CHAPTER 3

MICROBIOLOGY

Amber Kuhn

INTRODUCTION

The Terminal Island Water Reclamation Plant's (TIWRP) National Pollutant Discharge Elimination System (NPDES) permit mandates indicator bacteria monitoring in the Los Angeles Harbor receiving waters. This chapter reports the 2006-2007 bacteriological monitoring data in accordance with those requirements specified in NPDES permit No. CA0053856, Order No. R4-2005-0024, as adopted by the California State Water Resources Control Boards (SWRCB) and Regional Water Quality Control Board (RWQCB) and became effective on May 27, 2005.

The Environmental Monitoring Division (EMD) of the Bureau of Sanitation, City of Los Angeles, began its compliance monitoring program of the Los Angeles Harbor receiving waters and the Cabrillo Beach shoreline in 1993 to assess water quality and to mitigate public health risk. Microbiological water quality monitoring is primarily based on tests for indicator bacteria. There is no single bacterial indicator that can universally be used for all purposes of water quality surveillance. Indicator bacteria most commonly monitored are of fecal origin and the fundamental and most important requirement is that indicator bacteria should be present whenever pathogens are present The three bacterial indicators currently used for water quality assessment under the TIWRP NPDES permit are total coliform, fecal coliform (or *E. coli*), and enterococcus. The SWRCB has promulgated total coliform, fecal coliform (or *E. coli*) and enterococcus limitation standards for recreational Bathing Waters and areas of Shellfish Harvesting in permit No. R4-2005-0024.

The construction of breakwaters, slips, and the dredging of navigation channels over the course of many years has resulted in the reconfiguration of the Los Angeles Harbor, thereby changing the tidal flow patterns and water circulation within the Harbor itself. The flow pattern has become more cyclical, exhibiting a seasonal trend of higher bacterial levels during months with lower temperatures (HEP 1980; CLA, EMD 2002). Prior to these modifications, the Harbor received a steady influx of freshwater by way of the Dominguez Channel on a year-round basis (CLA, EMD 2002). In late summer 2002, the Port of Los Angeles Channel Deepening Project was initiated and involved dredging the Harbor's primary navigation channels (Los Angeles Main Channel, West Basin, East Channel, East Basin, and Cerritos Channel) to allow larger, deeper container vessels to enter and dock in the Port of Los Angeles. In order to accommodate the resulting dredged sediments from this project, the Los Angeles Harbor Department developed several disposal alternatives, including the Pier 400 Submerged Storage Site (P400 SSS). Construction of the P400 SSS began in September 2002 and measures approximately 120 acres in size. Situated southeast of Pier 400 and adjacent to the TIWRP outfall pipe, this site will also be used to house future fill material from

Table 3-1. Summary of the Los Angeles Harbor and Cabrillo Beach Microbiological Monitoring Program for 2006-2007.

2005 NPDES PERMIT
Shoreline stations: CB1, CB2, total coliform, fecal coliform, enterococcus, ankle-deep water, daily (5 times/week)
L.A.Harbor weekly at 7 stations: HW07, HW16, HW29, HW33, HW49, HW56, HW64, total coliform, fecal coliform, enterococcus, surface, 5 times/month
L.A.Harbor monthly at 7 stations: HW20, HW24, HW44, HW50, HW53, HW54, HW62, fecal coliform, surface, monthly
Water Quality "Plume tracking" at 12 stations: HW20, HW23, HW24, HW33, HW44, HW49, HW50, HW53, HW54, HW56, HW62, HW64, fecal coliform, surface, quarterly

other dredging activities in the Harbor, or remain as a base for construction that would expand Pier 400 (CLA, EMD 2002).

The City of Los Angeles, Environmental Monitoring Division, was granted approval from the RWQCB to switch methods for testing shoreline samples, including CB1 and CB2, in October 2002. The switch from membrane filtration (MF) to chromogenic substrate (CS) for analyzing total coliform and *E. coli* was implemented in December 2002. Enterococcus was not analyzed using the CS method for CB1 and CB2 samples. Parallel testing on this indicator was conducted from April 2004 to August 2004 using both MF and CS, and data assessment is pending review. The study also investigated the rate of false positives that are observed using CS for enterococcus analysis and its role in the increased number of perceived exceedences for this indicator. The non-shoreline LA Harbor samples were not affected by this switch of methodologies. These samples continued to be analyzed by the MF method. In September 2005, the City of Los Angeles conducted a study to compare the MF method with the CS method for LA Harbor and Santa Monica Bay receiving waters. This report is also pending review.

MATERIALS AND METHODS

SAMPLING LOCATIONS

In 2006-2007, as part of TIWRP compliance monitoring, the City of Los Angeles, Environmental Monitoring Division (EMD), conducted more than 5000 tests for indicator bacteria at sites within the Cabrillo Beach and the Outer Los Angeles Harbor (Harbor) areas to help protect public health.

Cabrillo Beach shoreline samples were collected five days a week at two stations (Table 3-1) and analyzed for total coliform, *E. coli*, and enterococcus. Seven Harbor receiving water stations were collected five times per month and tested for total coliform, fecal coliform and enterococcus. An additional seven Harbor receiving water stations were sampled monthly and tested for fecal coliform. In conjunction with the Water Quality Program (see Chapter 4), twelve stations were sampled quarterly and tested for fecal coliform and ammonia.

METHODOLOGY

All samples were collected in sterile sample bottles with 1 to 2 inches of airspace. Shoreline samples were collected at ankle depth. Harbor samples were

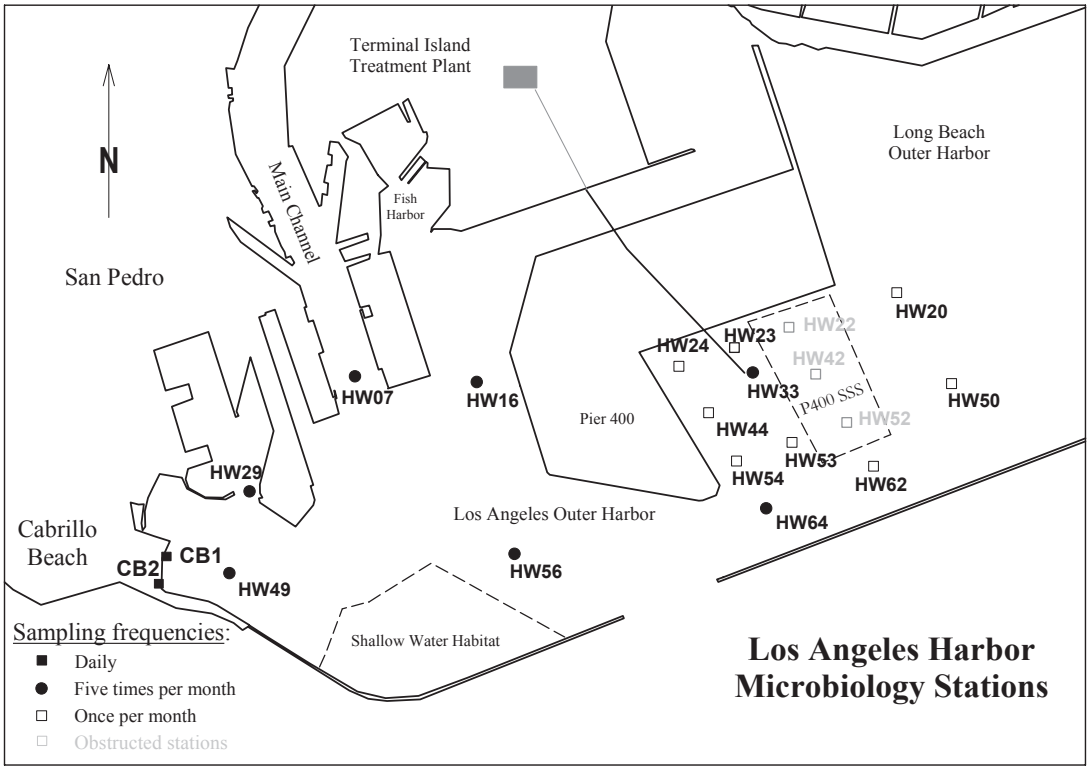

Figure 3-1. Map of Los Angeles Harbor showing microbiology stations.

collected 0.5 meters below the surface. LA Harbor samples were analyzed by the membrane filtration method (MF) for total coliform, fecal coliform, and enterococcus in accordance with Standard Methods (APHA, 1998). Beginning December of 2002, with approval of the RWQCB, Cabrillo Beach shoreline samples were analyzed for total coliform and *E. coli* using the chromogenic substrate method (APHA, 1998). However, Cabrillo Beach samples were still analyzed by membrane filtration for enterococcus.

Harbor weekly and monthly samples were collected five times per month aboard one of the City's monitoring vessels, usually the Marine Surveyor, and brought back to the laboratory for analyses. Once per quarter, water quality samples for the Plume Tracking survey in conjunction with the regular Harbor weekly samples were filtered at sea and initially incubated on board. After the vessel was docked, the MF plates were transferred to laboratory incubators for the remainder of the incubation period.

Visual observations were made at each sampling location. Observations at shoreline stations consisted of tallying items of sewage origin (plastic goods - feminine tampon applicators, or rubber goods - rings from male condoms), non-sewage origin (ocean debris, seaweed, beach refuse, tar, and dead marine organisms), people in the water, people out of the water, and wildlife along a 50-foot reach of shoreline on both sides of the station. Other shoreline observations included any unusual odors, particularly those that could be of sewage origin, the volume of flow from storm drains near the station, changes in water color due to plankton, and the presence of oil. Additionally, at station CB2, observations included water and air temperature, weather, wind direction and speed, wave height, and sea conditions. Harbor observations included water color, odor, air temperature, turbidity, and presence of items of sewage and non-sewage origin. Observations of wind speed and direction, weather, and tidal stage were made every 4 hours on board the monitoring vessel. Daily rainfall data were obtained from the National Weather Service in Los

Angeles at the University of Southern California (USC) rain gage.

Quality assurance and quality control measures were performed to verify the validity of the analytical data collected. All aspects that influence the reported data were subjected to established microbiological quality control procedures in accordance with Standard Methods. These included sampling techniques, sample handling and preservation, facilities, personnel, equipment, supplies, media, and analytical test procedures. In addition, duplicate analyses were performed on ten percent of all samples. When quality control results were not within acceptable limits, corrective action was taken. The laboratory also participated in Performance Evaluation (PE) studies. The PE samples were provided by independent vendors accredited by the National Institute of Science and Technology (NIST), National Environmental Laboratory Accreditation Conference (NELAC). The quality assurance program helped ensure the production of uniformly high quality and defensible data. The California Department of Health Services (CDHS), through in their Environmental Laboratory Accreditation Program (ELAP), certified the EMD microbiology laboratory for 2006-2007.

Insert Figure 3-1. Microbiological sampling stations in Los Angeles Harbor and Cabrillo Beach.

DATA ANALYSIS

Application of most statistical techniques requires the assumption of symmetrical distributions such as the normal curve. Microbial distributions, however, are not symmetrical. Bacterial counts often have a skewed distribution because of many low values and a few high values. For this reason, it is necessary to convert microbiological data from a skewed to a symmetrical (or normal) distribution using a log transformation prior to data analyses.

A geometric mean is statistically the best estimate of central tendency for log-normalized data. For data comparison, geometric means were calculated for each of the three bacterial indicator groups. The current TIWRP NPDES permit prohibits sampling during or within 72 hours following the rain event. Rainfall amounts were recorded using data from the Los Angeles, USC rain gauge. Regulatory agencies have defined wet weather as the day of rain (>0.1 inch) plus the three subsequent days.

The indicator bacterial counts were submitted in written reports on a monthly and annual basis to the RWQCB and EPA. In addition, all indicator bacterial counts were transmitted 5 days per week by electronic mail to the RWQCB and Los Angeles County Department of Public Health (LACDPH). This daily communication helped protect public health by enabling the LACDPH to inform the public of high indicator bacterial counts in recreational waters and post warning signs as warranted by California State Assembly Bill 411 (CDHS, Health and Safety Code, Assembly Bill 411, 1997).

RESULTS

OUTER HARBOR - WEEKLY

Annual geometric means for the seven Outer Harbor stations during dry-weather periods were calculated for total coliform, fecal coliform, and enterococcus for 2006 and 2007 (Figure 3-2). Dry-weather geometric means were highest at stations HW29 and HW33 for total coliform, fecal coliform and enterococcus for both years. Station HW49 enterococci geometric mean was equally as high as HW33 in 2006. In 2007, HW64 was as high as HW29 for fecal coliform. Station HW29 is situated at the entrance to a boat marina, station HW33 is located at the terminus of the TIWRP outfall pipe, and station HW49 is located between Cabrillo Beach and the Shallow Water Habitat (Figure 3-1). The lowest dry-weather geometric means were observed at stations HW16 and HW56. Stations HW16 and HW56 are located in mid-harbor between the TIWRP outfall and the Cabrillo Beach stations. Visual observations routinely taken at each sampling station during the weekly monitoring at the Harbor

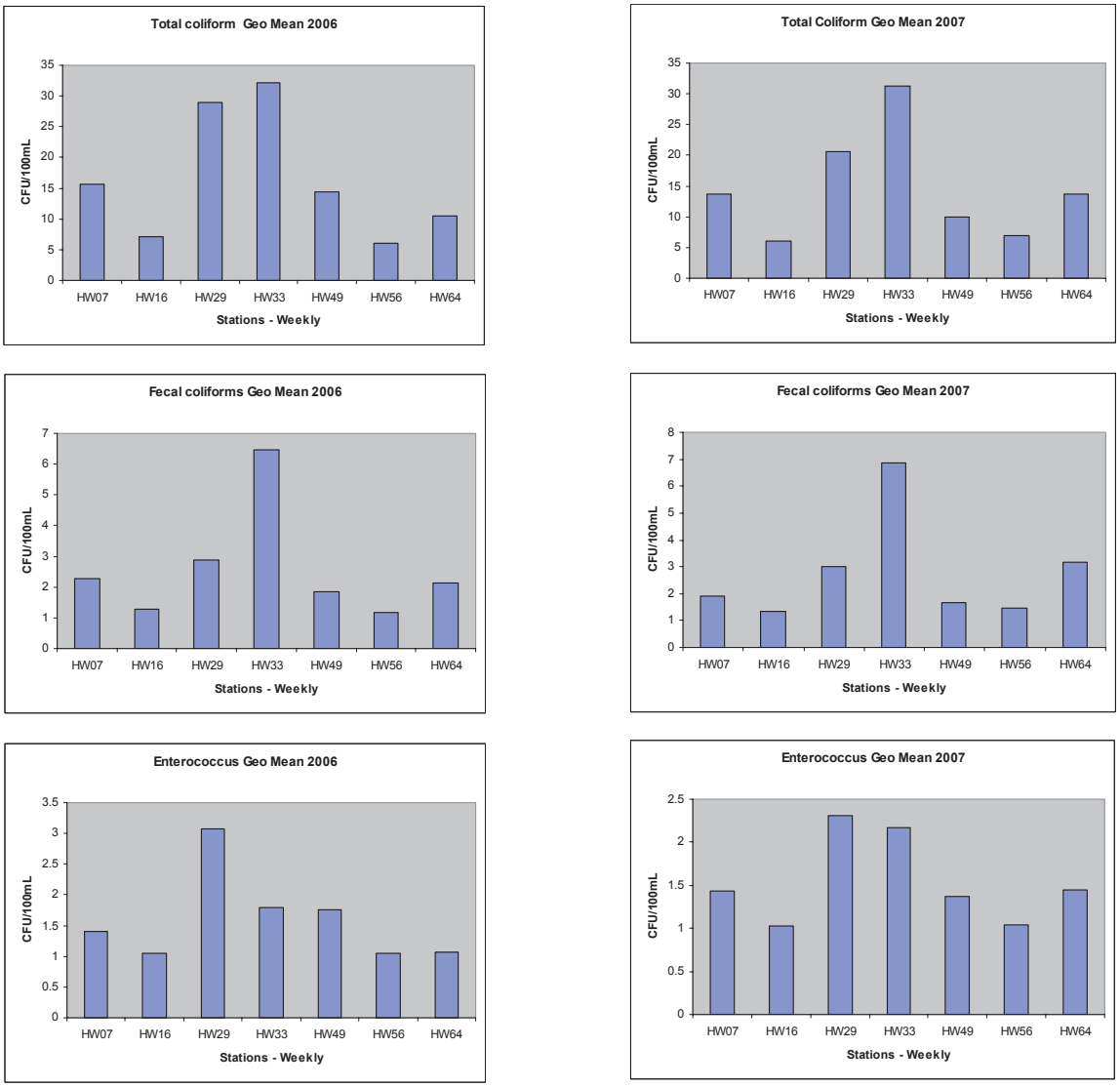

Figure 3-2. Dry-weather annual geometric means at Los Angeles Harbor surface stations, 2006 and 2007.

noted no presence of materials of sewage origin in 2006-2007.

OUTER HARBOR - MONTHLY

In addition to the weekly samples, seven stations were analyzed for fecal coliform monthly. Annual geometric means for fecal coliform were calculated for the years 2006 and 2007(Figure 3-3). Station HW24 had the highest fecal coliform density, followed by HW44. Stations HW24 and HW44 are immediately west of the outfall. Stations HW20 and HW50, located farthest east of the outfall, showed the lowest fecal coliform densities. With the exception of stations HW24 and HW44, all other monthly stations had counts as low as the harbor stations located outside of the outfall discharge area. No materials of sewage origin were observed at any station.

WATER QUALITY PROGRAM "PLUME TRACKING"

Annual means for fecal coliform were calculated for the twelve water quality "plume tracking" stations for the years 2006 and 2007 (Figure 3-4). Overall, station HW24 had the highest fecal coliform density, followed by HW23, HW44, and

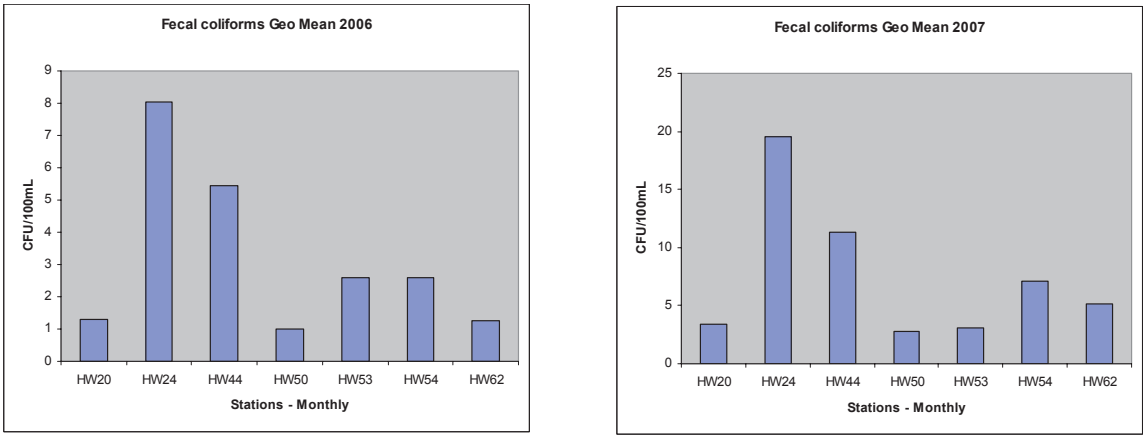

Figure 3-3. Annual geometric means for fecal coliform bacteria at Los Angeles Harbor monthly stations, 2006 and 2007.

then HW33; however, the density rank of stations differed between years. Station HW33 is located at the mouth of the outfall and HW24 and HW44 are immediately west of the outfall. Stations HW20 and HW50, located farthest east of the outfall, was among the lowest fecal coliform densities. With the exception of stations HW24, HW23, HW44, and HW33, all other plume tracking stations had counts as low as the harbor stations located outside of the outfall discharge area. No materials of sewage origin were observed at any station.

CABRILLO BEACH

Monthly geometric means were calculated for each of the three indicator bacteria at the two Cabrillo Beach shoreline stations, CB1 and CB2, for dry-weather periods in 2006 and 2007. Dry-weather bacterial counts were relatively low throughout the year of 2006 for both stations; however, the winter months had higher counts than the summer months for both stations (Figure 3-5). Overall, CB2 had higher counts than CB1. Dry-weather bacterial counts for 2007 were relatively low and comparable to 2006 (Figure 3-6). CB2 had higher counts than CB1, except for April and May, in which CB2 was inaccessible due to a sand replacement project. One day at CB2 a single material of sewage origin was observed on one occasion (Table 3-2).

In 2006 and 2007, station CB1 had a higher percent compliance than station CB2. Station CB1 exhibited 100% compliance for 3 of 9 standards in 2006 and 2007, while station CB2 showed 100% compliance for 1 of 9 standards in 2006 and 2007 (Tables 3-3 and 3-4). From 2006 to 2007, there was an increase in compliance for CB1, while data for CB2 showed an increase in compliance for all standards except for the total coliform/*E. coli* ratio (Tables 3-3 and 3-4).

Visual observations at the two shoreline stations (Table 3-4) were made 5 times a week from January 2006 through December 2007 for a total of 1,218 times. During these visual observations, one occurrence of materials of sewage origin was observed at CB2 for rubber/plastic goods.

DISCUSSION

The vast majority of samples collected in the Harbor indicated good water quality during the dry-weather periods of 2006-2007. The water quality at Cabrillo Beach station CB1 was found to be better than at CB2. In 2006, percent compliance at Station CB1 was 83% to 100% for six of the nine NPDES Bathing Water and Shellfish Harvesting standards, but Station CB2 had more non-compliance days and was 100% compliant for only one of nine standards. For 2007, percent compliance at station CB1 was 86% to 100% for seven out of nine standards and

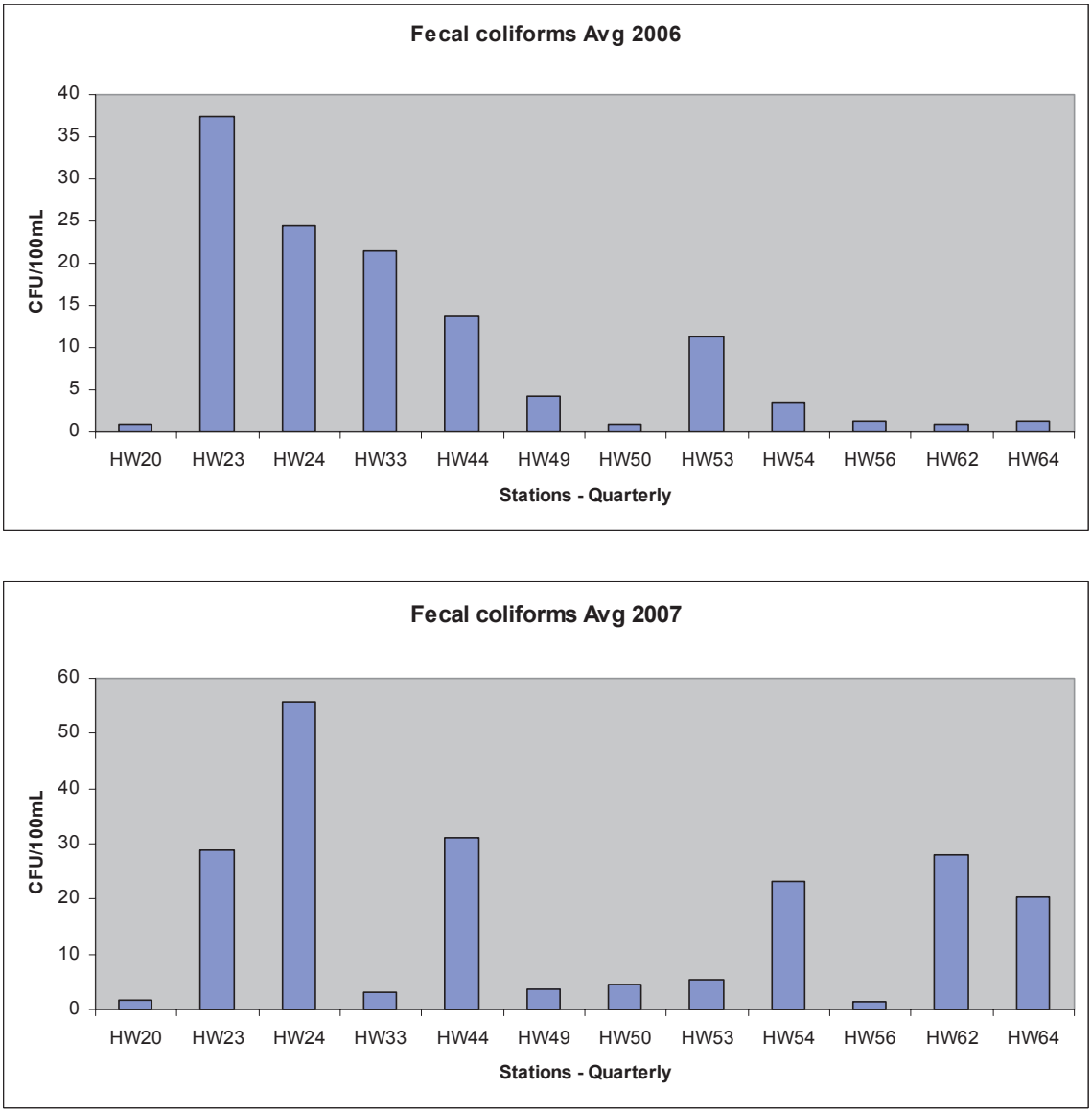

Figure 3-4. Annual means for fecal coliform bacteria at Los Angeles Harbor water quality plume tracking stations, 2006 and 2007.

station CB2 was compliant 82% to 100% for six of the nine standards. Shellfish Harvesting standards were never met during 2006-2007 at CB2 and fared slightly better at station CB1. Plume tracking and Outer Harbor data (as discussed below) indicates that the wastewater discharge from the TIWRP outfall does not impact the Cabrillo Beach shoreline, and is not the cause of its non-compliance with water quality standards.

OUTER HARBOR

During dry weather, Stations HW29 and HW33 were found to have the highest bacterial geometric means of all harbor stations in 2006 and 2007. Station HW29, located at the entrance to the Cabrillo Marina, had higher enterococcus counts than HW33, which is located at the terminus of the TIWRP outfall. Station HW29 is subject to influences from activities within the marina and storm drains in the vicinity. However, station HW33 exhibited higher total and fecal coliform counts. During the two-year period, station HW33 showed the highest fecal

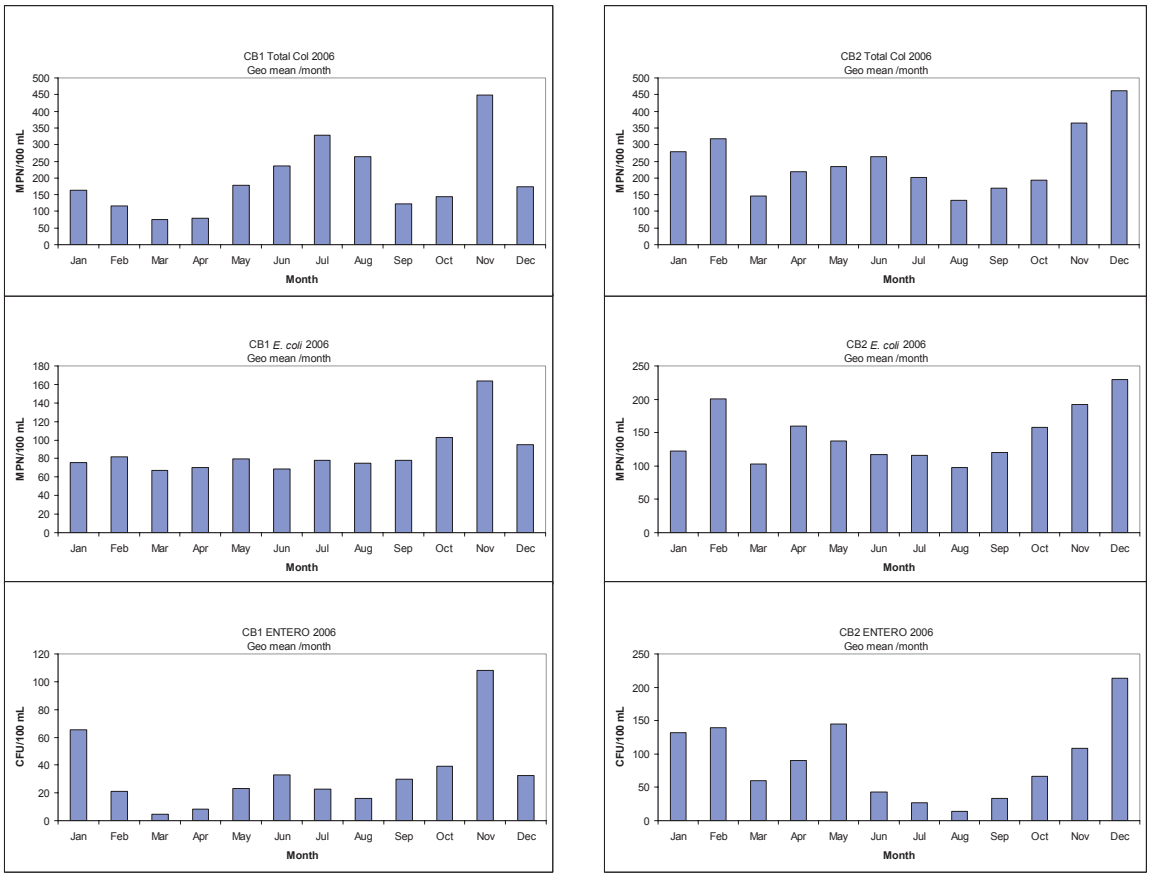

Figure 3-5. Monthly dry-weather geometric means for indicator bacteria at Cabrillo Beach shoreline stations, 2006.

coliform counts for dry-weather periods. Given that the presence of fecal bacteria may be an indication of sewage contamination and also given its location, it is not surprising that Station HW33 reflected the presence of the TIWRP effluent. However, due to quick dispersal of the plume (CLA, EMD 2002), as evidenced by the lower counts seen at the majority of the other LA Harbor monitoring stations, with the exception of HW29, the TIWRP discharge generally has only a small to moderate impact on the receiving waters. The lowest bacterial counts were seen at Stations HW16 and HW56. These two stations are located in mid-harbor between the TIWRP outfall and the Cabrillo Beach stations and have a higher probability of not being as affected by the plume, the Main Ship Channel, or surface runoff, as other more proximal stations, due to distance from the plume, impervious surfaces, and dispersal and dilution factors. A large clockwise eddy produced in this area brings substantial circulation and flushing, which may also contribute to the low bacterial counts seen at these two stations.

WASTEWATER DISCHARGE "PLUME TRACKING"

Stations HW23, HW24, HW33, and HW44 had the highest fecal coliform counts of all water quality monitoring sites in 2006. Since the completion of Pier 400, HW24 has consistently shown the highest geometric means, even greater than HW33, located at the terminus of the outfall. This indicates that the discharge flows northwest into the corner of Pier 400 (Figure 3-1), which gives rise to higher counts at HW44, just west of HW33. To further corroborate this, "Probability estimates obtained from salinity anomaly measurements show that the wastewater field is most frequently located in the northwestern portion of the discharge area" (CLA, EMD 2004). Because of their locations, these stations may not

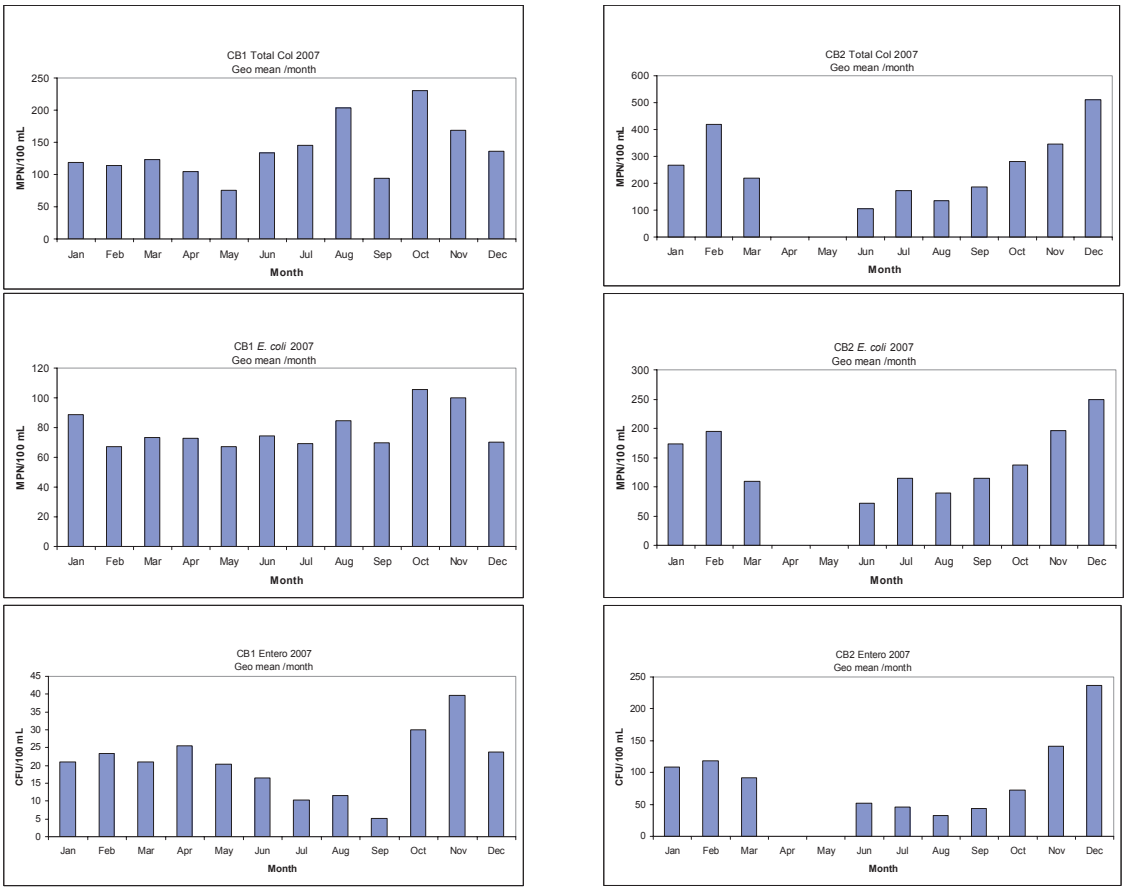

Figure 3-6. Monthly dry-weather geometric means for indicator bacteria at Cabrillo Beach shoreline stations, 2007.

be as exposed to harbor currents and flows as other stations, and waters at these stations may remain stagnant longer than at other plume monitoring sites. In 2007, HW33 had one of the lowest fecal coliform counts of the stations. HW54, HW62, and HW64 had higher counts for fecal coliform. One possibility is that water was circulating out of the corner and flowing towards these stations. All of the stations were at least eighty percent below bathing water quality standards, suggesting low to insignificant impact of the TIWRP discharge on the surrounding waters. Because of plume dispersal and low indicator bacterial counts throughout the Harbor, it is unlikely that the higher counts seen at the Cabrillo Beach shoreline are the result of the discharge from the TIWRP outfall.

Terminal Island Water Reclamation Plant, although lacking disinfection through chlorination, is considered a tertiary treatment facility. Although the TIWRP effluent itself is not tested for indicator bacteria, current TIWRP treatment processes, the low counts at the mouth of the outfall, and low counts in the receiving waters, suggest the plant discharge is not a major source of bacteria in the harbor.

CABRILLO BEACH

Station CB1 had lower dry-weather bacterial counts than station CB2 for most months during 2006-2007. Station CB1 also had higher percent compliance with NPDES Bathing Water Standards when compared to its companion station CB2. Station CB1 is located at the boat launch and is sampled at the 2-feet drop of the launch ramp. It is adjacent to a restroom, an L-shaped jetty, and a

Table 3-2. Number of occurrences and percent compliance with all materials of sewage origin at Cabrillo Beach shoreline stations in 2006-2007.

Station	Grease Particles	Suspended Solids	Odor	Rubber Plastic Goods	Total Non-Compliance
CB1	0	0	0	0	0
CB2	0	0	0	1	1
%Compliance	100.0%	100.0%	100.0%	99.9%	99.9%

Table 3-3. Number of dry-weather* non-compliance days and percent compliance for NPDES Bathing Water and Shellfish Harvesting coliform limits at Cabrillo Beach shoreline stations in 2006.

	Station	Bathing Water Limits				Shellfish Harvesting Limits		30-Day Geometric Mean		
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
CB1	#Non-compliance/Yr	1	10	35	9	207	287	0	0	106
	% Compliance	100%	95%	83%	96%	28%	0%	100%	100%	63%
CB2	#Non-compliance/Yr	2	32	75	23	287	287	0	23	202
	% Compliance	99%	84%	63%	89%	0%	0%	100%	92%	30%

Table 3-4. Number of dry-weather non-compliance days and percent compliance for NPDES Bathing Water and Shellfish Harvesting coliform limits at Cabrillo Beach shoreline stations in 2007.

	Station	Bathing Water Limits				Shellfish Harvesting Limits		30-Day Geometric Mean		
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
CB1	#Non-compliance/Yr	1	7	25	9	45	322	0	0	84
	% Compliance	100%	97%	89%	96%	86%	0%	100%	100%	74%
CB2	#Non-compliance/Yr	2	31	76	25	322	322	0	22	197
	% Compliance	99%	82%	82%	86%	0%	0%	100%	93%	39%

(1) Total coliform exceeding 10,000 MPN/100mL (calculated daily) - Bathing Water Limit
(2) Fecal coliform exceeding 400 MPN/100mL (calculated daily) - Bathing Water Limit
(3) Enterococcus exceeding 104 MPN/100mL (calculated daily) - Bathing Water Limit
(4) Total coliform exceeding 1000 MPN/100mL, if the ratio of Fecal-Total coliform exceeds 0.1 (calculated daily) - Bathing Water Limit
(5) Total coliform six-month median exceeding 70 MPN/100mL in any six month period (calculated daily) - Shellfish Harvest Limit
(6) Total coliform >10% exceeding 230 MPN/100mL in any six-month period (caculated daily) - Shellfish Harvest Limit
(7) Total coliform geometric mean exceeding 1000 MPN/100mL (calculated daily)
(8) Fecal coliform geometric mean exceeding 200 MPN/100mL (calculated daily)
(9) Enterococcus geometric mean exceeding 35 MPN/100mL (calculated daily)

parking lot that is frequented by launch users as well as visitors to the beach area and the Cabrillo Marine Aquarium. The L-shaped jetty limits the exposure of the site to harbor currents thereby reducing potential contamination from the harbor area outside the jetty. As indicator bacterial counts at the immediate TIWRP discharge area (HW33) are lower than counts at CB1 and considering the low counts at stations HW49 and HW56, both just outside the Cabrillo Beach shoreline area, it is unlikely that any impact from the TIWRP effluent would be detectable at this site. The floor of the restroom and the adjacent sidewalk are hosed down daily, and while restroom wash is directed to the sewer, the sidewalk runoff flows across the boat launch area and drains to CB1. Collectively, the above may help explain the bacterial exceedances observed at the sampling site.

Station CB2 often exceeds the majority of the standards for NPDES Bathing Water and Shellfish Harvesting. As in the case of CB1, CB2 also had indicator counts higher than HW33 and, as the indicator counts decreased with distance from the

outfall, it is unlikely that the source of bacterial contamination at CB2 is the TIWRP discharge (Figure 3-1). It is more probable that the source of bacterial contamination and the cause of NPDES exceedances at CB2 are local. Total coliform counts between CB1 and CB2 were comparable, but fecal coliform and enterococcus counts for CB2 were more than double those for CB1. This may be indicative of a source of sewage or, more likely, animal fecal contamination at CB2.

In conclusion, the Bureau of Sanitation will continue to monitor the water quality at the Inner Cabrillo Beach swimming area on a regular basis to comply with AB411 and the TIWRP NPDES permit. This water quality monitoring will assist in determining the effectiveness of the programs implemented to address bird fecal contamination and other possible sources that may impact water quality at Cabrillo Beach. As additional information is gathered, remedial measures may need to be modified and/or supplemented.

LITERATURE CITED

APHA. See American Public Health Association.

American Public Health Association. 1998. Standard methods for the examination of water and wastewater, 20th ed. American Public Health Association, Washington, DC, pp. 9-1 to 9-140.

CLA, EMD. See City of Los Angeles, Environmental Monitoring Division

City of Los Angeles, Environmental Monitoring Division. 2002. Marine Monitoring in the Los Angeles Harbor: Annual Report for the period January 2001 through December 2001. Report submitted to EPA and RWQCB (Los Angeles). Department of Public Works, Bureau of Sanitation, Terminal Island Treatment Plant, San Pedro, California, pp. 1-1 to 8-15 + appendices.

City of Los Angeles, Environmental Monitoring Division. 2004. Marine Monitoring in the Los Angeles Harbor: Annual Report for the period January 2003 through December 2003. Report submitted to EPA and RWQCB (Los Angeles). Department of Public Works, Bureau of Sanitation, Terminal Island Treatment Plant, San Pedro, California, pp. 1-1 to 7-13 + appendices.

Harbors Environmental Projects. 1980. The marine environment in Los Angeles and Long Beach Harbors during 1978 in Soule, D.F. and Oguri, M., eds., Marine Studies of San Pedro Bay, California, Part 17. The Office of Sea Grant and Allan Hancock Foundation, Institute of Marine and Coastal Studies, University of Southern California, pp. 1-667.

HEP. See Harbors Environmental Projects.