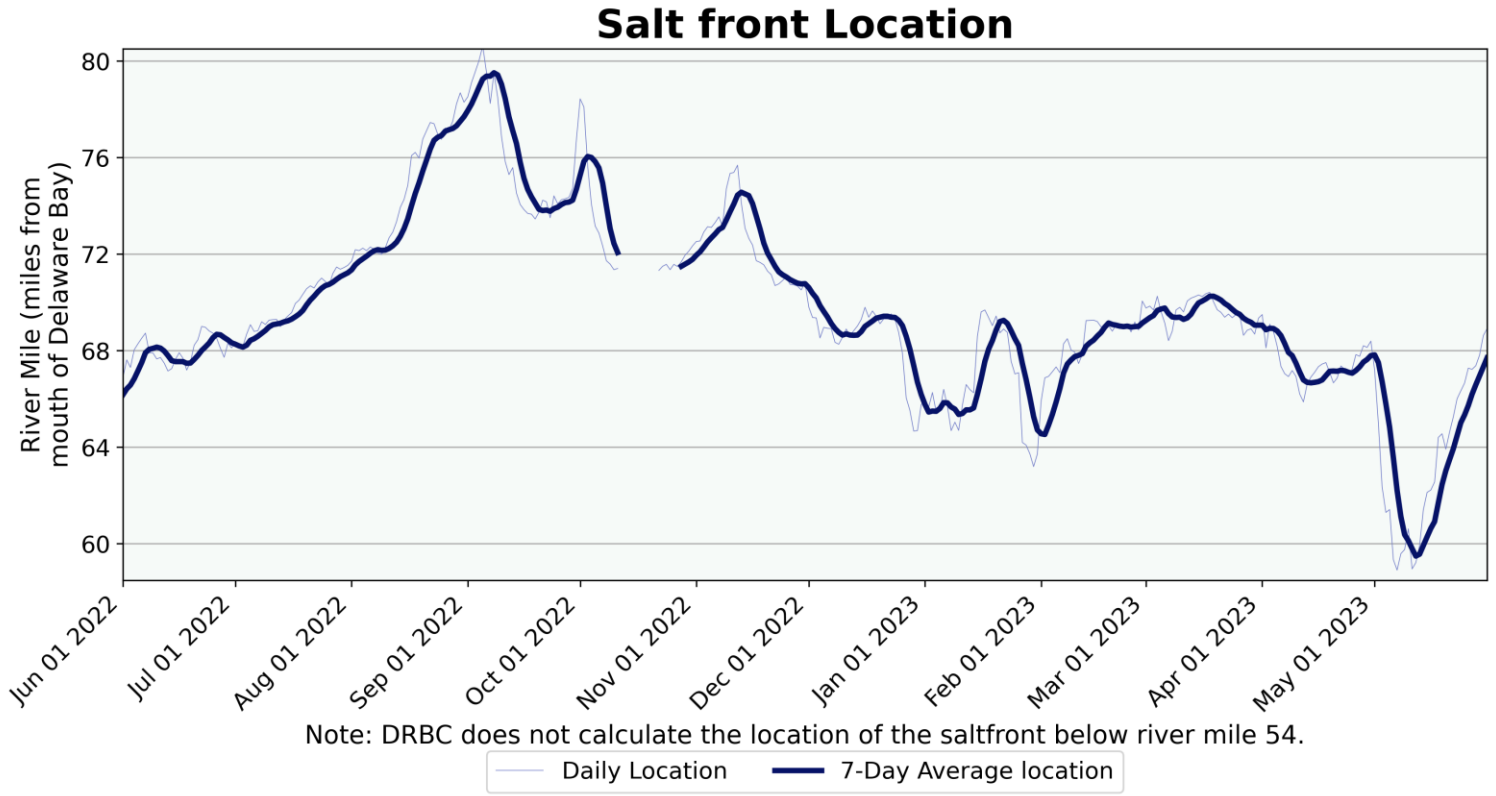


	Spill Volume (MG)	Days
Cannonsville	27,770	40
Pepacton	10,652	25
Neversink	3,611	19

	All L1 Discharge Mitigation Releases (MG)	Number of days above CSSO (L1-a, L1-b)
Cannonsville	48100	104
Pepacton	28844	118
Neversink	11866	110

Data Source: NYCDEP

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

Summary
FFMP 2022-2023

* Warm water temperatures during June, July, and August of 2022 required use of the thermal mitigation bank on twenty-six separate days.
* The maximum water temperature exceeded 24 ^{0}C on 2 days at Lordville and 3 days at Bridgeville.
* Dry conditions during July and August required releases of approximately 20.4 BG to meet the Montague Flow Objective.
* Additional releases were made during November 2022, February 2023 and May 2023 bringing the total directed releases for Montague to approximately 21.5 BG
* Releases of approximately 1.5 BG were made from lower basin reservoirs Beltzville and Blue Marsh to meet the Trenton Equivalent Flow Objective.
* The conservation releases were based on Table 4G for 82.2% of the year.
* The three NYC reservoirs were below the CSSO for most of the time between June 2022 and November 2022. From November 2022 until May 2023:
  * Neversink was above the CSSO except at the end of May
  * Pepacton was above the CSSO except during December and at the end of May
  * Cannonsville was above the CSSO except during the second part of December and at the end of May

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 (4E, 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. REV1 amounts refer to the first revision of D-77-20 CP and are the total amount over the release year that would have been released based on this release program.
* Slide 15: Conservation releases, same as slide 13 but displayed as a graph.
* Slide 15: Plot and table of the number of days in each FFMP table from the NYC WSCC end-of-month reports, column AA.
* Slide 19: Bank Use: was obtained from the accumulated Daily River Master Data, dated June 1, 2023.
* Slide 29: 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.

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Presentation Available On DRBC's Website

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