NOAA FISHERIES

NOAA Chesapeake Bay Office

# Chesapeake Bay Water-Column Hypoxia Monitoring End-of-Year Data Report 2023

April 26–December 31, 2023

March 2024

# Chesapeake Bay Water-Column Hypoxia Monitoring End-of-Year Data Report 2023

Prepared by Max Ruehrmund, NOAA Chesapeake Bay Office

NOAA Chesapeake Bay Office
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
200 Harry S. Truman Parkway, Suite 460
Annapolis, MD 21401
https://www.fisheries.noaa.gov/topic/chesapeake-bay

March 2024

Editors

- Max Ruehrmund, Electronics Technician, NOAA Chesapeake Bay Office, 200 Harry S. Truman Parkway, Suite 460, Annapolis, MD 21401
- Charles Pellerin, Data Scientist, ERT/NOAA Chesapeake Bay Office, 200 Harry S. Truman Parkway, Suite 460, Annapolis, MD 21401
- Anthony Johnson II, Chesapeake Conservation and Climate Corps/NOAA Chesapeake Bay Office, 200 Harry S. Truman Parkway, Suite 460, Annapolis, MD 21401
- Nicholas Colman, Physical Science Technician, NOAA Chesapeake Bay Office, 200 Harry S. Truman Parkway, Suite 460, Annapolis, MD 21401
- Kim Couranz, Communications Specialist, NOAA Chesapeake Bay Office, 200 Harry S. Truman Parkway, Suite 460, Annapolis, MD 21401

Contributors

- Jay Lazar, Physical Scientist, NOAA Chesapeake Bay Office, 200 Harry S. Truman Parkway, Suite 460, Annapolis, MD 21401
- Doug Wilson, Consultant, Caribbean Wind, LLC, 6058 Signal Flame Ln., Clarksville, MD 21029
- Lieutenant Commander, Jacob Barbaro, NOAA Commissioned Officer Corps, 200 Harry S. Truman Parkway, Suite 460, Annapolis, MD 21401
- David Bruce, Habitat Ecologist/GIS Analyst, NOAA Chesapeake Bay Office, Cooperative Oxford Laboratory, 904 South Morris Street, Oxford, MD 21654
- Emma Venarde, NOAA Chesapeake Bay Office 2023 Summer Intern, Brown University

# Table of Contents

# Summary

In 2023, the NOAA Chesapeake Bay Office (NCBO) completed its first full season of deploying buoy-based stations that continuously acquire data on water quality throughout the water column. Three monitoring buoys were strategically deployed in the Chesapeake Bay, continuously collecting data from April to December 2023. These “hypoxia buoys” mark a milestone in Chesapeake Bay monitoring by providing, for the first time, semi-permanent real-time water column data on dissolved oxygen (DO), conductivity, and temperature—crucial parameters for assessing seasonal hypoxic conditions. The NCBO field team spent 30 days on the water, addressing challenges such as data reliability, insufficient cleaning, and a shortage of spare parts.

Despite facing these challenges, temperature and DO data demonstrated resilience, showcasing their potential for providing consistent and reliable information even during extended periods without maintenance. In contrast, conductivity data encountered various difficulties, primarily due to biofouling, emphasizing the necessity for innovative solutions to improve accuracy and reliability, especially in the context of long-term monitoring initiatives.

The project implemented rigorous quality assurance and quality control measures, aligning with methods employed by regional partners. Innovative data management techniques were developed to process and visualize the collected data, ensuring its applicability for a variety of analyses. This report comprehensively details the standards, policies, and procedures used for field asset management and data characterization. Additionally, it includes a robust collection of graphs and plots that highlight information about data quality from all three hypoxia buoys in 2023.

Analysis of the collected data reveals a noteworthy correlation between data quality and the proximity of buoys to Oxford, Maryland, the central deployment point for NCBO vessels. The most-reliable Lower Choptank buoy is also the closest buoy to Oxford, Maryland—the home port for NCBO vessels that service the buoys. The findings indicate a relationship between the reliability of data and the frequency of station visits, with buoys closer to the central deployment point experiencing more frequent visits and also more dependable data.

# 1. Project Background

Water-quality impairment in the Chesapeake Bay, caused primarily by excessive long-term nutrient input from runoff and groundwater, is characterized by seasonal hypoxia, particularly in the bottom layers of the deeper mainstem (although it is often present elsewhere) (Bever et al., 2018). In addition to obvious negative effects in the areas where it occurs, hypoxia represents the integrated effects of watershed-wide nutrient pollution. Therefore, monitoring to measure the vertical and horizontal extent and duration of the hypoxic regions is important to assessing Chesapeake Bay health and restoration progress.

Current Chesapeake Bay Program water-quality monitoring is broadly distributed spatially and temporally: Monthly or bimonthly monitoring is accomplished at single fixed stations that are separated by several kilometers. The need for continuous, real-time, vertically sampled profiles of dissolved oxygen has been long recognized in order to begin to assess short-duration water-quality criteria. Improvements in hypoxia modeling and sensor technology now make this monitoring achievable. A recent publication from Bever, et al. (2018) shows that total Chesapeake Bay hypoxic volume can be estimated using a few analytically selected fixed continuous DO profiles.

Toward that end, vertical arrays supporting real-time transmission of DO data and other parameters have been deployed to evaluate their ability to efficiently and sustainably provide DO data to monitor Chesapeake Bay hypoxia. Following a pilot project in the summer of 2019, two additional pilot deployments took place in December 2021 and the summer of 2022. Building upon insights gained from these tests, the first comprehensive deployment involving three individual buoy systems was initiated in April 2023, concluding in December 2023.

Water-quality data produced by this project will be used to define water column habitat, including seasonal hypoxia, salinity, and temperature conditions necessary to support living resource management decision making. The information will also be used to develop and assess water-quality criteria standards with the goal of restoring regulatory segments of water in the Bay and its tidal rivers toward their attainment goals. Water-quality data is required to support refinement, calibration, and validation of the Chesapeake Bay Eutrophication and Watershed Models. In essence, this data establishes the foundation for ongoing endeavors to enhance water-quality monitoring in Chesapeake Bay, underscoring the significance of addressing technical challenges for more precise and sustainable data collection.

Since the inaugural pilot launch, the field work for the project has served as a valuable educational opportunity. Ten college students have actively participated in the effort. This not only contributed to the acquisition of valuable data but also enhanced the educational experience for the upcoming generation of researchers and environmental scientists.

This report documents the standards, policies, and procedures used by the NOAA Chesapeake Bay Office's (NCBO) activities related to the project's third year. It discusses lessons learned and justifications for actions not outlined in the Quality Assurance Protection Plan (QAPP) submitted to the Environmental Protection Agency (EPA). Serving as a comprehensive guide, this document aids NCBO and its partners that are engaged in continuous water-quality monitoring activities. It also serves as a valuable resource for identifying memoranda, publications such as the QAPP and Maryland Department of Natural Resources (MD-DNR) Chesapeake Bay Hypoxia Report, and other relevant literature that offers detailed insights into techniques and requirements. Moreover, this document provides recommendations for the 2024 deployment and helps the user of data understand its significance and impact.

This report includes information on updated NCBO's policies and procedures in quality assurance/quality control (QA/QC) that will be referenced in the 2024 version of the Quality Assurance Project Plan and the release of continuous water-quality monitoring data to the Chesapeake Bay Program (NOAA Chesapeake Bay Office, 2023). The policies and procedures complement NCBO's QA/QC plans for the real-time collection of real-time water-quality data in the Chesapeake Bay. Furthermore, this report describes data deemed acceptable ("good data"), suspect, or unusable ("bad data") and the evidence backing its classification. This report provides the necessary information needed for determining the quality of data collected for understanding hypoxic conditions in Chesapeake Bay. Ultimately, data acceptable for the use in policy-related decisions is at the discretion of the user of data.

# 2. 2023 Project Description

From April 2023 to December 2023, the National Oceanic and Atmospheric Administration (NOAA) deployed three vertical arrays of sensors to monitor the water-quality conditions, with a focus on hypoxia, in the Chesapeake Bay (Map 1).

- The Choptank station (CHOMH_01) 38° 37′ 45.996″ N / 076° 19′ 10.002″ W was located in the mouth of the Choptank River.
- The Mid-Bay station (CB5MH_01) 38° 12′ 32.400″ N / 076° 13′ 46.560″ W was located adjacent to the main channel one mile south of Hoopers Island Lighthouse.
- The Lower Potomac station (POTMH_01) 38° 02′ 54.960″ N / 076° 21′ 34.200″ W was located in the mouth of the Potomac River, north of its channel and adjacent to the NOAA Chesapeake Bay Interpretive Buoy System (CBIBS) long-term surface monitoring Point Lookout buoy.

The stations were located near historically long-term Chesapeake Bay Program water-quality monitoring stations (Image 1). Station duration deployments are defined as periods where at least one sensor on the array was collecting reliable DO data or at the end of 2023 (Table 1).

| **Station** | **Data Collection Duration** |
|---|---|
| CHOMH_01 | Apr 26 to Aug 31 |
| | Sept 20 to Dec 31 |
| POTMH_01 | May 25 to Aug 29 |
| | Sept 12 to Nov 15 |
| CB5MH_01 | May 15 to Oct 18 |
| | Nov 6 to Dec 22 |

*Table 1: Timeline of hypoxia station deployments where a station had at least one working DO sensor.*

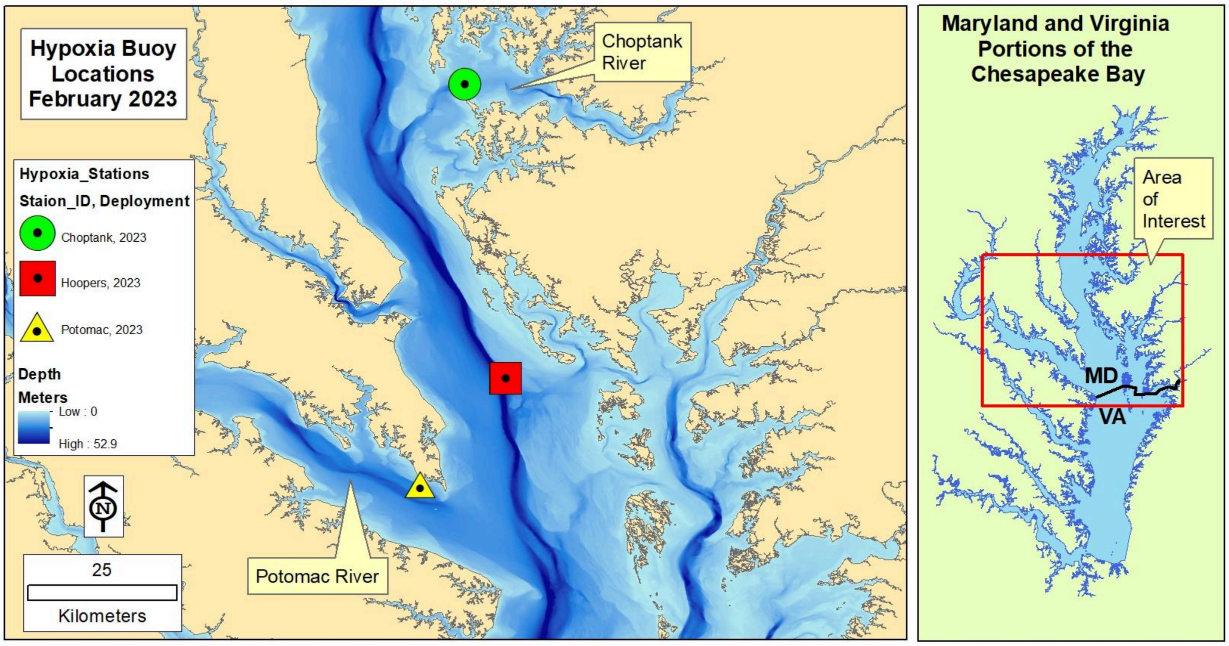


*Image 1. Chesapeake Bay hypoxia buoy deployment for 2023. The three stations are shown in green, red, and yellow.*

## 2.1 Station Design

Each 2023 station consisted of a UB45-IM buoy on the surface, inductive cable, and a mooring system at the bottom. The surface buoy was a Soundnine UBC-ISC Ulti-Buoy, which contained a GPS, cellular modem, inductive magnet, and integrated solar panel and batteries. Attached to the inductive cable suspended through the water column were XIM-CTP-DO data sondes, which collected conductivity, temperature, pressure, and DO (Figure 1). In addition, an independent fish telemetry receiver was attached to each buoy. Each station had XIM-CTP-DO evenly distributed throughout the water column based on the depth at each station. CHOMH_01 had sensors placed at 1m, 5m, 8m; POTMH_01 had sensors placed at 3m, 7m, 10m; and CB5MH_01 had sensors placed at 5m, 9m, 13m, and 17m.

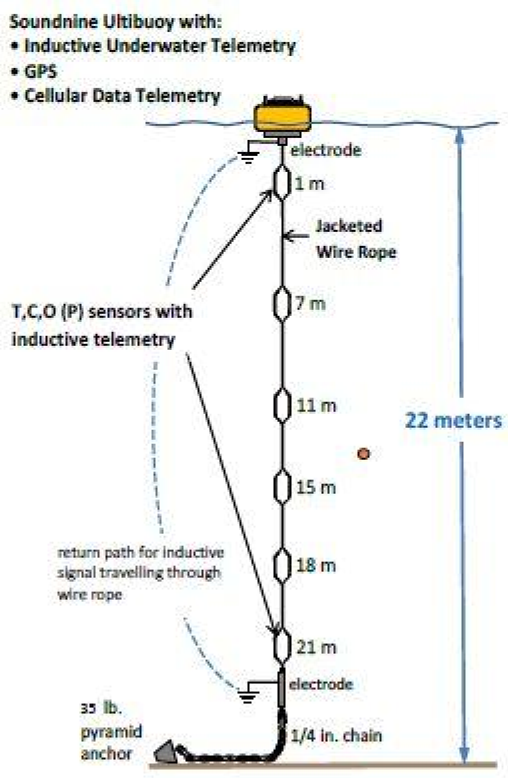


*Figure 1: Hypoxia buoy schematic diagram outlining how the deployed station sits in the water column. Parameters collected in this diagram are evenly distributed vertically in the water column. Directly measured parameters include temperature (Deg C), conductivity (S/m), DO concentration (mg/L), and pressure (db).*

## 2.2 Validation Lab Work

All new factory-calibrated sensors and sensors in the field that report suspect or bad data are validated at the Oxford Cooperative Laboratory in Oxford, Maryland. After fouled instruments are cleaned (outlined in section 3.2), sensors are placed in 150-gallon tanks to begin the validation process. Each tank can be filled with filtered water from the Choptank River or with municipal water from the Town of Oxford, Maryland. Tank water conditions are then manipulated to reflect relevant water-quality conditions similar to those observed in the Chesapeake Bay for sensor accuracy validation.

New hypoxia instruments arrive with factory-calibrated coefficients. At the factory, DO is calibrated at 100% saturation, while conductivity uses a multi-point calibration ranging from ocean to estuary conditions. Calibrations are finalized by comparing all instruments against each other. Upon delivery, NOAA’s validation lab ensures their accuracy, functionality, and compatibility with NCBO’s information technology systems.

Tank water conditions can be set up as in Table 2. These conditions are designed to test whether sensors are within accuracy specifications under typical Chesapeake Bay conditions. If specifications are not met, sensors may be returned for factory recalibration or have values adjusted by corrections to raw data (if corrections can be adequately accomplished by linear corrections). Tank values are targets to cover the typical range of values in the Chesapeake Bay; they need not be exact, but should be stable during the test period. Any of the tanks can be aerated to DO saturation (generally about 103%).

| | TANK 1 | TANK 2 | TANK 3 | TANK 4 |
|---|---|---|---|---|
| TEMP C | 10 | 15 | 20 | 25 |
| SAL PSU | 8 | 15 | 20 | 25 |
| COND S/m | 0.986 | 1.899 | 2.894 | 3.926 |
| DO Saturation | Ambient | Ambient | Ambient | Air Saturated |

*Table 2: Example of possible tank configurations in the Oxford Laboratory for the validation of sensors.*

Hypoxia sensors are placed in validation tanks next to a factory-calibrated SeaBird SBE37 microCAT CTD-DO as a side-by-side comparison. Sensors acclimate for 30 minutes in validation tanks that reflect DO, salinity, and temperature levels observed in the Chesapeake Bay. Hypoxia sensors are validated within a <3% tolerance against a factory-calibrated SeaBird microCAT CTD-DO. Sensors that do not meet these tolerances are returned to the manufacturer for calibration or repair. SeaBird instruments are calibrated yearly by the manufacturer; this process is documented. Service and calibration methods performed by SeaBird Scientific can be found at https://www.seabird.com/service-calibration-information.

All calibration documentation is stored on a cloud-based server and can be accessed upon request. Additional descriptions can be found in the Water-Column Hypoxia Monitoring Quality Assurance Project Plan (QAPP) (NOAA Chesapeake Bay Office, 2023).

# 3. Discussion of On-the-Water Operations

## 3.1 Challenges with Long-Term Monitoring

Hypoxia buoys are a vital tool in environmental monitoring, designed to collect and transmit data on various water parameters over extended periods. However, prolonged deployments in areas abundant with biological growth pose significant challenges that lead to potential mechanical issues. A buoy's sensors and mechanical components are susceptible to fouling caused by the accumulation of algae, barnacles, and other marine organisms. This biological growth can compromise the accuracy of data collected, and even obstruct or impede sensor functionality. Additionally, exposure to harsh environmental conditions may lead to corrosion and wear and tear on a buoy's mechanical components. Long deployments exacerbate these issues, increasing the likelihood of mechanical breakdowns. Regular maintenance and cleaning become imperative in such environments to mitigate the effects of biological growth and to ensure the buoy's prolonged and reliable operation in monitoring water quality.

Over the course of the year, the quality of data collected by the buoys gradually declined as a result of persistent biofouling and the unavailability of replacement parts. The initial stages of deployment saw the buoys' sensors and mechanical components operating at optimal levels, providing accurate and reliable data on key parameters such as temperature, DO, and conductivity. However, as time progressed, the buoys' sensors became increasingly colonized by biofouling organisms, including algae, barnacles, and sea squirts. This biological growth interfered with the sensors' ability to accurately measure water properties, leading to skewed readings and compromised data quality for windows of time. Notably, the growth of organisms did not equally skew data. DO and temperature data showed remarkable resistance to marine growth when regular maintenance could not be conducted. However, the conductivity cells were susceptible to cracking and to having small organisms grow inside the glass that were challenging to remove once established (Image 2).

*Image 2: Established barnacles inside the conductivity cell (left). Conductivity cell cracks at the middle of the glass cell (middle). Excessive algae growth due to a lack of maintenance or overly active biological conditions (right).*

To reduce time on the water and allow for a thorough cleaning of components on land, initial maintenance plans involved swapping dirty XIM-CTP-DO data sondes with new XIM-CTP-DO data sondes once biological growth began. However, the lack of immediately available replacement data sondes compounded the biofouling issues, as worn-out or damaged components could not be promptly replaced. It was determined that if a XIM-CTP-DO data sonde had a working DO sensor, it could remain in the field while the team applied manual flags to data that could not be reliably recorded. Breakdowns, such as the failure of conductivity cells, were at times not addressed due to the unavailability of spare parts. Consequently, the buoys' ability to maintain proper sensor functionality diminished, further exacerbating the degradation of full sensor functionality. The cumulative impact of biofouling and the absence of replacement parts resulted in a gradual deterioration of the buoys' performance, highlighting the importance of regular maintenance, timely replacement of components, and strategic planning to ensure sustained high-quality data collection in challenging marine environments.

In addition to maintenance issues, poor weather conditions presented challenges in servicing the instruments. Servicing all three stations required traversing approximately 90nm on a vessel and needed to be done with sea states one foot or less. Calm sea states did not evenly present across the Chesapeake Bay; it was observed CB5MH_01 had disproportionately unsettled sea states despite forecasts indicating favorable weather conditions. Additionally, in the winter months, ice accumulation and an observed increase in storms impeded access to the hypoxia buoys, making it difficult for NOAA staff to perform maintenance tasks safely. Extreme cold conditions also increased the risk of ice accumulation on the surface of the buoy, or of ice sheets moving across Chesapeake Bay potentially causing them to sink. Furthermore, the threat of ice accumulation around NOAA vessels at dock could make them inaccessible, preventing routine maintenance visits.

In response to these challenges, a decision was made to prioritize the protection of government property, and two (POTMH_01 and CB5MH_01) of the three buoys were removed from the water in the colder months. This strategic move aimed to prevent further deterioration of the buoys and safeguard their valuable components. While this decision temporarily halted data collection from those buoys, it was deemed a necessary measure to ensure the long-term integrity of the equipment and to facilitate comprehensive servicing on land in preparation for redeployment once weather conditions improved. The removal allowed for thorough cleaning, repair, and replacement of critical components, reinforcing the importance of adaptability and strategic planning in maintaining water-quality monitoring systems under challenging environmental conditions.The third buoy, CHOMH_01, remained in the water over winter.

## 3.2 Field Visits

CHOMH_01, CB5MH_01, and POTMH_01 were deployed on April 26, May 15, and May 25, respectively, with target maintenance visits occurring once per week (Table 3). NCBO’s R/V *Potawaugh* was the primary vessel used for on-the-water operations due to its stability, deck space, and protected accommodation of NOAA staff. A davit and electric motor were used to recover the hypoxia buoy with the use of adjustable and static lifting hooks (Image 3). To recover a buoy, the adjustable hook is lowered into the water, attached to pick points on the inductive cable, and lifted out of the water. Weight is then transferred to a static line, allowing the adjustable line to be lowered to the next pick point on hypoxia buoy’s inductive cable (Image 4).

Image 3: NOAA scientists use a davit and electric motor to lift a buoy from the water.

Image 4: Static line on the left holds the weight of the inductive cable plus hypoxia array while the line on the right lifts the buoy up to the vessel.

When visiting a hypoxia buoy, a conductivity, temperature, depth, and DO (CTD-DO) vertical cast was performed to validate hypoxia system functionality and calibration (Image 5). A recently calibrated SeaBird SB19 CTD-DO profiled the water column with the use of a winch to maintain a constant drop velocity. Casts were conducted as close as vessel safety allowed to the hypoxia array). CTD-DO data is then compared against the hypoxia station (Figure 2). Additional details can be found in the NOAA QAPP (NOAA Chesapeake Bay Office, 2023).

*Image 5: After field work, NOAA staff download and process CTD-DO data (left). NOAA interns begin to lower CTD-DO into the water prior to recovering a hypoxia buoy (right).*

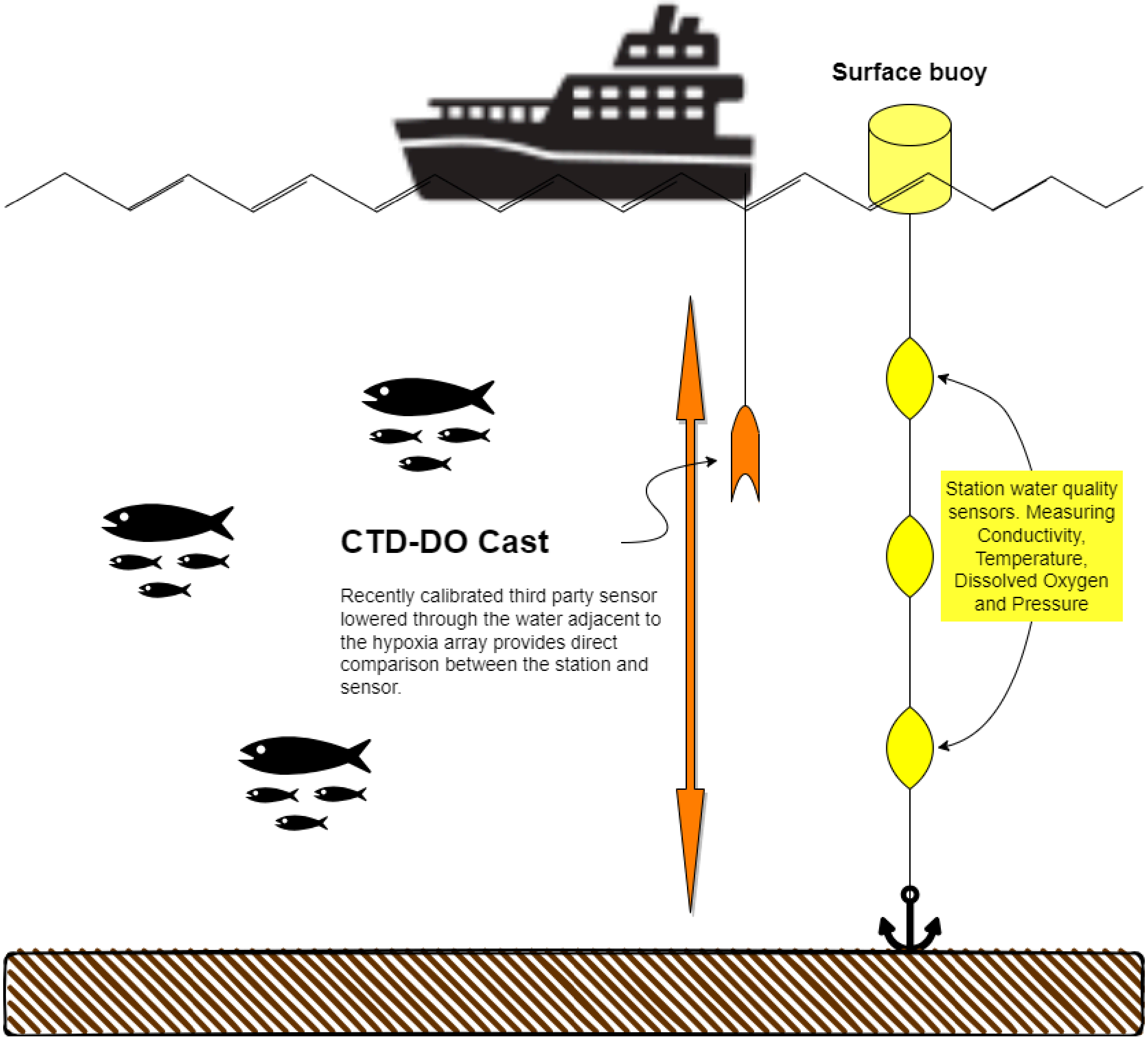
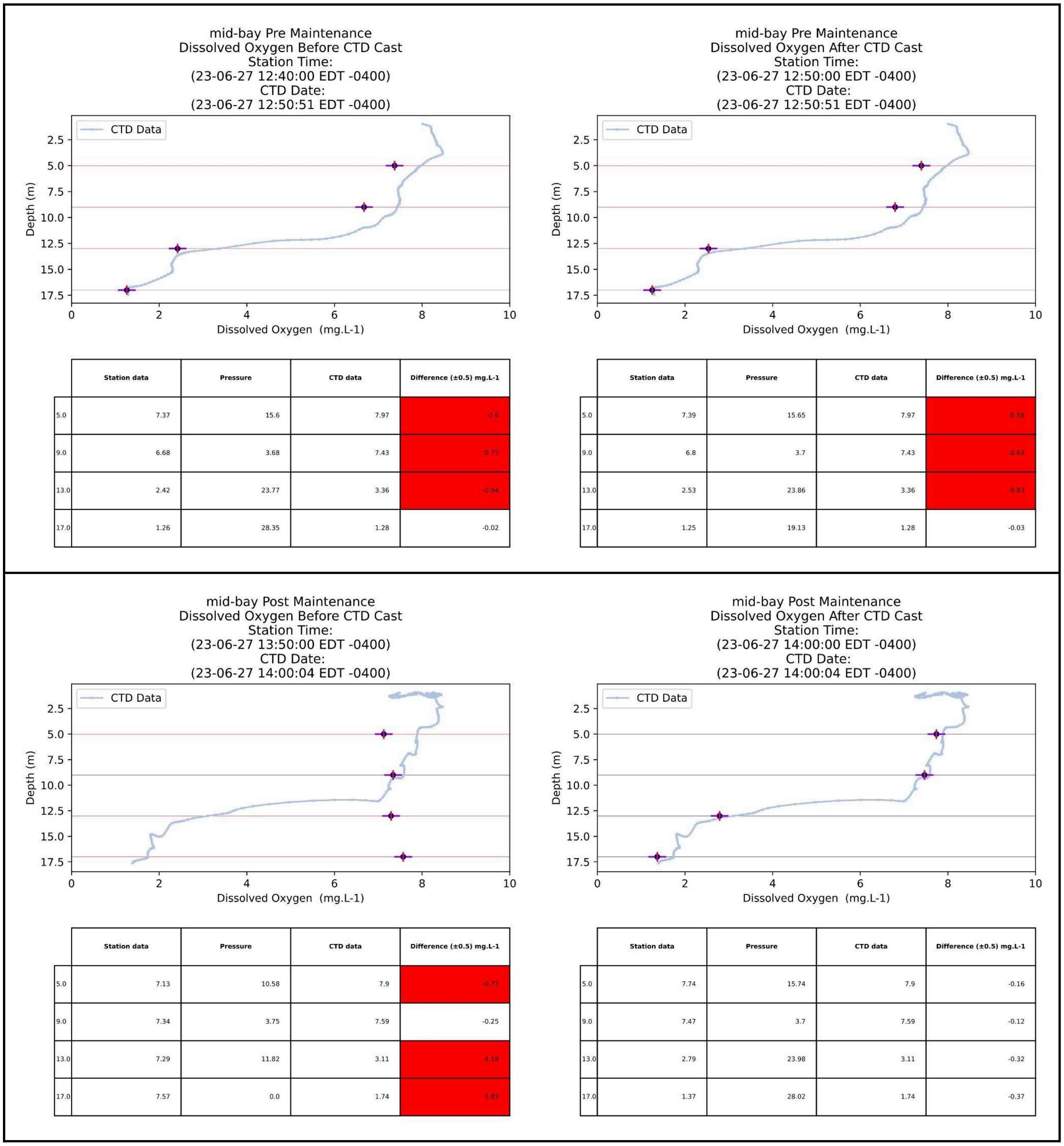


*Figure 2. CTD DO cast (orange) adjacent to hypoxia array (yellow).*



mid-bay Pre Maintenance
Dissolved Oxygen Before CTD Cast
Station Time:
(23-06-27 12:40:00 EDT -0400)
CTD Date:
(23-06-27 12:50:51 EDT -0400)

| | Station data | Pressure | CTD data | Difference (±0.5) mg.L-1 |
|---|---|---|---|---|
| 5.0 | 7.37 | 15.6 | 7.97 | -0.6 |
| 9.0 | 6.68 | 3.68 | 7.43 | -0.75 |
| 13.0 | 2.42 | 23.77 | 3.36 | -0.94 |
| 17.0 | 1.26 | 28.35 | 1.28 | -0.02 |

mid-bay Pre Maintenance
Dissolved Oxygen After CTD Cast
Station Time:
(23-06-27 12:50:00 EDT -0400)
CTD Date:
(23-06-27 12:50:51 EDT -0400)

| | Station data | Pressure | CTD data | Difference (±0.5) mg.L-1 |
|---|---|---|---|---|
| 5.0 | 7.39 | 15.65 | 7.97 | -0.58 |
| 9.0 | 6.8 | 3.7 | 7.43 | -0.63 |
| 13.0 | 2.53 | 23.86 | 3.36 | -0.83 |
| 17.0 | 1.25 | 19.13 | 1.28 | -0.03 |

mid-bay Post Maintenance
Dissolved Oxygen Before CTD Cast
Station Time:
(23-06-27 13:50:00 EDT -0400)
CTD Date:
(23-06-27 14:00:04 EDT -0400)

| | Station data | Pressure | CTD data | Difference (±0.5) mg.L-1 |
|---|---|---|---|---|
| 5.0 | 7.13 | 10.58 | 7.9 | -0.77 |
| 9.0 | 7.34 | 3.75 | 7.59 | -0.25 |
| 13.0 | 7.29 | 11.82 | 3.11 | 4.18 |
| 17.0 | 7.57 | 0.0 | 1.74 | 5.83 |

mid-bay Post Maintenance
Dissolved Oxygen After CTD Cast
Station Time:
(23-06-27 14:00:00 EDT -0400)
CTD Date:
(23-06-27 14:00:04 EDT -0400)

| | Station data | Pressure | CTD data | Difference (±0.5) mg.L-1 |
|---|---|---|---|---|
| 5.0 | 7.74 | 15.74 | 7.9 | -0.16 |
| 9.0 | 7.47 | 3.7 | 7.59 | -0.12 |
| 13.0 | 2.79 | 23.98 | 3.11 | -0.32 |
| 17.0 | 1.37 | 28.02 | 1.74 | -0.37 |

*Figure 3: CTD-DO validation plots pre and post cleaning. Legend definitions found in Section 4.1. Image above shows station and CTD-DO data prior to recovering buoy for cleaning while image below shows station and CTD-DO post sensor cleaning. Red blocks indicate data failing to meet quality control standards.*

Upon recovery, sensors were washed with sponges and a mild acidic solution to remove marine growth from the exterior of the sensor. In the event of extensive biofouling or blockage of conductivity cells, sensors were placed in a mild acidic solution to dissolve barnacles and kill marine growth. Conductivity cells that were blocked with growth had the solution circulated through them for no less than 10 minutes (Image 6). Additional maintenance included replacing the fine copper mesh covering the conductivity cells or the copper screen covering the face of the sensor.

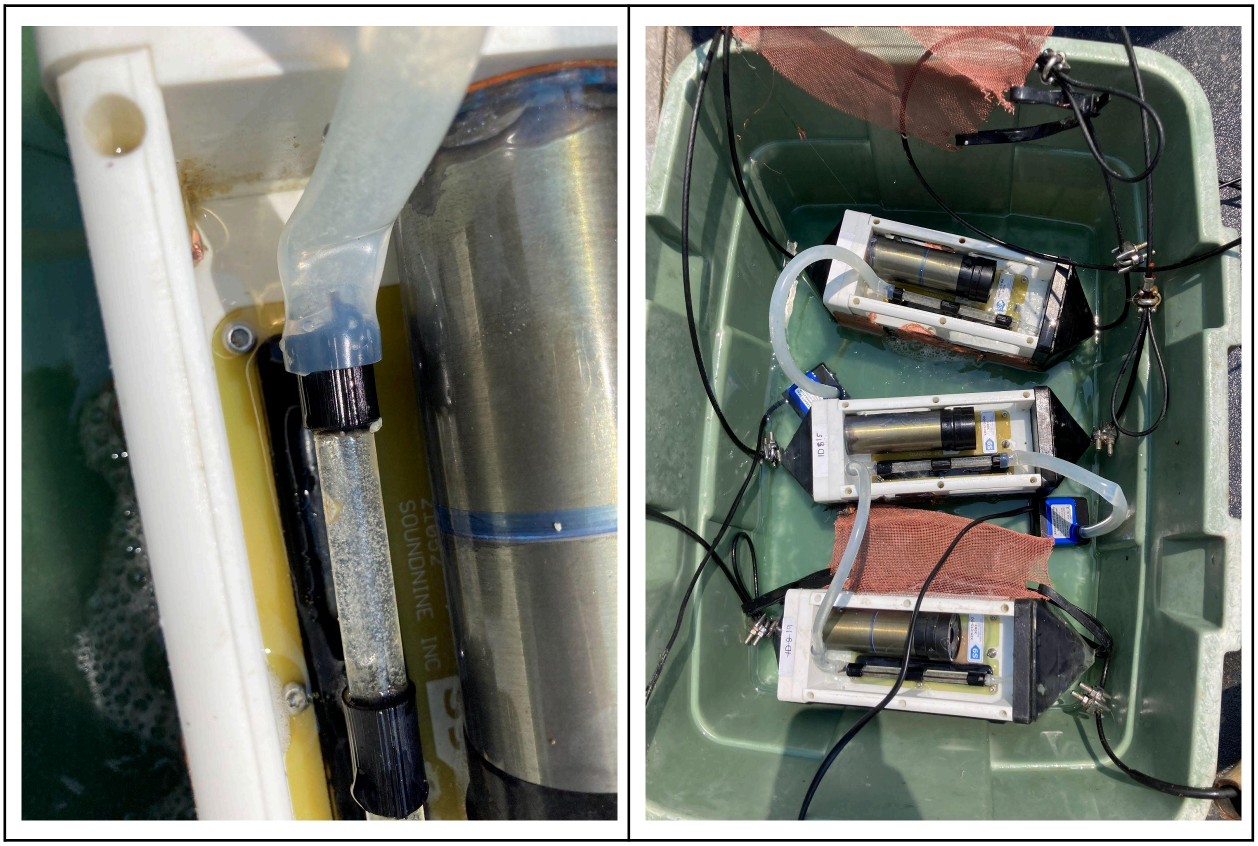


*Image 6: Medical tubing sliding over conductance cell to allow acidic solution to circulate through (left). Sensors sitting in a tub with pumps circulating solution (right).*

## 3.3 Notable Actions

Following is a timeline of notable actions at each of the stations during the 2023 season.

### Lower Choptank CHOMH_01

- 4/26/23 @ 1050: Deployed buoy
- 12/22/23 @ 1242: Replaced 1m sensor
- 8/31/23 @ 1000: Buoy mooring broke; buoy drifted 5 miles south and was recovered the next day
- 9/20/23 @ 0957: Redeployed buoy
- 10/11/23 @ 1145: Removed 8m sensor
- 11/15/23 @ 1354: Installed 8m sensor
- 12/22/23 @ 1124: Removed 1m sensor and swapped for a new one
- 12/31/23 @ 1259: End of 2023 data, buoy remained in water

### Mid-Bay CB5MH_01

- 5/15/23 @ 1447: Deployed buoy
- 7/7/23 @ 1115: Removed 9m sensor
- 7/7/23 @ 1200: Buoy moved 0.125nm NNW for better cell signal to 38° 12′ 36.888″ N / 076° 13′ 49.962″ W
- 10/18/23 @ 1240: Buoy was extensively dirty and the mooring termination was beginning to fail; decision was made to recover the buoy for repairs on land
- 11/6/23 @ 1220: Redeployed buoy with new sensors
- 12/22/23 @ 1124: Recovered buoy for season

### Lower Potomac POTMH_01

- 5/25/23 @ 1100: Buoy deployed
- 9/20/23 @ 1358: Removed 7m sensor
- 10/11/23 @ 1145: Removed 10m sensor
- 11/15/23 @ 1135: Recovered buoy for season

## 3.4 Maintenance Schedule

The following table summarizes how field resources were deployed during the 2023 field season.

| Field Day | Date | Task CHOMH_01 | Task CB5MH_01 | Task POTMH_01 |
|---|---|---|---|---|
| 1 | 4/26/2023 | Array Deployment | | |
| 2 | 5/8/2023 | Array Maintenance | | |
| 3 | 5/15/2023 | | Array Deployment | |
| 4 | 5/22/2023 | Array Maintenance | | |
| 5 | 5/24/2023 | Array Maintenance | | |
| 6 | 5/25/2023 | | | Array Deployment |
| 7 | 5/31/2023 | Array Maintenance | Array Maintenance | |
| 8 | 6/5/2023 | | | Array Maintenance |
| 9 | 6/7/2023 | Array Maintenance | Array Maintenance | |
| 10 | 6/13/2023 | | Array Maintenance | Array Maintenance |
| 11 | 6/27/2023 | Array Maintenance | Array Maintenance | |

| | | | | |
|---|---|---|---|---|
| 12 | 6/28/2023 | | | Array Maintenance |
| 13 | 7/7/2023 | Array Maintenance | Array Maintenance | |
| 14 | 7/17/2023 | Array Maintenance | Array Maintenance | Array Maintenance |
| 15 | 7/26/2023 | Array Maintenance | Array Maintenance | Array Maintenance |
| 16 | 8/1/2023 | Array Maintenance | Array Maintenance | Array Maintenance |
| 17 | 8/9/2023 | Array Maintenance | | |
| 18 | 8/23/2023 | Array Maintenance | Array Maintenance | Array Maintenance |
| 19 | 8/29/2023 | Array Maintenance | Array Maintenance | Array Recovery |
| 20 | 8/31/2023 | Array Break Away | | |
| 21 | 9/5/2023 | | Array Maintenance | |
| 22 | 9/12/2023 | | | Array Deployment |
| 23 | 9/20/2023 | Array Deployment | Array Maintenance | Array Maintenance |
| 24 | 10/3/2023 | Attempted Maintenance | | |
| 25 | 10/11/2023 | Array Maintenance | Array Maintenance | Array Maintenance |
| 26 | 10/18/2023 | Array Maintenance | Array Recovery | |
| 27 | 11/6/2023 | Array Maintenance | Array Deployment | |
| 28 | 11/15/2023 | Array Maintenance | Array Maintenance | Array Recovery |
| 29 | 11/30/2023 | Array Maintenance | | |
| 30 | 12/22/2023 | Array Maintenance | Array Recovery | |
| | **Total Station Visits** | **23** | **18** | **13** |
| | No Visit | Array was not visited | | |
| | Array Deployment | Array placed in water | | |
| | Array Recovery | Array recovered and returned to shore | | |
| | Array | Routine visit to clean array and | | |

| | | | | |
|---|---|---|---|---|
| | Maintenance | conduct validation CTD-DO | | |
| | Array Break Away | Array broke off mooring and recovered | | |
| | Attempted Maintenance | Weather prevented the safe recovery of array | | |

*Table 3. Field maintenance was attempted once per week from April to December 2023. However, weather conditions, personnel availability, or vessel mechanical breakdowns caused occasional delays in visiting stations. For the 2023 season, field work required 30 days on the water with a field team of two to three people. CHOMH_01, CB5MH_01 and POTMH_01 were visited 23, 18, and 13 times respectively.*

## 3.5 Fieldwork Recommendations Based on 2023 Experiences

### Hardware Upgrades

Recovery of each system was less straightforward than anticipated, necessitating creative solutions to maintain each station. Multiple cable loops were affixed to the inductive cable line to offer support during the recovery of the mooring system in buoy maintenance. These cable loops are secured using two stainless steel wire rope clips and tightened with nylon ring lock nuts. Despite the successful adoption of lock nuts as an alternative method, incidents of cable loop snapping did still occur sporadically. In the event of a cable snapping, the breakage typically occurred at the cable loop junctions used for lifting, as detailed in Section 3.2. It is presumed that these cable snaps result from the corrosion and loosening of the clips over time.

Safety precautions are implemented during buoy maintenance, including a thorough inspection of each loop before releasing a buoy. Additionally, personnel are positioned away from the potential hazard of a buoy being rapidly ejected back into the water due to a malfunctioning cable loop

### Cable Snaps and Ground Termination

The inductive cable used for data transmission and as a mooring has a protective plastic covering acting as a barrier between the seawater and ferric metal. If the coating becomes punctured, saline water will rust the exposed metal and weaken the cable, leading to potential breakage. In places where punctures occur or the plastic coating needs to be removed (for instance, grounding the cable), liquid electrical tape was applied, followed by friction tape for additional protection.

### Cell Signal

It was observed that stations would miss data transmissions for hours at a time. It was theorized and tested that the cell signal would drop during periods of high network demand, including evenings and weekends. Furthermore, upon investigating cell signal maps, it was determined sections of the Bay did not have adequate cell coverage to transmit data. To resolve this issue, cell maps were used to relocate CB5MH_01. Additionally, it was suggested to the buoy manufacturer to increase the size of the buoy to allow the antenna not to be submerged as frequently in rough seas.

## Cleaning Solutions and Their Effect on Vessels

Cleaning solutions are a vital part of cleaning the retrieved sensors. One of the most-used solutions is Barnacle Buster. Barnacle Buster is a safe, nontoxic, biodegradable marine growth remover. The active ingredient is phosphoric acid, which is very effective in removing organisms that foul the sensors. Although Barnacle Buster is immensely useful, the solution is very corrosive, affecting the boat deck when used. After use, the team must thoroughly spray down the deck of the vessel with fresh water to protect the deck from corrosion. However, during the winter season, vinegar (acidic acid) is used as the primary cleaning solution for the sensors because the fresh-water system used to spray down the deck is winterized. While vinegar is less effective compared to Barnacle Buster, vinegar is the best solution to use during the low biofouling season because it is less harmful to the vessel.

## Prioritizing Parameters

The relationship between time investment and data quality is evident in the maintenance of conductivity sensors, where the time spent maintaining the conductivity sensors was the fundamental need to perform weekly maintenance. The effort required to maintain conductivity sensors is particularly noteworthy, as once colonized with biofouling, these sensors must be returned to the manufacturer for replacement. A noteworthy consideration lies in the potential for cost reduction and improved efficiency by excluding conductivity measurements from the data collection process. 2023 data demonstrates 37-22% of conductivity data was deemed acceptable, this is likely due to the absence of a resilient anti-biofouling mechanism on the XIM-CTP-DO sonde. This strategic and practical adjustment not only alleviates the maintenance burden, minimizing the frequency of buoy visits, but also contributes to an overall reduction in unit costs.

# 4. Data Management

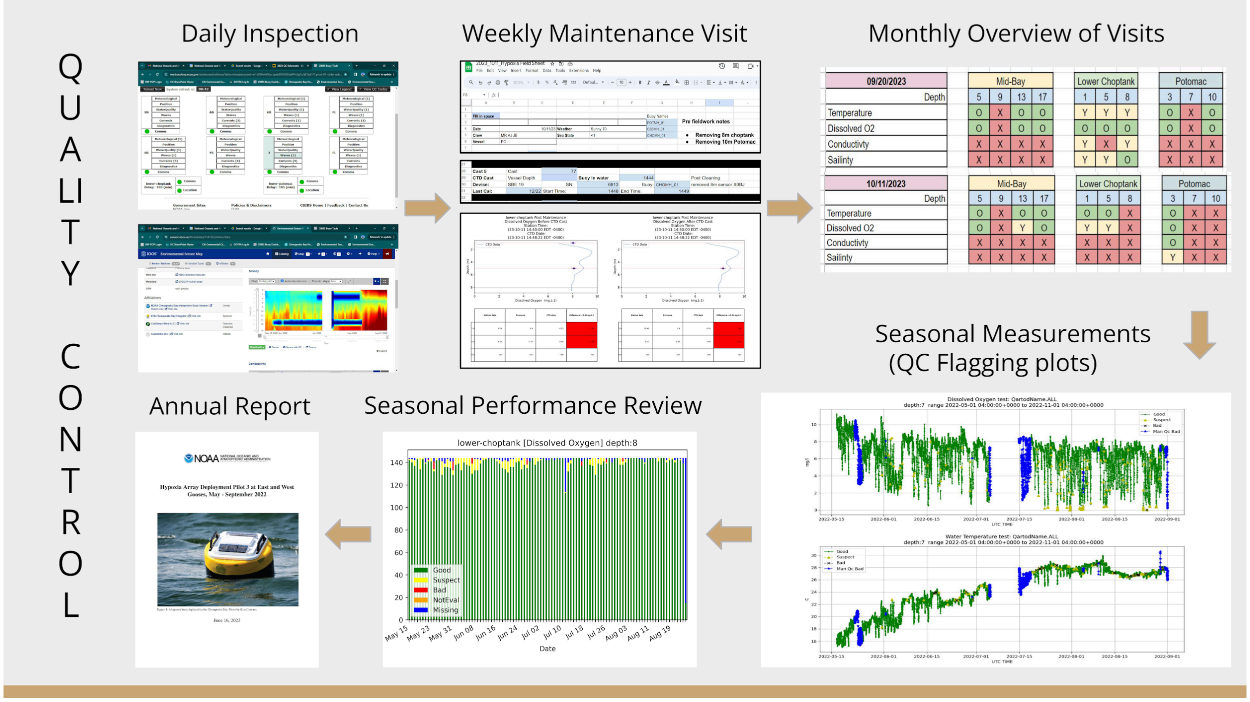
## 4.1 Quality Assurance and Quality Control

Water-quality data management is a critical aspect of environmental monitoring. Ensuring the accuracy and reliability of information is essential for safeguarding aquatic ecosystems. The integration of automatic and manual data flags enhances the quality assurance and quality control (QA/QC) processes in this domain. Automatic data flags employ algorithms to detect anomalies or outliers in real-time, swiftly identifying potential issues such as sensor malfunctions or sudden fluctuations in water parameters. Manual data flags involve human intervention to review and validate data, addressing nuanced situations that automated systems may not capture accurately. This dual approach provides a comprehensive strategy for ensuring data integrity, combining the efficiency of automated systems with the nuanced judgment of human experts. Together, automatic and manual data flags contribute to a robust water-quality data management system that supports informed decision making.

Specific details outlining quality control policies can be found in the NOAA Quality Assurance Protection Plan (https://www.chesapeakebay.net/who/group/hypoxia-collaborative-team). As discussed above, a combination of manually applied and automatic data flags are used to evaluate water-quality data day to day (Figure 4). Flags are used to account for data that should not be used for seasonal assessments or require additional investigation due to the conditions in which data was recorded. Manual flags are applied to data from physical actions taken by NOAA staff on the arrays that can include removing arrays from the water for maintenance or noting data from a CTD-DO validation cast that does not agree with data from arrays. Automatic flags are applied as data is recorded following the U.S. Integrated Ocean Observing System Program (IOOS) Quality Assurance/Quality Control of Real Time Oceanographic Data (QARTOD) procedures.

The integration of manual and automatic flags as part of the QC procedures plays a crucial role in generating data for various stages of maintenance and review. Maintenance visits are informed by automatic flags, which detect anomalies or deviations in real-time data. These automatic flags trigger alerts for immediate attention to potential issues, allowing for prompt intervention during regular visits to address and rectify emerging problems. NOAA staff review of in-situ CTD-DO plots addresses nuanced situations that automated systems may not capture accurately and definitively informs the Sensor Status Sheet (Figure 6) to provide a monthly overview of data coming off each sensor.

On a seasonal basis, an overview of visits incorporates the cumulative information gathered during weekly maintenance checks. With the manual and automatic QC data, QC flagging plots are then generated, consolidating data over longer time frames to reveal seasonal variations or recurring challenges. This helps in understanding the impact of seasonal environmental changes on data quality. Finally, data collected are applied to a Seasonal Performance Review. This comprehensive assessment evaluates the overall performance of all the sensors.



| 09/20/2023 | Mid-Bay | | | | Lower Choptank | | | Potomac | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Depth | 5 | 9 | 13 | 17 | 1 | 5 | 8 | 3 | 7 | 10 |
| Temperature | O | X | O | O | Y | Y | Y | O | X | O |
| Dissolved O2 | O | X | O | O | O | O | O | O | X | O |
| Conductivty | X | X | X | X | Y | X | Y | X | X | X |
| Sailinty | X | X | X | X | Y | Y | O | X | X | X |

| 10/11/2023 | Mid-Bay | | | | Lower Choptank | | | Potomac | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Depth | 5 | 9 | 13 | 17 | 1 | 5 | 8 | 3 | 7 | 10 |
| Temperature | O | X | O | O | O | O | X | O | X | X |
| Dissolved O2 | O | X | Y | O | Y | Y | X | O | X | X |
| Conductivty | X | X | X | X | X | X | X | O | X | X |
| Sailinty | X | X | X | X | X | X | X | Y | X | X |

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Hypoxia Array Deployment Pilot 3 at East and West Gooses, May - September 2022

June 16, 2023

*Figure 4: Summary of quality control documents generated from maintenance visits.*

## 4.2 Daily Review of Real-Time Data

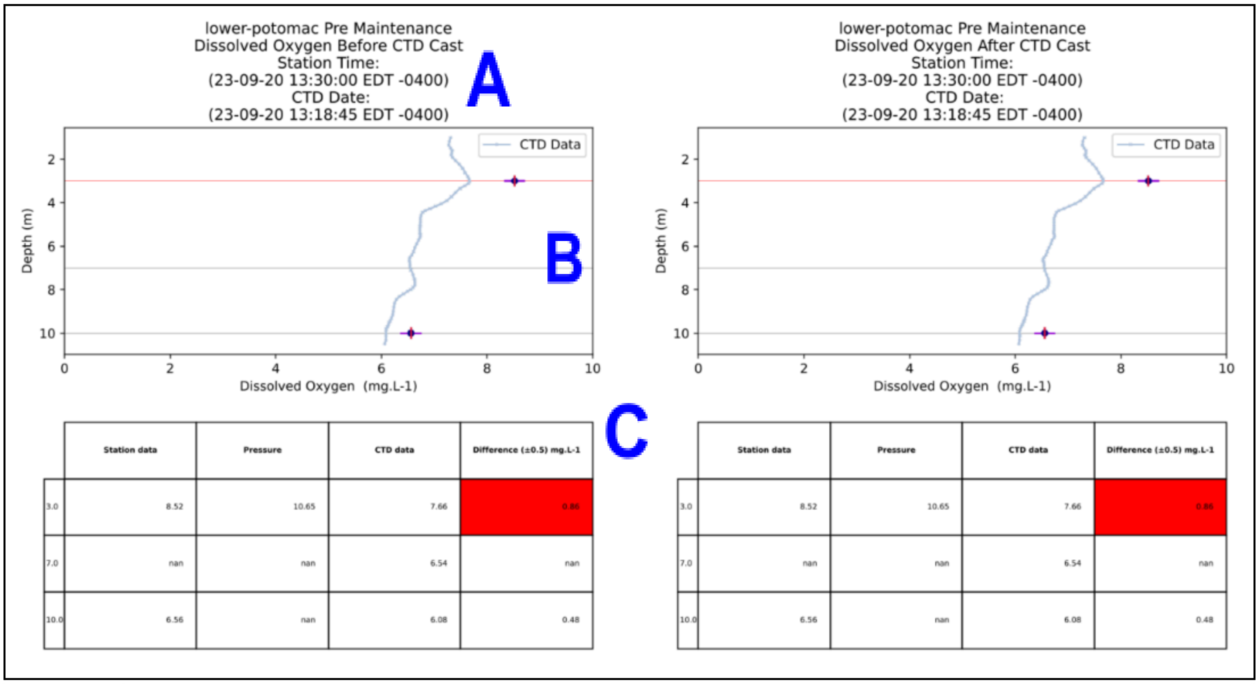
To monitor the buoys effectively, two daily quality control inspections are conducted, utilizing both the dashboard and IOOS websites (Figure 3). The dashboard serves as an online platform enabling NOAA staff to assess various aspects of the buoys, including their location (latitude and longitude), battery life, communication of water-quality data, and internal temperature. It is essential to regularly monitor these components to ensure the continuous and proper functioning of the buoys. The following section elaborates on the process of viewing data in the IOOS database.

## 4.3 Field Maintenance

### Field Records

In addition to daily inspections, detailed field observations and generated CTD-DO validation plots are reviewed per maintenance trip. Field observations include documents and general information about the station visits such as the date, time, station, and weather condition. Additionally, field observations include the CTD-DO cast time, buoy in/out of water time, and other notes of actions that were done during each station visit (e.g., sensor removed, mooring broken). All components in the field observation notes support the conclusion in deciding a sensor’s data quality. Post field work, observation documents used to help generate CTD-DO validation plots (Figure 5). These plots are generated line plots showing the difference between the buoy data and CTD-DO cast data at a given time period. A total of four validation plots are created based on its data collection time. On occasion, only one cast was collected without recovering the hypoxia buoy.

## CTD Validation Sheet and Parameters


lower-potomac Pre Maintenance
Dissolved Oxygen Before CTD Cast
Station Time:
(23-09-20 13:30:00 EDT -0400)
CTD Date:
(23-09-20 13:18:45 EDT -0400)

lower-potomac Pre Maintenance
Dissolved Oxygen After CTD Cast
Station Time:
(23-09-20 13:30:00 EDT -0400)
CTD Date:
(23-09-20 13:18:45 EDT -0400)

| | Station data | Pressure | CTD data | Difference (±0.5) mg.L-1 |
|---|---|---|---|---|
| 3.0 | 8.52 | 10.65 | 7.66 | 🟥 0.86 |
| 7.0 | nan | nan | 6.54 | nan |
| 10.0 | 6.56 | nan | 6.08 | 0.48 |

| | Station data | Pressure | CTD data | Difference (±0.5) mg.L-1 |
|---|---|---|---|---|
| 3.0 | 8.52 | 10.65 | 7.66 | 🟥 0.86 |
| 7.0 | nan | nan | 6.54 | nan |
| 10.0 | 6.56 | nan | 6.08 | 0.48 |

| Key | Meaning |
|---|---|
| A | Information describing the station, parameter measured, date, and time of CTD-DO cast. The plots will either be Pre or Post maintenance. Pre is considered to be a CTD-DO cast prior to recovering the buoy for cleaning and inspection. Both plots will indicate Before/After CTD cast |
| B | During a pre or post buoy cleaning CTD-DO cast, data 10 minutes before and after CTD-DO cast are recorded from the buoy to account for sensors acclimating to the water or variation in the water column The purple mark on each graph represents a data point from a sensor at a designated depth at a given time. |
| C | The table shows the difference between the CTD-DO data and station data 10 before and after validation cast. A red box indicates data fell outside the acceptable thresholds. If a difference is observed between the station and CTD-DO data this is recorded as bad in the manual flag data sheet. |
| A total of 4 plots are developed after one station maintenance: Pre-maintenance/Before CTD-DO Cast, Pre-maintenance/After CTD-DO Cast, Post-maintenance/Before CTD-DO Cast, Post-maintenance/After CTD-DO cast | |

| Parameter | Value |
|---|---|
| Dissolved Oxygen | ∓0.5 mg/L |
| Conductivity | ∓5% of true value |
| Water Temperature | ∓0.2 °C |

*Figure 5. Example of acceptable variation tolerances for hypoxia array based on thresholds as described in Michael et al., 2021.*

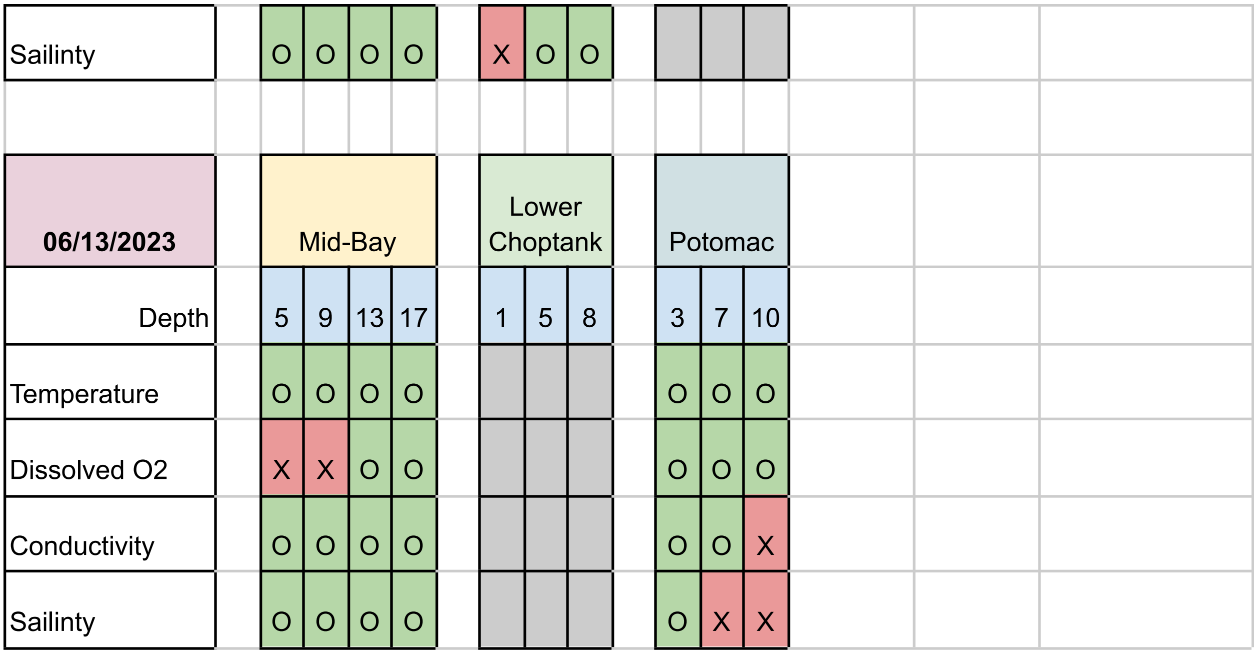
Daily inspections and weekly maintenance are important protocols that influence the monthly overview findings. The CTD-DO Sensor Status (Figure 6) is an organized data sheet describing the status of a buoy's sensor after a field visit cleaning as a visual record. The status is primarily based on the combination of CTD-DO validation plots, field notes, and dashboard if necessary. Each station has its own table. The table describes the status of the sensor's functionality in measuring water parameters at several depths. Good data aligns with the CTD-DO sensor validation plots (no indication of difference) and is depicted as a "green circle." Bad data does not align with CTD-DO sensor validation plots (indicates difference between samples) depicted as a "red X." Suspect data is marked "suspect" based on NOAA staff reviews depicted as a "yellow Y." Suspect data does not align with CTD-DO sensor validation plots (indicates difference between samples); however, the difference is extremely small.

## CTD Sensor Status Sheet

| **06/05/2023** | Mid-Bay | | | | Lower Choptank | | | Potomac | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Depth | 5 | 9 | 13 | 17 | 1 | 5 | 8 | 3 | 7 | 10 |
| Temperature | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | O | O | O |
| Dissolved O2 | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | O | X | O |
| Conductivity | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | O | O | X |
| Sailinty | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | O | O | X |

| **06/07/2023** | Mid-Bay | | | | Lower Choptank | | | Potomac | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Depth | 5 | 9 | 13 | 17 | 1 | 5 | 8 | 3 | 7 | 10 |
| Temperature | O | O | O | O | Y | O | O | ▨ | ▨ | ▨ |
| Dissolved O2 | X | X | O | O | O | O | X | ▨ | ▨ | ▨ |
| Conductivity | O | O | O | O | O | O | O | ▨ | ▨ | ▨ |

| **Symbol** | **Meaning** |
|---|---|
| O | Working |
| X | Not working |
| Y | Working but exceeds threshold |
| ▨ | Did not visit station |
| - | No sensor data |
| | Only enter post cleaning CTD |



| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sailinty | O | O | O | O | X | O | O | | | |
| | | | | | | | | | | |
| **06/13/2023** | Mid-Bay | | | | Lower Choptank | | | Potomac | | |
| Depth | 5 | 9 | 13 | 17 | 1 | 5 | 8 | 3 | 7 | 10 |
| Temperature | O | O | O | O | | | | O | O | O |
| Dissolved O2 | X | X | O | O | | | | O | O | O |
| Conductivity | O | O | O | O | | | | O | O | X |
| Sailinty | O | O | O | O | | | | O | X | X |

*Figure 6: CTD Sensor Status Sheet is used as a review visualization of CTD-DO validation casts.*

Yearly and monthly plots are constructed by incorporating QC flagging and historical data (Figure 7), providing a comprehensive display of all QC assessments throughout the season. These plots form a QC plot sensor summary, illustrating the performance of each sensor and the measured water parameters on a monthly and yearly basis. The generation of all plots and statistical charts is accomplished using the Pycharm Python platform. Each plot includes a legend and subheadings to differentiate the captured data sets, with subheadings specifying the buoy station, measured water parameter, and sensor depth. The x-axis denotes the date and time, while the y-axis represents the unit of the water parameter. The legend encompasses all identifying components of the plot. These QC plot sensor summaries are incorporated into the annual report within Appendix A.

*Figure 7: Yearly and monthly time series of data from a sonde on the hypoxia station.*

## 4.4 Viewing Data in the IOOS Database

The Integrated Ocean Observing System (IOOS) maintains an online database that contains continuous real-time, non-QCed, data available for the public. IOOS allows users to graphically display and download data throughout a period of interest ranging from one day to multiple months. Examples of IOOS graphics can be found in Section 6.4 (Figure 8-18), where curtain plots are used to illustrate water-quality parameters during the duration of buoy deployment. Notably, the curtain plots use a color gradient to represent the range of data. While red is used to indicate bad or questionable data in other parts of this document, red data on the IOOS curtain plots simply represent the higher end of a given water parameter's range. Beneath the curtain plots is a bar chart that provides metrics on the data quality based on quality control procedures.

*IOOS Station Links:*

**Lower Choptank:** *https://sensors.ioos.us/#metadata/127732/station/data*

**Mid-Bay:** *https://sensors.ioos.us/#metadata/128678/station/data*

**Lower Potomac:** *https://sensors.ioos.us/#metadata/128758/station/data*

## 4.5 QARTOD Tests

Automated, or automatic, flags are the first level of QA/QC used in the review of Quality Assurance/Quality Control of Real-Time Oceanographic Data (QARTOD) as discussed in section 4.1. Described in this section is the publicly available Python code used in the review of data collected by the hypoxia buoys. IOOS keeps the most up-to-date version record on their website: https://ioos.github.io/ioos_qc/.

Automatic flag thresholds can be found in Table 5.

| QC Codes | Value | Meaning |
|---|---|---|
| **1** | Good | Data fell within acceptable thresholds outlined in table 5 |
| **2** | Not Evaluated, Not Available, Unknown | Data was not measured or no attempt was made |
| **3** | Questionable or Suspect | Data begins to raise doubts or concerns about their accuracy, reliability, or validity. |
| **4** | BAD | Data fell outside acceptable thresholds outlined in table 5 |
| **9** | Missing | Data was not collected / received following the known interval of data transmission |

*Table 4. A detailed description of how each finalized QC plot was determined.*

## QARTOD Thresholds

| | Water Temperature (Celsius) | Salinity (Practical Salinity Scale) | Dissolved Oxygen (Milligram per Liter) | Conductivity (Microsiemens Per Centimeter) | Sea Water Pressure (Decibar) |
|---|---|---|---|---|---|
| **Gross Range Test** | | | | | |
| suspect_span | (-2.0 °C, 35.0 °C) | (0.5 PSS, 30.0 PSS) | (0.5 mg/L, 15 mg/L) | (0.0 mS/cm, 46.0 mS/cm) | (0.5 dbar, 28.4.0 dbar) |
| fail_span | (-5.0 °C, 45.0 °C) | (0.002 PSS, 35.0 PSS) | (0 mg/L, 20 mg/L) | (0.0 mS/cm, 53.0 mS/cm) | (0.0 dbar, 30.0 dbar) |
| **Flat Line Test** | | | | | |
| tolerance | 0.01 °C | 0.001 PSS | 0.005 mg/L | 5.0E-4 mS/cm | 0.001 dbar |
| suspect_threshold | 2700 s | 2700 s | 2700 s | 2700 s | 2700 s |
| fail_threshold | 3600 s | 3600 s | 3600 s | 3600 s | 3600 s |
| **Rate Of Change Test** | | | | | |
| threshold | 0.003 °C/s | 0.0005 PSS/s | 0.003 mg/L/s | 0.002 mS/cm/s | 7.0E-4 dbar/s |
| **Spike Test** | | | | | |
| suspect_threshold | 2.0 °C | 3.0 PSS | 5 mg/L | 1.0 mS/cm | 0.5 dbar |
| fail_threshold | 10.0 °C | 6.0 PSS | 10 mg/L | 5.0 mS/cm | 1.0 dbar |

*Table 5: Minimum parameter thresholds for data to pass QA/QC in IOOS. Note that conductivity (mS/cm) measurements are inherently temperature dependent and there is a prevailing standard of assuming a temperature of 25C/77F. Most salinity measurements in literature follow this convention.*

## Integrated Ocean Observing System Program (IOOS) QA/QC Tests

1. Gross Range Test: Check that values are within reasonable bounds. Given a 2-tuple of minimum/maximum values, flag data outside of the given range as FAIL data. Optionally, also flag data that falls outside of a user-defined range as SUSPECT. Missing and masked data are flagged as UNKNOWN.

2. Flat Line Test: Check for consecutively repeated values within a tolerance. Missing and masked data are flagged as UNKNOWN.

3. Rate of Change Test: Checks the first order difference of a series of values to see if there are any values exceeding a threshold defined by the inputs. These are then marked as SUSPECT. It is up to the test operator to determine an appropriate threshold value for the absolute difference to not exceed. Threshold is expressed as a rate in observations units per second. Missing and masked data are flagged as UNKNOWN.
4. Spike Test: Check if the difference in values between a data point and its neighbors exceeds a threshold. Determine if there is a spike at data point n-1 by subtracting the midpoint of n and n-2 and taking the absolute value of this quantity, and checking if it exceeds a low or high threshold. Values that do not exceed either threshold are flagged GOOD, values that exceed the low threshold are flagged SUSPECT, and values that exceed the high threshold are flagged FAIL. Missing and masked data are flagged as UNKNOWN.

## 4.6 Data Flow

Moving water-quality data from the hypoxia buoys through the QA/QC process has a number of steps. Water-quality data is collected by a SoundNine Ulti-buoy controller. This uses SoundNine inductive modem technology to record data from sensors at various depths. Data is sent over the internet via a cellular transmission and processed on the SoundNine server before being sent to a NOAA relational database.

NCBO uses an “Extract, Transform, and Load” process to extract the data and store it in a postgres database. This process is written in JAVA and runs on a schedule pulling the source database for changes. After loading data, a QARTOD process is run, applying the automated flags to the data. The flags are associated with each measurement, and the original source data is not modified. The QA/QC software is developed by IOOS and can be found here: https://ioos.github.io/ioos_qc. The QC thresholds are set locally on the NCBO system and are auditable using a software version control system; these thresholds are described in Section 4.3.

Manual flags are applied for events such as sensor cleaning and erroneous sensor readings and are stored in the database. The manual and automated flags are combined into one final QARTOD status and can be re-run to update flags as needed.

The NCBO data can be accessed via REST API that exports data in a JSON format. NCBO also provides plots of the data that display QARTOD values.

Some definitions of the software terminologies:

- REST: https://www.redhat.com/en/topics/api/what-is-a-rest-api
- JSON: https://www.w3schools.com/whatis/whatis_json.asp
- ETL: https://www.ibm.com/topics/etl
- API: https://www.ibm.com/topics/api

# 5. Key Findings

## 5.1 Overview and Definitions of Data

The assessment of data quality adheres to the metrics outlined by Michael et al., 2021, with a specific focus on their water-quality thresholds in this project. Special attention was given to the correlation between the hypoxia arrays and data obtained from the independent CTD-DO cast. In reviewing the data, it is essential to recognize the considerable variability inherent in the dynamic nature of coastal ecosystems, especially during flood or ebb tides and rough sea states.

Chesapeake Bay's dynamic nature and the inherent variability in the water column contribute to dynamic fluctuations in water-quality parameters, such as DO, over both long and short time periods. Factors such as temperature, salinity, microbial activity, and gas exchange with the atmosphere influence the distribution of DO. Notably, while stratification in the water column may occur, seasonal changes, storms, and wind-induced turbulence can lead to mixing events, redistributing DO throughout the water column.

Observations revealed that water stratification could result in rapid changes in in-situ measurements, even in close proximity to the hypoxia buoys. For instance, a slight misalignment in timing of only a few minutes between a hypoxia station and the CTD-DO cast could cause misalignment of measurements due to changing conditions. Additionally, it was noted that the stations' data sondes could take more than 10 minutes to equilibrate to conditions post cleaning, introducing further complexity in validating station data. Consequently, discrepancies in CTD-DO validation casts could arise, leading to the potential validation failure of a station despite recent servicing.

To address these challenges, a pragmatic approach was adopted during the validation cast review. Two CTD-DO casts are conducted during each maintenance visit. Instances where data failed a validation cast then passed a week later prior to cleaning were occasionally classified as suspect. For example, Image 7 data initially failed a post-cleaning CTD-DO validation cast in early October, marking it as bad. However, upon revisiting the station a week later, the pre-cleaning CTD-DO cast indicated that the data had passed the validation process before recovering the buoy. Consequently, the initial bad flag applied in early October was updated to suspect, as it was likely a result of conducting the CTD-DO validation cast before the sensor had acclimated sufficiently to the water after cleaning.

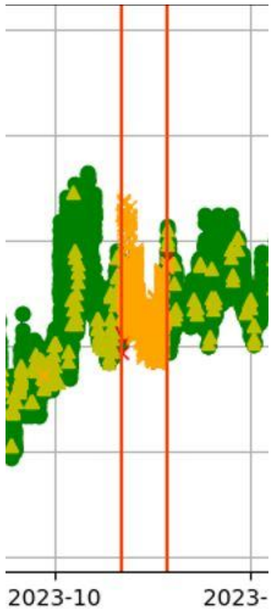


*Image 7: Snapshot of a yearly DO plot. The red vertical lines indicate station visits. Green circles indicate good data, dark orange Xs are suspect data, and yellow triangles are missing data.*

## Calculated Measurements

The hypoxia buoys collect a suite of metadata every 10 minutes to determine the functionality of sensors in an effort to accurately measure temperature (Deg C), conductivity (S/m), DO concentration (mg/L), and pressure (db). Additionally, the buoy computers have the ability to continuously calculate salinity (S/m) and salinity-adjusted DO (mg/L) from the prior measurements.

### Salinity-Adjusted Dissolved Oxygen Calculation

Salinity-adjusted DO is calculated to more accurately measure the oxygen concentration in seawater, as its concentration can be influenced by factors including temperature and salinity. When water temperature and salinity change, they can affect the solubility of oxygen in seawater. Warmer water generally holds less DO, while higher salinity can increase oxygen solubility. To isolate the effect of salinity on DO concentration, researchers use salinity-adjusted DO values.

The adjustment is typically done using the oxygen solubility values corresponding to specific temperature and salinity conditions. By normalizing the DO measurements to a standard salinity level, usually expressed as DO concentrations at a reference salinity of 35 parts per thousand (ppt), scientists can compare oxygen levels across different water masses and locations more accurately.

This salinity adjustment allows for the identification of patterns and variations in DO concentrations that are independent of changes in salinity, providing a clearer understanding of the underlying processes affecting oxygen distribution in the ocean. It is especially important for comparing data collected from different regions with varying salinity levels, making the interpretation and analysis of DO data more robust in the context of oceanographic research and environmental monitoring.

- The equation to compensate DO readings for salinity is:

  DO_C = :DO * exp(-1*:SAL*(0.017674+(-10.754+2140.7/:TEMPK)/:TEMPK)))

  Where :DO is the measured DO in mg/l, :SAL is the salinity in g/kg brine, and :TEMPK is the water temperature in Kelvin.

- The equation to express DO as a percent of saturation is:

  DO% = (:DO_C/:DOSAT)*100

  Where :DO_C is the compensated DO reading in mg/l and :DOSAT is the DO saturation value in mg/l at the measured temperature and salinity.

- The equation to calculate DO saturation in mg/l is:

  DOSAT = exp(-139.34411+(1.575701E5+(-6.642308E7+(1.2438E10-8.621949E11/:TEMPK)/:TEMPK)/:TEMPK)/:TEMPK)*exp(-1*:SAL*(0.017674+(-10.754+2140.7/:TEMPK)/:TEMPK)))

  Where :SAL is the measured salinity in g/kg brine and :TEMPK is the water temperature in Kelvin.

Source: Benson, B.B. and Krause Jr, D., 1984.

### Calculating Salinity from Conductivity

The relationship between electrical conductivity and salinity is used to estimate salinity in seawater. This method is based on the fact that the electrical conductivity of seawater is primarily influenced by the concentration of dissolved ions, which in turn is related to salinity.

The most commonly used formula for salinity estimation from conductivity is the Practical Salinity Scale (PSS-78), which relates conductivity, temperature, and pressure to salinity. The formula takes into account the variations in seawater properties with depth and temperature.

S = C (15^t) / K

Where:

- S is the salinity,

- C is the conductivity,
- t is the temperature in degrees Celsius, and
- K is a constant related to specific instrument calibration.

Source: Rice, E.W., Bridgewater, L. and American Public Health Association eds., 2012

## Interpreting Good, Suspect, and Bad Data

In collecting data for this project, immense effort was undertaken to ensure data could be backed by in-situ measurements guided by methods established by regional partners. Robust quality control measures were implemented to assess and categorize the data as either good, bad, or suspect, forming a critical framework to ensure the accuracy and reliability of the collected information. These measures ensure the accuracy and reliability of the collected information by adhering to set protocols, NCBO systematically evaluates data points, applying stringent criteria to distinguish between high-quality, acceptable data and instances where data integrity may be compromised.

Of important note, while data is classified into quality categories, users have the discretion to determine its application and significance. In this project, methods adapted from the guidelines in Michael et al., 2021, and as indicated in NOAA Chesapeake Bay Office., 2023, were systematically followed to categorize data. Users can independently assess data reliability, recognizing that its significance may vary based on the specific application.

### Acceptable data

Acceptable data is referred to in this document as “good data.” The sensor has undergone a thorough review and is operating under optimal conditions. This data meets predefined criteria, standards, or quality control measures, indicating its reliability. Acceptability is determined by comparing the data to established benchmarks, ensuring it is free from significant errors, biases, or anomalies that could compromise the validity and reliability of results. Additionally, the data has been either directly compared against equivalent sensors in controlled conditions or compared against third-party sensors deployed in the field.

### Suspect data

Suspect data is referred to in this document as “suspect data.” Suspect data refers to measurements that may be questionable or raise concerns about accuracy, reliability, or validity. Sensors reporting suspect data before field deployment are returned to the manufacturer for troubleshooting. This classification arises when a sensor deployed in the field begins to exhibit erroneous data compared to an independent sensor. Suspect data may result from equipment malfunctions, calibration errors, and environmental variability, requiring further investigation. The data is considered usable for analysis if additional evidence suggests the erroneous data could be due to variability in the water column. However, it is crucial to acknowledge errors observed during CTD-DO validation casts or potential bias by changing data classification as discussed earlier in this section.

### Bad data

Bad data is referred to in this document as “bad data.” Bad data refers to measurements that are deemed unreliable, inaccurate, or unsuitable for the intended purpose due to significant errors, inconsistencies, or anomalies. This type of data does not meet the established quality standards or criteria set for in the QAPP and should not be considered for making assessments of quantified environmental conditions.

## Data Deliverables

Data requests should be made through NCBO in an effort to control QA/QC’d data. For each station, two versions will be provided: one with automatic and manual flags, the other with original data. Files will be in CSV format with files limited to 500 rows. Headers will Include:

- "Station Name"
- "GPS Latitude (Deg)"
- "GPS Longitude (Deg)"
- "depth (m)"
- "Observation Timestamp (UTC)"
- "Sea Water Temperature (C)"
- "Sea Water Temperature (C) QC"
- "Conductivity (s/m)"
- "Conductivity QC"
- "Salinity (PSU)"
- "Salinity QC"
- "O2 Concentration (mg/l)"
- "O2 Concentration (mg/l) QC"
- "O2 Concentration Salinity Adjusted (mg/l)"
- "O2 Concentration Salinity Adjusted (mg/l) QC"
- "x0_o2_sol__mg_l"
- "x0_o2salfactor"
- "Pressure (dbar)"

# 5.2 Data Parameters

Seasonal data was organized into multiple parameters including:

- Station: Unique ID indication hypoxia buoy
- Depth: Depth in meters a data sonde was located in the water column
- Variable: Measured parameter including water temperature, salinity, conductivity, DO, and salinity-adjusted DO
- Begin Timestamp: Initial buoy deployment at beginning of season when data collection begins
- End Timestamp: End of buoy deployment and end of data collection for 2023
- Good: Data meeting expected thresholds as determined by in-situ CTD-DO cast

- Suspect: Data collected during CTD-DO pre- or post-validation indicated station variables passed one cast and failed another (see section 4.1)
- Bad: Data collected during CTD-DO validation failed post cleaning
- Unknown: Data transmitted to server was corrupt and unreadable
- Null: Data where timestamps did not align with expected data collection on a 10-minute interval
- Total Expected: Total data expected expected during beginning and end timestamps
- Total Missing: Total data missing from database
- Maintenance: Windows of time where buoy was out of water for maintenance but still transmitting data

The normalization of data underwent three independent reviews by NOAA staff. This ensured the accurate application of both automatic and manual flags and compliance with the rules outlined in Section 4 for flagging data, while also considering dependent variables such as flagging salinity-adjusted DO when conductivity readings were incorrect.

The procedure to determine the percentage of data suitable for analysis involved several steps. Every day while a buoy is deployed, 145 transmissions are received by NOAA servers, the sum of a station’s deployment is considered the total expected value. The data was first segregated by stations and organized based on parameters, with the calculation of the sum for each parameter’s total expected value. The usable collected data was determined by subtracting the combined sum of unknown, null, total missed, and maintenance from the total expected of all parameters received from the deployment. Subsequently, the percentages of good, bad, and suspect values for each respective parameter were computed by dividing them individually by total expected value for each parameter.

Cumulative plots were generated by summing up all good, bad, and suspect parameters and dividing them by the total expected for each station. This comprehensive approach allowed for a thorough evaluation of the data's usability and its distribution across different parameters and stations.

Data was only accounted for in the total expected value while a buoy was on station and had a sensor actively collecting data. Instances where a sonde was removed from the station did not count against the total expected for the whole station.

## 5.3 Data Discussion

The data obtained from the three buoys, Lower Choptank, Mid-Bay, and Lower Potomac, provide insights into the water-quality parameters, including temperature, conductivity, salinity, DO, and DO salinity adjusted. The percentages of quantified data for each parameter are categorized into good, suspect, bad, and good + suspect for each station, allowing for a comprehensive comparison and analysis.

1. Temperature:

- Mid-Bay has the highest percentage of good data (68.57%), while Choptank has the highest cumulative good and suspect data (76.35%). Lower Potomac falls in between.
- Lower Choptank and Lower Potomac have a substantial percentage of bad data (20.88% and 44.62%, respectively) compared to Mid-Bay (23.7%).

2. Conductivity:

- Lower Choptank and Mid-Bay have the equal percentages of good data (37.32%), while Mid-Bay has the highest percentage of suspect data (14.39%).
- Lower Choptank and Mid-Bay have a relatively close percentage of good + suspect data (48.24% and 51.71%, respectively).

3. Salinity:

- Lower Choptank consistently shows higher percentages of good data in comparison to Lower Choptank and Lower Potomac.
- Lower Potomac has the lowest percentage of good data (29.36%), while Lower Choptank has the lowest percentage of suspect data (1.13%).

4. Dissolved Oxygen:

- Lower Choptank consistently exhibits the highest percentage of good data for DO (59.28%), followed by Mid-Bay (57.78%) and Lower Potomac (45.51%).
- Lower Potomac has the highest percentage of bad data (44.88%), while Lower Choptank has the lowest (24.09%).

5. Dissolved Oxygen Salinity Adjusted:

- For this parameter, Lower Choptank and Mid-Bay have relatively similar percentages of good data (37.2% and 35.48% respectively), while Lower Potomac shows a slightly lower percentage (22.1%). Lower Potomac has the highest percentage of good + suspect data (77.36%), indicating a more comprehensive evaluation.

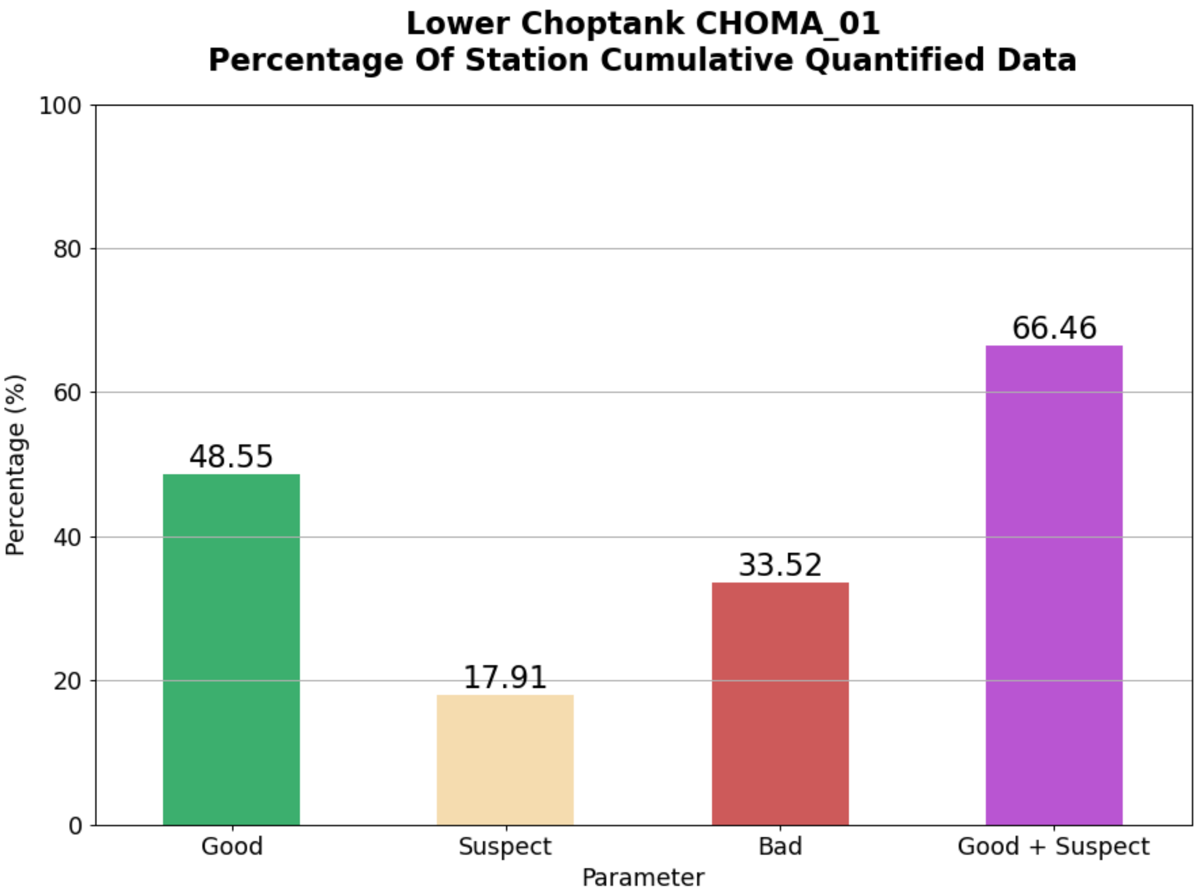
6. Cumulative Comparison:

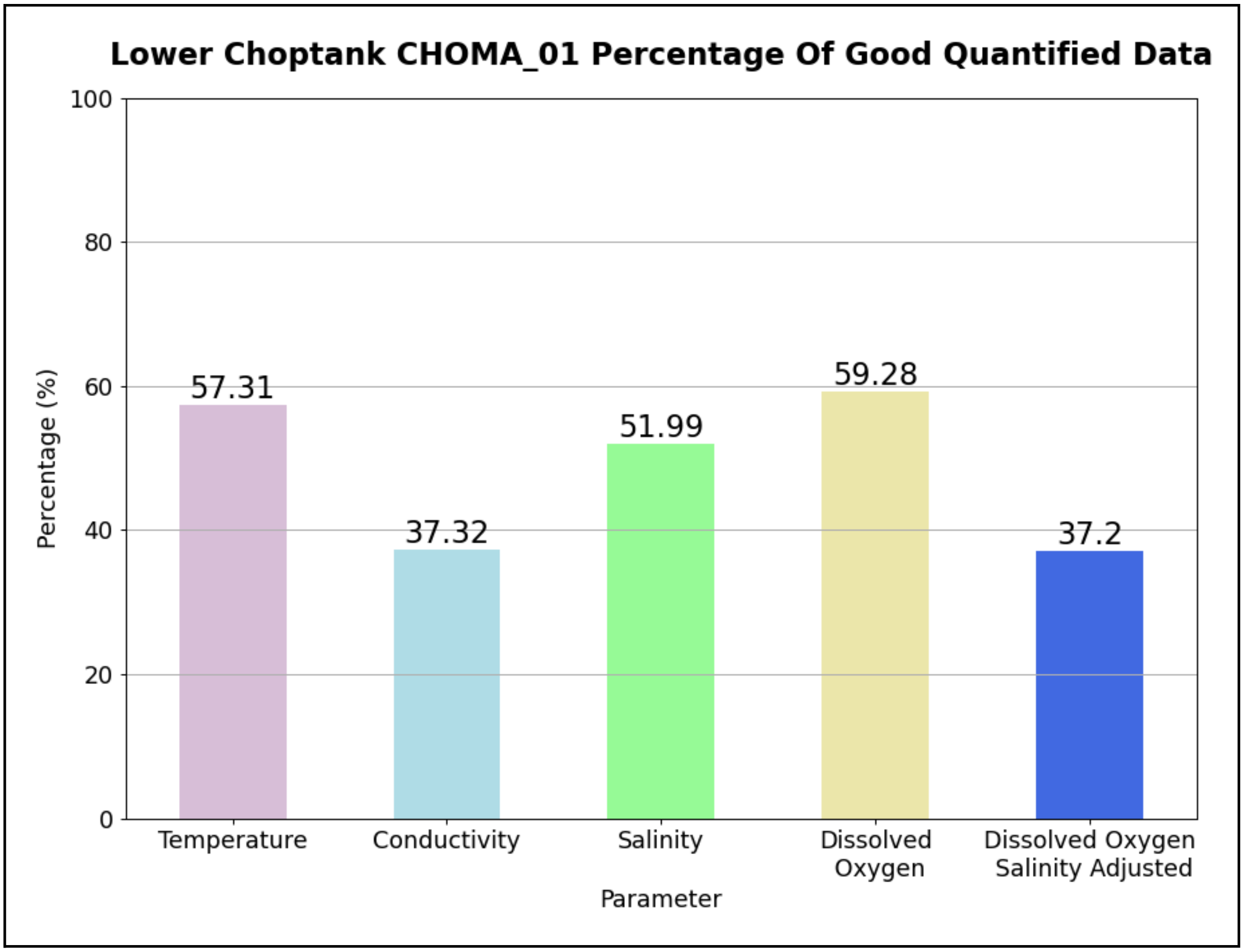
- In terms of cumulative good data, Mid-Bay ranks the highest, followed by Lower Choptank and Lower Potomac.
- The cumulative bad data is highest in Lower Potomac, followed by Lower Choptank and Mid-Bay.
- The cumulative suspect data is highest in Mid-Bay, followed closely by Lower Choptank, and then Lower Potomac.
- The cumulative good + suspect data is highest in Lower Potomac, followed by Mid-Bay and then Lower Choptank.

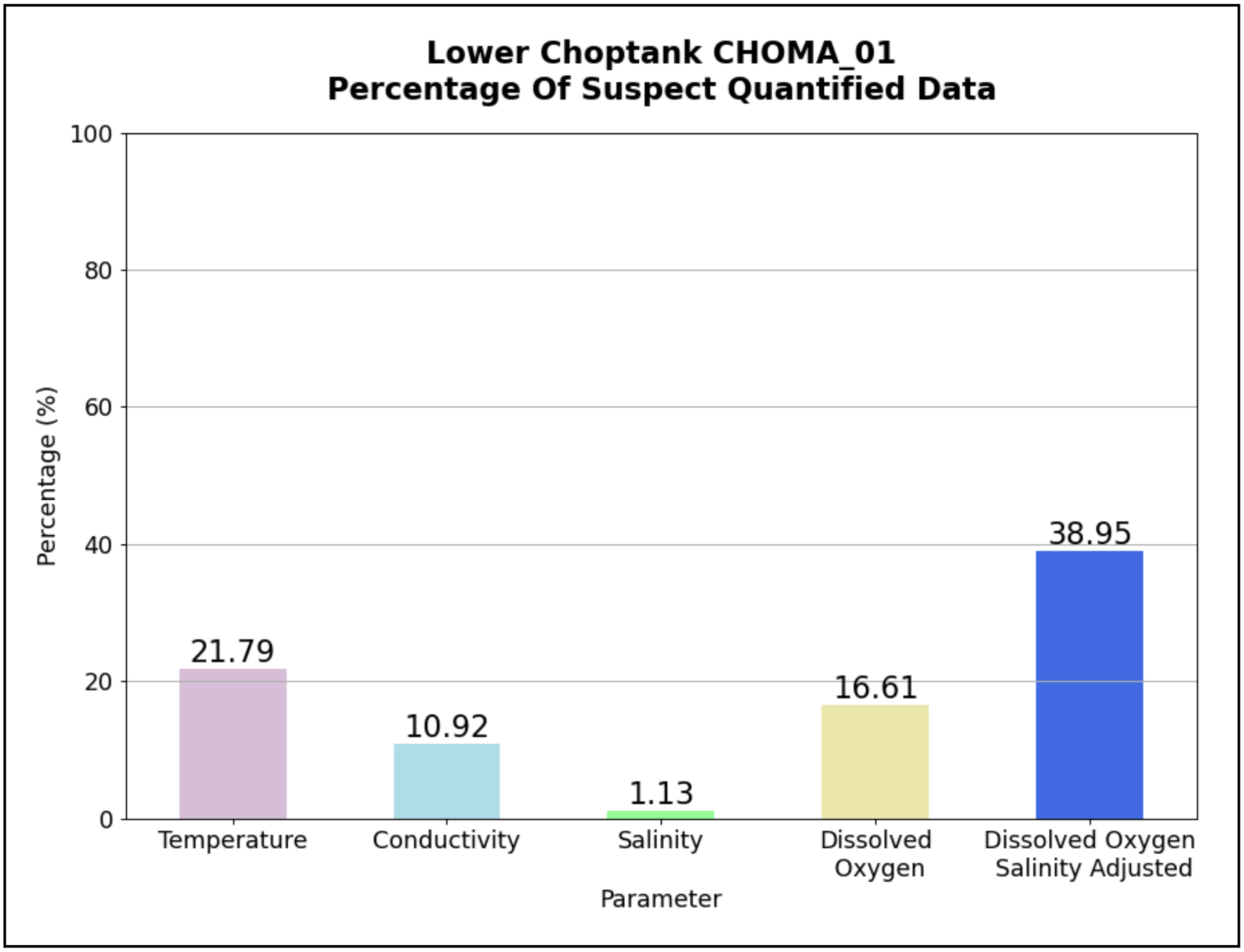
Lower Choptank was the most accessible of the three stations due to its proximity to the marina where NCBO vessels were docked and its location being protected from wind and waves. As a result it was visited 23 times for maintenance or validation checks. Through the season the station had the most reliable DO data with a combined (75.9%) (CD) good + suspect data score and the second most complete data set from the season. Mid-Bay, the second most visited station at 18 visits for maintenance or validation checks, =as a whole had the highest percentage of overall good data (49.28%) and marginally second highest good DO data (57.78%) when compared to Lower Choptank (59.27%). Lower Potomac was the least-accessible station, which likely contributed to a decrease in data quality. All five parameters had the highest scores of bad data when compared to Lower Choptank and Mid-Bay.

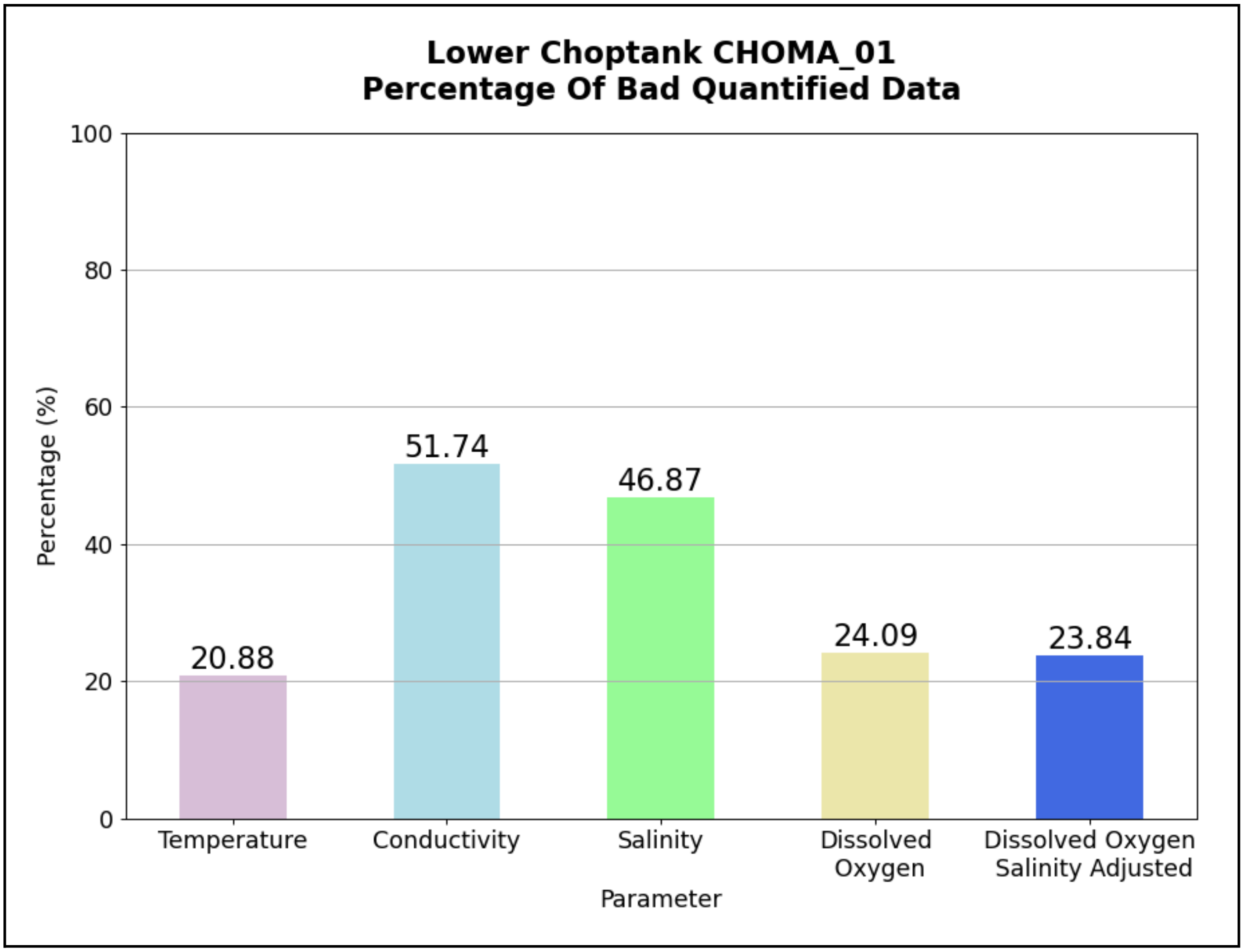
## 5.4 Lower Choptank Metrics

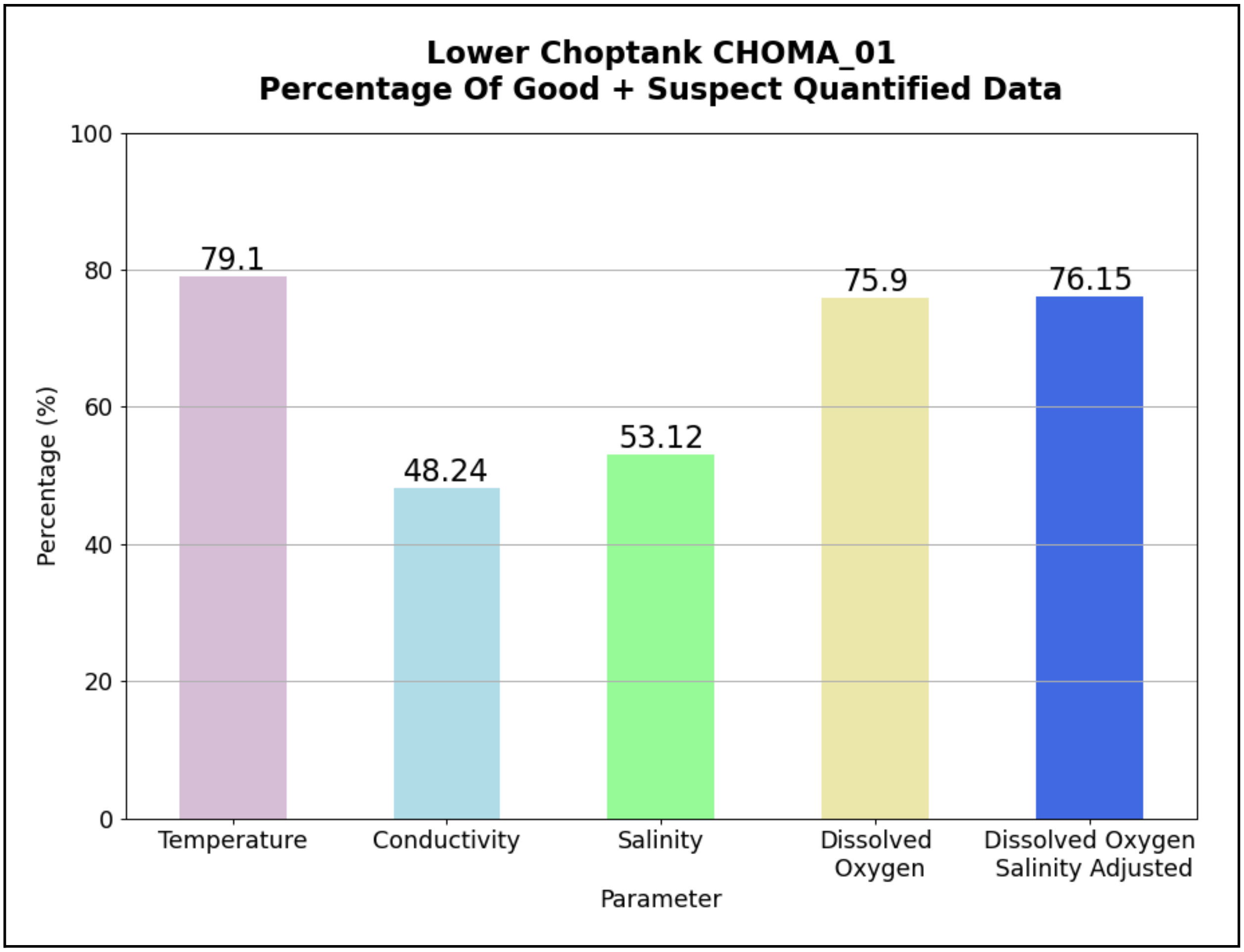
### Lower Choptank Figures




Lower Choptank CHOMA_01 Percentage Of Good Quantified Data
Percentage (%)
100
80
60
40
20
0
57.31
37.32
51.99
59.28
37.2
Temperature
Conductivity
Salinity
Dissolved Oxygen
Dissolved Oxygen Salinity Adjusted
Parameter


Lower Choptank CHOMA_01
Percentage Of Suspect Quantified Data
Percentage (%)
100
80
60
40
20
0
21.79
10.92
1.13
16.61
38.95
Temperature
Conductivity
Salinity
Dissolved Oxygen
Dissolved Oxygen Salinity Adjusted
Parameter


Lower Choptank CHOMA_01
Percentage Of Bad Quantified Data
100
80
60
40
20
0
Percentage (%)
20.88
51.74
46.87
24.09
23.84
Temperature
Conductivity
Salinity
Dissolved Oxygen
Dissolved Oxygen Salinity Adjusted
Parameter

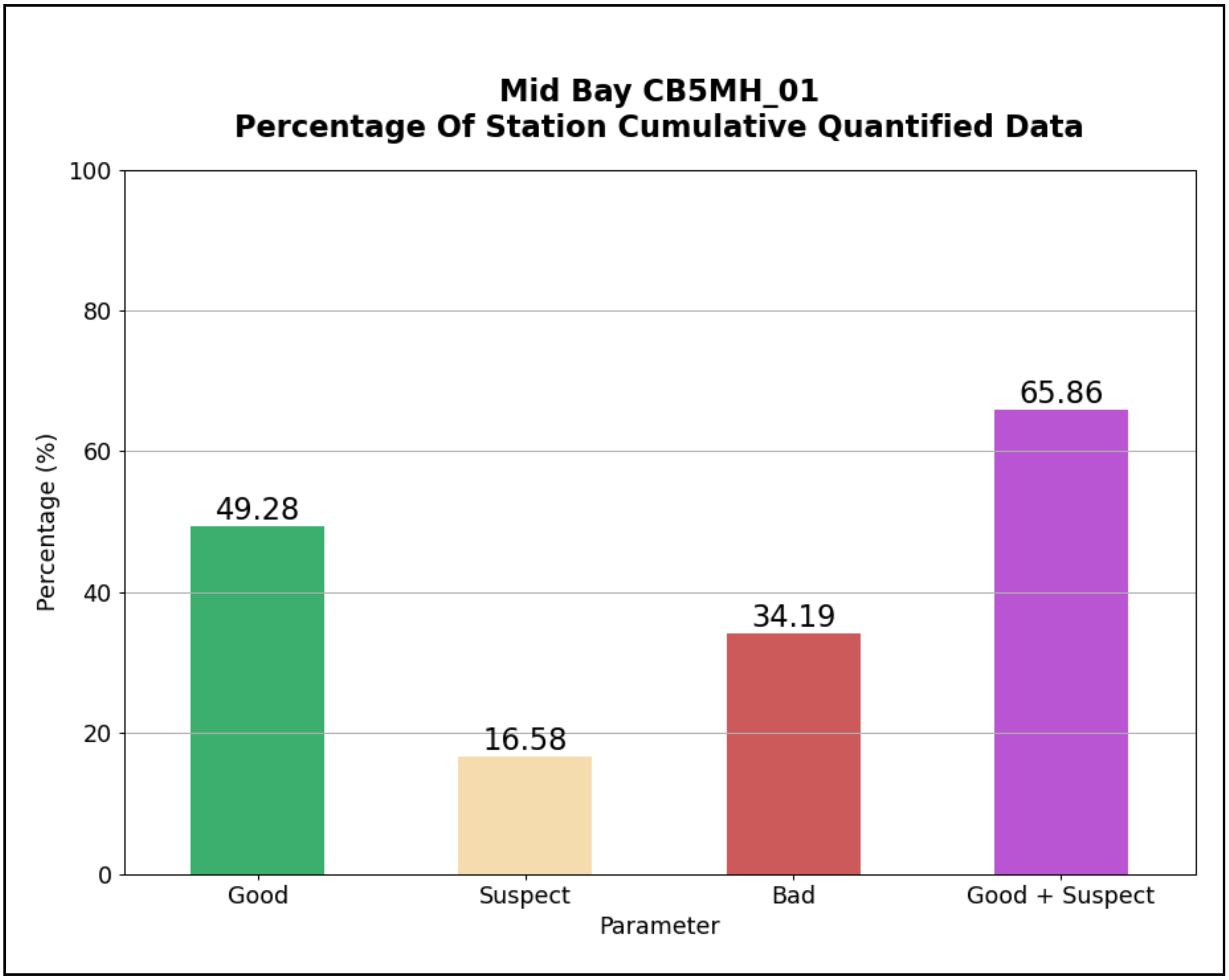

Lower Choptank CHOMA_01
Percentage Of Good + Suspect Quantified Data
Percentage (%)
100
80
60
40
20
0
79.1
48.24
53.12
75.9
76.15
Temperature
Conductivity
Salinity
Dissolved Oxygen
Dissolved Oxygen Salinity Adjusted
Parameter

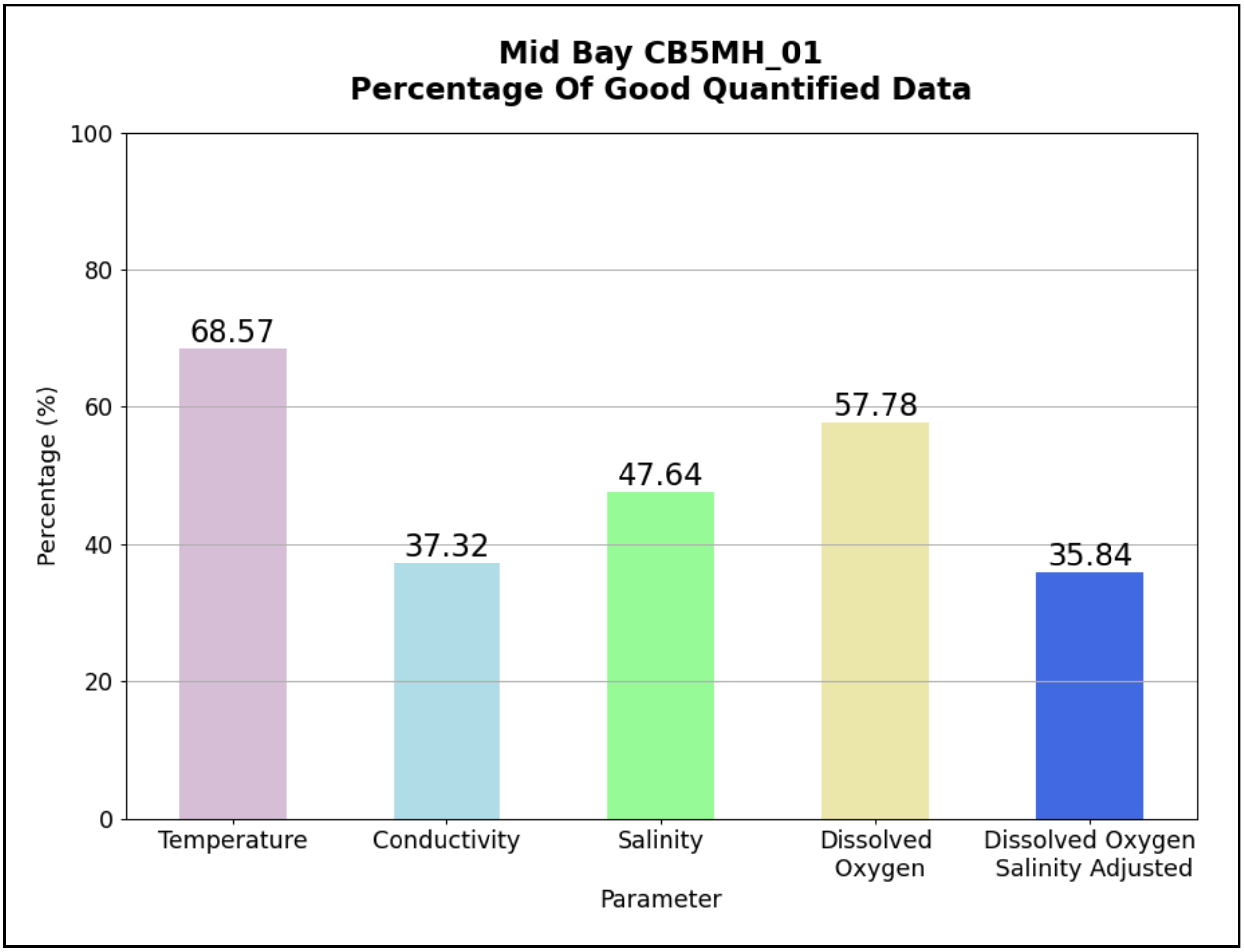
## Lower Choptank Tables

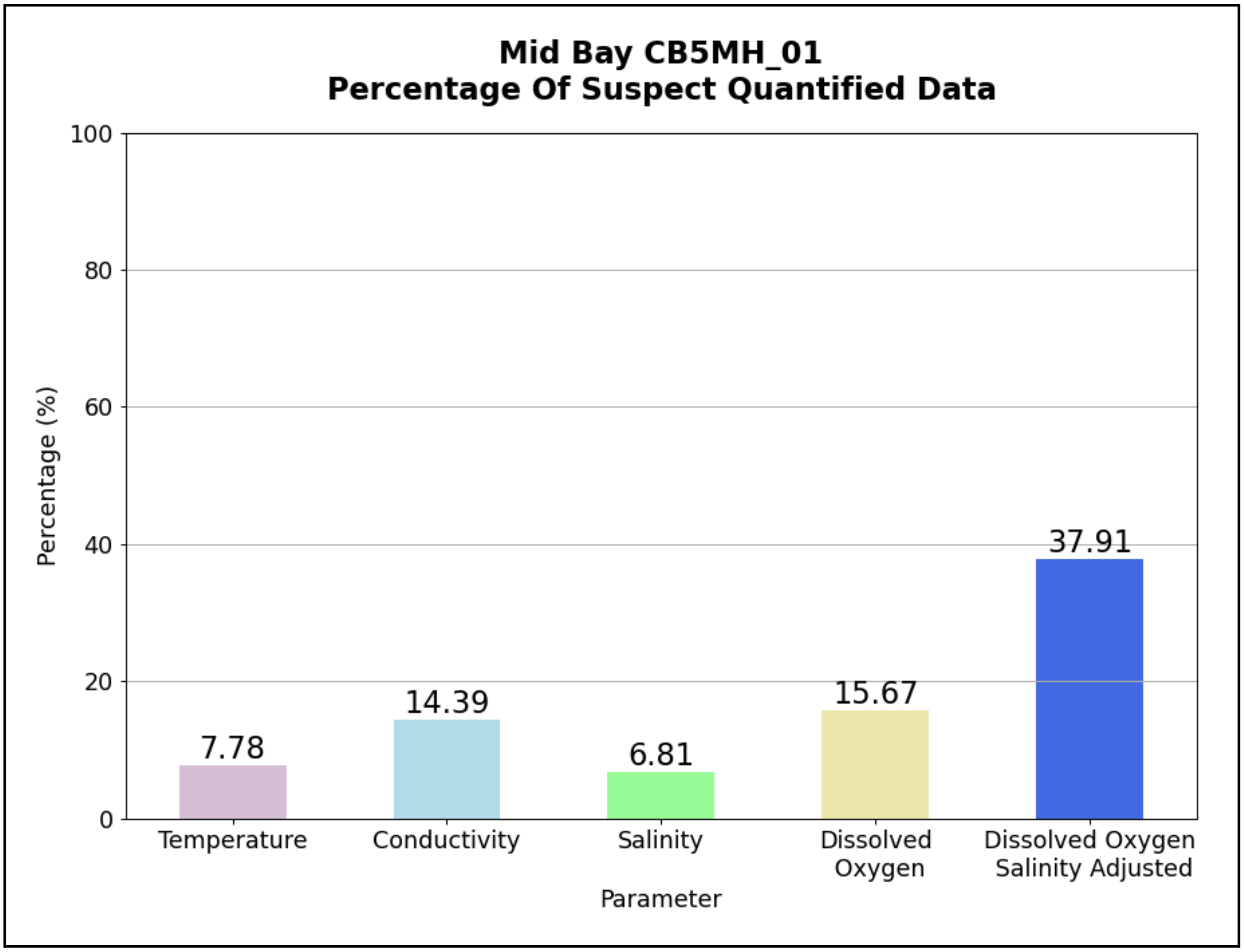
| **Lower Choptank - Good Data** | **% of Quantified Data** |
|---|---|
| Temperature | 57.31 |
| Conductivity | 37.32 |
| Salinity | 51.99 |
| Dissolved Oxygen | 59.28 |
| Dissolved Oxygen Salinity Adjusted | 37.2 |
| **Lower Choptank - Suspect** | |
| Temperature | 21.79 |
| Conductivity | 10.92 |
| Salinity | 1.13 |
| Dissolved Oxygen | 16.61 |
| Dissolved Oxygen Salinity Adjusted | 38.95 |
| **Lower Choptank - Bad** | |
| Temperature | 20.88 |
| Conductivity | 51.74 |
| Salinity | 46.87 |
| Dissolved Oxygen | 24.09 |
| Dissolved Oxygen Salinity Adjusted | 23.84 |
| **Lower Choptank - Good + Suspect** | |
| Temperature | 79.1 |
| Conductivity | 48.24 |
| Salinity | 53.12 |
| Dissolved Oxygen | 75.9 |
| Dissolved Oxygen Salinity Adjusted | 76.15 |
| **Lower Choptank - Whole Station** | |
| Good | 48.55 |
| Suspect | 17.91 |
| Bad | 33.52 |
| Good + Suspect | 66.46 |

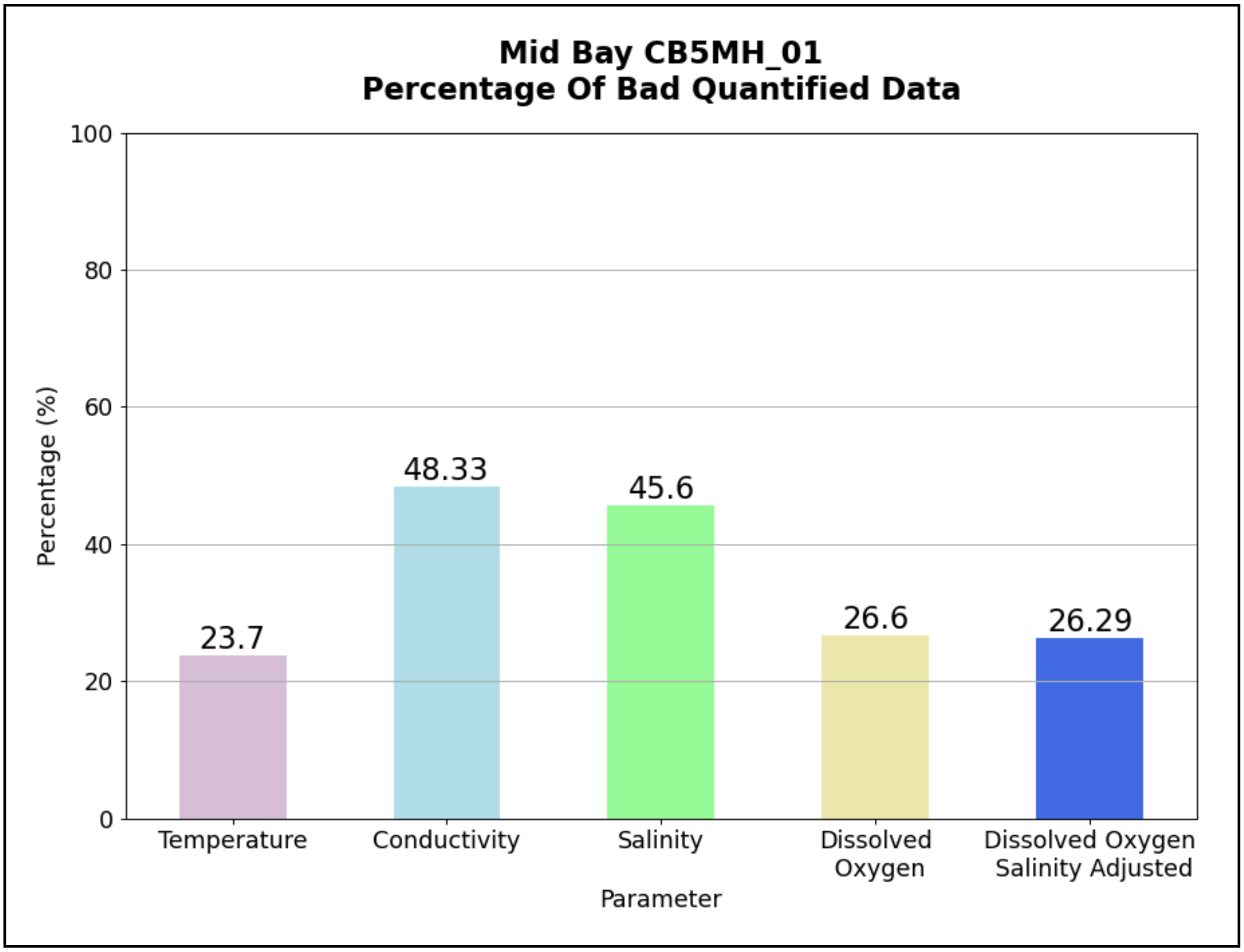
## 5.5 Mid-Bay Metrics

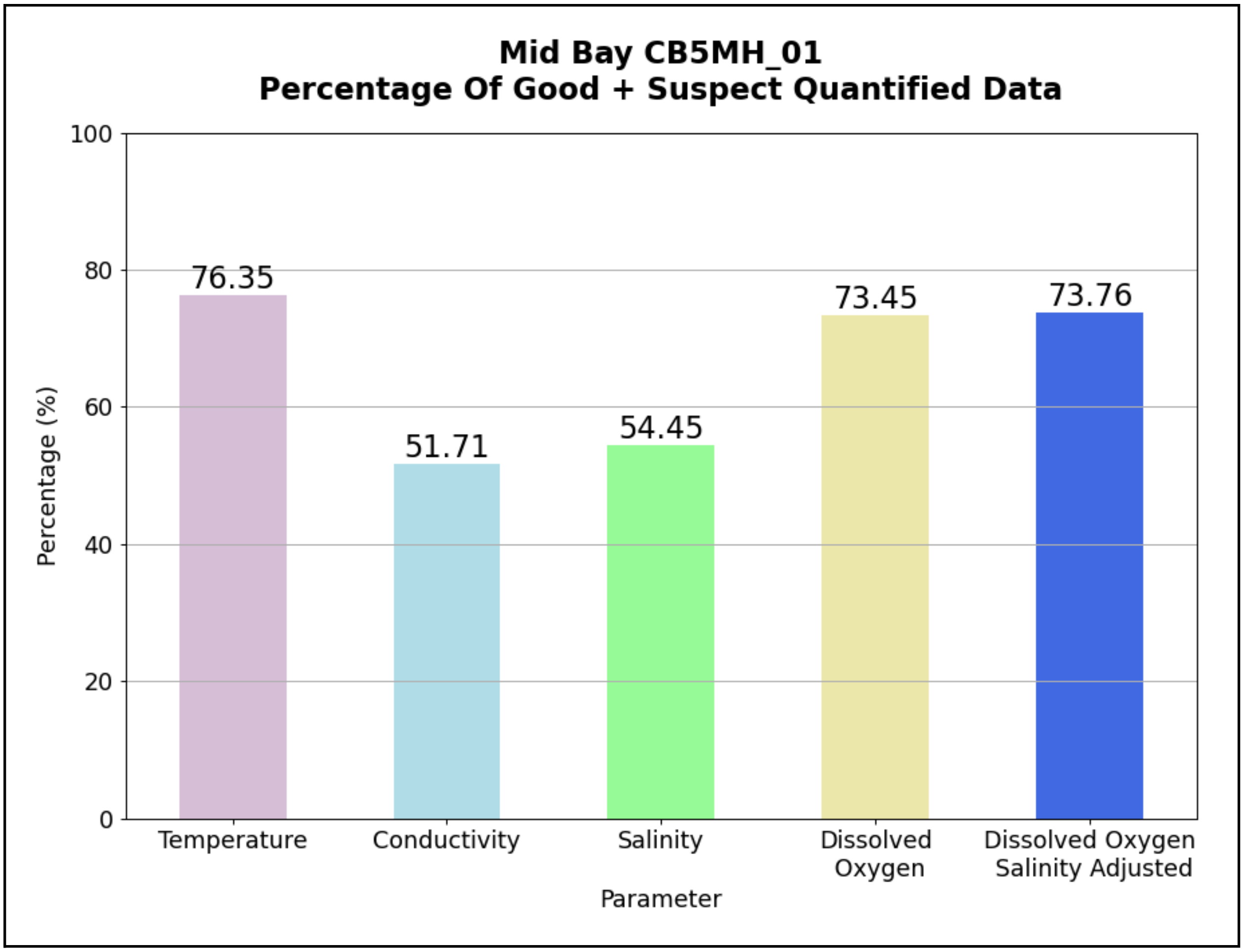
### Mid-Bay Figures




Mid Bay CB5MH_01
Percentage Of Good Quantified Data
Percentage (%)
100
80
60
40
20
0
68.57
37.32
47.64
57.78
35.84
Temperature
Conductivity
Salinity
Dissolved Oxygen
Dissolved Oxygen Salinity Adjusted
Parameter


Mid Bay CB5MH_01
Percentage Of Suspect Quantified Data
Percentage (%)
0
20
40
60
80
100
7.78
14.39
6.81
15.67
37.91
Temperature
Conductivity
Salinity
Dissolved Oxygen
Dissolved Oxygen Salinity Adjusted
Parameter


Mid Bay CB5MH_01
Percentage Of Bad Quantified Data
Percentage (%)
100
80
60
40
20
0
23.7
48.33
45.6
26.6
26.29
Temperature
Conductivity
Salinity
Dissolved Oxygen
Dissolved Oxygen Salinity Adjusted
Parameter

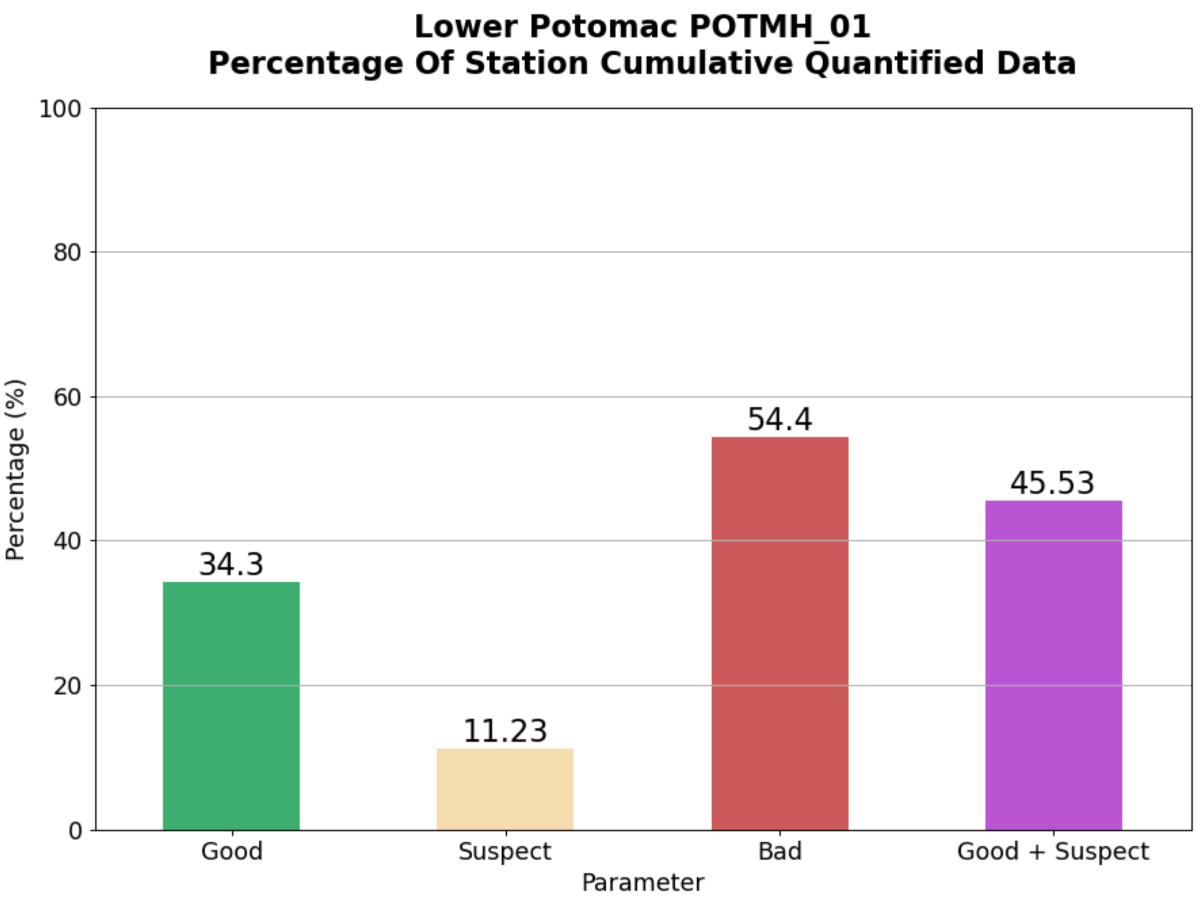

Mid Bay CB5MH_01
Percentage Of Good + Suspect Quantified Data
Percentage (%)
100
80
60
40
20
0
76.35
51.71
54.45
73.45
73.76
Temperature
Conductivity
Salinity
Dissolved Oxygen
Dissolved Oxygen Salinity Adjusted
Parameter

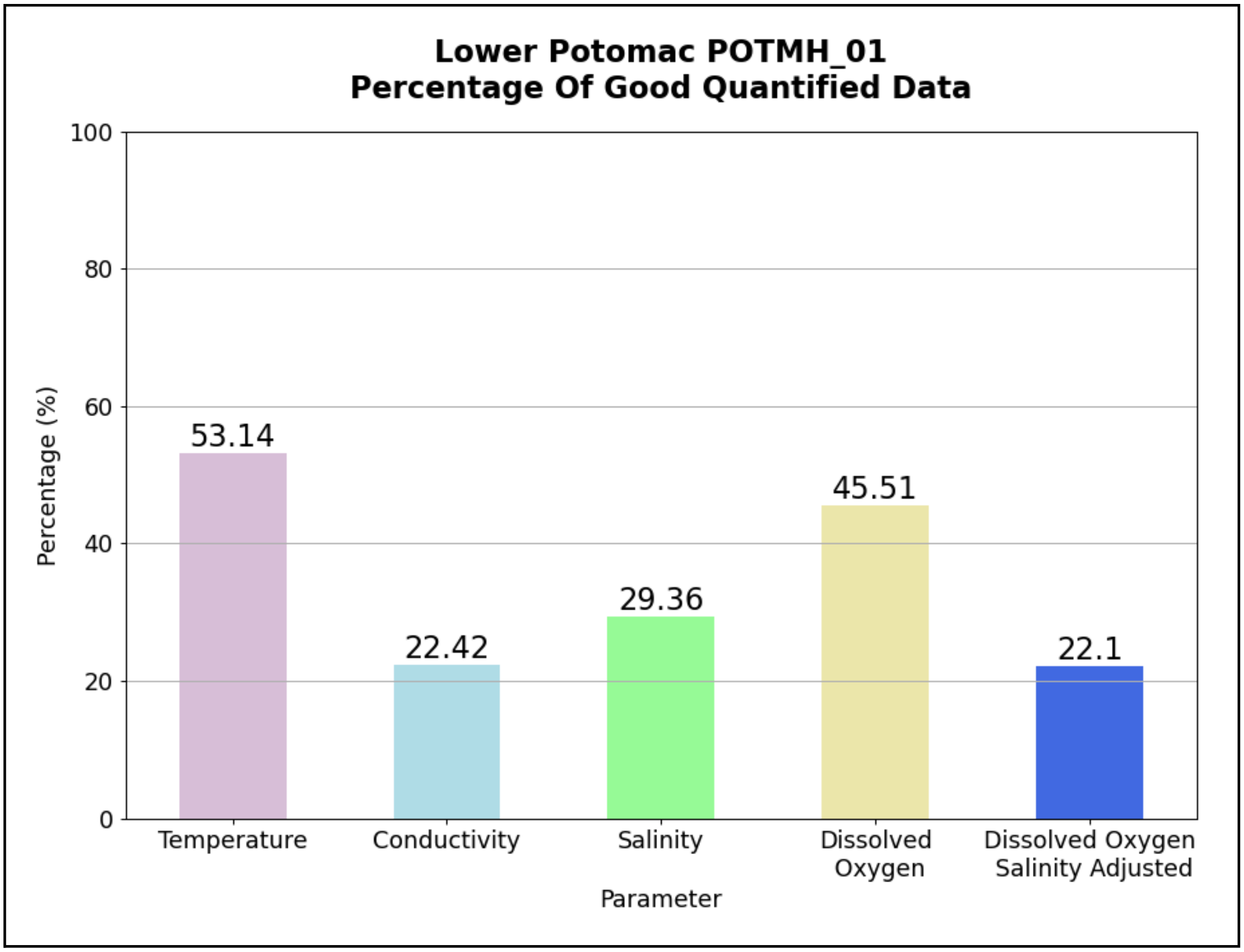
## Mid-Bay Tables

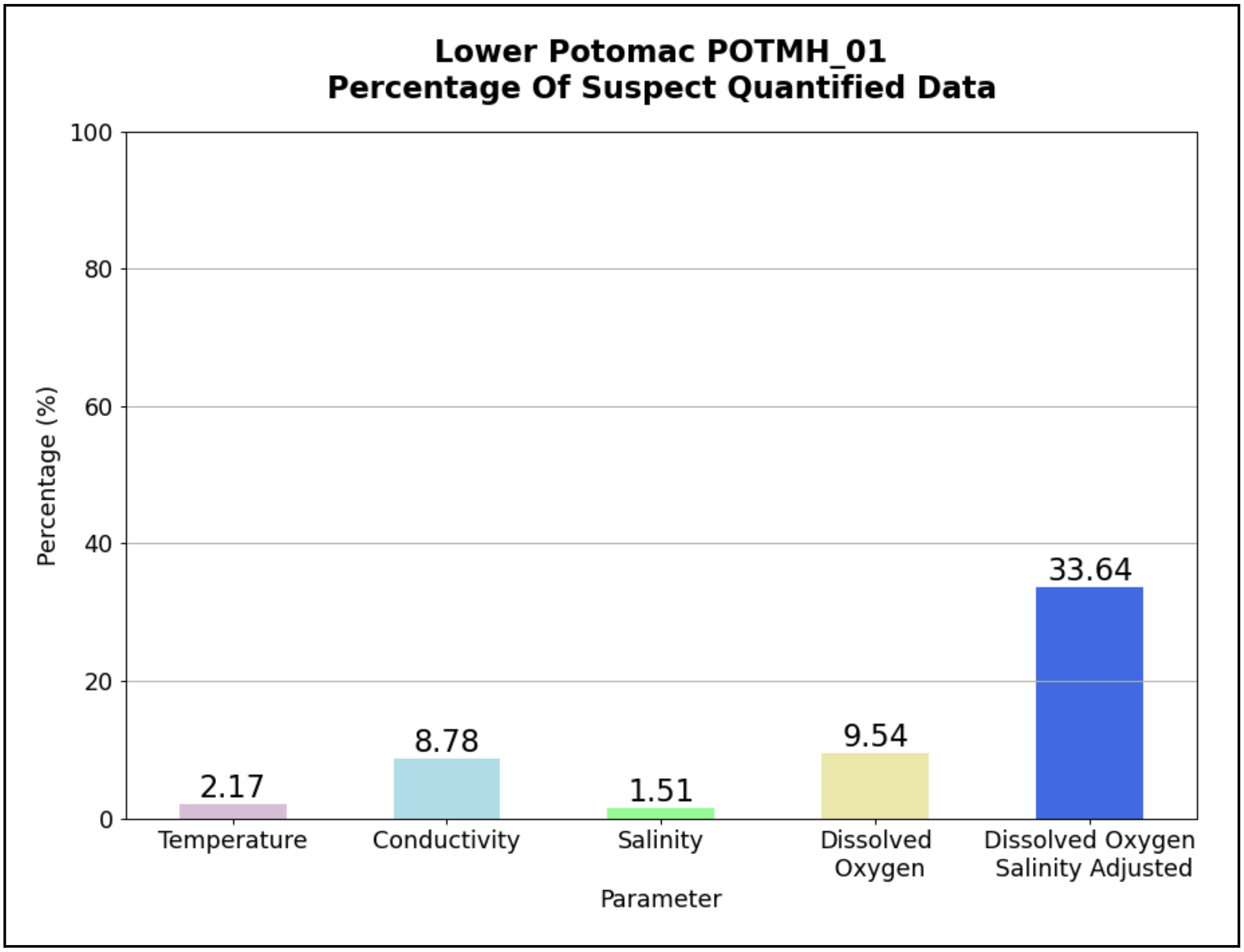
| **Mid-Bay - Good Data** | **% of Quantified Data** |
|---|---|
| Temperature | 68.57 |
| Conductivity | 37.32 |
| Salinity | 47.64 |
| Dissolved Oxygen | 57.78 |
| Dissolved Oxygen Salinity Adjusted | |
| **Mid-Bay - Suspect** | |
| Temperature | 7.78 |
| Conductivity | 14.39 |
| Salinity | 6.81 |
| Dissolved Oxygen | 15.67 |
| Dissolved Oxygen Salinity Adjusted | |
| **Mid-Bay - Bad** | |
| Temperature | 23.7 |
| Conductivity | 48.33 |
| Salinity | 45.6 |
| Dissolved Oxygen | 26.6 |
| Dissolved Oxygen Salinity Adjusted | |
| **Mid-Bay - Good + Suspect** | |
| Temperature | 76.35 |
| Conductivity | 51.71 |
| Salinity | 54.45 |
| Dissolved Oxygen | 73.45 |
| Dissolved Oxygen Salinity Adjusted | |
| **Mid-Bay - Whole Station** | |
| Good | 49.28 |
| Suspect | 16.58 |
| Bad | 34.19 |
| Good + Suspect | 65.86 |

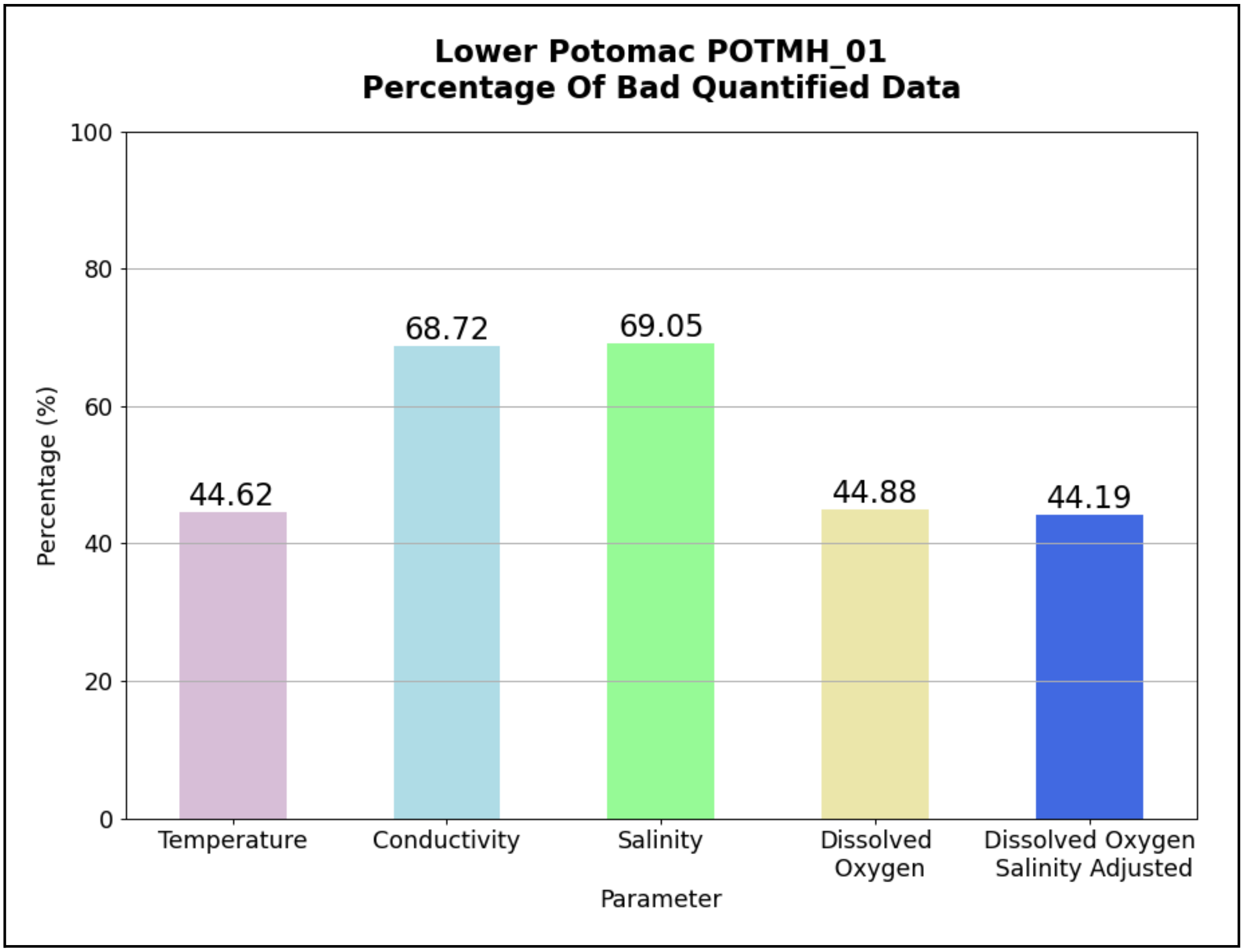
## 5.6 Lower Potomac Metrics

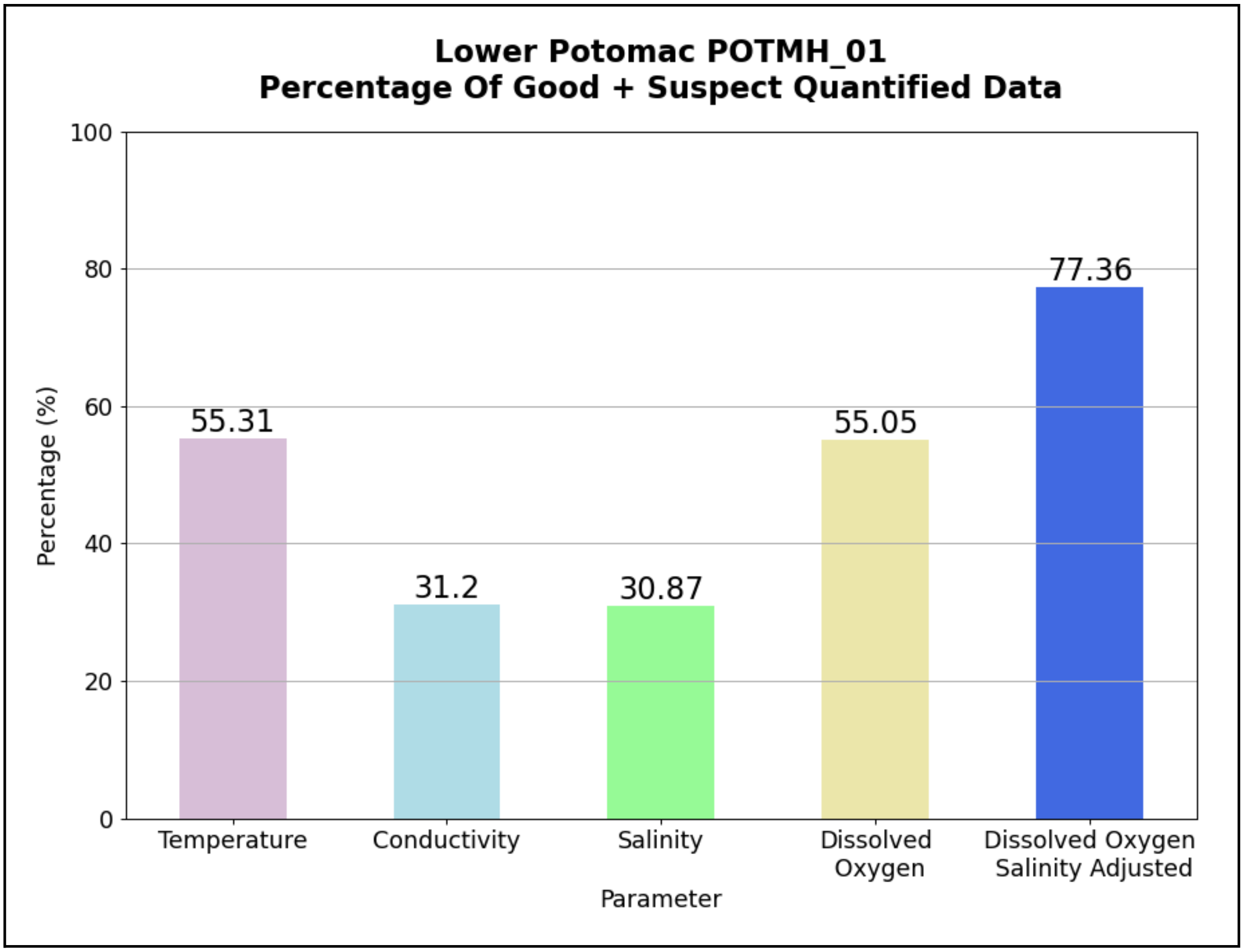
### Lower Potomac Figures




Lower Potomac POTMH_01
Percentage Of Good Quantified Data
Percentage (%)
0
20
40
60
80
100
53.14
22.42
29.36
45.51
22.1
Temperature
Conductivity
Salinity
Dissolved Oxygen
Dissolved Oxygen Salinity Adjusted
Parameter


Lower Potomac POTMH_01
Percentage Of Suspect Quantified Data
Percentage (%)
100
80
60
40
20
0
2.17
8.78
1.51
9.54
33.64
Temperature
Conductivity
Salinity
Dissolved Oxygen
Dissolved Oxygen Salinity Adjusted
Parameter


Lower Potomac POTMH_01
Percentage Of Bad Quantified Data
Percentage (%)
100
80
60
40
20
0
44.62
68.72
69.05
44.88
44.19
Temperature
Conductivity
Salinity
Dissolved Oxygen
Dissolved Oxygen Salinity Adjusted
Parameter


Lower Potomac POTMH_01
Percentage Of Good + Suspect Quantified Data
Percentage (%)
100
80
60
40
20
0
55.31
31.2
30.87
55.05
77.36
Temperature
Conductivity
Salinity
Dissolved Oxygen
Dissolved Oxygen Salinity Adjusted
Parameter

## Lower Potomac Tables

| **Lower Potomac - Good Data** | **% of Quantified Data** |
|---|---:|
| Temperature | 53.14 |
| Conductivity | 22.42 |
| Salinity | 29.36 |
| Dissolved Oxygen | 45.51 |
| Dissolved Oxygen Salinity Adjusted | 22.1 |
| **Lower Potomac - Suspect** | |
| Temperature | 2.17 |
| Conductivity | 8.78 |
| Salinity | 1.51 |
| Dissolved Oxygen | 9.54 |
| Dissolved Oxygen Salinity Adjusted | 33.64 |
| **Lower Potomac - Bad** | |
| Temperature | 44.62 |
| Conductivity | 68.72 |
| Salinity | 69.05 |
| Dissolved Oxygen | 44.88 |
| Dissolved Oxygen Salinity Adjusted | 44.19 |
| **Lower Potomac - Good + Suspect** | |
| Temperature | 55.31 |
| Conductivity | 31.2 |
| Salinity | 30.87 |
| Dissolved Oxygen | 55.05 |
| Dissolved Oxygen Salinity Adjusted | 77.36 |
| **Lower Potomac - Whole Station** | |
| Good | 34.3 |
| Suspect | 11.23 |
| Bad | 54.4 |
| Good + Suspect | 45.53 |

# 6. References

Benson, B.B. and Krause Jr, D., 1984. The concentration and isotopic fractionation of oxygen dissolved in freshwater and seawater in equilibrium with the atmosphere 1. Limnology and oceanography, 29(3), pp.620-632.

Bever, A.J., Friedrichs, M.A., Friedrichs, C.T. and Scully, M.E., 2018. Estimating hypoxic volume in the Chesapeake Bay using two continuously sampled oxygen profiles. Journal of Geophysical Research: Oceans, 123(9), pp.6392-6407.

Michael, B., Ebersole, E.L., Trice, M. and Heyer, C.J., 2021. Quality assurance project plan for the Maryland Department of Natural Resources Chesapeake Bay shallow water quality monitoring program. Maryland Department of Natural Resources.

NOAA Chesapeake Bay Office, 2023. Chesapeake Bay Water-Column Hypoxia Monitoring Quality Assurance Project Plan (QAPP). https://www.chesapeakebay.net/what/publications/chesapeake-bay-water-column-hypoxia-monitoring-quality-assurance-project-plan-qapp

Rice, E.W., Bridgewater, L. and American Public Health Association eds., 2012. Standard methods for the examination of water and wastewater (Vol. 10). Washington, DC: American public health association.

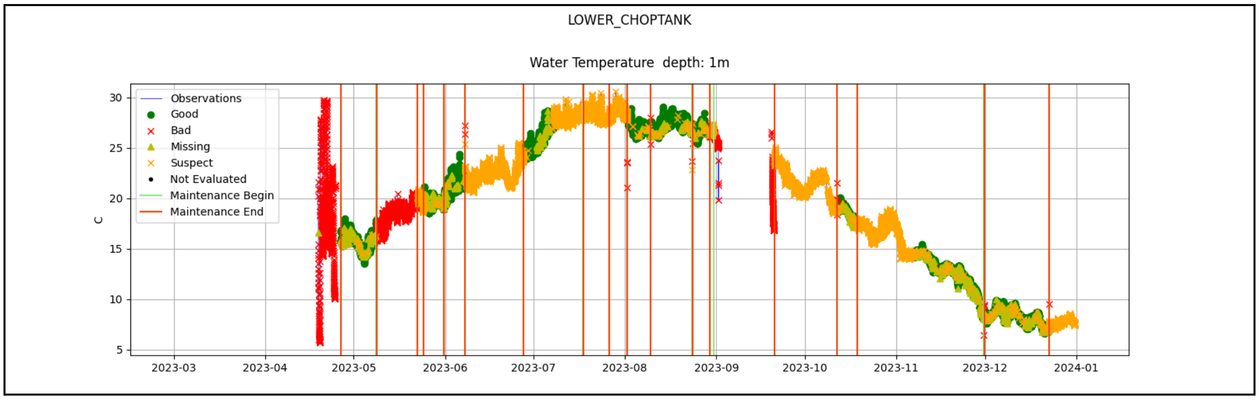
# Appendix A: Time Series Plots

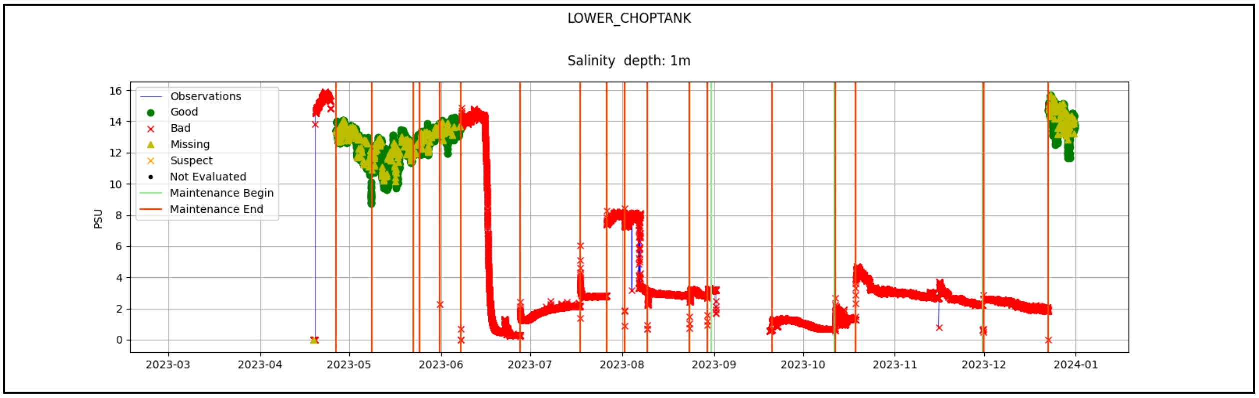
## A.1 Time Series Plots Legend

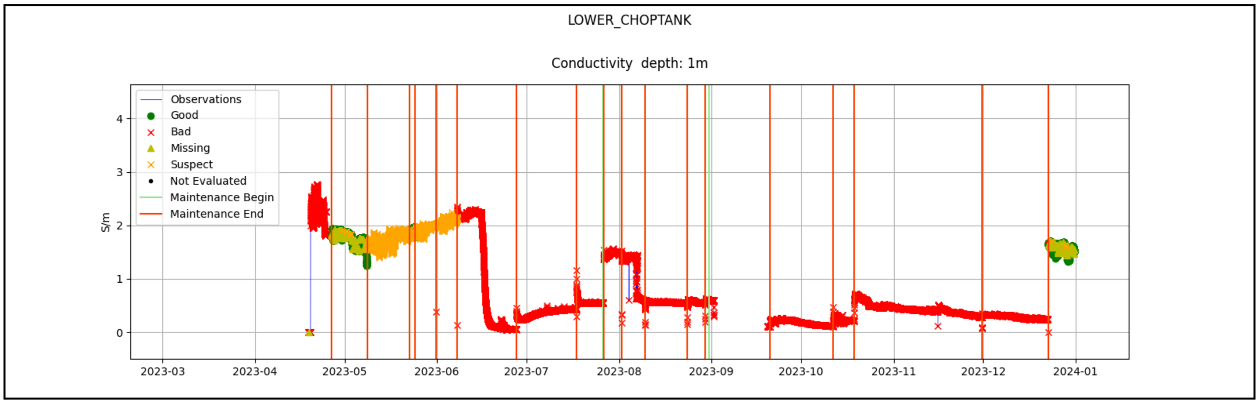
Yearly and monthly time series plots in sections A.2 and A.3, respectfully, illustrate trends in annual data for water-quality parameters collected by monitoring buoys deployed in three sections of the Chesapeake Bay. The monitoring station, depth of data collection, and depicted parameter are listed at the top of the figure. The top left or right corner of each figure features a key that describes how colors and shapes in each figure correspond to data. The y-axis represents the unit of measurement of a given parameter, while the x-axis represents the date. Plots include DO, temperature, DO adjusted, conductivity, and salinity.

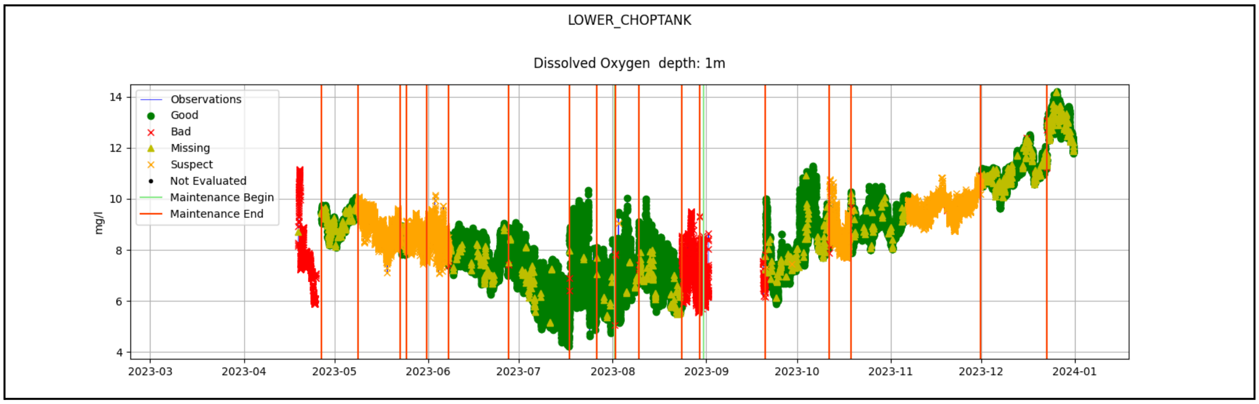
## A.2 Yearly

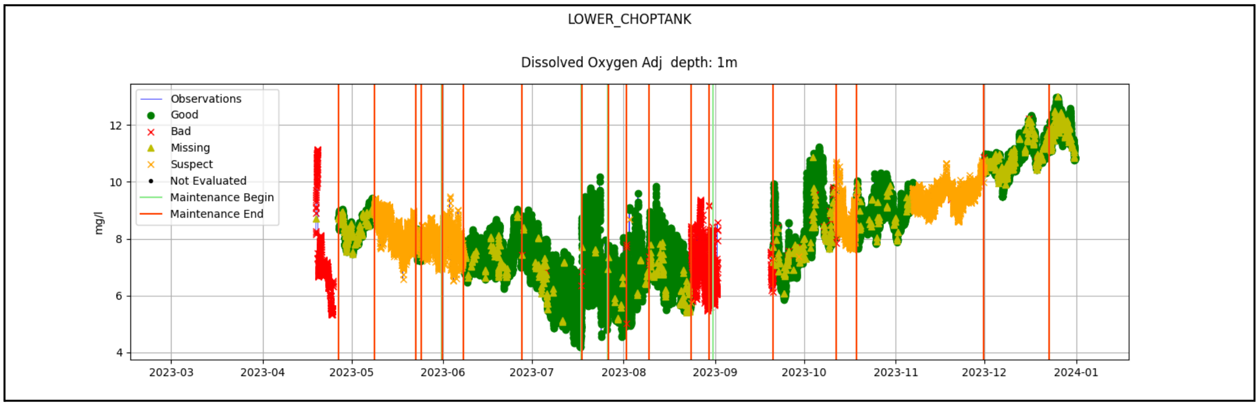
### Lower Choptank: d=1m



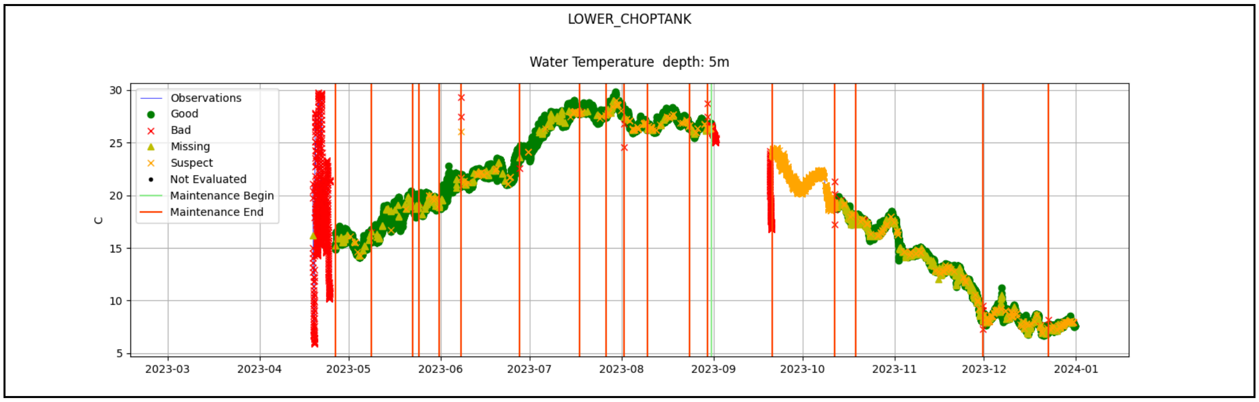


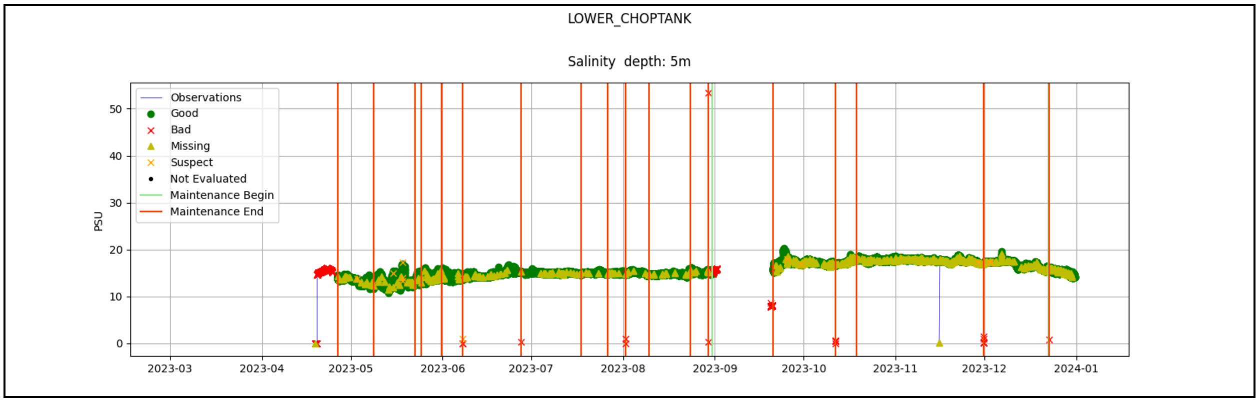

LOWER_CHOPTANK
Conductivity depth: 1m
S/m
4
3
2
1
0
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
2023-03
2023-04
2023-05
2023-06
2023-07
2023-08
2023-09
2023-10
2023-11
2023-12
2024-01

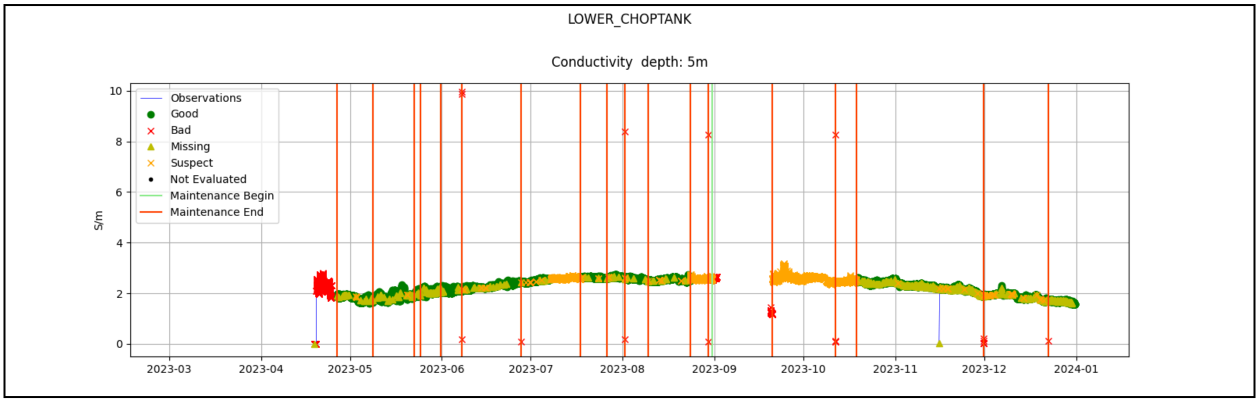

LOWER_CHOPTANK
Dissolved Oxygen depth: 1m
mg/l
14
12
10
8
6
4
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
2023-03
2023-04
2023-05
2023-06
2023-07
2023-08
2023-09
2023-10
2023-11
2023-12
2024-01

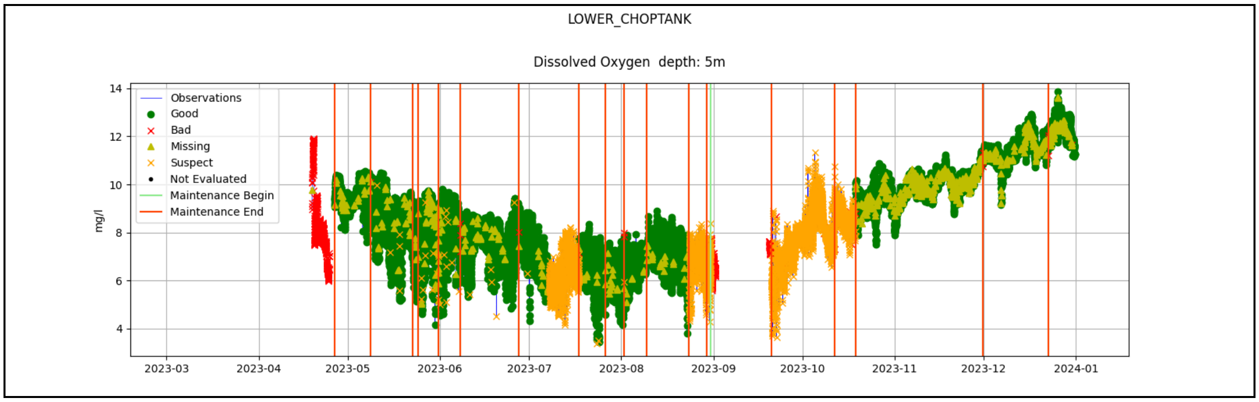

LOWER_CHOPTANK
Dissolved Oxygen Adj depth: 1m
mg/l
12
10
8
6
4
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
2023-03
2023-04
2023-05
2023-06
2023-07
2023-08
2023-09
2023-10
2023-11
2023-12
2024-01

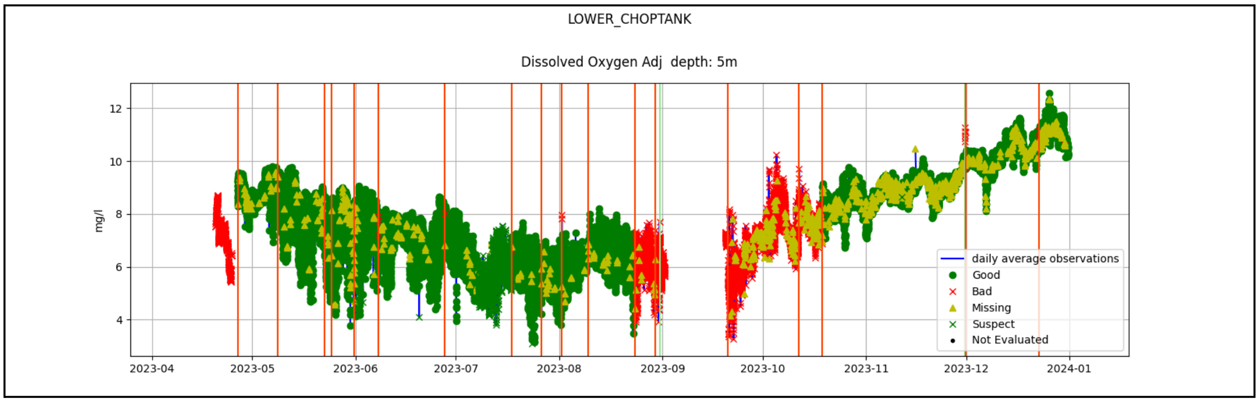
# Lower Choptank: d=5m



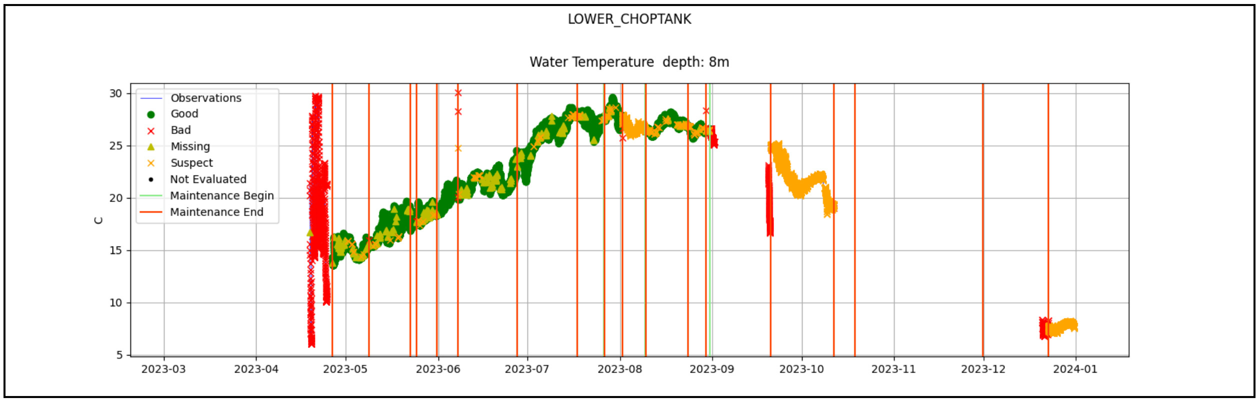


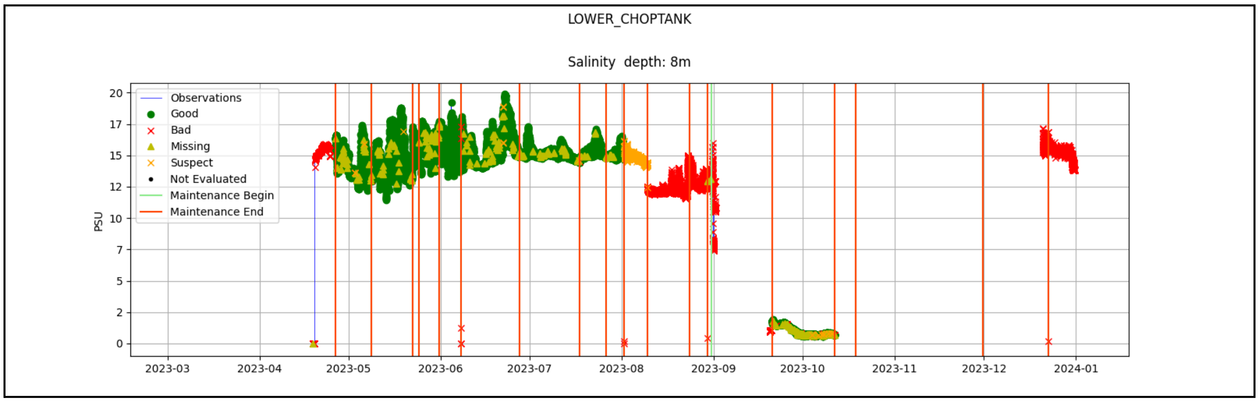


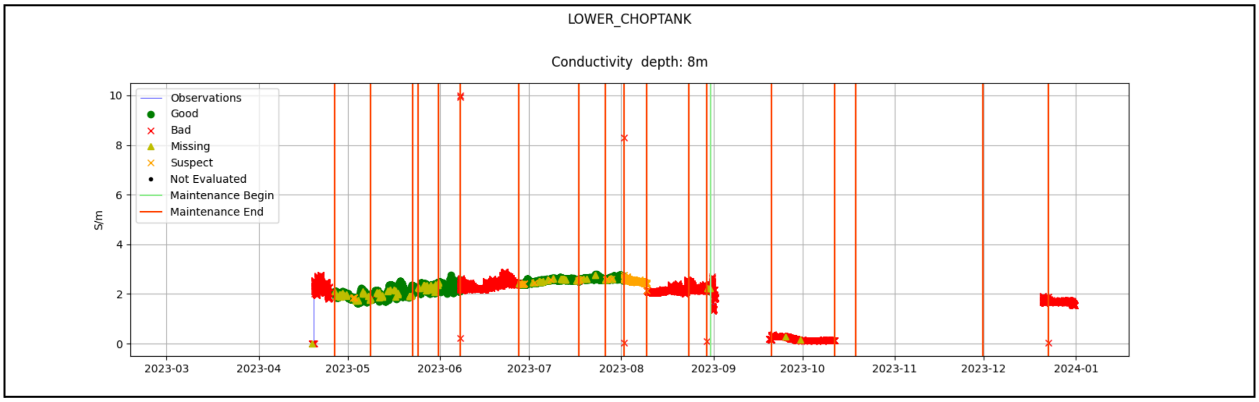

LOWER_CHOPTANK
Dissolved Oxygen depth: 5m
mg/l
14
12
10
8
6
4
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
2023-03
2023-04
2023-05
2023-06
2023-07
2023-08
2023-09
2023-10
2023-11
2023-12
2024-01

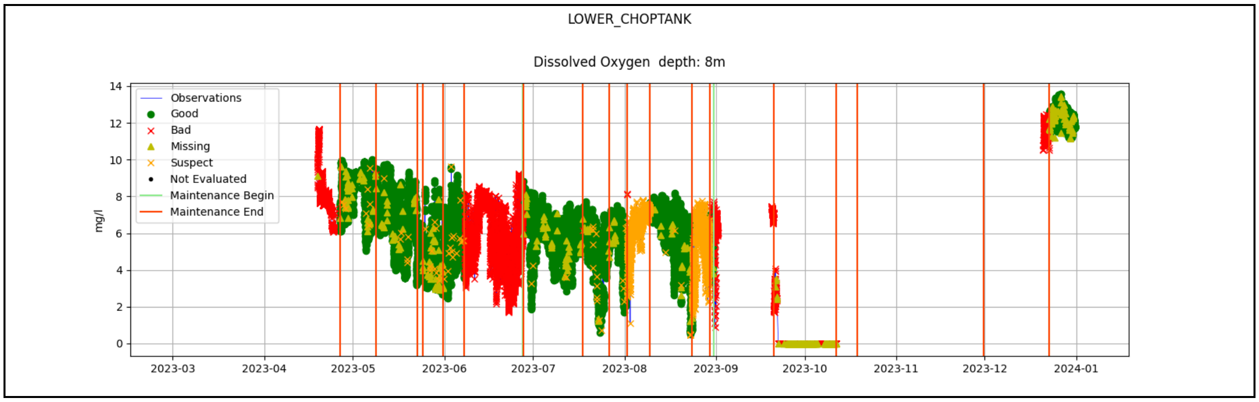

LOWER_CHOPTANK
Dissolved Oxygen Adj depth: 5m
mg/l
12
10
8
6
4
daily average observations
Good
Bad
Missing
Suspect
Not Evaluated
2023-04
2023-05
2023-06
2023-07
2023-08
2023-09
2023-10
2023-11
2023-12
2024-01

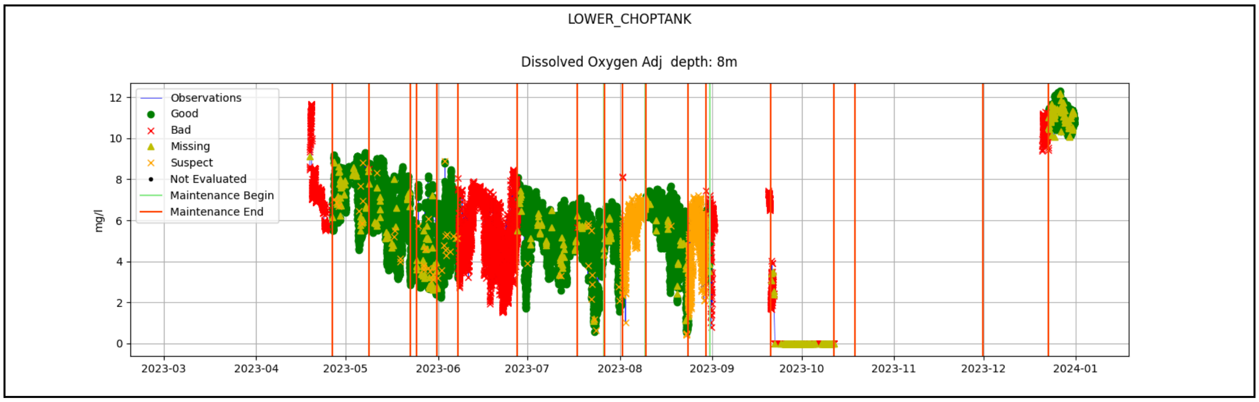
## Lower Choptank: d=8m



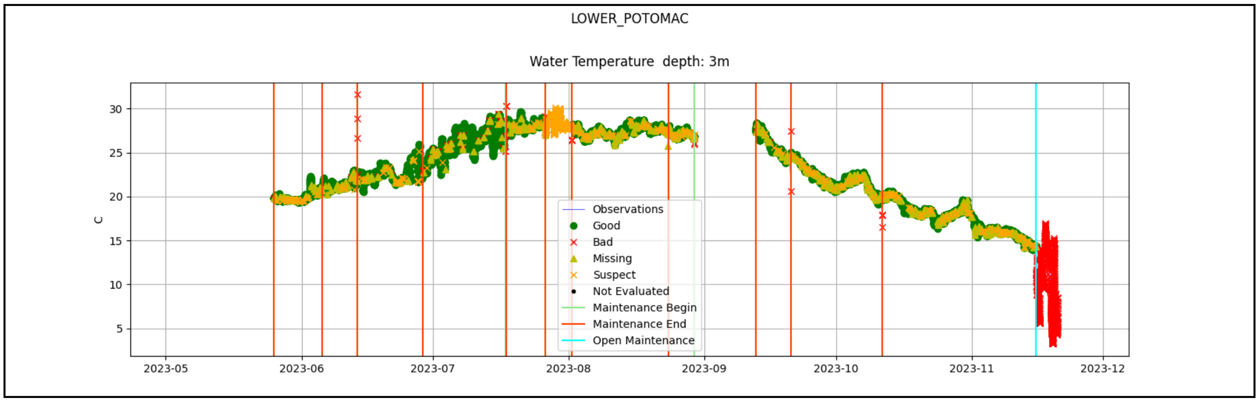


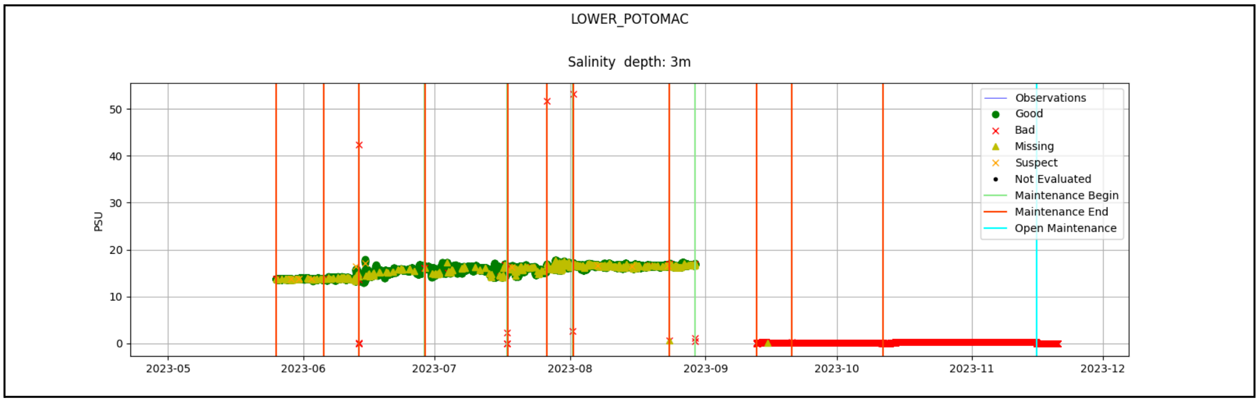


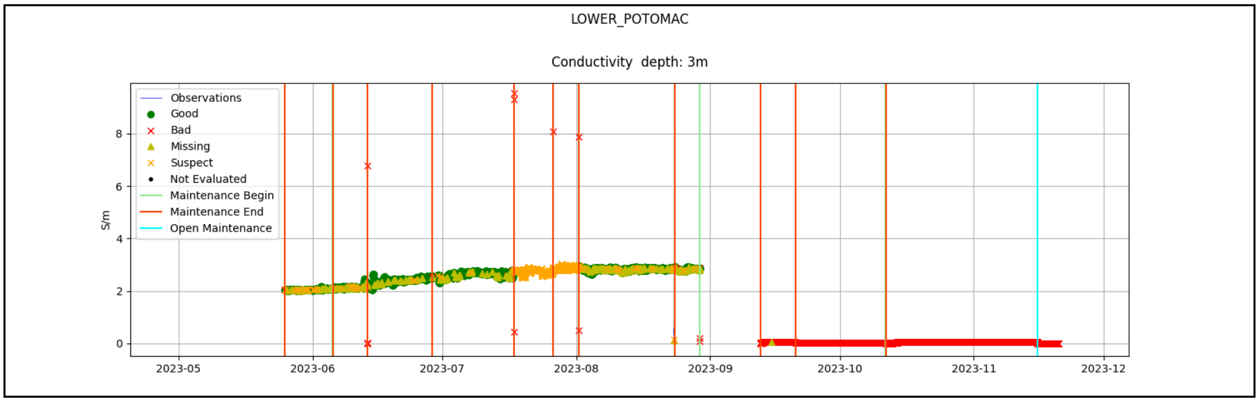

LOWER_CHOPTANK
Dissolved Oxygen depth: 8m
mg/l
0
2
4
6
8
10
12
14
2023-03
2023-04
2023-05
2023-06
2023-07
2023-08
2023-09
2023-10
2023-11
2023-12
2024-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

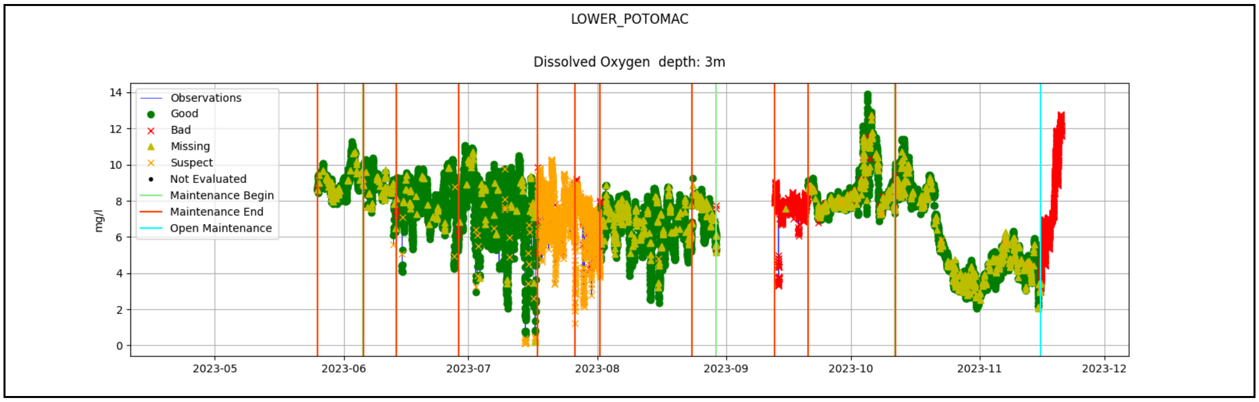

LOWER_CHOPTANK
Dissolved Oxygen Adj depth: 8m
mg/l
0
2
4
6
8
10
12
2023-03
2023-04
2023-05
2023-06
2023-07
2023-08
2023-09
2023-10
2023-11
2023-12
2024-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

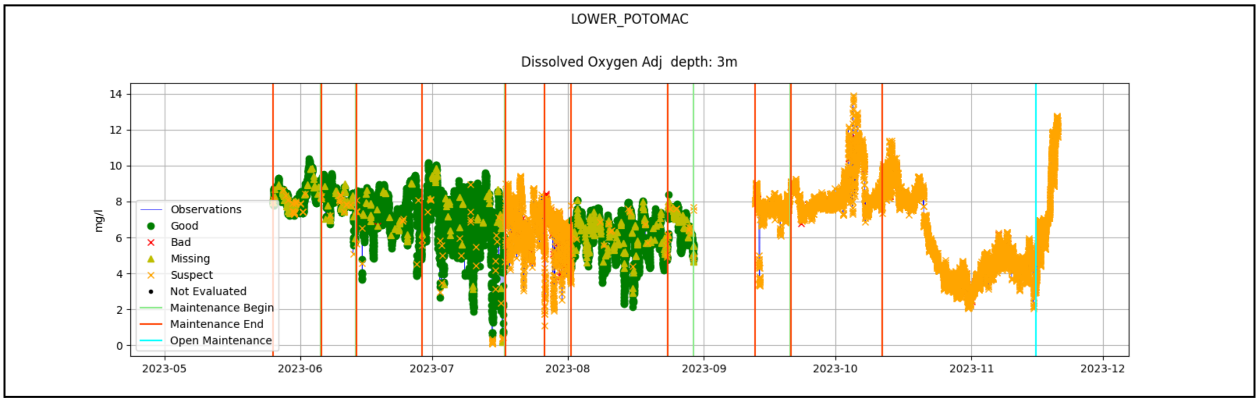
# Lower Potomac: d=3m



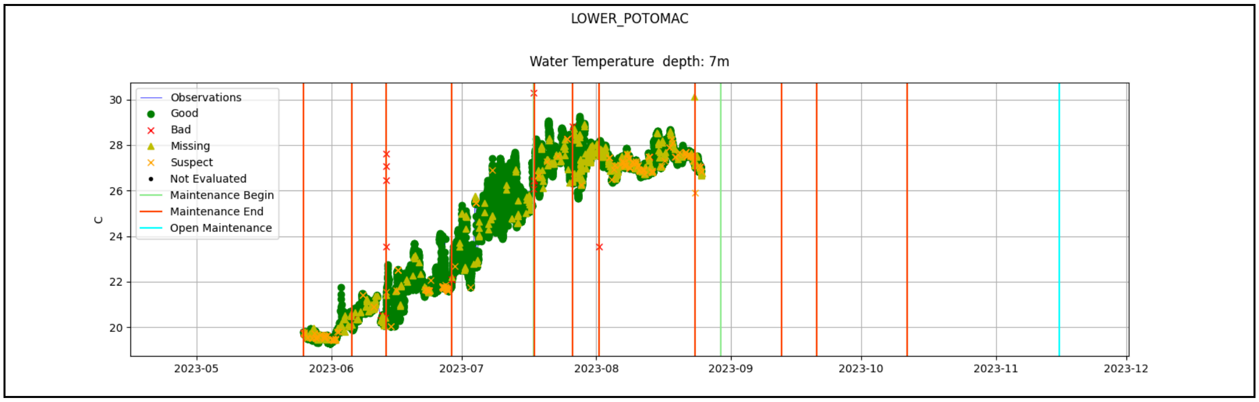


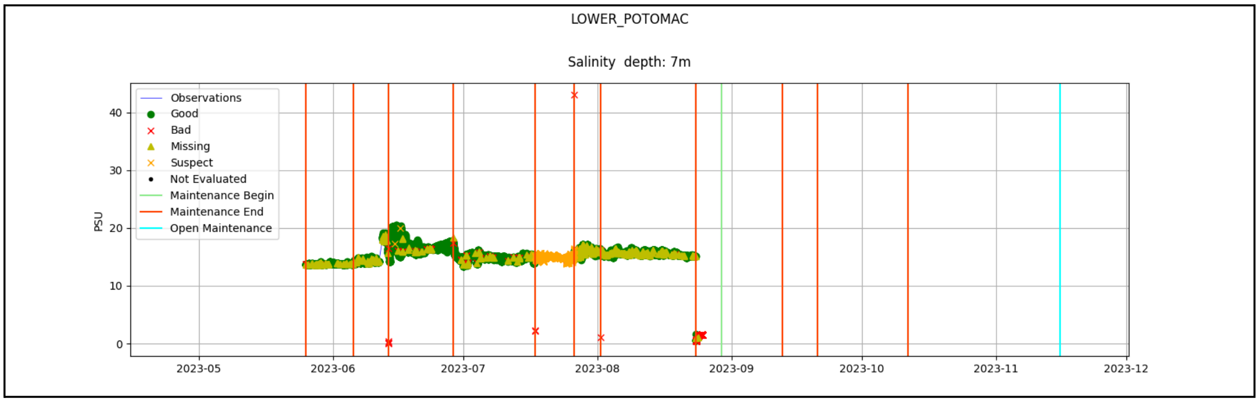


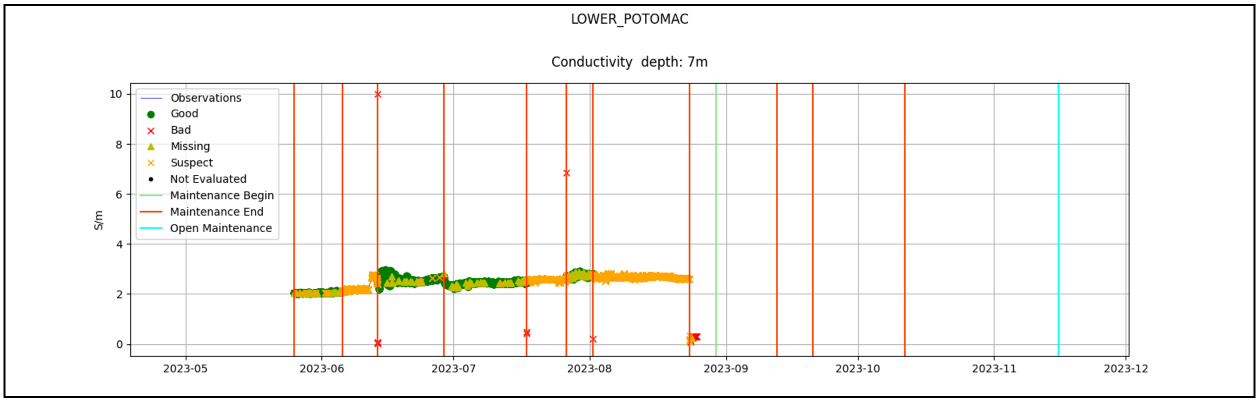

LOWER_POTOMAC
Dissolved Oxygen depth: 3m
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Open Maintenance
mg/l
0
2
4
6
8
10
12
14
2023-05
2023-06
2023-07
2023-08
2023-09
2023-10
2023-11
2023-12


LOWER_POTOMAC
Dissolved Oxygen Adj depth: 3m
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Open Maintenance
mg/l
0
2
4
6
8
10
12
14
2023-05
2023-06
2023-07
2023-08
2023-09
2023-10
2023-11
2023-12

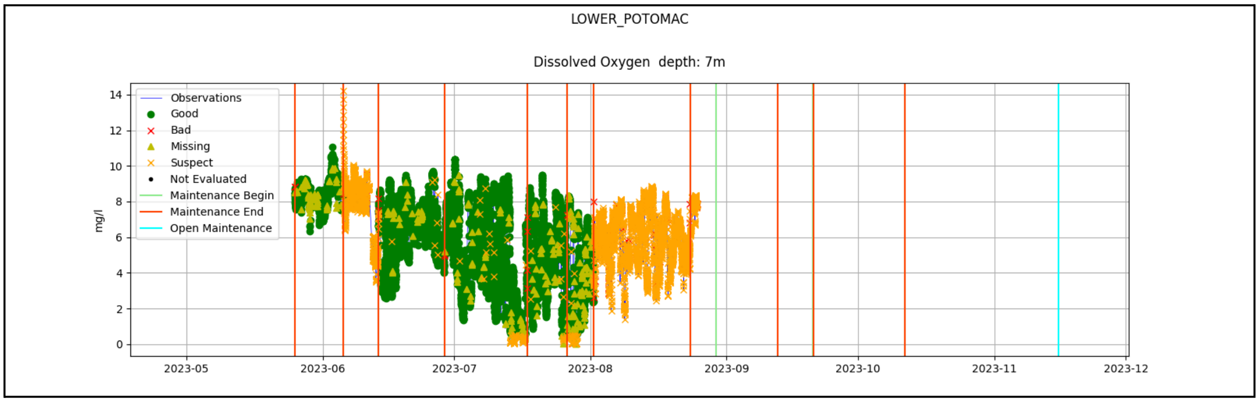
# Lower Potomac: 7m



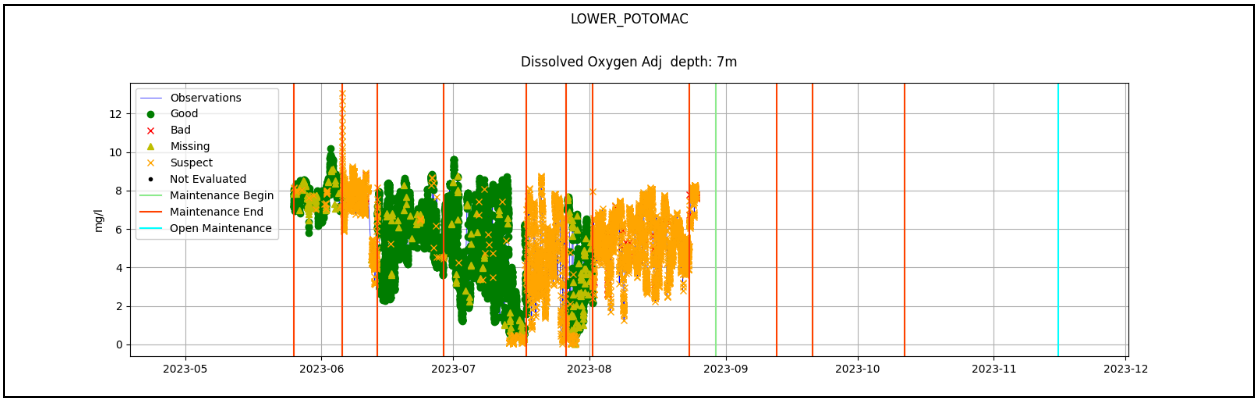



LOWER_POTOMAC

Conductivity depth: 7m

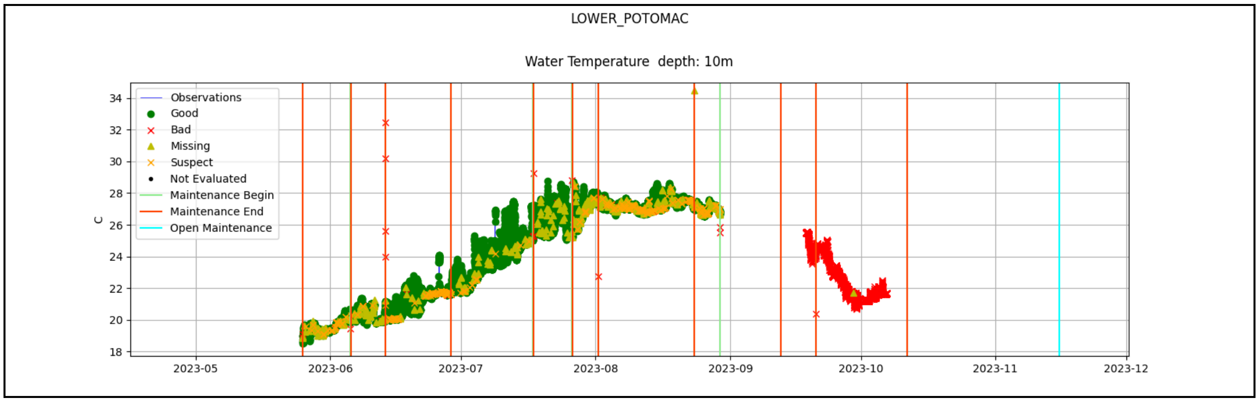

LOWER_POTOMAC

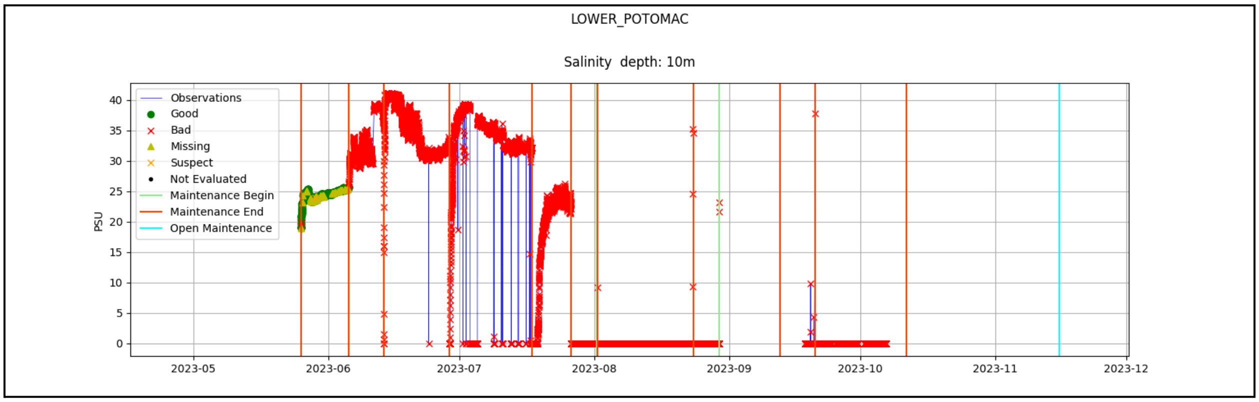
Dissolved Oxygen depth: 7m

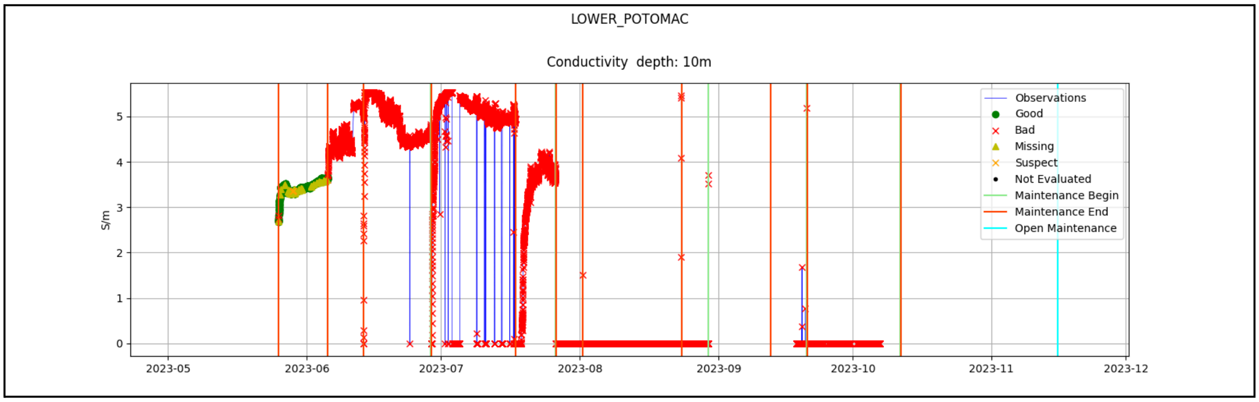

LOWER_POTOMAC

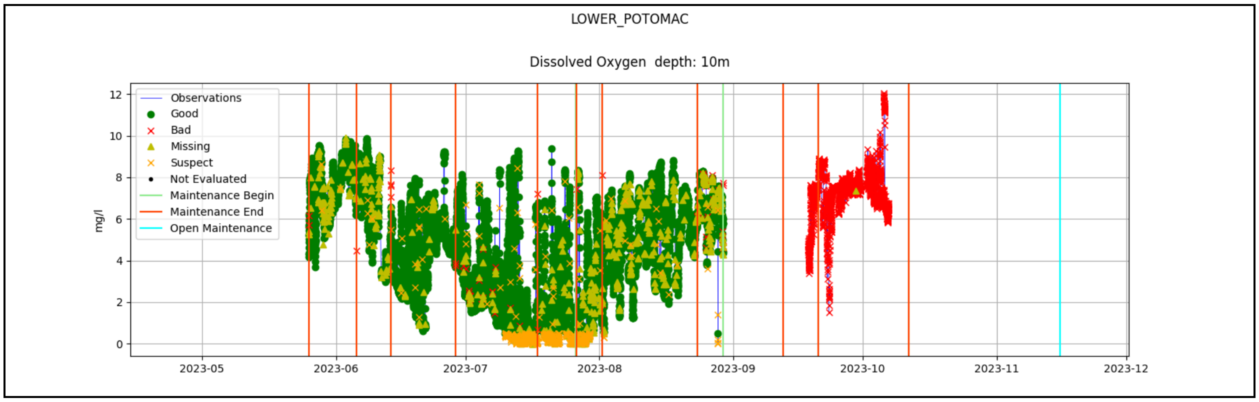
Dissolved Oxygen Adj depth: 7m

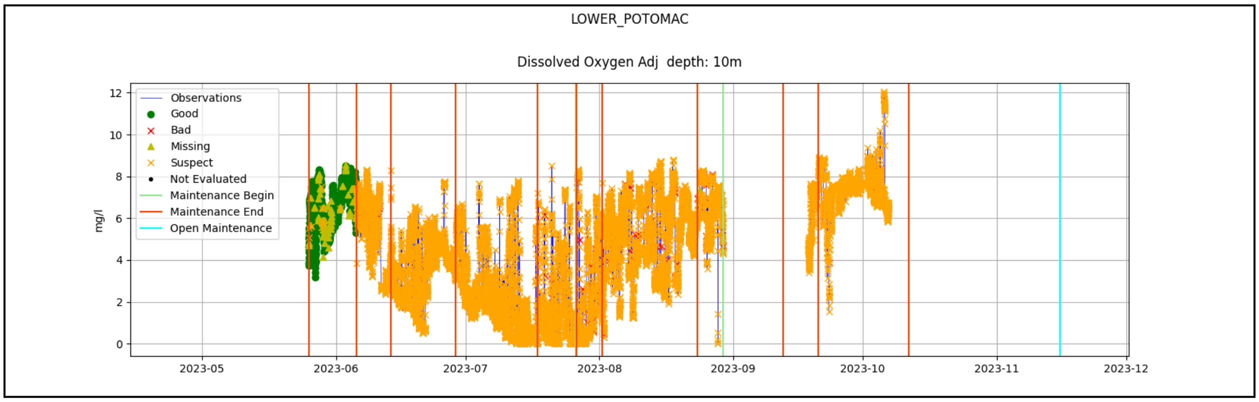
## Lower Potomac: d=10m



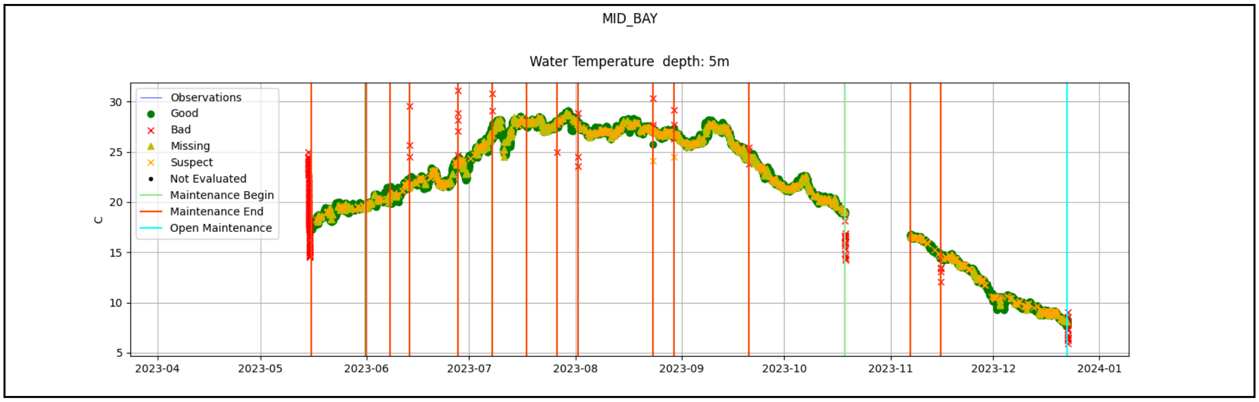


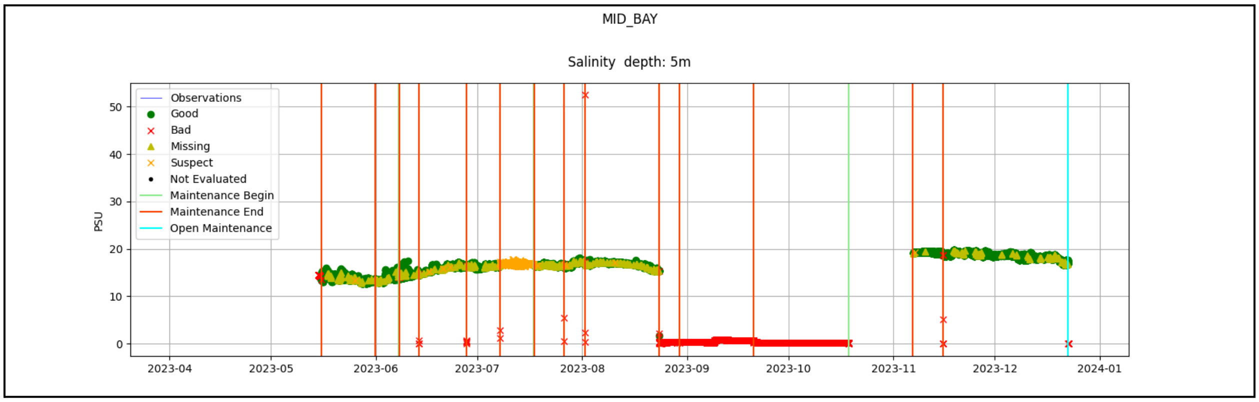


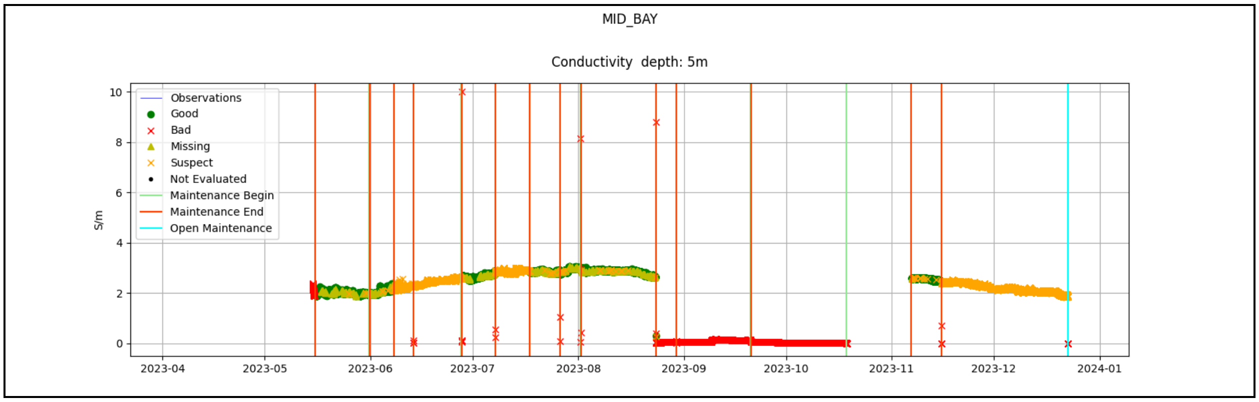

LOWER_POTOMAC
Dissolved Oxygen depth: 10m
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Open Maintenance
mg/l
0
2
4
6
8
10
12
2023-05
2023-06
2023-07
2023-08
2023-09
2023-10
2023-11
2023-12

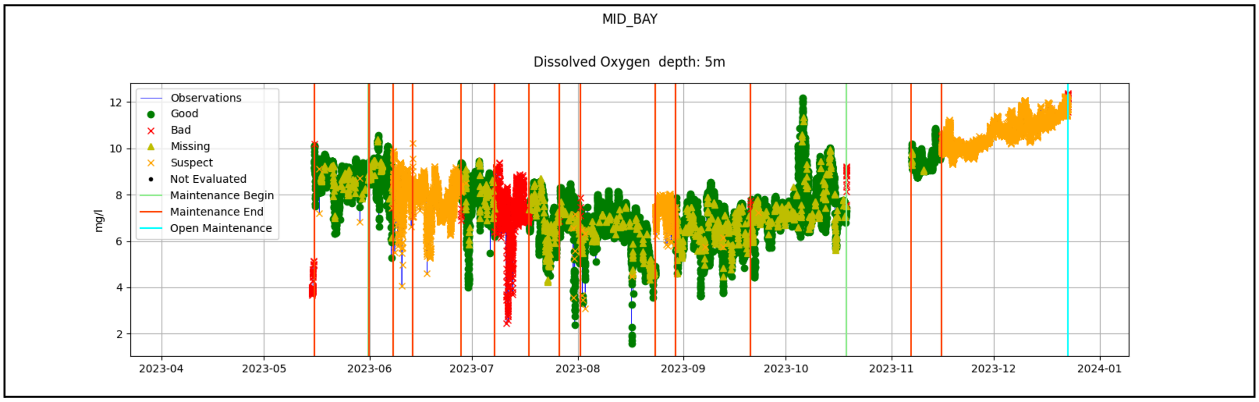

LOWER_POTOMAC
Dissolved Oxygen Adj depth: 10m
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Open Maintenance
mg/l
0
2
4
6
8
10
12
2023-05
2023-06
2023-07
2023-08
2023-09
2023-10
2023-11
2023-12

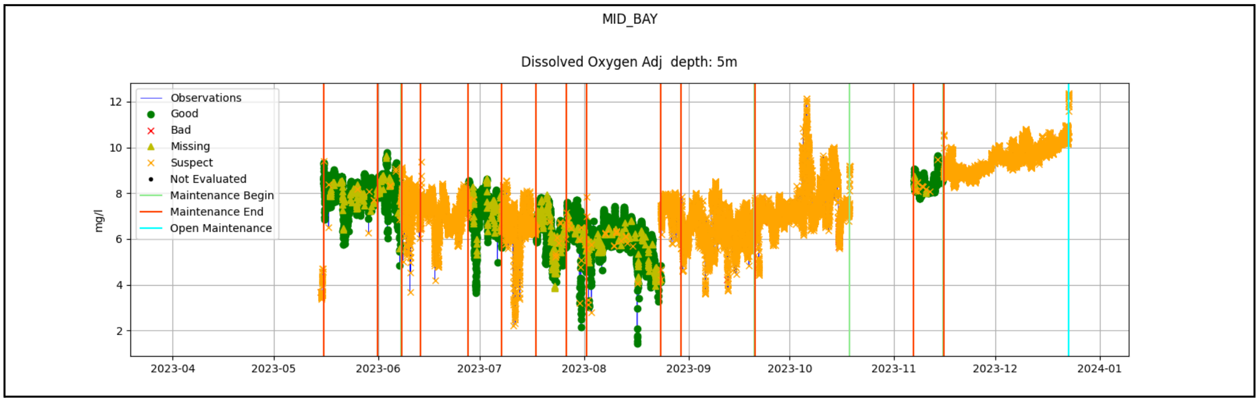
# Mid-Bay: 5m


MID_BAY
Water Temperature depth: 5m
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Open Maintenance
C
30
25
20
15
10
5
2023-04
2023-05
2023-06
2023-07
2023-08
2023-09
2023-10
2023-11
2023-12
2024-01

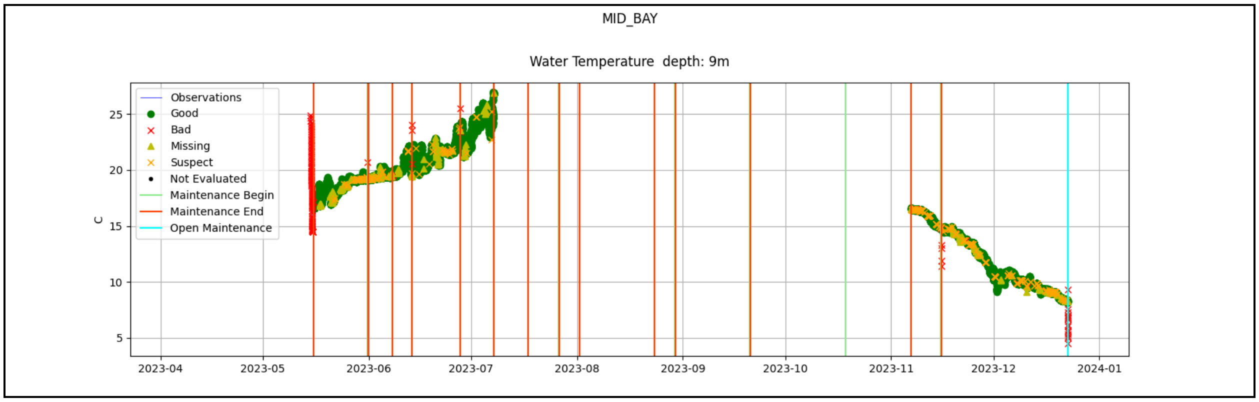

MID_BAY
Salinity depth: 5m
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Open Maintenance
PSU
50
40
30
20
10
0
2023-04
2023-05
2023-06
2023-07
2023-08
2023-09
2023-10
2023-11
2023-12
2024-01

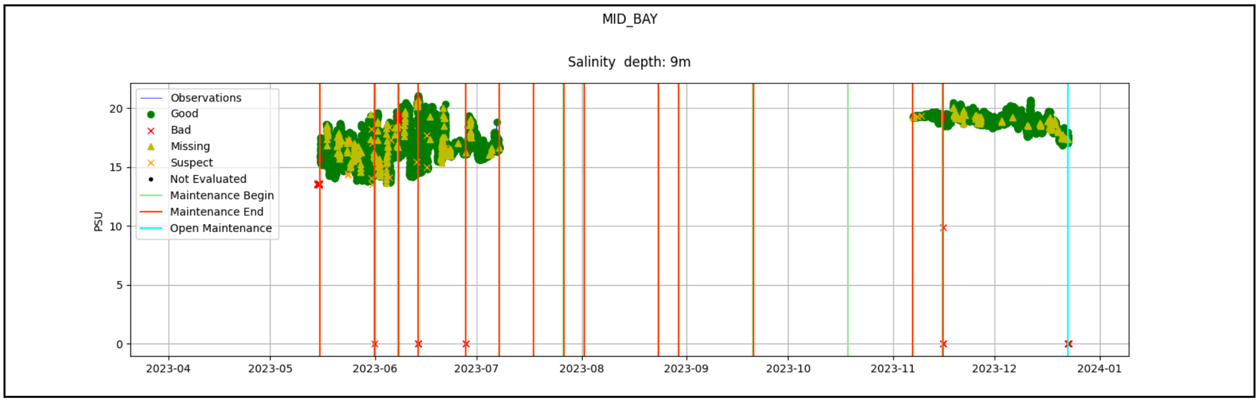

MID_BAY
Conductivity depth: 5m
S/m
10
8
6
4
2
0
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Open Maintenance
2023-04
2023-05
2023-06
2023-07
2023-08
2023-09
2023-10
2023-11
2023-12
2024-01

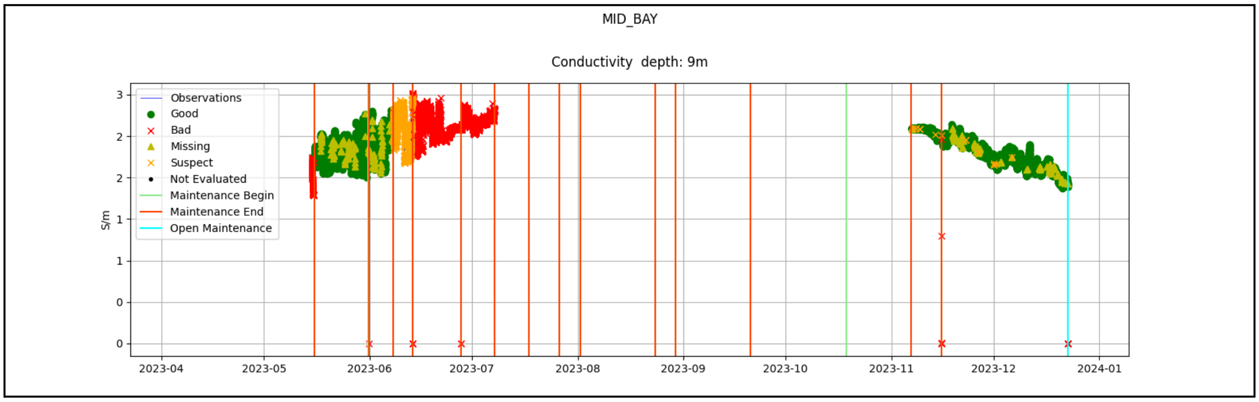

MID_BAY
Dissolved Oxygen depth: 5m
mg/l
12
10
8
6
4
2
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Open Maintenance
2023-04
2023-05
2023-06
2023-07
2023-08
2023-09
2023-10
2023-11
2023-12
2024-01

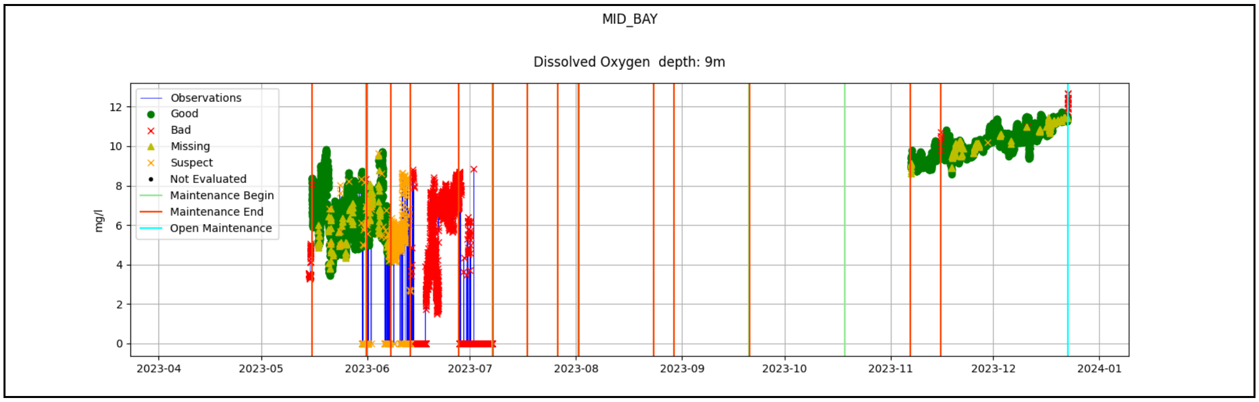

MID_BAY
Dissolved Oxygen Adj depth: 5m
mg/l
12
10
8
6
4
2
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Open Maintenance
2023-04
2023-05
2023-06
2023-07
2023-08
2023-09
2023-10
2023-11
2023-12
2024-01

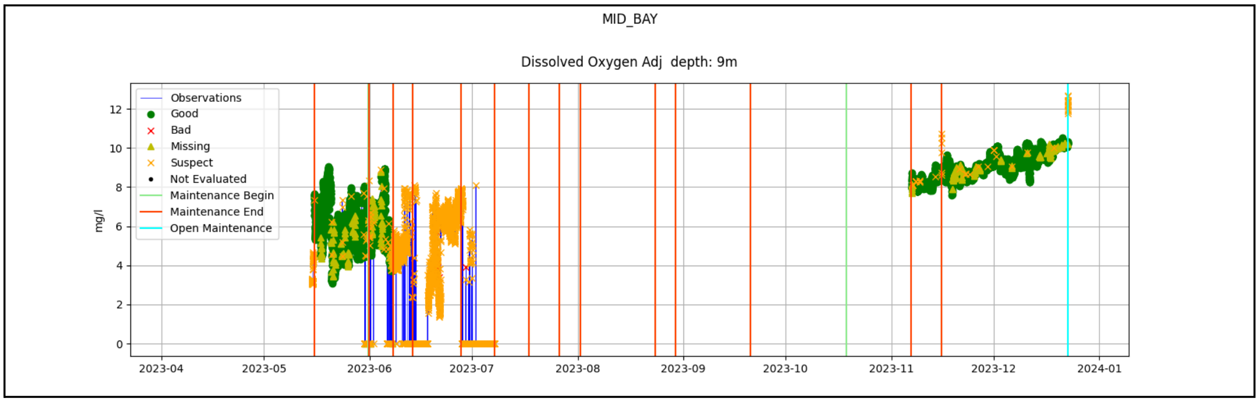
## Mid-Bay: 9m


MID_BAY
Water Temperature depth: 9m
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Open Maintenance
C
25
20
15
10
5
2023-04
2023-05
2023-06
2023-07
2023-08
2023-09
2023-10
2023-11
2023-12
2024-01

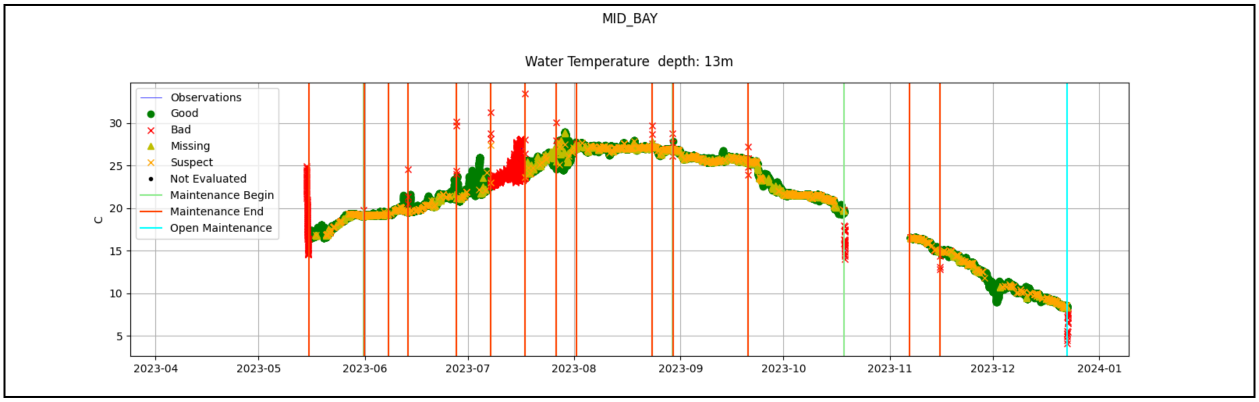

MID_BAY
Salinity depth: 9m
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Open Maintenance
PSU
20
15
10
5
0
2023-04
2023-05
2023-06
2023-07
2023-08
2023-09
2023-10
2023-11
2023-12
2024-01

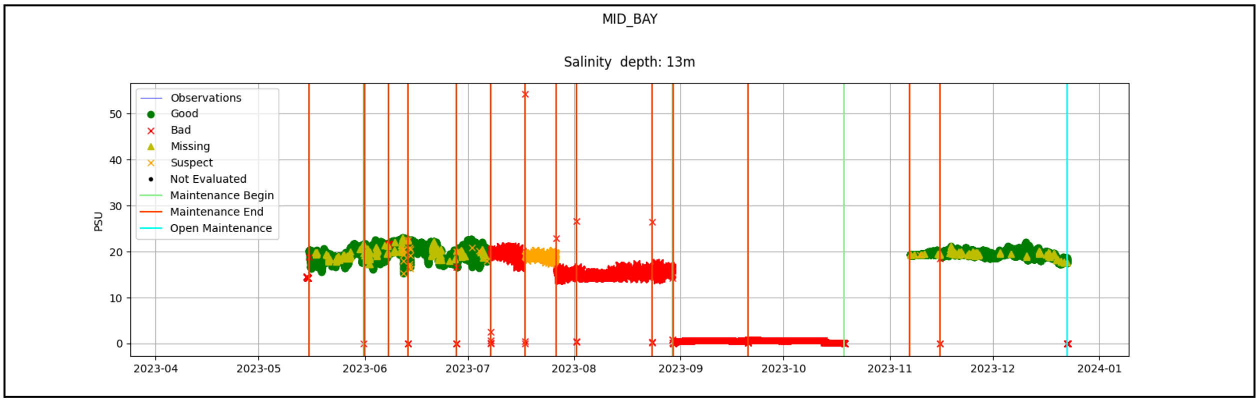

MID_BAY
Conductivity depth: 9m
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Open Maintenance
S/m
3
2
2
2
1
1
0
0
2023-04
2023-05
2023-06
2023-07
2023-08
2023-09
2023-10
2023-11
2023-12
2024-01

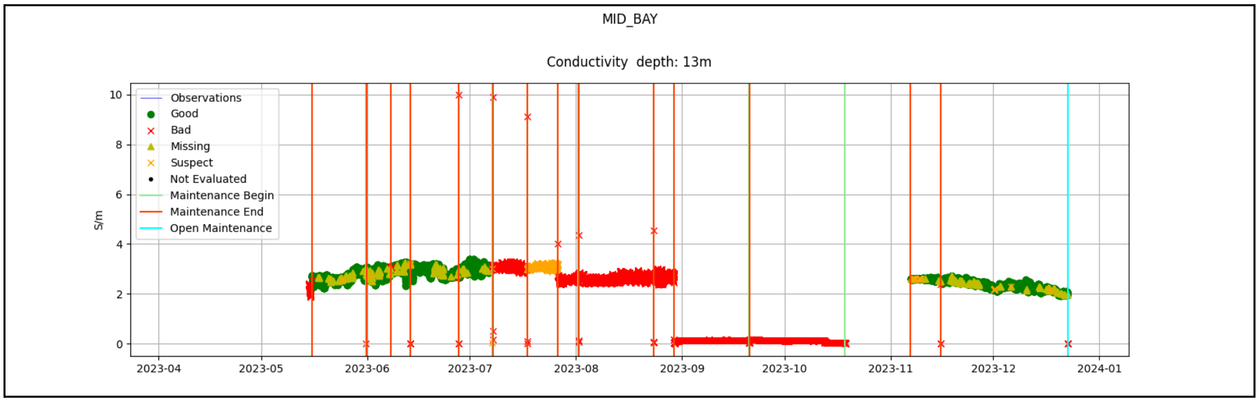

MID_BAY
Dissolved Oxygen  depth: 9m
mg/l
0
2
4
6
8
10
12
2023-04
2023-05
2023-06
2023-07
2023-08
2023-09
2023-10
2023-11
2023-12
2024-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Open Maintenance

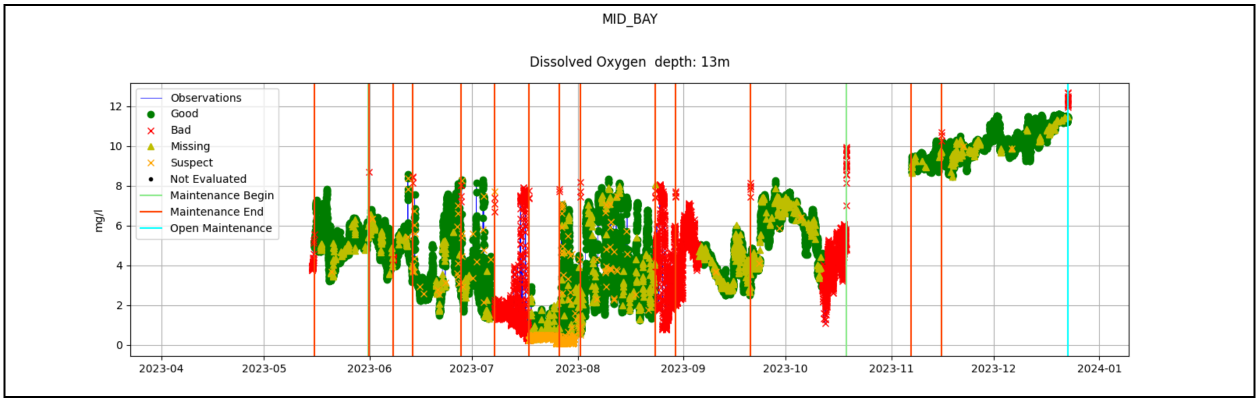

MID_BAY
Dissolved Oxygen Adj  depth: 9m
mg/l
0
2
4
6
8
10
12
2023-04
2023-05
2023-06
2023-07
2023-08
2023-09
2023-10
2023-11
2023-12
2024-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Open Maintenance

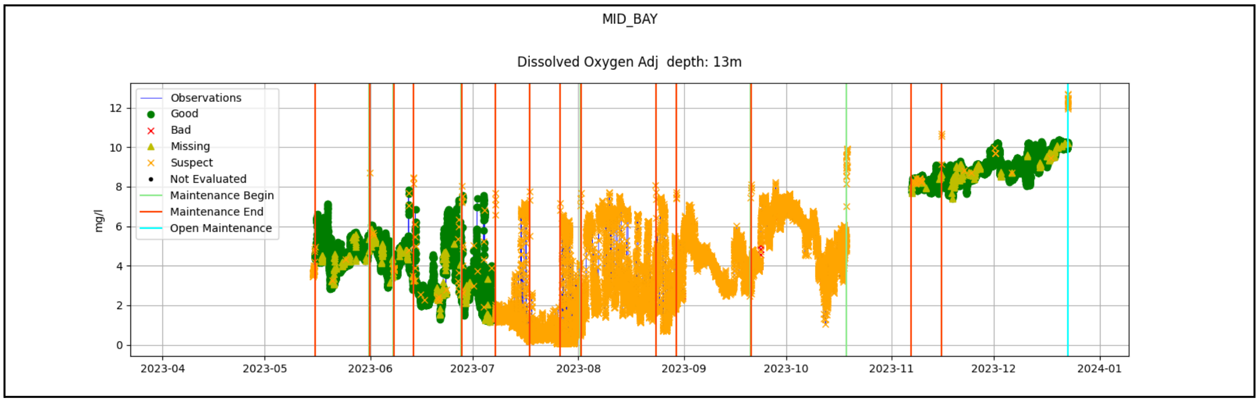
# Mid-Bay: 13m


MID_BAY
Water Temperature depth: 13m
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Open Maintenance
C
5
10
15
20
25
30
2023-04
2023-05
2023-06
2023-07
2023-08
2023-09
2023-10
2023-11
2023-12
2024-01

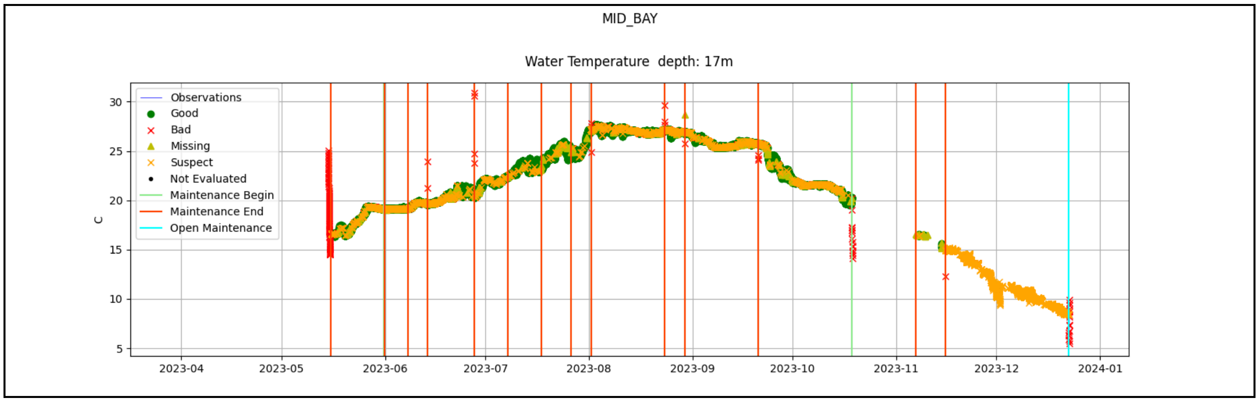

MID_BAY
Salinity depth: 13m
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Open Maintenance
PSU
0
10
20
30
40
50
2023-04
2023-05
2023-06
2023-07
2023-08
2023-09
2023-10
2023-11
2023-12
2024-01

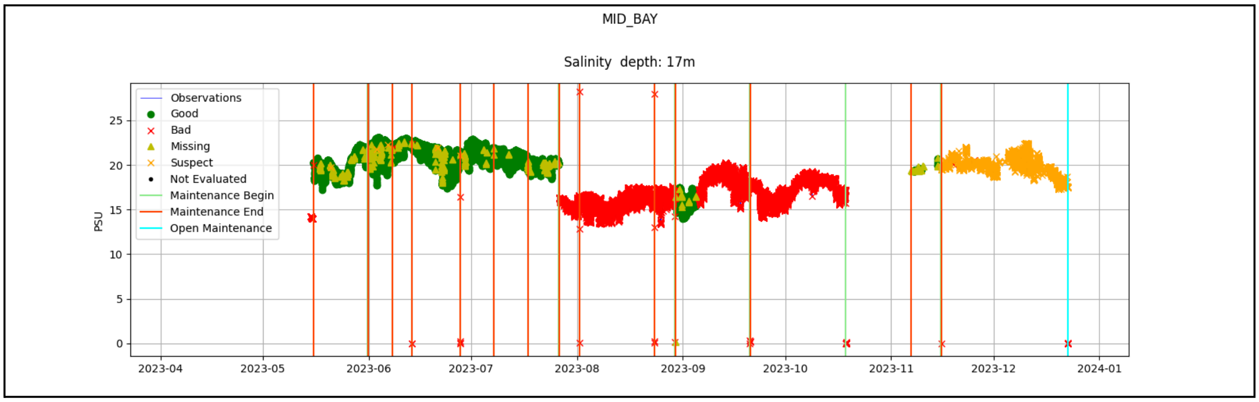

MID_BAY
Conductivity depth: 13m
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Open Maintenance
S/m
0
2
4
6
8
10
2023-04
2023-05
2023-06
2023-07
2023-08
2023-09
2023-10
2023-11
2023-12
2024-01

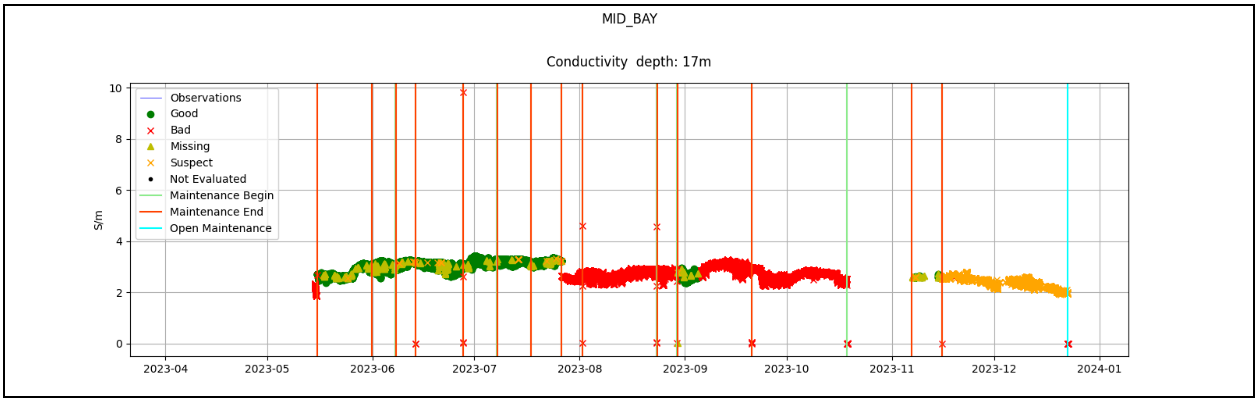

MID_BAY
Dissolved Oxygen depth: 13m
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Open Maintenance
mg/l
0
2
4
6
8
10
12
2023-04
2023-05
2023-06
2023-07
2023-08
2023-09
2023-10
2023-11
2023-12
2024-01

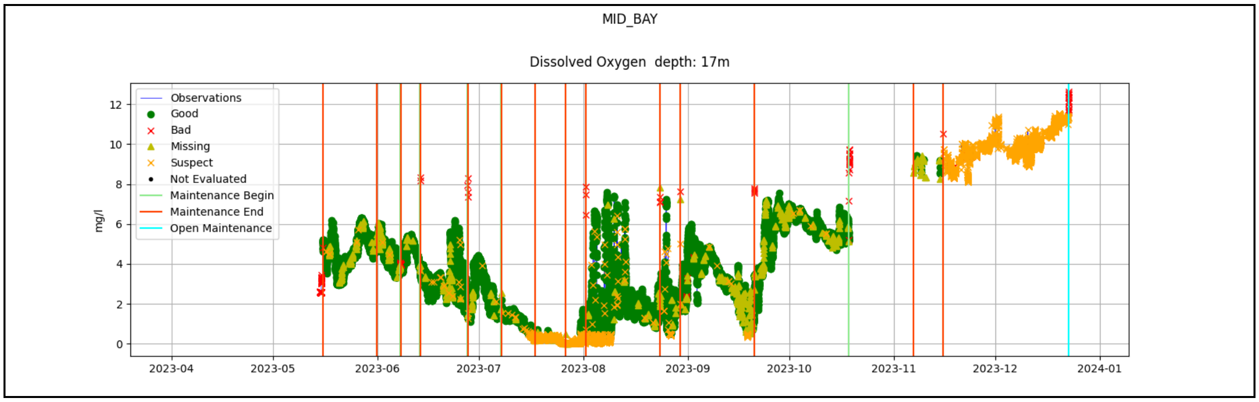

MID_BAY
Dissolved Oxygen Adj depth: 13m
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Open Maintenance
mg/l
0
2
4
6
8
10
12
2023-04
2023-05
2023-06
2023-07
2023-08
2023-09
2023-10
2023-11
2023-12
2024-01

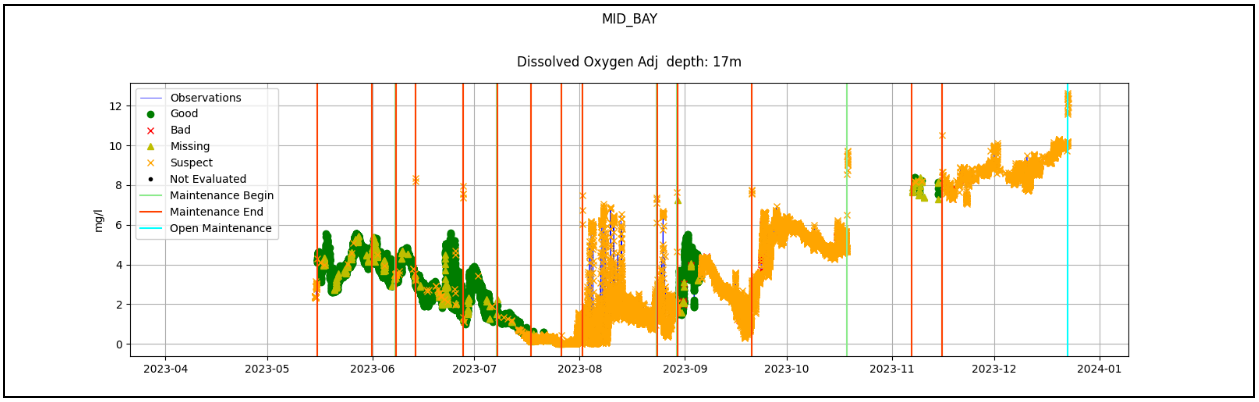
# Mid-Bay: 17m


MID_BAY
Water Temperature depth: 17m
C
30
25
20
15
10
5
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Open Maintenance
2023-04
2023-05
2023-06
2023-07
2023-08
2023-09
2023-10
2023-11
2023-12
2024-01


MID_BAY
Salinity depth: 17m
PSU
25
20
15
10
5
0
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Open Maintenance
2023-04
2023-05
2023-06
2023-07
2023-08
2023-09
2023-10
2023-11
2023-12
2024-01

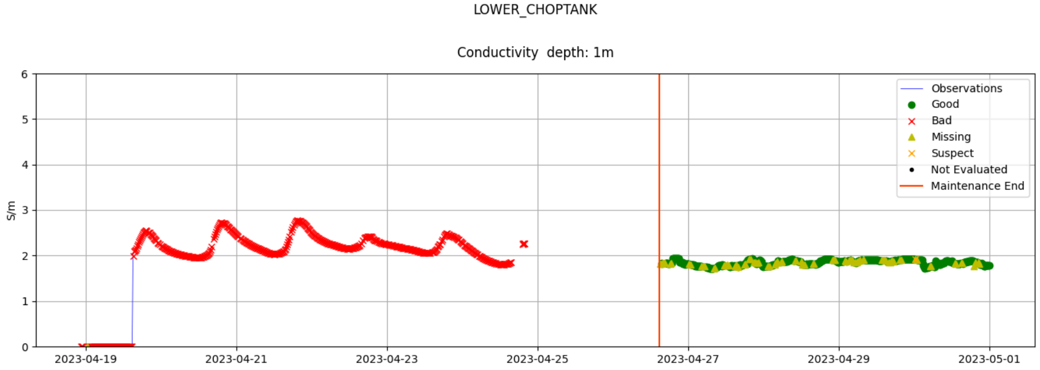

MID_BAY
Conductivity depth: 17m
S/m
10
8
6
4
2
0
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Open Maintenance
2023-04
2023-05
2023-06
2023-07
2023-08
2023-09
2023-10
2023-11
2023-12
2024-01

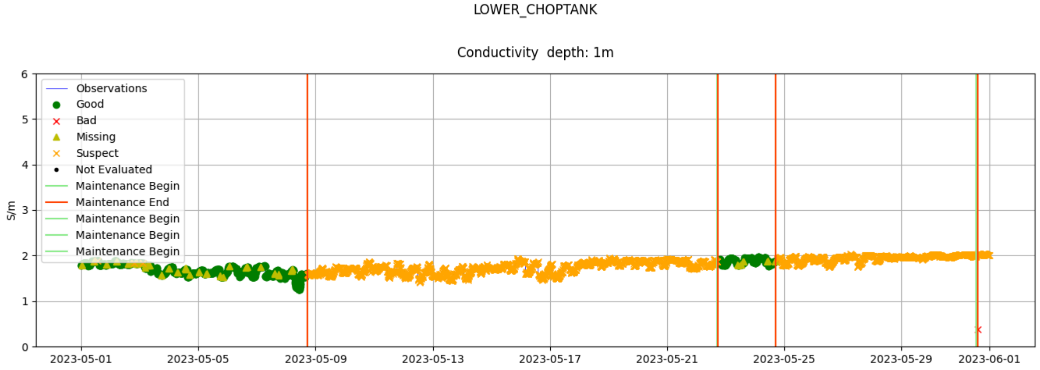

MID_BAY
Dissolved Oxygen depth: 17m
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Open Maintenance
mg/l
0
2
4
6
8
10
12
2023-04
2023-05
2023-06
2023-07
2023-08
2023-09
2023-10
2023-11
2023-12
2024-01

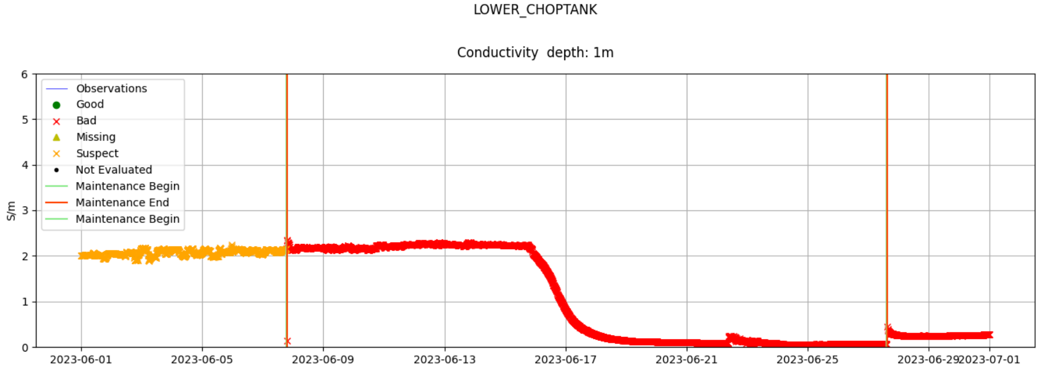

MID_BAY
Dissolved Oxygen Adj depth: 17m
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Open Maintenance
mg/l
0
2
4
6
8
10
12
2023-04
2023-05
2023-06
2023-07
2023-08
2023-09
2023-10
2023-11
2023-12
2024-01

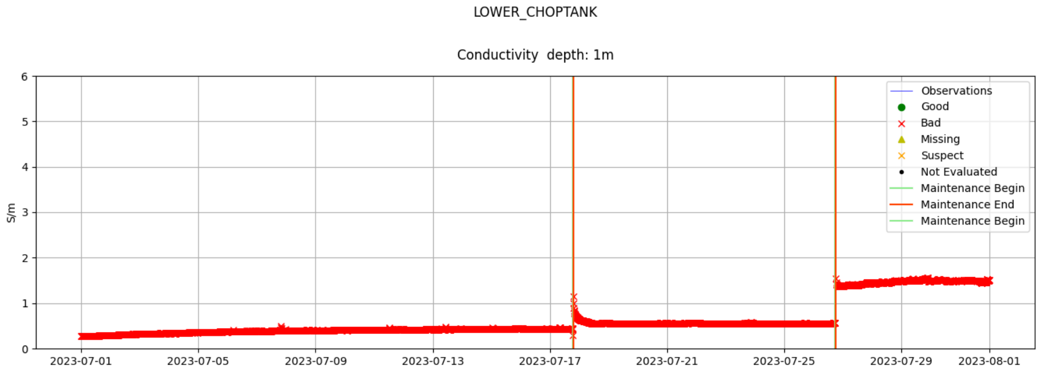
# A.3 Monthly

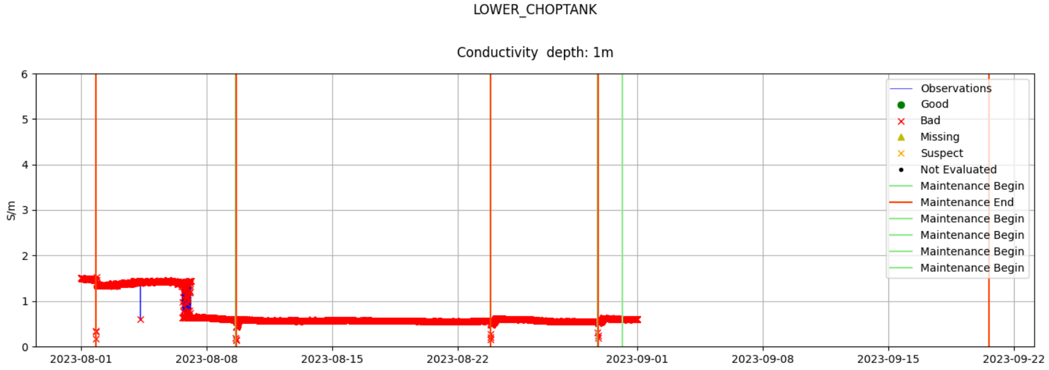
## Lower Choptank Conductivity Depth=1m

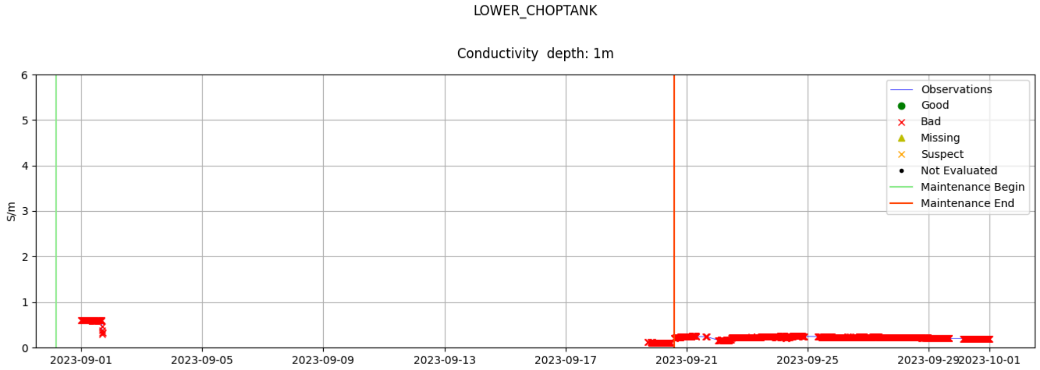






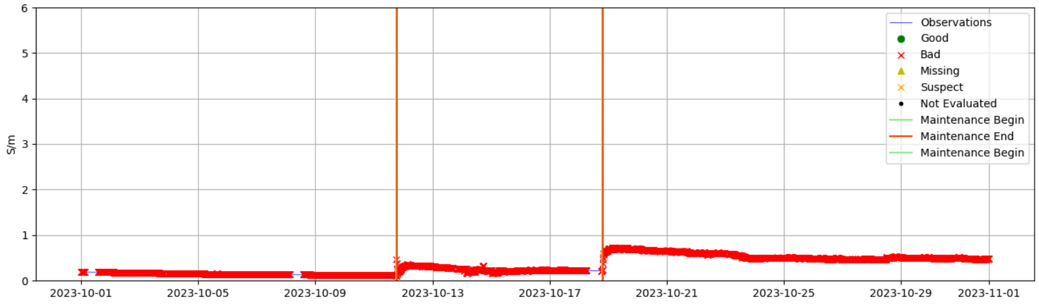

LOWER_CHOPTANK
Conductivity depth: 1m
S/m
0
1
2
3
4
5
6
2023-07-01
2023-07-05
2023-07-09
2023-07-13
2023-07-17
2023-07-21
2023-07-25
2023-07-29
2023-08-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin


LOWER_CHOPTANK
Conductivity depth: 1m
S/m
0
1
2
3
4
5
6
2023-08-01
2023-08-08
2023-08-15
2023-08-22
2023-09-01
2023-09-08
2023-09-15
2023-09-22
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin
Maintenance Begin
Maintenance Begin
Maintenance Begin


LOWER_CHOPTANK
Conductivity depth: 1m
S/m
0
1
2
3
4
5
6
2023-09-01
2023-09-05
2023-09-09
2023-09-13
2023-09-17
2023-09-21
2023-09-25
2023-09-29
2023-10-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

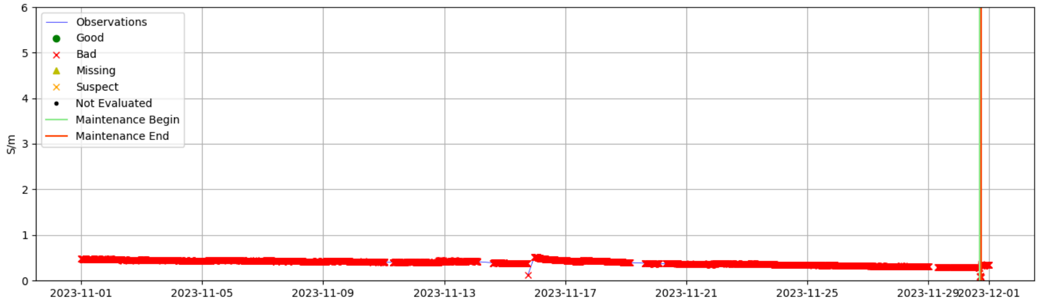
LOWER_CHOPTANK

Conductivity depth: 1m



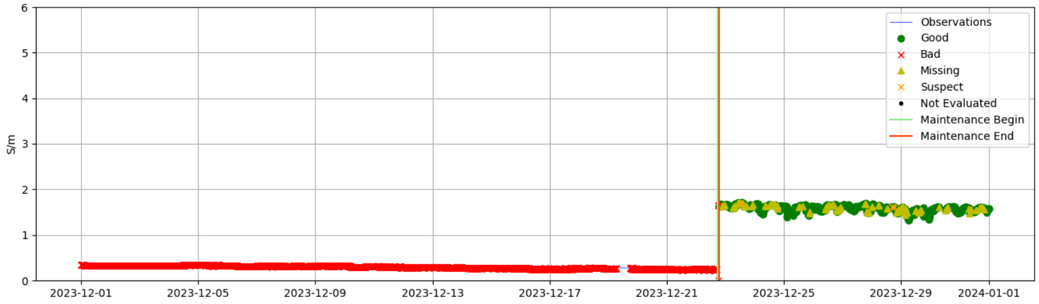
LOWER_CHOPTANK

Conductivity depth: 1m

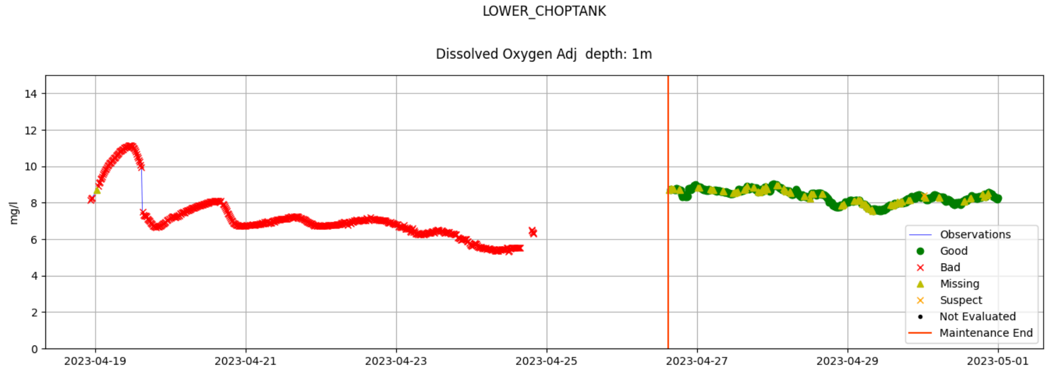


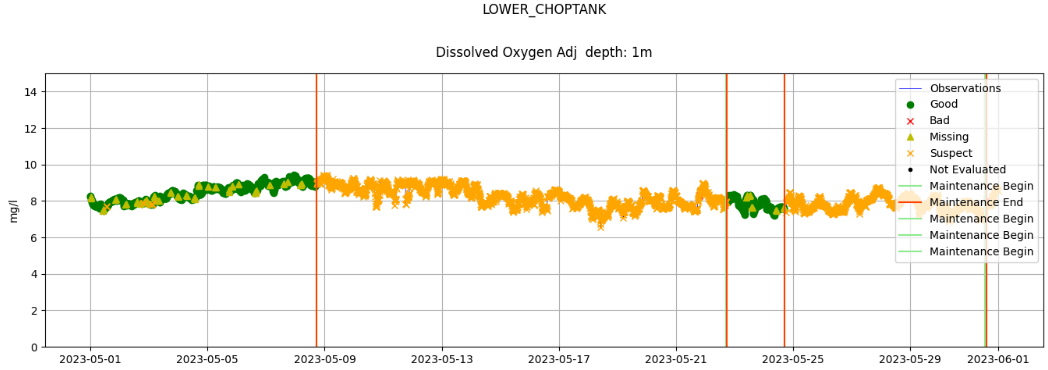
LOWER_CHOPTANK

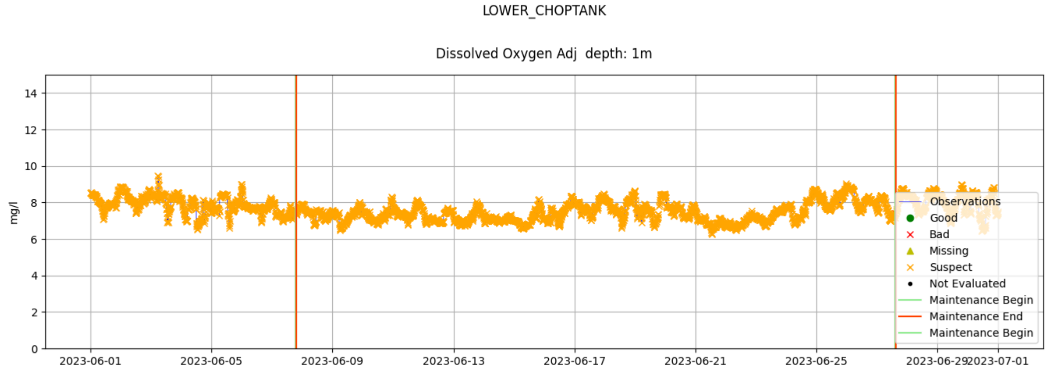
Conductivity depth: 1m

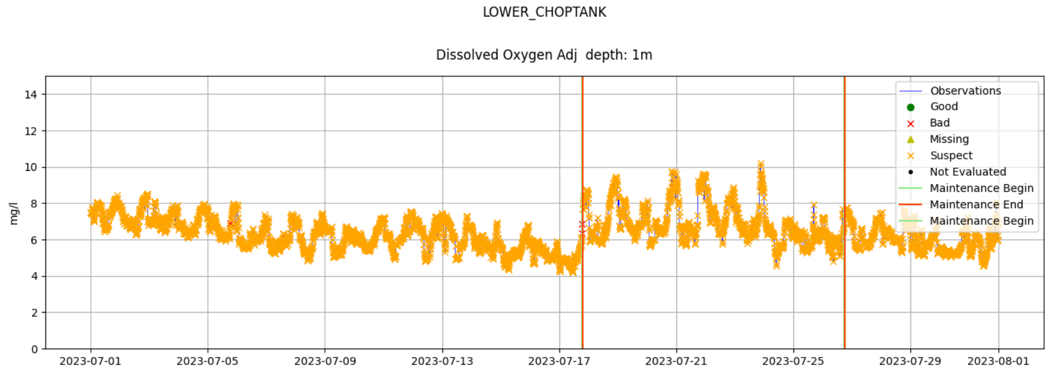


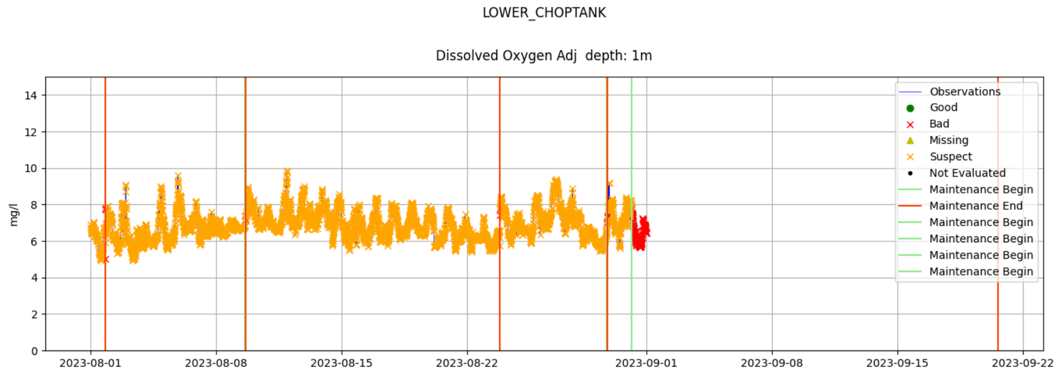
# Lower Choptank Adjusted Dissolved Oxygen Depth=1m

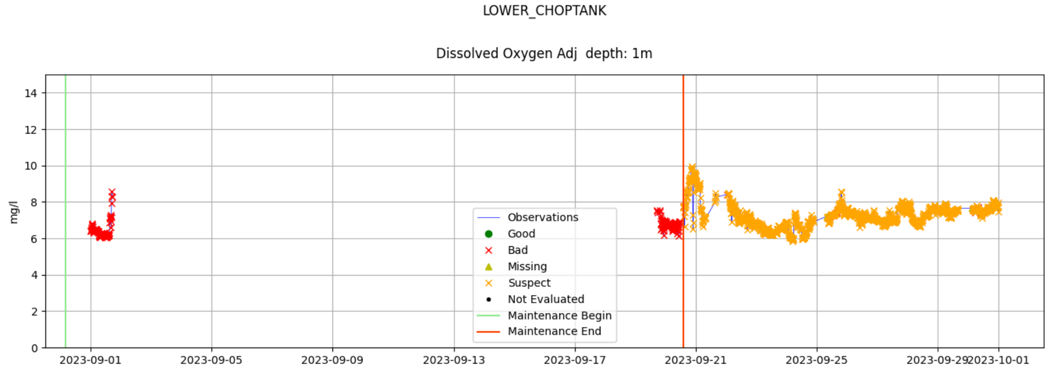


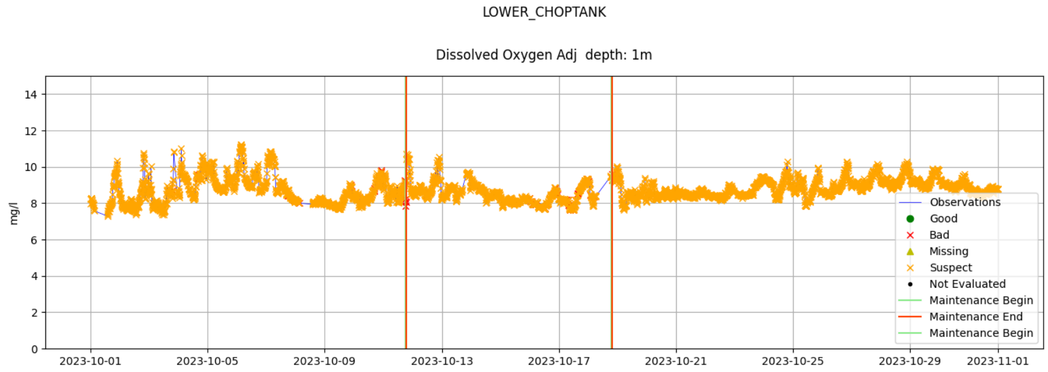




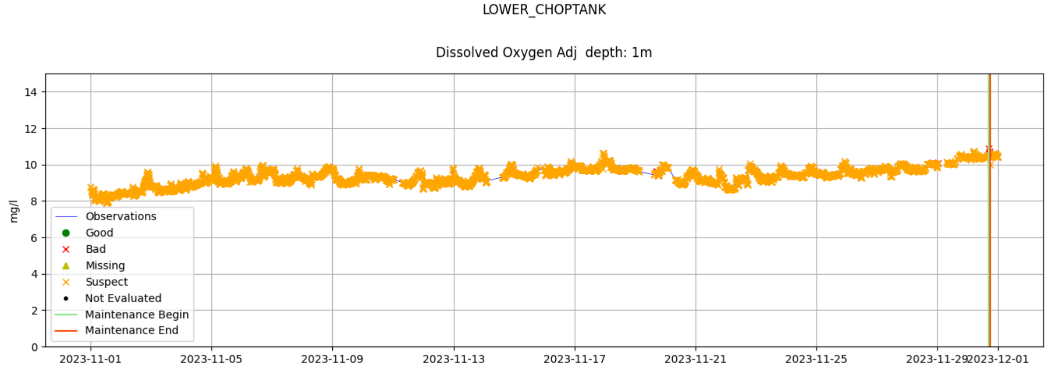

LOWER_CHOPTANK
Dissolved Oxygen Adj depth: 1m
mg/l
0
2
4
6
8
10
12
14
2023-07-01
2023-07-05
2023-07-09
2023-07-13
2023-07-17
2023-07-21
2023-07-25
2023-07-29
2023-08-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin


LOWER_CHOPTANK
Dissolved Oxygen Adj depth: 1m
mg/l
0
2
4
6
8
10
12
14
2023-08-01
2023-08-08
2023-08-15
2023-08-22
2023-09-01
2023-09-08
2023-09-15
2023-09-22
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin
Maintenance Begin
Maintenance Begin
Maintenance Begin

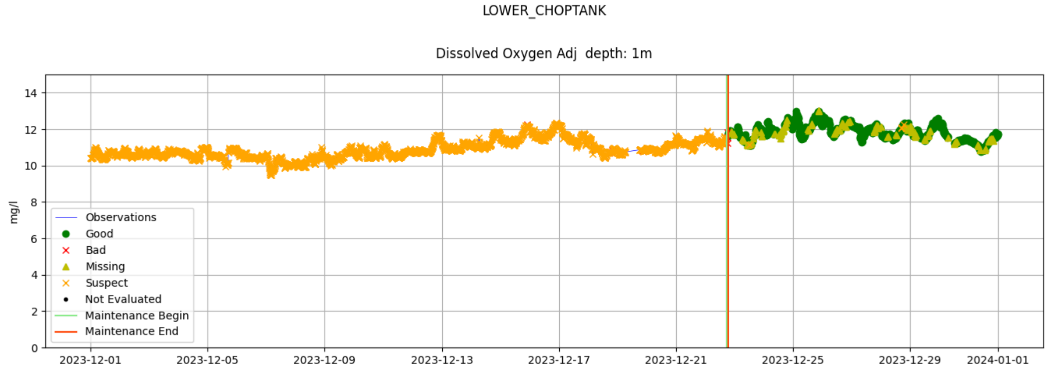

LOWER_CHOPTANK
Dissolved Oxygen Adj depth: 1m
mg/l
0
2
4
6
8
10
12
14
2023-09-01
2023-09-05
2023-09-09
2023-09-13
2023-09-17
2023-09-21
2023-09-25
2023-09-29
2023-10-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End


LOWER_CHOPTANK

Dissolved Oxygen Adj depth: 1m

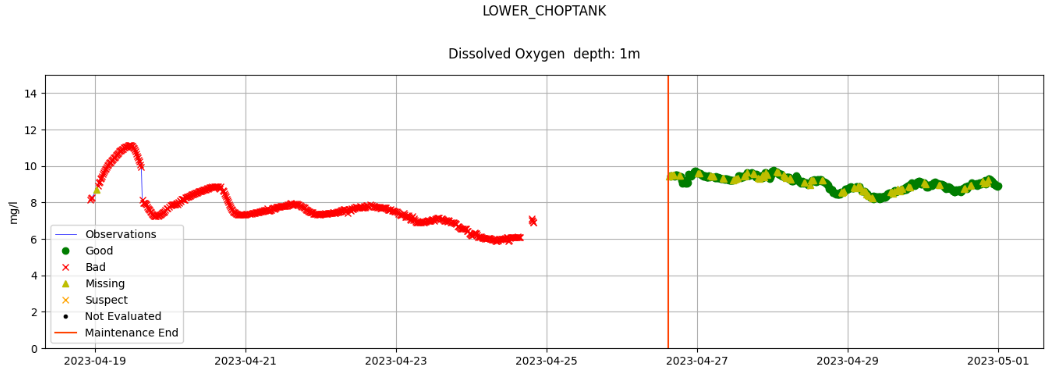

LOWER_CHOPTANK

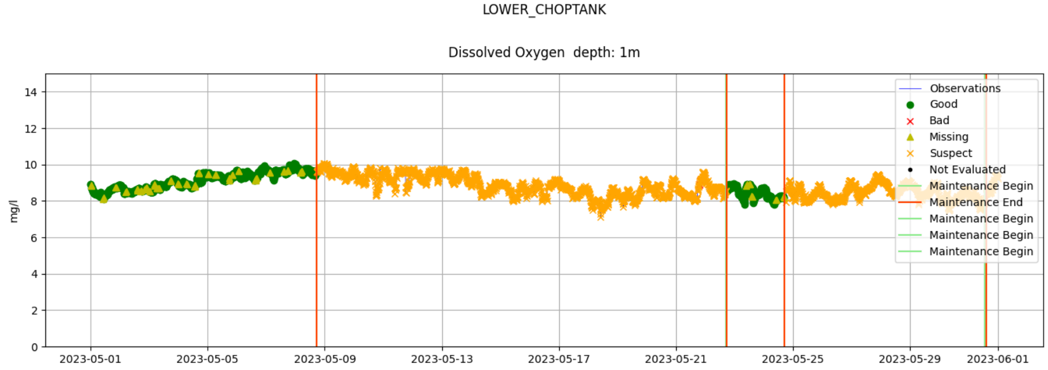
Dissolved Oxygen Adj depth: 1m

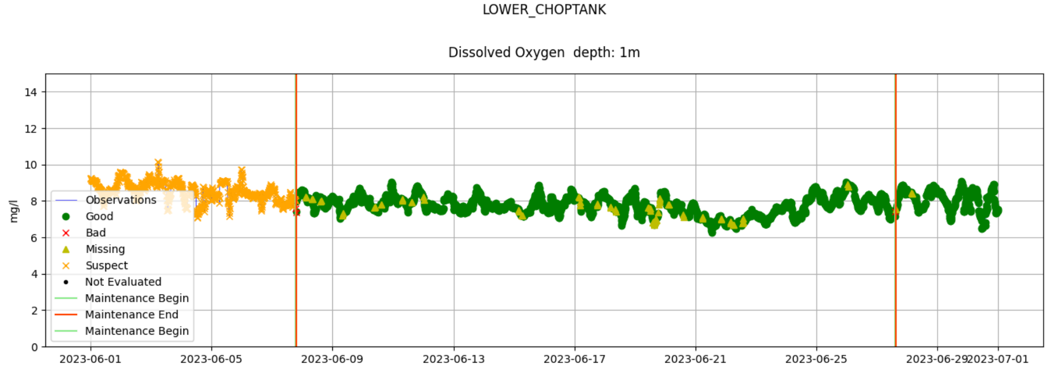

LOWER_CHOPTANK

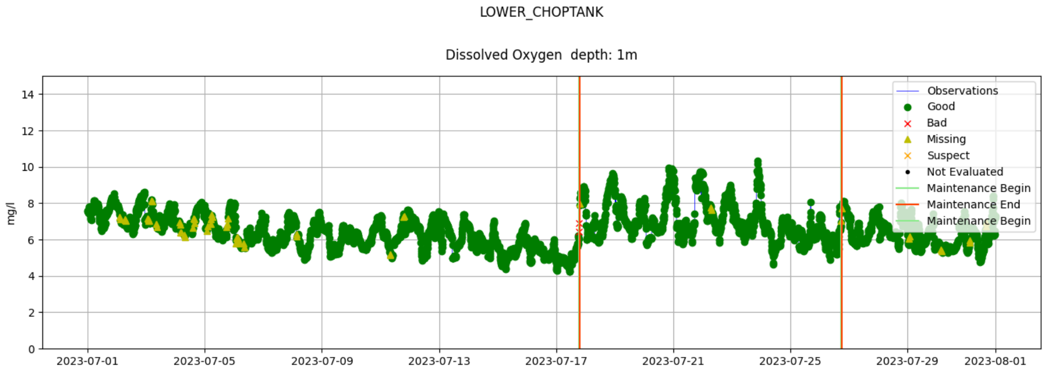
Dissolved Oxygen Adj depth: 1m

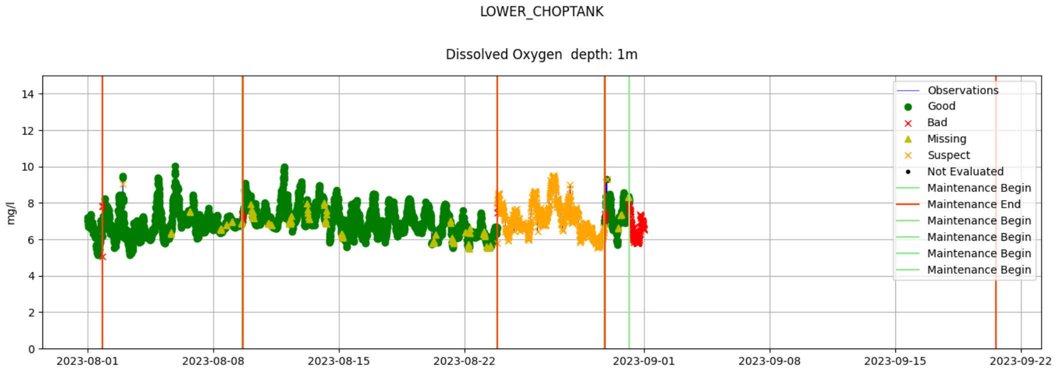
# Lower Choptank Dissolved Oxygen Depth=1m

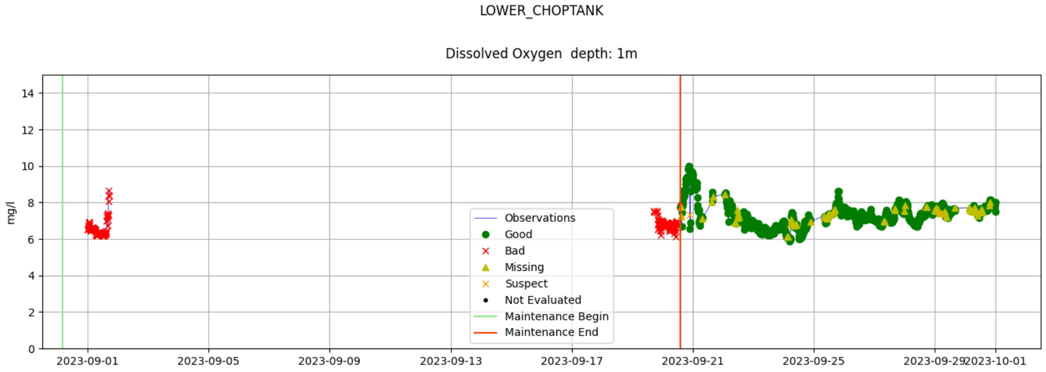


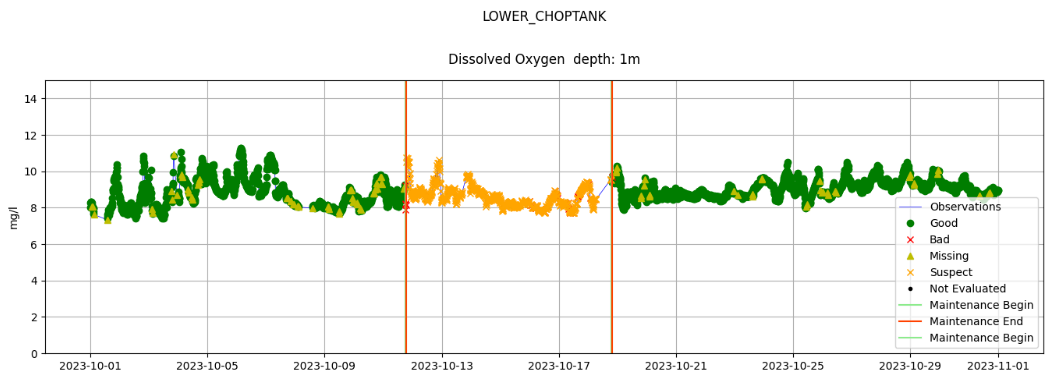





LOWER_CHOPTANK
Dissolved Oxygen depth: 1m
mg/l
0
2
4
6
8
10
12
14
2023-07-01
2023-07-05
2023-07-09
2023-07-13
2023-07-17
2023-07-21
2023-07-25
2023-07-29
2023-08-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin

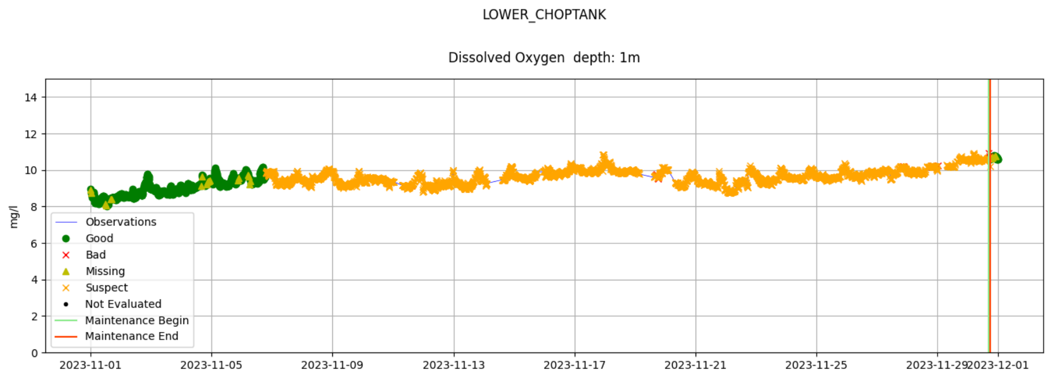

LOWER_CHOPTANK
Dissolved Oxygen depth: 1m
mg/l
0
2
4
6
8
10
12
14
2023-08-01
2023-08-08
2023-08-15
2023-08-22
2023-09-01
2023-09-08
2023-09-15
2023-09-22
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin
Maintenance Begin
Maintenance Begin
Maintenance Begin


LOWER_CHOPTANK
Dissolved Oxygen depth: 1m
mg/l
0
2
4
6
8
10
12
14
2023-09-01
2023-09-05
2023-09-09
2023-09-13
2023-09-17
2023-09-21
2023-09-25
2023-09-29
2023-10-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End



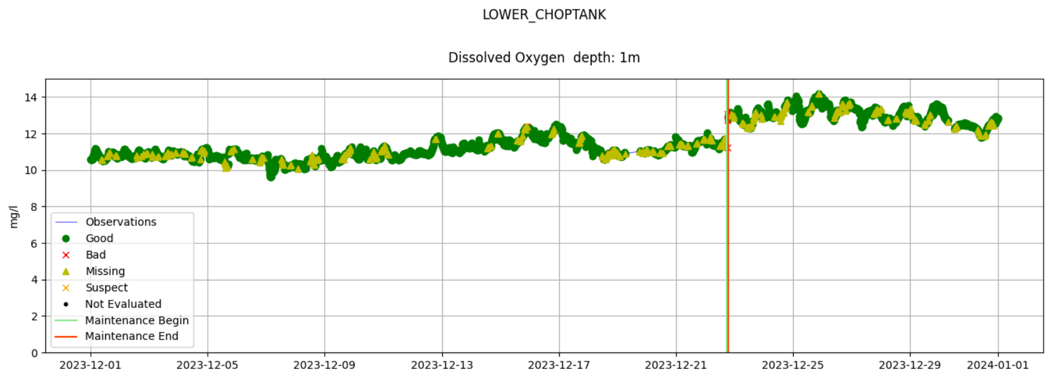
LOWER_CHOPTANK

Dissolved Oxygen depth: 1m



LOWER_CHOPTANK

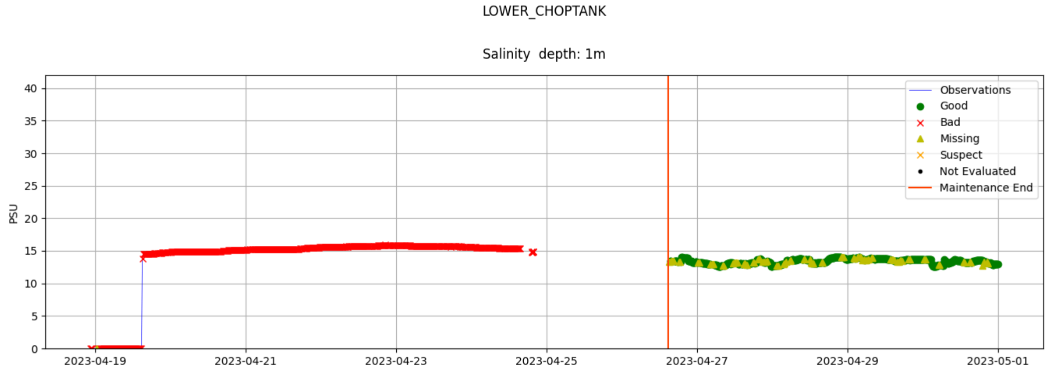
Dissolved Oxygen depth: 1m

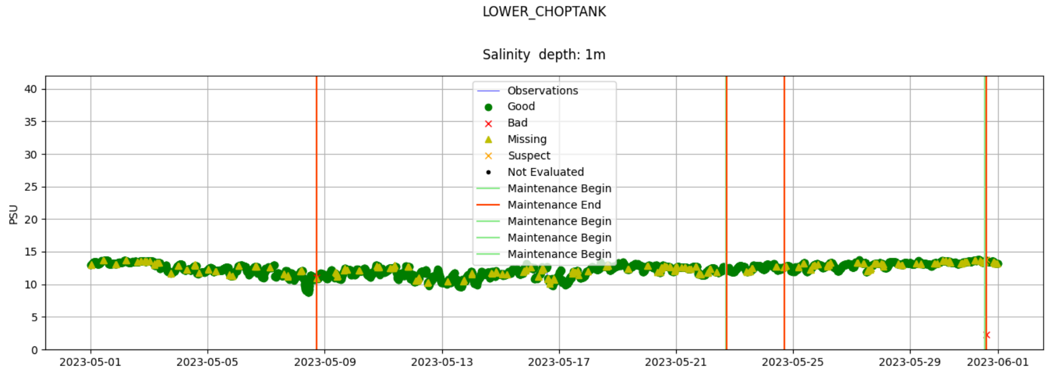


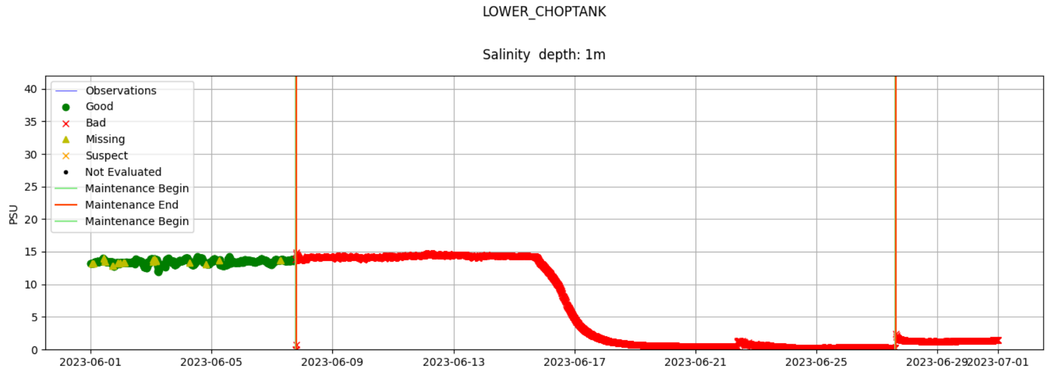
LOWER_CHOPTANK

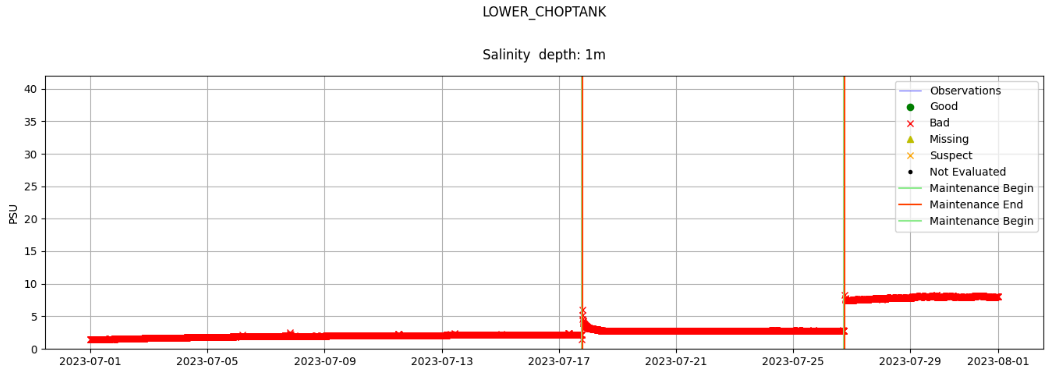
Dissolved Oxygen depth: 1m

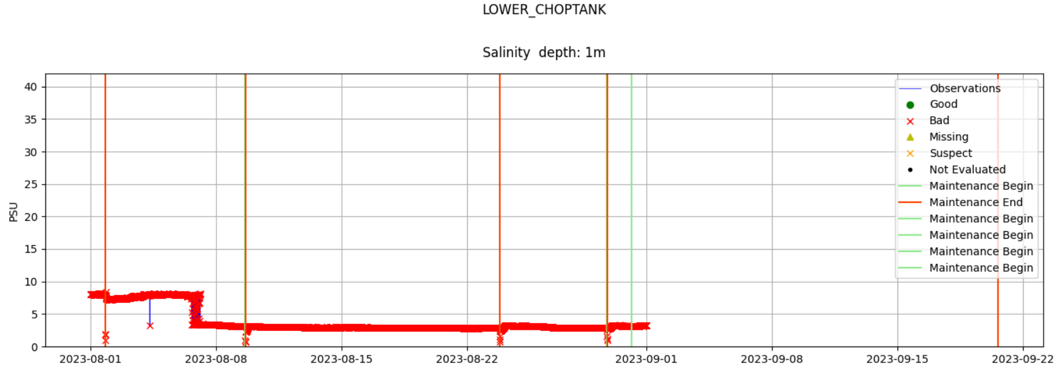
# Lower Choptank Salinity Depth=1m

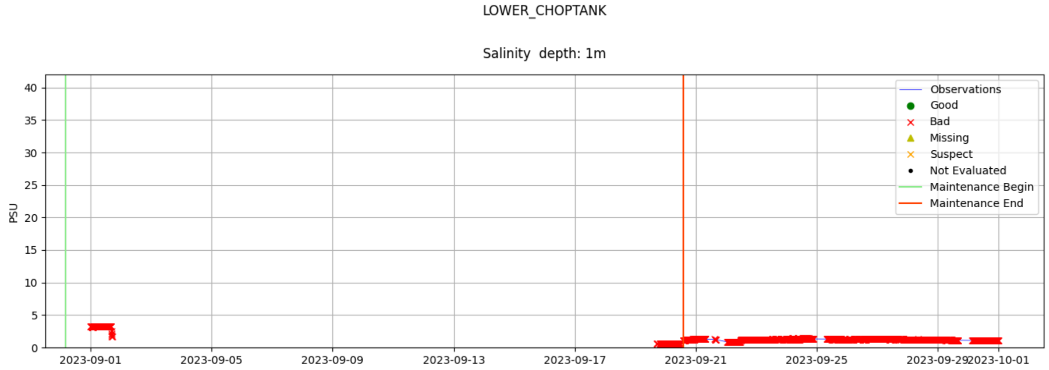


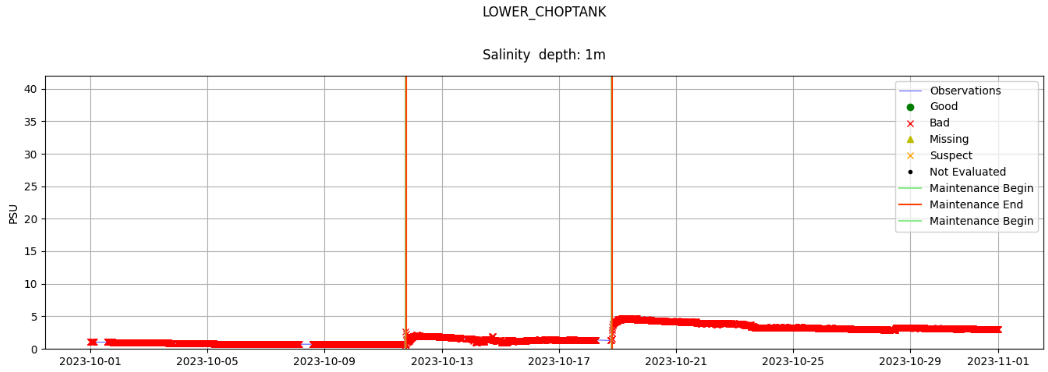


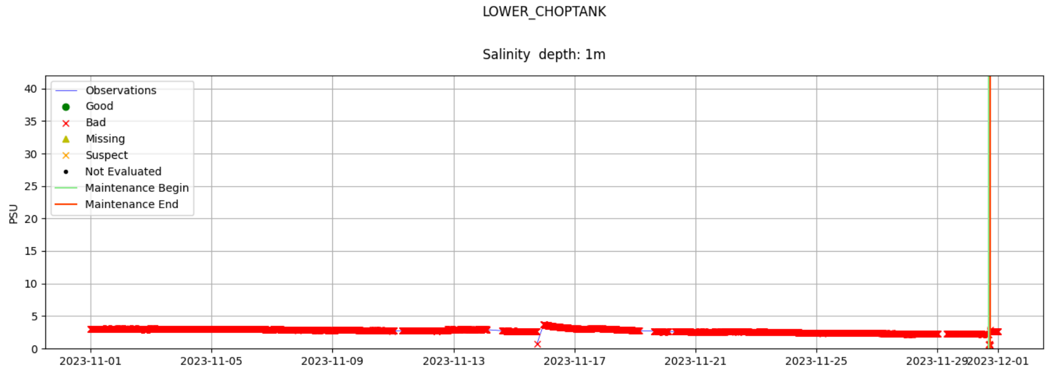


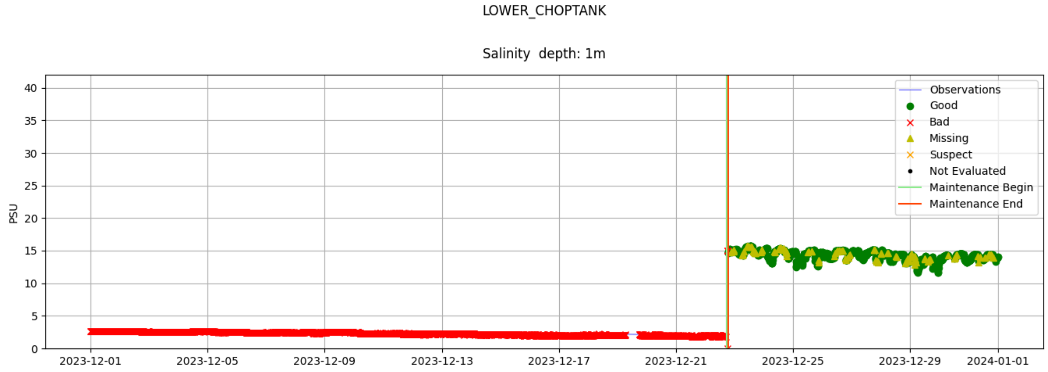

LOWER_CHOPTANK
Salinity depth: 1m
PSU
0
5
10
15
20
25
30
35
40
2023-07-01
2023-07-05
2023-07-09
2023-07-13
2023-07-17
2023-07-21
2023-07-25
2023-07-29
2023-08-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin


LOWER_CHOPTANK
Salinity depth: 1m
PSU
0
5
10
15
20
25
30
35
40
2023-08-01
2023-08-08
2023-08-15
2023-08-22
2023-09-01
2023-09-08
2023-09-15
2023-09-22
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin
Maintenance Begin
Maintenance Begin
Maintenance Begin

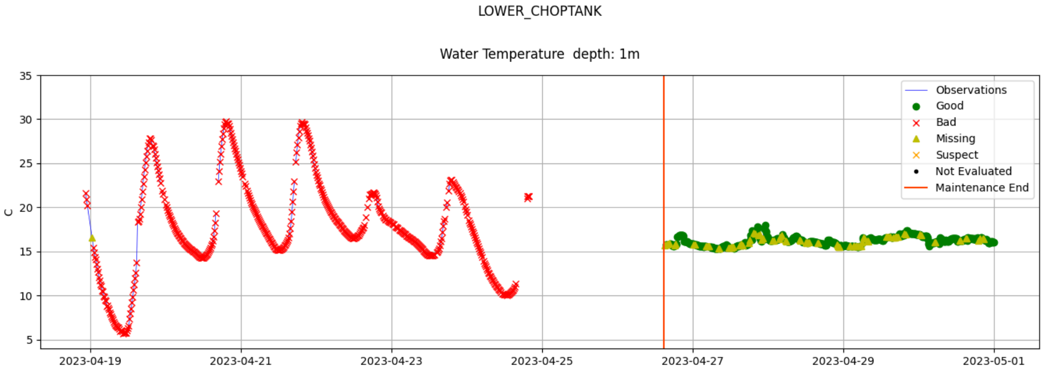

LOWER_CHOPTANK
Salinity depth: 1m
PSU
0
5
10
15
20
25
30
35
40
2023-09-01
2023-09-05
2023-09-09
2023-09-13
2023-09-17
2023-09-21
2023-09-25
2023-09-29
2023-10-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

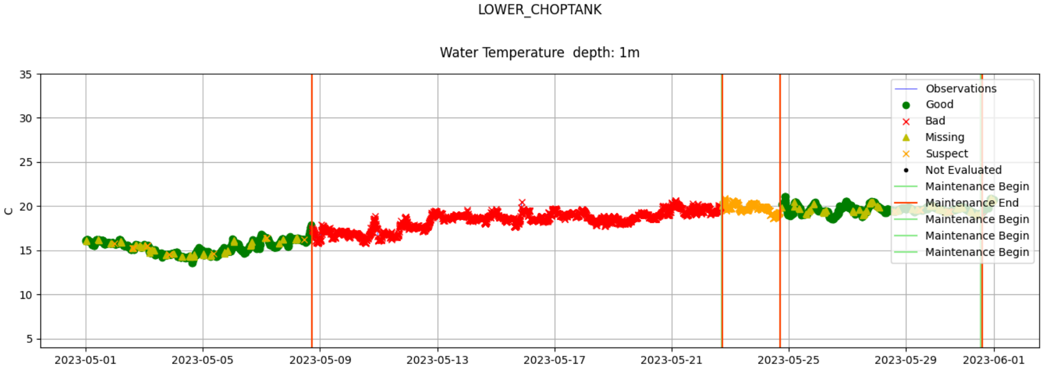

LOWER_CHOPTANK
Salinity depth: 1m
PSU
40
35
30
25
20
15
10
5
0
2023-10-01
2023-10-05
2023-10-09
2023-10-13
2023-10-17
2023-10-21
2023-10-25
2023-10-29
2023-11-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin

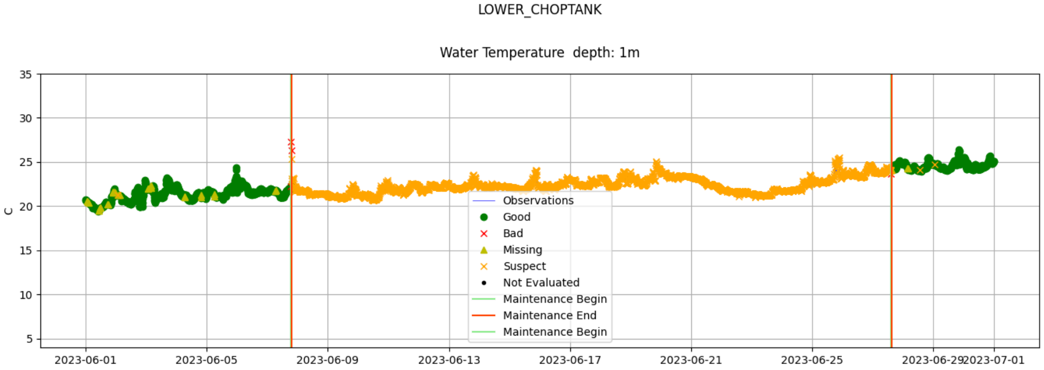

LOWER_CHOPTANK
Salinity depth: 1m
PSU
40
35
30
25
20
15
10
5
0
2023-11-01
2023-11-05
2023-11-09
2023-11-13
2023-11-17
2023-11-21
2023-11-25
2023-11-29
2023-12-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

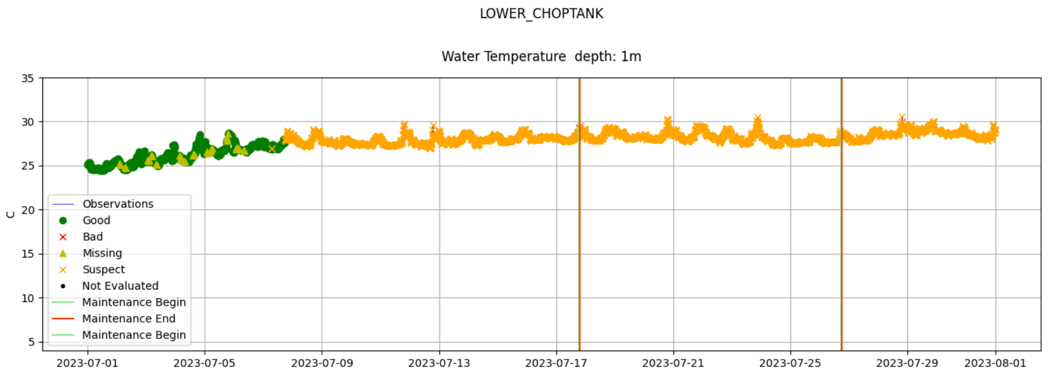

LOWER_CHOPTANK
Salinity depth: 1m
PSU
40
35
30
25
20
15
10
5
0
2023-12-01
2023-12-05
2023-12-09
2023-12-13
2023-12-17
2023-12-21
2023-12-25
2023-12-29
2024-01-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

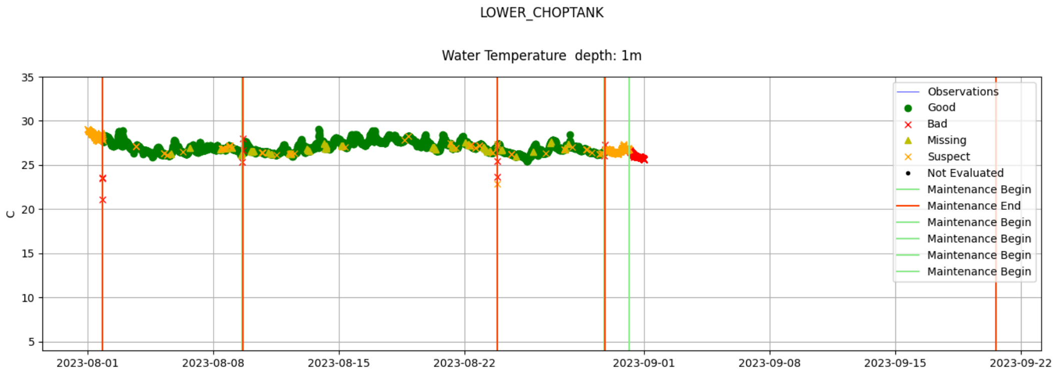
# Lower Choptank Water Temperature Depth=1m

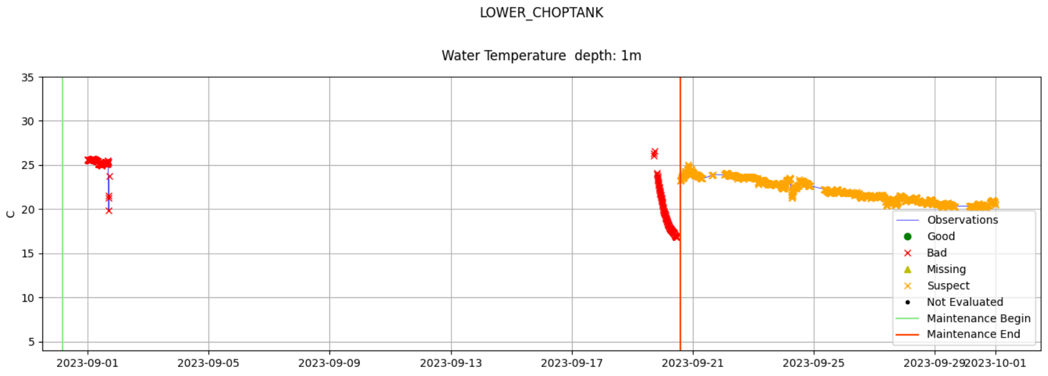


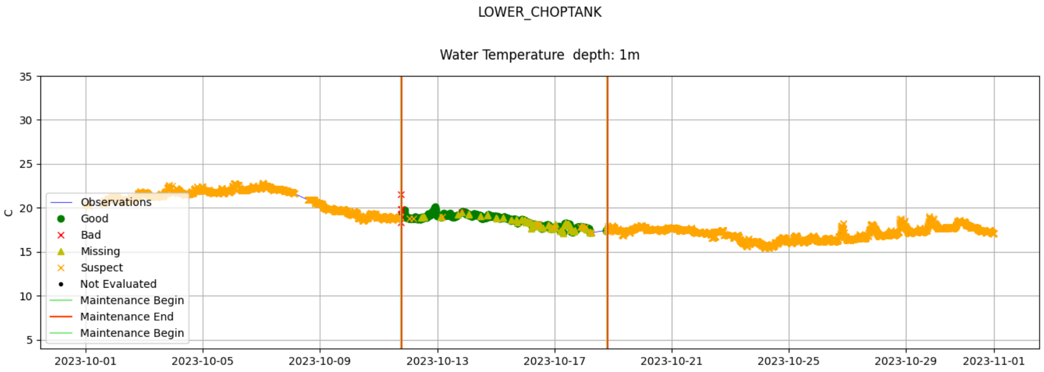


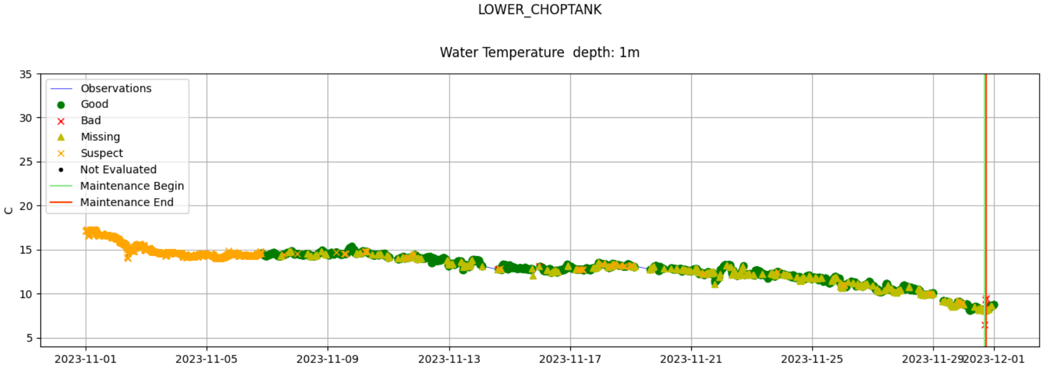


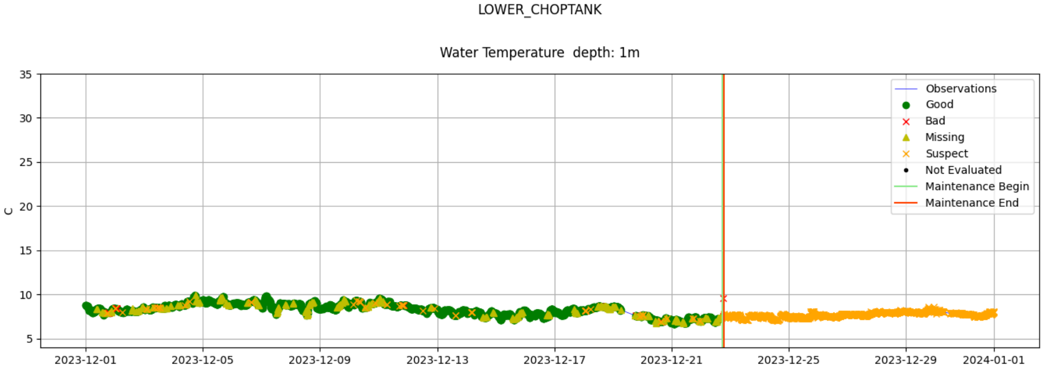

LOWER_CHOPTANK
Water Temperature depth: 1m
35
30
25
20
15
10
5
C
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin
2023-07-01
2023-07-05
2023-07-09
2023-07-13
2023-07-17
2023-07-21
2023-07-25
2023-07-29
2023-08-01


LOWER_CHOPTANK
Water Temperature depth: 1m
35
30
25
20
15
10
5
C
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin
Maintenance Begin
Maintenance Begin
Maintenance Begin
2023-08-01
2023-08-08
2023-08-15
2023-08-22
2023-09-01
2023-09-08
2023-09-15
2023-09-22

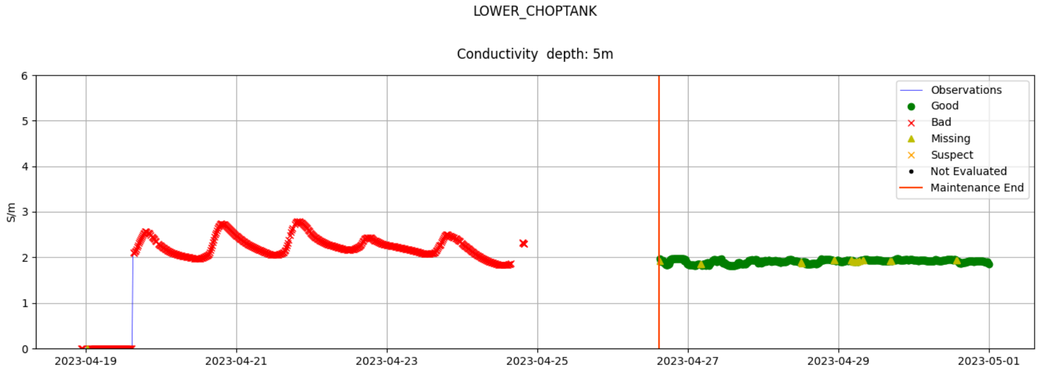

LOWER_CHOPTANK
Water Temperature depth: 1m
35
30
25
20
15
10
5
C
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
2023-09-01
2023-09-05
2023-09-09
2023-09-13
2023-09-17
2023-09-21
2023-09-25
2023-09-29
2023-10-01

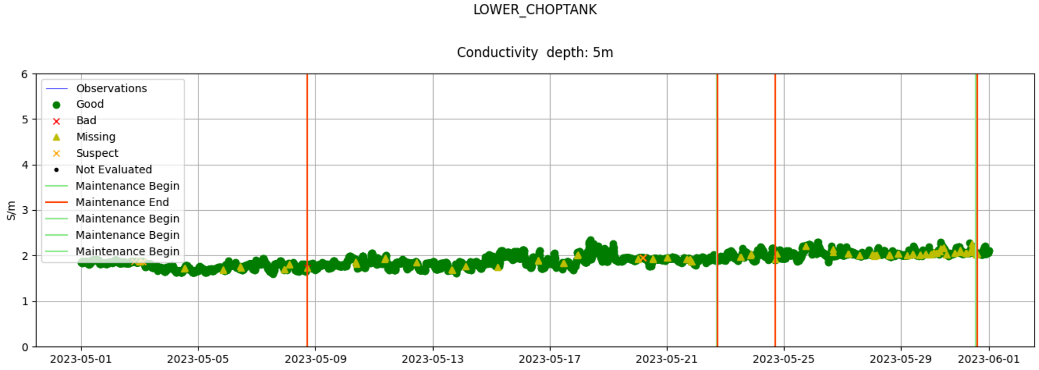

LOWER_CHOPTANK
Water Temperature depth: 1m
C
35
30
25
20
15
10
5
2023-10-01
2023-10-05
2023-10-09
2023-10-13
2023-10-17
2023-10-21
2023-10-25
2023-10-29
2023-11-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin

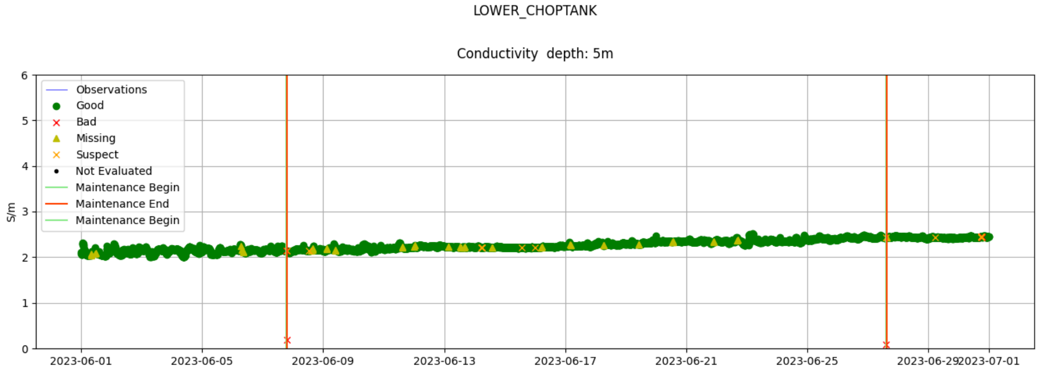

LOWER_CHOPTANK
Water Temperature depth: 1m
C
35
30
25
20
15
10
5
2023-11-01
2023-11-05
2023-11-09
2023-11-13
2023-11-17
2023-11-21
2023-11-25
2023-11-29
2023-12-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

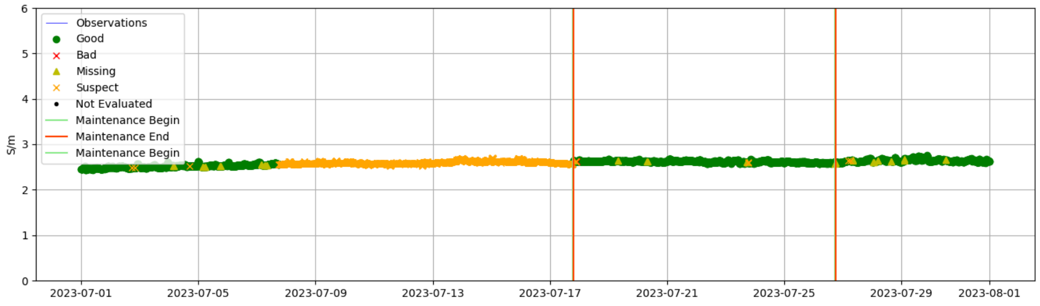

LOWER_CHOPTANK
Water Temperature depth: 1m
C
35
30
25
20
15
10
5
2023-12-01
2023-12-05
2023-12-09
2023-12-13
2023-12-17
2023-12-21
2023-12-25
2023-12-29
2024-01-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

# Lower Choptank Conductivity Depth=5m

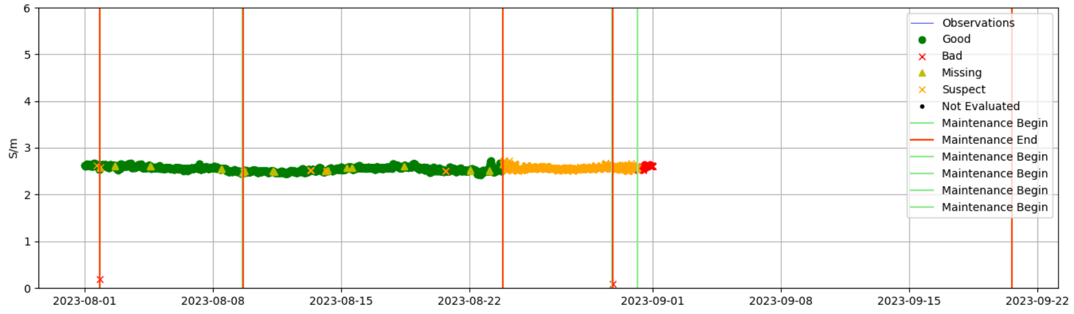




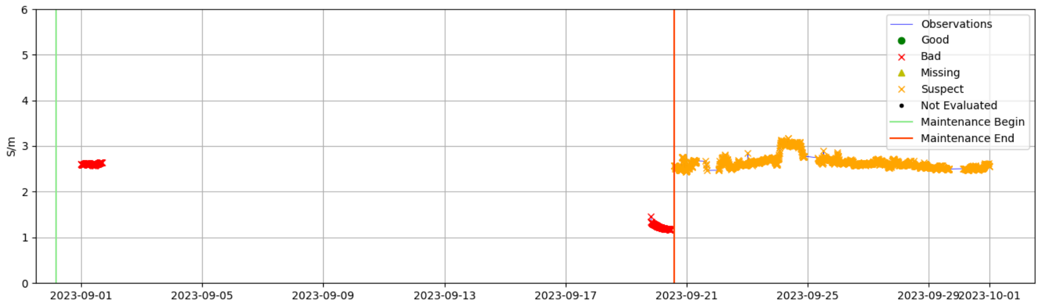



LOWER_CHOPTANK

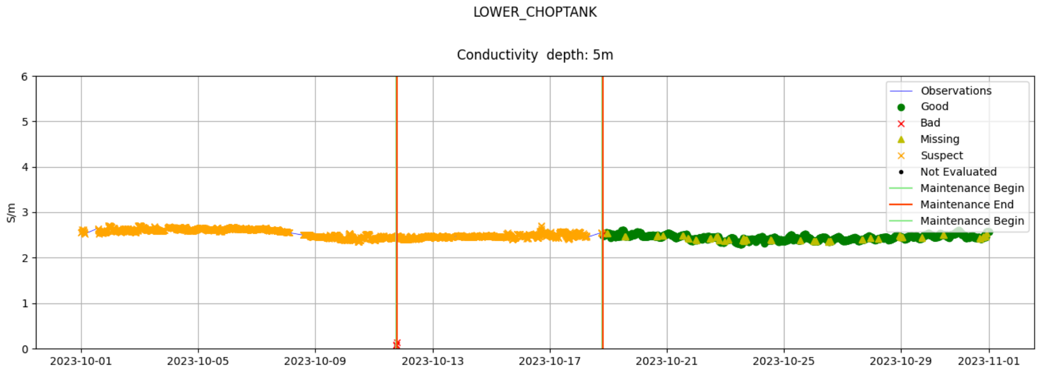
Conductivity  depth: 5m


LOWER_CHOPTANK

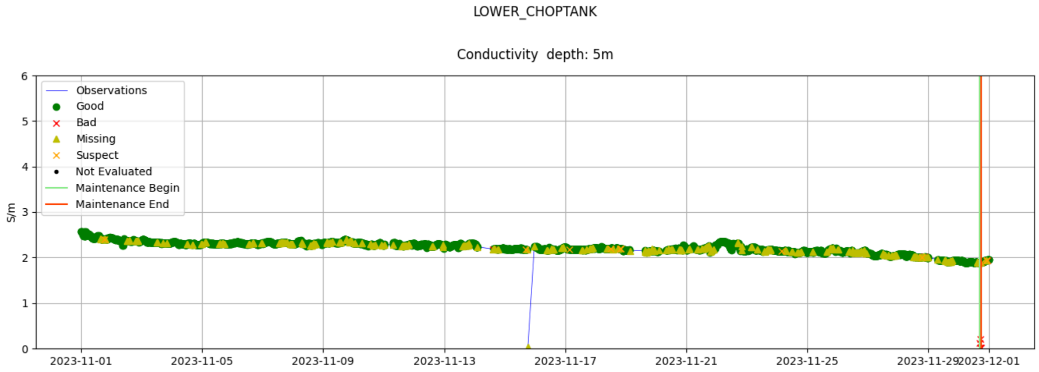
Conductivity  depth: 5m


LOWER_CHOPTANK

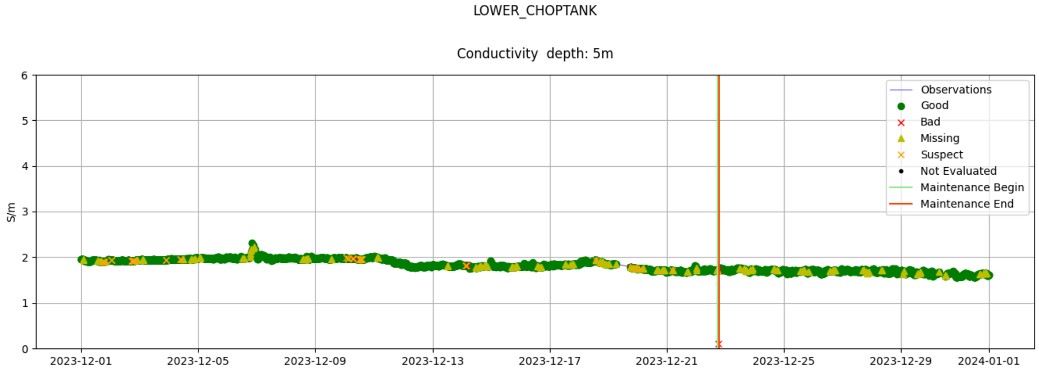
Conductivity  depth: 5m


LOWER_CHOPTANK

Conductivity depth: 5m

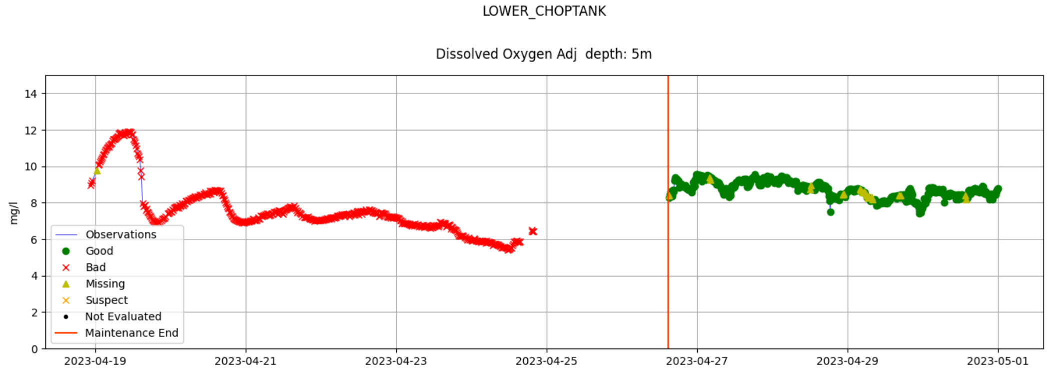

LOWER_CHOPTANK

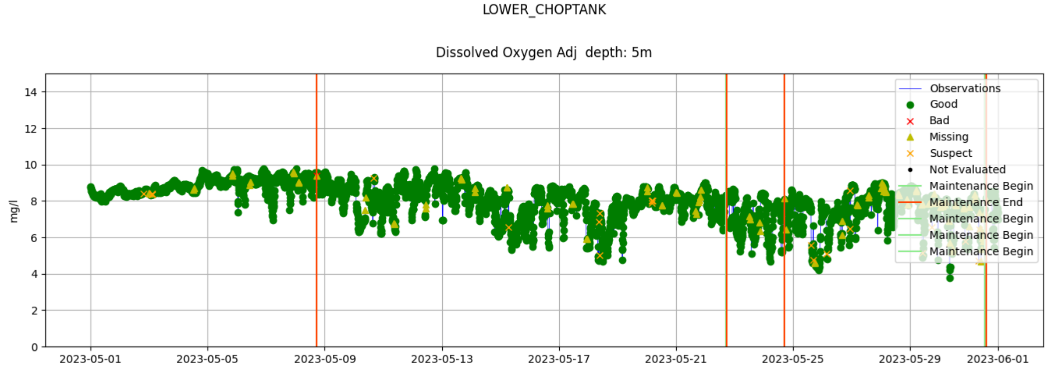
Conductivity depth: 5m

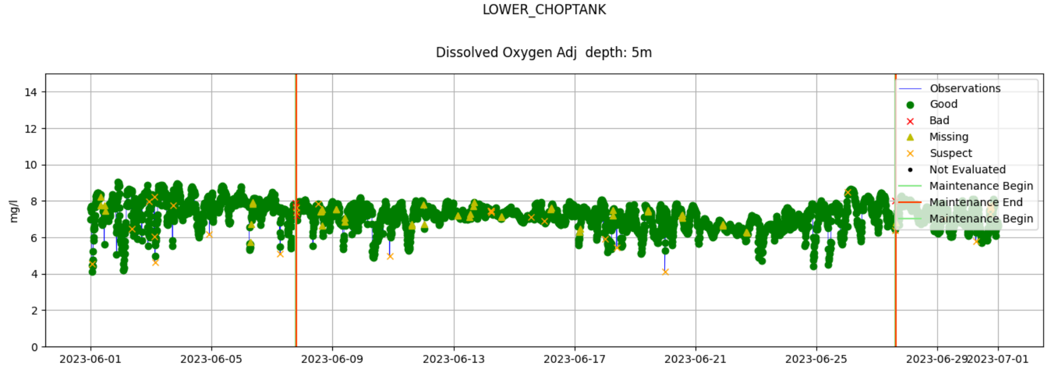

LOWER_CHOPTANK

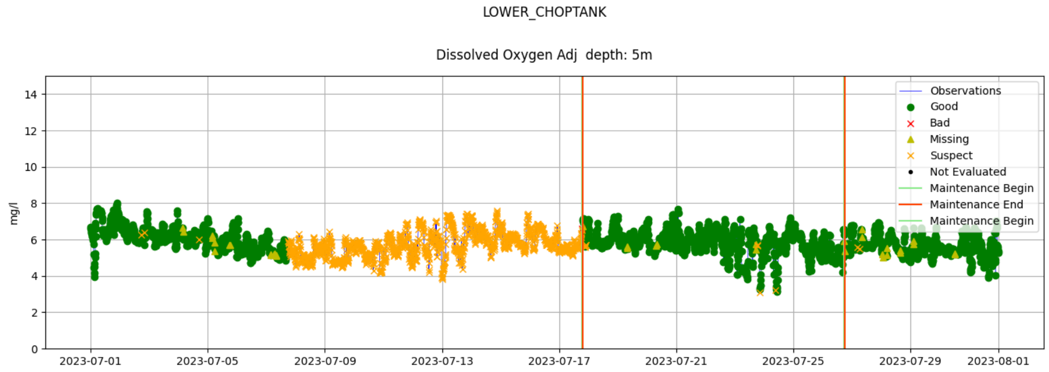
Conductivity depth: 5m

# Lower Choptank Dissolved Oxygen Depth=5m

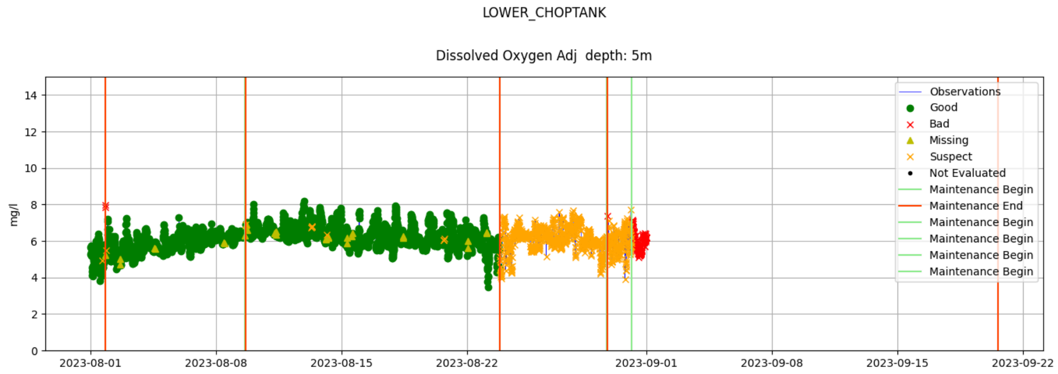




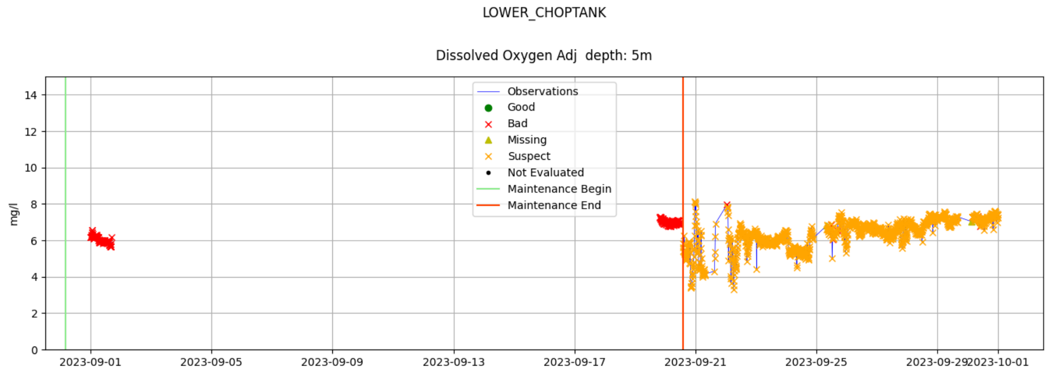



LOWER_CHOPTANK

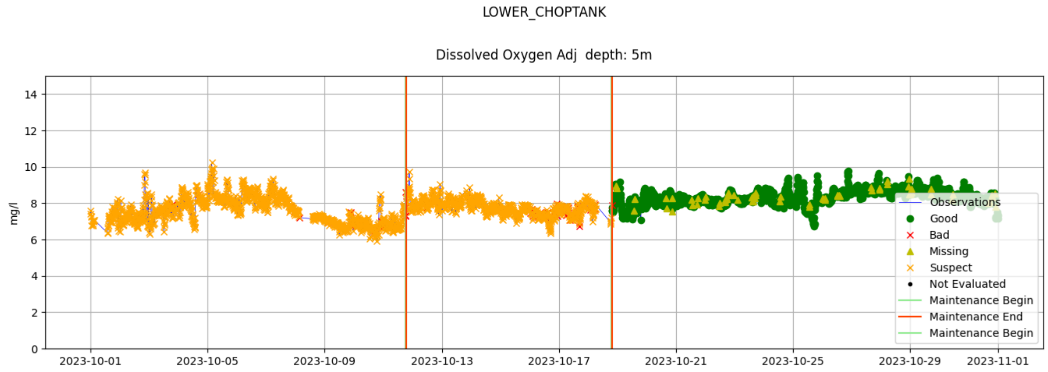
Dissolved Oxygen Adj depth: 5m


LOWER_CHOPTANK

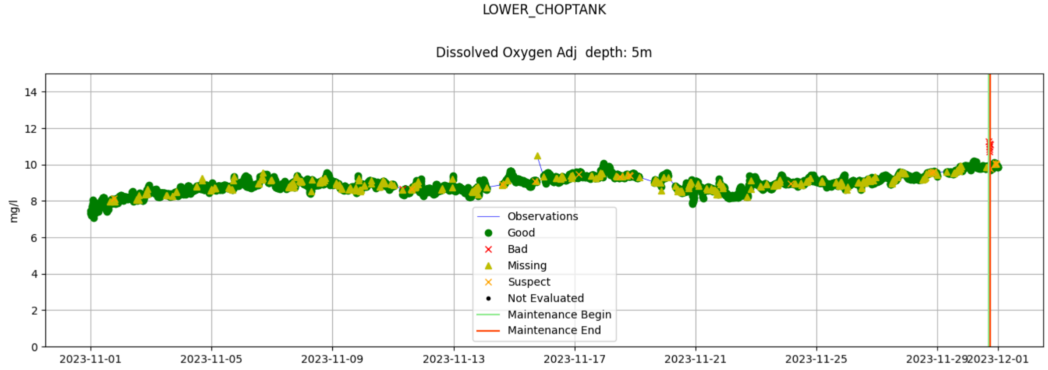
Dissolved Oxygen Adj depth: 5m


LOWER_CHOPTANK

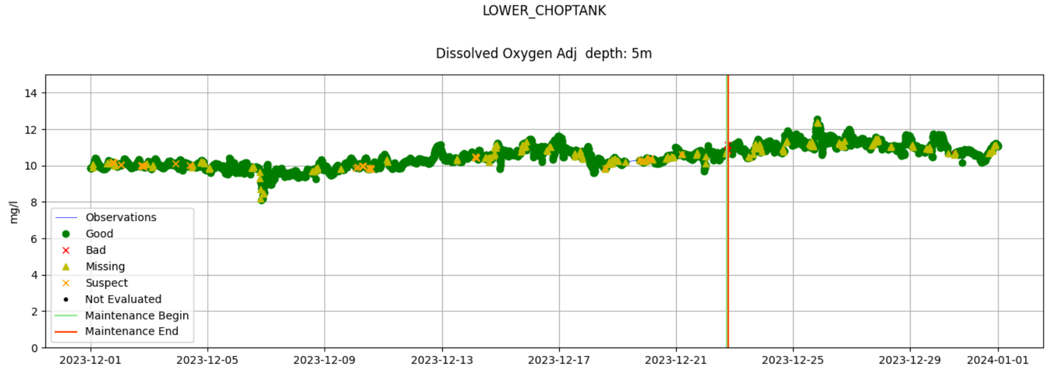
Dissolved Oxygen Adj depth: 5m


LOWER_CHOPTANK

Dissolved Oxygen Adj depth: 5m

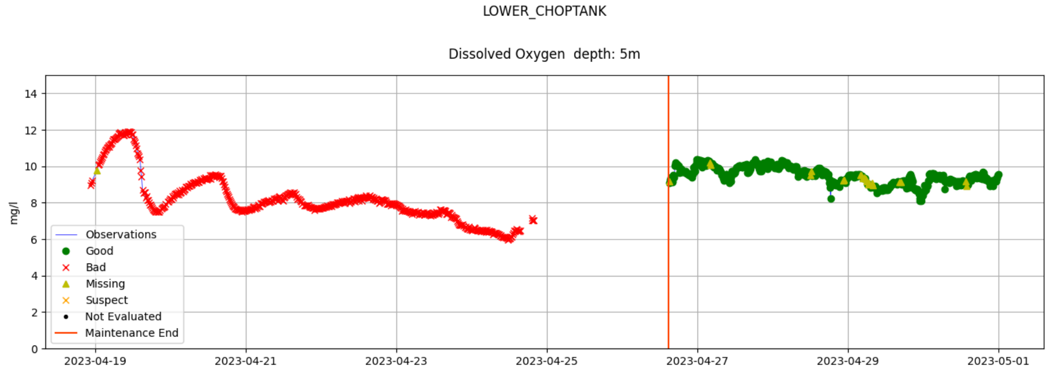

LOWER_CHOPTANK

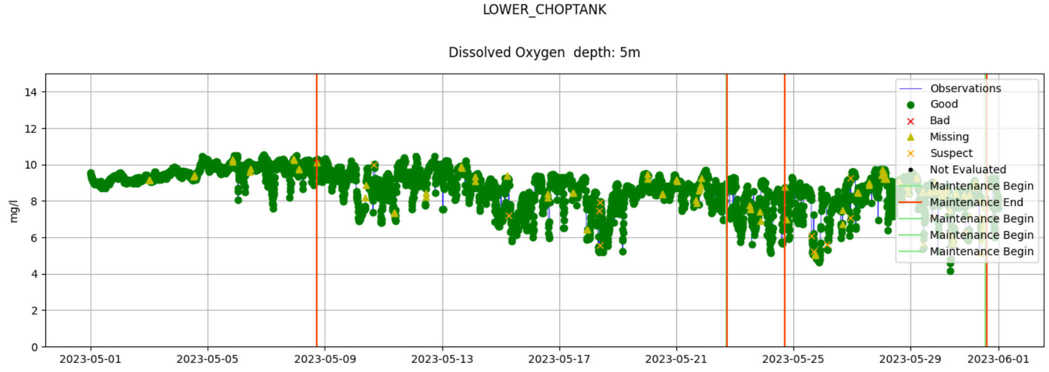
Dissolved Oxygen Adj depth: 5m

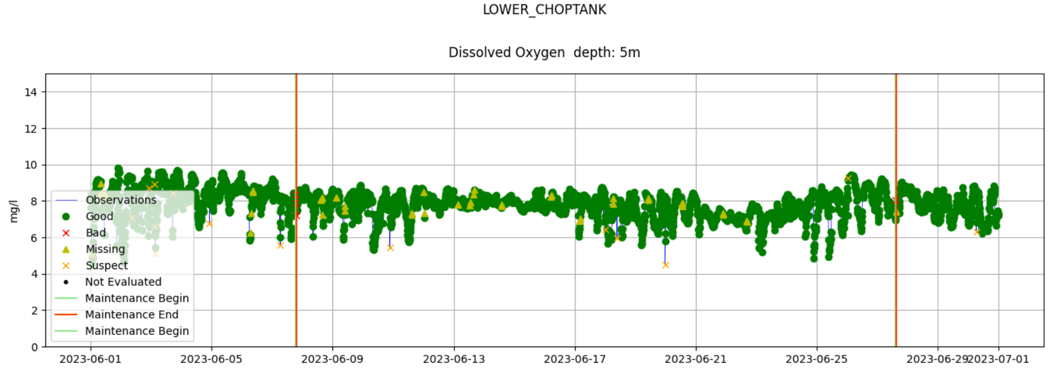

LOWER_CHOPTANK

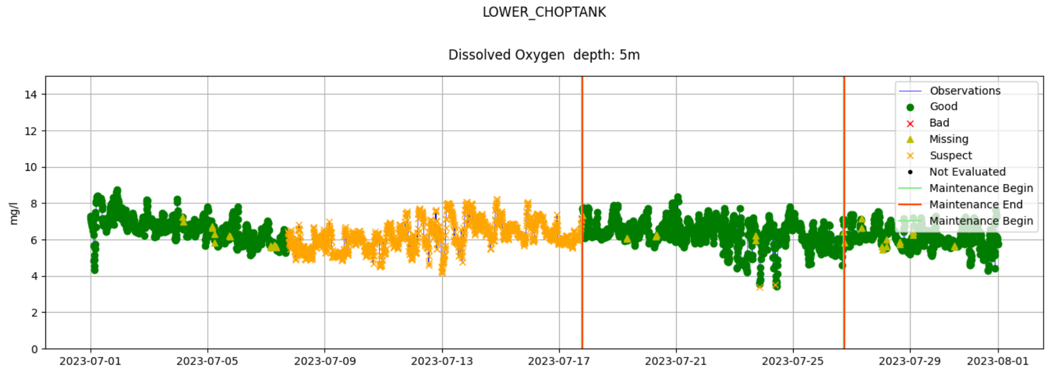
Dissolved Oxygen Adj depth: 5m

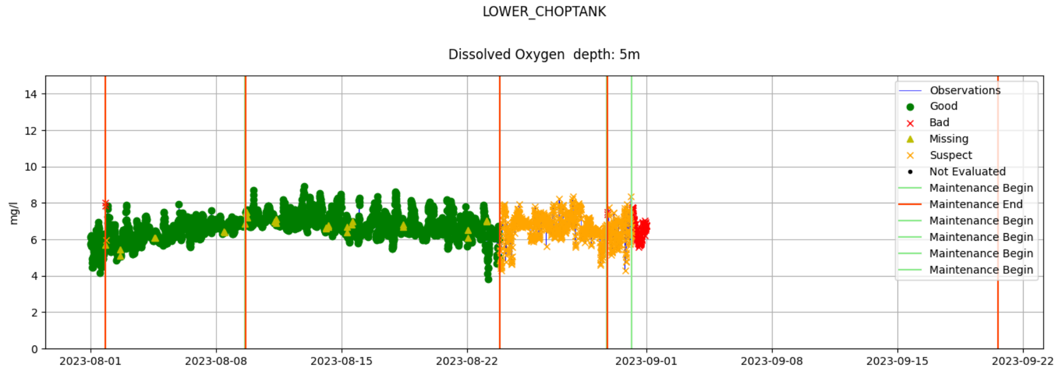
# Lower Choptank Dissolved Oxygen Depth=5m

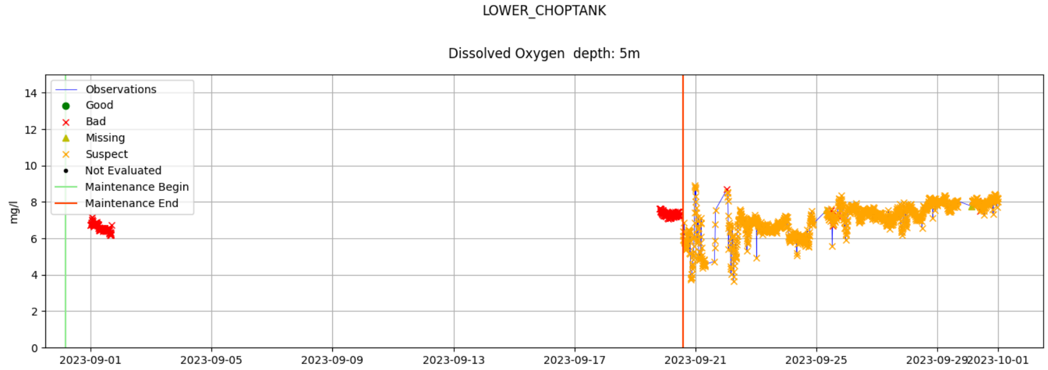


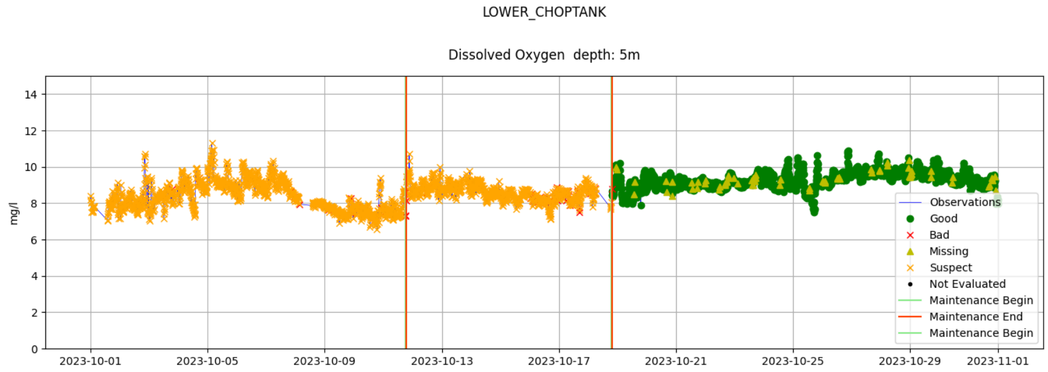


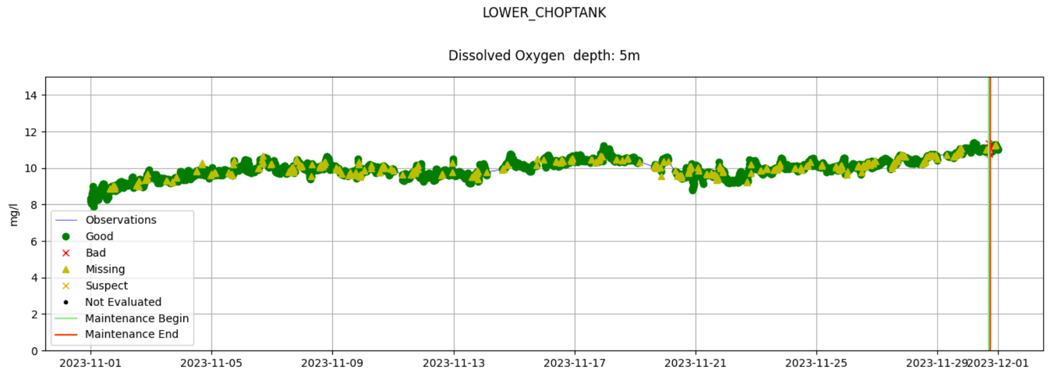


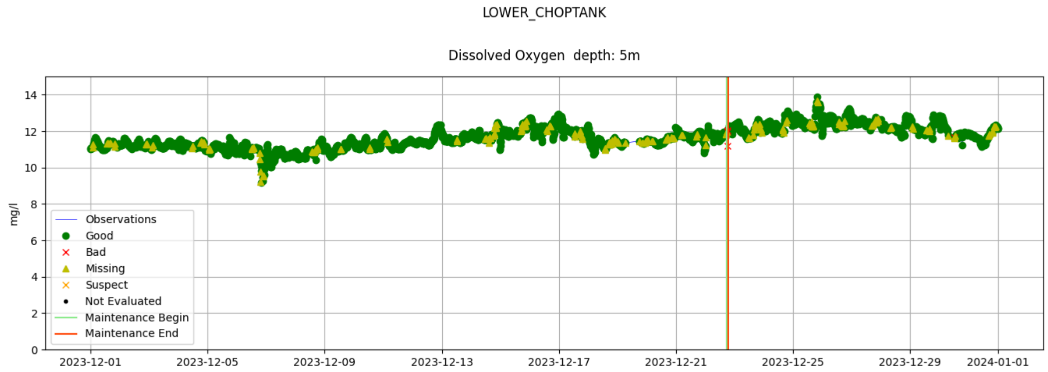

LOWER_CHOPTANK
Dissolved Oxygen depth: 5m
mg/l
0
2
4
6
8
10
12
14
2023-07-01
2023-07-05
2023-07-09
2023-07-13
2023-07-17
2023-07-21
2023-07-25
2023-07-29
2023-08-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin


LOWER_CHOPTANK
Dissolved Oxygen depth: 5m
mg/l
0
2
4
6
8
10
12
14
2023-08-01
2023-08-08
2023-08-15
2023-08-22
2023-09-01
2023-09-08
2023-09-15
2023-09-22
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin
Maintenance Begin
Maintenance Begin
Maintenance Begin

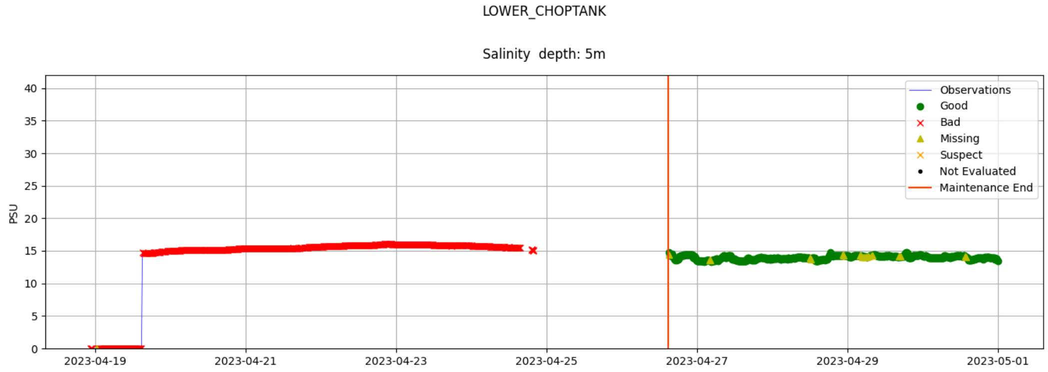

LOWER_CHOPTANK
Dissolved Oxygen depth: 5m
mg/l
0
2
4
6
8
10
12
14
2023-09-01
2023-09-05
2023-09-09
2023-09-13
2023-09-17
2023-09-21
2023-09-25
2023-09-29
2023-10-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

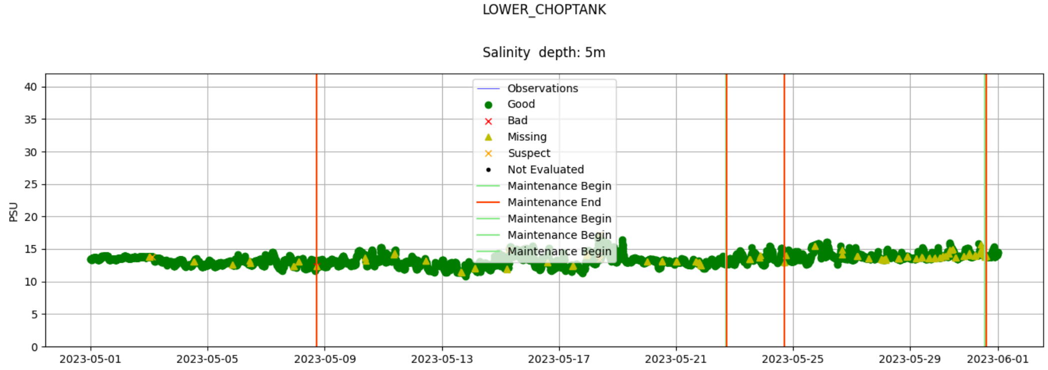

LOWER_CHOPTANK
Dissolved Oxygen  depth: 5m
mg/l
0
2
4
6
8
10
12
14
2023-10-01
2023-10-05
2023-10-09
2023-10-13
2023-10-17
2023-10-21
2023-10-25
2023-10-29
2023-11-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin

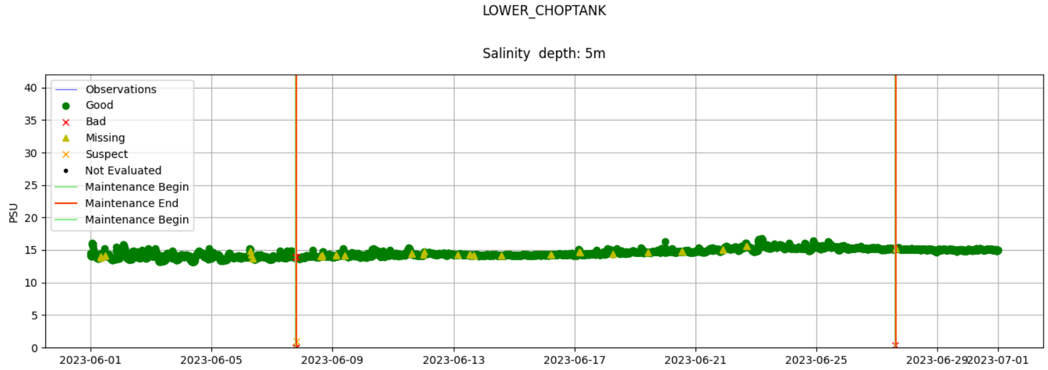

LOWER_CHOPTANK
Dissolved Oxygen  depth: 5m
mg/l
0
2
4
6
8
10
12
14
2023-11-01
2023-11-05
2023-11-09
2023-11-13
2023-11-17
2023-11-21
2023-11-25
2023-11-29
2023-12-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

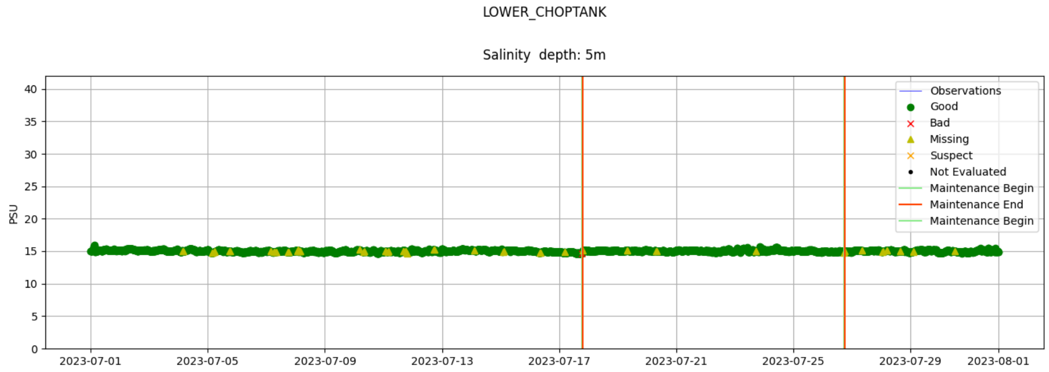

LOWER_CHOPTANK
Dissolved Oxygen  depth: 5m
mg/l
0
2
4
6
8
10
12
14
2023-12-01
2023-12-05
2023-12-09
2023-12-13
2023-12-17
2023-12-21
2023-12-25
2023-12-29
2024-01-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

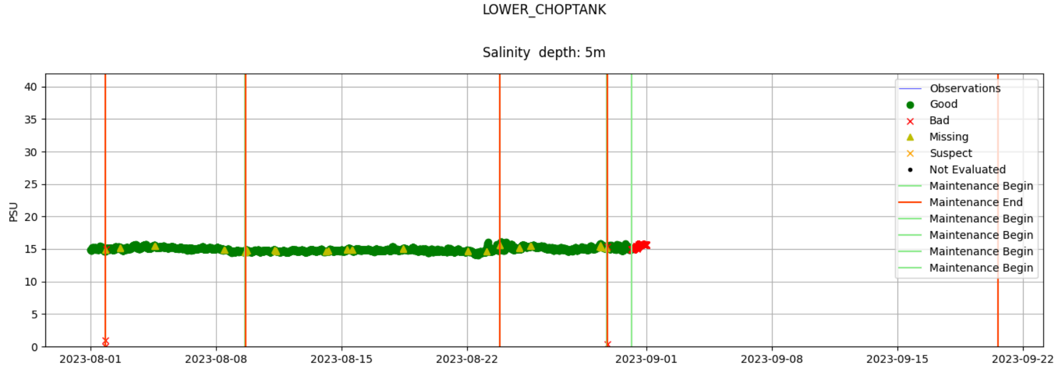
# Lower Choptank Salinity Depth=5m

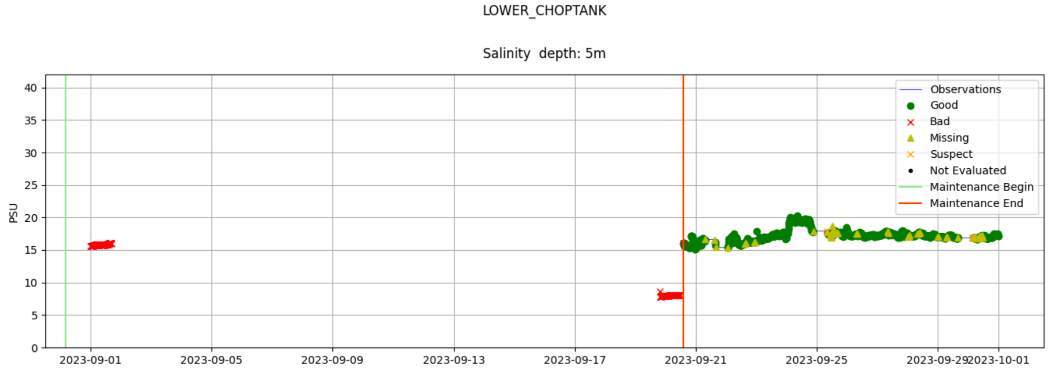


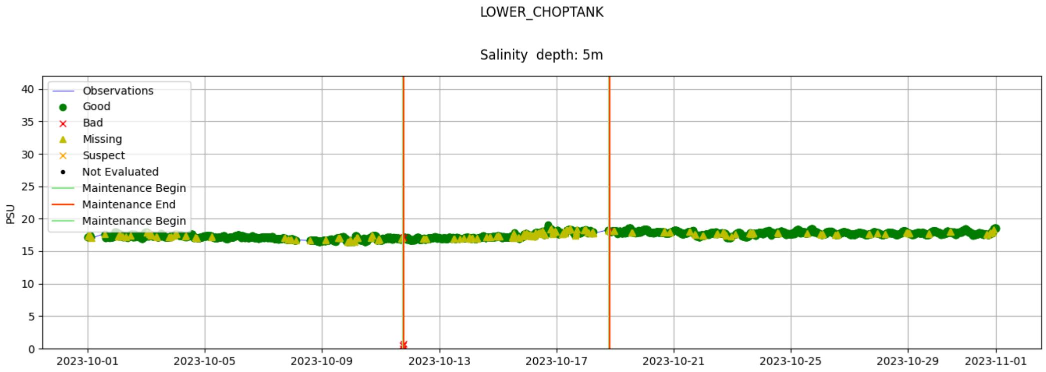


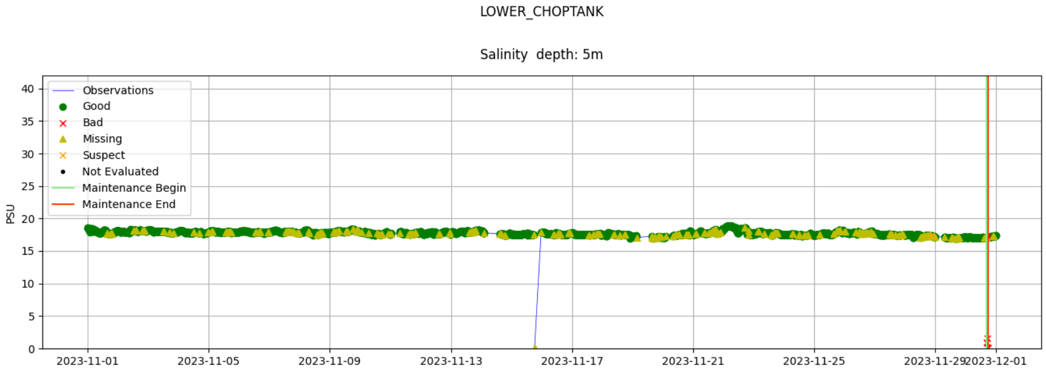


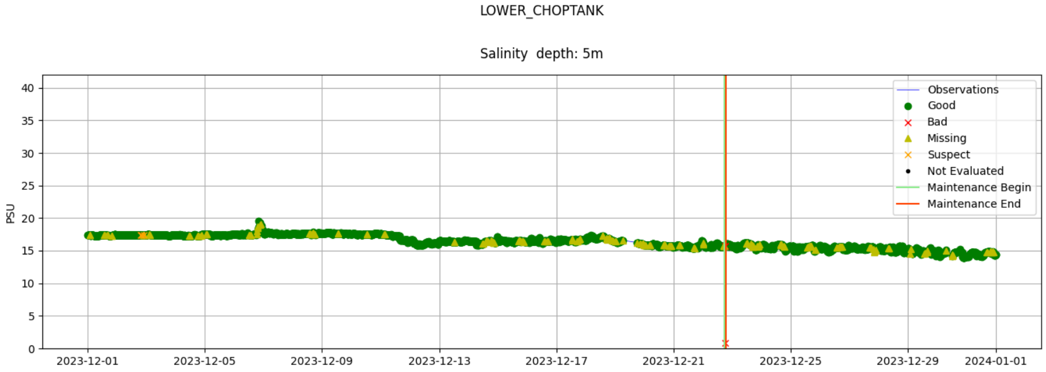

LOWER_CHOPTANK
Salinity depth: 5m
PSU
0
5
10
15
20
25
30
35
40
2023-07-01
2023-07-05
2023-07-09
2023-07-13
2023-07-17
2023-07-21
2023-07-25
2023-07-29
2023-08-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin


LOWER_CHOPTANK
Salinity depth: 5m
PSU
0
5
10
15
20
25
30
35
40
2023-08-01
2023-08-08
2023-08-15
2023-08-22
2023-09-01
2023-09-08
2023-09-15
2023-09-22
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin
Maintenance Begin
Maintenance Begin
Maintenance Begin

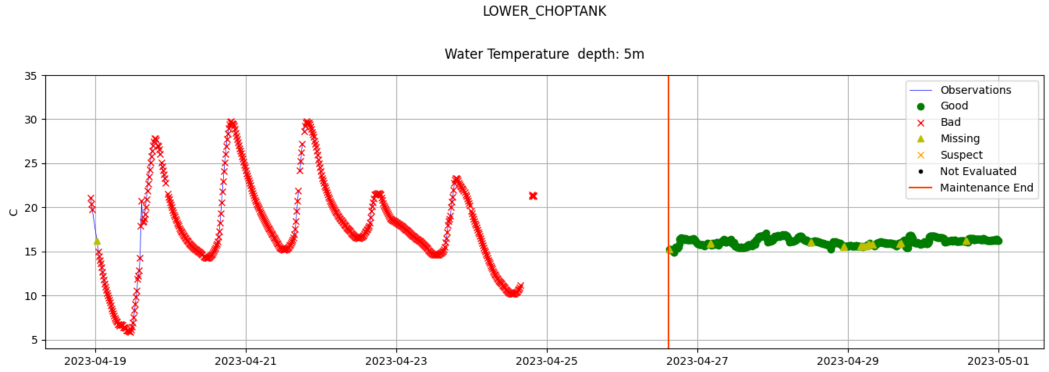

LOWER_CHOPTANK
Salinity depth: 5m
PSU
0
5
10
15
20
25
30
35
40
2023-09-01
2023-09-05
2023-09-09
2023-09-13
2023-09-17
2023-09-21
2023-09-25
2023-09-29
2023-10-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

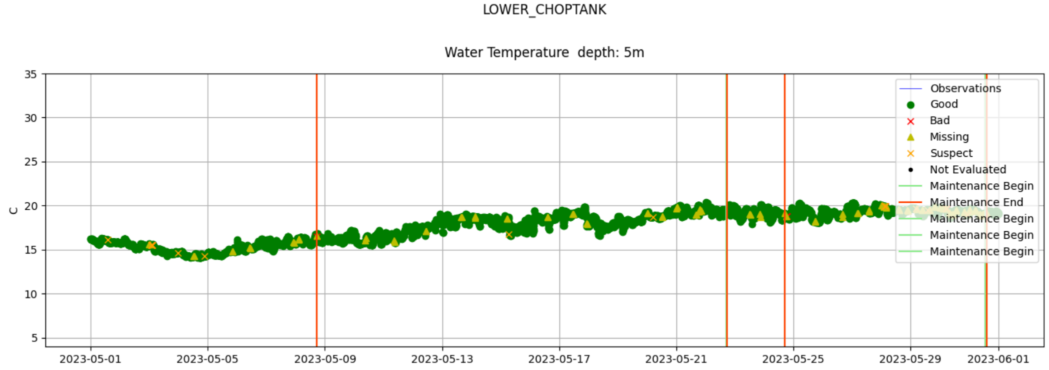

LOWER_CHOPTANK
Salinity depth: 5m
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin
PSU
0
5
10
15
20
25
30
35
40
2023-10-01
2023-10-05
2023-10-09
2023-10-13
2023-10-17
2023-10-21
2023-10-25
2023-10-29
2023-11-01

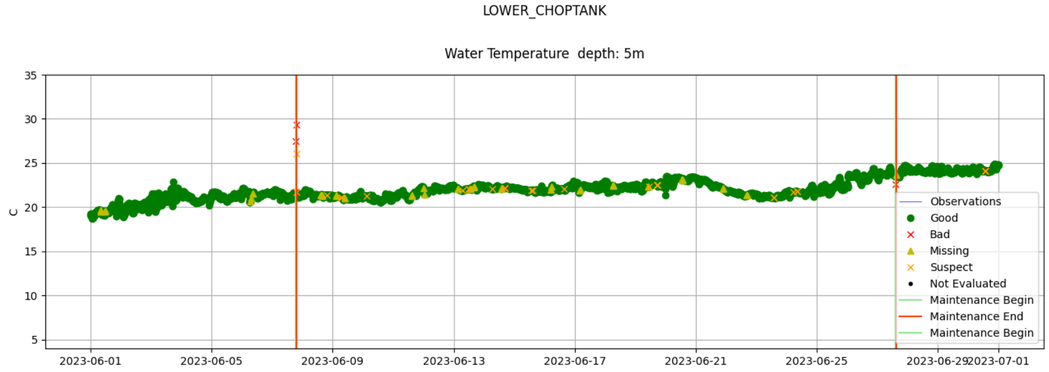

LOWER_CHOPTANK
Salinity depth: 5m
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
PSU
0
5
10
15
20
25
30
35
40
2023-11-01
2023-11-05
2023-11-09
2023-11-13
2023-11-17
2023-11-21
2023-11-25
2023-11-29
2023-12-01

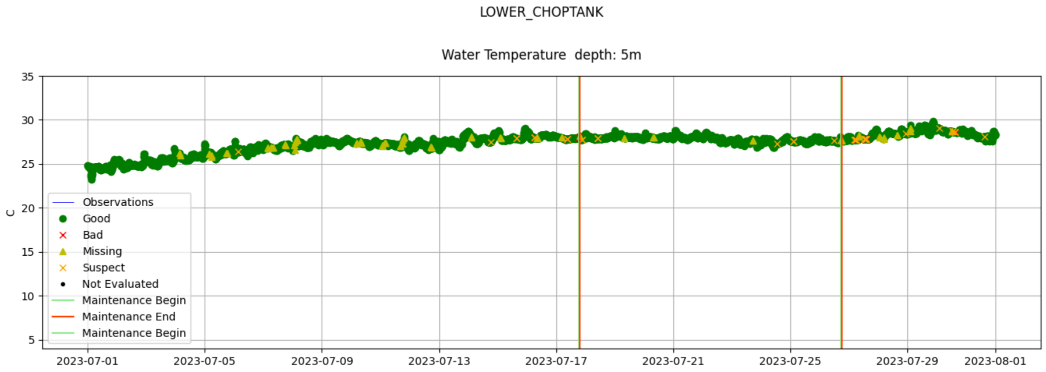

LOWER_CHOPTANK
Salinity depth: 5m
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
PSU
0
5
10
15
20
25
30
35
40
2023-12-01
2023-12-05
2023-12-09
2023-12-13
2023-12-17
2023-12-21
2023-12-25
2023-12-29
2024-01-01

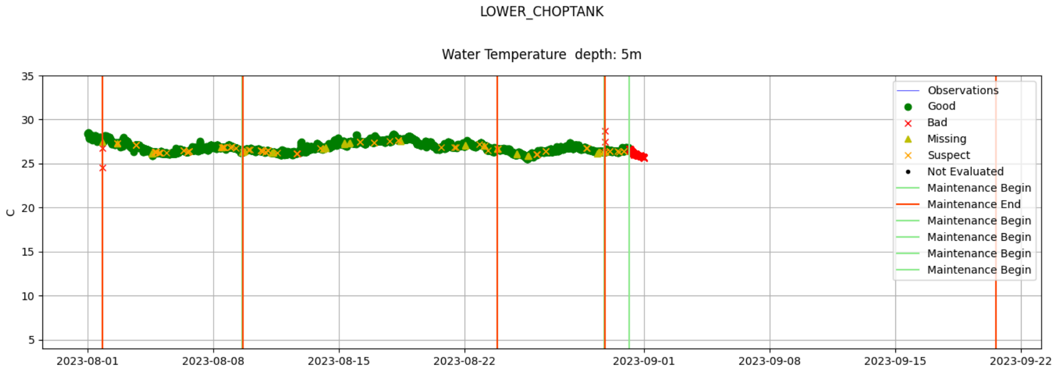
# Lower Choptank Water Temperature Depth=5m

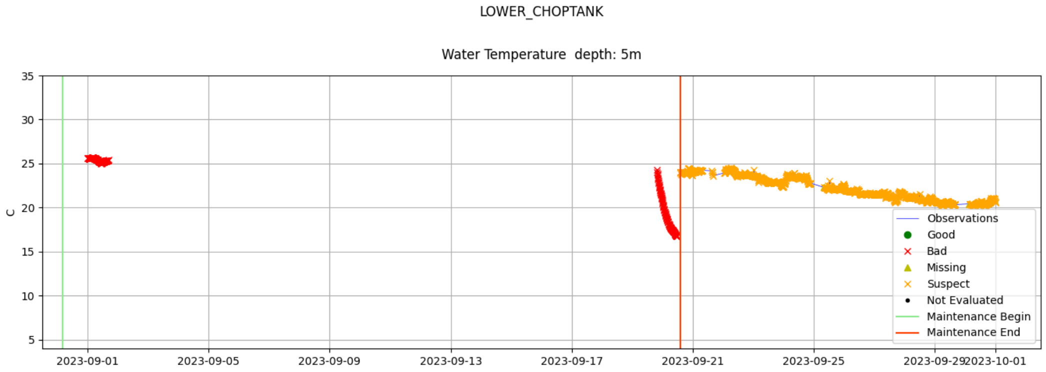


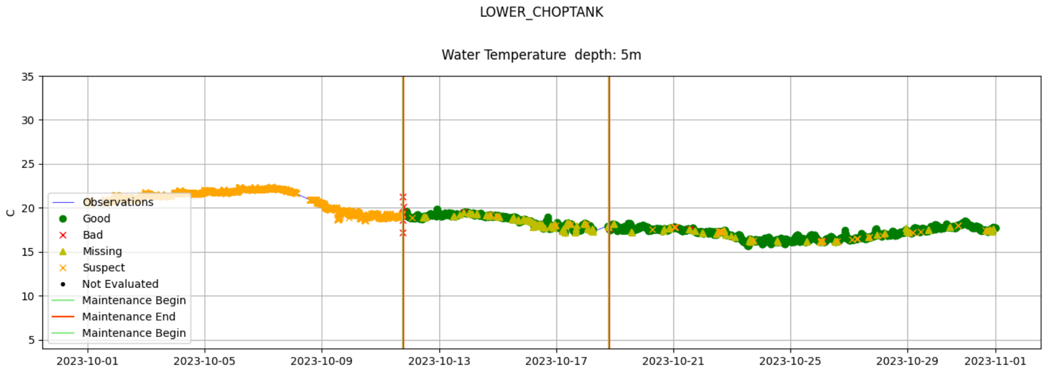


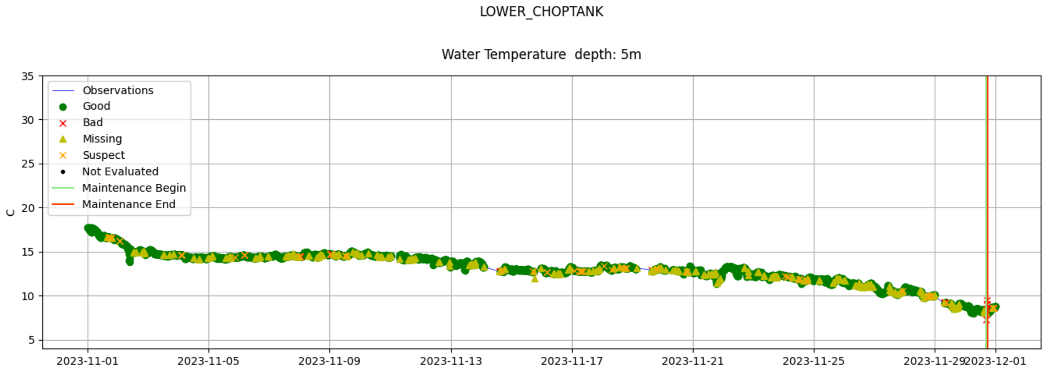


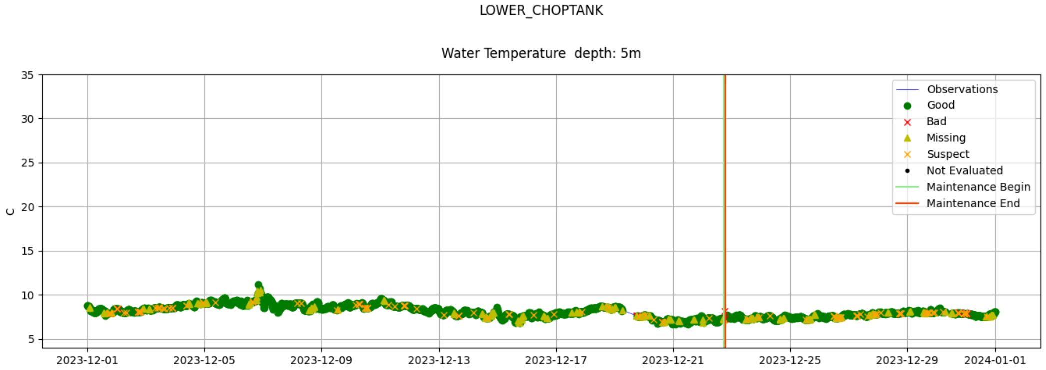

LOWER_CHOPTANK
Water Temperature depth: 5m
C
35
30
25
20
15
10
5
2023-07-01
2023-07-05
2023-07-09
2023-07-13
2023-07-17
2023-07-21
2023-07-25
2023-07-29
2023-08-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin


LOWER_CHOPTANK
Water Temperature depth: 5m
C
35
30
25
20
15
10
5
2023-08-01
2023-08-08
2023-08-15
2023-08-22
2023-09-01
2023-09-08
2023-09-15
2023-09-22
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin
Maintenance Begin
Maintenance Begin
Maintenance Begin

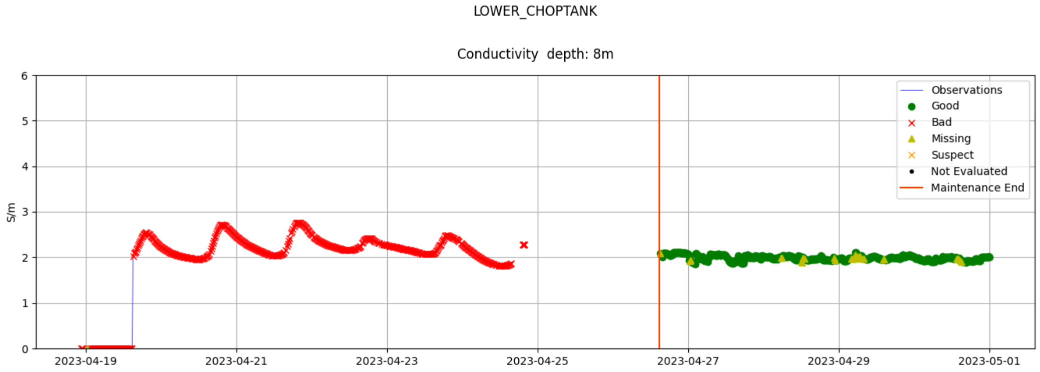

LOWER_CHOPTANK
Water Temperature depth: 5m
C
35
30
25
20
15
10
5
2023-09-01
2023-09-05
2023-09-09
2023-09-13
2023-09-17
2023-09-21
2023-09-25
2023-09-29
2023-10-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

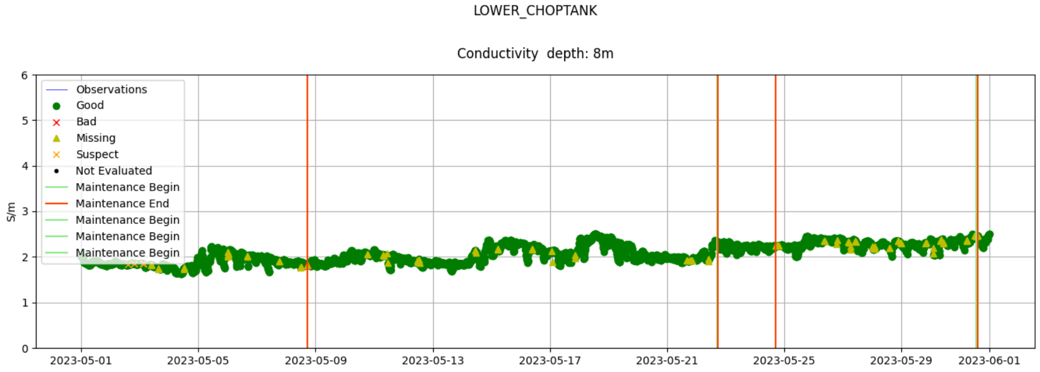

LOWER_CHOPTANK
Water Temperature depth: 5m
C
35
30
25
20
15
10
5
2023-10-01
2023-10-05
2023-10-09
2023-10-13
2023-10-17
2023-10-21
2023-10-25
2023-10-29
2023-11-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin

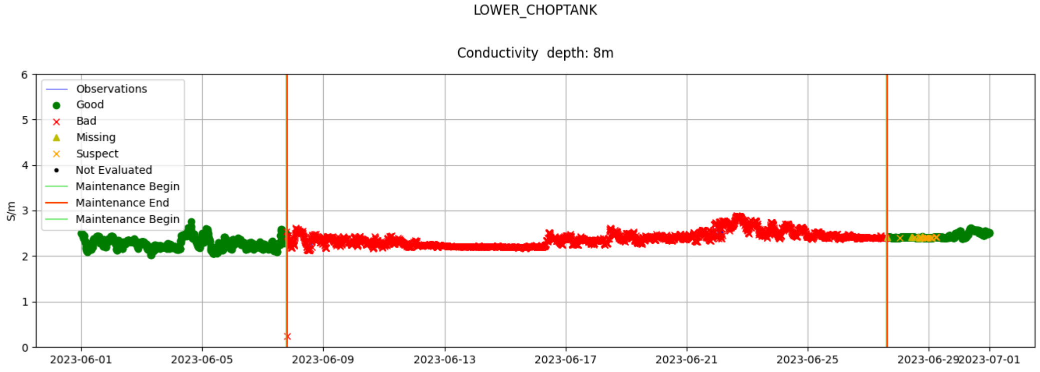

LOWER_CHOPTANK
Water Temperature depth: 5m
C
35
30
25
20
15
10
5
2023-11-01
2023-11-05
2023-11-09
2023-11-13
2023-11-17
2023-11-21
2023-11-25
2023-11-29
2023-12-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

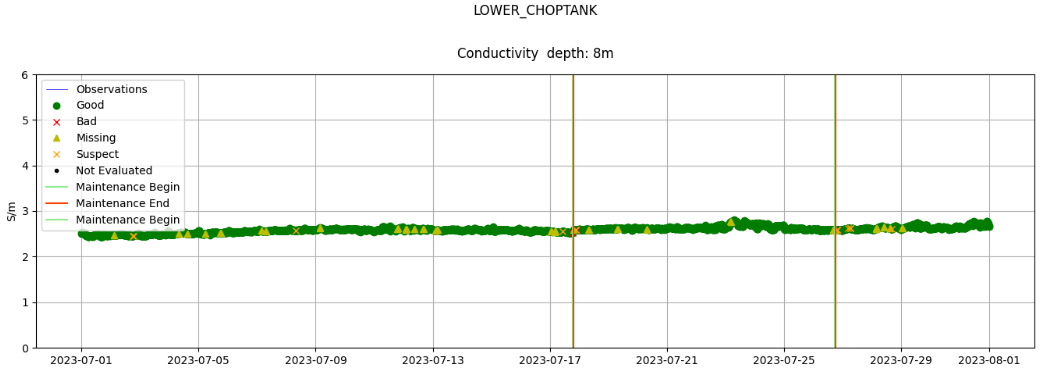

LOWER_CHOPTANK
Water Temperature depth: 5m
C
35
30
25
20
15
10
5
2023-12-01
2023-12-05
2023-12-09
2023-12-13
2023-12-17
2023-12-21
2023-12-25
2023-12-29
2024-01-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

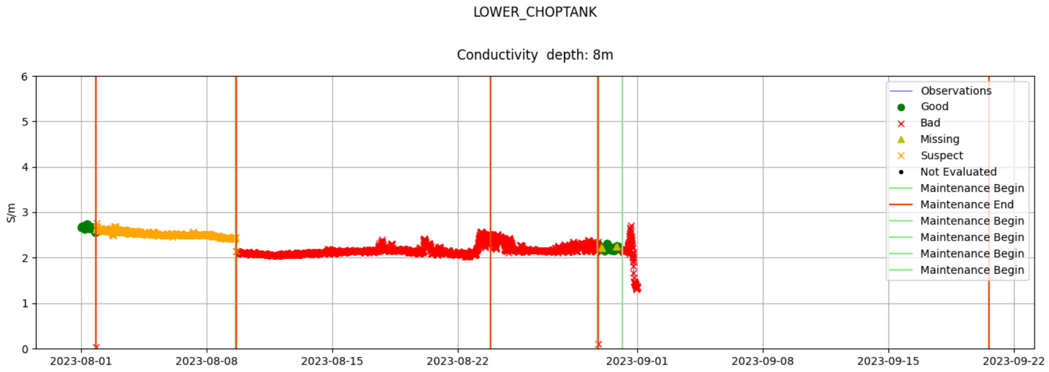
# Lower Choptank Conductivity Depth= 8m

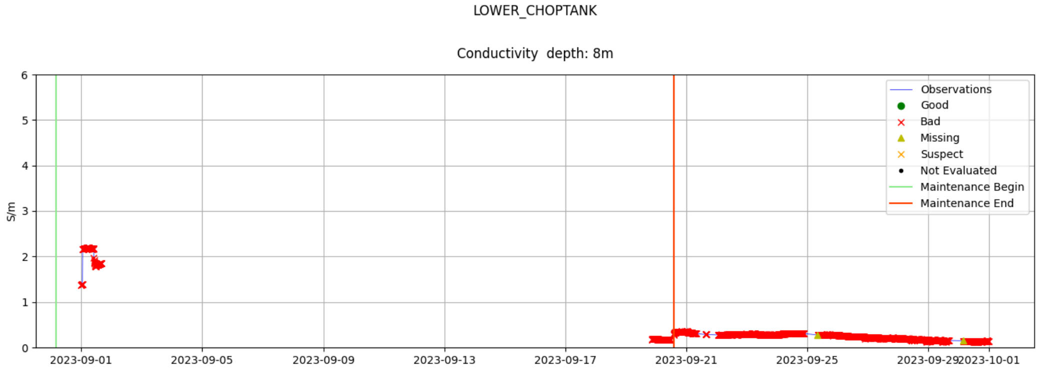


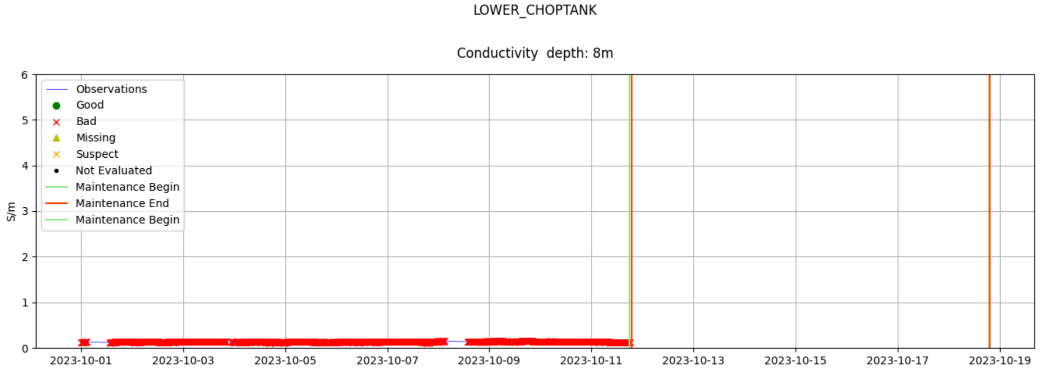


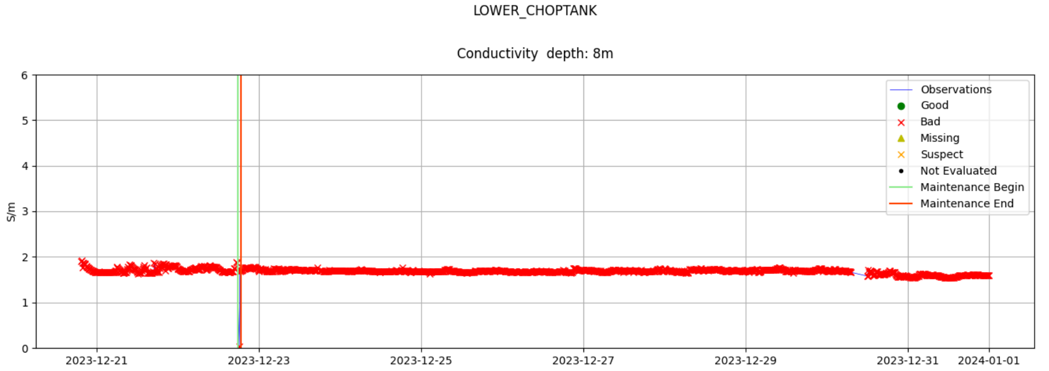




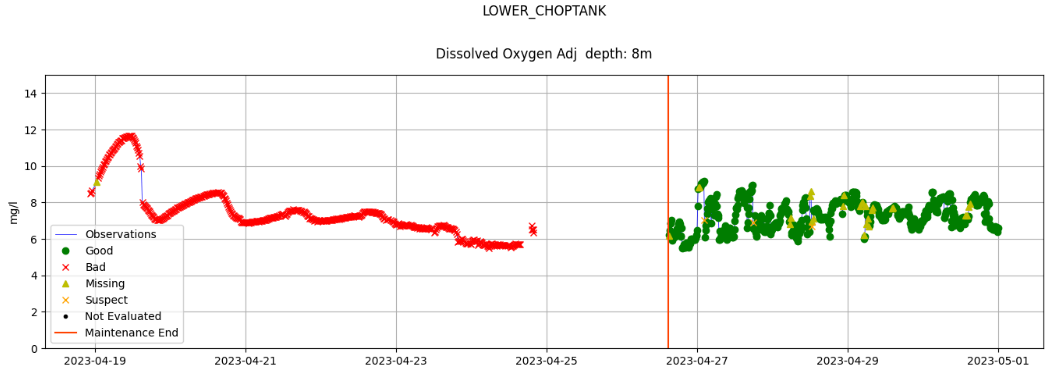

LOWER_CHOPTANK
Conductivity depth: 8m
S/m
0
1
2
3
4
5
6
2023-08-01
2023-08-08
2023-08-15
2023-08-22
2023-09-01
2023-09-08
2023-09-15
2023-09-22
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin
Maintenance Begin
Maintenance Begin
Maintenance Begin

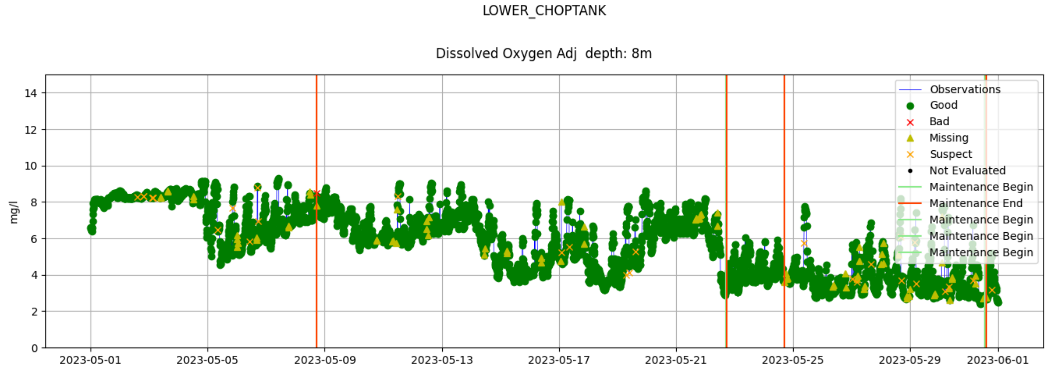

LOWER_CHOPTANK
Conductivity depth: 8m
S/m
0
1
2
3
4
5
6
2023-09-01
2023-09-05
2023-09-09
2023-09-13
2023-09-17
2023-09-21
2023-09-25
2023-09-29
2023-10-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

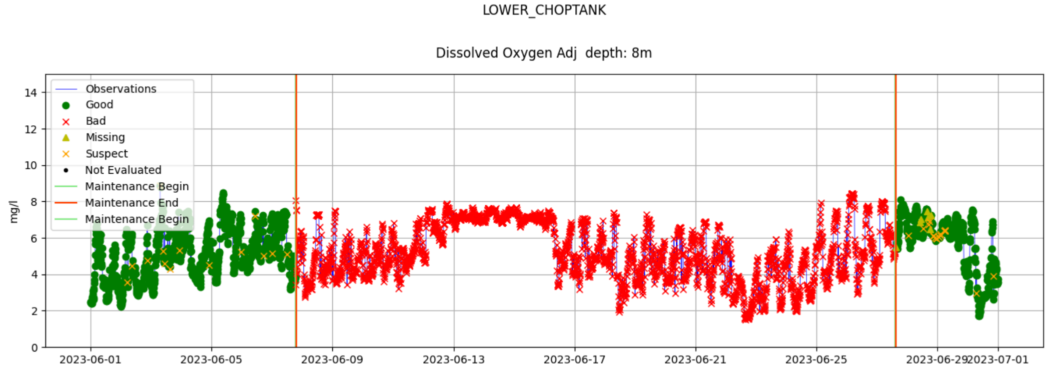

LOWER_CHOPTANK
Conductivity depth: 8m
S/m
0
1
2
3
4
5
6
2023-10-01
2023-10-03
2023-10-05
2023-10-07
2023-10-09
2023-10-11
2023-10-13
2023-10-15
2023-10-17
2023-10-19
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin

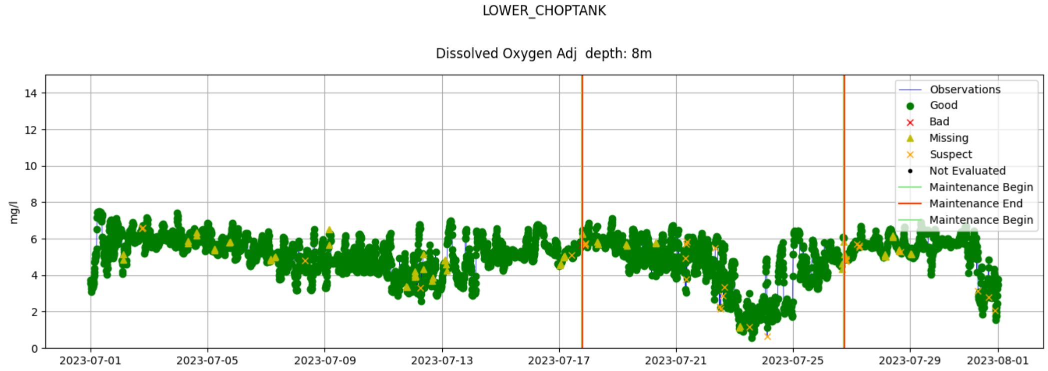

LOWER_CHOPTANK
Conductivity depth: 8m
S/m
0
1
2
3
4
5
6
2023-12-21
2023-12-23
2023-12-25
2023-12-27
2023-12-29
2023-12-31
2024-01-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

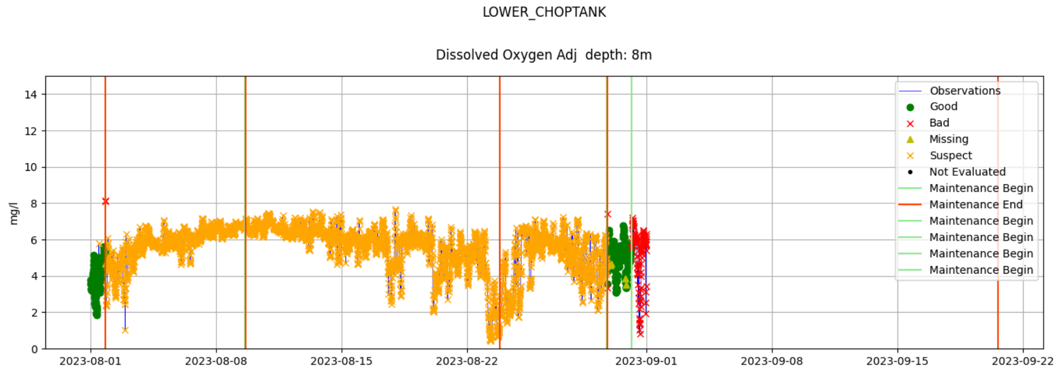
# Lower Choptank Adjusted Dissolved Oxygen Depth= 8m

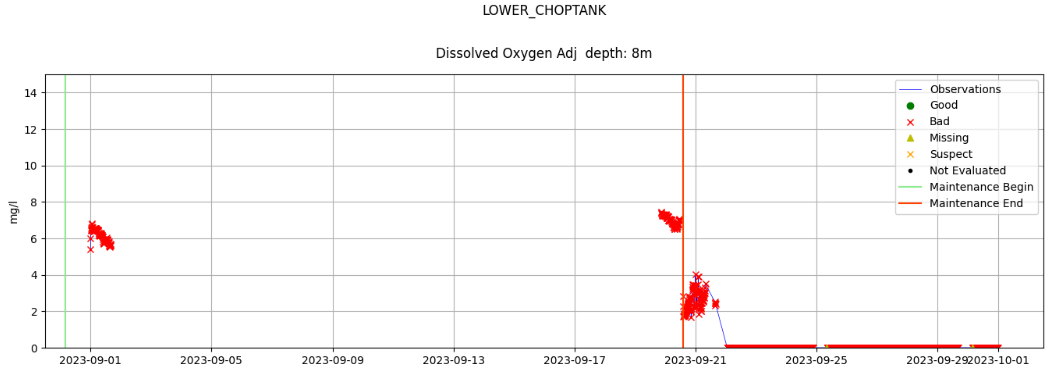


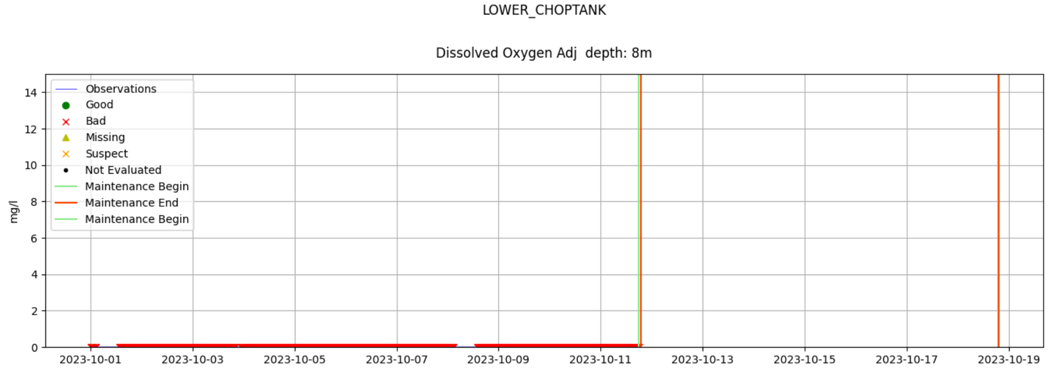


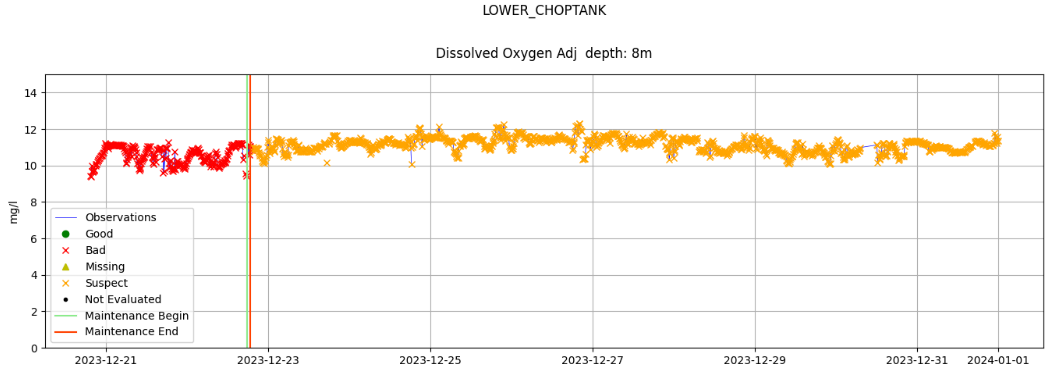




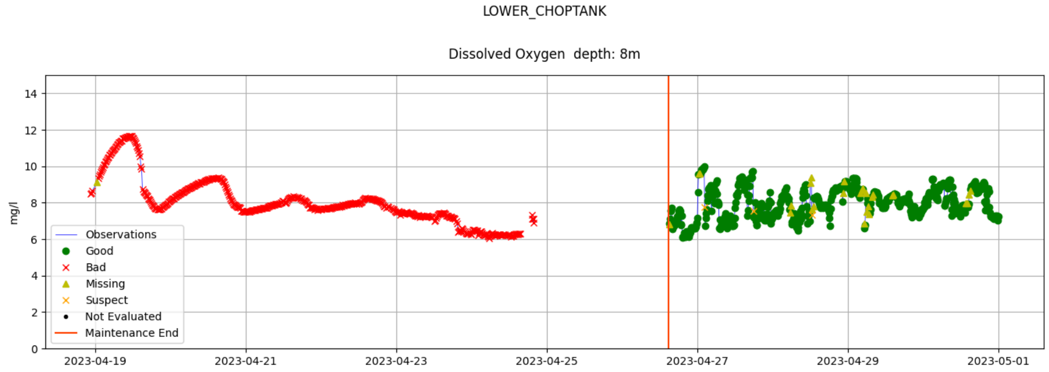

LOWER_CHOPTANK
Dissolved Oxygen Adj  depth: 8m
mg/l
0
2
4
6
8
10
12
14
2023-08-01
2023-08-08
2023-08-15
2023-08-22
2023-09-01
2023-09-08
2023-09-15
2023-09-22
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin
Maintenance Begin
Maintenance Begin
Maintenance Begin

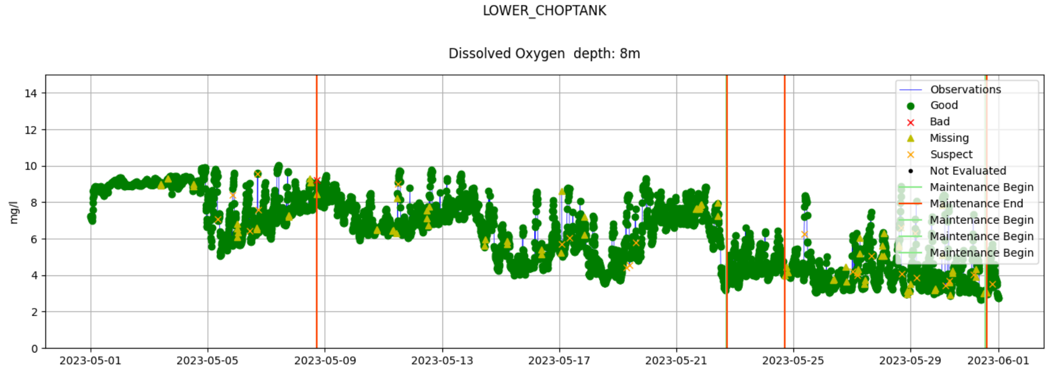

LOWER_CHOPTANK
Dissolved Oxygen Adj  depth: 8m
mg/l
0
2
4
6
8
10
12
14
2023-09-01
2023-09-05
2023-09-09
2023-09-13
2023-09-17
2023-09-21
2023-09-25
2023-09-29
2023-10-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

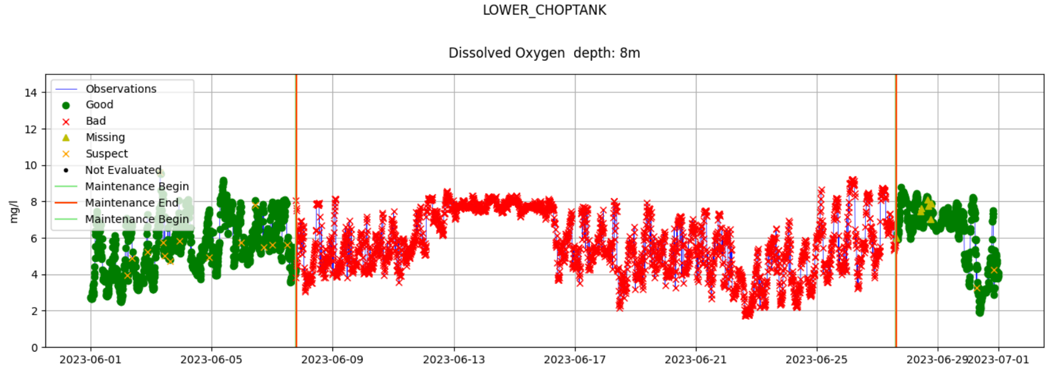

LOWER_CHOPTANK
Dissolved Oxygen Adj  depth: 8m
mg/l
0
2
4
6
8
10
12
14
2023-10-01
2023-10-03
2023-10-05
2023-10-07
2023-10-09
2023-10-11
2023-10-13
2023-10-15
2023-10-17
2023-10-19
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin

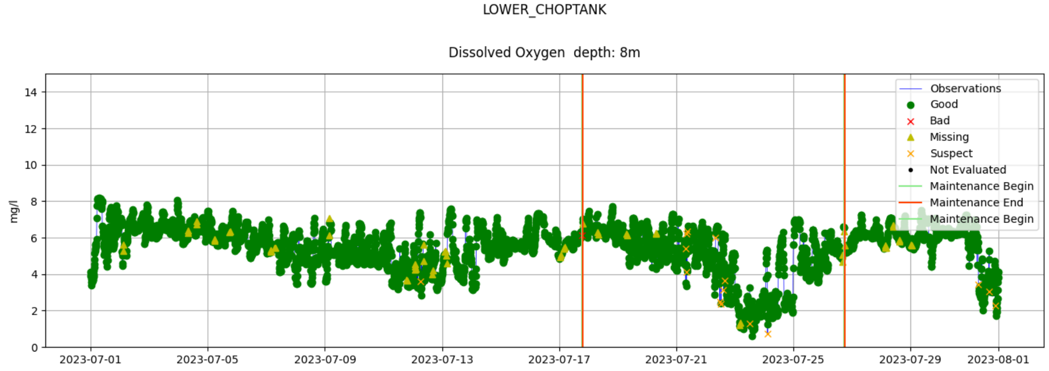

LOWER_CHOPTANK
Dissolved Oxygen Adj  depth: 8m
mg/l
0
2
4
6
8
10
12
14
2023-12-21
2023-12-23
2023-12-25
2023-12-27
2023-12-29
2023-12-31
2024-01-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

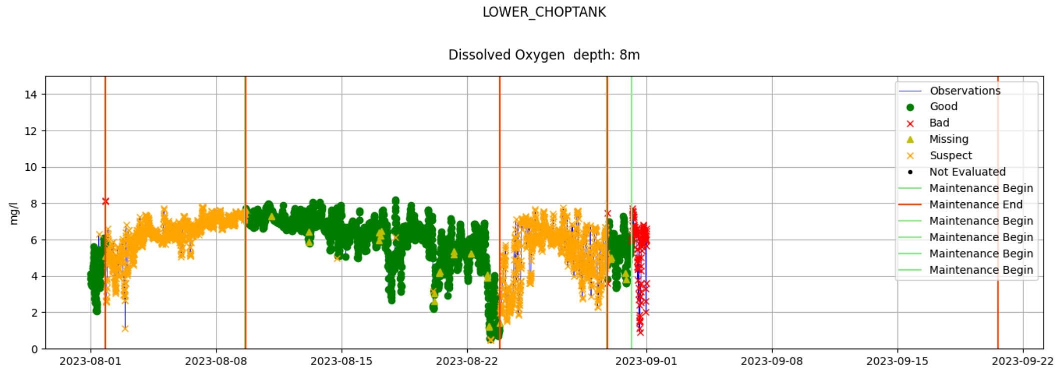
# Lower Choptank Dissolved Oxygen Depth=8m

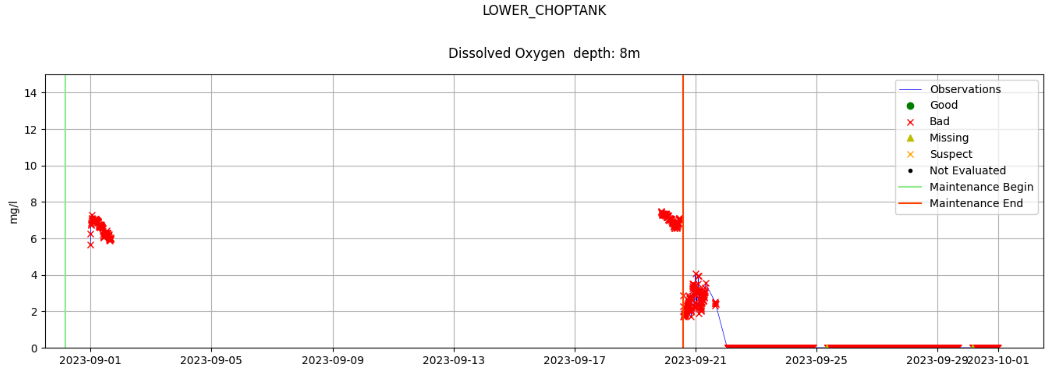


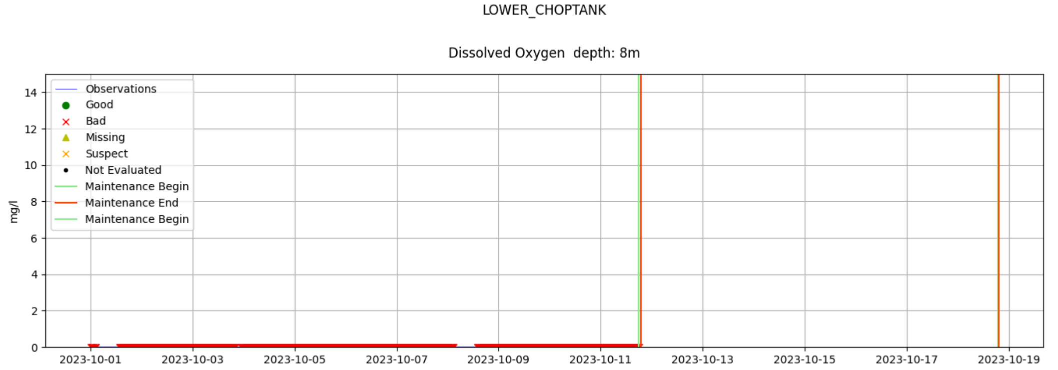


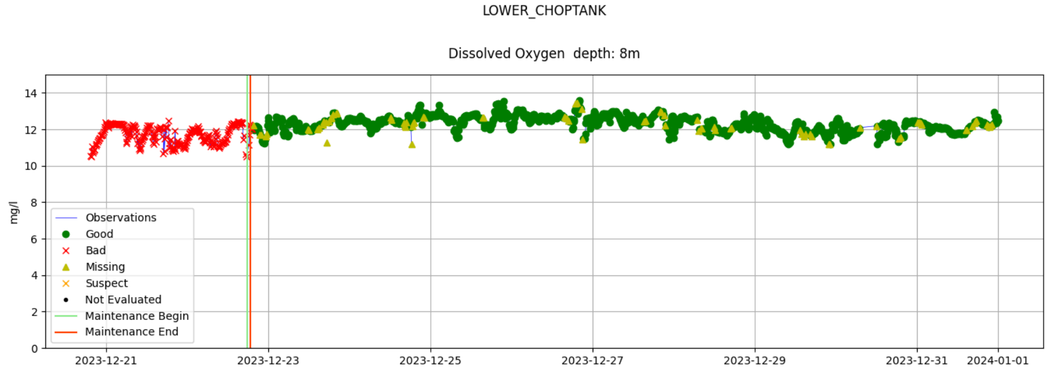




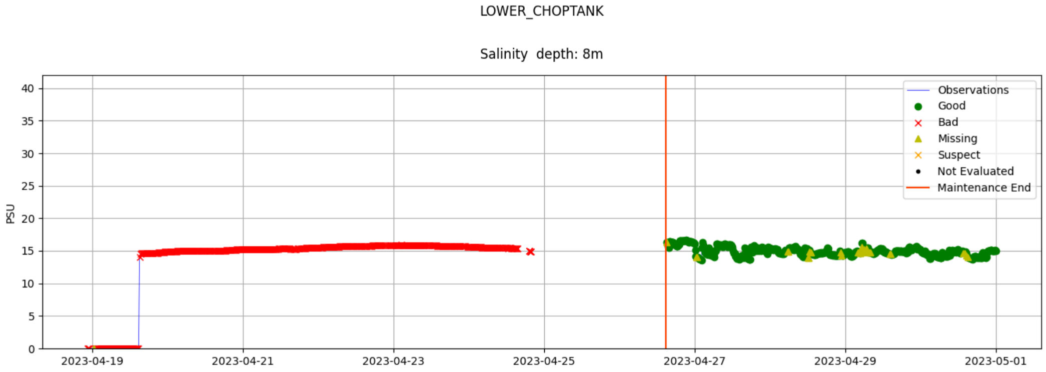

LOWER_CHOPTANK
Dissolved Oxygen depth: 8m
mg/l
0
2
4
6
8
10
12
14
2023-08-01
2023-08-08
2023-08-15
2023-08-22
2023-09-01
2023-09-08
2023-09-15
2023-09-22
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin
Maintenance Begin
Maintenance Begin
Maintenance Begin

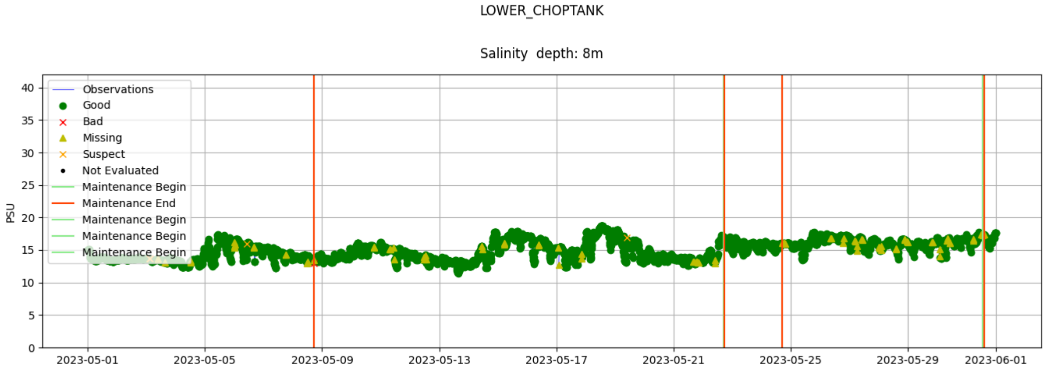

LOWER_CHOPTANK
Dissolved Oxygen depth: 8m
mg/l
0
2
4
6
8
10
12
14
2023-09-01
2023-09-05
2023-09-09
2023-09-13
2023-09-17
2023-09-21
2023-09-25
2023-09-29
2023-10-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

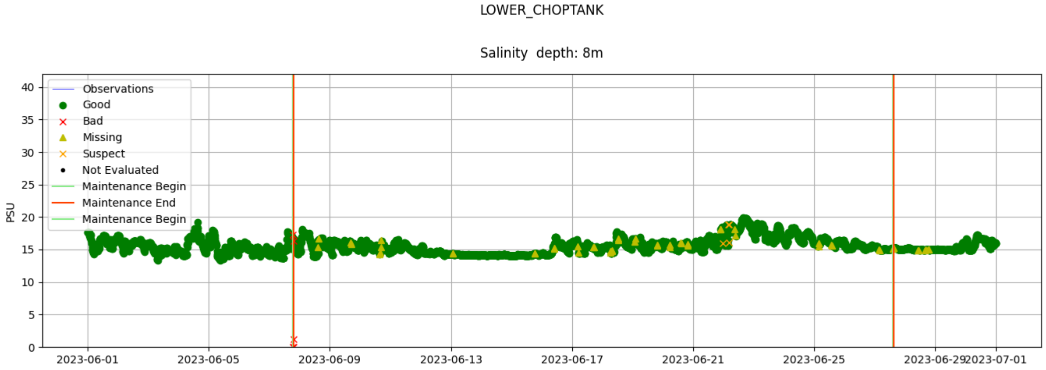

LOWER_CHOPTANK
Dissolved Oxygen depth: 8m
mg/l
0
2
4
6
8
10
12
14
2023-10-01
2023-10-03
2023-10-05
2023-10-07
2023-10-09
2023-10-11
2023-10-13
2023-10-15
2023-10-17
2023-10-19
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin

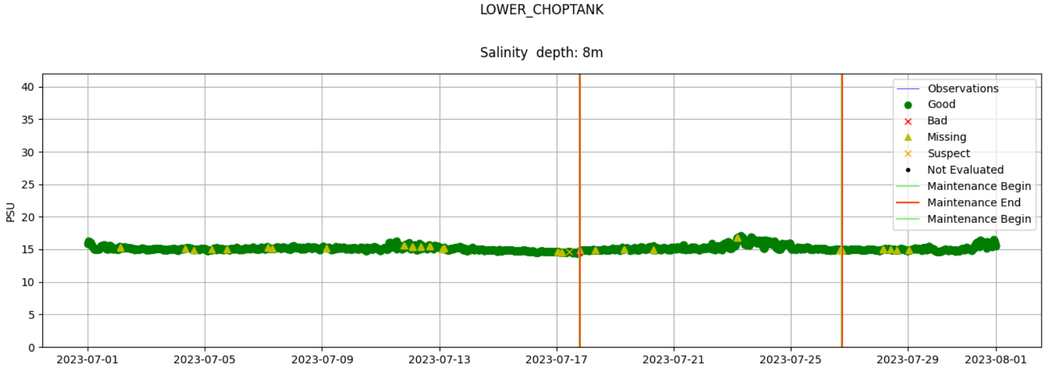

LOWER_CHOPTANK
Dissolved Oxygen depth: 8m
mg/l
0
2
4
6
8
10
12
14
2023-12-21
2023-12-23
2023-12-25
2023-12-27
2023-12-29
2023-12-31
2024-01-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

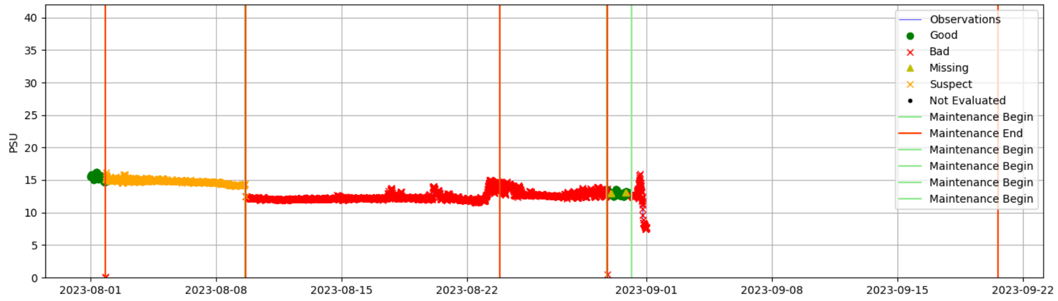
# Lower Choptank Salinity Depth=8m



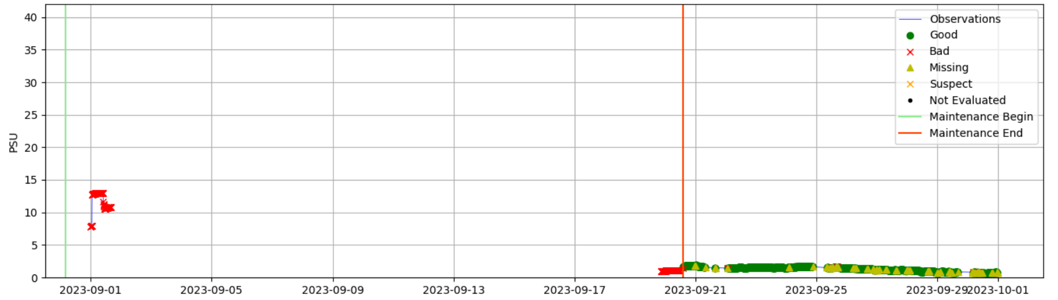




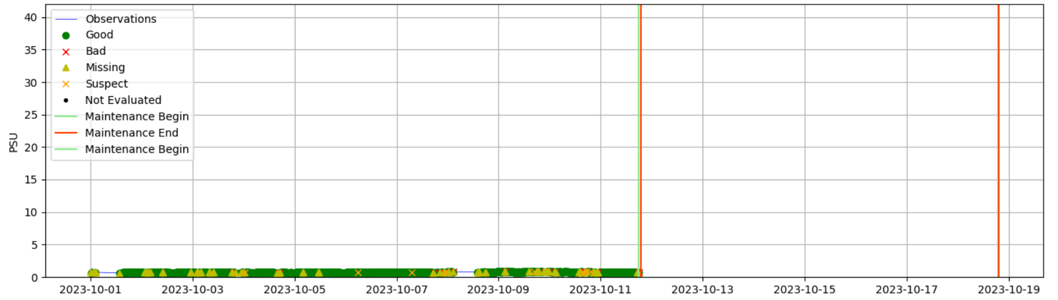



LOWER_CHOPTANK

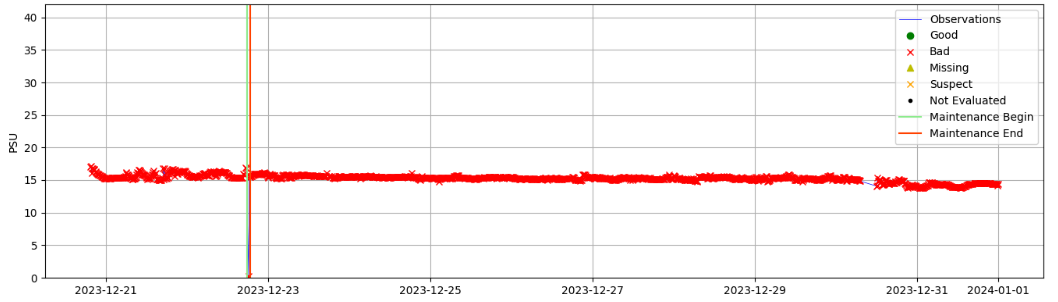
Salinity depth: 8m


LOWER_CHOPTANK

Salinity depth: 8m

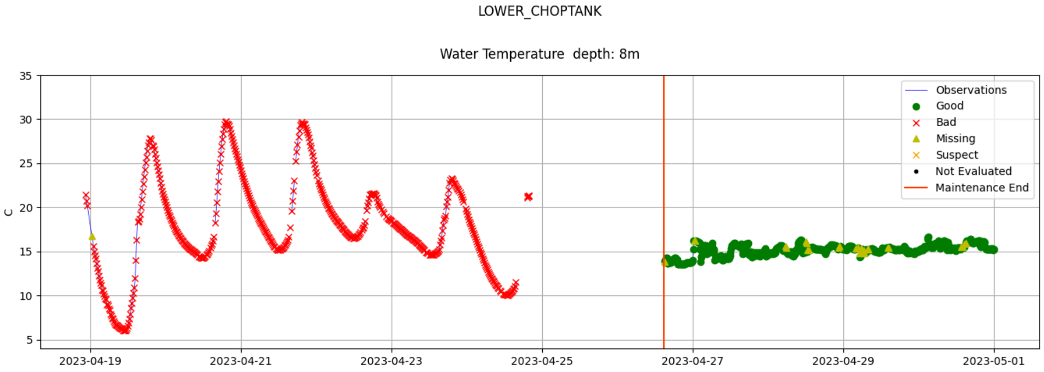

LOWER_CHOPTANK

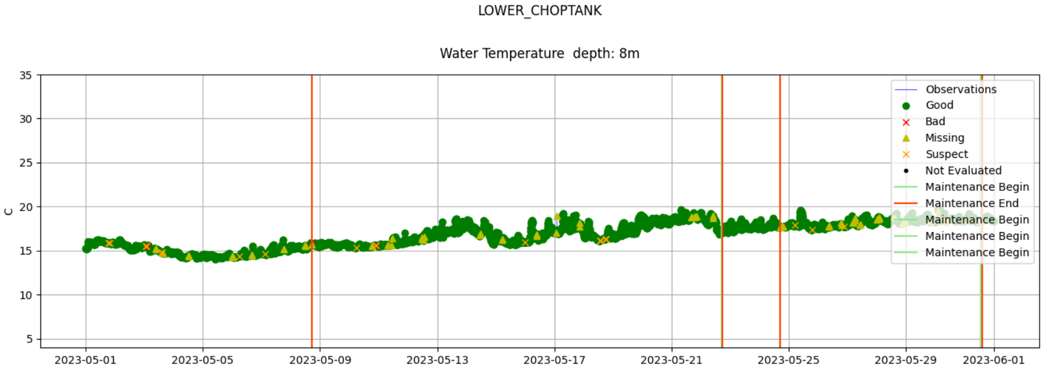
Salinity depth: 8m

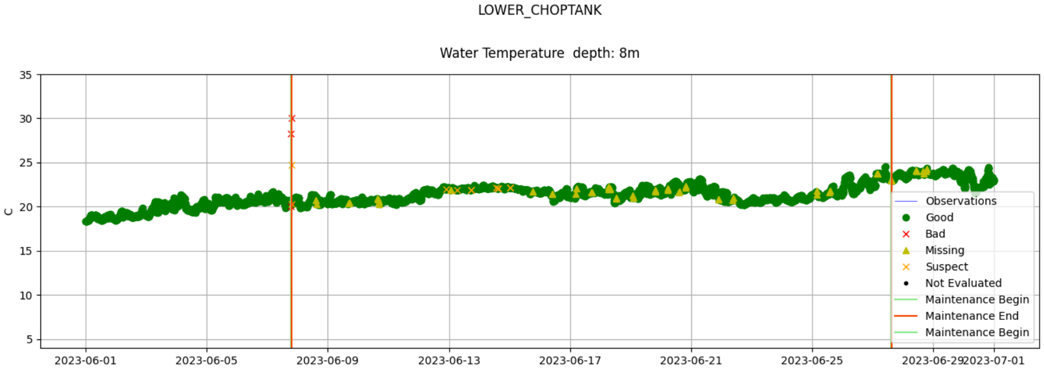

LOWER_CHOPTANK

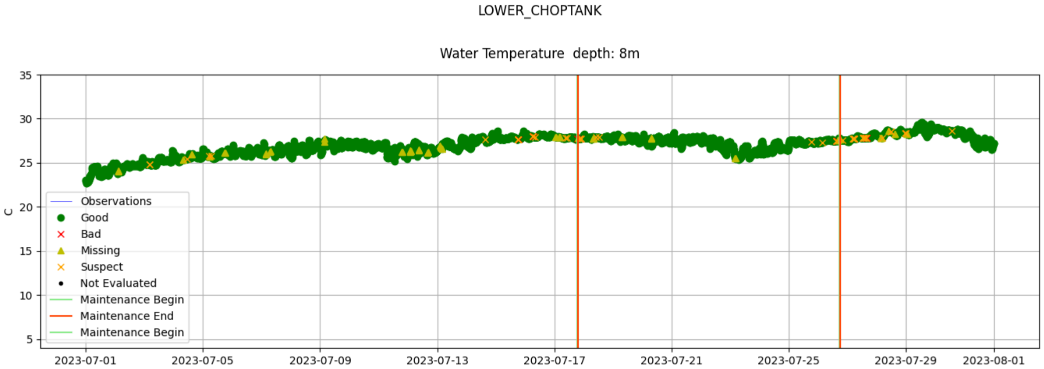
Salinity depth: 8m

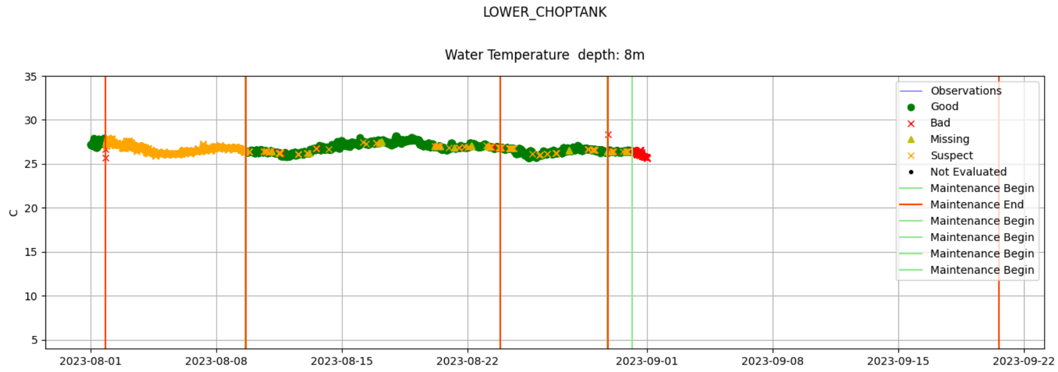
# Lower Choptank Water Temperature Depth=8m

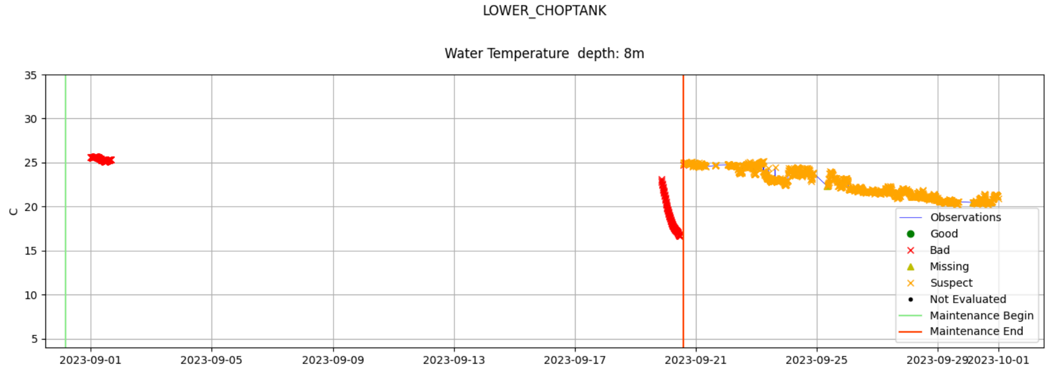


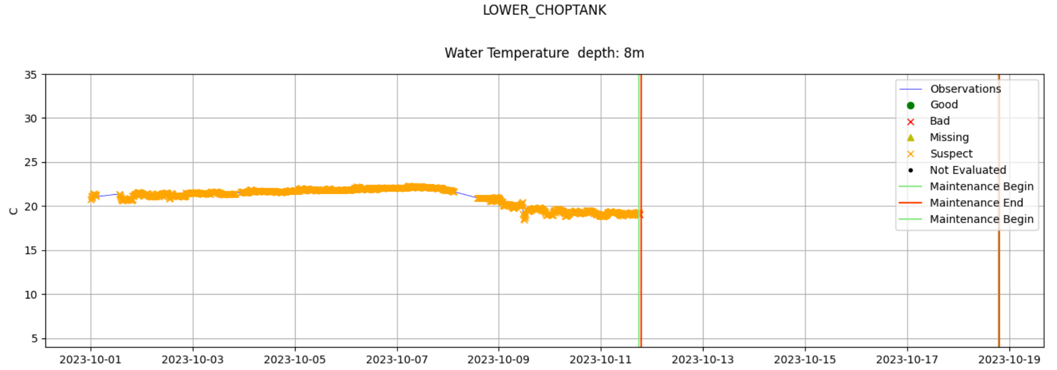


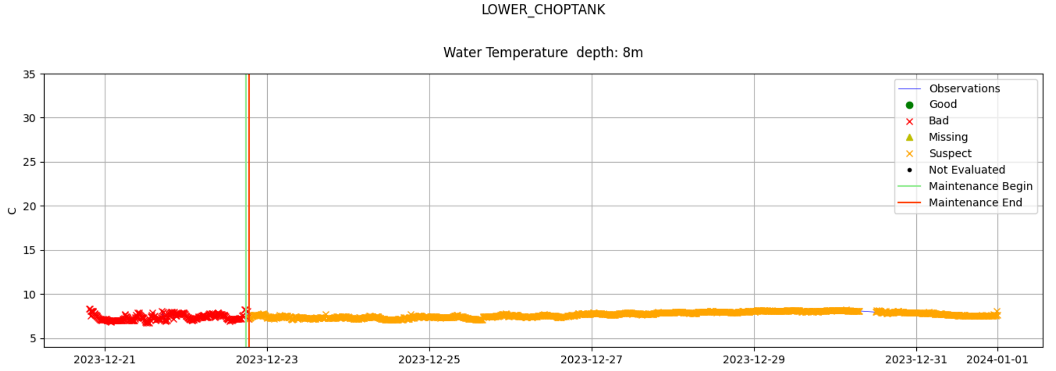




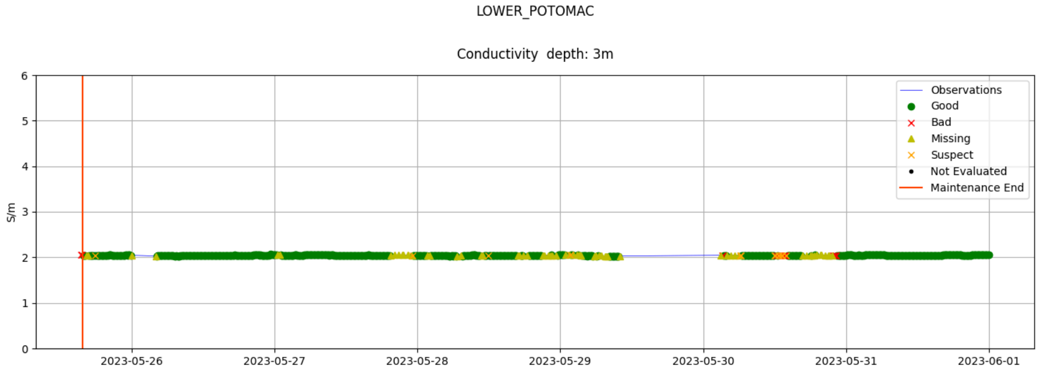

LOWER_CHOPTANK
Water Temperature depth: 8m
C
35
30
25
20
15
10
5
2023-08-01
2023-08-08
2023-08-15
2023-08-22
2023-09-01
2023-09-08
2023-09-15
2023-09-22
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin
Maintenance Begin
Maintenance Begin
Maintenance Begin

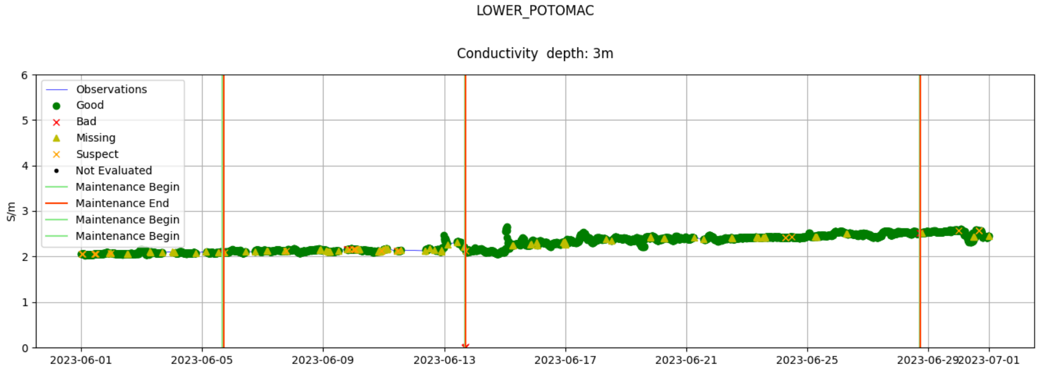

LOWER_CHOPTANK
Water Temperature depth: 8m
C
35
30
25
20
15
10
5
2023-09-01
2023-09-05
2023-09-09
2023-09-13
2023-09-17
2023-09-21
2023-09-25
2023-09-29
2023-10-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

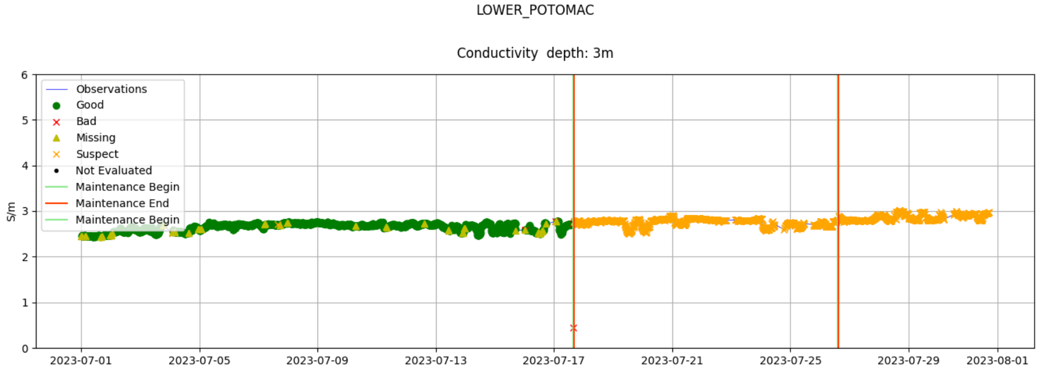

LOWER_CHOPTANK
Water Temperature depth: 8m
C
35
30
25
20
15
10
5
2023-10-01
2023-10-03
2023-10-05
2023-10-07
2023-10-09
2023-10-11
2023-10-13
2023-10-15
2023-10-17
2023-10-19
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin

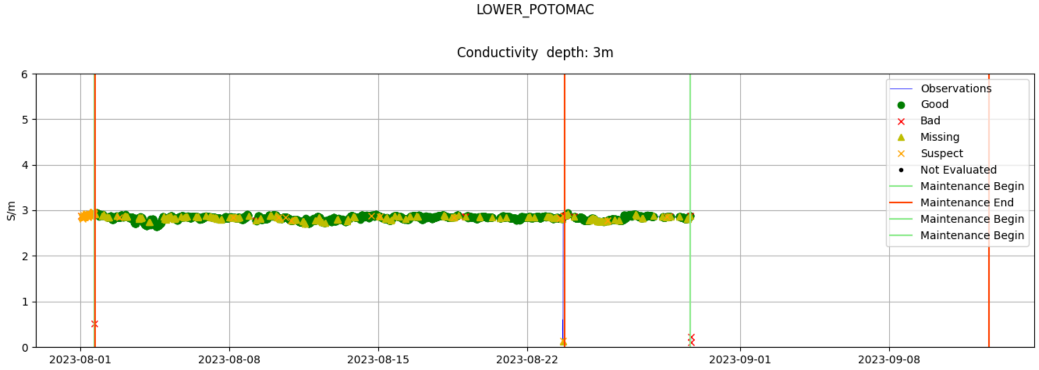

LOWER_CHOPTANK
Water Temperature depth: 8m
C
35
30
25
20
15
10
5
2023-12-21
2023-12-23
2023-12-25
2023-12-27
2023-12-29
2023-12-31
2024-01-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

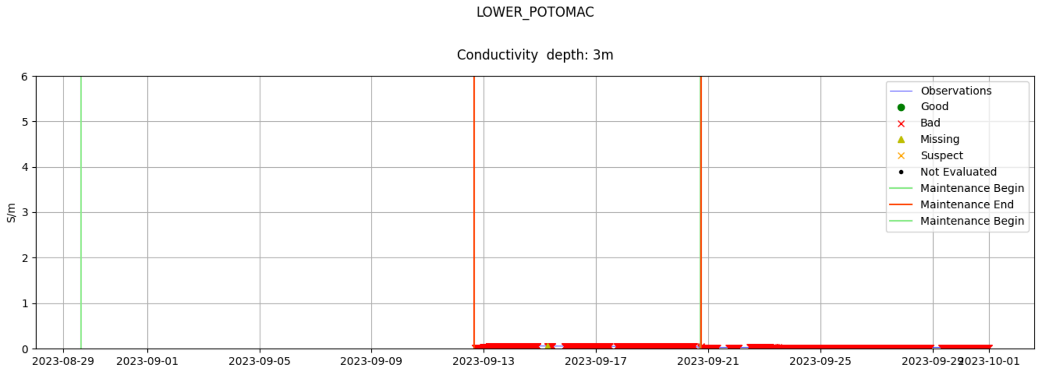
# Lower Potomac Conductivity Depth=3m

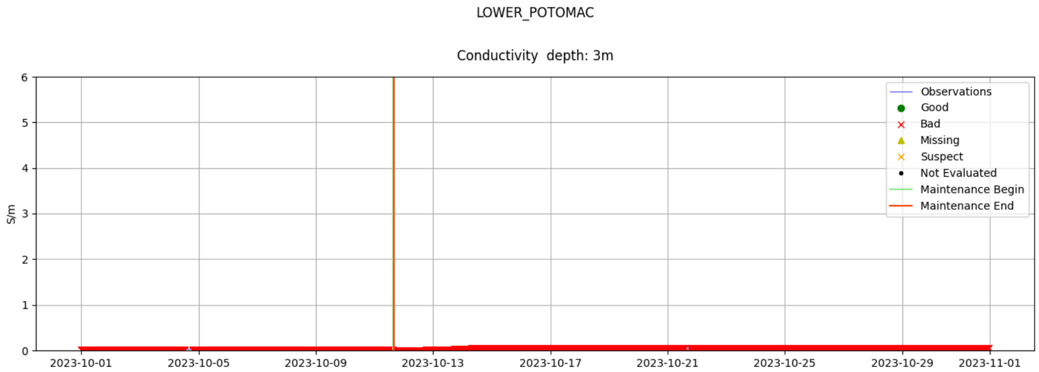


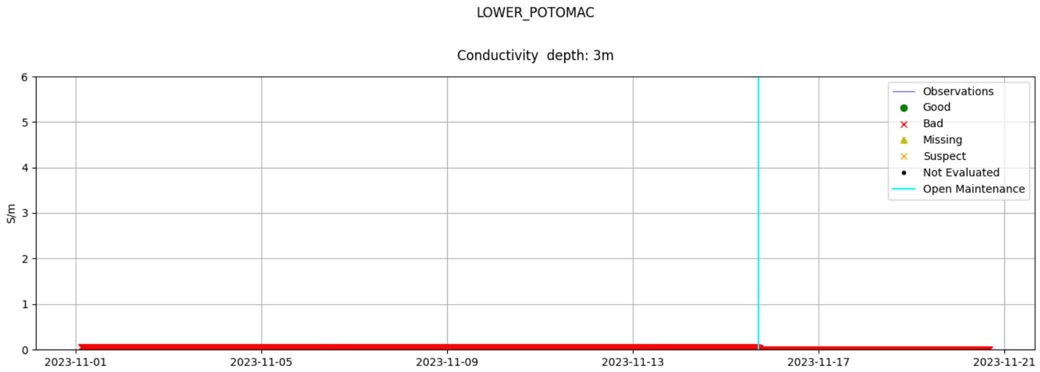




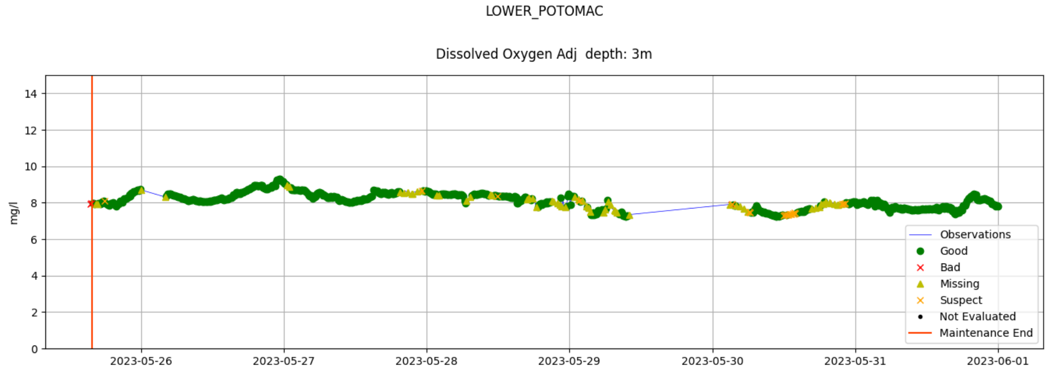


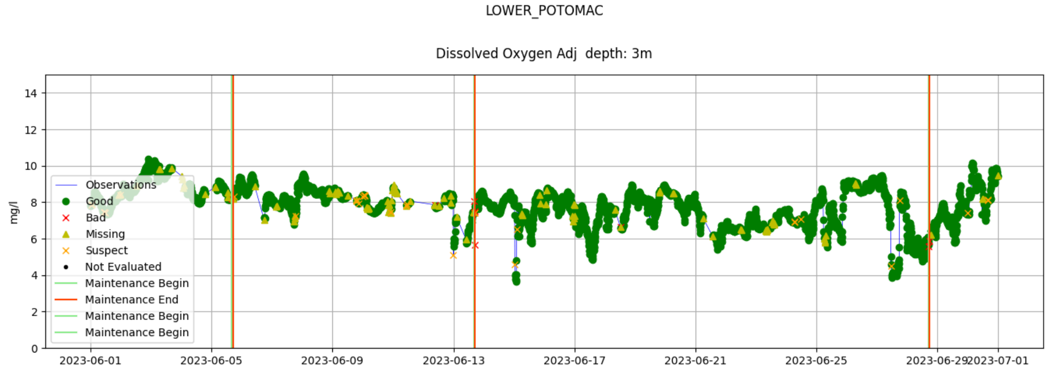

LOWER_POTOMAC
Conductivity depth: 3m
S/m
0
1
2
3
4
5
6
2023-08-29
2023-09-01
2023-09-05
2023-09-09
2023-09-13
2023-09-17
2023-09-21
2023-09-25
2023-09-29
2023-10-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin

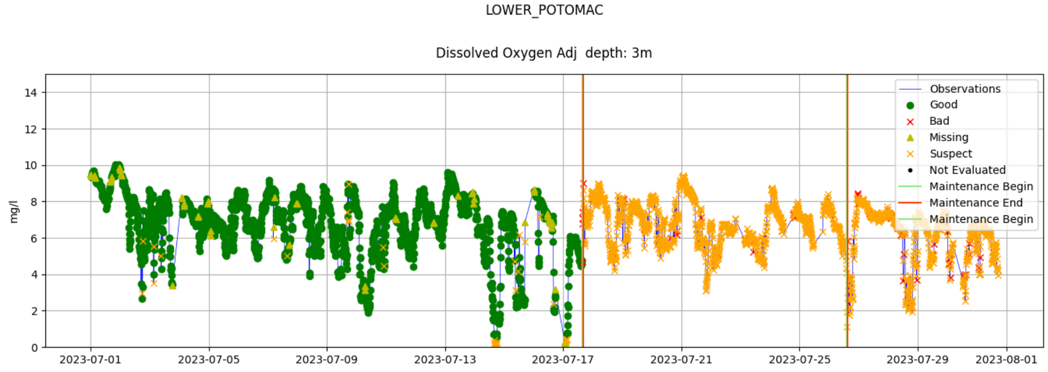

LOWER_POTOMAC
Conductivity depth: 3m
S/m
0
1
2
3
4
5
6
2023-10-01
2023-10-05
2023-10-09
2023-10-13
2023-10-17
2023-10-21
2023-10-25
2023-10-29
2023-11-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

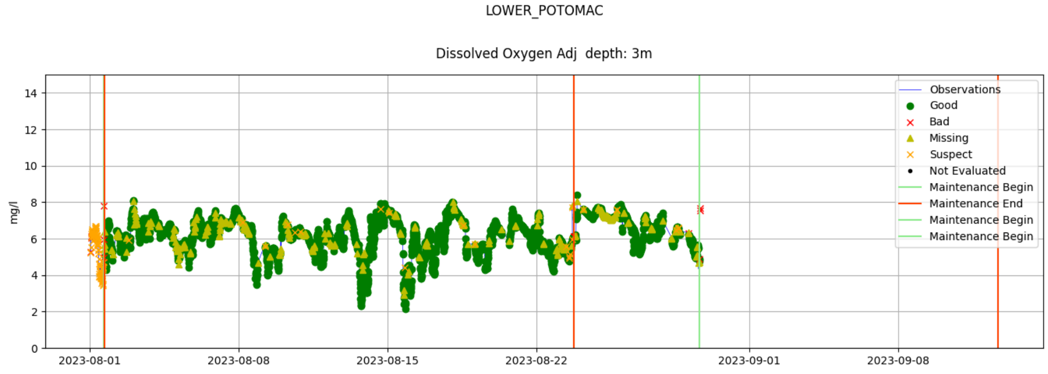

LOWER_POTOMAC
Conductivity depth: 3m
S/m
0
1
2
3
4
5
6
2023-11-01
2023-11-05
2023-11-09
2023-11-13
2023-11-17
2023-11-21
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Open Maintenance

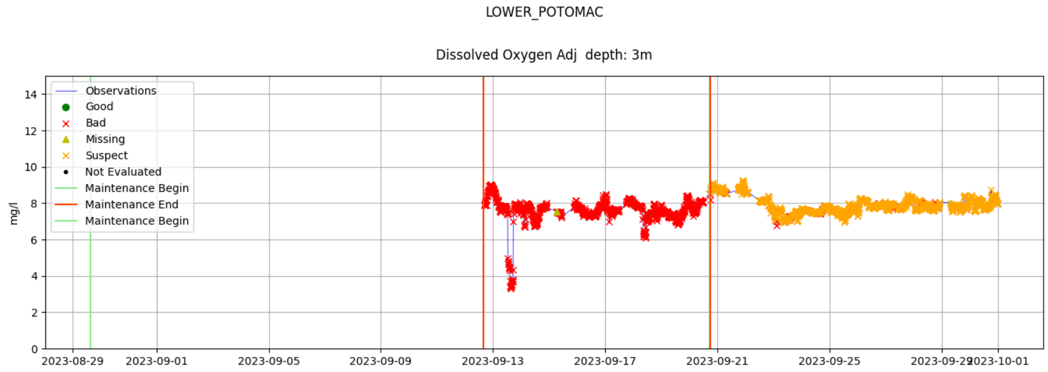
# Lower Potomac Adjusted Dissolved Oxygen Depth=3m

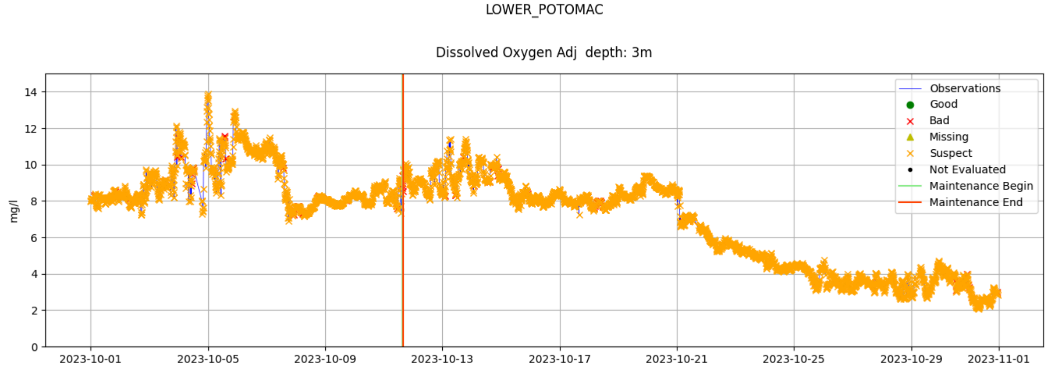


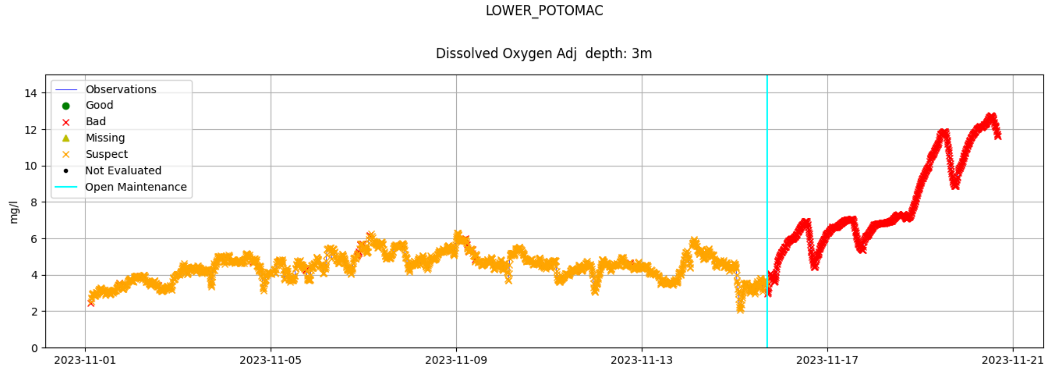




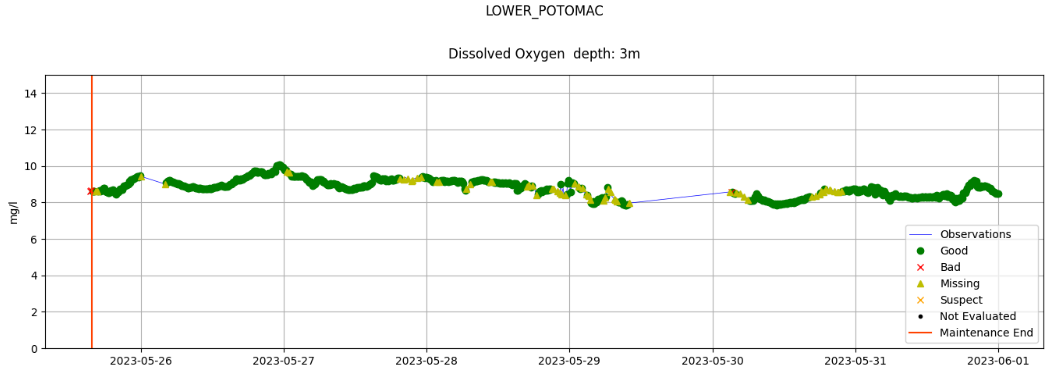


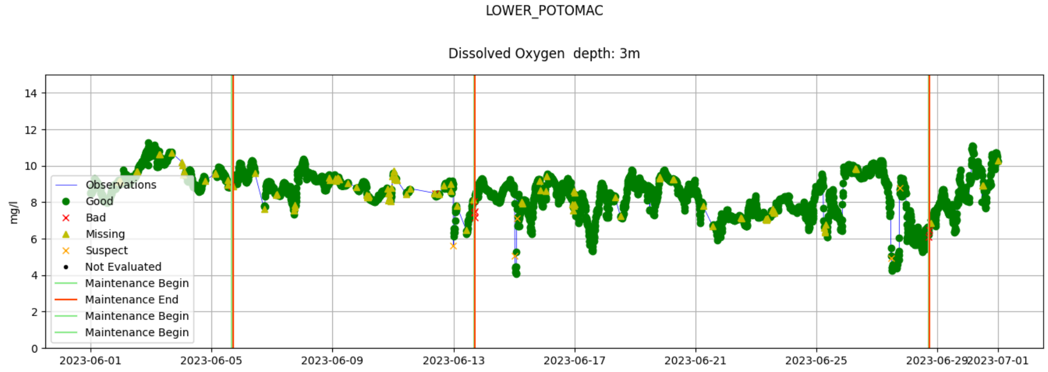

LOWER_POTOMAC
Dissolved Oxygen Adj depth: 3m
mg/l
0
2
4
6
8
10
12
14
2023-08-29
2023-09-01
2023-09-05
2023-09-09
2023-09-13
2023-09-17
2023-09-21
2023-09-25
2023-09-29
2023-10-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin

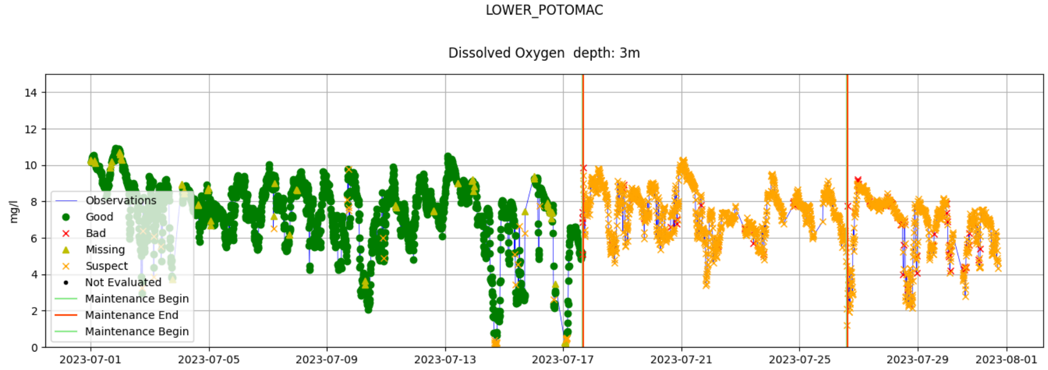

LOWER_POTOMAC
Dissolved Oxygen Adj depth: 3m
mg/l
0
2
4
6
8
10
12
14
2023-10-01
2023-10-05
2023-10-09
2023-10-13
2023-10-17
2023-10-21
2023-10-25
2023-10-29
2023-11-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

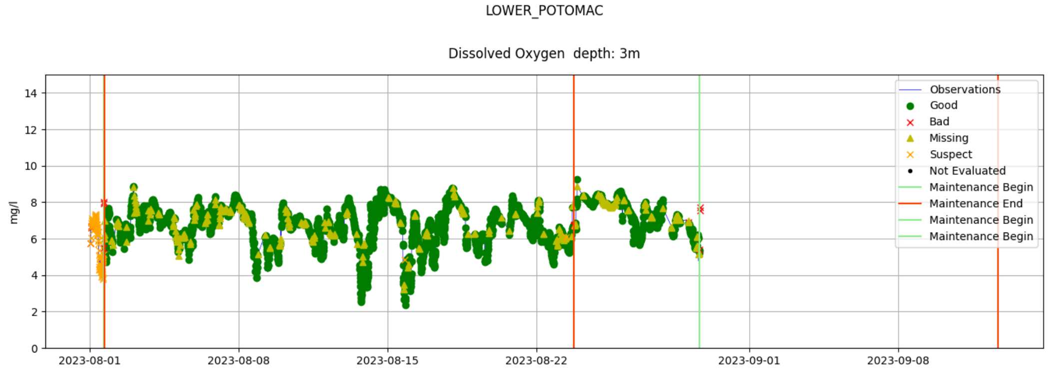

LOWER_POTOMAC
Dissolved Oxygen Adj depth: 3m
mg/l
0
2
4
6
8
10
12
14
2023-11-01
2023-11-05
2023-11-09
2023-11-13
2023-11-17
2023-11-21
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Open Maintenance

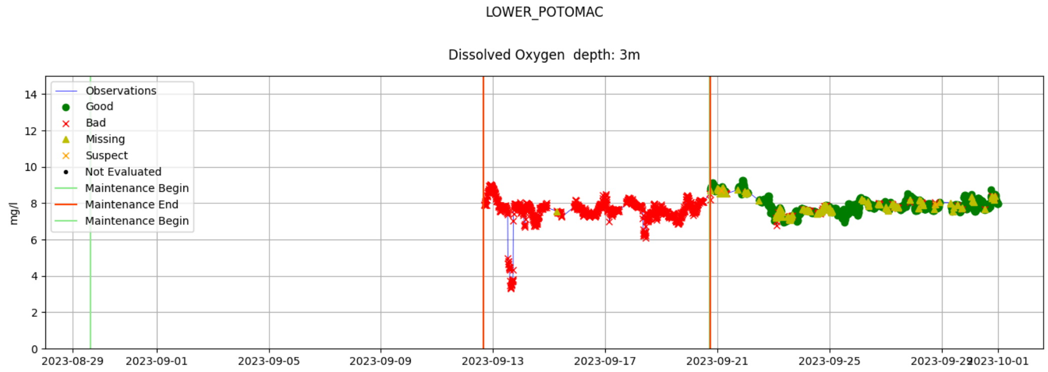
# Lower Potomac Dissolved Oxygen Depth=3m

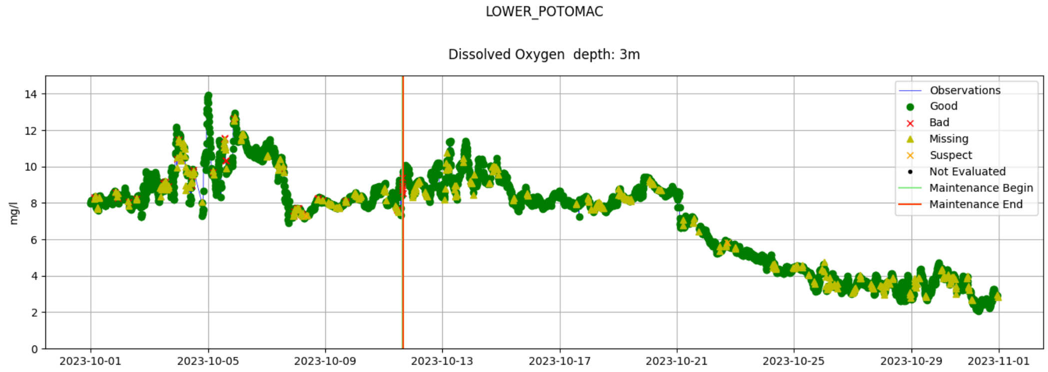


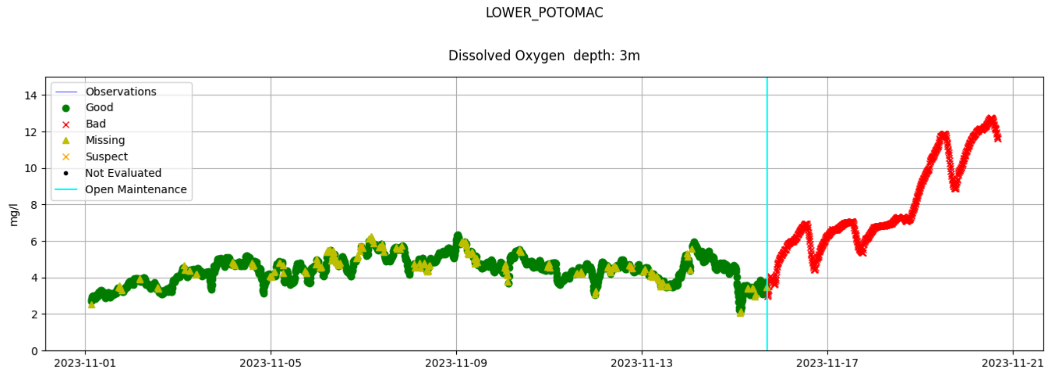




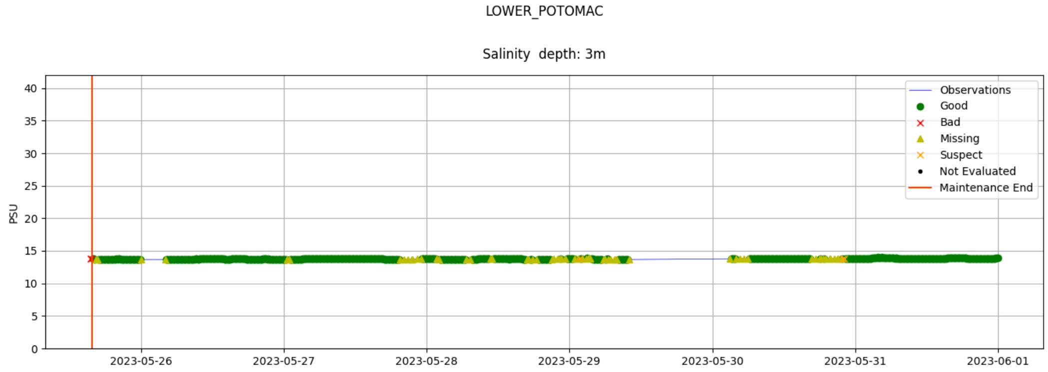


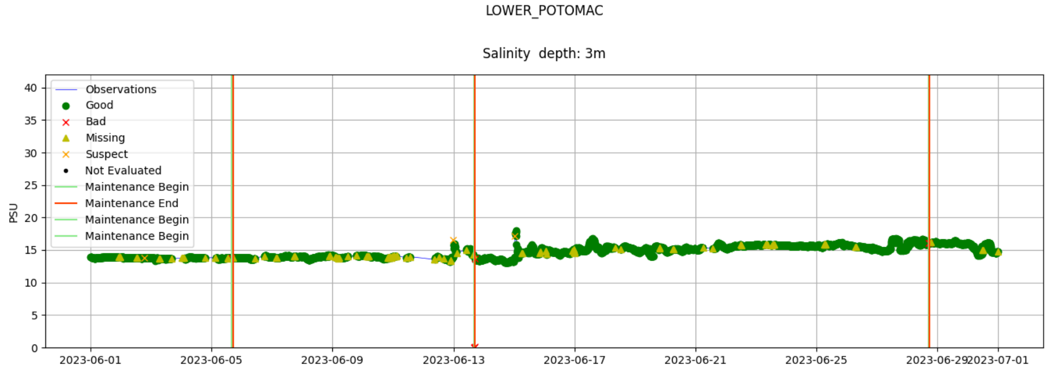

LOWER_POTOMAC
Dissolved Oxygen depth: 3m
mg/l
0
2
4
6
8
10
12
14
2023-08-29
2023-09-01
2023-09-05
2023-09-09
2023-09-13
2023-09-17
2023-09-21
2023-09-25
2023-09-29
2023-10-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin

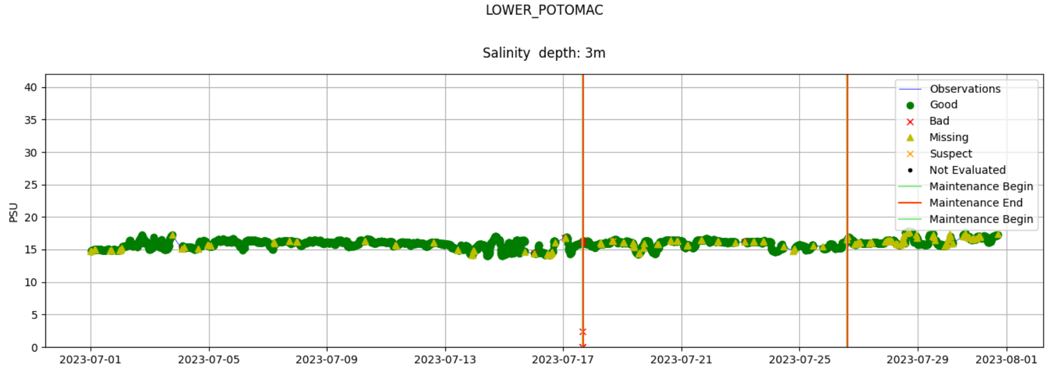

LOWER_POTOMAC
Dissolved Oxygen depth: 3m
mg/l
0
2
4
6
8
10
12
14
2023-10-01
2023-10-05
2023-10-09
2023-10-13
2023-10-17
2023-10-21
2023-10-25
2023-10-29
2023-11-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

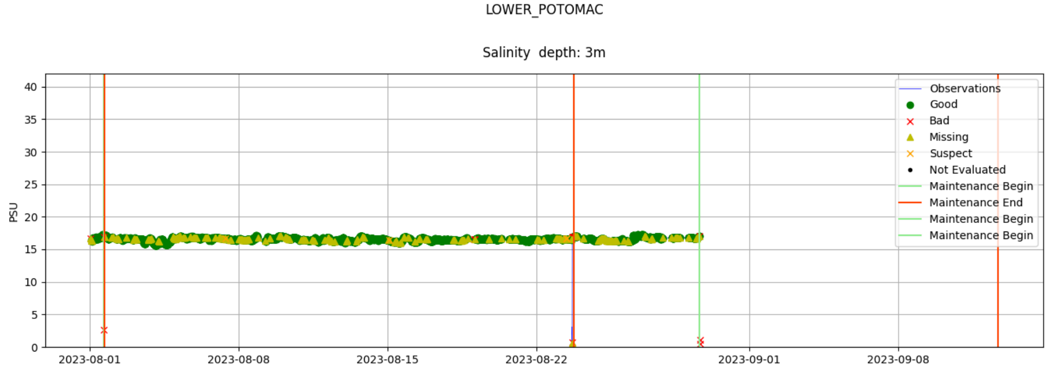

LOWER_POTOMAC
Dissolved Oxygen depth: 3m
mg/l
0
2
4
6
8
10
12
14
2023-11-01
2023-11-05
2023-11-09
2023-11-13
2023-11-17
2023-11-21
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Open Maintenance

# Lower Potomac Salinity Depth=3m



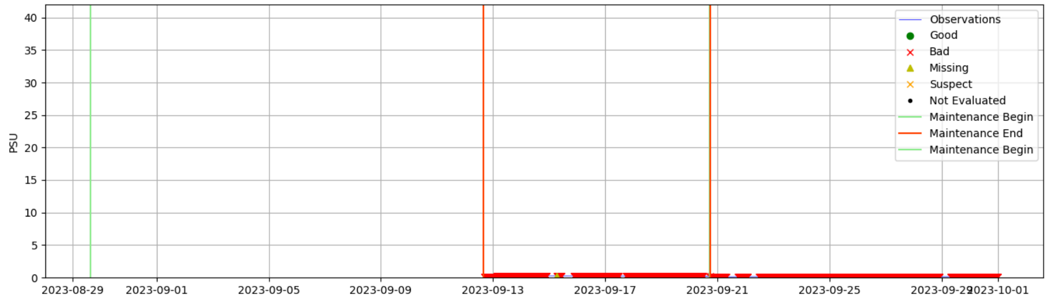






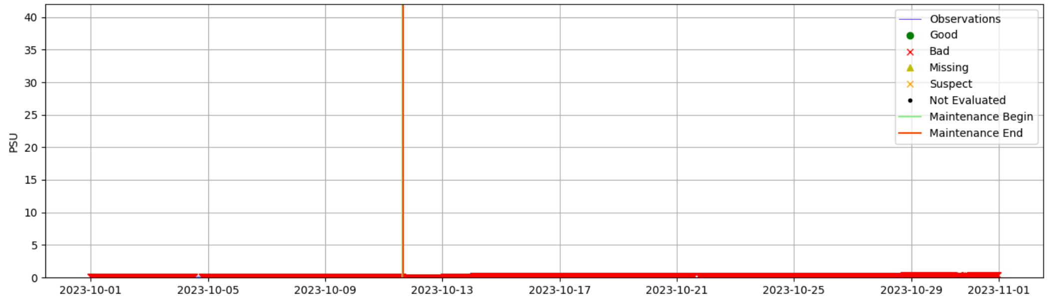
LOWER_POTOMAC

Salinity depth: 3m



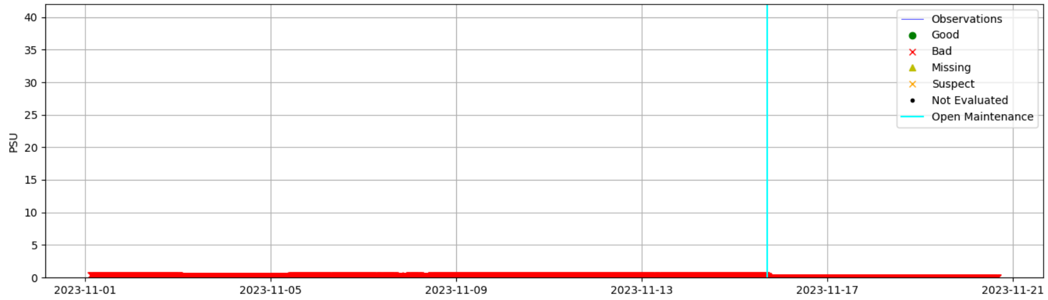
LOWER_POTOMAC

Salinity depth: 3m

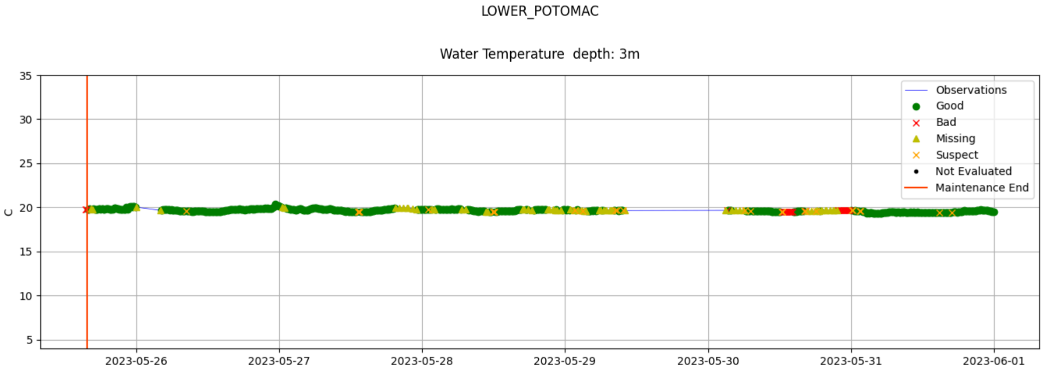


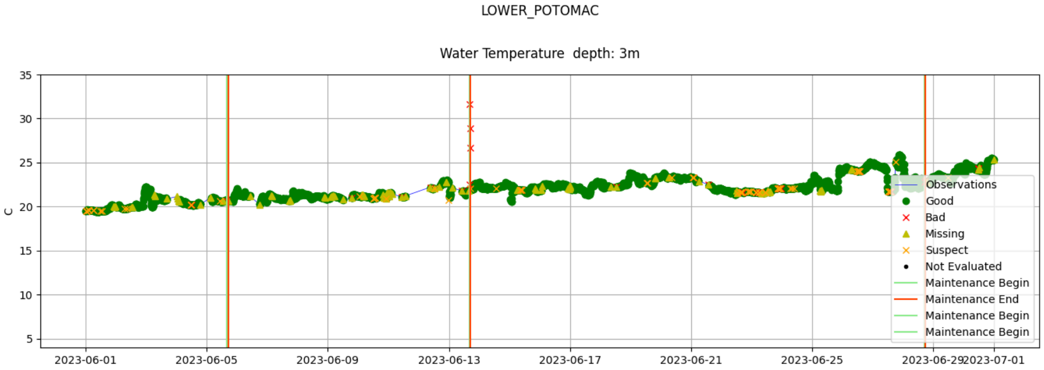
LOWER_POTOMAC

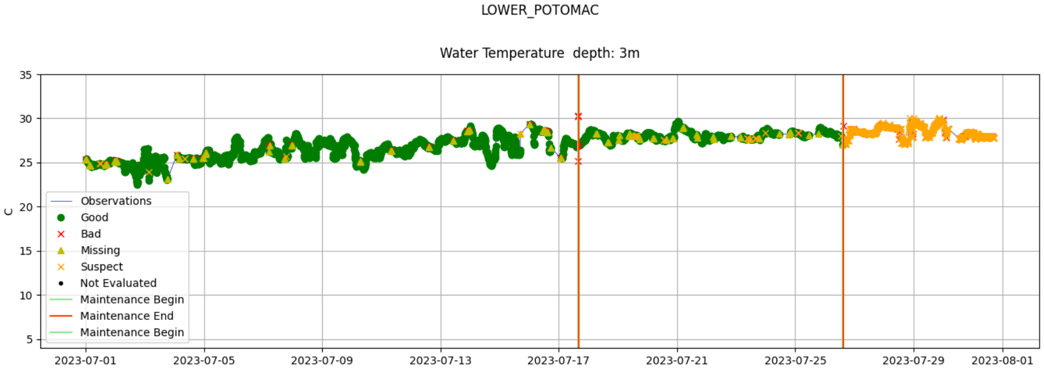
Salinity depth: 3m

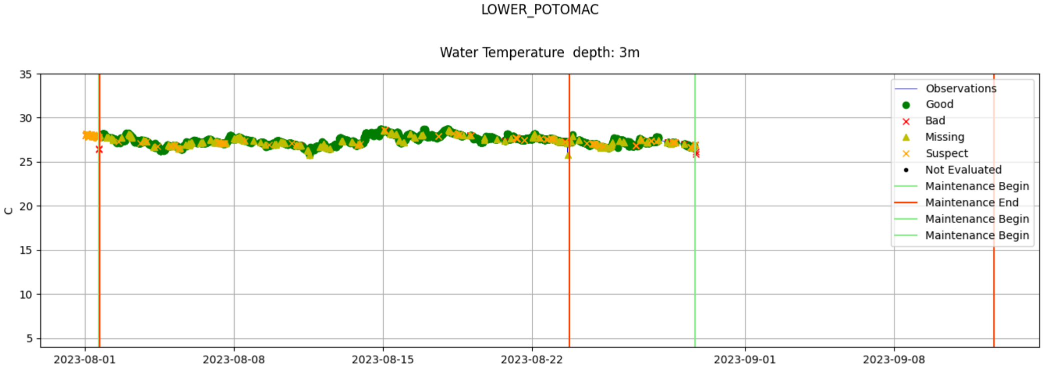


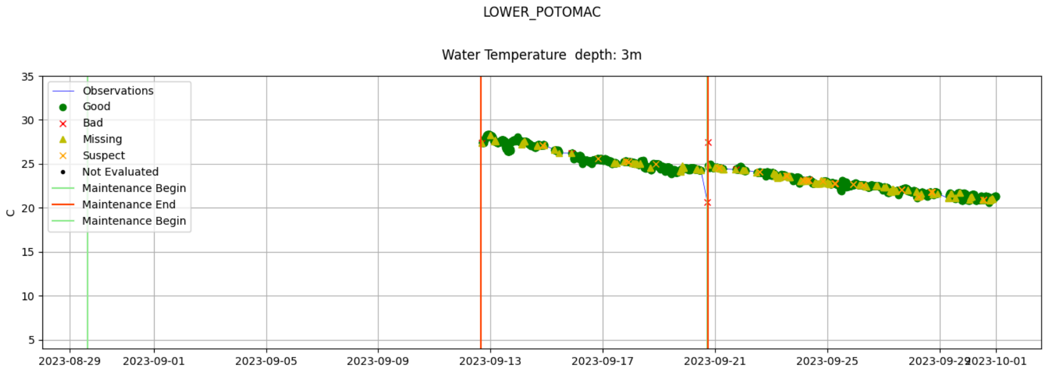
## Lower Potomac Water Temperature Depth=3m

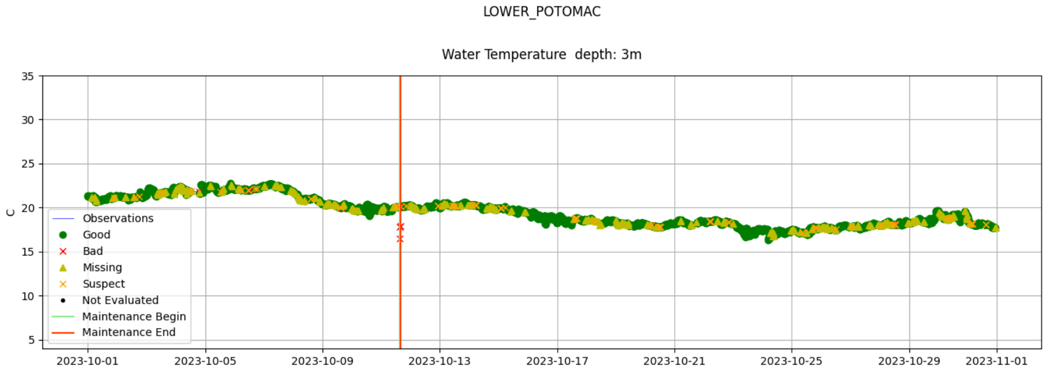


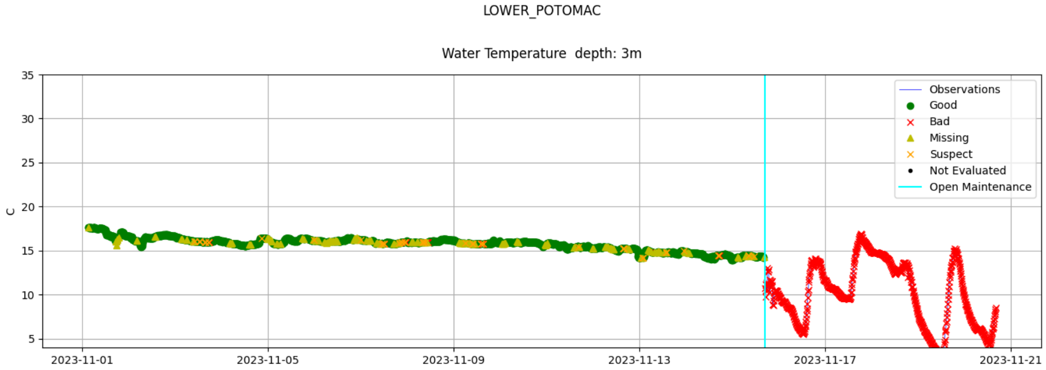




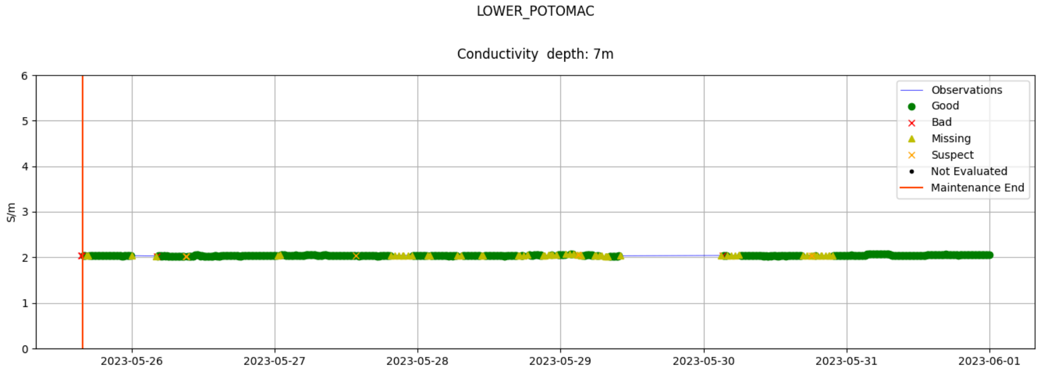


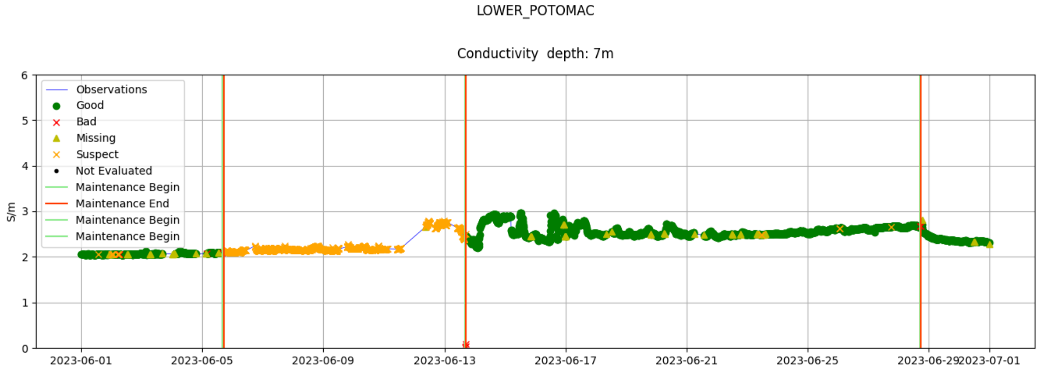

LOWER_POTOMAC
Water Temperature depth: 3m
C
35
30
25
20
15
10
5
2023-08-29
2023-09-01
2023-09-05
2023-09-09
2023-09-13
2023-09-17
2023-09-21
2023-09-25
2023-09-29
2023-10-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin

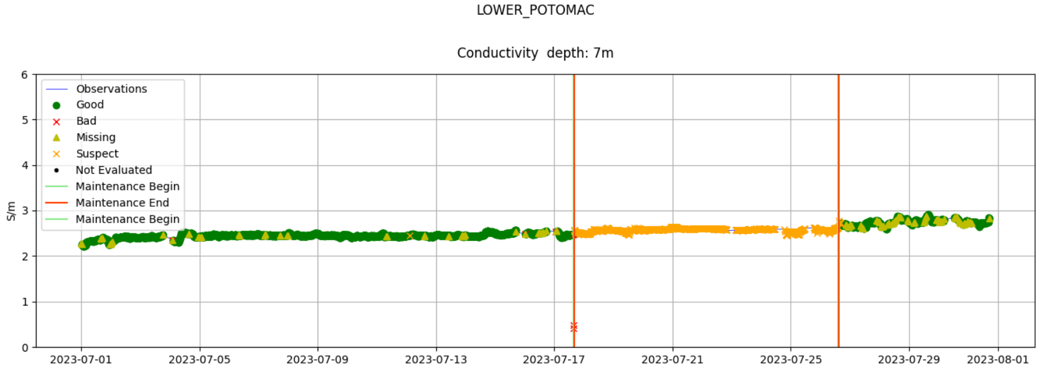

LOWER_POTOMAC
Water Temperature depth: 3m
C
35
30
25
20
15
10
5
2023-10-01
2023-10-05
2023-10-09
2023-10-13
2023-10-17
2023-10-21
2023-10-25
2023-10-29
2023-11-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

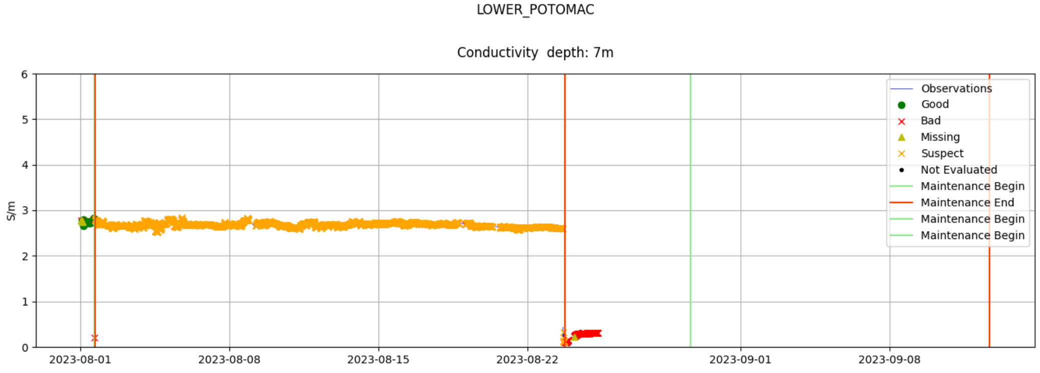

LOWER_POTOMAC
Water Temperature depth: 3m
C
35
30
25
20
15
10
5
2023-11-01
2023-11-05
2023-11-09
2023-11-13
2023-11-17
2023-11-21
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Open Maintenance

# Lower Potomac Conductivity Depth=7m

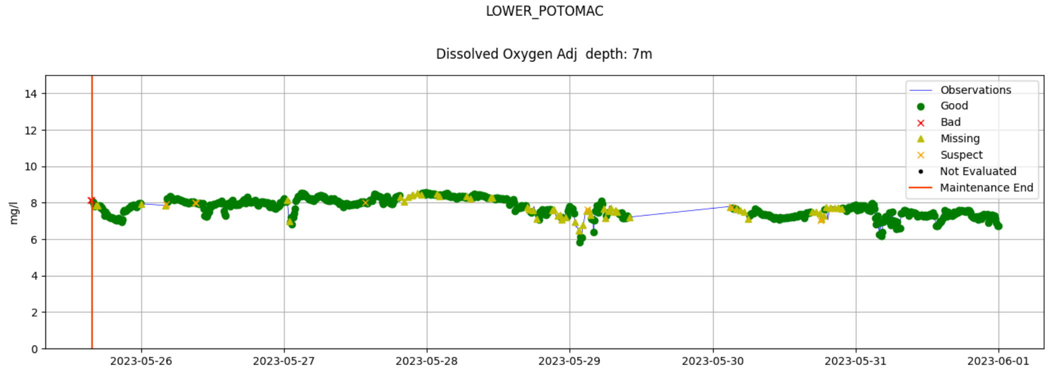


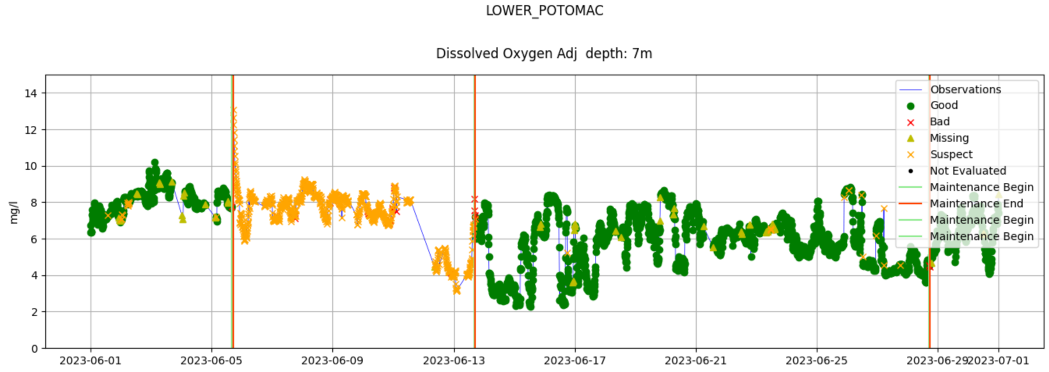


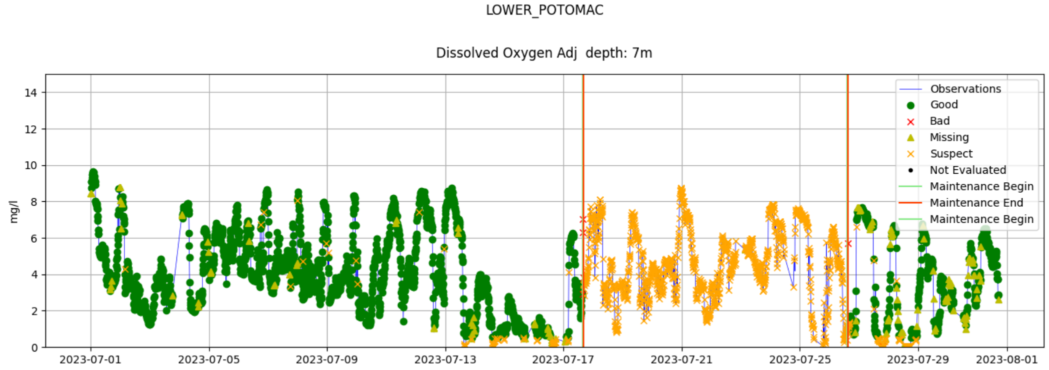


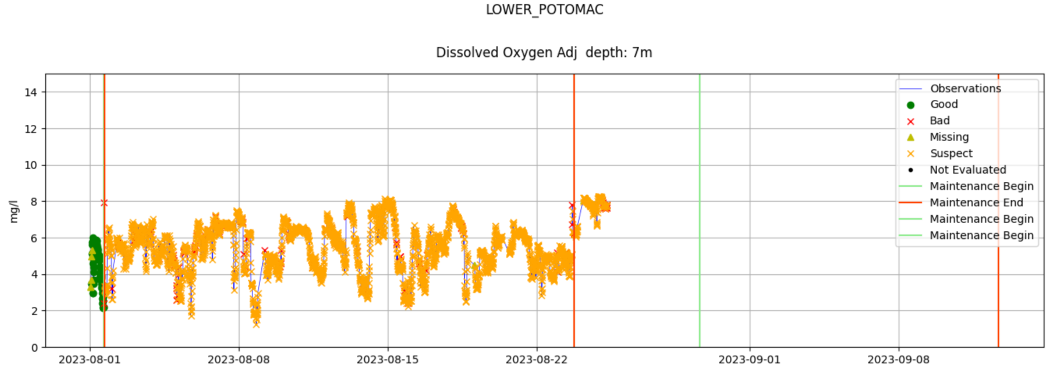


# Lower Potomac Adjusted Dissolved Oxygen Depth=7m

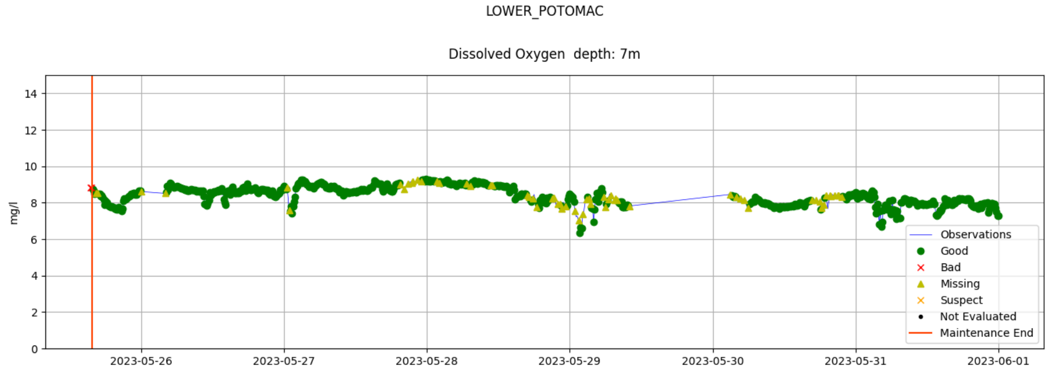


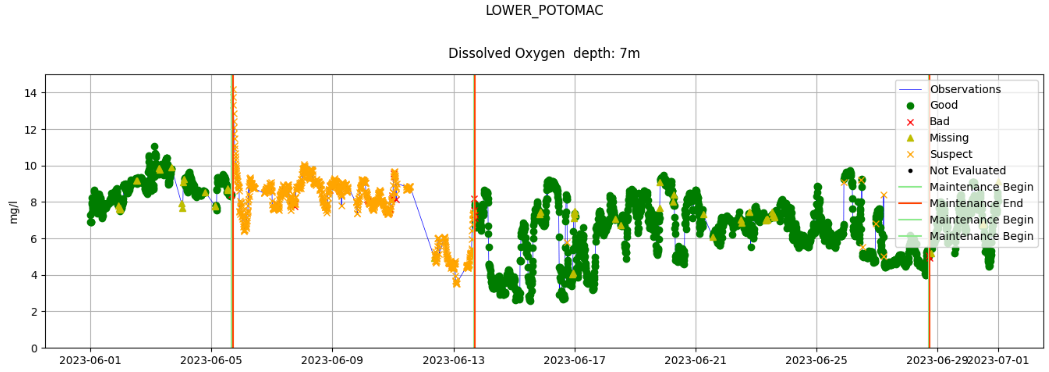


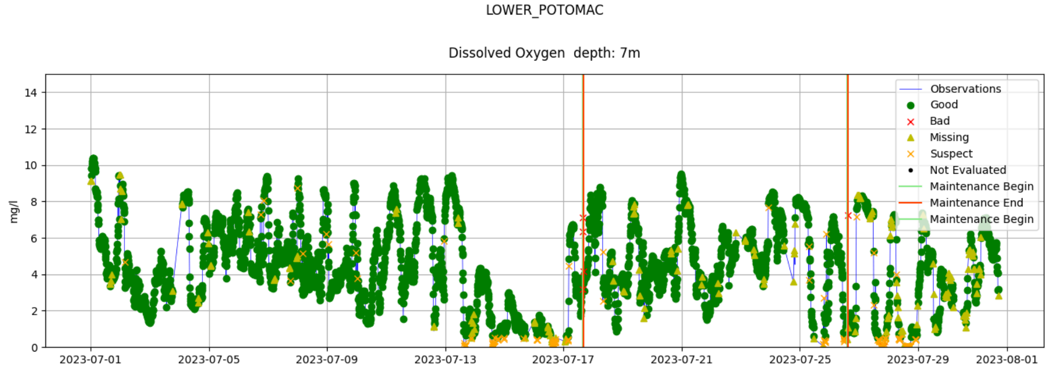


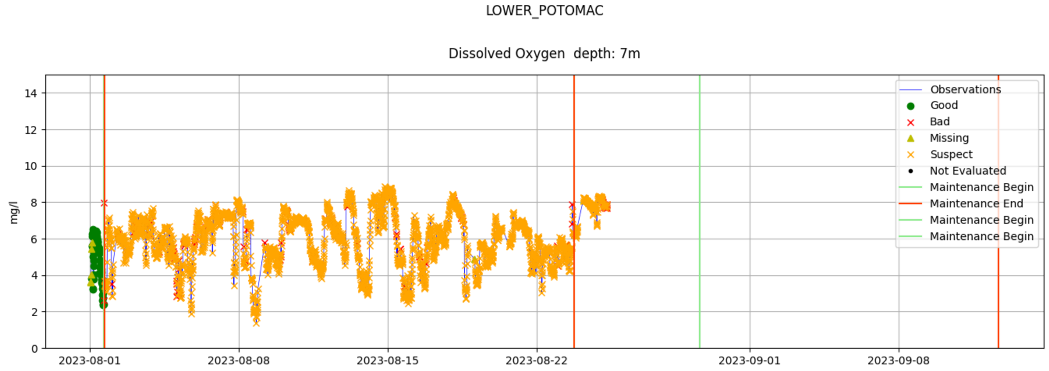


# Lower Potomac Dissolved Oxygen Depth=7m

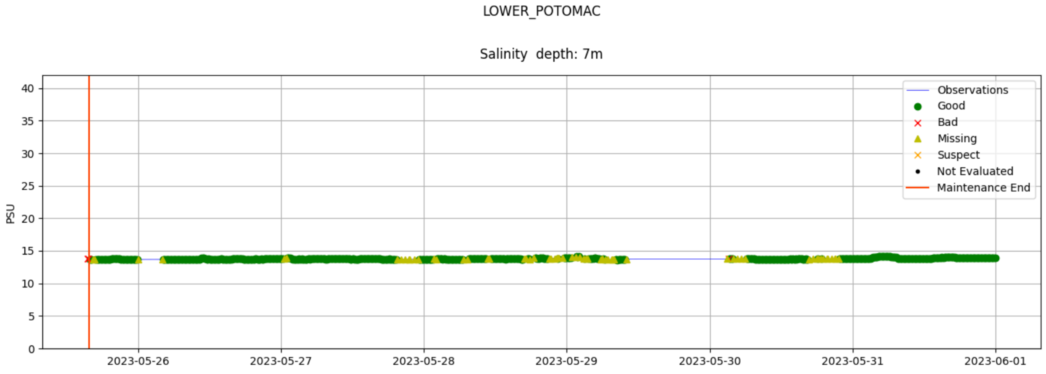


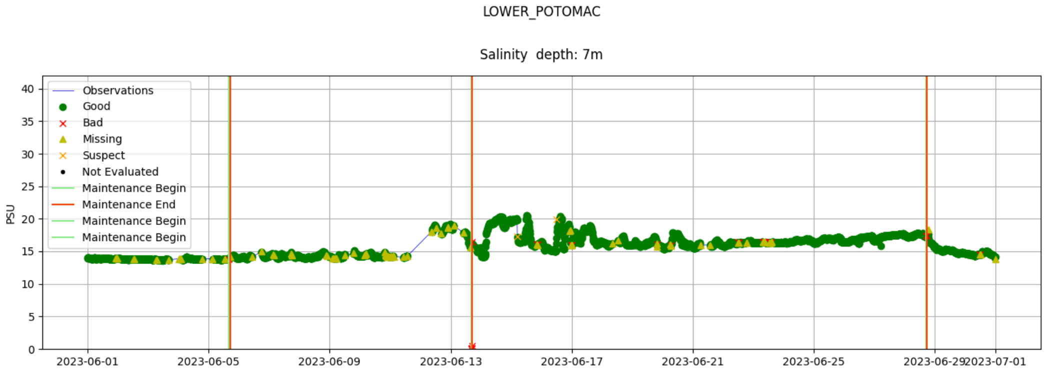


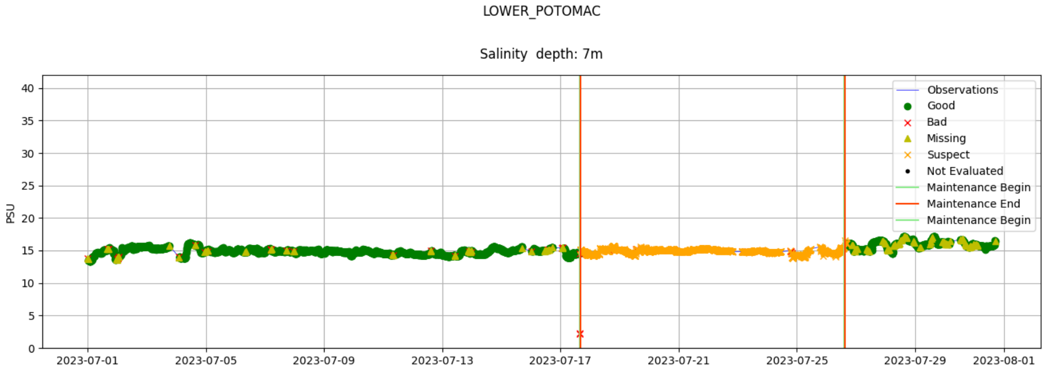


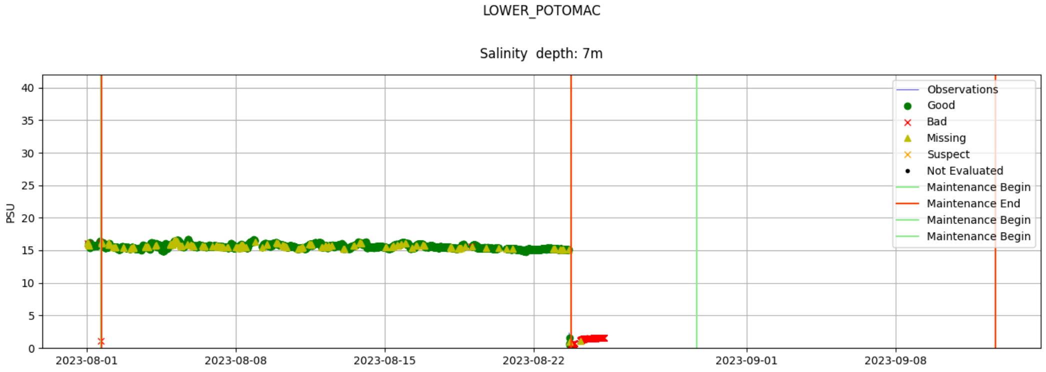


# Lower Potomac Salinity Depth=7m

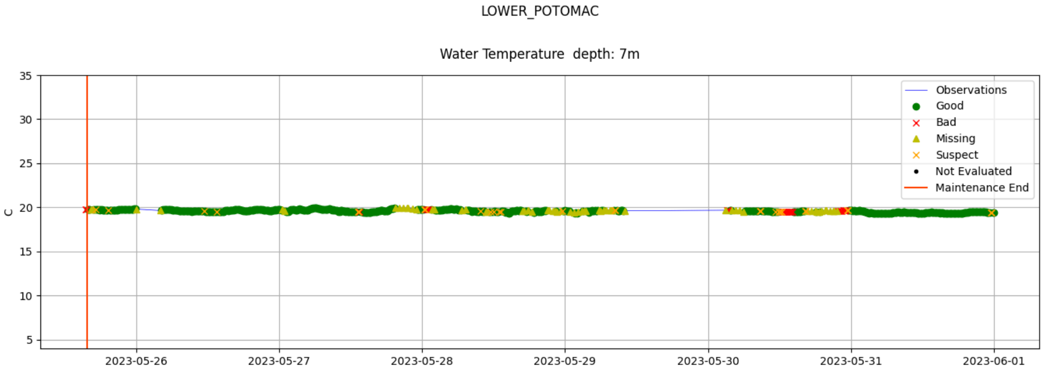


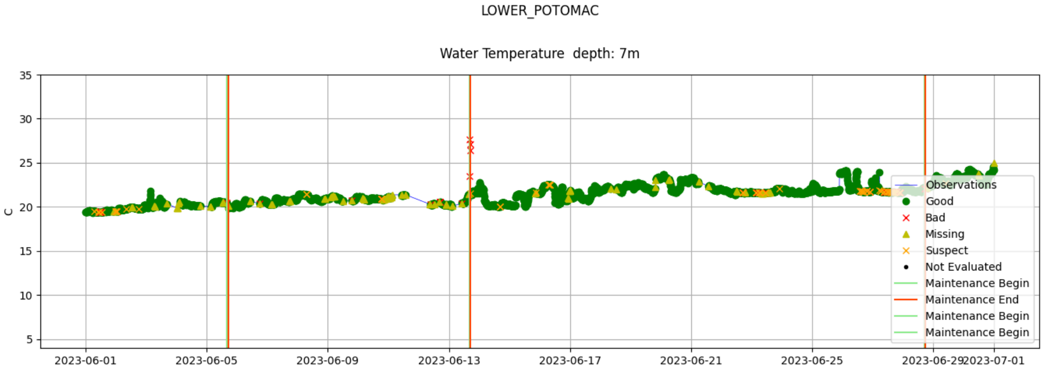


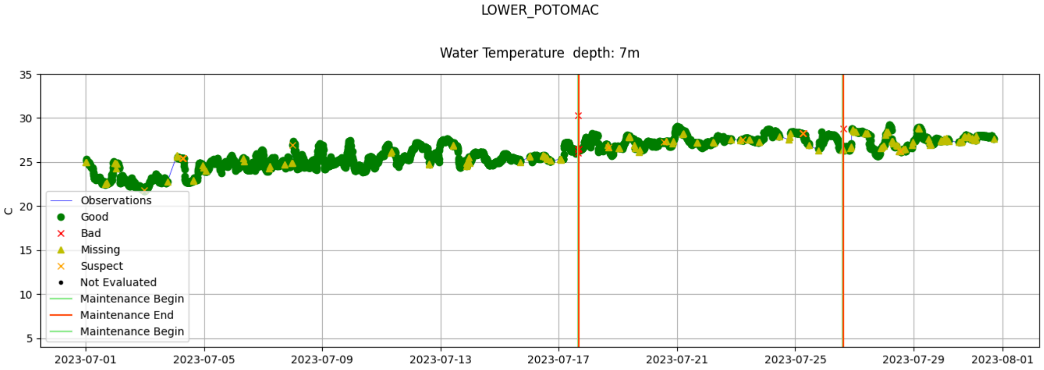


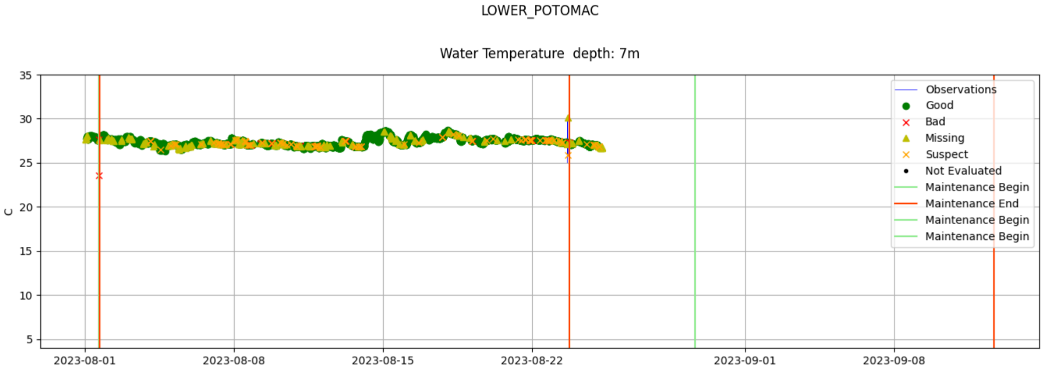


## Lower Potomac Water Temperature Depth=7m

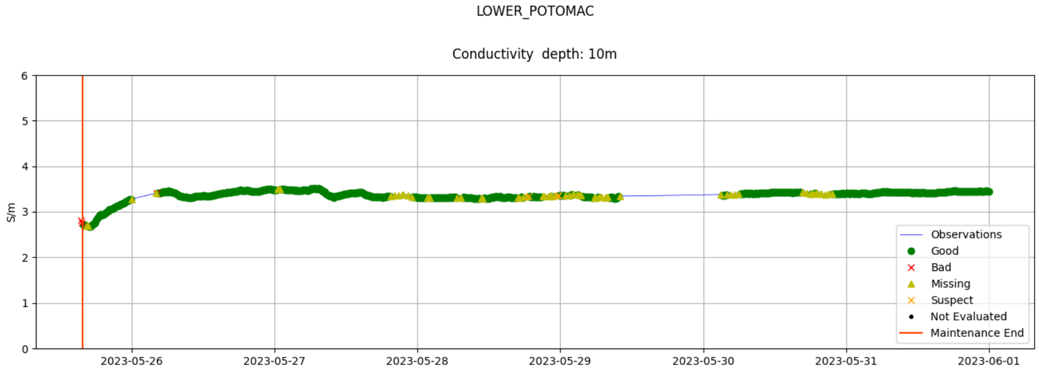


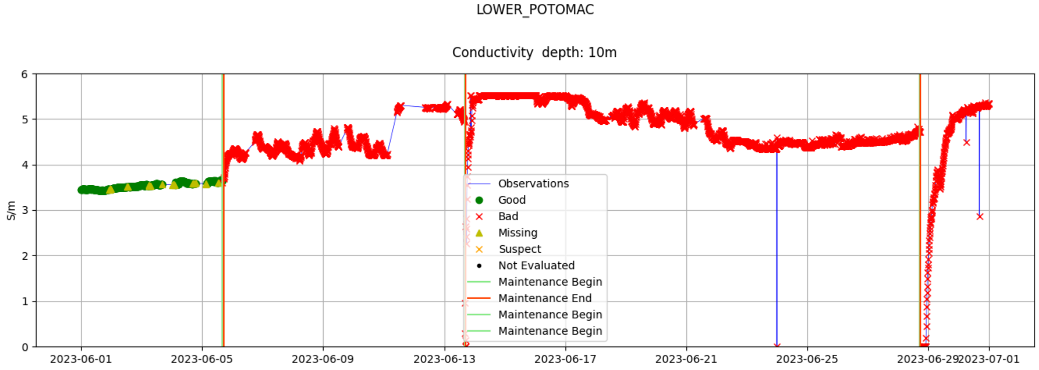


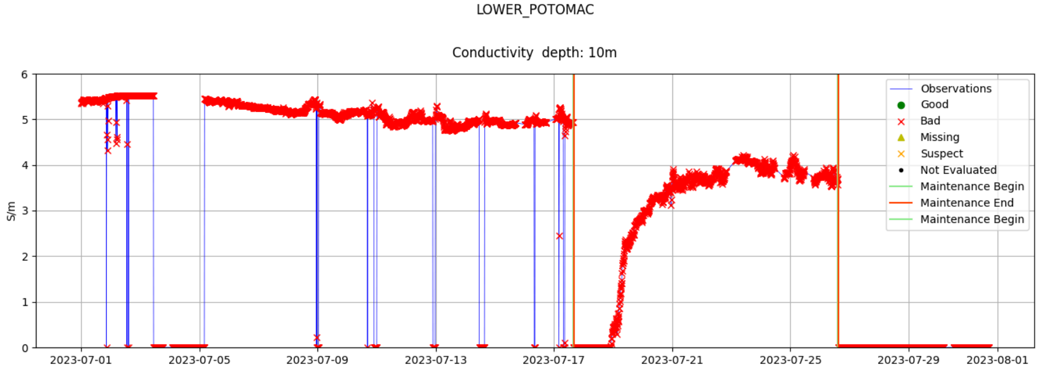


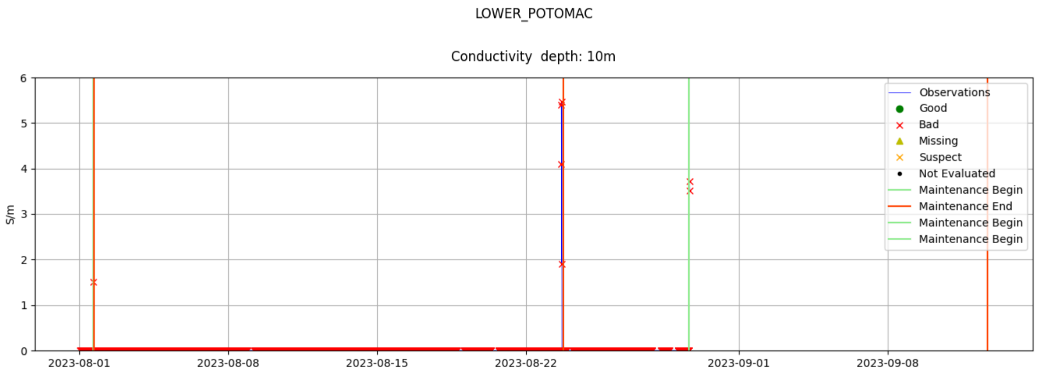


# Lower Potomac Conductivity Depth=10m

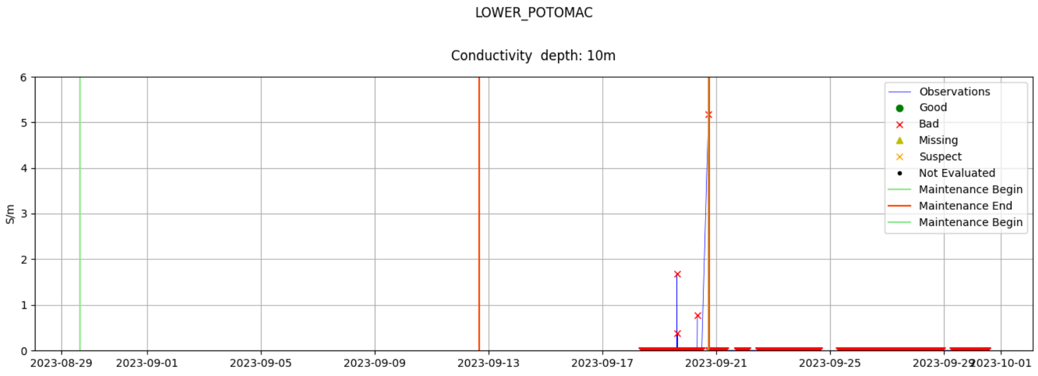




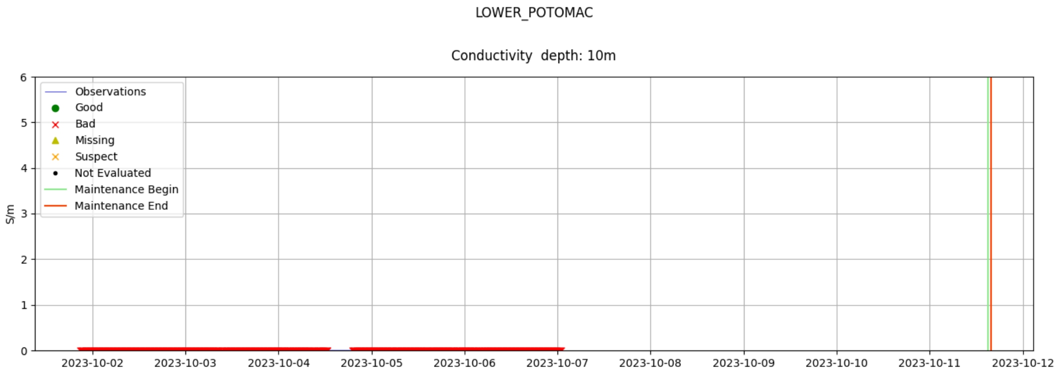



LOWER_POTOMAC

Conductivity depth: 10m

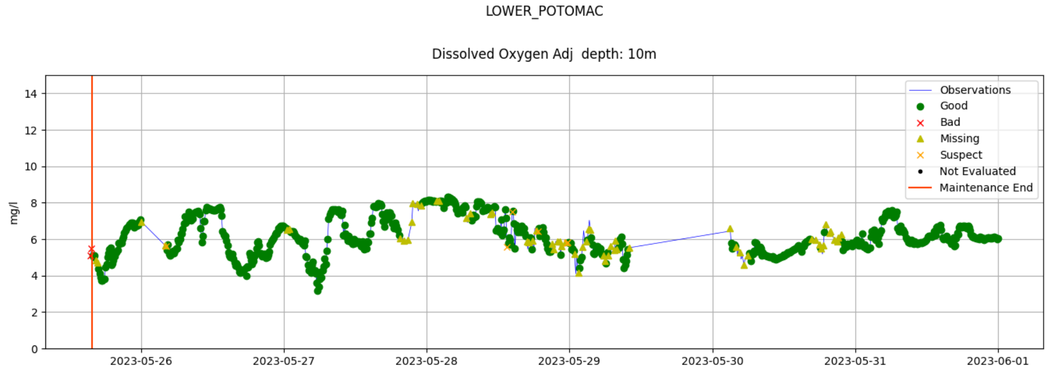

LOWER_POTOMAC

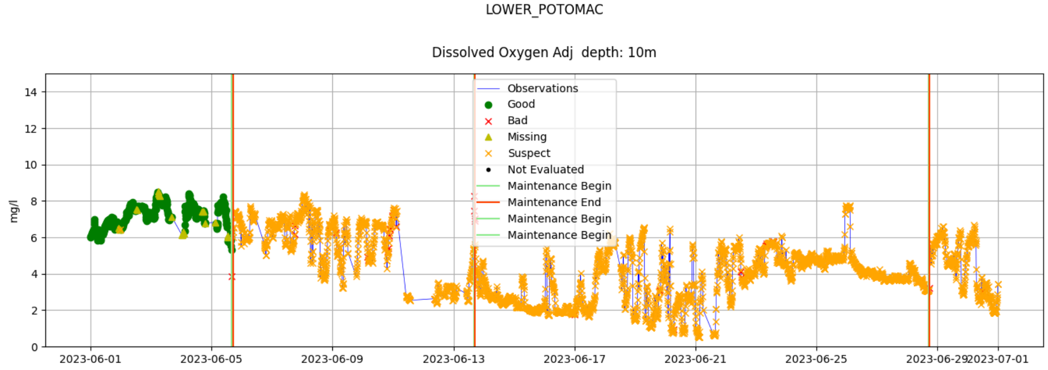
Conductivity depth: 10m

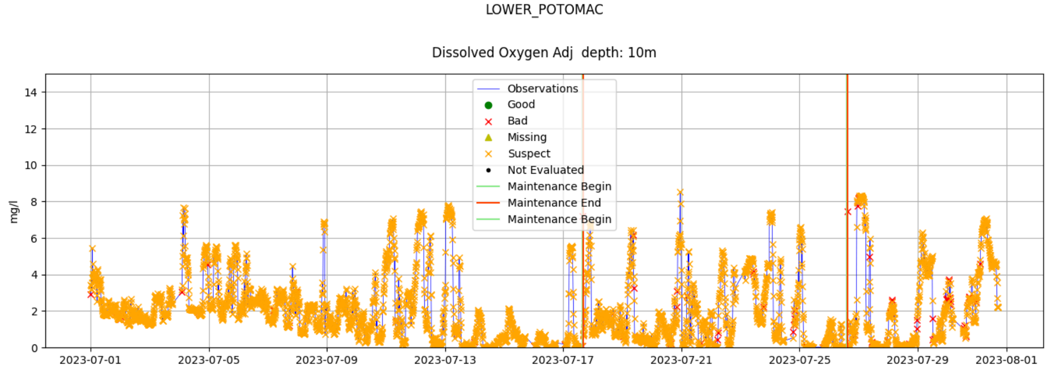

LOWER_POTOMAC

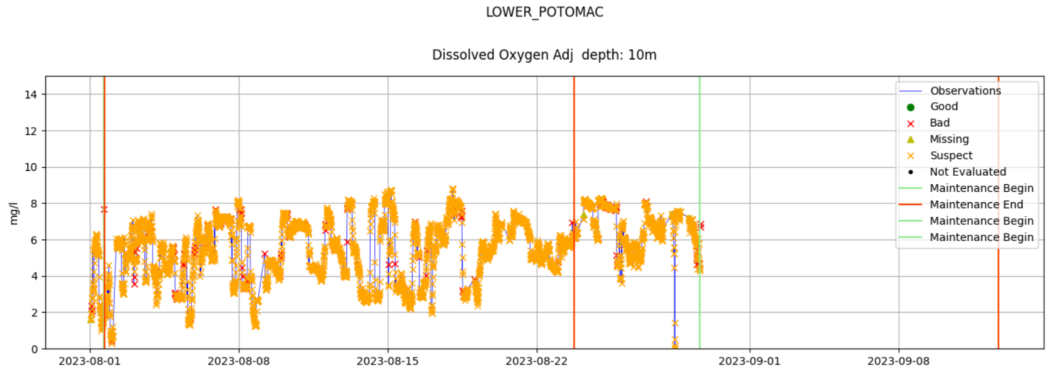
Conductivity depth: 10m

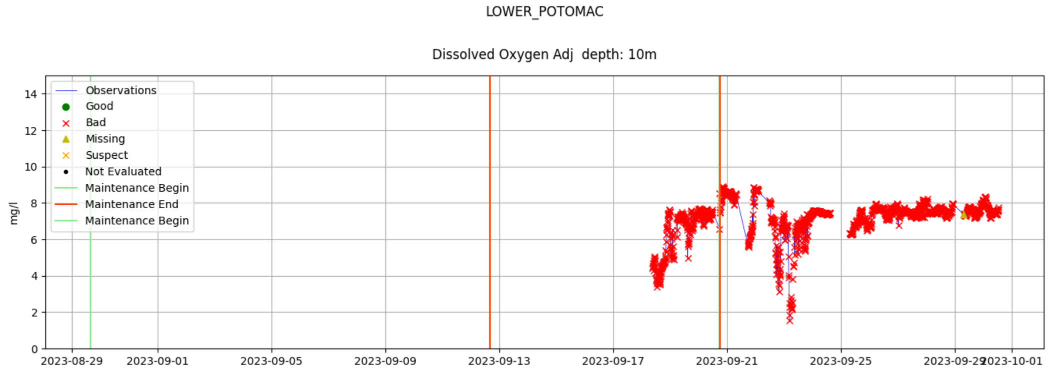
# Lower Potomac Adjusted Dissolved Oxygen Depth=10m

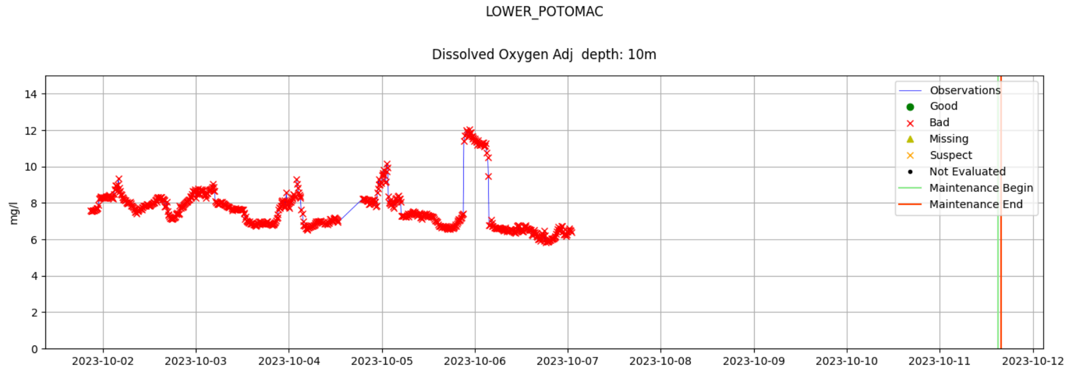




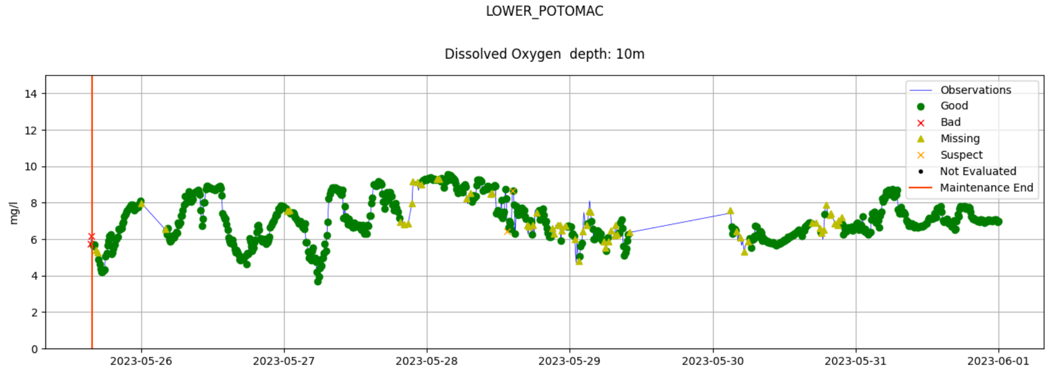


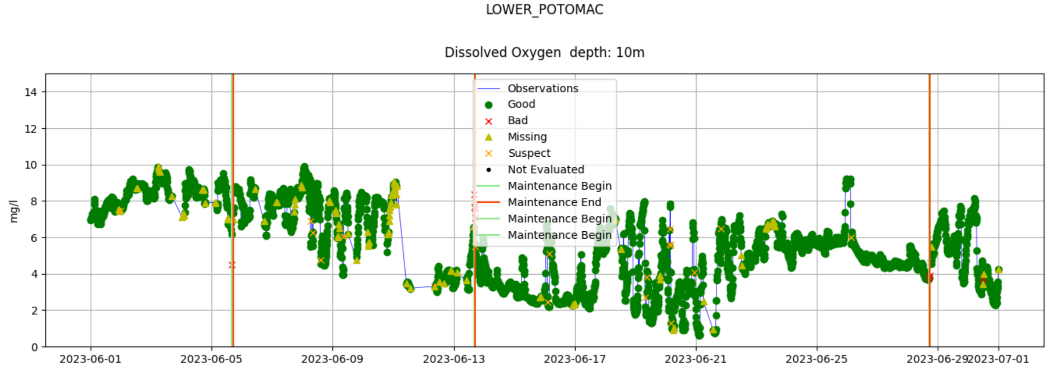

LOWER_POTOMAC
Dissolved Oxygen Adj depth: 10m
mg/l
0
2
4
6
8
10
12
14
2023-08-01
2023-08-08
2023-08-15
2023-08-22
2023-09-01
2023-09-08
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin
Maintenance Begin

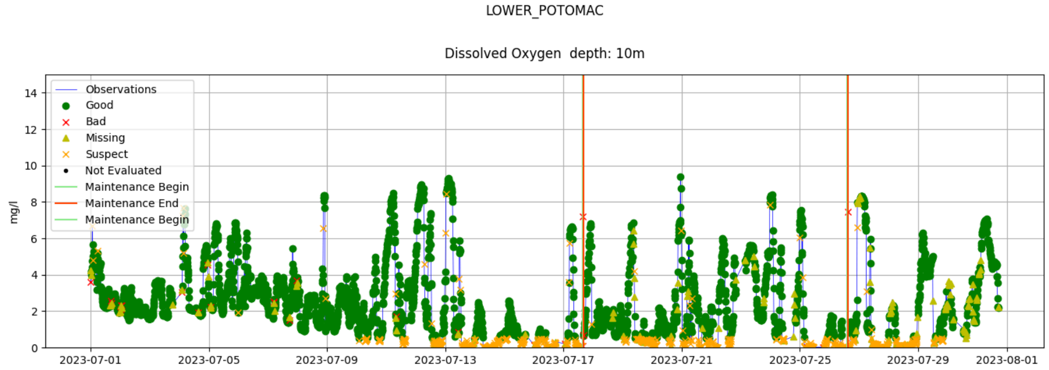

LOWER_POTOMAC
Dissolved Oxygen Adj depth: 10m
mg/l
0
2
4
6
8
10
12
14
2023-08-29
2023-09-01
2023-09-05
2023-09-09
2023-09-13
2023-09-17
2023-09-21
2023-09-25
2023-09-29
2023-10-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin

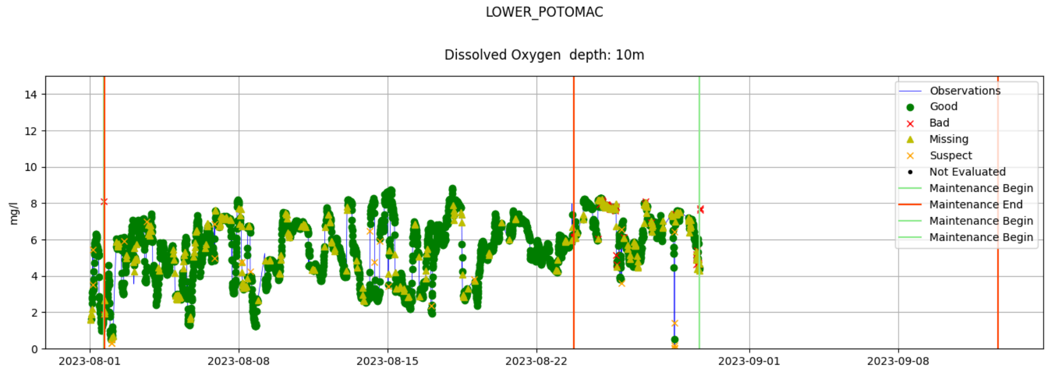

LOWER_POTOMAC
Dissolved Oxygen Adj depth: 10m
mg/l
0
2
4
6
8
10
12
14
2023-10-02
2023-10-03
2023-10-04
2023-10-05
2023-10-06
2023-10-07
2023-10-08
2023-10-09
2023-10-10
2023-10-11
2023-10-12
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

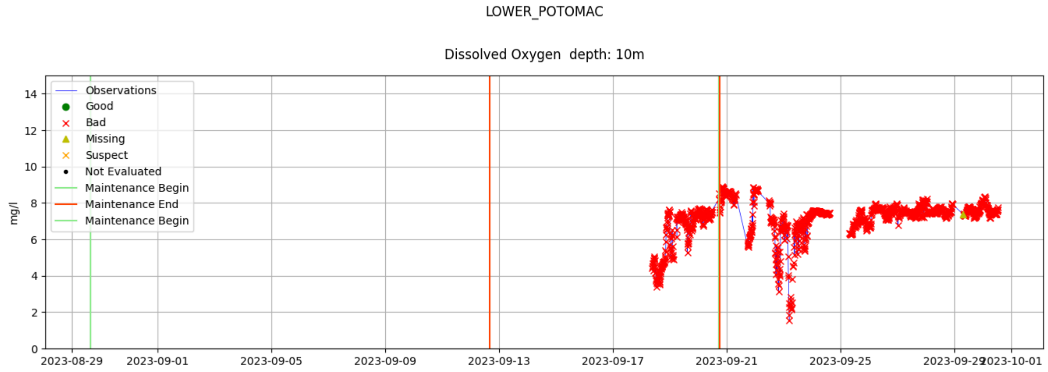
# Lower Potomac Dissolved Oxygen Depth=10m

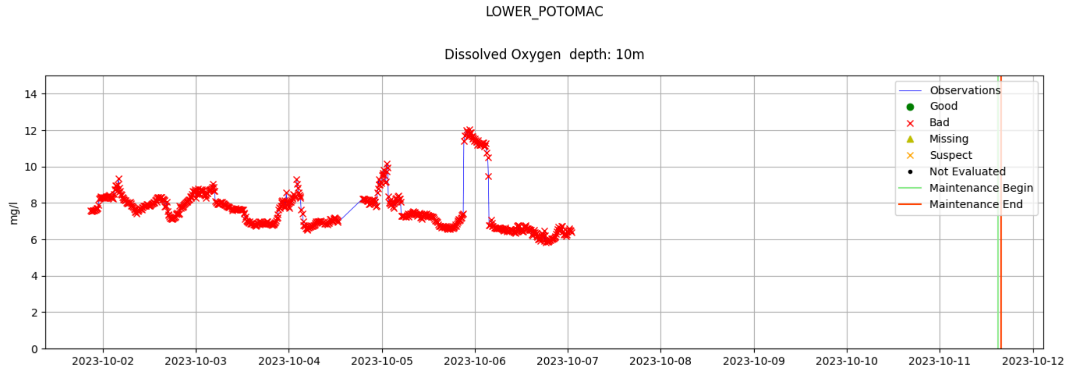




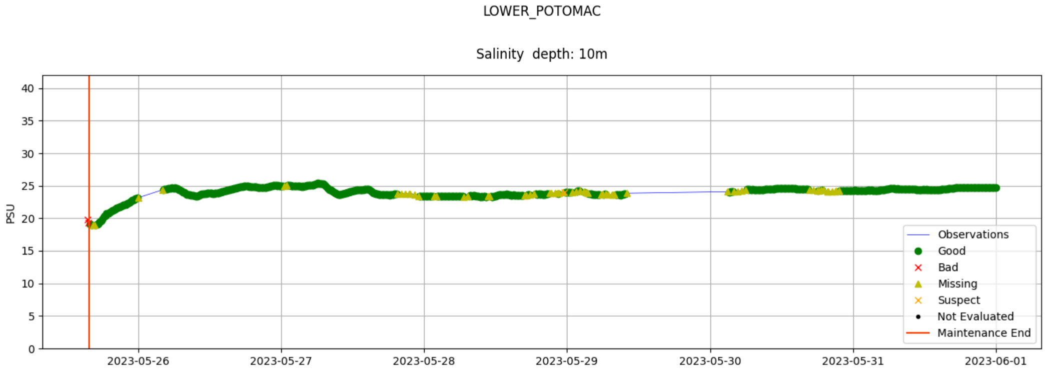


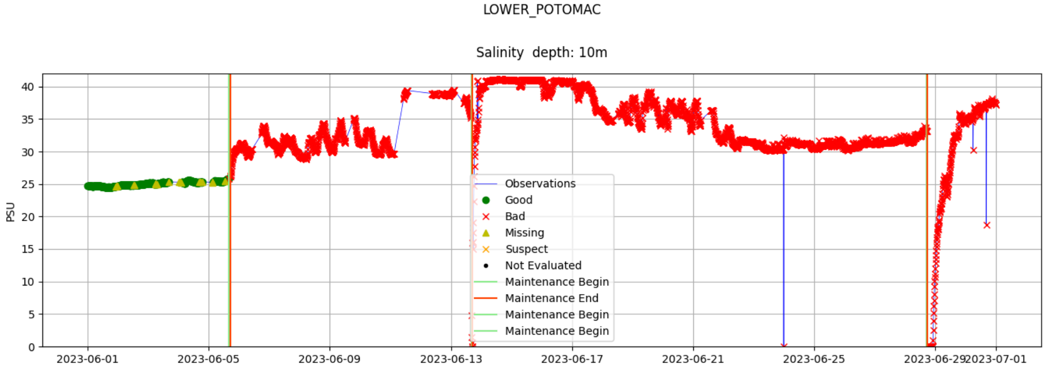

LOWER_POTOMAC
Dissolved Oxygen depth: 10m
mg/l
0
2
4
6
8
10
12
14
2023-08-01
2023-08-08
2023-08-15
2023-08-22
2023-09-01
2023-09-08
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin
Maintenance Begin

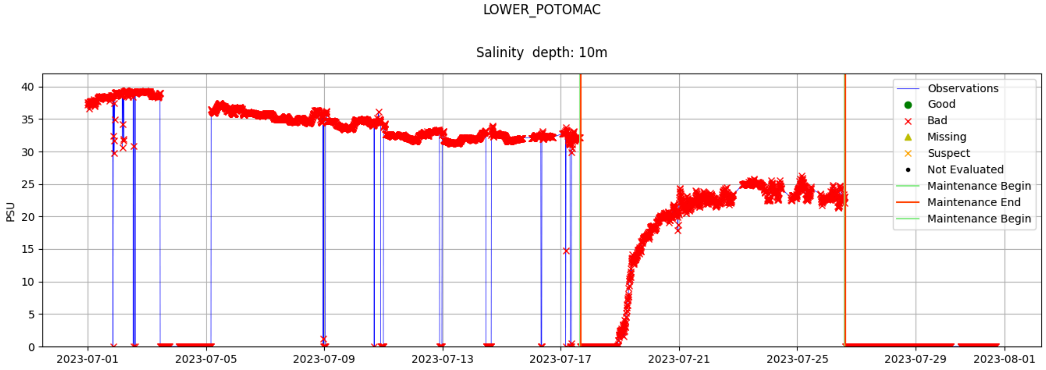

LOWER_POTOMAC
Dissolved Oxygen depth: 10m
mg/l
0
2
4
6
8
10
12
14
2023-08-29
2023-09-01
2023-09-05
2023-09-09
2023-09-13
2023-09-17
2023-09-21
2023-09-25
2023-09-29
2023-10-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin

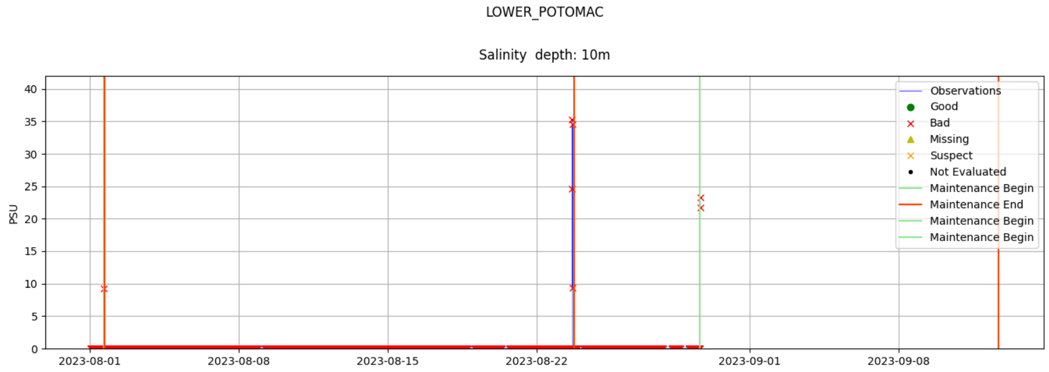

LOWER_POTOMAC
Dissolved Oxygen depth: 10m
mg/l
0
2
4
6
8
10
12
14
2023-10-02
2023-10-03
2023-10-04
2023-10-05
2023-10-06
2023-10-07
2023-10-08
2023-10-09
2023-10-10
2023-10-11
2023-10-12
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

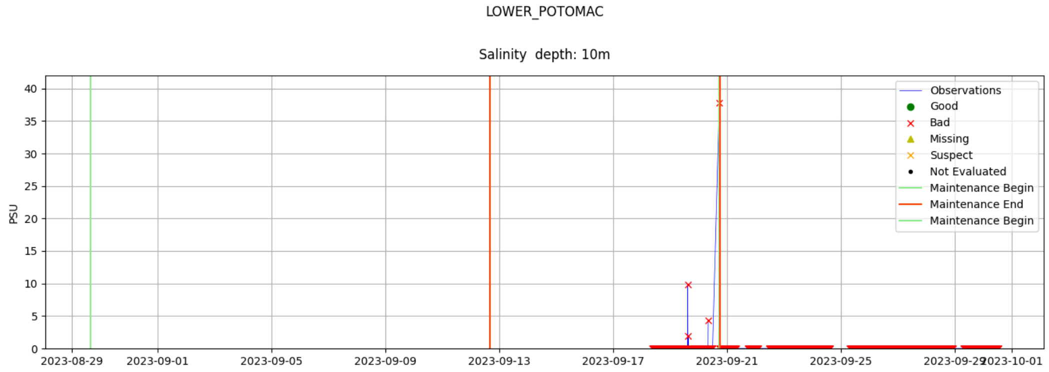
# Lower Potomac Salinity Depth=10m

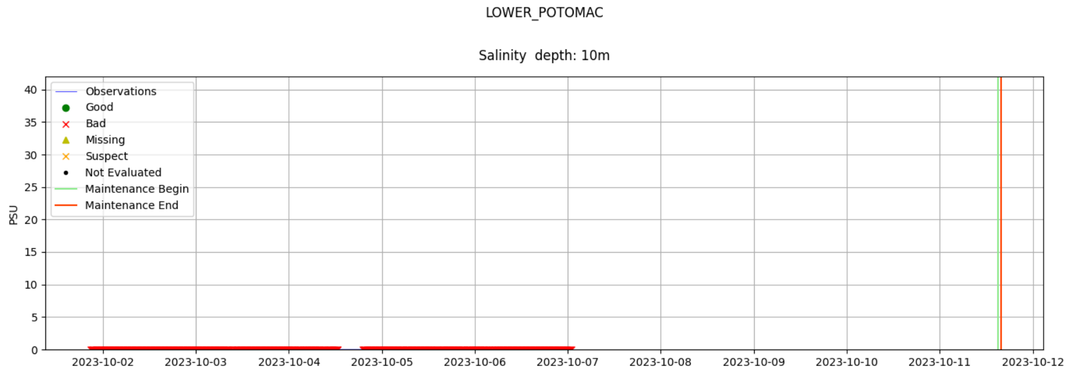




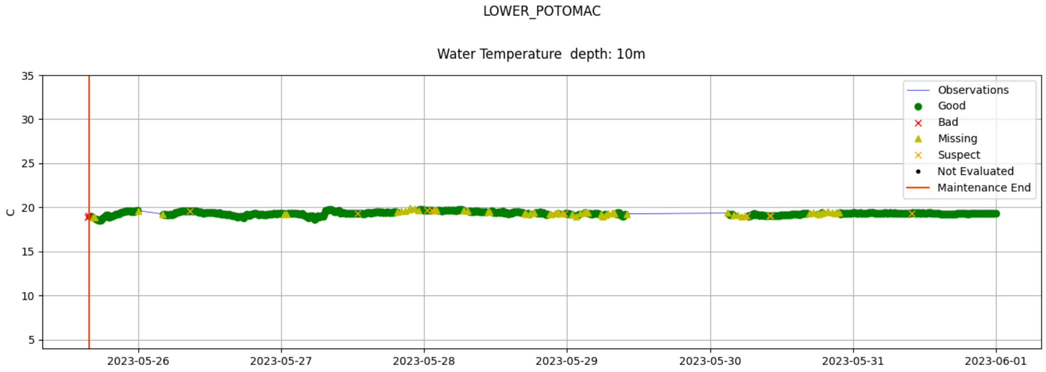


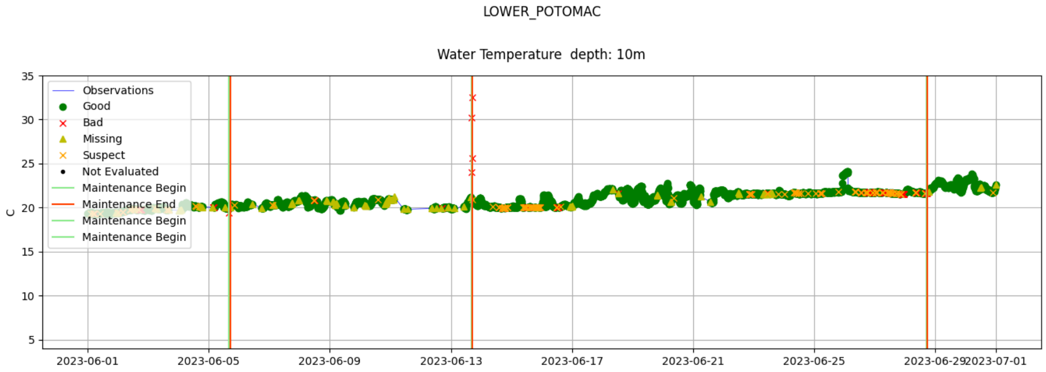

LOWER_POTOMAC
Salinity depth: 10m
PSU
0
5
10
15
20
25
30
35
40
2023-08-01
2023-08-08
2023-08-15
2023-08-22
2023-09-01
2023-09-08
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin
Maintenance Begin

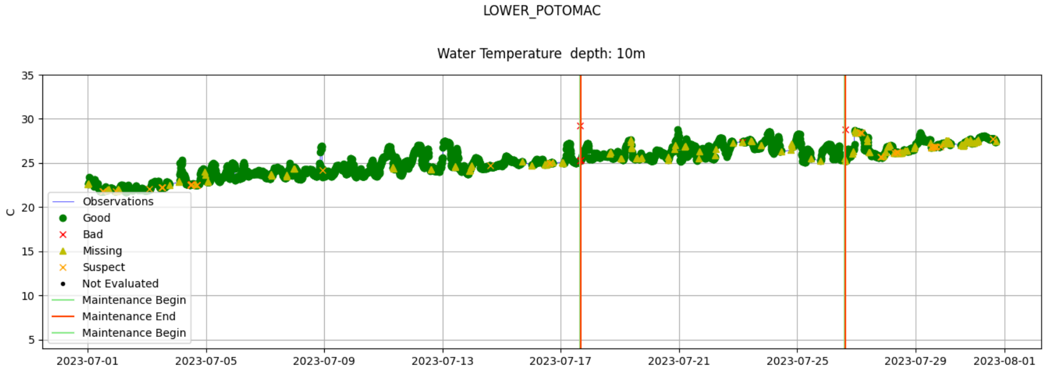

LOWER_POTOMAC
Salinity depth: 10m
PSU
0
5
10
15
20
25
30
35
40
2023-08-29
2023-09-01
2023-09-05
2023-09-09
2023-09-13
2023-09-17
2023-09-21
2023-09-25
2023-09-29
2023-10-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin

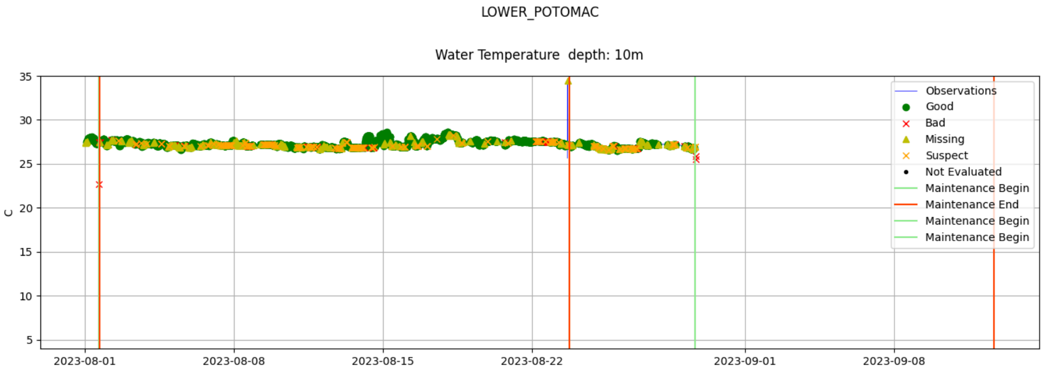

LOWER_POTOMAC
Salinity depth: 10m
PSU
0
5
10
15
20
25
30
35
40
2023-10-02
2023-10-03
2023-10-04
2023-10-05
2023-10-06
2023-10-07
2023-10-08
2023-10-09
2023-10-10
2023-10-11
2023-10-12
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

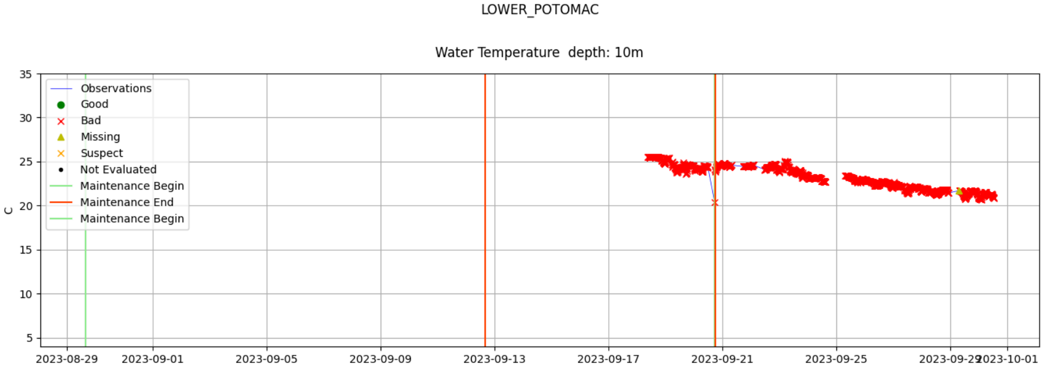
# Lower Potomac Water Temperature Depth= 0m

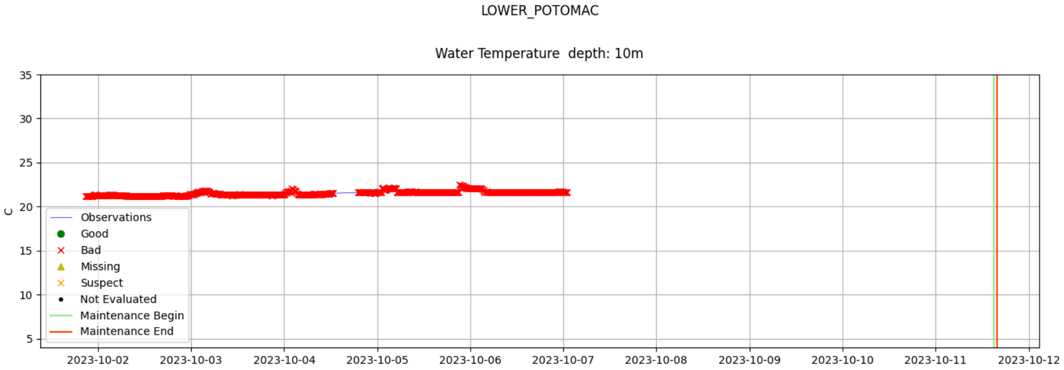




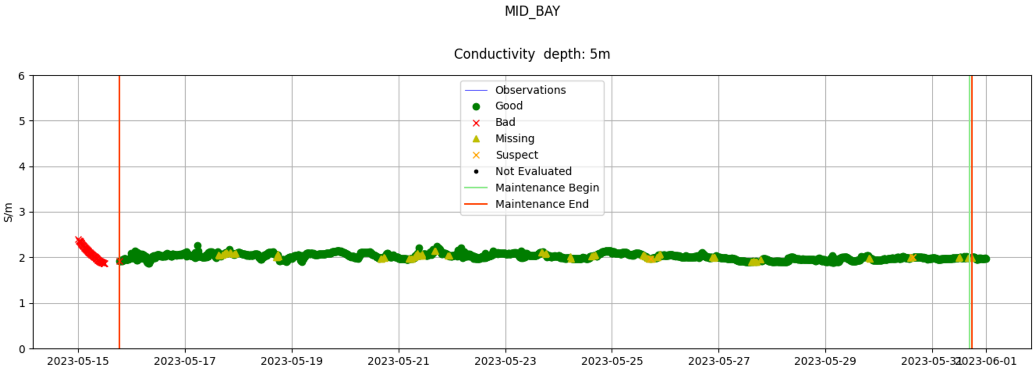


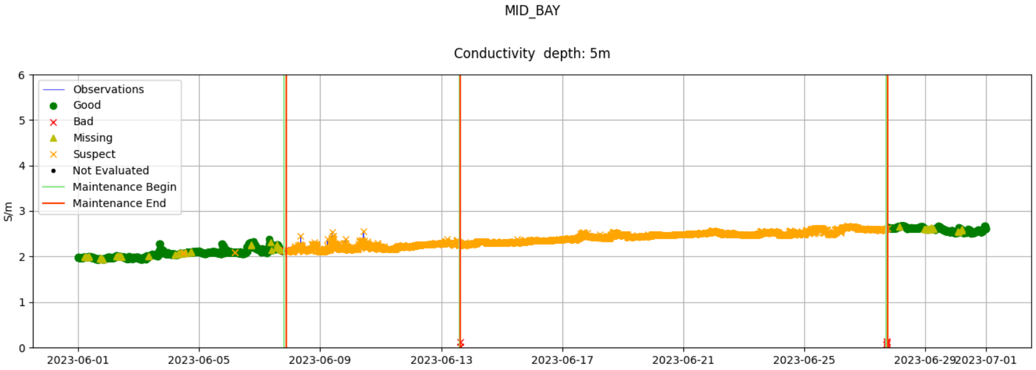

LOWER_POTOMAC
Water Temperature depth: 10m
C
35
30
25
20
15
10
5
2023-08-01
2023-08-08
2023-08-15
2023-08-22
2023-09-01
2023-09-08
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin
Maintenance Begin

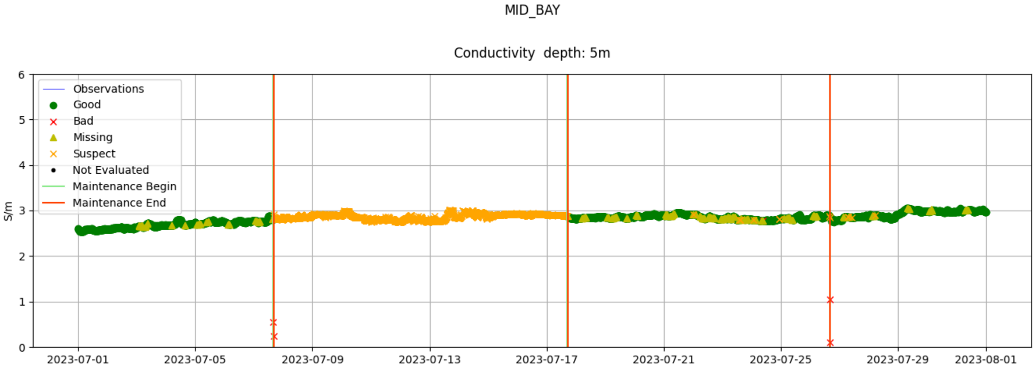

LOWER_POTOMAC
Water Temperature depth: 10m
C
35
30
25
20
15
10
5
2023-08-29
2023-09-01
2023-09-05
2023-09-09
2023-09-13
2023-09-17
2023-09-21
2023-09-25
2023-09-29
2023-10-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin

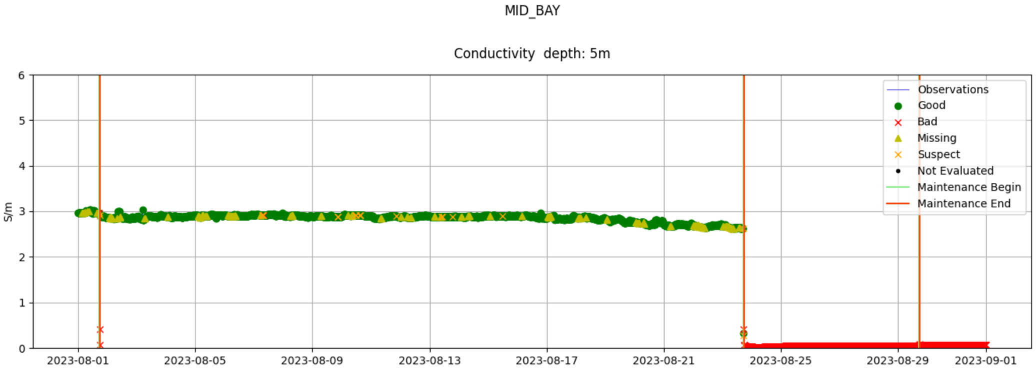

LOWER_POTOMAC
Water Temperature depth: 10m
C
35
30
25
20
15
10
5
2023-10-02
2023-10-03
2023-10-04
2023-10-05
2023-10-06
2023-10-07
2023-10-08
2023-10-09
2023-10-10
2023-10-11
2023-10-12
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

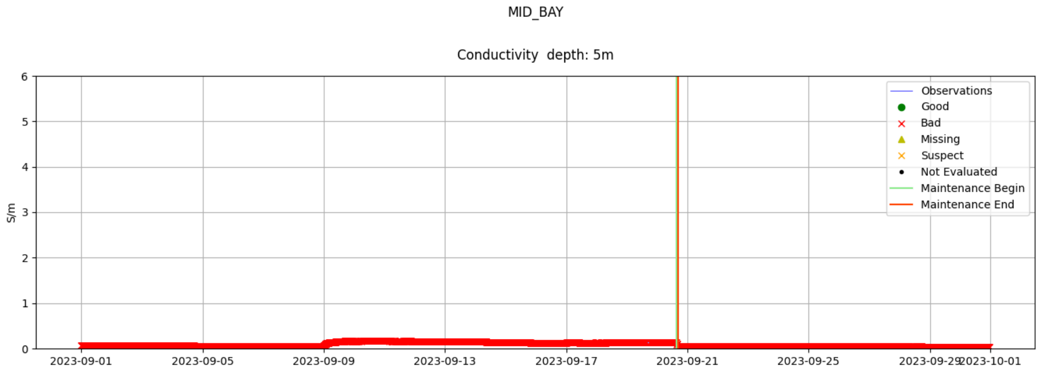
# Mid-Bay Conductivity Depth=5m

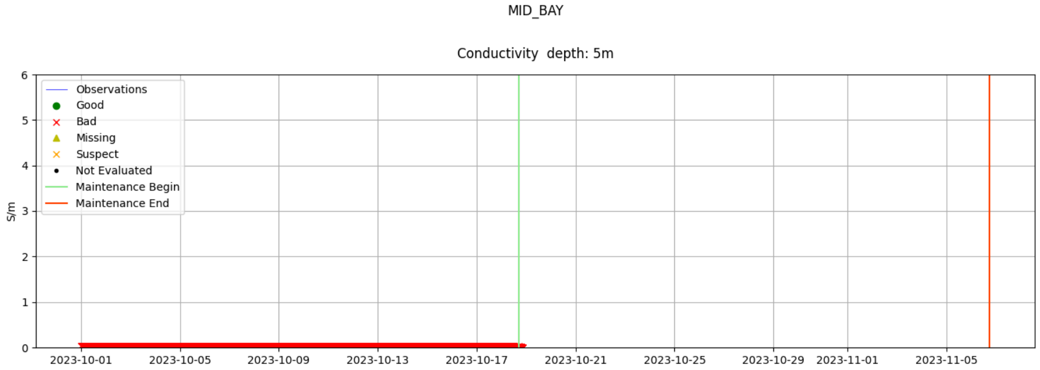


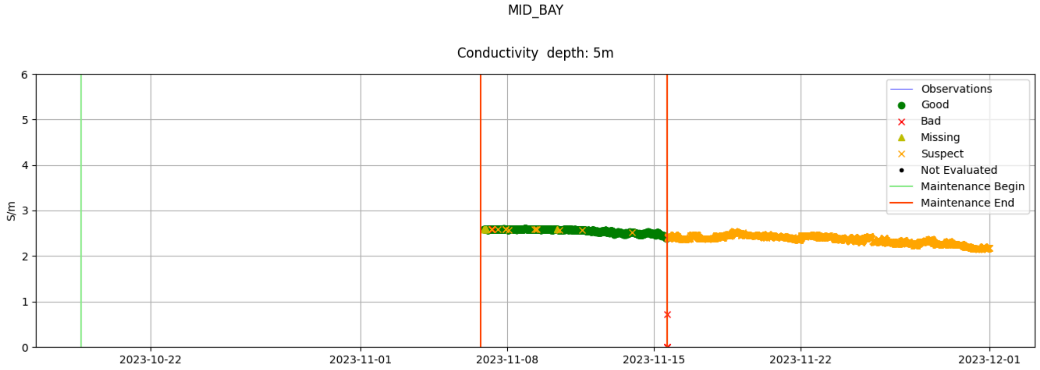


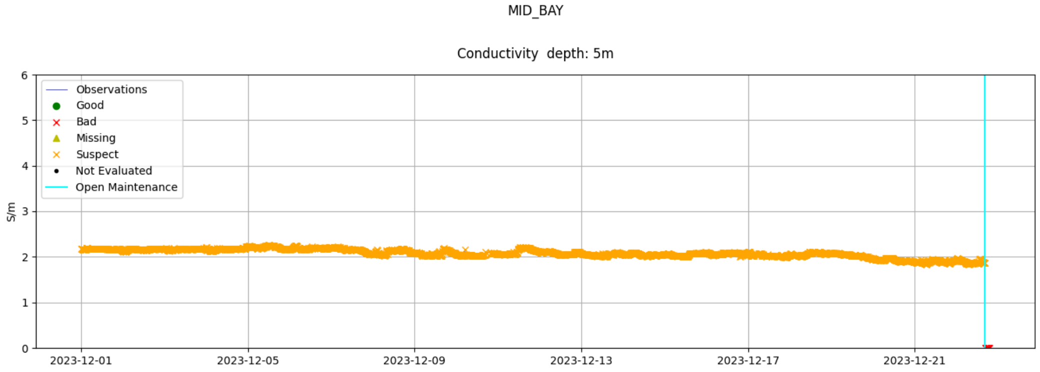




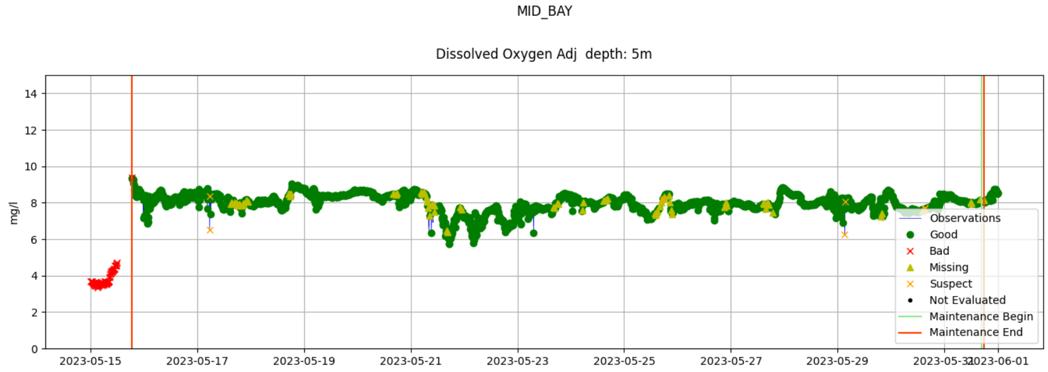

MID_BAY
Conductivity  depth: 5m
S/m
0
1
2
3
4
5
6
2023-09-01
2023-09-05
2023-09-09
2023-09-13
2023-09-17
2023-09-21
2023-09-25
2023-09-29
2023-10-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

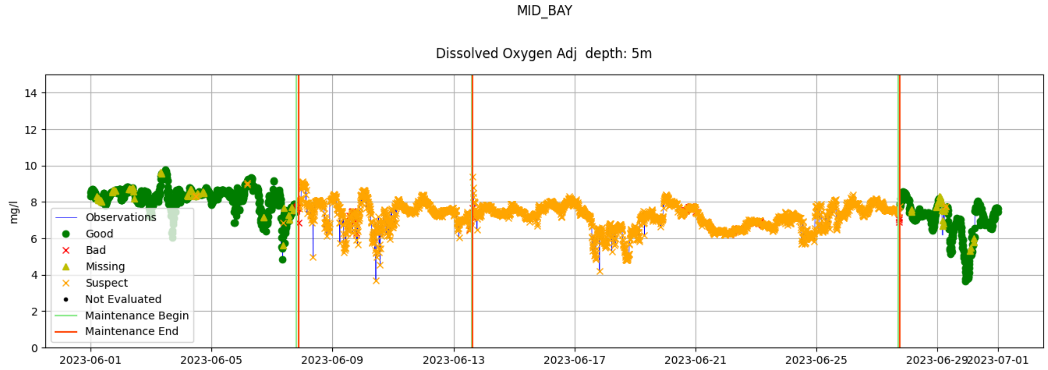

MID_BAY
Conductivity  depth: 5m
S/m
0
1
2
3
4
5
6
2023-10-01
2023-10-05
2023-10-09
2023-10-13
2023-10-17
2023-10-21
2023-10-25
2023-10-29
2023-11-01
2023-11-05
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

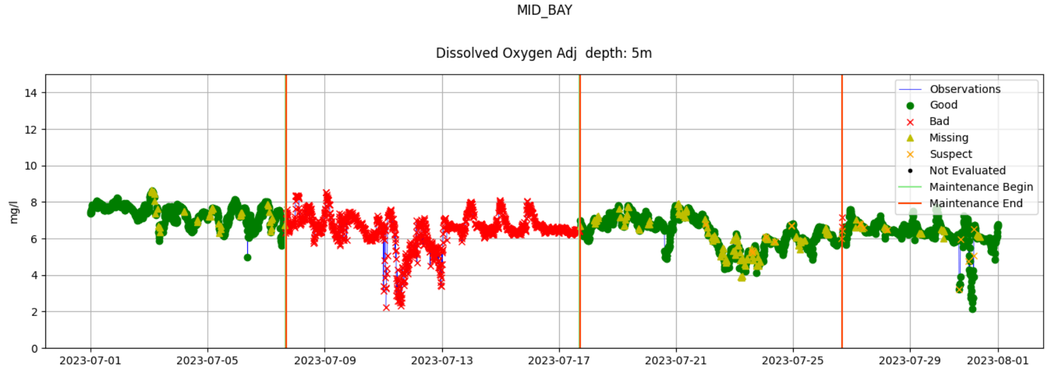

MID_BAY
Conductivity  depth: 5m
S/m
0
1
2
3
4
5
6
2023-10-22
2023-11-01
2023-11-08
2023-11-15
2023-11-22
2023-12-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

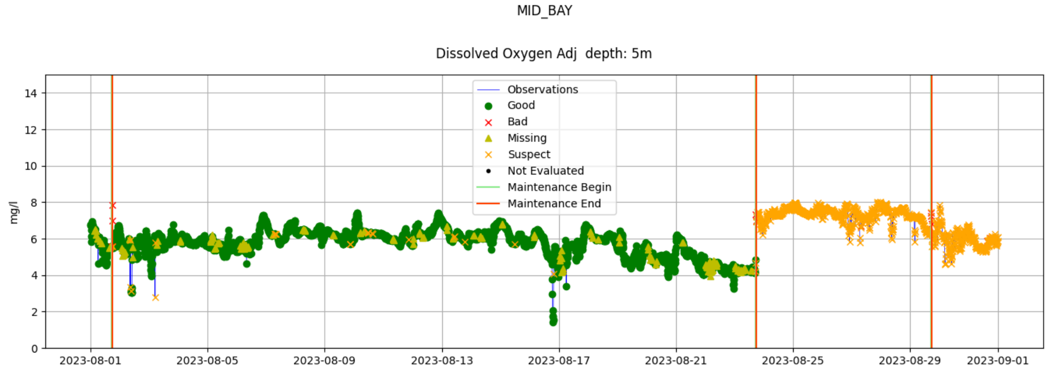

MID_BAY
Conductivity  depth: 5m
S/m
0
1
2
3
4
5
6
2023-12-01
2023-12-05
2023-12-09
2023-12-13
2023-12-17
2023-12-21
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Open Maintenance

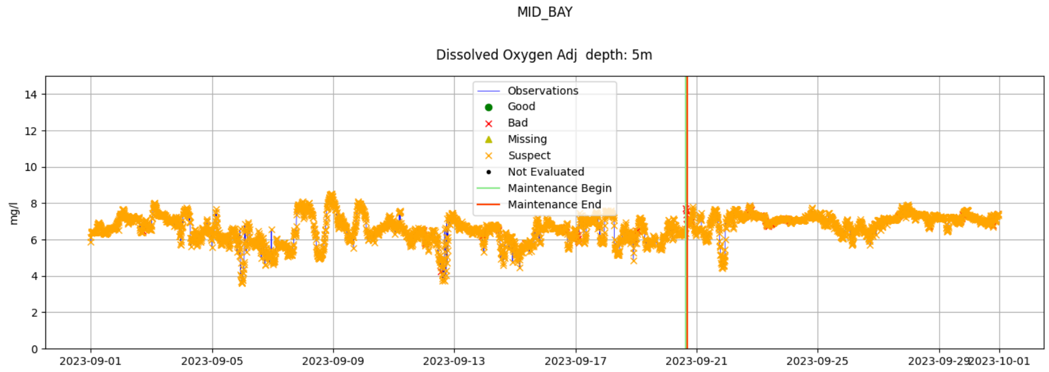
# Mid-Bay Adjusted Dissolved Oxygen Depth=5m



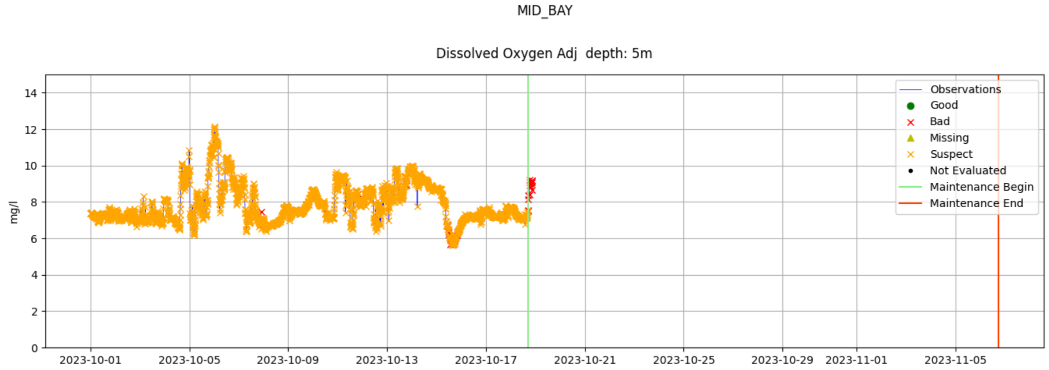




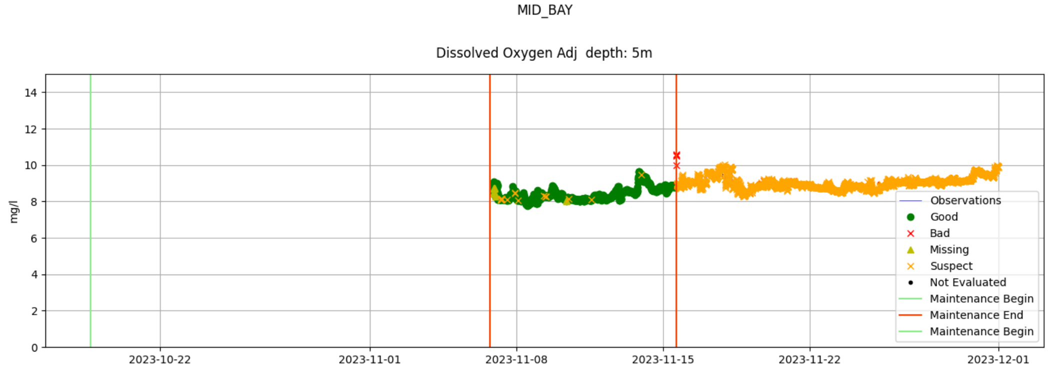



MID_BAY

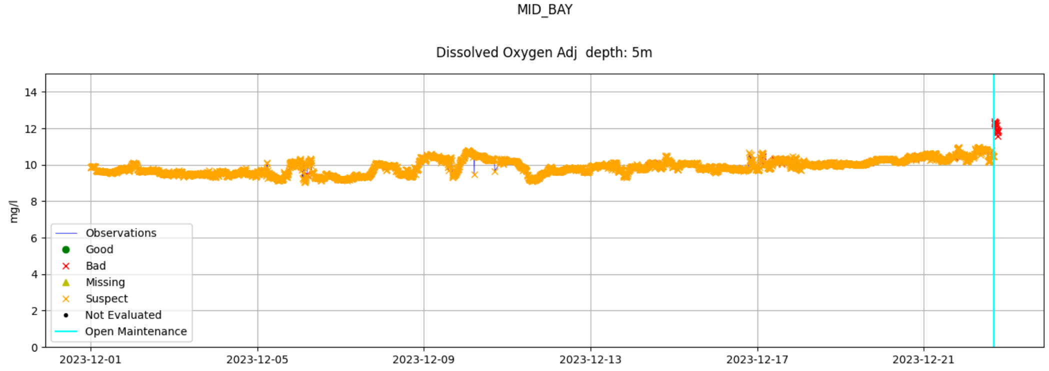
Dissolved Oxygen Adj depth: 5m


MID_BAY

Dissolved Oxygen Adj depth: 5m

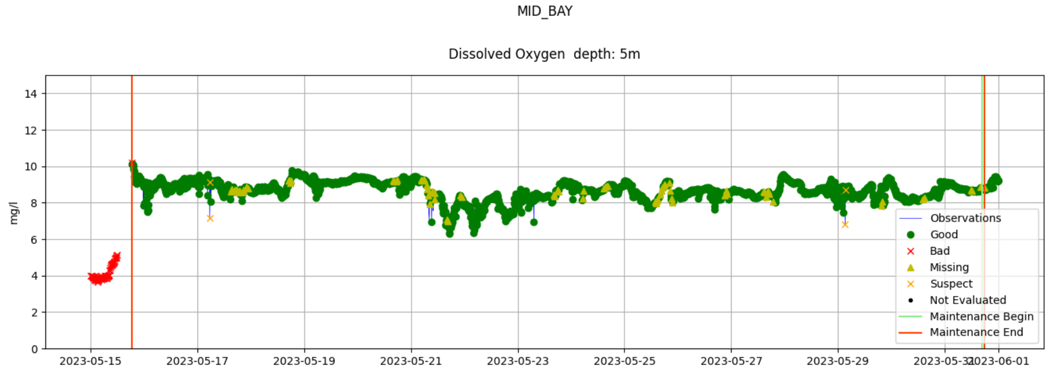

MID_BAY

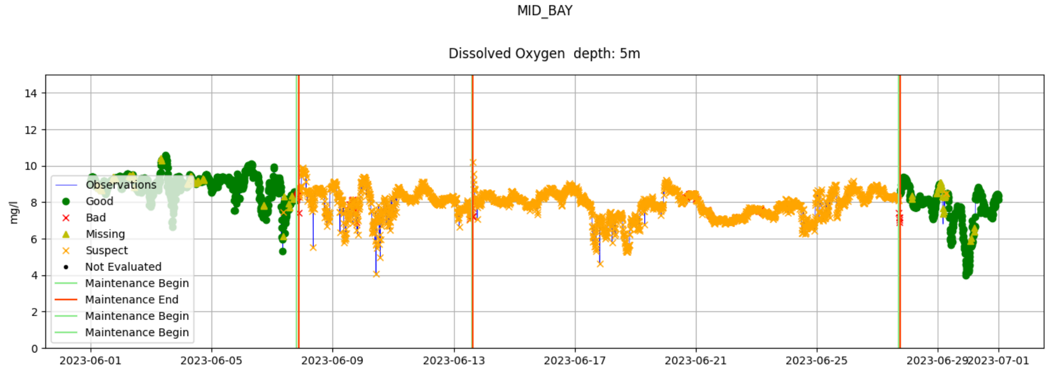
Dissolved Oxygen Adj depth: 5m

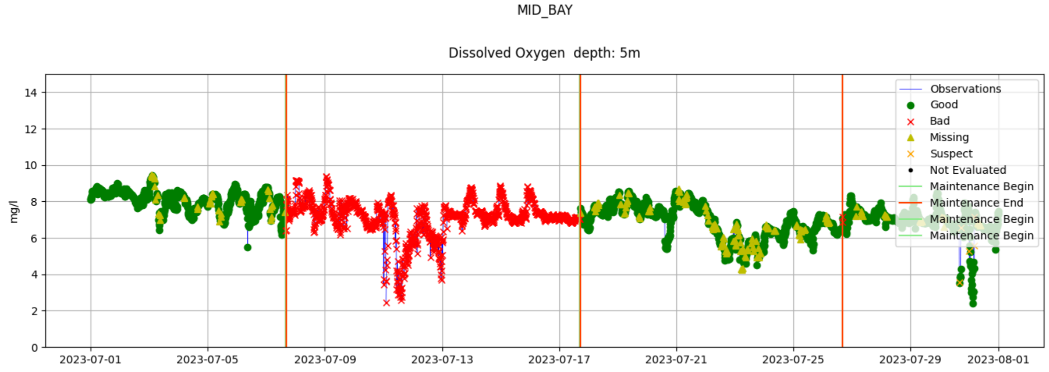

MID_BAY

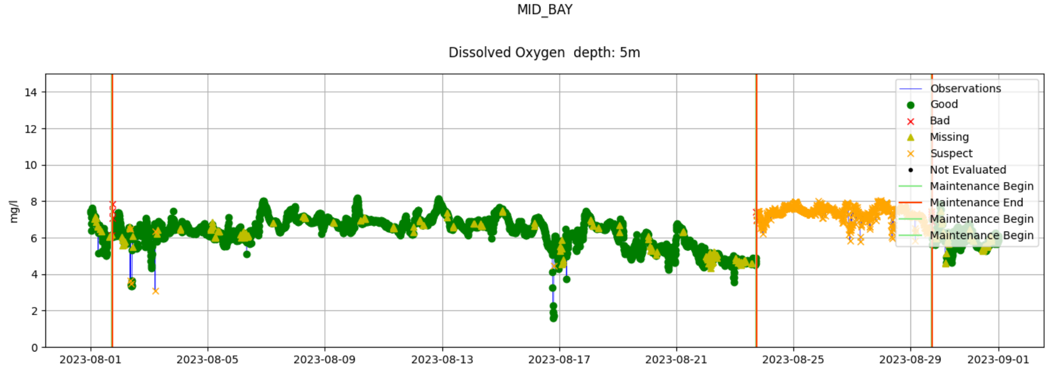
Dissolved Oxygen Adj depth: 5m

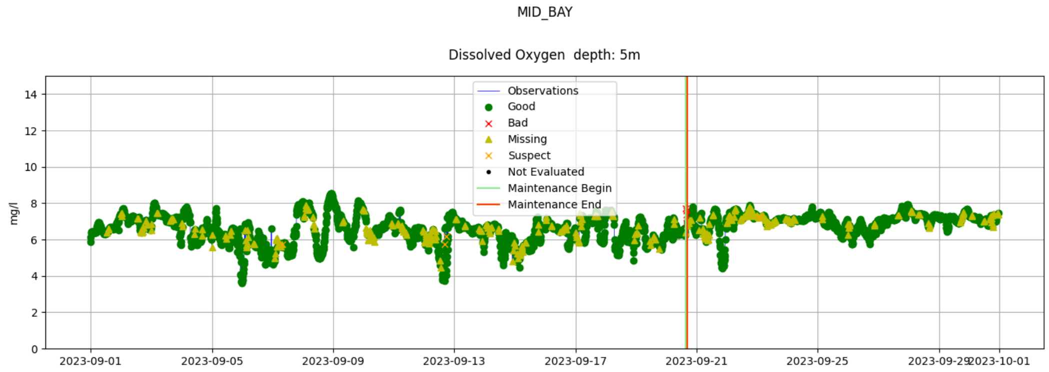
# Mid-Bay Dissolved Oxygen Depth=5m

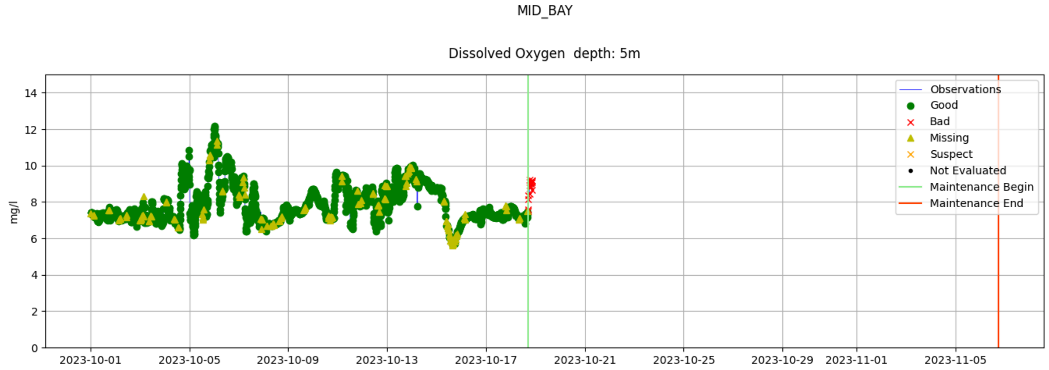


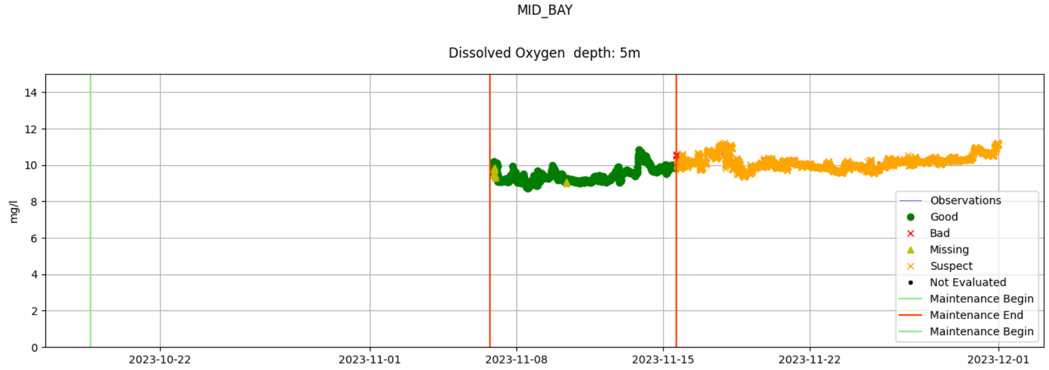


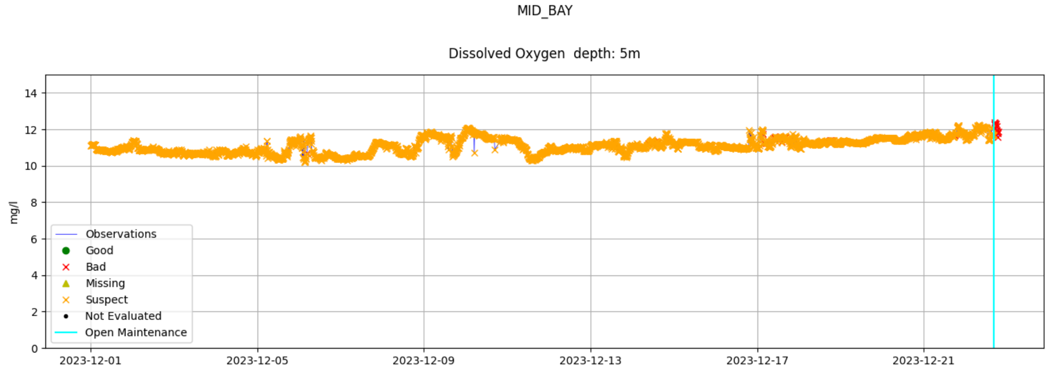




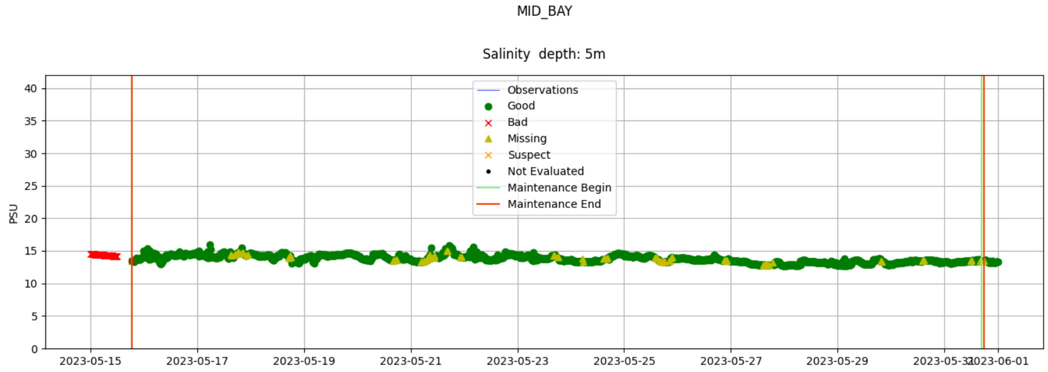

MID_BAY
Dissolved Oxygen depth: 5m
mg/l
0
2
4
6
8
10
12
14
2023-09-01
2023-09-05
2023-09-09
2023-09-13
2023-09-17
2023-09-21
2023-09-25
2023-09-29
2023-10-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

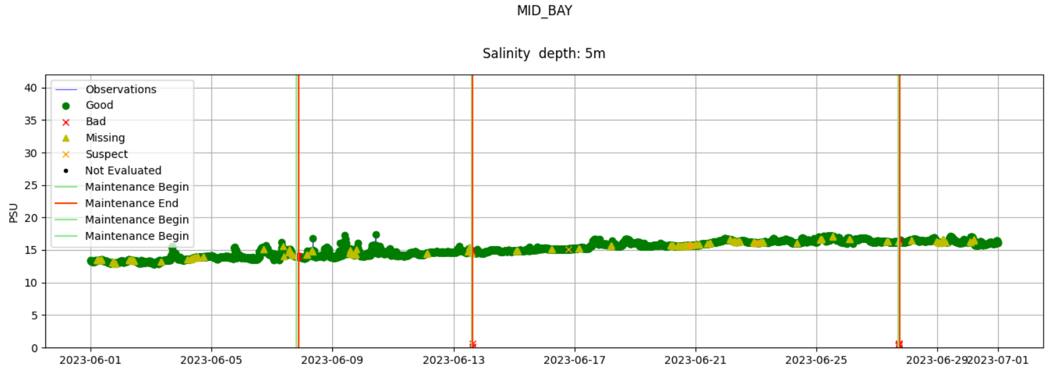

MID_BAY
Dissolved Oxygen depth: 5m
mg/l
0
2
4
6
8
10
12
14
2023-10-01
2023-10-05
2023-10-09
2023-10-13
2023-10-17
2023-10-21
2023-10-25
2023-10-29
2023-11-01
2023-11-05
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

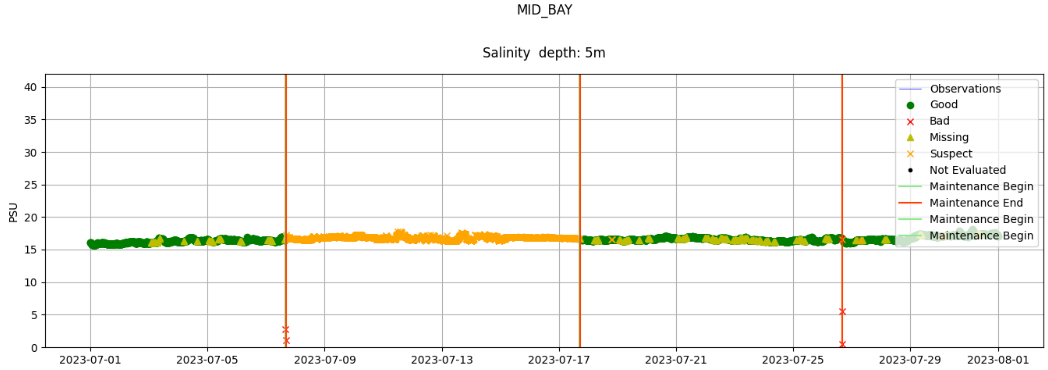

MID_BAY
Dissolved Oxygen depth: 5m
mg/l
0
2
4
6
8
10
12
14
2023-10-22
2023-11-01
2023-11-08
2023-11-15
2023-11-22
2023-12-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin

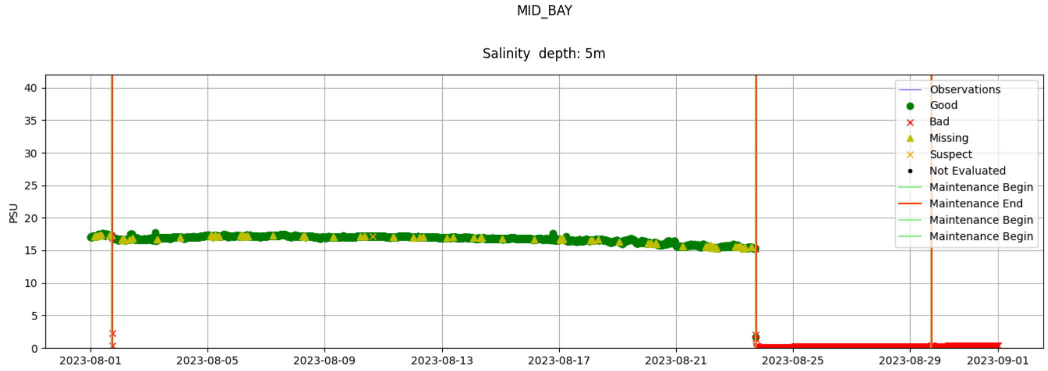

MID_BAY
Dissolved Oxygen depth: 5m
mg/l
0
2
4
6
8
10
12
14
2023-12-01
2023-12-05
2023-12-09
2023-12-13
2023-12-17
2023-12-21
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Open Maintenance

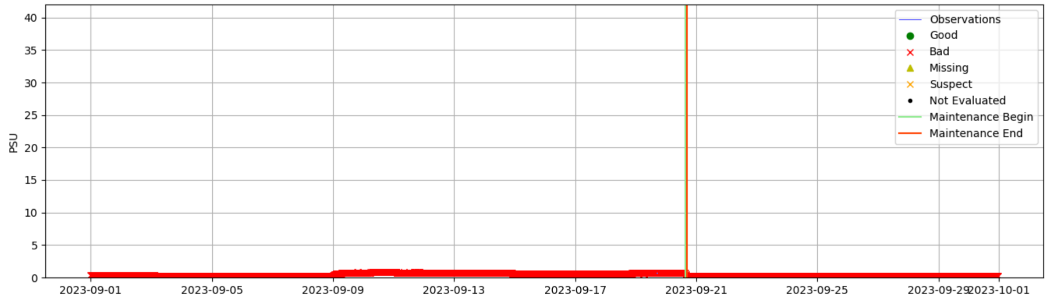
# Mid-Bay Salinity Depth=5m





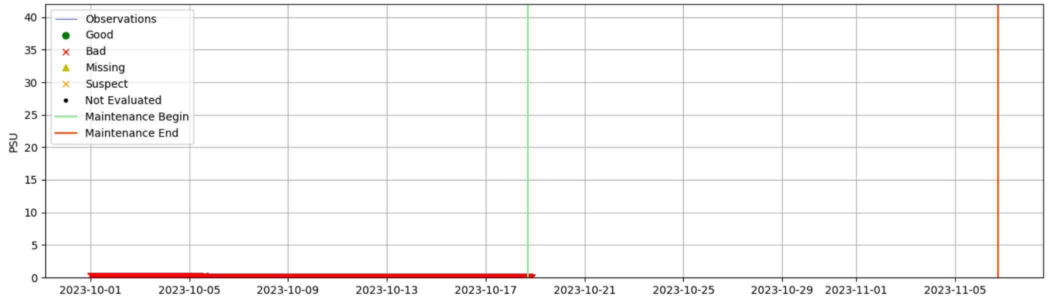






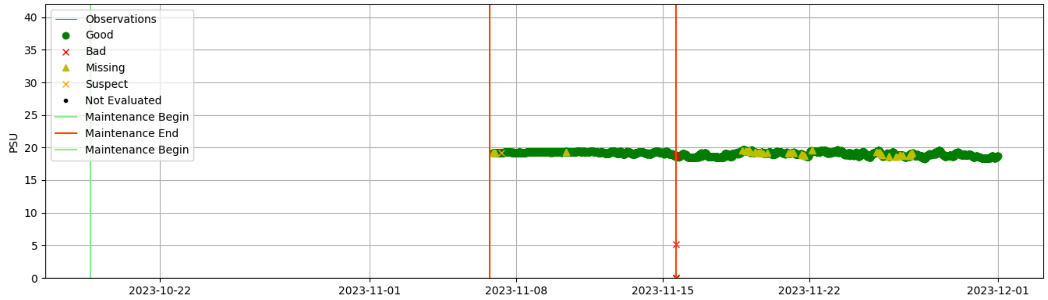
MID_BAY

Salinity depth: 5m



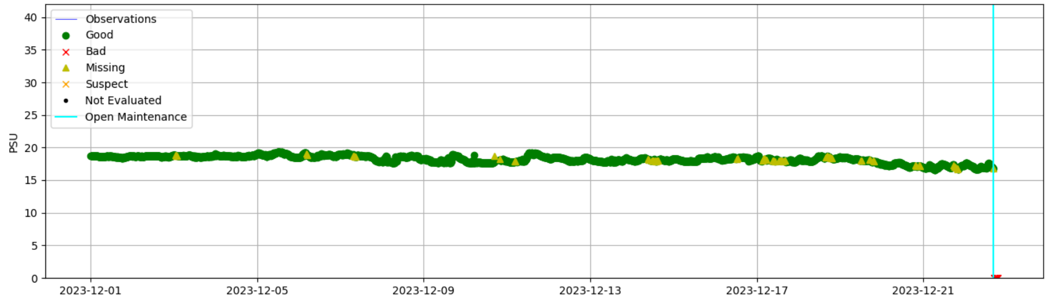
MID_BAY

Salinity depth: 5m



MID_BAY

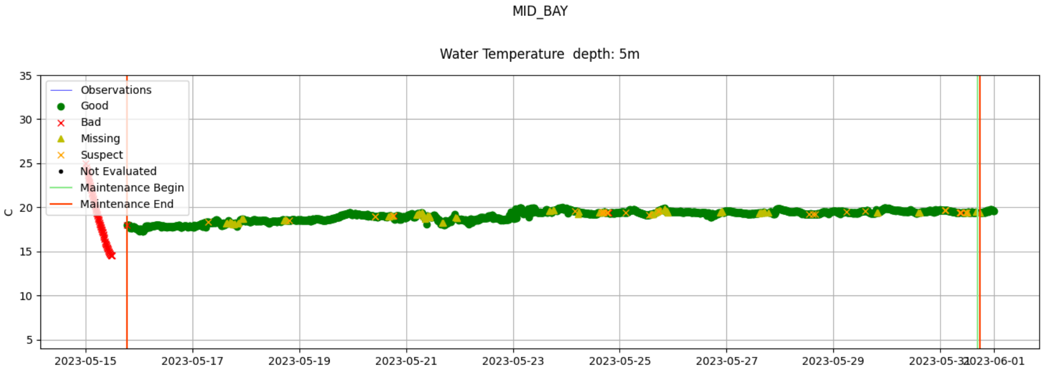
Salinity depth: 5m

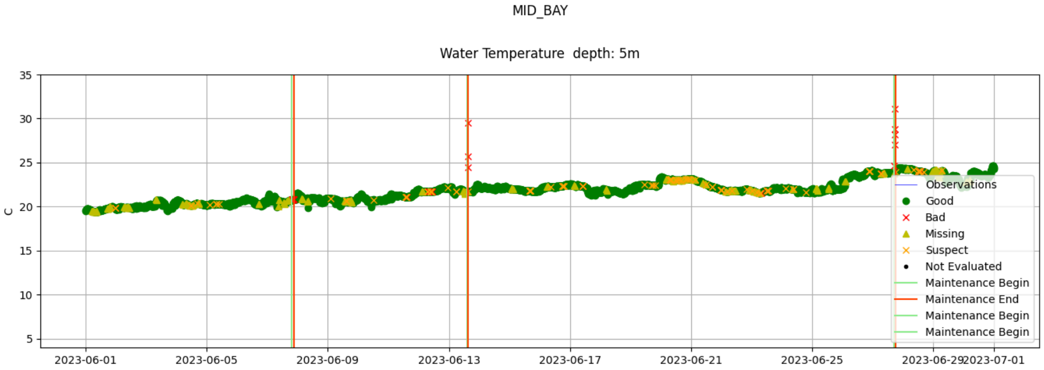


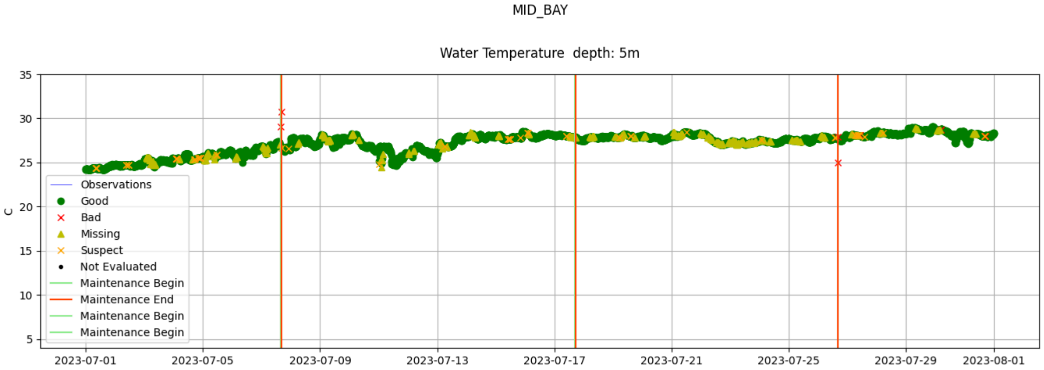
MID_BAY

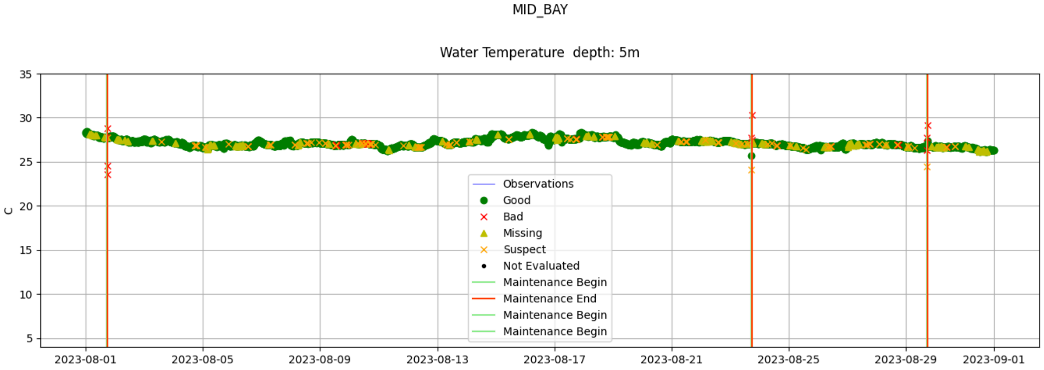
Salinity depth: 5m

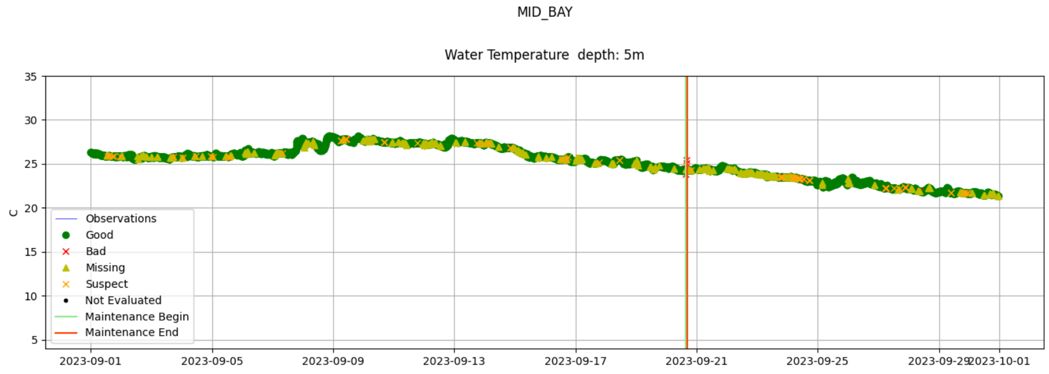
# Mid-Bay Water Temperature Depth=5m

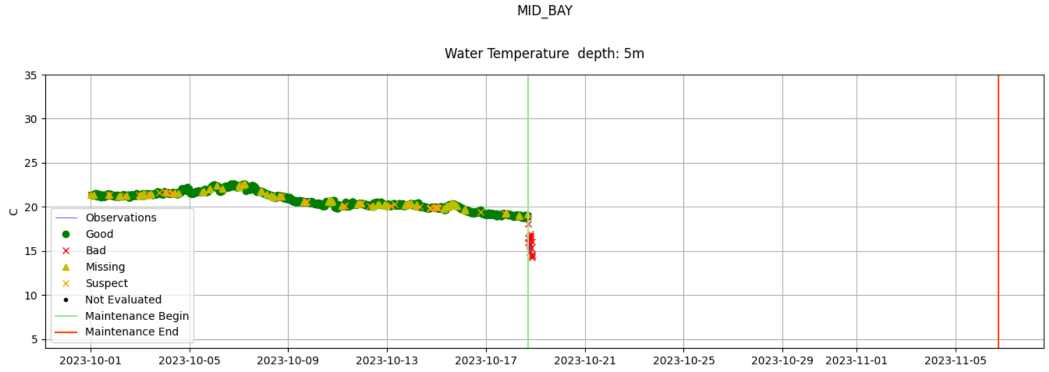


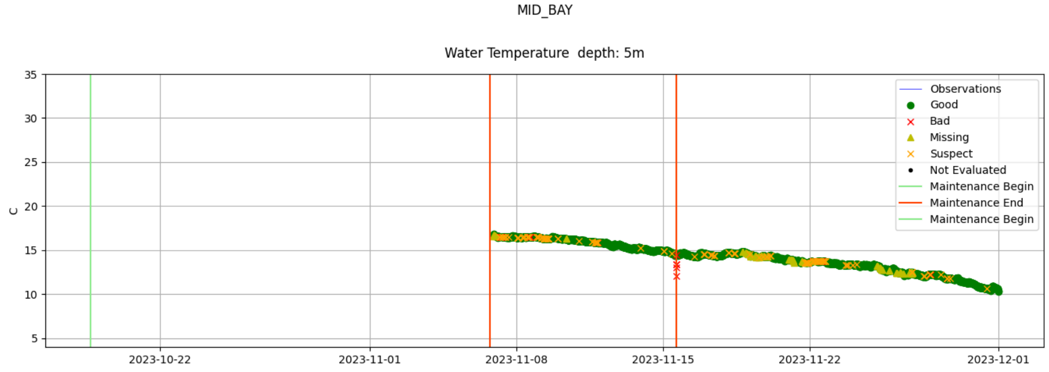


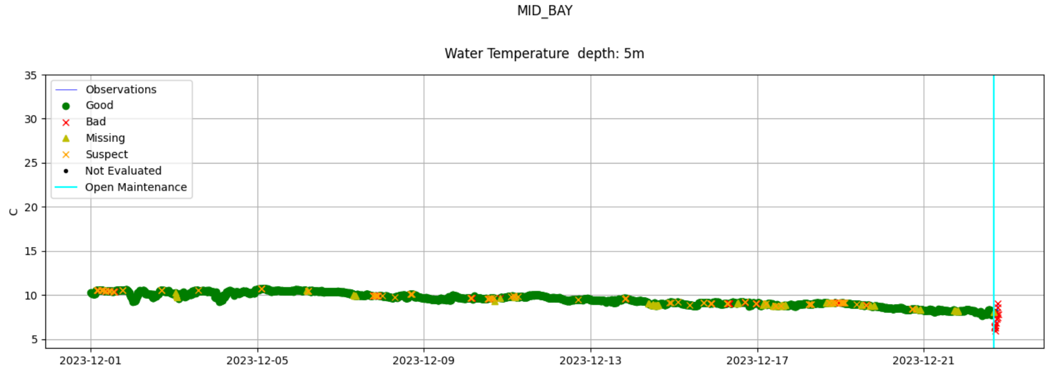




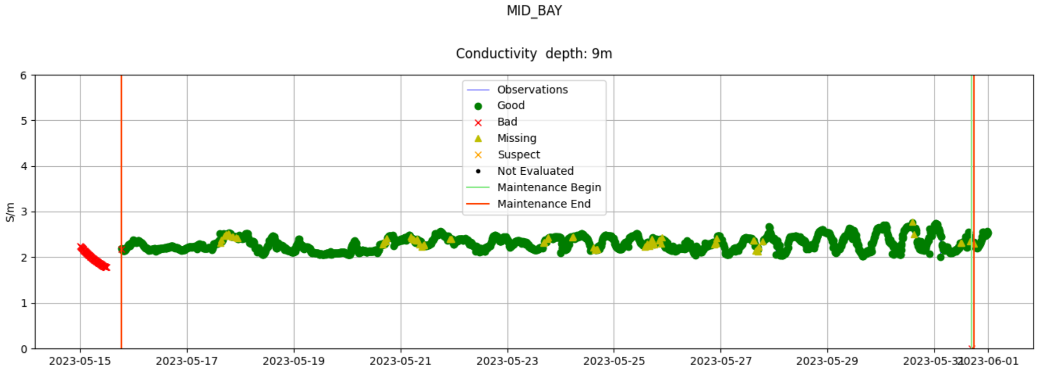

MID_BAY
Water Temperature depth: 5m
C
35
30
25
20
15
10
5
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
2023-09-01
2023-09-05
2023-09-09
2023-09-13
2023-09-17
2023-09-21
2023-09-25
2023-09-29
2023-10-01

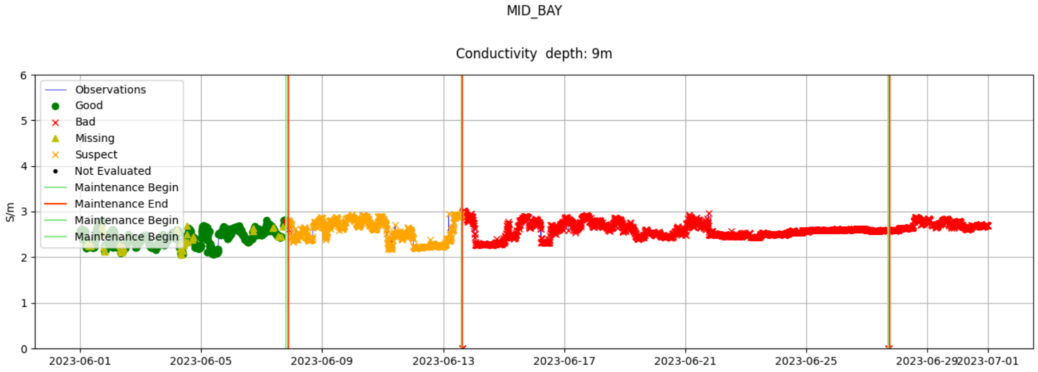

MID_BAY
Water Temperature depth: 5m
C
35
30
25
20
15
10
5
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
2023-10-01
2023-10-05
2023-10-09
2023-10-13
2023-10-17
2023-10-21
2023-10-25
2023-10-29
2023-11-01
2023-11-05

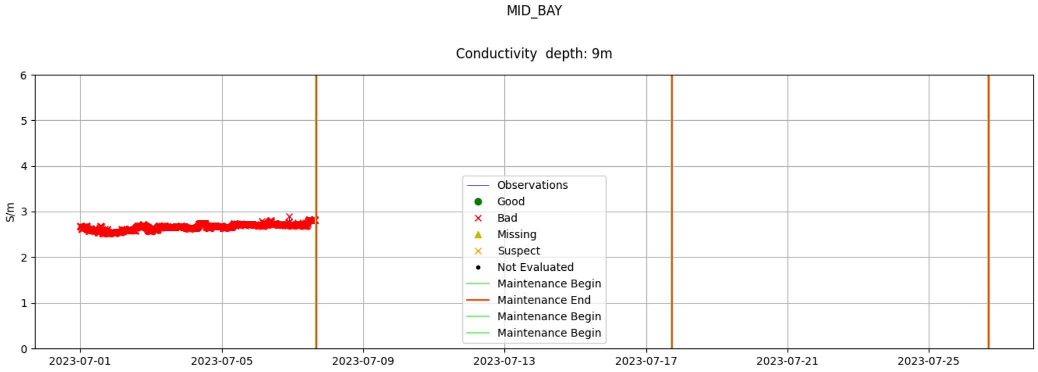

MID_BAY
Water Temperature depth: 5m
C
35
30
25
20
15
10
5
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin
2023-10-22
2023-11-01
2023-11-08
2023-11-15
2023-11-22
2023-12-01

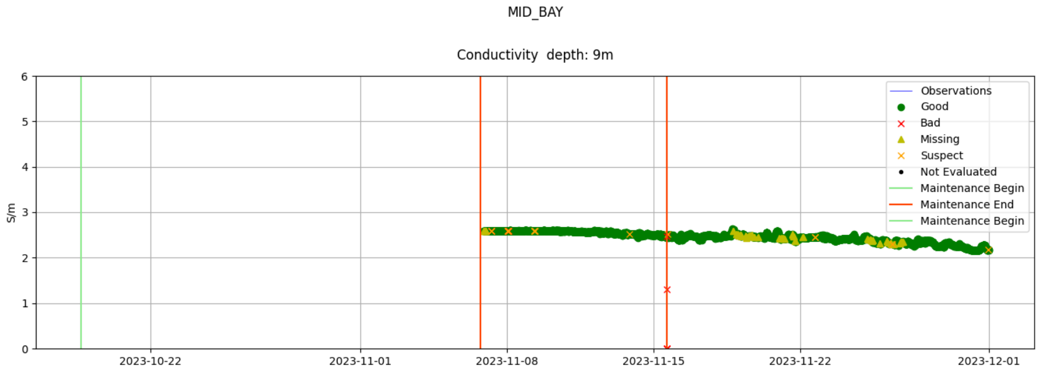

MID_BAY
Water Temperature depth: 5m
C
35
30
25
20
15
10
5
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Open Maintenance
2023-12-01
2023-12-05
2023-12-09
2023-12-13
2023-12-17
2023-12-21

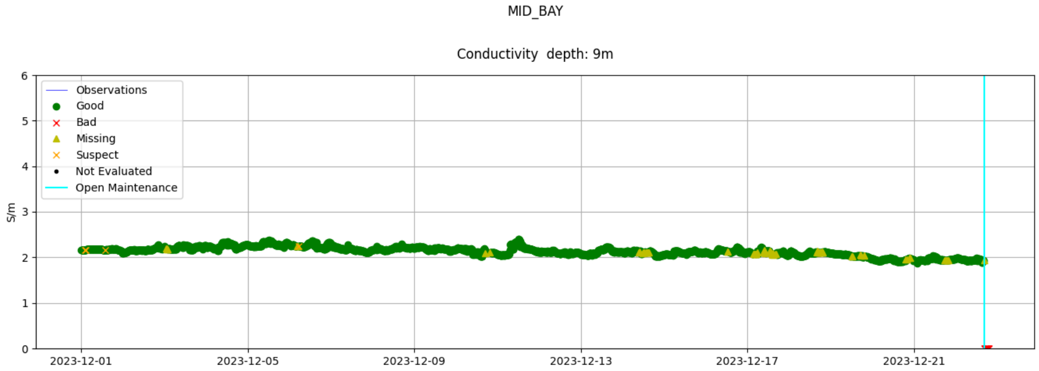
# Mid-Bay Conductivity Depth=5m







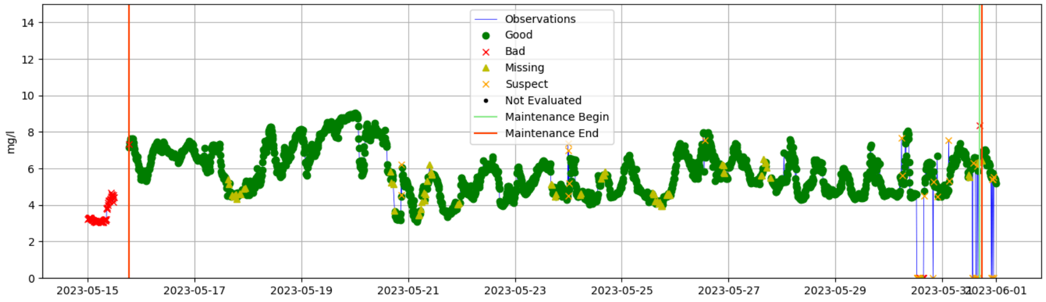

MID_BAY
Conductivity depth: 9m
S/m
0
1
2
3
4
5
6
2023-10-22
2023-11-01
2023-11-08
2023-11-15
2023-11-22
2023-12-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin


MID_BAY
Conductivity depth: 9m
S/m
0
1
2
3
4
5
6
2023-12-01
2023-12-05
2023-12-09
2023-12-13
2023-12-17
2023-12-21
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Open Maintenance

# Mid-Bay Adjusted Dissolved Oxygen Depth=5m

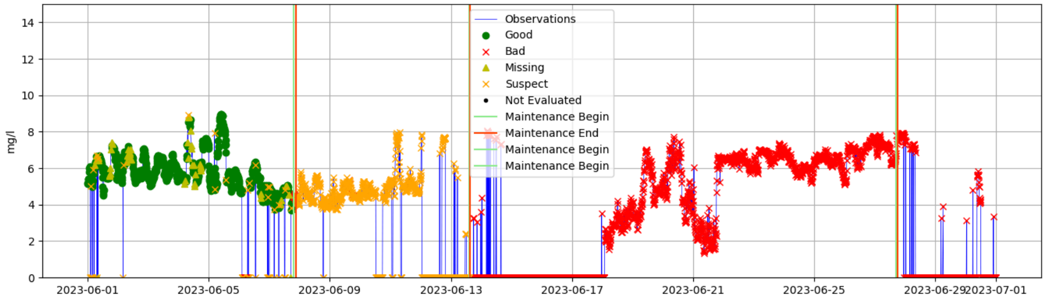
MID_BAY

Dissolved Oxygen Adj depth: 9m



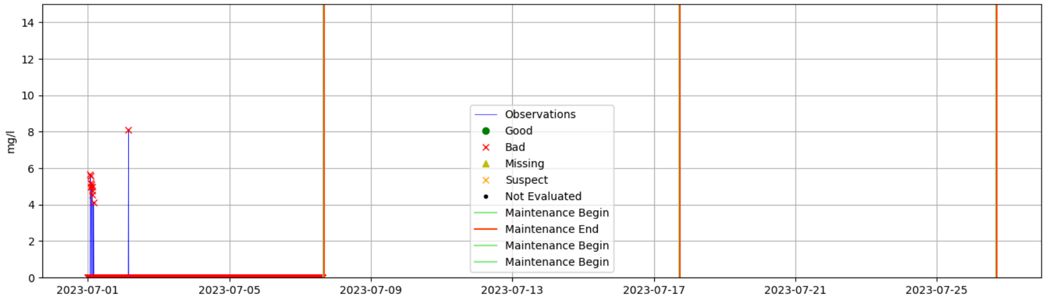
MID_BAY

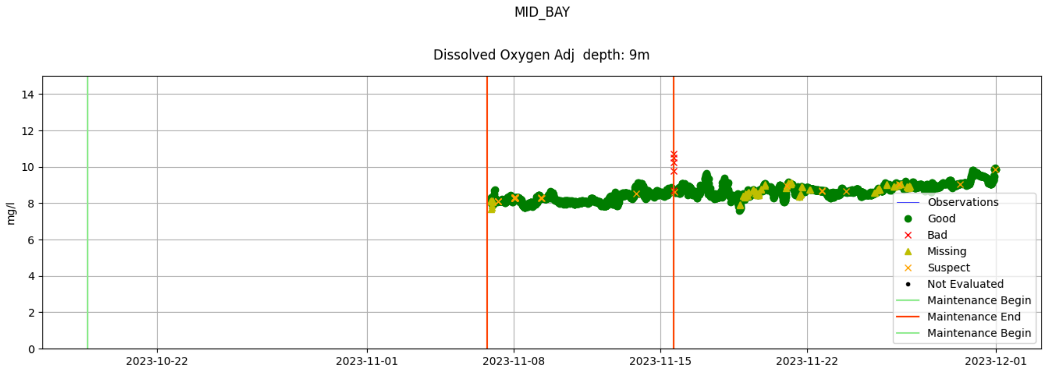
Dissolved Oxygen Adj depth: 9m

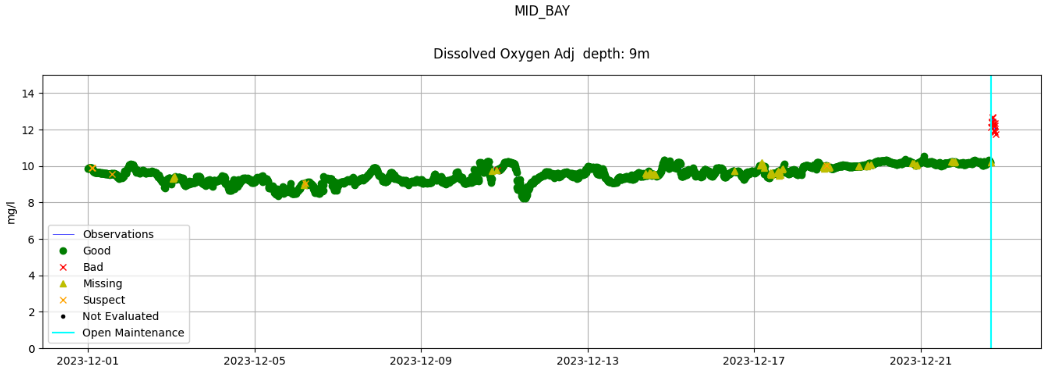


MID_BAY

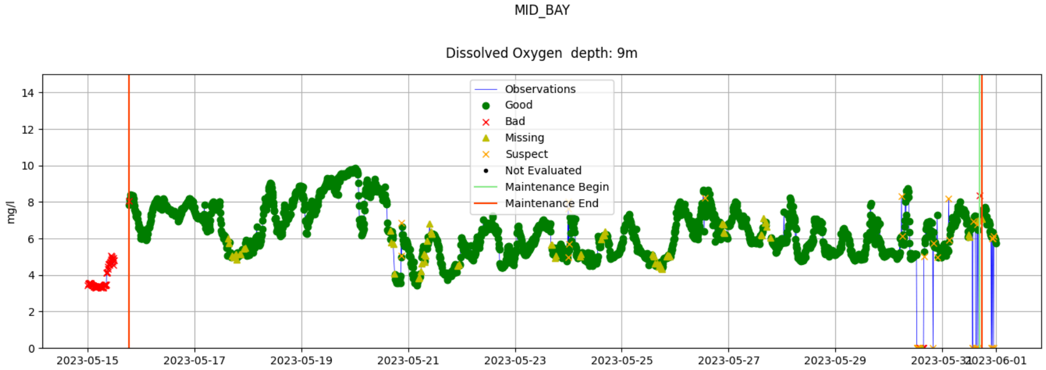
Dissolved Oxygen Adj depth: 9m

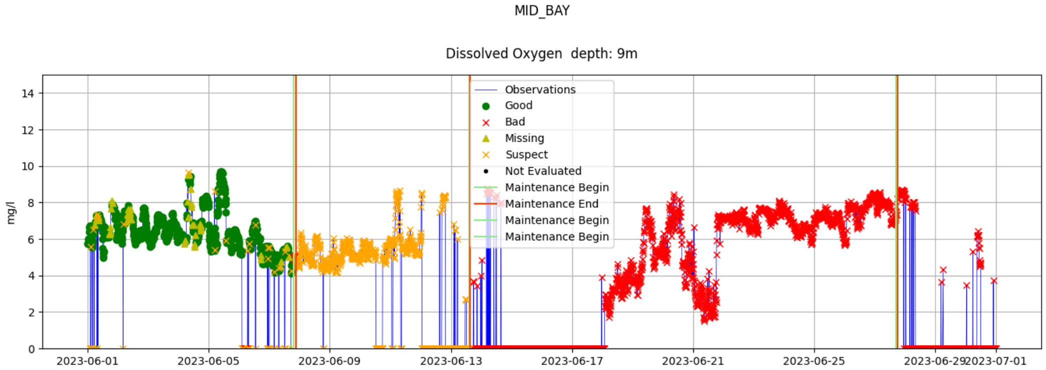


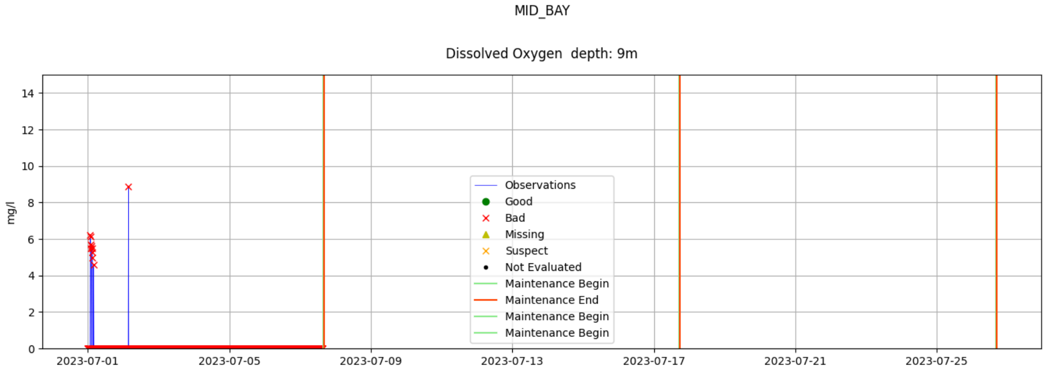

MID_BAY
Dissolved Oxygen Adj depth: 9m
mg/l
0
2
4
6
8
10
12
14
2023-10-22
2023-11-01
2023-11-08
2023-11-15
2023-11-22
2023-12-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin

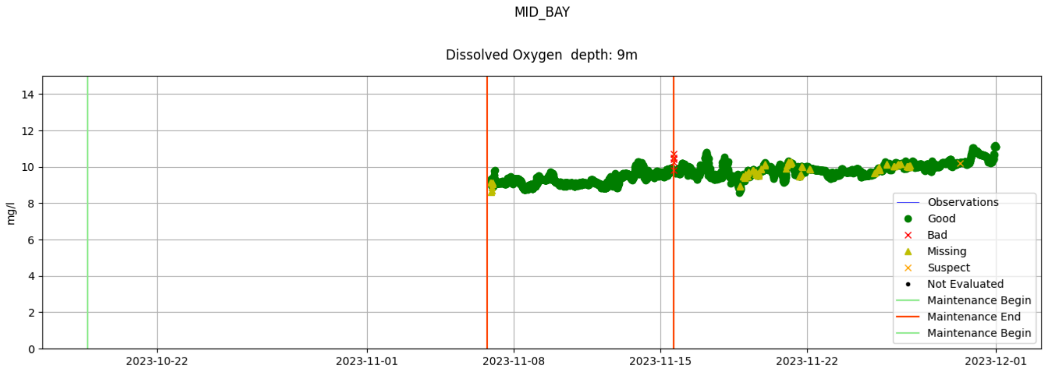

MID_BAY
Dissolved Oxygen Adj depth: 9m
mg/l
0
2
4
6
8
10
12
14
2023-12-01
2023-12-05
2023-12-09
2023-12-13
2023-12-17
2023-12-21
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Open Maintenance

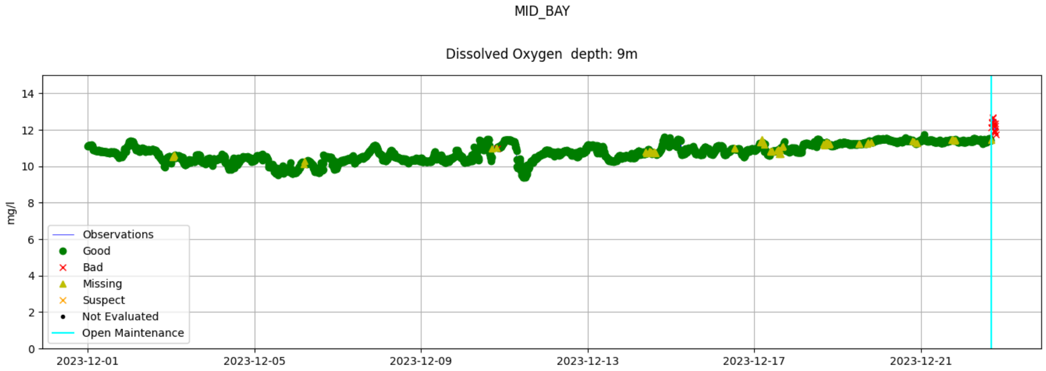
# Mid-Bay Dissolved Oxygen Depth=9m



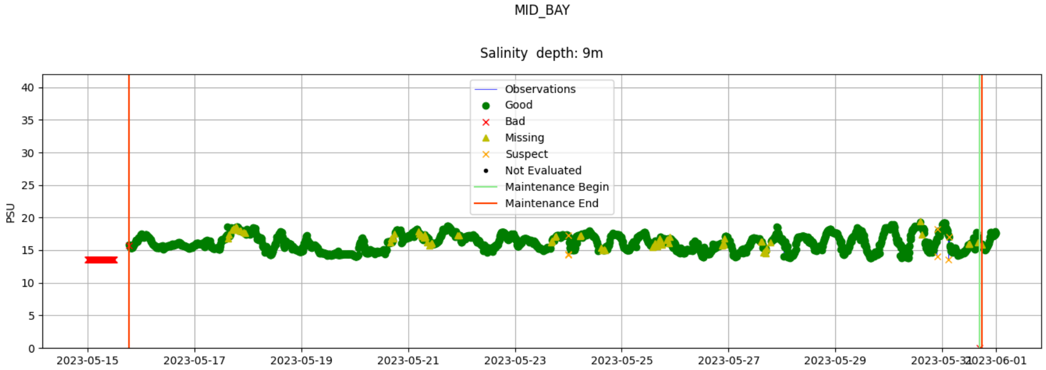


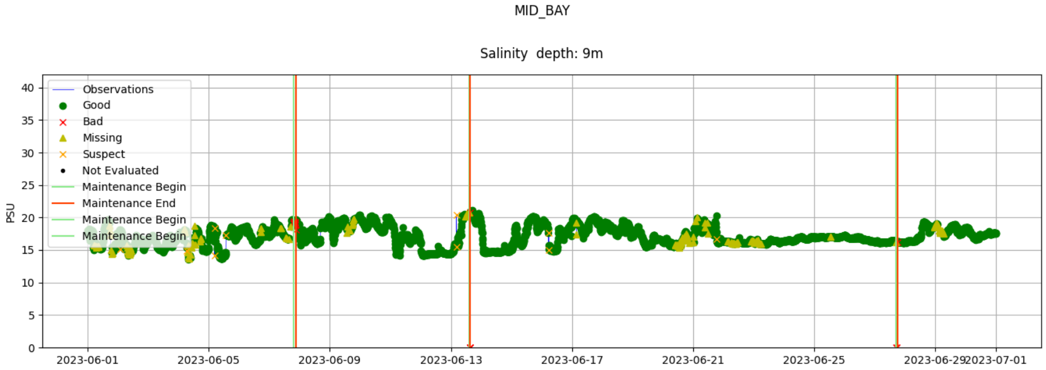


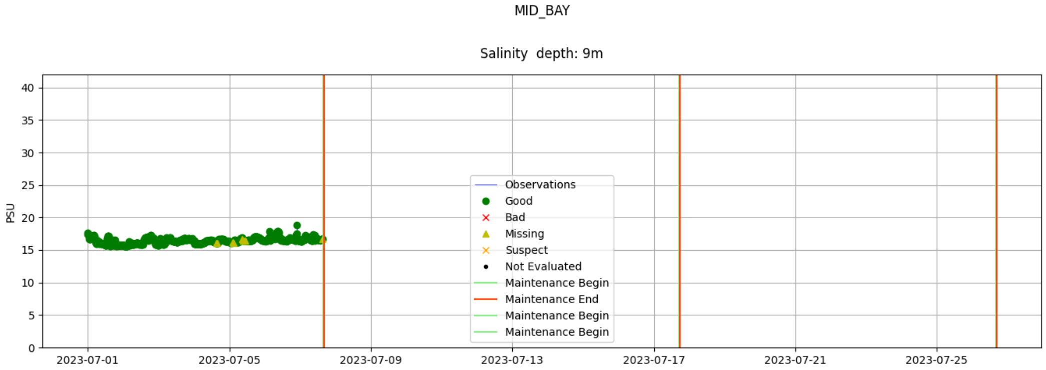

MID_BAY
Dissolved Oxygen  depth: 9m
mg/l
0
2
4
6
8
10
12
14
2023-10-22
2023-11-01
2023-11-08
2023-11-15
2023-11-22
2023-12-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin

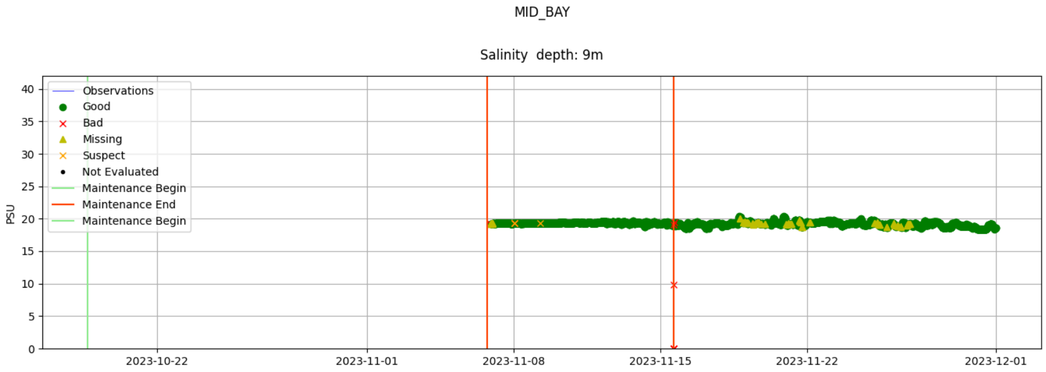

MID_BAY
Dissolved Oxygen  depth: 9m
mg/l
0
2
4
6
8
10
12
14
2023-12-01
2023-12-05
2023-12-09
2023-12-13
2023-12-17
2023-12-21
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Open Maintenance

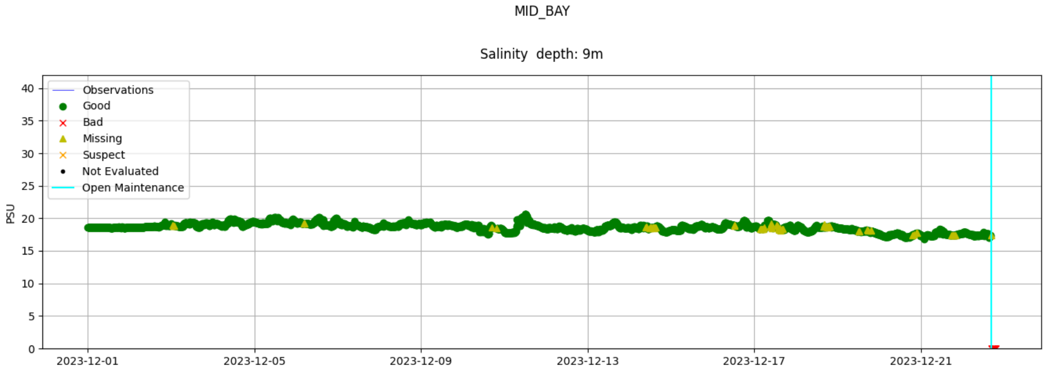
# Mid-Bay Dissolved Oxygen Depth=9m



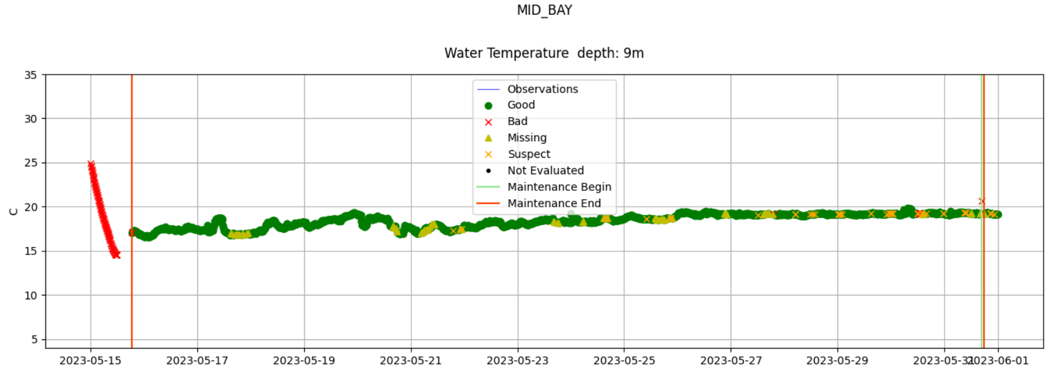


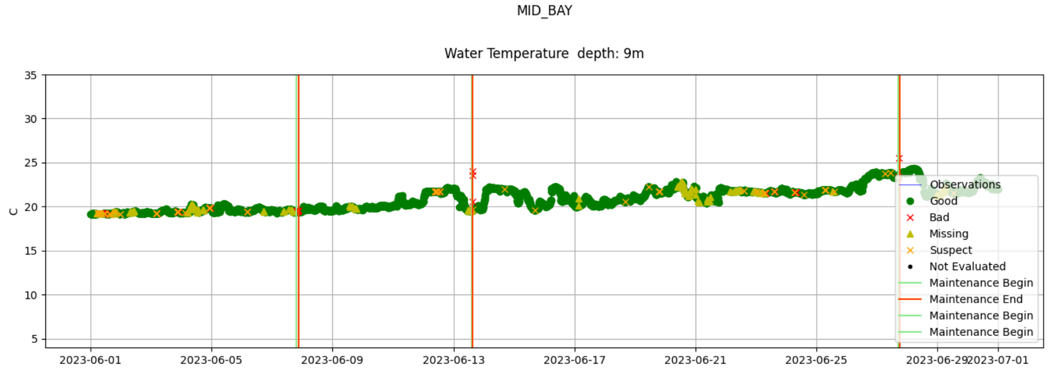


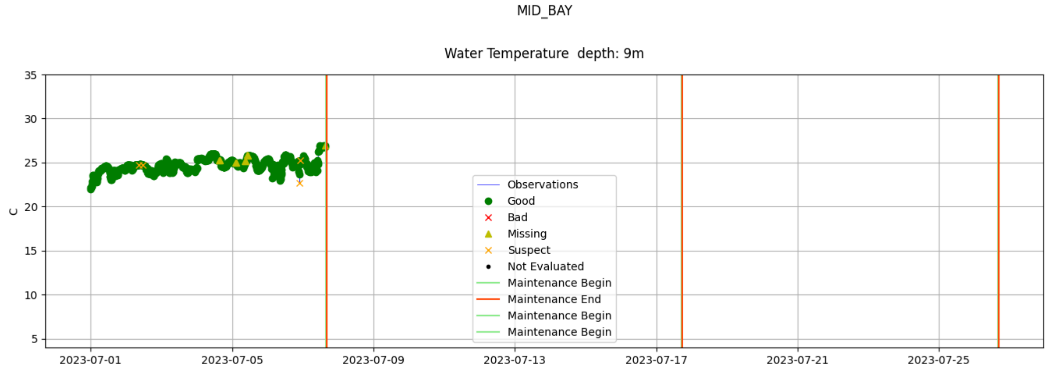

MID_BAY
Salinity depth: 9m
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin
PSU
40
35
30
25
20
15
10
5
0
2023-10-22
2023-11-01
2023-11-08
2023-11-15
2023-11-22
2023-12-01

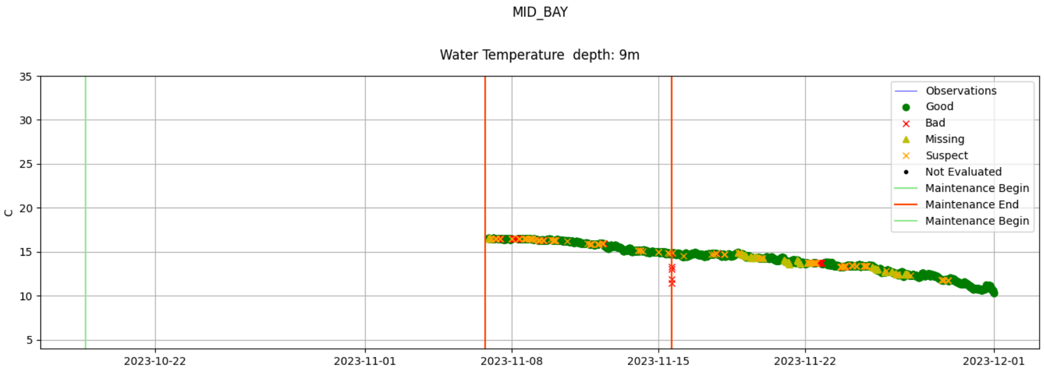

MID_BAY
Salinity depth: 9m
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Open Maintenance
PSU
40
35
30
25
20
15
10
5
0
2023-12-01
2023-12-05
2023-12-09
2023-12-13
2023-12-17
2023-12-21

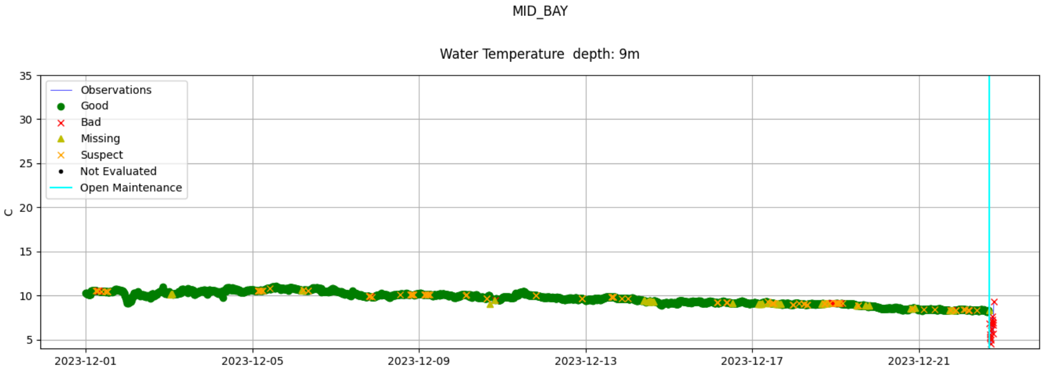
# Mid-Bay Water Temperature Depth=9m



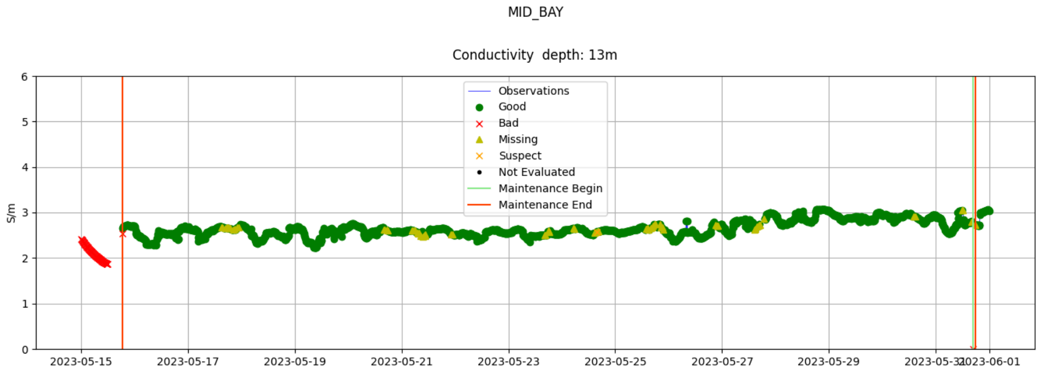


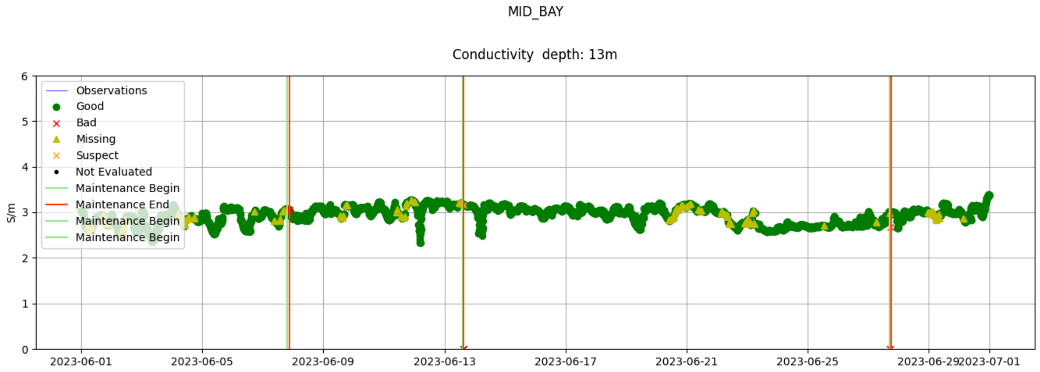


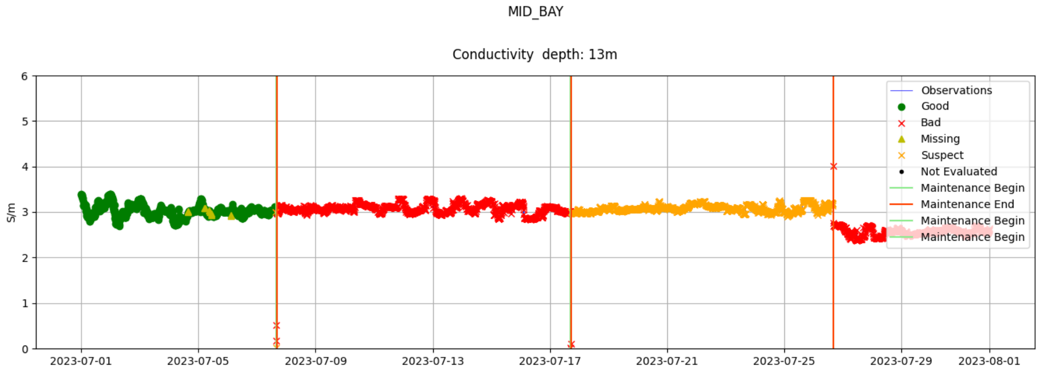

MID_BAY
Water Temperature depth: 9m
35
30
25
20
15
10
5
C
2023-10-22
2023-11-01
2023-11-08
2023-11-15
2023-11-22
2023-12-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin

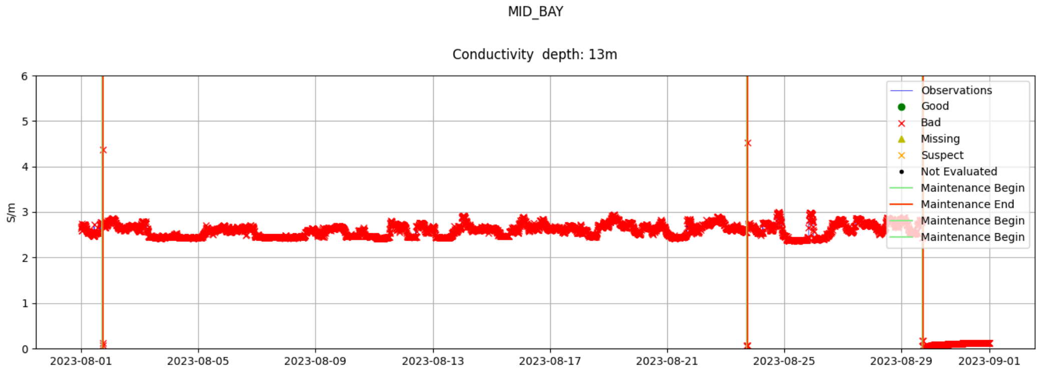

MID_BAY
Water Temperature depth: 9m
35
30
25
20
15
10
5
C
2023-12-01
2023-12-05
2023-12-09
2023-12-13
2023-12-17
2023-12-21
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Open Maintenance

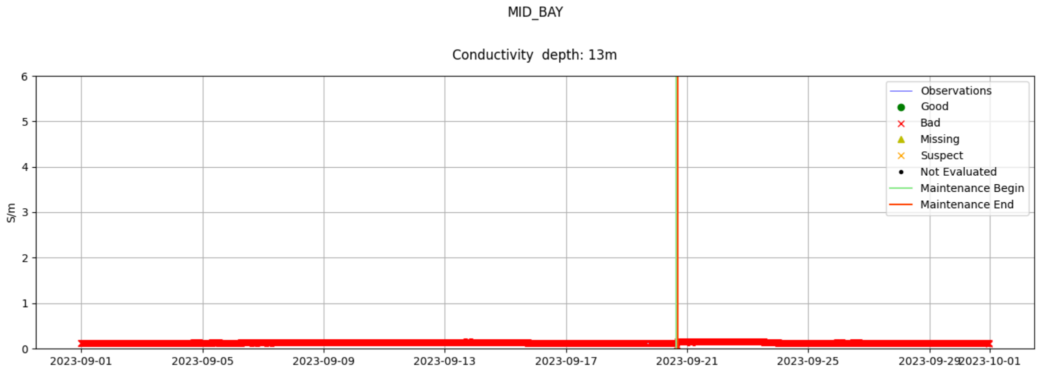
# Mid-Bay Conductivity Depth=13m

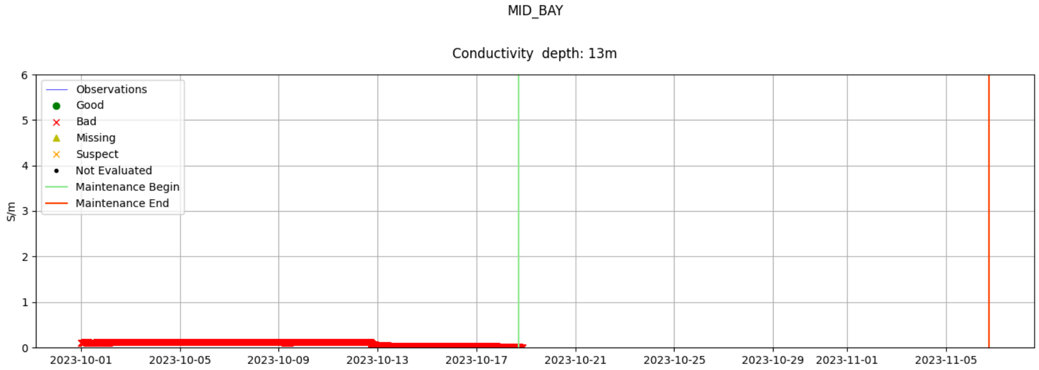


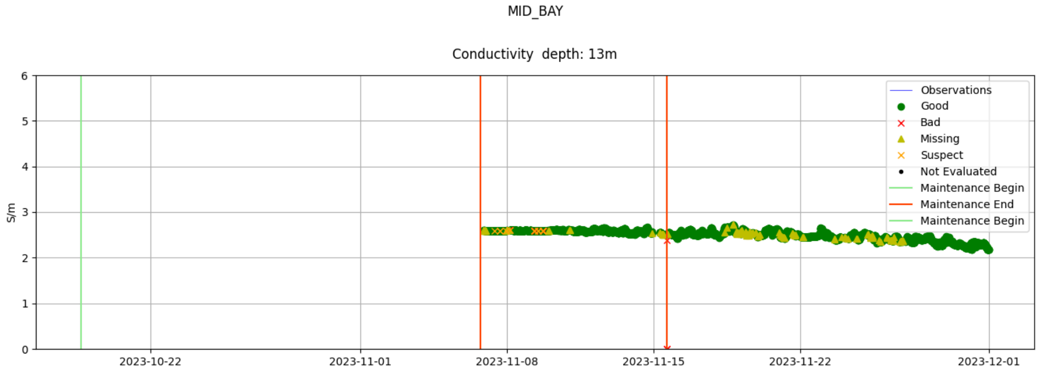


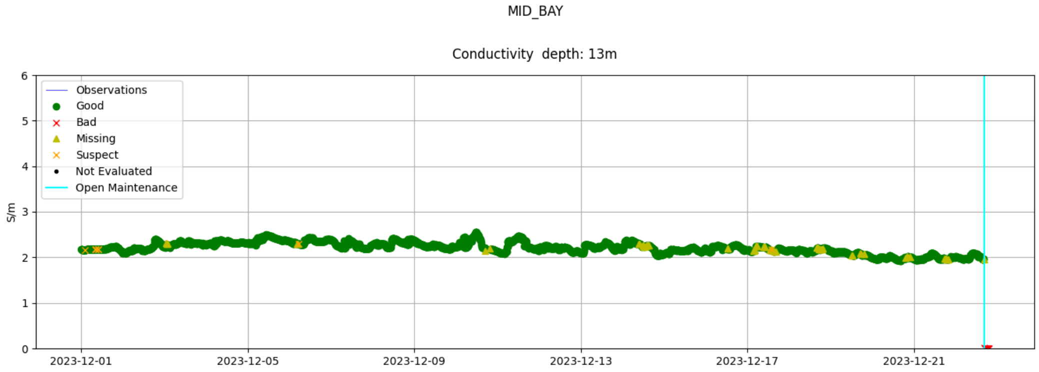




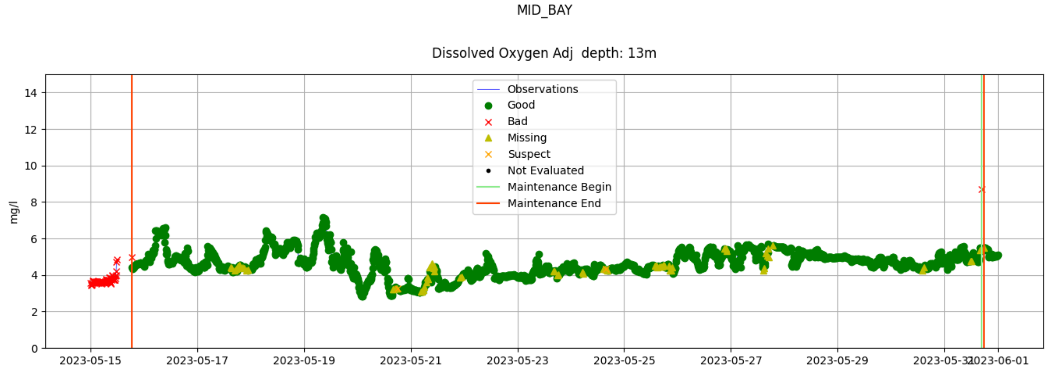

MID_BAY
Conductivity depth: 13m
S/m
0
1
2
3
4
5
6
2023-09-01
2023-09-05
2023-09-09
2023-09-13
2023-09-17
2023-09-21
2023-09-25
2023-09-29
2023-10-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

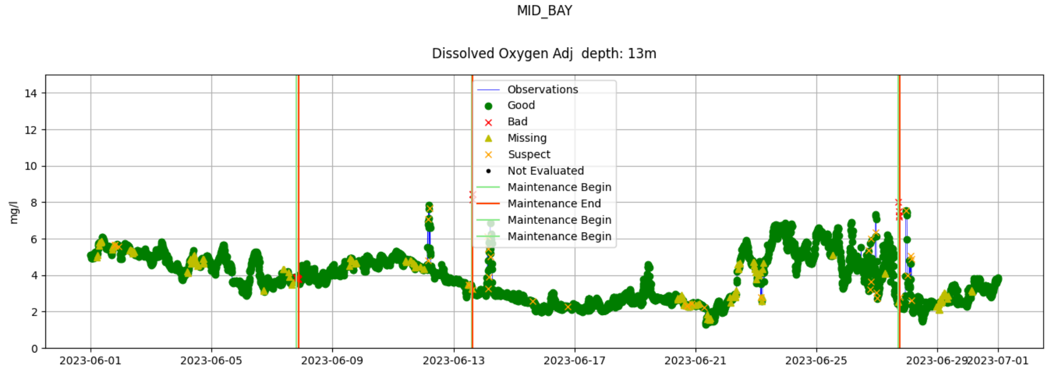

MID_BAY
Conductivity depth: 13m
S/m
0
1
2
3
4
5
6
2023-10-01
2023-10-05
2023-10-09
2023-10-13
2023-10-17
2023-10-21
2023-10-25
2023-10-29
2023-11-01
2023-11-05
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

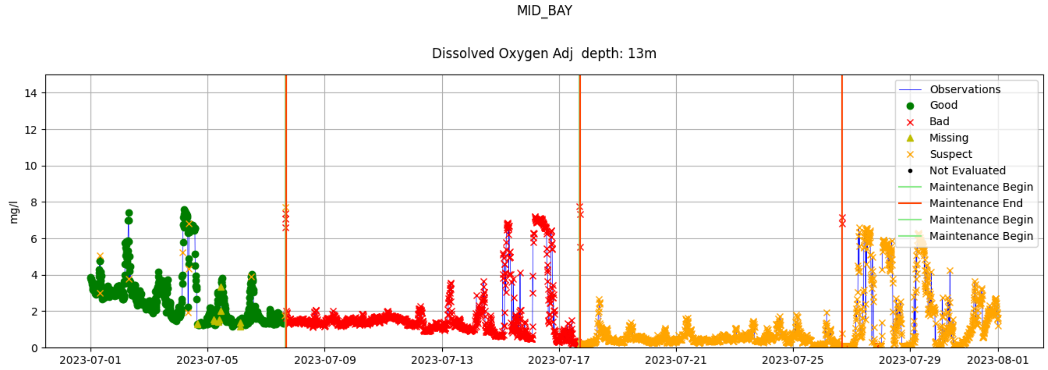

MID_BAY
Conductivity depth: 13m
S/m
0
1
2
3
4
5
6
2023-10-22
2023-11-01
2023-11-08
2023-11-15
2023-11-22
2023-12-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin

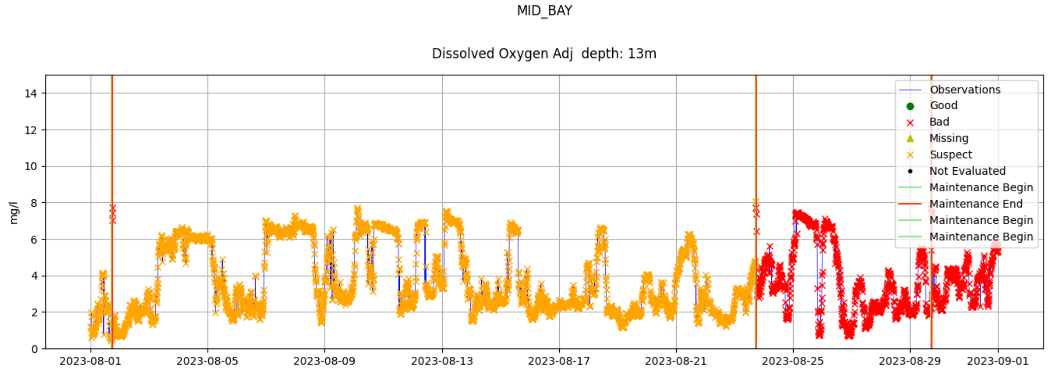

MID_BAY
Conductivity depth: 13m
S/m
0
1
2
3
4
5
6
2023-12-01
2023-12-05
2023-12-09
2023-12-13
2023-12-17
2023-12-21
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Open Maintenance

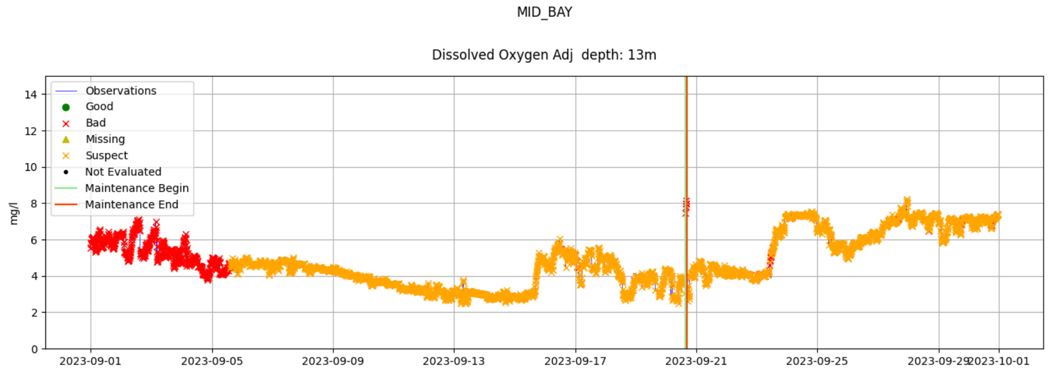
# Mid-Bay Adjusted Dissolved Oxygen Depth=13m

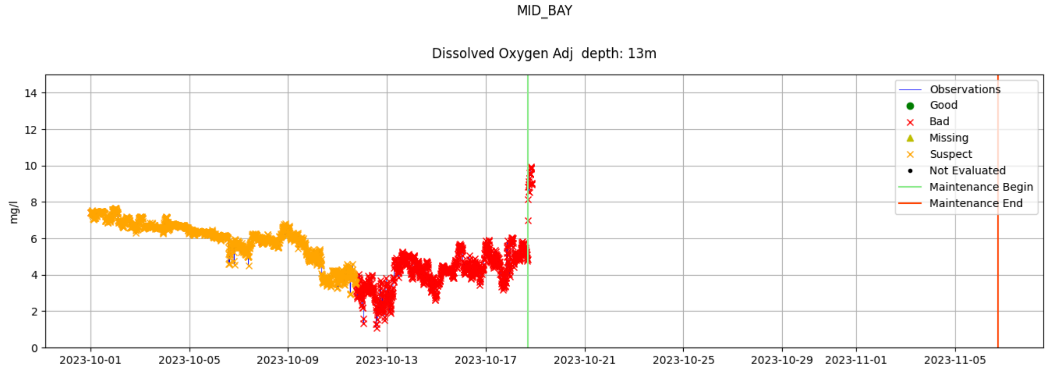


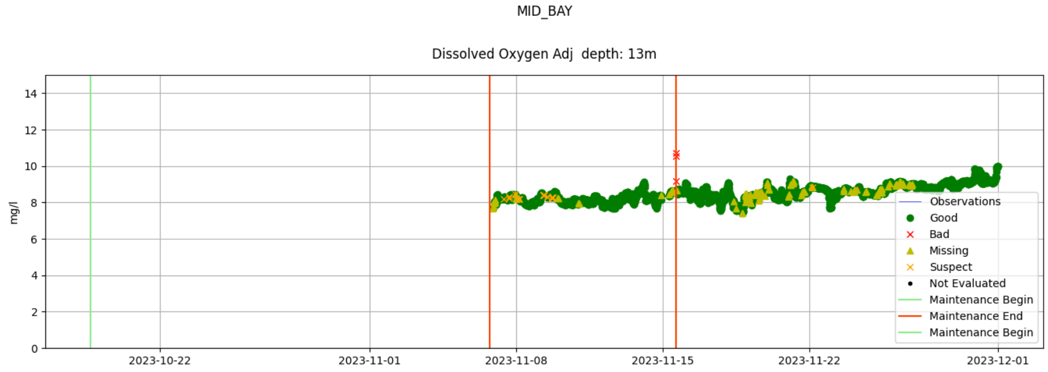


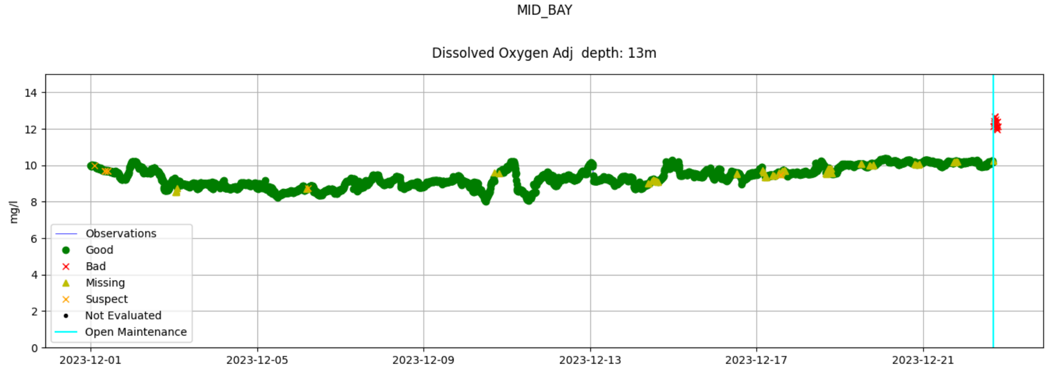




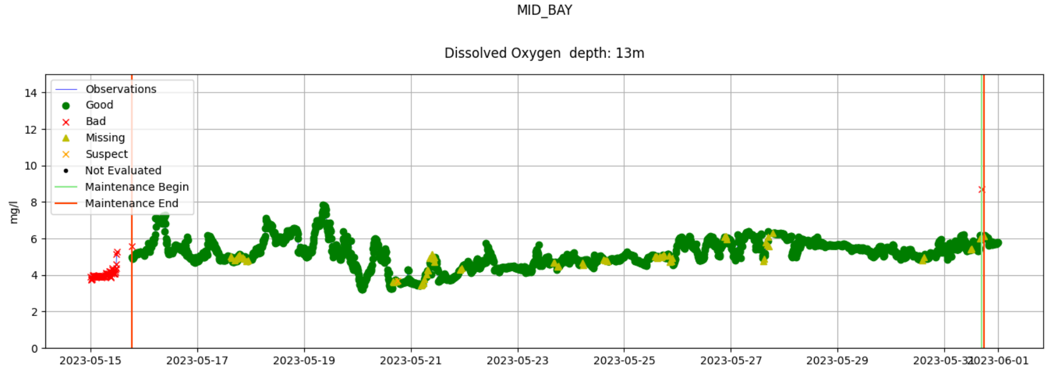

MID_BAY
Dissolved Oxygen Adj depth: 13m
mg/l
0
2
4
6
8
10
12
14
2023-09-01
2023-09-05
2023-09-09
2023-09-13
2023-09-17
2023-09-21
2023-09-25
2023-09-29
2023-10-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

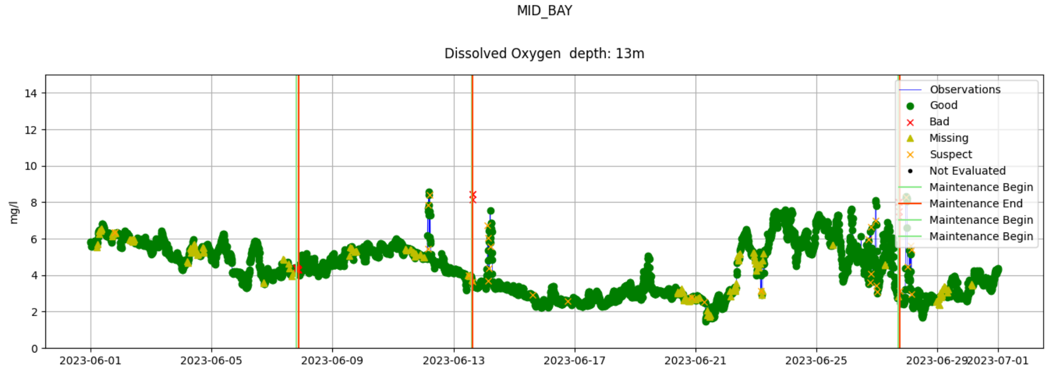

MID_BAY
Dissolved Oxygen Adj depth: 13m
mg/l
0
2
4
6
8
10
12
14
2023-10-01
2023-10-05
2023-10-09
2023-10-13
2023-10-17
2023-10-21
2023-10-25
2023-10-29
2023-11-01
2023-11-05
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

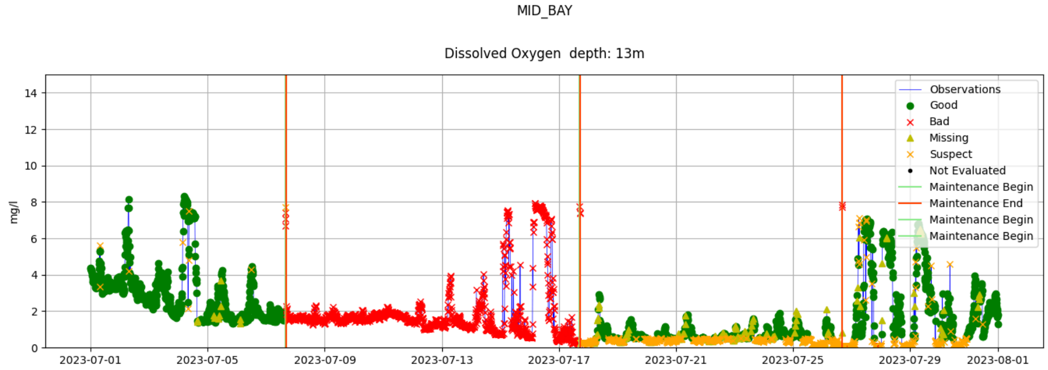

MID_BAY
Dissolved Oxygen Adj depth: 13m
mg/l
0
2
4
6
8
10
12
14
2023-10-22
2023-11-01
2023-11-08
2023-11-15
2023-11-22
2023-12-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin

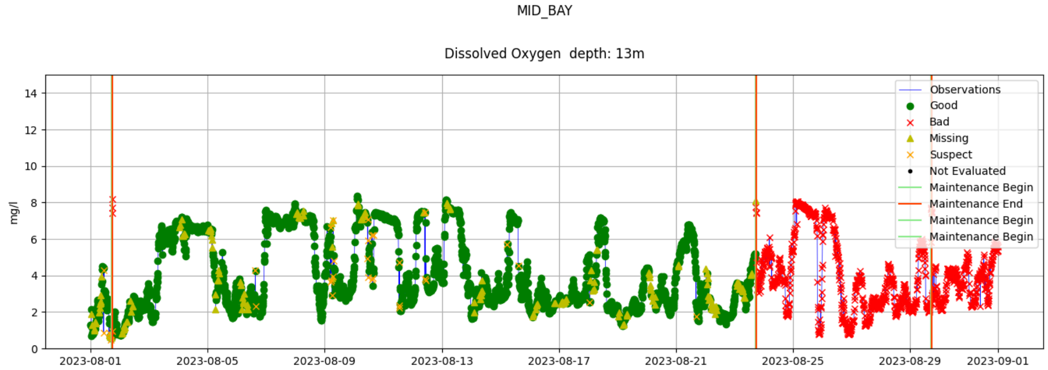

MID_BAY
Dissolved Oxygen Adj depth: 13m
mg/l
0
2
4
6
8
10
12
14
2023-12-01
2023-12-05
2023-12-09
2023-12-13
2023-12-17
2023-12-21
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Open Maintenance

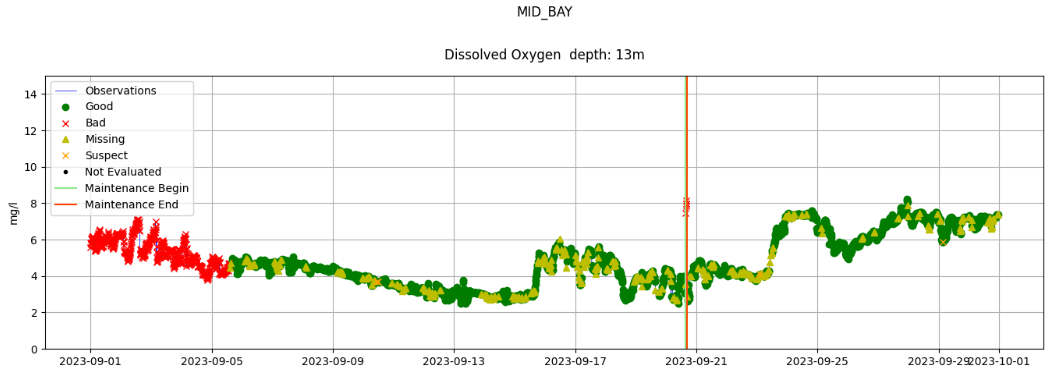
# Mid-Bay Dissolved Oxygen Depth=13m

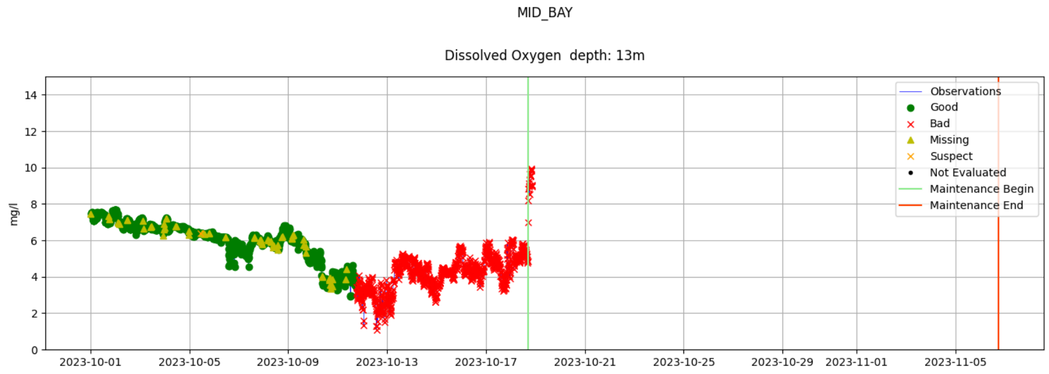


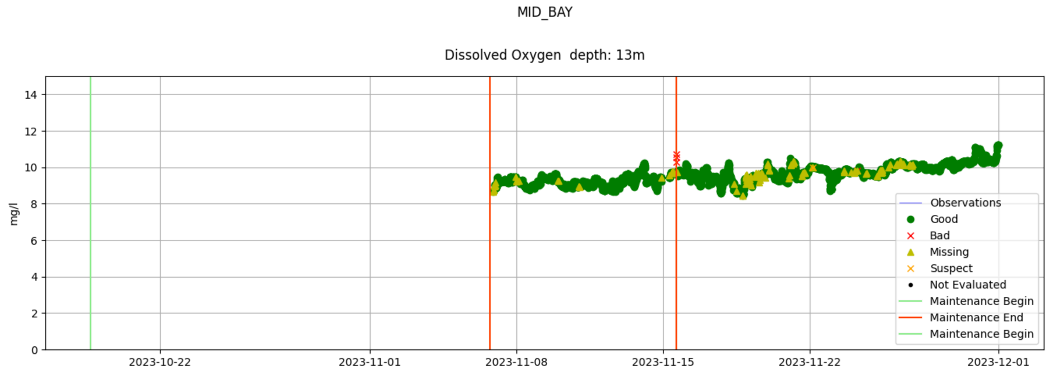


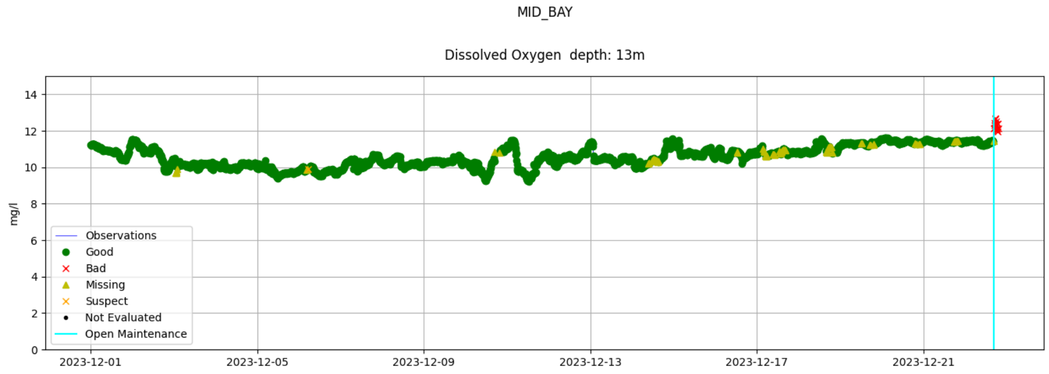




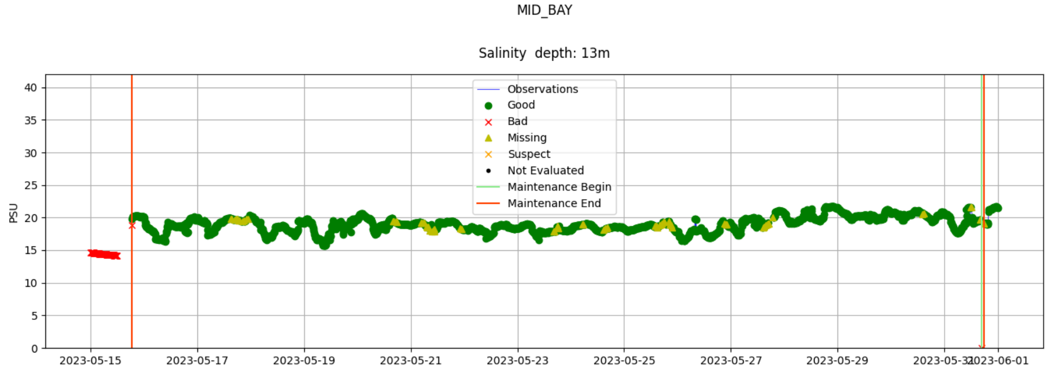

MID_BAY
Dissolved Oxygen  depth: 13m
mg/l
0
2
4
6
8
10
12
14
2023-09-01
2023-09-05
2023-09-09
2023-09-13
2023-09-17
2023-09-21
2023-09-25
2023-09-29
2023-10-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

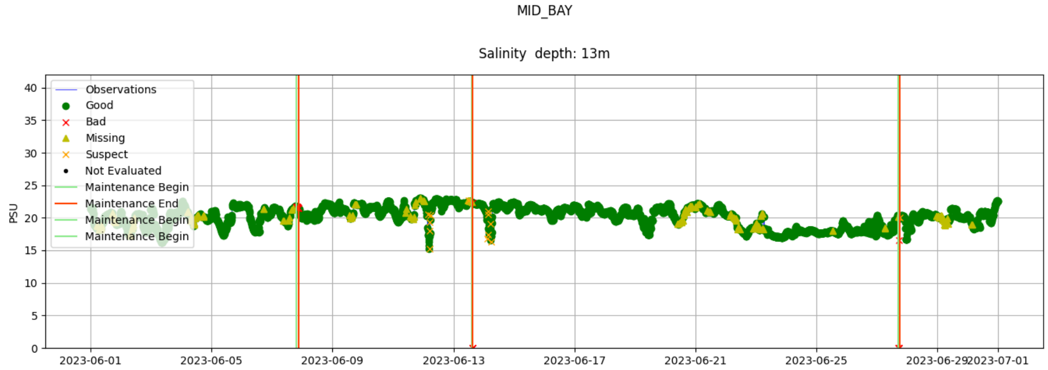

MID_BAY
Dissolved Oxygen  depth: 13m
mg/l
0
2
4
6
8
10
12
14
2023-10-01
2023-10-05
2023-10-09
2023-10-13
2023-10-17
2023-10-21
2023-10-25
2023-10-29
2023-11-01
2023-11-05
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

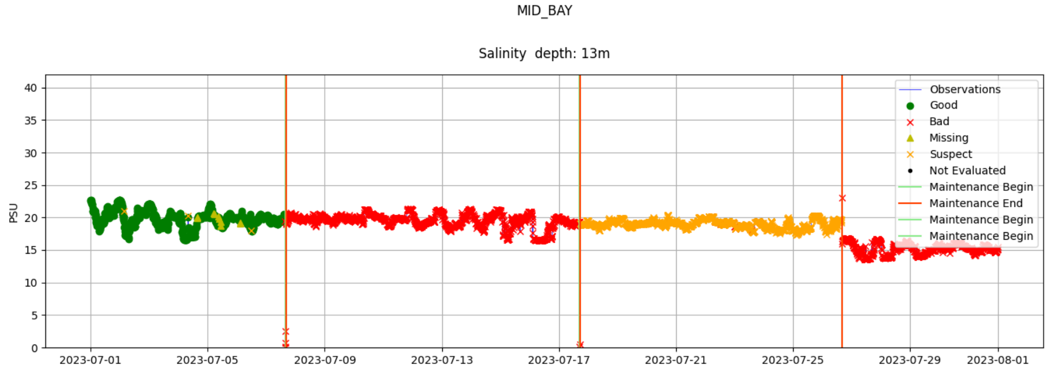

MID_BAY
Dissolved Oxygen  depth: 13m
mg/l
0
2
4
6
8
10
12
14
2023-10-22
2023-11-01
2023-11-08
2023-11-15
2023-11-22
2023-12-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin

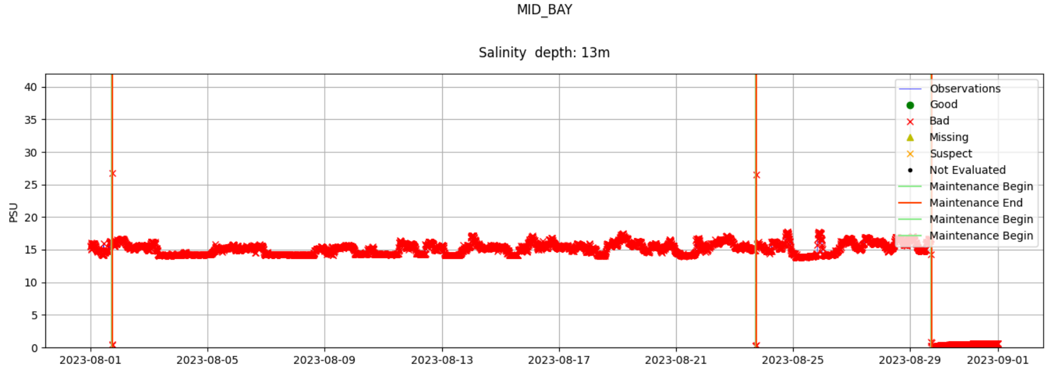

MID_BAY
Dissolved Oxygen  depth: 13m
mg/l
0
2
4
6
8
10
12
14
2023-12-01
2023-12-05
2023-12-09
2023-12-13
2023-12-17
2023-12-21
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Open Maintenance

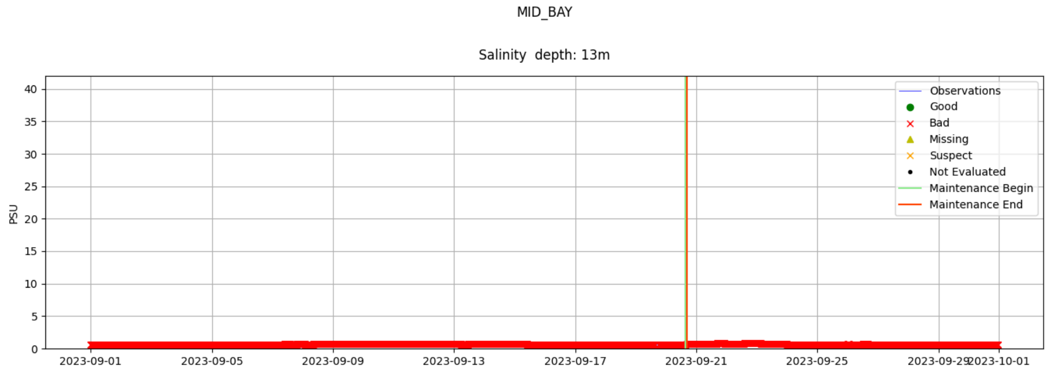
# Mid-Bay Salinity Depth=13m

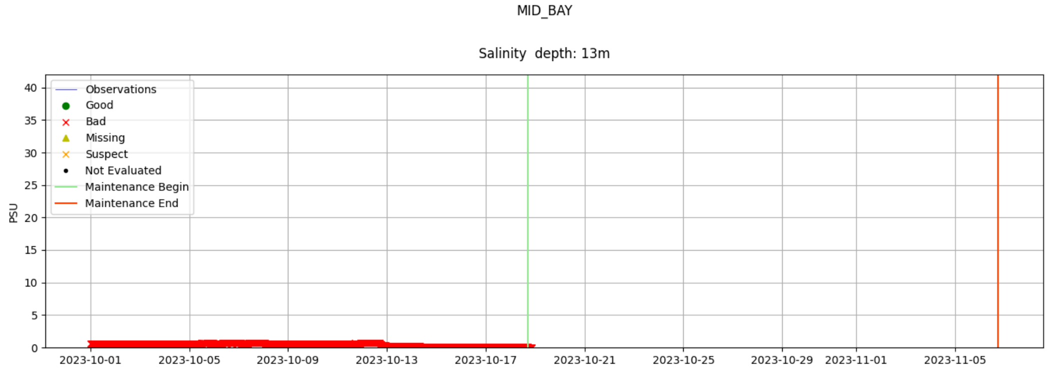


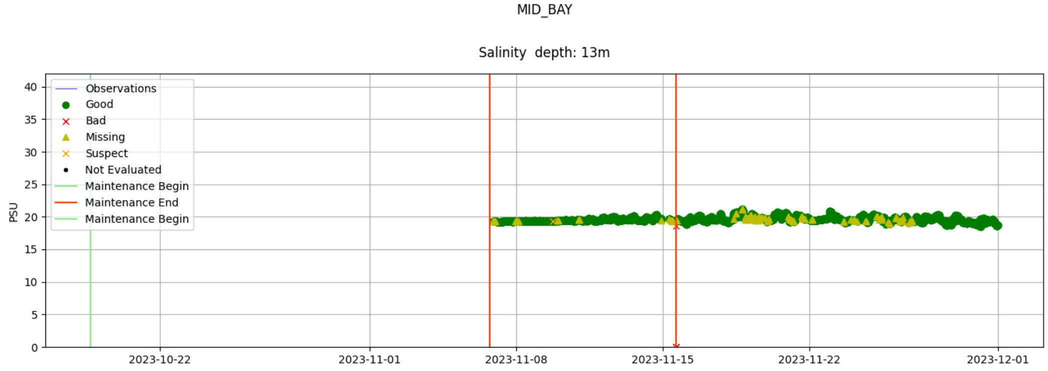


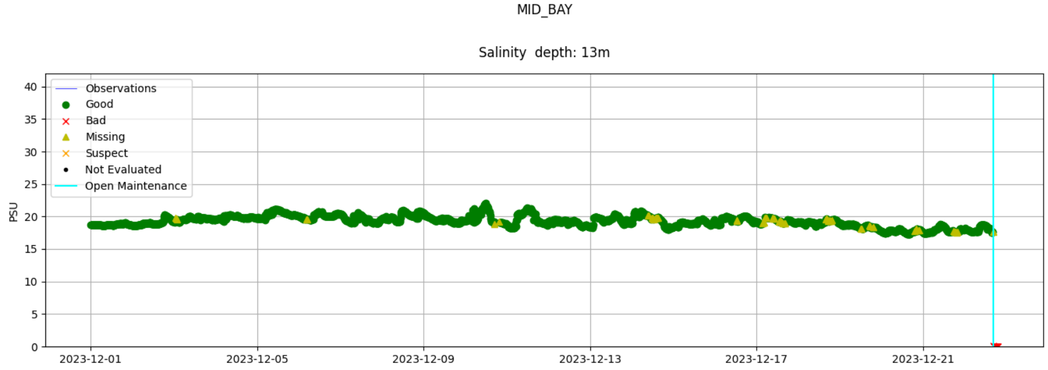




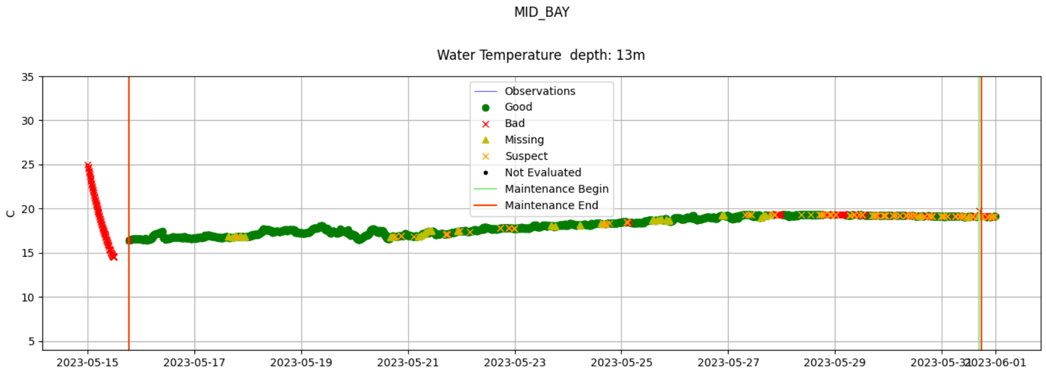

MID_BAY
Salinity depth: 13m
PSU
0
5
10
15
20
25
30
35
40
2023-09-01
2023-09-05
2023-09-09
2023-09-13
2023-09-17
2023-09-21
2023-09-25
2023-09-29
2023-10-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

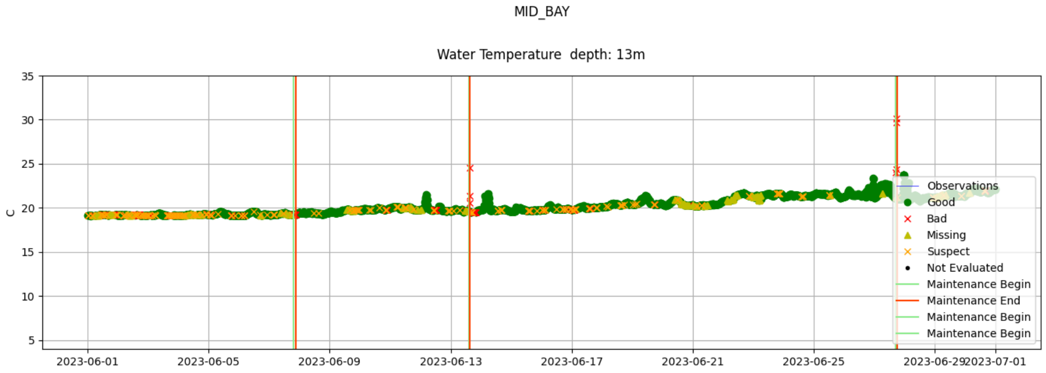

MID_BAY
Salinity depth: 13m
PSU
0
5
10
15
20
25
30
35
40
2023-10-01
2023-10-05
2023-10-09
2023-10-13
2023-10-17
2023-10-21
2023-10-25
2023-10-29
2023-11-01
2023-11-05
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

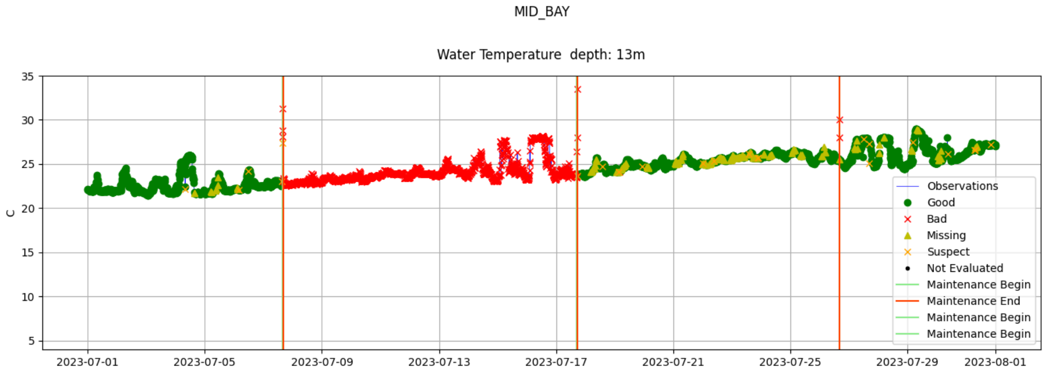

MID_BAY
Salinity depth: 13m
PSU
0
5
10
15
20
25
30
35
40
2023-10-22
2023-11-01
2023-11-08
2023-11-15
2023-11-22
2023-12-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin

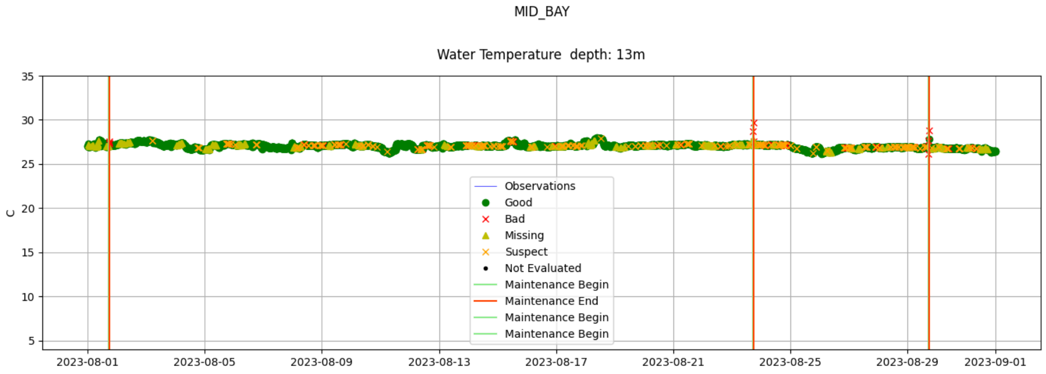

MID_BAY
Salinity depth: 13m
PSU
0
5
10
15
20
25
30
35
40
2023-12-01
2023-12-05
2023-12-09
2023-12-13
2023-12-17
2023-12-21
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Open Maintenance

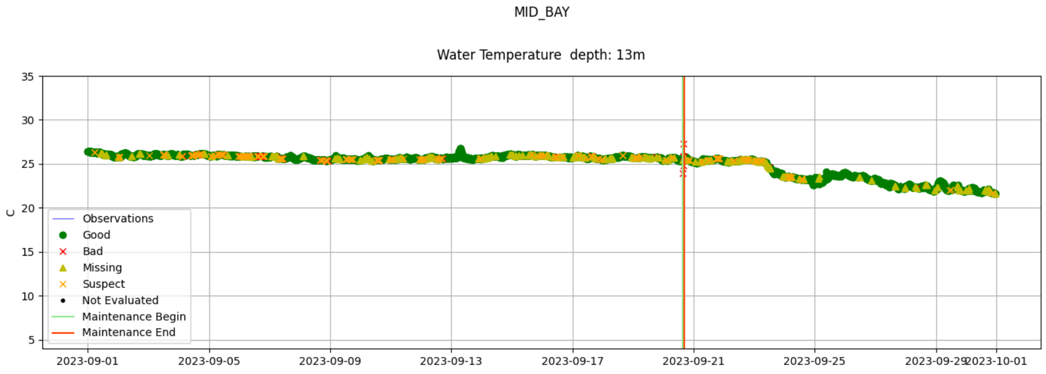
# Mid-Bay Water Temperature Depth=13m

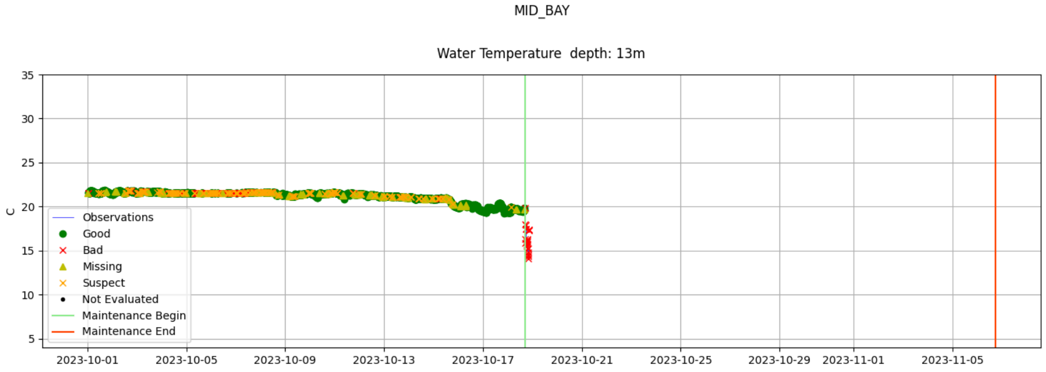


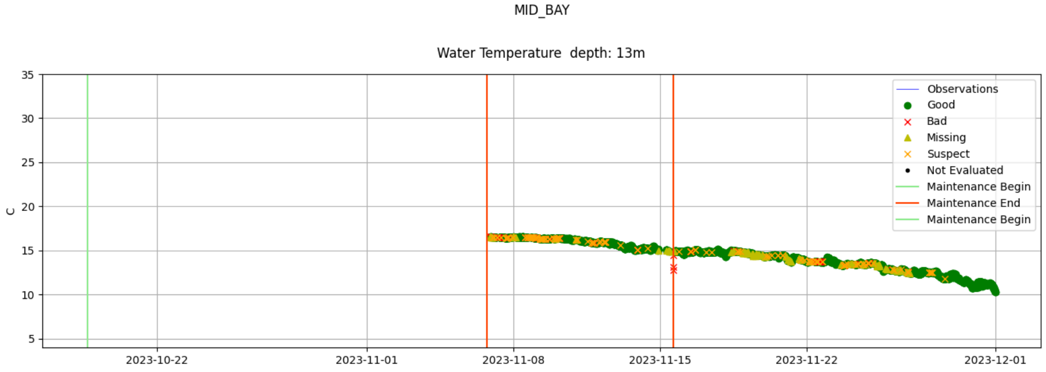


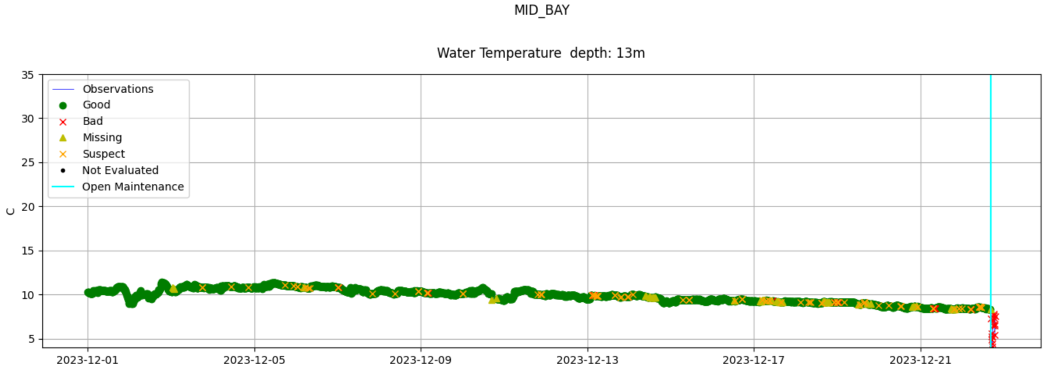




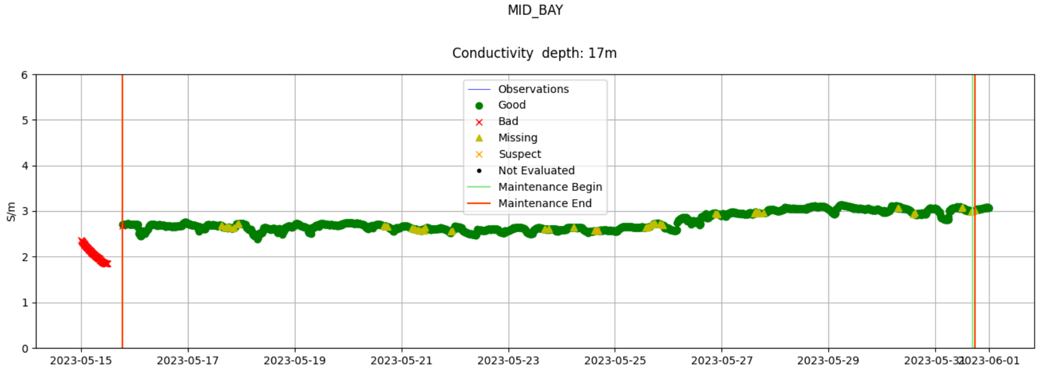

MID_BAY
Water Temperature depth: 13m
C
35
30
25
20
15
10
5
2023-09-01
2023-09-05
2023-09-09
2023-09-13
2023-09-17
2023-09-21
2023-09-25
2023-09-29
2023-10-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

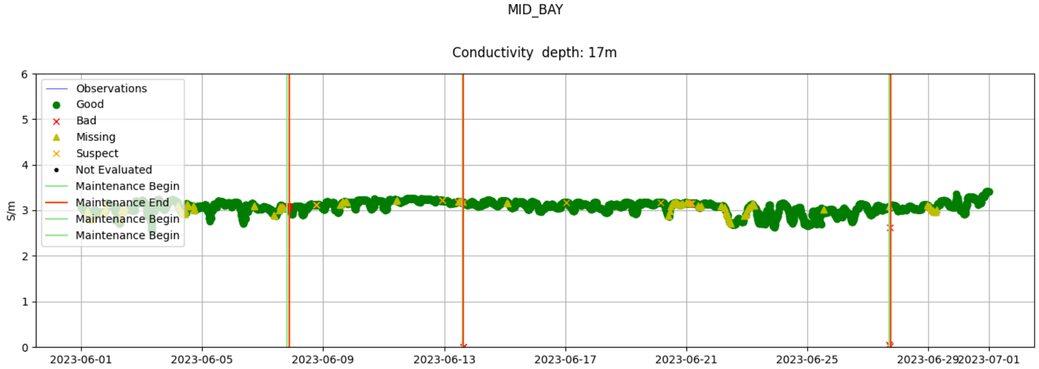

MID_BAY
Water Temperature depth: 13m
C
35
30
25
20
15
10
5
2023-10-01
2023-10-05
2023-10-09
2023-10-13
2023-10-17
2023-10-21
2023-10-25
2023-10-29
2023-11-01
2023-11-05
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

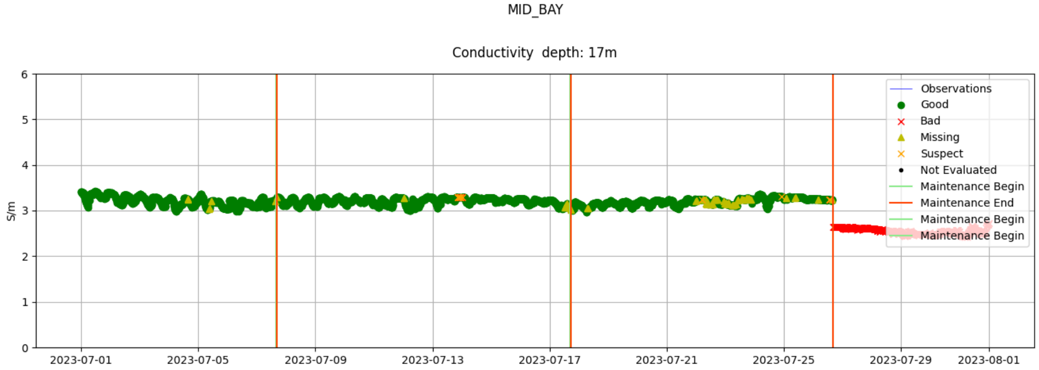

MID_BAY
Water Temperature depth: 13m
C
35
30
25
20
15
10
5
2023-10-22
2023-11-01
2023-11-08
2023-11-15
2023-11-22
2023-12-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin

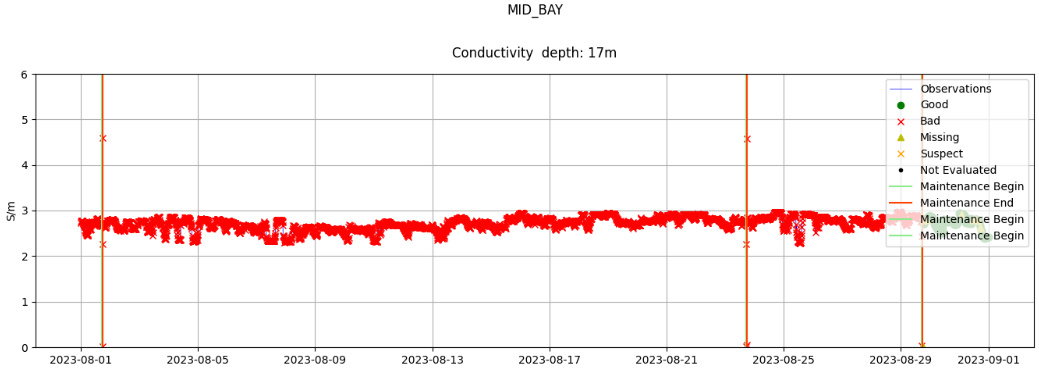

MID_BAY
Water Temperature depth: 13m
C
35
30
25
20
15
10
5
2023-12-01
2023-12-05
2023-12-09
2023-12-13
2023-12-17
2023-12-21
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Open Maintenance

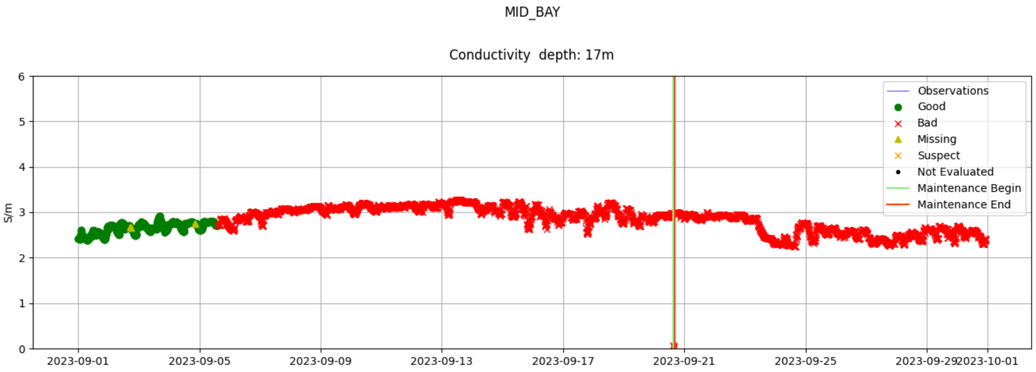
# Mid-Bay Conductivity Depth=17m

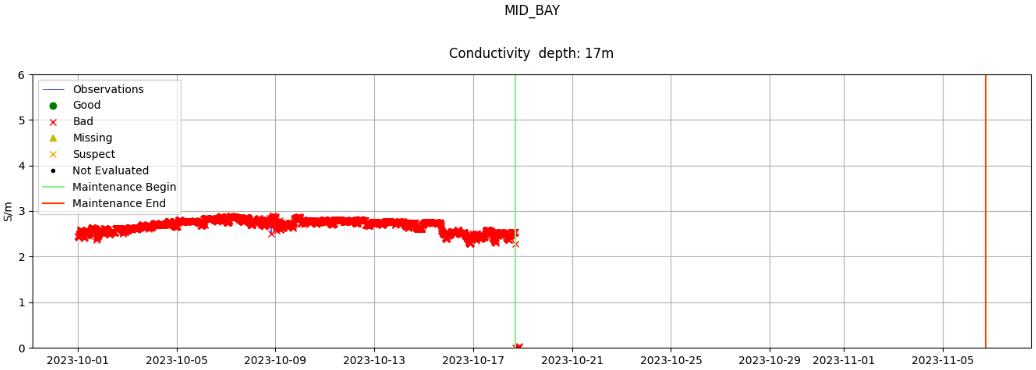


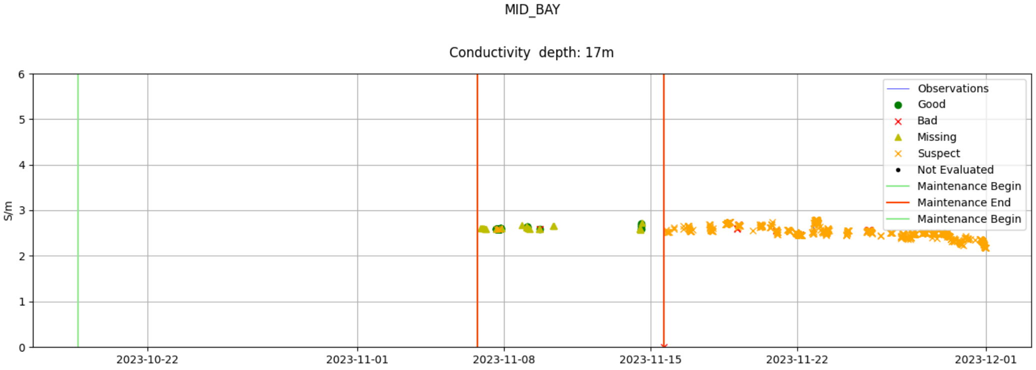


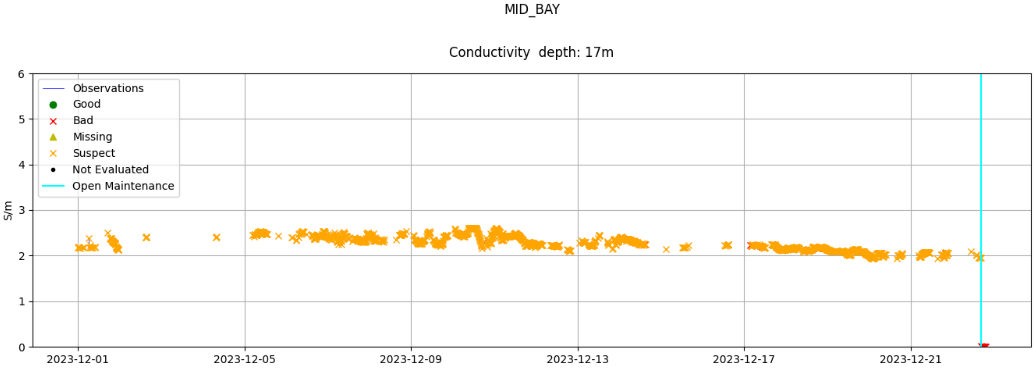




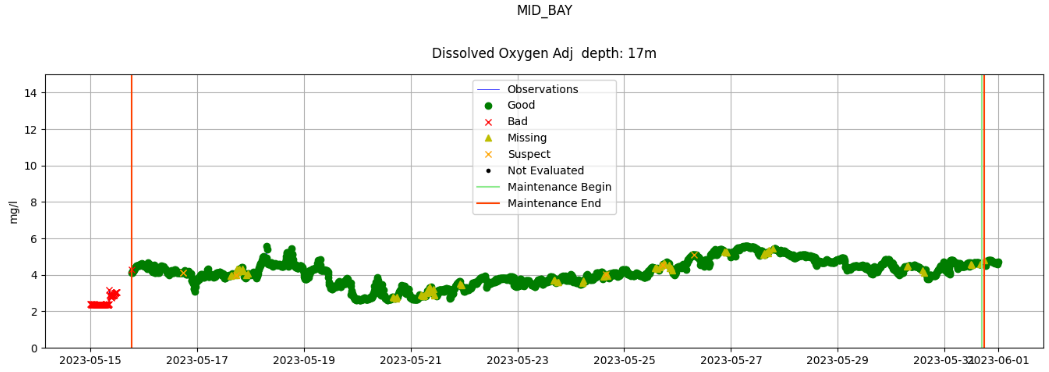

MID_BAY
Conductivity depth: 17m
S/m
0
1
2
3
4
5
6
2023-09-01
2023-09-05
2023-09-09
2023-09-13
2023-09-17
2023-09-21
2023-09-25
2023-09-29
2023-10-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End


MID_BAY
Conductivity depth: 17m
S/m
0
1
2
3
4
5
6
2023-10-01
2023-10-05
2023-10-09
2023-10-13
2023-10-17
2023-10-21
2023-10-25
2023-10-29
2023-11-01
2023-11-05
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

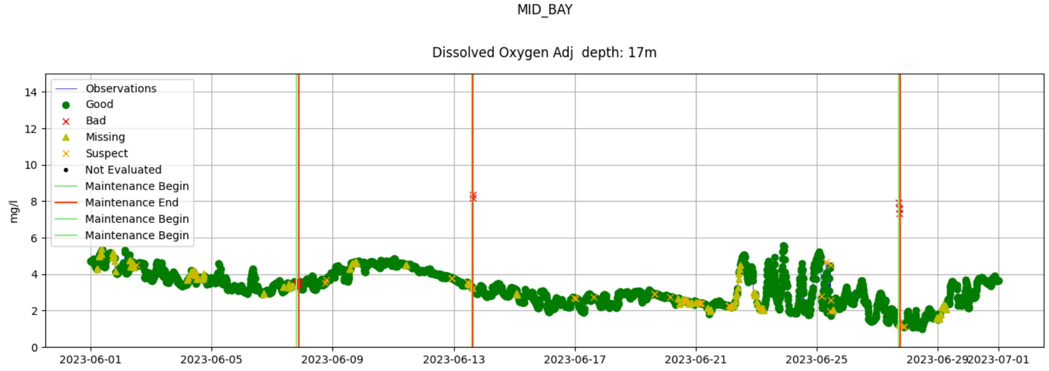

MID_BAY
Conductivity depth: 17m
S/m
0
1
2
3
4
5
6
2023-10-22
2023-11-01
2023-11-08
2023-11-15
2023-11-22
2023-12-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin


MID_BAY
Conductivity depth: 17m
S/m
0
1
2
3
4
5
6
2023-12-01
2023-12-05
2023-12-09
2023-12-13
2023-12-17
2023-12-21
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Open Maintenance

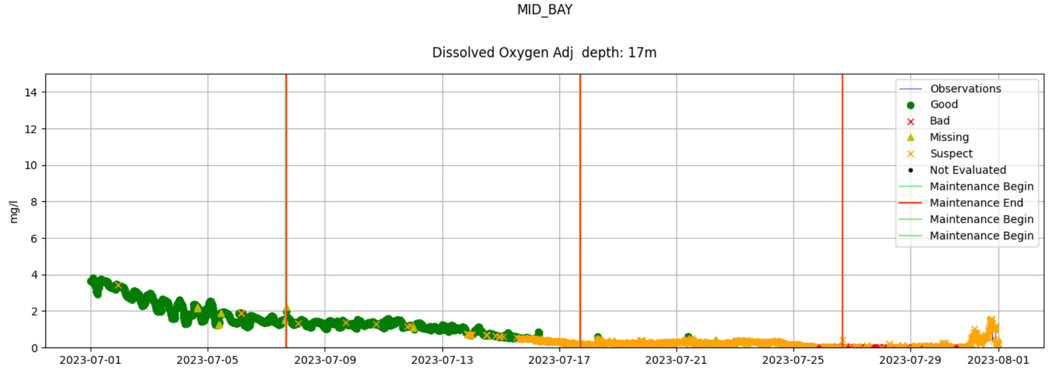
# Mid-Bay Adjusted Dissolved Oxygen Depth=17m


MID_BAY

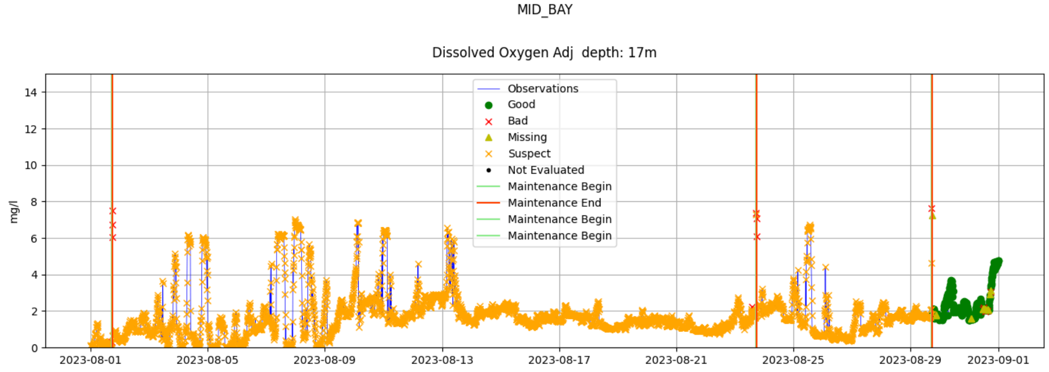
Dissolved Oxygen Adj  depth: 17m


MID_BAY

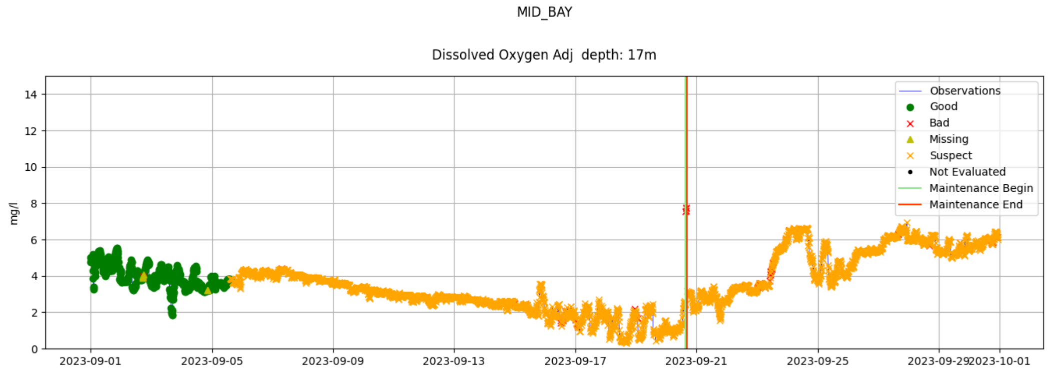
Dissolved Oxygen Adj  depth: 17m

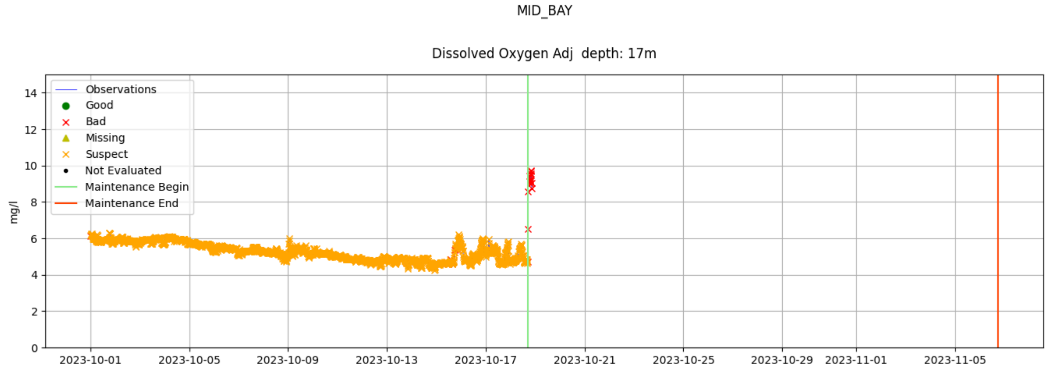

MID_BAY

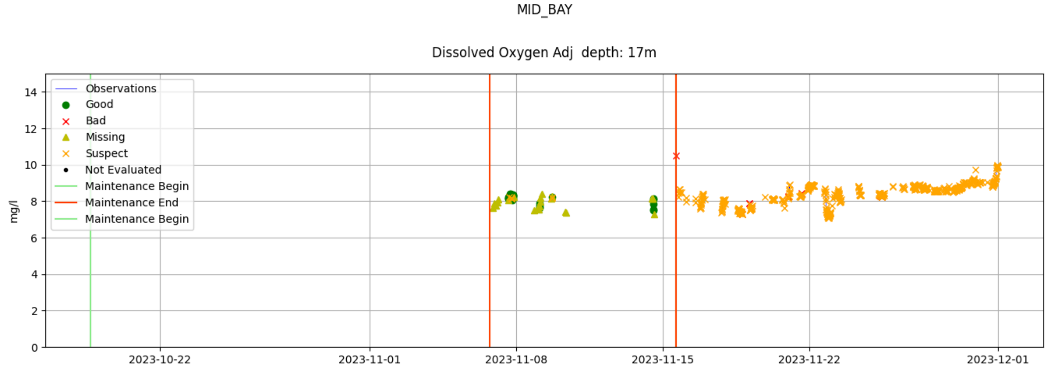
Dissolved Oxygen Adj  depth: 17m

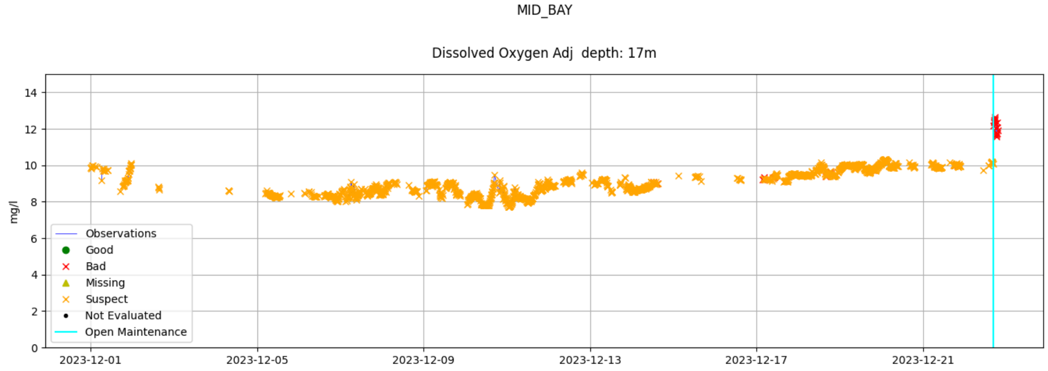

MID_BAY

Dissolved Oxygen Adj  depth: 17m

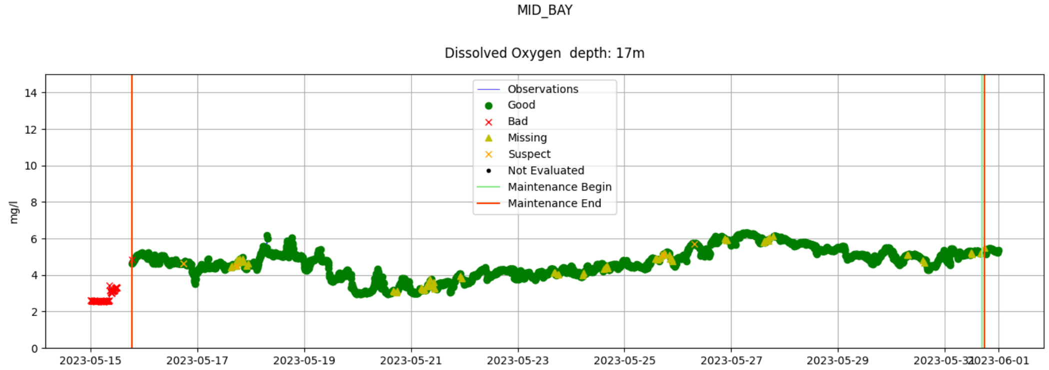

MID_BAY
Dissolved Oxygen Adj depth: 17m
mg/l
0
2
4
6
8
10
12
14
2023-09-01
2023-09-05
2023-09-09
2023-09-13
2023-09-17
2023-09-21
2023-09-25
2023-09-29
2023-10-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

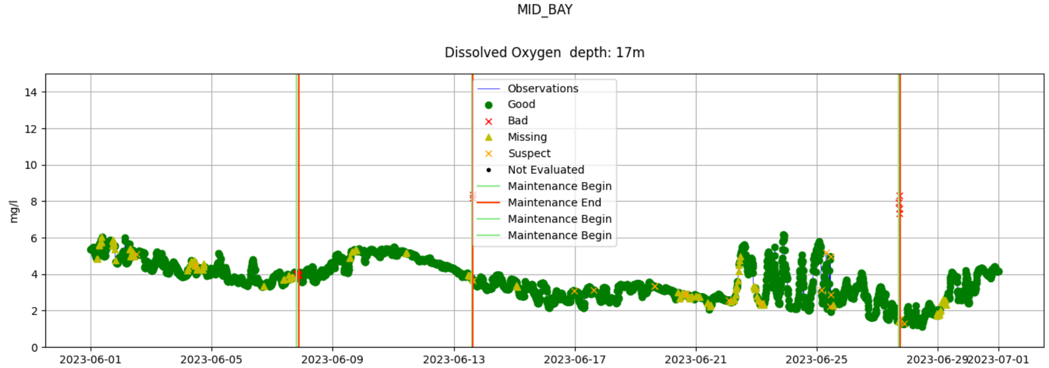

MID_BAY
Dissolved Oxygen Adj depth: 17m
mg/l
0
2
4
6
8
10
12
14
2023-10-01
2023-10-05
2023-10-09
2023-10-13
2023-10-17
2023-10-21
2023-10-25
2023-10-29
2023-11-01
2023-11-05
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

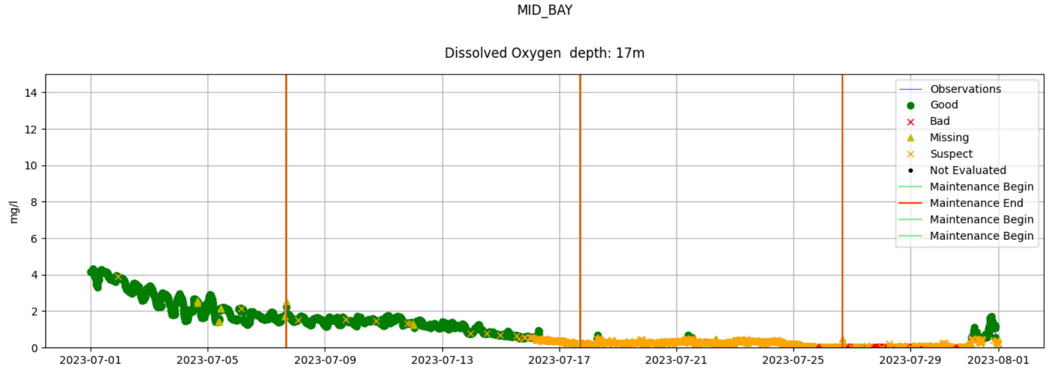

MID_BAY
Dissolved Oxygen Adj depth: 17m
mg/l
0
2
4
6
8
10
12
14
2023-10-22
2023-11-01
2023-11-08
2023-11-15
2023-11-22
2023-12-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin

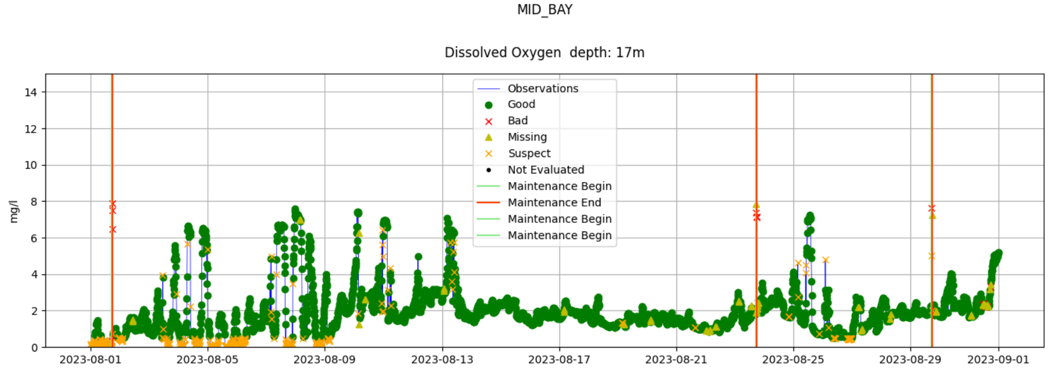

MID_BAY
Dissolved Oxygen Adj depth: 17m
mg/l
0
2
4
6
8
10
12
14
2023-12-01
2023-12-05
2023-12-09
2023-12-13
2023-12-17
2023-12-21
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Open Maintenance

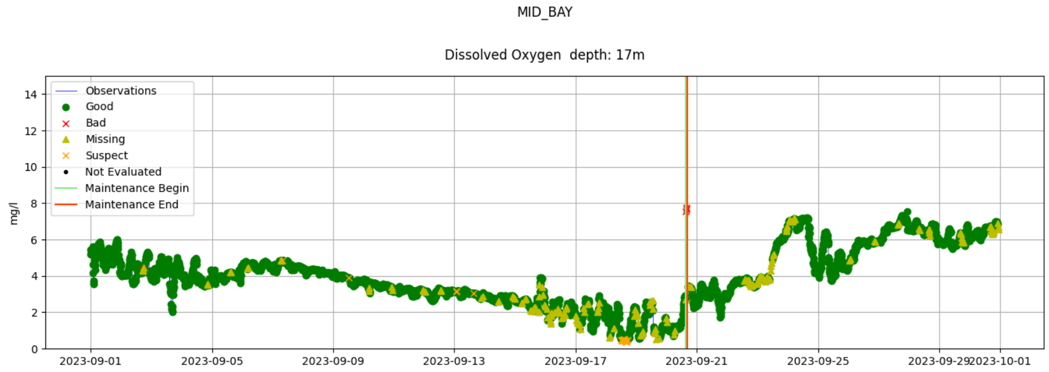
# Mid-Bay Dissolved Oxygen Depth=17m

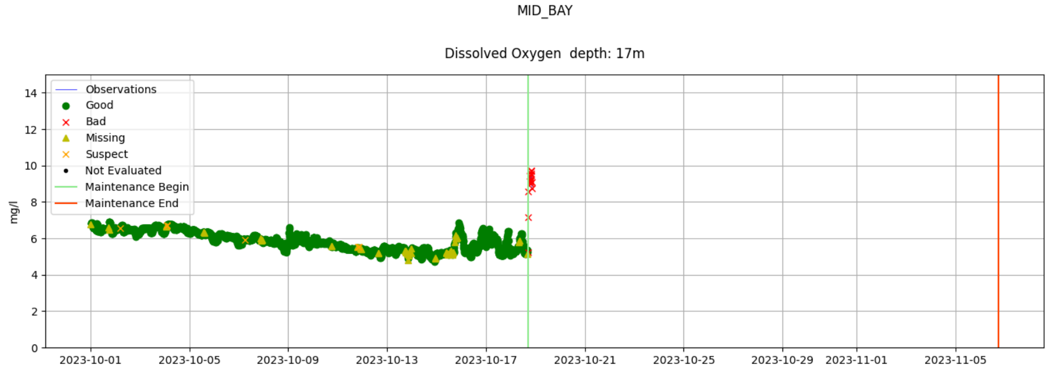


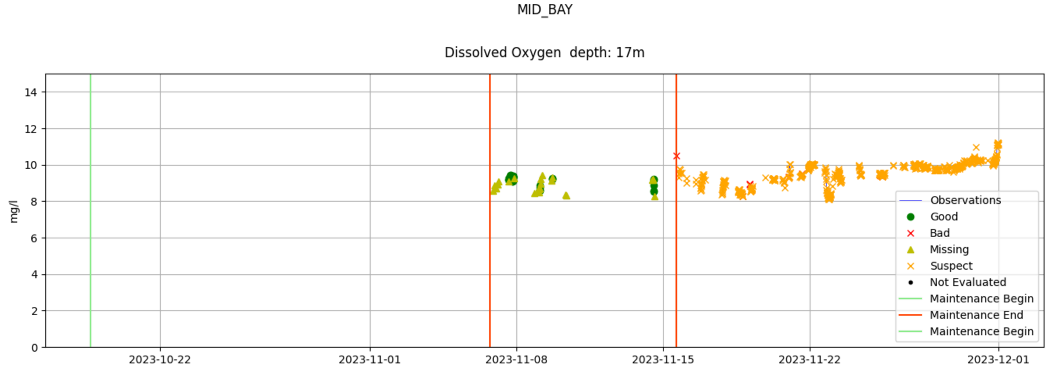


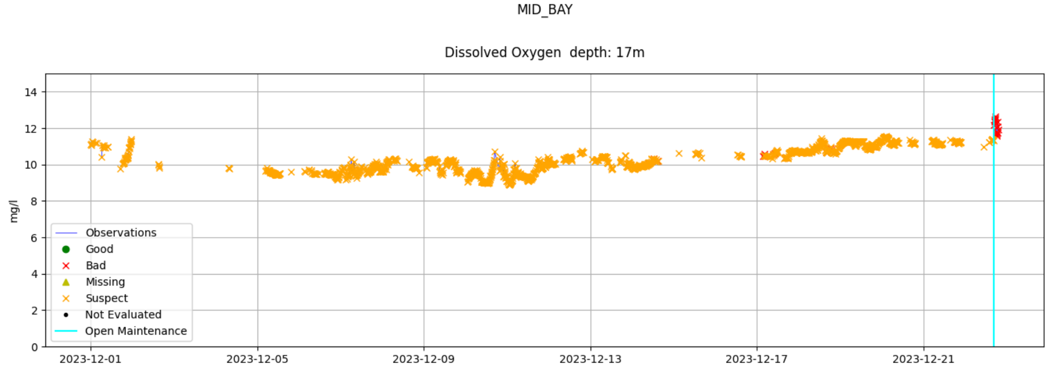




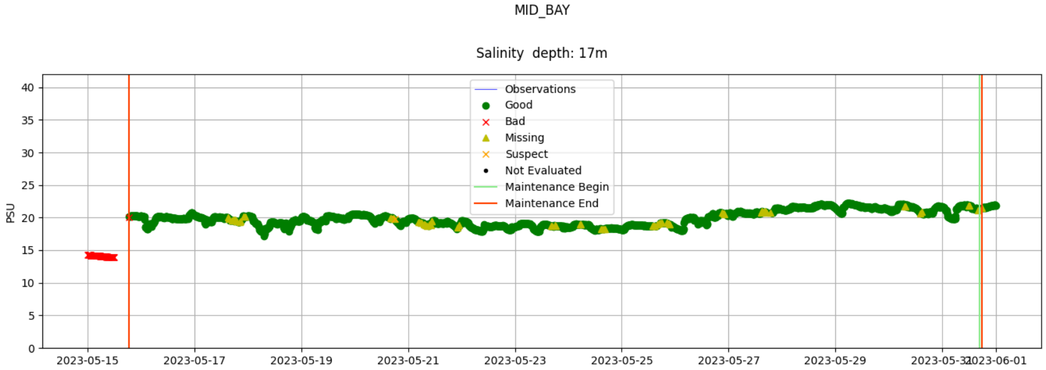

MID_BAY
Dissolved Oxygen depth: 17m
mg/l
0
2
4
6
8
10
12
14
2023-09-01
2023-09-05
2023-09-09
2023-09-13
2023-09-17
2023-09-21
2023-09-25
2023-09-29
2023-10-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

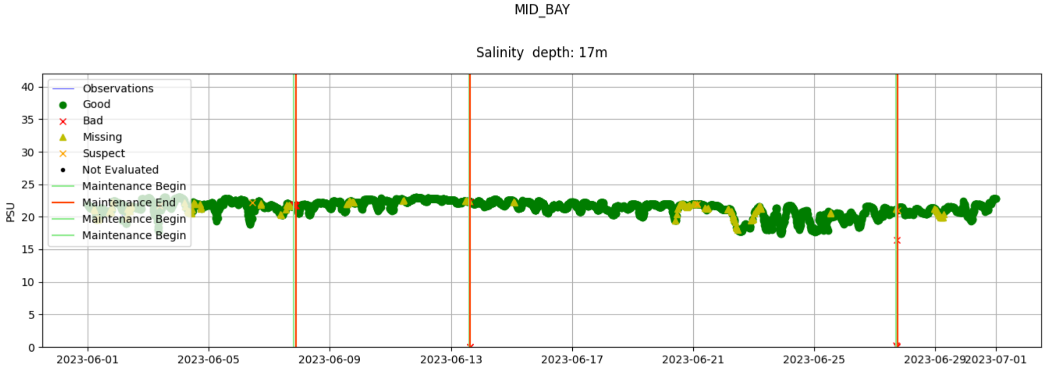

MID_BAY
Dissolved Oxygen depth: 17m
mg/l
0
2
4
6
8
10
12
14
2023-10-01
2023-10-05
2023-10-09
2023-10-13
2023-10-17
2023-10-21
2023-10-25
2023-10-29
2023-11-01
2023-11-05
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End

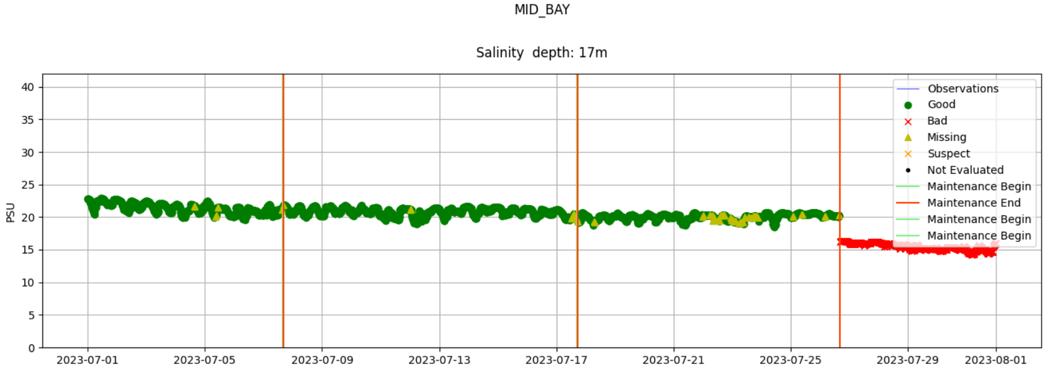

MID_BAY
Dissolved Oxygen depth: 17m
mg/l
0
2
4
6
8
10
12
14
2023-10-22
2023-11-01
2023-11-08
2023-11-15
2023-11-22
2023-12-01
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin

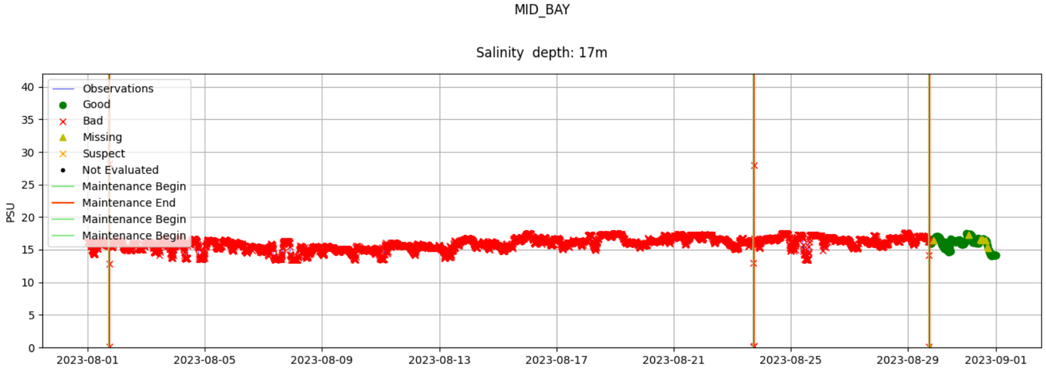

MID_BAY
Dissolved Oxygen depth: 17m
mg/l
0
2
4
6
8
10
12
14
2023-12-01
2023-12-05
2023-12-09
2023-12-13
2023-12-17
2023-12-21
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Open Maintenance

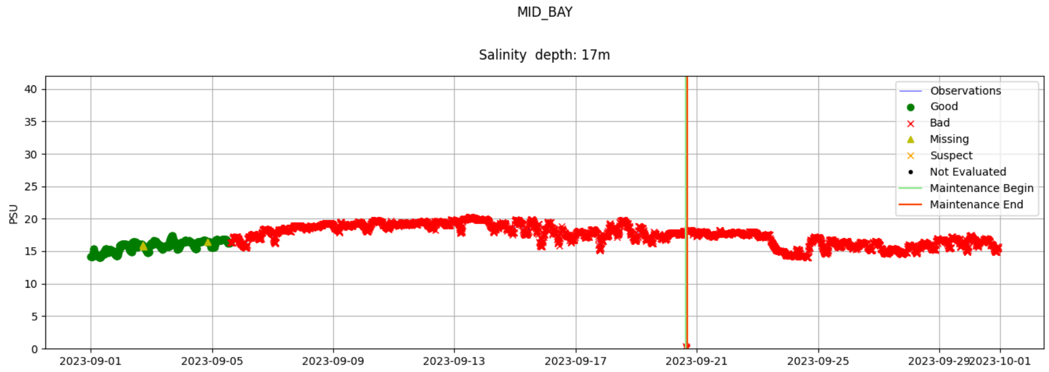
# Mid-Bay Salinity Depth=17m



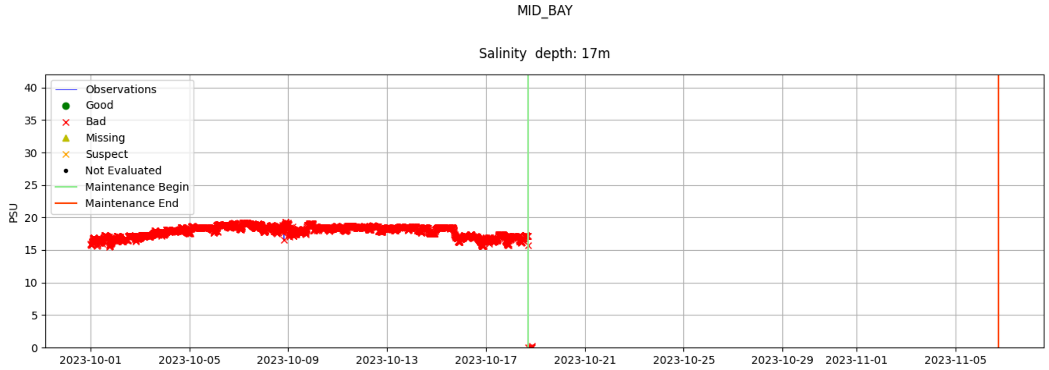




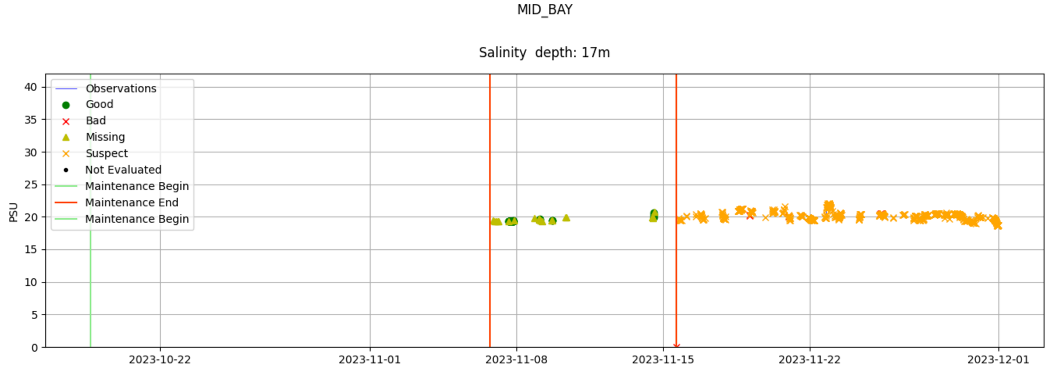



MID_BAY

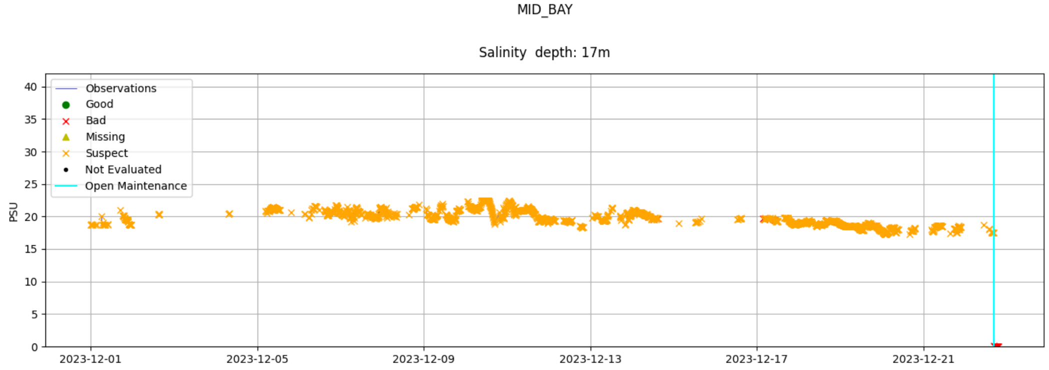
Salinity depth: 17m


MID_BAY

Salinity depth: 17m

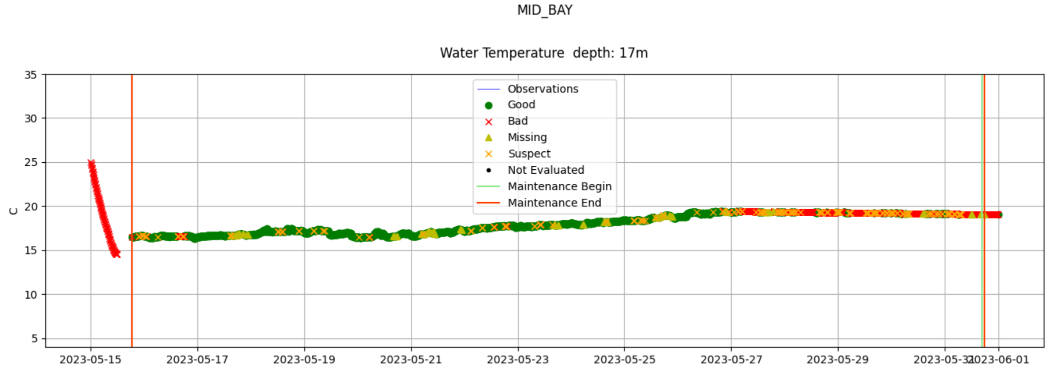

MID_BAY

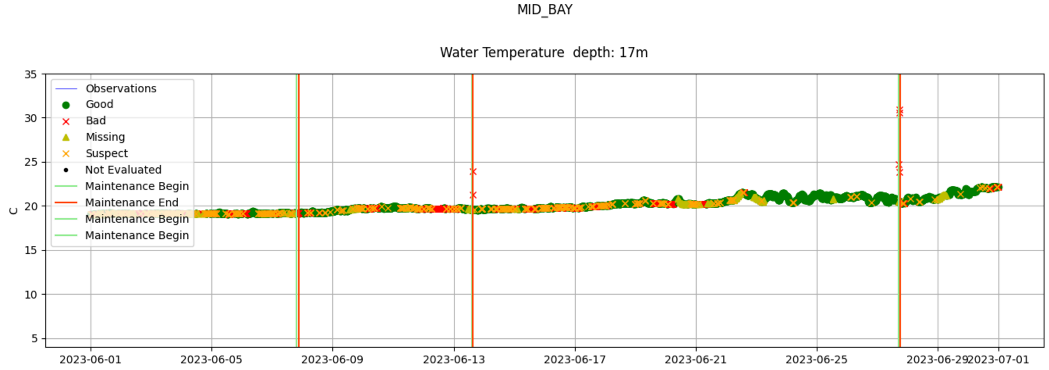
Salinity depth: 17m

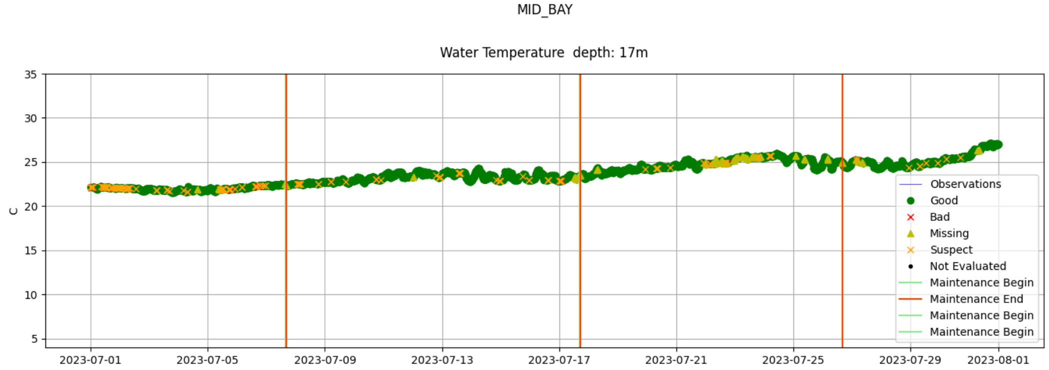

MID_BAY

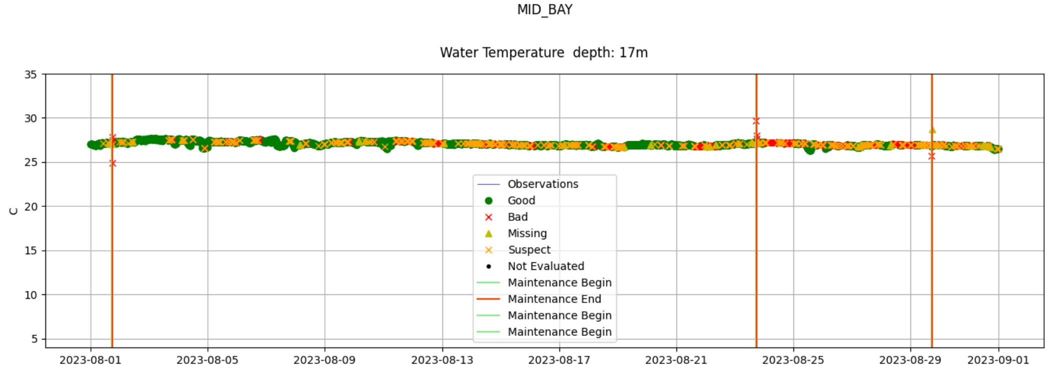
Salinity depth: 17m

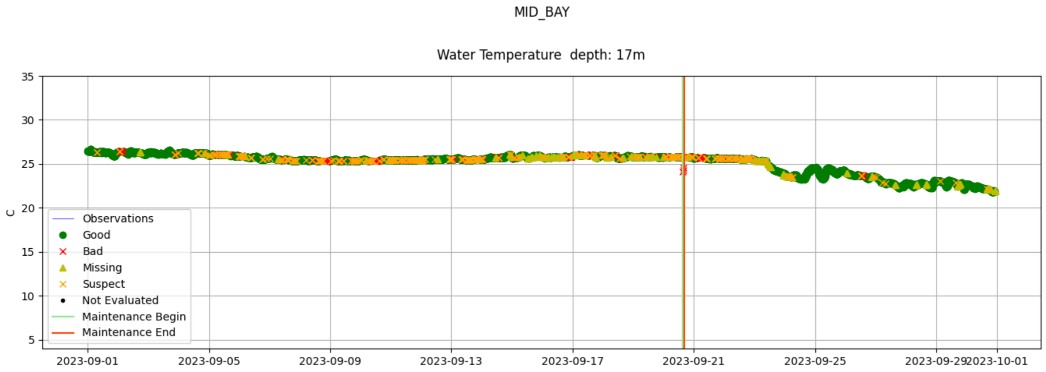
# Mid-Bay Water Temperature Depth=17m

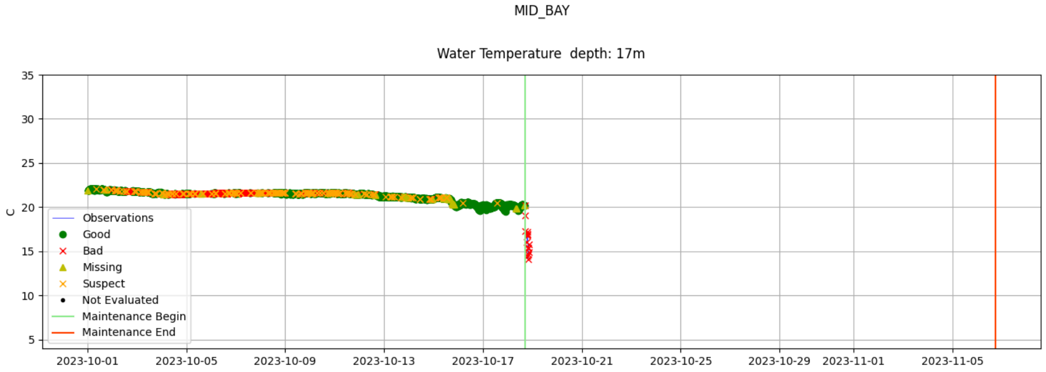


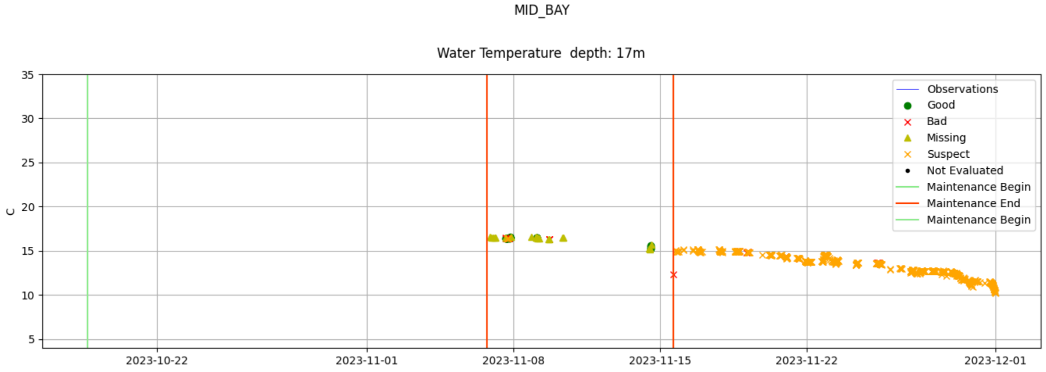


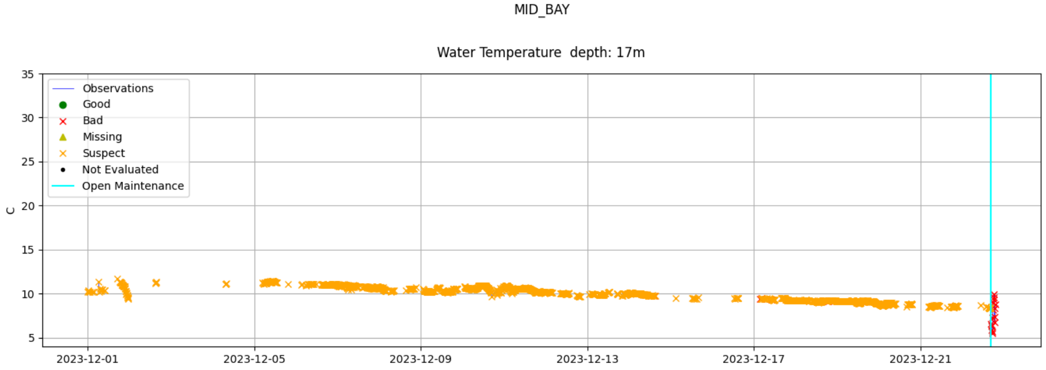





MID_BAY
Water Temperature depth: 17m
C
35
30
25
20
15
10
5
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
2023-09-01
2023-09-05
2023-09-09
2023-09-13
2023-09-17
2023-09-21
2023-09-25
2023-09-29
2023-10-01


MID_BAY
Water Temperature depth: 17m
C
35
30
25
20
15
10
5
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
2023-10-01
2023-10-05
2023-10-09
2023-10-13
2023-10-17
2023-10-21
2023-10-25
2023-10-29
2023-11-01
2023-11-05


MID_BAY
Water Temperature depth: 17m
C
35
30
25
20
15
10
5
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Maintenance Begin
Maintenance End
Maintenance Begin
2023-10-22
2023-11-01
2023-11-08
2023-11-15
2023-11-22
2023-12-01


MID_BAY
Water Temperature depth: 17m
C
35
30
25
20
15
10
5
Observations
Good
Bad
Missing
Suspect
Not Evaluated
Open Maintenance
2023-12-01
2023-12-05
2023-12-09
2023-12-13
2023-12-17
2023-12-21

# A.4 IOOS Plots

## Lower Choptank

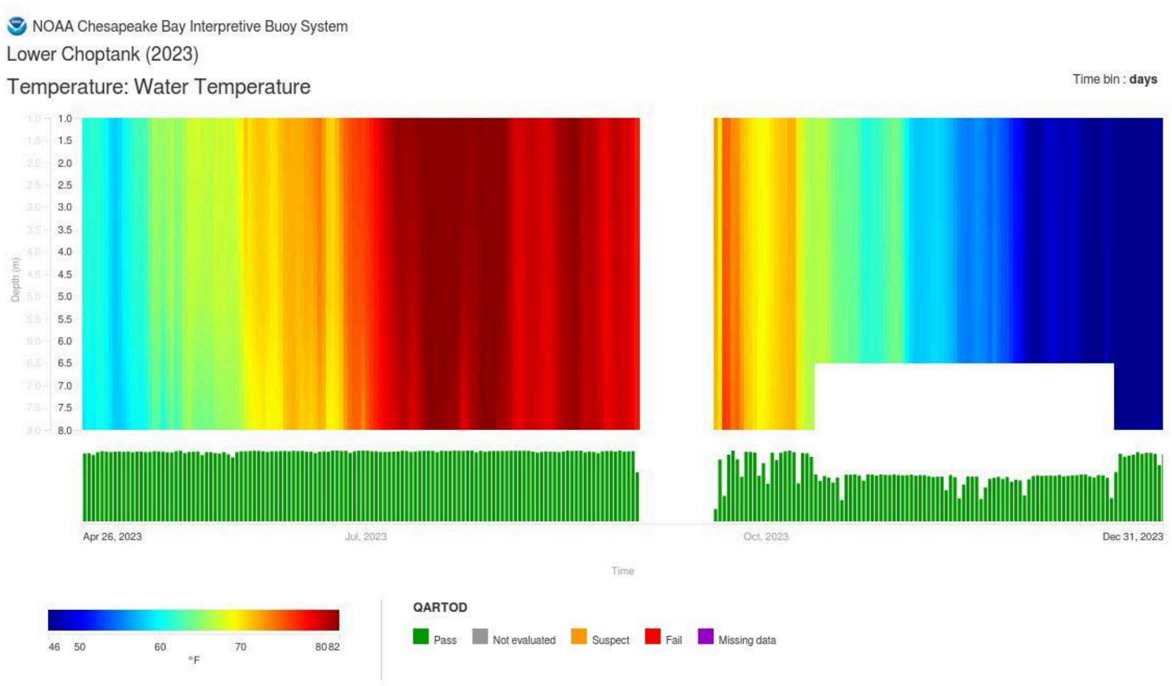


*Figure 8. Lower Choptank water temperature time plot from April 26 to December 31. Top plot indicates water temperature in degrees Fahrenheit, while bottom plot indicates IOOS Quality Assurance/Quality Control of Real-Time Oceanographic Data.*

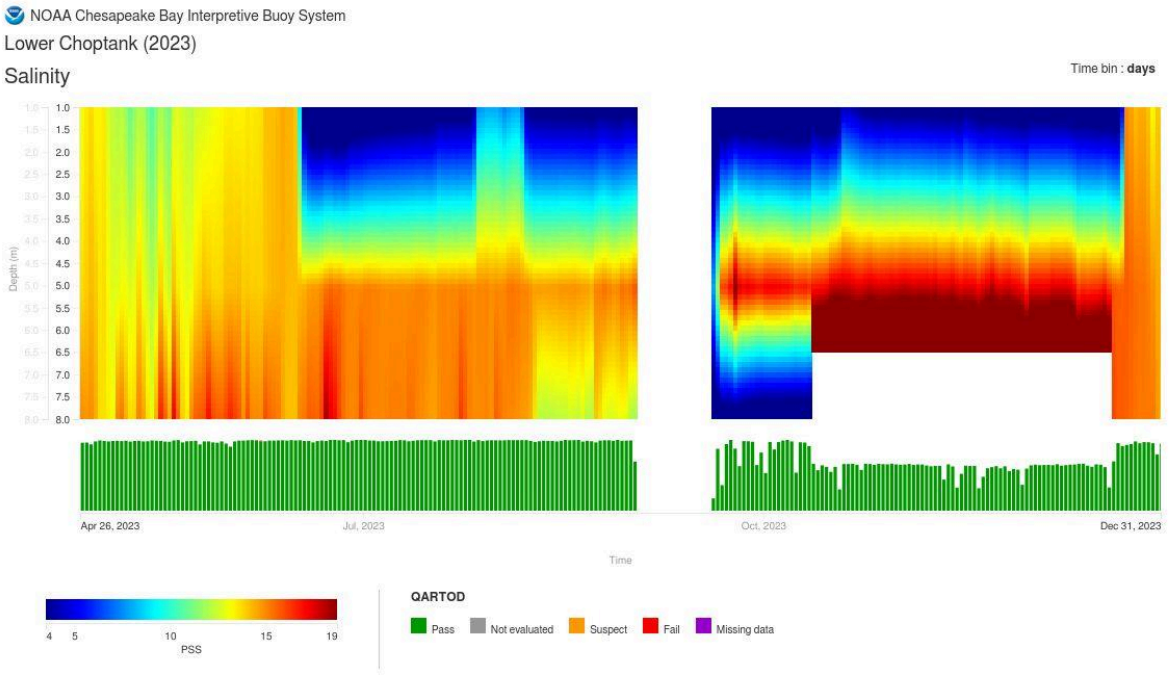


*Figure 9. Lower Choptank salinity time plot from April 26 to December 31. Top plot indicates salinity on the Practical Salinity Scale (PSS), while bottom plot indicates IOOS Quality Assurance/Quality Control of Real-Time Oceanographic Data.*

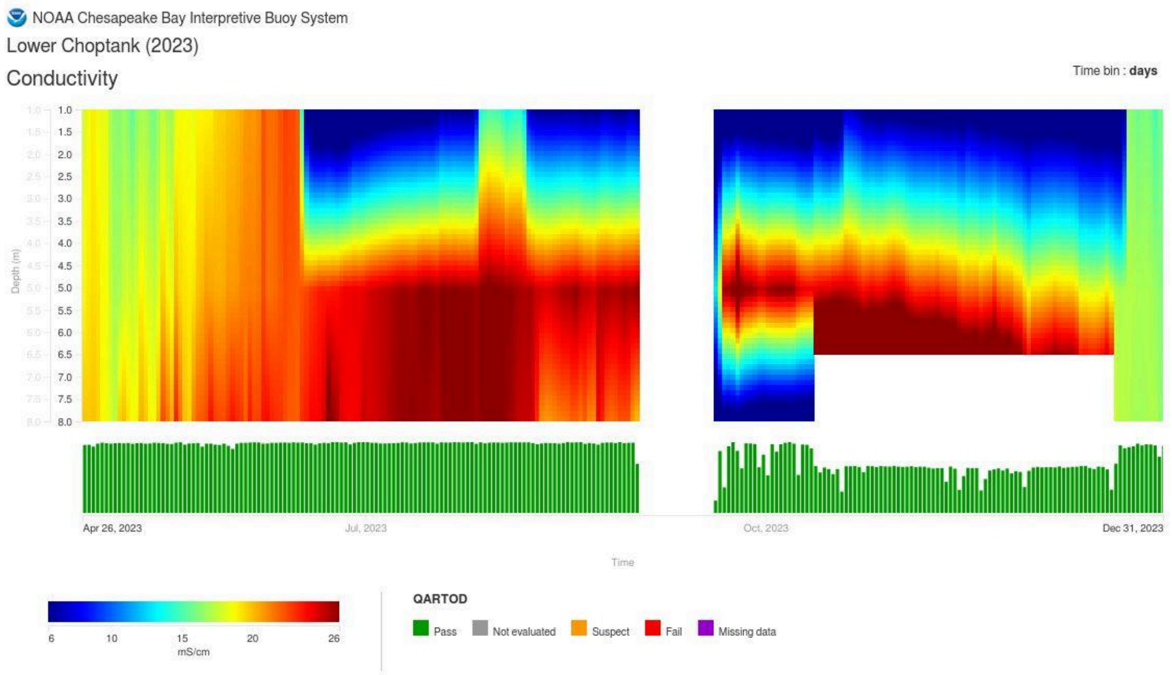


*Figure 10. Lower Choptank conductivity time plot from April 26 to December 31. Top plot indicates conductivity in milliSiemens per centimeter (mS/cm), while bottom plot indicates IOOS Quality Assurance/Quality Control of Real-Time Oceanographic Data.*

## Mid-Bay

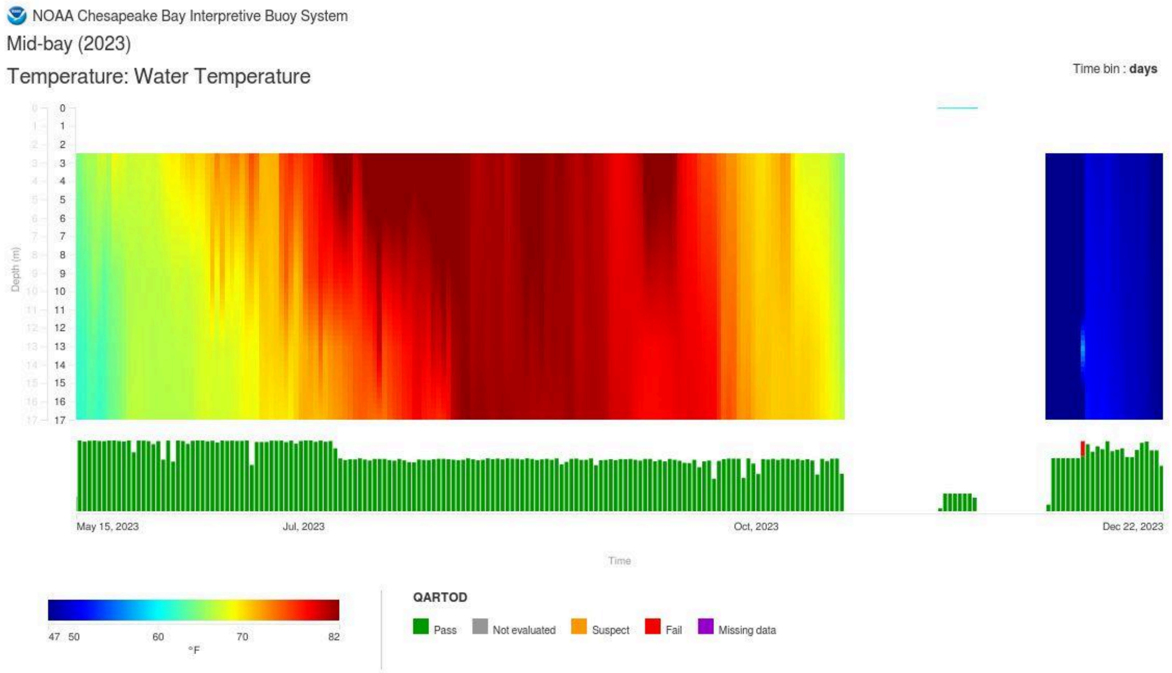


*Figure 11. Mid-Bay water temperature time plot from May 15 to December 22. Top plot indicates water temperature in degrees Fahrenheit, while bottom plot indicates IOOS Quality Assurance/Quality Control of Real-Time Oceanographic Data.*

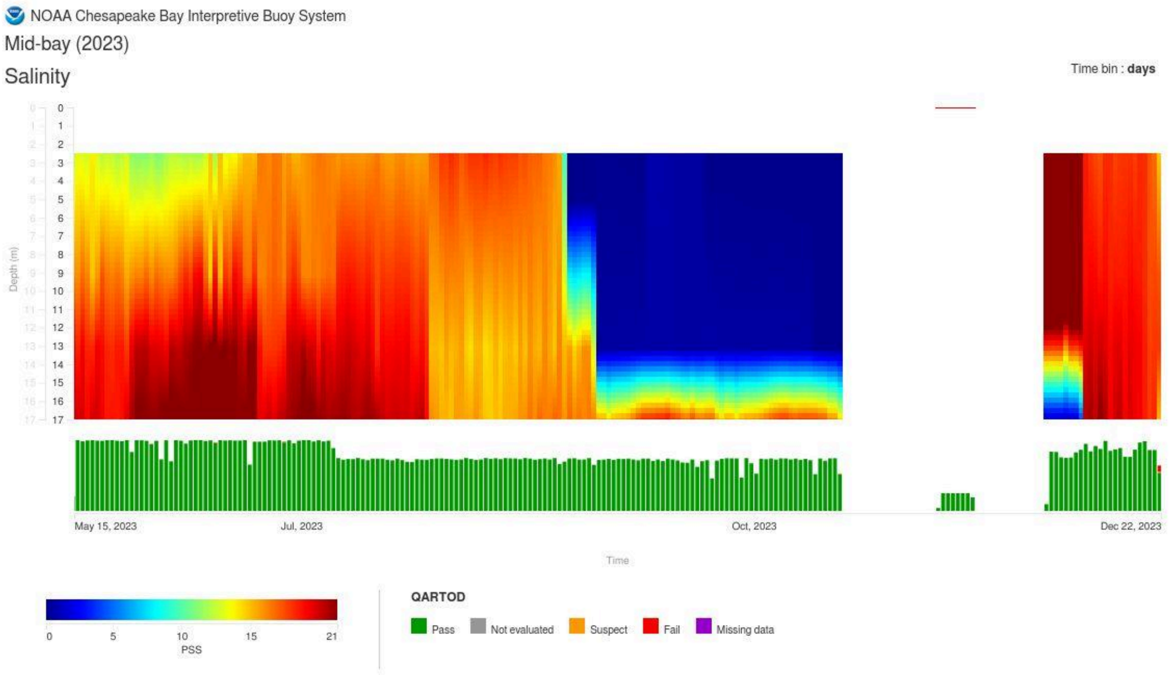


*Figure 12. Mid-Bay salinity time plot from May 15 to December 22. Top plot indicates salinity on the Practical Salinity Scale (PSS), while bottom plot indicates IOOS Quality Assurance/Quality Control of Real-Time Oceanographic Data.*

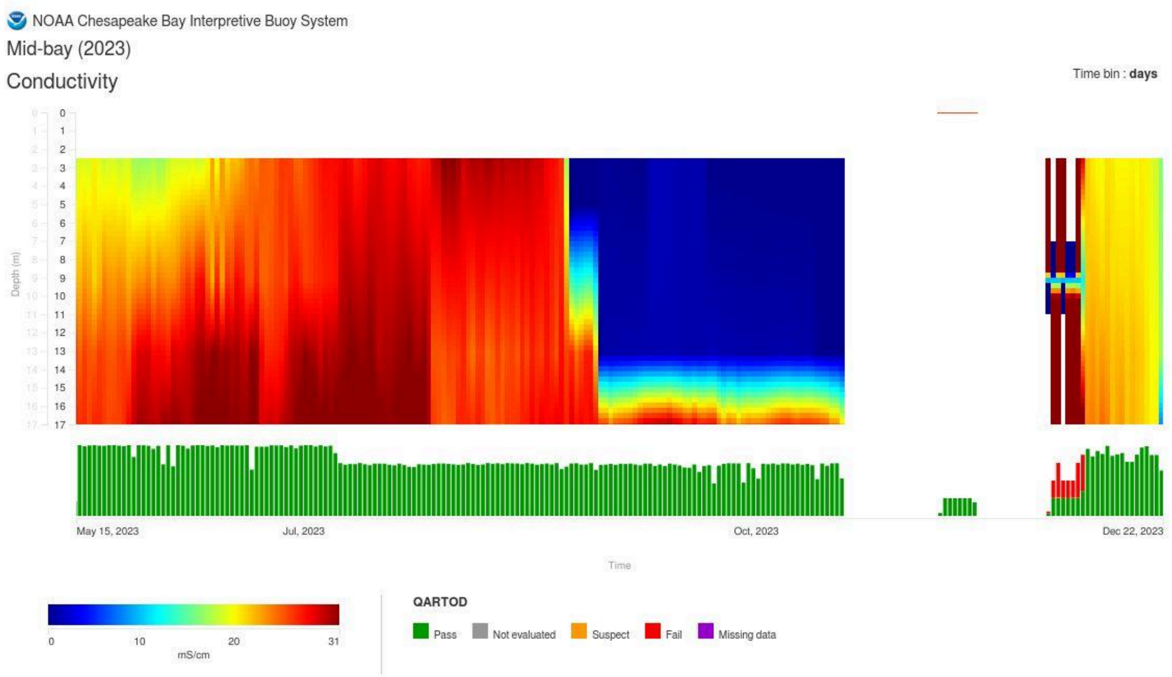


*Figure 13. Mid-Bay conductivity time plot from May 15 to December 22. Top plot indicates conductivity in milliSiemens per centimeter (mS/cm), while bottom plot indicates IOOS Quality Assurance/Quality Control of Real-Time Oceanographic Data.*

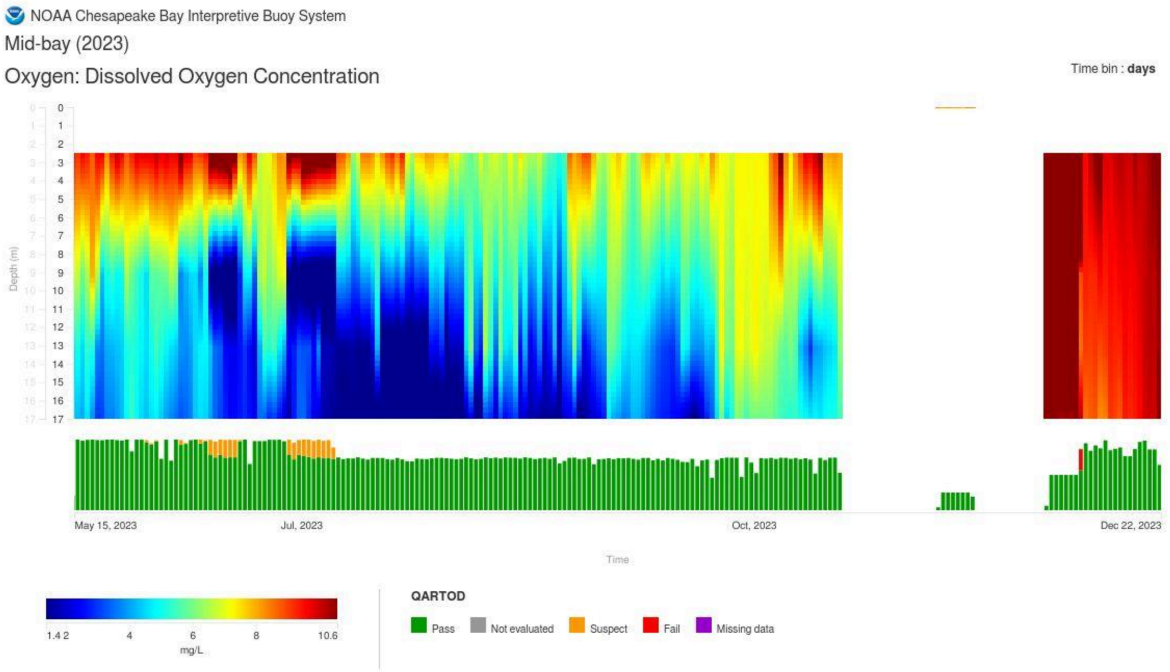


*Figure 14. Mid-Bay DO time plot from May 15 to December 22. Top plot indicates DO in milligrams per liter (mg/L), while bottom plot indicates IOOS Quality Assurance/Quality Control of Real-Time Oceanographic Data.*

## Lower Potomac

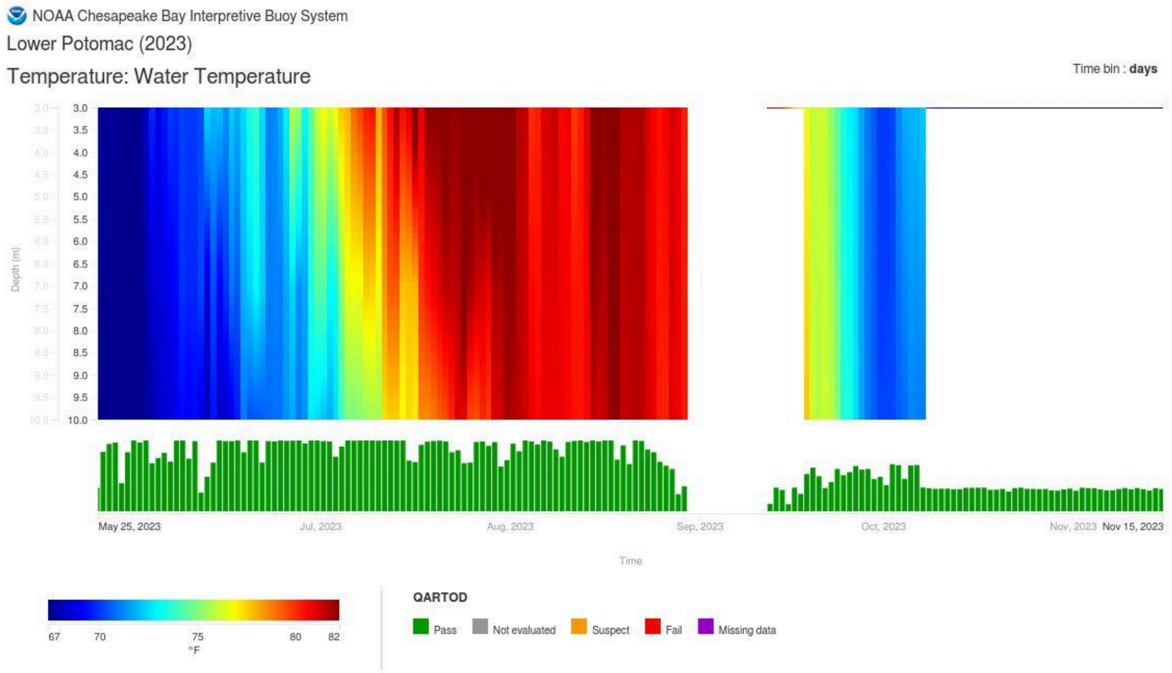


*Figure 15. Lower Potomac temperature time plot from May 25 to November 15. Top plot indicates temperature in degrees Fahrenheit, while bottom plot indicates IOOS Quality Assurance/Quality Control of Real-Time Oceanographic Data.*

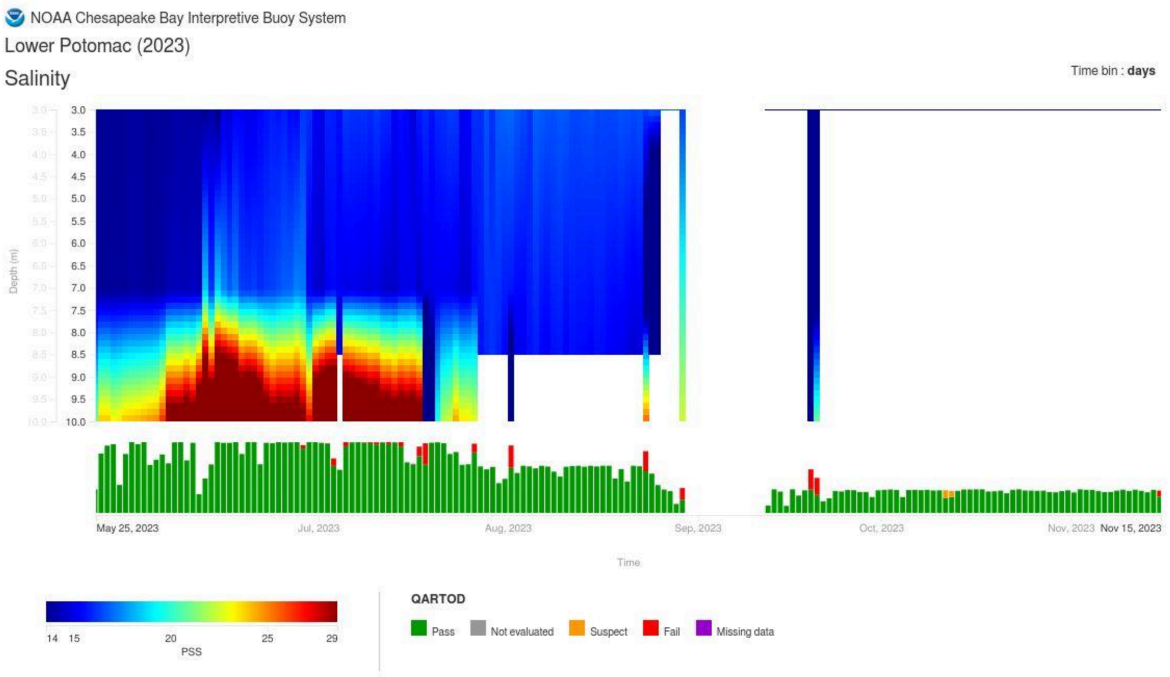


*Figure 16. Lower Potomac salinity time plot from May 25 to November 15. Top plot indicates salinity on the Practical Salinity Scale (PSS), while bottom plot indicates IOOS Quality Assurance/Quality Control of Real-Time Oceanographic Data.*

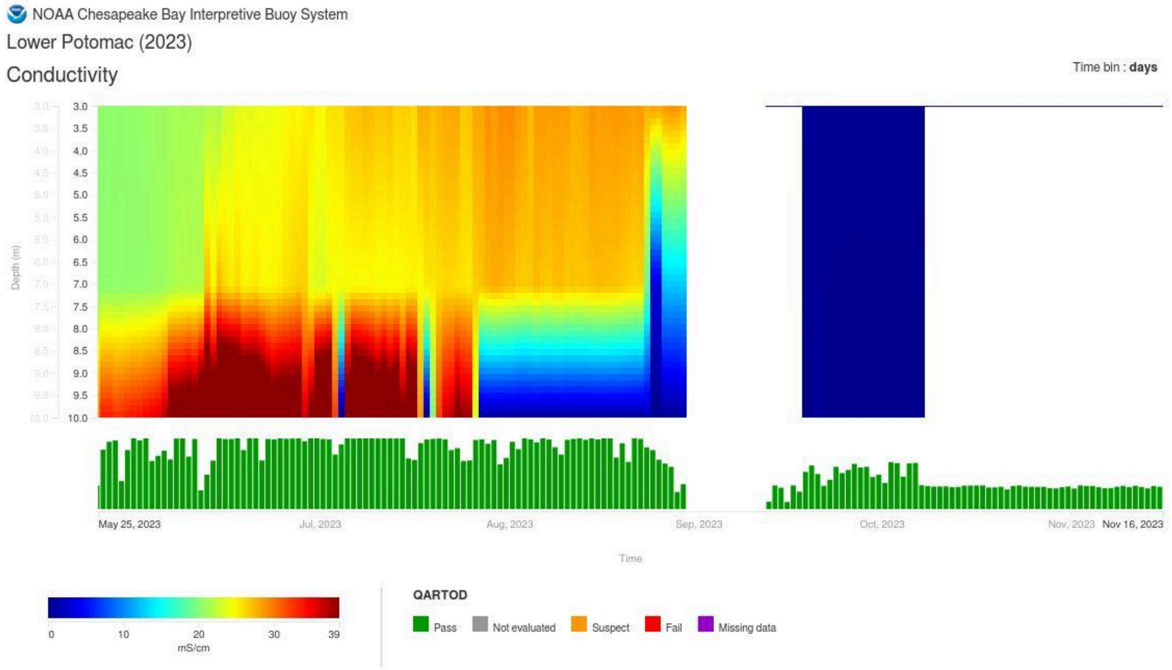


*Figure 17. Lower Potomac conductivity time plot from May 25 to November 15. Top plot indicates conductivity in milliSiemens per centimeter (mS/cm), while bottom plot indicates IOOS Quality Assurance/Quality Control of Real-Time Oceanographic Data.*

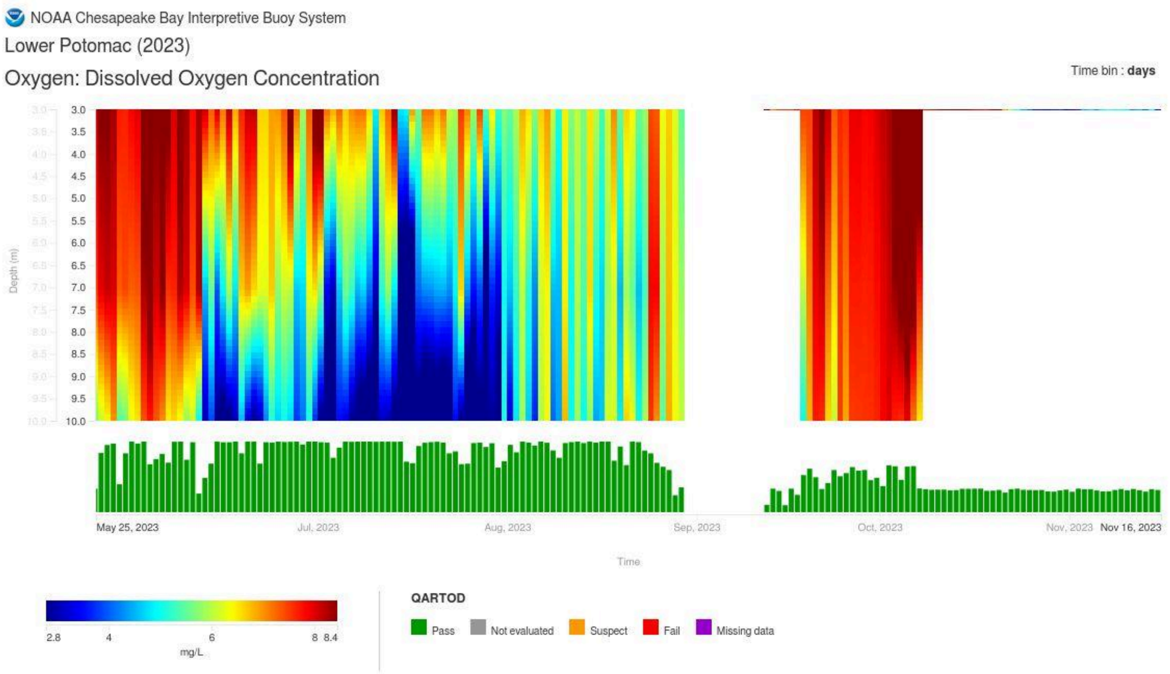


*Figure 18. Lower Potomac DO time plot from May 25 to November 15. Top plot indicates DO in milligrams per liter (mg/L), while bottom plot indicates IOOS Quality Assurance/Quality Control of Real-Time Oceanographic Data.*

# Appendix B: Python Code with Thresholds Used for the 2023 Season

```
class QCSettings:
    def __init__(self):
        self.configs = {}  # Dictionary of test
        self.setupConfig()
    def setupConfig(self):
        self.configs["water_temp_config"] = {
            "qartod": {
                "gross_range_test": {"fail_span": [-5.0, 45], "suspect_span": [-2.0, 35.0]},
                "flat_line_test": {
                    "tolerance": 0.01,
                    "suspect_threshold": 2700,
                    "fail_threshold": 3600
                },
                "rate_of_change_test": {
                    "threshold": 0.003
                },
                "spike_test": {
                    "suspect_threshold": 2.0,
                    "fail_threshold": 10.0
                }
            }
        }
        self.configs["salinity_config"] = {
            "qartod": {
                "gross_range_test": {"fail_span": [0.002, 35.0], "suspect_span": [0.5, 30.0]},
                "flat_line_test": {
                    "tolerance": 0.001,
                    "suspect_threshold": 2700,
                    "fail_threshold": 3600
                },
                "rate_of_change_test": {
                    # "threshold": .0005 # Testing a different threshold
                    "threshold": .004
                },
                "spike_test": {
                    "suspect_threshold": 3.0,
                    "fail_threshold": 6.0
                }
            }
        }
        self.configs["dissolved_oxygen_config"] = {
            "qartod": {
                "gross_range_test": {"fail_span": [0.0, 20.0], "suspect_span": [0.5, 15.0]},
                "flat_line_test": {
                    "tolerance": 0.005,
                    "suspect_threshold": 2700,
```

```
            "fail_threshold": 3600
        },
        "rate_of_change_test": {
            "threshold": .003
        },
        "spike_test": {
            "suspect_threshold": 5.0,
            "fail_threshold": 10.0
        }
    }
}
self.configs["dissolved_oxygen_adj_config"] = {
    "qartod": {
        "gross_range_test": {"fail_span": [0.0, 20.0], "suspect_span": [0.5, 15.0]},
        "flat_line_test": {
            "tolerance": 0.005,
            "suspect_threshold": 2700,
            "fail_threshold": 3600
        },
        "rate_of_change_test": {
            "threshold": .003
        },
        "spike_test": {
            "suspect_threshold": 0.5,
            "fail_threshold": 1.0
            # "suspect_threshold": 5.0,
            # "fail_threshold": 10.0
        }
    }
}
self.configs["dissolved_oxygen_adj_config"] = {
    "qartod": {
        "gross_range_test": {"fail_span": [0.0, 20.0], "suspect_span": [0.5, 15.0]},
        "flat_line_test": {
            "tolerance": 0.005,
            "suspect_threshold": 2700,
            "fail_threshold": 3600
        },
        "rate_of_change_test": {
            "threshold": .003
        },
        "spike_test": {
            "suspect_threshold": 5.0,
            "fail_threshold": 10.0
        }
    }
}
self.configs["conductivity_config"] = {
    "qartod": {
        "gross_range_test": {"fail_span": [0.0, 53.0], "suspect_span": [0.0, 46.0]},
        "flat_line_test": {
```

```
            "tolerance": 0.0005,
            "suspect_threshold": 2700,
            "fail_threshold": 3600
        },
        "rate_of_change_test": {
            "threshold": .002
        },
        "spike_test": {
            "suspect_threshold": 1.0,
            "fail_threshold": 5.0
        }
    }
}
self.configs["pressure_config"] = {
    "qartod": {
        "gross_range_test": {"fail_span": [0.0, 30.0], "suspect_span": [0.5, 28.4]},
        "flat_line_test": {
            "tolerance": 0.001,
            "suspect_threshold": 2700,
            "fail_threshold": 3600
        },
        "rate_of_change_test": {
            "threshold": .0007
        },
        "spike_test": {
            "suspect_threshold": 0.5,
            "fail_threshold": 1.0
        }
    }
}
```