IN-WATER HULL CLEANING SUMMARY REPORT
US DOT – MARITIME ADMINISTRATION
ALAMEDA, CALIFORNIA

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Acronyms and Abbreviations

BAT	Best Available Technology economically feasible
BMP	Best Management Practice
COC	constituent of concern
gpm	gallons per minute
MARAD	Maritime Administration
psi	pounds per square inch
PVC	polyvinyl chloride
RL	reporting limit
ROS	reduced operating status
RWQCB	Regional Water Quality Control Board
SWRCB	State Water Resources Control Board
Terraphase	Terraphase Engineering Inc.
µg/L	microgram per liter (part per billion)
USEPA	United States Environmental Protection Agency
US DOT	United States Department of Transportation
USI	Underwater Services International, Inc.
VGP	Vessel General Permit
WQO	Water Quality Objective

Certification

All engineering information, conclusions, and recommendations in this document have been prepared by a California Professional Engineer.

Ryan Janoch

11-28-2012

Ryan Janoch Date

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EXECUTIVE SUMMARY

Regulatory Background

Under the United States Environmental Protection Agency (USEPA) National Pollutant Discharge Elimination System (NPDES) Vessels General Permit for Discharges Incidental to the Normal Operation of Vessels (VGP), underwater hull husbandry (in-water hull cleaning) is a permitted discharge. In-water hull cleaning is being conducted in ports throughout the United States using commercially available methods and best management practices (BMPs). Hull cleaning benefits the environment by reducing a vessel's emission of greenhouse gas pollutants and fuel consumption, the potential for engine damage as the ship's engine doesn't have to work as hard to propel the vessel, and the risk of transferring aquatic species from one bio-geographic region to another by removing exobiotic organisms from the ship. However, the State of California has prohibited in-water hull cleaning and associated discharges, because there is no accepted Best Available Technology economically feasible (BAT) to control discharges of metals to state and federal waters that result from in-water cleaning. The California exception to the VGP and lack of available and approved BAT creates regulatory difficulties and places commercial marine operators in California at a significant disadvantage compared to those in other states.

Water Quality Objectives

The prohibition on in-water hull cleaning has to do largely with the water quality objective (WQO) for copper in receiving waters. Copper is toxic to aquatic organisms (mainly dissolved copper due to its bioavailability), which makes it a good biocide, but its use can cause unintended consequences when anti-fouling paint containing copper is discharged as particulates into the water column.

Purpose of the Study

To identify and evaluate a BAT to capture and treat metal particulates in hull cleaning process water, the United States Department of Transportation (US DOT) – Maritime Administration (MARAD), conducted an in-water hull cleaning test under the oversight of the California San Francisco Bay Regional Water Quality Control Board (RWQCB) on a MARAD owned reduced operating status (ROS) vessel, the Cape Orlando. This report summarizing the hull cleaning study is being submitted by MARAD to the RWQCB and State Water Resources Control Board (SWRCB) as evidence of a BAT for in-water hull cleaning and in support of their application for a general NPDES discharge permit.

Containment and Capture

A scrubber unit with rotating plastic brushes was used to clean a section of the Cape Orlando's hull. During this operation, water samples were collected from the ambient water around the scrubber unit to monitor for containment and capture of the biological material and particulates being removed from the vessel's hull. The in-water hull cleaning test successfully demonstrated the containment and capture of process water containing the removed biological material and small amounts of anti-fouling paint through the use of a suction line on the discharge of the scrubber unit and rubber edging on the scrubber unit which maintained a seal between the scrubber and the hull.

Process Water Treatment

To provide treatment of the collected process water, a treatment system utilizing filter cartridges and a filtration media (organo-clay) was designed and tested. The treatment system proved to be effective at removing total copper and zinc from the process water via the filter cartridges and dissolved copper and zinc from the process water via the organo-clay filtration media.

Mixing Zone Study

Although the treatment system was not capable of reducing dissolved copper and zinc concentrations to the WQOs of the receiving water, a mixing zone study was conducted in San Francisco Bay to determine the mixing zone (dilution credit) necessary to meet the WQOs of the receiving water. Based on the rhodamine dye and dissolved zinc concentrations measured during the mixing zone study, complete mixing occurred and the receiving water’s water quality objectives were met during discharge of treated water.

Summary

This project successfully identified and demonstrated that a BAT is available for conducting in-water hull cleaning. The BAT includes a scrubber unit capable of containing and capturing process water containing removed biological material and particulates and a treatment system that can remove copper, zinc, and particulates from the process water.

1.0 INTRODUCTION

Terraphase Engineering Inc. (Terraphase) has prepared this summary report of the in-water hull cleaning test conducted for the United States Department of Transportation (US DOT) – Maritime Administration (MARAD), at the former Naval Air Station located in Alameda, California. The in-water hull cleaning test was conducted under the oversight of the California San Francisco Bay Regional Water Quality Control Board (RWQCB) to identify and evaluate a Best Available Technology economically feasible (BAT) to capture and treat metals in hull cleaning process water. This summary report includes the water quality sampling data collected from the treatment system and San Francisco Bay during in-water hull cleaning and the discharge of treated wastewater. A discussion of the surface water quality and treatment system data is also included as it relates to the San Francisco Bay Basin Plan.

The general objectives of this summary report are to:

- Summarize and evaluate the capture of metals during the in-water hull cleaning operation;
- Determine whether methodologies used to collect and treat in-water hull cleaning process water in this study satisfy the requirements of BAT for in-water hull cleaning; and
- Evaluate the size of the mixing zone necessary to discharge treated water under a RWQCB and/or State Water Resources Control Board (SWRCB) general discharge permit for ship hull cleaning operations.

2.0 PROJECT BACKGROUND

MARAD is the government agency responsible for maintaining the readiness of several operational vessels throughout California waters and the United States. These vessels are strategic national assets, in a reduced operating status (ROS), with small crews, berthed at several locations (e.g., Alameda, San Francisco, Long Beach, and San Diego). These vessels do not operate (sail) regularly. Therefore, their hulls collect organic growth that can be grouped into three categories: hard growth, consisting of hard or flaky algae encrustations; soft growth, consisting of thin bacterial growth; and animal growth, including invertebrate organisms such as mussels, barnacles, and tubeworms.

2.1 Benefits of Hull Cleaning

A growing body of data suggest that aquatic growth (hull bio-fouling) on vessels presents a risk of transferring aquatic species from one bio-geographic region to another. Therefore, fouled vessels from the San Francisco Bay area travelling to other regions, may transfer aquatic species. In order to reduce this risk, biota removal from hulls must occur while the vessels are in their current bio-geographic locations, using the BAT. Hull bio-fouling on operating vessels increases the vessel's drag and thus increases the vessel's emission of greenhouse gas pollutants, fuel consumption and increases the potential for engine damage, due to overloading.

2.2 Current Regulations

Under the United States Environmental Protection Agency (USEPA) National Pollutant Discharge Elimination System (NPDES) Vessels General Permit for Discharges Incidental to the Normal Operation of Vessels (VGP), underwater hull husbandry (in-water hull cleaning) is a permitted discharge. In-water hull cleaning is being conducted in ports throughout the United States using commercially available methods and best management practices. However, the State of California has prohibited in-water hull cleaning and associated discharges, because there is no accepted (by California regulators) BAT to control discharges of metals that result from in-water cleaning to state and federal waters. In-water hull cleaning will be allowed in California only after BAT, as determined by the SWRCB and the California State Lands Commission (CSLC), is established.

The prohibition on hull cleaning except in emergency situations has to do largely with the water quality objectives (WQO) for the receiving water (San Francisco Bay) in the San Francisco Bay Basin Water Quality Control Plan (Basin Plan). The Basin Plan includes WQOs for many metals, but the WQO most applicable to hull cleaning is for copper, due to its presence as a biocide in anti-fouling hull coatings. Copper is toxic to aquatic organisms (especially dissolved copper due to its bioavailability), which makes it a good biocide, but its use can cause unintended consequences when anti-fouling paint containing copper is discharged as particulates into the water column. For the hull cleaning test, two constituents of concern (COC) were established for in-water hull cleaning activities, copper and zinc.

2.3 Current Practices

Since 2006, the removal of hull bio-fouling from MARAD vessels around the country has been conducted in accordance with procedures recommended by the United States Coast Guard and agreed to by MARAD. These procedures require the use of non-metal brushes and the stipulation that only the soft growth be removed in order to minimize the disturbance of the paint coating.

Currently, anti-fouling hull coatings contain copper as a biocide to inhibit biologic growth. However, as noted above, there is still an accumulation over time, especially on (ROS) vessels which tend to remain in a fixed location for long periods of time. During the hull cleaning process, even using non-metallic brushes, biological growth and small amounts of the anti-fouling coating are removed from vessels' hulls and introduced into the process water being generated. Current practices elsewhere in the United States allow for the process water to be directly discharged into the surrounding water, provided a visible plume is not present.

Although California and federal law require that vessel operators maintain their hulls in a clean condition, the California exception to the VGP and lack of available and approved BAT creates regulatory difficulties and roadblocks. MARAD and several commercial maritime operators in California are compelled by the current requirements to avoid normal in-water hull cleaning and must dry dock their vessels in order to clean the hulls. The cost of an in-water hull cleaning operation around the country averages approximately $50,000 for a large commercial vessel. Currently, MARAD and commercial vessel operators are cleaning their vessel hulls in dry dock at a cost of hundreds of thousands of dollars per vessel. Another impractical, costly and dangerous option is cleaning the vessel hulls outside California's jurisdictional limits (three miles offshore). The inability to conduct in-water hull cleaning places commercial marine operators in California at a significant disadvantage compared to those in other states.

3.0 HULL CLEANING TEST

In July 2012, MARAD conducted a pilot project in the San Francisco Bay area to demonstrate the effectiveness of capturing and containing particulate matter and soluble metals generated during in-water hull cleaning activities. A ROS vessel, the Cape Orlando, berthed in Alameda, California was the vessel selected for this project. A containment system for the hull cleaning equipment was used to capture the material removed from the hull. Baseline concentrations of the COCs (copper and zinc) in the ambient water were characterized, and the effectiveness of the contain system to reduce the introduction of the COCs to the ambient water was evaluated. In addition, the effectiveness of a treatment system to reduce concentrations of these COCs in the process water was evaluated in order to establish it as a viable BAT for in-water hull cleaning.

3.1 Test Location

The hull cleaning test was conducted on Pier 2 at the former Naval Air Station Alameda located in Alameda, California on San Francisco Bay (Figure 1). The hull of the Cape Orlando was used for the test. The captured process water was pumped into the treatment and storage system on Pier 2 prior to undergoing additional treatment and eventual discharge (described in Section 4). Underwater Services International, Inc. based in Jacksonville, Florida conducted the in-water hull cleaning using their proprietary hull cleaning technology (described generally in Section 3.2).

3.2 Technology Description

The hull cleaning system (the scrubber) utilizes an in-water approach but provides recovery of removed material as well as seawater drawn into the scrubber to prevent discharge of the COCs to the surrounding water. The scrubber is a diver-operated, hydraulic-driven, 5-foot by 5-foot steel unit with three rotary brushes. It is configured with rotating brushes that form a square, with a propeller in the middle of the brushes that holds the unit against the hull with approximately 1,000 pounds of pressure per square foot (see the photo below). The propeller on the scrubber creates a vacuum that draws removed material into the discharge of the propeller wash (capture described below). There is a rubber gasket around the three quarters of the outside edge that creates a seal against the hull. The rubber gasket is open on the leading edge of the unit so that existing biological growth is not scraped off while the unit travels forward. A pressure differential of approximately four pounds per square inch (psi) exists between the inside of the scrubber and the surrounding water.

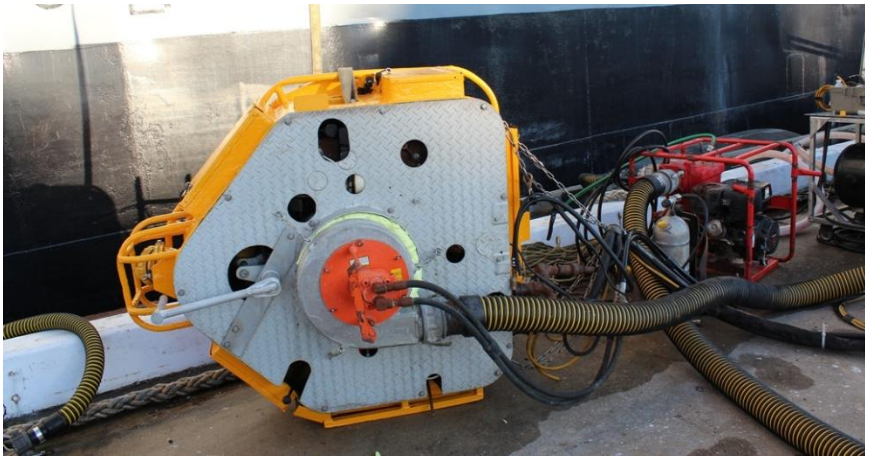
Scrubber unit with rotating brushes, suction propeller, and rubber edging.

Polypropylene brush heads were used for maximum abrasion of the soft growth from the hull while minimizing the removal of the anti-fouling paint coating. In addition to polypropylene brushes, other brush material (e.g. nylon or stainless steel) and abrasive discs are available to handle almost any type of marine fouling on a hull. The brushes are 30-inches in diameter and overlap each other for complete coverage of the surface area. The brush bristles are set at a 33 degree angle to minimize gouging of the painting coating (other hull cleaning companies often will use brushes that are set a 90 degree angles). The brush bristles lay flat against the hull, cleaning it with a sweeping motion.

The speed of brush rotation and the scrubber’s wheels, which propel it along the hull, can be adjusted by the diver to produce the type of cleaning action required. For example, light biological growth allows the brushes to rotate slower while the wheels should move faster resulting in minimal paint removal, maximum growth removal, and more surface area cleaned per minute. Conversely, with heavy encrustations, the wheels should move slower and the brushes rotate quicker to ensure adequate growth removal.

The diver guides the scrubber unit over the hull in lateral passes from bow to stern and completes the job by manually polishing the propeller, running gear, etc. The scrubber unit is capable of cleaning a hull at speeds up to 60 feet per minute (300 square feet per minute).

The propeller mounted in the center of the unit provides the suction to adhere the unit to the vessel's hull while also providing a discharge point for the removed material. In other applications, the removed material is discharged by the propeller into the surrounding water. For our pilot project, the discharge outlet was modified to attach a suction line to the unit (see photo below). The suction line was connected to a portable centrifugal pump capable of pumping up to 400 gallons per minute (gpm). The pump was used to pump the discharged material and seawater up to the treatment system located on Pier 2.



Suction line connected to the discharge outlet from the scrubber unit.

3.3 Test Process

On July 10, 2012, the divers deployed the scrubber unit for approximately 40 minutes to clean the biological growth from an area approximately 100 feet by 30 feet on the hull of the Cape Orlando. Approximately 12,000 gallons of process water (seawater and removed material) were collected as part of this activity.

3.4 Treatment System

The treatment system consisted of a particulate filter followed by a weir tank (Tank 1), which discharged through a filter cartridge array. Process water was pumped from the scrubber unit (approximately 12,000 gallons) into the particulate filter, which is a 100-micron (µm) stainless steel mesh screen (see photo below). Large particulates were trapped on the mesh screen and the filtered water was pumped into an 18,000-gallon weir tank. The particulates were periodically washed off of the mesh screen into a 20-gallon tub. A portable centrifugal pump with a 2-inch diameter suction line with a 10-µm fabric mesh sock on it was used to decant the wash water from the 20-gallon tub into the weir tank.

Mesh screen (100-µm openings) in the primary particulate filter.

On July 10, 2012, at the conclusion on the hull cleaning test, the filtered water was pumped at a rate of approximately 25 gpm from the weir tank through two 10-µm filter cartridges in series then through a 5-µm filter cartridge into a 1,000-gallon portable vinyl open top tank. Approximately 500 gallons of water was pumped into the portable tank to allow for water quality samples to be collected. After the samples were collected, the treated water was pumped back into the weir tank.

On July 13, 2012, the filtered water was pumped at a rate of approximately 25 gpm from the weir tank through two 10-µm filter cartridges in series, a 5-µm filter cartridge, and a pressure vessel containing 2,000 pounds of organo-clay (modified zeolite) into the 1,000-gallon portable vinyl open top tank. Approximately 750 gallons of process water was treated. The filtered water was then pumped again at 25 gpm through the pressure vessel containing 2,000 pounds of organo-clay and discharged back into the weir tank. This was done to allow for additional water quality samples to be collected to determine treatment system performance.

View (left to right) of the storage tank, pressure vessel, and filter cartridge array.

3.5 Sampling Locations

The Cape Orlando had a draft of approximately 15 feet below the water surface during the time of the hull cleaning test (July 9 through 13, 2012), so water quality samples were collected at a depth of 7.5 feet below the water surface (mid-depth) unless otherwise noted. On July 9, 2012 (one day prior to the hull cleaning test), four water quality samples were collected next to it's hull at the bow, stern, starboard, and port side (Section 4.1 below contains the results). The Cape Orlando was moored south of the pier with the bow facing west and the stern to the east.

On the day of the hull cleaning test (July 10, 2012), ambient water quality samples were collected from the surface water at the bow and stern of the Cape Orlando (Figure 2) approximately 1 hour prior to the introduction of divers or equipment into the water.

The hull cleaning equipment was deployed from the southwest corner of Pier 2. The scrubber unit cleaned along the hull of the Cape Orlando (located south of the pier) heading west towards the bow for approximately 40 minutes (operated by one member of the dive team), while the second diver collected water quality samples (Figure 2). Water quality samples were collected from approximately 7.5 feet below the water surface at the times and locations described in the table below to monitor the capture of COCs.

Ambient Water Sampling Summary

Sample Identification	Time Elapsed After Cleaning Began (minutes)	Location in Relation to the Scrubber
Hull 20-1	1	1 foot away
Hull 20-50E	10	50 feet east
Hull 20-50W	15	50 feet west
Hull 40-1	21	1 foot away
Hull 20-50N	29	50 feet north
Hull 40-50W	38	50 feet west
Hull 40-50E	45	50 feet east

Note: The Cape Orlando was located south of the pier, oriented east to west. A sample collected 50 feet east of the scrubber was collected between the pier and the hull 50 feet east of the scrubber location.

On July 10, 2012, additional water quality samples were collected from the weir tank (last chamber) and the treatment system (after being filtered through the 5-micron filter cartridge). On July 13, 2012, water quality samples were collected from the influent and effluent of the pressure vessel during the first pass through and during the second pass (effluent sample only) through the treatment system.

3.6 Sample Analysis

The water quality samples collected on July 10, 2012 were collected in a one liter container by the diver and sub-sampled into separate containers for dissolved and total metals. The water quality samples from the treatment system were collected in separate containers for dissolved and total metals. The water quality samples for dissolved metals were collected in 500-milliliter (mL) polyethylene containers (unpreserved) and samples for total metals were collected in 250-mL polyethylene containers preserved with nitric acid. The samples were submitted to the analytical laboratory for CAM 17[1] metals plus tin analysis for both dissolved and total metals concentrations. All samples were stored in a cooler, on ice, at a temperature of 4 degrees Celsius, or less, and delivered to the analytical laboratory within 24 hours of sample collection. The dissolved metals samples were filtered in the laboratory using a 0.45-μm filter.

The water quality samples collected during the operation of the treatment system on July 13, 2012 were collected in 1-liter polyethylene containers. All samples were stored in a cooler, on ice, at a temperature of 4 degrees Celsius, or less, and delivered to the

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[1] CAM 17 metals include Antimony, Arsenic, Barium, Beryllium, Cadmium, Chromium, Cobalt, Copper, Lead, Mercury, Molybdenum, Nickel, Selenium, Silver, Thallium, Vanadium, and Zinc.

analytical laboratory within 24 hours of sample collection. The samples were submitted to the analytical laboratory for CAM 17 metals plus tin analysis for both dissolved and total metals concentrations. The analytical laboratory sub-sampled the containers in the laboratory for total and dissolved metals. The dissolved metals samples were filtered in the laboratory using a 0.45-μm filter.

4.0 HULL CLEANING TEST RESULTS AND DISCUSSION

Based on the results of the analysis of ambient water and treatment system samples and an examination of applicable Basin Plan WQOs, copper and zinc were identified as the COCs. Thus, for the purposes of this summary report, just copper and zinc concentrations (the COCs) relative to the Basin Plan WQO's are reported and discussed. The Basin Plan water quality objectives for dissolved copper are 9.4 μg/L (from Table 3-3A of the Basin Plan) and for dissolved zinc are 90 μg/L (from Table 3-3 of the Basin Plan).

4.1 Test Results (Bay Water)

Zinc was not detected above the WQO in the water quality samples collected from the Bay during the in-water hull cleaning. The dissolved zinc concentrations were less than the laboratory reporting limit of 50 μg/L.

Dissolved copper was detected in the background water quality sample collected at the stern of the Cape Orlando at a concentration of 13 μg/L (slightly above the Basin Plan WQO of 9.4 μg/L). Dissolved copper was also detected in two of the seven samples collected during the hull cleaning test, at concentrations of 11 μg/L (Hull 20-1) and 15 μg/L (Hull 20-50W). However, these concentrations are similar to the background sample collected a day earlier.

In one of the samples, the total copper was reported as less than the dissolved copper. This is likely due to the sub-sampling of the collection container. There were likely slight differences in the water in each container (e.g. the container for total metals contained less particulate than the container for dissolved metals).

Background Results Summary (9JUL12)

Sample Identification	Total Copper (µg/L)	Dissolved Copper (µg/L)	Total Zinc (µg/L)	Dissolved Zinc (µg/L)	Location in Relation to the Scrubber
Mid-depth level bow	10	<5.0	<50	<50	150 feet west
Mid-depth level stern	8.5	13	<50	<50	450 feet east
Mid-depth level starboard	<5.0	<5.0	<50	<50	150 feet east
Mid-depth level port mid-ship	<5.0	<5.0	<50	<50	150 feet southeast

Note: The Cape Orlando was located south of the pier, oriented east to west. A background sample collected 150 feet east of the scrubber was collected between the pier and the hull 150 feet east of the scrubber starting location the next day (the southwest corner of the pier).

Hull Cleaning Test Results Summary (10JUL12)

Sample Identification	Total Copper (µg/L)	Dissolved Copper (µg/L)	Total Zinc (µg/L)	Dissolved Zinc (µg/L)	Location in Relation to the Scrubber
Amb 5b	<5.0	<5.0	<50	<50	150 feet west
Amb 5s	<5.0	<5.0	<50	<50	450 feet east
Hull 20-1	37	11	<50	<50	1 foot away
Hull 20-50E	7.5	<5.0	<50	<50	50 feet east
Hull 20-50W	35	15	63	<50	50 feet west
Hull 40-1	18	<5.0	<50	<50	1 foot away
Hull 20-50N	<5.0	<5.0	<50	<50	50 feet north
Hull 40-50W	5.6	<5.0	<50	<50	50 feet west
Hull 40-50E	6.4	<5.0	<50	<50	50 feet east

Note: The Cape Orlando was located south of the pier, oriented east to west. A background sample collected 150 feet east of the scrubber was collected between the pier and the hull 150 feet east of the scrubber starting location the next day (the southwest corner of the pier).

4.2 Treatment System

The capture of the removed material is evident by the high copper and zinc concentrations seen in the sample collected from the weir tank (Tank 1). The water in the weir tank consisted of the seawater and removed material discharged from the scrubber and pumped to the treatment system on Pier 2. The total copper concentration of the water quality sample from the weir tank (post 100-μm filtering) was 1,800 µg/L with a dissolved copper concentration of 520 µg/L; the total zinc concentration was 1,300 µg/L with a dissolved zinc concentration of 650 µg/L.

As expected due to its presence in the anti-fouling coating, the majority of the copper (over 70%) is in the particulate form. Half of the zinc is in the particulate form and is likely from another paint coating or from the hull of the vessel.

The COCs were also detected in the water quality sample collected after being filtered by the one 5-μm filter cartridge in series with the two 5-μm filter cartridge cartridges in parallel. The total copper concentration was 680 µg/L with a dissolved copper concentration of 530 µg/L. The majority of the larger particulates (greater than 5-μm were removed in the treatment process). The dissolved copper concentration in the process water was approximately the same post-filter cartridge treatment as in the weir tank, indicating little uptake by microorganisms in the weir tank or binding to other constituents. The total zinc concentration was 980 µg/L with a dissolved zinc concentration of 460 µg/L. There was some zinc particulate removal, but not as much as was expected.

After using the pressure vessel with organo-clay, the dissolved copper concentration dropped from approximately 500 µg/L (after the 5-μm filter cartridge) to approximately 200 μg/L. A second pass through the pressure vessel resulted in approximately 50% removal of dissolved copper to a concentration of approximately 100 µg/L. The corresponding dissolved zinc concentration dropped from approximately 800 µg/L prior to the pressure vessel (organo-clay) to approximately 600 µg/L after the second pass through. The organo-clay removed approximately 80% of the dissolved copper and approximately 25% of the dissolved zinc from the process water.

Treatment System Test Results Summary

Sample Identification	Sample Date	Total Copper (µg/L)	Dissolved Copper (µg/L)		Total Zinc (µg/L)	Dissolved Zinc (µg/L)	
Set 50	7-10-2012	1,800	520		1,300	650	
Filt 5	7-10-2012	680	530		980	460	
INF-1	7-13-2012	480	560	510	760	800	760
EFF-1	7-13-2012	76	210	190	580	700	650
EFF-2	7-13-2012	86	89	92	570	560	610

Note: Duplicate sample results reported in the split columns.

5.0 TREATMENT SYSTEM

RWQCB, per the VGP, prohibits discharge of in-water hull cleaning process water directly to the San Francisco Bay, because it would cause an exceedence of the San Francisco Basin Plan's receiving water's WQOs. However, a mixing zone (dilution) is often allowed by the RWQCB for dischargers (such as wastewater treatment plants) to meet these objectives. In preparation for a mixing zone study, the collected process water (12,000 gallons) was treated using the filter cartridges and filtration media (organo-clay) identified above that had proved effective at removing dissolved copper and zinc.

5.1 Process Water Treatment

On August 27, 2012, the stored process water (approximately 12,000 gallons) collected during the in-water hull cleaning test was treated. The untreated process water was pumped at a flow rate of approximately 50 gpm from an 18,000 gallon tank (Tank 1) through one 10-μm filter cartridge arranged in series with two 5-μm filter cartridges installed in parallel. From the filter cartridge array, the water was conveyed through a pressure vessel containing 2,000 pounds of organo-clay (modified zeolite). The treated water was discharged into a second 18,000 gallon tank (Tank 2).

Following the cleaning of Tank 1 on August 29, 2012, the water stored in Tank 2 was pumped through the pressure vessel with the organo-clay at an average flow rate of approximately 50 gpm into the clean Tank 1. This procedure served to evaluate the use of two organo-clay vessels in series as the BAT.

5.2 Water Quality Monitoring

A grab sample was collected from the tank (Tank 1) prior to the start of treatment. Two samples were collected from the influent and effluent of the pressure vessel during the first treatment period on August 27, 2012 (total of two sample pairs). The first set of samples (influent [INF-1] and effluent [EFF-1]) was collected shortly (less than 30 minutes) after beginning treatment and the second set (influent [INF-1A] and effluent [EFF-1A]) approximately three hours later. A set of field duplicates was collected (influent [INF-1] and effluent [EFF-1]) at the same time the first set of samples was collected and submitted to a different analytical laboratory. These samples were analyzed for total and dissolved copper and zinc (the COCs). One set of water quality samples (influent [INF-2] and effluent [EFF-2]) was collected from the influent and effluent of the pressure vessel shortly (less than 30 minutes) after treatment began during the second treatment period on August 29, 2012. A second effluent sample (EFF-2A) was collected after approximately four hours.

5.3 Sample Analysis

The water quality samples collected during the operation of the treatment system were collected in 1-liter polyethylene containers. All samples were stored in a cooler, on ice, at a temperature of 4 degrees Celsius, or less, and delivered to the analytical laboratory within 24 hours of sample collection. The analytical laboratory sub-sampled the containers in the laboratory for total and dissolved metals. The dissolved metals samples were filtered in the laboratory using a 0.45-μm filter.

Samples collected from the treatment system on August 27, 2012 were analyzed for total and dissolved copper and zinc. Samples collected from the treatment system on August 29, 2012 were analyzed for dissolved copper and zinc.

5.4 Results and Discussion

The total and dissolved copper and zinc concentrations were lower than expected in the weir tank (Tank 1). Dissolved copper concentration was 6.5 μg/L and the dissolved zinc concentration was 54 μg/L. However, this is likely due to the process water sitting for 6 weeks. Even small particulates would have had time to settle out over this period and the presence of organisms and other biological activity in the process water could have resulted in the uptake of the copper and zinc or the formation of metal-ligand complexes.

The effluent samples collected from the treatment system initially had elevated dissolved zinc levels (580 μg/ and 670 μg/L). This likely was due to the process water sitting in the pressure vessel for the 6 weeks, as the salinity of the water could have caused the organo-clay to release the zinc ions into the water. Effluent samples collected approximately three hours later had minimal rises in dissolved zinc concentrations (influent concentration was 210 μg/L and effluent concentration was 300 μg/L).

However, the dissolved copper concentrations dropped from 17 μg/L to 7.3 μg/L (first set of influent and effluent samples, respectively) and from 20 μg/L to 15 μg/L (influent and effluent samples collected approximately three hours later, respectively) with treatment.

Influent and effluent samples collected during the second pass through the pressure vessel (organo-clay filter) show that there was little effect on the dissolved copper and zinc concentrations. This is likely due to the dissolved copper concentrations, which the organo-clay had been previously shown to be preferential for over the dissolved zinc, already being very low.

During full-scale in-water hull cleaning, the organo-clay would be used to filter process water as it is being pumped from the scrubber discharge. This likely will eliminate the potential for zinc to be released from the organo-clay.

Treatment System Test Results Summary

<table>
<tr><th>Sample Identification</th><th>Sample Date</th><th colspan="2">Total Copper (µg/L)</th><th colspan="2">Dissolved Copper (µg/L)</th><th colspan="2">Total Zinc (µg/L)</th><th colspan="2">Dissolved Zinc (µg/L)</th></tr>
<tr><td>Tank-1</td><td>8-27-2012</td><td colspan="2">32</td><td colspan="2">6.5</td><td colspan="2">61</td><td colspan="2">54</td></tr>
<tr><td>INF-1</td><td>8-27-2012</td><td>21</td><td>25</td><td>20</td><td>17</td><td>57</td><td>63</td><td>60</td><td>69</td></tr>
<tr><td>EFF-1</td><td>8-27-2012</td><td>10</td><td>10</td><td>9.9</td><td>7.3</td><td>590</td><td>710</td><td>580</td><td>670</td></tr>
<tr><td>INF-1A</td><td>8-27-2012</td><td colspan="2">35</td><td colspan="2">20</td><td colspan="2">210</td><td colspan="2">210</td></tr>
<tr><td>EFF-1A</td><td>8-27-2012</td><td colspan="2">20</td><td colspan="2">15</td><td colspan="2">370</td><td colspan="2">300</td></tr>
<tr><td>INF-2</td><td>8-27-2012</td><td colspan="2">--</td><td colspan="2">9.7</td><td colspan="2">--</td><td colspan="2">260</td></tr>
<tr><td>EFF-2</td><td>8-27-2012</td><td colspan="2">--</td><td colspan="2">13</td><td colspan="2">--</td><td colspan="2">400</td></tr>
<tr><td>EFF-2A</td><td>8-27-2012</td><td colspan="2">--</td><td colspan="2">15</td><td colspan="2">--</td><td colspan="2">420</td></tr>
</table>

Note: Duplicate sample results reported in the split columns.

6.0 MIXING ZONE STUDY

To determine the size of mixing zone necessary to meet the water quality objectives, the treated process water (12,000 gallons) was discharged to San Francisco Bay. Water quality samples were collected during the discharge of the treated water to delineate the extent of the mixing zone necessary.

6.1 Mixing Zone Sizing

The size of the mixing zone was calculated based on the ambient and treated water dissolved copper concentrations of 5 μg/L and 100 μg/L[2], respectively. The dissolved copper concentration in the ambient water was assumed to be less than 5 μg/L, which is the analytical method reporting limit (RL) for USEPA Method 6010. Based on the above background and treated water dissolved copper concentrations, approximately 270,000-gallons of ambient water was necessary to mix with the 12,000 gallons of treated water to achieve a dissolved copper concentration below the water quality objective of 9.4 μg/L in the Basin Plan (RWQCB 2011). Dissolved copper concentrations were used to calculate the mixing zone size as it was more conservative than the expected zinc concentrations in the treated water[3].

The 270,000 gallon volume (36,000 cubic feet) fills a 20-foot high (based on a discharge point 10 feet below the water surface), 20-foot wide, and 90-foot long area in San Francisco Bay. However, with a safety factor of 10, the volume grows to 180 feet long and 100 feet wide (20 feet high). Based on these estimates, surface water sampling locations were selected so that some would potentially have elevated (over background) dissolved copper concentrations.

These sampling locations were based on a minimum volume of approximately 270,000 gallons of ambient water necessary for complete mixing to reduce the treated water dissolved copper and zinc concentrations to below the applicable Basin Plan water quality standards. Due to the highly variable nature of the San Francisco Bay with constantly changing and unknown currents, a conservative mixing zone calculation was necessary. Accounting for incomplete mixing and a margin of safety of 10 times the minimum volume necessary and a mixing depth of 20 feet, the mixing zone length and width is expected to be approximately 135 feet in each direction.

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[2] The initial treatment resulted in a dissolved copper concentration of less than 100 ug/L after 2 passes through the pressure vessel containing organo-clay.

[3] With an expected dissolved zinc concentration of 600 μg/L in the treated water and a background concentration of 50 μg/L (laboratory RL), the ambient water necessary to achieve the water quality objective of 90 μg/L was estimated to be approximately 87,000 gallons.

6.2 Treated Water Discharge

On August 30, 2012, a portable centrifugal pump was used to convey the treated water via a 6-inch diameter hose from Tank 1 to the mooring platform (Figure 3) located approximately 200 feet from the end of Pier 2. The discharge point was located approximately 10 feet below the water surface. The water was discharged into San Francisco Bay at a flow rate of approximately 400 gpm, which is the expected rate during in-water hull cleaning operations, for 30 minutes.

Mooring platform and discharge hose from the pier.

The discharge of the treated water was conducted at slack tide (lowest current) in order to have the most conservative mixing dynamic. Initially, the discharge of the water was to occur at 1230. However, due to the arrival of a large MARAD operational vessel and support tug boats in the area of our mixing zone study (photo below), the study was suspended prior to water discharge. The water was discharged at 1830, which was the next slack tide on August 30, 2012.

Vessel coming through the mixing zone sampling area.

6.3 Sampling Locations

Water quality samples were collected at a depth of approximately 10 feet below the water surface, the same depth as the discharge point. Samples were collected from twenty sampling locations (S-1 through S-20), as shown on Figure 3. Sample locations S-1 through S-7 were accessed from the mooring platform. Sample locations S-16 and S-20 were accessed from Pier 2. The remaining sampling locations were accessed via small boats.

Sampling station in San Francisco Bay being sampled from a small boat.

Samples S-1 and S-7 were located approximately 5 feet from the discharge point. Sample locations S-2, S-6, S-8, S-9, S-10, S-11, and S-12 were located approximately 40 feet from the discharge point. Sample location S-3 was located approximately 60 feet from the discharge point. Sample locations S-4 and S-5 were located approximately 75 feet from the discharge point. Sample locations S-13 through S-16 were located approximately 150 feet from the discharge point. Sample Locations S-17 through S-20 were located approximately 300 feet from the discharge point in order to evaluate if the mixing zone is elongated more than expected or if the dilution time is longer than expected.

Placement of the sampling stations in San Francisco Bay.

Sample locations S-8, S-10, S-11, and S-12 were observed to drift approximately 20 to 30 feet during the mixing zone study due to the tidal forces. The approximate resulting sampling locations are shown in Figure 3.

6.4 Sample Timing

Background water quality samples were collected from each sampling location prior to discharge of the treated water. Water quality samples were then collected from sampling location S-1 through S-16 approximately 20, 40, and 60 minutes after the start of treated water discharge. Discharge of treated water ended after approximately 30 minutes had elapsed; however, samples were collected after 40 and 60 minutes had elapsed in order to monitor for dilution and dispersion of the dissolved COCs in the receiving water. In addition, samples were collected from sample locations S-17 through S-20 after 70 minutes had elapsed.

A duplicate field sample was also collected at a frequency of one per sample period (e.g. one duplicate during the background sample, one during the 20-minute sample period, etc.).

A sample was collected from Tank 1 prior to the start of discharge and again 20 minutes after discharge began.

6.5 Sample Stations

A custom designed sample station was constructed for the mixing zone study for the sampling locations accessed by boat. The sample station was constructed of a closed cell foam block (a 2 foot square that was 3 inches thick) with a 12-foot long polyvinyl chloride (PVC) pipe through the center. A 20 foot long ¼-inch diameter polyethylene tubing was attached to the side of the PVC pipe. Ten feet of tubing and PVC pipe were beneath the foam block and a 2-foot section of PVC pipe stuck up above the foam block with the additional 10-foot section of tubing. The foam block was anchored to a cement-filled 5-gallon bucket (anchoring the sample station to a fixed location) via a ½-inch polypropylene rope with an elastic band on the end. The elastic band allowed for the sample station to rise and fall with the tides. Samples were collected using a peristaltic pump with dedicated ½-inch diameter silicon and ¼-inch diameter polyethylene tubing at each sample location.

Sampling stations on Pier 2 prior to deployment in San Francisco Bay.

The sample stations on the pier and the mooring platform were constructed using a 20 to 30-foot long piece of ¼-diamter polyethylene tubing that was secured to the pilings. The end of the tubing was weighted with a sand-filled PVC pipe and set approximately 10 feet below the water surface (marked with a float). Samples were collected using a peristaltic pump with dedicated ½-inch diameter silicon and ¼-inch diameter polyethylene tubing at each sample location.

Sample station for the mooring platform prior to installation.

6.6 Sample Collection

Surface water quality samples were collected from the outlet of the tubing after purging a minimum of 0.15 gallons or 600 milliliters of water[4]. Purging was performed in order to ensure that the residual water in the tubing had been removed and that the sample collected was from the receiving water. Purge water was collected in a five-gallon bucket and disposed of with the Tank 1 wash water. Field personnel (“samplers”) changed gloves (nitrile gloves were used) before collecting each sample to mitigate cross contamination of samples.

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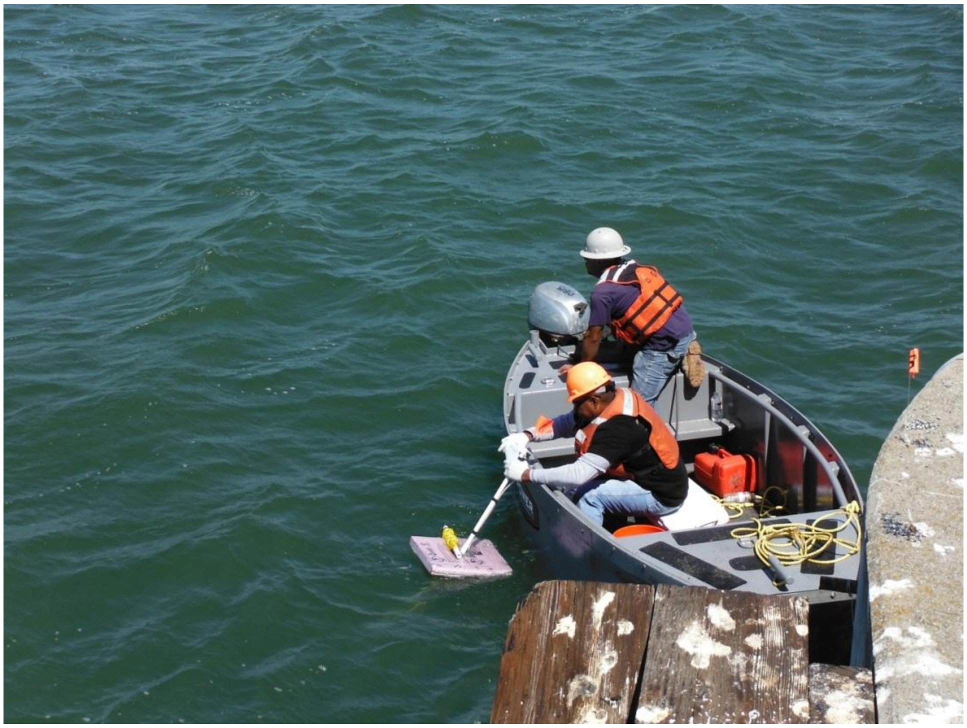
[4] A 20-foot long piece of ¼-inch inside diameter sample tubing contains approximately 0.05 gallons of water. A safety factor of 3 was used to account for extra tubing and to ensure a new water sample was collected.



Collection of a sample from the floating sampling station.

Each sampler was responsible for the sample locations as follows:

- Sampler 1 – S-1 through S-3, and S-7
- Sampler 2 – S-4 through S-6
- Sampler 3 – S-8, S-12, S-13, and S-17
- Sampler 4 – S-9, S-10, S-14, and S-18
- Sampler 5 – S-11, S-15, and S-19
- Sampler 6 – S-16 and S-20

Samples were collected in laboratory-supplied, 1-liter or 500-milliliter polyethylene containers (unpreserved). Samples were stored in a cooler, on ice, at a temperature of 4-degrees Celsius, or less, pending delivery to the California state-certified analytical laboratory. The samples were delivered to the analytical laboratory the morning following sample collection, to allow for timely filtration by the analytical laboratory and analysis of dissolved metals.

6.6.1 Field Duplicates

Sample field duplicates were collected in separate containers, but from the same location as the original primary sample. These were analyzed as a separate sample from the primary water quality sample to measure the total system variability (field and laboratory variance). Field duplicate samples were collected from the following sample locations:

- S-5 (prior to discharge);
- S-4 and S-10 (20 minutes after discharge began);
- S-13 (40 minutes after discharge began);
- S-15 (60 minutes after discharge began); and
- S-19 (70 minutes after discharge began).

6.6.2 Equipment Blank

The equipment blank consisted of distilled water sampled using the ¼-inch diameter polyethylene tubing from one of the sample locations after 0.25 gallons of distilled water had been purged through the tubing. This quality control sample served as a check on the effectiveness of the purging process. One equipment blank was collected and submitted for analysis and identified as sample “S-EB”.

6.6.3 Source Blank

A source blank consisted of commercially available distilled water used by sampling personnel for the equipment blank. The distilled water was placed into the sampling container and analyzed for the same parameters as the water samples. This quality control sample served as a check on the cleanliness of the distilled water used for the equipment blank. One source blank was prepared and submitted with sample designation “S-FB”.

6.7 Sample Analysis

The analytical laboratory filtered the containers for dissolved metals analysis in the laboratory using a 0.45-μm filter. The samples collected during this investigation were analyzed using USEPA Method 200.8 and USEPA Method 200.7 for dissolved metals.

6.8 Sample Documentation

Samples were labeled based on the sample location (S-X) and sample time period (XX). The sample identification was S-X-XX (e.g. for sample location S-1 after 40 minutes had elapsed after the start of the discharge; S-1-40). Field duplicate samples were labeled -

FD at the end of the designation (e.g. S-1-40-FD). The equipment blank sample was labeled S-EB and the source blank sample was labeled S-FB.

Sample documentation was tracked on chain-of-custody forms. Field log sheets were used to record the actual time of sample collection by the sampler for each time period. Synchronized watches were provided to the samplers so ensure that sample collection times were consistent and recorded accurately.

6.9 Tracer Dye Monitoring

To better understand the mixing dynamics of the area where the treated water was discharged, rhodamine dye was mixed into the treated water in Tank 1 (Photograph below). A volume of 182 milliliters of 2.5% rhodamine dye solution was added to the treated water stored in Tank 1 in order to achieve a concentration of approximately 100 parts per billion or μg/L. The rhodamine dye was added into Tank 1 and a portable centrifugal pump was used to circulate the water for approximately three to four hours prior to discharge.

View of Tank 1 after adding rhodamine dye.

A field meter was used to measure the rhodamine dye concentration in the field. The YSI field meter has a minimum detection limit of 0.1 μg/L and an operational range of up to 200 μg/L. The YSI field meter with rhodamine sensor was calibrated by the equipment rental company prior to the sampling event using the rhodamine dye to be used during the tracer analysis.

A baseline sample was collected from the tank prior to discharge of the treated water into the San Francisco Bay. During the mixing zone study, water samples for rhodamine measurement were collected from sampling locations S-1 through S-20 in conjunction with the collection of water quality samples for dissolved zinc and copper. Samples were collected at a depth of 10 feet below the water surface and analyzed using a YSI field meter with rhodamine sensor.

7.0 MIXING ZONE TEST RESULTS AND DISCUSSION

Surface water samples collected during the mixing zone study were originally submitted for analysis using USEPA method 200.8, which uses Inductively coupled plasma mass spectrometry (ICP-MS), due to its lower reporting limit (0.5 μg/L for copper and 5 μg/L for zinc) rather than USEPA method 200.7 (ICP). A dilution factor of 10 was expected based on the hull cleaning test sampling, due to the heavy concentration of other constituents (namely sodium, calcium, and magnesium) in the seawater. However, the laboratory had to use a 20 times dilution factor for most of the samples due to the heavy concentration of other constituents (matrix interference). Unfortunately that would have resulted in a reporting limit of 10 μg/L for copper and 100 μg/L for zinc, which are greater than their respective water quality objectives.

The analytical laboratory was able to re-run the samples using USEPA Method 200.7, which normally has a higher RL for copper and zinc, 5 μg/L and 20 μg/L respectively. However, due to the difference in analytical equipment used a two times dilution factor was necessary. While the RL for dissolved copper did not change (10 μg/L), the RL for dissolved zinc was much lower (40 μg/L).

However, the mixing zone water quality samples collected (including field duplicates, equipment blank, and field blank) did not contain dissolved copper or zinc above the respective laboratory reporting limits (10 μg/L and 40 μg/L, respectively). These results indicate that the treated water mixed quickly and completely with the receiving water.

As an additional measure of the mixing zone dynamics, the concentration of rhodamine dye was measured in water samples collected in conjunction with the water quality samples submitted for metals analysis. The concentration of rhodamine dye in Tank 1 was measured to be 101 mg/L after addition of the dye solution. The concentration of rhodamine in Tank-1 20 minutes after the start of treated water discharge was measured to be approximately 165 mg/L. This is likely due to incomplete mixing of the rhodamine dye in the tank. In the surface water samples collected during the mixing zone test, rhodamine was measured at concentrations ranging from 0.0 to 4.6 μg/L, as compared with a concentration of 0.3 μg/L in a background sample of distilled water. The variance in concentrations measured is likely due to the presence of organic compounds and other constituents in the samples that can be read by the field meter as rhodamine. The results strongly correlate with the dissolved copper and zinc results that complete mixing was occurring. The results of the rhodamine sample analysis are included in Appendix A along with the copper and zinc results.

8.0 SUMMARY

Although California and federal law require that vessel operators maintain their hulls in a clean condition and hull bio-fouling increases greenhouse gas emissions and fuel consumption, increases the risk of engine damage due to overloading, and increases the risk of transferring aquatic species from one region to another, the California exception to the VGP and lack of available and approved BAT creates regulatory difficulties and roadblocks. The inability to conduct in-water hull cleaning places commercial marine operators in California at a significant disadvantage compared to those in other states. The in-water hull cleaning test, evaluation of a BAT, and delineation of a mixing zone shows that in-water hull cleaning is a viable option for marine operators in the San Francisco Bay area, while meeting the Basin Plan's water quality objectives for the receiving water

8.1 In-Water Hull Cleaning Test

This in-water hull cleaning test demonstrated the containment and capture of process water containing the removed biological material and small amounts of anti-fouling paint through the use of a suction line on the discharge of the scrubber unit. The scrubber unit outfitted with discharge water capture lines and rubber edging to maintain a seal against the hull represents the BAT in the industry today. Since the conclusion of this test, pressure gauges have been installed on the latest version of the scrubber unit to monitor the pressure difference between inside the scrubber unit and the ambient water (ensuring proper sealing). In addition, discharge of the process water should occur at a minimum of 350 gpm to also ensure a proper seal between the scrubber and the hull.

To provide treatment of the process water, a treatment system utilizing filter cartridges and a filtration media (organo-clay) was developed and tested. The system proved to be effective at removing total copper and zinc via the filter cartridges and dissolved copper and zinc via the organo-clay. Other filtration media, such as proprietary resins could potentially remove the COCs. However, due to the higher cost (three to five times as expensive) of those media and their unknown ability to provide effective treatment (the constituent of seawater do not react well with many media) makes identifying a BAT difficult. In addition, the treatment system must be capable of treating process water at a flow rate of approximately 400 gpm with a minimal footprint as the hull cleaning is often staged from a work barge.

Although the treatment system was not capable of reducing dissolved copper and zinc concentrations to the WQOs of the receiving water, a mixing zone (dilution credit) can be employed per the RWQCB for full-scale implementation. Based on the rhodamine dye and dissolved copper and zinc concentrations, the results of the mixing zone study show that complete mixing was occurring and the receiving water's water quality objectives were met.

8.2 Proposed BAT and Discharge Permit

Based on the results of this test, the proposed BAT for in-water hull cleaning includes the following:

- The use of a scrubber unit with non-metal brushes, a rubber seal against the vessel hull, pressure differential monitoring between the inside of the scrubber unit and the ambient water with a minimum differential pressure of 3 psi, and collection of the process water at a minimum of 350 gpm;
- The stipulation that only the soft growth be removed in order to minimize the disturbance of the paint coating;
- The filtering of process water in a treatment system through a maximum of a 5-μm filter prior to discharge (larger filters can be used earlier in the treatment train to remove larger particles in steps);
- The use of a treatment system to reduce dissolved copper concentrations to approximately 100 μg/L; and
- The use of a treatment system to reduce dissolved zinc concentrations to approximately 600 μg/L.

In conjunction with the above BAT, a discharge permit is necessary from the RWQCB and/or SWRCB to discharge the treated process water. The discharge permit should employ a mixing zone based on the above-mentioned dissolved copper and zinc concentrations. The mixing zone based on a 10-hour work day, 400 gpm discharge rate in one location (at a depth of 10 feet below the water surface), and a dilution factor of 10, would be approximately 600 feet wide and 600 feet long.[5]

The proposed sampling criteria for the discharge permit are based on the mixing zone identified above. Each work day, at the conclusion of treated water discharge, one sample should be collected 300 feet in each direction (north, south, east, and west) from the discharge point to measure for compliance with the mixing zone. These samples should be submitted for analysis for dissolved zinc (minimum RL of 90 μg/L) and

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[5] This is based on the dissolved copper concentration in the treated process water being the limiting factor in achieving the receiving water WQO. A dissolved copper concentration of 5 μg/L (laboratory RL) in the background receiving water and a dissolved copper concentration of 100 μg/L in the treated water being discharged were assumed. Approximately 5.5 million gallons of ambient water would be necessary to dilute the treated water in order to reach the WQO.

dissolved copper (minimum RL of 10 μg/L). In addition, one effluent sample should be collected from the treatment system each day to monitor treatment effectiveness. In the event dissolved copper concentrations are greater than 100 μg/L or dissolved zinc concentrations are greater than 600 μg/L (trigger concentrations), the treatment system should be evaluated regarding contaminant loading (e.g. filtration media is spent) and the additional treatment technology that potentially can be used (e.g. additional filtration media).

9.0 REFERENCES

Regional Water Quality Control Board (RWQCB). 2011. San Francisco Bay Region (Region 2) Water Quality Control Plan (Basin Plan). December 31.

United States Department of Transportation Maritime Administration. 2012. Proposed Best Available Technology Testing Program for Contained In-Water Hull Cleaning in the San Francisco Bay Area. March.

FIGURES

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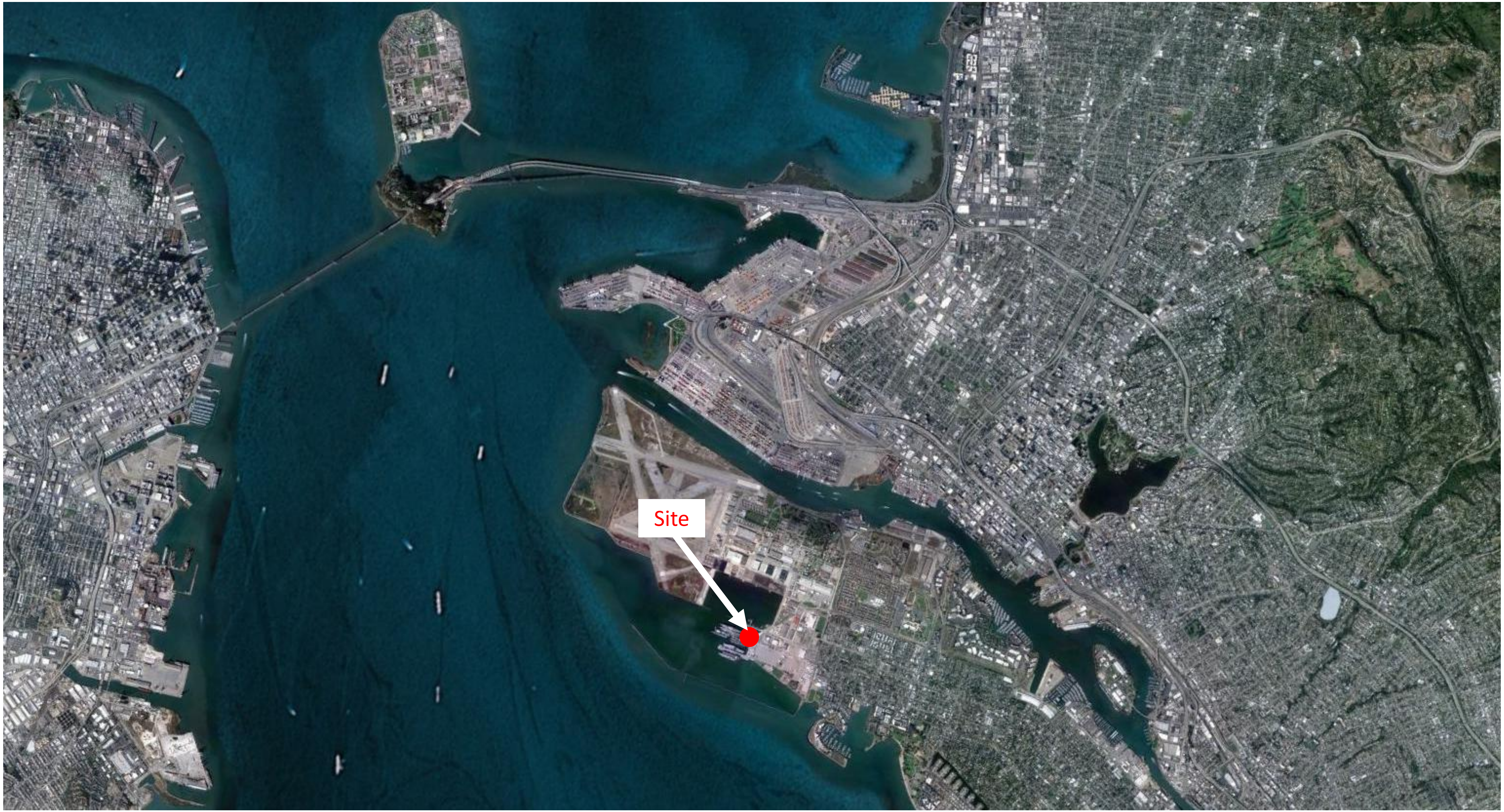

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SAFETY FIRST

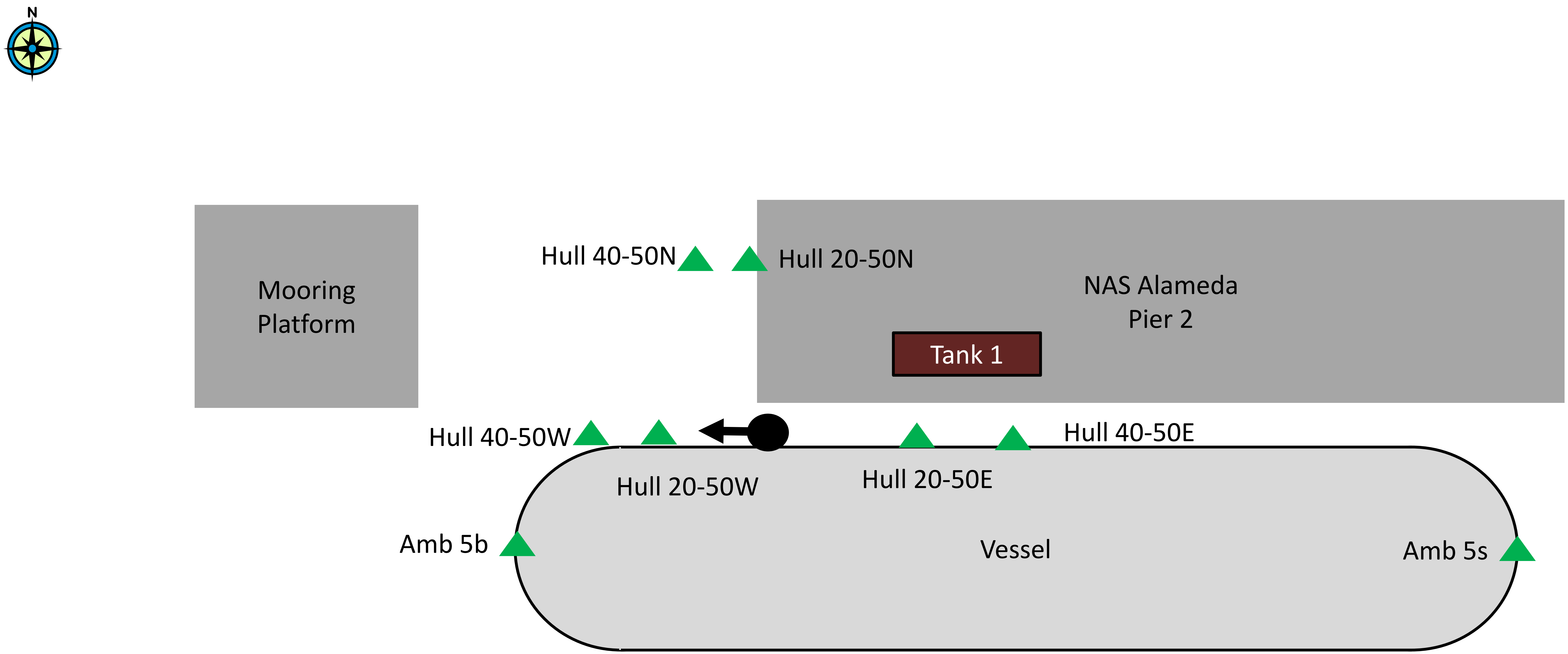
SUSTAINABLE GROUP

terraphase JV

CLIENT:	U.S. Maritime Administration
PROJECT:	Hull Cleaning Mixing Zone Test
PROJECT NUMBER:	JV03.001.001

Site Vicinity Map

FIGURE 1



Legend:

▲ Approximate Sample Location

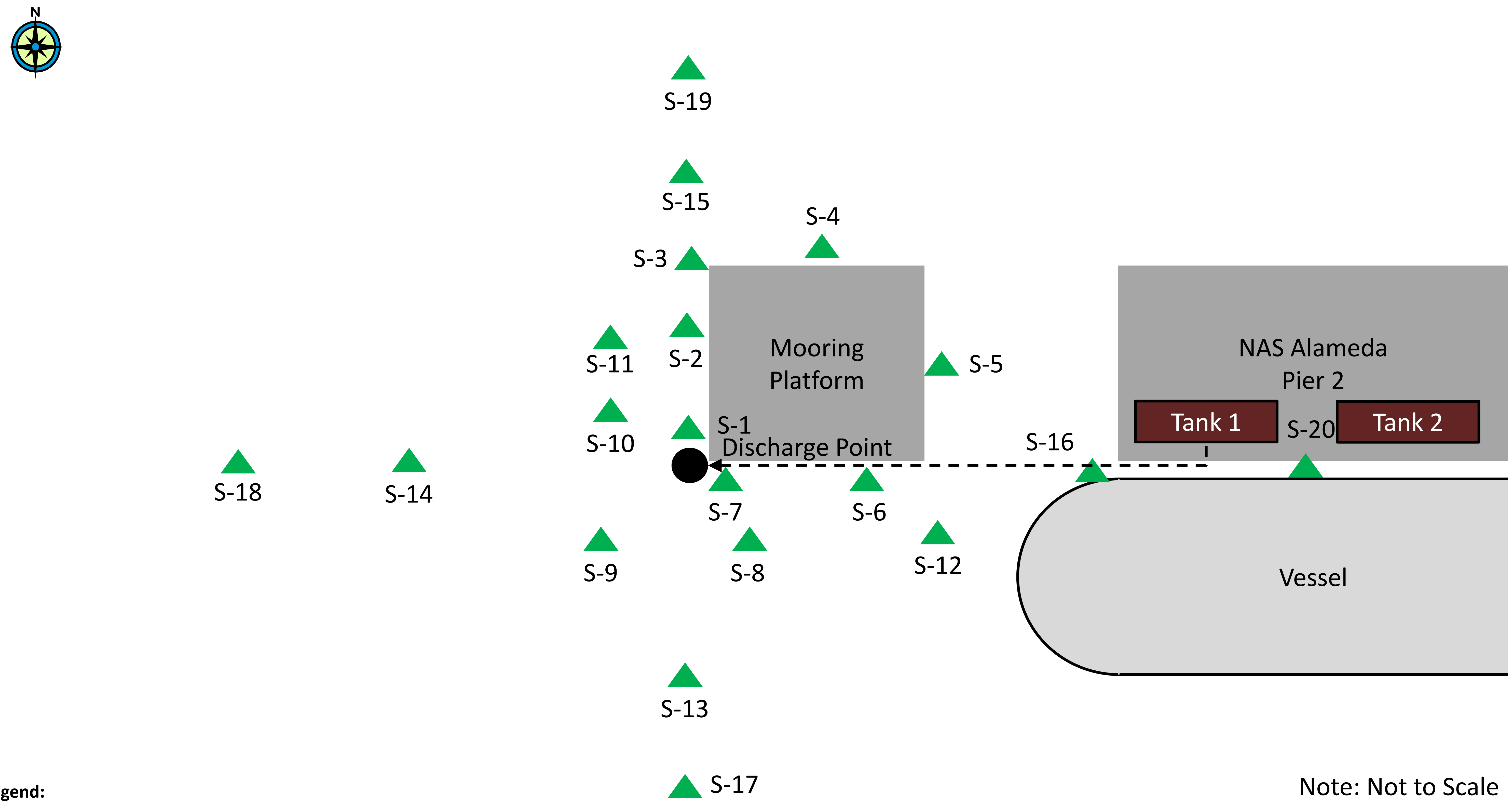
● Start of Hull Cleaning

← Direction of Scrubber Unit

Note: Not to Scale

SAFETY FIRST	CLIENT: U.S. Maritime Administration	**Hull Cleaning** **Sample Locations**
SUSTAINABLE GROUP terraphase JV	PROJECT: Hull Cleaning Mixing Zone Test	
	PROJECT NUMBER: JV03.001.001	**FIGURE 2**

File Name:fig-1-mixing-zone-test.pptx Prepared by: RJ Checked by: WC



Note: Not to Scale

Legend:

▲ Approximate Sample Location

● Discharge Point

← – – Discharge Line

SAFETY FIRST	CLIENT: U.S. Maritime Administration	**Mixing Zone Test** **Sampling Locations**
SUSTAINABLE GROUP terraphase JV	PROJECT: Hull Cleaning Mixing Zone Test	
	PROJECT NUMBER: JV03.001.001	**FIGURE 3**

File Name:fig-1-mixing-zone-test.pptx Prepared by: RJ Checked by: WC

APPENDIX A

MIXING ZONE STUDY ANALYTICAL RESULTS

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Appendix A - Table 1
Mixing Zone Test - Analytical Results

US DOT - Maritime Administration
Alameda, CA

Sample ID	Sample Date	Total Copper (µg/L)	Dissolved Copper (µg/L)	Total Zinc (µg/L)	Dissolved Zinc (µg/L)	Rhodamine (µg/L)
S-1-0	8/30/2012	-	<10	-	<40	--
S-1-20	8/30/2012	<10	<10	<40	<40	--
S-1-40	8/30/2012	-	<10	-	<40	--
S-1-60	8/30/2012	-	<10	-	<40	--
S-2-0	8/30/2012	-	<10	-	<40	--
S-2-20	8/30/2012	-	<10	-	<40	0.4
S-2-40	8/30/2012	-	<10	-	<40	1
S-2-60	8/30/2012	-	<10	-	<40	0.7
S-3-0	8/30/2012	-	<10	-	<40	--
S-3-20	8/30/2012	-	<10	-	<40	0
S-3-40	8/30/2012	-	<10	-	<40	0.4
S-3-60	8/30/2012	-	<10	-	<40	0
S-4-0	8/30/2012	-	<10	-	<40	--
S-4-20	8/30/2012	-	<10	-	<40	0
S-4-20-FD	8/30/2012	-	<10	-	<40	--
S-4-40	8/30/2012	-	<10	-	<40	0
S-4-60	8/30/2012	-	<10	-	<40	0
S-5-0	8/30/2012	-	<10	-	<40	--
S-5-0-FD	8/30/2012	-	<10	-	<40	--
S-5-20	8/30/2012	-	<10	-	<40	--
S-5-40	8/30/2012	-	<10	-	<40	--
S-5-60	8/30/2012	-	<10	-	<40	0.4
S-6-0	8/30/2012	-	<10	-	<40	--
S-6-20	8/30/2012	-	<10	-	<40	0.3
S-6-40	8/30/2012	-	<10	-	<40	0.5
S-6-60	8/30/2012	-	<10	-	<40	0.4
S-7-0	8/30/2012	-	<10	-	<40	0
S-7-20	8/30/2012	<10	<10	<40	<40	--
S-7-40	8/30/2012	-	<10	-	<40	1.1
S-7-60	8/30/2012	-	<10	-	<40	0
S-8-0	8/30/2012	-	<10	-	<40	--
S-8-20	8/30/2012	-	<10	-	<40	0.1
S-8-40	8/30/2012	-	<10	-	<40	0.8
S-8-60	8/30/2012	-	<10	-	<40	--
S-9-0	8/30/2012	-	<10	-	<40	--
S-9-20	8/30/2012	-	<10	-	<40	0
S-9-40	8/30/2012	-	<10	-	<40	0.4
S-9-60	8/30/2012	-	<10	-	<40	--
S-10-0	8/30/2012	-	<10	-	<40	--
S-10-20	8/30/2012	-	<10	-	<40	0.1
S-10-20-FD	8/30/2012	-	<10	-	<40	--
S-10-40	8/30/2012	-	<10	-	<40	1.2
S-10-60	8/30/2012	-	<10	-	<40	0.2
S-11-0	8/30/2012	-	<10	-	<40	--
S-11-20	8/30/2012	-	<10	-	<40	4.6
S-11-40	8/30/2012	-	<10	-	<40	0.3
S-11-60	8/30/2012	-	<10	-	<40	--
S-12-0	8/30/2012	-	<10	-	<40	--
S-12-20	8/30/2012	-	<10	-	<40	1.3
S-12-40	8/30/2012	-	<10	-	<40	0.6
S-12-60	8/30/2012	-	<10	-	<40	1.4
S-13-0	8/30/2012	-	<10	-	<40	--
S-13-20	8/30/2012	-	<10	-	<40	--

Appendix A - Table 1
Mixing Zone Test - Analytical Results

US DOT - Maritime Administration
Alameda, CA

S-13-40	8/30/2012	-	<10	-	<40	1
S-13-40-FD	8/30/2012	-	<10	-	<40	--
S-13-60	8/30/2012	-	<10	-	<40	0.2
S-14-0	8/30/2012	-	<10	-	<40	--
S-14-20	8/30/2012	-	<10	-	<40	--
S-14-40	8/30/2012	-	<10	-	<40	0.8
S-14-60	8/30/2012	-	<10	-	<40	0.4
S-15-0	8/30/2012	-	<10	-	<40	--
S-15-20	8/30/2012	-	<10	-	<40	1.9
S-15-40	8/30/2012	-	<10	-	<40	0.6
S-15-60	8/30/2012	-	<10	-	<40	--
S-15-60-FD	8/30/2012	-	<10	-	<40	--
S-16-0	8/30/2012	-	<10	-	<40	--
S-16-20	8/30/2012	-	<10	-	<40	0.3
S-16-40	8/30/2012	-	<10	-	<40	0
S-16-60	8/30/2012	-	<10	-	<40	--
S-17-70	8/30/2012	-	<10	-	<40	0.7
S-18-70	8/30/2012	-	<10	-	<40	--
S-19-70	8/30/2012	-	<10	-	<40	0.1
S-19-70-FD	8/30/2012	-	<10	-	<40	--
S-20-70	8/30/2012	-	<10	-	<40	0.1
S-EB	8/30/2012	-	<10	-	<40	--
S-FB	8/30/2012	-	<10	-	<40	0.3
Tank	8/30/2012	-	<10	-	210	101