MARYLAND
DEPARTMENT OF
NATURAL RESOURCES

2022 – 2024 Middle Branch – Patapsco River Shallow Water Monitoring Data Report
DRAFT

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2022 – 2024 Middle Branch – Patapsco River Shallow Water Monitoring Data Report

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Executive summary

In 2021, a plan was proposed for restoration and revitalization of the Middle Branch, an inlet in the upper reaches of the tidal Patapsco River. This plan, which was approved by Baltimore City's planning commission in 2023, called for improved access to the waterfront through the restoration and construction of wetlands, parks, trails, and equitable economic development in and around the Middle Branch (see https://www.reimaginemb.com/). In preparation for this project and to collect baseline water quality and habitat data, the Maryland Department of Natural Resources (DNR) deployed a continuous water quality monitor beginning in September 2022, ahead of construction and restoration activities. DNR maintained a deployed continuous monitor in the Middle Branch until February 2024, when it was removed due to structural safety concerns of the pier from which the continuous monitor was deployed.

Results from 18-months of monitoring indicate poor habitat conditions in the Middle Branch. Dissolved oxygen concentrations, which were excessively low and often at levels detrimental to living resources, coincided with high algal concentrations and frequent blooms. Water clarity conditions during the growing season were also not conductive to the growth of submerged aquatic vegetation. Together, these results indicate that excessive runoff and associated nutrients into the Middle Branch are clouding the water, fueling algal blooms, and degrading dissolved oxygen levels within the water.

All continuous monitoring data collected by DNR are available on the "Eyes on the Bay" website (https://eyesonthebay.dnr.maryland.gov/contmon/ContMon.cfm). Data from in-situ measurements collected while onsite are available through the Chesapeake Bay Program's Data Hub (https://www.chesapeakebay.net/what/data). Data collected specifically from the Middle Branch station at the time of each instrument replacement (Secchi disk depth; ambient water quality data) are available for direct download via the following link: https://datahub.chesapeakebay.net/api.CSV/WaterQuality/WaterQuality/9-8-2022/2-6-2024/0/4/2/Station/64957/21,31,55,60,63,65,71,73,74,76,77,78,82,83,85,88,94,104,105,116,121,123.

Introduction

In 2021, the Reimagine Middle Branch Plan was proposed by the City of Baltimore, South Baltimore Gateway Partnership, and Parks & People. The plan called for a new vision to the Middle Branch and the neighborhoods surrounding it by constructing and restoring 11 miles and 50 acres of wetlands, parks and trails, as well as increasing investments into the communities to foster equitable economic development. This plan was approved by Baltimore City's Planning Commission in February 2023 and officially launched in April 2024.

In September 2022, in preparation for assessing the impacts of the environmental restoration projects on the habitat quality of the Middle Branch, the Resource Assessment Service of the Maryland Department of Natural Resources (DNR) began monitoring water quality to collect baseline data prior to construction activities. DNR deployed a continuous water quality monitor at the Middle Branch Marina off Waterview Avenue in South Baltimore. This continuous monitor collected data every 15 minutes on a suite of water quality parameters, including dissolved oxygen, salinity, temperature, turbidity, pH, and chlorophyll. Data from this monitor were telemetered to the DNR website, "Eyes on the Bay" (eyesonthebay.net), and displayed in near real-time. DNR personnel visited the station every two to four weeks to replace the meters and to collect onsite measurements of ambient water quality and Secchi disk depth. The continuous water quality monitor was permanently removed from the Middle Branch Marina in February 2024 due to structural concerns about the pier from which the monitor was deployed.

The continuous monitoring site at Middle Branch was one of four continuous monitoring stations located in the upper Patapsco during this time. The other sites were deployed adjacent to the National Aquarium in the Baltimore Harbor and in Masonville Cove.

Description of continuous monitoring

Between September 2022 and February 2024, a data collection device known as a sonde was attached to a pier piling at the Middle Branch Marina (39.2586°, -76.6253°; see Figure 1 for station location). The total depth at this location was approximately 1.8-meters and for the first ten months of monitoring, the instrumentation was deployed anchored 0.8-meter off the bottom. On July 5th, 2023, the configuration was changed and the sonde was deployed floating 1-meter below the water surface until the station was permanently removed on February 6th, 2024. The data sonde deployed in Middle Branch was a YSI™ EXO2 (Yellow Springs Instruments, Yellow Springs, Ohio), which housed several water quality sensors and central cleaning wiper (Figure 2). The water quality indicator data collected by each sensor are explained in greater detail in the following section. The sonde collected a reading from each sensor simultaneously every 15 minutes for the duration of its deployment. These readings were stored in the sonde's data memory and sent, by attached cellular telemetry equipment, to DNR headquarters in Annapolis. There, the data were posted on DNR's "Eyes on the Bay" website (eyesonthebay.net) for easy public access. This website enables the public to access near real-time water quality data for numerous locations throughout Maryland. The data are called "near real-time" because there is a lag of approximately 30-minutes to one hour between the time that the sonde collects the data and the time that the data are posted on the website.

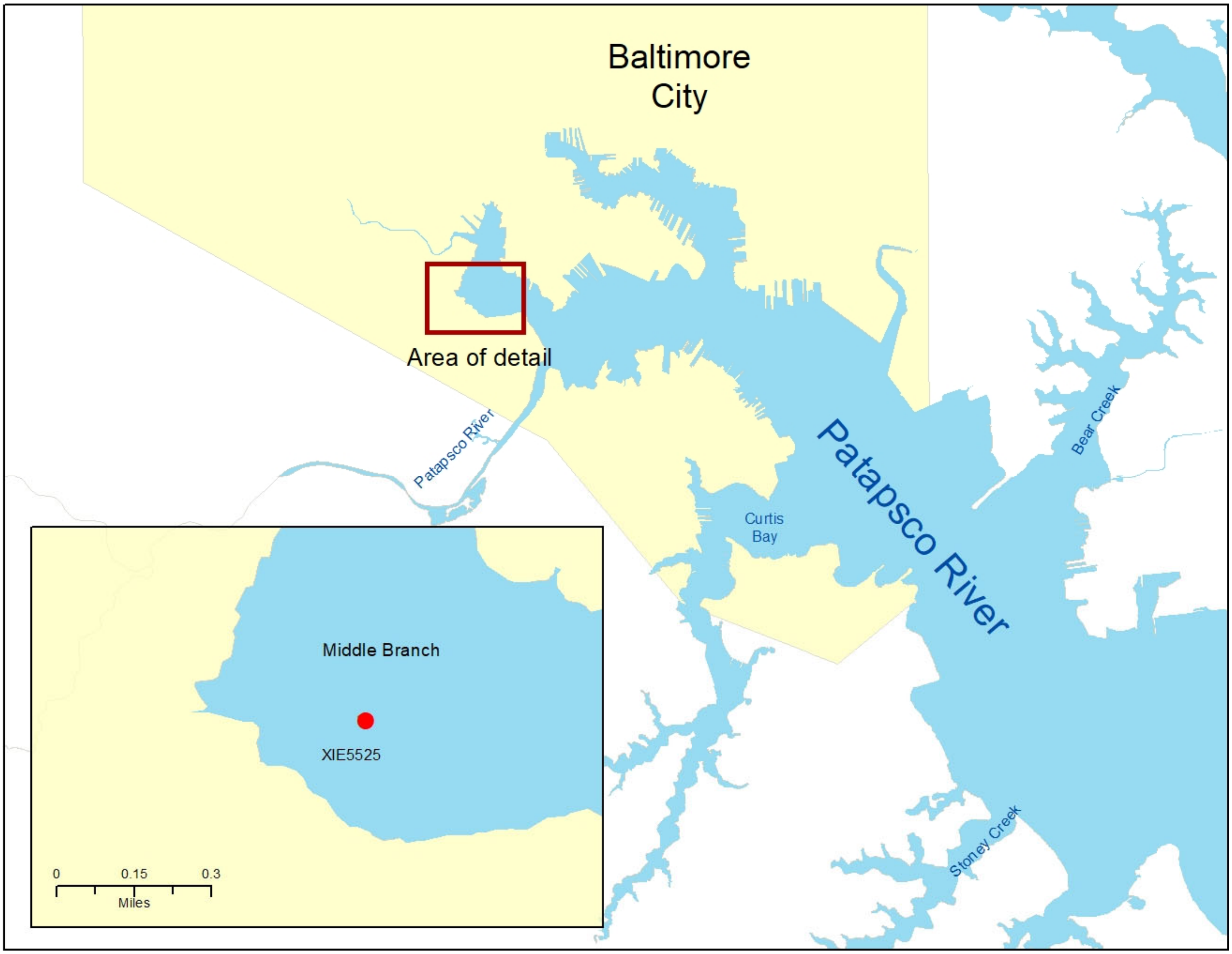

Figure 1. Map of the Patapsco River and Middle Branch. The inset shows where the continuous monitor is located within the Middle Branch.

Figure 2. YSI EXO2 continuous monitoring sonde showing individual sensors and central wiper. Image courtesy of YSI, Inc.

Continuous monitoring parameters

The continuous monitor in the Middle Branch, like all continuous monitors in the DNR Shallow Water Monitoring Program, collect data on six water quality parameters:

1. Dissolved oxygen (DO): Fish and other aquatic life require DO to survive. Maryland state water quality criteria require a minimum DO concentration of 5 milligrams per liter (mg/L) (COMAR 1995). This threshold is necessary for the survival of many fish and shellfish species, including blue crabs (*Callinectes sapidus*) and striped bass (*Morone saxitilis*).
2. Salinity: Salinity, or salt concentration, is calculated automatically by the continuous monitoring sonde from conductivity and temperature readings. Salinity in the Patapsco River comes from the Chesapeake Bay. Therefore, areas closer to the Bay have higher salinities, except perhaps during large freshwater releases from the Conowingo Dam on the Susquehanna River. During periods of low precipitation and river flow, salinity increases as salty water intrudes further up the river. During wetter periods, salinity decreases. Salinity also cycles in relation to tides, increasing during flood tides and decreasing during ebb tides. Salinity levels are important to aquatic organisms, as some organisms are adapted to live only in brackish or salt water, while others require fresh water.
3. Water temperature: Water temperature is another variable affecting the suitability of waterways for aquatic organisms. Many aquatic organisms can tolerate gradual temperature changes associated with changing seasons, but sudden changes can cause stress. Higher water temperatures cause more dissolved oxygen to come out of solution and enter the air, decreasing the amount available to fish and other aquatic organisms.
4. pH: The acidity of water is indicated by pH. A neutral pH is 7; lower values indicate more acidity, while higher numbers indicate more alkaline conditions. pH is affected by salinity (higher salinities tend to buffer pH in the 7-8 range) and algal blooms (large algal blooms can raise the pH of water over 8 in low salinity).
5. Turbidity: Turbidity is a measure of water clarity. Events that stir up sediment or cause runoff, such as storms, will increase turbidity. Dense algal blooms will also cause increased turbidity. Relatively clear water (low turbidity) is required for the growth and survival of Submerged Aquatic Vegetation (SAV).

6. Chlorophyll: Chlorophyll concentration is a surrogate measure of the density of algae in the water. Chlorophyll is the main photopigment responsible for photosynthesis, the process by which sunlight is converted into food energy. Chlorophyll concentrations are calculated from fluorescence values collected by the sensors.

Collection of ambient water quality data and Secchi depths

Ambient water quality data and Secchi disk depth were obtained by DNR staff during deployment and replacement of continuous monitoring data sondes. Data sondes were removed and replaced with freshly calibrated instruments on a biweekly basis between April and October and once a month between November and March. At the time of each instrument replacement, Secchi disk depth was recorded for use in water clarity determination, and water column profiles were taken. During profiles, an instrument was lowered into the water and collected readings for depth, water temperature, pH, dissolved oxygen, and salinity.

Middle Branch continuous monitor deployment

Between September 8th, 2022, and February 6th, 2024, a continuous monitor in the Middle Branch was deployed the entire time. Data sondes collected 49,534 data records and 23 ambient water quality profiles and Secchi disk depths were recorded. Water quality profiles and Secchi disk depths were recorded when sondes were changed out every two weeks between April and October and every four weeks between November and March. Automated telemetry generally operated when deployed, but there were times when telemetry did not work properly, which led to gaps in near real-time web presentation of the data. Telemetry issues did not, however, impede the sonde from collecting data. Any gaps in the data are where questionable data were masked in the published dataset for quality assurance purposes.

Precipitation and Discharge Events

Precipitation increases runoff into waterways, which can lead to a higher input of nutrients that fuel algal blooms, decrease water clarity, and suppress SAV growth. Although beyond the scope of sampling for this report, precipitation has also been tied to increased loads of contaminants from urban and industrial centers in and around Baltimore (Leffler and Greer 2001).

Total precipitation at Baltimore Washington International (BWI) Thurgood Marshall Airport between September 2022 and February 2024 was essentially equivalent to the long-term norm (Figure 3). Total precipitation was 66.12-inches, which is 0.08-inches below the 30-year average of those same months. Total precipitation was above monthly averages in eight of the eighteen months that sondes were deployed in the Middle Branch. July, September, and December 2023, and January 2024 were the four wettest months during this period as over 6-inches of precipitation was recorded each month. January, March, May, and October 2023, and February 2024 all had less than 2-inches of precipitation.

Daily mean discharge at the United States Geological Survey (USGS) gaging station in the Gwynns Falls reflected the pattern of precipitation seen during the Middle Branch monitoring period (Figure 4). Gage data show numerous spikes throughout this time, which are indicative of the precipitation events that affected the region. The largest flows occurred on December 18th, 2023, and January 9th, 2024, in association with heavy rains around that time. These flow events were more than 800 cubic feet per second (cfs) greater than the daily medians measured over 58 years, reflecting very high discharge levels into the Patapsco River and the Chesapeake Bay. Extremely high flows more than 300 cfs greater than the daily median were also measured following heavy rains on December 15th, 16th, and 23rd, 2022, September 24th, 2023, November 22nd, 2023, December 11th, 2023, and January 10th and 28th, 2024.

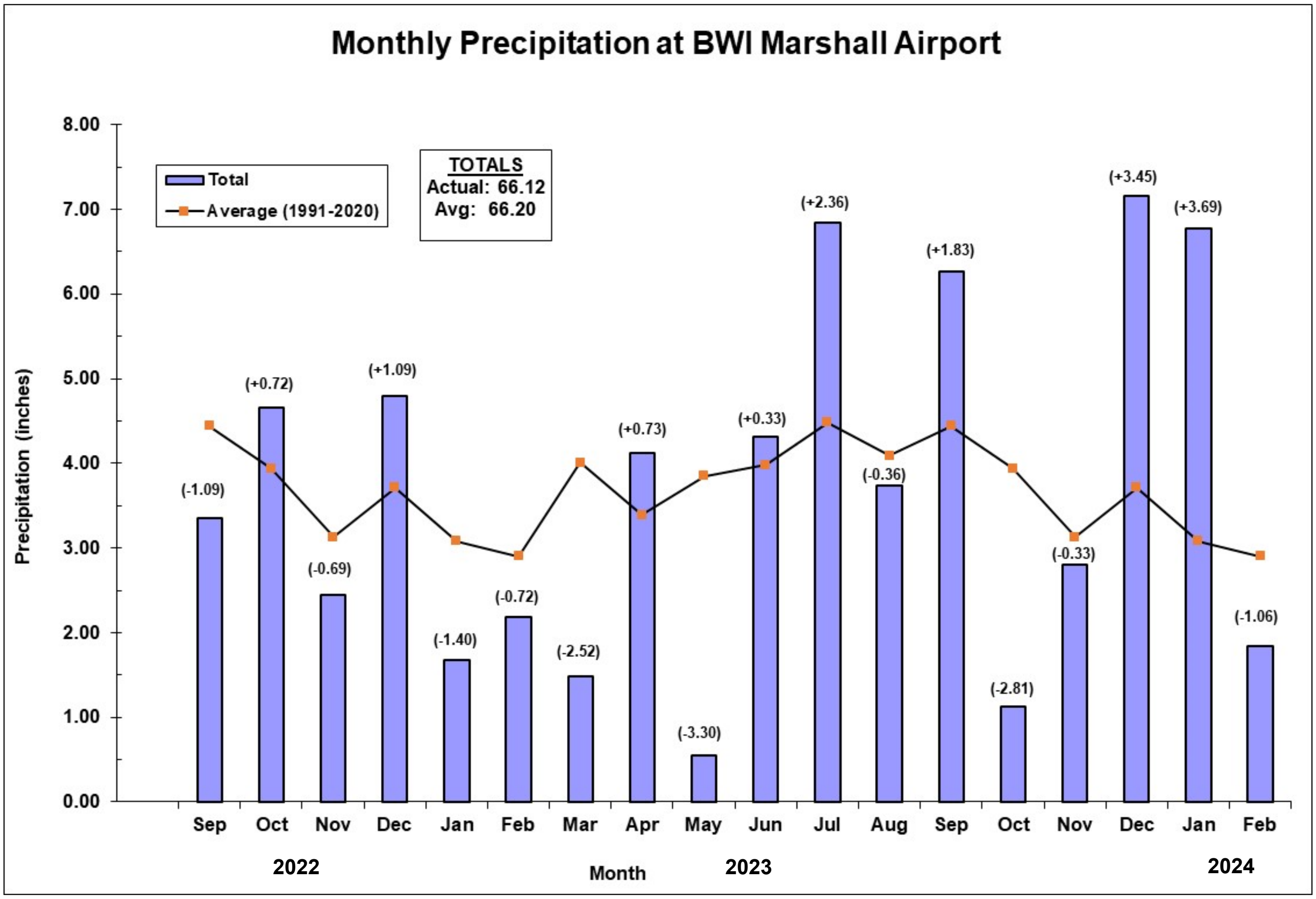

Figure 3. Total monthly precipitation at BWI Thurgood Marshall Airport compared to 30-year averages. Data source: National Weather Service (https://www.weather.gov/media/lwx/climate/bwiprecip.pdf).

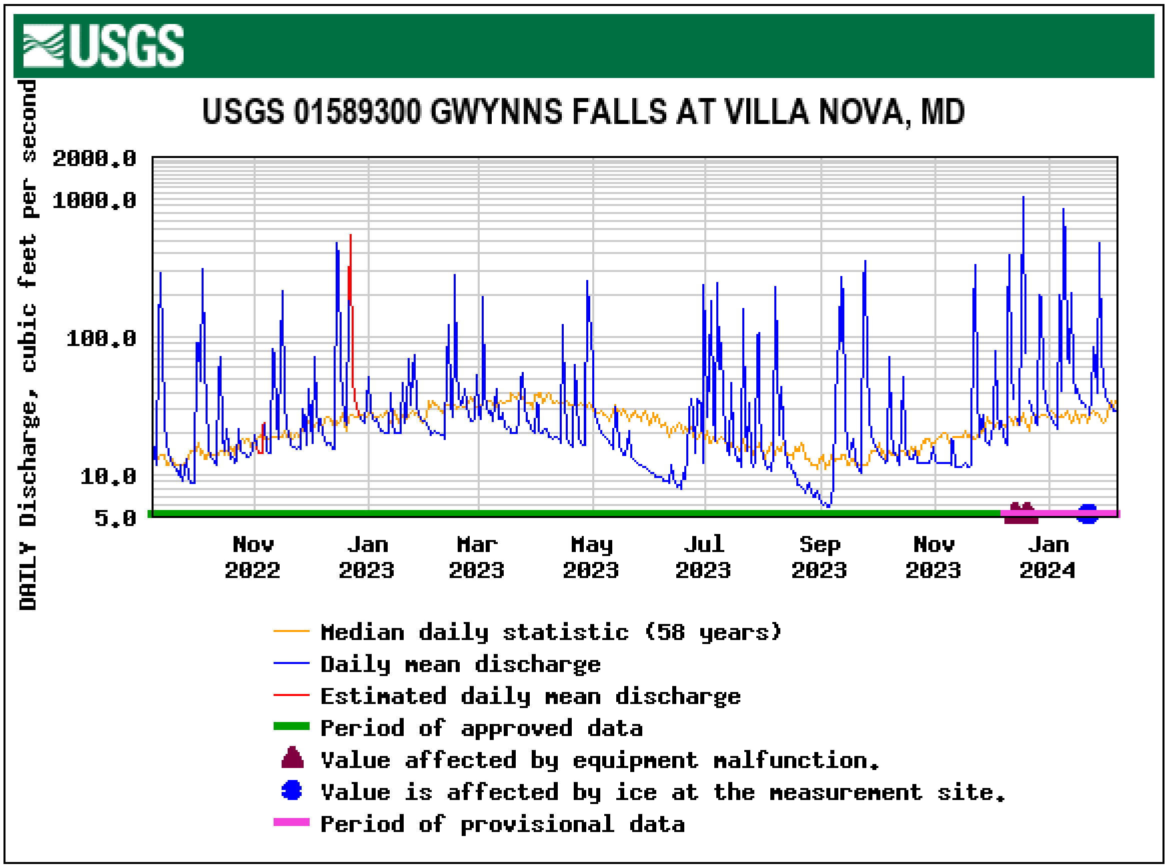

Figure 4. Daily discharge in cubic feet per second measured at a USGS gaging station northwest of Middle Branch. Graph courtesy of the United States Geological Survey (https://waterdata.usgs.gov/nwis/dv/?site_no=01589300).

Continuous Monitoring Data

Water temperature

Water temperatures at Middle Branch decreased predictably between deployment in September 2022 and the end of 2022 as air temperatures decreased (Figure 5). Temperatures declined to approximately 3.5°C (38º F) in late December 2022 and generally remained near those levels through early February 2023. Temperatures then increased for the next five months and peaked at 32°C (90º F) on July 7th, 2023. Heavy rains in early July stunted the increase in water temperatures and they remained relatively steady into mid-September 2023. As air temperatures cooled through the rest of the year, water temperatures followed this pattern and declined to 2.7°C (37º F) in late January 2024. Variability in the plots in Figure 5 was most likely a result of diel variation in temperature (warming temperatures during the day and cooling temperatures during the night).

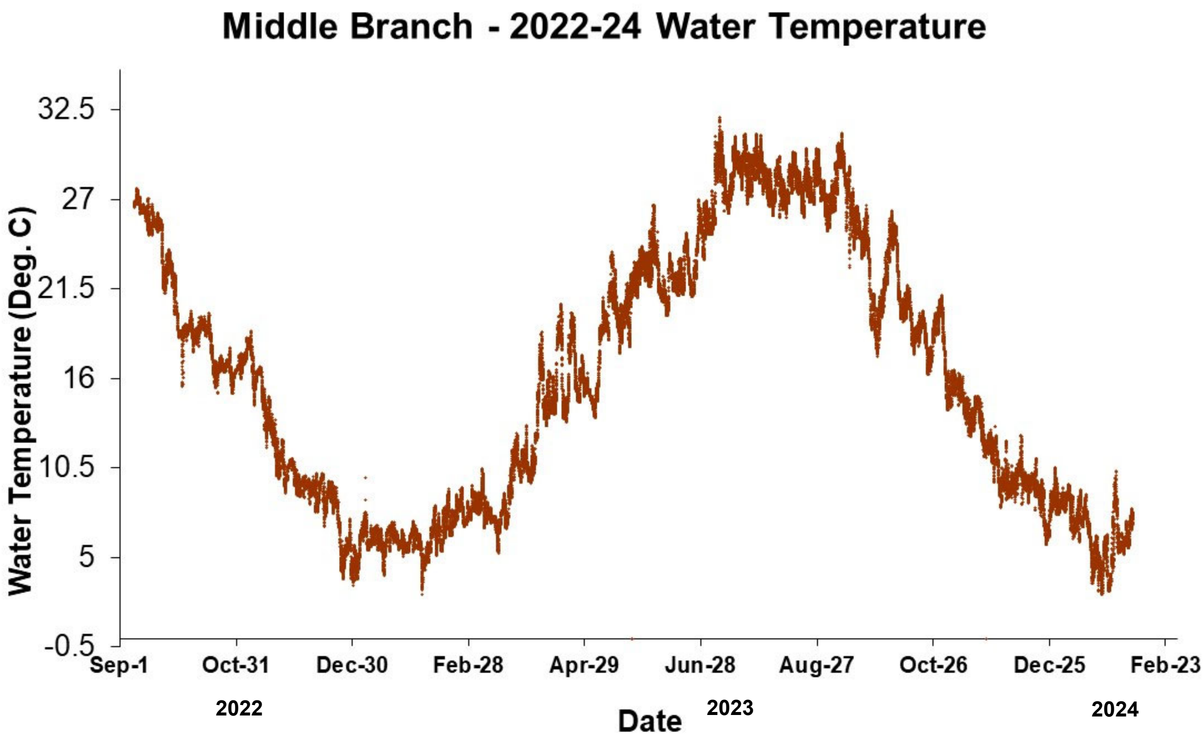

Figure 5. Water temperature at the Middle Branch continuous monitoring station.

Salinity

Salinity tends to vary with precipitation and streamflow. The general annual trend in salinity that has been observed at other monitoring station in the Patapsco River* is higher values in late winter and early spring, a drop in readings during the wetter summer months, and a rise in values again in the late fall and early winter. The overall pattern at Middle Branch (Figure 6) began with increasing salinities in late summer and autumn 2022. Concentrations peaked at 17.1 parts per thousand (ppt) in mid-December, before rains in late December 2022 and early January 2023 decreased salinity readings to approximately 5.7 ppt on January 5th, 2023. Salinity concentrations then increased to almost 15 ppt in late March before spring rains precipitated a decline in salinity concentrations to less than 10 ppt. Concentrations generally remained below 10 ppt into late September 2023, before increasing to 16.3 ppt during a dryer than normal October 2023 (Figure 3). Both December 2023 and January 2024 were much wetter than normal with regional rainfall totaling approximately 7-inches during both months. This influx of freshwater led to precipitous declines in salinity readings, sometimes to near 0 ppt, during both months. **(*Additional data reports available at https://eyesonthebay.dnr.maryland.gov/eyesonthebay/stories.cfm)**

Salinity readings in the Patapsco River often quickly drop to near 0 ppt following rain events, before quickly rebounding to prior levels. This ‘flashiness’ pattern is often observed in urban environments and reflects how quickly flow in a river or stream increases and decreases during a storm. Flashy patterns are common in urbanized areas because stormwater runoff reaches the waterways much more quickly than rural areas due to a higher amount of impervious surfaces.

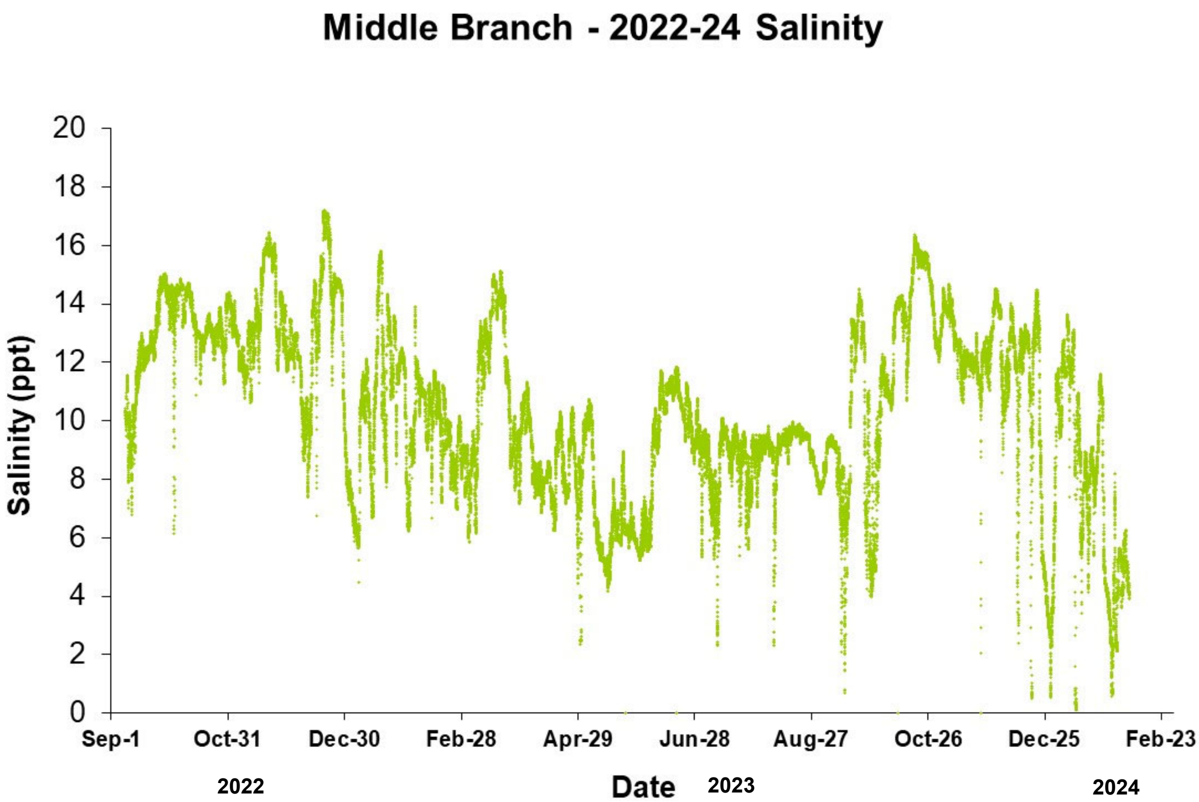

Figure 6. Salinity levels at the Middle Branch continuous monitoring station.

Dissolved oxygen

There were numerous extremely low dissolved oxygen (DO) values during the first few weeks of deployment in September 2022 (Figure 7). 74% of all DO values recorded in September 2022 were less than 5 mg/L (Table 1). Prolonged periods of low DO concentrations below 5 mg/L can stress and be detrimental to the survival of juvenile fish and other aquatic animals (U.S. Environmental Protection Agency, 2003). DO concentrations during this time often displayed large daily swings, from greater than 10 mg/L during the day to hypoxic levels (< 2 mg/L) at night. This pattern is indicative of algal bloom conditions as oxygen concentrations can become super-saturated (greater than 100% saturation) and peak during the day when algal cells are photosynthesizing and producing large amounts of oxygen. However, DO can drop to very low levels at night when photosynthesis ceases, and oxygen is consumed through cellular respiration. Chlorophyll data (see below) indicate algal blooms were prevalent in the Middle Branch between September and November 2022 (Table 8).

Between early October 2022 and early January 2023, DO concentrations steadily increased in the Middle Branch as water temperatures cooled (Figure 5), an expected pattern since cooler waters can hold more dissolved oxygen than warmer waters. Algal bloom conditions were then observed in the Middle Branch (Figure 8), which coincided with a drop in DO concentrations in mid-January 2023. Concentrations remained relatively stable, between 7 mg/L and 14 mg/L, through mid-April. An increase in algal blooms through the summer of 2023 was then observed in the Middle Branch, which coincided with large swings in DO concentrations, included super saturated concentrations, and a high frequency of low values less than 5 mg/L (Figure 7). Throughout the summer and early fall of 2023 and into January of 2024, algal blooms coincided with super-saturated DO concentrations in mid-May (19 mg/L; 222% saturation), late July (19.4 mg/L; 263% saturation), late September (21.2 mg/L; 287% saturation), late October (22.8 mg/L; 269% saturation), late December (16 mg/L; 142% saturation), and late January 2024 (18 mg/L; 153% saturation).

Decreases in DO concentrations can also coincide with the death and decomposition of large algal blooms. The decomposition process can consume significant amounts of oxygen in the water and can lead to conditions harmful to aquatic organisms. Large drops in chlorophyll levels (Figure 8), indicative of the dieback of algal blooms, coincided with large drops in DO concentrations to extremely low levels in the fall of 2022 and throughout the summer of 2023 (Figure 7). These fluctuations between super-saturated and extremely low values indicate that frequent algal blooms are a strong driver of DO concentrations within the Middle Branch.

As part of the 1987 Chesapeake Bay Agreement, the signatories agreed "to provide for the restoration and protection of living resources, their habitats and ecological relationships." Further, the Chesapeake Executive Council (CEC) committed to "develop and adopt guidelines for the protection of water quality and habitat conditions necessary to support the living resources found in the Chesapeake Bay system, and to use these guidelines in the implementation of water quality and habitat protection programs." Because prolonged periods of low DO concentrations can stress and be detrimental to the survival of juvenile fish and other aquatic animals (U.S. Environmental Protection Agency, 2003), a document was produced by the Chesapeake Bay Program outlining dissolved oxygen thresholds for various living resources (Jordan et al. 1992). The State of Maryland adopted these dissolved oxygen thresholds as standards in 1995 (COMAR 1995). For shallow water habitats, the DO criteria are a 30-day average of 5 mg/L and an instantaneous minimum of 3.2 mg/L.

Table 1 shows the percentage of time that Middle Branch DO concentrations fell below these criteria values during September 2022 and June through September 2023. which are generally the times of year that DO values are the lowest due to warmer waters. In September 2022, DO failure rates were below 5 mg/L 73.7% of the time and below 3.2 mg/L for 50.7% of readings. These rates decreased during June through September 2023 (40.3% for 5 mg/L; 19.4% for 3.2 mg/L). Combining the two years, DO failure rates were below 5 mg/L 45.6% of the time and below 3.2 mg/L for 24.4% of readings.

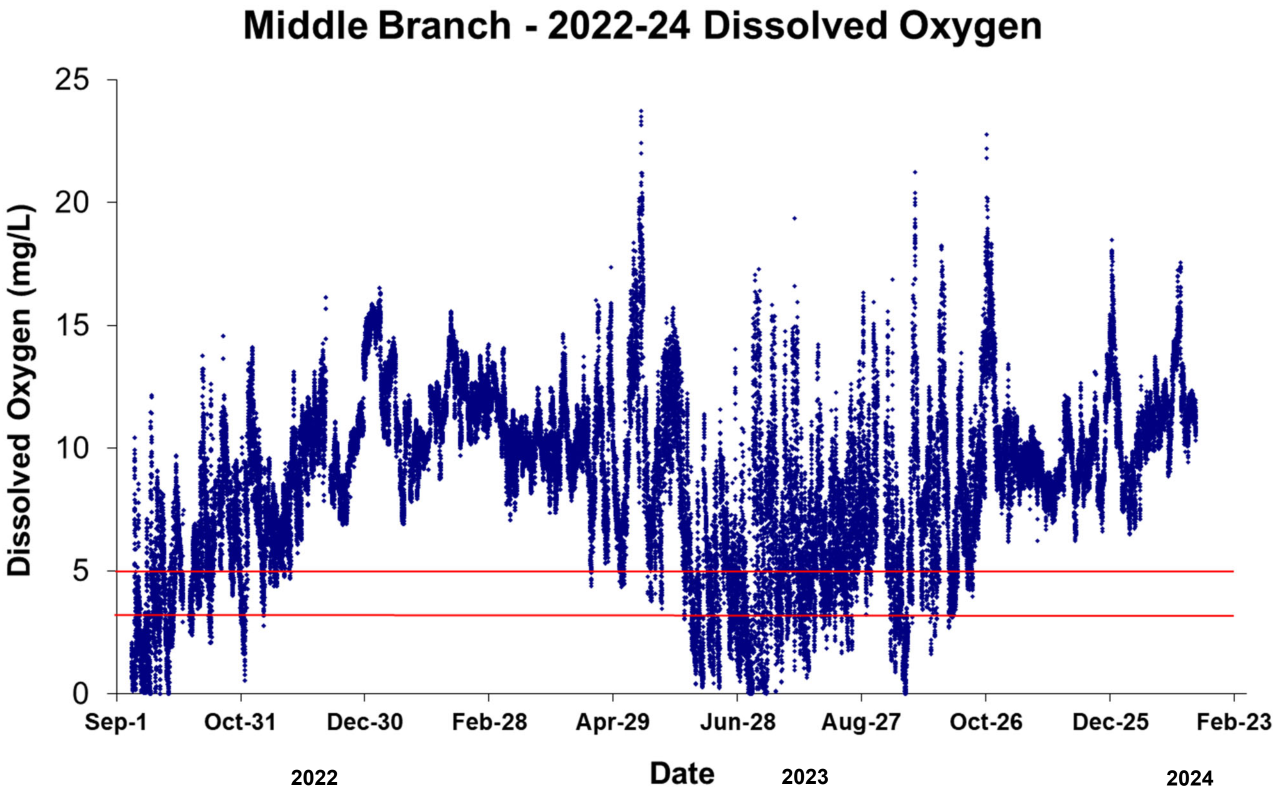

Figure 7. Dissolved oxygen levels at the Middle Branch continuous monitoring station. (*Red lines indicate 5 mg/L and 3.2 mg/L criteria.)*

Table 1. Dissolved oxygen criteria failure at the Middle Branch continuous monitoring station during September 2022 and June through September 2023.

Continuous Monitor	2022	2023	**Two- Year Total**
Dissolved oxygen readings less than 5 mg/L	73.7%	40.3%	**45.6%**
Dissolved oxygen readings less than 3.2 mg/L	50.7%	19.4%	**24.4%**

Chlorophyll

Chlorophyll concentrations tend to vary with and are an indicator of algal (phytoplankton) levels. Readings above 15 micrograms per liter (µg/L) represent algal blooms that can negatively affect living resources. Chlorophyll concentrations greater than 50 µg/L represent significant algal blooms and concentrations above 100 µg/L represent severe blooms. In the Middle Branch, measured chlorophyll values indicate that significant or severe algal blooms occurred in all eighteen months of sonde deployment (Figure 8).

Chlorophyll sonde data indicate significant bloom conditions within the Middle Branch through much of the late summer and early fall in 2022 (Figure 8). Chlorophyll sonde data were censored from the published dataset as suspect data between mid-November and mid-December 2022. When the published dataset resumes, significant to severe bloom conditions were observed in early January 2023 and mid-February into early March 2023. Severe bloom conditions became more prominent in the Middle Branch beginning in mid-April 2023 and continuing into August and September. Measurements exceeded concentrations indicative of severe algal blooms each month during this time, specifically in mid-April (137 µg/L), mid-May (248 µg/L), late June (278 µg/L), mid-July (360 µg/L), late August (149 µg/L), mid-September (177 µg/L), and late October (140 µg/L). Chlorophyll concentrations then decreased through late November 2023, before increasing to significant and severe algal bloom levels through the winter until the sonde was removed in February 2024. The highest chlorophyll concentration recorded during the entirety of Middle Branch monitoring occurred on December 27th, 2023 (472 µg/L).

As stated previously, chlorophyll readings greater than 15 µg/L and 50 µg/L indicate blooms with potential ecosystem effects and significant blooms, respectively. Table 2 lists the percentage of data readings that exceed these thresholds in the Middle Branch during the portion of the sonde deployment that coincided with SAV growing season (September – October 2022; March – October 2023). Algal blooms during this period may impede the ability of SAV to grow and reproduce. In 2022, chlorophyll levels exceeded the 15 µg/L threshold during 57.7% of readings and exceeded the 50 µg/L threshold during 7.6% of readings. The exceedance rate increased in 2023 to 81.5% for 15 µg/L and 12.2% for 50 µg/L. Over the two growing seasons, over three-quarters of all chlorophyll readings were indicative of algal blooms that would have detrimental effects on the ecosystem.

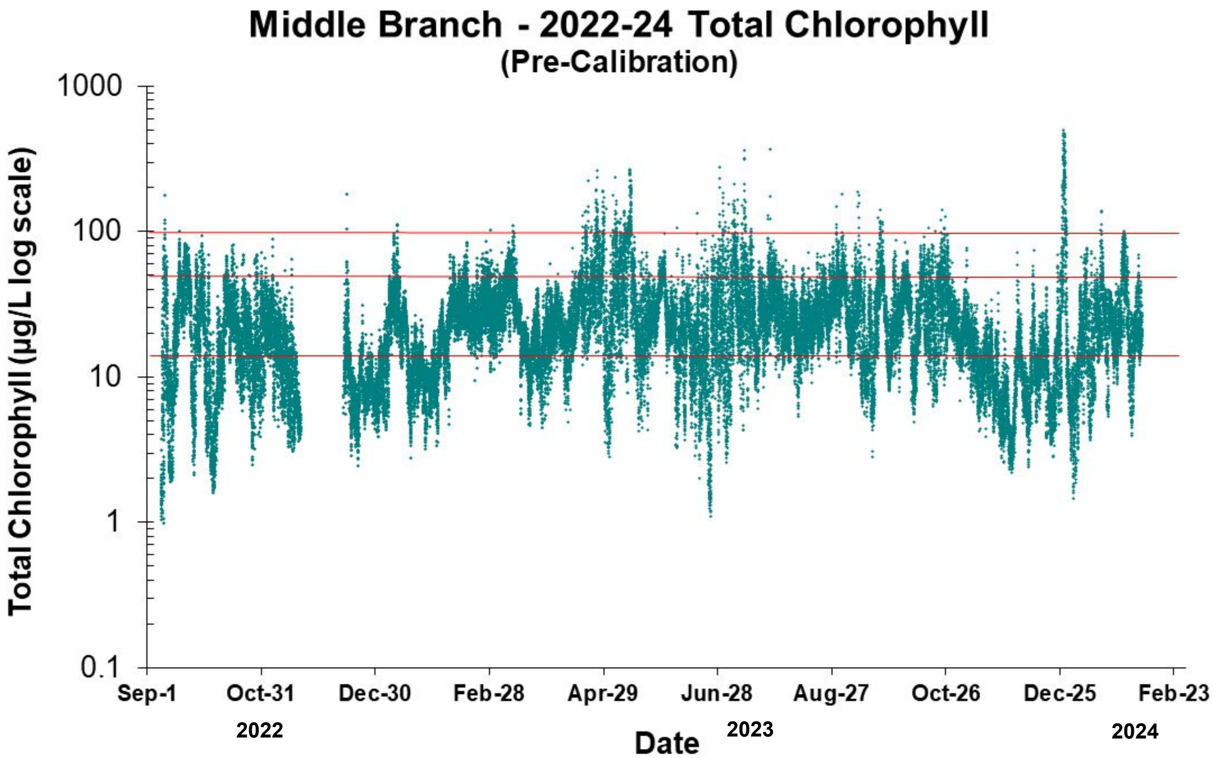

Figure 8. Total chlorophyll levels at the Middle Branch continuous monitoring station. *(Red lines indicate thresholds above which levels may have harmful effects on aquatic ecosystems—15 µg/L—are considered significant blooms—50 µg/L—or are considered severe blooms—100 µg/L.)*

Table 2. Chlorophyll threshold failure at the Middle Branch continuous monitoring station during September and October 2022 and March through October 2023.

Continuous Monitor	2022	2023	Two- Year Total
Chlorophyll readings greater than 15 µg/L	57.7%	81.5%	**77.2%**
Chlorophyll readings greater than 50 µg/L	7.6%	12.2%	**11.4%**

pH

pH readings tend to fluctuate between 7 and 9 in most Chesapeake Bay tidal waters, with spikes above 9 indicating potential algal blooms. In the Middle Branch, 416 pH values exceeded a value of 9 between September 2022 and February 2024 (Figure 9). All of these high values occurred during the severe algal bloom conditions observed in mid-May 2023 and late December 2023 (Figure 8). The highest pH value of the monitoring period (9.87) was recorded on December 27th, 2023.

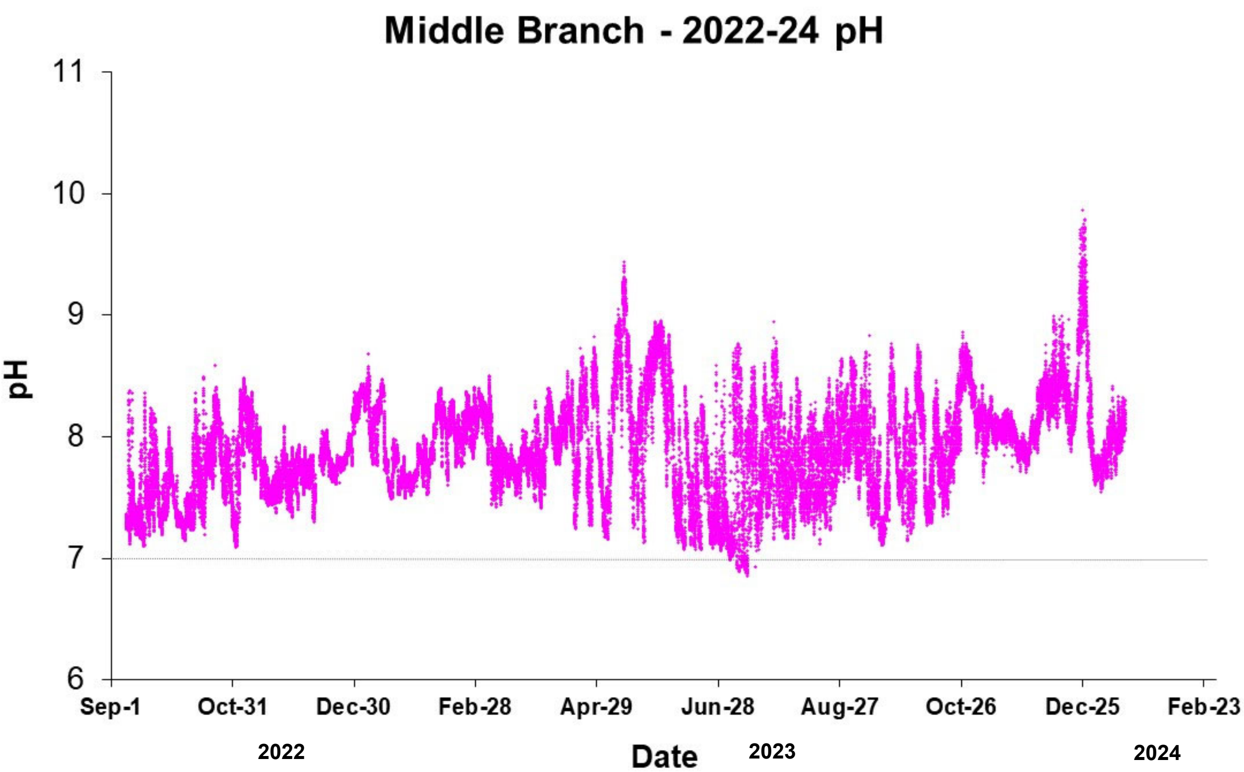

Figure 9. pH levels at the Middle Branch continuous monitoring station. *(Line indicates neutral pH.)*

Turbidity

Turbidity is quantified by measuring how much light is reflected from suspended particles in the water and is used to determine water clarity. Lower turbidity values indicate less reflection and, therefore, clearer water, while values above 7 Formazin Nephelometric Units (FNU) are generally thought to be detrimental to SAV growth based on the effects of elevated turbidity in other systems (M. Trice, MD DNR, personal communication). Heavy rains and associated discharge events can lead to runoff that bring high concentrations of particles and sediment into waterways, leading to increased turbidity levels. Algal blooms can also cloud the water and increase turbidity measurements. During the monitoring period, turbidity readings in the Middle Branch spiked to high levels for short periods of time (Figure 10), generally following precipitation events. These high readings were more frequent after July 2023 as more rain occurred after this time than before (Figure 3). However, the majority (72%) of turbidity values throughout the monitoring period were at or below 7 FNU (mean value: 5.8 FNU; median value: 5.4 FNU).

During late summer and early fall 2022, turbidity values generally ranged between 5 FNU and 15 FNU, with a couple spikes above 20 FNU. Turbidity sonde data were censored from the published dataset as suspect data between mid-November and mid-December 2022. When the published dataset resumes, turbidity readings were generally between 1 FNU and 4 FNU, except for a single spike to 20 FNU in late December 2022, coinciding with a rain event that impacted the region. Turbidity readings began to steadily increase in early February 2023, which coincided with an increase in chlorophyll concentrations (Figure 8). Values ranged between 4 FNU and 15 FNU into mid-summer 2023.

After July 2023, spikes in turbidity levels to above 50 FNU increased in frequency, which coincided with an increase in regional rainfall (Figure 3). The highest turbidity levels recorded in the Middle Branch occurred during this time, specifically in early August 2023 (50.7 FNU), mid-September 2023 (82.5 FNU), mid-December 2023 (64.4 FNU), and early January 2024 (92.4 FNU). October and November 2023 were, however, dryer than normal (Figure 3), which coincided with suppressed turbidity levels between 1 FNU and 3 FNU between early November and early December 2023.

Turbidity measurements above 7 FNU, as stated previously, are considered a threshold for detrimental effects on SAV. Table 3 lists the percentage of data readings that exceed this threshold in the Middle Branch during the portion of the sonde deployment that coincided with SAV growing season (September – October 2022; March – October 2023). In 2022, turbidity levels exceeded the 7 FNU threshold during 63.3% of readings. The exceedance rate decreased in 2023 to 31.3% of all readings. In total, over one-third of all readings collected in the Middle Branch during the growing season were indicative of levels that would have detrimental effects on the growth of SAV.

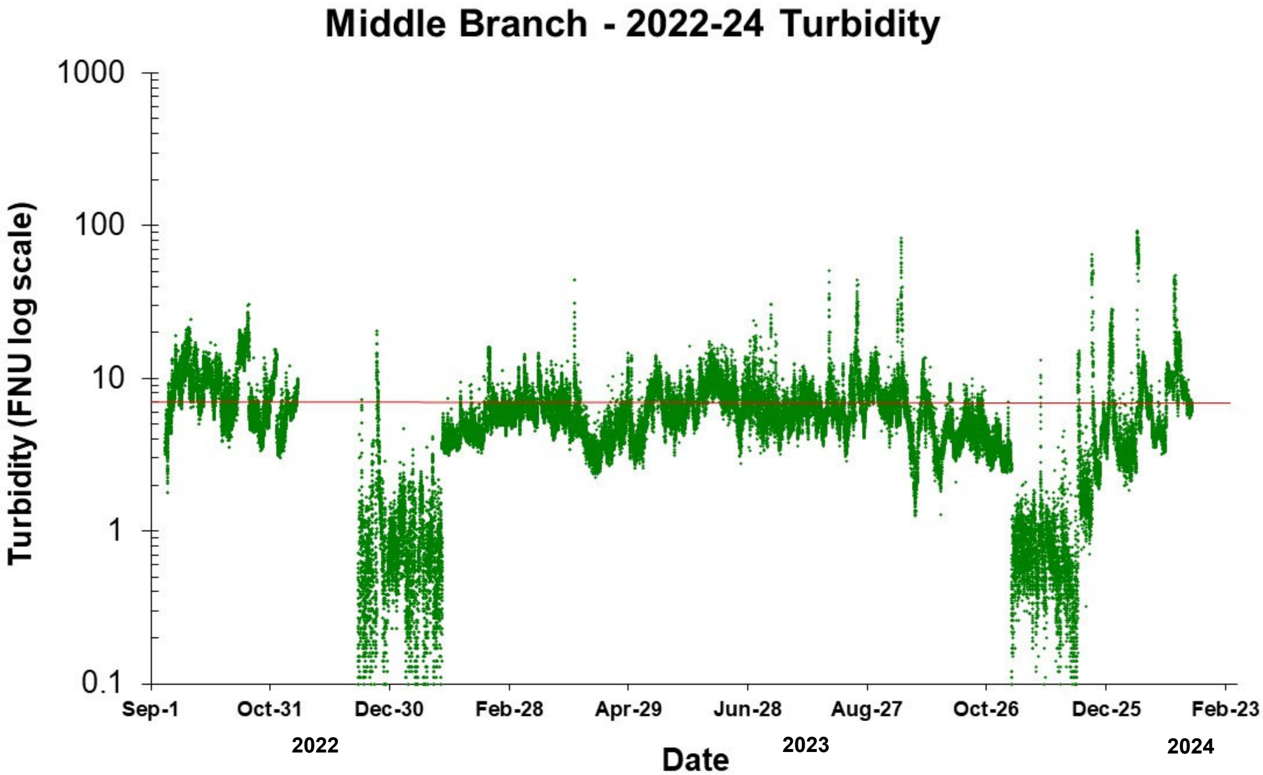

Figure 10. Turbidity levels at the Middle Branch continuous monitoring station. *(Red line indicates threshold above which levels are considered detrimental to bay grass growth.)*

Table 3. Turbidity threshold failure at the Middle Branch continuous monitoring station during September and October 2022 and March through October 2023.

Continuous Monitor	2022	2023	**Two- Year Total**
Turbidity readings greater than 7 FNU	63.3%	31.3%	**37.1%**

Secchi Depths and Ambient Water Quality

When possible, onsite measurements of ambient water quality and Secchi disk depth, a measure of water clarity, were taken at the Middle Branch station when the YSI meters were exchanged during continuous monitoring service visits. Damage to the pier from which the continuous monitor was deployed precluded collection of these data during a few service visits (See Table 4 for details). Except as noted in Table 4, ambient water quality data (salinity, dissolved oxygen, water temperature, and pH) were collected as a profile, with readings recorded at 0.5 meter depth intervals through the water column. For additional details on methods, procedures, and analyses, refer to the Quality Assurance Project Plan (QAPP) for the Shallow Water Monitoring Program. This document can be found at: https://eyesonthebay.dnr.maryland.gov/eyesonthebay/documents/SWM_QAPP_July2023.pdf. Secchi depth measurements and ambient water quality data are presented graphically in Appendix A (Figures A-1 through A-5). In the ambient water quality graphs, the individual readings within a profile are represented by separate data points. The solid line on each graph intersects the mean value for the parameter on each sampling date. Secchi disk depths and ambient water quality data are also documented in Tables A-1 and A-2 of Appendix A.

Table 4. Deployment and station visit record for the Middle Branch Cove continuous monitoring station.

Station visit date	Comment
September 8th, 2022	Station deployed. Sonde deployed anchored 0.8 m off the bottom.
September 20th, 2022	Unable to install telemetry equipment due to space limitations.
October 6th, 2022	Telemetry equipment installed but not operational.
October 20th, 2022	
October 21st, 2022	Telemetry data established. No ambient water quality and Secchi disk readings taken.
November 3rd, 2022	
November 7th, 2022	Replacement sonde deployed due to malfunction. No ambient water quality and Secchi disk readings taken.
December 13th, 2022	
January 25th, 2023	
February 15th, 2023	
March 21st, 2023	
April 11th, 2023	
April 25th, 2023	
May 9th, 2023	
May 23rd, 2023	
June 6th, 2023	
June 21st, 2023	
July 5th, 2023	Station configuration changed to floating the sonde 1.0 m below the surface starting 0915.
July 18th, 2023	
August 1st, 2023	
August 15th, 2023	
August 22nd, 2023	
September 7th, 2023	Dock damage noted.
September 19th, 2023	
October 3rd, 2023	Additional dock damage noted. Only a single ambient quality reading taken at 1.0m below the surface.

November 7th, 2023	Dock not repaired. No ambient water quality and Secchi disk readings taken. Any additional service visits postponed until dock repaired due to safety concerns.
January 4th, 2024	Station visited but not serviced due to continued disrepair of dock.
February 6th, 2024	Station removed.

Secchi depths

Secchi depth is a measurement of water clarity and can show an inverse relationship to chlorophyll concentration. An increase in chlorophyll concentrations may indicate increasing algal levels in the water column. This can lead to decreases in water clarity and a corresponding decline in Secchi depth measurements. This relationship was observed in the Secchi depth measurements in the Middle Branch, with the lowest values recorded during times of significant to severe algal blooms (Figure 8) in September 2022, April – May 2023, and August – September 2023. The highest Secchi depth values (>1.0m), were observed in late fall and early winter 2022 – 2023.

Salinity

Salinity concentrations in the Middle Branch began with a low value around 6 ppt in September 2022, but rapidly increased and remained above 10 ppt into early 2023. Concentrations dropped, in conjunction with rains, to approximately 6 ppt in April and May 2023. Salinity remained below 10 ppt for the duration of summer 2023, before increasing to 14 ppt during a dryer than normal October 2023 (Figure 3). Some stratification of the water column was evident in the salinity readings in September 2022 with surface and bottom readings differing by 7 ppt. Another stratification event was observed in February 2023 when surface and bottom water salinities differed by almost 5 ppt.

Dissolved oxygen

Dissolved oxygen concentrations greater than 5 mg/L are considered necessary to support a healthy marine ecosystem. Following typical seasonal patterns for the Chesapeake Bay, daily mean values of dissolved oxygen in the Middle Branch were higher in the winter and spring and low during most of the summer into the fall. Low dissolved oxygen concentrations were especially evident during significant to severe algal blooms (Figure 8) in September – October 2022 and July – August 2023. Dissolved oxygen measurements also reveal marked differences between oxygen levels in the shallow surface waters and in the deeper bottom waters. Particularly in the summer months, surface measurements of dissolved oxygen were often greater than 5 mg/L, but bottom water values frequently dropped to approximately 3 mg/L or lower.

Water temperature and pH

Water temperatures varied seasonally in the Middle Branch. In September 2022, water temperatures around 25°C were measured and then slowly declined for the next several months to a low of approximately 5°C in January 2023. As the weather warmed, water temperatures gradually rose to a peak value of approximately 28°C in July and remained near those levels before the next few months before beginning a decline in the fall of 2023.

Measured pH values in the Middle Branch generally fluctuated between 7 and 8.5 during the monitoring period. An increase in pH values is often observed with algal blooms, and this was evident during severe algal bloom conditions in early May 2023 (Figure 8). pH values on May 9th, 2023, peaked at 8.8 during this bloom event.

Conclusion

Shallow water monitoring was conducted in the Middle Branch of the upper Patapsco River between September 2022 and February 2024 to collect baseline data prior to the implementation of planned environmental restoration projects. Continuous monitoring data provide a critical function for assessing the health of Maryland's tidal waters in areas historically lacking water quality information. Shallow water data also provide information about the effects of nutrient pollution and weather events on the Middle Branch and the Patapsco River as a whole. During the monitoring period, algal blooms were a frequent occurrence and were a strong driver of frequently low DO concentrations within the Middle Branch. Salinity and turbidity measurements exhibited a 'flashy' pattern indicative of sediment laden stormwater runoff quickly reaching the waterway due to the high amounts of impervious surfaces in the watershed. Such a pattern of water clarity is generally not conducive to the growth of submerged aquatic vegetation. Thus, baseline habitat conditions in the Middle Branch are poor for living resources in the upper Patapsco River.

Shallow water monitoring information is not only used for characterizing the health of shallow water habitats, but it is also useful for: 1) assessing the Chesapeake Bay water quality criteria for dissolved oxygen, water clarity, and chlorophyll in shallow water habitats; 2) determining attainment or nonattainment of shallow water habitats for their designated uses; 3) assessing SAV habitats and identifying potential SAV restoration sites; 4) providing information to better understand ecosystem processes and the impact of extreme events (e.g. hurricanes, high flows, sanitary sewer overflows) in shallow water and open water environments; 5) providing data for calibrating the Bay Eutrophication and Watershed Model; and 6) assessing the effects of restoration and revitalization projects in the Middle Branch watershed on water quality and habitat.

References

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Appendix A

Ambient water quality and Secchi disk data for:
Middle Branch (Station XIE5525)

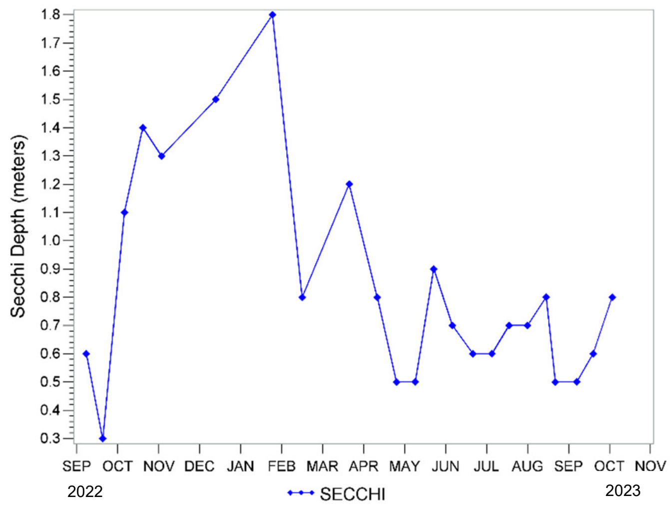

Figure A-1. Secchi depth at Middle Branch.

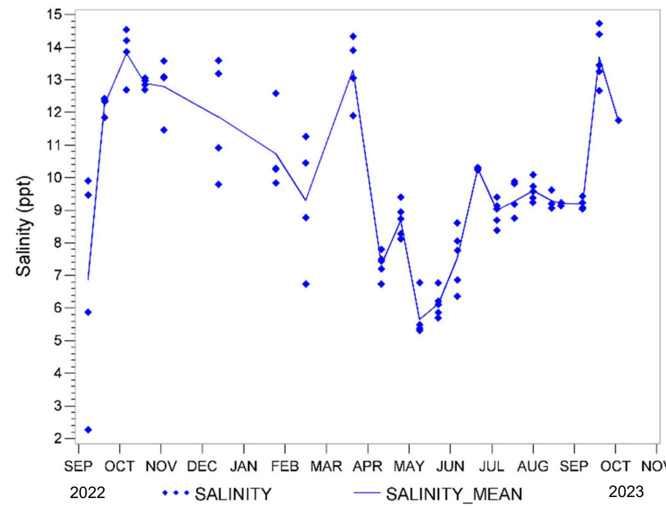

Figure A-2. Salinity concentrations at Middle Branch.

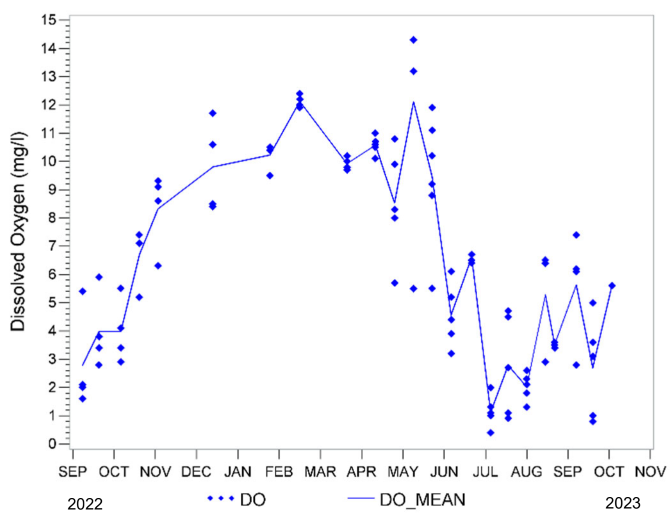

Figure A-3. Dissolved oxygen concentrations at Middle Branch.

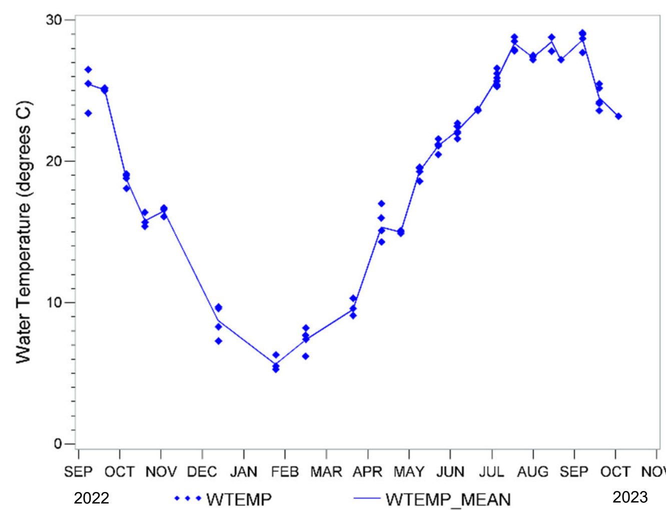

Figure A-4. Water temperature at Middle Branch.

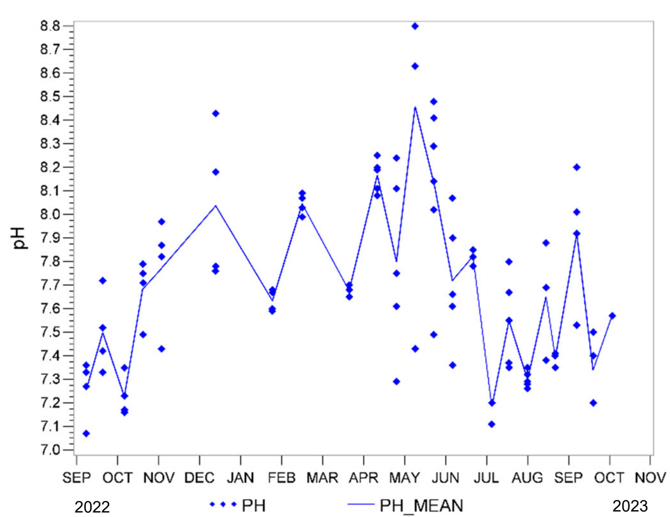

Figure A-5. Values of pH at Middle Branch.

Graphs with multiple y-values on a single point on the x-axis represent values measured at different depths in the water column. In such cases, lines intersect the mean value.

Table A-1. Table A-1. Secchi disk depths for the Middle Branch continuous monitoring station (XIE5525).

Date	Secchi Depth (m)
09/08/22	0.6
09/20/22	0.3
10/06/22	1.1
10/20/22	1.4
11/03/22	1.3
12/13/22	1.5
01/25/23	1.8
02/15/23	0.8
03/21/23	1.2
04/11/23	0.8
04/25/23	0.5
05/09/23	0.5
05/23/23	0.9
06/06/23	0.7
06/21/23	0.6
07/05/23	0.6
07/18/23	0.7
08/01/23	0.7
08/15/23	0.8
08/22/23	0.5
09/07/23	0.5
09/19/23	0.6
10/03/23	0.8

Table A-2. Ambient Water Quality Data for Dissolved Oxygen, pH, Salinity, and Water Temperature for the Middle Branch continuous monitoring station (XIE5525) (continued on next page).

Date	Sample Depth (m)	Dissolved Oxygen (mg/L)	pH	Salinity (ppt)	Water Temperature (°C)
09/08/22	0.5	5.4	7.33	2.27	23.4
09/08/22	1.0	1.6	7.07	5.87	25.5
09/08/22	1.5	2.0	7.27	9.47	26.5
09/08/22	2.0	2.1	7.36	9.91	26.5
09/20/22	0.5	5.9	7.72	11.85	25.2
09/20/22	1.0	3.8	7.42	12.33	25.0
09/20/22	1.5	3.4	7.52	12.39	25.0
09/20/22	2.0	2.8	7.33	12.43	25.1
10/06/22	0.5	5.5	7.35	12.69	18.1
10/06/22	1.0	4.1	7.23	13.86	18.8
10/06/22	1.7	3.4	7.16	14.21	19.0
10/06/22	2.2	2.9	7.17	14.54	19.1
10/20/22	0.5	7.4	7.75	12.70	15.4
10/20/22	1.0	7.1	7.71	12.85	15.7
10/20/22	1.4	7.1	7.79	12.98	15.7
10/20/22	1.9	5.2	7.49	13.05	16.4
11/03/22	0.5	9.3	7.97	11.46	16.1
11/03/22	1.0	8.6	7.82	13.06	16.7
11/03/22	1.5	9.1	7.87	13.09	16.6
11/03/22	2.0	6.3	7.43	13.58	16.6
12/13/22	0.5	11.7	8.43	9.80	7.3
12/13/22	1.0	10.6	8.18	10.91	8.3
12/13/22	1.4	8.4	7.76	13.59	9.6
12/13/22	1.9	8.5	7.78	13.19	9.7
01/25/23	0.5	10.5	7.68	9.84	5.3
01/25/23	1.0	10.5	7.67	10.26	5.5
01/25/23	1.4	10.4	7.60	10.29	5.5
01/25/23	1.9	9.5	7.59	12.58	6.3
02/15/23	0.5	12.2	8.09	6.74	7.7
02/15/23	1.0	12.0	8.03	8.78	8.2
02/15/23	1.5	12.4	8.07	10.45	7.4
02/15/23	2.0	11.9	7.99	11.26	6.2
03/21/23	0.5	9.7	7.68	11.90	10.3
03/21/23	1.0	10.0	7.70	13.06	9.6
03/21/23	1.5	10.2	7.65	13.90	9.1
03/21/23	2.0	9.8	7.68	14.33	9.1

Table A-2 (continued). Ambient Water Quality Data for Dissolved Oxygen, pH, Salinity, and Water Temperature for the Middle Branch continuous monitoring station (XIE5525) (continued on next page).

Date	Sample Depth (m)	Dissolved Oxygen (mg/L)	pH	Salinity (ppt)	Water Temperature (°C)
04/11/23	0.5	11.0	8.25	6.74	17.0
04/11/23	1.0	10.7	8.20	7.20	16.0
04/11/23	1.5	10.6	8.19	7.44	15.1
04/11/23	1.9	10.5	8.08	7.50	14.3
04/11/23	2.4	10.1	8.11	7.80	14.3
04/25/23	0.5	10.8	8.24	8.12	15.0
04/25/23	1.0	9.9	8.11	8.27	15.0
04/25/23	1.5	8.3	7.75	8.74	15.0
04/25/23	1.9	8.0	7.61	8.95	14.9
04/25/23	2.4	5.7	7.29	9.40	15.1
05/09/23	0.5	14.3	8.80	5.31	19.6
05/09/23	1.0	14.3	8.80	5.31	19.6
05/09/23	1.5	13.2	8.63	5.38	19.5
05/09/23	2.0	13.2	8.63	5.49	19.3
05/09/23	2.5	5.5	7.43	6.78	18.6
05/23/23	0.5	11.9	8.48	5.70	21.6
05/23/23	1.0	11.1	8.41	5.86	21.2
05/23/23	1.5	10.2	8.29	6.11	21.2
05/23/23	1.9	9.2	8.14	6.11	21.1
05/23/23	2.0	8.8	8.02	6.21	21.1
05/23/23	2.4	5.5	7.49	6.77	20.5
06/06/23	0.5	6.1	8.07	6.36	22.5
06/06/23	1.0	5.2	7.90	6.86	22.7
06/06/23	1.5	4.4	7.66	7.77	22.1
06/06/23	1.8	3.9	7.61	8.06	22.0
06/06/23	2.3	3.2	7.36	8.61	21.6
06/21/23	0.5	6.7	7.85	10.24	23.7
06/21/23	1.0	6.7	7.85	10.24	23.7
06/21/23	1.5	6.5	7.82	10.26	23.7
06/21/23	2.0	6.4	7.78	10.30	23.7
06/21/23	2.5	6.7	7.82	10.31	23.6
07/05/23	0.5	2.0	7.20	8.38	26.6
07/05/23	1.0	1.0	7.20	8.69	26.2
07/05/23	1.5	1.3	7.20	9.14	25.7
07/05/23	1.8	1.1	7.11	9.04	25.9
07/05/23	2.0	1.0	7.20	9.40	25.4
07/05/23	2.3	0.4	7.20	9.40	25.3

Table A-2 (continued). Ambient Water Quality Data for Dissolved Oxygen, pH, Salinity, and Water Temperature for the Middle Branch continuous monitoring station (XIE5525).

Date	Sample Depth (m)	Dissolved Oxygen (mg/L)	pH	Salinity (ppt)	Water Temperature (°C)
07/18/23	0.5	4.7	7.80	8.75	28.8
07/18/23	1.0	4.5	7.67	8.76	28.8
07/18/23	1.5	2.7	7.55	9.18	28.5
07/18/23	2.0	1.1	7.37	9.82	27.9
07/18/23	2.3	0.9	7.35	9.88	27.8
08/01/23	0.5	2.6	7.32	9.38	27.2
08/01/23	1.0	2.3	7.35	9.24	27.2
08/01/23	1.5	2.1	7.29	9.58	27.4
08/01/23	2.0	1.8	7.28	9.73	27.5
08/01/23	2.4	1.3	7.26	10.09	27.5
08/15/23	0.5	6.4	7.88	9.07	28.8
08/15/23	1.0	6.5	7.69	9.20	28.8
08/15/23	2.1	2.9	7.38	9.62	27.8
08/22/23	0.5	3.6	7.41	9.23	27.2
08/22/23	1.0	3.4	7.35	9.23	27.2
08/22/23	1.5	3.6	7.40	9.23	27.2
08/22/23	1.9	3.5	7.41	9.14	27.2
09/07/23	0.5	7.4	8.20	9.08	29.0
09/07/23	1.0	6.2	7.92	9.04	29.1
09/07/23	1.5	6.1	8.01	9.23	28.7
09/07/23	2.1	2.8	7.53	9.44	27.7
09/19/23	0.5	5.0	7.50	12.66	23.6
09/19/23	1.0	3.6	7.40	13.26	24.1
09/19/23	1.5	3.1	7.40	13.46	24.2
09/19/23	2.0	1.0	7.20	14.40	25.2
09/19/23	2.2	0.8	7.20	14.73	25.5
10/03/23	1.0	5.6	7.57	11.76	23.2