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A STUDY OF SEDIMENT COMPOSITION, TRANSPORT, AND DEPOSITION OFF PALOS VERDES

Final Report

to

County Sanitation Districts
of Los Angeles County

from

Southern California
Coastal Water Research Project
646 W. Pacific Coast Highway, Long Beach, California 90806

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TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

SUMMARY

Near-bottom currents off Palos Verdes in 60 m of water generally flow upcoast and offshore. The average net speed (during the spring-summer) is about two and one-half cm/sec (0.05 knots). The net offshore component is about 0.83 cm/sec. As a result of this offshore flow, if resuspended sediments remain in resuspension for periods of a half-day or longer (or undergo multiple resuspensions), they are likely to be carried offshore of the shelf break and into substantially deeper water.

Fluctuations of tidal periodicity dominate the variations about the mean motion in the longshore direction; shorter period changes dominate the cross-shore variations. The peak current speed observed 2 m above the bottom (53 m of water) was 25 cm/sec. It occurred about 0.1 percent of the time. The overall distribution of near-bottom current speeds is comparable with that observed (for the same season) in the vicinity of the Orange County outfall. The latter location, however, has an offshore component in the net flow that is about sixty percent stronger (1.3 cm/sec).

Sediment traps positioned near the ocean bottom in 30 m and 60 m of water yielded apparent sedimentation rates in the range of 1800 to 10,000 mg/sq.cm/yr. These rates are one to three orders of magnitude greater than estimates of the sedimentation rate of natural particles (10 - 200 mg/sq.cm/yr). The collection rates are relatively independent of position along the 60 m isobath. In 30 m of water, however, a three-fold increase in the rate was observed near San Pedro Harbor, and a fifty-percent increase was measured near the Portugese Point landslide area (relative to the rate near White Point).

In 60 m of water, the total volatile solids (TVS) and DDT concentrations of the particulates collected in the traps were lower than in the adjacent surface sediments. This suggests that the material collected in the trap came from a broad area and not just from the immediate vicinity of the mooring. There was a trend toward increased TVS and total DDT concentrations upcoast from the outfall(s), consistent with the net direction of flow of the currents and TVS concentrations in the natural (pre-discharge) sediments.

Cores collected in a two-dimensional grid of stations downstream from the outfall were analyzed for the accumulation of total DDT, total PCB, and effluent-related TVS. The accumulation of effluent-related TVS measured in 1987 was comparable (within 15 percent) of the accumulations observed in 1981. Accumulations of total DDT appeared to vary significantly among cores collected in different years--and even replicate cores collected in the same year. In general, the accumulations computed from the cores

collected and analyzed by SCCWRP in 1987 were about one-third those computed from the 1981 cores (analyzed by Los Angeles County Sanitation District personnel). This unexplained disparity casts some uncertainty on the sediment trap and surface sediment total DDT comparisons.

There did not appear to be a simple relationship between the cross-shore distribution of accumulated effluent-related material and distance from the 60 m isobath (or water depth). However, a Gaussian distribution with a half-width of about 0.6 km (at half- maximum) provides a rough approximation to the cross-shore accumulation of outfall material. In 1981, one core was collected at a station (8Z) in 480 m of water. This study collected a core sample at the same depth, but approximately 3 km farther upcoast (6Z). Analysis of both cores indicated increased accumulation of effluent material on the lower portion of the slope, relative to the accumulation on the outer edge of the shelf or the upper portion of the slope (A,B stations). As a result, the cross-shore accumulation of effluent material in this area is greater than estimated by the simple Gaussian distribution. This offshore increase is, however, consistent with the cross-shore accumulation of natural particles on the shelf and slope (i.e. prior to the commencement of the wastewater discharge).

Combining the 1981 and 1987 core data and contouring the distribution of accumulated effluent-related TVS indicates that approximately 22 percent of the discharged TVS has accumulated between Point Vicente and Long Point. After correcting for decay of orgainic material, this would correspond to about 28 percent of the discharged TVS. This fraction is greater than previous estimates--but it also includes a larger area.

NOTES

INTRODUCTION

This report discusses the results of a set of special studies carried out during the summer of 1987 in the vicinity of the White Point outfalls. The purpose of these studies was two-fold: (1) obtain data that could be used to supplement previous data, resulting in more accurate estimates of the distribution and accumulation of outfall-related materials, and (2) provide new information on the processes and mechanisms that govern the transport and accumulation of these materials.

Three types of studies are discussed in this report. The first task was to collect information on the characteristics of the near-bottom currents. Previous measurements of these flows during the summer of 1981 were during a period when the characteristics of the mid-water flows were not representative of "typical" flows. Thus there was some question about the suitability of these earlier near-bottom measurements for the assessment of resuspended sediment transport and for simulation purposes.

The second task was to estimate the flux of particles to the ocean bottom by using sediment traps positioned near the sea-sediment interface. These rates, and the chemical characteristics of the collected material, could be used to assess the source and transport of this material and evaluate the contribution of particles from the Portuguese Point landslide to the effluent sediment field.

The third task involved extensive coring of the sediment field between the 90-inch outfall and Point San Vicente. The objective of this task was to provide additional information on the cross-shore distribution of the accumulation of effluent-related material. This information could be used to provide improved estimates of both the areal distribution of effluent material and the fraction of discharged effluent particulate material that ultimately accumulates in the area.

A fourth task, measurements of the stress required to resuspend sediments in the vicinity of the outfall, is not reported here since the analysis of this data is still in progress.

CURRENT MEASUREMENTS

Methods

A current meter mooring was installed upcoast from the 90-inch outfall diffuser (Lat: 33d 42.48m-N, Long: 118d 20.90m-W -- see Figure 1) in 53 m of water on June 1, 1987. The mooring contained two SCCWRP "tiltmeter" current meters (Hendricks, 1985) positioned at elevations of 2 m and 12 m above the ocean bottom (depths of 51 and 41 m, respectively).

Data collection began on June 1 (Calendar day 152) at the 41 m depth, and on the following day at the 51 m depth. The mooring was recovered, serviced, and redeployed on July 2 (Calendar day 183), then recovered again and removed on August 3.

Observations of current speed and direction were recorded at 15-minute intervals, and analyzed at 45-minute intervals. Current meter tilt and direction of tilt were converted into current speed and direction using calibration tables obtained by towing the meters at known speeds in the wind-wave channel at the Hydraulics Laboratory of the Scripps Institution of Oceanography. The time-series of tilt and direction of tilt, were stored on a floppy diskette, converted to current speed and direction, and analyzed using a microcomputer.

Results and Discussion

Mean Flows

Table I lists the strength and direction of flow of the net (mean) current during each deployment period. The average mid-water flow (41 m depth) for the entire period of record (63 days) was upcoast and slightly onshore (280 degrees-mag.) at 4.8 cm/sec (0.09 kn). Near the bottom (2 m elev.), the net movement was upcoast and offshore (251 deg,-mag.) at 2.4 cm/sec (0.05kn).

The net upshore movement of the mid-water currents is consistent with the distribution of effluent particles in the sediments around the outfall, and with current observations from 1986. Measurements carried out during 1979 also yielded a net upcoast motion (Hendricks, 1980). However, measurements carried out during the spring-summer of 1981 yielded a downcoast or weak upcoast net movement.

A comparison of the mean flow near the bottom during May-August, 1987, with that observed during (April-May) 1981, indicated that the 1987 flow was stronger and directed upcoast, relative to the earlier observations. During all of the observation periods, the mean flow had an offshore

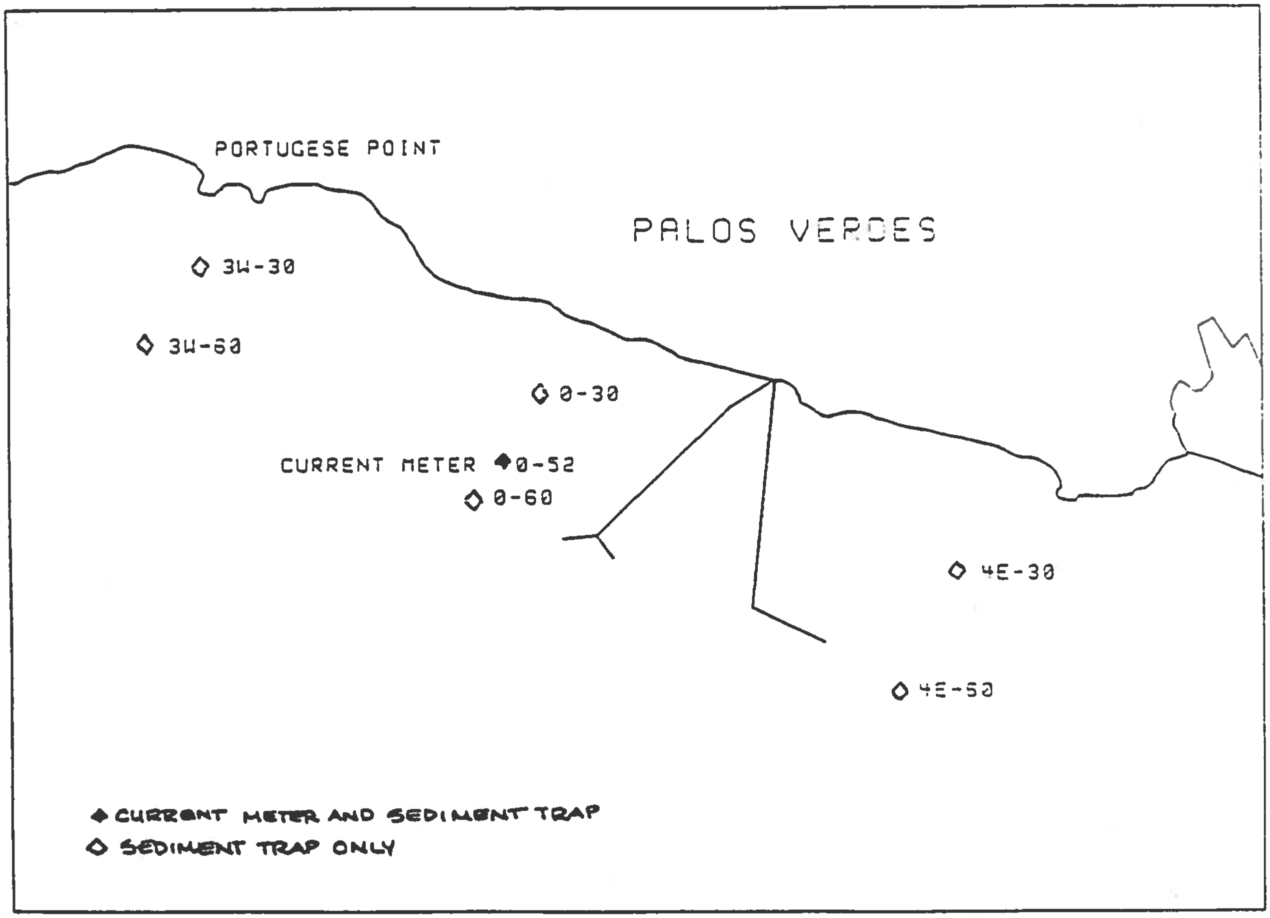

FIGURE 1. CURRENT METER AND SEDIMENT TRAP STATIONS.

component. Since the mid-water flows observed during the 1987 study are more characteristic of typical conditions than during the 1981 study, the near-bottom flows measured during 1987 also are likely to provide a more accurate description of the near bottom mean flows during "typical" flow conditions.

Mean Flow Variations

Table I also lists the root-mean-square (rms) speeds of the variations about these mean currents, relative to the principal (orthogonal) axes of variation. At the mid-water depth, the major principal axis during 1987 was approximately along a heading of 86-266 degrees (mag.), or roughly parallel to the local isobaths. This orientation is generally consistent with the orientations observed during previous measurements.

The average rms speed associated with the variations along this axis was about 8.4 cm/sec, or almost twice the speed of the average flow. The average rms speed for the principal minor axis (176-356 degrees) was 3.7 cm/sec. Again these values are consistent with the previous observations.

Near the bottom, the major principal axis was aligned along 89- 269 degrees (mag.), and the rms speed of the variations along this axis was 6.9 cm/sec (almost 3 times the speed of the mean current). The variations along the minor principal axis (179-359 deg.) had an average rms speed of 4.6 cm/sec (approximately 25 percent stronger than the cross-shore fluctuations at the mid-water depth). The strength and direction of these fluctuations were consistent with the measurements made in 1981--even though the mean flows during the two periods were substantially different. For the combined 1981 and 1987 observations, the near-bottom currents had an offshore component to the net flow equal to about 0.83 cm/sec.

Distribution of Current Speeds

Figure 2 shows the probability matrix representing the distribution of current speeds and direction of flow at the 41 m depth. The 50-percentile speed was 7.3 cm/sec, with about 10-percent of the observed speeds falling below 3.5 cm/sec or above 16.6 cm/sec.

Figure 3 contains the corresponding information for the 51 m depth. The distribution of speeds is nearly the same (50-percentile speed = 6.9 cm/sec, lower 10-percentile speed = 3.6 cm/sec), but with a slight reduction in the upper end of the speed distribution (upper 10-percentile speed = 13.1 cm/sec).

Table I

Mean Flow and Variability

"Mid-Water" Flow
****

Measurement Period	Depth D1	Depth D2	Mean Spd	Mean Dir	Variation Dir	Variation Vx	Variation Vy
6/ 1 -> 7/ 2/87	41	53	3.9	279	265	7.9	4.1
7/ 2 -> 8/ 3/87	41	53	5.6	282	267	8.9	3.3
10/ 1 -> 10/11/86	45	52	3.8	280	262	8.5	4.1
4/15 -> 5/17/81	40	60	1.3	314	270	6.2	3.6
5/17 -> 6/10/81	40	60	0.4	88	268	5.2	3.7
4/16 -> 9/18/79	41	56	5.5	284	275	8.1	5.5
Average:			4.2	284	271	7.7	4.7

"Near-Bottom" Flow
****

Measurement Period	Depth D1	Depth D2	Mean Spd	Mean Dir	Variation Dir	Variation Vx	Variation Vy
6/ 2 -> 7/ 2/87	51	53	2.3	247	267	6.7	4.9
7/ 2 -> 8/ 3/87	51	53	2.6	255	270	7.1	4.3
4/15 -> 5/15/81	58	60	0.8	206	253	6.4	5.0
5/15 -> 6/10/81	58	60	1.9	123	260	6.4	5.0
Average:			1.2	225	263	6.6	4.8

Notes:
- D1 = Current meter depth (m)
- D2 = Water depth (m)
- Spd = Speed (in cm/sec)
- Dir = Direction of mean flow or principal major axis (in degrees-magnetic)
- Vx = RMS (root-mean-square) speed of the variations along the principal major axis
- Vy = RMS speed of the variations along the principal minor axis

SPEED-DIRECTION PROBABILITY MATRIX NO. OCCURRENCES ELEMENT

DIR	SPEED CLASS 0-1	2-3	4-5	6-7	8-9	10-11	12-13	14-15	16-17	18-19	20-21	22-23	24-25	26-27	28-29
0	.	4	13	[illegible]	5	.	.	.	.	.	.	.	.	.	.
10	.	2	11	7	3	2	.	.	.	.	.	.	.	.	.
20	1	3	4	6	[illegible]	2	.	.	.	.	.	.	.	.	.
30	.	6	9	[illegible]	6	2	.	.	.	.	.	.	.	.	.
40	1	2	17	11	6	1	2	.	.	.	.	.	.	.	.
50	1	4	5	18	7	5	.	.	1	.	.	.	.	.	.
60	.	6	13	12	7	4	2	.	.	.	.	.	.	.	.
70	1	4	10	11	7	2	3	1	2	.	.	.	.	.	.
80	2	4	12	11	4	2	2	2	.	.	1	.	.	.	.
90	1	4	15	16	6	3	1	4	1	1	1	.	.	.	.
100	.	6	6	6	7	2	2	1	2	2	3	1	.	.	.
110	.	1	12	6	3	2	1	.	1	.	.	.	.	.	.
120	1	1	12	5	4	3	3	2	1	.	.	.	.	.	.
130	.	6	5	4	6	1	2	4	.	.	.	.	.	.	.
140	2	7	3	5	1	1	1	.	.	.	.	.	.	.	.
150	1	4	8	4	1	4	1	.	.	.	.	.	.	.	.
160	1	3	5	5	1	1	2	.	.	.	.	.	.	.	.
170	.	3	6	5	1	.	1	.	.	.	.	.	.	.	.
180	1	7	4	2	2	2	.	.	.	.	.	.	.	.	.
190	1	2	1	6	1	3	.	1	.	.	.	.	.	.	.
200	.	4	4	6	.	1	.	.	.	.	.	.	.	.	.
210	.	1	1	1	1	2	1	.	.	1	.	.	.	.	.
220	.	2	4	2	1	.	.	1	.	.	.	.	.	.	.
230	3	4	13	4	4	1	.	1	.	.	.	.	.	.	.
240	.	3	10	5	2	1	1	2	1	1	1	.	.	1	.
250	1	6	10	14	4	4	6	5	8	1	6	2	2	2	2
260	1	2	7	14	11	10	12	15	20	12	12	7	4	2	2
270	1	6	22	14	33	35	42	29	32	16	17	6	1	1	2
280		6	12	46	32	29	25	17	13	5	6	5	.	.	1
290	1	10	20	41	46	28	17	1	3	.	3	.	.	.	.
300	1	7	33	48	34	7	7	3	2	.	.	.	.	.	.
310	1	3	25	27	13	7	1	.	1	.	.	.	.	.	.
320	2	5	21	22	6	.	.	.	.	.	.	.	.	.	.
330	1	6	17	19	7	2	.	.	.	.	.	.	.	.	.
340	1	6	11	17	2	1	.	.	.	.	.	.	.	.	.
350	2	8	12	6	7	1	.	.	.	.	.	.	.	.	.

SPD .014 .203 .145 .069 .047 .026 .010 .004 0.000 0.000 0.000 0.000 0. [illegible]

PRB .081 .227 .089 .044 .020 .012 .003 .003 0.000 0.000 [illegible]

FIGURE 2. SPEED-DIRECTION PROBABILITY MATRIX FOR 41 m.
(TOTAL NUMBER OF OBSERVATIONS = 2,011)

SPEED/DIRECTION PROBABILITY MATRIX (NO. OCCURRENCES/ELEMENT)

DIR	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	[illegible]
(M)	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	[illegible]
0	.	1	14	16	3	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
10	.	2	11	8	4	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
20	.	[illegible]	4	10	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
30	2	.	10	8	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
40	.	3	5	4	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
50	.	2	5	2	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
60	.	1	9	8	4	1	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
70	.	7	11	7	5	4	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
80	.	1	9	10	7	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
90	2	3	7	5	16	5	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
100	.	6	10	12	9	3	3	6	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
110	.	2	10	13	17	10	8	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
120	.	8	10	27	6	2	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
130	1	1	22	7	15	5	2	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
140	.	2	13	11	13	2	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
150	.	5	18	10	4	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
160	.	3	12	10	1	1	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
170	.	9	10	5	8	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
180	.	6	10	14	8	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
190	.	.	11	5	4	1	1	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
200	2	3	12	12	5	3	1	.	2	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
210	2	2	14	7	4	6	3	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
220	.	1	7	10	12	3	6	4	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
230	.	3	11	9	5	5	.	1	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
240	1	7	6	10	12	6	14	5	3	2	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
250	.	2	8	20	20	10	15	12	10	8	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
260	.	3	7	10	3	10	19	6	10	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
270	.	2	7	15	21	13	6	2	4	7	7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
280	.	.	5	15	14	12	9	2	2	7	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
290	1	3	15	18	17	10	5	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
300	.	3	15	20	16	6	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
310	.	6	12	15	10	8	4	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
320	.	2	17	9	4	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
330	.	3	15	14	6	2	3	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
340	1	4	5	11	5	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
350	.	2	8	5	6	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	[illegible]
SPD	.008		.242		.179		.071		.025		.006		.001		0.000		0.000		0.000		0.000		0.000		0.000	
PRB		.074		.249		.089		.030		.018		.003		0.000		0.000		0.000		0.000		0.000		0.000		

FIGURE 3. SPEED-DIRECTION PROBABILITY MATRIX FOR 51 m.
(TOTAL NUMBER OF OBSERVATIONS = 1,588)

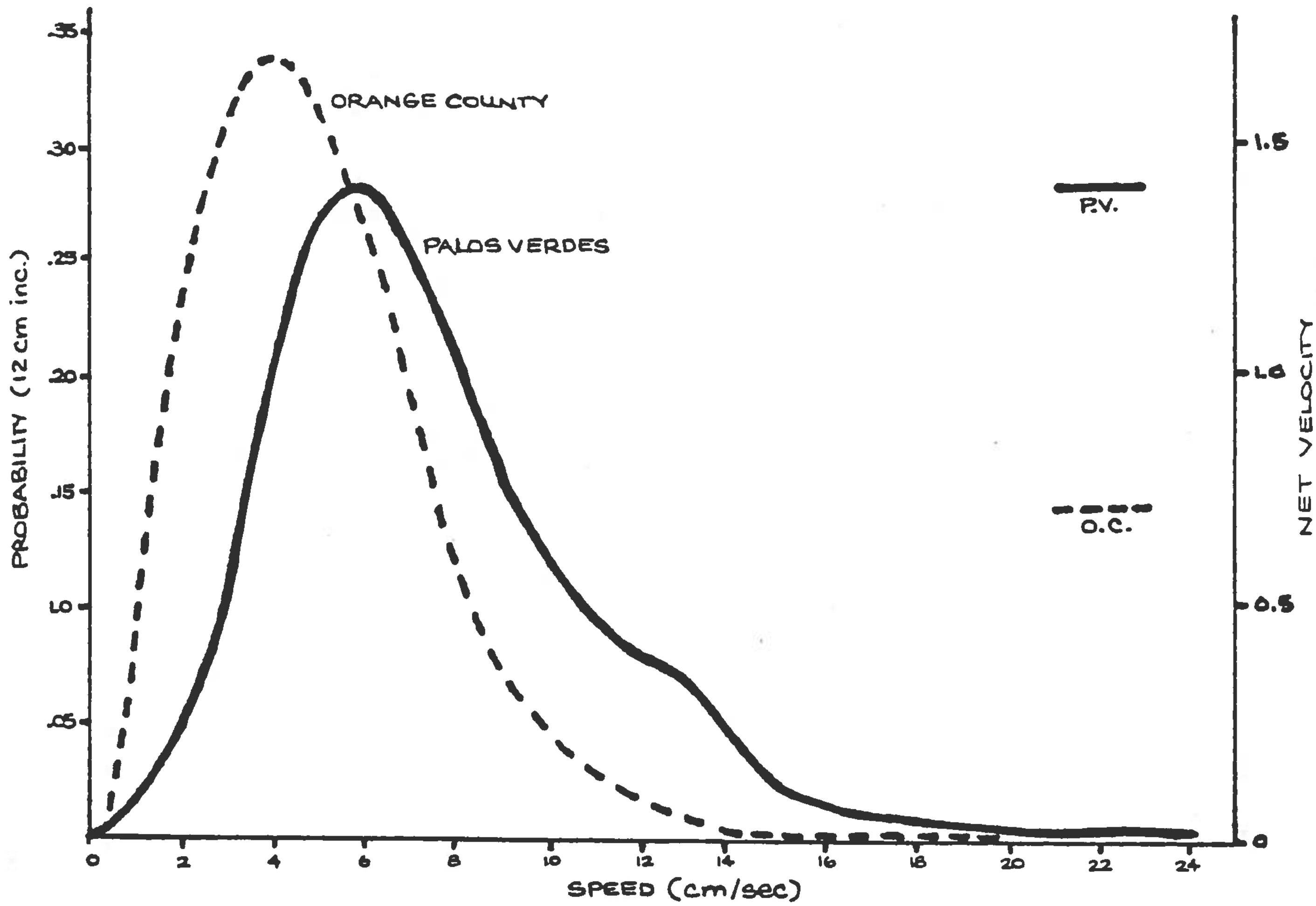

FIGURE 4. COMPARISON OF NEAR-BOTTOM CURRENT SPEEDS OFF PALOS VERDES AND ORANGE COUNTY.

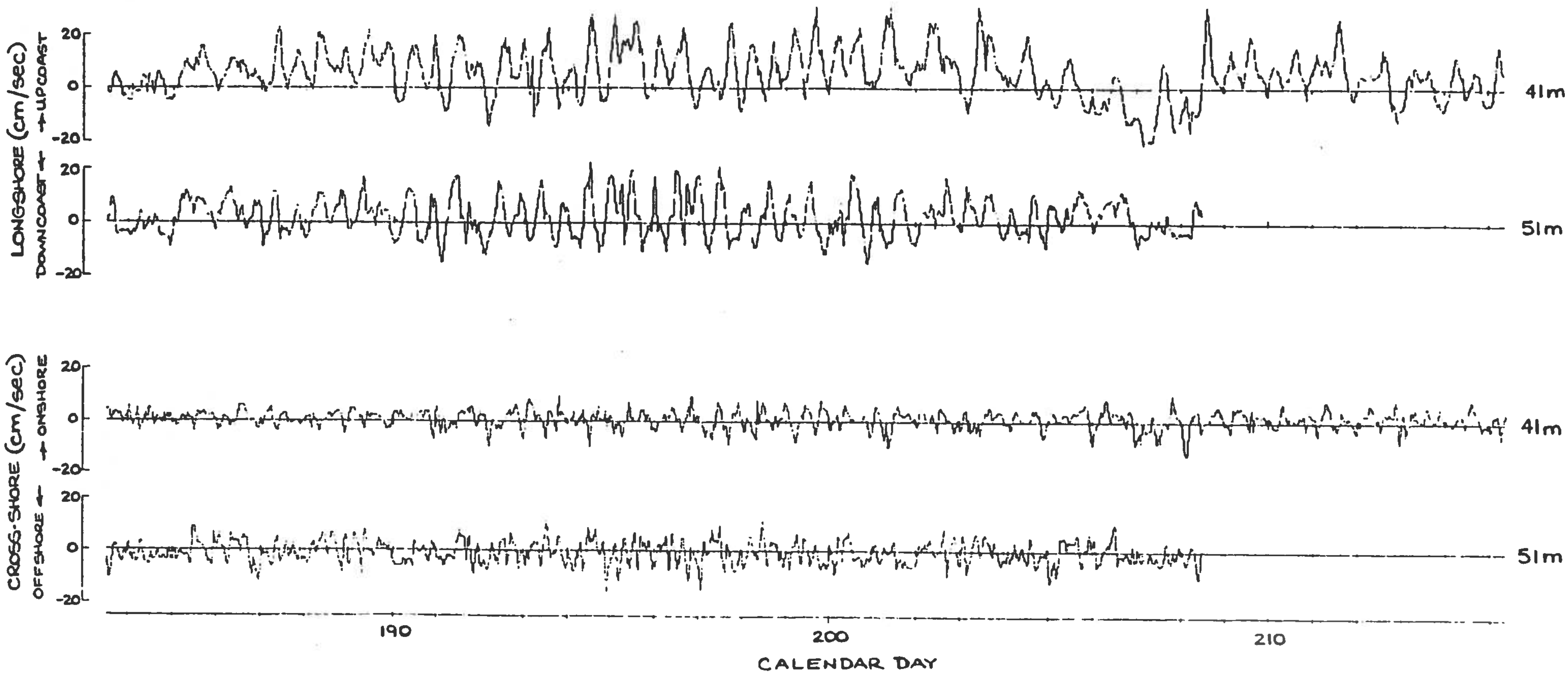

FIGURE 6. VELOCITY COMPONENTS FOR CALENDAR DAYS 183 - 215.

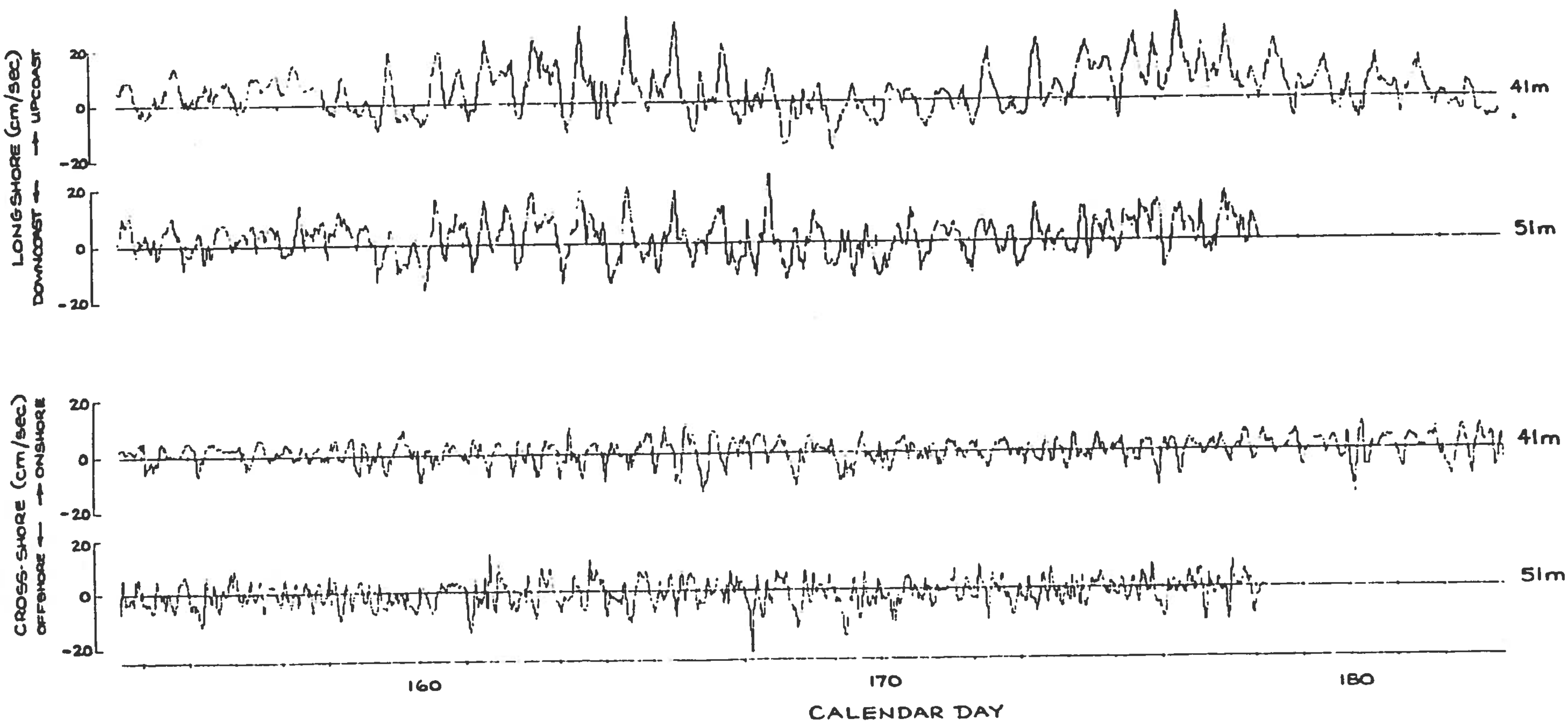

FIGURE 5. VELOCITY COMPONENTS FOR CALENDAR DAYS 153 - 183.

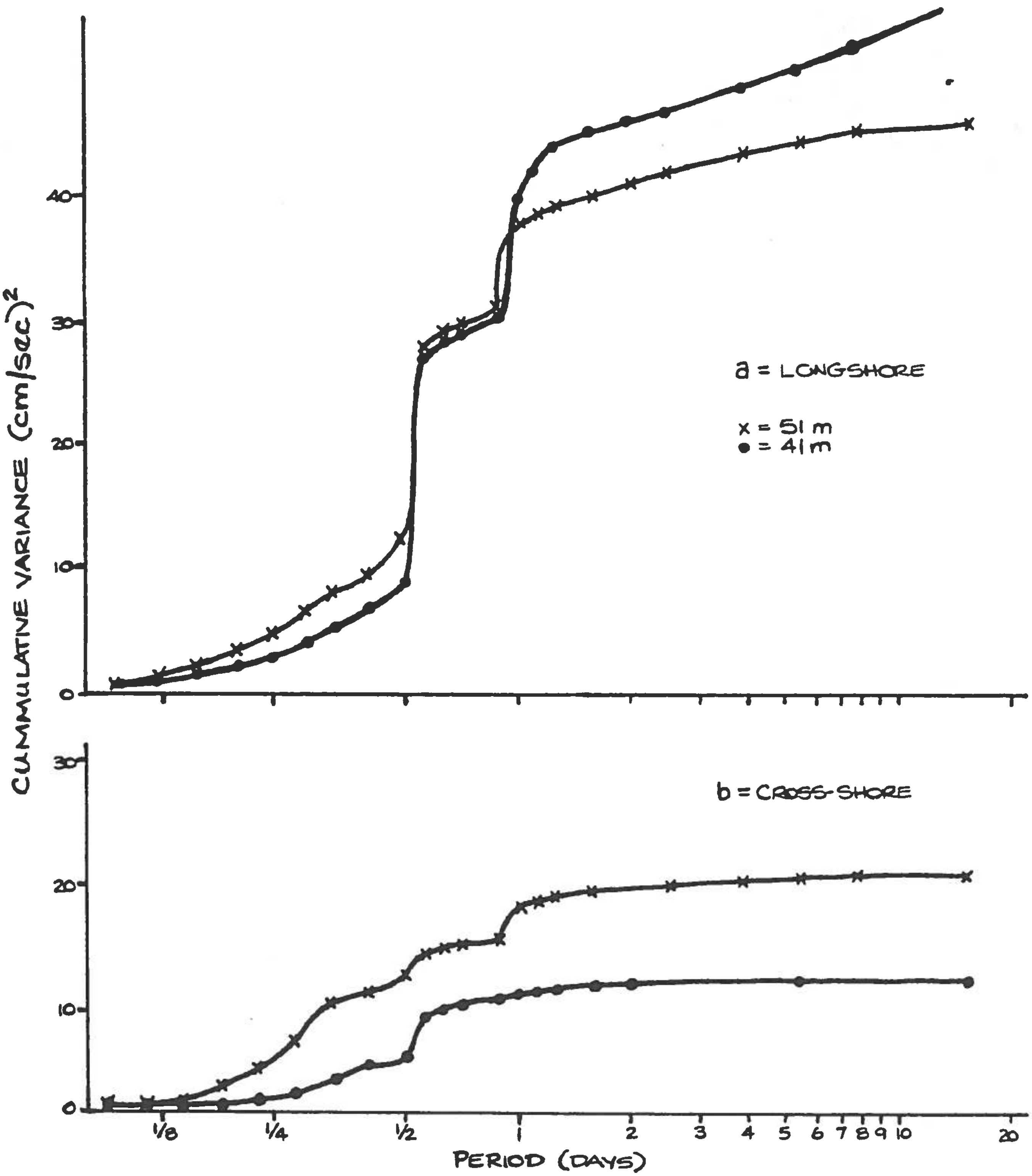

FIGURE 7. CUMMULATIVE VARIANCE

The maximum observed mid-water and near-bottom speeds were 31 and 25 cm/sec (probabilities of 0.2 and 0.1 percent) respectively.

Figure 4 compares the distribution of near-bottom current speeds for the 1981 and 1987 spring-summer season off Palos Verdes, and for the same season off Orange County. In general, the two distributions are similar, although the most probable speed is slightly higher off Orange County than it is off Palos Verdes. However, the highest speeds occur in the latter area.

Temporal Variability

Figure 5 shows the longshore (upper half of the figure) and cross-shore components of the currents at both depths for calendar days 153 to 183. Figure 6 contains similar information for the period from calendar day 183 to 215 (August 3). A wide range of time-scales, ranging from shorter than the semi-diurnal tidal period to days or weeks, characterizes the variations.

Figures 7a,b show the cummulative variance (mean flow removed) for the longshore and cross-shore components of the flow respectively. The variance is expressed as a function of the "periodicity" of the variations (i.e. associated with each term in a Fourier decomposition of the time-series of velocities).

For the mid-water longshore component of the flow (Figure 7a), the contributions associated with diurnal and semi-diurnal tidal periodicities contribute about 60 percent of the total variance. Semi-diurnal fluctuations account for about two-thirds of this tidal-band variability.

Fluctuations with periodicities longer than the tidal periods contribute an additional 25 percent to the total variance. This contribution is substantially less than observed in current meter records collected off Newport Beach (Hendricks, 1982), where long-period variations generally contribute more than 50 percent of the total variance. This diminished contribution of long-period fluctuations in the Palos Verdes area is, however, consistent with previous observations. Fluctuations with periodicities shorter than the semi-diurnal tide contribute the remaining 15 percent of the variance.

Near the bottom, fluctuations of tidal periodicity contribute about 51 percent of the variance--again, about two-thirds of this contribution is associated with the semi-diurnal tide. Sub-tidal periodicities contribute about 31 percent, and long-period fluctuations provide the remaining 18 percent. Thus the relative contributions of the long-period and short-period fluctuations are roughly reversed between the mid-water and the near-bottom longshore flows.

For the cross-shore motions (Figure 7b), variations with periodicities shorter than the semi-diurnal tide (12.42 hours) account for 50 percent, or more, of the variability in both the mid-water and near bottom currents. In the mid-water flow, fluctuations of tidal periodicity are dominated by the semi-diurnal tide (29 percent of the total variance). In contrast, near the bottom, diurnal period fluctuations are roughly twice as energetic (26 percent of the variance) as the contributions from the semi-diurnal period variations (11 percent).

The variance associated with long-period cross-shore fluctuations is on the order of 7 percent (mid-water) to 13 percent (near-bottom) of the total variance. It is noteworthy that the near-bottom cross-shore motions are about 65 percent more energetic than those occurring at the mid-water depth. Most of this difference is due to the increased energy of the short-period fluctuations.

SEDIMENT TRAPS

Methods

Seven sediment trap moorings were placed up- and downcoast from the 90-inch outfall (Figure 1). The moorings were serviced on approximately one-month intervals during the period from May 1 to August 3. A reduced set of moorings were deployed from August 3 to September 14, with a new mooring positioned in 30 m of water and closer to San Pedro harbor. The purpose of this new mooring was to provide additional information on the longshore gradients in sediment resuspension rates. Unfortunately, it was lost sometime during the deployment period.

Each mooring had three sediment traps of SCCWRP design (see Figure 8). The collection efficiency of these traps was determined previously by intercalibration with a "Soutar-type" grid-and-cone trap in the near-bottom waters (1 m elevation in 55 m of water) off Newport Beach. The mouth of the lowermost trap in the present study was positioned 0.5 m above the ocean bottom. The two other traps were positioned 2 m and 5 m above the bottom.

The material collected by the traps between servicings was analyzed for total (dry) mass and TVS. In addition, the material collected during the June-July and July-August deployments were analyzed for total DDT and total PCB. The methods used in these analyses are described in SCCWRP Standard Operating Procedures #'s ORG-3, ORG-5, SED-1 (SCCWRP, 1987). It should be noted, however, that the DDT measurements for the June-July deployment may not be directly comparable with those obtained for the July-August deployment, since the collected material was dried prior to analysis following the first deployment period, but not following the second.

The mass of material collected in a single set of traps typically decreases exponentially with elevation above the ocean bottom. An exponential relationship was used to estimate the mass that would have been collected at the sea-sediment interface (z=0) from the measurements at the three trap elevations. The rate of decrease of the collected mass with elevation is used to define a "characteristic thickness", Ho (i.e. $M(z) = M(0) \exp(-z/Ho)$). In general, the correlation coefficient (r) for this exponential representation is in excess of 0.900. In some cases, however, the mass collected by one of the three traps may deviate substantially from this dependence. In that case, the relationship is characterized by a value of $r < 0.900$, and the mass expected at the sea-sediment interface is assumed to be essentially the same as collected in the lower trap (0.5m elev.).

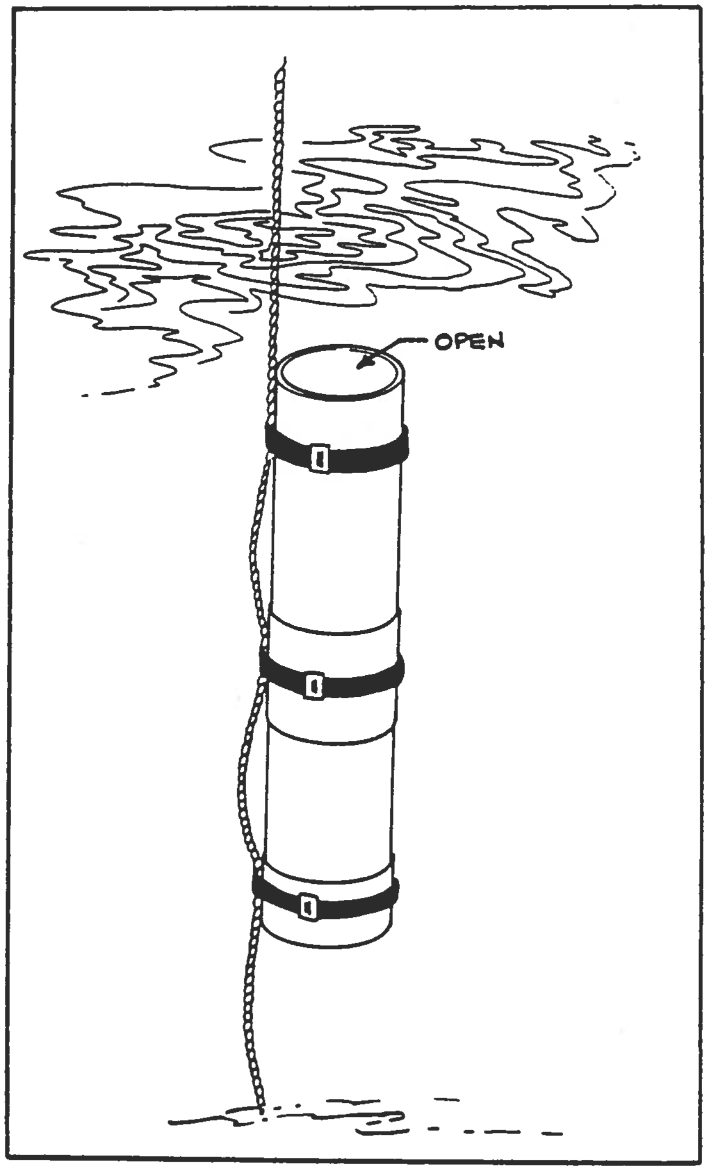

FIGURE 8. SCCWRP-DESIGN SEDIMENT TRAP.

Resuspension/redeposition flux rates were computed from the mass of collected material, the area of the mouth of the sediment trap (81.1 sq. cm.), and the duration of the deployment. These fluxes are expressed in units of $mg/cm^2/yr$ (to obtain the rates in $gm/m^2/yr$, the fluxes should be divided by 10).

Results and Discussion

Resuspension/Redeposition Fluxes

Table II summarizes the mass fluxes of material (computed for z = 0) at each mooring and for each deployment. In general, the largest fluxes were obtained during the first (May 1 -> June 1) deployment, and the lowest fluxes during the second (June 1 -> July 2) deployment. Typical fluxes downstream from the outfalls ranged from about 4,800 $mg/cm^2/yr$ (Mooring "0-30", Aug. 3 -> Sept. 14) to 1,800 $mg/cm^2/yr$ (Mooring "3W-60", June 1 -> July 2).

The fluxes at mooring "4E-30" (30 m of water at the east end of the study area) were, however, consistently higher than at the other moorings. They ranged from a high of 11,400 mg/cm**2/yr (May 1 -> June 1) to a low of 6,750 mg/cm**2/yr (July 2 -> Aug. 3). Offshore from this station (at Mooring "4E-60), the flux rates were comparable with those observed downstream from the outfall(s).

The fluxes measured at Mooring "3W-30", closest to the area of a landslide, were about 20 to 50 percent greater than those measured at Mooring "O-30" (located between 3W-30 and 4E-30).

The average fluxes for the period from May 1 to September 14 are shown in Figure 9 (fluxes were estimated for deployment periods when individual moorings were lost). Except for the increased flux near San Pedro harbor in 30 m of water, there is only a small increase in the fluxes observed at a water depth of 30 m, relative to those observed in water depths of 55 to 60 m.

In addition, Table II summarizes the "characteristic height" associated with the vertical distribution of total resuspended material. Also tabulated is the value of the correlation coefficient for an exponential distribution. Typical characteristic heights are in the range of 1.8 to 4.8 m --generally increasing during periods when the fluxes of collected material are small. On the average, a slightly greater height was observed for the mass distribution of TVS, but the difference is small and comparable with the uncertainty in the estimating procedure. The spatial dependence of the characteristic height is shown in Figure 10.

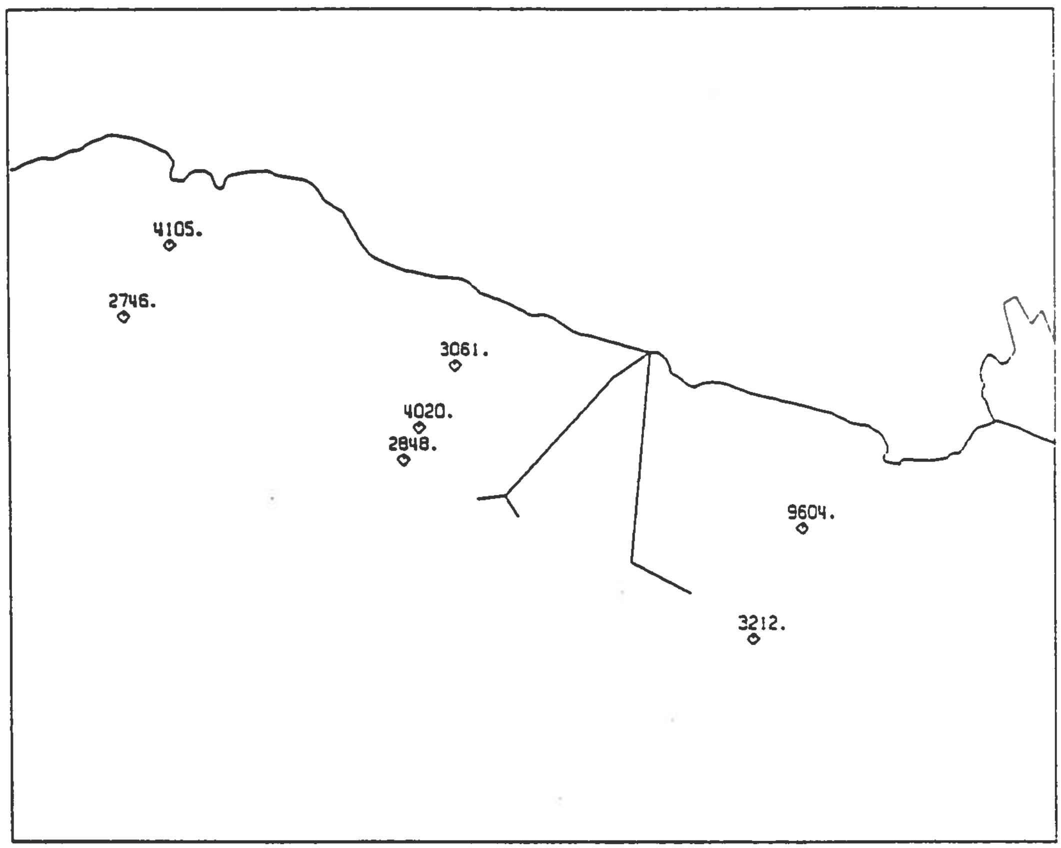

FIGURE 9. APPARENT SEDIMENTATION FLUX ($mg/cm^2/yr$)

TABLE II
Sedimentation Trap Fluxes

Date/Mooring	Depth	Flux	Height	r
May 1 -> June 1				
4E-30	30	11,414	1.8	-1.000
0-30	30	3,156	2.6	
3W-30	30	4,676	2.2	
4E-60	60	4,390	1.8	-0.997
0-52	52	4,101	2.0	-0.989
0-60	60	3,580	2.3	
3W-60	60	3,283	2.0	-0.964
June 1 -> July 2				
4E-30	30	10,646	2.2	-1.000
0-30	30	3,391	2.2	-0.948
3W-30	30	Mooring Lost		
4E-60	60	2,211	2.6	-0.752
0-52	52	Mooring Lost		
0-60	60	2,229	3.1	-0.721
3W-60	60	1,822	3.0	-0.916
July 2 -> August 3				
4E-30	30	6,754	3.4	-1.000
0-30	30	2,635	7.7	-0.510
3W-30	30	3,201	2.3	-1.000
4E-60	60	Mooring Lost		
0-52	52	4,749	2.6	-0.975
0-60	60	2,736	4.0	-0.990
3W-60	60	3,133	2.7	-0.979
August 3 -> Sept. 14				
SP-30	30	Mooring Lost		
4E-30	30	7,716	4.8	-0.999
0-30	30	4,842	6.1	-0.775
3W-30	30	Not Deployed		
4E-60	60	Mooring Lost		
0-52	52	Not Deployed		
0-60	60	3,253	5.4	-0.996
3W-60	60	Not Deployed		
Average (May 1 -> August 3)				
4E-30	30	9,604	2.5	
0-30	30	3,061	2.4	
3W-30	30	4,105e	2.2e	
4E-60	60	3,212e	2.3e	
0-52	52	4,020e	2.3e	
0-60	60	2,848	3.1	
3W-60	60	2,746	2.6	

Note: Fluxes in mg/cm**2/yr. Depths, heights in meters
Averages include estimates for periods when the mooring was lost (indicated by "e").

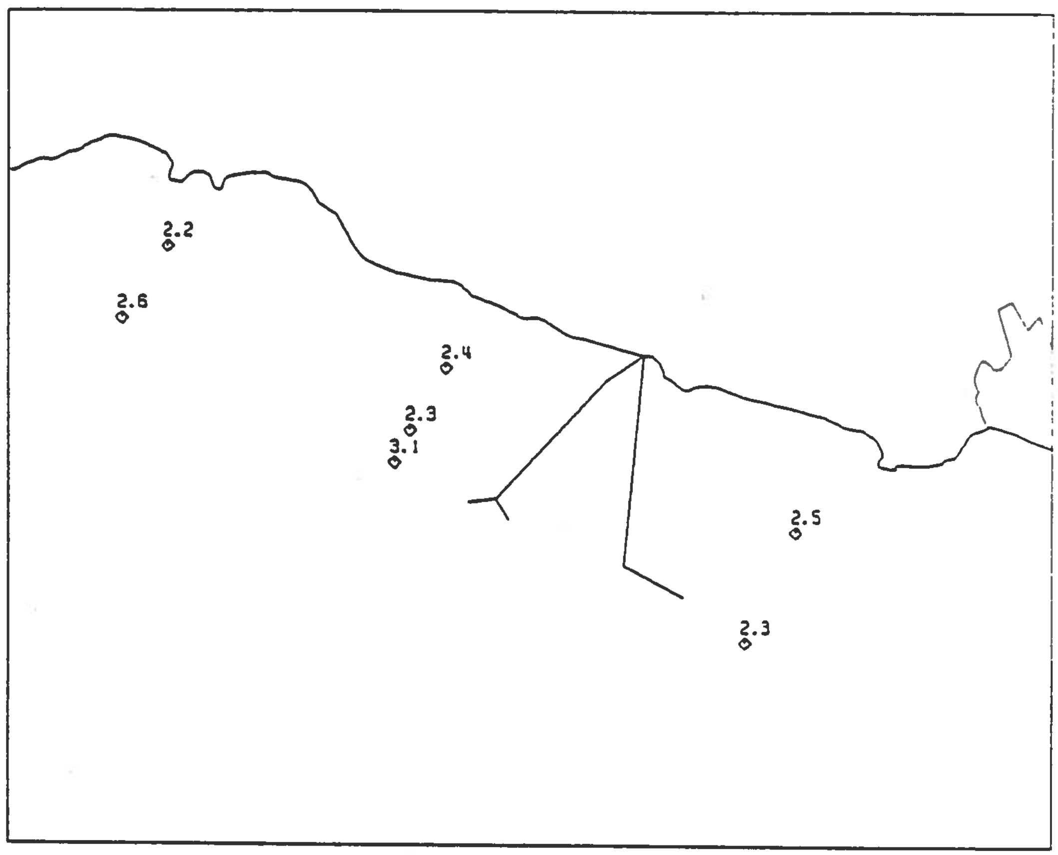

FIGURE 10. RESUSPENSION LAYER CHARACTERISTIC THICKNESS (IN METERS).

TVS, DDT, and PCB Concentrations

Table III summarizes the concentrations of TVS, total DDT, and total PCB observed at each of the moorings for the June 1 -> August 3 deployments. The TVS values are those extrapolated to the sea-sediment interface. Total DDT and total PCB concentrations are the geometrical averages of the values measured at the three elevations since they did not show a consistent trend with elevation above the bottom.

For three of the four deployment periods, the TVS concentrations ranged from about 5 to 10 percent. However, during the July-August deployment, the concentrations were about twice that range (9 to 22 percent). No reason for this difference could be identified. As might be expected from the distribution of TVS in the sediments around the outfall (and the characteristics of the mid-water and near-bottom currents), TVS concentrations tended to be higher in 60 m of water than in 30 m of water and upcoast from the outfalls. This spatial dependence is illustrated in Figure 11.

Total DDT concentrations (dry mass DDT/dry total mass) ranged from 634 ppb (4E-30, June-July) to 4400 ppb (O-60, July-August). The pattern of concentrations was similar to that observed for TVS: the lowest values were found downcoast from the outfall(s) and the highest values occurred near the 90-inch outfall. The spatial distribution of total DDT collected in the sediment traps is shown in Figure 12.

Overall, the total DDT concentrations during the July-August deployment were roughly one-third (0.30 ± 0.11) those measured during the June-July deployment. This difference was somewhat surprising--any effects associated with the difference in sample preparation between the two periods would have been expected to produce the opposite bias.

The high total DDT concentrations coincide with a period of generally reduced flux of total mass into the traps. This trend would be consistent with a reduced flux of material into the area from beyond the main body of effluent-affected sediments, but a sustained resuspension of outfall-influenced sediments. On the other hand, the period with the lowest concentrations of total DDT coincided with the period of highest TVS concentrations--contrary to what would be expected for this hypothesis.

Trends in the concentration of total PCB generally followed those observed for total DDT. The range of values was from 110 ppb (4E-30) to 650 ppb (3W-60) and followed the spatial distribution shown in Figure 13. Again there was an overall decrease in concentrations from the June-July collection to the July-August collection. The ratio of total DDT to total PCB was generally larger at the moorings in 60 m of water than at the moorings in 30 m. It also tended to increase in the vicinity of, and upcoast from, the outfalls. The ratio of total DDT to total PCB varied between 4.5 and 8.2. The spatial distribution is shown in Figure 14.

Table III

Sediment Trap TVS, Total DDT, Total PCB Concentrations

Date / Mooring	Depth	TVS	Total DDT	Total PCB
May 1 -> June 1				
4E-30	30	5.6	*	*
0-30		7.5	*	*
3W-30		9.5	*	*
4E-60	60	6.8	*	*
0-52	52	9.4	*	*
0-60	60	9.4	*	*
3W-60		8.4	*	*
June 1 -> July 2				
4E-30	30	5.0	1106	247
0-30		8.3	3205	353
3W-30		Mooring Lost		
4E-60	60	7.5	1515	327
0-52	52	Mooring Lost		
0-60	60	10.3	4398	572
3W-60		9.1	3718	651
July 2 -> August 3				
4E-30	30	9.4	634	110
0-30		10.7	918	159
3W-30		10.6	1615	295
4E-60	60	Mooring Lost		
0-52	52	21.8	1679	205
0-60	60	17.1	1846	241
3W-60		20.2	760	112
August 3 -> Sept. 14				
SP-30	30	Mooring Lost		
4E-30		6.7	*	*
0-30		7.3	*	*
3W-30		Not Deployed		
4E-60	60	Mooring Lost		
0-52	52	Not Deployed		
0-60	60	5.4	*	*
3W-60		Not Deployed		
Average (TVS: May 1->Aug.3; DDT,PCB: June 1->Aug.3)				
4E-30	30	6.7	837	165
0-30	30	8.8	1715	237
3W-30	30	10.0e	2613e	440e
4E-60	60	7.2e	1147e	248e
0-52	52	13.8e	2591e	316e
0-60	60	12.3	2849	371
3W-60	60	12.6	1681	270

Note: Depths in meters
TVS in percent; DDT, PCB in ppb(dry wt.)
* = not analyzed; e = includes est. value

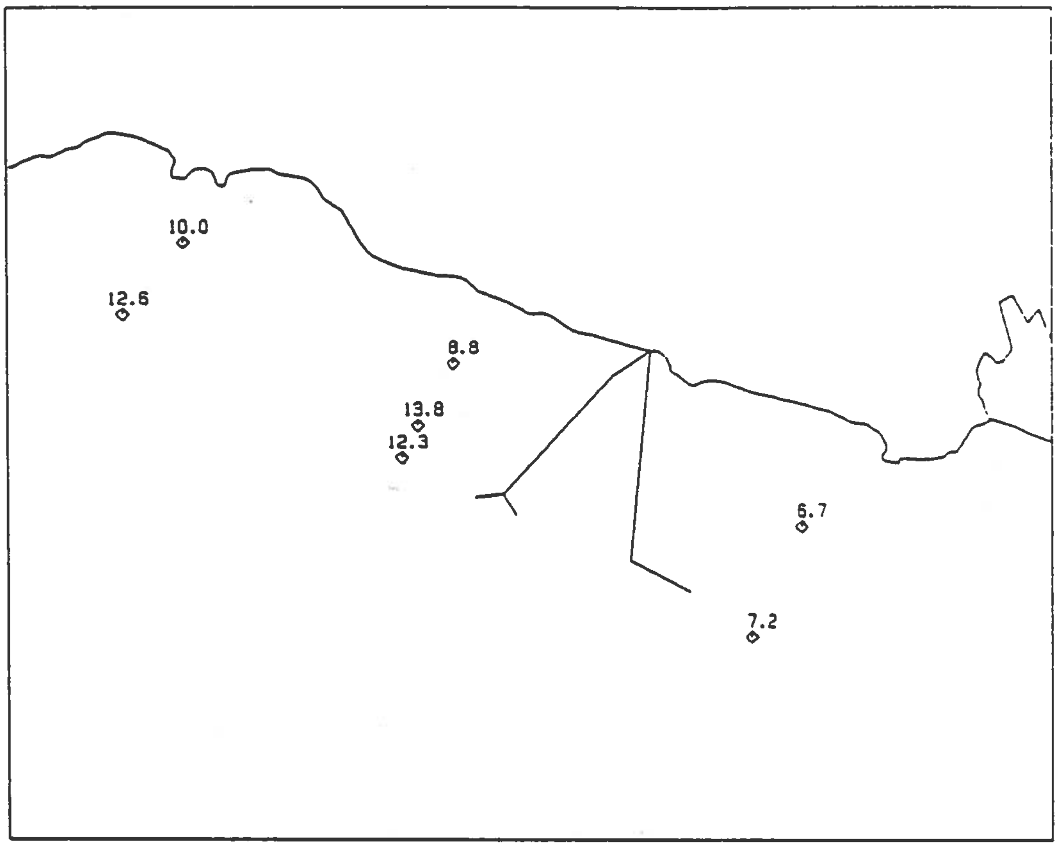

FIGURE 11. SEDIMENT TRAP TVS CONCENTRATIONS (PERCENT).

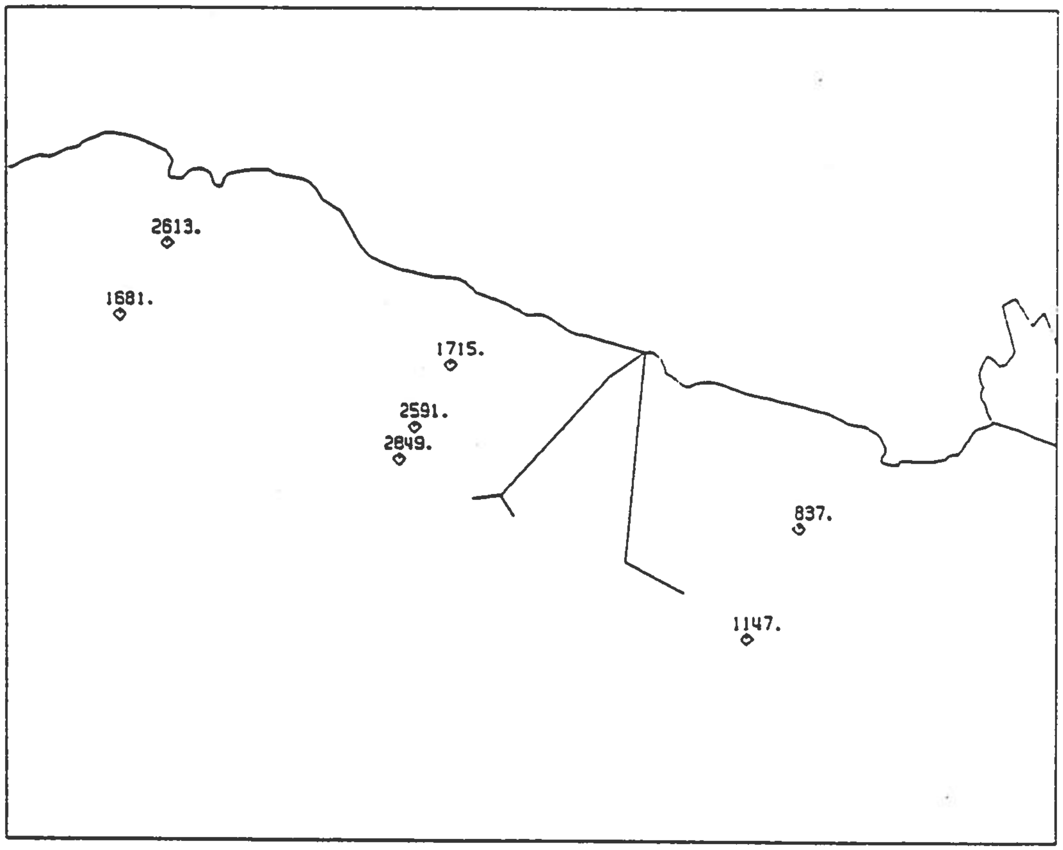

FIGURE 12. SEDIMENT TRAP TOTAL DDT CONCENTRATIONS (ppb-DRY).

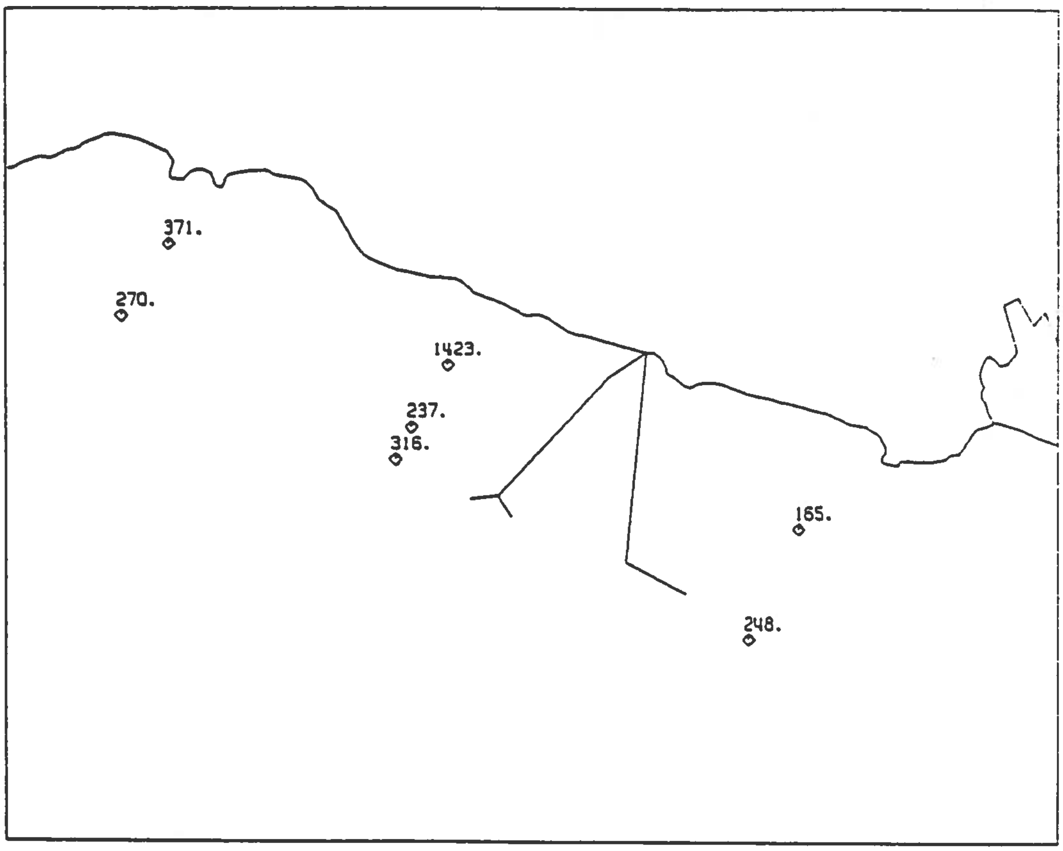

FIGURE 13. SEDIMENT TRAP TOTAL PCB CONCENTRATIONS (ppb- DRY).

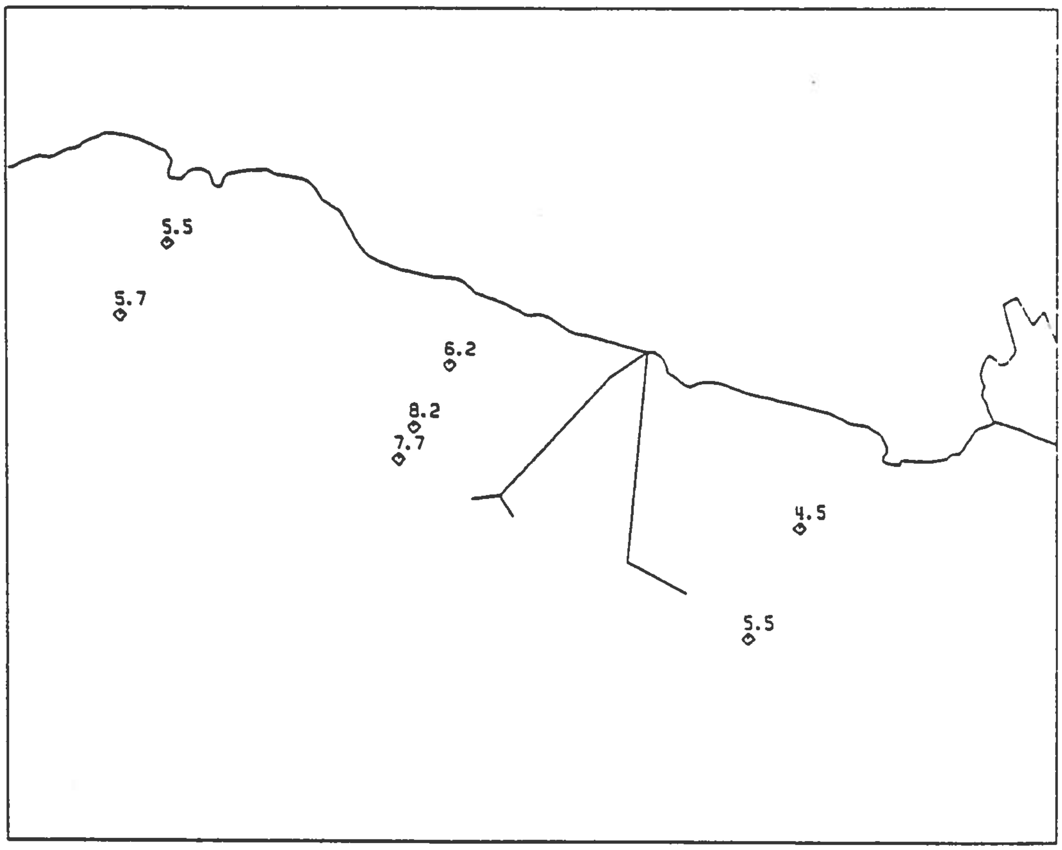

FIGURE 14. SEDIMENT TRAP TOTAL DDT/TOTAL PCB RATIOS.

CORES

Methods

Cores were collected with the SCCWRP "thin-wall" gravity corer (Bascom, 1982) at the 16 stations shown in Figure 15. These stations are distributed among four cross-shore transects ("1", "3", "6", and "7") and five water depths ("Z"-480 m, "A"-300 m, "B"-150 m, "C"-60 m, and "D"-30 m).

The cores were divided into two sections: (1) the lower 2 cm of the core and, (2) the remaining (upper) portion of the core. It was hoped that sufficient penetration would be obtained so that the lower 2 cm of the sample would be below the "effluent discharge horizon". The upper portion would then include a mix of both "natural" and "outfall-influenced" sediments.

The two sections were frozen on dry ice and transported to the laboratory for analysis. Each section was homogenized and sub- sampled for analysis of TVS, total DDT, and total PCB. The total (dry) mass of sediments was measured for the upper portion of the core. The analysis methods are discussed in SCCWRP SOP#'s ORG-3, ORG-5, SED-2 (SCCWRP, 1987).

Results and Discussion

Table IV summarizes the results of the core analysis. Total DDT concentrations in lower 2 cm of the core were generally low (relative to the average concentration in the upper portion of the core). However, at the stations in 30 m of water ("D"), and at Station 1C, the core apparently did not penetrate to the discharge horizon--at Station 7D, the highest concentrations of effluent material were found in the lower core. TVS concentrations among the set of cores are consistent with the distribution of total DDT concentrations.

The accumulated mass of total DDT in each core was computed from the concentration in the upper portion of the core and its total (dry) mass. The results are listed in Table V. Among the locations sampled, total DDT masses varied from a low of about 10-20 micro-g/cm^2 (Stations 1A,B; 3A,B,D; 6A,B) to a high of about 650-750 micro-g/cm^2 (Stations 6C, 7C). To convert these accumulations to metric tons of total DDT/square kilometer, divide by 100.

It is interesting to note that the accumulation of total DDT at station 6Z (480 m) was about 6 times the accumulation at station 6A (300 m). This increased accumulation at a depth of 480 m, relative to that at 300 m, is consistent with the only other measurement in 480 m of water (Station 8Z, 1981), and roughly mimics the accumulation of natural particles in

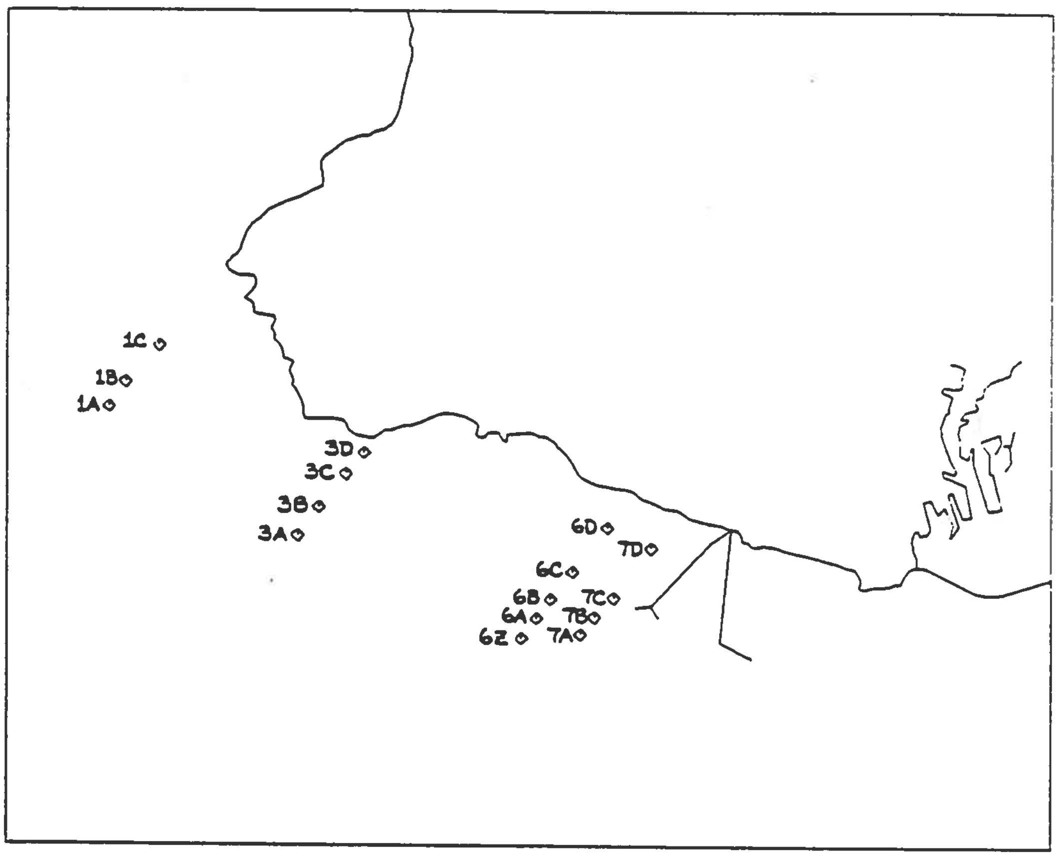

FIGURE 15. CORING STATIONS.

Table IV
Core Summary

	Upper Core				Lower Core		
Sta	Dry Mass	TVS	Total DDT	Total PCB	TVS	Total DDT	Total PCB
1A	20.8	3.9	548	149	3.6	13	6
1B	21.5	5.3	887	213	4.1	53	7
1C	15.0	7.1	5,382	1,667	4.3	2,669	443
3A	16.4	5.0	957	211	4.5	18	6
3B	18.8	4.1	878	166	3.7	14	0
3C	25.1	5.8	7,632	1,745	3.9	248	31
3D	33.1	4.6	613	180	2.8	202	92
6Z	41.1	5.0	2,722	634	4.0	20	6
6A	31.3	3.8	598	131	3.1	10	10
6B	27.7	6.4	11,937	3,324	4.5	10	0
6C	26.8	9.4	26,721	5,815	3.9	407	46
6D	46.6	3.7	630	164	3.6	574	107
7A	38.9	4.2	615	113	4.2	6	0
7B	17.6	7.0	11,550	2,475	3.9	97	12
7C	31.0	9.3	20,952	4,801	2.7	78	7
7D	19.6	1.7	630	151	4.8	2,428	295

Note: TVS in percent; Total DDT, PCB in ppb (dry)
Mass in gm/sq. cm.

this area (prior to commencement of the discharge) (Uchupi and Gaal, 1963).

A similar calculation was made for the outfall-related mass of TVS in each core. In this case, the analysis took into account the concentration of TVS on natural particulates, and was done in the following manner:

We note that the fluxes of effluent and natural particle total and TVS mass to the sediments can be expressed as:

$$S(total) = Se + Sn$$

$$S(TVS) = (Ce * Se) + (Cn * Sn)$$

where:

- S(total) = total mass flux of particles
- S(TVS) = mass flux of TVS
- Se = Flux of effluent particles
- Sn = Flux of natural particles
- Ce = Concentration of TVS in the effluent particles after decay (assumed = 49 percent - Myers, 1974)
- Cn = Concentration of TVS in the natural particles (obtained from the lower 2 cm section of the core)

for the portion of the core above the discharge horizon.

In a similar manner:

$$S(total) = Sn \quad \text{and} \quad S(TVS) = (Cn * Sn)$$

for the portion of the core below the discharge horizon.

Assuming that the upper portion of the core includes a period of time, T1, prior to discharge of effluent and a period equal to the duration of discharge, T2, the composition of the sediments in the upper core can be described by:

$$M(tot) = M1(tot) + M2(tot) = (Se * T2) + Sn * (T1+T2)$$

$$M(TVS) = M1(TVS) + M2(TVS) = (Ce * Se * T2) + (Cn * Sn) * (T1+T2)$$

and:

$$C = \frac{M(TVS)}{M(tot)}$$

where:

M(tot)	=	total (dry) mass of the upper segment of the core
M(TVS)	=	mass of TVS in the upper segment
M1(tot)	=	total mass of effluent particles
M2(tot)	=	total mass of natural particles
M1(TVS)	=	TVS mass of effluent particles
M2(TVS)	=	TVS mass of natural particles
C	=	Concentration of TVS in the upper core
Se	=	Average accumulaton rate of effluent mass during the period T2
Sn	=	Accumulation rate of natural particle mass (assumed constant)

Solving these equations for the total mass of effluent particles in the upper segment of the core yields:

$$M1(tot) = \frac{C - Cn}{Ce - Cn} * M(tot)$$

The corresponding effluent-related mass of TVS is:

$$M1(TVS) = Ce * M1(tot)$$

and the mass of natural particles in the sediments is:

$$M2(tot) = M(tot) - M1(tot)$$

or:

$$M2(tot) = \frac{Ce - C}{Ce - Cn} * M(tot)$$

The accumulated mass of effluent-related TVS associated with each core is summarized in Table V.

The accumulated mass of effluent-related TVS at each of the "C" (60 m) stations for the 1987 samples were compared with the corresponding accumulations in the 1981 cores (see Stull et. al., 1986). The results are summarized in Table VI. The accumulated masses are generally comparable, although the 1987 values are, on the average, about 15 percent lower than the 1981 values.

Since the 1981 and 1987 core analyses yielded comparable accumulations of effluent-related TVS, the 1981 cores were used to extend the inventory of accumulated TVS masses to beyond the area sampled in 1987. The resulting set of observations were then "mapped" onto a grid of cells and contoured. The results are shown in Figure 16. The total accumulated mass was 390×10^3 metric-tons of outfall-related TVS.

Table V
Accumulated Total DDT and Effluent-Related TVS

Station	Total DDT	Eff. TVS
1A	11.4	0.067
1B	19.1	0.281
1C	80.7	0.491
3A	15.7	0.090
3B	16.5	0.081
3C	191.6	0.518
3D	20.3	0.633
6Z	111.9	0.447
6A	18.7	0.235
6B	330.7	0.580
6C	716.3	1.602
6D	29.4	0.445
7A	23.8	0.000
7B	201.3	0.592
7C	649.5	2.165
7D	13.2	*

Note: DDT in micro-gm/sq.cm.
TVS in gm/sq.cm.

Assuming that the initial concentration of TVS on the effluent particles (70 percent) is reduced to 49 percent as the result of decay (Myers, 1974), the mass of TVS discharged from the outfall (after decay) from the commencement of discharge through the deep outfalls (1956) until 1981 was about 1400 x 10^3 metric tons (core data indicates relative little accumulation after 1983). Thus about 21-22 percent of the discharged effluent particle TVS has accumulated in this area, and about 27-28 percent settled in the area before decay. The latter figure is somewhat greater than previous estimates, but it includes a a larger area, extending both farther upcoast and offshore.

The accumulated masses of total DDT at various "C" stations were compared with the accumulations computed from cores collected in 1981, 1983, and 1985. Here there was less consistency (see Table VI) than for the accumulation of effluent-related TVS. Accumulated masses varied by factors of 1-4 between the different cores at the same station. The average ratio between the 1981 and 1985 cores was close to unity, but the ratios for individual cores showed a much greater variation (0.29 -> 1.82). The ratios between the 1987 cores and the 1981 cores were more consistent from location to location (0.24 -> 0.56), but also consistently less than unity. The reason(s) for these differences are not known and certainly cast some uncertainty into comparisons involving collections made at different times, or analyses carried out by different laboratories.

Since the results obtained from the 1981 cores are so different from those obtained in 1987, the 1981 data could not be used to extend the areal coverage (as was done for TVS) and it was not possible to obtain a reliable estimate of the total accumulated mass of total DDT in the discharge area.

The cross-shore distribution of accumulated effluent-related material (TVS and total DDT) in the 1987 cores is examined in Table VII. The accumulations at the "Z","A","B", and "D" stations are expressed as fractions of the accumulation at the "C" stations. On the average, the accumulation of total DDT is "confined" to a narrower region around the 60 m isobath than is the accumulation of effluent-related TVS. At the "B" stations, the ratio of accumulated TVS is about 25 percent greater than for total DDT; at the "A" stations (305 m), about 60 percent greater, and at the "Z" station (480m), about 80 percent greater. There is about a factor of ten difference in the two ratios at the inshore ("D" - 30 m) stations (e.g. 0.75 [TVS} versus 0.074 [DDT]), but these values are probably meaningless due to the limited penetration of the cores. Nevertheless, it should be noted that there is substantial variability in this ratio between stations (at the same depth) and individual cases of the opposite trend are also evident.

Table VI

Comparison of 1987 Accumulations with Previous Cores

Sta.	Effluent TVS 1981	Effluent TVS 1987	Effluent TVS Ratio	Total DDT 1981	Total DDT 1985	Total DDT Ratio	Total DDT 1987	Total DDT Ratio
1C	515	>490	>0.95	229	*	*	80	>0.35
3C	870	515	0.59	688	522	0.76	190	0.28
6C	1640	1600	0.98	1289	2345	1.82	715	0.56
7C	2475	2164	0.87	2747	*	*	650	0.24
8C	3330	*	*	8190	2366	0.29	*	*
Average:			>0.85 ± 0.18			0.96 ± 0.78		>0.36 ± 0.14

Note: Ratios relative to 1981 values.

Table VII

Ratio Describing
Cross-shore Distribution of Accumulated TVS and Total DDT

Station	TVS(Sta) / TVS(C)	DDT(Sta) / DDT(C)	TVS / DDT
*******	********	********	****
6Z	0.279	0.156	1.8
1A	0.137	0.141	1.0
3A	0.174	0.082	2.1
6A	0.146	0.026	5.6
7A	0.000	0.037	0.0
	-----	-----	---
	0.114 ±0.078	0.072 ±0.052	1.6
1B	0.537	0.237	2.3
3B	0.157	0.086	1.8
6B	0.362	0.462	0.8
7B	0.274	0.313	0.9
	-----	-----	---
	0.342 ±0.176	0.275 ±0.157	1.2
3D	1.222	0.106	11
6D	0.278	0.041	7
7D	*	*	
	-----	-----	--
	0.750 ±0.668	0.074 ±0.046	10

Figures 17a and 17b illustrate this cross-shore dependence. The cores are arranged by offshore or onshore distance from the 60 m isobath in Figure 17a; in 17b, the values are grouped by water depth, with the onshore-offshore distance corresponding to the average separation from the 60 m contour for transects 1, 3, 6, and 7. As previously noted, there is considerable variability among the various transects. However, the average cross-shore distribution can be approximated by a Gaussian distribution, with a half-width at half-maximum of 0.61 km (solid line in Figure 17) --except in water depths in excess of 300 m.

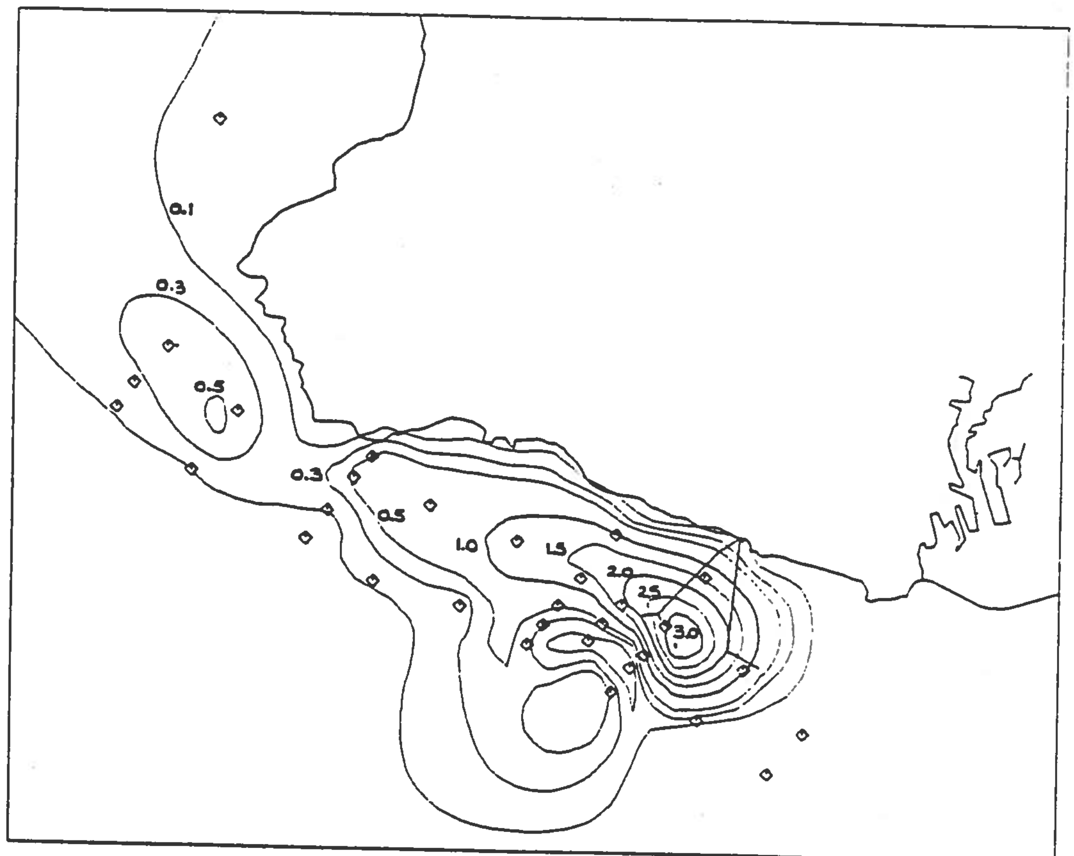

FIGURE 16. ACCUMULATION OF EFFLUENT-RELATED TVS (IN gm/cm^2) ◇ CORE LOCATIONS 1981 AND 1987.

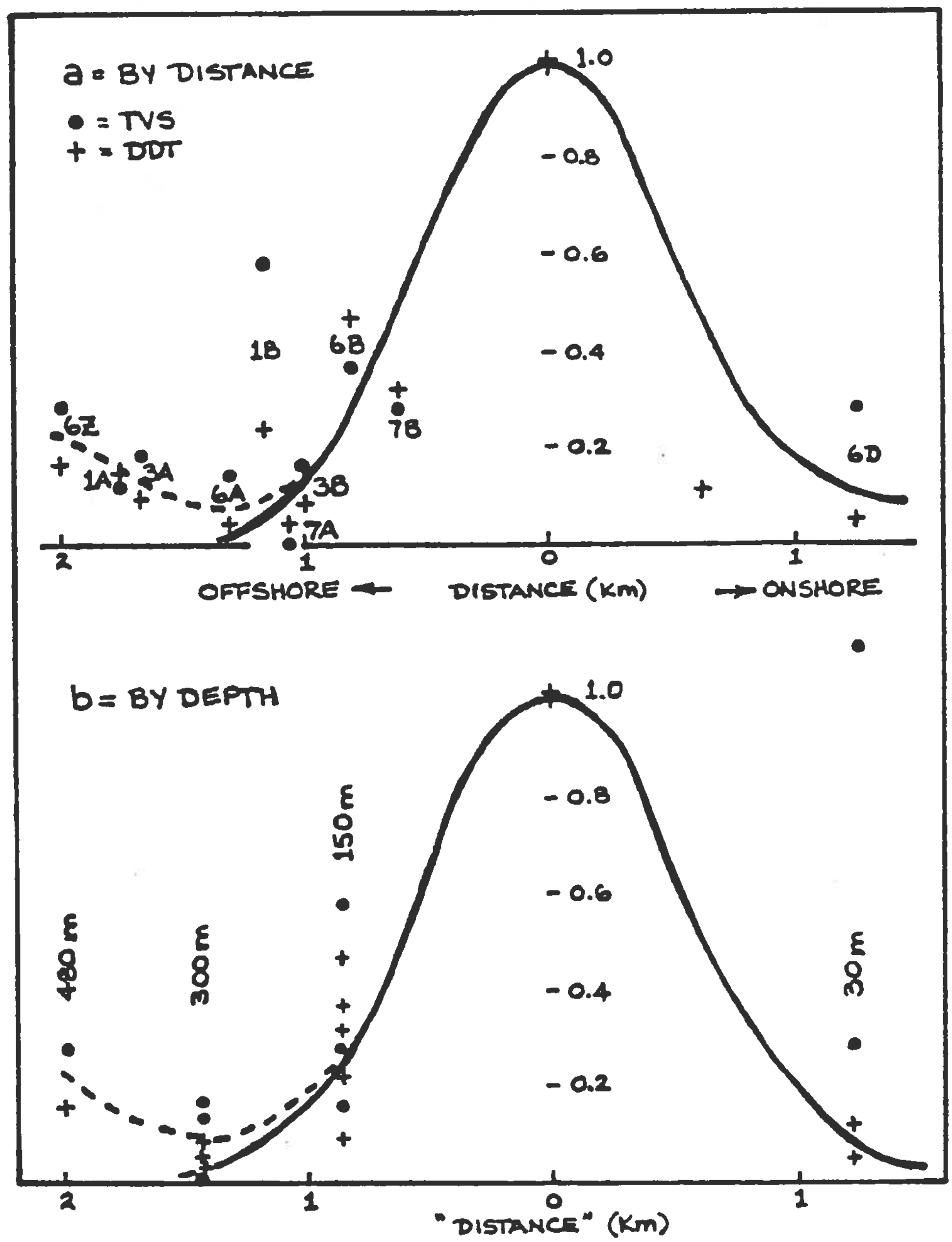

FIGURE 17. CROSS-SHORE RELATIVE ACCUMULATIONS.

GENERAL DISCUSSION AND CONCLUSIONS

The distribution and accumulation of effluent-related materials in the sediments around the two White Point ocean outfalls is governed by the rate and sedimentation of effluent and natural particles from the water column, and the rate of resuspension, transport, and deposition of these particles in the vicinity of the ocean bottom.

Flux rates collected in the sediment traps during this study varied from about 2000 to 10000 mg/sq.cm/yr. These values are consistent with limited measurements in the same area during the previous year. Sediment trap flux measurements carried out in the same area during the winter indicate substantial increases in the fluxes during the winter, with the greatest increases taking place at moorings in 30 m of water. On an annual basis, the average flux rates are on the order of 7600 and 4550 mg/sq.cm/yr in water depths of 30 m and 60 m respectively. These rates are somewhat in excess of those observed off Newport Beach, but within factors of 2-3 of those measured in similar environments and water depths along the coast of southern California (e.g. Oceanside, Point Loma, as well as Newport Beach).

The rate of accumulation of natural particles in this area has been variously estimated to range from about 10 mg/sq.cm/yr (Emery, 1960) to about 200 mg/sq.cm/yr (Logan, 1987). Thus the deposition rates obtained from the trap measurements are one to three orders-of-magnitude greater than the accumulation rate of natural particles. Three explanations can be proposed to explain this difference in flux rate:

1. The increased flux rates observed in the sediment traps are associated with the sedimentation of effluent particles.

2. Material collected by the traps is not subject to resuspension and therefore only represents one-half of the combined processes of deposition and resuspension.

3. The hydrodynamics of flow around the sediment traps results in greatly increased apparent sedimentation rates, relative to the actual sedimentation rate.

To test the last hypothesis, we earlier carried out an intercalibration study between the SCCWRP sediment traps and a "Soutar-style" trap. Both types of traps were positioned 1 m above the bottom in 55 m of water in the general vicinity of the Orange County outfall. The average apparent sedimentaton rate (1600 mg/sq.cm/yr) measured by the SCCWRP traps during the intercalibration study was within about 15 percent of the rate simultaneously measured by the Soutar trap. Thus, it appears that the collection efficiencies of the SCCWRP and Soutar traps are comparable.

Soutar traps had previously been used to measure water column sedimentation rates in the Santa Barbara Basin. The resulting rates were compared with those estimated from cores collected in the same area, and the two rates were found to be similar. More recently, Soutar traps have been used to measure sedimentation rates in the Santa Moncia Basin area. Again the rates were comparable with estimates based on radioactive tracers in cores collected from that area. Therefore, unless the near-bottom currents are significantly different in strength in the Palos Verdes area from those in the Santa Barbara Basin or Santa Monica Basin areas, the traps should provide a reasonable estimate of sedimentation rates.

It is unlikely that the high fluxes collected by the traps are the result of the deposition of effluent particles because: (1) the highest apparent sedimentation rate was associated with the lowest concentrations of TVS, total DDT and total PCB; (2) similar flux rates have been observed in areas removed from significant sources of effluent suspended solids: and (3) the total flux to the bottom would exceed the discharged flux of suspended solids.

Therefore, it also seems likely that the high apparent sedimentation rates, relative to the net accumulation rate of particles in the sediments, are a consequence of the fact that once particles settle in the trap, they are not available for resuspension. If the flux of resuspended (real) sediments is, however, comparable with the apparent sedimentation rate, the net accumulation rate could be small--as observed. In that case, an average particle will undergo a large number of resuspensions and redepositions before it becomes part of the "permanent" sediments. For example, for an annual average apparent sedimentation flux of 4550 mg/sq.cm/yr and an accumulation rate of 10 mg/sq.cm/yr in the sediments, the average number of resuspension and redepositions would be 455 (for an accumulation rate of 200 mg/sq.cm/yr, the number would be 23).

If the resuspended particles remain resuspended for only a short period of time, resulting in minimal transport by the near-bottom currents, the properties of the particles collected in the traps would be expected to be comparable with those of the surface sediments in the immediate vicinity of the sediment trap mooring. The locations of the two sediment trap moorings, 0-60 and 3W-60, correspond approximately to the locations of the coring station 6C, and mid-way between 6C and 3C, respectively. Table VIII compares the concentrations of TVS and total DDT at these stations (trap analysis carried out by SCCWRP; sediment analysis by JWPCP).

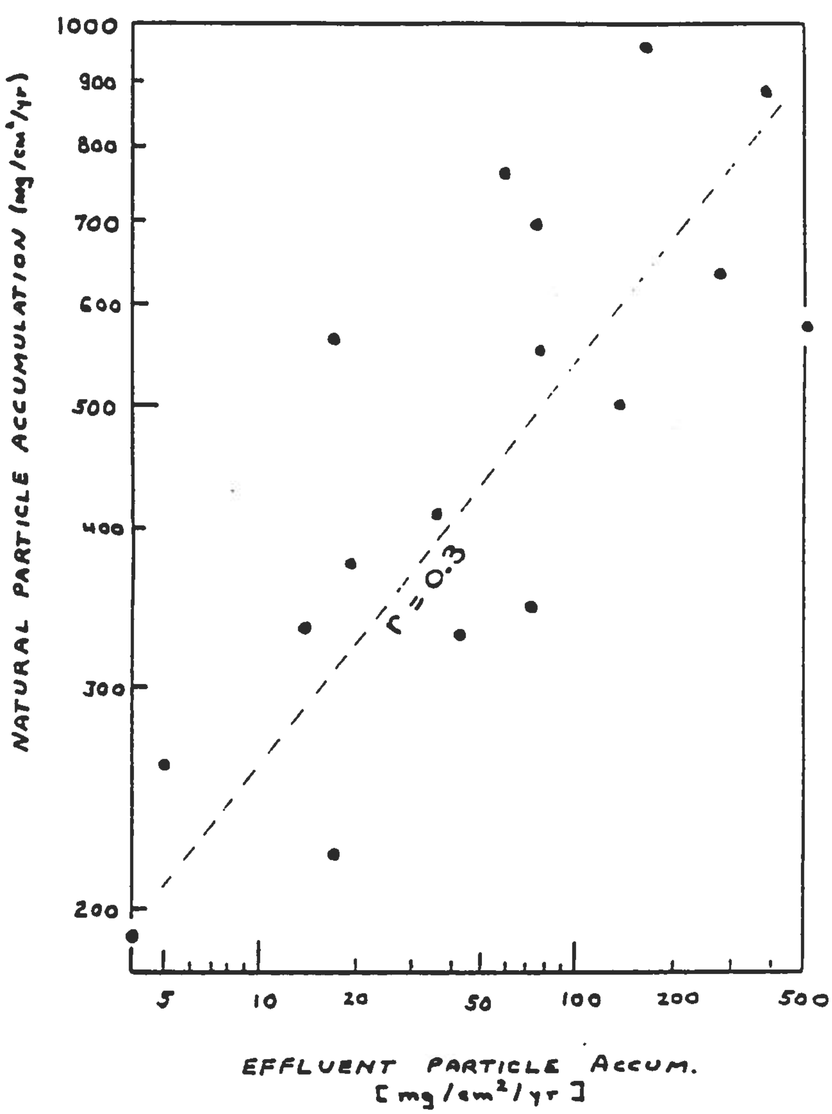

FIGURE 18. DEPENDENCE OF NATURAL PARTICLE ACCUMULATION ON EFFLUENT PARTICLE ACCUMULATION RATE (FROM 1981 CORES).

Table VIII

Sediment Trap Material and Surface Sediment Concentrations

Station	TVS	Total DDT
8C (core)	19.3	21100
6C (core)	14.2	10700
0-60 (trap)	12.3	2849
Avg.6C+3C(core)	13.7	9500
3W-60 (trap)	12.6	2746
3C (core)	13.3	8300

The TVS values for the material collected by the sediment traps are generally slightly less than, but comparable to, the concentrations measured in the upper 2 cm of the sediments in the vicinity of the traps. However, previous sediment trap measurements in areas with a relative uniform concentration of TVS in the sediments have generally yielded sediment trap material with TVS concentrations that are about double that of the surface sediments. Thus the material collected in the sediment traps off Palos Verdes would be expected to have higher TVS concentrations than the surface sediments at the mooring--unless the trap material includes particulates with substantially lower TVS concentrations that have originated away from the main body of the discharge-related sediment field.

This hypothesis is also supported by the observation that the concentration of total DDT in the trap material is about one-quarter (0.28 $\pm$ 0.02) that of the local sediments. However, there is some uncertainty about the validity of this conclusion since SCCWRP analysis of the 1987 SCCWRP cores yielded total accumulated masses of DDT that were about one-third that computed from the 1981 and 1985 cores that were analyzed by Joint Water Pollution Control Project (JWPCP) personnel. Thus, part or all of the sediment trap-surface sediment total DDT concentration difference might be related to different analytical methods. An inter-laboratory calibration using surface sediments containing representative levels of DDT should provide a more definitive conclusion about the relative concentrations (and the source of the trap material).

Hendricks (1987) has used the sediment trap fluxes, the accumulation rate of natural particles, and time-series of the near-bottom currents to numerically simulate the resuspension, transport, redeposition, and eventual accumulation of natural and effluent particles. The simulations predicted accumulation rates of effluent-related particles that were more than an order of magnitude less than the accumulation rate estimated from the cores--unless the effluent particles were only resuspended a few times before becoming part of the permanent sediments. In the latter case, the observed accumulation rates of discharged particles could be approximately reproduced along the 60 m isobath, but the concentration of TVS in the sediments was predicted to be significantly higher than measured. The observed levels of TVS in the sediments could be obtained, however, by increasing the accumulation rate of natural particles in the sediments when effluent particles were present. Hendricks (1987) used the cores collected in 1981 (Stull et.al., 1986) to estimate the concurrent fluxes of effluent-related material and natural material at each core station and found a relationship between the two fluxes, which supports this hypothesis (Figure 18).

In summary, this set of measurements is consistent with the following scenario for the fate of effluent particles that settle to the bottom in the vicinity of the outfall:

> As the effluent particles settle from the water column and approach to within 2 to 4 m of the bottom, they are mixed with natural (and effluent) particles resuspended in adjoining areas. After this collection of particles settle to the sediments, a fraction of them become incorporated into the permanent sediments. The magnitude of this fraction appears to vary with the characteristics of the particles. For natural sediments, the fraction may be quite small and the average particle may undergo ten to several hundred resuspensions before they become part of the permanent sediments. As a result of the large number of resuspensions, these particles may be transported over relatively large distances (e.g. kilometers). This supply of natural particles from beyond the perimeter of the main body of the effluent-related sediment field provides a dilution of the effluent particles (and their constituents).
>
> A much larger fraction (e.g. 0.2 - 0.5) of the effluent particles must be incorporated into the permanent sediments to account for the accumulation of effluent-related TVS in the sediments around the outfall. Therefore, the average effluent particle may only undergo 2 to 5 resuspensions (in the immediate vicinity of the outfall) before they become part of the permanent sediments.
>
> The presence of effluent particles also appears to promote an increase in the accumulation of natural particles--perhaps through aggregation with the effluent particles. As a result, the sedimentation of both effluent and natural particles is increased around the outfall where the rate of sedimentation of effluent particles from the water column is relatively high.
>
> The remaining particles are subsequently resuspended, where they are (on the average) transported upcoast and offshore by the near-bottom currents until they are again redeposited. This process continues until all the particles eventually become part of the permanent sediments.
>
> This scenario may provide a description of the fate of effluent particles under conditions where the characteristics of the sediments have achieved equilibrium with the discharge. In the case of changes in the flux (or character) of the effluent particles, it would be expected that the accumulation fraction of the sedimenting particles might also change.

At the present time, there is insufficient information to determine if this scenario is not only consistent with the observed characteristics of the sediments, but also with the actual processes governing these characteristics. However, it does provide one conceptual view of the effluent particle transport processes and mechanisms.

The character of the natural sediments changes toward the eastern end of the study area (in general, becoming coarser and with a lower organic content). Increased apparent sedimentation was also observed (in 30 m of water) in this area, suggesting that the change in sediment characteristics offshore (e.g. 60 m) may be the result of this increased flux. At the present time, the mechanism leading to this increased resuspension/redeposition flux is not known.

A small increase in apparent sedimentation rate was also observed in the vicinity of the landslide at Portugese Bend. Visual examination of the particles collected in this area (color, size) indicated that they were consistent with the slide material. However, the concentration of total DDT in the material collected in the traps during the one month when that information was available was relatively high, suggesting a significant contribution by a specific source (e.g. existing sediments, effluent particulates, or landslide material). The accumulation of the combination of effluent and natural particles, or the flux of resuspended particles available for transport into deeper water, depends on the difference between the sedimentation flux and the resuspension flux. Since the latter was not measured during this study, the potential contribution of landslide material to the region offshore (e.g. 60 m of water) cannot be estimated.

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