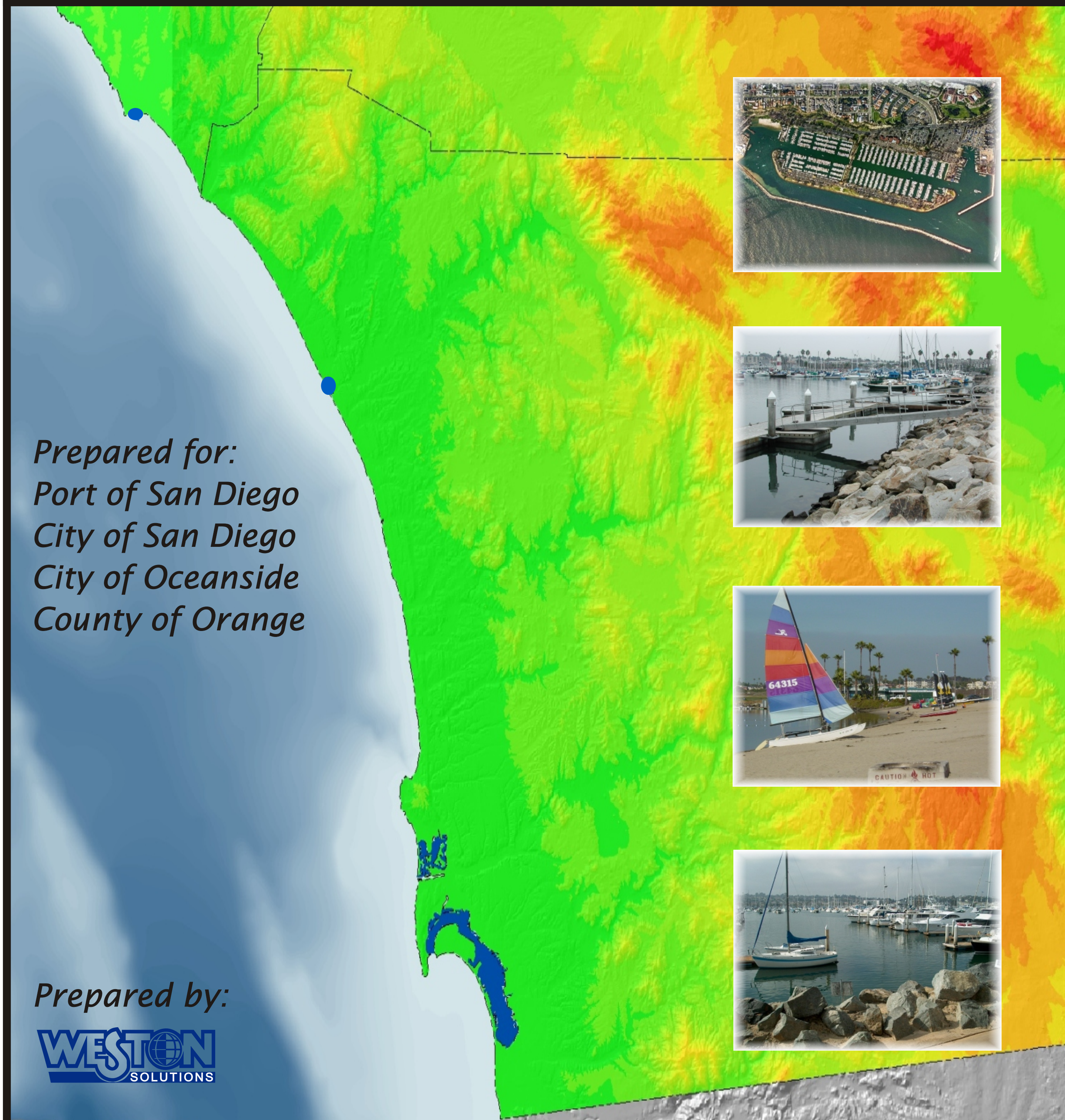
Regional Harbor Monitoring Program
Pilot Project
2005-06

Final Report



Prepared for:
Port of San Diego
City of San Diego
City of Oceanside
County of Orange

Prepared by:

WESTON SOLUTIONS

Regional Harbor Monitoring Program
Pilot Project
2005-06

Final Report

Prepared For:

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EXECUTIVE SUMMARY

The Regional Harbor Monitoring Program (RHMP) was developed by the Port of San Diego, City of San Diego, City of Oceanside, and County of Orange to address questions regarding the general water quality and condition of aquatic life in the four harbors within Region 9 (San Diego) of the State Water Resources Control Board. The RHMP was developed as a core monitoring program to address the overall condition of the harbors with supplemental focused studies to answer specific questions. The core monitoring program assesses the conditions found in the harbors and compares to reference values that are based on historical data from the four harbors.

A pilot program for the RHMP began in 2005 and will run for three years. The objective of the pilot program is to implement the RHMP core monitoring on a limited scale to verify the study design. Data from two strata (marinas and freshwater influence) will be statistically evaluated to establish the frequency of core monitoring needed to assess trends in water and sediment quality. Comparison of the pilot project data to historical data used in setting the threshold levels and target percentages is not a direct comparison because the historical data were collected throughout the harbors and include data from potentially cleaner sediments in the more open parts of the harbors. The comparisons made in this report are made to verify elements of the study design and not to make conclusions on the conditions in the harbors. This report presents the results of the water and sediment sampling performed in August 2005. The one sampling period is insufficient to make concrete assessments about the validity of study design, but it can provide indications of the conditions in the two sampling strata in the pilot program.

Based on the first year of data, the following statements can be made:

- Water column concentrations of copper in marinas are higher than those found in freshwater influenced areas and the proportion of marina samples with elevated concentrations is higher than the proportion found historically throughout the harbors.
- Concentrations of other metals and polyaromatic hydrocarbons in the water column were below water quality objectives.
- All bacterial concentrations were below AB 411 levels.
- Measurements of sediment quality were mixed compared to historical concentrations for metals.
- Biological indicators for benthic infauna indicate poorer habitat quality in both the marinas and freshwater influenced areas than was found historically throughout the harbors.
- Sediment toxicity tests indicate healthier conditions than found historically.

While one year of sampling does not provide enough data to validate or invalidate the study design, we were able to utilize data from a cooperative effort with SCCWRP to approximate the variability found in limiting sampling to ten stations per stratum. By randomly subsampling the 30 observations for dissolved copper in the surface waters of the harbors and comparing the percentage of samples below the water quality objective, it was determined that with ten samples, the percent of stations below the objective varied from 20% to 50%. When twenty samples were randomly selected, the percent varied with from 15% to 45% of stations below the objective. In comparison, four of the ten stations sampled for the pilot program were below the objective showing that, at least for water samples, ten samples are probably an adequate number to characterize the stratum. Data were not available for sediments to make a similar comparison; it may be advisable to collect additional samples in order to make an assessment on the variability for the sediments.

1.0 INTRODUCTION

The Regional Harbor Monitoring Program (RHMP) was developed by the Port of San Diego, County of Orange, the City of San Diego, and the City of Oceanside in response to a July 24, 2003 request by the San Diego Regional Water Quality Control Board (SDRWQCB) under §13225 of the California Water Code. The RHMP is a comprehensive effort to survey the general water quality and condition of aquatic life in the harbors and to determine whether beneficial uses are being met for the following four local harbors: San Diego Bay, Mission Bay, Oceanside Harbor, and Dana Point Harbor. The program is composed of a core monitoring program with potential focused studies to answer specific questions. The core monitoring program was designed to address the following five major questions posed in the SDRWQCB's request:

1. What are the contributions and spatial distributions of inputs of pollutants to harbors in the San Diego Region and how do these inputs vary over time?
2. Are the waters in the harbors safe for body contact activities?
3. Are fish in harbors safe to eat?
4. Do the waters and sediments in the harbors sustain healthy biota?
5. What are the long-term trends in water quality for each harbor?

Implementation of the RHMP began with a pilot program to verify the design of the program. Prior to the initiation of sampling in the pilot program the following tasks were completed to finalize the design:

- Acquire and analyze relevant available historical information.
- Complete detailed mapping to verify stratum areas.
- Identify the indicators to be monitored.
- Establish the threshold levels.
- Establish the preset target proportions.
- Develop a Quality Assurance Project Plan.

A key element of the RHMP is the identification of strata within and across the harbors. This element was modeled after the regional Southern California Bight (Bight) and national Environmental Monitoring and Assessment (EMAP) programs. The use of strata allows delineation of harbor inputs based on activities within each area. Five strata were identified for monitoring in the core program: marinas, industrial/port, freshwater influenced, shallow water, and deep water. The shallow and deep water strata encompass all areas within the harbors not within the other three specific strata. The freshwater influenced stratum includes areas that may be affected by input from streams or storm water runoff (Weston 2005a).

Sampling for the pilot program began in August 2005. The pilot program is designed to run for three years with sampling conducted during the summer months; full implementation of the RHMP will occur in 2008 and coincide with the next regional Bight monitoring program. The pilot program is a scaled down version of the RHMP that focuses on a limited number of indicator measurements and samples in two of the five identified strata. The strata sampled in the pilot program, marinas and freshwater influenced, were selected because the variability within them is anticipated to be greater and will provide a conservative estimate of the amount of sampling needed to detect trends.

Statistical analysis of the data obtained in the pilot program is performed with the application of a binomial model. This approach compares proportions of samples below (or above) an established threshold with an established target proportion and determines whether there is a significant increase in the proportion of samples below the threshold compared to the historical data. The proportions are tracked through time as the program progresses to measure improvement in the health of the harbors.

This report presents the results of the first year of the Pilot Program for the RHMP. As such, it focuses on the measurements made in summer 2005 for the marina and freshwater influenced strata in the four harbors, making comparisons using the binomial approach to historical data and compares the results of the two sampled strata to each other.

2.0 METHODS

2.1 Field Sampling

2.1.1 Station Selection

Station selection in Dana Point Harbor, Oceanside Harbor, Mission Bay, and San Diego Bay is based on a stratified random sampling design similar to that used in southern California regional monitoring programs. Uniformly sized hexagons were overlaid on maps of each of the bays. The size of the hexagons was determined by the smallest freshwater influenced area that could be safely sampled. Hexagons were set at 100 feet (ft) (~65 meters) per side with the nominal sampling station at the center of the hexagon. Ten stations were then randomly selected in the marina and freshwater influenced strata with the stipulation that at least one station was set in each harbor. All of the sampling occurred within a 30 meter (m) radius of the nominal station coordinates. The coordinates of the actual sampling station were recorded when sampling occurred.

The locations of the sampling stations in each of the harbors are shown in Figures 2-1 to 2-6. Marina stations in Dana Point Harbor and Oceanside Harbor were located near boat slips throughout the harbors. Marina stations in Mission Bay were located near Dana Landing and in Quivera Basin. In San Diego Bay, marina stations were located in America's Cup Harbor and the Shelter Island Yacht Basin.

The one freshwater influenced station in Dana Point Harbor was located adjacent to a storm drain. No freshwater influenced areas were identified in Oceanside Harbor. Freshwater influenced stations in Mission Bay were located near Rose Creek Inlet and Tecolote Creek. In San Diego Bay, they were located near the mouths of the Sweetwater River and Chollas Creek.

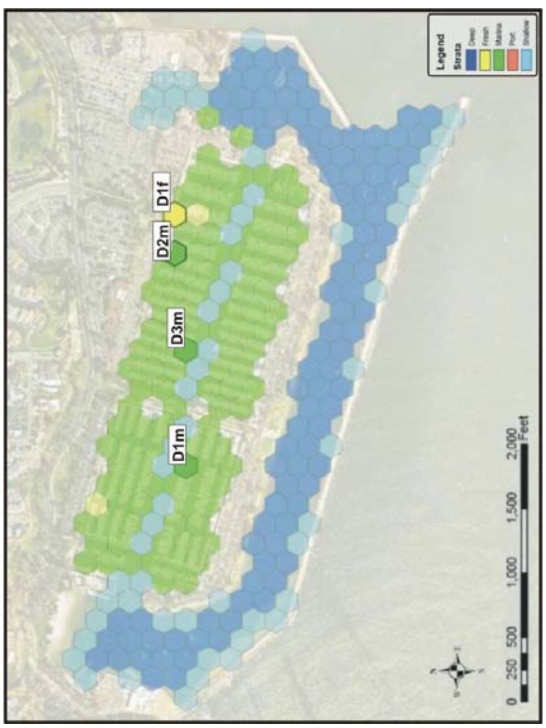

Figure 2-1. Sampling stations in Dana Point Harbor for 2005.

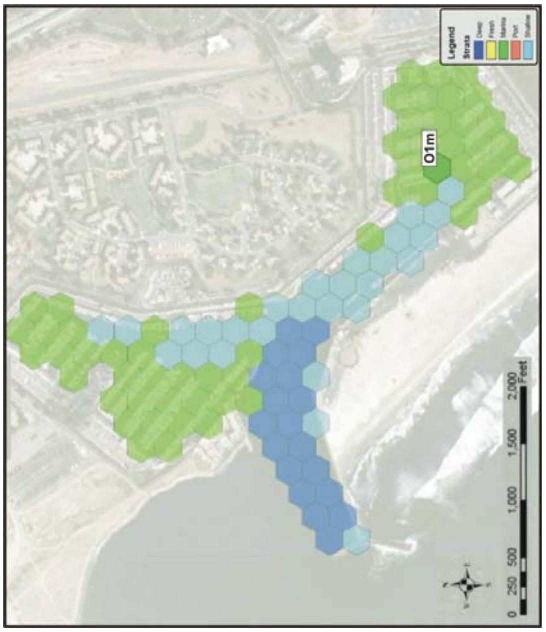

Figure 2-2. Sampling stations in Oceanside Harbor for 2005.

Figure 2-3. Sampling stations in Mission Bay for 2005.

Figure 2-4. Sampling stations in northern San Diego Bay for 2005.

Figure 2-5. Sampling stations in central San Diego Bay for 2005.

Figure 2-6. Sampling stations in southern San Diego Bay for 2005.

2.1.2 Water Quality Sampling

Water column sampling was performed by Weston in conjunction with the Southern California Coastal Water Research Project's (SCCWRP) Marina Copper Study in August 2005. A total of twenty stations were sampled, ten marina and ten freshwater influenced. Actual coordinates for sample locations were recorded on field data sheets. The actual locations of the stations and sampling dates are listed in Table 2-1.

Water column sampling was conducted using a Seabird SBE-25 Sealogger CTD (conductivity-temperature-depth) equipped with sensors that measure temperature, specific conductance, dissolved oxygen (DO), pH, and light transmission. Casts were taken at stations located with a differential global positioning system (dGPS). Dissolved oxygen and pH sensors were calibrated prior to each monitoring day. Transmissivity, conductivity, and temperature are calibrated annually by Sea-Bird Electronics, Inc. Before beginning a cast, a 3-minute equilibration was performed to bring the CTD sensors to thermal equilibration with the ambient sea water. The CTD was lowered at a speed of 0.25-0.50 m/sec until it was within 1m of the bottom. The instrument operated at a scan rate of 8 scans/sec.

After casts in each harbor were performed, the data were uploaded and saved onto a field computer. Data were checked to ensure the CTD turned on properly, the depth was accurate, and that all water quality measurements were recorded throughout a cast. Data were transferred to a disk upon returning to the laboratory. A post cruise calibration was performed following each day of sampling.

Discrete water samples were collected at each station one meter below the surface using a Niskin bottle. Water samples were transferred to labeled sample jars. Additional data such as the weather, wind speed and direction, and water color and odor were recorded on field data sheets. Samples to be analyzed for total organic carbon (TOC), dissolved organic carbon (DOC), total metals, total hardness (as $CaCO_3$), and polynuclear aromatic hydrocarbons (PAHs) were sent to CRG Marine Laboratories, Inc. (CRG) for chemical analyses. Samples to be analyzed for dissolved metals were collected using a pre-cleaned plastic syringe attached with a filter apparatus. Samples were passed through a 0.45 µm filter, frozen, and sent to Moss Landing Marine Laboratories by SCCWRP for analysis as part of a cost-sharing agreement between SCCWRP and Weston. Samples were subsequently also analyzed by CRG for reasons described in Appendix B. The CTD profiles and the samples for indicator bacteria, Enterococcus, were retained and analyzed by Weston Solutions, Inc. All of the samples were sent to the designated laboratories under the proper storage conditions and within holding times.

2.1.3 Sediment Sampling

Sediment sampling was performed in August 2005 at the same stations as those sampled for water quality using a dGPS to locate the stations. Field observations and actual coordinates for sample locations were recorded on sediment sampling data forms. Table 2-1 shows the actual locations of the stations and sampling dates.

Table 2-1. Station locations and the dates they were sampled.

Harbor	Station ID	Strata	Water Sampling			Sediment Sampling		
			Latitude	Longitude	Dates Sampled	Latitude	Longitude	Dates Sampled
Dana Point Harbor	D1M	M	33º 27' 36.24" N	117º42' 02.40" W	August 15, 2005	33º 27' 36.22" N	117º 42' 02.59" W	August 31, 2005
	D2M	M	33º 27' 37.62" N	117º41' 43.32" W	August 15, 2005	33º 27' 37.37" N	117º 41' 43.40" W	August 31, 2005
	D3M	M	33º 27' 36.42" N	117º41' 52.92" W	August 15, 2005	33º 27' 36.22" N	117º 41' 52.12" W	August 31, 2005
	D1F	F	33º 27' 37.50" N	117º41' 39.96" W	August 15, 2005	33º 27' 37.62" N	117º 41' 39.98" W	August 31, 2005
Oceanside Harbor	O1M	M	33º 12' 20.70" N	117º 23' 29.52" W	August 15, 2005	33º 12' 19.44" N	117º 23' 30.05" W	August 31, 2005
Mission Bay	M1M	M	32º 45' 49.62" N	117º 14' 15.48" W	August 15, 2005	32º 45' 50.04" N	117º 14' 15.00" W	August 24, 2005
	M2M	M	32º 45' 59.72" N	117º 14' 07.58" W	August 24, 2005	32º 45' 59.54" N	117º 14' 07.58" W	August 24, 2005
	M1F	F	32º 46' 12.50" N	117º 12' 34.99" W	August 24, 2005	32º 46' 12.50" N	117º 12' 34.99" W	August 24, 2005
	M2F	F	32º 47' 51.66" N	117º 13' 14.52" W	August 24, 2005	32º 47' 51.57" N	117º 13' 14.73" W	August 24, 2005
San Diego Bay	S1M	M	32º 43' 12.36" N	117º 13' 12.60" W	August 29, 2005	32º 43' 12.36" N	117º 13' 13.51" W	August 26, 2005
	S2M	M	32º 43' 10.26" N	117º 13' 20.58" W	August 29, 2005	32º 43' 10.09" N	117º 13' 21.22" W	August 26, 2005
	S3M	M	32º 43' 18.30" N	117º 13' 23.70" W	August 29, 2005	32º 43' 18.34" N	117º 13' 23.63" W	August 26, 2005
	S4M	M	32º 42' 56.94" N	117º 13' 40.68" W	August 29, 2005	32º 42' 56.99" N	117º 13' 40.91" W	August 26, 2005
	S1F	F	32º 38' 48.00" N	117º 07' 07.98" W	August 29, 2005	32º 38' 48.05" N	117º 07' 07.90" W	August 25, 2005
	S2F	F	32º 41' 08.64" N	117º 08' 12.24" W	August 29, 2005	32º 41' 07.40" N	117º 08' 11.65" W	August 25, 2005
	S3F	F	32º 41' 15.30" N	117º 08' 03.54" W	August 29, 2005	32º 41' 13.45" N	117º 08' 02.22" W	August 25, 2005
	S4F	F	32º 38' 55.26" N	117º 06' 50.34" W	August 29, 2005	32º 38' 55.00" N	117º 06' 50.65" W	August 25, 2005
	S5F	F	32º 38' 50.16" N	117º 07' 01.38" W	August 29, 2005	32º 38' 50.35" N	117º 07' 01.42" W	August 25, 2005
	S6F	F	32º 38' 49.26" N	117º 07' 10.20" W	August 29, 2005	32º 38' 49.13" N	117º 07' 09.91" W	August 25, 2005
	S7F	F	32º 38' 56.22" N	117º 06' 36.72" W	August 29, 2005	32º 38' 55.79" N	117º 06' 37.33" W	August 25, 2005

Benthic sediments were collected using a stainless steel, 0.1m^2 VanVeen grab sampler. A minimum of four sediment grabs per station were collected for the following: benthic infauna, acute toxicity, grain size, and chemistry including TOC, total metals, and PAHs. A sample was determined to be acceptable if the surface of the grab was even, there was minimal surface disturbance, and there was a penetration depth of at least 5 centimeters (cm). Rejected grabs were discarded and re-sampled.

Samples collected for infaunal analysis were rinsed through a 1.0 mm mesh screen and transferred to a labeled quart jar. A 7% magnesium sulfate ($MgSO_4$) seawater solution was added for approximately 30 minutes to relax the collected specimens. The samples were then fixed in a 10% buffered formalin solution. Infaunal samples were retained and analyzed by Weston.

Samples for acute toxicity and sediment chemistry were collected from the top 2 cm of the grab. Sediment within 1 cm of the sides of the grab was avoided. A total of 2 liters (L) of sediment was collected for toxicity and placed in two 1-L jars. Toxicity samples were then kept at 4°C on ice in coolers. Sediment for trace metals and organics (PAHs) analysis was placed in one 4-ounce jar. These samples were stored at 4°C on ice and frozen within 24 hours. Approximately 150-200 grams of sediment were collected for TOC and grain size. Samples were each placed in one quart sized Ziploc™ bag and kept on ice. The TOC samples were frozen within 24 hours of collection and the grain size stored at 4°C. The samples for acute toxicity, grain size, and TOC were retained and analyzed by Weston. The samples for trace metals and PAHs were shipped frozen to CRG Marine Laboratories, Inc. within a week of collection.

2.2 Laboratory Analysis

2.2.1 Chemistry

Chemical analyses were performed on both water and sediment samples collected; a complete list of chemical analytes with analytical methods and detection limits is provided in Table 2-2. For the water samples, the analyses included total organic carbon (TOC) and dissolved organic carbon (DOC), total and dissolved metals, total hardness measured as CaCO3, and polyaromatic hydrocarbons (PAHs). For the sediment samples, TOC, trace metals and PAHs were analyzed. Sediment samples were also analyzed for grain size to provide data on the size distributions of the sediment (gravel, sand, silt, and clay).

Table 2-2. RHMP Constituents to be Monitored and Corresponding Analytical Methods

Analyte	Method	Reporting Limit	Units
Water Samples			
pH	Collected in field	-	-
Specific Conductance	Collected in field	-	µS/cm
Dissolved Oxygen	Collected in field	-	mg/L
Temperature	Collected in field	-	ºC
Salinity	Collected in field	-	PSU
Transmissivity	Collected in field	-	%
Total Organic Carbon	EPA 415.1	1	mg/L
Dissolved Organic Carbon	EPA 415.1	0.5	mg/L
Total Hardness as CaCO3	SM 2340B	5.00	mg/L
Enterococcus	SM 9223	< 10	MPN/100ml
Dissolved Metals			
Aluminum (Al)	EPA 1640	0.125	µg/L
Antimony (Sb)	EPA 1640	0.015	µg/L
Arsenic (As)	EPA 1640	0.015	µg/L
Beryllium (Be)	EPA 1640	0.01	µg/L
Cadmium (Cd)	EPA 1640	0.01	µg/L
Chromium (Cr)	EPA 1640	0.01	µg/L
Cobalt (Co)	EPA 1640	0.01	µg/L
Copper (Cu)	EPA 1640	0.01	µg/L
Iron (Fe)	EPA 1640	0.025	µg/L
Lead (Pb)	EPA 1640	0.01	µg/L
Manganese (Mn)	EPA 1631E	0.01	µg/L
Mercury (Hg)	EPA 1640	0.001	µg/L
Molybdenum (Mo)	EPA 1640	0.01	µg/L
Nickel (Ni)	EPA 1640	0.01	µg/L
Selenium (Se)	EPA 1640	0.015	µg/L
Silver (Ag)	EPA 1640	0.01	µg/L
Thallium (Tl)	EPA 1640	0.01	µg/L
Tin (Sn)	EPA 1640	0.01	µg/L
Titanium (Ti)	EPA 1640	0.01	µg/L
Vanadium (V)	EPA 1640	0.01	µg/L
Zinc (Zn)	EPA 1640	0.01	µg/L
Total Metals			
Aluminum (Al)	EPA 1640	0.125	µg/L
Antimony (Sb)	EPA 1640	0.015	µg/L
Arsenic (As)	EPA 1640	0.015	µg/L
Beryllium (Be)	EPA 1640	0.01	µg/L
Cadmium (Cd)	EPA 1640	0.01	µg/L
Chromium (Cr)	EPA 1640	0.01	µg/L
Cobalt (Co)	EPA 1640	0.01	µg/L
Copper (Cu)	EPA 1640	0.01	µg/L
Iron (Fe)	EPA 1640	0.025	µg/L
Lead (Pb)	EPA 1640	0.01	µg/L
Manganese (Mn)	EPA 1640	0.01	µg/L
Mercury (Hg)	EPA 1631E	0.001	µg/L
Molybdenum (Mo)	EPA 1640	0.01	µg/L
Nickel (Ni)	EPA 1640	0.01	µg/L

Table 2-2. RHMP Constituents to be Monitored and Corresponding Analytical Methods

Analyte	Method	Reporting Limit	Units
Selenium (Se)	EPA 1640	0.015	µg/L
Silver (Ag)	EPA 1640	0.01	µg/L
Thallium (Tl)	EPA 1640	0.01	µg/L
Tin (Sn)	EPA 1640	0.01	µg/L
Titanium (Ti)	EPA 1640	0.01	µg/L
Vanadium (V)	EPA 1640	0.01	µg/L
Zinc (Zn)	EPA 1640	0.01	µg/L
Polynuclear Aromatic Hydrocarbons			
1-Methylnaphthalene	EPA 625	5	ng/L
1-Methylphenanthrene	EPA 625	5	ng/L
2,3,5-Trimethylnaphthalene	EPA 625	5	ng/L
2,6-Dimethylnaphthalene	EPA 625	5	ng/L
2-Methylnaphthalene	EPA 625	5	ng/L
Acenaphthene	EPA 625	5	ng/L
Acenaphthylene	EPA 625	5	ng/L
Anthracene	EPA 625	5	ng/L
Benz[a]anthracene	EPA 625	5	ng/L
Benzo[a]pyrene	EPA 625	5	ng/L
Benzo[b]fluoranthene	EPA 625	5	ng/L
Benzo[e]pyrene	EPA 625	5	ng/L
Benzo[g,h,i]perylene	EPA 625	5	ng/L
Benzo[k]fluoranthene	EPA 625	5	ng/L
Biphenyl	EPA 625	5	ng/L
Chrysene	EPA 625	5	ng/L
Dibenz[a,h]anthracene	EPA 625	5	ng/L
Fluoranthene	EPA 625	5	ng/L
Fluorene	EPA 625	5	ng/L
Indeno[1,2,3-c,d]pyrene	EPA 625	5	ng/L
Naphthalene	EPA 625	5	ng/L
Perylene	EPA 625	5	ng/L
Phenanthrene	EPA 625	5	ng/L
Pyrene	EPA 625	5	ng/L
Sediment Samples			
Total Organic Carbon	EPA 415.1	0.05	%
Grain Size Analysis	Plumb 1981	-	-
Acute Toxicity	EPA/600/R-94/025	-	%
Benthic Infauna	-	-	-
Total Metals			
Aluminum (Al)	EPA 6020	5	mg/kg
Antimony (Sb)	EPA 6020	0.05	mg/kg
Arsenic (As)	EPA 6020	0.05	mg/kg
Barium (Ba)	EPA 6020	0.05	mg/kg
Beryllium (Be)	EPA 6020	0.05	mg/kg
Cadmium (Cd)	EPA 6020	0.05	mg/kg
Chromium (Cr)	EPA 6020	0.05	mg/kg
Cobalt (Co)	EPA 6020	0.05	mg/kg
Copper (Cu)	EPA 6020	0.05	mg/kg
Iron (Fe)	EPA 6020	5	mg/kg
Lead (Pb)	EPA 6020	0.05	mg/kg

Table 2-2. RHMP Constituents to be Monitored and Corresponding Analytical Methods

Analyte	Method	Reporting Limit	Units
Manganese (Mn)	EPA 6020	0.05	mg/kg
Mercury (Hg)	EPA 245.7	0.00002	mg/kg
Molybdenum (Mo)	EPA 6020	0.05	mg/kg
Nickel (Ni)	EPA 6020	0.05	mg/kg
Selenium (Se)	EPA 6020	0.05	mg/kg
Silver (Ag)	EPA 6020	0.05	mg/kg
Strontium (Sr)	EPA 6020	0.05	mg/kg
Thallium (Tl)	EPA 6020	0.05	mg/kg
Tin (Sn)	EPA 6020	0.05	mg/kg
Titanium (Ti)	EPA 6020	0.05	mg/kg
Vanadium (V)	EPA 6020	0.05	mg/kg
Zinc (Zn)	EPA 6020	0.05	mg/kg
Polynuclear Aromatic Hydrocarbons			
1-Methylnaphthalene	EPA 8270C	5	µg/kg
1-Methylphenanthrene	EPA 8270C	5	µg/kg
2,3,5-Trimethylnaphthalene	EPA 8270C	5	µg/kg
2,6-Dimethylnaphthalene	EPA 8270C	5	µg/kg
2-Methylnaphthalene	EPA 8270C	5	µg/kg
Acenaphthene	EPA 8270C	5	µg/kg
Acenaphthylene	EPA 8270C	5	µg/kg
Anthracene	EPA 8270C	5	µg/kg
Benz[a]anthracene	EPA 8270C	5	µg/kg
Benzo[a]pyrene	EPA 8270C	5	µg/kg
Benzo[b]fluoranthene	EPA 8270C	5	µg/kg
Benzo[e]pyrene	EPA 8270C	5	µg/kg
Benzo[g,h,i]perylene	EPA 8270C	5	µg/kg
Benzo[k]fluoranthene	EPA 8270C	5	µg/kg
Biphenyl	EPA 8270C	5	µg/kg
Chrysene	EPA 8270C	5	µg/kg
Dibenz[a,h]anthracene	EPA 8270C	5	µg/kg
Fluoranthene	EPA 8270C	5	µg/kg
Fluorene	EPA 8270C	5	µg/kg
Indeno[1,2,3-c,d]pyrene	EPA 8270C	5	µg/kg
Naphthalene	EPA 8270C	5	µg/kg
Perylene	EPA 8270C	5	µg/kg
Phenanthrene	EPA 8270C	5	µg/kg
Pyrene	EPA 8270C	5	µg/kg

2.2.2 Toxicity

Solid phase (SP) bioassays were performed to estimate the potential toxicity of the collected sediments to benthic organisms. The test used was the same one performed to analyze toxicity in sediments collected for the 2003 Regional Monitoring Program (Bight 03'). The sediments were tested in a 10-day SP test using the marine amphipod *Eohaustorius estuarius*. On the day before the test a 2 cm aliquot of sample sediment was placed in a test chamber followed by prepared seawater. The samples were left overnight to allow establishment of equilibrium between the sediment and overlying water. On day one of the test, 20 amphipods were randomly placed in each of the test chambers. Any amphipods that did not bury in the sediment within 5-10 minutes were removed and replaced. Control sediment was used to determine the health of the amphipods. Samples were monitored daily for the emergence of amphipods. At the end of the test, organisms were removed from the test chambers by sieving the sediment through a 0.5-mm mesh screen and the total numbers of live and dead amphipods were recorded. The percent survival was calculated for the control and test sediments. The acceptability of the test was determined by evaluating the response of the control organisms. The test was considered acceptable if there was 90 percent mean control survival.

A 96-hour reference toxicity test was also conducted concurrently with the sediment test to establish sensitivity of the test organisms used in the evaluation of the sediments. The reference toxicant test was performed using the reference substance, cadmium chloride, with concentrations of 2.5, 5, 10, 20, and 40 mg Cd^{2+}/L. Ten test organisms were added to each of these concentrations. The concentration that caused 50% mortality of the organisms (the median lethal concentration, or LC_{50}) was calculated from the data. The LC_{50} values were then compared to historical laboratory data for the test species with the reference substance. The results of this test were used in combination with the control mortality to assess the health of the test organisms.

An additional reference toxicant test was also conducted using ammonium chloride with target concentrations of 15.625, 31.25, 62.5, 125, and 250 mg NH_4/L to evaluate potential influence of ammonia toxicity on the test results of the sediments.

2.2.3 Infauna

The benthic samples were brought back from the field to the laboratory where they remained in a formalin solution for 7 days. The samples were then transferred from formalin to 70% ethanol for laboratory processing. The organisms were sorted using a dissecting microscope into five main taxonomic groups: polychaetes, crustaceans, molluscs, echinoderms, and miscellaneous minor phyla. While sorting, technicians kept a rough count for QA/QC purposes. Qualified taxonomists identified each organism and kept an actual count. The organisms were identified to the lowest possible taxon for each phylum.

A QA/QC procedure was performed on each of the sorted samples to ensure a 95% sorting efficiency. A 10% aliquot of a sample was re-sorted by a senior technician trained in the QA/QC procedure. The number of organisms found in the aliquot was divided by 10% and added to the total number found in the sample. The original total was divided by the new total to calculate the percent sorting efficiency. When the sorting efficiency of the sample was below 95%, the remainder of the sample (90%) was re-sorted.

2.2.4 Microbiology

Water samples were analyzed for the indicator bacteria, Enterococcus, using IDEXX Enterolert™ methodology. All results were reported to a most probable number value with a minimum reporting limit of <10 MPN/100ml and a maximum reporting limit of 24,196 MPN/100ml. All samples were delivered to the analytical laboratory within the 6 hour holding time requirement. Sample analysis was initiated immediately upon receipt.

2.2.5 Profile Data Processing

Sea-Bird profile scans were processed by Sea-Bird data processing software to convert recorded voltages to parametric values. Scans were averaged into one meter bins for analysis.

2.3 Data Analysis

A binomial model was selected to assess changes in sediment and water quality over time and to make statistically valid statements about present day conditions in the four water bodies that comprise the harbor monitoring program. In Phase I of this project, historical data were compiled to establish threshold levels and preset targets by which to measure changes in the harbors (Table 2-3). The majority of the data were from the 1998 Regional Monitoring Program (Bight 98') and the Bay Protection and Toxic Cleanup Program (BPTCP). Data that had similar detection limits (chemistry), test species (toxicity), and sampling equipment and screen size (benthic infauna) were used to determine a threshold level (Weston 2005b).

Table 2-3. Studies used for establishing threshold levels.

Study Name	Year	Dana Point Harbor	Oceanside Harbor	Mission Bay	San Diego Bay
Sediment Chemistry					
America's Cup Harbor	2001				X
Bight 98	1998	X	X		X
BPTCP	1994, 1996	X	X	X	X
Central SD Bay Nav. Channel Deepening	1998, 2003				X
Chollas Creek	2003				X
10th Avenue Marine Terminal	2002				X
National City Wharf Extension	1999				X
Navy Arco	2000				X
Navy P-326	2000				X
Paleta Creek	2003				X
Reference reconnaissance	2003				X
Sediment sampling	2003	X			
Toxic Hot Spots Sediment	2003				X
Water and Sediment Testing Project	2001-2003			X	
Benthic Infauna					
Ambient Bay and Lagoon Monitoring	2003		X	X	
America's Cup Harbor	2002				X
Bight 98	1998	X	X		X
Reference reconnaissance	2003				X
Switzer Creek	2002				X
Sediment Toxicity					
Bight 98	1998				X
Benthic Infauna Analysis	2003-2004	X			
National City Wharf Extension	1999				X
Water and Sediment Testing Project	2001-2003			X	
Water Column Chemistry					
Baywide Copper	2002				X
Dana Point monitoring	1992-2002	X			
Paco Bay Water measurements	1992-1999				X

The selection of which indicators were going to be monitored in the Pilot Program was based on whether there was sufficient historical data to create a threshold level. The threshold levels were established as concentration levels for chemical constituents, toxicity levels for bioassays, and diversity measures and the Benthic Response Index (BRI) for infauna (Smith et al. 2003). Preset targets were determined by defining the proportion of historical samples previously collected in these harbors that were below the established threshold levels. Preset target proportions then became the constant in the binomial model for comparison to newer data from the harbors. Proportions of samples collected in the Pilot Program were compared to the preset target in order to measure changes in the harbors. If there is a significantly greater proportion of current samples above the preset targets than it would indicate that water or sediment quality conditions were improving (Weston 2005b). A summary of the established threshold levels and preset targets is presented in Table 2-4.

Indicators for the study were selected when there was sufficient historical data that could be used to compare to current data collected in the harbors. Primary indicators for the study were selected because they are either major constituents of concern (copper in water) or they provide information on a suite of measurements. Secondary indicators are used as supporting data to enhance the interpretation of the primary indicators (Weston 2005b). The selection of individual primary and secondary indicators for water column chemistry, sediment chemistry, sediment toxicity, and benthic infauna will be further discussed in Sections 2.3.1 through 2.3.4.

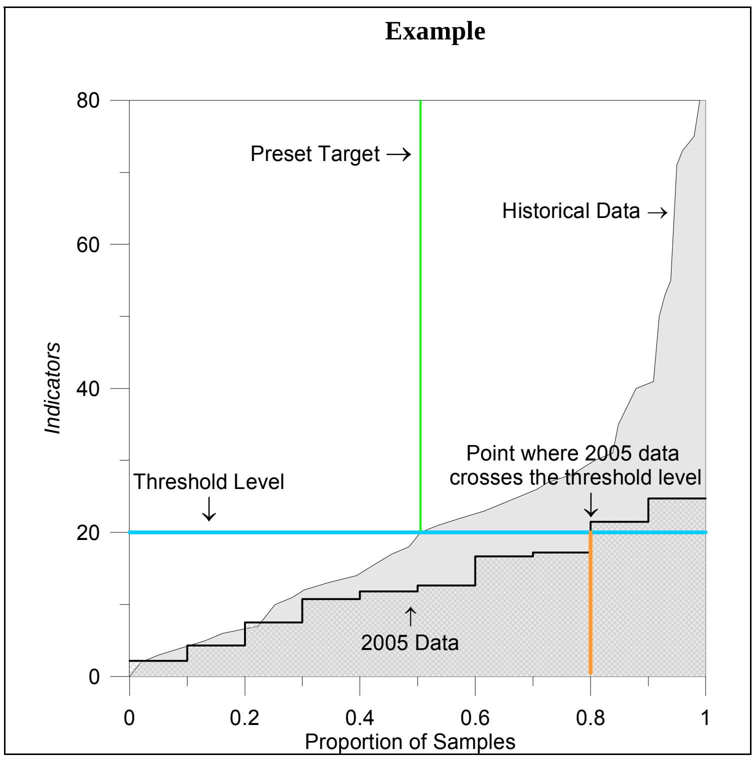

Figure 2-7. Example of a distribution curve that can be used as a reference guide

Each of the indicators measured in the Pilot Program were plotted for visual comparison to the threshold levels and preset targets. Figure 2-7 shows an example of a distribution curve that can be used as a reference guide. Both the historical and 2005 data are plotted as distribution curves with the 2005 data overlying the historical data. The 2005 data is shown as a step plot rather than a smooth curve because there are only ten samples analyzed from each stratum compared to the larger amount of samples used from historical data. The horizontal blue line is the threshold level for each indicator. The vertical green line is the preset target. The orange line represents where the distribution curve for the 2005 data crosses the threshold level. When the orange line is to the left of the preset target then the proportion of samples that are below the threshold level is lower than the proportion of samples historically observed below this level. This would indicate that water or sediment quality conditions for that particular indicator are poorer than historically throughout the harbors. If the orange line is to the right of the preset target then the proportion of samples below the threshold level is greater than the proportion of samples historically observed below the threshold. This would indicate progress towards improved water or sediment quality in the harbors.

Table 2-4. Summary of threshold levels and preset targets.

Measure	Threshold Level	Preset Target
Primary Indicators		
Dissolved Copper (water)	4.8 µg/L	70%
Total Copper (water)	5.8 µg/L	26%
ER-M Quotient	0.2	48%
BRI	31	37%
E. estuarius mortality	20%	51%
Secondary Indicators		
Dissolved Zinc (water)	90 µg/L	100%
Total Zinc (water)	95 µg/L	97%
Dissolved Nickel (water)	74 µg/L	100%
Total Nickel (water)	75 µg/L	100%
Sediment Cadmium	1.2 mg/kg	90%
Sediment Chromium	81 mg/kg	78%
Sediment Copper	175 mg/kg	68%
Sediment Lead	46.7 mg/kg	74%
Sediment Nickel	20.9 mg/kg	80%
Sediment Zinc	150 mg/kg	45%
Sediment Total PAHs	4022 µg/kg	74%
Shannon-Wiener diversity	2	90%
Number of taxa	24	92%

Results for each indicator were compared to the preset target to determine if they showed an increase in the proportion of samples below the threshold level. When the proportion of samples in the current year was higher than the preset target, the two proportions were compared to determine whether the increase was statistically significant. The null hypothesis was that the proportion of current samples below the threshold level was the same as the historical proportion of samples below the threshold level. The proportions were compared using methods described by Cohen (1977, Chapter 6). When the null hypothesis was rejected, it was determined that the current result is significantly greater than the preset value. This means that the current samples indicate an improved state when compared to historical data.

2.3.1 Water Column Chemistry

Historic observations of water column metal concentration were available for dissolved and total copper, nickel, and zinc (Weston 2005b). This data along with benchmark values from the California Toxics Rule (CTR) and the California Ocean Plan (COP) were evaluated to establish threshold levels. The CTR was created using both literature and toxicity test data, thus making the CTR the best threshold level to use for aqueous metals (CTR 2000). Only dissolved and total copper were selected as primary indicators for aqueous metals because of the large numbers of historical observations above the CTR. Dissolved and total zinc and nickel are used as secondary indicators. If the proportion of current samples above the threshold level is larger than the preset target it would indicate that water quality in the harbors was improving (Weston 2005b). The threshold levels and preset targets for these are listed in Table 2-4.

2.3.2 Sediment Chemistry

For sediment chemistry, the mean ER-M quotient is the primary indicator for comparing results in the monitoring program to preset targets. Briefly, the effects range-low (ER-L) and effects range-median (ER-M) are two effects-based sediment quality values developed to help interpret sediment chemistry measurements and their potential for causing adverse biological effects (Long et al. 1995). These parameters were developed from an extensive database of sediment toxicity bioassays and chemistry measurements. The ER-L was calculated as the lower tenth percentile of the observed effects concentrations and the ER-M as the 50^{th} percentile of observed effects concentrations.

The ER-M quotient, which is the ratio of sample concentration to the ER-M, can be used to evaluate the likelihood of benthic effects based on cumulative sediment chemistry. The quotient is derived by dividing each measured sediment chemical concentration by its respective ER-M. The mean ER-M quotient calculates an average quotient based on concentrations of all known contaminants relative to the ER-M values. Therefore, the ER-M quotient is a method of integrating the effects from multiple contaminants (Wenning et al. 2005).

Using historical data, the threshold level for the mean ER-M quotient was determined to be 0.2 based on recent projects with the San Diego RWQCB. Samples with ER-M quotients above 0.2 are more likely to have benthic effects associated with the sediment chemistry. Based on historical data, the preset target for the ER-M quotient was established as 48%. If the proportion of current sediment samples is significantly higher than the preset target than it would indicate that the overall conditions of sediment quality have improved. If the proportion of samples continues to be lower than the preset target over the course of the program then other indicators such as individual chemical constituents can be evaluated in conjunction with the ER-M quotient to help determine which contaminants are problematic in the harbors (Weston 2005b).

Total PAHs and metals including cadmium, chromium, copper, lead, nickel, and zinc are used as secondary indicators for the Pilot Program. These measures will be used to help interpret the mean ER-M quotient by showing which of the parameters are predominant or changing in the mean ER-M quotient. For total PAHs and all of the metals except copper, the ER-L was determined to be the best threshold level. The threshold level for copper was based on the level at which anthropogenic origins may be contributing to the overall copper concentrations in the sediment. To determine this concentration, historical data were used to plot copper concentrations against iron concentrations. At lower concentrations of copper there is a constant relationship with iron concentrations, this relationship changes at about 175 mg/kg as shown in Figure 2-8. This is the basis for using 175 mg/kg as the threshold level for sediment copper. A higher proportion of current samples below the threshold level compared to the preset target indicates that sediment quality conditions in the harbors are better than historically observed (Weston 2005b). Table 2-4 shows the threshold levels and preset targets.

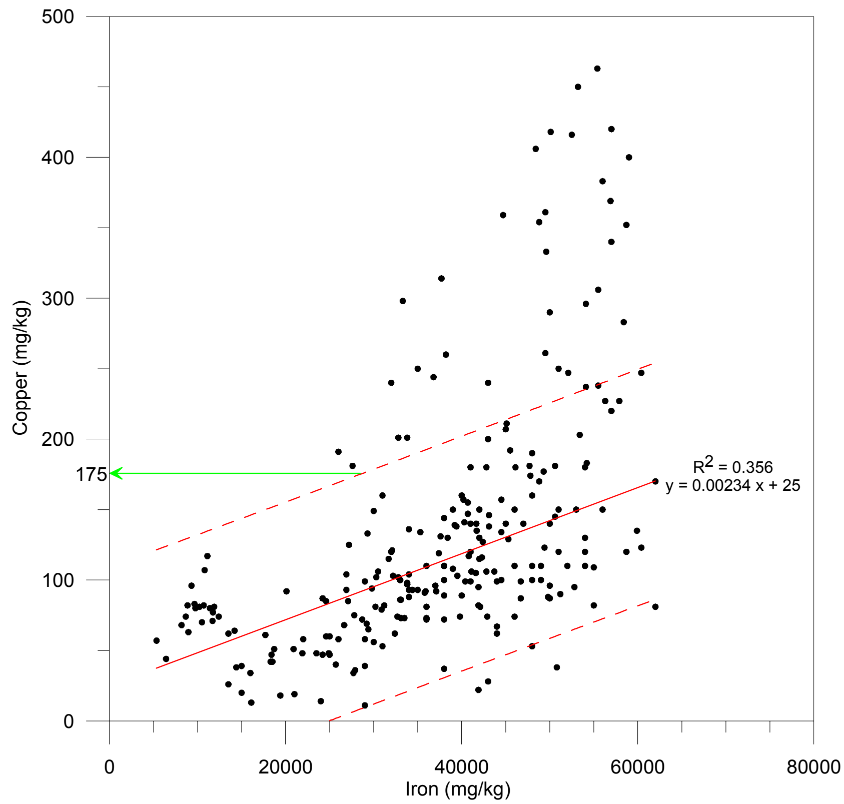

Figure 2-8. Relationship of copper to iron.

2.3.3 Sediment Toxicity

Historical toxicity test results for *Eohaustorius estuarius* were used to establish the threshold levels for sediment toxicity. *Eohaustorius estuarius* was selected as a primary indicator of improving harbor conditions because of its relative sensitivity and the large amount of data that exist on this species that can be used for comparison. Mortality of the test species rather than survival was used for analysis for purposes of consistency with other indicators (higher numbers represent poorer conditions). Test results were adjusted for control survival prior to analysis of the data. For this primary indicator, the threshold level was set at 20% mortality; a value that is typically used as an indicator of non-toxic sediments. Conditions are considered to have improved if significant changes over the preset target were observed (i.e. more than 51% of samples show less than 20% mortality) (Weston 2005b).

2.3.4 Benthic Infauna

Benthic infauna data from each of the harbors was assessed using various indices common to ecological community structure evaluations including Benthic Response Index (BRI), Shannon-Wiener Species Diversity Index, number of taxa, and abundance.

The BRI[1] is the primary indicator for evaluating infaunal changes in the harbors. The numerical criterion (i.e. community response levels) for this index is calculated by applying an abundance-weighted-average gradient that is correlated with sediment/habitat quality to the pollution tolerance of infaunal species. A reference threshold and four response levels help to characterize the degrees to which habitat conditions are deviating from reference conditions. Response level 1 is characterized as marginal deviation. Level 1 includes BRI values at which 5% of the reference species were lost. Response Levels 2-4 indicate increasingly disturbed benthic environments. Response level 2 is characterized as biodiversity loss which indicates a loss of 25% of reference species. Response level 3 is when there is a community function loss. BRI values at this level indicate a loss of 50% of reference species. Response level 4 is characterized by defaunation which indicates a loss of 80% of reference species (Ranasinghe et al. 2003). The range of BRI levels for each of these response levels is shown in Table 2-5.

Table 2-5. Characterization and BRI Ranges for Response Levels of Benthic Community Conditions.

BRI Threshold	Level	Characterization	Definition
<31	Reference		
31-42	Response Level 1	Marginal deviation	>5% of reference species lost
42-53	Response Level 2	Biodiversity loss	>25% of reference species lost
53-73	Response Level 3	Community function loss	>50% of reference species lost
>73	Response Level 4	Defaunation	>80% of reference species lost

The BRI threshold level for the Pilot Program was set at 31 which is the currently established value for reference conditions in embayments. After applying this value to historical data, a preset target was determined to be 37%. When more than 37% of samples are below the threshold level of 31 than it would be indicative of a healthier benthic community compared to what was observed historically.

The Shannon-Wiener diversity and number of taxa are used as secondary indicators. Threshold levels were determined to be 2 and 24, respectively, for these indices. The preset targets were set at 90% for the Shannon-Wiener diversity and 92% for the number of taxa. For these indicators only, the proportion of samples above the threshold is the target of interest. When more than 90% (Shannon-Wiener diversity) or 92% (number of taxa) of the samples are above their respective threshold levels than it would also be indicative of a healthier benthic community than historically observed throughout the harbors. (Weston 2005b).

[1] The BRI used here is the first iteration of the index for enclosed bays. The index is currently under revision by SCCWRP. BRI-3 is expected to be released later in 2006.

3.0 RESULTS

3.1 Water Quality

3.1.1 Chemistry

Surface water samples collected from marina and freshwater influenced stations in 2005 were analyzed for total and dissolved metals, hardness, DOC, TOC, and total PAHs (Table 3-1). The results for all of the total and dissolved metals that were analyzed are provided in Appendix A. Results for dissolved zinc are not available for 2005 due to the sample handling problems described in Appendix B.

Metals

Water samples from the marina stratum exceed the CTR for copper in each of the harbors. All Dana Point Harbor samples are above the CTR for both dissolved and total copper (Table 3-1). Dissolved copper concentrations in Oceanside Harbor do not exceed the CTR, however, total copper with a concentration of 51.40 µg/L is above its respective CTR. In Mission Bay, one of the two stations exceeds both the dissolved and total copper CTR values. In San Diego Bay, two of the four marina stations exceed the CTR for dissolved copper; all four stations are above the CTR for total copper. No samples exceed the CTR for nickel or total zinc.

In comparison, very few of the freshwater influenced stations exceed the CTRs for copper. In Dana Point Harbor, the one station in this stratum is well above both the CTR for dissolved copper at 12.0 µg/L and for total copper with a concentration of 24.6 µg/L. In San Diego Bay, three stations exceed the CTR for total copper; however, none are above the CTR for dissolved copper. Neither freshwater station in Mission Bay exceeds the CTRs for copper. All stations have nickel and zinc concentrations below their respective CTR.

Distribution curves for dissolved and total metals are presented in Figure 3-1 and Figure 3-2. The threshold level for each metal was based on the benchmark values from the CTR (Weston 2005b). A lower proportion of marina samples from 2005 have concentrations of dissolved copper (40%) and total copper (10%) below the threshold level in comparison with the preset targets of 70% and 26%, respectively. All of the marina samples have concentrations of dissolved and total nickel and total zinc below the threshold level. None of these three metals show a significantly greater proportion of values below the threshold level in 2005 compared to historical data. However, the data does indicate that dissolved and total copper concentrations in the water column may be higher in the marinas while concentrations of total zinc and dissolved and total nickel appear to be remaining at similar levels as seen in historical data.

Table 3-1. Surface water chemistry results for marina and freshwater influenced stations.

Marina Water Chemistry Results - Surface															
Analyte	Units	MDL	RL	CTR	COP	Station Code									
						D1M	D2M	D3M	O1M	M1M	M2M	S1M	S2M	S3M	S4M
Dissolved Copper (Cu)	µg/L	0.005	0.01	4.8	25	**6.54**	**9.71**	**12.10**	1.23	**5.19**	1.10	4.33	**5.27**	2.48	**8.21**
Dissolved Nickel (Ni)	µg/L	0.005	0.01	74	50	0.27	0.57	0.31	0.26	0.27	0.31	0.26	0.26	0.28	0.25
Dissolved Zinc (Zn)	µg/L	0.005	0.01	90	189	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Copper (Cu)	µg/L	0.005	0.01	5.8	30	**11.80**	**18.10**	**24.60**	**51.40**	**7.63**	1.93	**10.40**	**13.00**	**6.28**	**19.30**
Total Nickel (Ni)	µg/L	0.005	0.01	75	50	0.35	0.66	0.50	0.35	0.26	0.52	0.58	0.57	0.60	0.47
Total Zinc (Zn)	µg/L	0.005	0.01	95	200	28.20	34.00	44.90	19.50	14.50	6.86	12.10	13.50	7.02	22.90
Hardness as $CaCO_3$	mg/L	1.00	5.00	-	-	5320	5290	5410	5400	5420	5670	5270	5320	5310	5480
Total detectable PAHs	ng/L	1.00	5.00	-	-	0	5.6	5.2	140.5	22	4.1	21.1	15.4	13.4	15.5
TOC	mg/L	0.1	1.00	-	-	2.30	3.50	2.20	14.80	2.40	4.10	1.91	1.54	1.81	2.00
DOC	mg/L	0.032/0.32*	0.5/5*	-	-	ND	ND	ND	ND	ND	4.10	ND	ND	ND	ND
Temperature	ºC	-	-	-	-	19.94	20.01	20.01	21.25	21.78	18.63	19.86	20.85	20.76	20.28
Salinity	PSU	-	-	-	-	33.32	33.26	33.29	33.29	33.52	33.44	33.63	33.66	33.67	33.56
Conductivity	µS/cm	-	-	-	-	45804	45802	45829	47045	47866	44677	46107	47119	47040	46428
pH	pH units	-	-	-	-	7.90	7.71	7.72	6.91	7.99	7.87	7.76	7.76	7.79	7.85
Dissolved Oxygen	mg/L	-	-	-	-	5.85	4.72	5.32	0.11	6.30	5.93	6.09	6.04	6.36	7.32
Transmissivity	%	-	-	-	-	73.02	72.30	79.29	26.47	78.06	73.80	58.95	66.28	64.58	44.15
Enterococci	MPN/100 mL	1.00	10.00	-	-	<10	<10	<10	10	10	<10	10	<10	<10	<10

Freshwater Influenced Water Chemistry Results - Surface															
Analyte	Units	MDL	RL	CTR	COP	Station Code									
						D1F	M1F	M2F	S1F	S2F	S3F	S4F	S5F	S6F	S7F
Dissolved Copper (Cu)	µg/L	0.005	0.01	4.8	25	**12.00**	2.47	0.70	2.37	3.30	4.73	2.15	3.55	2.33	3.17
Dissolved Nickel (Ni)	µg/L	0.005	0.01	74	50	0.52	0.69	0.34	0.49	0.41	0.43	0.43	0.53	0.47	0.54
Dissolved Zinc (Zn)	µg/L	0.005	0.01	90	189	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Copper (Cu)	µg/L	0.005	0.01	5.8	30	**24.60**	4.05	1.18	4.13	4.97	**9.62**	**6.60**	**8.39**	4.39	4.37
Total Nickel (Ni)	µg/L	0.005	0.01	75	50	0.50	1.09	0.62	0.84	0.77	0.83	0.93	0.98	0.85	0.91
Total Zinc (Zn)	µg/L	0.005	0.01	95	200	44.90	13.50	2.98	3.46	5.03	7.10	7.36	6.31	3.41	3.32
Hardness as $CaCO_3$	mg/L	1.00	5.00	-	-	5360	6020	5730	5470	5500	5400	5490	5590	5490	5560
Total detectable PAHs	ng/L	1.00	5.00	-	-	5.5	6.1	0	17.8	21.9	22.9	89.2	13.6	51.4	26.2
TOC	mg/L	0.1	1.00	-	-	3.20	2.80	2.30	1.92	2.01	1.80	1.79	1.89	1.84	2.15
DOC	mg/L	0.032/0.32*	0.5/5*	-	-	ND	5.40	4.30	ND	ND	ND	ND	ND	ND	ND
Temperature	ºC	-	-	-	-	19.97	24.45	22.43	25.94	23.78	23.99	25.03	26.47	26.07	25.99
Conductivity	µS/cm	-	-	-	-	45748	52408	48908	53587	50583	50803	52576	54420	53788	53682
Salinity	PSU	-	-	-	-	33.25	34.94	33.84	34.66	34.07	34.08	34.61	34.86	34.71	34.69
pH	pH units	-	-	-	-	7.71	7.87	7.90	7.91	7.87	7.84	7.85	7.89	7.91	7.88
Dissolved Oxygen	mg/L	-	-	-	-	4.81	5.97	6.75	7.08	6.93	6.87	6.16	6.82	7.12	6.74
Transmissivity	%	-	-	-	-	68.27	55.82	79.29	71.17	66.76	67.58	50.11	57.08	69.98	54.38
Enterococci	MPN/100 mL	1.00	10.00	-	-	20	<10	<10	<10	<10	<10	<10	<10	<10	<10

* Reporting limits varied depending on the dilution factor used to analyze sample.
Bold-Above ER-L
MDL = Method Detection Limit
RL = Reporting Limit
CTR = California Toxics Rule
COP = California Ocean Plan

A high proportion of freshwater influenced samples have concentrations of dissolved copper (90%) and total copper (60%) below the threshold level compared to the preset targets of 70% and 26%, respectively. Dissolved and total nickel and total zinc concentrations for all of the freshwater influenced samples are below their respective threshold levels. Proportions of samples with concentrations of total and dissolved copper below the threshold levels are significantly higher than the preset target in the freshwater influenced stratum. This indicates that concentrations of copper are lower in freshwater influenced regions of the harbors than throughout the harbors in the past. There were no statistically significant changes in the number of samples with total zinc and dissolved and total nickel concentrations below the threshold level compared to the preset targets. The current data indicates that zinc and nickel concentrations are only slightly improving or remaining at similar levels as seen in the past. More metals data needs to be collected from both the marina and freshwater stratums before making a valid assessment as to whether water quality conditions have improved or declined in the harbors.

Dissolved and Total Organic Carbon

DOC and TOC analyses were conducted on all 20 of the surface water samples collected in 2005 (Table 3-1). Concentrations of DOC are non-detectable in all of the marina samples except at one station in Mission Bay which has a concentration of 4.10 mg/L. TOC concentrations in the marina samples range from 1.54 mg/L in San Diego Bay to 14.80 mg/L in Oceanside Harbor. Higher TOC concentrations in Oceanside Harbor may be due to decaying red tide conditions on the day samples were collected (Parsons and Takahashi 1973).

All of the freshwater influenced samples have non-detectable concentrations of DOC except for samples collected in Mission Bay. TOC concentrations in the freshwater influenced samples range from 1.79 mg/L in San Diego Bay to 3.20 mg/L in Dana Point Harbor.

Total Detectable PAHs

The results for total detectable PAHs in surface water samples are presented in Table 3-1. For samples collected at marina stations, concentrations range from zero (non-detectable) in Dana Point Harbor to 140.5 ng/L in Oceanside Harbor. Concentrations of PAHs in freshwater influenced samples comparatively range from zero (non-detectable) in Mission Bay to 89.2 ng/L in San Diego Bay. Insufficient data were available to establish threshold values and preset targets for PAHs in water; PAH data are collected in the Pilot Program to begin establishing a baseline for future comparisons.

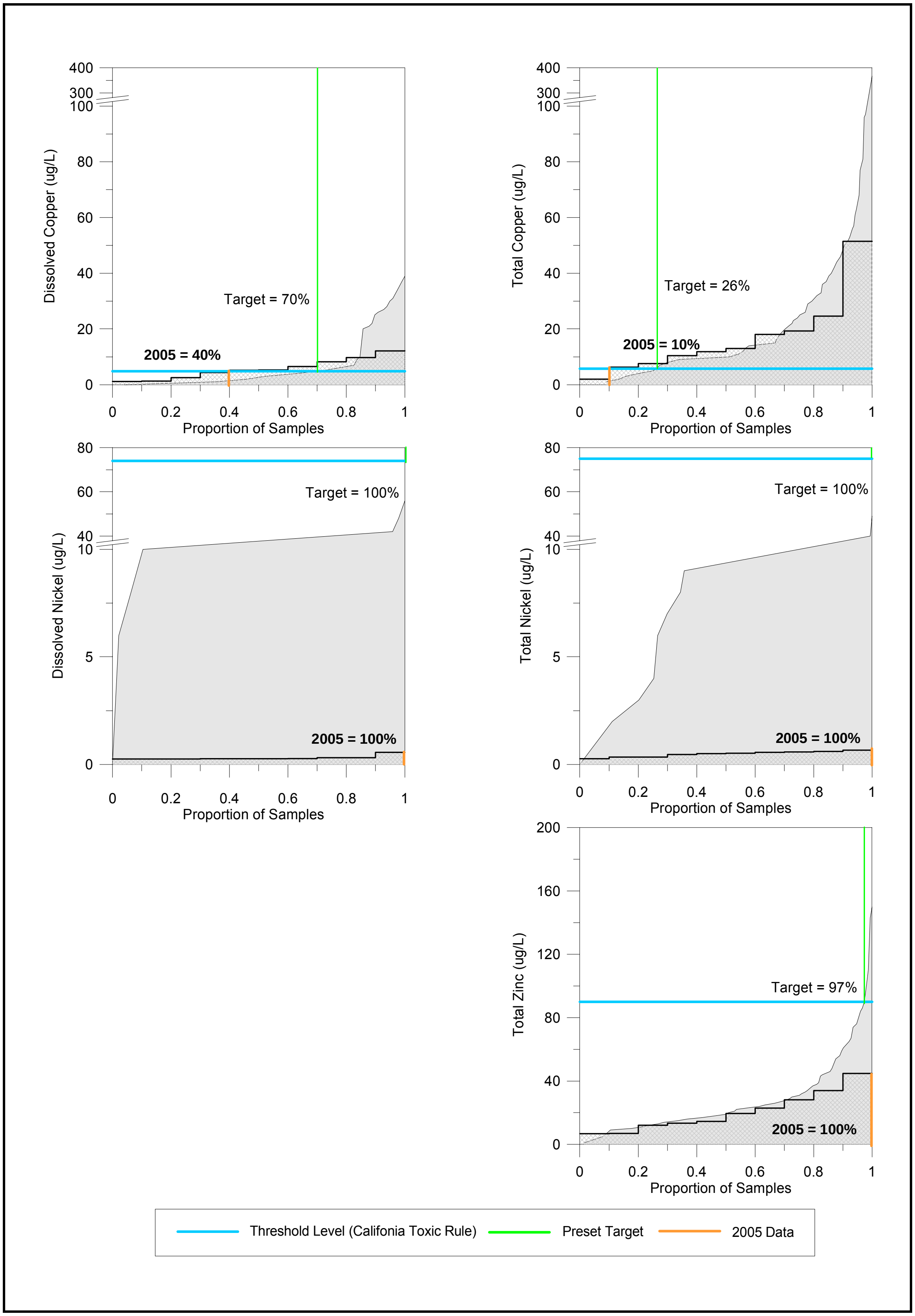

Figure 3-1. Distribution curves for dissolved and total water column metals in marina stations.

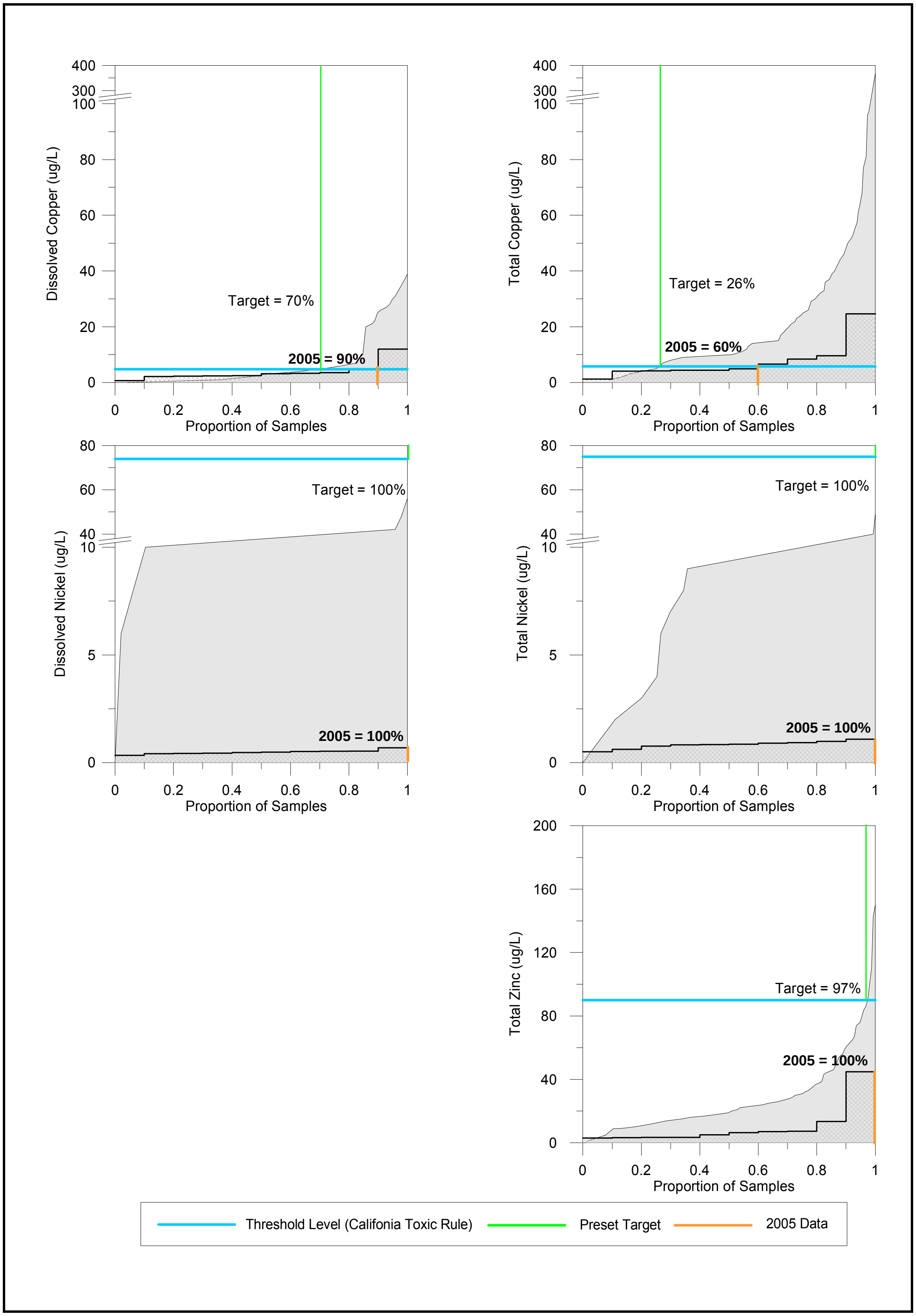

Figure 3-2. Distribution curves for dissolved and total water column metals in freshwater influenced stations.

3.1.2 Bacteria

The results of the water analysis for the indicator bacteria, Enterococcus, are presented in Table 3-1. None of the stations exceed the AB411 standards of 104 MPN/100mL. All stations have bacteria counts of 20 MPN/100mL or below. A threshold level and preset target have not been established for the indicator bacteria *Enterococcus,* however tracking concentrations of *Enterococcus* can help in determining whether the waters in the harbors are safe for body contact activities.

3.1.3 Water Column Profiles

Physical water column measurements for the 20 stations sampled in 2005 are presented in Figure 3-3 and Figure 3-4. Surface water data for individual monitoring stations are provided in Table 3-1. Summary data for all depths are provided in Appendix C. Measurements include temperature, salinity, pH, dissolved oxygen, and transmissivity. These measures, while not being compared to threshold levels, are useful to provide information about water quality that can help explain biological results and determine if the harbor waters can sustain a healthy biota.

Temperature
Maximum differences between surface and bottom temperatures for individual stations are less than 4 degrees Celsius (°C). Rapid changes of temperature with depth, indicative of a strong thermocline, are not evident at any of the sites. Surface temperatures range from 18.6°C to 21.8°C and bottom temperatures range from 17.4°C to 20.1°C.

Water temperatures measured in freshwater influenced stations are similar to those in marina stations. The presence of a thermocline is not evident at any of the stations. Surface water temperatures range from 20°C to 26.5°C while bottom temperatures range from 19.6°C to 25°C.

Salinity and pH
Salinity values varied little between any of the stations with values for both surface and bottom waters ranging between approximately 33 to 34 psu; typical of saline environments. Surface water pH values range from 6.9 to 8.0 and do not vary with depth.

Freshwater influenced stations have salinity and pH conditions similar to those observed at marina stations. Some immediate freshwater influence may be evident at station S2F with salinity measured below 30 psu near the bottom of the water column.

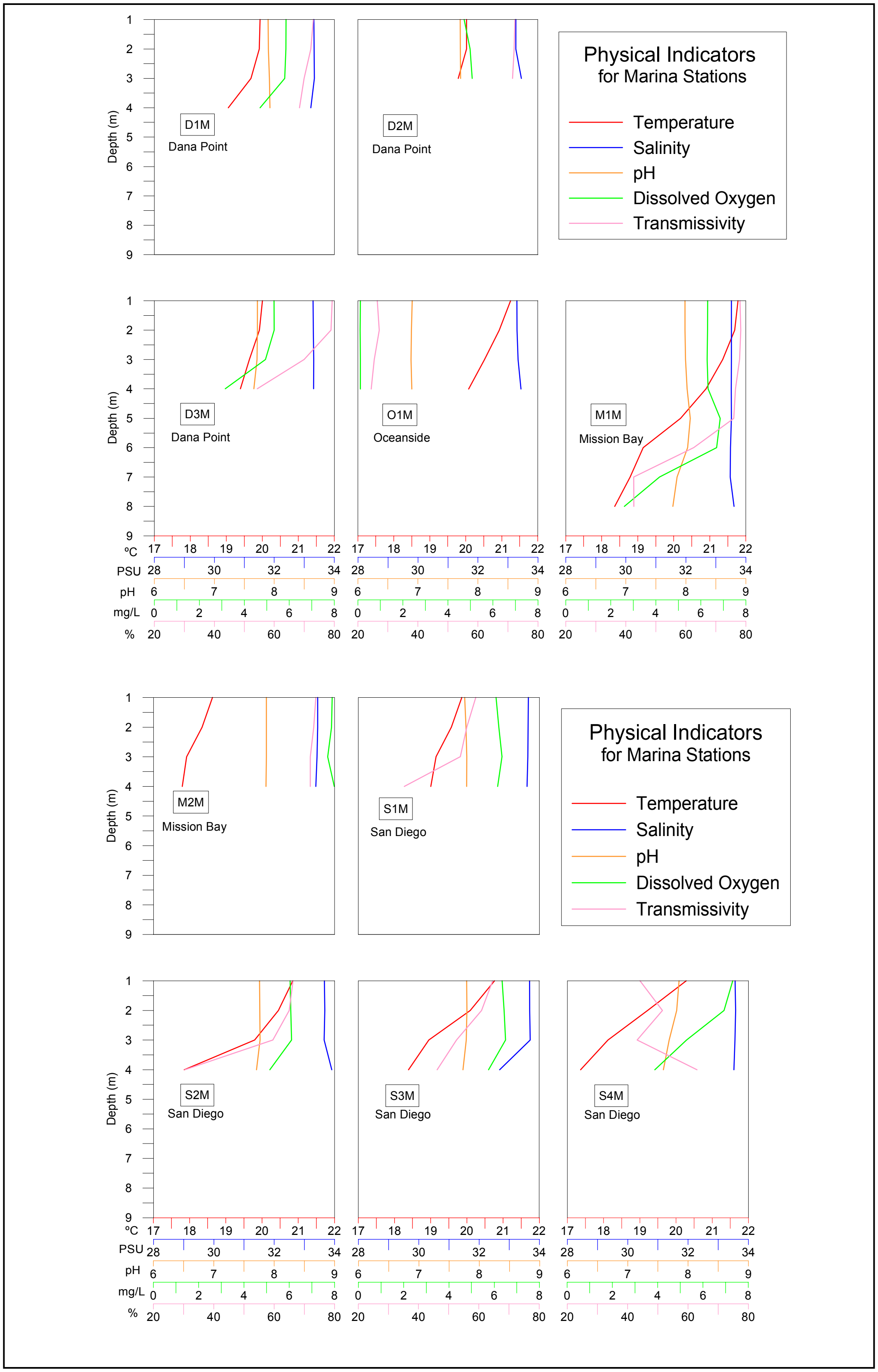

Figure 3-3. Physical indicators for marina stations.

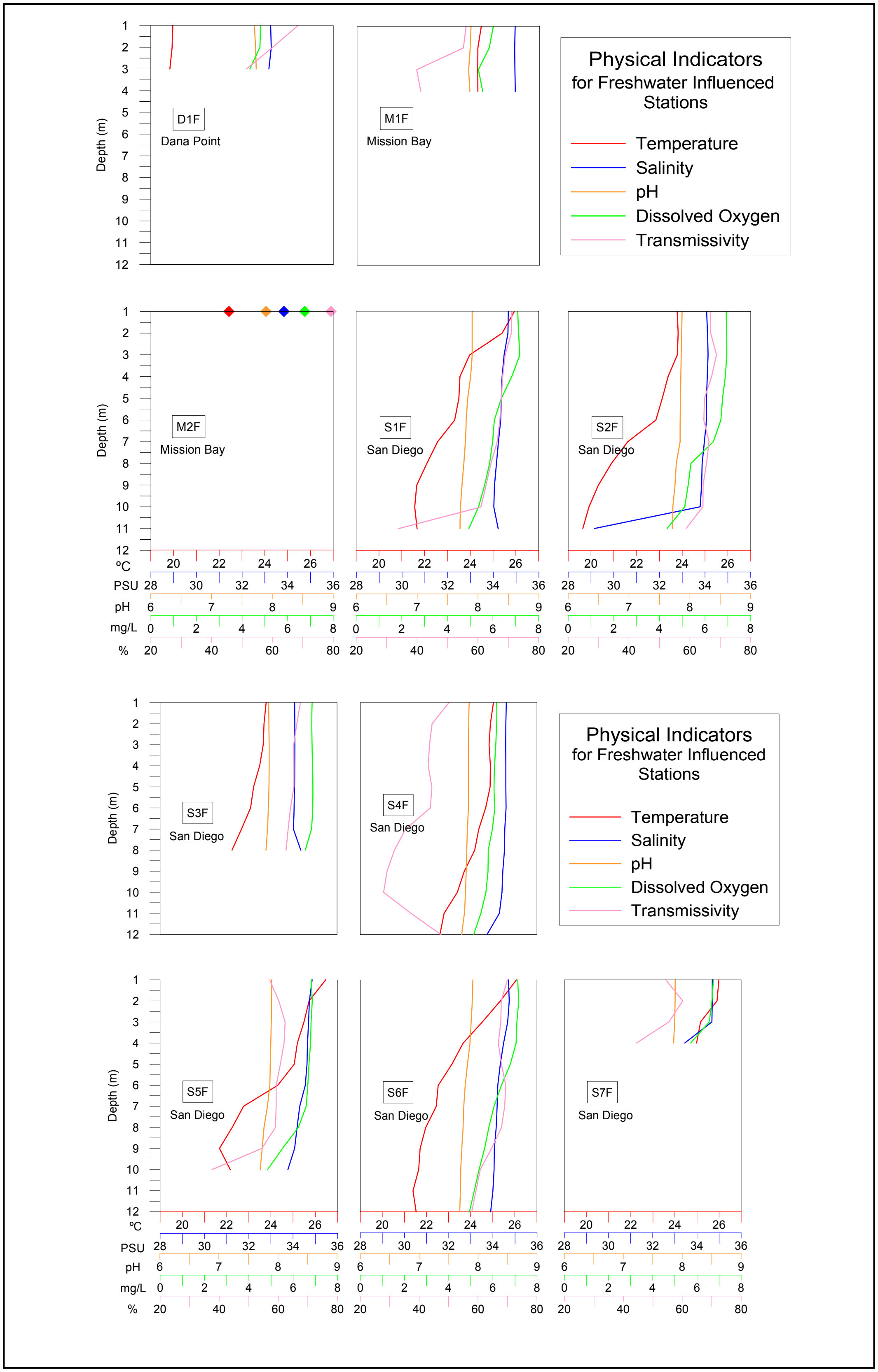

Figure 3-4. Physical indicators for freshwater influenced stations.

Dissolved Oxygen
Dissolved oxygen concentrations in nine of the ten marina stations are fairly low. As expected, dissolved oxygen concentrations are typically higher in surface waters decreasing slightly towards bottom waters. Dissolved oxygen concentrations in the surface waters of marina stations range from 4.7 mg/L to 7.3 mg/L and in bottom waters range from 2.6 mg/L to 6.2 mg/L. Due to red tide conditions on the day of sampling, the Oceanside Harbor station has extremely low dissolved oxygen concentrations averaging 0.11 mg/L throughout the water column.

Dissolved oxygen concentrations in surface waters of freshwater influenced stations range from 4.8 mg/L to 7.1 mg/L while concentrations in bottom waters range from 4.3 mg/L to 6.8 mg/L. Maximum differences in concentrations at individual stations between surface and bottom waters are 2.59 mg/L.

Transmissivity
Surface water values for light transmittance for nine of the ten stations range from 44% to 79%. Due to the occurrence of a red tide on the day of sampling, the water clarity in Oceanside Harbor was considerably lower than the other stations with 26% in surface waters and 25% in bottom waters. Relatively lower transmissivity values are typically found in bottom waters compared to surface and mid-depth waters.

Freshwater influenced stations have transmittance values similar to those found in the marina stations, ranging in surface waters from 50% to 79%. Station S4F, located near the mouth of Sweetwater River, has the lowest transmissivity values compared to all of the other freshwater influenced stations.

3.2 Sediment Analysis

3.2.1 Chemistry

Mean ER-M Quotient
The mean ER-M quotient is one of the primary indicators for sediment quality for the Pilot Program. The mean ER-M quotients for marina and freshwater (Table 3-2) influenced stations range between 0.1 and 0.7 with 20% and 30%, respectively, of the samples having an ER-M quotient below the threshold level of 0.2 (Figure 3-5). In comparison, the mean ER-M quotient for historical data from all strata in the harbors ranged from near zero to 16 with 48% of samples having an ER-M quotient below 0.2. This would indicate that overall conditions of sediment chemistry in the harbors were getting worse; however, additional data needs to be collected before making this assessment.

Metals
Six metals were identified as secondary indicators of sediment chemistry conditions. Results for 2005 are shown in Table 3-2. The results for all of the total and dissolved metals that were analyzed are provided in Appendix A.

Table 3-2. Sediment chemistry results for marina and freshwater influenced stations.

Marina Sediment Chemistry Results															
Analyte	Units	MDL	RL	ER-L	ER-M	Station Code									
						D1M	D2M	D3M	O1M	M1M	M2M	S1M	S2M	S3M	S4M
Cadmium (Cd)	mg/kg	0.025	0.05	1.2	9.6	0.58	0.89	0.69	0.77	0.73	0.65	0.33	0.50	0.42	0.31
Chromium (Cr)	mg/kg	0.025	0.05	81	370	45.40	69.70	53.60	66.20	46.50	36.30	16.90	65.90	30.40	26.70
Copper (Cu)	mg/kg	0.025	0.05	34	270	**212.00**	**370.00**	**219.00**	**224.00**	**216.00**	**55.50**	**47.30**	**251.00**	**92.30**	**91.80**
Lead (Pb)	mg/kg	0.025	0.05	46.7	218	20.00	30.10	21.40	24.60	42.80	20.70	14.60	56.10	24.80	19.50
Nickel (Ni)	mg/kg	0.025	0.05	20.9	51.6	20.90	**25.60**	20.20	**27.00**	14.70	11.20	4.55	17.00	7.63	7.23
Zinc (Zn)	mg/kg	0.025	0.05	150	410	**203.00**	**313.00**	**200.00**	**227.00**	**200.00**	113.00	66.00	**212.00**	110.00	99.20
Total Detectable PAHs	µg/kg	-	-	4022	44792	89.00	120.40	55.30	90.20	1065.30	127.20	421.10	745.40	557.60	190.40
ERM-Q	-	-	-	-	-	0.29	0.46	0.34	0.38	0.32	0.17	0.16	0.63	0.32	0.25
Gravel	%	-	-	-	-	0.80	0.21	0.10	0.30	0.06	0.17	0.00	0.09	0.08	0.33
Sand	%	-	-	-	-	31.52	1.00	23.42	9.69	25.18	37.84	74.80	10.80	50.04	71.43
Silt	%	-	-	-	-	34.99	53.75	36.91	54.32	41.86	48.58	17.23	56.07	36.12	13.93
Clay	%	-	-	-	-	32.69	45.04	39.56	35.69	32.90	13.40	7.96	33.04	13.77	14.30
Median	%	-	-	-	-	13.37	4.84	7.25	9.38	15.94	43.47	85.70	13.15	62.59	93.38
Fines (silt + clay)	%	-	-	-	-	67.68	98.79	76.47	90.01	74.76	61.98	25.19	89.11	49.89	28.23
TOC	%	0.01	0.05	-	-	1.50	1.83	1.59	1.81	2.68	2.02	0.38	1.23	0.66	0.64
E. estuarius mortality	%	-	-	-	-	22.00	17.00	12.00	25.00	8.00	4.00	2.00	17.00	11.00	13.00

Freshwater Influenced Sediment Chemistry Results															
Analyte	Units	MDL	RL	ER-L	ER-M	Station Code									
						D1F	M1F	M2F	S1F	S2F	S3F	S4F	S5F	S6F	S7F
Cadmium (Cd)	mg/kg	0.025	0.05	1.2	9.6	**4.36**	0.71	0.83	0.51	0.51	1.18	0.67	0.71	0.56	0.75
Chromium (Cr)	mg/kg	0.025	0.05	81	370	48.60	24.90	26.10	38.40	61.80	58.40	46.00	46.90	38.40	46.00
Copper (Cu)	mg/kg	0.025	0.05	34	270	**264.00**	24.00	**37.10**	**89.50**	**146.00**	**476.00**	**84.10**	**107.00**	**55.00**	**77.40**
Lead (Pb)	mg/kg	0.025	0.05	46.7	218	22.90	33.20	32.20	20.50	**62.10**	**91.90**	29.70	27.10	14.30	27.00
Nickel (Ni)	mg/kg	0.025	0.05	20.9	51.6	**22.90**	11.70	11.50	13.30	17.70	18.90	17.30	16.20	14.80	18.40
Zinc (Zn)	mg/kg	0.025	0.05	150	410	**336.00**	113.00	146.00	134.00	**243.00**	**555.00**	**153.00**	**177.00**	92.70	**182.00**
Total Detectable PAHs	µg/kg	-	-	4022	44792	780.20	445.20	211.40	171.50	1197.40	1246.30	474.00	580.60	68.10	198.50
ERM-Q	-	-	-	-	-	0.45	0.16	0.18	0.20	0.37	0.57	0.23	0.27	0.17	0.26
Gravel	%	-	-	-	-	1.87	1.22	0.28	1.22	2.18	0.55	1.85	0.02	8.80	0.13
Sand	%	-	-	-	-	22.94	38.67	49.12	42.22	32.85	62.15	30.59	28.70	30.31	13.27
Silt	%	-	-	-	-	37.85	27.02	28.50	29.33	25.65	19.14	26.09	36.05	29.08	44.26
Clay	%	-	-	-	-	37.34	33.09	22.10	27.23	39.32	18.16	41.48	35.23	31.81	42.33
Median	%	-	-	-	-	9.44	17.65	60.38	44.71	15.27	117.08	11.15	19.63	26.98	7.98
Fines (silt + clay)	%	-	-	-	-	75.19	60.11	50.60	56.56	64.97	37.30	67.57	71.28	60.89	86.59
TOC	%	0.01	0.05	-	-	3.80	1.56	2.28	0.95	1.78	1.72	1.24	1.15	1.03	1.39
E. estuarius mortality	%	-	-	-	-	55.00	22.00	6.00	22.00	22.00	3.00	43.00	10.00	16.00	26.00

Bold - Above ER-L
Shaded - Above ER-M
MDL = Method Detection Limit
RL = Reporting Limit
ER-L = Effects Range-Low
ER-M = Effects Range-Median

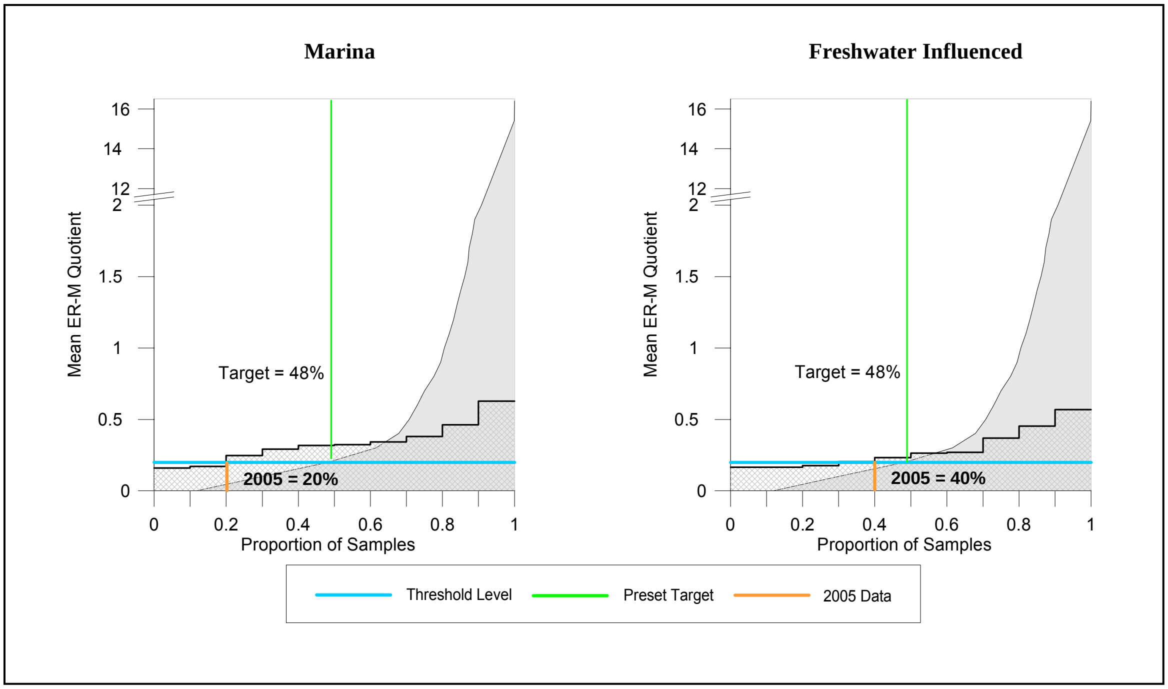

Figure 3-5. Distribution of the mean ER-M Quotient for marina and freshwater influenced sediments.

Marina sediments in all four of the harbors have levels of copper that exceed the ER-L value of 34 mg/kg. Copper concentrations range from 47.3 mg/kg to 370 mg/kg. One station in Dana Point Harbor, also exceeds the copper ER-M value of 270 mg/kg. Nickel exceeds the ER-L value of 20.9 mg/kg in Dana Point Harbor and Oceanside Harbor. Zinc exceeds the ER-L value of 150 mg/kg in all of the stations located in Dana Point Harbor, Oceanside Harbor, and at one station each in Mission Bay and San Diego Bay.

Freshwater influenced sediments at all of the stations, except one in Mission Bay, have copper concentrations that exceed the ER-L. Copper concentrations range from 24 mg/kg to 476 mg/kg. Lead exceeds the ER-L value of 46.7 mg/kg at two stations in San Diego Bay while zinc exceeds the ER-L in Dana Point Harbor and in San Diego Bay with concentrations ranging from 153 mg/kg to 555 mg/kg. One freshwater influenced station in San Diego Bay has concentrations of both copper and zinc above the ER-M values. Cadmium and nickel are observed above the ER-L at one station in Dana Point Harbor.

Distribution curves for concentrations of cadmium, chromium, copper, lead, nickel, and zinc overlaid with historical data are shown in Figure 3-6 and Figure 3-7. A high proportion (80-100%) of marina samples have concentrations of cadmium, chromium, lead, and nickel below the established threshold level. These proportions either equaled or exceeded the preset targets set for these four metals. Metals that show a significantly greater proportion of samples below the threshold level than the preset targets are cadmium, chromium, and lead. This would indicate that current concentrations of these three metals in marinas are better than historic conditions. In contrast, only 40% of the marina samples have concentrations of copper and zinc below the threshold level compared to the preset targets of 68% (copper) and 45% (zinc). This indicates that concentrations of copper and zinc in 2005 are worse than those observed historically.

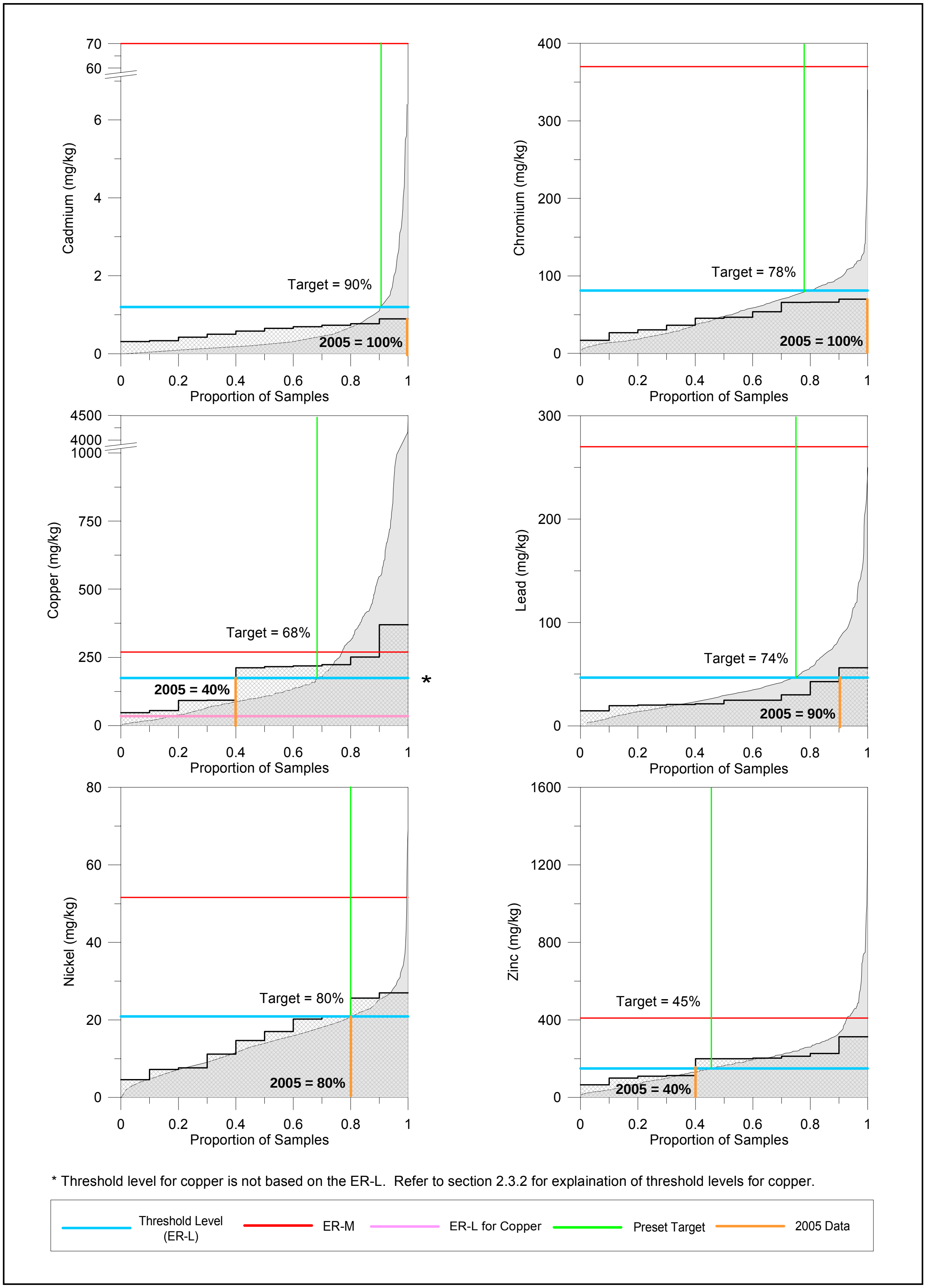

Figure 3-6. Distribution curves for metal concentrations in marina sediments.

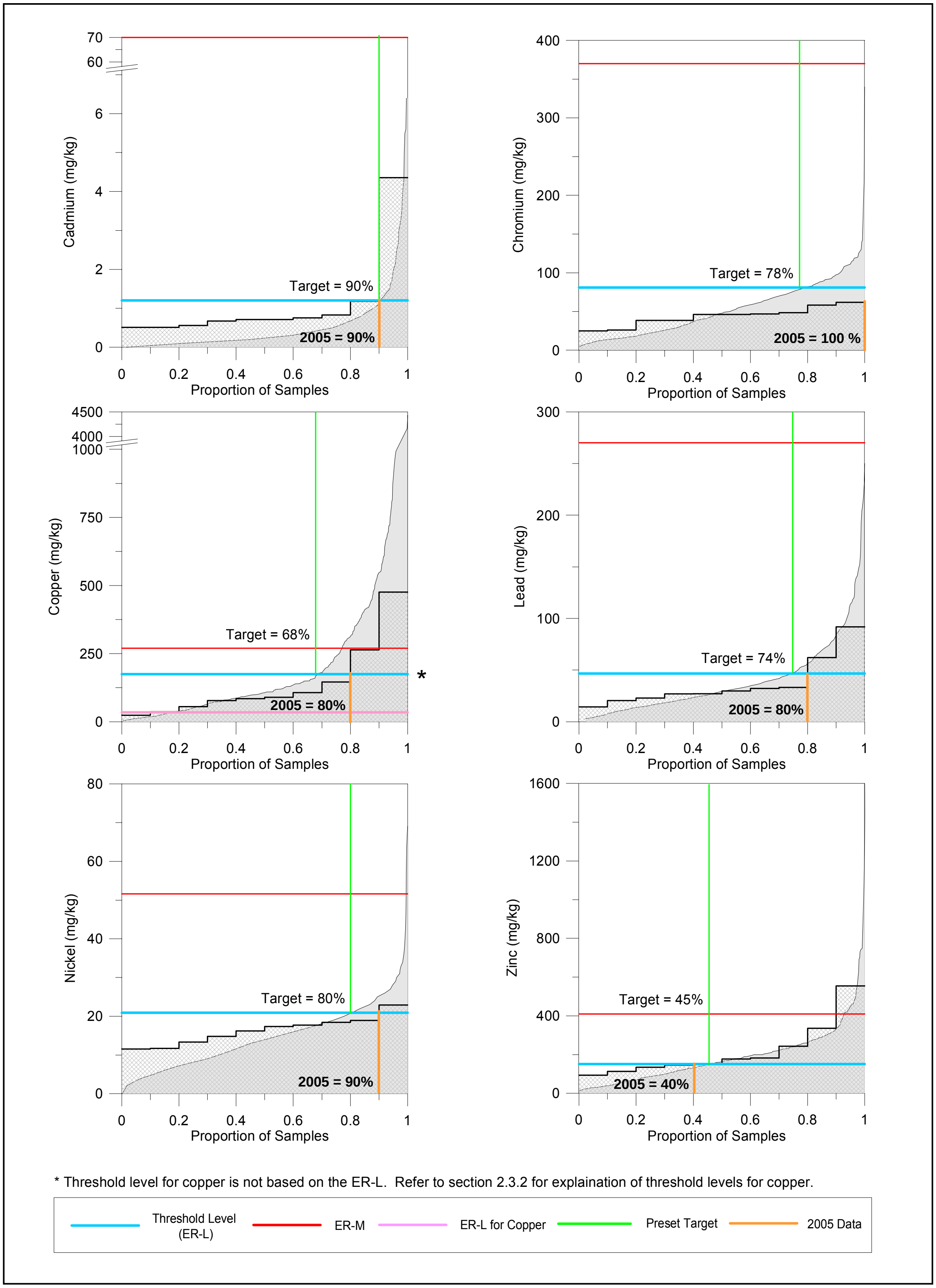

Figure 3-7. Distribution curves for metal concentrations in freshwater influenced sediments.

A high proportion (80-100%) of freshwater influenced samples have concentrations of cadmium, chromium, copper, lead, and nickel below the threshold level. All five of these metals either equaled or exceeded their respective preset targets. Chromium was the only metal that had a significantly greater proportion of samples below the threshold level than the preset target. This would indicate that concentrations of these five metals in freshwater influenced sediments are similar or improving compared to concentrations in historic sediments. For zinc concentrations, only 40% of the current samples were below the threshold level compared to the preset target of 45%. This would indicate that zinc concentrations in freshwater influenced regions of the harbor are about the same as historically observed; however, more metals data needs to be collected from both the marina and freshwater stratum in order to determine whether these assessments are valid.

Total Detectable PAHs

The results for total detectable PAHs are also presented in Table 3-2. Concentrations of PAHs in marina sediments range from 55.3 µg/kg in Dana Point Harbor to 1065.3 µg/kg in Mission Bay. Concentrations of PAHs in freshwater sediments range from 68.1 µg/kg to 1246.3 µg/kg. None of the PAH values exceed the ER-L value of 4022 µg/kg.

Distribution curves for concentrations of total detectable PAHs with their ER-L and ER-M levels are shown in Figure 3-8. The historical data shows that 74% of samples are below the threshold level of 4022 µg/kg. In contrast, 100% of the marina and freshwater influenced samples collected in 2005 are below the threshold level. There is a significantly greater difference between the results of the samples collected in 2005 and the preset target. This would indicate that PAH levels are better than historic conditions.

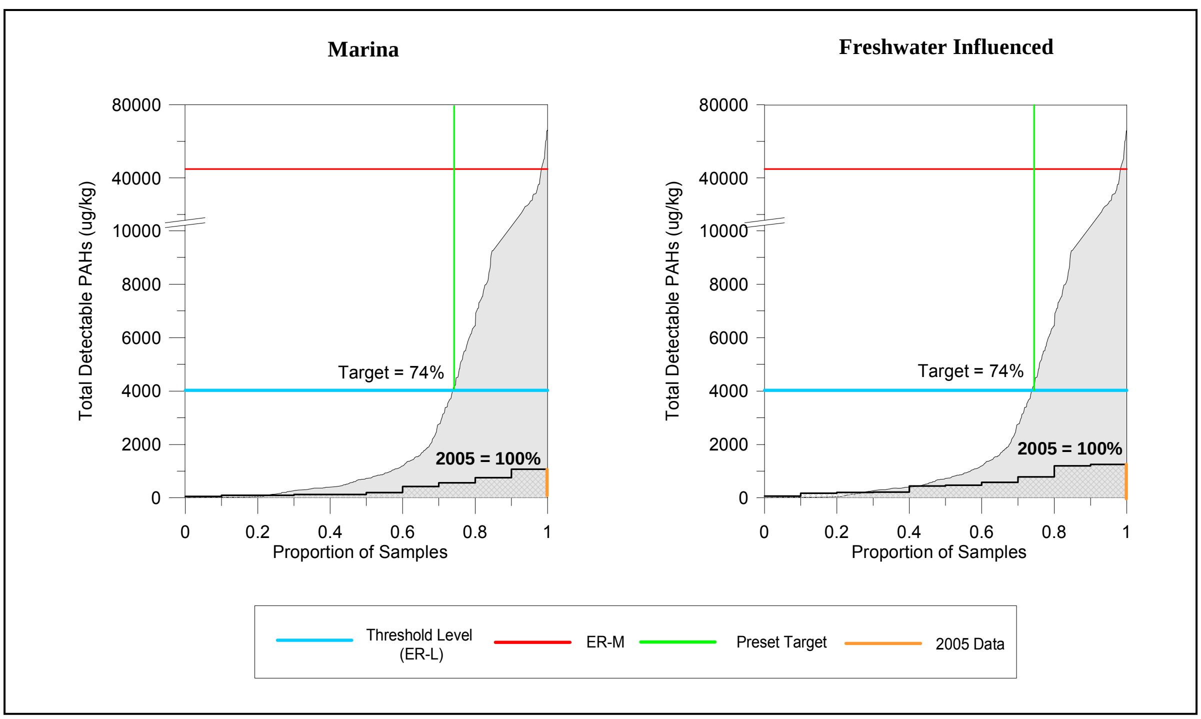

Figure 3-8. Distribution curves for total detectable PAHs in marina and freshwater sediments.

3.2.2 Toxicity

The results of the sediment toxicity test conducted with both the marina and freshwater influenced sediments are presented in Table 3-2. Additional supporting data are provided in Appendix D. The control adjusted percent mortality for *E. estuarius* in the marina sediments ranges from 2% to 25%. The percent mortality for freshwater sediments ranges from 3% to 55%.

Distribution curves for *E. estuarius* are presented in Figure 3-9. The threshold level used for this toxicity test is 20% mortality. Historical data show that 51% of samples had less than 20% mortality. Current results show that 80% of marina samples and 40% of freshwater samples are below the threshold level. The proportion of marina samples with mortality below 20% is significantly greater than the preset target of 51%. This would indicate sediment conditions are getting better in the marinas; however, conditions in freshwater influenced sediments may be getting worse compared to the harbor-wide historical data. More data needs to be collected in order to validate this assessment.

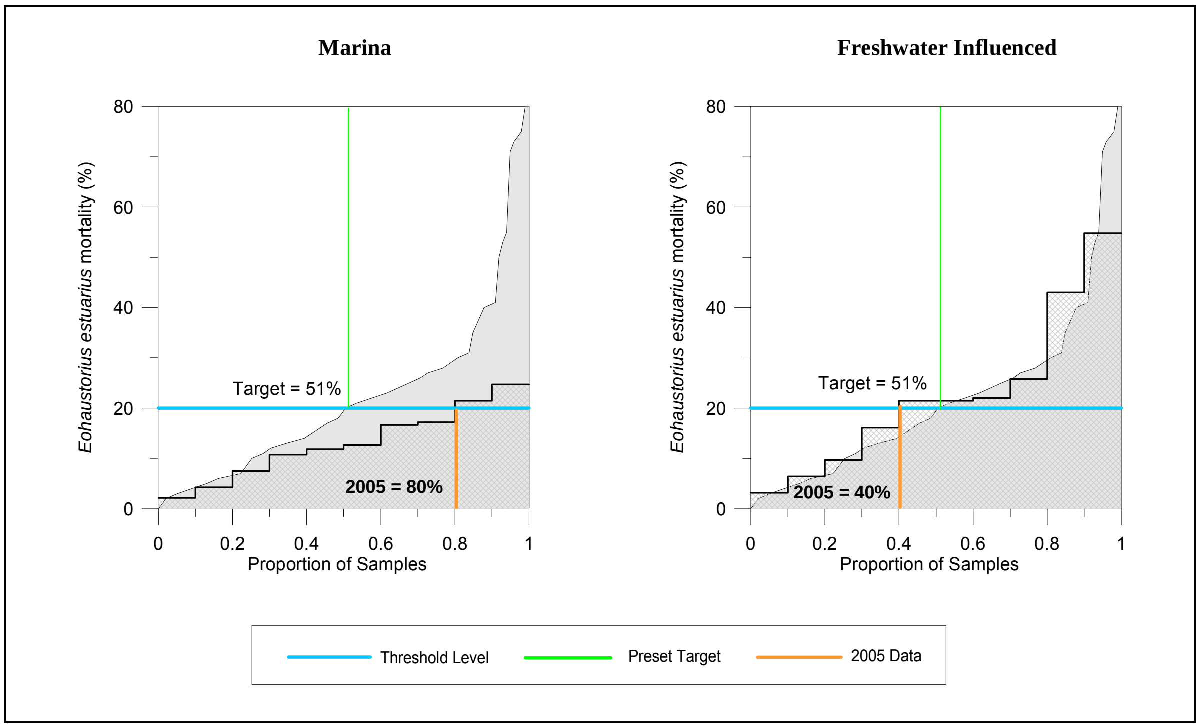

Figure 3-9. Distribution curves for toxicity in marina and freshwater influenced sediments.

3.2.3 Benthic Infauna

Benthic infaunal samples were collected and analyzed in the four harbors from 10 stations in two strata: marina and freshwater influenced. The number of taxa, abundance, Shannon-Wiener diversity, and BRI were calculated for each of the samples (Table 3-3). Species names and abundances for each taxon are provided in Appendix E. The number of unique taxa identified in marina samples range from 4 to 59 taxa; total abundance ranges from 8 organisms to1361 organisms. The Shannon-Wiener diversity value for marina samples ranges from 1.21 to 3.25. BRI scores vary widely within and among the harbors ranging from 18 to 65.

Table 3-3. Results of benthic infauna community measures for marina and freshwater influenced sediments.

Marina Sediments										
Station	D1M	D2M	D3M	O1M	M1M	M2M	S1M	S2M	S3M	S4M
Number of Taxa	35	9	15	5	18	59	59	27	4	43
Total Count	795	221	205	15	85	743	558	420	8	1361
Shannon-Wiener Diversity Index	1.93	1.56	2.04	1.49	2.50	3.25	2.90	2.39	1.21	2.44
BRI Score[1]	42	65	57	40	57	28	18	43	31	38

Freshwater Influenced Sediment										
Station	D1F	M1F	M2F	S1F	S2F	S3F	S4F	S5F	S6F	S7F
Number of Taxa	24	33	49	15	33	38	11	39	14	38
Total Count	1566	599	3999	42	868	1024	30	199	39	573
Shannon-Wiener Diversity Index	0.91	2.59	2.72	2.08	1.48	2.08	2.11	2.95	2.37	2.44
BRI Score[1]	58	50	38	48	29	37	47	43	45	36

[1] The BRI used here is the first iteration of the index for enclosed bays. The index is currently under revision by SCCWRP. BRI-3 is expected to be released later in 2006.

The number of taxa collected at freshwater influenced stations also varied, ranging from 11 to 49. Abundance is somewhat related to the number of taxa with higher numbers of organisms found at stations with greater diversity. Low Shannon-Wiener diversity values indicate the influence of large abundances of a few taxa, particularly at station D1F and S2F. Station D1F was largely dominated by the pollution tolerant polychaete *Capitella capitata* and S2F was dominated by the mollusk species *Musculista senhousei*. The BRI scores are similar to those observed at marina stations.

Distribution curves for BRI values, Shannon-Wiener diversity, and number of taxa for both marina and freshwater influenced sediments collected in 2005 are presented in Figure 3-10. The threshold level for the BRI was set at 31, the current level designating reference conditions in embayments. Samples that have BRI values below 31 are considered to be indicative of a healthier benthic community. Only 20% of the marina samples have BRI values below the threshold level in comparison to the preset target of 37%. The proportion of freshwater samples below the threshold level is even lower at 10%.

The Shannon-Wiener diversity and number of taxa were used as secondary indicators. Values that are above the threshold level of 2 and 24, respectively, are considered to be an indication of healthier benthic communities. The preset target for the Shannon-Wiener diversity is 90% and for the number of taxa it is 92%. In comparison, the proportion of marina samples collected in 2005 that have Shannon-Wiener diversity and number of taxa above the threshold level are 60% and 50%, respectively. For sediments collected from freshwater stations, 60% of the samples have a Shannon -Wiener diversity and 80% have a number of taxa above the threshold level. No benthic infaunal indicator shows proportions that are significantly greater than the preset targets. These results would indicate that benthic community assemblages in both the marina and freshwater influenced stratum are worse when compared to historic conditions; however, further data will need to be collected over time to determine if these evaluations are valid.

3.2.4 Grain Size and TOC

Sediment grain size and TOC for the 20 stations sampled in 2005 are summarized in Table 3-2. These measurements have no threshold levels for comparison; however, they can be used to help interpret biological responses. Marina samples collected in Mission Bay, Oceanside Harbor, and Dana Point Harbor are largely dominated by fine-grained sediments (particle diameter < 63 microns). These stations have relatively low TOC values ranging from 1.5% to 2.7%. Marina samples collected in San Diego Bay vary in sediment size. In Shelter Island Yacht Basin and near the mouth of America's Cup Harbor sand is the dominant sediment constituent at 71% and 75%, respectively. The other two stations within America's Cup Harbor vary; station S2M consists mainly of fine-grained particles (89%) while station S3M is an equal mix of both sand and fine grains. TOC values in San Diego Bay are lower than the other harbors with all values below 1.3%.

All of the sediments collected from freshwater influenced stations in San Diego Bay are fine-grained except for station S3F which is dominated by sand (62%). Freshwater influenced stations in Dana Point Harbor and Mission Bay are also mostly dominated by fine grains. TOC values for these stations range from 0.95% at station S1F to 3.8% at station D1F. There were no samples collected from freshwater influenced stations in Oceanside Harbor.

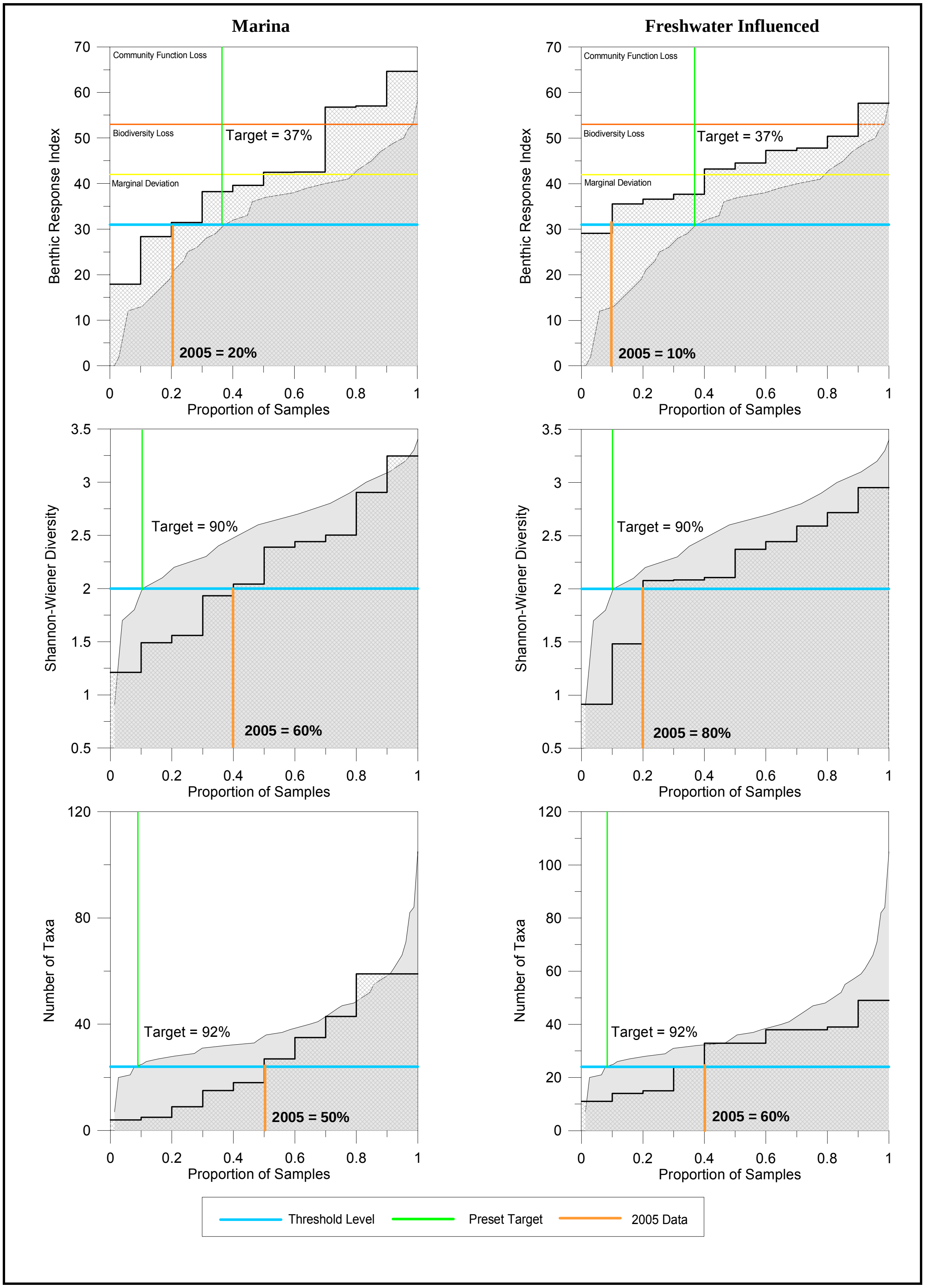

Figure 3-10. Distribution curves for benthic infauna community measures for marina and freshwater influenced sediments.

4.0 DISCUSSION

The objective of the pilot program is to implement the RHMP core monitoring on a limited scale to verify the study design. Data are to be statistically evaluated to establish the frequency of core monitoring needed to assess trends in water and sediment quality. Comparison of the pilot project data to historical data used in setting the threshold levels and target percentages is not a direct comparison because the historical data were collected throughout the harbors and include data from potentially cleaner sediments in the more open parts of the harbors. The comparisons made in this report are made to verify elements of the study design and not to make conclusions on the conditions in the harbors.

Water Column Measures

Examination of the 2005 sample results compared to the preset targets for the primary indicators, dissolved and total copper, shows differing results between the marina and freshwater influenced strata (Table 4-1). The percent of samples below the threshold level for both indicators are significantly higher than the preset targets in the freshwater influenced stratum and lower than the targets in the marina stratum. This suggests that conditions in the freshwater influenced area are better than what has been observed historically throughout the harbors; conversely, conditions in the marinas are worse than those historically observed. For the secondary indicators, dissolved and total nickel and total zinc, all stations in both strata had concentrations below the threshold levels. This is consistent with the preset targets. Other measured metals and PAHs were all found at concentrations below their respective CTRs. Therefore, the potentially degraded conditions in the water column of the marina stratum may be limited to copper contamination, a documented contaminant in San Diego Bay marinas (McPherson and Peters 1995, SDRWQCB 2005) as well as others in the San Diego region (Schiff et al. 2006).

Sediment Measures

The mean ER-M quotient is the primary indicator for sediment quality in the RHMP. Comparison of the percent of samples below a mean quotient of 0.2 shows that both the marina and freshwater influenced strata are below the preset target of 48% (Table 4-1), indicating that conditions in the marina or freshwater influenced strata are not better than the harbors as a whole were historically. This finding triggers examination of the secondary indicators for sediment chemistry, metals and total PAHs. As can be seen in Table 4-1, copper in marinas and zinc in both strata support the mean ER-M quotient conclusion. However, comparison of the percent of samples below the threshold levels for other metals and PAHs tend to contradict the conclusion based on the mean ER-M quotient. Cadmium, chromium, lead, nickel, and total PAHs have equal or higher percentages of samples below the threshold levels than the target percentage in both strata. Because the mean ER-M quotient is comprised of more than just these secondary indicators, other measured constituents were reviewed to see their contribution to the mean ER-M quotient (see Appendix A, Tables A-3 and A-4). Copper and zinc are contributors as are silver and mercury in the stations with the higher mean ER-M quotients in the marina stratum, while silver is also influential in the freshwater stratum. These metals were not identified as secondary indicators because they were not consistently available in the historical data. Bringing this information into the picture supports the use of the mean ER-M quotient as the primary indicator of sediment chemical quality.

Table 4-1. Comparison to threshold levels.

Measure	Threshold Level	Preset Target	Marina	Freshwater Influenced
Primary Indicators				
Dissolved Copper (water)	4.8 µg/L	70%	40%	90%*
Total Copper (water)	5.8 µg/L	26%	10%	60%*
ER-M Quotient	0.2	48%	20%	40%
E. estuarius mortality	20%	51%	80%*	40%
BRI	31	37%	20%	10%
Secondary Indicators				
Dissolved Zinc (water)	90 µg/L	100%	NA	NA
Total Zinc (water)	95 µg/L	97%	100%	100%
Dissolved Nickel (water)	74 µg/L	100%	100%	100%
Total Nickel (water)	75 µg/L	100%	100%	100%
Sediment Cadmium	1.2 mg/kg	90%	100%*	90%
Sediment Chromium	81 mg/kg	78%	100%*	100%*
Sediment Copper	175 mg/kg	68%	40%	80%
Sediment Lead	46.7 mg/kg	74%	90%*	80%
Sediment Nickel	20.9 mg/kg	80%	80%	90%
Sediment Zinc	150 mg/kg	45%	40%	40%
Sediment Total PAHs	4022 µg/kg	74%	100%*	100%*
Shannon-Wiener diversity	2	90%	60%	80%
Number of taxa	24	92%	50%	60%

* Indicates results significantly higher than preset target
NA = Not Available

E. estuarius toxicity in sediments, measured by the percent of samples with mortality less than 20%, is significantly above the target in marina sediments and about 10% less than the target in freshwater influenced sediments. This would indicate that marina sediments are less toxic than historical data suggest and freshwater influenced sediments slightly more toxic.

The primary benthic infaunal indicator, the BRI, suggests that both strata have poorer quality than observed throughout the harbors historically. This is substantiated by the data from 2005 for the secondary indicators (number of taxa and Shannon-Wiener diversity index). The data for these two indicators show that the proportion of samples above the threshold levels are less than the preset targets (for these indicators the measurement of interest is the proportion of samples above the threshold).

Thus, the three sets of indicator constituents for sediments show the freshwater influenced stratum to be of poorer quality in 2005 compared to previous data collected in all of the strata. The chemistry and benthic infauna data indicate the marina stratum is also in poorer condition than previously while toxicity results indicate healthier sediments in this stratum compared to historical data. These observations are only indicative of conditions sampled in 2005 and are not intended to make definitive statements about the health of the harbors.

Relationship Between Water and Sediment Chemistry

Results for common constituents measured in water and sediment were similar when compared to their respective threshold levels. The proportions of marina stations with copper concentrations below the threshold level were under the preset target for both water and sediment samples. In the freshwater influenced stratum, copper, nickel, and zinc were at or above the preset target in both water and sediment samples.

Variability in Primary and Secondary Indicators

The marina and freshwater influenced strata were selected for the pilot program because they were expected to have more variability in the results than the open water strata. Table 4-2 shows the variability in the primary and secondary indicators. The coefficient of variation (CV = ratio of standard deviation to mean expressed as percent, a smaller CV means lower variability in the data) is used for comparison of variability over the different indicators. Overall the freshwater influenced stratum (mean CV=65%) tends to be more variable than the marina stratum (mean CV=55%) with several indicators having standard deviations greater than their means. The freshwater influenced stratum is likely to be more variable due to the stations' more open locations and the differing types of freshwater inputs in each of the three harbors while the marinas are more enclosed with less water movement.

Table 4-2. Comparison of sample variability in primary and secondary indicators.

Constituent		Marina			Freshwater Influenced		
		Mean	St Dev	CV (%)	Mean	St Dev	CV (%)
Water	**Dissolved Metals**						
	Copper (Cu)	5.62	3.62	64	3.68	3.11	85
	Nickel (Ni)	0.30	0.09	31	0.49	0.09	19
	Total Metals						
	Copper (Cu)	16.4	14.1	86	7.2	6.6	91
	Nickel (Ni)	0.52	0.18	35	0.83	0.17	21
	Zinc (Zn)	20.3	12.3	61	9.7	12.8	131
Sediment	Cadmium (Cd)	0.59	0.19	33	1.08	1.17	108
	Chromium (Cr)	45.8	18.2	40	43.6	12.1	28
	Copper (Cu)	178	103	58	136	137	101
	Lead (Pb)	27.5	12.7	46	36.1	23.4	65
	Nickel (Ni)	15.6	7.9	50	16.3	3.5	22
	Zinc (Zn)	174	75	43	213	139	65
	Total Detectable PAHs	346	344	99	537	420	78
Toxicity	*E. estuarius* mortality	13.1	7.4	56	22.5	16.1	72
Infauna	Number of Taxa	27.4	20.9	76	29.4	12.7	43
	Total Count	441	432	98	894	1201	134
	Shannon-Wiener Diversity Index	2.17	0.65	30	2.17	0.60	28
	BRI Score	41.9	14.4	34	43.0	8.4	19
	Mean CV			55			65

Pilot Program Design - Are ten samples per stratum enough?
After one year of sampling there are not enough samples to make a determination for all indicators whether ten samples are enough to characterize each stratum. However, because of the cooperative effort with SCCWRP's marina copper study in the water column sampling, it is possible to get an estimate of how results for dissolved copper might change with more samples. The marina copper study (Schiff *et al*. 2006) collected samples for dissolved copper at 30 marina stations, 10 of these stations were the same marina stations sampled in the Pilot Program. The additional data collected by SCCWRP were used to approximate the variability that might be observed from a different set of ten random stations as well as from sets of 15 or 20 stations. To do this, the 30 stations were randomly sampled ten times and the number of stations with copper below the threshold level was counted. When ten stations are considered as the number per stratum, the percent of stations below the threshold level ranges from 20 to 50%; with 15 stations per stratum the range is 13 to 40%, and with 20 stations per stratum the range is 15 to 45%. Comparatively, 30% of the entire 30 stations had results below the threshold level. This limited analysis indicates that, for dissolved copper, ten stations give a similar comparison to the target percentage as would either 15 or 20 stations.

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