# Chapter 4. Sediment Characteristics

## INTRODUCTION

Sediment conditions can influence the distribution of benthic invertebrates by affecting the ability of various species to burrow, build tubes or feed (Gray 1981, Snelgrove and Butman 1994). In addition, many demersal fishes are associated with specific sediment types that reflect the habitats of their preferred prey (Cross and Allen 1993). Both natural and anthropogenic processes affect the distribution, stability and composition of sediments.

Natural factors that affect the distribution and stability of sediments on the continental shelf include bottom currents, wave exposure, the presence and abundance of calcareous organisms, and proximity to river mouths, sandy beaches, submarine basins, canyons and hills (Emery 1960). The analysis of various sediment parameters (e.g., particle size, sorting coefficient, percentages of sand, silt, and clay) can provide useful information relevant to the amount of wave action, current velocity, and sediment stability in an area.

The chemical composition of sediments can be affected by the geological history of an area. For example, sediment erosion from cliffs and shores, and sediment laden discharge from bays, rivers, and streams contribute metals and sedimentary detritus to a given area (Emery 1960). In addition, the organic content of sediments is greatly affected by primary productivity in nearshore waters, as well as terrestrial plant debris released from bays, estuaries, and rivers (Mann 1982, Parsons et al. 1990). Finally, concentrations of various constituents within sediments are often influenced by sediment particle size. For example, the levels of organic materials and trace metals within ocean sediments generally rise with increasing amounts of fine particles (Emery 1960, Eganhouse and Vanketesan 1993).

Ocean wastewater outfalls are one of many anthropogenic factors that can directly influence the composition and distribution of sediments through the discharge and deposition of a wide variety of organic and inorganic compounds. Some of the most commonly detected compounds in municipal wastewater discharges include various organic compounds (e.g., organic carbon, nitrogen, and sulfide compounds), trace metals, and pesticides (Anderson et al. 1993). Additionally, the physical structure of the outfall pipe can alter the hydrodynamic regime and subsequently substrate composition in the immediate area (see Shepard 1973).

This chapter presents summaries and analyses of sediment grain size and chemistry data collected during 2004 in the vicinity of the City of San Diego's Point Loma Ocean Outfall (PLOO). The major goals are to assess any impact of wastewater discharged through the outfall on sediment quality in the region. Included are analyses of the spatial and temporal patterns of the various sediment grain size and chemistry parameters in an effort to determine the presence of sedimentary and chemical footprints near the discharge site.

## MATERIALS AND METHODS

### Field Sampling

Sediment samples were collected during January 2004 at 22 stations surrounding the PLOO (**Figure 4.1**). These stations span the terminus of the outfall and are located along the 88, 98, and 116-m depth contours. The 17 "E" stations are located within 8 km of the outfall, while the five "B" stations are located greater than 11 km from the discharge site. In July, the sampling was limited to the 12 primary core stations along the 98-m contour due to participation in special strategic process studies as determined by the City in coordination with the

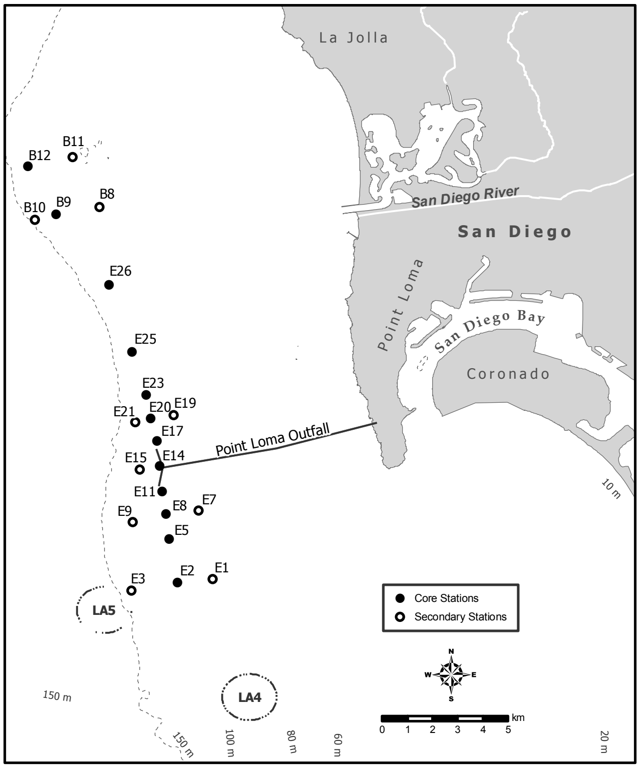



**Figure 4.1**
Benthic stations surrounding the City of San Diego's Point Loma Ocean Outfall. Core stations (filled circles) were sampled in January and July 2004. Secondary stations (open circles) were sampled July 2004.

Executive Officer of the RWQCB and the USEPA (City of San Diego 2005a).

Benthic sediment samples were collected using a modified 0.1-m$^2$ chain-rigged van Veen grab (see City of San Diego in prep). Sub-samples were taken from the top two cm of the sediment surface and handled according to United States Environmental Protection Agency guidelines (USEPA 1987).

### Laboratory Analyses

All sediment chemistry and grain size analyses were performed at the City of San Diego's Wastewater Chemistry Laboratory (see City of San Diego 2005b). Particle size analysis was performed using a Horiba LA-920 laser scattering particle analyzer, which measures particles ranging in size from -1 to 11 phi (i.e., 0.00049–2.0 mm; sand, silt, and clay fractions). Coarser sediments (e.g., very coarse sand, gravel, shell hash) were removed prior to analysis by screening the samples through a 2.0 mm mesh sieve. These data were expressed as the percent "Coarse" of the total sample sieved.

A more sensitive ICP-AES (Inductively Coupled Plasma Atomic Emission Spectrometry) technique for analysis of metals was introduced mid-year of 2003. An IRIS axial ICP-AES system replaced the Atomscan radial ICP-AES. The superior abilities of the IRIS axial ICP-AES lowered the method detection limits by approximately an order of magnitude. Consequently, low concentrations of metals that would not have been detected in previous surveys were detected during July 2003 and all subsequent surveys.

### Data Analyses

The data output from the Horiba particle size analyzer was categorized as follows: sand was defined as particles ranging in size from <2 to 62.5 mm, silt as particles from < 62.5 to 0.0039 mm, and clay as particles < 0.0039 mm (see **Table 4.1**). These data were standardized and incorporated with a sieved coarse fraction containing particles >2.0 mm in diameter to obtain a distribution of coarse, sand, silt, and clay fractions totaling 100%. The coarse fraction was included with the phi -1 fraction in the calculation of various particle size parameters, using a normal probability scale (see Folk 1968). These parameters included mean and median phi size, standard deviation of phi size (sorting coefficient), skewness, kurtosis, and percent sediment type (coarse materials, sand, silt, clay).

Chemical parameters analyzed were total organic carbon (TOC), total nitrogen, total sulfides, trace metals, chlorinated pesticides, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyl compounds (PCBs) (**see Appendix B.1**). Prior to analysis, these data were generally limited to values above the method detection level (MDL). In addition, some parameters were determined to be present in a sample with high confidence (i.e., peaks are confirmed by mass-spectrometry) but at levels below the MDL. These

## Table 4.1

A subset of the Wentworth scale representative of the sediments encountered in the PLOO region. Particle size is presented in phi, microns, and millimeters along with the conversion algorithms. The sorting coefficients (standard deviation in phi units) are based on categories described by Folk (1968).

| Wentworth Scale | | | | Sorting Coefficient | |
|---|---|---|---|---|---|
| Phi Size | Microns | Millimeters | Description | Standard Deviation | Sorting |
| -2 | 4000 | 4.000 | Pebble | Under 0.35 phi | very well sorted |
| -1 | 2000 | 2.000 | Granule | 0.35–0.50 phi | well sorted |
| 0 | 1000 | 1.000 | Very coarse sand | 0.51–0.70 phi | moderately well sorted |
| 1 | 500 | 0.500 | Coarse sand | 0.71–1.00 phi | moderately sorted |
| 2 | 250 | 0.250 | Medium sand | 1.01–2.00 phi | poorly sorted |
| 3 | 125 | 0.125 | Fine sand | 2.01–4.00 phi | very poorly sorted |
| 4 | 62.5 | 0.063 | Very fine sand | Over 4.00 phi | extremely poorly sorted |
| 5 | 31 | 0.031 | Coarse silt | | |

Conversions for Diameter in Phi to Millimeters: $D(mm) = 2^{-phi}$

Conversions for Diameter in Millimeters to Phi: D(phi) = -3.3219log10D(mm)

were included in the data as estimated values. Any null or "not detected" value was treated as a zero when performing statistical analysis or estimating overall means for the survey area.

Values for metals, TOC, TN, and pesticides (i.e., DDE) were compared to median values for the Southern California Bight. These bight-wide values were based on the cumulative distribution function (CDF) for each parameter (see Schiff and Gossett 1998) and are presented as the 50% CDF in the tables included herein. Levels of sediment contamination were further evaluated by comparing the results of this study to the available Effects Range Low (ERL) sediment quality guidelines of Long et al. (1995). The ERL represents chemical concentrations below which adverse biological effects were rarely observed.

## RESULTS AND DISCUSSION

### Particle Size Distribution

During 2004, ocean sediments off Point Loma were composed predominantly of very fine sand and coarse silt with a mean particle size of 0.068 mm or 3.9 phi (**Table 4.2**). Fine sediments (silt and clay fractions combined) averaged about 37% of the sediments overall, while sands accounted for 60%. Coarser materials such as shell hash and gravel comprised the remaining 3%. The sorting coefficients (standard deviation) were greater than 1.0 phi at every station, indicating that sediments within the survey area were poorly sorted (i.e., consisted of particles of varied sizes; see Table 4.1). This result reflects the multiple origins of sediments in the region (see Emery 1960), and suggests that these sites are subject to slow moving currents or reduced water motion (Gray 1981).

Sediments at most stations had particle sizes averaging between 0.05 and 0.09 mm in diameter (**Figure 4.2**). Sediments were coarsest (mean >0.09 mm) at northern reference station B12, station E3 near the LA-5 dredge disposal site, and station E9 southwest of the PLOO. The finest sediments (mean <0.05 mm) were found at just two stations (B8 and E7) located along the shallower 88-m depth contour. The coarser sediments at station B12 may be partially related to its location along the outer shelf edge where strong currents and internal waves export fine sediments down the slope and leave shell hash and larger particles behind (see Shepard and Marshall 1978, Heathershaw et al. 1987, Boczar-Karakiewicz et al. 1991). The sediments at stations E3 and E9 were generally composed of varying amounts of sandy materials likely related to their location between the LA-5 disposal site and the PLOO. Evidence that the main disposal mound has dispersed into areas outside the boundaries of LA-

## Table 4.2

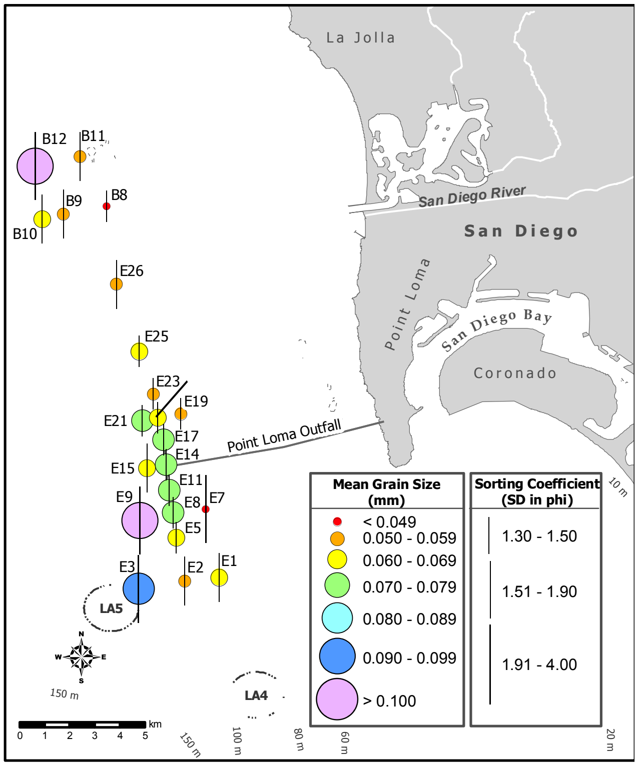
Summary of particle size parameters and organic loading indicators at PLOO stations during 2004. Data are expressed as annual means; n=2 for the core stations indicated in bold type; n=1 for all others. CDF=cumulative distribution functions (see text); NA=not analyzed. MDL=method detection limit. Area Mean=area mean for 2004. Values that exceed the median CDF are indicated in bold type.

| | | Particle Size | | | | | | Organic Indicators | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | Depth | Mean phi | Mean mm | SD phi | Coarse % | Sand % | Fines % | BOD mg/L | Sulfides ppm | TN WT% | TOC WT% | TVS WT% |
| *North reference stations* | | | | | | | | | | | | |
| B-11 | 88 | 4.2 | 0.056 | 1.9 | 3.7 | 49.5 | 46.8 | 390 | 1.1 | **0.087** | **0.891** | 4.47 |
| B-8 | 88 | 4.6 | 0.041 | 1.5 | 0.1 | 42.1 | 57.8 | 326 | 1.1 | **0.086** | **0.800** | 3.27 |
| **B-12** | 98 | 3.1 | 0.125 | 2.5 | 10.8 | 59.5 | 28.2 | 653 | 11.0 | **0.055** | **1.176** | 3.08 |
| **B-9** | 98 | 4.1 | 0.055 | 1.6 | 1.1 | 57.5 | 41.3 | 300 | 0.6 | **0.060** | 0.556 | 2.81 |
| B-10 | 116 | 4.0 | 0.062 | 1.8 | 0.5 | 68.2 | 28.1 | 337 | 1.0 | **0.066** | 0.542 | 3.02 |
| *Stations north of the outfall* | | | | | | | | | | | | |
| E-19 | 88 | 4.3 | 0.051 | 1.5 | 0.2 | 52.7 | 47.1 | 277 | 21.6 | **0.063** | 0.587 | 2.72 |
| **E-20** | 98 | 3.9 | 0.063 | 1.4 | 0.2 | 64.0 | 35.7 | 243 | 1.3 | **0.052** | 0.461 | 2.17 |
| **E-23** | 98 | 4.1 | 0.055 | 1.5 | 0.2 | 59.0 | 40.7 | 353 | 1.0 | **0.056** | 0.572 | 2.23 |
| **E-25** | 98 | 4.0 | 0.059 | 1.4 | 0.8 | 60.1 | 39.1 | 280 | 1.1 | **0.053** | 0.497 | 2.66 |
| **E-26** | 98 | 4.3 | 0.052 | 1.6 | 0.2 | 56.5 | 43.1 | 327 | 2.2 | **0.062** | 0.566 | 2.64 |
| E-21 | 116 | 3.8 | 0.072 | 1.3 | 0.1 | 70.4 | 29.5 | 188 | 2.0 | 0.039 | 0.350 | 2.07 |
| *Outfall stations* | | | | | | | | | | | | |
| **E-11** | 98 | 3.7 | 0.074 | 1.3 | 0.3 | 69.7 | 29.9 | 328 | 7.2 | 0.047 | 0.410 | 2.04 |
| **E-14** | 98 | 3.8 | 0.070 | 1.4 | 1.5 | 68.2 | 30.2 | 413 | 39.5 | 0.050 | 0.451 | 2.04 |
| **E-17** | 98 | 3.8 | 0.071 | 1.4 | 0.7 | 68.2 | 31.0 | 316 | 6.6 | 0.048 | 0.431 | 1.90 |
| E-15 | 116 | 4.0 | 0.064 | 1.6 | 0.8 | 67.2 | 32.0 | 304 | 2.7 | **0.052** | 0.478 | 2.46 |
| *Stations south of the outfall* | | | | | | | | | | | | |
| E-1 | 88 | 4.0 | 0.062 | 1.6 | 0.4 | 61.7 | 37.3 | 267 | 2.1 | 0.050 | 0.467 | 2.20 |
| E-7 | 88 | 4.6 | 0.042 | 2.4 | 0.0 | 49.3 | 45.7 | 279 | 1.0 | 0.043 | 0.413 | 2.43 |
| **E-2** | 98 | 4.2 | 0.056 | 1.8 | 2.5 | 52.5 | 44.9 | 293 | 5.4 | **0.076** | **0.719** | 2.52 |
| **E-5** | 98 | 3.9 | 0.065 | 1.5 | 0.3 | 65.3 | 34.2 | 231 | 2.0 | 0.046 | 0.417 | 2.09 |
| **E-8** | 98 | 3.8 | 0.070 | 1.3 | 0.3 | 68.1 | 31.5 | 226 | 0.9 | 0.043 | 0.380 | 2.00 |
| E-3 | 116 | 3.4 | 0.097 | 2.9 | 16.0 | 52.1 | 27.4 | 222 | 0.8 | 0.033 | 0.308 | 1.87 |
| E-9 | 116 | 3.1 | 0.120 | 4.0 | 26.9 | 36.2 | 31.9 | 231 | 0.4 | 0.049 | 0.456 | 2.12 |
| **Area Mean** | | 3.9 | 0.068 | 1.7 | 2.5 | 60.2 | 36.6 | 316 | 5.6 | 0.055 | 0.546 | 2.44 |
| **MDL** | | | | | | | | 2 | 0.14 | 0.005 | 0.010 | 0.11 |
| **50% CDF** | | | | | | | | NA | NA | 0.050 | 0.597 | NA |

5 have been previously detected by the United States Geological Survey (Gardner et al. 1998**; Figure 4.3**). Additionally, visual examination and observations of the field samples collected at several outfall stations have occasionally revealed the presence of coarse, black sand that was used as stabilizing material for the outfall pipe (see **Appendix B.2**). During 2004, this type of black sand was regularly present at s tations south and east of the outfall (i.e., E14, E8, E9, E11, E15) indicating the potential spread of this ballast material.

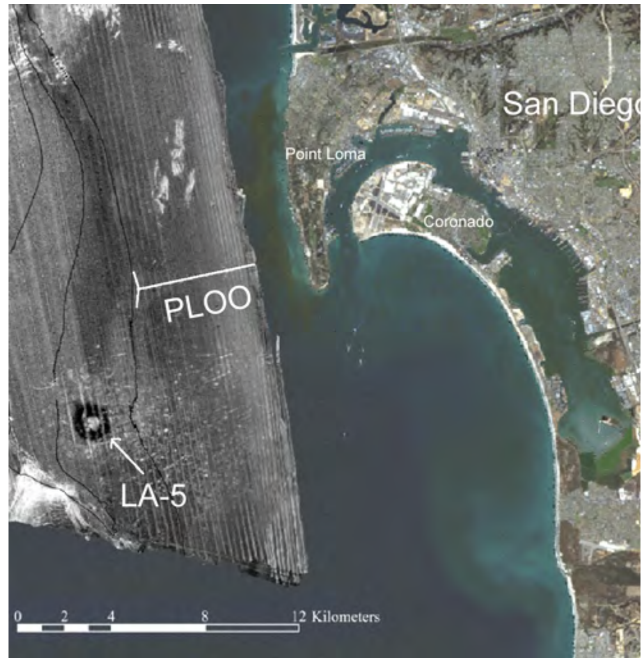
### Organic Indicators

Generally, the distribution of organic indicators in PLOO sediments during 2004 was similar to patterns seen prior to discharge (see City of San Diego 1995). The highest concentrations of biochemical oxygen demand (BOD), total nitrogen, total organic carbon (TOC), and total volatile solids were generally found north of the PLOO at stations that contained higher percentages




## Figure 4.2

Particle size distribution for sediment chemistry stations during 2004. n=2 for the core stations (see text); n=1 for all others. Mean particle size is based on diameter in millimeters, and sorting coefficient (standard deviation) is in phi units.




## Figure 4.3

The LA-5 dredge disposal site shown as an acoustic backscatter image superimposed on a Landsat-7 satellite land image of San Diego (USGS 1998). Lighter areas represent harder (more dense) substrates.

of fine particles (Table 4.2). Station B12 was an exception to this general pattern. It had the highest BOD (653 mg/L) and TOC (1.175 %), but as in several past surveys, had the coarsest sediments. The highest sulfide concentrations were found at station E14 (39.5 ppm) along with the second highest concentration of BOD (413 mg/L).

### Trace Metals

Aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, tin, and zinc were frequently detected at concentrations above their MDL in the sediments off Point Loma (**Table 4.3**). Silver occurred in concentrations that were often below their MDL, while selenium occured at one sute and thallium was not detected at any station.

Overall concentrations of the 17 frequently detected trace metals were less than the median values for the Southern California Bight (50% CDF) and well below ERL levels. Despite these generally low values sediments at six stations included three or more metals whose concentrations were higher than the median CDF. These included several northern stations (i.e., B8, B9, B11, B12), station E26 located between the outfall and the north reference stations, and station E2 located east of the LA-5 disposal site. Station B12 has historically contained some of the highest concentrations of metals as well the coarsest sediments in the PLOO survey area. This is possibly related to differences in geological origin of the sediments at this site. In contrast to the 28% fines at station B12, stations B8, B9, B11, E26, and E2 contained sediments consisting of >40% fine particles. In addition to the high percentage of fine particles, the deposition of metals-laden sediments dredged from San Diego Bay likely contributes to the elevated metal concentrations at station E2 (see City of San Diego 2003c). Metal concentrations were generally low at the stations near the outfall (E11, E14, E15, and E17). Overall, trace metal concentrations increased with increasing proportions of fine particles, and there

## Table 4.3

Concentrations of trace metals (parts per million) detected at each PLOO station during 2004; n=2 for the primary core stations indicated in bold type; n=1 for all others. CDF=cumulative distribution function (see text). MDL=method detection limit. ERL=Effects Range Low Threshold Value. NA=not available. Values that exceed the median CDF are indicated in bold type. The names of each trace metal represented by the periodic table symbol are presented in Appendix B.1.

| Station | Depth | Al | Sb | As | Ba | Be | Cd | Cr | Cu | Fe | Pb | Mn | Hg | Ni | Se | Ag | Sn | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *North reference stations* | | | | | | | | | | | | | | | | | | |
| B-11 | 88 | **10000** | **1.1** | 4.2 | 51.9 | 0.25 | **0.38** | 23.9 | 8.5 | **18000** | 7.62 | 115.0 | **0.050** | 9.6 | nd | 0.12 | 1.64 | 42.1 |
| B-8 | 88 | **10000** | **0.9** | 3.7 | 54.4 | 0.21 | 0.12 | 21.3 | 9.9 | 15200 | 8.20 | 116.0 | **0.047** | 9.4 | 0.25 | 0.05 | 1.98 | 38.4 |
| **B-12** | 98 | 8865 | **0.5** | 4.5 | 29.5 | **0.33** | 0.19 | 29.1 | 6.0 | **23400** | 6.55 | 123.7 | 0.021 | 6.8 | nd | 0.03 | 0.85 | 41.2 |
| **B-9** | 98 | **12645** | **0.9** | 3.7 | 99.0 | **0.29** | 0.10 | 25.4 | 7.1 | **18950** | 5.51 | 183.4 | 0.032 | 8.0 | nd | 0.02 | 2.08 | 40.5 |
| B-10 | 116 | 7450 | **0.7** | 2.4 | 28.5 | 0.19 | **0.33** | 19.1 | 5.5 | 12700 | 5.33 | 75.4 | 0.022 | 6.3 | nd | 0.08 | 1.59 | 31.1 |
| *Stations north of the outfall* | | | | | | | | | | | | | | | | | | |
| E-19 | 88 | **10400** | **1.1** | 2.7 | 50.5 | 0.18 | 0.15 | 19.1 | 8.2 | 12600 | 6.20 | 110.0 | 0.038 | 8.6 | nd | nd | 2.34 | 34.6 |
| **E-20** | 98 | **10605** | **0.6** | 3.2 | 36.6 | 0.19 | 0.12 | 17.6 | 6.3 | 13000 | 5.27 | 160.6 | 0.026 | 7.0 | nd | 0.02 | 1.73 | 30.2 |
| **E-23** | 98 | **13475** | **0.7** | 3.0 | 44.4 | 0.23 | 0.13 | 20.7 | 7.1 | 14750 | 4.92 | 194.1 | 0.029 | 7.9 | nd | 0.02 | 2.12 | 34.6 |
| **E-25** | 98 | **13140** | **0.6** | 2.9 | 42.2 | 0.23 | 0.13 | 20.7 | 7.2 | 14600 | 5.15 | 191.6 | 0.025 | 8.1 | nd | nd | 1.89 | 34.2 |
| **E-26** | 98 | **12480** | **0.5** | 2.8 | 42.6 | 0.23 | 0.14 | 20.5 | 8.1 | 15000 | 5.62 | 175.6 | 0.**041** | 8.5 | nd | 0.11 | 2.11 | 35.1 |
| E-21 | 116 | 5710 | **0.5** | 2.6 | 26.3 | 0.14 | 0.12 | 13.0 | 5.2 | 8270 | 4.85 | 68.7 | 0.024 | 5.8 | nd | 0.07 | 1.34 | 23.1 |
| *Outfall stations* | | | | | | | | | | | | | | | | | | |
| **E-11** | 98 | 8945 | **0.3** | 2.8 | 29.6 | 0.18 | 0.12 | 15.6 | 5.4 | 11655 | 4.34 | 151.3 | 0.022 | 6.1 | nd | 0.05 | 1.59 | 26.8 |
| **E-14** | 98 | 7650 | **0.3** | 3.3 | 33.0 | 0.16 | 0.13 | 15.3 | 6.8 | 10640 | 4.53 | 114.7 | 0.028 | 6.6 | nd | 0.06 | 1.34 | 26.1 |
| **E-17** | 98 | **11540** | **0.4** | 2.6 | 34.3 | 0.21 | 0.14 | 18.2 | 6.1 | 13950 | 4.16 | 197.3 | 0.026 | 6.7 | nd | 0.12 | 2.03 | 30.4 |
| E-15 | 116 | 6800 | **0.7** | 2.5 | 27.3 | 0.16 | 0.12 | 15.0 | 6.4 | 9600 | 5.27 | 74.7 | 0.030 | 6.5 | nd | 0.03 | 1.71 | 24.6 |
| *Stations south of the outfall* | | | | | | | | | | | | | | | | | | |
| E-1 | 88 | 8100 | **0.8** | 2.6 | 40.9 | 0.16 | 0.11 | 17.0 | 8.4 | 10300 | 6.80 | 84.9 | **0.049** | 7.6 | nd | 0.05 | 1.72 | 28.6 |
| E-7 | 88 | 8010 | **0.7** | 3.7 | 40.4 | 0.16 | 0.12 | 18.5 | 7.3 | 11500 | 6.09 | 91.5 | 0.034 | 8.6 | nd | 0.06 | 1.67 | 28.9 |
| **E-2** | 98 | **17000** | **1.1** | 2.6 | 74.6 | **0.27** | 0.13 | 22.8 | 13.2 | **19500** | 7.46 | 217.5 | **0.056** | 8.6 | nd | nd | 2.35 | 44.6 |
| **E-5** | 98 | **9960** | **0.3** | 2.6 | 36.1 | 0.19 | 0.11 | 16.0 | 7.2 | 12450 | 4.69 | 131.4 | 0.032 | 6.4 | nd | 0.05 | 1.66 | 27.6 |
| E-8 | 98 | **9730** | **0.5** | 2.6 | 32.1 | 0.19 | 0.11 | 16.6 | 6.5 | 11755 | 4.60 | 139.2 | 0.037 | 6.4 | nd | 0.01 | 1.81 | 28.2 |
| **E-3** | 116 | 8520 | **0.7** | 2.2 | 48.5 | 0.14 | 0.08 | 14.6 | 10.2 | 12200 | 6.94 | 99.9 | **0.056** | 5.2 | nd | nd | 1.52 | 30.7 |
| E-9 | 116 | 6150 | **0.7** | 3.5 | 27.5 | 0.17 | 0.09 | 17.8 | 9.0 | 10800 | 6.22 | 66.6 | 0.030 | 6.2 | nd | 0.05 | 1.58 | 32.9 |
| **MDL** | | 1.15 | 0.13 | 0.33 | 0.002 | 0.001 | 0.01 | 0.016 | 0.028 | 0.75 | 0.142 | 0.004 | 0.003 | 0.036 | 0.24 | 0.013 | 0.059 | 0.052 |
| **50% CDF** | | 9400 | 0.2 | 4.80 | NA | 0.26 | 0.29 | 34.0 | 12.0 | 16800 | NA | NA | 0.040 | NA | 0.29 | 0.17 | NA | 56.0 |
| **ERL** | | NA | NA | 8.2 | NA | NA | 1.2 | 81 | 34 | NA | 46.7 | NA | 0.2 | 20.9 | NA | 1.0 | NA | 150 |

was no discernable pattern of metal distribution related to proximity to the PLOO.

### Pesticides, PCBs, and PAHs

DDT was detected as its final metabolic degradation product (p,p-DDE) at two stations, and heptachlor epoxide occurred at one station (**Table 4.4**). Heptachlor epoxide occurred in concentrations well below the MDL (5700 ppt) at station E25. DDT was detected at stations E2 and E26. Concentrations of DDT were also below the MDL (3800 ppt for DDE) and well below the median CDF value for total DDT (10,000 ppt). However, the concentration of total-DDT at station E26 was 2750 ppt, which was slightly above the ERL (1580 ppt). Generally, pesticide concentrations appear to result from sources unrelated to the PLOO discharge. For example, total DDT concentrations throughout the study area peaked in 1993, just two years into a seven year period when ten large dredging projects disposed contaminated sediment from San Diego Bay at LA-5 (Steinberger et al. 2003) (see **Figure 4.4**). The decline in DDT values in 2004 relative to prior surveys continues a trend that began in 1996.

Polychlorinated biphenyl compounds (PCBs) were mostly undetected during 2004. The sediments at station E2 contained two congeners, PCB 101 and PCB 110, whose concentrations were equal to their MDLs of 2600 and 2900 ppt, respectively. Total PCB at this station (2750 ppt) was slightly higher than the median CDF of 2600 ppt and well below the ERL of 22,700 ppt (see Table 4.4).

Twenty-one polycyclic aromatic hydrocarbons (PAH) compounds were detected in low concentrations during 2004 (**Appendix B.3**). All total-PAH concentrations from the sampling area were well below the ERL of 4022 ppb, and near or below their respective MDL levels. The detection of low levels of PAHs at all stations appears to reflect a change in methodology where values below method detection limits can be reliably estimated with qualitative identification via a mass spectrophotometer (see Methods and Materials). The highest concentrations of total PAHs were found north of the outfall at station E23 (1583 ppb) and north of the LA-5 dredge materials disposal site at station E9 (1545 ppb). These two stations also had the greatest mix of PAH compounds, 20 and 12 different compounds, respectively. Station E9 is one of four stations (E1, E2, E3, E9) within the survey area where PAHs have been frequently detected (see City of San Diego 2000, 2001, 2002, 2003a–c). PAHs

## Table 4.4

Mean concentrations for pesticides (parts per trillion), total PCBs (parts per trillion), and total PAHs (parts per billion) in PLOO sediments during 2004. MDL=method detection limit. CDF=cumulative distribution function (see text). Undetected values are indicated by "nd." ERL=Effects Range Low Threshold Value. n=2 for the primary core stations indicated in bold type; n=1 for all others.

| Station | Depth | Heptachlor epoxide | Total DDT | Total PCB | Total PAHs |
|---|---|---|---|---|---|
| *North reference stations* | | | | | |
| B11 | 88 | nd | nd | nd | 191 |
| B8 | 88 | nd | nd | nd | 79 |
| **B12** | 98 | nd | nd | nd | 121 |
| **B9** | 98 | nd | nd | nd | 383 |
| B10 | 116 | nd | nd | nd | 65 |
| *Stations north of the outfall* | | | | | |
| E19 | 88 | nd | nd | nd | 171 |
| **E20** | 98 | nd | nd | nd | 162 |
| **E23** | 98 | nd | nd | nd | 1583 |
| **E25** | 98 | 2850 | | nd | 157 |
| **E26** | 98 | nd | 1900 | nd | 171 |
| E21 | 116 | nd | nd | nd | 187 |
| *Outfall stations* | | | | | |
| **E11** | 98 | nd | nd | nd | 114 |
| **E14** | 98 | nd | nd | nd | 109 |
| **E17** | 98 | nd | nd | nd | 240 |
| E15 | 116 | nd | nd | nd | 153 |
| *Stations south of the outfall* | | | | | |
| E1 | 88 | nd | nd | nd | 97 |
| E7 | 88 | nd | nd | nd | 47 |
| **E2** | 98 | nd | 290 | 2750 | 201 |
| **E5** | 98 | nd | nd | nd | 116 |
| **E8** | 98 | nd | nd | nd | 115 |
| E3 | 116 | nd | nd | nd | 73 |
| E9 | 116 | nd | nd | nd | 1545 |
| **MDL** | | 5700 | — | — | — |
| **50% CDF** | | | 10,000 | 2600 | NA |
| **ERL** | | | 1580 | 22700 | 4022 |

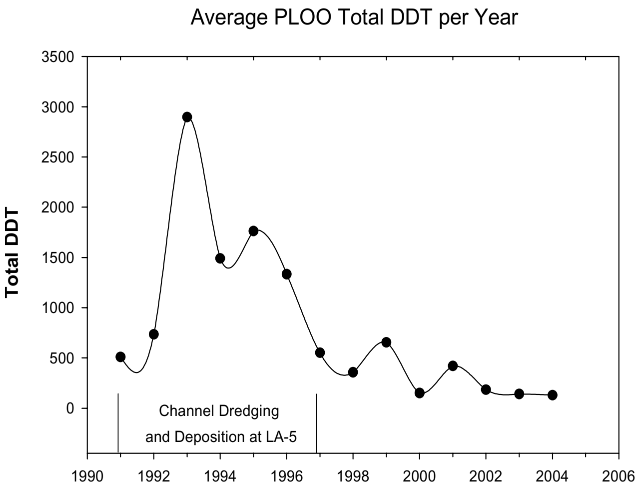



**Figure 4.4**
Changes in average total DDT within the PLOO sampling area are shown for the period 1991–2004. Several channel dredging projects occurred between 1991 and 1997.

at these stations have largely been attributed to misplaced dredge material deposits intended for LA-5 (see Anderson et al. 1993). In addition, low concentrations (≤ 240 ppb) of some PAHs were present at sites near the outfall (i.e., stations E11, E14, E15, E17), but there did not appear to be a pattern of distribution with respect to the outfall.

## SUMMARY AND CONCLUSIONS

Ocean sediments at stations surrounding the PLOO in 2004 consisted primarily of very fine sand and coarse silt with a mean particle size of 0.068 mm (3.9 phi). Area sediments were poorly sorted (i.e., consisting of particles of varied sizes), which suggests that the region was subject to low wave and current activity. Stations containing the finest particles were found along the 88-m contour, while those with the coarsest particles were found along the 98-m and 116-m contours at the northernmost reference site, near the LA-5 dredge disposal site, and a site southwest of the PLOO. Stations near the PLOO contained sand that was more coarse than surrounding sites, and several stations located between the outfall and LA-5 contained variable amounts of ballast sand, coarse particles, and shell hash. Generally, these results reflect multiple anthropogenic (e.g., outfall construction, dredge disposal) and natural influences (e.g., Pleistocene and recent detrital deposits) on the region's sediment composition (Emery 1960).

The distribution of organic indicators in 2004 was very similar to previous surveys. The highest concentrations of BOD, total nitrogen, total carbon, and total volatile solids occurred at sites north of the PLOO, while the highest values for sulfides occurred near the site of discharge at station E14. Stations located south of the outfall and near to the LA-5 disposal site generally had relatively low values of organic indicators.

Seventeen trace metals were frequently detected at concentrations above the MDL, and most of these occurred in concentrations well below median values for the Southern California Bight (50% CDF) and ERL levels. Only aluminum and antimony occurred in concentrations that were frequently above the 50% CDF values. Four northern reference sites, one site north of the PLOO, and one station near the LA-5 disposal site had concentrations of three or more trace metals that exceeded the 50% CDF. Metals associated with industry and antifouling materials were found at stations near LA-5 and may be associated with the disposal of dredged sediments from San Diego Bay (see City of San Diego 2003c). In general, the highest trace metal concentrations occurred at stations with relatively high amounts of fine particles (>40%). This is expected since the accumulation of fine particles generally influences the content of organic materials and metals in sediments (Eganhouse and Venkatesan 1993).

Two pesticides were detected at just three stations during the 2004 sediment surveys. Heptachlor epoxide was found at station E25 north of the PLOO in concentrations below the MDL. DDE, the final metabolic degradation product of DDT, was found west of LA-5 at station E3 and north of the PLOO at station E26. DDE concentrations at both sites were below the MDL; however, the concentration at station E26 was above the ERL sediment quality guideline. In past surveys DDE has shown a more widespread distribution within the PLOO area particularly from 1991 to 1996. Higher DDT levels during this period may have been caused by the dispersion of contaminated sediments into the survey area from the disposal of San Diego Bay dredge materials at LA-5. Even with a change in methodology where values below the MDL can be reliably estimated with qualitative identification, detection of DDE within the survey area was lower than previous years. An analysis of historical data indicates an ongoing reduction in detectable DDT concentrations since 1996.

Values for PAHs and PCBs were generally near or below method detection limits at all sampling sites. A change in methodology for determining values below MDL levels resulted in the detection of PAHs at all stations. The highest concentration was found north of the outfall, while relatively low concentrations were detected at stations surrounding the outfall. The low concentrations near the discharge site are not unexpected since a recent study found that PAHs were not detected in effluents from large municipal wastewater treatment facilities in southern California (Steinberger and Schiff 2003). PAHs and PCBs were found together at only two stations located near the LA-5 dredge materials disposal site (stations E2 and E9). In previous surveys, concentrations of PAHs and PCBs have been higher at these southern stations than elsewhere off San Diego, and are most likely the result of misplaced deposits of dredged material that were originally destined for LA-5. Previous studies have attributed elevated levels of various contaminants such as PAHs, PCBs, trace metals, and DDT in this area to the deposits from LA-5 (see Anderson et al. 1993; City of San Diego 2003c; Steinberger et al. 2003).

## LITERATURE CITED

Anderson, J.W., D.J. Reish, R.B. Spies, M.E. Brady, and E.W. Segelhorst. (1993). Human impacts. In: Dailey, M.D., D.J. Reish, and J.W. Anderson (eds.). Ecology of the Southern California Bight: A Synthesis and Interpretation. University of California Press, Berkeley, CA. p. 682–766.

Boczar-Karakiewicz, B., J.L. Bona, and B. Pelchat. (1991). Sand ridges and internal waves on continental shelves. In: Kraus, N., K. Gingerich, and D. Kriebel, (eds.). Coastal Sediments '91. Vol.1. American Society of Civil Engineers, New York. p. 527–541.

City of San Diego. (1995). Outfall Extension Pre-Construction Monitoring Report (July 1991–October 1992). City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2000). Annual Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 1999. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2001). Annual Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 2000. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2002). Annual Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 2001. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2003a). Annual Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 2002. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental

Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2003b). South Bay Ocean Outfall Annual Report (2002). CCity of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2003c). An Ecological Assessment of San Diego Bay: A Component of the Bight'98 Regional Survey. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2005a). EMTS Division Laboratory Quality Assurance Report, 2004. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2005b). Annual Reports and Summary: Point Loma Wastewater Treatment Plant and Point Loma Ocean Outfall. City of San Diego, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (in prep). EMTS Division Laboratory Quality Assurance Project Plan. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

Cross, J. N., and L. G. Allen. (1993). Fishes. In: Dailey, M.D., D.J. Reish, and J.W. Anderson (eds.). Ecology of the Southern California Bight: A Synthesis and Interpretation. University of California Press, Berkeley, CA. p. 459–540.

Eganhouse, R. P., and M.I. Venkatesan. (1993). Chemical oceanography and geochemistry. In: Dailey, M.D., D.J. Reish, and J.W. Anderson (eds.). Ecology of the Southern California Bight: A Synthesis and Interpretation. University of California Press, Berkeley, CA. p 71–189.

Emery, K.O. (1960). The Sea Off Southern California. John Wiley, New York. 366 pp.

Folk, R.L. (1968). Petrology of Sedimentary Rocks. Austin, TX. 182 pp. www.lib.utexas.edu/geo/FolkReady/TitlePage.html

Gardner, J.V., P. Dartnell, and M.E.Torresan. (1998). LA-5 Marine Disposal Site and Surrounding Area, San Diego, California: Bathymetry, Backscatter, and Volumes of Disposal Materials. Department of the Interior, US Geological Survey, Menlo Park, CA. 16 pp.

Gray, J.S. (1981). The Ecology of Marine Sediments: An Introduction to the Structure and Function of Benthic Communities. Cambridge University Press, Cambridge, England. 185 pp.

Heathershaw, A. D., A. L. New, and P. D. Edwards. (1987). Internal tides and sediment transport at the shelf break in the Celtic Sea. Continental Shelf Research., 7(5):485–517.

Long, E.R., D.L. MacDonald, S.L. Smith, and F.D. Calder. (1995). Incidence of adverse biological effects within ranges of chemical concentration in marine and estuarine sediments. Environ. Manage., 19(1):81–97.

Mann, K. H. (1982). The Ecology of Coastal Marine Waters: A Systems Approach. University of California Press, Berkeley. 322 pp.

Parsons, T. R., M. Takahashi, and B. Hargrave (1984). Biological Oceanographic Processes

3rd Edition. Pergamon Press, Oxford. 330 pp.

Schiff, K., and J. Cross. (1992). Estimates of ocean disposal inputs to the Southern California Bight. In: Southern California Coastal Water Research Project Annual Report 1990–1991 and 1991–1992. Long Beach, CA. p. 50–60.

Schiff, K.C., and R.W. Gossett. (1998). Southern California Bight 1994 Pilot Project: Volume III. Sediment Chemistry. Southern California Coastal Water Research Project, Westminister, CA. 132 pp.

Shepard, F.P (1973). Submarine Geology. Third Editon. Harper and Row, New York. 517 pp.

Shepard, F.P., and N.F. Marshall. (1978). Currents in submarine canyons and other sea valleys. In: Stanley, D.J., and G. Kelling (eds.). Sedimentation in Submarine Canyons, Fans, and Trenches. Dowden, Hutchinson and Ross, Inc., PA. p. 3–14.

Snelgrove, P.V.R., and C.A. Butman. (1994). Animal-sediment relationships revisited: cause versus effect. Oceanogr. Mar. Biol. Ann. Rev., 32:111–177.

Steinberger, A., and K. Schiff. (2003). Characteristics of effluents from large municipal wastewater treatment facilities between 1998 and 2000. In: Southern California Coastal Water Research Project Biennial Report 2001–2002. Long Beach, CA. p. 50–60.

Steinberger, A., E. Stein, and K. Schiff. (2003). Characteristics of dredged material disposal to the Southern California Bight between 1991 and 1997. In: Southern California Coastal Water Research Project Biennial Report 2001–2002. Long Beach, CA. p. 50–60.

[USEPA] United States Environmental Protection Agency. (1987). Quality Assurance and Quality Control (QA/QC) for 301(h) Monitoring Programs: Guidance on Field and Laboratory Methods. EPA Document 430/9-86-004. Office of Marine and Estuarine Protection. 267 pp.

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