CHAPTER 4

SEDIMENT CHEMISTRY

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INTRODUCTION

The primary objective of the sediment monitoring program is to evaluate the extent to which chemical and physical characteristics of sediments are affected by pollutants in the treated wastewater discharged from Hyperion Treatment Plant (HTP).

Hyperion Treatment Plant's current NPDES permit (NPDES Permit CA0109991, Order No. R4-2005-0020) became effective May 14, 2005. This chapter reports the sediment chemistry data collected under this and the previous HTP permit from January 2005 through December 2006 and summarizes contaminant trends in sediments from 2003 to 2006. Data for this reporting period are divided into two separate tables for each year. Additionally, separate historical investigations of changes in sediment chemistry are presented for the 5-Mile Outfall Station Z2, the defunct 7-Mile "sludge" Outfall Station E6, and a reference site Station C1 from 2003 through 2006.

This report covers samples collected utilizing the sampling array composed of a combination of fixed stations and random stations (Figures 4-1a and 4-1b), implemented in response to full secondary treatment at the Hyperion Treatment Plant. Continuous improvements in the quality of wastewater discharged into the Bay have resulted in cleaner surface deposits near the HTP outfall for the past decade. Increased removal of solids coupled with industrial waste control programs have resulted in higher quality effluent (Schafer 1989) and recovery of sediments to more natural conditions (Stull et al. 1986, CLA, EMD 1989-1995, 1997, 1998, 2001, 2003, and 2005). Since abatement of sludge disposal into Santa Monica Bay in 1987, levels of some contaminants have diminished in surface sediments around the old sludge outfall and biological recovery in the old sludge field is well underway (CLA, EMD 1989-1995, 1997, 1998, 2001, 2003, 2005, and Thompson 1992).

During the summer of 2003, the Environmental Monitoring Division (EMD) participated in the Bight'03 Regional Monitoring Survey. Most of the NPDES compliance sediment chemistry stations were substituted by stations selected for the regional program. Only five sampling sites (C1, C4, E6, C6, and Z2) from the existing program were retained.

In the summer survey of 2005, sediment quality monitoring samples were collected from all 44 NPDES permit mandated sites. During this monitoring period, the sampling grid used for the sediment monitoring program was modified from an equidistant, depth-contour based grid of 44 stations to a combination fixed/random station array in order to more effectively assess impact of Hyperion's full secondary treated discharge to Santa Monica Bay. Twenty-four fixed stations from the current NPDES permit's original sampling array were retained to maintain historical continuity to

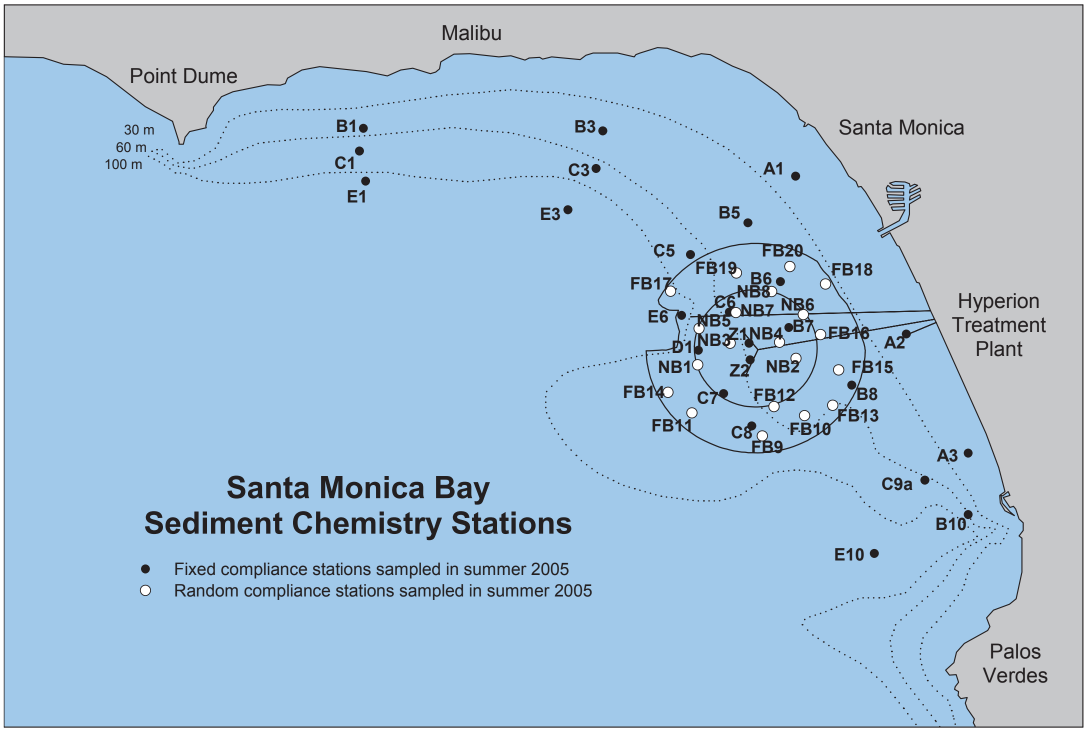

Figure 4-1a. Sediment chemistry stations sampled in Santa Monica Bay, summer 2005.

help distinguish naturally occurring changes from changes related to the plant's discharge. One set of 20 randomly placed stations (FB9 to FB20 and NB1 to NB8) were included for increased sensitivity and resolution of changes in the vicinity of the Plant's discharge.

In this chapter, data were examined for spatial and temporal patterns of contamination around the City's 5-Mile and 7-Mile outfalls. These concentrations were compared with background levels in the Southern California Bight and the sediment quality guidelines to assess the impact of Hyperion effluent discharge on sediment quality and its biological effects.

MATERIALS AND METHODS

FIELD SAMPLING

During summer surveys, a single sample of sediment was collected from each of 44 offshore stations in 2005 (Figure 4-1a) and 2006 (Figure 4-1b). Twenty four of these offshore stations in 2005 and 2006 were fixed stations from the current NPDES permit's original sampling array. One set of 20 stations were randomly located during each year.

Sediment samples from 44 designated offshore stations of Santa Monica Bay were collected and analyzed for TOC and Grain Size. Sediments from four stations (C1, C6, Z2, and E6) were analyzed for dissolved sulfides, and sediments from nine stations (Z2, C1, C3, C6, C7, C8, C9a, D1 and E6) were analyzed for selected priority pollutants, including nine trace metals and seventy-two organic contaminants. Station C7 was not sampled for selected priority pollutants in 2005 due to failed grab attempts.

Details of sample collection, preservation, and storage are described in Appendix C along with precise descriptions of all analytical procedures. Only general procedures are mentioned below.

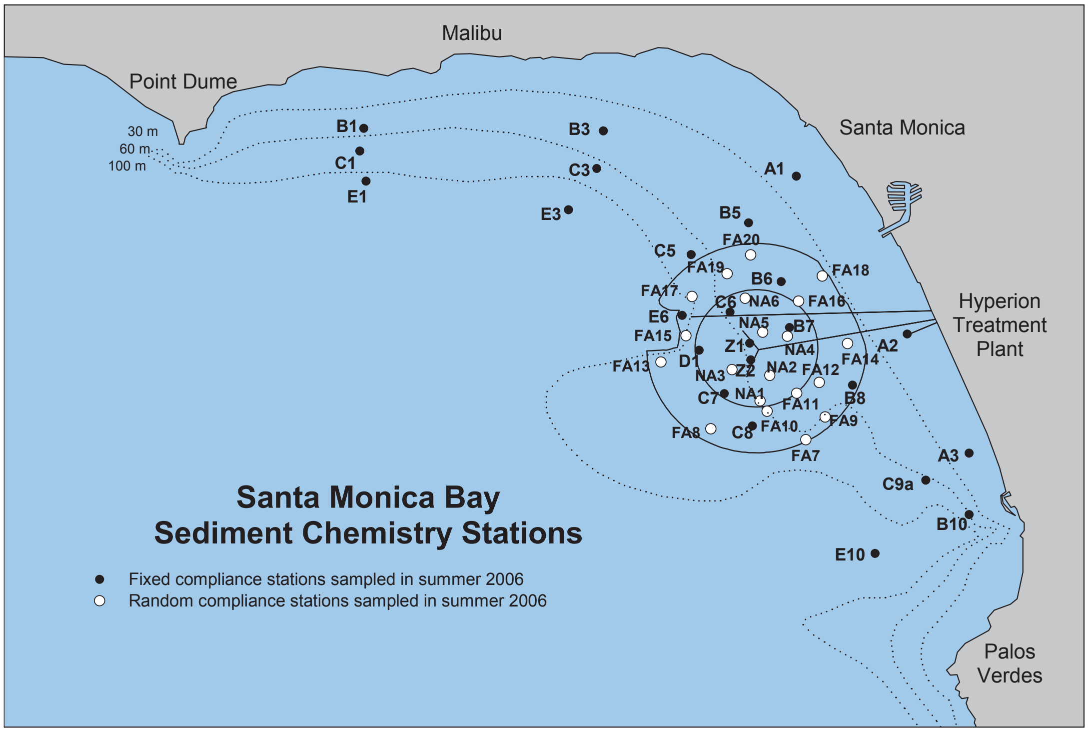

Figure 4-1b. Sediment chemistry stations sampled in Santa Monica Bay, summer 2006.

LABORATORY PROCEDURES

Sediment grain size was measured using a Beckman Coulter LS 13-230 particle size analyzer. Analyses were performed to determine percentages of gravel (particles >2 mm), sand (particles 63 µm – 2 mm), silt (particles 4 – 62 µm), and clay (particles <4 µm).

Dissolved sulfide was measured with the methylene blue colorimetric method (APHA 1998, Part 4500 D). TOC was analyzed using a TOC analyzer after persulfate digestion (APHA 1998, Part 5310 B).

For metal (except mercury) analyses, the sediments were first digested in strong acids (EPA 1996, Method 3050B) and analyzed by Inductively Coupled Plasma spectroscopy (EPA 1994, Method 200.7). Mercury was analyzed by Cold Vapor method (EPA 1994, Method 7471A).

For organic priority pollutants, the sediments were extracted by accelerated solvent extractor, subjected to a clean-up procedure, and concentrated prior to instrument analysis. Base/neutral and acid extractable organic compounds (BNA's) were analyzed by Gas Chromatograph/Mass Spectrometer (EPA 1996. Method 8270C). DDTs (o,p' and p,p' isomers of dichloro-diphenyl-trichloroethane and its degradation products) and PCBs (41 different Polychlorinated Biphenyl congeners) were analyzed by Gas Chromatograph equipped with electron capture detectors (EPA 1996. Method 8081/8082).

DATA ANALYSIS

Metals and organic contaminants have a greater affinity for finer grained sediments like silts and clays than for coarse sediments like sand and gravels (Klamer *et al.* 1990). Increased levels of fine sediments could correspondingly have higher levels of contaminants. To compensate for this, sediment chemistry data were normalized using the methods described by NOAA in their National Status and Trends Program (NOAA 1988). Following this

Table 4-1a. Grain size distribution of sediments in Santa Monica Bay during Summer 2005.

	Percent Composition					Percent Composition			
Station	Gravel	Sand	Silt	Clay	Station	Gravel	Sand	Silt	Clay
A2	0.0	88.8	9.5	1.7	Z1	0.1	78.9	18.5	2.4
A3	0.0	92.0	6.6	1.5	Z2	0.3	75.0	22.2	2.6
B1	0.0	26.3	63.9	9.8	FB9	0.0	65.7	30.0	4.3
B3	0.0	41.2	51.2	7.7	FB10	0.0	38.0	55.6	6.4
B5	0.0	49.1	44.6	6.3	FB11	0.0	60.0	34.5	5.6
B6	0.0	51.6	42.3	6.2	FB12	0.0	76.2	21.1	2.6
B7	0.0	43.4	50.1	6.5	FB13	0.0	50.2	44.3	5.5
B8	0.0	68.1	27.1	4.9	FB14	2.7	62.5	29.9	4.9
B10	0.0	57.1	36.9	5.9	FB15	0.0	56.4	37.8	5.7
					FB16	0.0	44.4	48.8	6.7
C1	0.0	25.3	65.2	9.4	FB17	0.0	81.1	15.9	2.8
C3	0.0	60.5	33.2	6.3	FB18	0.0	63.1	32.0	4.8
C5	0.0	81.6	15.2	3.2	FB19	0.0	68.6	26.6	4.8
C6	0.0	71.5	24.5	4.0	FB20	0.0	55.4	38.5	6.0
C8	0.0	70.5	25.6	3.9					
C9A	0.0	67.6	26.4	6.0	NB1	26.2	63.9	8.3	1.5
					NB2	0.0	43.7	50.3	6.0
D1	8.5	81.4	8.7	1.5	NB3	0.0	66.2	30.3	3.6
					NB4	0.0	53.5	41.6	4.8
E1	0.0	48.8	43.7	7.5	NB5	0.0	92.2	6.7	1.1
E3	0.0	37.1	54.1	8.8	NB6	0.0	47.6	46.2	6.2
E6	0.0	50.4	44.0	5.7	NB7	5.1	70.4	21.1	3.4
E10	0.0	53.6	37.7	8.8	NB8	0.0	63.9	31.6	4.6

technique, raw dry-weight based sediment data were normalized by dividing the analyte concentrations by the weight of silt and clay (particles less than 63 μm in diameter). Data were not normalized when the silt and clay fraction of the sediment was less than 20%. This was done to prevent misleadingly high metal values in sandy samples (NOAA 1988). Except stations A2, A3, C5, D1, FB17, NB1, and NB5, the silt and clay fractions in sediment at all 42 stations in 2005 were higher than 20%. During the 2006 survey, sediments containing less than 20% combined silt and clay were found at the following eleven stations: A1, A2, A3, C7, D1, Z1, Z2, FA8, FA10, FA17, and NA1.

For samples analyzed in duplicates, the average of the duplicate results was reported. In all reports, results less than the Method Detection Limit (MDL) were listed as Not Detected (ND), and a value of zero was used in calculating the average. Estimated values for results greater than the MDL but less than the Practical Quantitation Limit (PQL) were included in the average, and were reported as Detected Not Quantified (DNQ). Only values above the MDL were reported when a calculated average resulted in a value less than the MDL; then the average was reported as ND.

RESULTS

GRAIN SIZE

For the summer surveys of 2005 and 2006, sediments in the Bay were heterogeneous; comprised of

Table 4-1b. Grain size distribution of sediments in Santa Monica Bay during summer 2006.

	Percent Composition					Percent Composition			
Station	Gravel	Sand	Silt	Clay	Station	Gravel	Sand	Silt	Clay
A1	17.2	82.0	0.9	0.0	Z1	0.0	85.9	12.5	1.5
A2	0.0	93.2	5.8	1.0	Z2	0.0	82.1	16.0	1.8
A3	0.0	92.5	6.2	1.3					
					FA7	0.0	58.1	36.5	5.4
B1	0.0	29.5	62.8	7.7	FA8	0.0	80.9	16.1	3.0
B3	0.0	35.2	57.6	7.1	FA9	0.0	32.1	61.5	6.4
B5	0.0	49.4	44.8	5.8	FA10	37.1	46.9	15.0	0.9
B6	0.0	48.4	45.7	5.9	FA11	0.0	55.5	39.2	5.3
B8	0.0	72.2	24.0	3.8	FA12	0.0	46.9	46.7	6.4
B10	0.0	65.7	30.7	3.6	FA14	0.0	58.3	36.5	5.2
					FA16	0.0	46.2	48.4	5.4
C1	0.0	25.4	66.00	8.5	FA17	0.0	85.1	13.1	1.7
C3	0.0	63.2	31.4	5.4	FA18	0.0	62.0	33.3	4.7
C5	0.0	76.1	20.4	3.4	FA19	0.0	74.7	21.4	3.9
C6	0.0	75.4	21.1	3.4	FA20	0.0	58.0	36.7	5.4
C7	0.0	81.5	17.2	1.3					
C8	0.0	72.0	24.2	3.8	NA1	0.0	86.3	12.1	1.5
C9A	0.0	70.5	24.4	5.1	NA2	0.0	48.9	46.3	4.8
					NA3	0.0	78.3	19.5	2.3
D1	0.0	85.5	12.4	2.1	NA4	0.0	40.7	52.5	6.8
					NA6	0.0	71.2	25.1	3.6
E1	0.0	47.5	45.0	7.5					
E3	0.0	38.3	52.9	8.8					
E6	0.0	59.4	36.3	4.3					
E10	0.0	55.1	36.9	8.0					

varying levels of mainly sand and silt (Tables 4-1a and 4-1b). Fine grained sediments, mostly silt, were found in the northwestern part of the Bay at stations C1, B1, and E3, along the Malibu shelf. Particle size changed to sandy silt in central and southern portions of the Bay. Sand and gravel were dominant at the inshore stations A1 to A3, and in the area of Short Bank (D1), at stations C5 to C9a, and at the outfall stations Z1 and Z2 located along the 60-meter depth contour (Tables 4-1a and 4-1b). Grain size measurement data of the 2006 survey were similar to those found in 2005 (Figures 4-2a and 4-2b).

Among the random stations sampled in 2005, FB17, NB1 and NB5 were mostly sandy, and the other stations were sandy silt (Table 4-1a). In 2006, the random stations (FA8, FA10, FA17, and NA1) were mostly sandy, and the other stations were sandy silt (Table 4-1b).

TOTAL ORGANIC CARBON AND SULFIDE

During the 2005 summer survey, total organic carbon (TOC) was detected at all 42 sites; the highest concentration (27,100 mg/kg) was detected at C8 (Table 4-2a and Figure 4-3a). Dissolved sulfide was detected at stations C6, E6, and Z2 but not C1. The

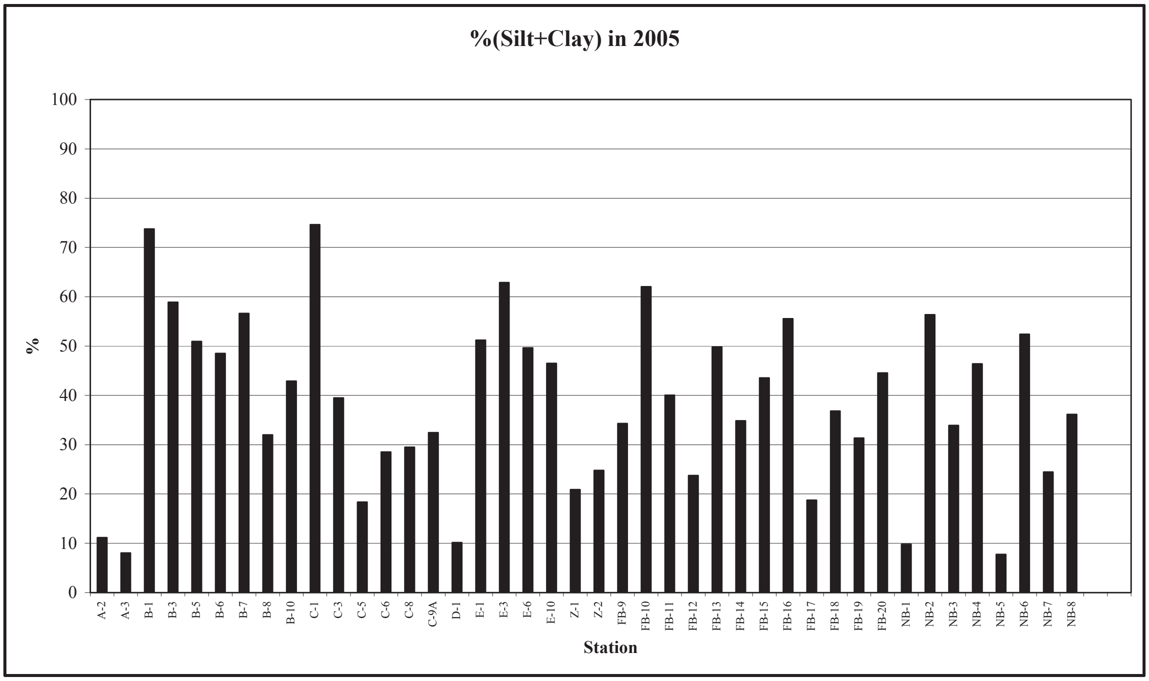

Figure 4-2a. Percentage of (Silt + Clay) in surface sediment of Santa Monica Bay in summer 2005.

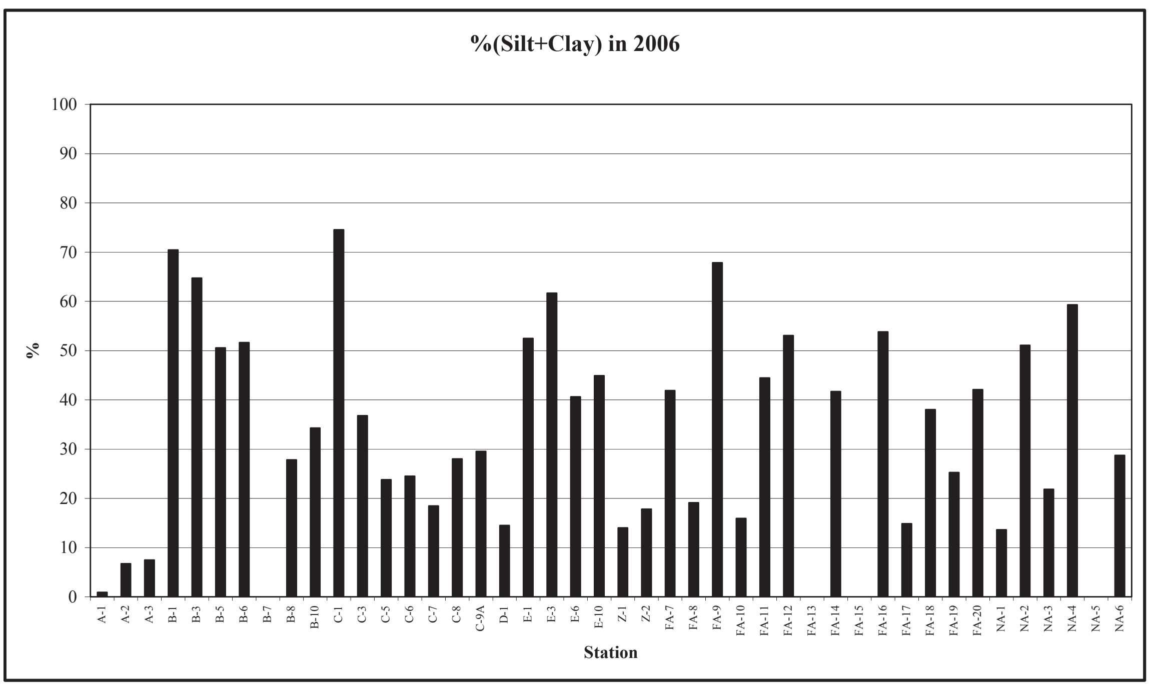

Figure 4-2b. Percentage of (Silt + Clay) in surface sediment of Santa Monica Bay in summer 2006.

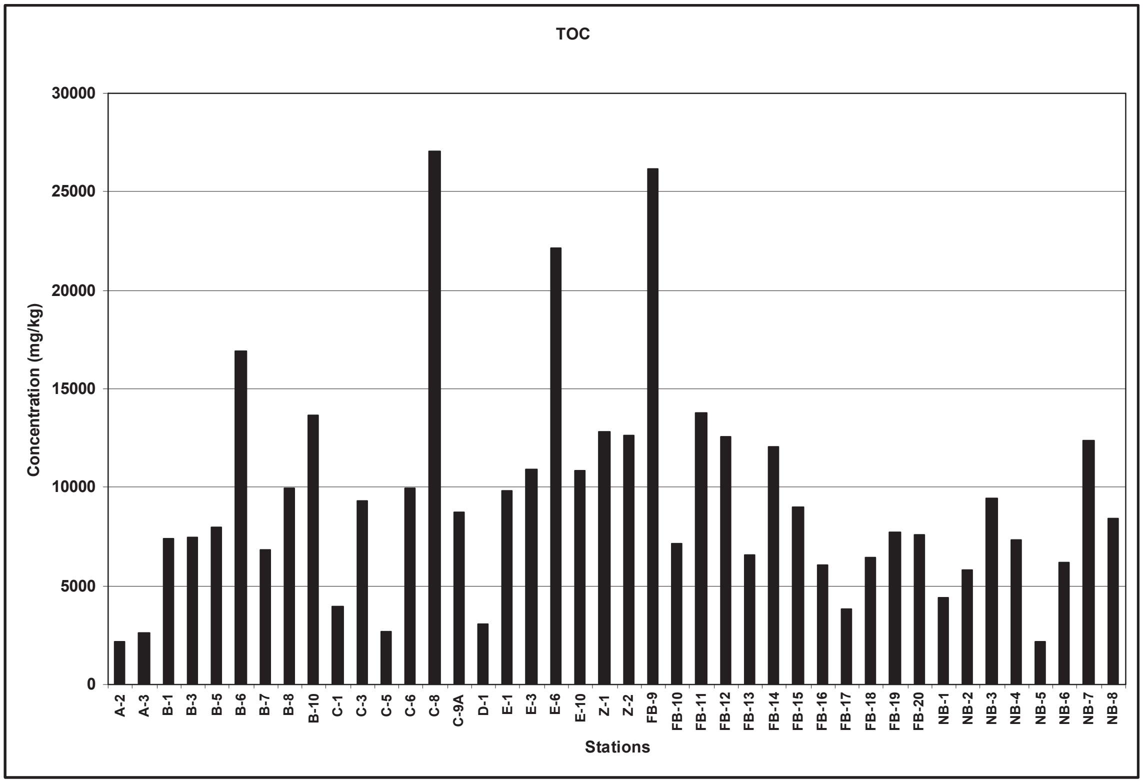

Figure 4-3a. Concentrations of TOC in surface sediments of Santa Monica Bay in summer 2005.

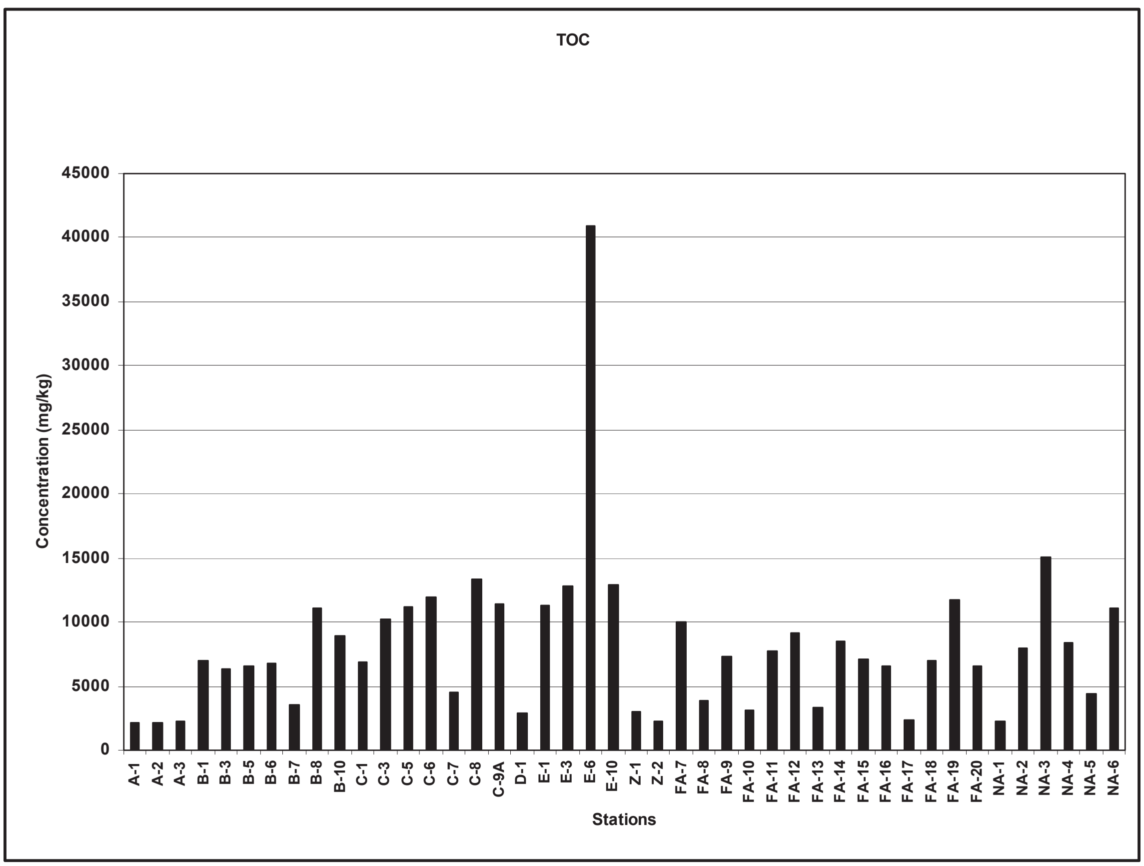

Figure 4-3b. Concentrations of TOC in surface sediments of Santa Monica Bay in summer 2006.

Table 4-2a. Pollutants in sediments of Santa Monica Bay, summer 2005. Concentrations normalized against fine grain.

Priority Pollutants	No. Stations Detected*	Santa Monica Bay Average**	Santa Monica Bay Range***
Metals (mg/kg)			
Arsenic	8	10.2	2.40 – 21.4
Cadmium	8	6.71	1.39 – 14.8
Chromium	8	115	27.3 - 294
Copper	8	78.4	14.9 - 331
Lead	8	30.3	6.8 – 86.3
Mercury	8	0.648	0.108 – 2.90
Nickel	8	29.3	5.50 – 49.8
Silver	8	5.24	0.469 – 27.8
Zinc	8	134	26.0 - 304
Pesticides & PCBs (μg/kg)			
A-Chlordane	1	1.39	ND – 11.2
2,4'-DDE	7	17.5	ND – 43.9
4,4'-DDE	8	123	15.8-287
4,4'-DDD	2	2.89	ND – 13.7
4,4'-DDT	1	0.37	ND-2.9
Aroclor 1254	2	103	ND - 720
Aroclor 1260	1	55.8	ND - 446
PCB-28	1	2.06	ND-16.5
PCB-44	1	2.58	ND-20.6
PCB-52	1	5.55	ND-44.4
PCB-66	2	7.42	ND-54.2
PCB-70	3	5.56	ND-35.1
PCB-74	1	2.02	ND-16.1
PCB-101	6	8.39	ND-39.5
PCB-110	4	9.1	ND-50.1
PCB-118	8	14.5	ND-52.0
PCB-128	1	1.71	ND-13.7
PCB-149	7	8.30	ND-32.3
PCB-151	1	1.57	ND-12.5
PCB-156	1	0.890	ND-7.12
PCB-170	1	2.13	ND-17.1
PCB-180	2	4.61	ND-33.0
PCB-187	1	2.57	ND-20.5
PCB-194	1	1.33	ND-10.6
PCB-201	1	2.27	ND-18.1
PCB-206	1	0.89	ND-7.13
Non-Priority Pollutants			
Dissolved Sulfide (mg/L)	3	0.335	ND – 1.06
Total Org. Carbon (mg/kg)	42	9380	2170 - 27100

ND - Not Detected

* These numbers include the stations with <20% silt plus clay
** Concentrations below detection limits were taken as zero and stations with <20% silt plus clay were not normalized against fine grain.

*** Stations with <20% silt plus clay were not normalized

Table 4-2b. Pollutants in sediments of Santa Monica Bay, summer 2006. Concentrations normalized against fine grain.

		Santa Monica Bay	
Priority Pollutants	**No. Stations Detected***	**Average****	**Range*****
Metals (mg/kg)			
Arsenic	9	10.6	2.56 – 24.8
Cadmium	9	10.7	0.89 – 48.5
Chromium	9	175	17.93 - 675
Copper	9	125	7.24 - 732
Lead	9	42.5	3.78 – 231
Mercury	9	1.53	0.08 – 9.83
Nickel	9	42.6	4.60 – 129
Silver	2	12.5	ND – 72.9
Zinc	9	222	19.3 - 978
Pesticides & PCBs (μg/kg)			
A-Chlordane	2	0.610	ND – 2.93
2,4'-DDE	3	7.32	ND – 43.8
4,4'-DDE	9	154	11.8 - 434
Aroclor 1254	8	356	ND - 1825
Aroclor 1260	9	240	20.9 - 1265
PCB-28	1	3.77	ND-33.9
PCB-44	1	4.15	ND-33.2
PCB-49	1	3.26	ND-26.0
PCB-52	4	8.20	ND-50.5
PCB-66	6	14.4	ND-83.9
PCB-70	3	8.00	ND-54.3
PCB-74	1	3.80	ND-30.4
PCB-87	1	4.13	ND-33.0
PCB-99	1	3.27	ND-26.1
PCB-101	5	10.9	ND-65.9
PCB-105	8	10.3	ND-55.1
PCB-110	6	11.1	ND-69.3
PCB-118	8	16.7	ND-82.6
PCB-119	1	0.17	ND-1.36
PCB-128	1	2.52	ND-20.2
PCB-138	6	19.3	ND-120
PCB-149	5	8.80	ND-47.1
PCB-151	1	2.08	ND-16.7
PCB-153	5	13.1	ND-74.6
PCB-156	1	1.63	ND-13.1
PCB-170	1	2.94	ND-23.5
PCB-177	1	1.91	ND-15.3
PCB-180	1	5.99	ND-48.0
PCB-183	1	1.47	ND-11.8
PCB-187	3	4.23	ND-28.5
PCB-194	1	1.67	ND-13.3
PCB-201	1	2.51	ND-20.1
Non-Priority Pollutants			
Dissolved Sulfide (mg/L)	4	0.750	0.05 – 1.90
Total Org. Carbon (mg/kg)	44	8090	2130 - 40900

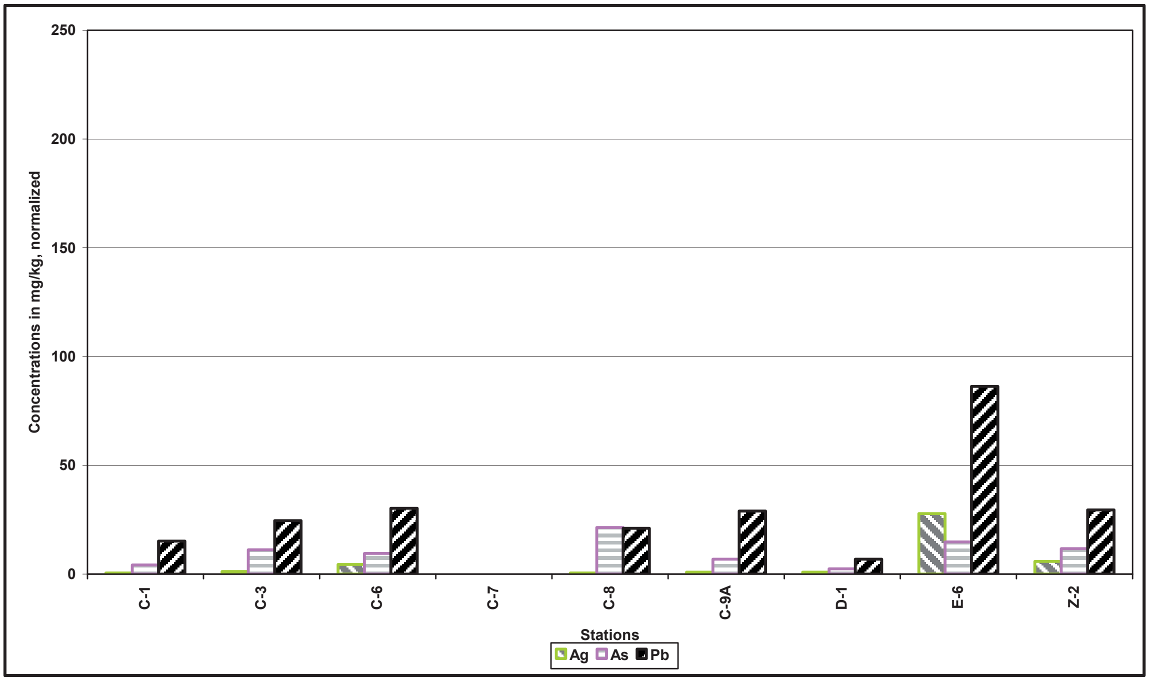

Figure 4-4a. Concentrations of Ag, As, and Pb in surface sediments of Santa Monica Bay in summer 2005.

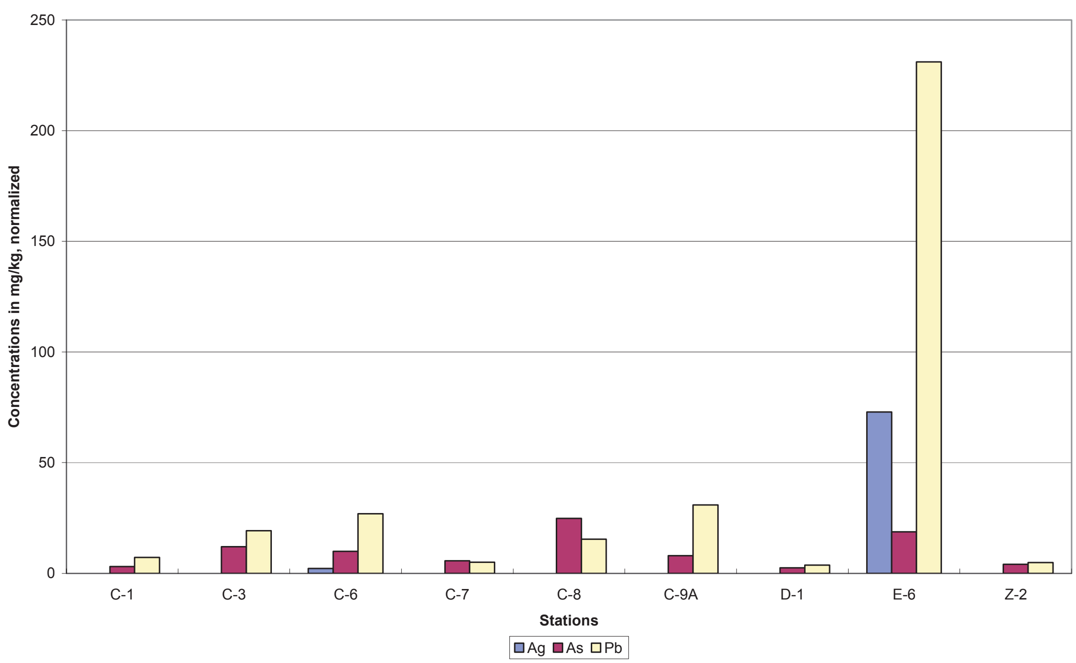

Figure 4-4b. Concentrations of Ag, As, and Pb in surface sediments of Santa Monica Bay in summer 2006.

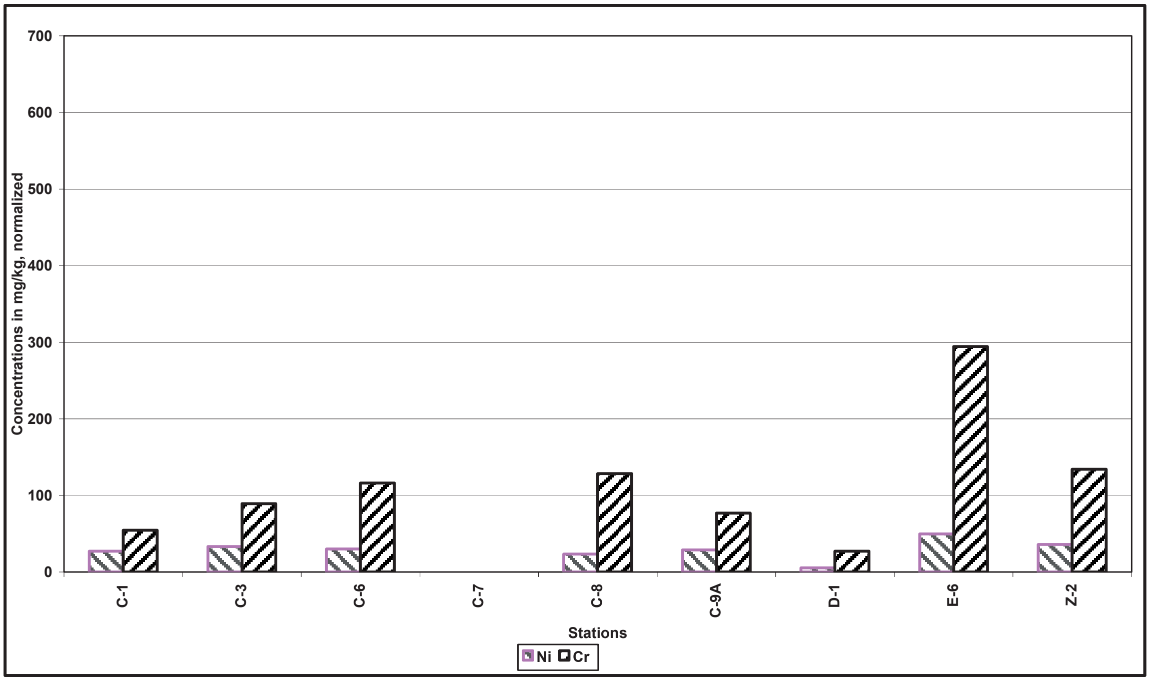

Figure 4-5a. Concentrations of Ni and Cr in surface sediments of Santa Monica Bay in summer 2005.

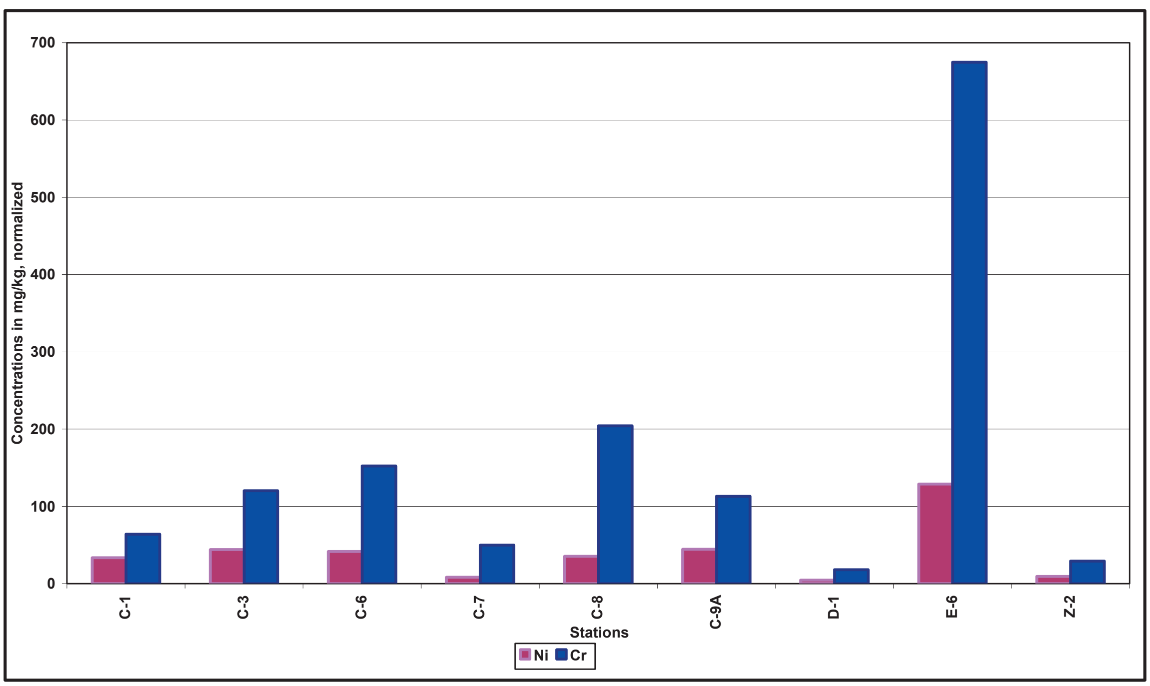

Figure 4-5b. Concentrations of Ni and Cr in surface sediments of Santa Monica Bay in summer 2006.

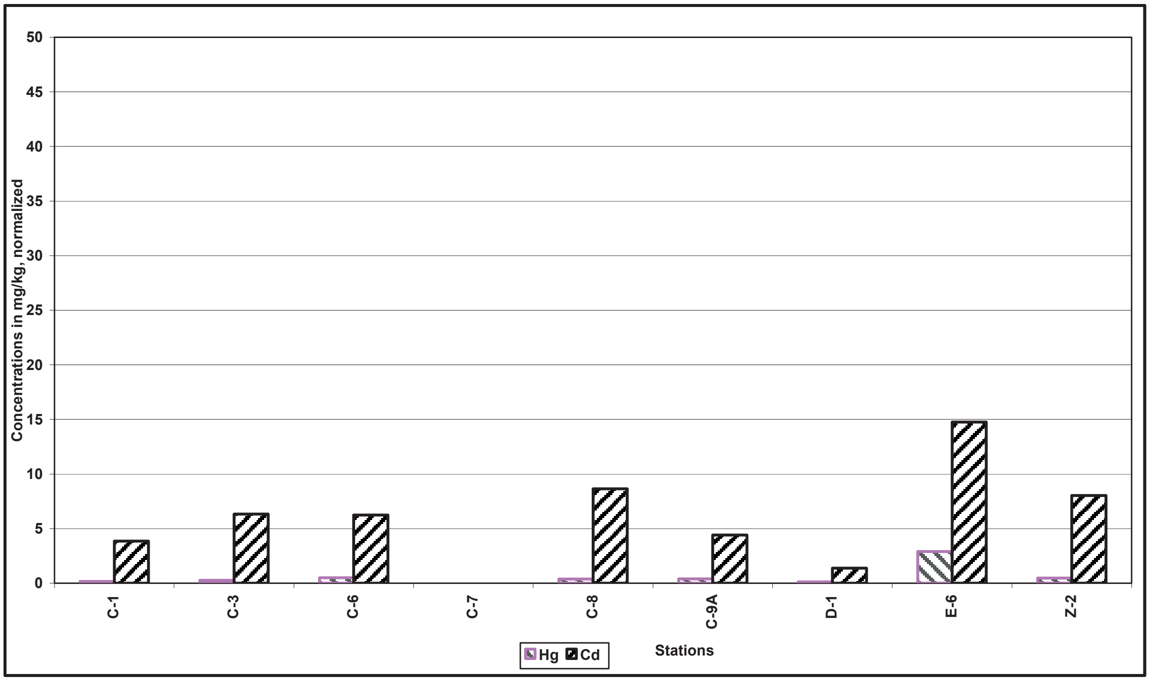

Figure 4-6a. Concentrations of Hg and Cd in surface sediments of Santa Monica Bay in summer 2005.

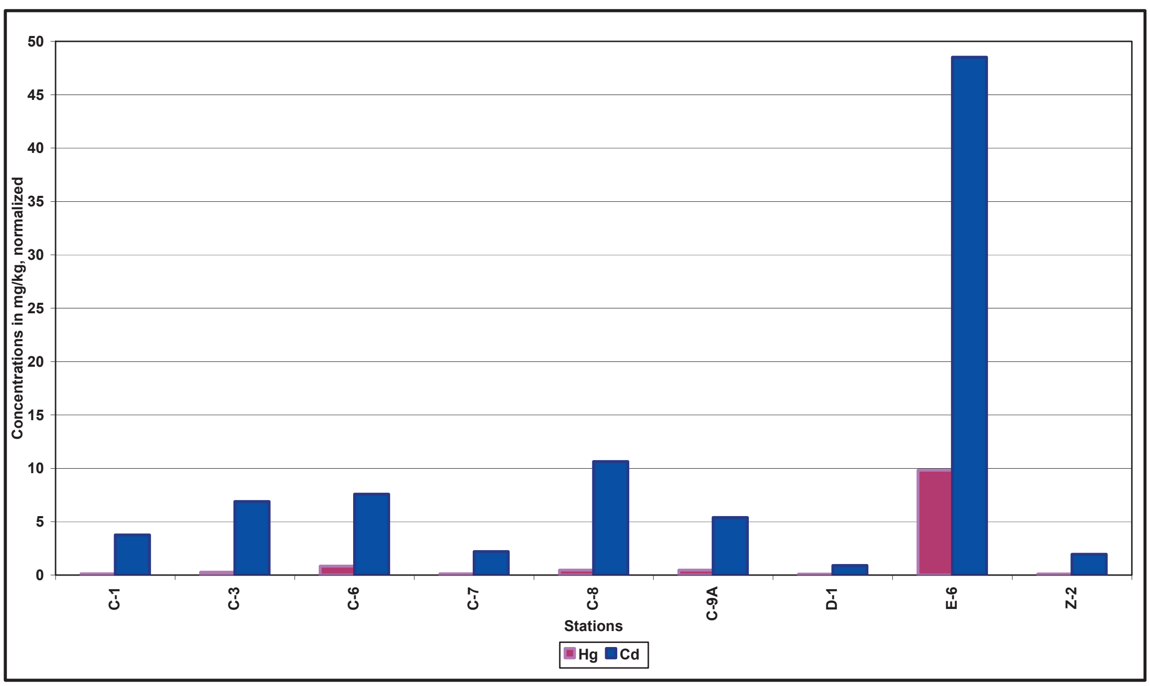

Figure 4-6b. Concentrations of Hg and Cd in surface sediments of Santa Monica Bay in summer 2006.

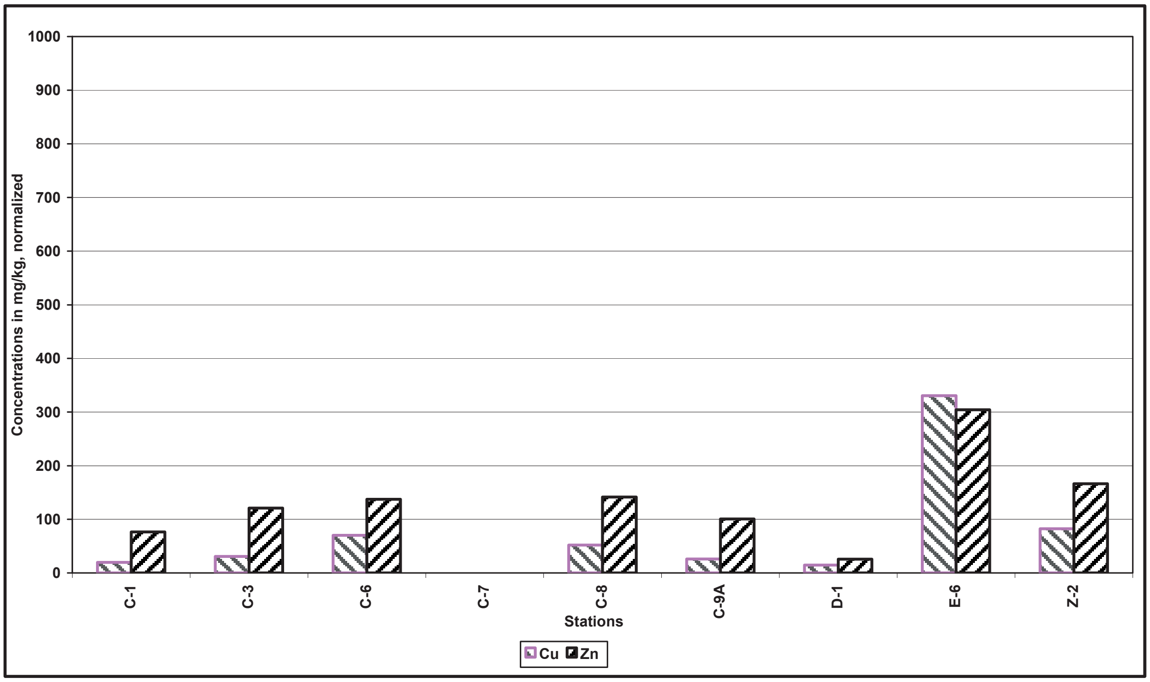

Figure 4-7a. Concentrations of Cu and Zn in surface sediments of Santa Monica Bay in summer 2005.

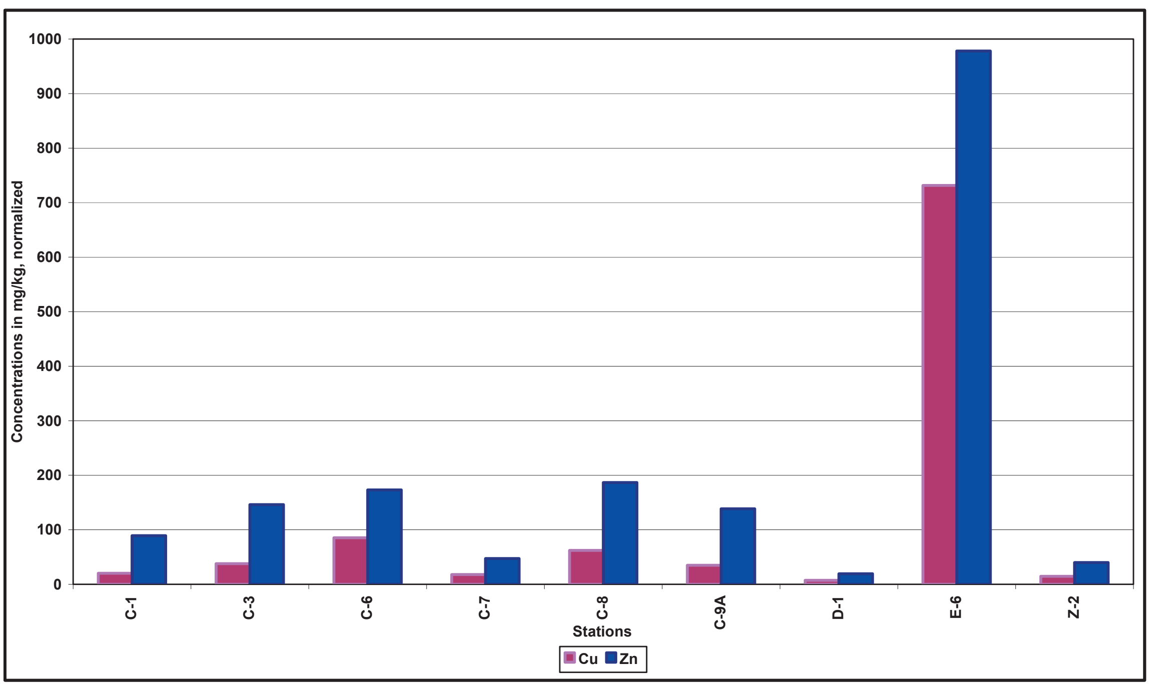

Figure 4-7b. Concentrations of Cu and Zn in surface sediments of Santa Monica Bay in summer 2006.

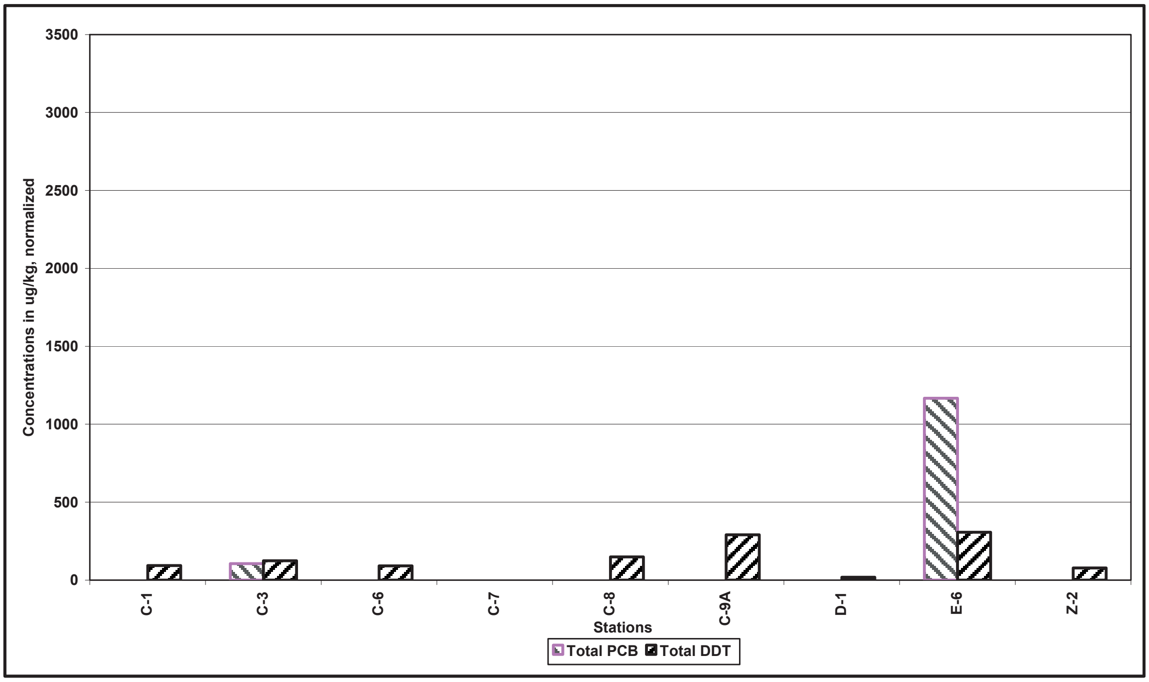

Figure 4-8a. Concentrations of total PCBs and total DDTs in surface sediments of Santa Monica Bay in summer 2005.

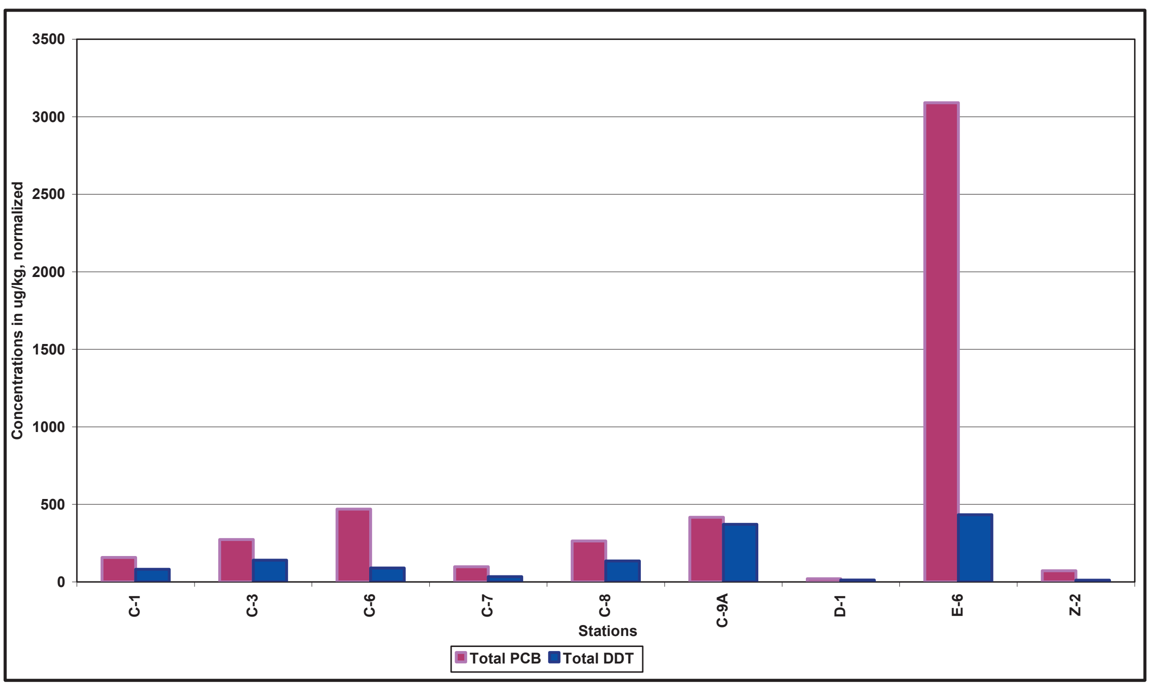

Figure 4-8b. Concentrations of total PCBs and total DDTs in surface sediments of Santa Monica Bay in summer 2006.

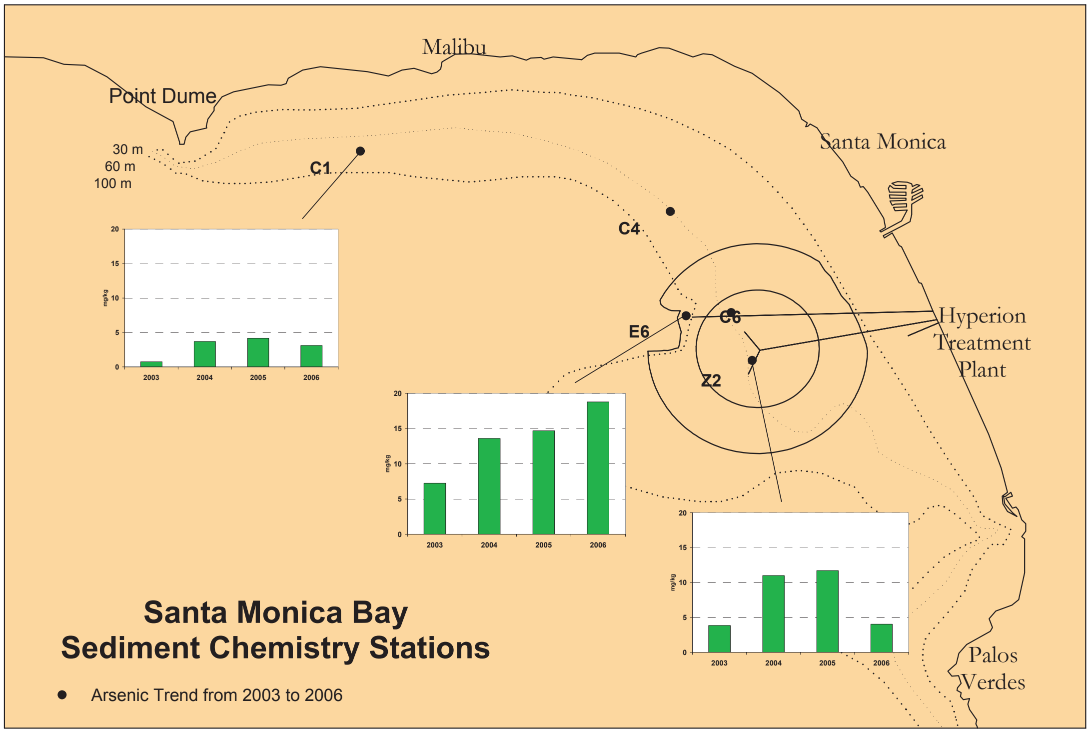

Figure 4-9. Concentrations (mg/kg) of arsenic in sediment at E6 (7-Mile), Z2 (5-Mile), and northern reference site (C1) from 2003 to 2006.

highest concentration (1.06 mg/L) of dissolved sulfide was detected at E6 and concentrations of less than 0.4 mg/kg were found at all other stations (Tables 4-2a).

In 2006, the maximum concentration (40,900 mg/kg) of TOC occurred at the old sludge field (station E6) located at the terminus of the 7-Mile outfall (Table 4-2b and Figure 4-3b). Dissolved sulfide was detected at all stations analyzed for dissolved sulfide. Similarly, the highest concentration of dissolved sulfide (1.9 mg/L) was found at station E6. Concentrations of both TOC and dissolved sulfide found at station E6 were higher in 2006 than in 2005.

PRIORITY POLLUTANTS: METALS AND ORGANICS

Out of 81 priority pollutants, 35 were detected in sediments collected at the eight sampling sites during summer of 2005 (Table 4-2a), and 41 were found in sediments collected at the nine sampling sites in the summer 2006 survey (Table 4-2b). A complete list of priority pollutants analyzed is presented in Appendix D.

Metals

In the 2005 summer surveys, all nine priority pollutant metals were detected at all sampling sites in Santa Monica Bay (Figure 4-4a to 4-7a). Except arsenic, they reached their maximum concentration at station E6 (in the vicinity of the 7-Mile outfall). The maximum concentration of arsenic was detected at station C8. The north-to-south distribution pattern of sediment metal concentrations in the Bay reached its highest peak at Station E6 and reduced concentrations at surrounding stations before reaching the second highest peak at station Z2.

Similar to 2005 survey, all nine priority pollutant metals, except silver, were detected at all sampling stations in the 2006 survey (Figure 4-4b to 4-7b). Metals such as lead, mercury, and silver are observed to associate with fine particles and show correlation

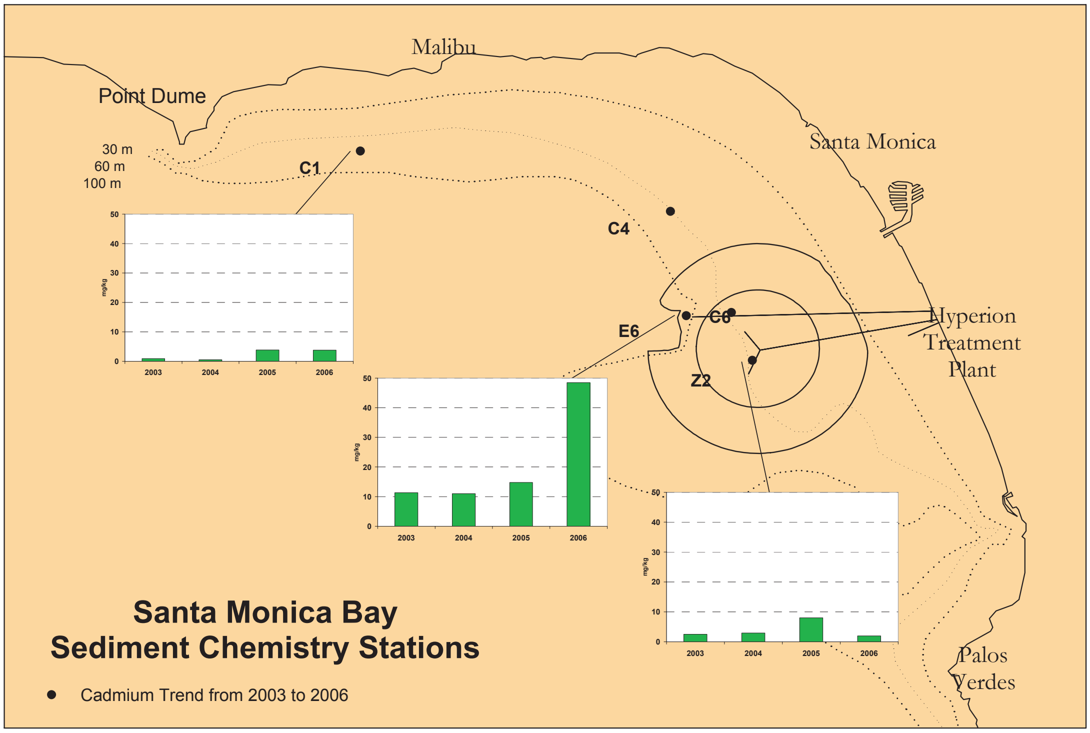

Figure 4-10. Concentrations (mg/kg) of cadmium in sediment at E6 (7-Mile), Z2 (5-Mile), and northern reference site (C1) from 2003 to 2006.

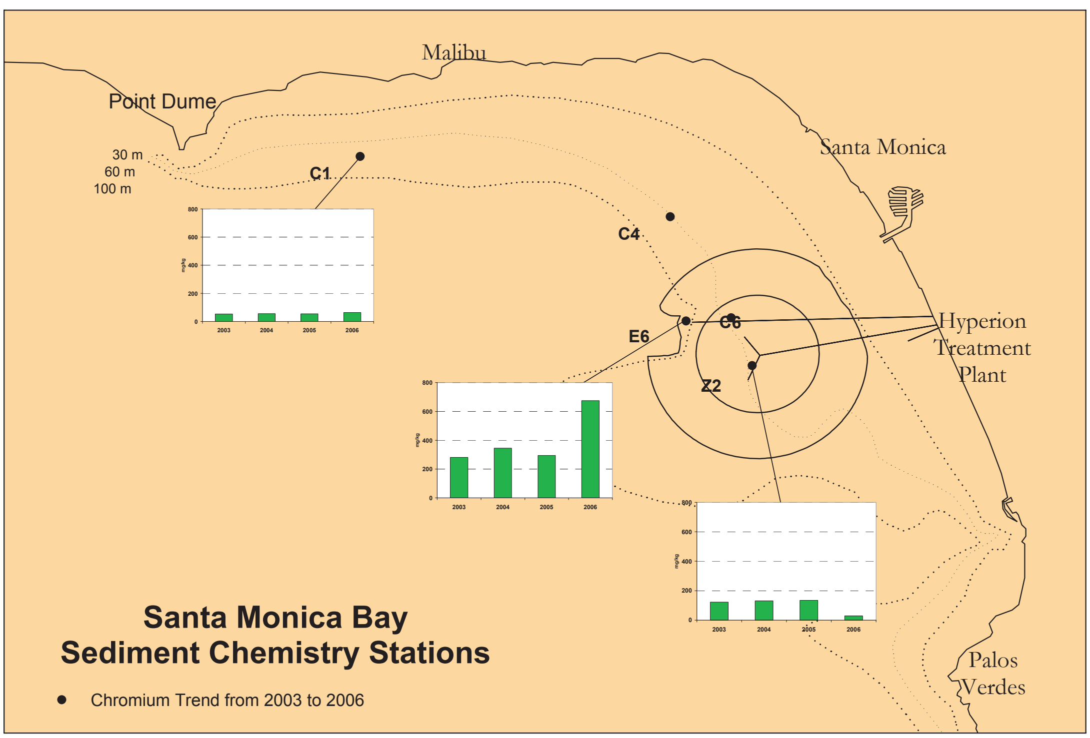

Figure 4-11. Concentrations (mg/kg) of chromium in sediment at E6 (7-Mile), Z2 (5-Mile), and northern reference site (C1) from 2003 to 2006.

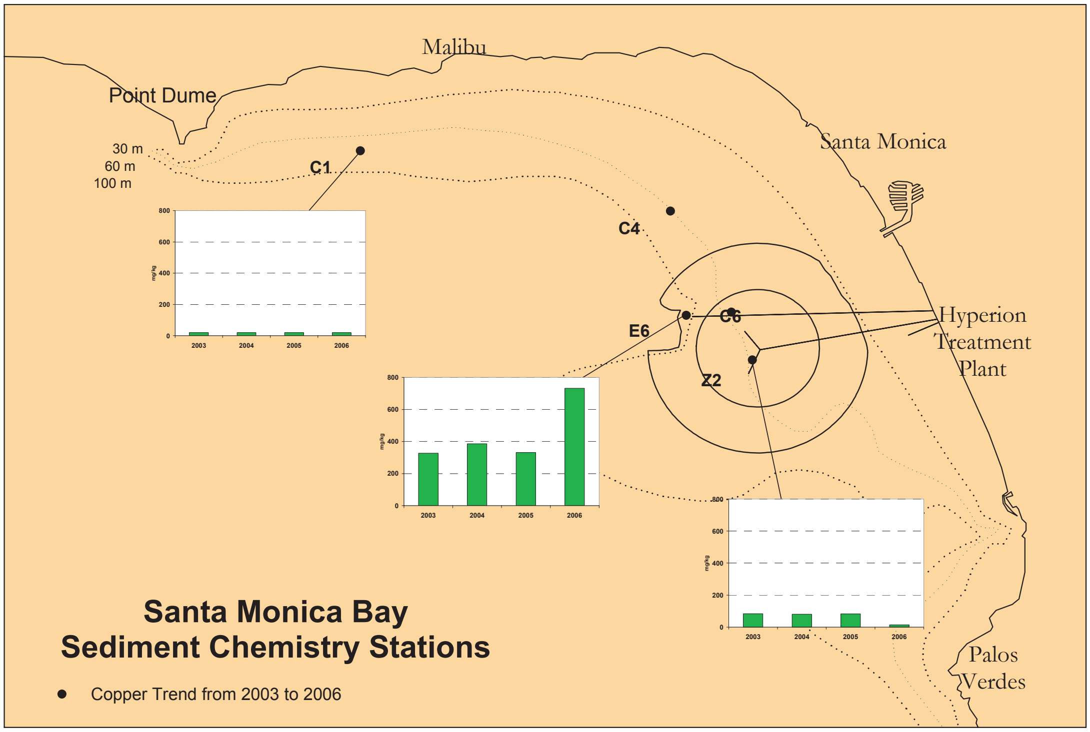

Figure 4-12. Concentrations (mg/kg) of copper in sediment at E6 (7-Mile), Z2 (5-Mile), and northern reference site (C1) from 2003 to 2006.

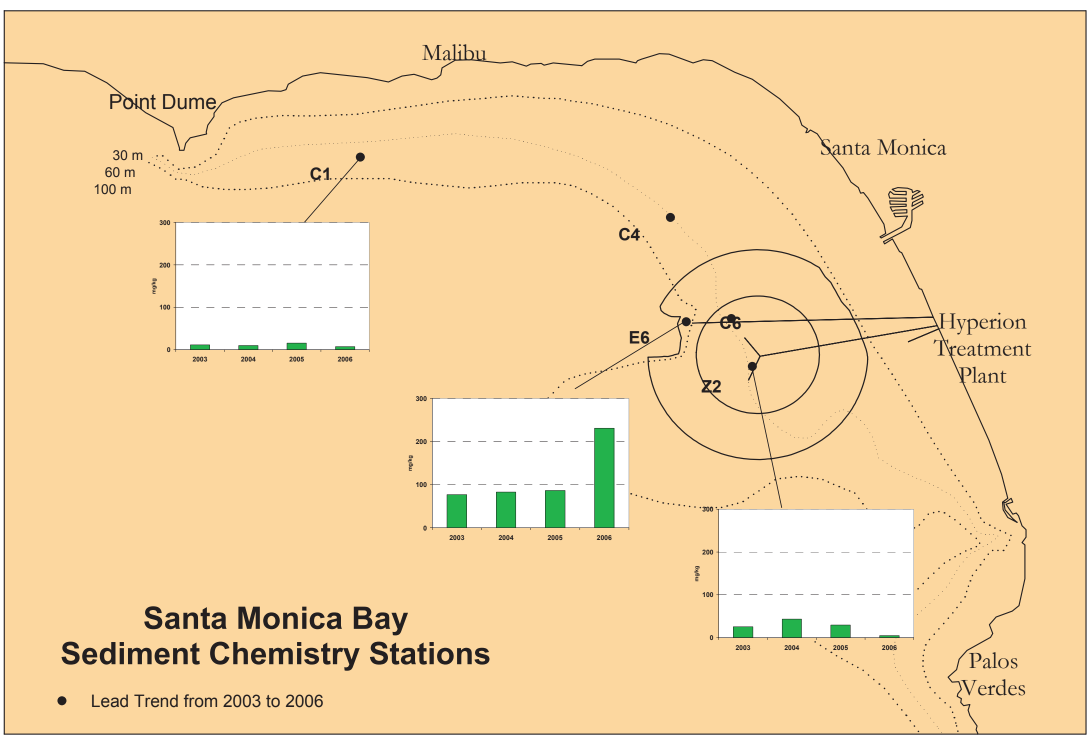

Figure 4-13. Concentrations (mg/kg) of lead in sediment at E6 (7-Mile), Z2 (5-Mile), and northern reference site (C1) from 2003 to 2006.

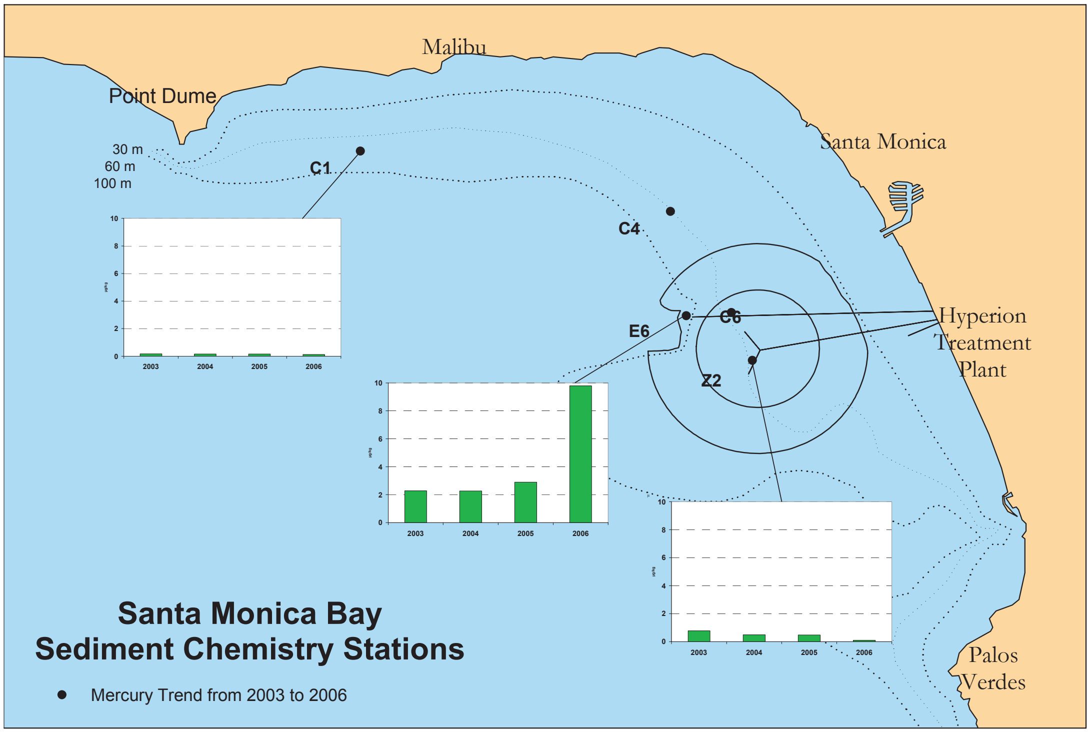

Figure 4-14. Concentrations (mg/kg) of mercury in sediment at E6 (7-Mile), Z2 (5-Mile), and northern reference site (C1) from 2003 to 2006.

between their concentrations with the amount of fine particles—the higher the % of fine particles, the higher the concentrations of these metals. Silver was detected at C6 and E6 only. Apparently, silver and mercury were higher in stations near the outfall.

The average metal concentrations in sediments collected from 2006 were generally higher than those from 2005.

DDTs and PCBs

Two DDT degradation products (2,4'-DDE and 4,4'-DDE) and 27 PCB congeners (PCB-28, 44, 49, 52, 66, 70, 74, 87, 99, 101, 105, 110, 118, 119, 128, 138, 149, 151, 153, 156, 170, 177, 180, 183, 187, 194, and 201) were detected in either the 2005 or 2006 summer survey. The pollutants detected in 2005 but not in 2006 are 4,4'-DDD, 4,4'-DDT, and PCB-206. The pollutants detected only in 2006 are PCB-49, 87, 99, 105, 119, 138, 153, 177, and 183 (Table 4-2a and 4-2b).

The average concentrations of all detected DDT derivatives and PCB congeners were higher in 2006 than in 2005 except 2,4'-DDE which was higher in 2005 (Table 4-2a and 4-2b). Hydrophobic organic pollutants such as PCBs are particle reactive and show correlation between their concentrations with the amount of fine particles—the higher the percentage of fine particles, the higher the potential PCB concentration. The highest levels of total PCBs and DDTs in 2005 and 2006 occurred at station E6 (Figure 4-8a and 4-8b). The second highest concentration level of total DDT was detected at station C9a. These DDTs may be attributed to the contaminated sediment originating from the Palos Verdes Shelf.

TEMPORAL TRENDS

Figures 4-9 to 4-17 depict temporal trends in the concentrations of arsenic (As), cadmium (Cd),

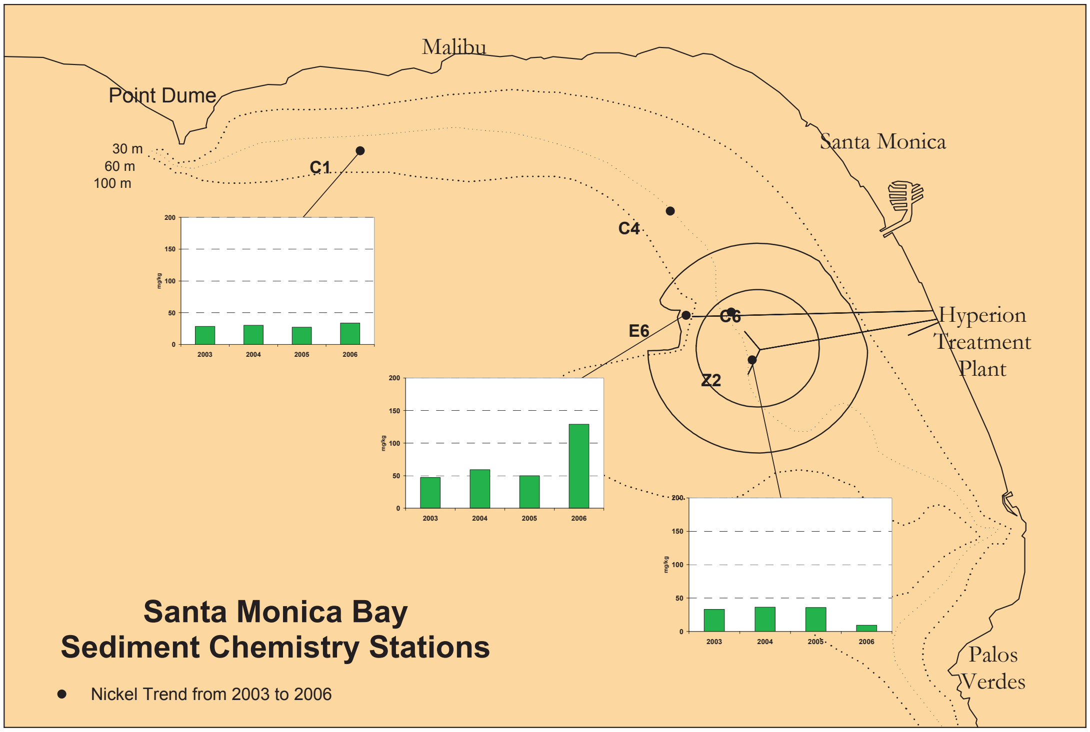

Figure 4-15. Concentrations (mg/kg) of nickel in sediment at E6 (7-Mile), Z2 (5-Mile), and northern reference site (C1) from 2003 to 2006.

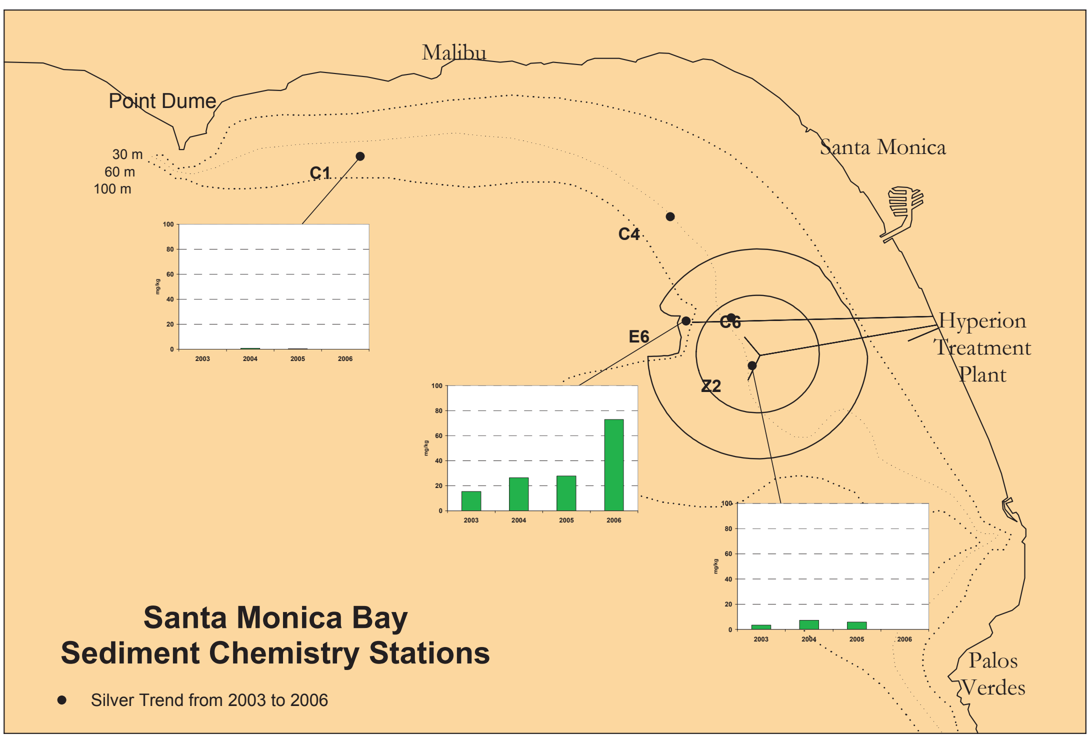

Figure 4-16. Concentrations (mg/kg) of silver in sediment at E6 (7-Mile), Z2 (5-Mile), and northern reference site (C1) from 2003 to 2006.

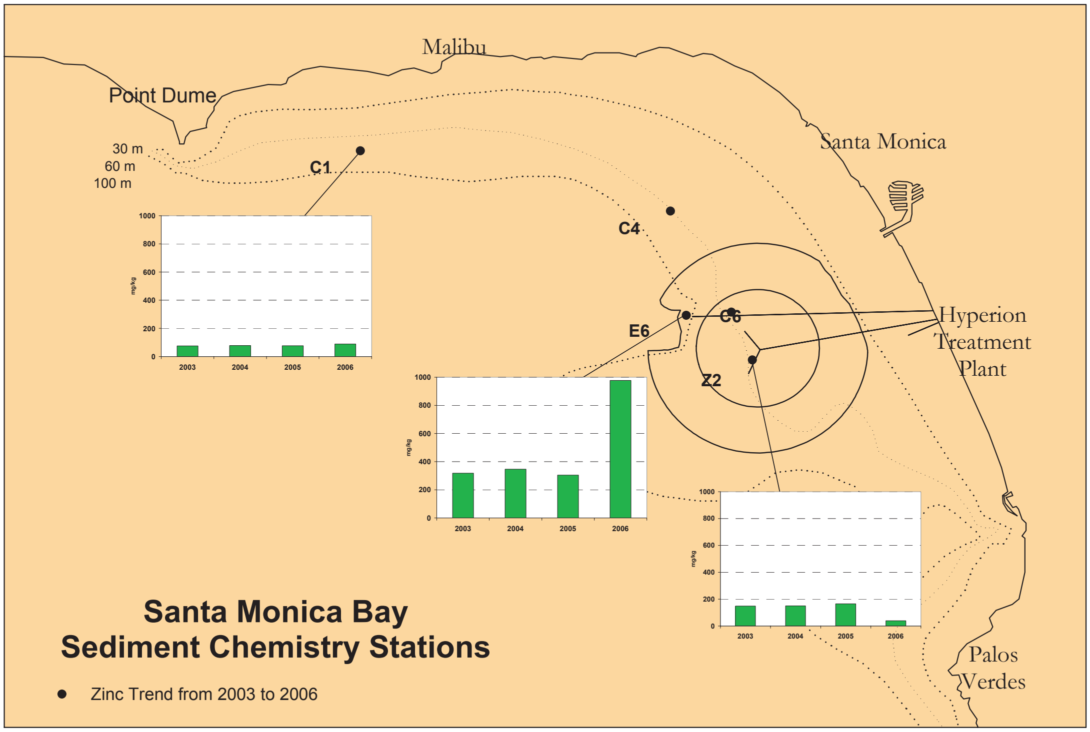

Figure 4-17. Concentrations (mg/kg) of zinc in sediment at E6 (7-Mile), Z2 (5-Mile), and northern reference site (C1) from 2003 to 2006.

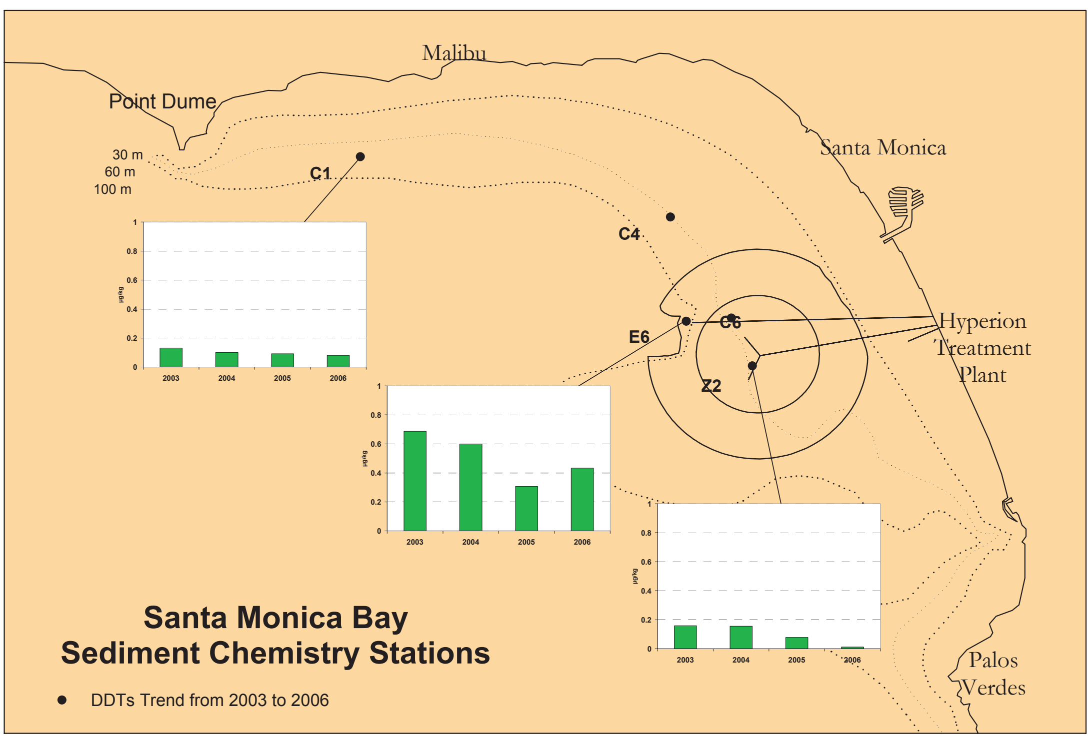

Figure 4-18. Concentrations (µg/kg) of Total DDTs in sediment at E6 (7-Mile), Z2 (5-Mile), and northern reference site (C1) from 2003 to 2006.

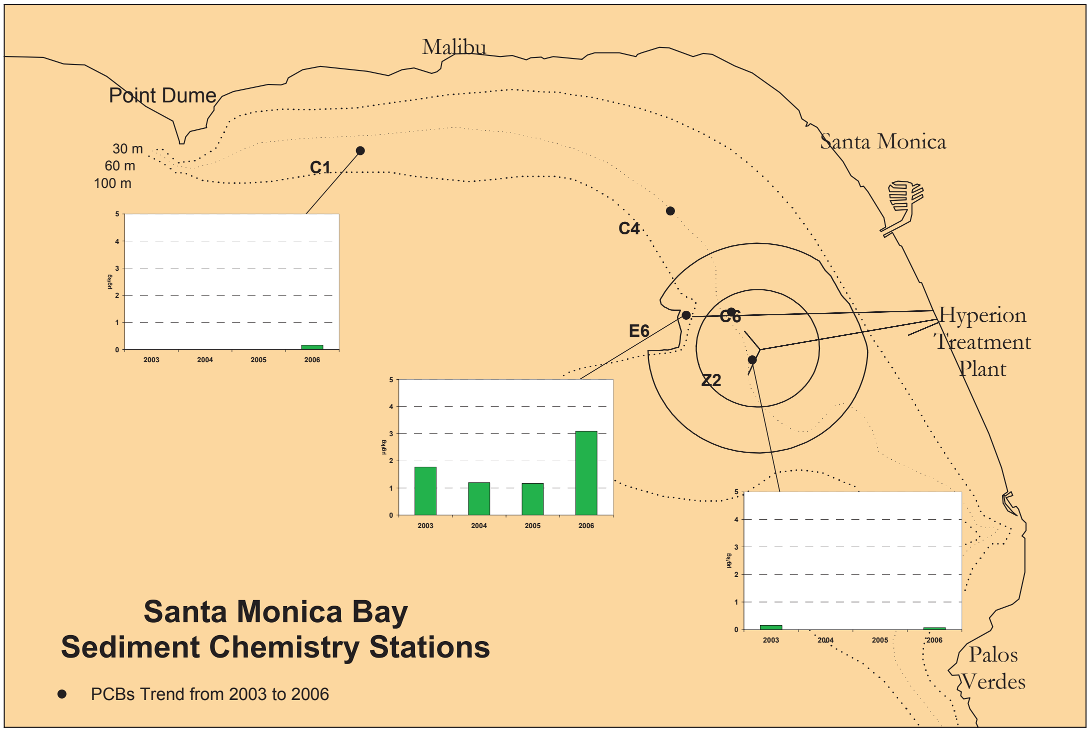

Figure 4-19. Concentrations (μg/kg) of Total PCBs in sediment at E6 (7-Mile), Z2 (5-Mile), and northern reference site (C1) from 2003 to 2006.

chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), silver (Ag), and zinc (Zn) at stations C1, Z2 (5-Mile), and E6 (7-Mile) during the last four years (from 2003 to 2006). Stations C1, Z2, and E6 were retained during the Bight'03 survey to maintain the continuity with historical data. Station C1 is a reference site. The levels of all nine metals at station E6 (in the vicinity of the 7-Mile outfall) remain high compared with the levels at stations C1 and Z2.

At station E6, the concentrations of all nine metals varied slightly from 2003 to 2005; however, a sharp increase in concentration levels for all metals occurred from 2005 to 2006. The concentrations of Cd, Pb, Hg, Ag, and Zn detected in 2006 were almost three times higher than they were in 2005. In 2006, the concentration levels of Cr, Cu, and Ni were twice as high as the concentrations detected in 2005.

The concentration of all nine metals at Z2 (5-Mile outfall) followed a decreasing trend from 2003 to 2006. The decline was especially noticeable from 2005 to 2006.

The trend of total DDTs and total PCBs from 2003 to 2006 at stations C1, Z2, and E6 is shown in Figure 4-18 and Figure 4-19. The highest levels of total DDTs levels were detected at E6. At station E6, the DDTs levels decreased from 2003 to 2005 then increased slightly in 2006. The DDTs levels of Z2 followed a decreasing trend from 2003 to 2006.

DISCUSSION

Santa Monica Bay is a semi-enclosed shelf, located centrally in the Southern California Bight; whereas the majority of the Bight coastline is an exposed narrow shelf (Hickey 1992). The currents are more complex than those found elsewhere along the west coast due to the complicated basin topography. The currents and topographic features affect the

Table 4-3. Contaminant levels at outfall and reference sites. Concentrations (mg/kg for metals: µg/kg for organics) normalized against sediment fine grains.

	Outfall Sites								Reference Sites	
Contaminants	**7-Mile (E6)**				**5-Mile (Z2)**				**C1***	**Dana Point****
	2003	**2004**	**2005**	**2006**	**2003**	**2004**	**2005**	**2006**	**2005-2006**	**1988**
As	7.22	13.6	14.7	18.8	3.84	11.0	11.7	4.03	3.64	29.8
Cd	11.3	11.0	14.8	48.5	2.48	3.06	8.02	1.96	3.82	1.37
Cr	321	345	294	675	128	143	134	29.1	59.2	141
Cu	327	386	331	732	84.2	87.2	83.0	14.4	20.0	30.2
Pb	77.0	82.9	86.3	231	25.3	43.2	29.4	4.86	11.2	51.4
Hg	2.28	2.26	2.90	9.80	0.77	0.54	0.48	0.10	0.15	0.63
Ni	48.2	59.2	49.8	129	32.0	36.4	35.9	9.4	30.4	25.5
Ag	15.4	26.5	27.8	72.9	3.49	7.30	5.81	ND	0.23	1.87
Zn	318	347	304	978	149	163	166	39.6	82.9	169
S^{-2} (mg/L)	2.01	27.1	1.06	1.90	ND	0.06	0.12	0.11	0.02	NA
4,4'-DDD	32.8	32.4	ND	ND	ND	ND	ND	ND	4.72	NA
2,4'-DDE	52.4	ND	19.3	ND	36.5	ND	15.5	ND	11.8	NA
4,4'-DDE	440	568	287	434	110	86.3	62.5	11.8	70.2	NA
Total DDT	687	600	307	434	159	86.3	77.9	11.8	86.8	NA
Total PCB	1770	1200	1170	3090	153	ND	ND	71.4	79.0	20.27

***: Average of 2005 and 2006 concentrations**
****: 1984-87 Reference site survey (NOAA 1988)**
ND = Not detected
NA = Not available

dispersion and transport of the particles discharged in the wastewater to the ocean and causes the fluctuations of sediment quality between years.

For the summer 2005 and 2006 Santa Monica Bay surveys, sediment around the 7-Mile outfall (station E6) had elevated levels of metals and DDT derivatives (Figures 4-9 to 4-18). Compared with the reference site in station C1, concentrations of most of these outfall contaminants were several fold higher in sediments near the 5-Mile site (Z2) and one to two orders of magnitude higher at station E6, located at the terminus of the 7-Mile outfall (Table 4-3). Elevated concentrations of these pollutants around the outfalls are expected because of their affiliation with effluent particles (Katz and Kaplan 1981). The sediment metal data at 7-Mile outfall in 2006 was substantially higher for all nine metals than in previous years (Table 4-3). In addition to the outfall areas, the derivatives of DDT, mainly p,p'-DDE and PCBs were concentrated in the southern Bay (Station C9a). This is consistent with the northward transport of these organic compounds from the Palos Verdes Shelf (Mearns and Young 1983) and dumpsites in the San Pedro Basin (Venkatesan *et al.* 1996).

Chen et al. (1974) reported that metals, absorbed onto effluent particles, were concentrated in sediments near outfalls. In 2005 and 2006 surveys, metal pollutants were widely distributed, but somewhat more concentrated at the 7-Mile and 5-Mile outfall sites (stations E6 and Z2), similar to the distribution of TOC. Many of these metals occur in the dissolved state in Hyperion's wastewater (Chen et al. 1974; EMD, unpublished data), thus accounting for their wide distribution in the Bay. Additionally, these metals could be introduced into the Bay from

Table 4-4a. Concentration of metals and organic pollutants detected in sediments of Santa Monica Bay, summer 2005, with comparison to Effective Levels* (ER-L and ER-M). Concentrations in dry weight. Unit = mg/kg.

PRIORITY POLLUTANTS	NO. STATIONS DETECTED	SANTA MONICA BAY Average*	5-MILE	ER-L**	ER-M**
Metals					
Arsenic	8	10.2	11.7	8.2	70.0
Cadmium	8	6.71	8.02	1.2	9.6
Chromium	8	115	134	81.0	370
Copper	8	78.4	83.0	34.0	270
Mercury	8	0.648	0.476	0.15	0.7
Lead	8	30.3	29.4	46.7	218
Nickel	8	29.3	35.9	20.9	51.6
Silver	8	5.24	5.81	1.0	3.7
Zinc	8	134	166	150	410
Pesticides and PCBs					
Total DDTs	8	0.144	0.078	0.0016	0.0461
Total PCBs	2	0.159	ND	0.0227	0.180

ND = Not Detected; Total DDTs = Sum of detected DDT derivatives; Total PCBs = Sum of detected PCB Aroclors
*Average of 8 stations. These numbers include the stations with <20% silt+clay. Concentrations below detection limit were taken as zero. For 5-Mile, data of outfall station Z2 was used.
** Source: Long et.al. (1995)

other sources including aerial fallout, storm drains, and other outfalls. The aerial deposition of trace metals on Santa Monica Bay was estimated as: Cr = 0.19 tons/yr; Cu = 1.28 tons/yr; Pb = 0.98 tons/yr; Ni = 0.68 tons/yr; and Zn = 4.65 tons/yr (Lu *et al.* 2003).

To assess the sediment quality of Santa Monica Bay, levels of metals, DDTs, and PCBs in the sediments were compared with the Effective Range-Low (ER-L) and the Effective Range-Median (ER-M) values derived from the cause-and-effect relationship between the observed toxicity and the individual contaminant (Long *et al.* 1995). A concentration below ER-L means adverse effects rarely occur and a concentration above ER-M means adverse effects frequently occur.

In the 2005 survey (Table 4-4a), the average concentrations of all metals (except silver) at all stations, including the 5-mile outfall site, was below their ER-M values. Except lead and zinc, the average concentrations of all metal pollutants at these stations exceeded ER-L values. Only the level of lead was lower than its respective ER-L values at the 5-Mile station.

In the 2006 summer survey (Table 4-4b), except for cadmium, mercury, and silver, the average concentrations of all metals in sediment samples from all nine stations (including the 5-Mile and 7-Mile Outfall stations) were below their respective ER-M values. The average metal concentrations, except lead, across all nine SMB sediment stations were above their respective ER-Ls. The sediment concentrations of all metals, except cadmium, at 5-Mile were below their respective ER-L values.

The average concentrations of DDTs across all 8 stations and at the 5-Mile station exceeded their respective ER-L and ER-M values in the summer survey of 2005. The average concentrations of PCBs were lower than the ER-M but exceeded ER-L values.

In the summer survey of 2006, the average concentrations of total DDTs and PCBs in the Santa Monica Bay sediments were above their respective ER-L and the ER-M values. However, the concentration of total DDTs and PCBs at 5-Mile

Table 4-4b. Concentration of metals and organic pollutants detected in sediments of Santa Monica Bay, summer 2006, with comparison to Effective Levels* (ER-L and ER-M). Concentrations in dry weight. Unit = mg/kg.

PRIORITY POLLUTANTS	NO. STATIONS DETECTED	SANTA MONICA BAY Average*	5-MILE	ER-L**	ER-M**
Metals					
Arsenic	9	10.6	4.03	8.2	70.0
Cadmium	9	10.7	1.96	1.2	9.6
Chromium	9	175	29.1	81.0	370
Copper	9	125	14.4	34.0	270
Mercury	9	1.53	0.1	0.15	0.7
Lead	9	42.5	4.86	46.7	218
Nickel	9	42.6	9.4	20.9	51.6
Silver	9	12.5	ND	1.0	3.7
Zinc	9	222	39.6	150	410
Pesticides and PCBs					
Total DDTs	9	0.162	0.012	0.0016	0.0461
Total PCBs	8	0.599	0.071	0.0227	0.180

ND = Not Detected; Total DDTs = Sum of detected DDT derivatives; Total PCBs = Sum of detected PCB Aroclors
*Average of 9 stations. These numbers include the stations with <20% silt+clay. Concentrations below detection limit were taken as zero. For 5-Mile, data of outfall station Z2 was used.
** Source: Long et.al. (1995)

was below the ER-M but above the ER-L values.

Based on their concentrations with respect to ER-L and ER-M, metals are expected to have low biological impact on benthic organisms at the 5-Mile and sampled SMB sites but total DDT and PCB are expected to have some biological impacts (Tables 4-4a and 4-4b).

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