

CHAPTER 4. WATER QUALITY

Ann Dalkey and James M. Rounds

I. INTRODUCTION

Water quality monitoring is conducted in the Los Angeles Harbor to document impacts upon water quality resulting from the Terminal Island Treatment Plant (TITP) wastewater discharge. The program is conducted as partial fulfillment of the National Pollutant Discharge Elimination System (NPDES) Permit, which includes a series of receiving water limitations regarding the effects of the discharged effluent (Table 4-1). Compliance with these limitations is determined through water quality measurements and observations collected each month at stations throughout the Harbor.

Originally the Los Angeles-Long Beach Harbor area was a large estuary of sloughs that received a constant, slow flow of freshwater. Development of the slips and channels of the modern Harbor created a highly modified environment, changing the circulation patterns and saline regime so that freshwater enters the Harbor in the form of intense winter flows (HEP 1980). The development of the Harbor also changed the natural seasonal pattern from one with a year-round supply of freshwater to one that is more cyclical (HEP 1980). Degradation of the Harbor environment was apparent in the early 1920's and continued into the 1950's when some areas of the Inner Harbor were nearly devoid of oxygen and marine life (Reish 1959). State and federal legislation for the control of marine pollution, implemented following Reish's reports, led to improved water quality in the Harbor so that present dissolved oxygen values are well above the compliance limit of 5.0 mg/L (MBC 1993). Seasonal patterns of water quality reflect the alternation of dry summers and wet winters with lower temperature and salinity (HEP 1980, MEC 1988).

Since construction of the breakwaters, the nature and movement of water in the Harbor has been primarily dependent upon tidally induced currents. Various configurations of the Harbor landfill and channels resulted in changes to water flow patterns within the Harbor. By 1999, the new Pier 400 structure was in-place, with dredging activities within the discharge area completed by April 2000. Models of the Pier 400 configuration predicted that a counter-clockwise gyre would form in the discharge area with the wastewater field traveling east into Long Beach Harbor during flood tides and out of the Harbor, through Angel's Gate during ebb tides (Engineering-Science 1993). They predicted a dilution of 424:1 in the Shallow Water Habitat for the Stage I Pier 400 configuration that was fully in place in 1998.

In previous years of Harbor monitoring, we found that the wastewater field in the Harbor primarily was detected using salinity data, augmented by density, temperature, and/or dissolved oxygen data (CLA, EMD 1994-2002). When detected in these surveys, the wastewater plume always rose to the surface and, therefore, was never detected as a subsurface field, even when density stratification was present. When the new outfall went online in 1996, we found

Table 4-1. NPDES receiving water limitations for the Terminal Island Treatment Plant.

1. The wastes discharged shall not cause the pH of the receiving water to be less than 6.5 nor more than 8.5. The wastes discharged shall not change the normal ambient pH levels by more than 0.2 pH units within any given 24-hour period.
2. The wastes discharged shall not cause the dissolved oxygen concentrations in the receiving waters to be depressed below 5.0 mg/L, except when natural conditions cause lesser concentrations, in which case the wastes discharged shall not cause additional reduction of the dissolved oxygen concentration.
3. The wastes discharged shall not cause the appearance of grease, oil or oily slick, or foam in the receiving waters.
4. The wastes discharged shall not cause objectionable odors to emanate from the receiving waters.
5. No sewage solids or other physical evidence of waste discharge shall be visible at any time in the water or on beaches, shores, rocks, or structures.
6. The wastes discharged shall not alter the color of the receiving waters, create a visual contrast with the natural appearance of the water, nor cause aesthetically undesirable discoloration of the water surface.
7. The wastes discharged shall not significantly reduce transmittance of natural light such that the mean of sampling results for any consecutive 30-day period would be beyond one standard deviation of the mean determined for natural levels for the same period.
8. The wastes discharged shall not cause a surface water temperature rise greater than 4 °F (2.2 °C) above ambient temperature of the receiving water at any time.

the wastewater field was smaller and was generally detected at a few of the stations within 0.5 km of the outfall diffuser. It was also more dilute than the field produced by the previous outfall, as predicted by Engineering-Science (1993). No evidence of the wastewater field was detected in the vicinity of the area of special concern, the Shallow Water Habitat.

The 2002 sampling year represents the sixth full year of water quality monitoring in the vicinity of the Pier 400 outfall. The results are summarized, assessed, and discussed below to describe the location of the wastewater field in Los Angeles Harbor for 2002.

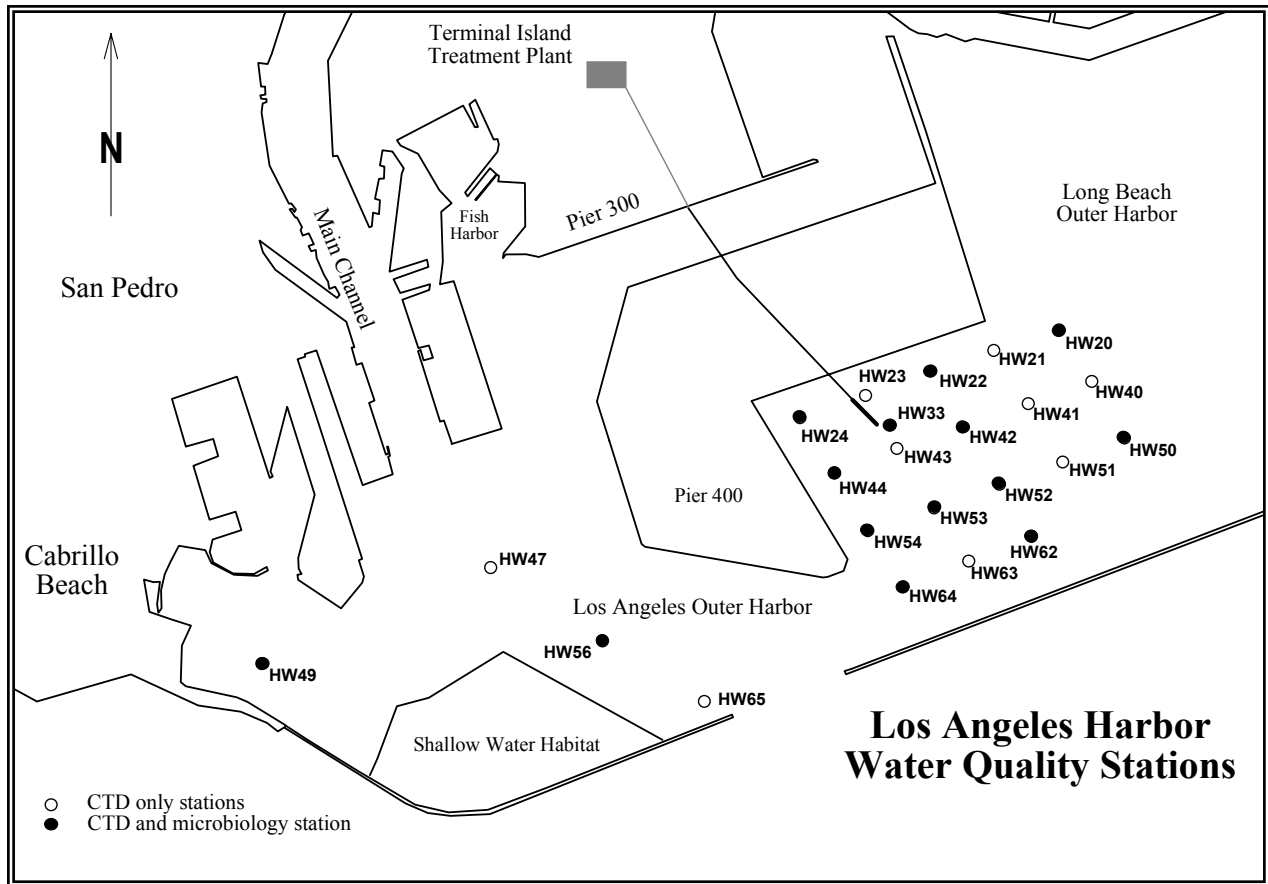


Figure 4-1. Water quality sampling stations in Los Angeles Harbor.

II. MATERIALS AND METHODS

A. FIELD SAMPLING

Water quality monitoring was conducted at a total of 23 stations, 19 arranged in a grid around the outfall, including one station at each end of the diffuser, and four arranged around the Shallow Water Habitat near Cabrillo Beach (Figure 4-1). However, construction activities for the Pier 400 Submerged Storage Site prevented access to some stations in November (HW21 and HW41) and December (HW22, HW42, and HW52). Sampling at the remaining stations consisted of monthly water quality profiles and weather and sea-surface observations. Surface discrete samples, taken monthly at 14 stations for fecal coliform microbiological analysis, were coordinated with CTD (conductivity-temperature-depth) operations in order to obtain the samples simultaneously with commencement of the CTD cast. Methodology for fecal coliform analysis is provided in Chapter 3.

Visual observations were made at each station and included water color, number and types of marine organisms encountered, and the presence of materials or odors of possible sewage origin

on the sea-surface (e.g., oil slicks, floatable material, sewage, sewage odor). Weather observations for cloud cover and wind speed and direction were recorded at each station.

Profiles for salinity (psu), temperature (°C), transmissivity (%), density (kg/m³), dissolved oxygen (mg/L), chlorophyll (µg/L), and pH were taken from surface to 2 m above the seabed using a Sea-Bird Electronics, Inc., Model SBE-25 conductivity-temperature-depth (CTD) system. Profile data were collected remotely using the CTD memory module, and then transferred to the laboratory database. Sensors for transmissivity, chlorophyll, and pH were calibrated to manufacturer's specifications prior to each cruise. Temperature, conductivity, pressure, and dissolved oxygen sensors were calibrated by the manufacturer during the annual maintenance inspection.

B. DATA ANALYSIS

Upon return from sea, Interactive Graphical Ocean Data System (IGODS) software developed by Alex Steele (Los Angeles County Sanitation Districts) was employed to critically inspect the data and remove outliers. Two types of data graphics were produced. First, x-y linear graphics were created for data submission to the California Regional Water Quality Control Board, Los Angeles Region. Then color graphics of CTD data were plotted to generate a 3-D representation of the data vertically and horizontally along depth transects. The shades of color used in these graphics illustrate the relative differences in the data between stations on a scale appropriate for each parameter. The graphics were examined for presence, degree, depth, and location of the wastewater field plus the presence and depth of stratification, and the presence/absence of any upwelling. Detailed notes were compiled for each parameter based on these observations of graphics from every CTD survey conducted. In addition, weather patterns were examined to determine the strength and direction of prevailing winds, and the presence/absence and duration of storms. Processed data were compiled into an Access database. All data and graphics are archived electronically and are available upon request.

Salinity anomaly was used to detect the location of the wastewater field, whereas color plots of temperature and salinity were used to determine the presence/absence of density stratification and secondarily for detecting events such as upwelling. Salinity anomaly is a measurement of the deviation of salinity at a particular station and depth from a mean salinity value calculated at three stations outside the outfall area (HW50, HW56, and HW65) using the following formula:

$$S_{Ai} = (1 - S_i / S_x) * 100$$

where S_{Ai} is the salinity anomaly at depth i , S_i is the salinity value at site and depth i , and S_x is the mean salinity at depth i calculated for each survey month.

The relationship between salinity anomaly and estimated wastewater dilution was developed by using theoretical S_A values computed for several wastewater dilutions ranging from >100:1 to 1000:1. The Terminal Island Treatment Plant effluent has an approximate salinity of 2 psu due to seawater intrusion into the trunk lines leading into the plant. Salinity was calculated for various

dilutions using the equation:

$$S_f = \frac{P_r S_r + P_e S_e}{P_t}$$

where, P_r is the number of parts of receiving water, S_r is the salinity of the receiving water, P_e is the number of parts of the effluent, S_e is the salinity of the effluent, P_t is the total parts (receiving water plus effluent), and S_f is the final salinity of the combined receiving water and effluent. The resulting salinities were then used to calculate the salinity anomaly. As dilution increases from 71:1 to 1000:1, S_A decreases from 1.30 to 0.09 (Figure 4-2).

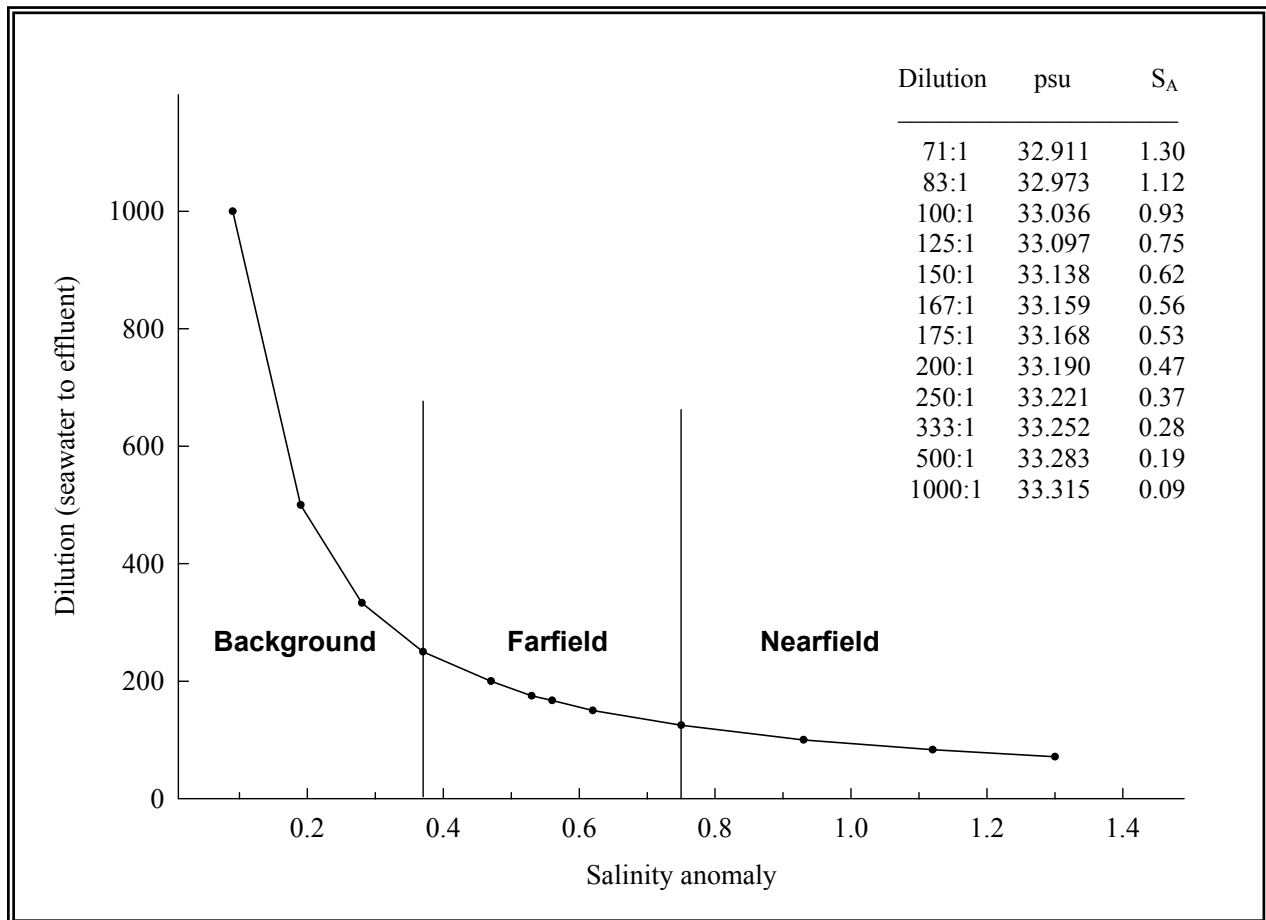


Figure 4-2. Calculated salinity anomaly (S_A) values for various dilutions based on a mean salinity of 33.346 psu and computed salinities.

The wastewater nearfield is defined in this report as water with salinity anomaly values greater than 0.75 with estimated dilutions less than 125:1. The wastewater farfield is defined as water with salinity anomaly values ranging from 0.37 to 0.75 and estimated dilution range of 250:1 to 125:1. Although the interpolative algorithm used to generate the graphics may give the appearance that the horizontal boundary of the wastewater nearfield and farfield is somewhere between two stations, this boundary is an interpolative construct whose location merely indicates the relative difference in the data between the two stations.

Surface fecal coliform measurements were plotted against surface salinity anomaly measurements to demonstrate the relationship between salinity data and coliform concentrations using SigmaPlot for Windows (Ver. 5). SigmaStat (Ver. 2.0) was used to perform a Spearman Rank Correlation analysis.

Wastewater field location probability estimates were calculated using salinity anomaly values >0.53 from surveys taken July 1997 – December 2001. The 95% confidence intervals were calculated with the following formula provided by Molly Leecaster, formerly of SCCWRP (personal communication):

$$95\% CL = \hat{\rho} \pm \left(z \text{ value} \left(\sqrt{\hat{\rho}(1 - \hat{\rho}) / n} \right) \right)$$

where CL = probability (percentage)

z = z value from t-distribution (Zar 1974)

n = number of salinity anomaly values >0.37.

III. RESULTS

A. COMPLIANCE WITH NPDES RECEIVING WATER LIMITATIONS

Examination of the data and color plots depicting DO, pH, and light transmittance profiles indicated that compliance limits for these parameters were achieved. There were no physical indications of the wastewater discharge and no discoloration of the water; however, a slight boil was visible along the length of the diffuser when the water was calm.

During all surveys, dissolved oxygen values were always greater than the 5.0 mg/L limit and pH values were always within the limits of 6.5 – 8.5 units. Due to the monthly sampling schedule, two requirements were not addressed: 1) there shall not be a change in the normal ambient pH levels by more than 0.2 pH units within any given 24-hour period, and 2) transmissivity values are to be assessed against a standard deviation from a consecutive 30-day period.

Table 4-2. Summary of 2002 survey dates, oceanic conditions, tides, nearfield and farfield station locations, and direction. Sampling generally was conducted between 0800 and 1200.

| Survey Date | Harbor Oceanic Conditions | Tides (Height Time) | | Nearfield | Farfield | Direction |
|-------------|---------------------------|---------------------|---------------|-------------------|-------------------------|-----------------------|
| 17Jan02 | Isothermal | + 5.0 1045 Hi | +0.2 1756 Lo | HW40, HW51 | HW21-33,40,41, 42,50,51 | Localized West, south |
| 14Feb02 | Isothermal | + 5.3 0955 Hi | 0.0 1641 Lo | HW21-24, 42-44,54 | HW22-24,33,44,54,64 | West, south |
| 28Mar02 | Isothermal | + 5.9 0843 Hi | -0.6 1500 Lo | Not detected | Not detected | |
| 15Apr02 | Isothermal | + 0.1 0537 Lo | + 3.5 1151 Hi | Not detected | HW23-24,33,44, | West |
| 30May02 | Weakly stratified | - 0.5 0726 Lo | + 3.5 1444 Hi | HW23 | HW22-24 | West, east |
| 24Jun02 | Weakly stratified | + 3.9 1038 Hi | + 2.2 1507 Lo | Not detected | HW23-24,44 | West |
| 11Jul02 | Stratified | - 1.1 0508 Lo | + 4.0 1145 Hi | Not detected | HW24,44,20 | West |
| 12Aug02 | Stratified | + 0.1 0637 Lo | + 5.2 1306 Hi | HW24,44 | HW22-24,33,44 | West, east |
| 24Sep02 | Weakly stratified | + 1.4 0455 Lo | + 5.2 1108 Hi | HW44 | HW23-24,44 | West |
| 17Oct02 | Isothermal | + 5.0 0824 Hi | + 1.5 1413 Lo | Not detected | HW22-24 | West |
| 14Nov02 | Isothermal | + 5.0 0618 Hi | + 1.7 1223 Lo | HW49 | HW22-24,49 | West |
| 12Dec02 | Isothermal | + 4.6 0456 Hi | + 2.2 1110 Lo | HW21,23 | HW21,23-24,33,43-44 | West, east |

B. DETECTION OF THE WASTEWATER FIELD

The location of the wastewater field was determined in 2002 through examination of color graphics. Although the wastewater field is a freshwater signal, detectable by areas of low salinity, we found that salinity anomaly is a superior parameter because it eliminates temporal fluctuations that exist in raw salinity plots that confound detection of the field. It was rarely detected as areas of low dissolved oxygen and temperature and was not evident in plots of pH and transmissivity.

The dates, oceanic conditions, and locations of the nearfield and farfield wastewater fields are summarized for each survey from 2002 and compiled in Table 4-2. Color plots of temperature and salinity for each survey are presented in Figures 4-3a through 4-3c.

The nearfield, identified as areas with salinity anomaly values greater than 0.75, generally was located close to the outfall and was detected during seven of the 12 surveys (January, February, May, August, September, November, and December) (Table 4-2). The nearfield was detected at the surface during January, February, November and December, below the surface in August and September, and at both the surface and subsurface in May. The depth of the nearfield ranged from one to two meters below the surface with the subsurface field occurring at 2-9 m. On two occasions, high salinity anomaly values indicating nearfield were identified outside the immediate discharge area in January (HW40 and HW51) and in November (HW49). The nearfield detected in November likely did not result from the discharged effluent. Instead, this field probably resulted from recent storm runoff inputs from sources adjacent to this station in the Cabrillo Beach vicinity. Table 4-2 provides tidal information for low and high tides at the time of sampling from which the strength of tidal change can be computed. The direction of wastewater nearfield movement appears to be unrelated to tidal flow for both flood and ebb tides, strong or weak.

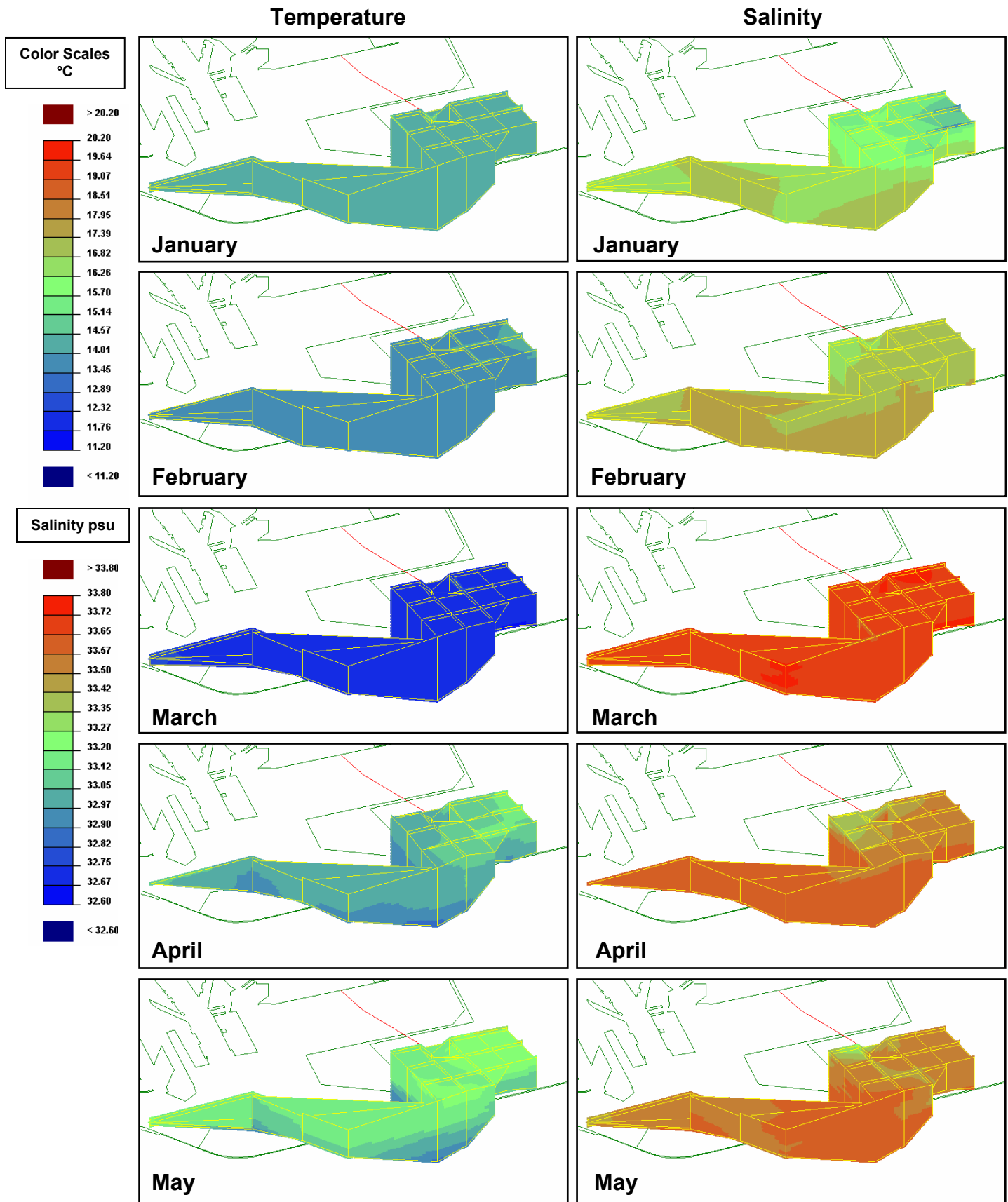


Figure 4-3a. Temperature and plots for January – May 2002.

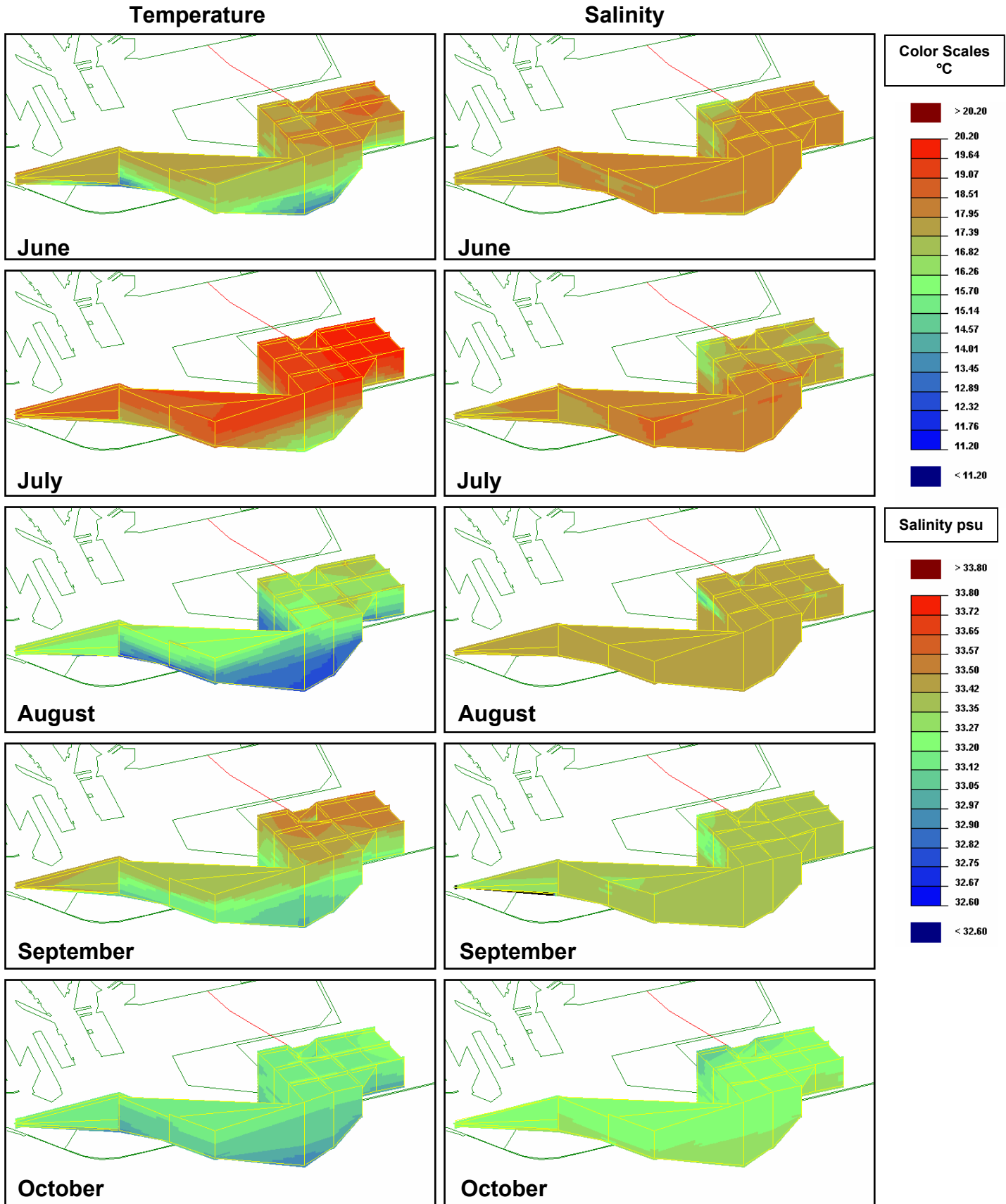


Figure 4-3b. Temperature and plots for June – October 2002.

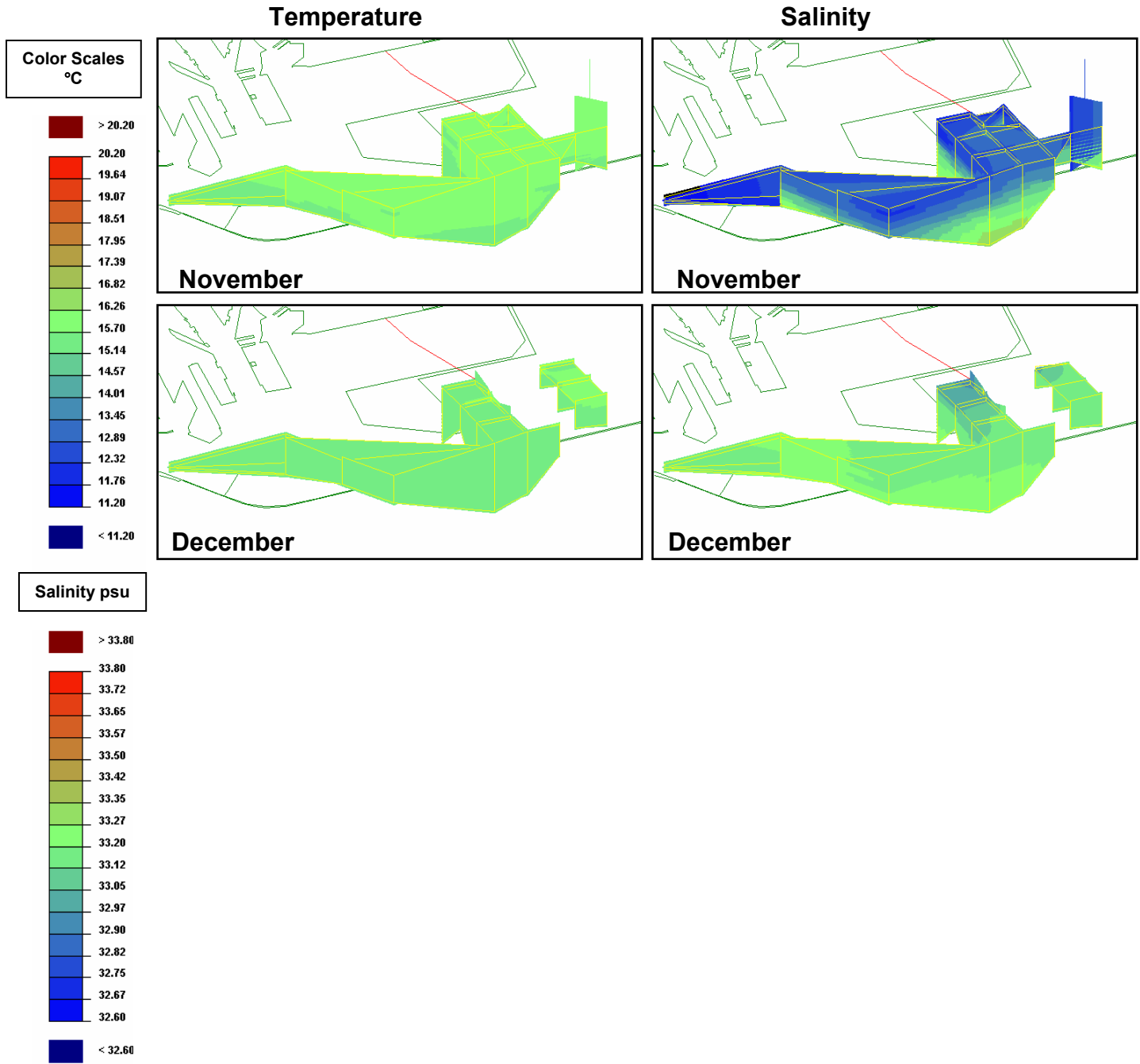


Figure 4-3c. Temperature and plots for November and December 2002.

The farfield, identified as areas with salinity anomaly values between 0.36 and 0.75, exhibited a distributional pattern similar to the nearfield, but was detected more frequently, possessed larger boundaries, and extended deeper into the water column (Table 4-2). It was detected most frequently at stations along the causeway and Pier 400, HW23 (outfall station), HW24 (480 m from the outfall), and HW44 (370 m from the outfall). It was detected less regularly throughout the Harbor at HW21 (680 m from the outfall), HW22 (360 m from the outfall), HW33 (outfall station), HW40 (1100 m from the outfall), and HW41 (740 m from the outfall). The farfield was detected at both the surface and subsurface during every month except March. The farfield direction of movement, as in the case for the nearfield, was unrelated to tidal conditions present at time of sampling.

Estimates of dilution, calculated from salinity anomaly values (Figure 4-2), indicate that high dilution of the wastewater usually occurred in the discharge area. The lowest dilutions occurred during April and August. Salinity anomaly values greater than 0.75, indicating dilutions greater than 125:1, occurred 20 times at various depths at stations nearest the outfall (HW21, HW22, HW23, HW24, HW33, HW40, HW41, HW43, and HW44). These 20 values account for a very small percent (0.9 %) of the total 2525 salinity measurements taken during 2002. In all surveys, salinity anomaly values within the nearfield decreased rapidly to 0.75 indicating approximate dilutions of 125:1 or more. Similarly, farfield salinity anomaly values decreased rapidly to 0.37 - 0.75, indicating approximate dilutions of 250:1 - 125:1.

Both fecal coliform and salinity anomaly followed similar patterns of higher levels near the outfall. However, the pattern of fecal coliform concentrations in the outfall area was less consistent than that exhibited by salinity anomaly. Figure 4-4 illustrates the relationship of high salinity anomaly values and fecal coliform data from combined 1997 through 2002 discrete water quality samples. When tested with a Spearman Rank Order Correlation analysis, the resulting correlation coefficient was low, though significant ($r = 0.583$ for $p < 0.001$).

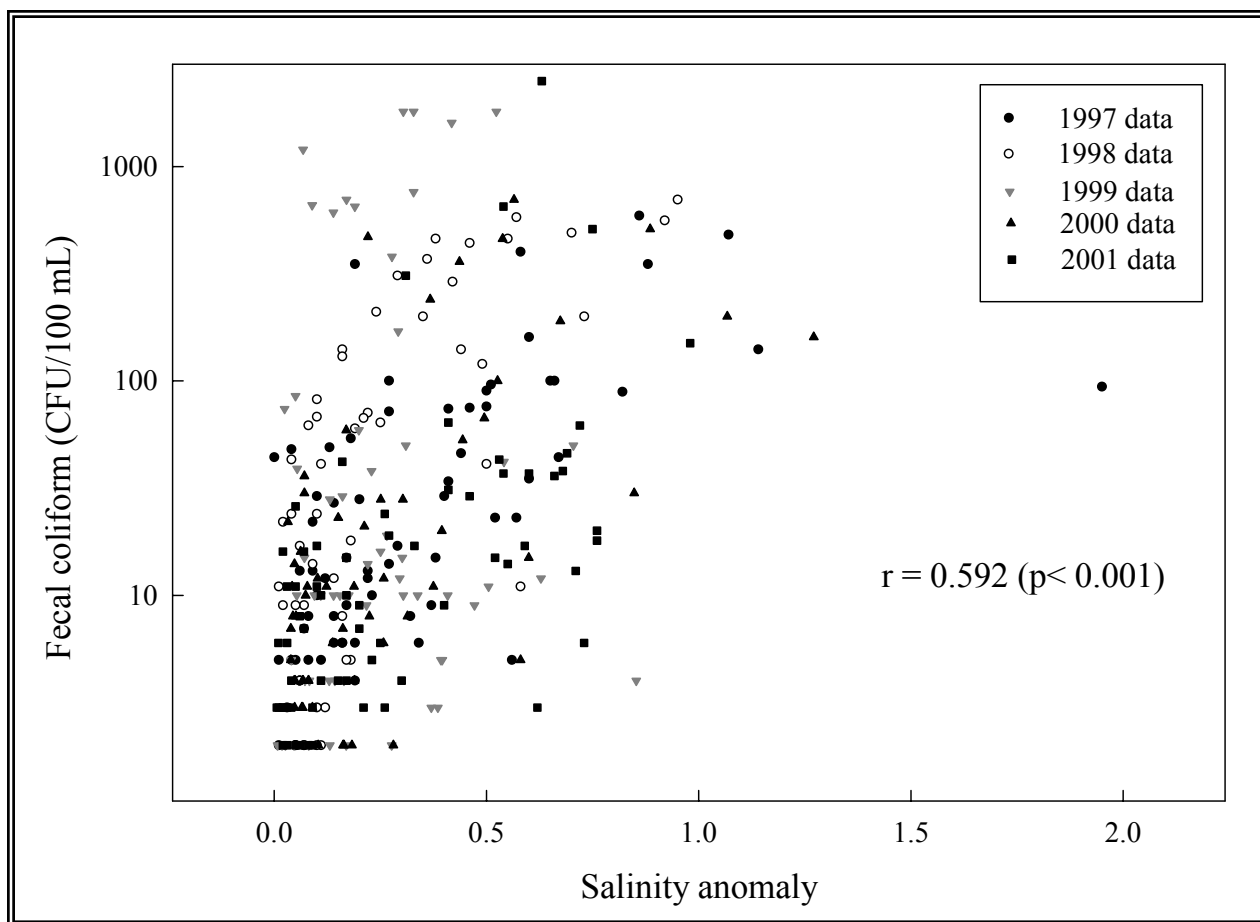


Figure 4-4. Plot of salinity values and fecal coliform measurements for 1997-2002 data exclusive of January and February 1998.

IV. DISCUSSION

A. COMPLIANCE WITH NPDES RECEIVING WATER LIMITATIONS

All Los Angeles Harbor water quality objectives as set forth in the Terminal Island Treatment Plant NPDES permit, excluding those not addressed, were met during 2002.

DETECTION OF WASTEWATER IN LOS ANGELES HARBOR, 2002

The distribution of the wastewater field in Los Angeles Harbor was consistently detected in 2002. The wastewater field generally was detected in a small area encompassing a few stations located within 0.5 km of the outfall, generally was distributed northward along the Pier 400

Table 4-3. List of stations and depths with most frequent wastewater field detection as determined by salinity anomaly values >0.37 with estimated dilutions of 250:1 or less.

| Probability CL | Station | Depth | N | 95% |
|-------------------|---------|-------|----|-------------|
| 27.8% | HW23 | 2 | 72 | 38.3%-17.3% |
| 26.8% | HW23 | 1 | 71 | 37.2%-16.3% |
| 25.0% | HW23 | 3 | 72 | 35.2%-14.8% |
| 20.8% | HW23 | 4 | 72 | 30.4%-11.3% |
| 19.7% | HW24 | 1 | 71 | 29.1%-10.3% |
| 14.1% | HW24 | 2 | 71 | 22.3%-5.9% |
| 14.1% | HW24 | 4 | 71 | 22.3%-5.9% |
| 12.7% | HW24 | 3 | 71 | 20.5%-4.8% |
| 12.5% | HW23 | 5 | 72 | 20.3%-4.7% |
| 11.3% | HW24 | 5 | 71 | 18.8%-3.8% |
| 11.3% | HW24 | 6 | 71 | 18.8%-3.8% |
| 10.1% | HW23 | 7 | 69 | 17.4%-2.9% |
| 9.7% | HW23 | 6 | 72 | 16.7%-2.8% |
| 9.6% | HW33 | 1 | 73 | 16.5%-2.7% |
| 9.6% | HW33 | 4 | 73 | 16.5%-2.7% |
| 9.6% | HW33 | 3 | 73 | 16.5%-2.7% |
| 9.6% | HW33 | 2 | 73 | 16.5%-2.7% |
| 9.6% | HW44 | 6 | 73 | 16.5%-2.7% |
| 9.6% | HW44 | 5 | 73 | 16.5%-2.7% |

causeway to the east or west with occasional southward movement. Direction of movement did not vary with tidal changes.

Typically, the wastewater field was dilute, possessing estimated dilutions greater than 125:1. Immediately outside the wastewater field, dilutions rapidly reached background levels. These dilutions were much greater than those predicted by Engineering-Science (1993). Probability estimates obtained from salinity anomaly measurements show that the wastewater field is most frequently located in the northwestern portion of the discharge area. The highest probabilities occurred at the diffuser station located nearest the Pier 400 causeway (HW23) where estimated dilutions of

250:1 or less occur approximately 28% of the time (Table 4-3). The other stations with high probabilities include HW24, HW33, and HW44.

Bacteriological data correlated with salinity anomaly values showing increasing bacterial concentrations with increasing salinity anomaly values (Figure 4-4). The presence of elevated fecal coliform bacterial counts obtained from discrete samples located within the wastewater field, as detected by the CTD, confirms the presence of wastewater. Conversely, the presence of high salinity anomaly values in the absence of elevated fecal coliform bacteria levels at sites located outside the immediate discharge area provides support that these high values are not a result of the wastewater discharge. For example, in November near Cabrillo Beach (HW49) high salinity anomaly values were measured, but the fecal coliform results were low (3 CFU/100 mL).

The Shallow Water Habitat is an area of special concern in Los Angeles Harbor. A highly dilute wastewater field was predicted to move into the Habitat during the tidal cycle with estimated dilutions of 424:1 (Engineering-Science 1993), below levels at which dilutions can be estimated from salinity anomaly. Surface salinity anomaly values at stations near the Habitat (HW56 and HW65) were at background levels, indicating high dilutions. The high level of shipping activity and land run-off from other areas provide potential non-point sources of freshwater in addition to the wastewater discharge.

In conclusion, the Pier 400 wastewater outfall produces a small, dilute wastewater field in the Outer Harbor. Dispersion of the wastewater field matched contoured depictions by Engineering-Science (1993), but at substantially greater dilutions. In the area of special concern, the Shallow Water Habitat, salinity anomaly, and bacterial data are at background levels as predicted.

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