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METALS IN SURFACE SEDIMENTS FROM POINT DUME TO POINT HUENEME

During 1980, the Project extended its comprehensive survey of the coastal shelf and slope of southern California by adding seventy-three stations between Point Dume and Point Hueneme, west of Santa Monica Bay. Previously, trace metal concentrations in sediments were reported for the shelf off Palos Verdes Peninsula (Hershelman *et al.* 1977, 1981) and for Santa Monica Bay (Jan and Hershelman 1980). These two previous surveys both included areas of major wastewater treatment plant outfall systems where there are highly elevated metal concentrations in surface sediments. Here, we report the measurements of seven trace metals and four physical parameters in a region where the Infaunal Index indicates normal conditions exist (Bascom *et al.* 1978). We found that the trace metals measured generally fall within control values and correlate positively with water depth, total volatile solids, and smaller particle size fractions of the sediments. There is a strong negative correlation between the metals and the dry to wet weight ratio of the sediments.

SURVEY REGION

The study area is the shelf west of Santa Monica Bay, extending from Point Dume to Point Hueneme. Two nearshore submarine canyons (Hueneme and Dume Canyons) border this region, with Mugu Canyon approximately in the middle (Figure 1). The small Ventura County outfall is located near Hueneme Canyon, discharging at 20 meters depth. Seventy-three stations along eleven transects were sampled at approximately the 20, 60, 100, 300, 500, 600,and 700 meter isobaths. At five stations, grab samples could not be taken because of rocky bottom conditions. Two stations, 95-100 and 95-200, adjacent to the rocky bottom rise at 34°N, 119°01'W were composed largely of shell fragments and thus, were not included in the statistical analysis. This region has previously been designated as one where control conditions exist (Word and Mearns 1979).

METHODS

Station locations and depths are shown in Figure 1 and Table 1. The overall plan of the survey, as well as sampling methods and equipment, were reported by Bascom (1978). Benthic grabs were taken with a modified Van Veen as described by Word (1976) and the upper 2 cm subsampled for metals. Methods for percent solids (dry/wet ratio x 100), total volatile solids (TVS), and grain size are reported in Word and Mearns (1979). Sample preparation, storage,and

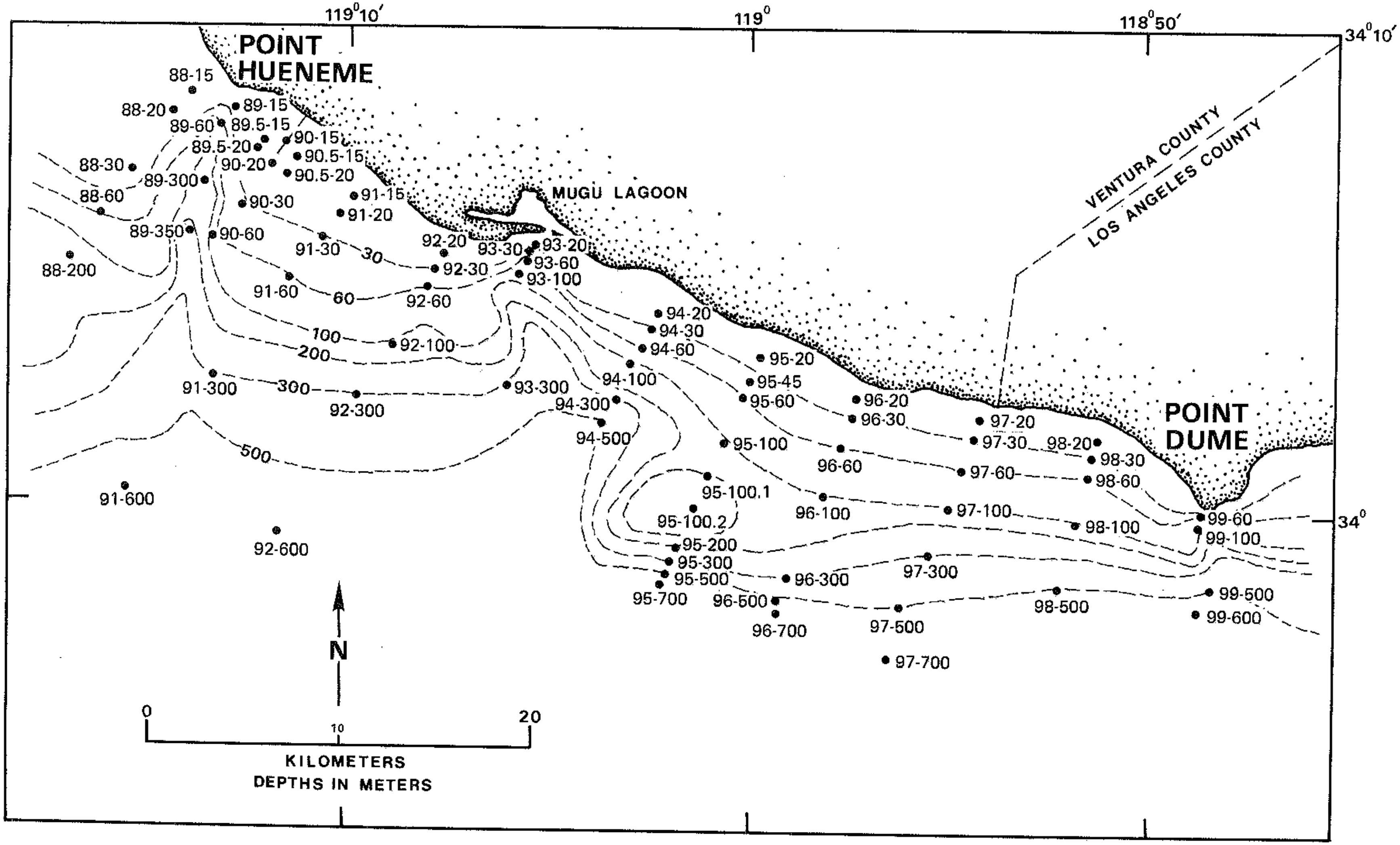

Figure 1. Benthic grab station locations

Table 1. Physical characteristics of surface sediments (0-2 cm) and concentrations of seven trace metals (mg/dry-kg) on the shelf and slope west of Santa Monica Bay, from Point Dume to Point Hueneme, 1980.

	LORAN-C Position				Percent			Parts Per Million Dry Weight						
Station	LOP 1	LOP 2	Infaunal* Index	Depth (m)	Dry weight	TVS	<63 m	Ag	Cd	Cr	Cu	Ni	Pb	Zn
99-60	28123.5	41229.0	60	58	66	3.8	34	0.08	0.90	49	13	23	29	45
99-100	28123.5	41227.1	ND**	103	60	5.0	51	0.20	1.7	49	22	36	25	70
99-500	28122.9	41221.5	56	520	46	5.3	77	1.3	1.4	120	38	36	20	91
99-600	28121.6	41222.0	45	573	50	7.0	71	0.31	1.2	84	27	35	17	77
98-20	28118.3	41247.1	70	20	80	0.8	3	<0.01	0.12	10	1.7	5.5	29	8.5
98-30	28117.6	41246.4	71	30	80	1.0	8	0.02	0.18	11	2.0	4.7	3.3	11
98-60	28117.0	41245.2	76	60	66	3.6	60	0.12	0.69	46	13	24	21	52
98-100	28115.2	41243.0	77	100	69	2.6	40	0.29	0.59	45	11	20	11	42
98-500	28113.1	41240.0	87	503	50	6.6	86	0.23	1.1	68	22	32	8.2	76
97-20	28110.7	41263.0	83	20	75	1.0	8.5	0.02	0.22	14	2.7	6.9	3.0	14
97-30	28110.1	41262.0	80	29	73	1.4	16	0.03	0.31	19	4.0	10	4.2	20
97-60	28108.6	41260.3	80	59	74	1.9	37	0.16	0.27	34	6.0	15	7.9	32
97-100	28107.5	41259.3	82	93	67	2.4	38	0.27	0.37	50	8.6	18	12	39
97-300	28105.1	41258.2	76	291	60	4.4	70	0.37	0.64	53	17	22	16	55
97-500	28102.4	41256.4	91	501	56	8.5	77	0.10	1.3	51	15	26	17	62
97-700	28101.4	41225.2	78	713	44	9.3	93	0.24	2.8	91	27	41	6.6	93
96-20	28103.2	41278.2	75	20	77	1.2	12	0.01	0.15	18	2.5	10	2.7	18
96-30	28102.7	41277.7	78	30	74	1.6	35	0.11	0.21	23	5.2	15	6.0	28
96-60	28101.2	41276.5	80	60	70	2.7	61	0.16	0.26	50	7.9	21	10	40
96-100	28098.8	41275.2	81	105	74	1.9	34	0.08	0.41	33	7.0	11	12	31
96-300	28095.8	41272.8	85	287	68	2.9	30	0.29	0.34	43	8.2	14	7.5	38
96-500	28095.4	41271.3	82	477	57	6.8	57	0.65	0.97	60	20	25	15	65
96-700	28094.4	41271.3	95	714	46	8.4	84	0.34	1.5	76	27	36	12	91
95-20	28097.3	41293.4	80	20	77	1.4	18	<0.01	0.36	13	3.3	5.0	3.0	19
95-45	28096.2	41292.8	85	45	71	2.5	61	0.12	0.40	36	9.2	15	4.4	43
95-60	28095.4	41292.6	83	60	77	2.5	72	0.13	0.52	38	10	13	6.5	37
95-100	28093.4	41291.4	76	97	68	5.4	44	0.22	1.7	40	9.0	11	4.5	35
95-100.1	28091.7	41290.1	-	98	-	-	-	-	-	-	-	-	-	-
95-100.2	28090.2	41289.5	-	98	-	-	-	-	-	-	-	-	-	-
95-200	28088.3	41288.5	84	187	69	3.6	16	0.10	0.29	45	6.5	3.5	3.5	41
95-300	28087.7	41288.1	-	354	-	-	-	-	-	-	-	-	-	-
95-500	28087.4	41288.1	81	523	56	8.0	51	0.14	1.5	65	22	31	12	62
95-700	28087.2	41287.4	100	745	44	7.6	77	0.13	2.0	78	28	36	7.6	85
94-20	28091.0	41309.0	66	20	79	0.85	3	<0.01	0.16	16	1.2	5.0	1.4	12
94-30	28090.2	41308.8	69	30	76	1.6	15	<0.01	0.37	12	3.5	5.9	2.4	24
94-60	28089.3	41308.4	82	61	69	3.4	74	0.11	0.74	33	10	18	5.2	46
94-100	28088.3	41308.2	84	100	66	2.7	74	0.21	0.91	44	13	18	3.9	50
94-300	28086.7	41307.4	74	315	54	6.7	84	0.17	1.3	51	23	25	12	72
94-500	28085.4	41306.9	94	508	54	4.7	65	0.21	0.99	70	18	20	6.1	61
93-20	28083.8	41329.0	67	25	76	2.5	28	0.05	0.43	18	6.7	15	6.3	28
93-30	28083.5	41329.2	-	32	-	-	-	-	-	-	-	-	-	-
93-60	28083.5	41328.7	66	54	62	5.1	80	0.15	1.2	44	19	25	13	60
93-100	28082.4	41326.5	78	106	66	2.8	48	0.28	0.77	55	12	20	11	49
93-300	28079.6	41320.5	80	305	56	4.9	84	0.11	1.0	59	19	24	8.7	72
92-20	28277.3	41339.0	85	19	76	1.2	22	0.14	0.22	14	4.5	6.5	5.9	24
92-30	28076.5	41338.8	76	29	74	1.8	57	0.11	0.59	19	6.1	11	6.9	32
92-60	28075.8	41338.2	82	62	64	5.1	75	0.28	1.3	39	16	22	22	53
92-100	28072.2	41337.5	73	103	75	2.2	24	0.26	0.38	22	5.9	9.9	8.1	36
92-300	28069.1	41337.1	78	345	59	3.9	88	0.50	1.6	38	21	26	18	70
92-600	28061.7	41335.0	73	597	50	6.3	89	0.42	1.5	86	24	34	15	87
91-15	28072.0	41354.9	77	14	79	0.79	13	<0.01	0.21	12	2.6	6.1	3.5	20
91-20	28071.0	41354.9	72	19	78	1.4	12	<0.01	0.13	14	3.0	12	3.9	19
91-30	28069.4	41354.9	78	30	74	2.3	30	0.02	0.41	18	5.9	11	6.5	29
91-60	28066.6	41354.9	80	59	76	1.7	32	0.13	0.48	24	6.4	11	13	35
91-300	28059.6	41355.5	83	302	64	4.8	72	0.16	0.73	38	13	19	14	54
91-600	28052.1	41356.2	82	598	52	7.9	94	0.47	1.5	56	22	28	15	80
90.5-15	28069.0	41364.5	80	16	79	1.6	8	<0.01	0.30	12	3.0	6.7	4.4	21
90.5-20	28068.0	41364.4	80	22	78	1.6	19	0.02	0.23	16	5.0	11	3.8	32
90-15	28068.3	41366.6	71	14	80	1.5	5	<0.01	0.25	13	2.9	11	6.9	24
90-20	28067.0	41366.9	74	18	76	2.8	11	0.74	0.35	23	8.3	18	7.3	48
90-30	28064.2	41367.0	81	28	76	1.8	38	0.14	0.27	14	3.8	10	5.2	30
90-60	28062.0	41366.5	82	55	70	3.4	52	0.13	0.40	28	9.0	20	6.6	53

Table 1 Continued

Station	LORAN-C Position		Infaunal* Index	Depth (m)	Percent			Parts Per Million Dry Weight						
	LOP 1	LOP 2			Dry weight	TVS	<63 m	Ag	Cd	Cr	Cu	Ni	Pb	Zn
89.5-15	28067.0	43169.6	74	15	80	1.2	6	<0.01	0.12	9.1	2.4	5.0	5.7	18
89.5-20	28065.8	41369.7	84	18	78	1.0	9	<0.01	0.19	14	2.9	8.7	5.2	27
89-15	28065.3	41375.9	62	15	78	1.4	12	0.10	0.42	15	5.3	9.0	4.5	33
89-60	28064.0	41376.0	81	60	63	5.2	87	0.31	1.0	37	17	25	15	71
89-300	28062.3	41373.1	68	260	54	7.1	94	0.67	1.1	71	26	36	26	99
89-350	28060.2	41370.1	71	359	56	6.8	91	0.34	1.2	57	25	38	20	91
88-15	28062.5	41382.5	-	15	-	-	-	-	-	-	-	-	-	-
88-20	28061.0	41382,5	67	20	78	2.2	27	0.05	0.17	21	6.4	9.4	6.0	34
88-30	28057.3	41382.5	65	30	74	2.6	31	0.07	0.33	20	6.6	11	6.6	43
88-60	28054.5	41381.6	75	62	70	2.0	46	0.14	0.49	24	8.8	15	9.6	47
88-200	28052.0	41381.5	77	196	72	3.0	32	0.15	0.25	25	7.2	14	6.7	41

* Infaunal Index values obtained by James Roney, David Tsukada, and Jimmy Laughlin.
** ND means no data.
Dash means rocky bottom condition, no grab sample retrieved.

trace metal analytical details are described in Jan and Hershelman (1980). Briefly, a wet ashing was performed with a hot nitric acid-hydrochloric acid digestion. After cooling, the digestate was filtered through acid-washed Whatman No. 40 filter paper (8-micron pore size) and diluted to 50 ml. Analyses were performed by aspiration into an air/acetylene flame of a Varian-Techtron atomic absorption spectrophotometer (Model AA-6), equipped with a premix burner and a simultaneous background corrector. When very low concentrations were encountered, quantification was done by injection into a carbon rod atomizer. There were no significant matrix interferences in detection of the elements in question, given a sample size of up to 2 grams. Analytical blanks were prepared along with the sediment samples, using the same procedures and reagents.

The resulting trace metal concentrations were compared with four physical measurements (including water depth) by linear regression. In the regression analyses, the arcsin transformation was employed to convert the non-normal distribution of proportion (percent) values used to describe the percent solids, percent total volatile solids, and the percent sediment particles less than 63 μm in size to the near normal distribution required. The arcsin transformation is expressed as the angle whose sine is the square root of some proportion X, or $X' = \arcsin \sqrt{X}$ (Zar, 1974).

RESULTS AND DISCUSSION

Concentrations of silver, cadmium, chromium, copper, nickel, lead, and zinc are presented in Table 1. Physical descriptions of the sediments are also shown. In addition, Infaunal Index values are listed. With the exception of two Dume Canyon stations, all are above the "normal" criteria of 60. The average Infaunal Index value is 77, indicating that this is an unimpacted region (Bascom 1978; Bascom *et al.* 1978; Word 1980).

Of the 67 stations sampled, 12 were at a depth of 60 meters. Trace metal concentrations at these stations generally fall within the range of 60 meter control values from a survey conducted along the entire southern California coast (Word and Mearns 1979). For comparison, the results are summarized in Table 2.

Even though only a single measurement per station for each parameter was performed, there was a high correlation ($P = < 0.001$) of trace metal concentrations with the physical compon-

Table 2. Summary of trace metal concentrations (ppm-dry weight) in sediments from 28 control stations collected along the southern California coast at a depth of 60 meters during 1977 (Word and Mearns 1979) and results for the twelve 60-meter stations of this study.

	(1977) 60 Meter Control Survey Point Conception to Mexico		(1980) 60 Meter Stations Point Dume to Point Hueneme	
	Median	Range	Median	Range
Silver	0.20	0.06-1.7	0.14	0.08-0.28
Cadmium	0.33	0.10-1.4	0.60	0.26-1.3
Chromium	22	6.5-43	38	24-50
Copper	8.3	2.8-31	10	6.4-19
Nickel	12	1.6-35	20	11-25
Lead	6.1	2.7-12	12	5.2-29
Zinc	43	9.8-62	46	32-71

ents of the sediments. These relationships are listed in Table 3. The trace metals measured are usually associated with the finer grain sizes presumably due to the higher adsorptive qualities of the smaller sediment particles. In deeper water, the sediments are composed of smaller particles. Therefore, trace metal concentrations increase with depth. There are numerous possible explanations for these sediment distributions, but resuspension and seaward motion of terrestrially derived sediment particles, progressively separated into finer size fractions is the most likely explanation (Emery 1960).

Total volatile solids also correlate positively with increasing water depth because of the adsorptive qualities of finer grain sizes. Figure 2 shows this relationship for the shelf and slope, down to 700 meters. Therefore, trace metal concentrations also correlate with total volatile solids, and in fact, some portion of trace metals may be attached to the volatile solids (Serne and Mercer 1975).

Percent solids yield high (negative) correlation coefficients with metals because low percent solids reflect more water content which occurs with finer grain size sediment.

Table 3. Correlation coefficients of physical characteristics versus trace metal concentrations in surficial sediments (0-2 cm). N = 66 except for silver, which is n = 56. $P < 0.001$ in all cases except % <63 μm vs. Ag, which is $P < 0.01$ and water depth vs. Pb, which is $P < 0.02$.

	% solids	% TVS	%<63 μm	Increasing water depth	Ag	Cd	Cr	Cu	Ni	Pb	Zn
% Solids	-	-0.942	-0.870	-0.899	-0.495	-0.898	-0.936	-0.962	-0.935	-0.482	-0.942
% TVS		-	0.867	0.850	0.398	0.882	0.844	0.913	0.923	0.510	0.932
%<63 μm			-	0.671	0.337	0.791	0.778	0.846	0.758	0.451	0.892
Increasing water depth				-	0.419	0.806	0.841	0.835	0.790	0.298	0.805

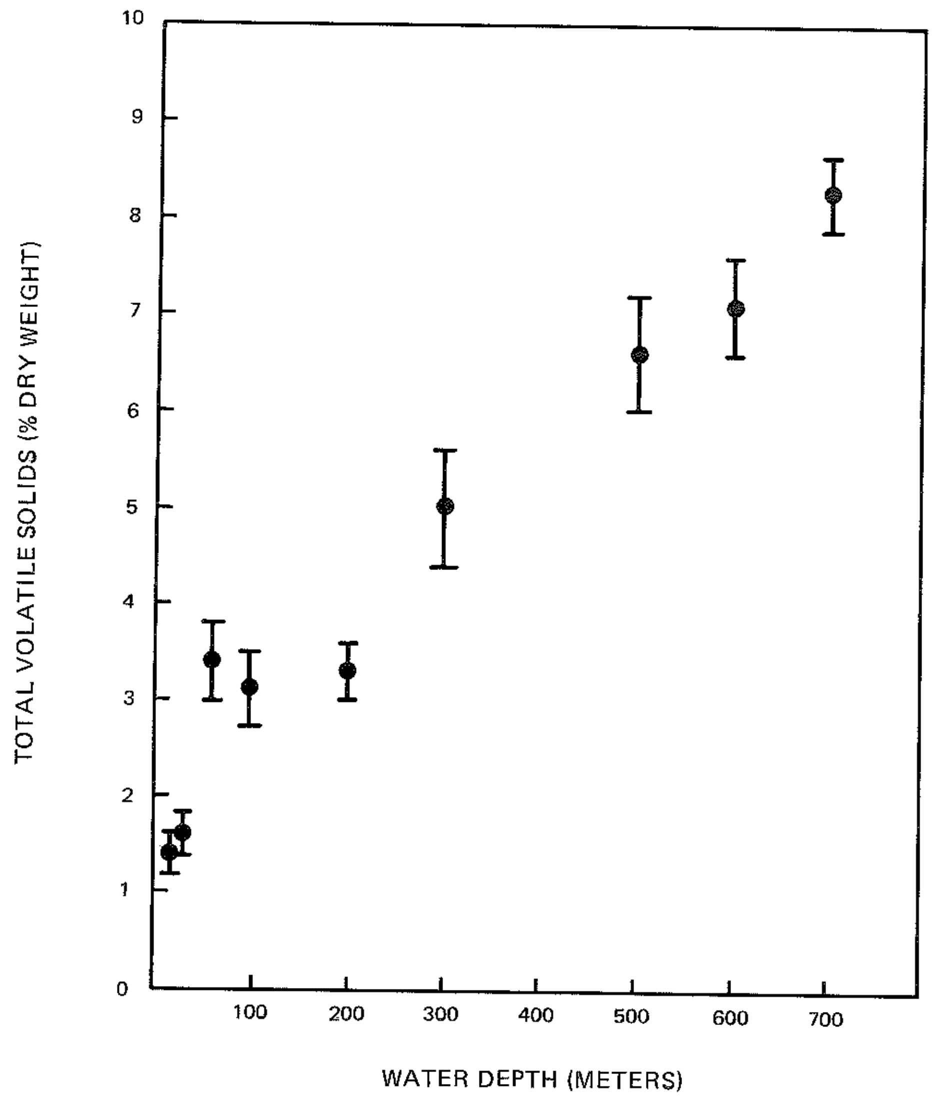

Figure 2. The relationship of total volatile solids in surface sediments (0-2 cm) to water depth on the shelf and slope from Point Dume to Point Hueneme. Trace metals correlate positively ($P < 0.001$) with increasing water depth and total volatile solids.

Lead yielded the lowest correlation coefficient with water depth, possibly because its presence is due to auto emissions along the heavily traveled Pacific Coast Highway in the Point Dume area. Silver also yielded lower (though statistically significant) correlation coefficients. Silver concentrations were very low at some stations, thus, the correlations could be affected by the larger analytical variation at or near the detection limit.

No effects were noted in the sediments within 1 km of the Ventura County outfall, which presently discharges 18 mgd of secondary treated effluent (for details see Schafer, this report).

The Project is presently continuing this survey of trace constituents in sediments on the shelf and slope off Orange County.

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