DRAFT
IN-WATER HULL CLEANING PAUSE WATER QUALITY MONITORING TECHNICAL REPORT

Submitted to:

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ACRONYMS AND ABBREVIATIONS

AFP	antifouling paint
Amec Foster Wheeler	Amec Foster Wheeler Environment & Infrastructure, Inc.
CEDEN	California Environmental Data Exchange Network
COC	chain-of-custody
CWA	Clean Water Act
ELAP	California Environmental Laboratory Accreditation Program
EMC	event mean concentration
ER	equipment rinsate
FB	field blank
Hull Cleaning Pause	In-Water Hull Cleaning Pause
ID	identifier
IE	initial exposure
LCS	laboratory control sample
LIMS	Laboratory Information Management System
max	maximum
min	minimum
MLLW	mean lower low water
MS	matrix spike
MS4	municipal separate storm sewer system
MSD	matrix spike duplicate
N/A	not applicable
NAVWAR	Naval Information Warfare Systems Command
ND	non-detect
NELAP	National Environmental Laboratory Accreditation Program
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NR	not recorded
Pause	In-Water Hull Cleaning Pause
PDF	Portable Document Format
PM	project manager
Port	Port of San Diego
Q	quarter
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
Regional Board	San Diego Regional Water Quality Control Board
SAP	Sampling and Analysis Plan
SE	standard error
SIYB	Shelter Island Yacht Basin
SIYB TMDL	Shelter Island Yacht Basin Dissolved Copper Total Maximum Daily Load
SM	Standard Method
SOP	standard operating procedure
SPAWAR	Navy Space and Naval Warfare Systems Center Pacific
SWAMP	Surface Water Ambient Monitoring Program
SWRCB	State Water Resources Control Board
TMDL	Total Maximum Daily Load

ACRONYMS AND ABBREVIATIONS (CONTINUED)

TSS	total suspended solids
USEPA	United States Environmental Protection Agency
Weck	Weck Laboratories, Inc.
Wood	Wood Environment & Infrastructure Solutions, Inc.
WQ	water quality
WQO	water quality objective

UNITS OF MEASURE

%	percent
±	plus or minus
°C	degree(s) Celsius
Cu $\mu g/cm^{-2}d^{-1}$	copper leach rate in microgram(s) per square centimeter per day
µg/L	microgram(s) per liter
µm	micrometer(s) or micron(s)
ft	foot/feet
kg/yr	kilogram(s) per year
mg/L	milligram(s) per liter
ppt	part(s) per thousand

EXECUTIVE SUMMARY

This technical report presents the findings of the In-Water Hull Cleaning Pause (Hull Cleaning Pause or Pause) Water Quality Monitoring Program conducted in Shelter Island Yacht Basin (SIYB) from November 2021 through March 2022. The Hull Cleaning Pause Monitoring Program was designed to evaluate the potential impacts of hull cleaning on water quality in SIYB.

SIYB waters contain dissolved copper concentrations that have exceeded the dissolved copper water quality objectives (WQOs) and may threaten and impair the wildlife habitat and marine habitat beneficial uses in the basin (San Diego Regional Water Quality Control Board [Regional Board], 2005). Because of these exceedances, SIYB was placed on the list of impaired water bodies compiled pursuant to federal Clean Water Act Section 303(d).

To address this impairment, the SIYB Dissolved Copper Total Maximum Daily Load (SIYB TMDL) was adopted in 2005 under Resolution No. R9-2005-0019 (Regional Board, 2005). As part of the TMDL process, a conceptual model was developed to assign loading estimates to various copper sources in SIYB and resolve impairment by requiring a reduction in loading of dissolved copper into SIYB waters from the identified sources. One of the primary sources of dissolved copper loading is the passive leaching of copper-based antifouling paints (AFPs) applied to the vessels moored in SIYB, and the other is the in-water hull cleaning of the copper-based AFPs.

In the SIYB TMDL Conceptual Model, 5 percent (%) of the annual dissolved copper load to SIYB is attributed to hull cleaning of copper-based AFPs, while 93% is attributed to passive leaching of copper-based AFPs (Regional Board, 2005). However, a more recent study (Earley et al., 2013) found that dissolved copper leach rates were enhanced not only during the initial cleaning, but for two to three days following the cleaning event, and then slowly declined until reaching a “pseudo steady state” approximately 30 days post-cleaning. As such, the Earley et al. (2013) study suggests that dissolved copper loading associated with hull cleaning may account for a greater load contribution (i.e., greater than 5%) than previously modeled in the TMDL.

To better understand the relationship between hull cleaning and water quality in SIYB, the Port of San Diego (Port) (1) implemented a temporary pause in hull cleaning of vessels with copper-based AFPs in SIYB, and (2) conducted water quality monitoring before, during, and after the Hull Cleaning Pause to evaluate dissolved copper levels in SIYB. This effort was conducted in partnership with the Regional Board.

Based on the findings presented in Earley et al. (2013), it was theorized that a complete pause in hull cleaning in SIYB for longer than the 30-day period expected for copper release rates to return to a “pseudo steady state” would result in an observable decrease in dissolved copper levels in the basin, as the load contribution from hull cleaning was reduced to zero. It was further theorized that if the hull cleaning load was substantially greater than the modeled 5% from the SIYB TMDL, then a corresponding decrease in dissolved copper may shift the basin-wide water quality substantially closer to the 3.1 micrograms per liter (µg/L) water quality standard.

The Hull Cleaning Pause Water Quality Monitoring Program was designed to address the following question:

> *How does a pause in hull cleaning affect dissolved copper concentrations in SIYB?*

The Port adopted an amendment to its Hull Cleaning Ordinance (Article 4.14 of the District Code) to implement a temporary pause in hull cleaning. The ordinance amendment prohibited the hull cleaning of vessels with copper-based AFPs in SIYB from December 19, 2021 through February 9, 2022 (approximately eight weeks).

To assess the effects that a pause in hull cleaning could have on dissolved copper levels in the water, a 16-week monitoring program was designed and implemented in SIYB concurrently with the Hull Cleaning Pause. The program included the following components:

1. Hull cleaning inspections and visual observations: To ensure compliance with the Hull Cleaning Ordinance amendment, Port staff conducted frequent inspections throughout SIYB during the Hull Cleaning Pause to look for hull cleaning activity and document visual observations of hull fouling and water conditions in the basin. Additionally, the Port established alternative locations to allow vessels with copper-based AFPs to be cleaned outside of SIYB during the Hull Cleaning Pause.
2. Weekly water quality monitoring: Surface water quality sampling was performed weekly for the duration of the monitoring program to evaluate concentrations of dissolved copper in SIYB for four weeks leading up to the Hull Cleaning Pause, eight weeks during the Pause, and four weeks following the Pause. Samples for dissolved copper analyses were collected from 13 core monitoring stations plus two reference stations every week and supplemented with samples from seven additional enhanced stations every other week.
3. Storm monitoring event: Stormwater sampling and surface water quality sampling was performed before and after one storm event during the monitoring program to evaluate potential effects of stormwater discharge on copper levels in SIYB and on the Hull Cleaning Pause monitoring results.

Key findings from each component of the monitoring program are presented below.

- There was an apparent increase in the dissolved copper levels throughout the basin during the Pre-Pause period and extending through the first two weeks of the Pause, particularly at the inner basin stations and the stations in closer proximity to vessels (i.e., enhanced stations). There was also a noticeable increase in hull cleaning activities in the last two weeks of the Pre-Pause period as boaters and hull cleaners prepared for the Hull Cleaning Pause. Under the assumption that dissolved copper leach rates spike following cleaning events, the increase in dissolved copper concentrations observed during the Pre-Pause period and beginning of the Pause period, particularly in the inner basin, could be attributed to an increase in hull cleaning activities.

- After the first two weeks of the Pause, dissolved copper concentrations began to trend downward over remainder of the Pause period. This trend continued through the Post-Pause period. This finding was consistent with that presented in Earley et al. (2013), with the expected spike in dissolved copper concentrations from hull cleaning activities gradually diminishing as concentrations returned to “pseudo steady state” after the first 30 days of the Pause. The hull cleaning inspections conducted throughout the eight-week Hull Cleaning Pause did not find any instances where divers were cleaning or had cleaned (via dive tag observations) vessels with copper-based AFPs. This finding was further supported by the notable increase in marine growth (fouling) on vessel hulls throughout the basin over the course of the Pause.

- Following the Pause, it was assumed that hull cleaning frequency would increase to Pre-Pause levels as cleaning activities resumed. However, observations during dock walks conducted in the Post-Pause period did not indicate a notable increase in hull cleaning, suggesting that there may have been a delay in resuming routine hull cleaning activities following the Pause. This may have contributed to the continued slight downward trend in dissolved copper concentrations following the Pause.

- The results of the pre- and post-storm weekly monitoring events suggested that stormwater discharge did not contribute a substantial amount of copper loading to SIYB. While the storm did appear to have an overall mixing effect on the spatial distribution of dissolved copper in SIYB (i.e., more uniform concentrations throughout the basin after the storm), the basin-wide average dissolved copper concentrations remained the same before and after the storm (11 µg/L). As such, storm events and associated stormwater runoff are not expected to have had any significant impact on dissolved copper levels or conclusions related to the effects of hull cleaning on dissolved copper concentrations throughout the monitoring program.

- While there was an observed decrease in basin-wide dissolved copper levels during the Pause and Post-Pause periods, it should be noted that the basin-wide average measured during the final week of the monitoring program (7.2 µg/L in Week 16) was similar to that measured during Week 1 (6.5 µg/L). These basin-wide average dissolved copper concentrations were also consistent with those measured during previous TMDL monitoring events (Wood, 2022a).

- While a pause in the hull cleaning of vessels with copper-based AFPs does decrease the load of dissolved copper into the basin, leading to subsequent reductions in dissolved copper concentrations, it appears that changes to the basin-wide dissolved copper concentrations are minimal when compared with the passive leaching of copper-based AFPs, which is the predominant source of copper loading to the basin.

- Despite observed decreases in dissolved copper levels during the Pause and Post-Pause periods, the total cessation of hull cleaning during the monitoring program was insufficient to reduce the basin-wide dissolved copper levels to a level that would achieve the current water quality standard (3.1 µg/L).

This report is intended to present results from the monitoring program to enable stakeholders, including regulatory agencies, to use this information to discuss and determine next steps for SIYB and other copper-related regulatory actions, where applicable. It should be noted that limitations to these findings include both the monitoring program location (i.e., SIYB) and duration of the Hull Cleaning Pause period. It is unknown whether a pause in hull cleaning of copper-based AFPs in a different location or for a longer duration would result in a more substantial reduction in dissolved copper.

1.0 INTRODUCTION

This technical report presents the results of the In-Water Hull Cleaning Pause (Hull Cleaning Pause or Pause) Water Quality Monitoring Program conducted in Shelter Island Yacht Basin (SIYB) from November 2021 through March 2022. This monitoring program was designed to evaluate the potential impacts of hull cleaning on water quality in SIYB.

To better understand the relationship between hull cleaning and water quality in SIYB, the Port of San Diego (Port) (1) implemented a temporary pause in hull cleaning of copper-based antifouling paints (AFPs) in SIYB, and (2) conducted water quality monitoring before, during, and after the Hull Cleaning Pause to evaluate dissolved copper levels in SIYB. This effort was conducted in partnership with the San Diego Regional Water Quality Control Board (Regional Board).

A combined Sampling and Analysis Plan (SAP) and Quality Assurance Project Plan (QAPP) was prepared by Wood Environment & Infrastructure Solutions, Inc. (Wood), in collaboration with the Port and Regional Board, and finalized in November 2021. The combined SAP/QAPP details the water quality monitoring program designed and implemented to address the following question:

How does a pause in hull cleaning affect dissolved copper concentrations in SIYB?

1.1 Background

SIYB waters contain dissolved copper concentrations that have exceeded the dissolved copper numeric water quality objectives (WQOs), as well as the toxicity and pesticides narrative WQOs. These water quality conditions may threaten and impair the wildlife habitat and marine habitat beneficial uses in the basin (Regional Board, 2005). Because of these exceedances, SIYB was placed on the list of impaired water bodies compiled pursuant to federal Clean Water Act Section 303(d). To address this impairment, the SIYB Dissolved Copper Total Maximum Daily Load (SIYB TMDL) was adopted in 2005 under Resolution No. R9-2005-0019 (Regional Board, 2005). As part of the TMDL process, a conceptual model was developed to assign loading estimates to various copper sources in SIYB and resolve impairment by requiring a reduction in loading of dissolved copper into SIYB waters from the identified sources. As stated in the SIYB TMDL, to achieve compliance by the end of 2022, the dissolved copper load must be reduced to an annual load of 567 kilograms per year (kg/yr).

Recreational marine vessels moored in harbors and marinas are subject to biofouling (i.e., attachment and growth of aquatic organisms on vessel surfaces). Vessel hulls are commonly coated with copper-based AFPs that act as a toxicant by releasing copper and inhibiting growth of fouling organisms. Periodic hull cleaning occurs throughout the coating life cycle to maintain a bottom surface that is free of marine organisms. Copper loading associated with passive leaching of AFPs and periodic cleaning activities to refresh the paint surface results in dissolved copper levels that exceed water quality regulatory criteria in SIYB.

The SIYB TMDL Conceptual Model identifies that copper-based AFP sources contribute the majority of dissolved copper loading to SIYB. The greatest source of loading is the passive leaching of copper-based AFPs applied to the vessels moored in SIYB, accounting for approximately 93 percent (%; 2,000 kg/yr of copper) of total loading. The SIYB TMDL Conceptual Model identifies that hull cleaning of copper-based AFPs accounts for approximately 5%

(100 kg/yr of copper) of total loading (Regional Board, 2005). Other sources[1] were found to be nominal in the SIYB TMDL Conceptual Model.

A study conducted by the Navy Space and Naval Warfare Systems Center Pacific (SPAWAR) (now known as Naval Information Warfare Systems Command [NAVWAR]) evaluated leach rates resulting from both the act of hull cleaning and its residual effects following the active cleaning of the hull over the life cycle of a paint. This study titled, *"Life Cycle Contributions of Copper from Vessel Painting and Maintenance Activities"* (Earley et al., 2013), used *in situ* data collection methods and best available science to evaluate copper loading and potential environmental impacts associated with hull cleaning. This study measured copper release rates following periodic hull cleaning events to better understand the relative contribution of passive leaching and hull cleaning to annual loading over an estimated three-year paint life cycle. A graphical depiction of the life cycle of a copper-based AFP based on the findings presented in Earley et al. (2013) is provided in Figure 1-1. The life cycle of the paint includes initial exposure (IE) after paint application, followed by cleaning events (SR_{CE}) every 21 days during summer months (June, July, August) and every 28 days during non-summer months.

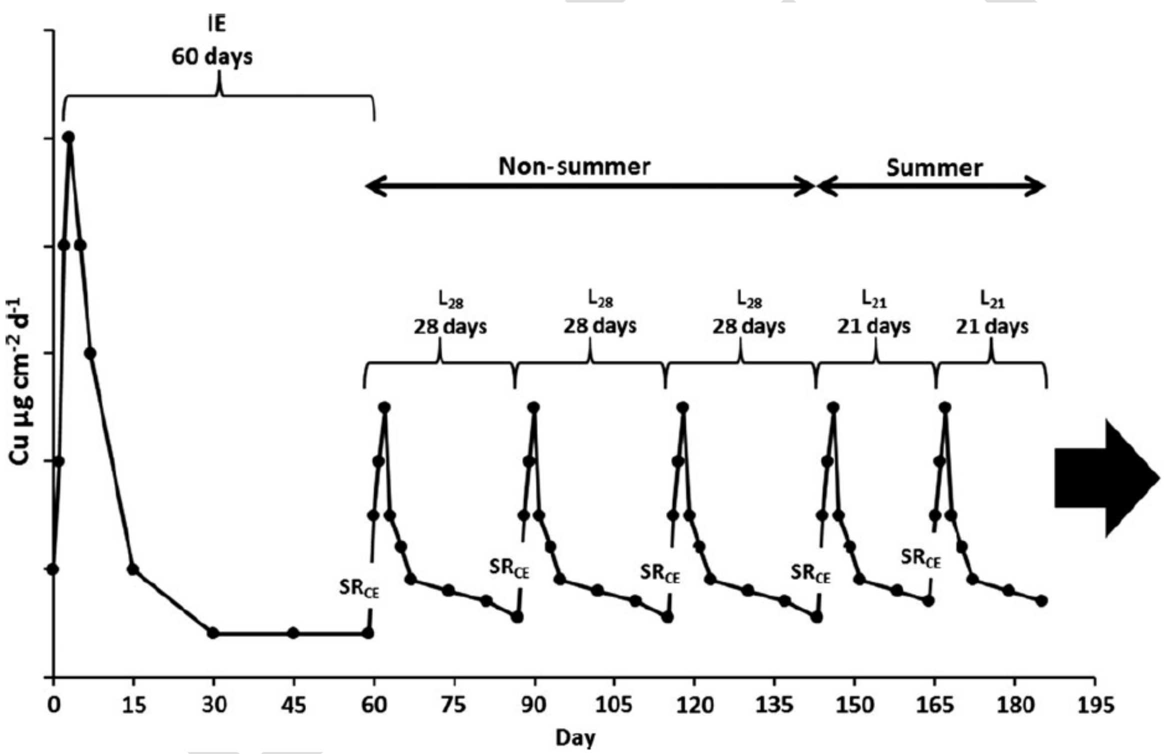

Figure 1-1. Copper Leach Rates Over Hull Paint Life Cycle (Earley et al. [2013])

Credit: Early et al. (2013)
Notes: Cu µg/cm^{-2}d^{-1} = copper leach rate in microgram(s) per square centimeter per day; IE = initial exposure; L21 = 21 days between cleaning events; L28 = 28 days between cleaning events; SR_{CE} = surface refreshment from cleaning event

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1 As stated in the Regional Board Technical Report, dissolved copper loading from urban runoff is marginal compared with loading from the other anthropogenic sources, at approximately 1% (30 kg/yr) of the total load. In addition, copper is found naturally in seawater, and background loading accounts for approximately 1% (30 kg/yr). Direct atmospheric deposition was also determined to be a relatively insignificant contributor of dissolved copper, accounting for less than 1% (3 kg/yr) of the total load. Lastly, sediment was found to act primarily as a sink, rather than a source, of dissolved copper under current loading conditions to SIYB (Regional Board, 2005).

The study results indicate that copper leach rates spike for two to three days following each cleaning event and then slowly decline until reaching a "pseudo steady state" approximately 30 days after cleaning. The study further indicates that increases in copper leach rates may occur for approximately 30 days following hull cleaning activity, which can vary the contribution of hull cleaning-related loading from 5% to more than 40% of annual copper load per vessel, depending on the cleaning methods and frequency.

Findings presented in Earley et al. (2013) suggest that loading associated with hull cleaning may account for a greater percentage of loading than previously modeled in the SIYB TMDL. However, the relationship between copper loading associated with hull cleaning and water quality (i.e., dissolved copper concentrations) is unclear. Thus, a recommendation was made in the *2020 SIYB Dissolved Copper TMDL Annual Monitoring and Progress Report* (Wood, 2021b) to fill data gaps associated with the effects of hull cleaning on water quality. The Hull Cleaning Pause and concurrent water quality monitoring program described in this report were designed and implemented to fulfill this recommendation.

1.2 Report Organization

This Hull Cleaning Pause Water Quality Monitoring technical report is organized as follows:

- Section 1, **Introduction**, introduces the Hull Cleaning Pause Water Quality Monitoring Program, including background information and objectives.
- Section 2, **Methods**, describes the monitoring program design components, including hull cleaning inspection, field sampling, and analytical methodology, as well as quality assurance (QA) and quality control (QC) procedures used during water quality monitoring and data analysis.
- Section 3, **Results and Discussion**, presents and discusses hull cleaning inspection and water quality monitoring results, including an assessment of data quality and usability for the analytical chemistry results.
- Section 4, **Summary of Monitoring Program Findings**, summarizes findings and addresses the monitoring program question and objectives.
- Section 5, **References**, lists references for literature sources cited in this document.

2.0 METHODS

The monitoring program was designed to evaluate how a pause in hull cleaning of vessels with copper-based AFPs affects dissolved copper concentrations in SIYB. The Port adopted an amendment to its Hull Cleaning Ordinance (Article 4.14 of the District Code) to implement a temporary pause in hull cleaning. The ordinance amendment prohibited the hull cleaning of vessels with copper-based AFPs in SIYB from December 19, 2021 through February 9, 2022 (approximately eight weeks).

To assess the effects that a pause in hull cleaning could have on dissolved copper levels in the water, a concurrent 16-week monitoring program was designed and implemented in SIYB in accordance with the project-specific SAP and QAPP (Wood, 2021a). The program included the following components:

1. Hull cleaning inspections and visual observations: To ensure compliance with the Hull Cleaning Ordinance amendment, Port staff conducted frequent inspections throughout SIYB during the Hull Cleaning Pause to look for hull cleaning activity and document visual observations of hull fouling and water conditions in the basin. Additionally, the Port established alternative locations to allow vessels with copper-based AFPs to be cleaned outside of SIYB during the Hull Cleaning Pause.
2. Weekly water quality monitoring: Surface water quality sampling was performed weekly for the duration of the 16-week monitoring program to evaluate concentrations of dissolved copper in SIYB before, during, and after the pause in hull cleaning.
3. Storm monitoring event: Stormwater sampling and surface water quality sampling was performed before and after one storm event during the monitoring program to evaluate potential effects of stormwater discharge on copper levels in SIYB and on the Hull Cleaning Pause monitoring results.

This section describes the methodology, as well as QA/QC procedures used throughout the monitoring program and subsequent data analyses.

2.1 Hull Cleaning Inspections and Visual Observations

The Hull Cleaning Pause inspection process included multiple phases: (1) check in/paperwork review, (2) dock walk inspections, and (3) enforcement, when necessary.

An inspection form was developed to document observations for each step of the inspection process. All parts of the inspection were completed while onsite. The process below summarizes inspection methods.

2.1.1 Check In/Paperwork Review

Inspectors notified the facility manager or dock master of their arrival and coordinated the paperwork review and inspection with that representative, as applicable. Inspectors reviewed the facility's check-in log to see which divers, if any, had accessed the facility that day, including those present at the time of inspection.

If divers were currently checked in or had been at that facility at any point during the day, inspectors recorded the diver name, hull cleaning company, and purpose of their activity as stated to the facility at check-in on the inspection form. Inspectors also reviewed the marina's check-in list to see whether cleaning may be occurring on vessels with non-copper hull paint.

Non-copper paints were confirmed and cleared for cleaning either prior to or during the Hull Cleaning Pause when either the marina manager, boat owner, or hull cleaning company provided documentation showing validation of non-copper paint for a specific vessel, along with facility and slip number, directly to Port staff. Port staff used the following tools to confirm the product was non-copper:

- Reviewed documentation verifying boatyard application of a non-copper paint;
- Compared provided product information with a list of commonly used confirmed non-copper paints in SIYB; or
- Performed online research to find additional information about the provided product to confirm its non-copper status.

When non-copper-painted vessels were confirmed, they were added to a list that was kept in the field binder, allowing inspectors to reference the paint status of a vessel in the field if divers were found cleaning the vessel during inspections.

2.1.2 Dock Walk Inspection

Upon arrival on the docks, inspectors conducted a broad and general assessment of the overall facility conditions in terms of topside and in-water activities, water conditions, and weather, and completed the "General Observations" section of the inspection form (see Appendix A).

Inspectors walked the dock slips to identify either the presence of hull cleaners conducting work[2] and/or dive tags/receipts left at slips as notification of a previous visit. Inspectors reviewed the business dive tags and recorded the information on the inspection form section, including date of visit, purpose of visit, company name, and slip number.

If divers were observed in the water, inspectors approached the vessel and observed their activities to see whether the diver was conducting hull cleaning or general vessel maintenance on non-copper AFP painted surfaces (such as the cleaning of propellers and/or zinc anode replacement). Inspectors inquired as to the divers' activities and requested to see their Port-authorized card and check the Port-generated authorized list for their name and business.

If cleaning was occurring on a pre-authorized non-copper hull, inspectors made note and continued their dock walk. If it appeared that hull cleaning was occurring on a vessel that may have copper paint, the diver was instructed by the inspector to stop work and exit the water. Documentation showing proper verification of non-copper paint was required to be provided to

2 Divers were permitted in the water to conduct routine maintenance (e.g., zinc anode replacement, engine maintenance) or to clean vessels with Port-verified non-copper hull paints.

the Port staff before cleaning activities could be resumed. The enforcement process was initiated if the hull cleaner and/or vessel owner were not able to provide hull paint verification.

Upon concluding the dock walk, inspectors checked out with the marina manager/dock master and discussed any discrepancies, including findings of hull cleaner activity on vessels with copper paints, or on vessels with potential non-copper paints that had not provided sufficient documentation.

2.1.3 Enforcement

The inspection process included steps for identifying instances that would trigger enforcement, if it was confirmed that a vessel with copper AFP was being cleaned. The process included a coordination step between Port staff and marina managers to identify the boater and obtain the needed information to begin enforcement procedures. It is important to note that for the entire inspection program, proper documentation of non-copper paints was provided in each instance of the cleaning that was observed in the field. As a result, no citations were issued.

2.1.4 Visual Observations for Marine Growth

Visual observations for marine growth were completed by inspectors throughout the monitoring program. Various vessels were photographed routinely during the monitoring program. Example photographs showing the steady increase in marine growth on vessel hulls over the course of the Hull Cleaning Pause are included in Section 3.1.2.

2.1.5 Alternative Cleaning Locations

During the Hull Cleaning Pause, boaters were able to clean their vessels outside of the SIYB if desired. The Port identified and advertised the following options for boaters who wanted to keep their hulls clean during the Hull Cleaning Pause.

- <u>Coordination with the local boatyards</u> – Boatyards were willing to have boaters contact them to schedule a haul-out for cleaning. Intrepid Landing offered special rates during the Hull Cleaning Pause to haul out and wash vessels from SIYB using a model of hauling out, cleaning, and putting vessels back into the water within a couple of hours. In addition to the special rates, the Port offered a subsidy that covered half the cost, making this a cost-effective alternative for power boats up to 40 feet and sailboats up to 45 feet. In total, approximately eight boaters utilized cleaning at Intrepid Landing.
- <u>Encouragement of vessel use during the Hull Cleaning Pause</u> – Boaters were encouraged to use their vessels during the Hull Cleaning Pause period as an alternative to hull cleaning. It has been established that the amount of fouling on a vessel hull can be reduced by regular use of a vessel.

Additionally, boaters were able to make their own arrangements for cleaning outside of SIYB if they chose to do so; however, tracking was not included as part of the inspection program.

2.2 Water Quality Monitoring Program

The water quality monitoring program included weekly dissolved copper monitoring before, during, and after the Hull Cleaning Pause, as well as a supplemental storm monitoring event. Detailed monitoring procedures, including monitoring station locations, timeline, sample collection, and analytical methods, are provided in the following subsections.

2.2.1 Monitoring Station Locations

Samples were collected weekly from 13 core monitoring stations in SIYB and two reference stations outside of SIYB (Table 2-1, Figure 2-1). A subset of the core monitoring stations and both reference stations were co-located with the stations monitored annually for TMDL compliance (SIYB-1 through SIYB-6, SIYB-REF-1, and SIYB-REF-2). Additional core monitoring stations were selected at the ends of docks along the outer edges of marinas[3] and the main channel of SIYB to measure changes in dissolved copper concentrations that may result from a pause in hull cleaning activities. Samples were also collected biweekly from seven additional enhanced monitoring stations located within the inner portions of the marinas to provide supplemental data at a higher resolution and in closer proximity to vessels than the stations on the outer edge of the marinas along and within the main channel (Table 2-1, Figure 2-1).

The effect of a single large storm event on the influx of total and dissolved copper from stormwater was assessed by collecting samples from two outfalls located along the northwestern shoreline in the central region within SIYB (Table 2-2, Figure 2-2). Samples were also collected from core monitoring and reference stations after the storm to assess the effects of stormwater runoff on dissolved and total copper concentrations in the surface waters within SIYB.

Monitoring station coordinates are provided in Table 2-1 and depicted in Figure 2-1 for the core and enhanced monitoring stations and in Table 2-2 and Figure 2-2 for the outfalls. All stations were located using the Differential Global Positioning System. Weekly samples were collected either by dock or by vessel, as indicated in Table 2-1. Outfall samples were collected from land. To the greatest extent possible, samples were collected within approximately ±3 meters of the target coordinates.

[3] Core monitoring stations were placed within or in the vicinity of each marina and yacht club in SIYB, as depicted in Figure 2-1.

Table 2-1.
Monitoring Station Target Coordinates – Weekly Monitoring

Collection Strategy	Station Type	Station ID[a]	Collection Order	Latitude	Longitude
Vessel	Reference	C-REF-2/SIYB-REF-2	1	32.70926	-117.22544
	Reference	C-REF-1/SIYB-REF-1	2	32.70406	-117.23232
	Enhanced	E-20	3[b]	32.71154	-117.23218
	Core	C-12/SIYB-5	4	32.71217	-117.23297
	Enhanced	E-19	5[b]	32.71517	-117.23316
	Core	C-10	6	32.71586	-117.23270
	Core	C-11	7	32.71448	-117.23569
	Core	C-9	8	32.71742	-117.23372
	Core	C-8/SIYB-4	9	32.71683	-117.23203
	Core	C-7/SIYB-3	10	32.71550	-117.22989
	Enhanced	E-17	11[b]	32.71722	-117.22882
	Core	C-5	12	32.71632	-117.22906
	Core	C-1/SIYB-1	13	32.71821	-117.22601
Dock	Core	C-13/SIYB-6	1	32.70858	-117.23514
	Enhanced	E-18	2[b]	32.71434	-117.22819
	Core	C-6/SIYB-2	3	32.71412	-117.22921
	Enhanced	E-16	4[b]	32.71557	-117.22658
	Core	C-4	5	32.71623	-117.22729
	Enhanced	E-15	6[b]	32.71646	-117.22573
	Core	C-3	7	32.71699	-117.22635
	Enhanced	E-14	8[b]	32.71739	-117.22452
	Core	C-2	9	32.71783	-117.22538

Notes:
C- = core; E- = enhanced; ID = identifier; REF- = reference; SIYB = Shelter Island Yacht Basin; TMDL = Total Maximum Daily Load
a. A subset of the core monitoring stations and both reference stations were co-located with the stations monitored annually for TMDL compliance. These stations include both the Hull Cleaning Pause station ID and the SIYB TMDL station ID for reference.
b. Enhanced stations were sampled biweekly and therefore were excluded from collection order during core monitoring events.

Table 2-2.
Monitoring Station Target Coordinates – Storm Event Outfall Monitoring

Collection Strategy	Station Type	Station ID	Latitude	Longitude
Landside	Stormwater Outfall	OF-1	32.71603	-117.23550
	Stormwater Outfall	OF-2	32.71892	-117.23144

Notes:
ID = identifier; OF- = outfall

Figure 2-1. Target Core and Enhanced Monitoring Stations

Notes: BCM = Bay Club Marina; CN = Crow's Nest Yachts; GCA = Gold Coast Anchorage; HMM; Half Moon Marina; KKM = Kona Kai Marina; LPYC = La Playa Yacht Club; SDYC = San Diego Yacht Club; SGYC = Silver Gate Yacht Club; SIYB = Shelter Island Yacht Basin; SIM = Shelter Island Marina; SWYC = Southwestern Yacht Club; TL = Tonga Landing

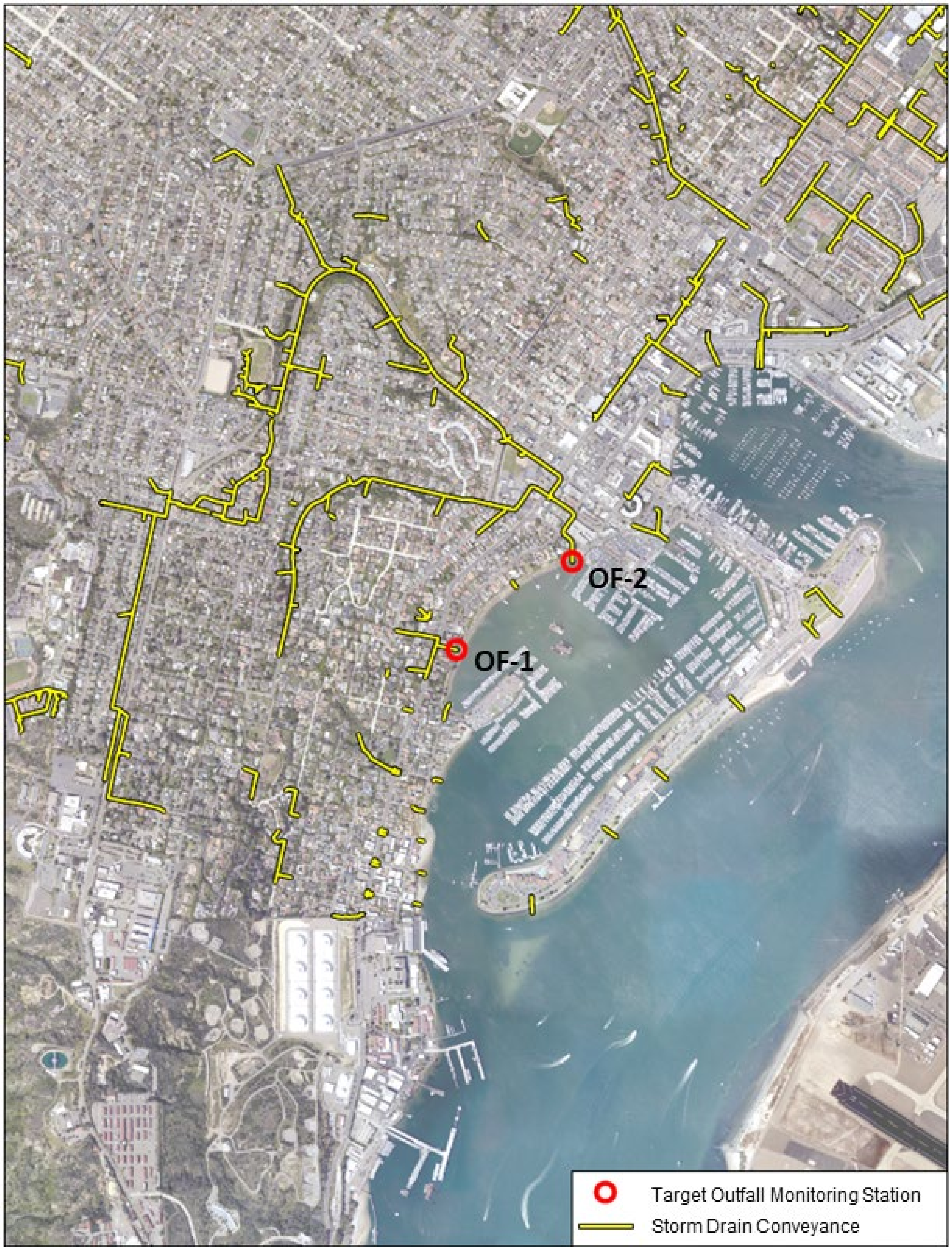

Figure 2-2. Target Outfall Monitoring Stations

2.2.2 Monitoring Timeline

The Hull Cleaning Pause monitoring program was divided into three phases spanning 16 weeks:

- **Pre-Pause** phase included weekly sampling for four weeks prior to the Hull Cleaning Pause.
- **Pause** phase included weekly sampling for eight weeks during the Pause.
- **Post-Pause** phase included weekly sampling for four weeks after the Pause.

Throughout the 16-week monitoring program, core and reference stations were sampled weekly, while enhanced stations were sampled biweekly (i.e., every other week; Table 2-3), to assess dissolved copper concentrations over time. Samples were collected at roughly the same time each week (generally Monday or Tuesday mornings), avoiding sampling immediately following rain events to minimize potential effects of stormwater runoff on sampling results. Because samples were collected weekly over a 16-week period, it was infeasible to collect samples at each individual station at the same tidal stage. However, the length of the monitoring program allowed for samples to be collected over a broad range of tidal cycles to be more representative of overall conditions in SIYB. To randomize the effects of tides over the course of the monitoring program, monitoring stations were sampled in the same order during each monitoring event. Sample collection times over the tidal cycle for each sampling date are shown in Figures 2-3 and 2-4.

In addition to weekly sampling, one qualifying storm event (i.e., event producing greater than 0.25 inch of rain) was sampled during the monitoring program to assess potential effects of stormwater runoff on copper levels in SIYB. Storm event sampling was conducted over three consecutive days (December 13–15, 2021) during Week 4 of the Pre-Pause phase, as follows:

- December 13, 2021: Pre-storm sampling at core and reference stations was conducted the day prior to the storm in conjunction with the routine weekly monitoring.
- December 14, 2021: The storm produced approximately 1 inch of rainfall at SIYB. Two major outfalls that discharge into SIYB (Figure 2-2) were sampled during the storm.
- December 15, 2021: Post-storm sampling at core and reference stations was conducted the day following the storm, during a similar tidal height and stage (outgoing tide) as the pre-storm sampling (Figure 2-4).

The stations sampled during each week of the monitoring program are outlined in Table 2-3.

Table 2-3.
Stations Sampled During Each Monitoring Event

Stations Sampled	Sampling Date															
	Pre-Pause (11/22/21–12/18/21)				Pause (12/19/21–2/9/22)								Post-Pause (2/10/22–3/8/22)			
	W1 11/22	W2 11/30	W3 12/7	W4 12/13	W5 12/20	W6 12/28	W7 1/4	W8 1/11	W9 1/19	W10 1/25	W11 1/31	W12 2/9	W13 2/14	W14 2/21	W15 3/1	W16 3/8
Core + Ref	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Enhanced		X		X		X		X		X		X		X		X
Storm[a]				X												

Notes:
"X" indicates samples were collected; W = week; core stations include Stations C-1 through C-13; enhanced stations include Stations E-14 through E-20; reference (Ref) stations include Stations C-REF-1 and C-REF-2 (Table 2-1 and Figure 2-1).
a. Pre-storm receiving water samples were collected on 12/13/21 during routine weekly sampling. Outfall samples were collected during the storm on 12/14/21. Post-storm receiving water samples were collected on 12/15/21.

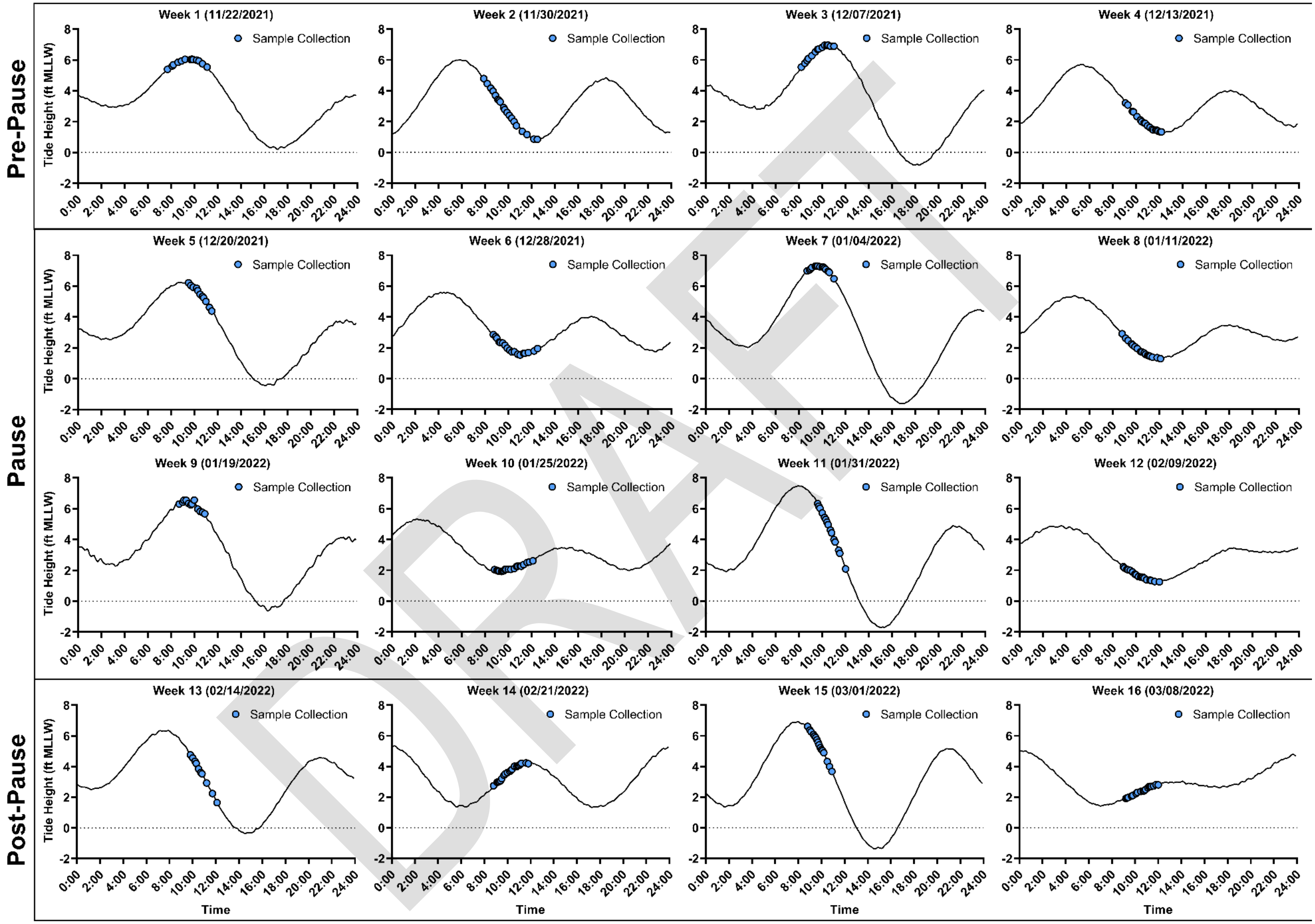

Figure 2-3. Sample Collection Times Over Tidal Cycles – Weekly Monitoring

Notes: ft = foot/feet; MLLW = mean lower low water; tide data obtained from National Oceanic and Atmospheric Administration (NOAA) San Diego Bay Station 9410170.

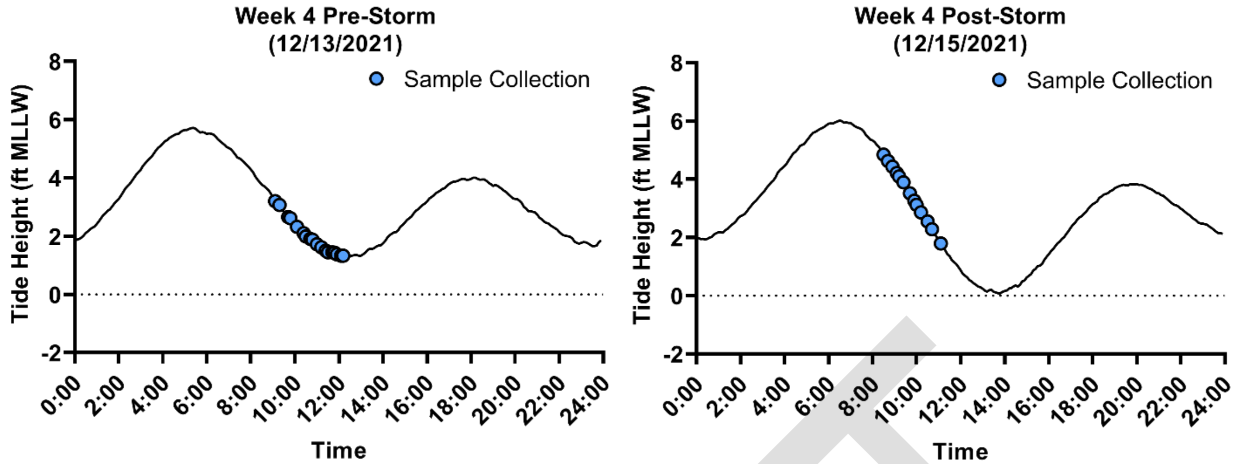

Figure 2-4. Sample Collection Times Over Tidal Cycles – Storm Monitoring Event

Notes: ft = foot/feet; MLLW = mean lower low water; tide data obtained from National Oceanic and Atmospheric Administration (NOAA) San Diego Bay Station 9410170.

2.2.3 Sample Collection

Samples were collected by two field teams; one team sampled directly from the docks, and one team sampled from a vessel[4], each using the same sampling techniques. Samples were collected starting at the reference stations and continuing from the mouth of the basin toward the head of the basin. Samples were collected in the same order during each monitoring event to randomize the effects of tides over the course of the 16-week monitoring program. The specific sample collection order for each field team is identified in Table 2-1 (Section 2.2.1).

Upon arrival at each monitoring station, field teams measured the temperature and salinity of the surface water (i.e., 1 meter below the surface) using calibrated YSI ProDSS water quality meters. Water clarity was also estimated using Secchi disks. In addition, field observations were made at each monitoring station for hull cleaning activities or other conditions/activities that may impact water quality (if observed). Field data sheets, including field measurements and detailed field notes, are in Appendix B.

During each monitoring event, discrete surface water samples (i.e., 1 meter below the surface) were collected at each monitoring station using a Niskin bottle deployed from the dock or vessel[2] in accordance with Surface Water Ambient Monitoring Program (SWAMP)-defined "Clean Hands/Dirty Hands" techniques (California State Water Resources Control Board [SWRCB], 2014) and the project-specific and approved SAP/QAPP (Wood, 2021a). As described in Section 2.2.2, core and reference monitoring stations were sampled weekly and enhanced monitoring stations were sampled biweekly for the duration of the monitoring program. Storm event sampling included collection of grab samples from two outfalls during the storm, as well as collection of surface water samples from the core monitoring and reference stations after the storm.

Upon collection, all water samples were immediately field-filtered through a 0.45-micrometer (µm) glass fiber filter using a bottle-top vacuum filtration system and transferred to labeled containers

4 The vessel used for monitoring is coated with a non-biocide hull paint (i.e., does not contain copper or other biocides).

for analysis of dissolved copper. For the post-storm monitoring event, separate unfiltered samples were collected for analysis of total copper (outfalls and receiving water) and total suspended solids (TSS; outfalls only).

All water samples were logged on chain-of-custody (COC) forms and placed in coolers on ice. Samples were stored on ice and in the dark until delivered to Weck Laboratories (Weck) the following day for analyses. Samples for copper analyses were preserved upon arrival to Weck.

Field photographs from weekly water quality monitoring and storm monitoring events are included in Figures 2-5 and 2-6, respectively.

2.2.4 Equipment Decontamination and Cleaning

The Niskin bottles (one per sampling team) were cleaned using Alconox and thoroughly rinsed with deionized water prior to each monitoring event. Upon deployment at each monitoring station, the Niskin bottles were rinsed thoroughly with site water and allowed to equilibrate at the sampling depth (i.e., 1 meter below the surface) for at least one minute prior to sample collection. After collection, water samples were transferred from the Niskin bottles to laboratory-certified, contaminant-free sample bottles using “Clean Hands/Dirty Hands” techniques (SWRCB, 2014). In between sample collection at each monitoring station, each Niskin bottle was stored in a plastic-lined tub.

Photo A. To ensure compliance with the Ordinance, Port staff conducted frequent inspections throughout SIYB during the Pause to look for hull cleaning activity and document visual observations of the water in the basin.

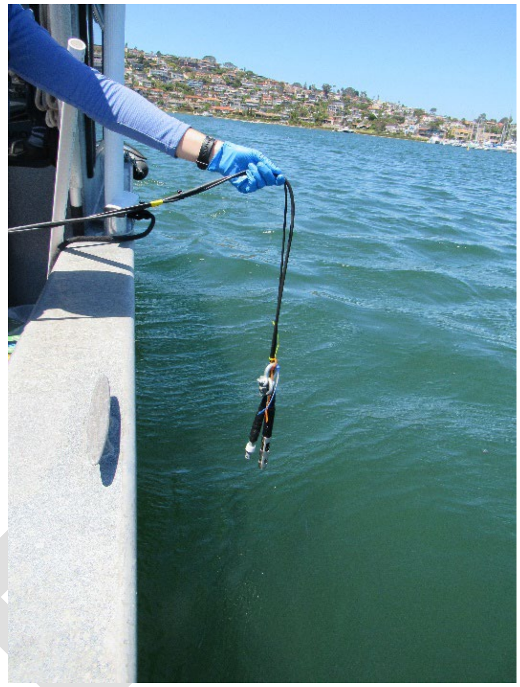

Photo B. Surface water quality readings of temperature and salinity were taken at each monitoring station using a YSI ProDSS water quality meter.

Photo C. Surface water samples were collected using a Niskin bottle and following clean sampling techniques.

Photo D. Water samples were filtered in the field immediately after collection for analysis of dissolved copper.

Figure 2-5. Weekly Water Quality Monitoring Field Photographs

Photo A. The storm event sampled during Week 4 produced approximately 1 inch of rainfall on December 14, 2021. Stormwater runoff from OF-1 at the time of sampling is depicted above.

Photo B. A large plume of particulates was visible in SIYB at the OF-1 discharge point.

Photo C. Stormwater grab samples were collected from two outfalls (OF-1 depicted in Photo A and OF-2 depicted in Photo C above).

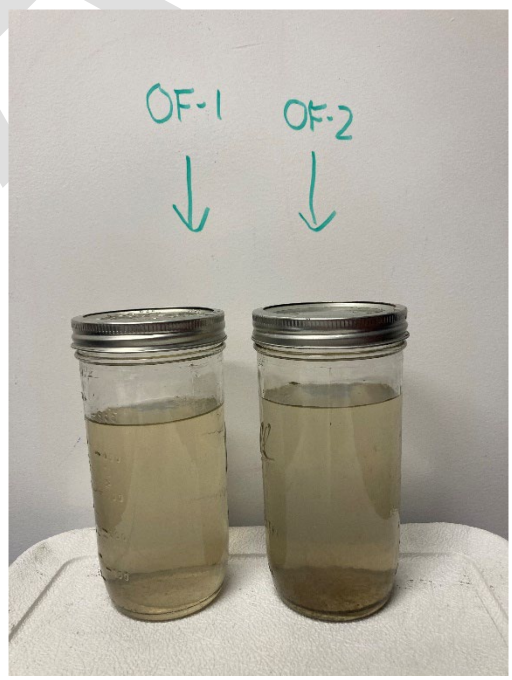

Photo D. Stormwater samples were analyzed for dissolved copper (field-filtered), total copper, and total suspended solids.

Figure 2-6. Storm Monitoring Event Field Photographs

2.2.5 Analytical Methods

Field measurements of temperature and salinity were taken at each station during each monitoring event. After each monitoring event, surface water samples were transported to the analytical laboratory (Weck) via courier under customary COC protocols. All weekly surface water samples were analyzed for dissolved copper. For the post-storm monitoring event, samples were also analyzed for total copper (outfalls and receiving water) and TSS (outfalls) to account for particulate copper that may be present in stormwater discharge. All chemical analyses were conducted by Weck in accordance with the certified United States Environmental Protection Agency (USEPA) analytical methods or Standard Methods (SM) listed in Table 2-4. The laboratory analytical methods and target method detection and reporting limits are specified in Table 2-4. Actual final method detection and reporting limits are provided in the chemistry laboratory reports in Appendix C.

Table 2-4.
Analytical Methods and Target Method Detection and Reporting Limits

Water Quality Measurement	Method	Method Detection Limit	Reporting Limit	Instrument Sensitivity
Salinity	Field-Measured (YSI ProDSS)	N/A	N/A	± 0.1 ppt
Temperature	Field-Measured (YSI ProDSS)	N/A	N/A	± 0.1 °C
Total Copper (seawater)	USEPA 1640	0.0038 µg/L	0.010 µg/L	N/A
Dissolved Copper (seawater)	USEPA 1640	0.0038 µg/L	0.010 µg/L	N/A
Total Copper (stormwater)	USEPA 200.8	0.13 µg/L	0.50 µg/L	N/A
Dissolved Copper (stormwater)	USEPA 200.8	0.13 µg/L	0.50 µg/L	N/A
Total Suspended Solids (stormwater)	SM 2540D	N/A	5 mg/L	N/A

Notes:
°C = degree(s) Celsius; µg/L = microgram(s) per liter; mg/L = milligram(s) per liter; N/A = not applicable; ppt = part(s) per thousand; SM = Standard Method; USEPA = United States Environmental Protection Agency; YSI = YSI Incorporated

2.3 Quality Assurance and Quality Control

This section describes the QA/QC procedures for all field activities and laboratory analyses. Specific QA/QC procedures are provided in detail in the approved project-specific SAP/QAPP (Wood, 2021a).

2.3.1 Field QA/QC

Strict QA/QC procedures were followed throughout the monitoring program, from mobilization through delivery of samples to the analytical laboratory to minimize the possibility of compromising sample integrity. The sample collection team was trained in and followed field sampling standard operating procedures (SOPs), as described in the project-specific SAP and QAPP (Wood, 2021a). Additionally, Port-approved field QA logs were used during the first monitoring event, and periodically thereafter at a subset of monitoring stations, to ensure that all field collection procedures were consistent between monitoring events and among stations, and all required field data were recorded properly (see Appendix B).

Field water quality meters were checked and calibrated in accordance with the manufacturer's specifications prior to each monitoring event. During sample collection, field team members wore powder-free nitrile gloves and avoided contamination of samples at all times by using the SWAMP "Clean Hands/Dirty Hands" techniques. All samples were collected in laboratory-supplied, laboratory-certified, contaminant-free sample bottles.

As required by SWAMP protocols, a co-located field duplicate (hereafter referred to as a field duplicate) was collected at one randomly selected monitoring station during each monitoring event. Each field duplicate sample consisted of a second sample collected for analysis to assess variability in sampling procedures, as well as ambient conditions. The field duplicate samples were analyzed for the same suite of parameters used for the primary test samples. In addition to the field duplicate samples, one equipment rinse blank[5] and one field blank were collected for each monitoring event.

Customary COC procedures were used for all samples throughout the collection, transport, and analytical processes. Completed COC forms are provided in the laboratory reports in Appendix C. The project-specific SAP/QAPP (Wood, 2021a) provides more information regarding COC procedures.

2.3.2 Laboratory Analytical QA/QC

The analytical laboratory (Weck) is accredited by the National Environmental Laboratory Accreditation Program (NELAP; Certificates #4047-008 and #4047-009) and/or California Environmental Accreditation Program (ELAP; Certificate #1132) for the specific analytical methods that were performed at the time the samples were analyzed. The QA objectives for chemical analyses conducted by Weck are provided in their laboratory QA manual and in the project-specific SAP/QAPP (Wood, 2021a). Results of all laboratory QA/QC analyses are provided in the laboratory reports in Appendix C. Any QC samples that failed to meet the specified QA/QC criteria in the methodology or QAPP were identified, and the corresponding data were appropriately qualified in the final laboratory reports. A QA/QC summary discussing any QA/QC issues encountered and associated corrective actions is included in Section 3.5 of this report.

2.4 Data Review, Management, and Analysis

Field and laboratory data were reviewed for completeness and accuracy prior to data analysis and reporting and were stored in a project-specific Excel database, as described further below.

2.4.1 Data Review

After each monitoring event, field data sheets were checked for completeness and accuracy by the field staff and field project manager (PM). In addition, all sample COC forms were checked

5 Because two Niskin bottles were required (one for each sampling team), the equipment rinse blanks were collected from one Niskin bottle per week, alternating between bottles over the 16-week monitoring program.

against sample labels prior to sample transport to the analytical laboratory. In the analytical laboratory, technicians documented sample receipt in laboratory logbooks, and samples were logged into the electronic Laboratory Information Management System (LIMS) for sample tracking purposes to ensure that holding times were met and samples were efficiently analyzed. Logbooks were maintained for each instrument to provide hardcopy documentation of analytical runs, and data generated by each instrument were directly uploaded to the LIMS for data review and processing. Data validation was performed within the LIMS and included application of both performance-based and project-specific QC criteria to reject or accept specific data. Data for laboratory analyses were entered directly onto data sheets. The technician who generated the data had primary responsibility for the accuracy and completeness of the data.

All data were subsequently reviewed and verified by each laboratory section supervisor and released to the laboratory PM to determine whether data quality objectives had been met for final reporting, and whether appropriate corrective actions had been taken when necessary. Any necessary corrective actions were coordinated with the laboratory project manager, the laboratory QA/QC director, and the Wood PM for resolution.

2.4.2 Data Management

After completion of the data review by the analytical laboratory PM, results were forwarded to Wood in Adobe Portable Document Format (PDF) for internal review by the Wood Analytical QA Officer. Analytical reports received from the laboratory for each monitoring event are included in Appendix C. All reviewed analytical data were compiled into an Excel database and uploaded into the California Environmental Data Exchange Network (CEDEN).

2.4.3 Data Analysis

Following internal QA/QC review of the analytical data by Wood's QA Officer, raw data were summarized in data tables and figures presented in Section 3 and Appendix D. All data included in summary tables and figures were compared with raw laboratory reports to ensure completeness and accuracy.

This 16-week monitoring program was designed to measure and compare dissolved copper concentrations before, during, and after the Hull Cleaning Pause. Data analysis included a comparison of the dissolved copper concentrations during each phase of the monitoring program for (1) the basin as a whole (i.e., basin-wide averages), (2) individual monitoring stations, and (3) inner, middle, and outer basin regions. Basin regions were chosen based on the results of the 2018 Time Series Study (Amec Foster Wheeler Environment & Infrastructure, Inc. [Amec Foster Wheeler], 2018), which suggested that tides affect dissolved copper levels to varying degrees in the inner, middle, and outer basin. Figure 2-7 shows how monitoring stations were grouped for analyses by region. Note that lines delineating each region are arbitrary and are intended only to outline station groupings.

Figure 2-7. Basin Region Designations for Each Monitoring Station

3.0 RESULTS AND DISCUSSION

This section discusses results from the Hull Cleaning Pause Water Quality Monitoring, including dock inspections, weekly monitoring, and storm monitoring event results.

3.1 Hull Cleaning Inspections and Visual Observations

Daily hull cleaning inspections were performed during the eight-week Hull Cleaning Pause period (December 19, 2021 through February 9, 2022), except for Christmas Day, New Year's Day, and January 15, 2022, when a tsunami warning was issued. A total of 217 inspections were performed in SIYB, including all SIYB marinas, yacht clubs, and the Port's transient dock.

3.1.1 General Facility and Water Quality Conditions

General facility conditions were recorded, including general facility activity, topside maintenance activity, weather conditions, and general water quality conditions.[6] General facility activity was categorized as quiet (10 or fewer people), moderate (10 to 50 people), or busy (more than 50 people) based on the number of people observed throughout the docks at a facility at the time of inspection. Throughout the Hull Cleaning Pause, general facility activity varied with 122 (58%) inspections noting quiet conditions, 81 (38%) inspections noting moderate conditions, and 8 (4%) inspections noting busy conditions (Figure 3-1). Dates and locations for the eight inspections defined as "busy" are detailed in Table 3-1, along with other visual observations.

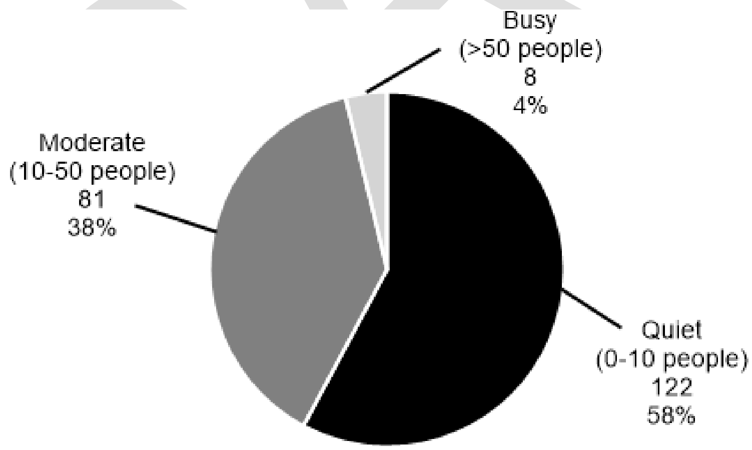

Figure 3-1. General Facility Activity During Hull Cleaning Pause Inspections

The presence of topside maintenance was also evaluated during the Hull Cleaning Pause. Topside maintenance activity was categorized as quiet (0 to 3 vessels), moderate (4 to 10 vessels), or busy (more than 10 vessels) based on the number of vessels where topside maintenance was observed. A total of 149 (71%) inspections noted quiet maintenance, 45 (21%) inspections noted moderate maintenance, and 17 (8%) noted busy maintenance activities (Figure 3-2). Dates and locations for the 17 inspections defined as "busy" are detailed in Table 3-1, along with other visual observations.

[6] It should be noted that visual observations of general facility activity and topside maintenance were not recorded for six of the 217 inspections and therefore are not included in the following calculations.

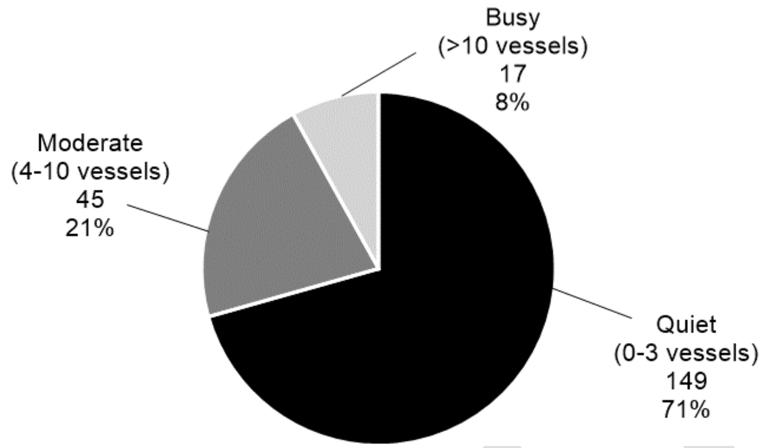

Figure 3-2. Topside Maintenance Activity During Hull Cleaning Pause Inspections

Weather conditions were recorded at the time of inspections. A total of 14 inspections noted rainfall observed within the prior 72 hours, as detailed in Table 3-1. General water quality conditions within the facilities at the time of inspection were also recorded, including noticeable floatables, vegetation, and odors.[7] Of the 210 total visual observations recorded for floatables, no inspections noted visible sewage, four (2%) noted visible trash, and 13 (6%) noted visible foam within the facilities at the time of inspection (Figure 3-3). No visible floatables were observed at the time of the remaining 193 (92%) inspections. Of the 210 total visual observations recorded for vegetation, 10 (5%) noted excessive vegetation, 11 (5%) noted limited vegetation, and four (2%) noted normal vegetation within the facility at the time of inspection (Figure 3-3). No vegetation was observed during the remaining 185 (88%) inspections.

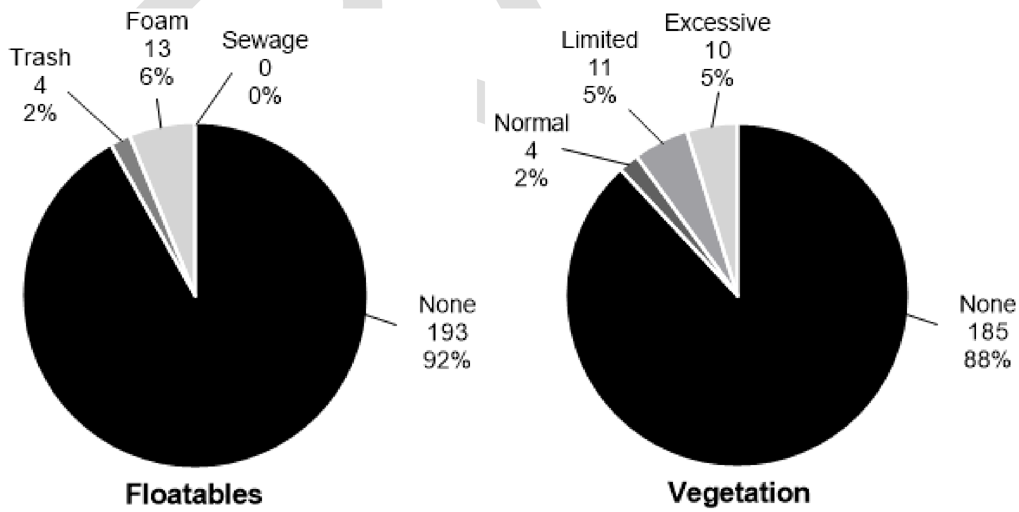

Figure 3-3. Floatables and Vegetation Observed During Hull Cleaning Pause Inspections

7 It should be noted that visual observations of general water quality conditions were not recorded for seven of the 217 inspections and therefore are not included in the following calculations.

Table 3-1.
Summary of Significant Visual Observations During the Hull Cleaning Pause

Inspection Date & Time		Location	Marina Activity	Topside Maintenance	Floatables	Vegetation
12/19/2021	11:00	Kona Kai Marina	Moderate (10-50 people)	Quiet (0-3 vessels)	None	***Limited***
12/19/2021	10:00	Silver Gate Yacht Club	Quiet (0-10 people)	Quiet (0-3 vessels)	None	***Limited***
12/20/2021	11:45	San Diego Yacht Club	Moderate (10-50 people)	***Busy (>10 vessels)***	None	***Limited***
12/20/2021	8:00	Kona Kai Marina	Moderate (10-50 people)	Moderate (4-10 vessels)	***Foam***	None
12/20/2021	9:30	Shelter Island Marina	Moderate (10-50 people)	Moderate (4-10 vessels)	***Trash***	None
12/21/2021	10:00	Kona Kai Marina	Moderate (10-50 people)	***Busy (>10 vessels)***	None	None
12/21/2021	10:45	Silver Gate Yacht Club	Quiet (0-10 people)	Quiet (0-3 vessels)	None	***Excessive***
12/21/2021	12:00	Half Moon Marina	Quiet (0-10 people)	Quiet (0-3 vessels)	None	None
12/22/2021	10:55	Kona Kai Marina	Moderate (10-50 people)	***Busy (>10 vessels)***	None	***Limited***
12/23/2021	8:00	Southwestern Yacht Club	Quiet (0-10 people)	Quiet (0-3 vessels)	***Foam***	None
12/23/2021	11:00	Bay Club Marina	Quiet (0-10 people)	Quiet (0-3 vessels)	None	***Limited***
12/23/2021	10:30	Kona Kai Marina	Moderate (10-50 people)	Moderate (4-10 vessels)	None	***Limited***
12/24/2021	10:20	Half Moon Marina	Quiet (0-10 people)	Quiet (0-3 vessels)	None	***Limited***
12/24/2021	8:00	Kona Kai Marina	Quiet (0-10 people)	Quiet (0-3 vessels)	***Foam***	***Excessive***
12/24/2021	10:00	Bay Club Marina	Quiet (0-10 people)	Quiet (0-3 vessels)	***Foam***	***Excessive***
12/24/2021	11:00	San Diego Yacht Club	Moderate (10-50 people)	Quiet (0-3 vessels)	None	***Excessive***
12/26/2021	13:30	Shelter Island Marina	***Busy (>50 people)***	Quiet (0-3 vessels)	None	None
12/26/2021	12:15	Kona Kai Marina	Moderate (10-50 people)	Quiet (0-3 vessels)	None	***Limited***
12/27/2021	9:00	Kona Kai Marina	Quiet (0-10 people)	Moderate (4-10 vessels)	***Foam***	None
12/30/2021	12:30	Southwestern Yacht Club	Moderate (10-50 people)	Moderate (4-10 vessels)	None	***Limited***
12/31/2021	9:30	San Diego Yacht Club	***Busy (>50 people)***	***Busy (>10 vessels)***	***Foam***	***Excessive***
12/31/2021	8:15	Gold Coast Marina	Quiet (0-10 people)	Quiet (0-3 vessels)	None	***Limited***
1/3/2022	9:00	Kona Kai Marina	Moderate (10-50 people)	***Busy (>10 vessels)***	None	None
1/3/2022	11:30	Half Moon Marina	Quiet (0-10 people)	Quiet (0-3 vessels)	None	***Excessive***
1/3/2022	9:00	Shelter Island Marina	***Busy (>50 people)***	Quiet (0-3 vessels)	None	None

Notes:
Shaded rows indicate inspections in which rain was observed in the last 72 hours.
Bold and Italicized rows indicate significant visual observations observed at the time of inspection.

Table 3-1. (continued)
Summary of Significant Visual Observations During the Hull Cleaning Pause

Inspection Date & Time		Location	Marina Activity	Topside Maintenance	Floatables	Vegetation
1/4/2022	8:30	Kona Kai Marina	Moderate (10-50 people)	Moderate (4-10 vessels)	***Foam***	Normal
1/6/2022	8:15	San Diego Yacht Club	Moderate (10-50 people)	***Busy (>10 vessels)***	None	None
1/6/2022	10:00	Kona Kai Marina	Moderate (10-50 people)	***Busy (>10 vessels)***	None	None
1/7/2022	11:15	Kona Kai Marina	Moderate (10-50 people)	***Busy (>10 vessels)***	None	None
1/7/2022	9:00	Southwestern Yacht Club	Quiet (0-10 people)	Quiet (0-3 vessels)	None	***Excessive***
1/16/2022	9:00	San Diego Yacht Club	***Busy (>50 people)***	Quiet (0-3 vessels)	None	None
1/17/2022	9:45	Kona Kai Marina	Moderate (10-50 people)	***Busy (>10 vessels)***	***Trash***	Normal
1/17/2022	10:45	Shelter Island Marina	Moderate (10-50 people)	***Busy (>10 vessels)***	None	None
1/17/2022	NR	Bay Club Marina	Quiet (0-10 people)	Quiet (0-3 vessels)	***Trash***	Normal
1/18/2022	11:15	Kona Kai Marina	***Busy (>50 people)***	***Busy (>10 vessels)***	***Trash***	***Excessive***
1/19/2022	11:25	San Diego Yacht Club	***Busy (>50 people)***	***Busy (>10 vessels)***	None	None
1/21/2022	10:00	San Diego Yacht Club	Moderate (10-50 people)	Moderate (4-10 vessels)	***Foam***	Normal
1/26/2022	13:09	Kona Kai Marina	Moderate (10-50 people)	***Busy (>10 vessels)***	None	None
1/27/2022	10:00	San Diego Yacht Club	Moderate (10-50 people)	***Busy (>10 vessels)***	None	None
1/28/2022	10:15	Silver Gate Yacht Club	Quiet (0-10 people)	Quiet (0-3 vessels)	***Foam***	***Excessive***
1/28/2022	8:50	Kona Kai Marina	Moderate (10-50 people)	Moderate (4-10 vessels)	***Foam***	***Excessive***
1/30/2022	8:30	San Diego Yacht Club	***Busy (>50 people)***	Quiet (0-3 vessels)	None	None
2/4/2022	12:40	Kona Kai Marina	Moderate (10-50 people)	***Busy (>10 vessels)***	None	None
2/4/2022	12:00	Shelter Island Marina	Moderate (10-50 people)	***Busy (>10 vessels)***	None	None
2/5/2022	9:15	San Diego Yacht Club	***Busy (>50 people)***	Quiet (0-3 vessels)	None	None
2/5/2022	10:45	Southwestern Yacht Club	Moderate (10-50 people)	Quiet (0-3 vessels)	***Foam***	None
2/6/2022	10:45	Silver Gate Yacht Club	Quiet (0-10 people)	Quiet (0-3 vessels)	***Foam***	None
2/6/2022	10:01	Shelter Island Marina	Quiet (0-10 people)	Quiet (0-3 vessels)	***Foam***	***Limited***
2/7/2022	12:35	Kona Kai Marina	Moderate (10-50 people)	***Busy (>10 vessels)***	None	None
Total Significant Observations		**49**	**8**	**17**	**17**	**21**

Notes:
Shaded rows indicate inspections in which rain was observed in the last 72 hours.
Bold and Italicized rows indicate significant visual observations observed at the time of inspection.
NR = not recorded

3.1.2 Diver Activity

During hull cleaning inspections, diver activity was recorded by reviewing check-in records, observing divers in the field, and recording the information from diver tags left on individual vessel slips after dive activity. Throughout the eight-week Hull Cleaning Pause, 342 instances were recorded of observed diver activity to conduct non-cleaning types of maintenance and/or to replace zinc anodes (Table 3-2). Figure 3-4 identifies the locations of all recorded dive tags during each quarter (Q1–Q4) of the Hull Cleaning Pause along with all confirmed non-copper hull cleanings.

Table 3-2.
Instances of Observed Diver Activity During the Hull Cleaning Pause

Source of Diver Activity Observation	Number of Observed Instances
Divers Encountered in the Field	50
Divers Checked In	68
Diver Tags Observed	224
Total Observed Instances	**342**

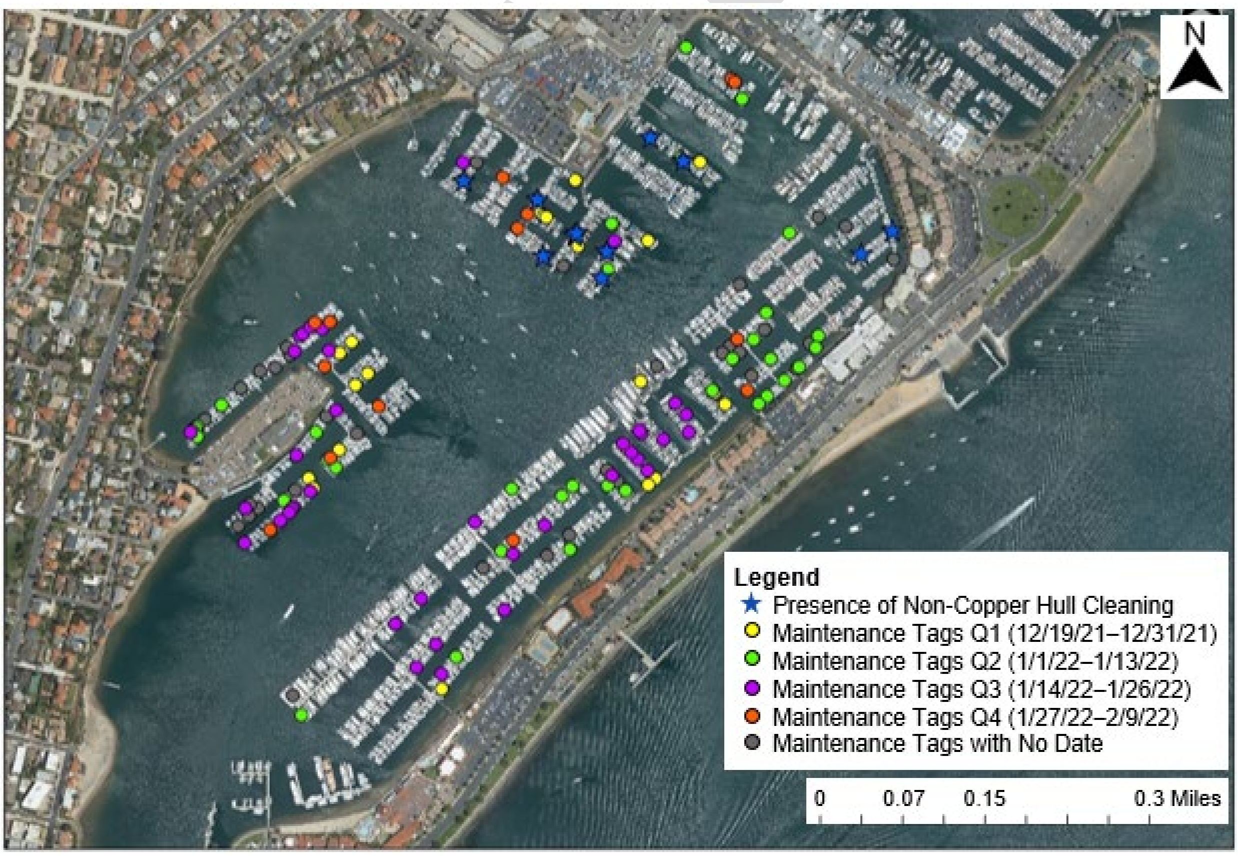

Figure 3-4. Map of Non-Copper Hull Cleanings and Diver Tags Observed During the Hull Cleaning Pause

Note: Each maintenance tag point symbolizes a single slip. Slips in which multiple dive tags were observed throughout the Hull Cleaning Pause are symbolized by the maintenance tag with the latest date.

In all instances in which diver activity was observed, efforts were made to ensure that the cleaning of hulls with copper-based AFPs was not occurring. These efforts included reviewing diver check-in records at a facility, corresponding with divers in the field, and documenting visual hull fouling observations. Of the 342 total instances of dive activity, 19 instances (6%) were confirmed cleaning of vessels with Port-verified non-copper paints. The remainder of observed diver activity (323; 94%) were confirmed to include routine maintenance activities only, such as replacing zincs and metals (Figure 3-5). No cleaning of vessel hulls coated copper-based AFPs was observed during any inspection during the Hull Cleaning Pause, and as a result, no enforcement actions were taken.

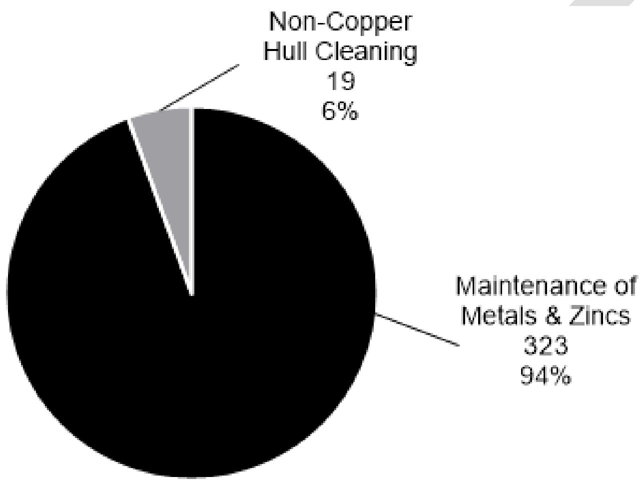

Figure 3-5. Characterization of Observed Diver Activity During the Hull Cleaning Pause

A total of 11 vessels with Port-verified, non-copper paints were observed to have been cleaned during the Hull Cleaning Pause. Two of the 11 vessels painted with non-copper paints were cleaned on three separate occasions, four of the 11 vessels painted with non-copper paints were cleaned on two separate occasions, and the remaining five vessels painted with non-copper paints were cleaned once for a total of 19 non-copper hull cleanings (Table 3-3).

Table 3-3.
Observed Instances of Non-Copper Hull Cleaning During the Hull Cleaning Pause

Date of Cleaning[a]	Location	Source of Observation
12/22/2021	San Diego Yacht Club	Diver Encountered in the Field
12/23/2021	San Diego Yacht Club	Observed Tag
12/28/2021	San Diego Yacht Club	Diver Encountered in the Field
12/28/2021	San Diego Yacht Club	Diver Encountered in the Field
12/28/2021	San Diego Yacht Club	Diver Encountered in the Field
12/30/2021	San Diego Yacht Club	Observed Tag
12/31/2021	San Diego Yacht Club	Diver Encountered in the Field
12/31/2021	San Diego Yacht Club	Diver Checked In
1/3/2022	Half Moon Marina	Diver Encountered in the Field
1/6/2022	San Diego Yacht Club	Diver Checked In
1/7/2022	San Diego Yacht Club	Diver Encountered in the Field
1/7/2022	San Diego Yacht Club	Observed Tag
1/17/2022	Half Moon Marina	Diver Encountered in the Field
1/19/2022	San Diego Yacht Club	Diver Checked In
1/24/2022	San Diego Yacht Club	Observed Tag
1/25/2022	San Diego Yacht Club	Observed Tag
2/1/2022	San Diego Yacht Club	Observed Tag
2/1/2022	San Diego Yacht Club	Observed Tag
2/4/2022	San Diego Yacht Club	Observed Tag

Notes:
a. A total of 11 vessels with approved non-copper paint were observed to have been cleaned during the Pause. Two of the 11 vessels were cleaned on three separate occasions, four of the 11 vessels were cleaned on two separate occasions, and the remaining five vessels were cleaned once for a total of 19 non-copper hull cleanings.

Inspection staff observed and documented the presence of fouling on vessels with copper-based AFPs during the Hull Cleaning Pause. Overall, general vessel observations suggested an obvious visual increase in fouling over time, confirming hull cleaning was not being performed on a wide-scale basis during the approximately eight-week Hull Cleaning Pause (Figure 3-6).

Figure 3-6. Photos of Fouling on Vessel Hulls During the Hull Cleaning Pause

February 9, 2022 (Last Day of Hull Cleaning Pause)

Figure 3-6 (continued). Photos of Fouling on Vessel Hulls During the Hull Cleaning Pause

3.2 Weekly Water Quality Monitoring

Weekly water quality monitoring events were conducted in SIYB for four weeks leading up to the Hull Cleaning Pause, eight weeks during the Pause, and four weeks following the Pause. Each monitoring event included collection of field water quality measurements and surface water samples for dissolved copper analysis. As discussed in Section 2.2.2, core monitoring stations and reference stations were sampled every week, while enhanced monitoring stations were sampled biweekly. The following sections present results and discussion related to the weekly water quality monitoring.

3.2.1 Weekly Physical Water Quality Parameters

Upon arrival at each monitoring station during weekly monitoring events, the field teams measured surface water temperature and salinity at a depth of 1 meter using a YSI ProDSS meter, and water clarity was evaluated using a Secchi disk. Weather and surface water conditions were also documented on field data sheets.

Ranges of temperature, salinity, and water clarity measured throughout SIYB during each weekly monitoring event are summarized in Table 3-4. The average water quality parameters for the two reference stations are also provided in Table 3-4 for comparison. Daily rainfall that occurred during the monitoring program is also presented in Figure 3-7. Raw field water quality data for all stations and monitoring events are provided on field data sheets in Appendix B.

Temperature: Surface water temperature varied slightly throughout the basin and over time during the monitoring program. During a given monitoring event, temperature varied by 1.5 degrees Celsius (°C) or less across all monitoring stations within SIYB. In general, temperatures were coolest at the reference stations and mouth of SIYB and increased moving toward the head of the basin, where the water depths are shallower. Over the course of the 16-week monitoring program, temperatures generally decreased over the first seven weeks of the monitoring program and then began to warm over the subsequent nine weeks, ranging from 14.2 to 17.5°C across all stations and monitoring events.

Salinity: Surface salinity was relatively consistent across all monitoring stations throughout the monitoring program, ranging from 32.9 to 34.4 parts per thousand (ppt). The average variation in salinity in SIYB for a given monitoring event was 0.5 ppt. Average salinity within SIYB was slightly lower during weeks following large storm events (see further discussion in Section 3.3).

Water Clarity: Based on Secchi disk measurements, the water clarity over the course of the monitoring program ranged from 4 to 23 feet within SIYB. Water clarity was generally highest at the reference stations (ranging from 15 to 27 feet) and decreased moving toward the head of SIYB.

Table 3-4.
Weekly Surface[a] Water Quality Parameters Before, During, and After Pause

Water Quality Parameter	Metric	Sampling Date															
		Pre-Pause (11/22/21–12/18/21)				Pause (12/19/21–2/9/22)								Post-Pause (2/10/22–3/8/22)			
		W1 11/22	W2 11/30	W3 12/7	W4 12/13	W5 12/20	W6 12/28	W7 1/4	W8 1/11	W9[d] 1/19	W10 1/25	W11 1/31	W12 2/9	W13 2/14	W14 2/21	W15 3/1	W16 3/8
SIYB Stations																	
Temperature (°C)	Min	16.8	16.4	16.0	15.4	14.7	14.6	14.2	14.3	15.2	15.2	15.2	14.8	15.7	15.7	14.7	15.6
	Max	17.5	17.2	16.5	15.9	15.3	15.0	14.6	15.0	15.7	15.9	15.7	15.5	16.6	16.3	16.1	16.5
Salinity (ppt)	Min	33.5	33.1	33.2	34.1	33.6	32.9	33.0	33.0	33.0	33.2	33.2	33.4	33.9	33.4	33.2	33.0
	Max	34.4	34.4	33.5	34.3	34.1	33.3	33.3	33.4	33.4	33.5	33.4	33.8	34.2	34.2	33.6	33.5
Secchi Depth (ft)	Min	5[c]	4	5	4	5	7	7	5	10	7	7	6	6	5	9	7
	Max	10[c]	17	14	14	18	16	20	16	20	16	16	14	15	16	23	20
Total Rainfall in Prior 72 Hours (in.)[b]	Sum	0	0	0	0	0.01	0.31	0	0	0.13	0	0	0	0	0	0	0.01
Total Rainfall Since Prior Monitoring Event (in.)[b]	Sum	0	0	0	0.11	0.99	1.13	0.35	0	0.16	0	0	0	0	0.22	0.48	0.63
Tidal Stage		Slack high	Out	In	Out	Out	Slack low	Slack high	Out	Slack high	In	Out	Out	Out	In	Out	In
Reference Stations																	
Temperature (°C)	Average	16.1	16.4	15.8	15.6	14.8	14.7	14.6	14.5	15.0	15.2	14.9	14.9	15.3	15.4	14.6	15.6
Salinity (ppt)	Average	34.2	33.1	33.4	34.2	34.1	33.4	33.5	33.3	33.6	33.5	33.4	33.7	34.0	34.2	33.2	33.0
Secchi Depth (ft)	Average	NR[c]	18	19	20	21	19	24	23	17	16	16	17	19	22	17	22

Notes:
°C = degree(s) Celsius; ft = foot/feet; in. = inch(es); In = incoming; Max = maximum; Min = minimum; Out = outgoing; NOAA = National Oceanic Atmospheric Administration; NR = not recorded; ppt = part(s) per thousand; SIYB = Shelter Island Yacht Basin; Sum = summation; W = week
a. Field surface water quality measurements of temperature and salinity were taken at a depth of 1 meter to be consistent with the sample collection depth.
b. Rain totals obtained from NOAA Weather Station “USW00023188” located at the San Diego International Airport.
c. Secchi depth was recorded only at a subset of stations (n=5) during Week 1. Starting in Week 2, Secchi depth was recorded at all stations during each monitoring event.
d. The Week 9 monitoring event occurred four days after a tsunami event.

<u>Rainfall:</u> Over the course of the 16-week monitoring program, seven rain events (i.e., events generating >0.1 inch of rainfall) of varying magnitudes occurred, generating a total of approximately 4 inches of rainfall (Figure 3-7). With the exception of Weeks 6 and 9[8], monitoring events were conducted more than 72 hours after rain events to minimize potential effects of stormwater on dissolved copper levels. To evaluate potential effects of stormwater discharge on dissolved copper levels in SIYB, pre- and post-storm monitoring events were conducted during Week 4 of the monitoring program. Results for the Week 4 storm monitoring event are presented in Section 3.3.

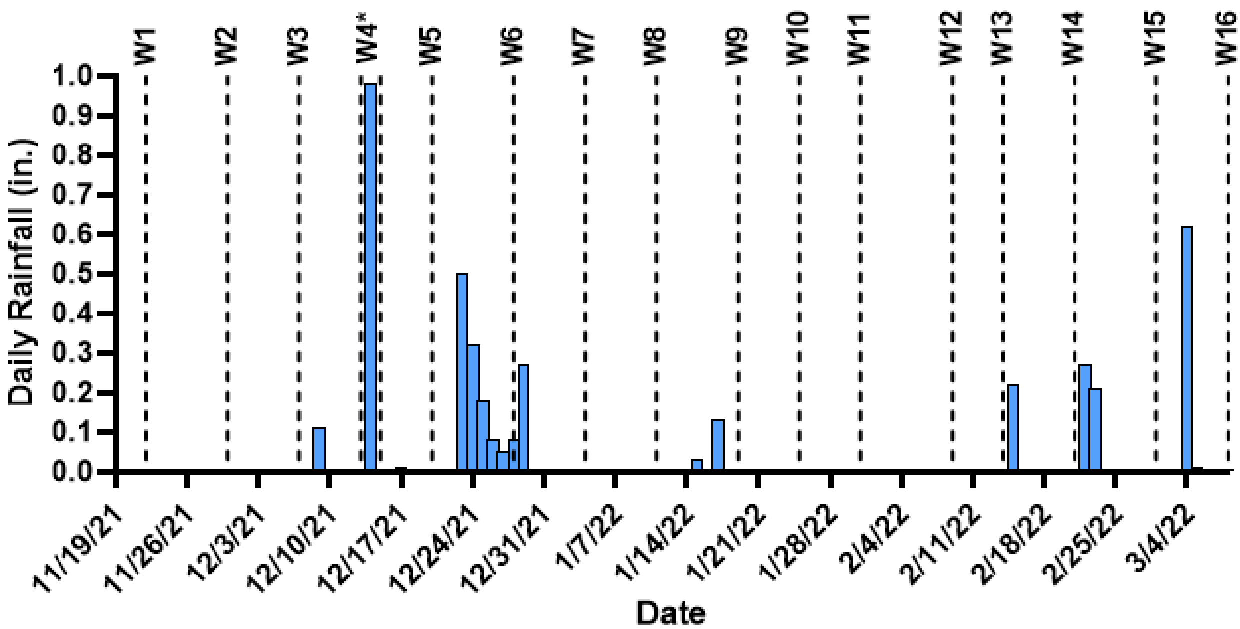

Figure 3-7. Daily Rainfall Over the Course of the Monitoring Program

Notes: Rainfall totals obtained from NOAA Weather Station "USW00023188" located at the San Diego International Airport. *Week 4 monitoring included pre-storm (12/13/21) and post-storm (12/15/21) sampling (see Section 3.3).

<u>Tides:</u> As discussed in Section 2.2.2, samples were collected over a broad range of tidal cycles over the course of the monitoring program. The general tidal stage that was captured during each monitoring event is included in Table 3-4. Specific sample collection times are plotted on tide charts for each monitoring event in Figures 2-3 and 2-4.

<u>Tsunami:</u> The Week 9 monitoring event was conducted on January 19, 2022, four days following a tsunami event (January 15, 2022) that was generated from an underwater water volcanic eruption off the coast of Tonga in the southwestern region of the Pacific Ocean. The surging and receding tsunami waves generated strong currents in SIYB that may have disrupted typical water circulation dynamics and resuspended sediments throughout the basin. However, there were no notable changes in temperature, salinity, or water clarity measured during the week following the tsunami.

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[8] During Week 6, a storm system brought seven consecutive days of rain (0.31 inch in the 72 hours prior to sampling). During Week 9, a small rain event (0.13 inch) occurred approximately 48 hours prior to sampling. In accordance with the SAP/QAPP, sampling events were scheduled to avoid rain events to the extent practicable while still collecting samples weekly.

Summary of Physical Water Quality Parameters

Temperature, salinity, and water clarity measurements taken during the monitoring program were consistent with those measured historically in SIYB during the winter months (Amec Foster Wheeler, 2018; Wood, 2022b). As expected, slight decreases in average salinity were observed in SIYB following large rain events, likely resulting from freshwater mixing following stormwater discharge. No other apparent changes or anomalies in field water quality parameters were observed during the monitoring program, including after storm events and after the tsunami in Week 9. Further, there were no strong correlations between water quality parameters measured and dissolved copper concentrations, suggesting that temperature, salinity, and water clarity did not have substantial effects on dissolved copper concentrations in SIYB over the course of the monitoring program.

3.2.2 Weekly Dissolved Copper Monitoring

Surface water samples were collected weekly throughout the 16-week monitoring program and analyzed for dissolved copper.

Weekly dissolved copper results for each individual monitoring station are provided in Table 3-5. The complete analytical chemistry laboratory reports are provided in Appendix C. A QA/QC summary of all analytical laboratory data is in Section 3.5.

In this section, the data are presented graphically in three different ways:

1. Weekly averages – Data are first summarized as weekly average dissolved copper concentrations for core monitoring stations compared with enhanced monitoring stations (Figure 3-8). Dissolved copper concentrations for both reference stations are also included for comparison. This data summary approach allows for an assessment of dissolved copper concentrations over time for the basin as a whole, as well as for comparison of results from the core and enhanced monitoring stations.
2. Individual stations – Weekly dissolved copper concentrations are then presented for each monitoring station to show variability between individual stations throughout the basin (Figure 3-9). Plots of dissolved copper concentrations for all individual monitoring stations over time (by station and by week) are also included in Appendix D.
3. Basin regions – To further examine dissolved copper measurements in different areas of SIYB, dissolved copper data were pooled and compared for three regions, including the inner (i.e., head), middle, and outer (i.e., mouth) basin. These regions were chosen based on the results of the 2018 Time Series Study (Amec Foster Wheeler, 2018), which suggested that tides affect dissolved copper levels to varying degrees in the inner, middle, and outer basin. Monitoring stations included in each region for analysis are included in Figure 2-7 (Section 2.4.3) and in Table 3-5.

Following the presentation of results and the associated discussion of each data analysis approach presented above, findings from the monitoring program are then summarized in Section 4.0.

Table 3-5.
Weekly Dissolved Copper Concentrations Before, During, and After Pause

Basin Region	Station ID[a]	Dissolved Copper Concentration (µg/L)															
		Pre-Pause (11/22/21–12/18/21)				Pause (12/19/21–2/9/22)								Post-Pause (2/10/22–3/8/22)			
		W1 11/22	W2 11/30	W3 12/7	W4 12/13	W5 12/20	W6 12/28	W7 1/4	W8 1/11	W9[b] 1/19	W10 1/25	W11 1/31	W12 2/9	W13 2/14	W14 2/21	W15 3/1	W16 3/8
Inner	C-1/SIYB-1	7.6	10	11	13	11	11	8.3	11	12	9.8	8.8	9.4	9.2	8.6	7.6	7.0
Inner	C-2	7.4	11	10	16	11	13	8.9	11	15	12	8.6	9.5	9.1	9.2	8.3	7.5
Inner	C-3	8.0	9.9	11	15	11	15	8.7	10	14	11	8.4	10	9.5	9.9	8.2	7.1
Inner	C-4	9.2	11	7.4	14	11	14	8.7	9.3	12	10	9.1	9.8	9.5	5.1	7.7	7.3
Inner	C-5	7.0	9.4	7.9	14	11	11	7.7	9.0	9.7	11	7.9	9.6	9.6	7.3	7.6	9.0
Middle	C-6/SIYB-2	7.0	12	10	13	11	11	7.2	8.6	9.7	9.7	11	10	9.1	7.2	7.4	7.6
Middle	C-7/SIYB-3	7.1	9.9	8.1	12	9.5	9.7	6.5	7.7	9.7	8.1	8.2	9.2	9.2	5.7	6.7	7.4
Middle	C-8/SIYB-4	5.9	9.8	6.2	9.7	8.6	9.0	5.7	8.4	11	7.5	8.7	9.7	9.8	7.7	7.8	7.9
Middle	C-9	7.9	11	11	13	8.4	8.0	6.6	9.4	8.4	6.9	11	10	9.4	6.8	6.8	6.7
Middle	C-10	7.3	10	10	11	8.1	8.9	6.4	8.3	10	7.6	8.6	8.5	8.3	7.7	6.4	7.0
Middle	C-11	5.1	7.2	8.1	7.3	9.7	9.1	6.4	7.6	7.4	7.7	8.1	7.9	8.5	6.3	6.2	5.9
Outer	C-12/SIYB-5	3.4	7.1	3.1	5.9	5.0	11	3.8	7.2	6.9	8.3	6.0	5.7	6.0	6.1	6.0	6.7
Outer	C-13/SIYB-6	1.9	3.5	1.6	3.6	2.8	7.3	2.3	3.1	2.2	3.4	3.0	3.6	3.6	1.6	1.9	5.6
Inner	E-14	--	10	--	10	--	14	--	9.8	--	9.2	--	9.6	--	9.1	--	7.5
Inner	E-15	--	13	--	10	--	14	--	10	--	11	--	10	--	9.2	--	6.6
Inner	E-16	--	13	--	9.9	--	14	--	8.9	--	11	--	9.5	--	9.2	--	7.5
Inner	E-17	--	14	--	10	--	11	--	9.0	--	10	--	12	--	9.5	--	8.0
Middle	E-18	--	11	--	12	--	12	--	9.0	--	11	--	10	--	8.8	--	7.2
Middle	E-19	--	11	--	9.3	--	9.1	--	8.0	--	7.7	--	9.5	--	7.9	--	7.7
Outer	E-20	--	6.9	--	6.0	--	10	--	5.4	--	7.2	--	6.8	--	5.2	--	7.1
Basin-wide Minimum		**1.9**	**3.5**	**1.6**	**3.6**	**2.8**	**7.3**	**2.3**	**3.1**	**2.2**	**3.4**	**3.0**	**3.6**	**3.6**	**1.6**	**1.9**	**5.6**
Basin-wide Maximum		**9.2**	**14**	**11**	**16**	**11**	**15**	**8.9**	**11**	**15**	**17**	**11**	**12**	**9.8**	**9.9**	**8.3**	**9.0**
Basin-wide Average ± Standard Error		**6.5 ± 0.6**	**10 ± 0.5**	**8.1 ± 0.8**	**11 ± 0.7**	**9.1 ± 0.7**	**11 ± 0.5**	**6.7 ± 0.5**	**8.5 ± 0.4**	**9.8 ± 0.9**	**9.4 ± 0.6**	**8.3 ± 0.6**	**9.0 ± 0.4**	**8.5 ± 0.5**	**7.4 ± 0.5**	**6.8 ± 0.5**	**7.2 ± 0.2**
Reference	C-REF-1/SIYB-REF-1	0.55	1.1	0.40	0.76	0.16	1.6	0.35	1.3	0.35	1.8	0.56	1.6	0.94	1.1	0.26	1.9
Reference	C-REF-2/SIYB-REF-2	0.58	1.5	0.44	0.81	0.50	2.0	0.32	1.5	0.44	1.8	0.90	1.3	0.85	1.3	0.30	2.1

Notes: -- = no enhanced stations sampled; µg/L = microgram(s) per liter; C = core; E = enhanced; ID = identifier; REF = reference; SIYB = Shelter Island Yacht Basin; TMDL = Total Maximum Daily Load; W = week; a. A subset of the core monitoring stations and both reference stations were co-located with the stations monitored annually for TMDL compliance. These stations include both the Hull Cleaning Pause station ID and the SIYB TMDL station ID for reference. b. The Week 9 monitoring event occurred four days after a tsunami event.

Weekly Averages: Core and Enhanced Monitoring Stations

Core monitoring and reference stations were sampled on a weekly basis over the course of the 16-week monitoring program. Seven additional enhanced stations were sampled on a biweekly basis to provide supplemental data at a higher resolution and in closer proximity to vessels than the stations on the outer edge of the marinas along and within the main channel. Weekly average dissolved copper concentrations for the core and enhanced stations are shown in Figure 3-8, along with results from the two reference stations.

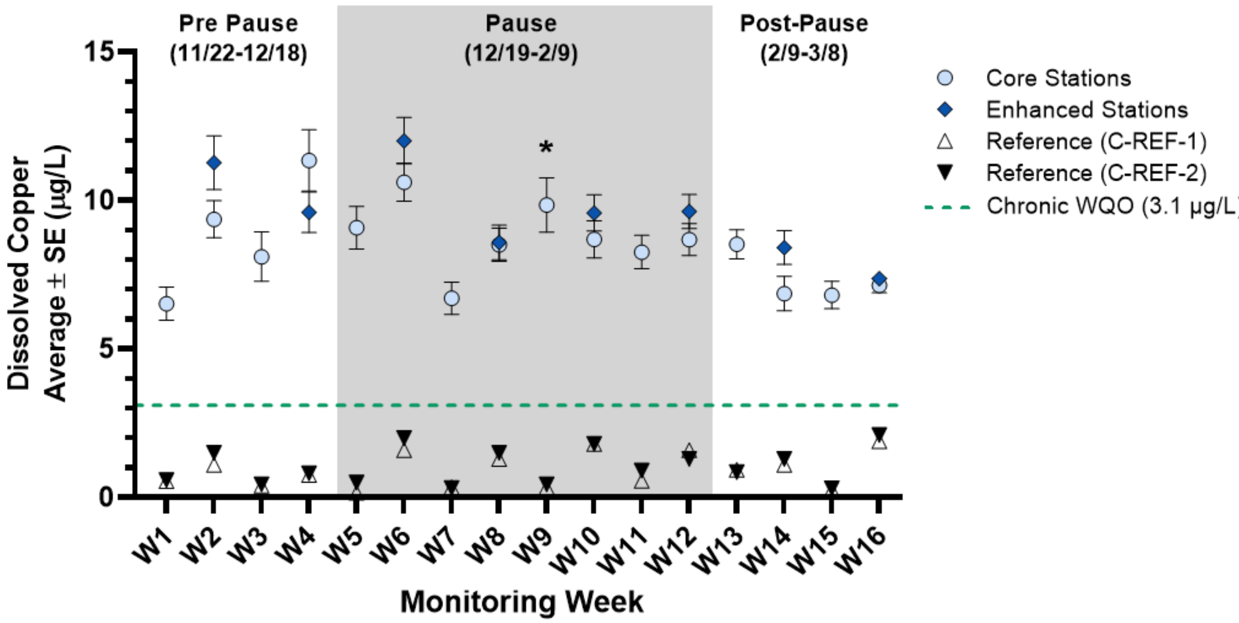

Figure 3-8. Weekly Average Dissolved Copper Concentrations at Core and Enhanced Monitoring Stations Over Time

Notes: µg/L = microgram(s) per liter; REF = reference; SE = standard error; W = week; WQO = water quality objective
* The Week 9 monitoring event occurred four days after a tsunami event.
SE bars for Week 16 are smaller than the size of the symbol and therefore are not visible.

Weekly basin-wide average copper concentrations (including core and enhanced stations) ranged from 6.5 to 11 micrograms per liter (µg/L) (Table 3-5). With the exception of Week 4 (12/13), average dissolved copper concentrations at the enhanced stations, located in the inner portions of the marinas, were higher than those at the core stations on the outer edges of marinas and in the main channel of SIYB.

While the results were somewhat variable over the 16-week monitoring program, an apparent pattern in the data in Figure 3-8 shows an increase in average dissolved copper concentrations at the core and enhanced stations during the Pre-Pause period and the first two weeks of the Pause, followed by a slight downward trend for the remainder of the Pause and Post-Pause periods. It should be noted that a tsunami occurred four days before the Week 9 monitoring event. Dissolved copper concentrations measured in Week 9 were slightly elevated compared with concentrations in previous weeks; however, by the following week (Week 10), dissolved copper concentrations returned to levels similar to those measured before the tsunami (Week 8). Overall, despite slight decreases in dissolved copper concentrations during the Pause and Post-Pause period, average dissolved copper concentrations remained well above the chronic WQO (3.1 µg/L) within SIYB.

At the reference stations, dissolved copper concentrations varied slightly from week to week, ranging from 0.16 µg/L (C-REF-1 in Week 5) to 2.1 µg/L (C-REF-2 in Week 16). However, dissolved copper concentrations at the reference stations were below the chronic WQO (3.1 µg/L) throughout the monitoring program.

Individual Stations

Dissolved copper results for each individual monitoring station are presented in Figure 3-9. Plots of dissolved copper concentrations for all individual monitoring stations over time (by station and by week) are included in Appendix D.

Dissolved copper concentrations were highly variable across the individual monitoring stations over the course of the monitoring program. At the innermost stations (e.g., C-1/SIYB-1 through C-4), there was a clear incremental increase in dissolved copper concentrations during the Pre-Pause period, followed by somewhat of a downward trend during the Pause and Post-Pause periods. Similar increasing trends were apparent during the Pre-Pause period at some monitoring stations in the middle of the basin (e.g., C-9 through C-11); however, there were no clear decreasing trends in dissolved copper concentrations during the Pause and Post-Pause periods at these stations. Results from the outermost stations (C-12/SIYB-5, C-13/SIYB-6, and E-20) showed no clear trends in dissolved copper concentrations over the 16-week monitoring program.

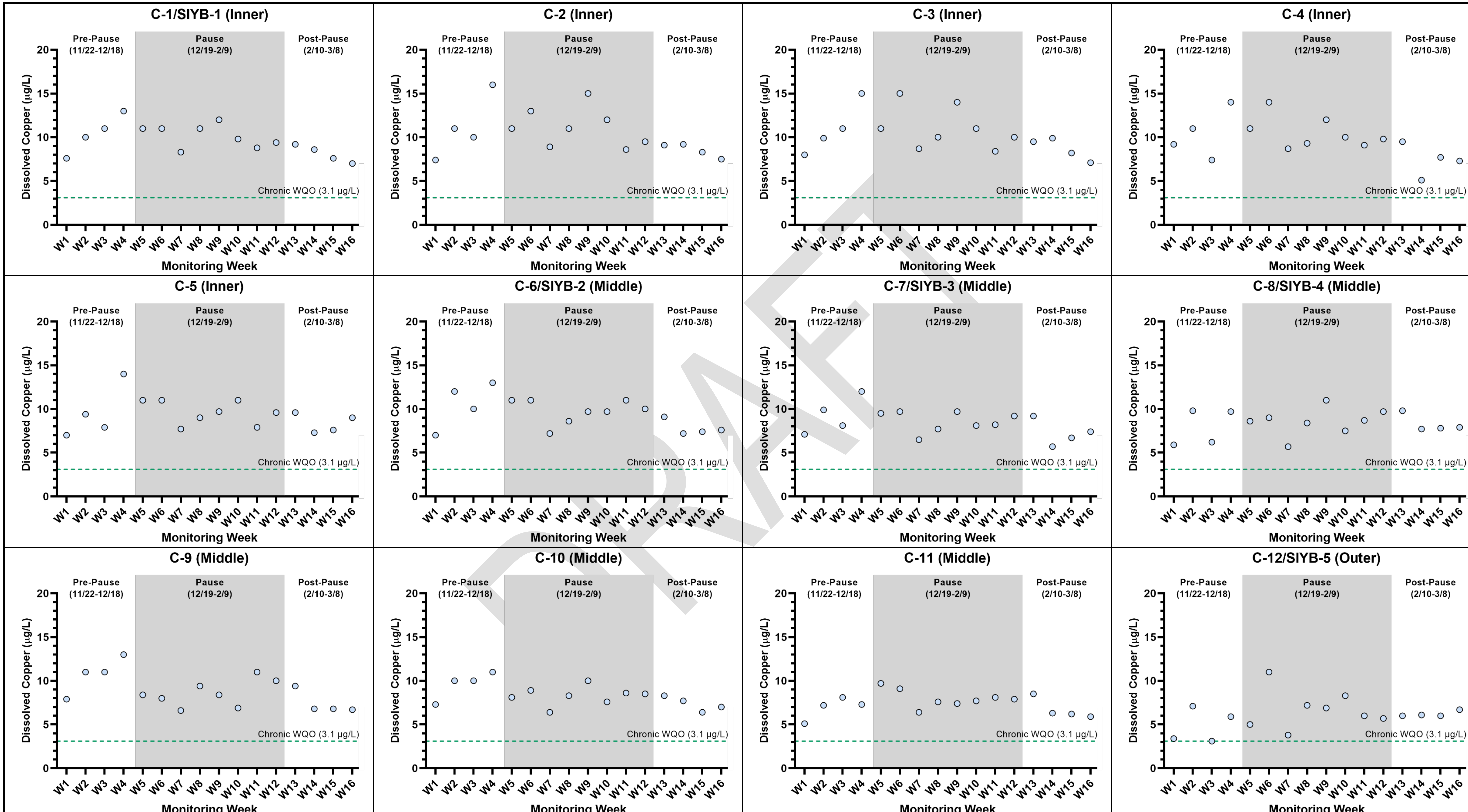

Figure 3-9. Dissolved Copper Concentrations at Individual Monitoring Stations Over Time

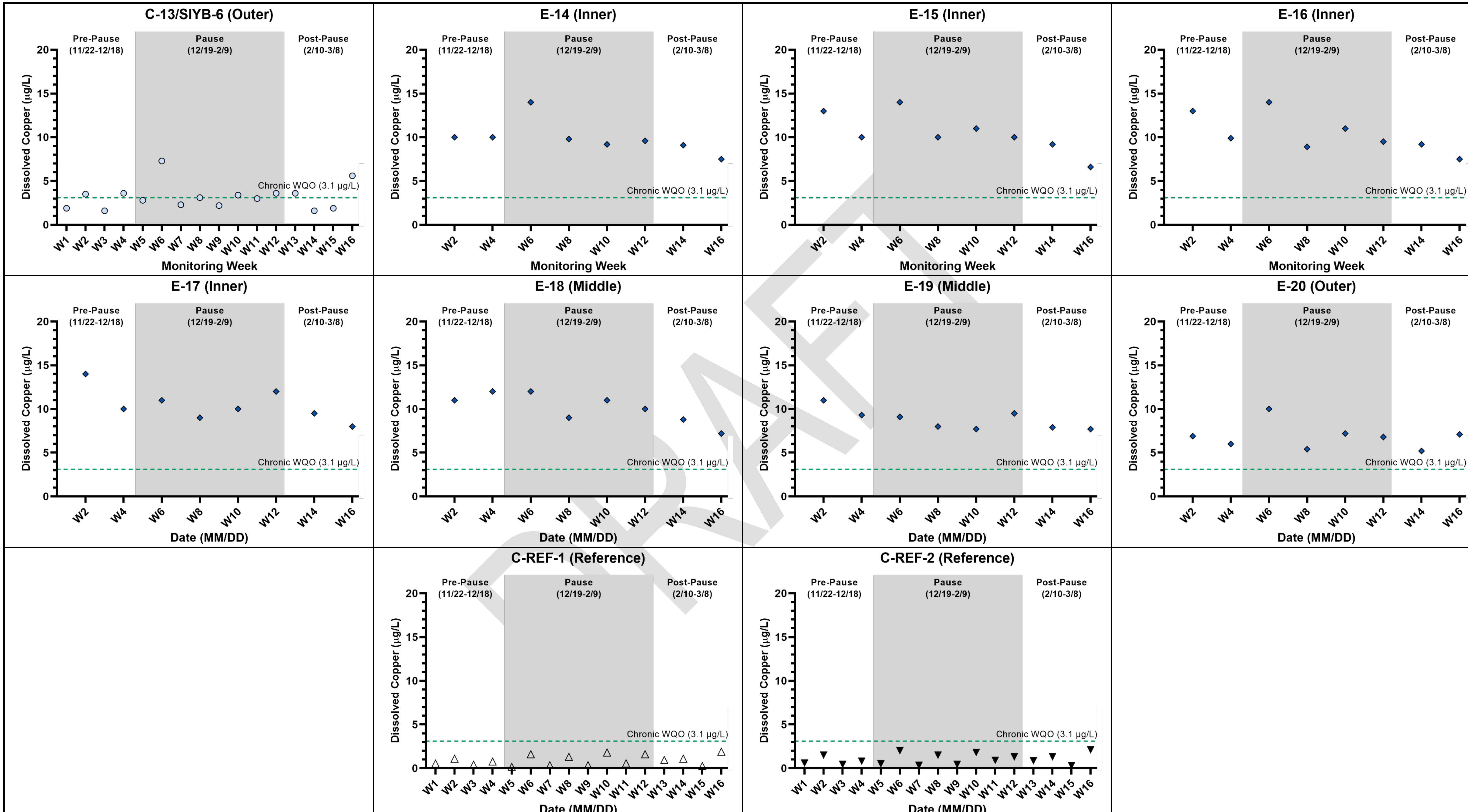

Figure 3-9. Dissolved Copper Concentrations at Individual Monitoring Stations Over Time (continued)

As depicted in Figure 3-9, dissolved copper concentrations varied over time at different monitoring stations throughout the basin. In general, similar trends were observed at monitoring stations in the inner, middle, and outer portions of the basin. To further examine regional trends in dissolved copper concentrations within SIYB, data from inner, middle, and outer monitoring stations were pooled and compared for each monitoring phase, as shown in Figure 3-10. Each box plot shows the quartiles (boxes), median (center line), and range of the data (whiskers).

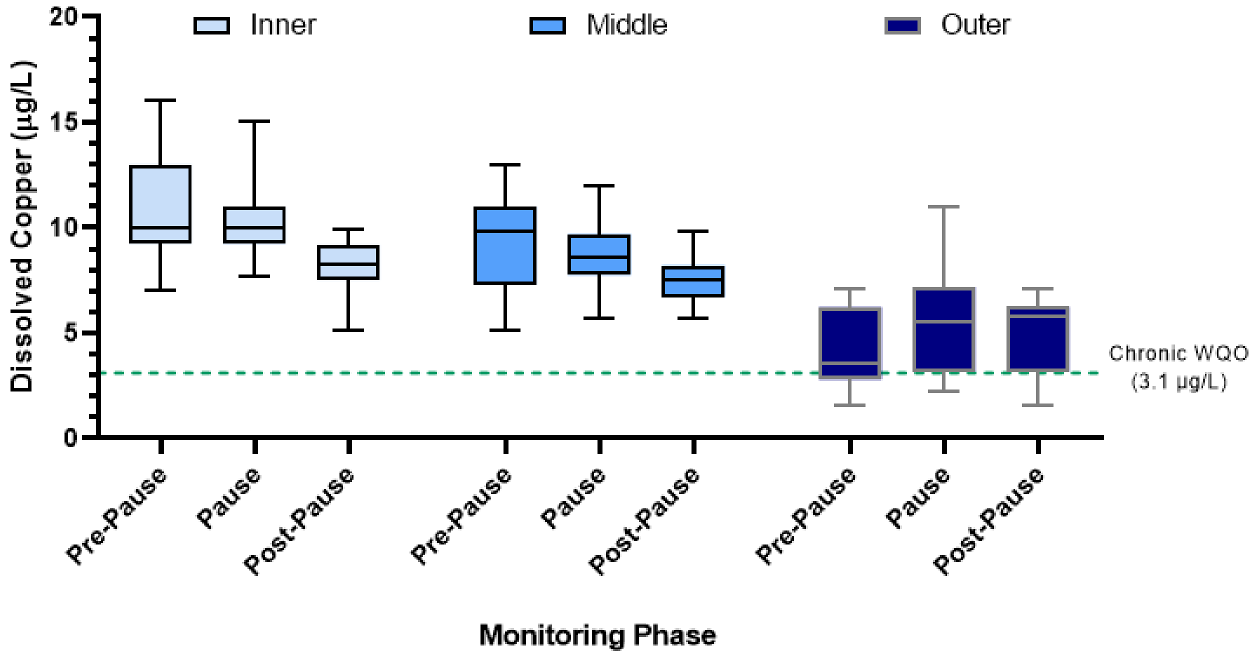

Figure 3-10. Dissolved Copper Concentrations By Region During Each Monitoring Phase

Notes: µg/L = microgram(s) per liter; WQO = water quality objective
Boxes represent the 25th, 50th (i.e., median), and 75th percentiles of the data, and whiskers represent the minimum and maximum.

There is a gradient in dissolved copper concentrations throughout the basin, with higher concentrations in the inner region (i.e., head of the basin) and lower concentrations in the outer region (i.e., mouth of the basin). This gradient remained consistent through all phases of the monitoring program.

As shown in Figure 3-10, in general, a decrease in dissolved copper concentrations was observed during the Pause and Post-Pause periods in the inner and middle regions of the basin. However, there does not appear to be a recognizable decrease in dissolved copper concentrations in the outer region of SIYB, with similar overlapping distributions in dissolved copper levels throughout the 16-week monitoring program.

Summary of Dissolved Copper Monitoring Results

As described previously, dissolved copper concentrations were highly variable over the course of the 16-week monitoring program. In general, there was an apparent increase in dissolved copper concentrations during the Pre-Pause period and first two weeks of the Pause, followed by a slight, but recognizable, decrease in concentrations during the remainder of the Pause and Post-Pause periods. These trends in dissolved copper concentrations were most pronounced in the inner and middle regions of the basin where vessels are most concentrated.

While the amount of hull cleaning that occurred prior to the Hull Cleaning Pause was not specifically quantified as part of the monitoring program's inspection component, staff observations made during preparatory pre-pause site visits suggested that a considerable amount of cleaning occurred during the Pre-Pause period. In particular, inspectors observed increases in the number of hull cleaners checking into facilities and the number of diver tags dated in the weeks leading up to the Pause. This increase in cleaning may have been responsible for the higher dissolved copper concentrations during the first six weeks of monitoring. The increase in dissolved copper levels in the basin at the outset of the monitoring program was not totally unexpected. It was assumed that there would be considerably more hull cleaning in the basin (relative to an average winter week) as the hull cleaners and boaters adjusted their cleaning schedules to accommodate the upcoming Hull Cleaning Pause.[9]

During the Pause period, frequent inspections were conducted by Port staff to ensure compliance with the Hull Cleaning Ordinance. Based on the 217 inspections conducted by Port staff, no hull cleaning of vessels with copper-based AFPs was observed in SIYB during the eight-week Pause. In addition, visual observations and photographs taken over the course of the Pause documented an increase in fouling on the vessels in SIYB (see Figure 3-6). This provided further evidence that vessels were not being cleaned during the Pause. As the Pause period progressed, the amount of fouling increased concurrently, which also supported the inspection findings that hull cleaning was not occurring.

Over the course of the monitoring program, there seemed to be a noticeable decrease in the dissolved copper levels, particularly in the inner and middle regions. The apparent downward trend in dissolved copper levels that was observed during the Pause was also observed during the four-week Post-Pause period. While it was expected that hull cleaning would resume immediately following the Pause, it is possible that this did not happen to the extent that it was occurring in the Pre-Pause period. During Post-Pause dock walks, Port inspectors observed less cleaning activity than expected. This observation suggests that hull cleaning may not have increased to normal levels during the Post-Pause period, potentially contributing to the continued slight downward trend in dissolved copper concentrations observed during Weeks 13 through 16 of the monitoring program.

3.3 Storm Monitoring Event

In addition to routine weekly water quality monitoring, sampling was conducted during a single large storm event in Week 4 of the monitoring program to assess the potential effects of stormwater discharge on dissolved copper levels in SIYB. Field water quality measurements and surface water samples were collected from core monitoring and reference stations before and after the storm for comparison. The following sections present results and discussion related to the pre- and post-storm monitoring events.

[9] Inspectors also communicated with several hull cleaners and boaters who indicated that they were performing cleaning in preparation for the Hull Cleaning Pause.

3.3.1 Storm Event Physical Water Quality Parameters

Upon arrival at each monitoring station, field teams measured surface water temperature and salinity at a depth of 1 meter using a YSI ProDSS meter. Water clarity was also evaluated at each station using a Secchi disk.

Ranges of surface water temperature, salinity, and water clarity measured at the core monitoring stations throughout SIYB before and after the December 14, 2021 storm event are summarized in Table 3-6. The average water quality parameters for the two reference stations are also provided for comparison. Raw field water quality data for all stations and monitoring events are provided on field data sheets in Appendix B.

Table 3-6.
Water Quality Parameters Before and After Week 4 Storm

WQ Parameter	Metric	Sampling Date	
		Week 4 Pre-Storm	Week 4 Post-Storm
		12/13/21	12/15/21
SIYB Stations			
Temperature (°C)	Min	15.4	14.5
	Max	15.9	15.5
Salinity (ppt)	Min	34.1	33.0
	Max	34.3	33.4
Secchi Depth (ft)	Min	4	6
	Max	12	11
Total Rain in Prior 72 Hours (in.)[a]	Sum	0	0.98
Reference Stations			
Temperature (°C)	Average	15.6	14.9
Salinity (ppt)	Average	34.2	33.6
Secchi Depth (ft)	Average	20	9

Notes:
°C = degree(s) Celsius; ft = foot/feet; in. = inch(es); Max = maximum; Min = minimum; NOAA = National Oceanic and Atmospheric Administration; ppt = part(s) per thousand; SIYB = Shelter Island Yacht Basin; Sum = summation; WQ = water quality
a. Rain totals obtained from NOAA Weather Station "USW00023188" located at the San Diego International Airport.

The Week 4 storm event produced 0.98 inch of rainfall on December 14, 2021. Following the storm, there was a measurable decrease in temperature and salinity of the receiving water at monitoring stations within SIYB and at the reference stations. Water clarity within SIYB was similar before and after the storm but decreased substantially at the reference stations after the storm.

Summary of Storm Event Physical Water Quality Parameters

Overall, there were no anomalous field water quality results during the pre- and post-storm monitoring events. Observed decreases in temperature and salinity were likely a result of freshwater mixing in the marine environment following stormwater discharge. In addition, sampling was conducted on an outgoing tide following the storm, which may have transported storm-related particulates and debris from within SIYB and elsewhere along the shorelines of San Diego Bay to the reference stations. This may have contributed to the decrease in water clarity at the reference stations following the storm.

3.3.2 Storm Event Analytical Chemistry

Stormwater samples were collected from two outfalls (OF-1 and OF-2; Figure 2-1) during the Week 4 storm. For reference, OF-1 is located approximately 170-m north of Station C-11; OF-2 is located approximately 270-m northeast of Station C-9. Analytical chemistry results from the stormwater samples are presented in Table 3-7. In addition, surface receiving water samples were collected from core monitoring and reference stations before and after the December 14, 2021 storm. Copper results for each station are provided in Table 3-8. The complete analytical chemistry laboratory reports are provided in Appendix C. A QA/QC summary of all analytical laboratory data is in Section 3.5.

Table 3-7.
Outfall Chemistry Results from 12/14/21 Storm

Station ID	Dissolved Copper (µg/L)	Total Copper (µg/L)	Total Suspended Solids (mg/L)
OF-1	17	63	170
OF-2	23	30	33

Notes: µg/L = microgram(s) per liter; ID = identifier; OF = outfall; mg/L = milligram(s) per liter

Table 3-8.
Receiving Water Chemistry Results Before and After 12/14/21 Storm

Basin Region	Station ID[a]	Week 4 Pre-Storm (12/13/21)	Week 4 Post-Storm (12/15/21)	
		Dissolved Copper (µg/L)	Dissolved Copper (µg/L)	Total Copper (µg/L)
Inner	C-1/SIYB-1	13	12	14
Inner	C-2	16	12	15
Inner	C-3	15	12	13
Inner	C-4	14	13	14
Inner	C-5	14	13	15
Middle	C-6/SIYB-2	13	12	14
Middle	C-7/SIYB-3	12	9.6	11
Middle	C-8/SIYB-4	9.7	11	13
Middle	C-9	13	11	13
Middle	C-10	11	11	13
Middle	C-11	7.3	11	12
Outer	C-12/SIYB-5	5.9	11	12
Outer	C-13/SIYB-6	3.6	7.0	7.9
Basin-wide Average ± SE		**11 ± 0.7**	**11 ± 0.4**	**12.8 ± 0.5**
Reference	C-REF-1/SIYB-REF-1	0.76	0.71	0.91
Reference	C-REF-2/SIYB-REF-2	0.81	0.44	0.67

Notes:
µg/L = microgram(s) per liter; C = core; E = enhanced; ID = identifier; REF = reference; SE = standard error; SIYB = Shelter Island Yacht Basin; TMDL = Total Maximum Daily Load
a. A subset of the core monitoring stations and both reference stations were co-located with the stations monitored annually for TMDL compliance. These stations include both the Hull Cleaning Pause station ID and the SIYB TMDL station ID for reference.

Dissolved copper results from the two outfalls ranged from 17 µg/L to 23 µg/L. The average event mean concentration (EMC) for dissolved copper measured over the past 13 monitoring seasons (2008–2021) at OF-2 as part of the City of San Diego's Municipal Separate Storm Sewer System (MS4) discharge monitoring required by the SIYB TMDL (Wood, 2021c) is 23 µg/L. This is the same dissolved copper concentration measured in the OF-2 grab sample collection for this effort. Although this monitoring program's grab sample is not directly comparable with flow-weighted pollutograph samples collected over the entire storm, the result appears to be consistent with concentrations found during routine monitoring of OF-2. The City of San Diego does not conduct sampling at OF-1 during wet weather for MS4 monitoring purposes, so there is no directly comparable value for OF-1. These instantaneous dissolved copper results obtained from OF-1 and OF-2 are less than the 32.6 µg/L dissolved copper EMC value used to evaluate dissolved copper load from urban runoff in the Appendix 2 of the SIYB TMDL (Regional Board, 2005).

In the SIYB receiving water before the storm, there was a clear gradient in dissolved copper, with concentrations decreasing from the head of basin (C-1/SIYB-1) to the mouth of the basin (C-13/SIYB-6) and reference stations (Figure 3-11). However, after the storm, dissolved copper concentrations were relatively consistent throughout the basin, with the exception of Station C-13/SIYB-6 located at the mouth of SIYB.

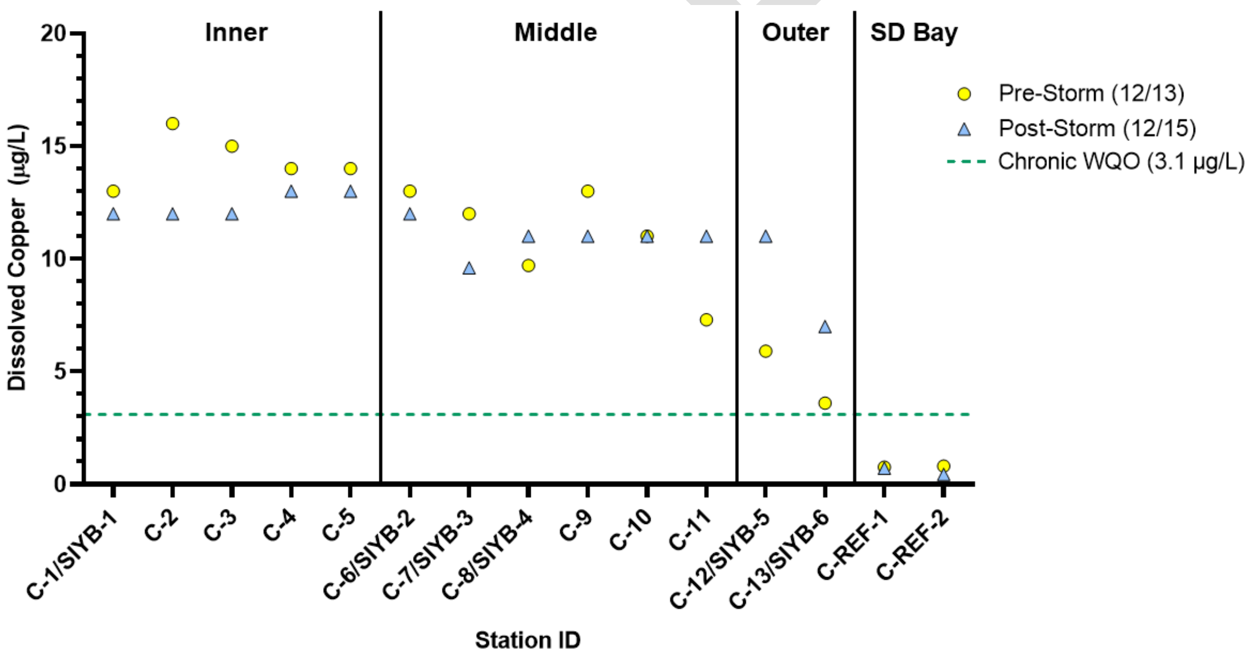

Figure 3-11. Dissolved Copper Concentrations Before and After Storm Event

Notes: µg/L = microgram(s) per liter; C = core; REF = reference; SD = San Diego; SIYB = Shelter Island Yacht Basin; WQO = water quality objective

Summary of Storm Event Analytical Chemistry Results

As depicted in Figure 3-11, the storm that occurred on December 14, 2021 appeared to affect the spatial distribution of dissolved copper in SIYB, with more uniform dissolved copper concentrations observed throughout the basin after the storm. The storm generated strong winds and currents that likely resulted in mixing of stormwater and receiving water throughout the basin. However, the basin-wide average dissolved copper concentrations remained the same before and after the storm (11 µg/L; Table 3-8). This finding suggests that stormwater discharge did not contribute a substantial amount of copper loading to SIYB.

Additionally, based on the annual loading estimates performed by the City of San Diego for the MS4 component of the SIYB TMDL, the stormwater contribution has consistently been less than the waste load allocation of 30 kg/yr every year since 2011 (Wood, 2020). This represents less than 1% of the annual dissolved copper load to SIYB estimated in the SIYB TMDL. These results are consistent with the outfall and receiving water results measured during the Pause stormwater monitoring event.

3.4 Other Environmental Factors to Consider

The objective of the Hull Cleaning Pause Water Quality Monitoring Program was to evaluate how a pause in hull cleaning affects dissolved copper levels in SIYB. However, there are other factors that may also have had effects on the dissolved copper levels in the basin. For example, a 2018 study showed a direct link between tidal fluctuations and dissolved copper levels at certain locations in SIYB (Amec Foster Wheeler, 2018). Consequently, several environmental factors were evaluated to assess whether they may have influenced the Hull Cleaning Pause monitoring results. This evaluation is presented in Table 3-9. Overall, despite small-scale variability in the ambient dissolved copper levels that may have resulted from factors other than hull cleaning, these factors were determined to have limited influence on the overall findings related to hull cleaning effects on dissolved copper concentrations.

Table 3-9.
Evaluation of Environmental Factors that May Affect Ambient Copper Levels in SIYB

Environmental Factor	Evaluation
Potential for rainfall and associated stormwater runoff	Over the course of the 16-week monitoring program, seven rain events (i.e., events generating >0.1 inch rainfall) of varying magnitudes occurred, generating a total of approximately 4 inches of rainfall. To assess the potential impacts of associated stormwater discharge on copper levels in SIYB, one storm event (0.98 inch of rainfall) was sampled during Week 4 of the Pre-Pause period. As presented in Section 3.3, results from the pre- and post-storm monitoring events indicated that the storm event affected the spatial distribution of copper throughout the basin, with increased mixing and less of a gradient in copper levels throughout the basin after the storm. However, the basin-wide average concentrations before and after the storm were the same (11 µg/L), which suggests that stormwater discharge had minimal effects on copper levels in SIYB overall. This finding is consistent with the SIYB TMDL model and the City of San Diego SIYB TMDL monitoring, which indicate that stormwater contributes 1% of annual dissolved copper load to SIYB to urban runoff. As such, storm events and associated stormwater runoff are not expected to have had any significant impact on dissolved copper levels or findings related to the effects of hull cleaning on dissolved copper concentrations throughout the monitoring program.
Seasonality	As expected, surface water temperatures measured in SIYB throughout the 16-week monitoring program conducted in the winter were lower than those measured during previous SIYB TMDL compliance monitoring events conducted in the summer. Over the 16 weeks, surface water temperatures within the basin ranged from 14.2 to 17.5°C compared with an average of 22.1°C (range: 18.8–25.9°C) measured during the SIYB TMDL summer compliance monitoring program. Despite the cooler water temperatures, dissolved copper concentrations measured before, during, and after the Pause period were similar to or higher than those measured in SIYB during previous SIYB TMDL compliance monitoring events conducted in the summer. Further, there was no significant correlation between temperature and dissolved copper measured during the monitoring program, suggesting that temperature did not have substantial effects on dissolved copper concentrations in SIYB during the monitoring program. Therefore, changes in temperature throughout the monitoring program are not expected to have had any significant impact on findings regarding the effects of hull cleaning on dissolved copper concentrations.
Variation in surface water dissolved copper levels due to tides	Because of the 16-week monitoring program design, it was not feasible to coordinate sample collection at a given monitoring station at the same tidal stage. However, monitoring stations were sampled in the same order over the 16 weeks, capturing a broad range of tidal stages at each monitoring station to better represent the overall conditions in SIYB (see Figure 2-3). Overall, monitoring results appeared consistent with those observed during the 2018 Time Series Study (Amec Foster Wheeler, 2018). In particular, the variability in copper concentrations at different tidal stages was most prominent at the mouth of the basin and decreased toward the head of the basin. At the outermost monitoring stations, there was an oscillating pattern in dissolved copper concentrations observed every other week during the monitoring program that corresponded well with tidal cycles and patterns in copper concentrations at the reference sites. Concentrations of dissolved copper at both the reference sites and within SIYB (middle and outer locations) were consistently greater during outgoing tides compared with that measured during incoming tides in both this monitoring program and the 2018 special study. While tides contributed to variability in dissolved copper concentrations in the basin observed during this monitoring program (and the Time Series Study), tides did not have a substantial impact on overall findings regarding the effects of hull cleaning on dissolved copper concentrations.

Table 3-9. (continued)
Evaluation of Environmental Factors that May Affect Ambient Copper Levels in SIYB

Environmental Factor	Evaluation
Tsunami	A tsunami was generated on January 15, 2022, following an underwater volcanic eruption off the coast of Tonga. Tsunami waves caused the waters in San Diego Bay to rise 1.4 feet. The surging and receding tsunami waves generated strong currents in SIYB that may have disrupted typical water circulation dynamics and briefly resuspended sediments throughout the basin. An evaluation was conducted to assess potential impacts of the tsunami on dissolved copper levels in SIYB. Notably, basin-wide average dissolved copper levels generally correlated with tides, with slightly higher average concentrations on outgoing tides and slightly lower average concentrations on incoming tides. However, this trend was not apparent during the week following the tsunami (Week 9). Samples during Week 9 were collected following a steep incoming tide, which was reflected in the relatively low dissolved copper results at the reference stations; however, dissolved concentrations within SIYB were slightly higher than those measured in previous weeks. This suggests that slightly elevated dissolved copper concentrations in Week 9 may have been related to residual effects from the tsunami (e.g., water circulation patterns, resuspension of sediment, etc.). While slight increases in dissolved copper concentrations were measured during Week 9 of the monitoring program following the tsunami, the Week 9 data points were not outliers and fell within the range of dissolved copper concentrations measured during the Pause. Further, by the following week (Week 10), the dissolved copper concentrations returned to levels similar to those measured before the tsunami (Week 8). Therefore, the tsunami was not expected to have had any significant impact on findings related to the effects of hull cleaning on dissolved copper concentrations

Notes:
% = percent; µg/L = microgram(s) per liter; °C = degree(s) Celsius; SIYB = Shelter Island Yacht Basin; TMDL = Total Maximum Daily Load

3.5 Quality Assurance and Quality Control

This section provides an assessment of data quality and usability for the analytical chemistry results. The chemistry laboratory reports prepared by Weck (Appendix C) also include detailed QC results sections.

For each monitoring event (16 weekly events and 1 post-storm event), all samples were submitted to the analytical chemistry laboratory on the day after they were collected. The samples were received on ice and in good condition at Weck. The samples for dissolved copper analyses were field-filtered by Wood immediately following collection and preserved by the laboratory upon receipt. All samples met holding time requirements for analysis.

Analytical chemistry results underwent a thorough QA/QC evaluation; they were determined to meet the data quality objectives in the QAPP and were deemed acceptable for reporting purposes, with the qualifications noted in the QC section of the laboratory reports (Appendix C).

A review of data quality indicators and evaluation of potential data impact associated with the analytical chemistry results are provided below:

- Low-level detections of dissolved copper were measured in some of the field blanks (FBs; 6 of 17 events) and equipment rinsate (ER) blanks (12 of 17 events).
    - Measurable concentrations of dissolved copper in FB samples ranged from 0.012 to 0.038 µg/L. Concentrations measured in ER blanks ranged from 0.005 to 0.53 µg/L. These low-level detections may indicate trace contamination in the field and equipment blanks, laboratory contamination, and/or a combination of calibration offset near the method reporting limit. The low-level concentrations were negligible relative to the sample concentrations measured within SIYB, and there is no impact on data usability.
- Low-level detections of dissolved copper were measured in some of the method blanks (5 of 17 events).
    - Measurable concentrations of dissolved copper in the method blanks ranged from 0.007 to 0.1 µg/L, which are orders of magnitude below SIYB sample concentrations. These ultra-low-level detections are expected due to the low method detection limit of 0.0038 µg/L. This trace-level laboratory contamination is considered to be negligible, and there is no impact on data usability.
- Laboratory control sample (LCS) recoveries for all sample batches ranged from 91 to 111% and were well within performance-based recovery limits (70–130%).
    - Of the 35 LCS results reported, recoveries averaged 99.7%, indicating excellent overall accuracy. In addition, the 91 to 111% recovery range demonstrates very good precision.
- Matrix spike (MS) and matrix spike duplicate (MSD) recoveries were all within performance-based recovery limits, with the exception of one MS sample from Week 6.
    - Of the 34 MS/MSD pairs reported, recoveries averaged 99.8%, indicating very good overall accuracy. In addition, the 80 to 131% recovery range demonstrated good precision (SD=10.6). There was one control limit exceedance of 131% recovery for a MS sample. However, this single exceedance was attributable to low spiking concentration relative to sample concentration. The data are flagged accordingly and reported as measured with no other data qualification.
- Five samples were reanalyzed due to anomalous results, including one site sample from Station C-9 (Week 2; ND [non-detect]), one site sample from Station C-10 (Week 2; ND), one site sample from Station C-12 (Week 10; 17 µg/L), one ER blank (Week 10; 1.9 µg/L), and one field blank (Week 12; 1.1 µg/L).
    - These results were reported as measured in the reanalysis without other data qualification.

4.0 SUMMARY OF MONITORING PROGRAM FINDINGS

The purpose of this monitoring program was to assess how a pause in hull cleaning of vessels with copper-based AFPs affects dissolved copper concentrations in SIYB. As described in this report, surface water samples for dissolved copper analyses were taken prior to, during, and after the Hull Cleaning Pause to conduct the assessment. The monitoring results provide information regarding the relationship between dissolved copper loading from hull cleaning and water quality in SIYB.

With regard to the specific findings of this monitoring program, there was an apparent increasing trend in dissolved copper concentrations during the Pre-Pause period and first two weeks of the Pause, followed by a slight downward trend in the remaining Pause and Post-Pause periods. This trend was particularly evident in the inner and middle regions of the basin where vessels are most concentrated. No clear trends in dissolved copper concentrations were observed in the outer portions of the basin near the mouth.

As previously discussed (Section 1.1), the 2005 SIYB TMDL Conceptual Model assumed that hull cleaning of copper-based AFPs contributed 5% to the total dissolved copper load to SIYB (compared with 93% for passive leaching), while a more recent study (Earley et al., 2013) indicated that the SIYB TMDL's hull cleaning load assumption may be an underestimate. The SIYB TMDL Model assigned the 5% hull cleaning load based on the assumption that each cleaning event is an instantaneous one-day event resulting in enhanced copper release rates only during the active cleaning of a vessel with copper-based AFP. In contrast, Earley et al. (2013) found that dissolved copper release rates were not only enhanced during the cleaning event, but for two to three days following the cleaning event, and then slowly declined until reaching a "pseudo steady state" approximately 30 days post-cleaning. As such, the Earley et al. (2013) study suggests that dissolved copper loading associated with hull cleaning occurs over a longer period of time following a cleaning event and consequently may account for a greater load contribution (i.e., >5%) than previously predicted in the TMDL.

Based on the findings presented in Earley et al. (2013), it was theorized that a complete pause in hull cleaning in SIYB for longer than the 30-day period expected for copper release rates to return to a "pseudo steady state" would result in an observable decrease in dissolved copper levels in the basin, as the load contribution from hull cleaning was reduced to zero. It was further theorized that if the hull cleaning load was substantially greater than the modeled 5% from the SIYB TMDL, then a corresponding decrease in dissolved copper may shift the basin-wide water quality substantially closer to the 3.1 µg/L water quality standard.

This report is intended to present results from the monitoring program to enable stakeholders, including regulatory agencies, to use this information to discuss and determine next steps for SIYB and other copper-related regulatory actions, where applicable. Specific findings from this monitoring program are highlighted below.

- There was an apparent increase in the dissolved copper levels throughout the basin during the Pre-Pause period and extending through the first two weeks of the Pause, particularly at the inner basin stations and the stations in closer proximity to vessels (i.e., enhanced stations). There was also a noticeable increase in hull cleaning activities in the last two weeks of the Pre-Pause period as boaters and hull cleaners prepared for the Hull Cleaning

Pause. Under the assumption that dissolved copper leach rates spike following cleaning events, the increase in dissolved copper concentrations observed during the Pre-Pause period and beginning of the Pause period, particularly in the inner basin, could be attributed to an increase in hull cleaning activities.

- After the first two weeks of the Pause, dissolved copper concentrations began to trend downward over remainder of the Pause period. This trend continued through the Post-Pause period. This finding was consistent with that presented in Earley et al. (2013), with the expected spike in dissolved copper concentrations from hull cleaning activities gradually diminishing as concentrations returned to "pseudo steady state" after the first 30 days of the Pause. The hull cleaning inspections conducted throughout the eight-week Hull Cleaning Pause did not find any instances where divers were cleaning or had cleaned (via dive tag observations) vessels with copper-based AFPs. This finding was further supported by the notable increase in marine growth (fouling) on vessel hulls throughout the basin over the course of the Pause.

- Following the Pause, it was assumed that hull cleaning frequency would increase to Pre-Pause levels as cleaning activities resumed. However, observations during dock walks conducted in the Post-Pause period did not indicate a notable increase in hull cleaning, suggesting that there may have been a delay in resuming routine hull cleaning activities following the Pause. This may have contributed to the continued slight downward trend in dissolved copper concentrations following the Pause.

- The monitoring program also included a stormwater sampling component to evaluate the potential effects of stormwater discharge on copper levels in SIYB and on the Hull Cleaning Pause monitoring results. The results of the pre- and post-storm weekly monitoring events suggested that stormwater discharge did not contribute a substantial amount of copper loading to SIYB. While the storm did appear to have an overall mixing effect on the spatial distribution of dissolved copper in SIYB (i.e., more uniform concentrations throughout the basin after the storm), the basin-wide average dissolved copper concentrations remained the same before and after the storm (11 µg/L). As such, storm events and associated stormwater runoff are not expected to have had any significant impact on dissolved copper levels or conclusions related to the effects of hull cleaning on dissolved copper concentrations throughout the monitoring program.

- While there was an observed decrease in basin-wide dissolved copper levels during the Pause and Post-Pause periods, it should be noted that the basin-wide average measured during the final week of the monitoring program (7.2 µg/L in Week 16) was similar to that measured during Week 1 (6.5 µg/L). These basin-wide average dissolved copper concentrations were also consistent with those measured during previous TMDL monitoring events (Wood, 2022a).

- While a pause in the hull cleaning of vessels with copper-based AFPs does decrease the load of dissolved copper into the basin, leading to subsequent reductions in dissolved copper concentrations, it appears that changes to the basin-wide dissolved copper concentrations are minimal when compared with the passive leaching of copper-based AFPs, which is the predominant source of copper loading to the basin.

- Despite observed decreases in dissolved copper levels during the Pause and Post-Pause periods, the total cessation of hull cleaning during the monitoring program was insufficient to reduce the basin-wide dissolved copper levels to a level that would achieve the current water quality standard (3.1 µg/L).

The following points should be considered when interpreting results from this monitoring program:

- It is not currently known what the dissolved copper levels would be if the study were to be extended over a longer period of time. However, the findings of this study suggest that a complete elimination of hull cleaning would not likely result in achievement of water quality standards in SIYB.

- It is not currently known how the effects of hull cleaning on dissolved copper levels may differ in other marina basins with different characteristics (e.g., number of vessels, size, hydrodynamics).

- Careful consideration must be given to balancing the value of hull cleaning in protecting, maintaining and preserving vessel hulls and in preventing invasive species with the environmental concerns related to cleaning.

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APPENDIX A

IN-WATER HULL CLEANING INSPECTION REPORTS

APPENDIX B

WATER QUALITY MONITORING FIELD DATA SHEETS AND QA CHECKLISTS

APPENDIX C

WECK LABORATORIES ANALYTICAL CHEMISTRY REPORTS

APPENDIX D

SUPPLEMENTAL DATA ANALYSIS AND GRAPHS