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INTERIM REPORT ON THE EFFECTS OF SLUDGE IN SANTA MONICA BAY

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IN SANTA MONICA BAY

SUMMARY

Our scientific study of the ecological effects of the 7-mile outfall is not yet complete; we intend to take additional samples and make more measurements. This is an interim report on what we have learned through 1976. It is possible that subsequent findings will make it necessary to modify the statements herein.

About 4.8 million gallons per day of liquid containing 0.76% solids is discharged out the end of the 24" diameter sludge line into the head of Santa Monica submarine canyon nearly seven miles offshore in water 100 meters deep. The momentum of discharge carries the particulate material outward and it immediately separates according to size. Many of the larger particles settle 100 to 200 meters away while the very fine particles, which constitute about 96% of the total, remain suspended in the water and drift with the subsurface currents, which usually flow down the canyon. It is most unusual to see any sign of this outfall at the surface.

The thickest deposits of sludge particles yet measured (in what seems to be the most concentrated area of deposition) are in the range of 30 to 80 cm. The area of bottom in which sludge is visible or can be detected by smell is about two square kilometers. If the area of sludge is defined by bottom sediments that exceed 6% volatile solids (background for the bay) the area is somewhat larger, perhaps as much as 10 km^2. The total area of Santa Monica Bay is about 500 km^2.

The sludge particles discharged in effluent are 96% smaller than 0.25 mm but only 0.6% of that material becomes part of the nearby sediment. This suggests that only about one seventyfifth (or 1.3%) of the sludge particles settle to the bottom. The sludge particles observed are virtually all vegetable matter (leaf fragments and seeds). However, band-aids, aluminum foil fragments and miscellaneous plastic chips are also brought up in trawls and grabs.

PCB attached to fine particulates from this outfall can be measured at very low levels and thus can be used to trace the movement of sludge particles. PCB in the sediments drops off sharply towards shore indicating very little movement of sludge particles in that direction.

Our measurements of benthic animals in the sludge area range from 7 to 26 species and from 3,240 to 30,180 individuals per square meter. This compares with 51 species and 1,500 individuals per square meter in the control area.

Bottom fish are present in large numbers in the maximum sludge areas: 23 species and 1,279 individual adults plus 250 juveniles were collected in a single trawl. This compares with an average of 10 species and 139 individuals caught elsewhere in Santa Monica Bay over the last 12 years. In the same trawl 24 invertebrate species and 1,400 individuals were caught; there are no numbers available for invertebrate comparison.

The exposed pipe and its end structure are covered with and surrounded by animals such as metridium, starfish, bocaccio, rockfish and sole. Hook and line fishing tests by the project off the outfall captured 6 species and 47 individuals weighing 23.2 kilograms in 5.5 hours. (This is the area used by several of the sportfishing boats from Marina del Rey and King harbors).

We have compared the Los Angeles sludge problem with that of New York which is quite different in volume, material and ocean situation.

We do not find evidence that the sludge disposal area in Santa Monica Canyon has changed in the last 5 - 10 years; whatever the situation, it is stable.

The Problem

The Hyperion 7-mile sludge outfall has been in operation for about 17 years, discharging an average of 4.8 million gallons per day of liquids containing various possible pollutants, including about three quarters of one percent solids, into the head of the Santa Monica submarine canyon.

Existing legislation requires that this discharge be stopped, presumably with the intention that some less environmentally damaging disposition be made of the sludge. At this writing, no generally acceptable alternative solution seems to have been found.

A variety of statements have appeared in the press about the effects of this sludge discharge, but some of these are not supported by careful measurements.

Therefore, in hope of better informing the public, we have assembled this progress report which describes what we know now about the effects of the present discharge.

The position of this project on the matter of ocean disposal

The scientists of this project are dedicated to determining the effects on the ocean environment of municipal waste disposal. Our task is to study all aspects of this matter and to report the findings to the public.

It is not our policy to comment on sewage treatment methods, disposal techniques, or costs. As professional ecologists we hope that the ecological advantages and disadvantages of all disposal methods and sites will be fairly compared before a final decision is made.

Material Discharged

The daily discharge from the 24" 7-mile long sludge line into 50 fathoms (300 ft) of water averages as follows:

1.3 mgd of screened, digested (primary) sludge

1.0 mgd of waste-activated (secondary) sludge

2.5 mgd of secondary effluent

4.8 mgd total

Average solids content is 7,340 mg/l or 0.73%

Details of the average concentrations and tonnages of material discharged per year are given in Tables 1 and 2. A total of 61,000 metric tons (dry weight) of solids is discharged each year. This compares with 195,000 metric tons dumped off New York. The wet volume of 61,000 tons is about 300,000 cubic meters. However, we believe that less than 2% of this material remains near the discharge point.

Upon discharge the momentum of the liquid carries it outward, the relatively high temperature and salinity cause it to rise slightly (perhaps to the bottom of the ocean surface layer which is about half the water depth), and the existing currents modify the direction slightly. Mixing by a factor of 50 to 150 probably takes place in the first 200 meters. At that time particles larger than about 0.25 mm tend to settle to the bottom; the very fine ones which represent about 96% of the material discharged apparently drift away (generally in a down-canyon direction).

Most of the sludge particles that are observed (the material samples from the bottom are screened) appear to be bits of

Table 1 . Average Concentration of Constituents seven mile pipe (1971 - 1975) as measured by Hyperion Laboratory.

	1971	1972	1973	1974	1975	Average
Flow mgd	5.	4.6	4.8	4.7	4.3	4.7
	mg/l					
Total Suspended Solids	3,000	8,600	7.500	7,300	10,300*	7,340
Oil and Grease	760	636	922	900	970	838
Ammonic Nitrogen	160			300		230
Total Phosphorus	130			663	80	291
Cyanide (CN)		.10	.11	.53	.67	.353
	mg/l					
Silver	.03	.299	.8	.4	.8	.466
Arsenic		.03	.27	.18	.29	.19
Cadmium	.23	.42	.98	1.28	1.17	.816
Chromium	2.1	8.23	18.2	15.1	11.7	11.07
Copper	12.2	7.58	13.6	13.9	16.8	12.82
Mercury	.1	.125	1.4	.15	.108	.377
Manganese	1.6	.67	.37		.19	.71
Nickle	2.6	2.04	3.7	3.1	3.1	2.91
Lead	.51	1.8	1.57	1.13	2.05	1.41
Zinc	16.5	10.74	27.0	23.9	23.1	20.2
Selenium		.25	.45	.4	.27	.343
	ug/l					
DDT			4.03	2.59	6.49	4.21
PCB			25.4	3.30	15.3	15.3

* Digester cleaning in 1975 significantly but temporarily raised the average suspended solids.

Table 2 . Total of Materials Discharged from the Seven-Mile Outfall each year.

	Average/Year for last 5 years.	Total in 20 Years
	(Metric Tons dry wt)	
Total Suspended Solids	47,710	954,200
Oil and Grease	5,447	108,940
Ammonic Nitrogen	1,495	29,900
Total Phosphorus	1,891	37,820
Cyanide (CN)	2.29	45.80
Trace Metals	(Metric Tons dry wt)	
Silver	3.1	62.0
Arsenic	1.25	25.0
Cadmium	5.3	106.0
Chromium	72.0	1,440
Copper	83.2	1,664.0
Mercury	2.45	49.0
Manganese	4.6	92.0
Nickle	18.9	378.0
Lead	9.2	184.0
Zinc	131.3	2,626.0
Selenium	2.2	44.0
Chlorinated Hydrocarbons	(Kilograms)	
DDT*	27.4	548.0
PCB*	99.5	1,990.0

* Based on average after 1972

vegetable material; seeds, fibers, and bits of leaves that were not adequately digested.

The solids discharged are supposed to be screened in the treatment plant. However, a considerable number (but very small percentage) of small objects are found in the sediment near the outfall. These are such things as band-aids, cigarette filters, wads of tin or aluminum foil, and plastic spoons.

Partition upon Discharge

Analysis of particle sizes in effluent and in sediments at the discharge site provides some idea of the expected size of the sludge field offshore.

Two representative samples of effluent and two samples of sludge sediment from near the discharge point were screened and the particle size compared.

Almost all of the surface sediment near the outfall appeared to be of effluent origin. The distributions of particle sizes were very different for the two kinds of samples; 96% of the effluent particles were very fine ($<$ .25 mm) and only 0.9% were large ($>$ 4 mm) whereas 43% of the sediment was composed of fines and 6.9% were large particles (Table 3). If one assumes that all of the largest particles ($>$ 4 mm) settle near the outfall and the percentages of the other particles on the bottom are proportioned in accordance with the screened data, it is possible to estimate the amount of sludge that remains near the discharge point.

It takes 7,500 grams of effluent solids to produce the same amount of large particles ($>$4 mm) that is found in 100 grams of sediment:

	Total Wt.	Percent of Solids > 4 mm	Grams of Solids > 4 mm
Effluent Solids	7,500	.0925	6.9
Outfall Sediment	100	6.9	6.9

The ratio of sediment to effluent solids is 1:75. This suggests that 1.3% of the discharged material settles near the outfall.

Table 3

Particle Size mm		Effluent Solids % of Solids	Sediments % of Solids
	>4	.09	6.9
4 >	>2	.24	1.85
2 >	>1	.69	5.35
1 >	>.5	1.82	17.05
.5 >	>.25	1.12	25.75
.25 >		95.98	43.2
		100.00	100.00

Table 4

Particle Size mm		Grams/7,500 gr of Effluent Solids	Grams/100 gr of Sediment	Estimated Percent Deposited
	>4	6.9	6.9	100.*
4 >	>2	17.7	1.85	10.5
2 >	>1	52.1	5.35	10.2
1 >	>.5	136.7	17.05	12.5
.5 >	>.25	84.3	25.75	30.5
.25 >		7,199.	43.2	0.6**
		7,500.	100.	1.3

* Assumes 100 percent deposition
** Note only .6 percent of 96 percent fines in the effluent fall near the outfall.

By calculating the weight that each particle size contributes to the 7,500 gm and comparing these amounts with those found in 100 gram of sediment we can estimate percent of deposition for each size of particle (Table 4).

The overall solids discharge volume is 300,000 cubic meters (m^3) per year. An estimate of 1.3 percent settling near the outfall might be too conservative. If we assume 5 percent settles, then this produces an annual deposition of 15,000 m^3 for a total deposition of 255,000 m^3 for the last 17 years of discharge. This latter figure is roughly equal to two square kilometers (.77 sq mi.) covered to a depth of 12 cm (5 inches).

To date other field measurements do not indicate the field is much larger than this size. More samples from a wider area and deeper cores will help better define the actual size and depth.

Mapping and navigation

The position of the sludge deposits is largely controlled by the steep slopes of the bottom contours and by the canyon's influence on currents. This required us to make an accurate chart of the bottom in the discharge area in order to understand the meaning of the variations in our measurements. The chart is also useful in assessing the television information and in deciding where to take additional samples.

Much of the past information collected by various groups is of little value because of uncertainties in the position of the measurements or samples. Eventually we will enlarge the chart presented herein until all the area which exceeds baseline values is included (mainly down-canyon and further offshore).

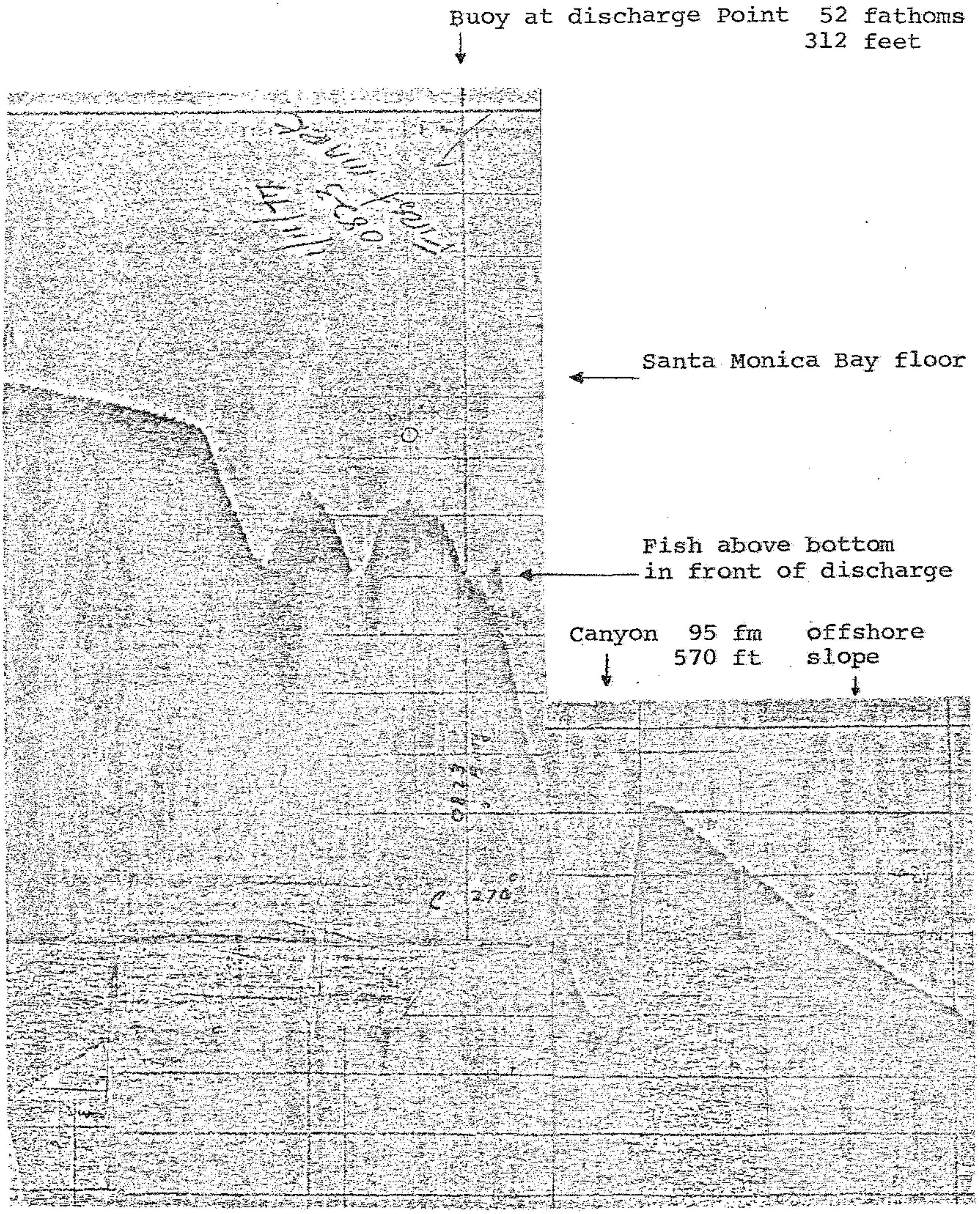


Figure 2. Echo sounder record of Jan. 11, 1977 (50 Kh)
Ship moving 270° Magnetic at 800 RPM (8 Kts)

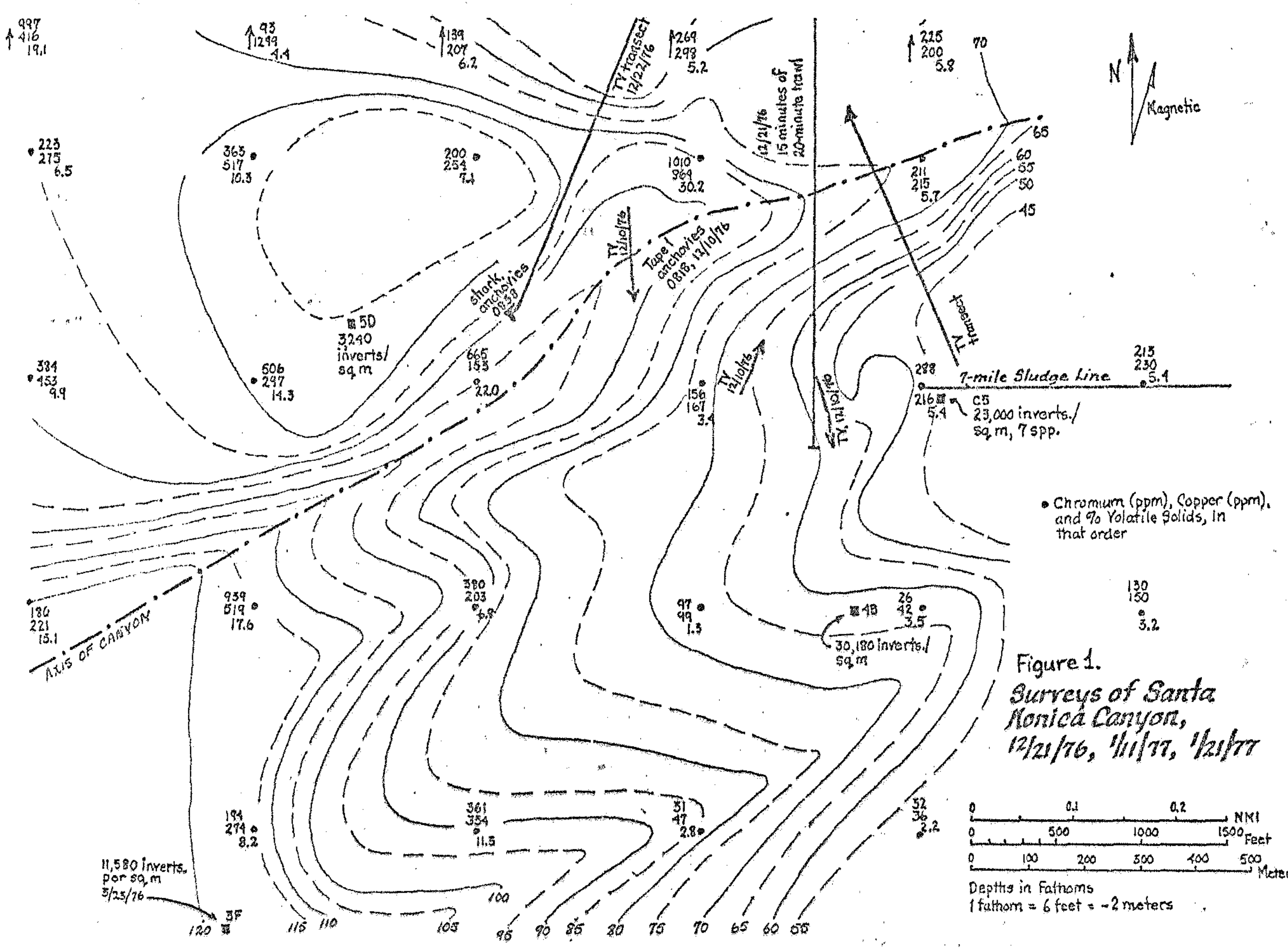


Figure 1.
Surveys of Santa Monica Canyon, 12/21/76, 1/11/77, 1/21/77

Sonar observations

Our principal surveying tool has been a Honda HE-103-C 50 Kh sonar with a beam width of 40° that sends/receives 74 pulses per minute. This instrument is primarily used for obtaining the depth of water beneath the ship but it is also useful as a "fish finder" and for observing plankton in the water column.

On nearly every visit we have made to the area schools of fish could be seen on the sonar record. On some occasions (such as on Dec. 10, 15, 21, 22,1976) the record shows a heavy haze in the canyon and well up in the water column. We believe this to be clouds of plankton; on Dec. 22 we lowered the television through it in 10 meter steps and observed unidentifiable white particulates.

On other days (Jan. 11, 21, 1977) no such reflection was recorded. Since the outfall presumably was discharging the same sort of material on all occasions, this suggests that the waste particulates are transparent to this sonar and that these reflections are probably plankton (small marine plants and animals).

Oceanography of Santa Monica Bay

Santa Monica Bay and its submarine canyon lie adjacent to the deep (950 m) Santa Monica Basin. This basin contains cold water, low in oxygen content, which greatly influences conditions in the submarine canyon and bay. In January and June 1974, the Coastal Water Research Project conducted hydrographic cruises in the northeast portion of the Santa Monica Basin to: (1) provide new information on the temperature, dissolved oxygen content, and coliform concentrations at several depths in the water from surface to bottom, (2) determine if the values of these parameters had changed from previous years, and (3) to compare the waters in the nearshore shelf area of Santa Monica Bay with those of the basins.

Water samples were taken on three transects covering nine stations. Bottom depths ranged from 100 to 900 m. The transects were sampled aboard the R/V Vantuna (Occidental College) on 14 and 15 January and again on 6 and 7 June 1974. At each station (Figure 3), temperature, dissolved oxygen, salinity, and clarity, were measured at the surface, at 20 m, and at every 200 m thereafter to the bottom. Nansen bottles with reversing thermometers were used to collect subsurface water samples and to determine the in situ temperatures of deep waters. A bathythermograph was lowered to 400 and 900 m at each station to record temperature and thermocline profiles. Dissolved oxygen content was measured using the Winkler azide-modification titration method. We obtained salinity values with a Beckman induction salinometer and recorded pH with a Corning pH meter. The clarity of the surface water layer was determined with a

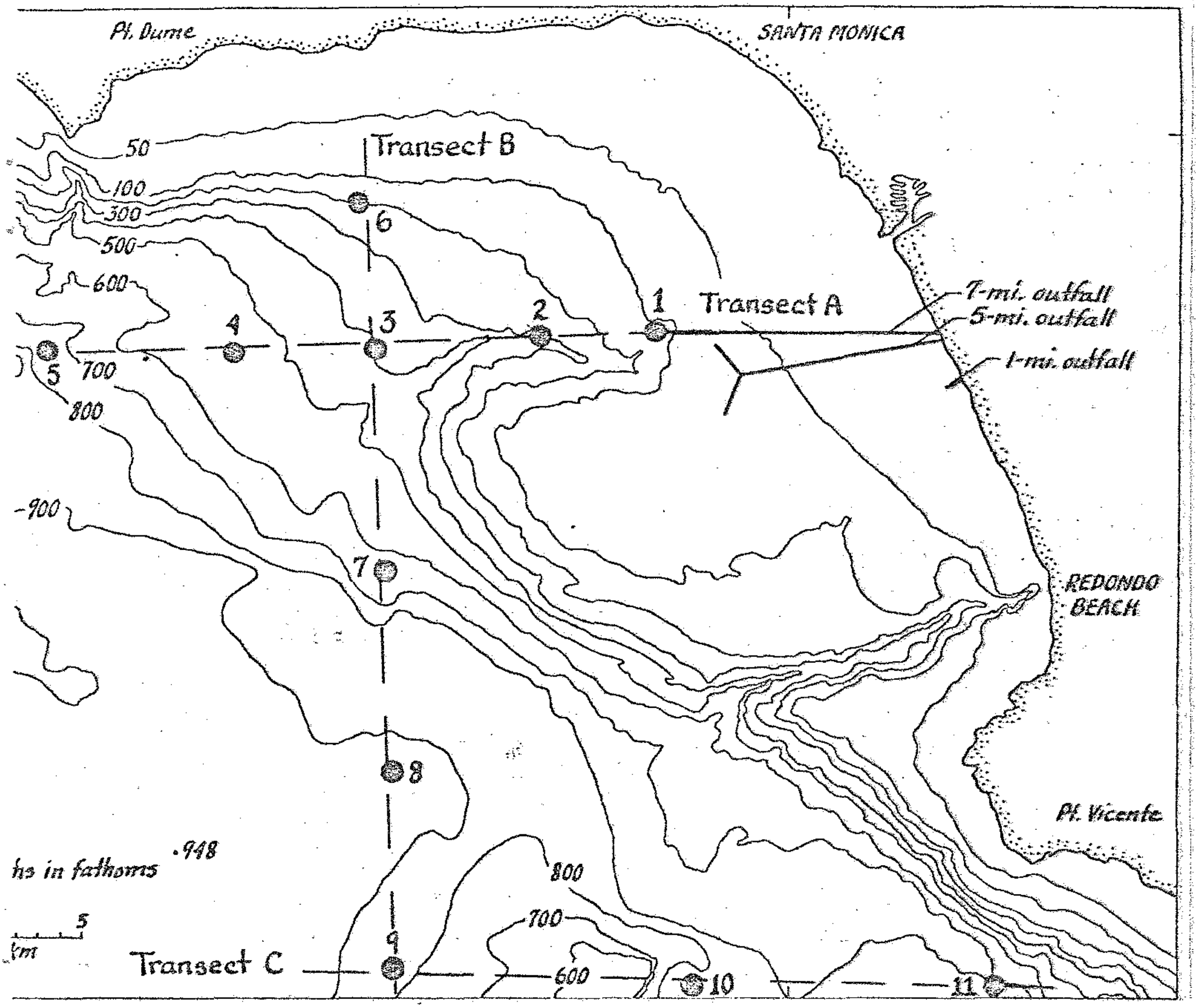


Figure 3. Oceanographic Stations sampled in Santa Monica Basin, January and June, 1974.

standard Secchi disc.

During both cruises, the bay and basin waters were stratified, with seasonal warming affecting only the upper 200 m of water (Figure 4). Dissolved oxygen concentration near the sludge discharge area were about 6 mg/l in January and 4 mg/l in June (arrows, Figure 4). This change was accompanied by decreased temperature and increased salinity, indicating the decrease in oxygen was primarily a response to movement of basin water rather than to the sludge discharge.

We compared the 1974 data on temperature and dissolved oxygen with similar data collected in the early 1950's in Santa Monica Basin (summarized by Emery 1960); the results are presented in Figure 5. From 200 m to the sill depth (737 m), both temperature and oxygen curves closely approximate those of the open ocean. These data suggest that there has been no major change in deepwater oxygen concentration over a period of at least 14 years.

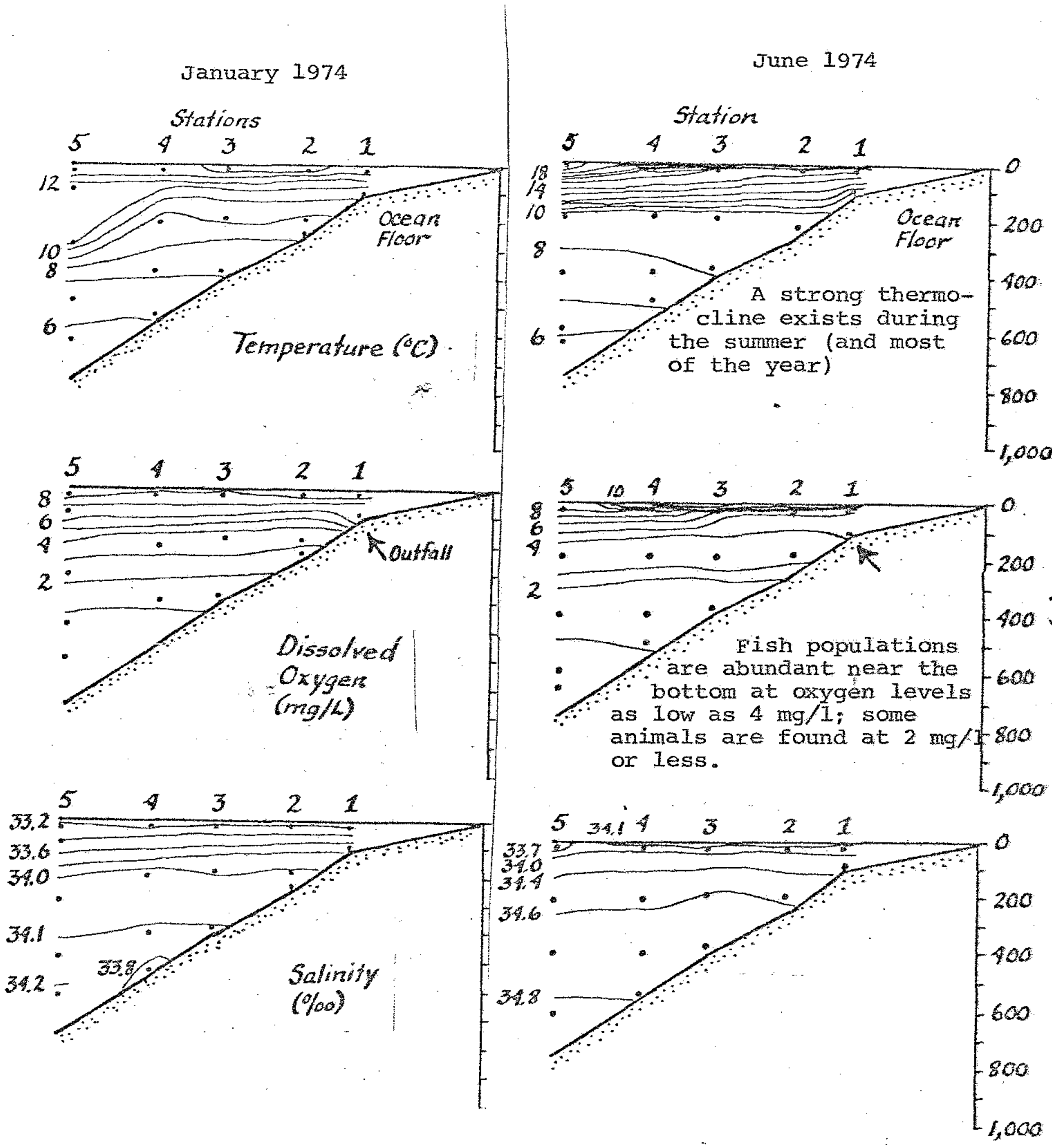


Figure 4. Profiles of temperature, dissolved oxygen and salinity for Santa Monica Bay and Basin, January and June, 1974.

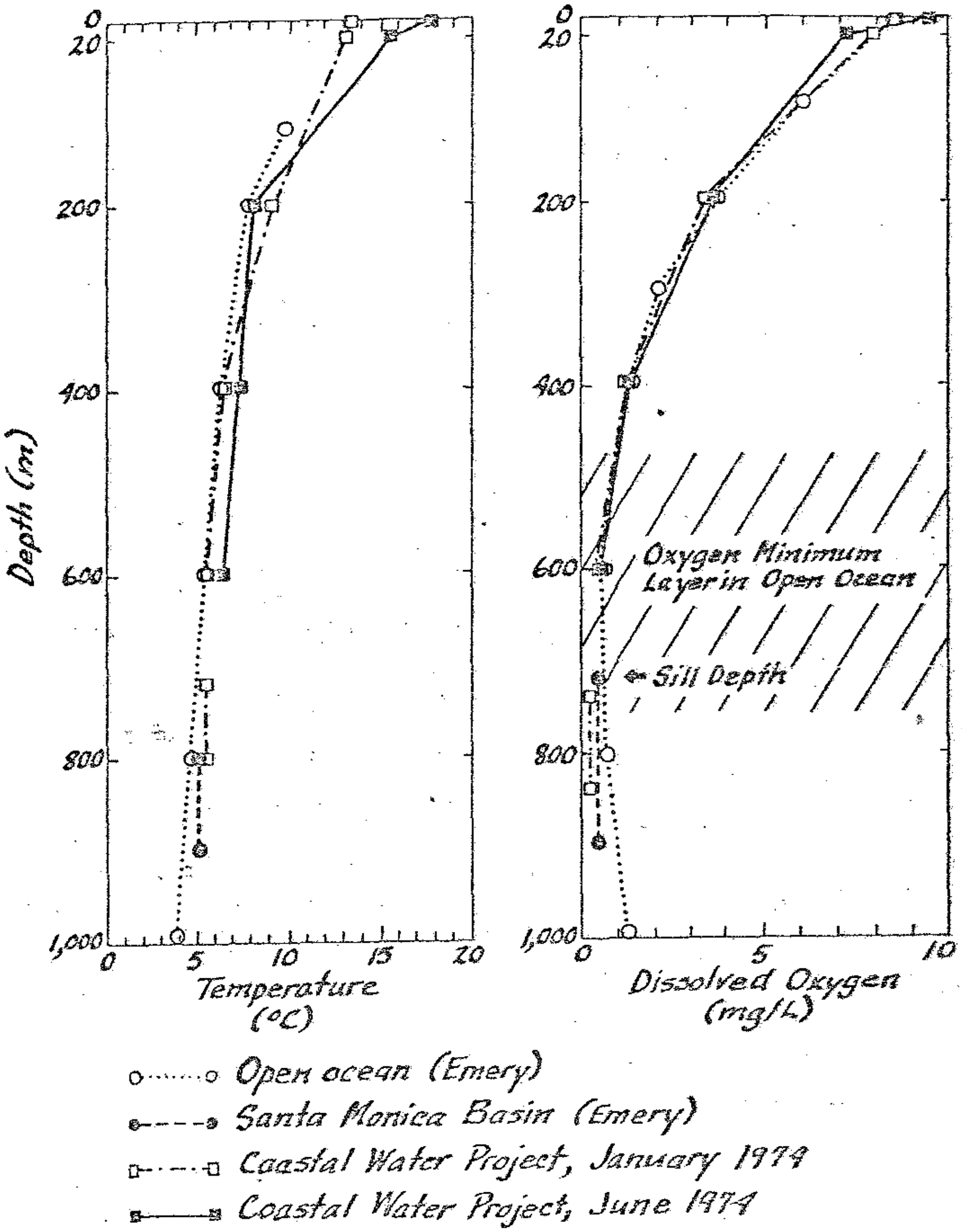


Figure 5. Comparison of recent temperature and dissolved oxygen data for Santa Monica Basin with data summarized by Emery (1960).

Currents in Santa Monica Canyon

Currents within Santa Monica Canyon have been measured on at least two occasions: June 8 to June 10, 1972 (Shepherd, et al. in 470 m of water) and September 12 to October 4, 1974 (SCCWRP, in 370 m of water). Throughout these measurements the net flow was down-canyon (with speeds of 2.4 and 3.5 cm/sec, respectively). When this is combined with semi-daily and daily tidal velocities which are typically about 15 cm/sec., maximum velocities up or down the canyon can be determined. Occasionally the up-canyon tidal flow is greater than the net down-canyon flow and brief periods of up-canyon flow result. The maximum up-canyon movement of a watermass calculated from either record was 2.8 km; the net down-canyon movement for the longer record was about 70 km.

Since measurements have not been made in other areas of the canyon, the properties of the currents in these areas remain unknown. Observations made by Shepherd, et al in other canyons off the southern California coast, however, permit some speculation on the flows in other parts of Santa Monica Canyon. These studies showed, for example, that the currents in the water column along the axis of the canyon should be similar to the near bottom currents. In addition, the tidal period oscillations probably are replaced by shorter period fluctuations (apparently associated with progressive internal waves) as one moves up the canyon into shallower water. Since these fluctuations oscillate more rapidly, the up-canyon displacements associated with these fluctuations may also diminish.

Intense but relatively short-lived down-canyon flows have occasionally been observed during strong onshore winds associated with storms. These flows, which are driven by the increased density of near-bottom water laden with suspended sediments, have been observed to exceed 190 cm/sec and to effectively scour the bottom of the canyon. Although these turbidity currents have not been observed during the two brief periods of current measurements in Santa Monica Canyon, they may occasionally occur here as well.

Currents at the head of the canyon will probably be more complex due to the combined influences of the canyon and nearshore shelf flows. The latter are believed to generally move inshore in the area of the sludge outfall, then bend to the west to form a counter-clockwise gyre which then flows out of the northwest end of Santa Monica Bay.

PCB as a Tracer

Polychlorinated biphenyls (PCB's) are an effective tracer of municipal wastewater particulates. These industrially-important synthetic organics are common contaminants of such wastes. During a half-year study in our laboratory we found no evidence that PCB's washed off bottom sediments that were collected from near a major wastewater outfall. Thus we believe they are reliable tracers of particulate wastes.

PCB concentrations in sediments collected during 1976 near the sludge outfall terminus range up to 5 parts-per-million, among the highest we have found around any southern California outfall. However, the concentration of PCB decreases rapidly away from the end of the outfall. Values outside a two kilometer radius (a little more than one mile) are usually one-tenth or one-twentieth of the highest concentration measured near the outfall terminus. The sediment concentrations measured roughly one-half kilometer from the base of the sludge line at El Segundo Beach are less than one one-hundreth of this maximum value (5 ppm). This is strong evidence that the large majority of sludge particles discharged from the seven-mile (eleven kilometer) outfall are not moving towards shore.

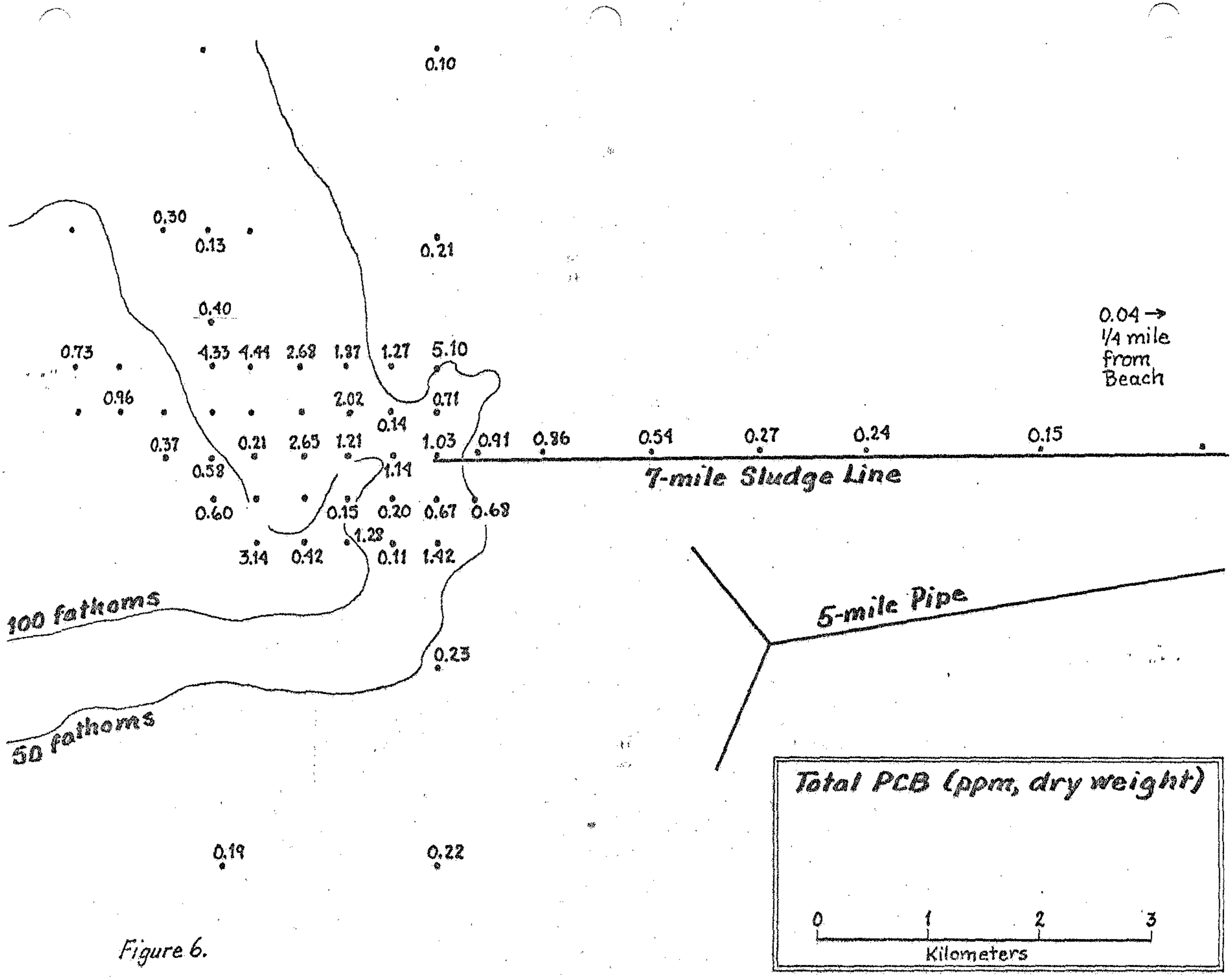

0.10
0.30
0.13
0.21
0.40
0.73
4.33 4.44 2.68 1.87 1.27 5.10
0.96
2.02
0.71
0.14
0.37
0.21 2.65 1.21
1.03 0.91 0.86 0.54 0.27 0.24 0.15
0.58
1.14
0.60
0.15 0.20 0.67 0.68
1.28
3.14 0.42 0.11 1.42
0.23
0.19
0.22
0.04 → 1/4 mile from Beach
7-mile Sludge Line
5-mile Pipe
100 fathoms
50 fathoms
Total PCB (ppm, dry weight)
0 1 2 3
Kilometers

Figure 6.

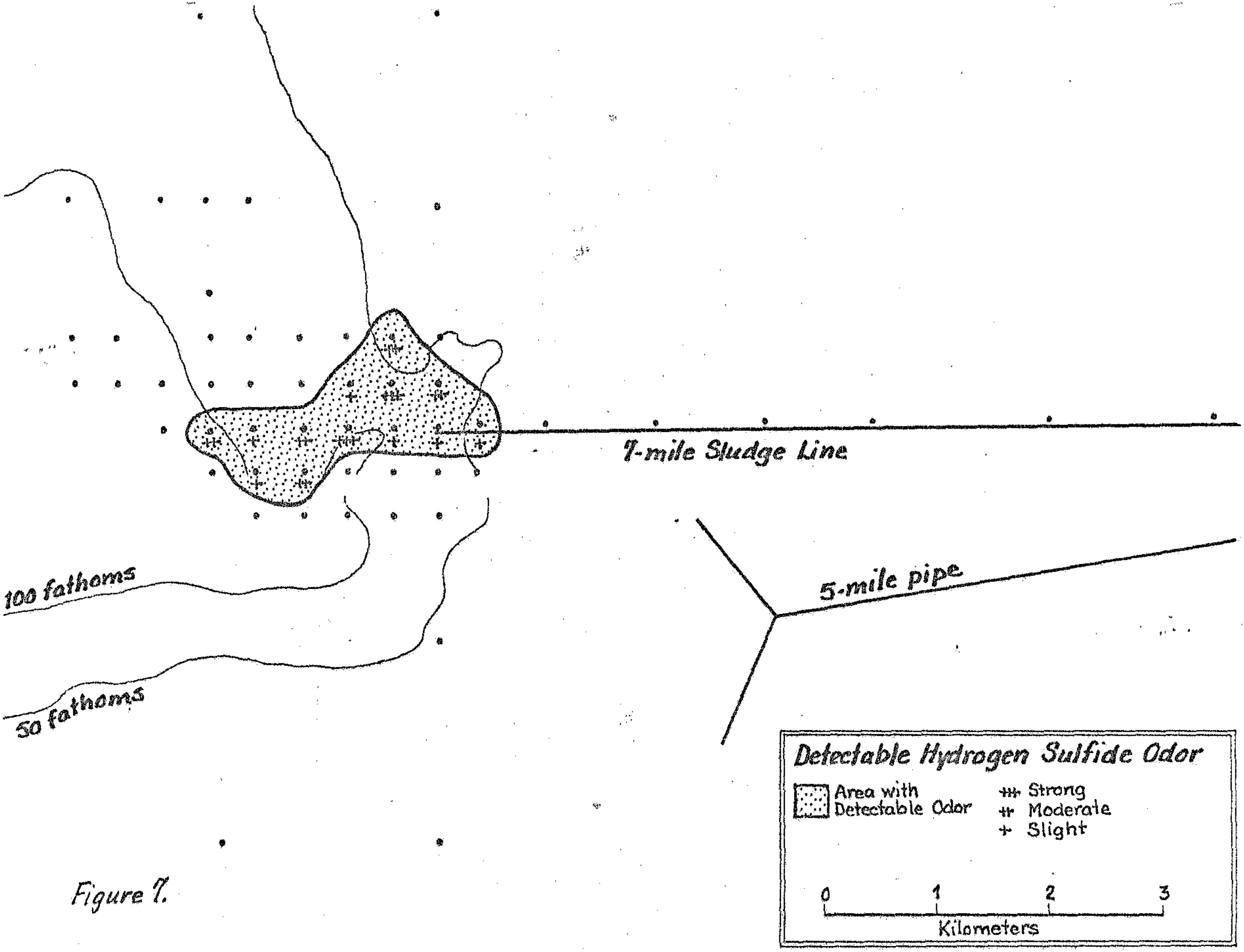
The Size of the Sludge Field

The size of the area of bottom that contains sludge depends on how one defines sludge. The area where sludge can be seen and smelled, and where some animals are exceptionally abundant, is rather small, perhaps 2 square kilometers immediately in front of the discharge point. This corresponds with our estimate of the area that would be covered by the estimated amount of material available for sedimentation.

The attached chart of hydrogen sulfide odor (detected by smelling samples taken at all stations as soon as they reach the surface) is one indication of the size of that area. It corresponds quite well with the direct observation of the bottom by television.

The area defined by chemical measurements can be substantially larger, depending on the criteria chosen. Sludge is predominantly organic material so we have used the increase in organic background. The natural level of organic detritus in the surface sediments of Santa Monica Bay is about 6% total volatile solids. This is about the quantity of volatile solids measured in Catalina canyon on the far side of that island. Thus, if the sludge area is defined as being where the sediment contain more than 6% volatile solids, about 10 square kilometers would be included. This is all within the canyon and deeper then 50 fathoms (300'). However, we do not have sufficient measurements to say how far down the canyon this condition extends.

Interferences from many other sources including other outfalls, the run-off from Ballona creek, thermal, (past) industrial discharges, boats and harbors, aerial fallout, oil seeps, etc. make other chemical measurements valueless for establishing a sludge perimeter.



7-mile Sludge Line
5-mile pipe
100 fathoms
50 fathoms
Detectable Hydrogen Sulfide Odor
Area with Detectable Odor
⧺ Strong
++ Moderate
+ Slight
0
1
2
3
Kilometers

Figure 7.

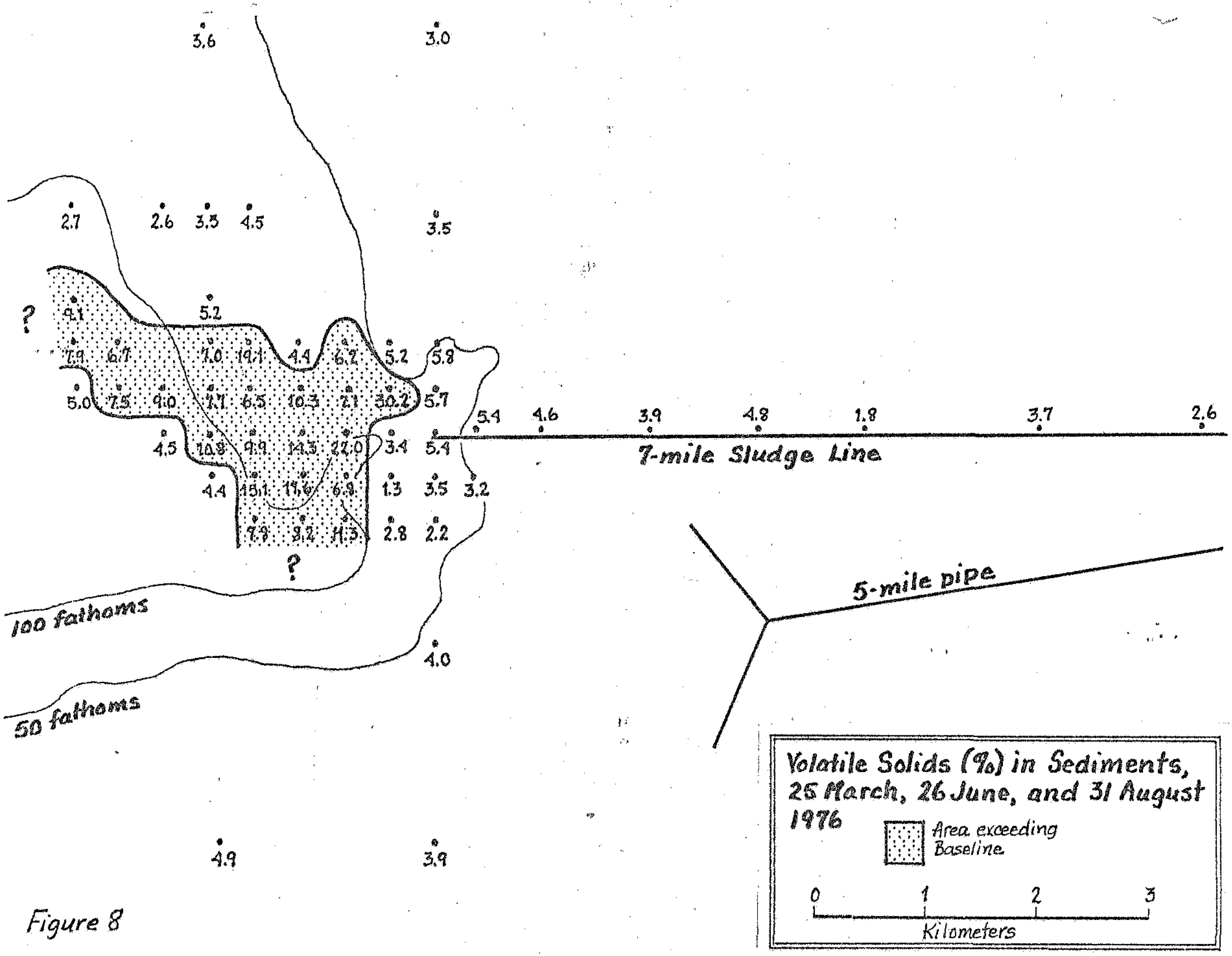

7-mile Sludge Line
5-mile pipe
100 fathoms
50 fathoms
Volatile Solids (%) in Sediments, 25 March, 26 June, and 31 August 1976
Area exceeding Baseline
0
1
2
3
Kilometers

Figure 8

Jim Allen

Life on the pipe

Near its end at a depth of 100 meters the 7-mile pipe is covered almost entirely by the sea anemone, Metridium senile. This is because the pipe is a hard substrate and attracts species that are characteristic of rocky bottoms. Some of these anemones, still attached to the pipe, mark it even at the edge of the canyon where the pipe is buried by sediments. This anemone is common on the towing sled which is still attached to the end of the pipe adjacent to the sludge discharge. The starfishes, Astropectin verrilli and Luidia foliolata, are very common on the surrounding soft-bottom (especially on the north side of the pipe) and are even found in the sludge near the end of the pipe. The gastropods, Kelletia kelleti, Megasercula carpenteriana, and Terebra sp., were also common on the soft-bottom.

The larger rockfish utilize the pipe as a point of reference for schooling; schools of bocaccio (Sebastes paucispinis) and vermilion rockfish (Sebastes miniatus) are common near the end and individual bocaccio have been seen cruising along the pipe. Schools of the smaller shortbelly rockfish (Sebastes jordani), were also frequently observed above the pipe. Individual cow rockfish (Sebastes levis) occurred near the Metridium and Dover sole (Microstomus pacificus) were noted on the soft-bottom and on the pipe, particularly near the region where it is buried.

TABLE 5. Marine organisms appearing in 5% or more photographs (57 photographs) taken at 100 m in Santa Monica Bay.

	Species	Common Name	Frequency of Occurrence (%)
1.	*Metridium senile*	Sea Anemone	45.6
2.	*Astropectin verrilli*	Sand Star	45.6
3.	*Sebastes paucispinis*	Bocaccio	19.3
4.	*Luidia foliolata*	Star	14.0
5.	*Sebastes levis*	Cow Rockfish	12.3
6.	*Sebastes minatus*	Vermilion Rockfish	12.3
7.	*Kelletia kelleti*	Kellet's Whelk	7.0
8.	*Megasercula carpenteriana*	Snail	7.0
9.	*Sebastes jordani*	Shortbelly Rockfish	7.0
10.	*Microstomus pacificus*	Dover sole	7.0
11.	*Terebra* sp.	Snail	5.3

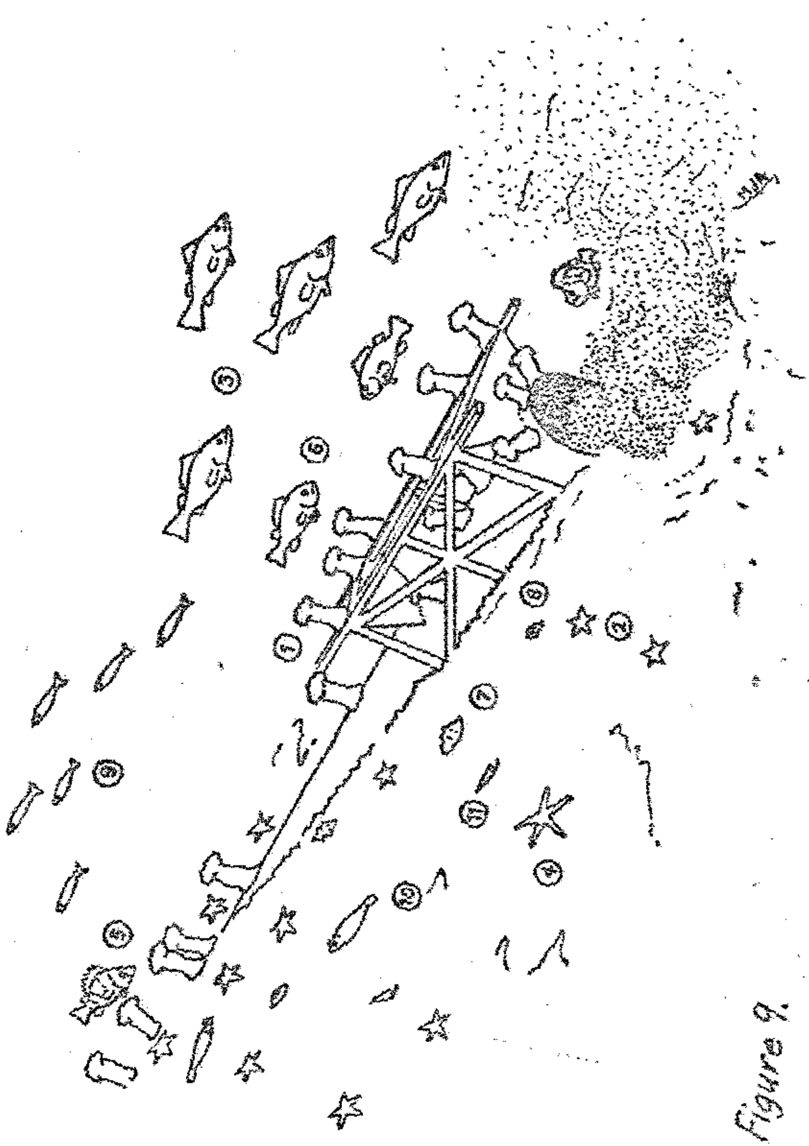


Figure 9.

Life on the Bottom (Television Survey)

The ocean bottom in the vicinity of the 7-mile discharge and at the head of Santa Monica Canyon was examined by television. Sediments were generally firm on the shelf inshore of the canyon, becoming softer along the pipe and very soft within the canyon where the television sled sank to a depth of at least 0.6 m in material that seems to be largely sludge particulates. Bottom materials in the canyon consisted of large particulates that, when disturbed, were suspended briefly before settling; water of a different refractive index was observed near the water-sediment interface when the bottom was disturbed.

The water was moderately clear away from the pipe and either very clear or very turbid immediately above the sludge field. Sea pens (Virgularidae) and sand stars (*Astropectin verrilli*) were common but not abundant inshore of the canyon, but were not observed in the sludge field. Fishes were more abundant in the sludge field than inshore of the canyon ($0.42/m^2$ vs. $0.05/m^2$); dominant species in the sludge field were white croaker (*Genyonemus lineatus*) and shiner perch (*Cymatogaster aggregata*) with densities of 0.18 and 0.06 per m^2 respectively whereas dominant species outside the sludge field were longspine combfish (*Zaniolepis latipinnis*), pink sea perch (*Zalembius rosaceus*) and sanddabs (*Citharichthys* spp.) with densities of 0.02, 0.01, and 0.01 per m^2 respectively. Pacific electric rays (*Torpedo californica*) occurred in high densities ($0.04/m^2$) in the sludge field, presumably feeding on schooling fishes. Schools of northern anchovy (*Engraulis mordax*) were observed in the canyon area near the bottom. We observed both white croaker and shiner perch picking at the bottom, presumably obtaining food organisms or material. One white croaker we observed may have had tail erosion.

Life on the Bottom (trawl survey)

Bottom fishes and invertebrates are relatively abundant and diverse in the vicinity of the Hyperion sludge field. An otter trawl sample (20 min. tow) across the sludge field at 120 to 140 m depths on Dec. 21, 1976, yielded 1,279 fish (89.3 kg) representing 23 species, and 1,426 invertebrates (22.1 kg) representing 24 species. Average fish catches for 10 min trawls in Santa Monica Bay are 139 fish (7.9 kg) representing 10 species. The most numerous fishes in the trawl were the Dover sole (Microstomus pacificus), white croaker (Genyonemus lineatus), and pink sea-perch (Zalembius rosaceus); these species feed predominantly on bottom-living organisms. Dominant invertebrates included the sand star (Astropectin verrilli), ridgeback prawn (Sicyonia ingentis), snails (Simnia sp.) and sea pens (Virgularidae). White croaker, a schooling species, and Pacific electric rays (Torpedo californica), a large predator, accounted for 50% of the biomass.

A number of species taken (including white croaker, Dover sole, Pacific electric ray, shiner perch (Cymatogaster aggregata), and ridgeback prawn) are abundant around other deepwater outfall areas in southern California. On the other hand, a number of species generally found at these depths elsewhere in southern California were not taken. These included sablefish (Aroplopoma fimbria), blacktip poacher (Xeneretmus latifrons), brittle stars, sea urchins, and shelled gastropods (except Simnia).

The incidence of Dover sole and white croaker with tumors was relatively low (1.2% and 0.3%) respectively; fin erosion was not observed in any species. White croaker, California lizardfish (<u>Synodus</u> <u>lucioceps</u>), and ridgeback prawn were in spawning condition and juvenile white coraker and pink seaperch were very abundant.

Table 6 compares the results of this trawl in the canyon/sludge area with the median of 853 trawls taken elsewhere in Santa Monica Bay. The canyon/sludge trawl had more than twice the number of species and about ten times as many individuals and biomass.

INVERTEBRATE SPECIES BT-1 12-21-76	NUMBER OF INDIVID.	WEIGHT (KG)	OBSERVED W/TV	GUT CONTENT	SEX & MATURITY	COMMENTS
1 Astropecten verrilli	718	6.0	✓		SOME ♀ GRAVID	Starfish
2 Mediaster aequalis	7					Starfish
3 Sicyonia ingentis	340	5.0	✓		GRAVID ♀; ♂ VERY FERTILE (TESTIS PRESENT IN LARGE AMOUNTS)	Large Shrimp
4 Solemya sp.	80	0.8				Sludge Clam
5 Simnia sp.	50 - 100	*	✓			Gastropod
6 Sea Pens, family Virgularidae	50 - 100		✓			Sea Pen
7 Crangon alaskensis elongata	~ 50	*				Small Shrimp
8 Armina californica	24	*				Opisthobranch
9 Parastichopus californicus	12	3.1	✓			Sea Cucumber
10 Pleurobranchaea californica	11	1.5				Opisthobranch
11 Lironeca vulgaris	1 - 10	*				Parasitic Isopod
12 Cancer anthonyi	7		✓		3♀, 4♂	Crab, yellow
13 Cancer productus	1	2.4			♂	Crab
14 Mursia gaudichaudii	1		✓		♂	Pointer Crab
15 Listriolobus pelodes	1 - 10	*				Sea Grape-Echiura
16 Pinnixa sp.	2 - 5	*				POSSIBLY COMMENSAL Crab w/ SOLEMYA SP. Clam
17 Octopus? rubescen	2	0.5				Octopus
18 Metridium senile	2	2.0	✓			Sea Anemone
19 Tritonia exsulans	1		✓			Nudibranch
20 Heptacarpus tennuissimus	1					Shrimp
21 Cerebratulus sp.	1					Nemertea
22 Glycera americana	1	*				Polychaeta
23 Lucinoma annulata	1					Clam
24 Pandalus platyceros	1					Shrimp
* Combined weight estimate		* 0.8				
TOTAL	1365-1486	22.1				

MISSING SPECIES: Ophiuroids (Brittle starfish), Echinoids (Sea urchins), Shelled Gastropods, except Simnia sp., Crinoids (Sea lilies), Polychaetes (Tube dwelling), Luidia foliolata (Folliated starfish), Crangon zacae, C. resima, C. communis, Spirontocaris holmesi, Pandalus jordani, Parvilucina (clam), Nemocardium (clam), Acila (clam).

Table 6a.
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FISH SPECIES BT-1 12-21-76	NUMBER OF INDIVID.	WEIGHT KG	AVERAGE (SL) SIZE (mm)	GUT CONTENT	SEX & MATURITY	OBSERVED W/TV	COMMENTS
1 Dover Sole	329	5.1	100 (95%)		JUVENILE	✓	4 w/ TUMOR; NO FIN ROT 1 LIP PAPILLOMA
2 White Croaker	312	36.5	180	LISTRIOLOBUS	180 MM MATURE; GRAVID ♀ AND ♂	✓	≈ 200 / CM. JUVENILES
3 Pink Sea Perch	195	6.5	120		♀ GRAVID, ♂ RIPE	✓	≈50 2-3 CM. JUVS, JUST BORN
4 Longspine Combfish	182	6.3	160			✓	
5 Speckled Sanddab	93		70			✓	
6 Pacific Sanddab	28		10				
7 English Sole	5	2.5				✓	
8 Curlfin Sole	4						
9 Hornyhead Turbot	3						
10 Bigmouth Sole	1						
11 Shiner Perch	38	0.7	90			✓	
12 Stripe Tail Rockfish	35					✓	
13 Plainfin Midshipman	16	2.0	270				
14 Ratfish	13	6.5	500	SOLEMYA, OCTOPUS, SHELL FRAGMENTS, JUV. CROAKER, ASTROPECTEN	12 ♀, 1 ♂	✓	
15 Pacific Electric Ray	8	21.8	600	1 w/ ANCHOVEY	ALL ADULT ♂	✓	
16 Greenblotched Rockfish	5					✓	
17 Spotted Cuskeel	3		200			✓	
18 Shortspine Combfish	3		140				
19 Shortbelly Rockfish	2						
20 Lizard Fish	1	0.4	400		ADULT ♀ GRAVID	✓	
21 Gulf Sanddab	1		40		JUVENILE		
22 Cow Rockfish	1		40		JUVENILE	✓	
23 Tongue Fish	1						
Combined estimate weight of others		1					
23 TOTAL	1279	89.3					
MISSING SPECIES	Queenfish, Rex Sole, Northern Anchovy, Sablefish, Pacific Hake, Bocaccio, Splitnose Rockfish, Spiny Dogfish, Blacktip Poacher, Blackbeely Eelpout						

Table 6a continued
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Table 6b Comparison of Trawl Catch in the Canyon at the Outfall with average values for Santa Monica Bay.

Trawl Category		Fish No. Species	Fish No. Individuals	Fish Biomass (kg)
20 min Trawl (Santa Monica Canyon, Dec. 21, 1976) 120-140 m depth	Vertebrates	23	1,279	89.3
	Invertebrates	24	1,400	22.1
Average of 853 10 Min. Trawl taken in Santa Monica Bay, 1957-1975 with mean and standard error.	Vertebrates	10.0 ±0.4	139 ±17	7.6 ±2.6
	Invertebrates	not recorded		

Benthic Infauna as Indicators

The physical and chemical conditions of the bottom largely determine the density and variety of benthic organisms living in the bottom (the infauna). The kind, quantity and grouping of animals is known as the community structure. Benthic organisms, for instance, often show high densities, but low numbers of species near wastewater discharge sites; for example, densities of polychaete worms are generally high while brittle stars (ophiuroids) are generally absent. Conversely, benthic organisms show lower densities and higher numbers of species in many areas distant from the outfalls; there the polychaete densities are low and brittle star densities are high. Large numbers of deposit-feeding clams characterize intermediate areas where there is some outfall influence.

A survey of benthic organisms in the vicinity of the 7-mile pipe from July to December 1974 showed that benthic organisms typical of outfall conditions occupied an area estimated at 1.9 km (mostly offshore of the pipe in Santa Monica Canyon).

This area, designated "A" in the attached Figure is characterized by a low number of species (15-20 per 0.1 m^2), the large number of individuals (3,275 - 14,512 m^2), large numbers of very few species (70% of the individuals were represented by 1-3 species), very few deposit-feeding clams (3-8% of the individuals) and 91-96% polychaetes.

The Type "B" fauna, which included an area of at least 10.2 sq km, was distinguished by large numbers of individuals (3,300 - 21,000/m^2), large numbers of deposit feeding clams

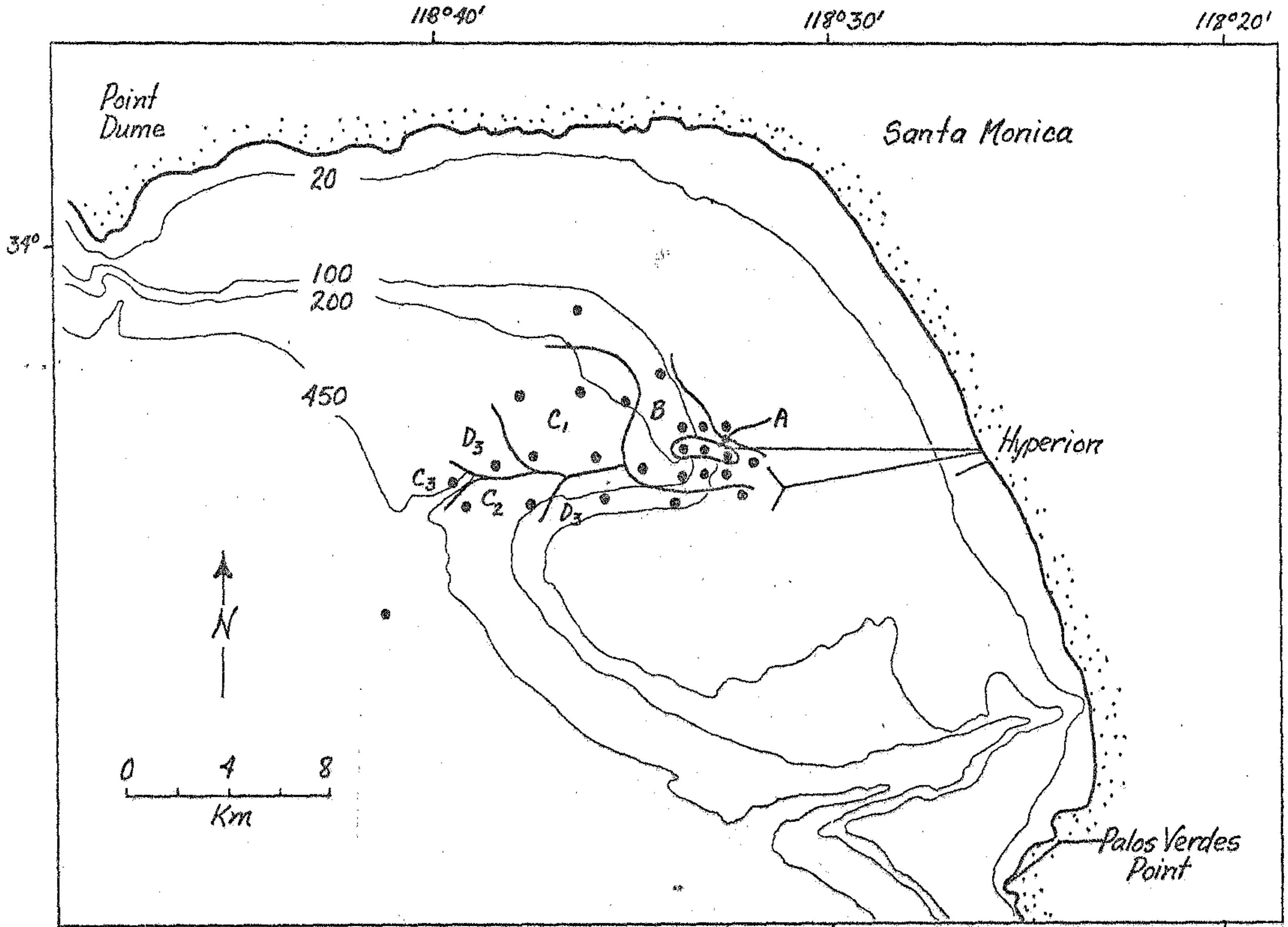

Figure 10. Invertebrate communities in Santa Monica Bay.

(eg., Parvilucina tenuisculpta, 1,642 - 8,127/m^2), large numbers of very few species (70% of the individuals were represented by 1 - 3 species), much lower percentage of polychaetes (14 -32%), an and the much higher percentage of clams (52 - 84%).

The Type"C" deeper water fauna was characterized by the low numbers of individuals (1,400 - 6,000/m^2), decreased numbers of deposit feeding clams (eg., Parvilucina tenuisculpta, 156 - 2100/m^2), the relatively high numbers of species (37-65/0.1 m^2), and the increase of a polychaete genus (Tharyx sp.), an arthropod (Euphilomedes sp.), or the presence of an ophiuroid (Amphiodia (Amphispina) sp.).

Type"D" categories are represented by more species (53-74/0.1 m^2), much lower numbers of individuals (561 - 2,150/m^2), the presence of low numbers of deposit feeding clams (eg., Parvilucina tenuisculpta, 0-136/m^2), and the presence of large numbers of ophiuroids (Amphiodia (Amphispina) sp., 60-255/m^2).

Based on studies elsewhere, we believe community types "C" and "D" are marginally indicative of outfall effects. Additional quantitative sampling would help clarify and refine this picture.

Hook-and-line Fishing nearby

Sportfish are relatively abundant and diverse along the edge of the coastal shelf near the sludge field. During spring 1975, rod and reel and 100-hook setlines were used to collect demersal (bottom) fishes at stations in Santa Monica Bay that had been previously sampled by otter trawl. The greatest number and variety of fish were taken at the station nearest the end of the 7-mile pipe (approximately 0.6 km upcoast in 100 m of water) where 47 fish of 6 species weighing 23.2 kg were caught during 5.5 hr of rod-and-reel fishing. Bocaccio (*Sebastes paucispinis*), vermilion rockfish (*Sebastes miniatus*), and sablefish (*Anoplopoma fimbria*) dominated the catch at this station. The biomass, numbers of fish, and numbers of fish species caught by rod and reel at 100 m increased downcoast toward the 7-mile pipe although setline catches were lower and showed no obvious trends. Of 393 fishes and invertebrates captured during the survey, four showed external diseases; three of the four diseased fishes, including two greenblotched rockfish (*Sebastes rosenblatti*) with a fin erosion disease and a sablefish with a mouth deformity, were captured at the outfall station.

Sportfishing boats were frequently observed in the area, presumably fishing near the head of Santa Monica Canyon and along the 7-mile pipe. Rockfishes such as the bocaccio and vermilion rockfish that occur there are desirable species to sportfishermen.

Diseased Fish

Over the past 20 years numerous diseased fish have been collected from Santa Monica Bay and elsewhere in southern California. The causes have been considered by scientists and it is popularly believed that the diseases result from sewage discharges.

During the past six years biologists from the Coastal Water Research Project have been studying numerous fishes including diseased and parasitized fishes from Ventura to Point Loma and at some of the offshore Islands. Nearly 290,000 fishes representing 151 species have been examined in an attempt to determine the types and frequency of diseases, which species are affected, and whether or not wastewater outfalls are a likely cause of disease. In addition, a variety of laboratory experiments have been conducted to learn more about the causes of fish diseases.

Two types of diseases have received most attention: external tumors on croakers and flatfish and fin erosion (or fin rot) diseases in a variety of nearshore fish.

Present evidence indicates that in southern California skin tumors occur only in Dover sole. The tumors are similar to a disease affecting very young flatfish in Japan, Alaska, British Columbia, Washington, and Oregon and northern California. Prevalence of tumors in young Dover sole is low in southern California compared with sites in the Pacific Northwest and Alaska, and diseased fish have been captured as far south as Cedros Island in Baja California. The cause may be a virus, a chemical or a genetic abnormality. Whatever it is, it is widespread and has been present in coastal areas of the North Pacific for many years. It does not appear to be caused by southern California sewage and sludge discharges.

Lip tumors in white croaker seem to have a different cause. Only older fish are affected. We are not sure what the cause of this disease is since the tumors occur in fishes that live in areas at considerable distances from wastewater discharges.

In contrast to the tumors, fin erosion disease is clearly related to sewage discharge in the Palos Verdes area (and to contaminated sediments in New York and Seattle). Dover sole are most consistently affected, averaging 39% of the Palos Verdes population between 1972 and 1975. Prevalence in Santa Monica Bay during the same period was 1.7 percent (Table 7). There is evidence that the affected fish in San Pedro Bay are migrants from Palos Verdes and it is possible that diseased fish in Santa Monica Bay are also migrants from Palos Verdes. Field and Laboratory studies indicate that fin erosion disease is not caused by pathogenic bacteria or hydrogen sulfide from decaying organic matter, but is related to high tissue and sediment levels of chlorinated hydrocarbons.

The recent trawl (21 December, 1976) through the sludge deposit in the Santa Monica canyon produced data which is consistent with these findings. Of 1279 fish taken, there were five diseased fish: four of 329 Dover sole (mostly young fish) had skin tumors and one of 312 white croaker had a lip papilloma (tumor). All remaining fish appeared healthy and showed no signs of fin erosion or other external disease.

TABLE 7. Prevalence of Dover sole with fin erosion in Southern California coastal waters, 1972-75. From Sherwood and Mearns, 1975.

	Oxnard	Santa Monica Bay	Palos Verdes Shelf	San Pedro Bay	Dana Point	Point Loma	Santa Catalina Island
No. of Samples	59	60	144	73	78	17	28
No. of Samples with Dover sole	16	39	106	44	45	15	16
Sampling Period	1973-74	1972-73	1972-73	1972-73	1972-74	1975	1972-74
No. of Dover sole	45	516	14,277	3,842	881	100	135
No. with eroded fins	0	9	5,594	88	6	0	0
Percent with eroded fins	0	1.7	39	2.3	0.68	0	0
Density of fish No./10 mm haul	0.5	7.4	101	59.2	16.5	8.0	7.4
No./Positive haul	2.8	13.2	134	87.3	19.6	9.1	8.4

Body Levels of Potential Toxicants

The Dover sole is a particularly appropriate organism for study because it is widely distributed along the southern California coast and can usually be obtained by trawl in relatively large numbers from the bottom sediments both near to and far from submarine outfalls. Research has shown that specimens of this flatfish associated with sediments that have elevated concentrations of trace metals, such as those off the 7-mile sludge line, do not have significantly higher concentrations of these contaminant metals in their livers. Sometimes these fish have lower concentrations than do specimens living on uncontaminated sediments far from the discharges. Table 8 presents de Goeji's measurements of the concentrations of eleven potentially toxic trace metals in the livers of Dover sole from four regions of varying sediment contamination.

Dover sole collected from near the 7-mile outfall show elevated muscle tissue concentrations of PCB's (polychlorinated biphenyls) compared to those collected from uncontaminated island and coastal control stations. The median concentrations of PCB in muscle of Dover sole trawled during 1974-75 from near the 7-mile outfall and from the Plaos Verdes and Orange County discharge zones were 2.0, 1.3, and 0.6 ppm. In comparison, values for coastal and island control specimens were 0.2 and 0.05 ppm, respectively.

Mussels (Mytilus californianus) translocated from Point Sal to the 7-mile outfall buoy showed a rapid uptake of PCB, which reached a peak of 0.62 ppm wet wt in two weeks.

Table 8 Trace-element concentrations, shown to a 95% confidence level, in Dover sole liver collected from four locations with different degrees of pollution.

All concentrations are given in parts-per-million, except for silver which is presented in arbitrary units.

Trace element	Degree of sediment pollution, and number of samples used.	
	"natural" 6 samples	"high" 12 samples
Antimony	0.0035	0.0022
Arsenic	3.1	1.5
Cadmium	0.58	0.33
Cobalt	0.061	0.043
Copper	2.2	3.4
Iron	182	176
Mercury	0.11	0.19
Molybdenum	0.13	0.081
Selenium	1.2	0.97
Silver	2.2	6.3
Zinc	27	25

(1) <u>Natural</u> The Santa Catalina Island area, assumed to have natural trace-metal concentrations in surface sediments;

(2) <u>High</u> Three areas (directly off the Hyperion 7-mile outfall, and off the northern and southern tips of the Palos Verdes Peninsula) that have significant enrichment of trace elements in surface sediments.

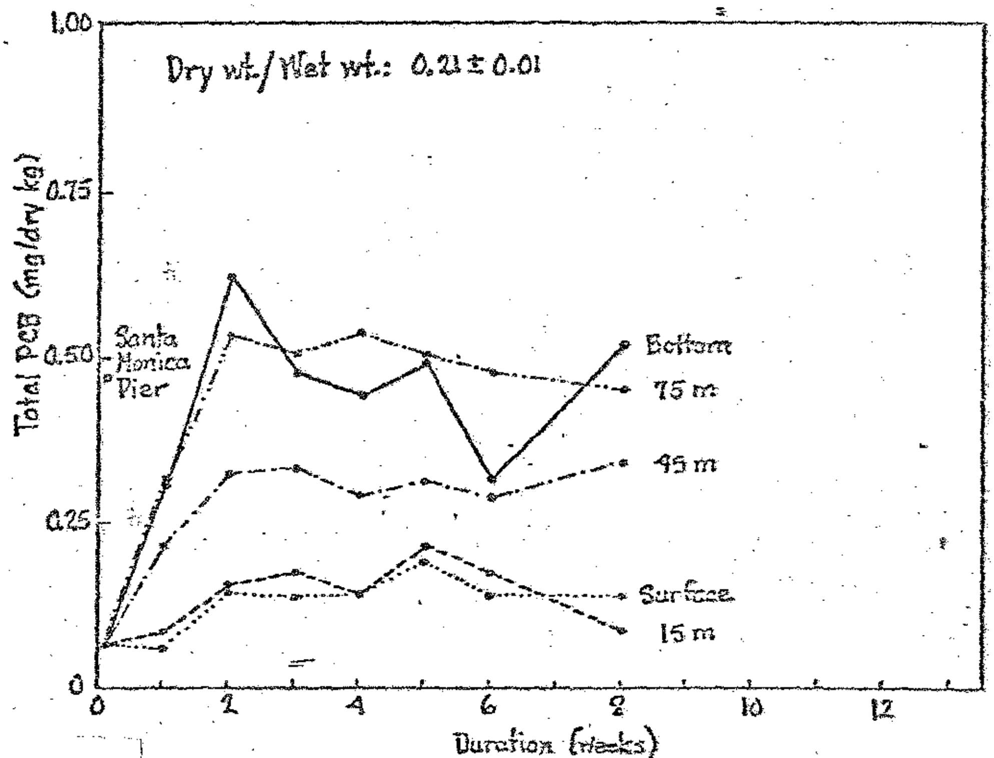

Figure 11 Uptake curves for total PCB in mussels trans-located in January 1976 from Point Sal to the Hyperion sludge outfall buoy system.

The concentration of PCB increased with depth and proximity to the outfall terminus where as total DDT concentrations showed no relation with depth.

The present submarine discharges are not causing DDT or PCB levels in seafood organisms to exceed the Public Health Service 5 ppm action guidelines.

Confusion with Pollutants from other Sources

Evaluation of the effects of sludge discharged from the Hyperion 7-mile outfall into Santa Monica Bay must be tempered by the fact that there are other important sources of possible pollutants in this region. For example, the Hyperion 5-mile outfall and the Los Angeles County outfall off Palos Verdes, located 4 and 35 kilometers away from the 7-mile outfall terminus, may have some influence. Each discharges approximately 350 mgd of wastewater (about seventy times that of the 7-mile outfall). In addition, during 1975 these two outfalls discharged 131,000 and 40,000 metric tons of "suspended solids", compared to 61,000 tons from the 7-mile. For "oil and grease", the respective values were 29,000; 10,000; and 5,700 tons; for chromium, 380, 60, and 70 tons; for total PCB, 650, 160, and 240 kg.

There are other important routes of input for pollutants found in the Bay. For example, during 1971 urban runoff from Ballona Creek carried 11,000 tons of suspended solids and 1,100 tons of oil and grease. Also, roughly as much copper from vessel antifouling paints, and lead from aerial fallout, entered the coastal waters as was discharged via the major municipal outfalls.

Thus, with the exception of the immediate vicinity of a submarine outfall, the relatively close proximity of these three municipal wastewater sources and the presence of other inputs create considerable difficulties in identifying the actual source of a specific contamination of the marine environment off Los Angeles.

The New York area sludge problem

We are invariably asked about New York City's ocean sludge problem. Therefore, a summary of that matter will permit the reader to draw his own comparisons.

Thirtythree separate sewage plants in the New York area make sludge which is disposed of offshore in a rectangular dump site (2 miles by 3 miles); its minimum distance to shore is 10 miles (either to New Jersey or Long Island). Four self-propelled barges operated by the city each discharge sludge there once or twice daily, six days a week, throughout the year. Normally these vessels begin dumping as soon as they reach the designated area and the dump continues for at least five miles. The sludge, which averages 5% solids, is discharged at depths of 4.5 to 2.5 meters below the surface. It is immediately diluted with seawater by a factor of 500 to 1,000. Sonar measurements of settling particles show that bottom animals rise to meet this sinking food supply.

The amount of solids discharged each year in this fashion is 195,000 dry metric tons (compared with 61,000 dry metric tons for the 7-mile discharge). Sludge has not come ashore in the New York area and the bottom is not a "Dead Sea" as reported in the press. According to Dr. Grant Gross, the bottom "responds to high nutrient concentrations from sewage discharges in the harbor by supporting levels of productivity higher than normal for ocean areas outside of upwelling areas".

The N.Y. area accounts for 80% of all ocean dumping and New York has several special problems: (1) it also dumps large volumes of acid wastes, cellar dirt, and dredged material at nearby sites, thus confusing the source of pollutants. (2) The continental shelf in this area is wide and, in some years, including 1976, the natural circulation is poor, creating a large area where the water is low in oxygen (this was caused mainly by an algal bloom, not by waste disposal). (3) Barge discharge deliberately mixes sludge with surface water, thus giving it the density of those waters; this tends to keep it at the surface (California pipe discharge mixes the sludge effluent with cold bottom water which keeps the material below the surface).

A comment by Richard T. Dewling, Director of the Surveillance and Analysis Division and Peter W. Anderson, chief of the Marine Protection Program at the U.S. Environmental Protection Agency, Region II, New York, is helpful in understanding the New York situation: "It must be clearly recognized that handling sludge--a waste product that has no public acceptablility--involves some form of environmental trade-off. No matter what method is used --landfill, incineration, pyrolysis, recycling, ocean dumping, lagooning, or placing on sand beds--some environmental impact will result. The underlying concern in selecting a particular alternative is to minimize the impact. We do not now live, nor have we ever lived, in a world of zero risk; rather, we attempt, as scientists or administrators, to reduce to a reasonable minimum those risks over which we have control. Thus teamwork,between the scientist, administrator, and public, is needed to resolve, in an environmentally acceptable manner, the pollution problems in the New York Bight. Polarization, a condition that presently exists between these three interest groups, can only hinder attainment of the common goal-- a safer and cleaner environment. To echo Dr. Gross, there is an immediate need for improving communications between these "communities," particularly on the subject of the New York Bight, for we cannot afford another public display of technically unsupported claims and predictions about a "sludge monster" rising from the deep to engulf the beaches of Long Island.

Recent reports in the news media about the washing up of sludges on Long Island beaches (for example, New York Times, 6/24/76) are prime examples of such claims. What has been reported as raw sewage or sewage sludge was, in fact, burned wood, plastics, paper, oil and grease, and other floatables that resulted from inland runoff, pier fires, storm water overflows, and other similar incidents in the New York Harbor complex and its vicinity."

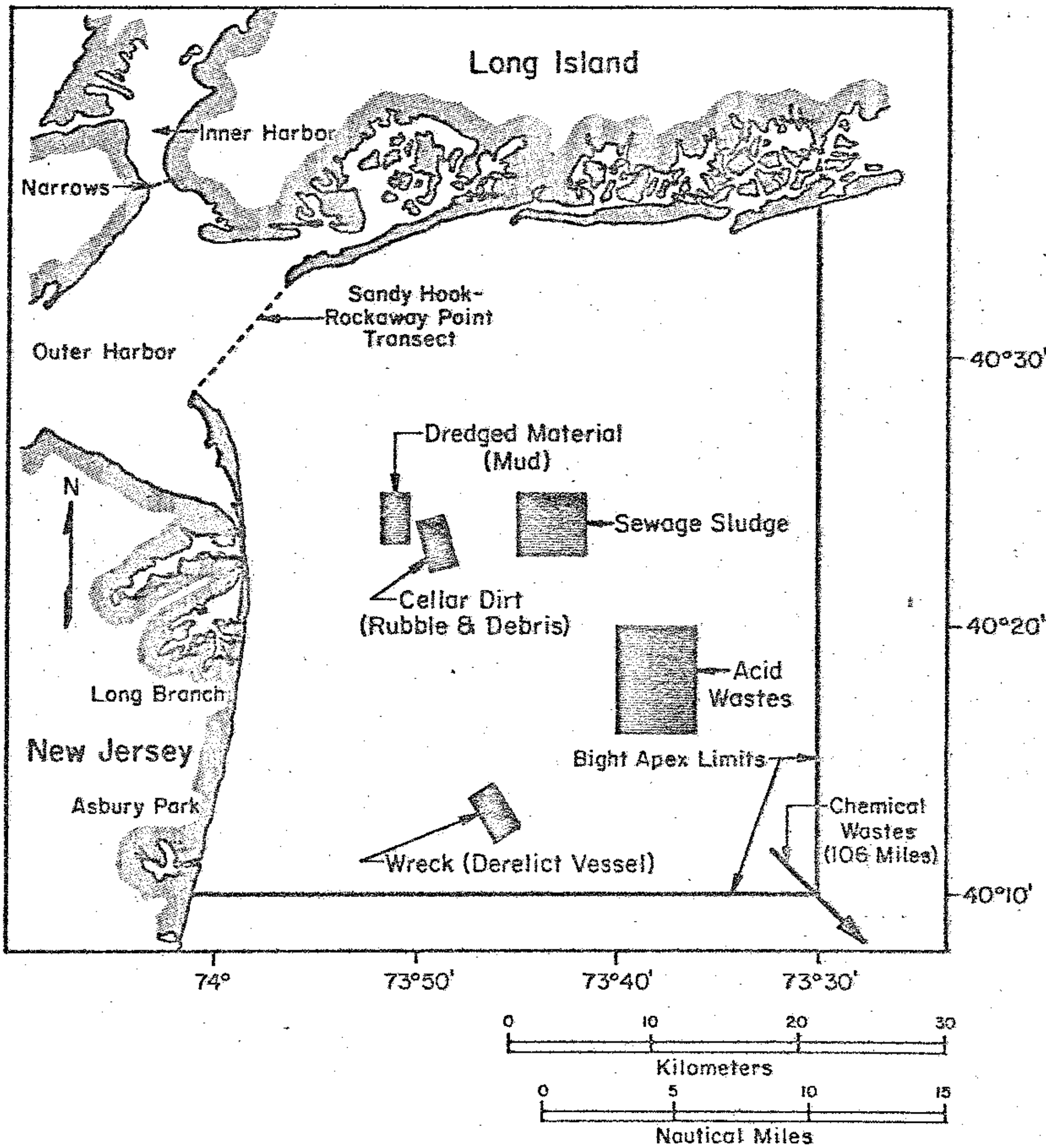

Figure 12. *New York Bight Apex and existing dump sites.*

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