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FORECASTING EFFECTS OF SEWAGE SOLIDS ON MARINE BENTHIC COMMUNITIES

by

Alan J. Mearns

and

Jack Q. Word

Southern California Coastal Water Research Project
1500 East Imperial Highway
El Segundo, California 90245

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ABSTRACT

A method is described which relates the size (sq km) and biomass of altered macrobenthic communities to the mass emmission rate of suspended solids from ocean wastewater discharges. The approach also relates altered function of communities as measured by the Infaunal Trophic Index to the rate of suspended solids discharge.

The relationships are useful in projecting the size of areas altered by wastewater emmissions and in projecting possible ecological consequences of reductions or increases in solids emmissions. The exponential nature of the relationships suggests the possibility of substantial benefits from solids control of large discharges but minor benefits for smaller discharges.

INTRODUCTION

Many government agencies need methods for predicting the magnitude and quality of biological changes caused by wastewater discharges. At the present time, marine scientists are able to suggest which of a number of benthic species will increase or decrease in abundance in response to a particular discharge (Pearson and Rosenberg 1976; Word *et al*. 1977) but to our knowledge, no one has suggested how to forecast the total magnitude of effect that a particular discharge might create in a benthic ecosystem.

This paper describes an approach that may be useful in quantitatively projecting some of the effects of sewage solids on marine benthic communities of the Southern California mainland shelf. The approach is based on a comparison of the size of bottom areas now affected by changes in benthic biomass and community trophic structure at a number of small, medium and large municipal outfall sites located on the Southern California shelf.

Municipal wastewaters contain a mixture of gross and trace constituents which, in the absence of toxic concentrations of toxicants, can enhance phytoplankton production in the water column (Eppley *et al*. 1972) and stimulate the growth of a number of benthic invertebrates (Smith 1974; Word et al 1977; Young and Young, in press). Under equilibrium conditions, therefore, it should be possible to demonstrate a direct relationship between the input of nutrients or organic matter and the total population sizes of organisms whose growth is stimulated by the input. These equilibrium conditions are essentially those of a chemostat which requires (a) a continuous, controlled and constant input of growth-promoting material, (b) an overall flow rate through (or past) the system that is either constant or equally variable in all experiments and (c) a population or community which has reached a constant biomass or size.

Such conditions can only be met in carefully controlled laboratory studies. However, we believe they are partially met in benthic environments surrounding major outfalls which discharge treated sewage at a number of deepwater (20 to 60 m) localities along the Southern California mainland shelf. (Figure 1). For example, each of the five outfalls cited in this report have been discharging rather constant amounts of growth-promoting materials (suspended solids, BOD, COD, nitrogen, phosphorus, etc.) for one or more decades (Schafer, 1977 and 1979). This could satisfy the first criterion. Current measurements indicate that all sites are subjected to longshore currents which are variable, but which do have similar energy spectra (Hendricks 1977); thus, the second criterion is partially met. Finally, repeated quarterly, semi-annual and annual benthic surveys around these sites indicate that both chemical contamination of sediments and that certain parameters of the composition of benthic infaunal communities are generally constant and predictable within a given distance of each discharge site (Mitchell and Schafer 1975; Mearns, in press; Word _et al_. 1977). Thus, it is reasonable to assume that chemical and biological conditions at these sites are generally in equilibrium with inputs.

Increased biomass (ie. gm/m^2) of infauna is one response common to the benthic infaunal communities adjacent to major

Southern California ocean outfalls (Mearns and Greene 1976). It is likely that this increase is related to increased secondary production which has been documented at other sites (eg. Smith et al. 1973) and which results from utilization of the increased organic carbon input into the benthic ecosystem.

Organic carbon input rates have not yet been measured for the Southern California benthic communities affected by sewage outfalls. However, in the past, benthic chemical and biological conditions have responded rapidly and dramatically to changes in total suspended solids mass emmission rates (such as at Point Loma; Orlab 1977). If we assume that the overall organic content of sewage solids does not differ substantially among domestic effluents, then there should be a direct quantitative relationship between suspended solids mass emmission rates and sizes of stimulated benthic populations, when discharges of different mass emmission rates are compared.

Unfortunately, no one has attempted to assess total "excess" benthic population sizes around discharge sites. One way to do this is to simply extrapolate the total size of excess biomass from field benthic surveys around the discharge sites. Another way, in the absence of adequate data on biomass, is to use some indicator of the size of changed populations; eg. the area (sq km) occupied by distinctly different populations or communities. To do this, some criterion is needed to delineate a boundary of continuous effect around a discharge site. Numerical classification techniques (Smith and Greene 1976; Boesh 1977) might be useful.

However, this is difficult at southern California outfall sites because the outfalls discharge near the slope of the mainland shelf, affect different depth-related faunal assemblages and produce site-groups which are distinguished mainly by depth (Smith and Greene 1976).

Word (1979) has suggested a solution to this problem by classifying benthic organisms according to feeding strategies and examining benthic communities in terms of trophic strucutre rater than community structure. From several recent regional surveys, Word (1979) concluded that the diverse macrofauna of relatively uncontaminated regions of the mainland shelf is dominated by suspension-feeding invertebrates such as the brittle star, Amphiodia urtia (4,000/m^2), along the 60 meter isobath. At the most impacted sites near several waste-discharges, the macrofauna is dominated by sub-surface deposit feeding animals such as Capitella capitatta and the dorvilleid polychaete Schistomeringus longicornis; in between these "control" and "degraded" regions are large areas dominated by many surface deposit-feeding organisms such as the bivalve Parvilucina tenuisculpta. By examining feeding and behavioral information on shallower and deeped water organisms, Word (1979) prepared a list of nearly 50 taxa which could be incorporated into an Infaunal Trophic Index. The Index was then used to delineate regions of similar trophic structure, over a depth range of 20 to 200 meters around several discharges which are located at depths of 60 to 100 m (Bascom 1979).

In summary then, our approach was to estimate the size of altered benthic macrofaunal populations, either in terms of biomass or in terms of area of effect (in terms of excess biomass and altered Infaunal Trophic Indicies); determine to what extent these variables could be quantitatively accounted for by input rates of one gross constituent (suspended solids) and, then, to forecast biological consequences of changing those inputs.

METHODS

Inputs.

Each of the five major southern California dischargers measure flow and gross effluent constituents from daily and weekly composites. From these data, Schafer (1977 and 1979) computed annual mass emmission rates. For this report, we used 1977 suspended solids mass emmission rate data to compare with 1977 and 1978 Infaunal Trophic Index surveys of the outfall sites and averages of 1975 through 1977 suspended solids mass emmission rate data to compare with 1975 through 1977 benthic biomass surveys.

Benthic Surveys.

Benthic infaunal data from both discharge self-monitoring programs and from special surveys conducted by the Southern California Coastal Water Research Project were used in this analysis.

Since 1973 each discharge site received at least four and as many as 14 synoptic benthic macrofaunal grab surveys with two to four replicate samples taken at from 10 to 44 stations depending on the survey site (Mearns and Greene 1976). Various grab devices (from 0.04 m^2 Shipek grabs to 0.16 m^2 Van Veen grabs) and several screen sizes were used in the surveys. An overall summary of the samples inspected for this report is summarized in Table 1.

The differences resulting from these methods were studied (Word *et al*. 1976; Word 1976) and certain numerical data and biomass data were modified. More recent collections of samples have standardized on methods of collecting, seiving samples and grab types. The techniques used for identification, enumeration, and weighing were standardized with all the present monitoring and investigative groups through a specialized program (Taxonomic Standardization Program, Word et al. 1976; Word 1977). This program has resulted in a taxonomic data base that is internally consistant.

Charts showing contoured data from these areal surveys are given in Bascom (1979) for Santa Monica Bay, Palos Verdes, Orange County and Point Loma, in M B C, Inc., (1975) for Oxnard and in Greene, (1976) for Orange County.

Estimates of Population Sizes Or Their Indicators.

We chose three variables from these surveys to compute estimates or indicies of population size. First, we estimated the total excess standing crop (mt) of infauna around each of the five major discharge sites. Values of benthic biomass (g/m^2) for discrete single surveys were plotted and contoured to reveal the size and shape of regions of enhanced biomass. Next, a planimeter was used to determine the total area of each contour; then, we summed the products of average biomass area for each contour interval and subtracted from this "gross" standing crop the "background" standing crop expected for the area based on average biomass values for adjacent control transects. This produced an estimate of the Excess Standing Crop (in mt, wet weight) for each site and survey.

Contours of benthic biomass also resulted in estimates of total area (in sq km) occupied by the Excess Standing Crop and this was used as a second dependent variable.

Our third dependent variable was the area (in sq km) occupied by infaunal communities dominated by deposit-feeding organisms as determined by the Infaunal Trophic Index (Word 1979). This method of analysis provides a numerical index (from 0-100) of the relative abundance of four generalized categories of detrital feeding in benthic invertebrates in a grab sample. The lowest index values indicate numerical dominance by sub-surface deposit feeding organisms while the highest values indicate that the majority of the fauna is dominated by invertebrates that feed by capturing suspended particles. This numerical index is highly correlated with measurements of organic materials in the sediments (Word 1979) which in turn are related to the amounts of organic materials released from the discharges. The species used in this index (Table 2) account for 60% of the individuals collected in Southern California benthic samples at shelf depths of 20-200 m in fine sediments. As shown in Table 2, the species are categorized into four generalized strategies of feeding. The Index is calculated with the following formula:

$$\text{Infaunal Trophic Index} = 100 - \left[33\ 1/3\left(\frac{0N_1 + 1N_2 + 2N_3 + 3N_4}{N_I + N_2 + N_3 + N_4}\right)\right]$$

Where N_i = the number of individuals in group "i"

Infaunal Trophic Index values were calculated from over 300 Van Veen samples taken around the four major urban outfall sites in Santa Monica and San Pedro Bays and off Palos Verdes and Point Loma (Bascom 1979). We considered areas with Infaunal Trophic Index values between 30 and 60 to be "changed" and dominated by surface deposit feeding infauna and areas with Infaunal Trophic Index values below 30 to be "degraded" and dominated by subsurface deposit-feeding infauna (Bascom *et al*. 1979) and estimated the sizes of these areas by planimetry.

Correlation With Inputs.

Once completed, estimates of sizes of affected areas and excess standing crops were plotted against suspended solids mass emmission rates and correlations and bestfit lines computed using linear regression on log transformed data.

RESULTS.

During 1977, there was a 100-fold range of nutrient, BOD and suspended solid mass emmission rates among the five major discharges ranging from 1500 MT/Y at Oxnard to 102,000 MT/Y at Palos Verdes, (Table 3). Previous data (Schafer 1977) indicates these emmissions have been relatively constant during the past decade.

Contours of sediment volatile solids benthic infaunal biomass and Infaunal Trophic Index from areal benthic surveys indicate that the size and shape of affected bottom areas vary among the discharge sites. For example, at Point Loms, volatile solids increased from a bachground of 2.8% to a high value of 5.6% near the outfall while benthic biomass increases from 70 g/m^2 to 120 g/m^2 and Infaunal Trophic Index dropped from 93.5 to 33. Overall, a total of 5.5 sq km were involved in elevated biomass and 4 sq km in Infaunal Trophic Index values below 60. In contrast, peak values for volatile solids and benthic biomass at Palos Verdes reach 27 percent and 879 g/m^2, respectively and Infaunal Trophic Index reached a minimum of 0.3. Overall, an area of 30 sq km were involved in Infaunal Trophic Indicies below 60. Conditions for Santa Monica Bay, Orange County and Oxnard sites are reported in Bascom et al (1979) and Mearns and Greene (1976).

The area of biological effects of these sites are summarized in Table 4 together with estimates of excess standing crop. It is apparent in Table 4 that both excess standing crops and areal extent of enhanced biomass and depressed Infaunal Trophic Index are generally related to suspended solids mass emmission rates.

Since values of excess standing crop, sizes of affected areas and suspended solids mass emmission rates range from 1.5 to nearly 4 orders of magnitude, we plotted relations between the independent variable (suspended solids mass emmission rate) and the dependent variables (excess standing crops and areas) on log-log paper (Figures 2, 3 and 4). As a first approximation, the four relationships between suspended solids mass emmission rates (Je) and benthic effects shown in these figures can be described by linear regressions of $\log_{10}$ transformed data (Figures 2, 3, and 4).

DISCUSSION.

Characteristics of the Relationships.

Inspections of the exponents in these equations indicates that each biological variable has a markedly different response to increases or decreases in suspended solids emmission. For example, back calculations indicate that doubling suspended solids emmissions from 25,000 to 50,000 MTY (typical range of values for moderate outfalls) will increase excess standing crop by a factor of 3.4 (from 760 to 2,550 MT), the area occupied by that standing crop by a factor of 2 (from 9.4 to 18.2 sq km), the area occupied by both surface and subsurface deposit feeding infauna (characterized by infaunal trophic indicies ≤ 60) by a factor of 4.5 (from 5 to 22 sq km) and the area occupied only by subsurface deposit feeders (such as Capitella capitata) by a factor of 5.9 (from 0.002 to 0.16 sq km, Table 5).

Forecast for a Southern California Ocean Outfall.

Our main concern for southern California ocean sewage outfalls was to estimate the ecological benefits of reductions of suspended solids by various treatment strategies. We used similar relationships and projected, for example, that 85 percent reduction in suspended solids from the JWPCP treatment plant discharging offshore of Palos Verdes would eventually produce a 97 percent reduction in size of the excess standing crop (from 13,390 to 450 MT) an 85 percent reduction in the area occupied by that excess standing crop (from 41 to 6 sq km, Mearns 1979) and an 89 percent reduction in the lineal distance over which Infaunal Trophic Index conditions approached background (ITI = 80, from 48 to 5 km; Word 1979). In addition to providing the dischargers and regulatory agencies with some idea of the magnitude of changes that would eventually occur with this level of reduction, the projection also provided a testable hyposhesis and guidance for changes in sampling design for future monitoring.

Application to the New York Bight.

We are not certain whether these relationships will work for the New York Bight or other coastal areas where sewage solids are discharged or dumped. Based on a mass emmission (dumping) rate of 165,560 MT per year for barged sewage solids into the Apex (computed from Mueller et al 1976) we project that there might be an excess standing crop of infaunal on the order of 21,000 MT occupying on area of 57 sq km and that an area of about 300 sq km might be dominated by surface and subsurface deposit feeding infauna within which is an area of 24 sq km dominated by mainly subsurface deposit feeding infauna (Table 5). To our knowledge, biomass has not been determined from Apex benthic surveys, but Boesch (1979) pointed out an area on the order of 10-15 sq km affected by depauperate fauna surrounded by a larger area of 240 sq km characterized as an "enhanced transitional area." In addition, our inspection of data in Stimele et al. (1979) suggest an area of 150 sq km is nearly devoid of suspension-feeding

Ampeliscid amphipods which in southern California are among the first to disappear from areas impacted by sewage outfalls; they occur in samples characterized by I T I >60 but are rare <60. These estimates of measurable change in benthic communities are well within a factor of two of our projection suggesting the possibility that it might work and should be further explored.

Uncertainties and Limitations.

Pursuing our approach for projecting effects at these and other locations requires carefully reexamining each assumption and bringing in other information such as corrections for suspended solids settling rate differences (Herring and Abati 1979). We also realize there are a number of uncertainties and problems with our present approach and recommend the reader develop his own relationships and equations. Our assumption that mass emmission rates have been relatively constant is not, in fact, valid; during 1977-79, suspended solids emmission for the JWPCP plant actually dropped by 30 percent and recent benthic data will have to be examined. More importantly, none of the benthic surveys were actually designed for the purposes of estimating total population sizes and only a few (Bascom 1979) were designed for the purpose of clearly resolving the size and shape of affected bottom areas. New surveys should be conducted to more accurately estimate both parameters and new equations computed. We also included an outfall (Oxnard) which was significantly shallower than the rest (20 m vs. 60 m). Even if solids settling characteristics of this effluent were identical to those from the other outfalls, the increased currents and wave action inshore could lead to an underestimate of the impact of the Oxnard 1500 MT/yr suspended solids mass emmission rate on benthic communities in deeper water.

We are also assuming that the relation between benthic biomass and suspended solids is due to the nutritive (organic carbon) content of the solids, that all effluent solids have the same assimilative capacity and that production and cropping (mortality) rates are proportional to emmissions at all sites. We know, in fact, that solids from waste activated sludge discharged via the Hyperion 7-mile outfall have a different organic (BOD) content than the solids remaining in the 5-mile effluent. As an extreme example, it would be invalid to compare effects of suspended solids of dredged material with those from the same discharge of sewage solids. In addition, we know from stomach content analysis that the infauna is indeed cropped by fish but rates are unknown. Finally, we are also assuming that toxic effects are of second order importance. We think this is true for most sites, but not at Palos Verdes where high concentration of H_2S and DDT prevail over a large area (Smith and Greene 1976) within which occurs low biomass.

In spite of these problems and uncertainties, we believe further development of untraditional approaches, such as this, are needed and will help to resolve real management problems and provide a more quantitative approach for projecting the full magnitude of effects of discharges on benthic communities.

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LITERATURE CITED

Bascom, W. 1979. Life in the Bottom: San Pedro and Santa Monica Bays, Palos Verdes and Point Loma Peninsulas. 57-80. In Coastal Water Research Annual Report 1978. Southern California Coastal Water Research Project, El Segundo, CA 90245.

Bascom, W., A.J. Mearns and J.Q. Word. 1979. Establishing boundaries between normal, charged and degraded areas. 81-94. In Coastal Water Research Project Annual Report, 1978. Southern California Coastal Water Research Project, El Segundo, CA 90245.

Boesch, D.F. 1977. Application of numerical classification in ecological investigations of water pollution. EPA 600/3-77-033. March, 1977. 114 pp.

Eppley, R.W., A.F. Carlucci, O. Holm-Hansen, D. Kiefer, J.J. McCarthy and P.M. Williams. 1972. Evidence for extrophication in the sea near southern California coastal sewage outfalls. July, 1970. CalCOFI Rpts 16:74-83.

Greene, C.S. 1976. Response and recovery of the benthos at Orange County. 197-203. In Coastal Water Research Project Annual Report, 1976. NTIS PB 274461/AS, U.S. Dept. Comm., Springfield, Va 22161.

Hendricks, T.J. 1977. Coastal currents. 53-62. In Coastal Water Research Project Annual Report, 1977. NTIS PB274463/AS. U.S. Dept. Comm., Springfield, VA 22161

Herring, J.R. and A.L. Abati. 1971. Effluent particle dispersion. 113-125. In Coastal Water Research Project Annual Report, 1978. Souther California Coastal Water Research Project, El Segundo, CA 90245.

M B C, Inc. 1975. Predischarge receiving water monitoring study. Final Summary Report. Submitted to City of Oxnard, Dept. of Public Works, Oxnard, CA 93030.

Mearns, A.J. 1979. Changes in the biomass of benthic infauna. 172-179. In U.S. Congress, Hearings before Subcommittee on Water Resources, Committee on Public Works and Transportation House of Representatives, Ninty-fifth Congress, 24-25, May, 1978. U.S. APO 1978.

Mearns, A.J. In Press. Effects of municipal discharges on open Coastal ecosystems. In Geyer, R.A. (ed), Studies in Marine Environmental Pollution, Elsivier Press. In press.

Mearns, A.J. and C.S. Greene. 1976. Comparison of the benthos at several waste water discharge sites. 211-216. In Coastal Water Research Project Annual Report 1976. NTIS PB274461/AS, U.S. Dept. Comm., Springfield, VA 22161.

Mueller, J.A., J.S. Jervis, A.R. Anderson and C.F. Hughes. 1976. Contaminant inputs to the New York Bight. NOAA Tech. Mem. ERL MESA - 6, Boulder, Co. 347 p.

Mitchell, F.K. and H.A. Schafer. 1975. Effects of ocean sludge dispersal. 153-162. In Coastal Water Research Project Annual Report, 1975. NTIS PB274467/AS, U.S. Dept. Comm., Springfield, VA 22161.

Orlab, G.T. 1977. Impacts of domestic wastewater discharge on the ocean environment of Point Loma, California. A review of ocean monitoring by the City of San Diego, January, 1975. through April, 1976. RMA 6160. Rpt. to California State Water Research Control Board, RMA Assoc., Lafayette, CA 94544.

Pearson, T.H. and R. Rosenberg. 1976. A Comparative study of the Effects on the marine environment of wastes from cellulose industries in Scotland and Sweden. Ambio 5(2):77-79.

Schafer, H.A. 1979. Characteristics of municipal wastewater discharges, 1977. 97-101. In Coastal Water Research Project Annual Report, 1978. Southern California Coastal Water Research Project, El Segundo, CA 90245.

Smith, G.B. 1974. Some effects of sewage discharge to the marine environment. PhD. Dissertation, Scripps Institution of Oceanography, La Jolla, CA 334 pp.

Smith, K.L. Jr., G.T. Rowe and J.A. Nichols. 1973. Benthic community respiration near the Woods Hole sewage outfall. Estuarine and Coastal Marine Science 1:65-70.

Smith, R.W. and C.S. Greene. 1976. Biological communities near submarine outfall. Jour. Water Poll. Cart. Fed. 48(8) 1894-1912.

Word, J.Q. 1976. Biological comparison of grab sampling devices. 189-194. In Coastal Water Research Project Annual Report 1976. NTIS PB274461/AS. U.S. Dept. Comm., Springfield, VA 22161.

Word, J.Q. 1977. Taxonomic Standarization developments, 85-87. In Coastal Water Research Project Annual Report 1977. NTIS PB274473/AS. U.S. Dept. Comm., Springfield, VA 22161.

Word, J.Q. 1979. Changes in indicator organisms as reflected by the Infaunal Index. 164-171 In. U.S. Congress, Hearings before Subcommittee on Water Resources, Committee on Public Works and Transportation, House of Representatives, Ninety-fifth Congress, 24-25 May, 1978. USGPO, 1978.

Word, J.Q. 1979. The Infaunal Trophic Index. In Coastal Water Research Project Annual Report 1978. Southern California Coastal Water Reserach Project, El Segundo, Ca 90245.

Word, J.Q., B.L. Myers and L. Harris, 1976. Taxonomic standardization program. 195-196. In Coastal Water Research Project Annual Report, 1976. NTIS PB274461/AS. U.S. Dept. Comm., Springfield, VA 22161.

Word, J.W., T.J. Kawling and A.J. Mearns. 1976. A comparative field study of benthic sampling devices used in southern California benthic surveys. Task Report, Grant R801152, U.S. EPA, Corvallis, Oregon.

Word, J.Q., A.J. Mearns, and B.L. Myers. 1977. Animals that are indicators of marine pollution. 199-206. In Coastal Water Research Project Annual Report, 1977. NTIS PB 274463/AS. U.S. Dept. Comm., Springfield, VA 22161.

Young, M.W. and D.K. Young. In press. Marine macrobenthos as indicators of environmental stress. In MESA Symposium on Ecological Effects of Environmental Stress. New York, New York, 11-15 June, 1979.

Table 1. Summary of benthic surveys used to calculate infaunal trophic indicies, biomass and relations between suspended solids emmissions and sizes of affected bottom areas.

Agency	Program	No. Samples	Sampler Type	Dates	Screen Size
SCCWRP	60	70	Van Veen	Apr-Aug 1977	1.0mm
SCCWRP	Bight Survey	310	Van Veen	Feb-Dec 1978	1.0mm
SCCWRP	Orlosan Survey	230	Van Veen	Mar 75, Aug 75	1.0mm & 0.5mm
SCCWRP	Grab Survey	154	F Samplers	Dec 74, Mar 75	1.0, 0.7, & 0.5mm
LACOSAN	Monitoring	2378	Shipek	1973 to present	1.0mm
ORLOSAN	Monitoring	90	Forest-Petersen	1975-1976	1.0mm
ORLOSAN	Monitoring	252	Van Veen	1976-1978	1.0mm
POINT LOMA	Monitoring	360	Ponar/petersen	1973-1975	1.0mm
POINT LOMA	Monitoring	510	Van Veen	1976-1979	1.0mm
OXNARD	Monitoring	297	Shipek	1973-1978 (less 1975)	0.5mm
HYPERION	Monitoring	1056	Shipek	July 1971-Dec 1977	1.0mm
HYPERION	Monitoring	85	Van Veen	1978 to present	1.0mm
ALLEN HANCOCK FOUNDATION	State Survey	862 (176 completed)	Orange Peel Bucket	1956-1958	0.7mm

Table 2. Groups of species considered in calculating the Infaunal Trophic Index. The wastewater discharge factor affecting the abundance of each group appears to be the deposition or accumulation of organic particulate material.

Group and Description	Species	
I Suspension feeders primarily; dominant in control or background areas; decrease in abundance with increasing proximity to wastewater discharges; 19 species, 7 taxa	*Amphiodia (Amphispina) urtica* *Amphiodia (Amphispina) digitata* *Amphiodia psara* *Amphiodia occidentalis* *Amphiodia* spp. *Ampelisca pacifica* *Ampelisca hancocki* *Ampelisca brevisimulata* *Ampelisca macrocephala* *Ampelisca cristata*	*Paraphosux bicuspidatus* *Metaphoxus frequens* *Heterophoxus oculatus* *Ampelisca* sp. *Paraphoxus* sp. *Metaphoxus* sp. *Heterophoxus* sp. *Sthenelenella uniformis* *Phoronis* sp.
II Suspension and surface detritus feeders; may be abundant in control areas but are not dominant; increase in abundance in areas slightly affected by wastewater discharges; 14 species, 7 taxa	*Photis brevipes* *Photis californica* *Photis* spp. *Euphilomedes producta* *Euphilomedes carcharodonta* *Euphilomedes longiseta*	*Mediomastus* spp. *Myriochele gracilis* *Myriochele* sp. *Axinopsida serricata* *Mysella pedroana* *Mysella tumida*
III Surface detritus feeders primarily; often present but never abundant in control areas; most abundant in areas moderately affected by wastewater discharges; 4 species, 4 taxa	*Parvilucina tenuisculpta* *Macoma carlottensis* *Bittium* spp. *Spiochaetopterus costarum*	
IV Subsurface detritus feeders; rare at control sites; most abundant in areas heavily affected by wastewater discharges; 10 species, 8 taxa	*Armandia bioculata* *Schistomeringos longicornis* *Schistomeringos* sp. *Ophryotrocha* sp. *Dorvelleidae*, UI	*Capitella capitata* *Tubificidae*, UI *Solemya panamensis* *Solemya* sp. Stenothoidae, UI

Table 3. Total Mass Emmission Rates and Concentrations of Various Constituents in Southern California Discharges, 1977.

	JWPCP	Hyperion 5-Mile	Hyperion 7-Mile	Orange County	Point Loma	Oxnard
Flow:						
Total (liters/year X 10^9)	463	441	6.4	247	160	15.5
Conc. (liters/Day X 10^6)	1,268	1,207	17.4	681	439	42.4
Total Suspended Solids:						
Total (Metric tons/year)	102,000	27,300	51,500	33,300	20,500	1,500
Conc. (Mg/L)	220	62	8,100	132	128	98
Five-Day B.O.D.:						
Total (Metric tons/yr.)	102,000	63,900	ND	47,900	26,700	3,900
Conc. (Mg/L)	220	145	ND	197	167	258
Ammonia Nitrogen:						
Total (Metric tons/yr.)	18,000	7,590	1,650	9,830	3,810	317
Conc. (Mg/L)	39	17.2	259	36	23.8	20.5

Table 4. Summary of Estimates of Excess Standing Crops (Mt, wet weight) and areas (sq.km) occupied by Excess Standing Crop and Infaunal Trophic Indicies characteristic of deposit feeding communities at five Southern California Waste Discharge Sites.

	OXNARD	POINT LOMA	ORANGE COUNTY	SANTA MONICA BAY	PALOS VERDES
Suspended Solids Mer, Mt/Yr. 1975	2,181	18,725	33,396	110,180	130,966
1977	1,500	20,500	33,300	78,800	102,000
Excess Standing Crop, mt. 1975-1977	17	150	455	5,625	11,760
Area (sq. km) Occupied by: Excess Stand. Crop.	1	5	5	30	45
Infaunal Trophic index					
≤ 60	0 (<0.01)[1]	≤ 4.0	10.8	>57.7	>94
≤ 30	0 (<0.01)[1]	≤ 0.16[2]	0.25[3]	3.3	8.4

[1]Not detected; arbitrary assignment

[2]One station within 0.4 km of outfall had value <30 on several occassions. Limit of detection based on station density in grid.

[3]One station within 0.5 km of diffuser had value <30 on one occassion. Limit of detection based on station density in grid.

Table 5. Calculations of benthic Excess Standing Crop (Se), and areas (sq km) affected by Se, Infaunal Trophic Indicies ≤60 (Ai_{60}), Infaunal Trophic Indicies ≤30 (Ai_{30}) and average Excess Biomass (g/m^2) for a variety of sewage suspended solids mass emmission rates.

Sus. Solids Mer, MT/yr.	Se	Ae	Ai_{60}	Ai_{30}
10,000	153	3.9	0.7	0.018
25,000	759	9.4	5.0	0.195
50,000	2,553	18.2	22.4	1.141
70,000	4,600	25.1	46.0	2.69
100,000	8,588	35.4	100.4	6.68
165,560[1]	20,753	57	299	24.2

[1] New York Bight Sewage Sludge, Mueller et al. 1976.

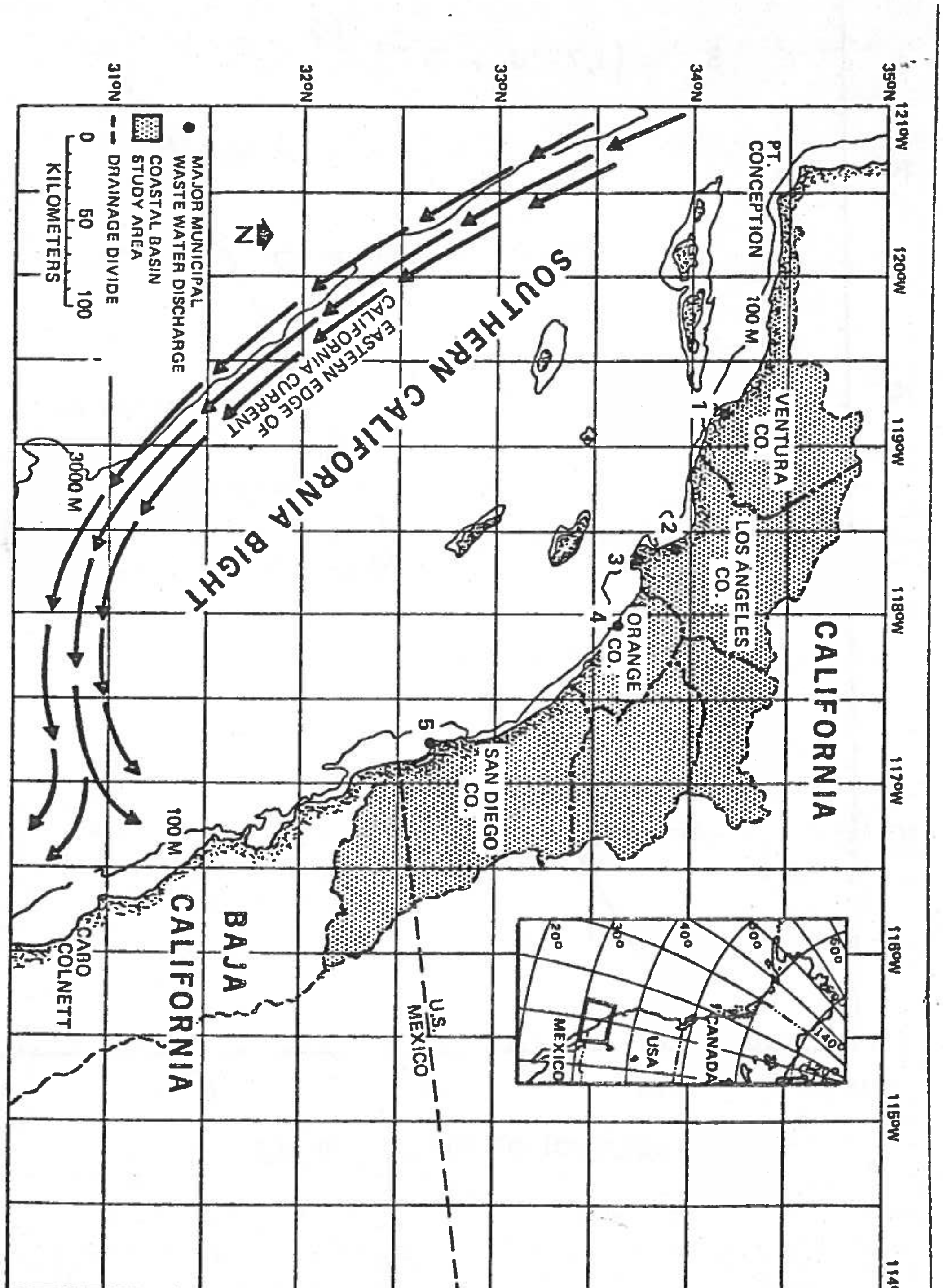
FIGURES

Fig. 1. The Southern California Bight and adjacent coastal basin. Major municipal wastewater discharges are (1) City of Oxnard, (2) City of Los Angeles Hyperion Treatment Plant in Santa Monica Bay, (3) County Sanitation Districts of Los Angeles Joint Water Pollution Control Plant at Palos Verdes, (4) County Sanitation Districts of Orange County and , (5) City of San Diego Point Loma Treatment Plant.

Fig. 2. Relation between suspended solids mass emmission rates and total excess standing crop of benthic infauna surrounding six outfalls on the southern California mainland shelf. Hyperion 5-mile (effluent) and 7-mile (sludge) outfalls plotted separately.

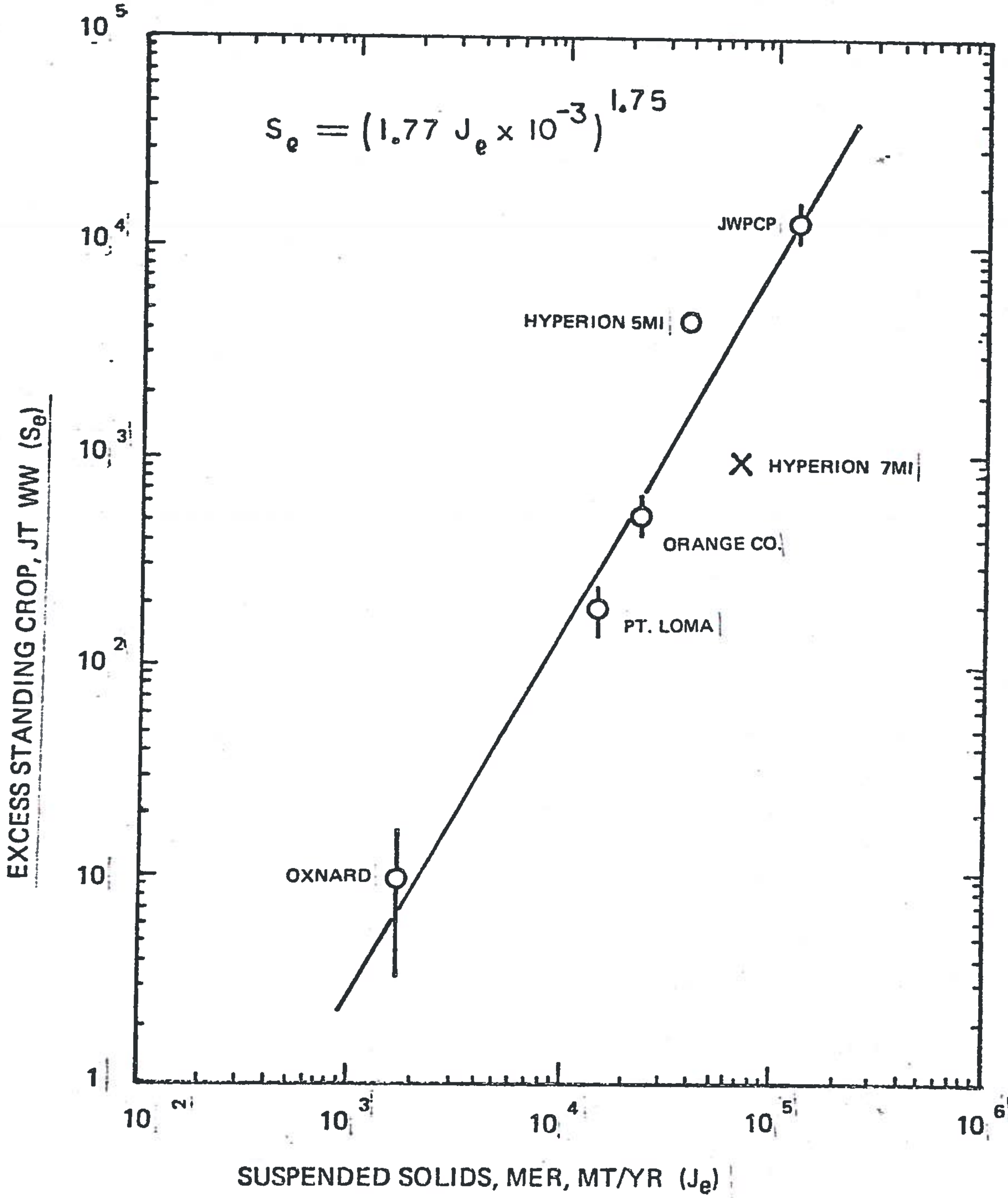
Fig. 3. Relation between suspended solids mass emmission rates and size of areas (km^2) occupied by total excess standing crop of infauna surrounding six southern California Mainland shelf.

Fig. 4. Relation between suspended solids mass emmission rates and size of areas occupied by macrobenthic fauna dominated by subsurface deposit feeding organisms ($i \leq 30$) and by surface and subsurface deposit feeding organisms ($i \leq 60$); calculations based on the Infaunal Trophic Index (see text).



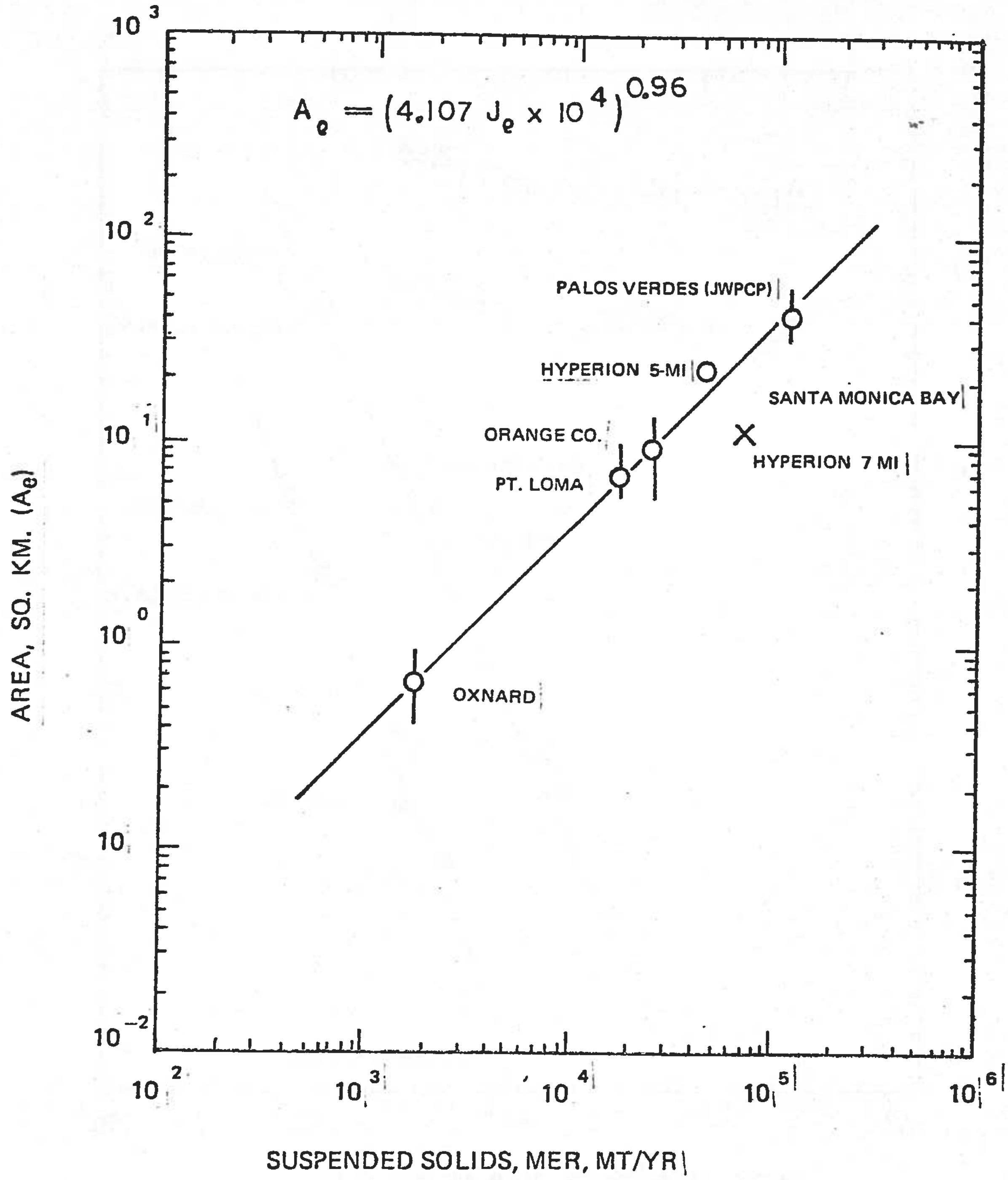
SOUTHERN CALIFORNIA BIGHT
CALIFORNIA
BAJA CALIFORNIA
PT. CONCEPTION
VENTURA CO.
LOS ANGELES CO.
ORANGE CO.
SAN DIEGO CO.
U.S. MEXICO
CABO COLNETT
EASTERN EDGE OF CALIFORNIA CURRENT
100 M
3000 M
1
2
3
4
5
N
MAJOR MUNICIPAL WASTE WATER DISCHARGE
COASTAL BASIN STUDY AREA
DRAINAGE DIVIDE
0 50 100
KILOMETERS
35ºN
34ºN
33ºN
32ºN
31ºN
121ºW
120ºW
119ºW
118ºW
117ºW
116ºW
115ºW
114ºW
CANADA
USA
MEXICO
20º
30º
40º
50º
60º
140º

Fig. 1.



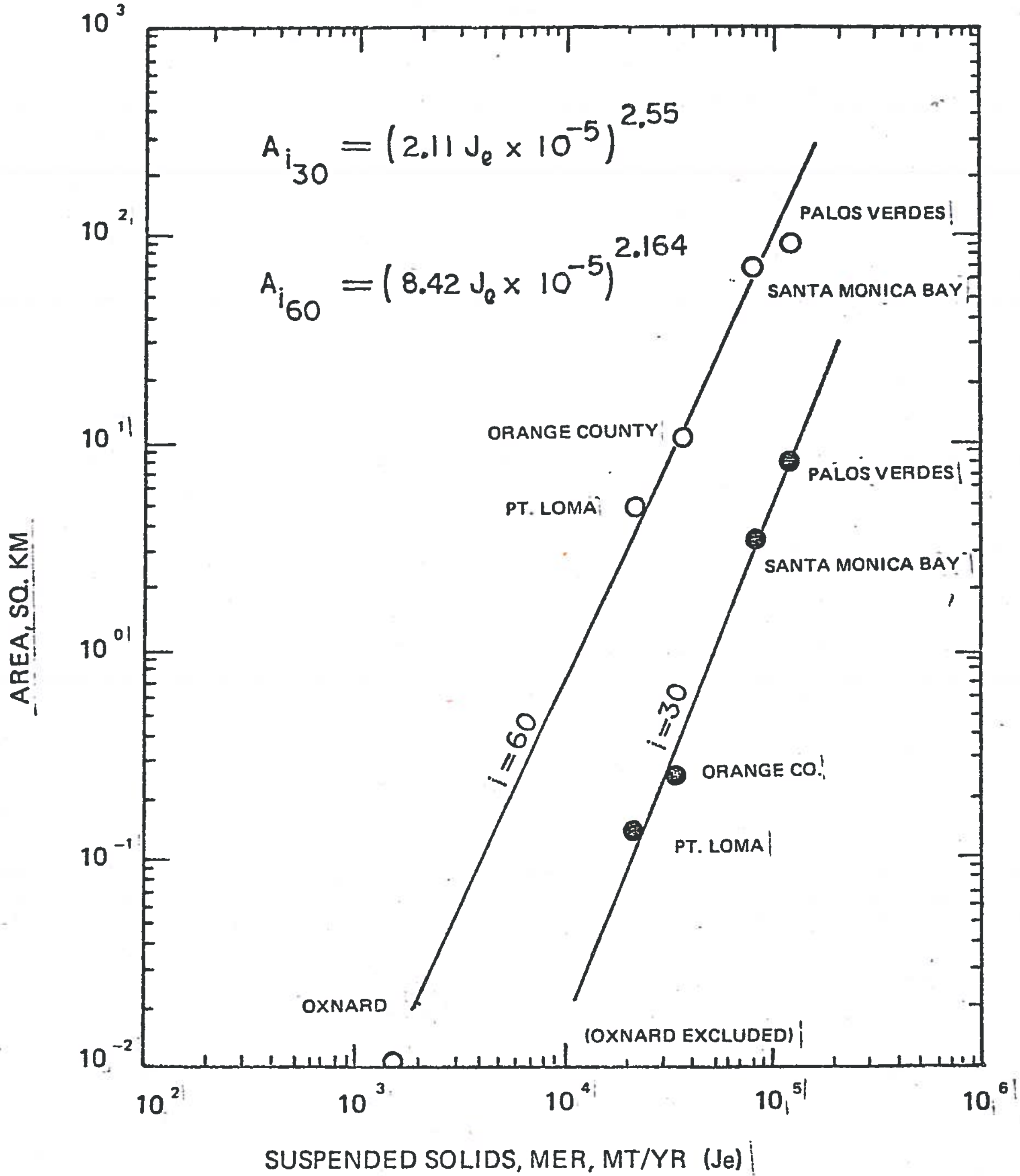
$S_e = (1.77\ J_e \times 10^{-3})^{1.75}$
JWPCP
HYPERION 5MI
HYPERION 7MI
ORANGE CO.
PT. LOMA
OXNARD
EXCESS STANDING CROP, JT WW (S_e)
SUSPENDED SOLIDS, MER, MT/YR (J_e)
10^5
10^4
10^3
10^2
10
1
10^2
10^3
10^4
10^5
10^6

Fig. 2.



$A_\ell = (4.107\, J_\ell \times 10^4)^{0.96}$
PALOS VERDES (JWPCP)
HYPERION 5-MI
SANTA MONICA BAY
ORANGE CO.
HYPERION 7 MI
PT. LOMA
OXNARD
AREA, SQ. KM. (A_ℓ)
SUSPENDED SOLIDS, MER, MT/YR

Fig. 3.



$A_{i_{30}} = (2.11\ J_e \times 10^{-5})^{2.55}$
$A_{i_{60}} = (8.42\ J_e \times 10^{-5})^{2.164}$
PALOS VERDES
SANTA MONICA BAY
ORANGE COUNTY
PT. LOMA
PALOS VERDES
SANTA MONICA BAY
i=60
i=30
ORANGE CO.
PT. LOMA
OXNARD
(OXNARD EXCLUDED)
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}
AREA, SQ. KM
SUSPENDED SOLIDS, MER, MT/YR (Je)

Fig. 4.