United States
Environmental Protection Agency
Region 10
1200 Sixth Avenue
Seattle, Washington 98101

Total Maximum Daily Load (TMDL) for Settleable Solid Residues in the Waters of South Unalaska Bay, Alaska

In compliance with the provisions of the Clean Water Act, 33 U.S.C. § 1251 et seq., as amended by the Water Quality Act of 1987, P.L. 100-4, the Environmental Protection Agency is hereby establishing a TMDL to limit discharges of settleable solid residues to the waters of south Unalaska Bay, Alaska.

This TMDL shall become effective immediately, and is incorporated into the water quality management plans for the state of Alaska under Clean Water Act § 303(e). Subsequent actions must be consistent with this TMDL.

Signed this 12th day of Feb, 1995.

Charles E. Findley, Director
Water Division

Total Maximum Daily Load for

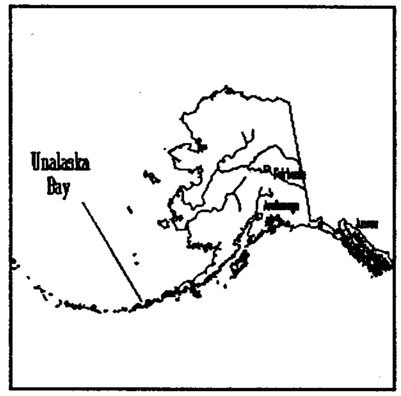
Settleable Solid Residues

in the Waters of

South Unalaska Bay, Alaska

TMDL AT A GLANCE:

Water Quality-Limited?	*Yes*
Segment Identifier:	*30102-603*
Standard of Concern:	*Residues*
Pollutant of Concern:	*Settleable solids*
Primary Use Affected:	*Aquatic life*
Sources:	*UniSea/Dutch Harbor Seafoods, Alyeska Seafoods, Royal Aleutian Seafoods and Queen Fisheries*
Loading Capacity:	*3,300,000 lbs SS/yr*
Load Allocation:	*0 lbs SS/yr*
Total Wasteload Allocation:	*1,785,953 lbs SS/yr (53%)*
Waste pile decay:	*1,349,047 lbs SS/yr (42%)*
Margin of Safety:	*165,000 lbs SS/yr (5%)*



Background

Section 303(d)(1)(C) of the Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (EPA) implementing regulations (40 CFR Part 130) require the establishment of Total Maximum Daily Loads (TMDL)for waters for which the technology-based controls required by Section 301 of the CWA or other legally required pollution control mechanisms are inadequate to ensure the achievement of state water quality standards. A TMDL is an implementation plan which identifies the degree of pollution control needed to attain and maintain compliance with state water quality standards using an appropriate margin of safety (EPA 1991). The focus of the implementation plan is the reduction of pollutant inputs to a level (or "daily load") that will meet the water quality standard and thus fully support the beneficial uses of a given waterbody. The mechanisms used to address water quality problems through the TMDL process can include effluent limits, best management practices and monitoring requirements in National Pollutant Discharge Elimination (NPDES) permits.

The state of Alaska has identified south Unalaska Bay as being water quality-limited for seafood wastes (ADEC 1992). EPA Region 10 completed a TMDL Water Quality Assessment ("TMDL Problem Assessment") of the pollutants discharged to greater Unalaska Bay and concluded that seafood processing wastes from five facilities contribute significantly to extensive deposits of settleable solid residues on the seafloor of south Unalaska Bay (Table 1; EPA 1995). Two of these facilities, UniSea and Dutch Harbor Seafoods, jointly discharge a commingled effluent through a common treatment and outfall system and therefore their discharges of pollution willbe discussed, analyzed and regulated as a single source herein and hereafter referred to as UniSea/Dutch Harbor Seafoods. Based on the TMDLWater Quality Assessment, an annual TMDLis proposed for settleable solids (SS) in south Unalaska Bay. Settleable solids is a parameter directly related to the impact of effluent discharges of residues deposited on the seafloor in a receiving water.

In the following discussion it willbe convenient to use acronyms and symbols for the names of departments, statutes and parameters which are referred to frequently. These are presented here for referral:

AAC - Alaska Administrative Code,
ADEC - Alaska Department of Environmental Conservation,
CFR - Code of Federal Regulations,
CWA - the Clean Water Act, or Federal Water Pollution Control Act,
EPA - U.S. Environmental Protection Agency,
r_d - rate of decay,
SS - settleable solids,
TSS - total suspended solids,
TMDL - total maximum daily load,
v_c - velocity of current,
WASP - Water Quality Analysis Simulation Program,
WLA - wasteload allocation, and
ZOD - zone of deposit.

Loading Capacity

The two largest seafood processors in south Unalaska Bay may discharge as much as 193,000 lbs total suspended solids (TSS) per day during the B-season pollock fishery in August, September and October (Table 1). This is almost five times the permissible monthly average discharge of all of the the municipal wastewater treatment plants for the cities of Anchorage, Fairbanks and Juneau (cumulative total of 40,565 lbs TSS per day). UniSea/Dutch Harbor Seafoods (monthly average discharge of 122,405 lbs TSS per day, 9/94) and Alyeska Seafoods (monthly average discharge of 71,352 lbs BOD5 per day, 9/94) discharge almost all of this.

As indicated in the revised TMDL Water Quality Assessment of south Unalaska Bay, the Bay's capacity to assimilate SS loading without a violation of the State water quality standard for residues is dependent not only on the volume of SS discharged but also on the allowable size of the pile of seafood waste which accumulates on the seafloor. The Alaska water quality standard states that residues "shall not ....cause a sludge, solid, or emulsion to be deposited beneath or upon the surface of the water, within the water column, on the bottom, or upon adjoining shorelines" [Alaska Administrative Code (AAC) §18.70.020]. However, Alaska Department of Environmental Conservation (ADEC) is empowered to issue or certify a permit that allows an area of deposit of substances on the bottom in marine waters within limits set by the Department (AAC § 18.70.033). The area of seafloor authorized by ADEC for coverage by deposits of settleable solid residues is termed a "zone of deposit" (ZOD).

Four seafood processing facilities discharge to the receiving waters of south Unalaska Bay on the southwest side of Amaknak Island: UniSea/Dutch Harbor Seafoods (a joint, commingled discharge), Alyeska Seafoods, Royal Aleutian Seafoods and Queen Fisheries (a.k.a. East Point Seafoods). At present none of these facilities have State-authorized zones of deposit. However, ADEC has indicated that it would certify a one-acre ZOD as a standard for all seafood processing facilities permitted under the proposed reissuance of NPDES general permit AKG-52-0000. This TMDLassumes that each of the above seafood processors willalso be authorized one-acre ZODs and utilizes the same computer model for settleable solids which supports the NPDES general permit. If the State authorizes ZODs of other sizes, the wasteload allocations and NPDES permit limitations willbe adjusted as appropriate.

The Water Quality Analysis Simulation Program (WASP, Ambrose et al. 1988, 1993) computer model of the fate, transport and persistence of settleable seafood processing waste solids was developed for and described at length in the "Ocean discharge criteria evaluation for the NPDES general permit for Alaskan seafood processors" (Tetra Tech 1994a; Appendix A). EPA developed the WASP model of circulation and water quality as a dynamic compartmental modeling system that can be used to analyze a variety of water quality problems in a diverse set of water bodies (including estuaries and coastal waters). The WASP computer model consists of a grid of parallelograms (Figure 1). The "blocked" waste piles of WASP were contoured using SURFER software in order to produce a more realistic (and somewhat larger) simulation of the waste pile (Figures 2 and 3).

The WASP computer model for settleable solid residues estimates the potential area of deposition caused by the discharge of such residues. A number of biological, chemical and physical factors control the fate of the discharged waste solids. Biological factors include microbial decay and scavenging of the waste by organisms. Chemical factors include the chemical composition of the waste, particularly the content of protein and soluble organic compounds, fats and carbohydrates, and skeletal and connective tissue. Physical factors that control the fate, transport and persistence of the waste include density stratification, storm-, tidal- and wind-induced currents, and water temperature.

Three hypothetical discharge scenarios were evaluated in the "Unalaska Bay TMDL waste pile modeling" (Tetra Tech 1994b; Appendix B): a very low current speed (1 cm/sec or 0.02 knots), a low current speed (5 cm/sec or 0.1 knot) and a medium current speed (15 cm/sec or 0.3 knots). The model simulated a steady waste discharge from 2 m (6.6 ft) above the seafloor in 15.2 m (50 ft) of water. Processing waste solids were assigned a density of 1.13 g/cm ^{2} based upon the proportional composition of water, protein, fat/carbohydrate and bone/chitin. Three particle size-classes were used, consisting of sixty percent solids with diameters of 1.3 cm (0.5 in), twenty percent solids with diameters of 0.635 cm (0.25 in), and twenty percent solids with diameters of 0.318 cm (0.125 in). The settling velocities assigned to these particle classes [0.085 m/sec (0.28 ft/sec), 0.045 m/sec (0.15 ft/sec), and 0.022 m/sec (0.072 ft/sec), respectively] are based on the qualitative observations of Stevens and Haaga (1994).

The first-order solids decay rate (r, for the exponential equation, $W_t = W_0e^{-rt}$) used in these simulations was based on best professional judgement, as no measurements of the decay of seafood waste solids have been made. A conservative decay rate of 0.002/day was selected which roughly corresponds with the median of the sediment organic matter decay rates found in the literature and summarized in Table 2. EPA's "Revised section 301(h) technical support document" for the evaluation of waiver applications recommends the use of 0.01/day to simulate the accumulation and decay of deposits of fine-grained organic matter discharged from municipal waste treatment facilities (EPA 1982). Evaluations of the decomposition of waste residues have been completed for the seafood industry using rates of 0.1, 0.01 and 0.001 per day for aerobic decay and 0.01, 0.005 and 0.0005 per day for anaerobic decay in previous evaluations of seafood wastes (Tetra Tech 1986). In accordance with this range of values, decay rates of 0.001, 0.002, 0.005, 0.01 and 0.02 were evaluated for information purposes (Figure 4). The selected value of 0.002/day for bottom discharges may be considered a first-approximation of the actual decay rate of the seafood waste solids discharged to south Unalaska Bay.

The WASP seafood waste model was run iteratively to determine, for each of the three scenarios, the steady seafood waste discharge rate that would result in the accumulation of waste piles of from 0.4 to 1.4 acres at steady-state. SURFER contouring analyses then determined the amount of seafood waste discharge which would result in the accumulation of waste piles of one acre at steady state. As a measure of safety, EPA has used the minimum discharge rate which produces one acre area of coverage as the total allowable discharge. The analysis indicates that a facility may discharge 2,800,000 lbs/yr (total annual wet weight) of settleable seafood processing wastes with a decay rate of 0.002/day from a bottom outfall into receiving waters with very low current speeds of 1 cm/sec without exceeding a one-acre waste pile (Table 3). The analysis indicates that a facility may discharge 1,500,000 lbs/yr (total annual wet weight) of settleable seafood processing wastes with a decay rate of 0.002/day from a bottom outfall into receiving waters with low current speeds of 5 cm/sec without exceeding a one-acre waste pile (Table 3). The analysis indicates that a facility may discharge 600,000 lbs/yr (total annual wet weight) of settleable seafood processing wastes with a decay rate of 0.002/day from a bottom outfall into receiving waters with medium current speeds of 15 cm/sec without exceeding a one-acre waste pile (Table 3).

Circulation studies of south Unalaska Bay conducted by CH2M-Hill(1994) indicate that UniSea/Dutch Harbor Seafoods discharges into receiving waters of low current speeds (annual average current velocity ≈ 5 cm/sec) and that Alyeska Seafoods, Royal Aleutian Seafoods and Queen Fisheries discharge into receiving waters of medium current speeds (annual average current velocity ≈ 15 cm/sec). Based on the results of mathematical modeling, a loading capacity of 3,300,000 lbs SS/yr is estimated for the composite of four one-acre ZODs in south Unalaska Bay, one for two facilities discharging commingled effluent into low velocity currents and three for three facilities discharging into medium velocity currents.

The relationship between particle size and density and both the settling velocity and resuspension current speed is pronounced (Table 5). EPA's analysis indicates that seafood waste particles with densities of 1.13 g/cm ^{3} and diameters of 1 mm have very low settling velocities (≈ 2 cm/sec) and are resuspended in current speeds of 11 cm/sec or greater. EPA's analysis indicates that seafood waste particles with densities of 1.13 g/cm ^{3} and diameters of 0.5 mm have extremely low settling velocities (≈ 1 cm/sec) and are resuspended in current speeds approximately 10 cm/sec or greater). EPA has therefore determined that the limitation on settleable solid residues applies only to particles of more than 1 mm diameter in average current speeds of more than 10 cm/sec and applies only to particles of more than 0.5 mm diameter in average current speeds of 10 cm/sec or less.

Load and Wasteload Allocations

The settleable solids loading capacity of the receiving water of south Unalaska Bay is allocated to four sources identified as contributing pollutant loads to the waterbody. In this case, the two largest sources of SS discharges have been identified: UniSea/Dutch Harbor Seafoods (a joint, commingled discharge) and Alyeska Seafoods. Two other sources of SS discharges have been identified: Royal Aleutian Seafoods and Queen Fisheries.

The significance of the history of the discharges of settleable seafood waste solids cannot be overstated. The large waste piles adjacent to Alyeska Seafoods' outfall (7.3 acres) and the UniSea/Dutch Harbor Seafoods' outfall (6.9 acres) expanded during roughly four years of pollock processing without concomitant screening of waste solids (EnviroTech Diving 1993, 1994). Previous to this these waste piles are estimated to have been one to two acres in size; this is more comparable to the present waste piles of Royal Aleutian Seafoods (1.5 acres) and Queen Fisheries (0.9 acres).

In accordance with CWA § 303(d)(1)(C) and federal regulations (40 CFR § 130.7), a margin of safety (MOS) was established to account for uncertainty in the relationship between effluent limitations and water quality. A margin of safety may be provided (1) by using conservative assumptions in the calculation of the loading capacity of the waterbody or (2) by establishing allocations that in total are lower than the defined loading capacity (so that the unallocated portion represents the margin of safety). In the case of the south Unalaska Bay analysis for settleable solids, both approaches were relied upon to establish a safety margin. In the first instance, EPA has selected the decay rate of 0.002/day as a conservative assumption regarding the disappearance of the wastes. EPA has also interpreted the results of the modeling conservatively, using the lowest discharge rate which is analyzed as producing a one acre waste pile. In addition to the conservative assumptions used within and in the interpretation of the WASP model, EPA has proposed a numerical margin of safety of 5% of the loading capacity of settleable solids at each waste pile to allow for uncertainty in the modeling analysis.

Based upon field studies in the eastern Aleutian Islands (e.g., Jones and Stokes 1992, Tetra Tech 1993), EPA believes that the contribution of settleable solids from natural sources is negligible and assigns a value of zero to load allocation. Therefore, wasteloads comprising 95% of the loading capacity are allocated to the four seafood processors.

It is important to address the existence of waste piles in south Unalaska Bay which exceed the proposed one acre ZODs. The following are alternate approaches to address the problem: (1) removal of some or all of the material through suction, dredging or some other method, (2) temporary or permanent authorization of the existing areas of deposition as ZODs, or (3) division of each processor's allocation into a fraction for current annual discharges and a fraction for the decomposition of the existing wastepiles. EPA believes that the removal option would have the potential to impose a significant instantaneous biochemical oxygen demand on and a significant hydrogen sulfide release in south Unalaska Bay and unreasonably degrade this waterbody. EPA proposes to implement options (2) and (3).

EPA suggests that the State of Alaska consider a time-series of incrementally smaller ZODs be authorized for each seafood processor with an end-point of one acre per facility at the end of no more than five years (option #2). EPA also proposes that wasteload allocations be divided into fractions for discharge and decay (option #3). As waste piles decrease in size discharge wasteload allocations can increase in the future in proportion to the decrease in the size of the waste pile, up to a maximum of 95% of the loading capacity of the receiving water. If the size of the waste piles are reduced more quickly through the application of bacteria-nutrient additives or any other means which accelerate decomposition, the discharge wasteload allocation willincrease more quickly.

EPA has assigned some part of the allowable discharge of settleable solids to the decay of waste piles which currently exceed one acre. The simulation of waste pile decay indicates that waste piles deposited in relatively slower currents are thicker and more massive per area than waste piles deposited in relatively faster currents (Table 3). The simulation of the decomposition of the waste piles also indicates that the thicker waste piles of slow current receiving waters require more time to decompose than relatively thinner waste piles found in moderate currents. For instance, three years are required for a 50% reduction in the areal extent of seafood residues in slow currents while two years are required for a 50% reduction in moderate currents.

Existing waste piles which exceed one acre by a significant margin (specifically, UniSea/Dutch Harbor Seafoods and Alyeska Seafoods) require the assignment of a substantial portion of the allowable discharge to a "reserve" for the decomposition of their existing waste piles. Existing waste piles below one acre (specifically, Queen Fisheries), require no such assignment. The division of each discharger's allocation (after the allocation of 5% to a margin of safety) into a fraction for current discharges and the decomposition of the waste pile of past discharges (i.e., annual discharge:waste pile decay) is as follows: UniSea/Dutch Harbor Seafoods - 1:2, Alyeska Seafoods - 1:1, Royal Aleutian Seafoods - 4:1, and Queen Fisheries - 1:0. These ratios were determined using the relationship of mass emission rates to waste pile size (Tables 3, 4 and 5) and the long-term decrease in waste pile size upon termination of discharge (Table 6), assuming that a waste pile of one acre will be achieved for each discharge within 5 years.

Based on the information available at this time, EPA establishes the following allocations for each source:

Source	SS Allocation
Natural Sources of SS	negligible
UniSea/Dutch Harbor Seafoods	
($v_c \approx 5$ cm/sec; $r_d \approx 0.002$/day)	
Annual discharge (≈32%)	474,953 lbs SS/yr
Waste pile decay (≈63%)	950,047 lbs SS/yr
Margin of Safety (5%)	75,000 lbs SS/yr
Alyeska Seafoods	
($v_c \approx 15$ cm/sec; $r_d \approx 0.002$/day)	
Annual discharge (47.5%)	285,000 lbs SS/yr
Waste pile decay (47.5%)	285,000 lbs SS/yr
Margin of Safety (5%)	30,000 lbs SS/yr
Royal Aleutian Seafoods	
($v_c \approx 15$ cm/sec; $r_d \approx 0.002$/day)	
Annual discharge (76%)	456,000 lbs SS/yr
Waste pile decay (19%)	114,000 lbs SS/yr
Margin of Safety (5%)	30,000 lbs SS/yr
Queen Fisheries	
($v_c \approx 15$ cm/sec; $r_d \approx 0.002$/day)	
Annual discharge (95%)	570,000 lbs SS/yr
Waste pile decay (0%)	0 lbs SS/yr
Margin of Safety (5%)	30,000 lbs SS/yr

The allocations for the seafood processors will constitute the basis of the SS limitations in the modification or reissuance of any NPDES permits for these facilities.

Monitoring Requirements

It is assumed that the seafloor monitoring program conducted by the seafood processors under their NPDES permits will continue under the modified or reissued permits, as will monitoring of process wastewater discharges for total suspended solids and settleable solids. Any monitoring required will be designed and conducted to meet the requirements of a comprehensive and efficient program of assessment (e.g., NRC 1990). The data generated from monitoring can be used to refine and calibrate the water quality model of greater Unalaska Bay and to adjust the wasteload allocation and NPDES permit limitations as appropriate.

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Table 1. Amounts of seafood processed and biochemical oxygen demand (BOD5) and total suspended solids (TSS) discharged to Greater Unalaska Bay in the months July through October of 1993 and 1994[1,2,3].

Facility, NPDES permit, and Processing Capacity[4]	Time Period	Seafood Processed (lbs/day)		BOD5 Discharge (lbs/day)		TSS Discharge (lbs/day)	
		Average	Maximum	Average	Maximum	Average	Maximum
ALYESKA SEAFOODS,	7/93	103,876	301,640	n.a.	n.a.	n.a.	n.a.
	8/93	926,877	1,376,620	n.a.	n.a.	n.a.	n.a.
permit no. AK-000027-2;	9/93	1,249,719	1,515,807	n.a.	n.a.	n.a.	n.a.
	10/93	830,114	1,385,510	n.a.	n.a.	n.a.	n.a.
fish: 2,000,000 lbs/day							
crab: 500,000 lbs/day	7/94	70,797	226,280	e. 4,697	e. 14,686	n.a.	n.a.
meal: 1,400,000 lbs/day	8/94	1,227,036	1,696,956	e. 148,202	e. 232,350	76,660	132,176
	9/94	1,346,138	1,541,910	147,290	192,289	71,352	138,874
	10/94	434,507	1,755,902	82,007	95,454	45,088	61,795
UNISEA,	7/93	4,400	456,457	n.a.	n.a.	n.a.	n.a.
	8/93	1,284,567	3,025,742	258,116	429,893	155,365	334,257
permit no. AK-002865-7;	9/93	2,847,371	3,192,283	282,609	569,376	124,881	151,603
	10/93	610,946	3,266,562	221,415	221,415	137,186	137,186
fish: 3,500,000 lbs/day							
crab: 300,000 lbs/day	7/94	190,021	2,023,044	27,122	35,752	16,865	22,314
meal: 1,600,000 lbs/day	8/94	1,370,857	3,173,745	261,282	388,853	113,150	140,846
	9/94	2,865,665	3,320,315	303,153	304,870	122,405	153,278
	10/94	703,908	3,341,534	98,940	246,243	41,013	109,857
DUTCH HARBOR	7/93	0	0	0	0	0	0
SEAFOODS,	8/93	0	0	0	0	0	0
	9/93	0	0	0	0	0	0
permit no. AK-002842-8;	10/93	0	0	0	0	0	0
fish: 80,000 lbs/day	7/94	e. 0	0	0	0	0	0
crab: 100,000 lbs/day	8/94	0	0	0	0	0	0
meal: 0 lbs/day	9/94	0	0	0	0	0	0
	10/94	e. 0	0	0	0	0	0
ROYAL ALEUTIAN	7/93	m. 202,619	n.a.	n.a.	n.a.	n.a.	n.a.
SEAFOODS,	8/93	m. 740,108	n.a.	n.a.	n.a.	n.a.	n.a.
	9/93	m. 349,286	n.a.	n.a.	n.a.	n.a.	n.a.
permit no. AK-002618-2;	10/93	m. 200,797	n.a.	n.a.	n.a.	n.a.	n.a.
fish: 150,000 lbs/day	7/94	m. 499,281	n.a.	n.a.	n.a.	n.a.	n.a.
crab: 160,000 lbs/day	8/94	m. 476,385	n.a.	n.a.	n.a.	n.a.	n.a.
meal: 0 lbs/day	9/94	m. 547,447	n.a.	n.a.	n.a.	n.a.	n.a.
	10/94	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
QUEEN FISHERIES,	7/93	0	n.a.	n.a.	n.a.	0	0
	8/93	m. 143,343	n.a.	n.a.	n.a.	n.a.	n.a.
permit no. AK-002025-7;	9/93	m. 116,845	n.a.	n.a.	n.a.	m. 43,232	n.a.
	10/93	n.a.	n.a.	n.a.	n.a.	0	0
fish: 74,000 lbs/day							
crab: 180,000 lbs/day	7/94	m. 23,000	n.a.	n.a.	n.a.	n.a.	n.a.
meal: 0 lbs/day	8/94	18,802	75,752	n.a.	n.a.	1,689	1,770
	9/94	m. 619,500	n.a.	n.a.	n.a.	1,870	2,426
	10/94	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
WESTWARD SEAFOODS,	7/93	70,000	195,000	343	788	514	2,598
	8/93	1,644,000	1,826,000	84,495	148,462	27,419	60,849
permit no. AK-004978-6;	9/93	1,761,000	2,293,000	87,146	230,710	55,334	107,273
	10/93	1,810,000	2,206,000	60,700	101,563	36,102	83,184
fish: 2,156,000 lbs/day							
crab: 176,000 lbs/day	7/94	82,000	107,000	1,539	3,509	189	364
meal: 880,000 lbs/day	8/94	1,389,000	2,058,000	70,194	155,637	28,227	53,878
	9/94	1,960,000	n.a.	57,149	116,193	27,350	35,357
	10/94	1,373,000	n.a.	48,738	81,650	25,165	39,529

Note: 1/ Values are based upon data submitted to EPA by seafood processing facilities permitted under NPDES in Discharge Monitoring Reports.
2/ Data for 1993 and 1994 were utilized to reflect the current management regime of fishing seasons for pollock and other target species.
3/ "n.a." indicates that data was "not available" in the Discharge Monitoring Report (DMR).
4/ Processing capacity is based upon data in the NPDES applications submitted by the permittees.
"e" Designates estimates based on best available information within the record of DMRs for a facility.
"m" Designates monthly level of production which, lacking information on the number of processing days, could not be converted to daily values.

TABLE 2 RANGE OF SEDIMENT DECAY RATE CONSTANTS (K) FOR ORGANIC MATERIAL

(day^{-1})	Degraded Substrate	Measurement Method	Location	Reference
$1.6x10^{-6}$ [a]	Refractory organic material	Benthic chamber, core incubation, pore water	Santa Monica Basin, CA	Jahnke 1990
$<8.2x10^{-5}$ [a]	Organic material	^{14}C	Resurrection Bay, AK	Henrichs and Doyle 1986
$>4.1x10^{-4}$ [a]	Labile organic material	Benthic chamber, core incubation, pore water	Santa Monica Basin, CA	Jahnke 1990
$1.2x10^{-3}$ [a]	Organic material	^{14}C	Long Island Sound, NY	Turekian et al. 1980
$1.7x10^{-3}$ - $6.0x10^{-3}$ [a]	Organic material	Pore water nitrogen	North Sea	Billen 1982
$2.3x10^{-3}$ [b]	Refractory algal material	^{35}S	Long Island Sound, NY	Westrich and Berner 1984
$2.7x10^{-3}$ [b]	Refractory organic material	^{35}S	Long Island Sound, NY	Westrich and Berner 1984
$2.7x10^{-3}$ - $8.2x10^{-3}$ [a]	Refractory algal material	^{14}C	Resurrection Bay, AK	Henrichs and Doyle 1986
$1.0x10^{-2}$ [c]	--	--	--	EPA 1982
$2.0x10^{-2}$ [b]	Labile organic material	^{35}S	Long Island Sound, NY	Westrich and Berner 1984
$2.4x10^{-2}$ [b]	Labile algal material	^{35}S	Long Island Sound, NY	Westrich and Berner 1984
$1.4x10^{-1}$ [a]	Labile algal material	^{14}C	Resurrection Bay, AK	Henrichs and Doyle 1986
Range: $1.6x10^{-6}$ - $1.4x10^{-1}$ day^{-1}				

[a] Total degradation was measured.

[b] Only anoxic degradation was measured.

[c] No experiments were conducted.

TABLE 3. EVALUATION OF THE STEADY SHORE-BASED SEAFOOD WASTE DISCHARGE THAT WOULD RESULT IN A 1.0-ACRE WASTE PILE (Page 1 of 4)

Case ID	Mass Emission Rate	Water Depth	Decay Rate	Areal Coverage SURFER	Areal Coverage WASP5	Deposit Depth SURFER	Deposit Depth WASP
	(million wet lbs/yr)	(ft)	(per day)	(acres)**		(cm)	
*Low current speed cases (1 cm/sec)							
cas1301a	1.4	50	0.001	1.0	0.6	249	457
cas1301b	1.5	50	0.001	1.0	0.6	267	490
cas1301c	1.6	50	0.001	1.0	0.6	284	522
cas1301d	1.8	50	0.001	1.0	0.6	320	588
cas1301e	2.0	50	0.001	1.0	0.6	356	653
cas1301g	2.3	50	0.001	1.1	0.6	409	751
cas1302a	1.9	50	0.002	0.9	0.5	169	310
cas1302b	2.0	50	0.002	0.9	0.6	178	327
cas1302c	2.1	50	0.002	0.9	0.6	187	343
cas1302d	2.2	50	0.002	0.9	0.6	196	359
cas1302e	2.3	50	0.002	0.9	0.6	204	375
cas1302f	2.4	50	0.002	0.9	0.6	213	392
cas1302g	2.8	50	0.002	1.0	0.6	249	458
cas1302h	3.0	50	0.002	1.0	0.6	267	490
cas1302i	3.2	50	0.002	1.0	0.6	284	521
cas1302j	3.5	50	0.002	1.0	0.6	311	571
cas1302k	4.0	50	0.002	1.0	0.6	357	656
cas1302l	4.5	50	0.002	1.1	0.6	401	736
cas1305e	7.0	50	0.005	1.0	0.6	249	457
cas1305f	7.5	50	0.005	1.0	0.6	266	489
cas1305g	8.0	50	0.005	1.0	0.6	285	523
cas1305h	8.5	50	0.005	1.0	0.6	302	555
cas1305i	9.0	50	0.005	1.0	0.6	320	588
cas1305j	11.0	50	0.005	1.1	0.6	391	718
cas131e	13.0	50	0.01	0.9	0.6	231	424
cas131f	14.0	50	0.01	1.0	0.6	249	457
cas131g	16.0	50	0.01	1.0	0.6	285	523
cas131h	17.0	50	0.01	1.0	0.6	302	555
cas131i	18.0	50	0.01	1.0	0.6	320	588
cas131j	23.0	50	0.01	1.1	0.6	409	752
cas132a	16.0	50	0.02	0.8	0.5	142	261
cas132b	17.0	50	0.02	0.8	0.5	151	278
cas132e	20.0	50	0.02	0.9	0.6	178	327
cas132f	28.0	50	0.02	1.0	0.6	249	457
cas132g	30.0	50	0.02	1.0	0.6	267	490
cas132h	32.0	50	0.02	1.0	0.6	283	520
cas132i	35.0	50	0.02	1.0	0.6	311	571
cas132j	45.0	50	0.02	1.1	0.6	399	732

TABLE 3. EVALUATION OF THE STEADY SHORE-BASED SEAFOOD WASTE DISCHARGE THAT WOULD RESULT IN A 1.0-ACRE WASTE PILE
(Page 2 of 4)

Case ID	Mass Emission Rate	Water Depth	Decay Rate	Areal Coverage SURFER	Areal Coverage WASP5	Deposit Depth SURFER	Deposit Depth WASP
	(million wet lbs/yr)	(ft)	(per day)	(acres)**		(cm)	
*Low current speed cases (5 cm/sec)							
case001a	0.1	50	0.001	0.5	0.2	16	29
case001b	0.2	50	0.001	0.6	0.2	33	57
case001c	0.3	50	0.001	0.7	0.5	49	86
case001d	0.4	50	0.001	0.8	0.5	65	115
case001e	0.5	50	0.001	0.8	0.6	81	143
case001f	0.6	50	0.001	0.9	0.6	97	172
case001g	0.7	50	0.001	0.9	0.8	114	201
case001h	0.8	50	0.001	1.0	0.8	130	229
case001i	0.9	50	0.001	1.0	0.8	146	258
case001j	1.0	50	0.001	1.1	0.8	163	287
case001k	1.1	50	0.001	1.1	0.8	178	315
case001l	0.9	50	0.002	0.8	0.5	73	129
case001m	1.0	50	0.002	0.8	0.6	81	144
case001n	1.1	50	0.002	0.9	0.6	89	158
case001o	1.2	50	0.002	0.9	0.6	97	172
case001p	1.3	50	0.002	0.9	0.8	106	187
case001q	1.4	50	0.002	0.9	0.8	114	201
case001r	1.5	50	0.002	1.0	0.8	122	215
case01a	1.6	50	0.002	1.0	0.8	130	230
case001a	1.7	50	0.002	1.0	0.8	138	244
case001b	1.8	50	0.002	1.0	0.8	142	251
case001c	1.8	50	0.002	1.0	0.8	148	262
case001d	1.9	50	0.002	1.0	0.8	154	273
case001e	2.0	50	0.002	1.1	0.8	161	285
case001f	2.1	50	0.002	1.1	0.8	168	297
case001g	2.2	50	0.002	1.1	0.8	174	308
case001h	2.2	50	0.002	1.1	0.8	181	319
case001i	3.0	50	0.002	1.2	0.9	244	430
case001j	4.0	50	0.002	1.4	0.9	326	576
case001k	5.0	50	0.002	1.5	0.9	405	716
case005a	2.0	50	0.005	0.8	0.5	65	115
case005b	3.0	50	0.005	0.9	0.6	98	172
case005c	3.3	50	0.005	0.9	0.8	106	187
case005d	3.5	50	0.005	0.9	0.8	114	201

TABLE 3. EVALUATION OF THE STEADY SHORE-BASED SEAFOOD WASTE DISCHARGE THAT WOULD RESULT IN A 1.0-ACRE WASTE PILE
(Page 3 of 4)

Case ID	Mass Emission Rate	Water Depth	Decay Rate	Areal Coverage SURFER	Areal Coverage WASP5	Deposit Depth SURFER	Deposit Depth WASP
	(million wet lbs/yr)	(ft)	(per day)	(acres)**		(cm)	
*Low current speed cases (5 cm/sec) (Continued)							
case005e	3.8	50	0.005	1.0	0.8	121	215
case005f	4.0	50	0.005	1.0	0.8	129	229
case005g	4.3	50	0.005	1.0	0.8	138	245
case005h	4.5	50	0.005	1.0	0.8	146	259
case005i	4.8	50	0.005	1.1	0.8	154	273
case005j	5.0	50	0.005	1.1	0.8	162	287
case101a	2.0	50	0.01	0.6	0.2	33	57
case101b	4.0	50	0.01	0.8	0.5	65	115
case101c	6.0	50	0.01	0.9	0.6	97	172
case101d	7.0	50	0.01	0.9	0.8	114	201
case101e	8.0	50	0.01	1.0	0.8	130	229
case101f	9.0	50	0.01	1.0	0.8	146	258
case101g	10.0	50	0.01	1.1	0.8	162	286
case101h	12.0	50	0.01	1.1	0.8	195	345
Case 1	16.0	50	0.02	1.0	0.8	230	
*Medium current speed cases (15 cm/sec)							
case002b	0.4	50	0.002	0.8	0.4	27	44
case002c	0.5	50	0.002	0.8	0.4	32	53
case02d	0.5	50	0.002	0.9	0.4	33	56
case002d	0.6	50	0.002	0.9	0.4	37	62
case02e	0.6	50	0.002	1.0	0.4	40	67
case002e	0.7	50	0.002	1.0	0.4	47	78
case02f	0.8	50	0.002	1.1	0.6	53	89
case002f	0.8	50	0.002	1.1	0.6	53	89
case002g	1.0	50	0.002	1.1	1.0	67	112
case002h	1.2	50	0.002	1.2	1.0	80	134
case002i	3.0	50	0.002	1.8	1.2	200	334
case002j	4.0	50	0.002	2.1	1.4	267	445
case002k	5.0	50	0.002	2.2	1.4	333	557
case025p	1.5	50	0.005	1.0	0.4	40	67
case025o	1.6	50	0.005	1.0	0.4	43	71
case025n	1.7	50	0.005	1.0	0.4	45	76
case025m	1.8	50	0.005	1.0	0.4	48	80
case025l	1.9	50	0.005	1.1	0.6	51	85
case025k	2.0	50	0.005	1.1	0.6	53	89
case025j	2.1	50	0.005	1.1	0.6	56	93
case025i	2.2	50	0.005	1.1	0.6	59	98
case025h	2.3	50	0.005	1.1	0.8	61	102
case021x	3.0	50	0.01	1.0	0.4	40	67
case021w	3.1	50	0.01	1.0	0.4	41	69
case021v	3.2	50	0.01	1.0	0.4	43	71

Case ID	Mass Emission Rate	Water Depth	Decay Rate	Areal Coverage SURFER	Areal Coverage WASP5	Deposit Depth SURFER	Deposit Depth WASP
TABLE 3. EVALUATION OF THE STEADY SHORE-BASED SEAFOOD WASTE DISCHARGE THAT WOULD RESULT IN A 1.0-ACRE WASTE PILE (Page 4 of 4)							
	(million wet lbs/yr)	(ft)	(per day)	(acres)**		(cm)	
*Medium current speed cases (15 cm/sec) (Continued)							
case021u	3.3	50	0.01	1.0	0.6	44	73
case021t	3.4	50	0.01	1.0	0.4	45	76
case021s	3.5	50	0.01	1.0	0.4	47	78
case021r	3.6	50	0.01	1.0	0.4	48	80
case021q	3.7	50	0.01	1.0	0.4	49	82
case021p	3.8	50	0.01	1.0	0.4	51	85
case021o	3.9	50	0.01	1.1	0.4	52	87
case021n	4.0	50	0.01	1.1	0.4	53	89
case022w	7.4	50	0.02	1.0	0.6	49	82
case022x	7.5	50	0.02	1.0	0.6	50	83
Case 2	12.0	50	0.02	1.2	1.0	133	

* Shore-based discharge, flat bottom, 1, 5, and 15 cm/sec alongshore long-term, net-drift current speeds.
** Areal coverage of the waste pile greater than 1 cm in depth.

TABLE 4. EVALUATION OF THE STEADY SURFACE-BASED SEAFOOD WASTE DISCHARGE THAT WOULD RESULT IN A 1.0-ACRE WASTE PILE

Case ID	Mass Emission Rate	Water Depth	Decay Rate	Areal Coverage SURFER	Areal Coverage WASP5	Deposit Depth SURFER	Deposit Depth WASP
	(million wet lbs/yr)	(ft)	(per day)	(acres)**		(cm)	
*Low current speed cases (1 cm/sec)							
cas1401a	0.1	100	0.001	0.6	0.5	12	20
cas409a	0.3	100	0.001	1.0	0.6	29	49
cas1401c	0.3	100	0.001	1.1	0.8	35	59
cas409b	0.5	100	0.001	1.4	1.1	59	98
cas1401f	0.6	100	0.001	1.5	1.3	70	117
cas1402a	0.3	100	0.002	0.8	0.6	18	29
cas209a	0.5	100	0.002	1.0	0.6	29	49
cas1402f	0.8	100	0.002	1.3	1.0	47	79
cas209b	1.0	100	0.002	1.4	1.1	59	98
cas1405a	0.6	100	0.005	0.7	0.6	14	24
cas509a	1.0	100	0.005	0.9	0.6	24	39
cas1405e	1.2	100	0.005	1.0	0.6	29	48
cas509b	1.5	100	0.005	1.1	0.8	35	59
cas141a	1.2	100	0.01	0.7	0.6	14	24
cas309a	2.0	100	0.01	0.9	0.6	24	39
cas141e	2.5	100	0.01	1.0	0.6	29	49
cas1401f	3.0	100	0.01	1.1	0.8	35	59
cas309b	4.0	100	0.01	1.3	1.0	47	79
cas142b	2.5	100	0.02	0.7	0.6	15	25
cas109a	4.0	100	0.02	0.9	0.6	24	39
cas142c	5.0	100	0.02	1.0	0.6	29	49
cas142a	6.0	100	0.02	1.1	0.8	35	59
cas109b	8.0	100	0.02	1.3	1.0	47	78

*Surface-based discharge, flat bottom, 1 cm/sec alongshore long-term, net-drift current speed.
**Areal coverage of the waste pile greater than 1 cm in depth.

TABLE 5. ESTIMATED SETTLING VELOCITIES AND CURRENT SPEEDS NECESSARY TO RESUSPEND DIFFERENT SIZES OF SEAFOOD SOLID WASTE PARTICLES

Seafood Waste Particle Diameter (cm)	Settling Velocity[a] (m/sec)		Resuspension Current Speed[b] (m/sec)		
	ρ = 1.13	ρ = 1.05	ρ = 1.05	ρ = 1.13	ρ = 1.4
	For a Given Particle Density in g/cm^3				
0.05	0.0068	0.0020	0.06	0.10	0.17
0.1	0.017	0.0057	0.07	0.11	0.20
0.2	0.036	0.014	0.08	0.15	0.28
0.3	0.055	0.021	0.09	0.18	0.37
0.318 (1/8 in.)	0.058	0.022	0.09	0.19	0.38
0.4	0.072	0.029	0.10	0.22	0.44
0.5	0.089	0.036	0.12	0.25	0.51
0.6	0.105	0.042	0.13	0.28	0.58
0.635 (1/4 in)	0.111	0.045	0.14	0.29	0.60
0.7	0.122	0.049	0.14	0.31	0.64
0.8	0.138	0.055	0.16	0.34	0.70
0.9	0.154	0.062	0.17	0.37	0.76
1.0	0.165	0.068	0.18	0.40	0.82
1.1	0.174	0.075	0.19	0.42	0.86
1.2	0.181	0.081	0.20	0.45	0.90
1.27 (1/2 in)	0.186	0.085	0.21	0.47	0.93
1.3	0.189	0.087	0.22	0.47	0.95

[a] Stokes fall velocity (Sleath 1984). Assumes a seawater density of 1.025 g/cm^3 and a kinematic viscosity of seawater at 5^{o} C equal to 1.52x10^{-6} m^2/sec.

[b] The calculation of the resuspension current speed [i.e., the current speed 1 m (3.3 ft) above the seafloor (U_{100}) that is sufficient to cause resuspension of particles] is based on use of Shield's diagram (Vanoni 1977) to compute the critical shear velocity u_* and the relation $u_* = (0.003)^{.5}\ U_{100}$ (Sternberg 1972).

Conversion Factors:

To convert cm to in multiply cm*0.3937

To convert m/sec to knots multiply m/sec*1.9438

To convert m/sec to ft/sec multiply m/sec*3.2808

TABLE 6. SIMULATION OF THE LONG-TERM DECREASE IN WASTE PILE SIZE FOLLOWING TERMINATION OF DISCHARGE.

Case ID	Decay Rate	Areal Coverage SURFER	Areal Coverage WASP5	Deposit Depth SURFER	Deposit Depth WASP
	(per day)	(acres)[3]		(cm)	
[1]Low current speed case - 1.9 million pounds (wet wt) per year					
Year					
1	0.002	0.8	0.5	74	132
2	0.002	0.7	0.5	36	63
3	0.002	0.5	0.2	17	31
5	0.002	0.2	0.2	4	7
10	0.002	0	0	0.1	0.2
[2]Medium current speed case - 0.7 million pounds (wet wt) per year					
Year					
1	0.002	0.7	0.4	23	38
2	0.002	0.5	0.2	11	18
3	0.002	0.3	0.2	5	9
5	0.002	0.1	0.1	1	2
10	0.002	0.0	0.0	0.03	0.05

[1]Shore-based discharge, flat bottom, 5 cm/sec alongshore long-term, net-drift current speed.
[2]Shore-based discharge, flat bottom, 15 cm/sec alongshore long-term, net-drift current speed.
[3]Areal coverage of the waste pile greater than 1 cm in depth.

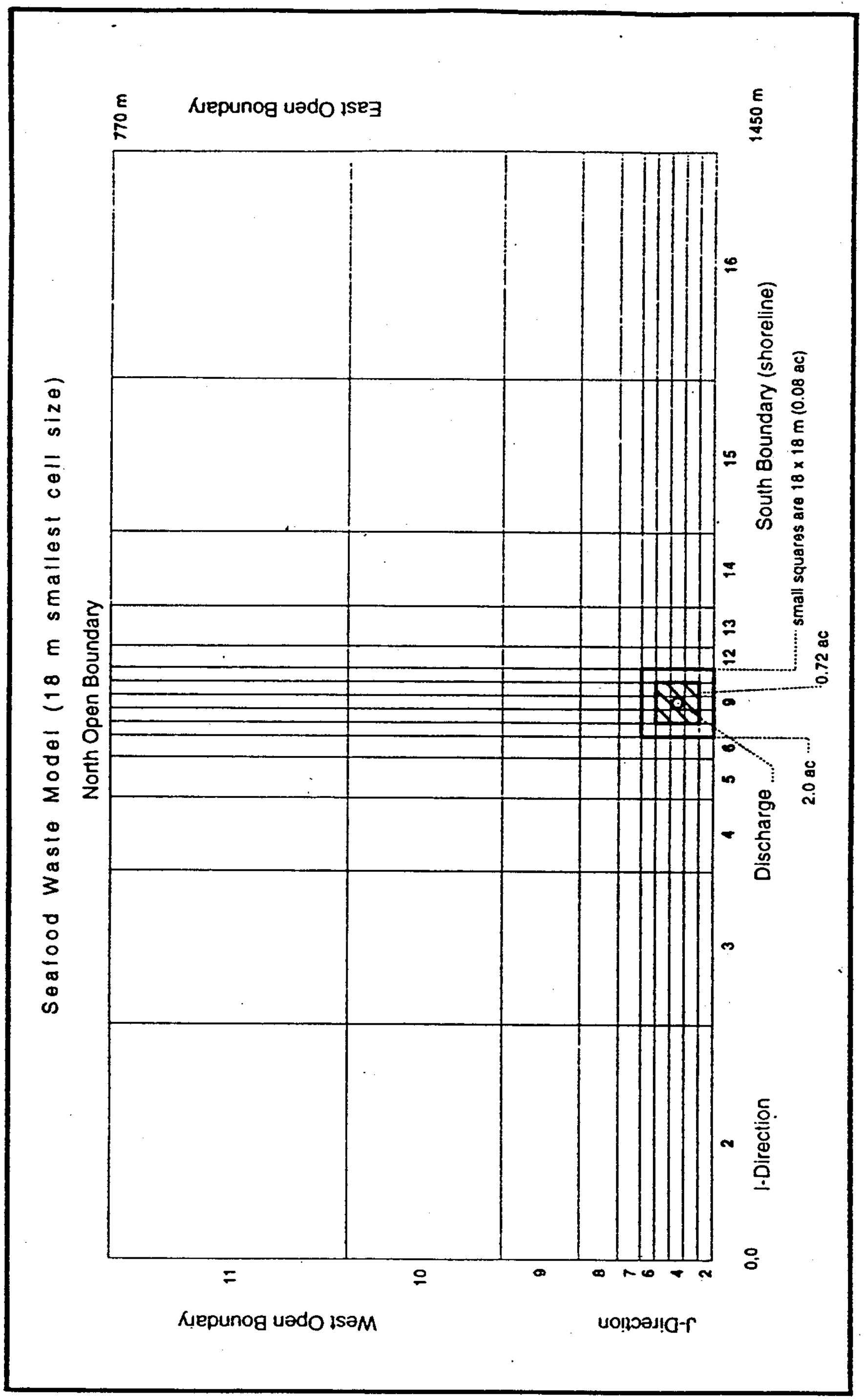

Figure 1. Variable-Spaced Model Grid for Shore-Based Seafood Waste Model.

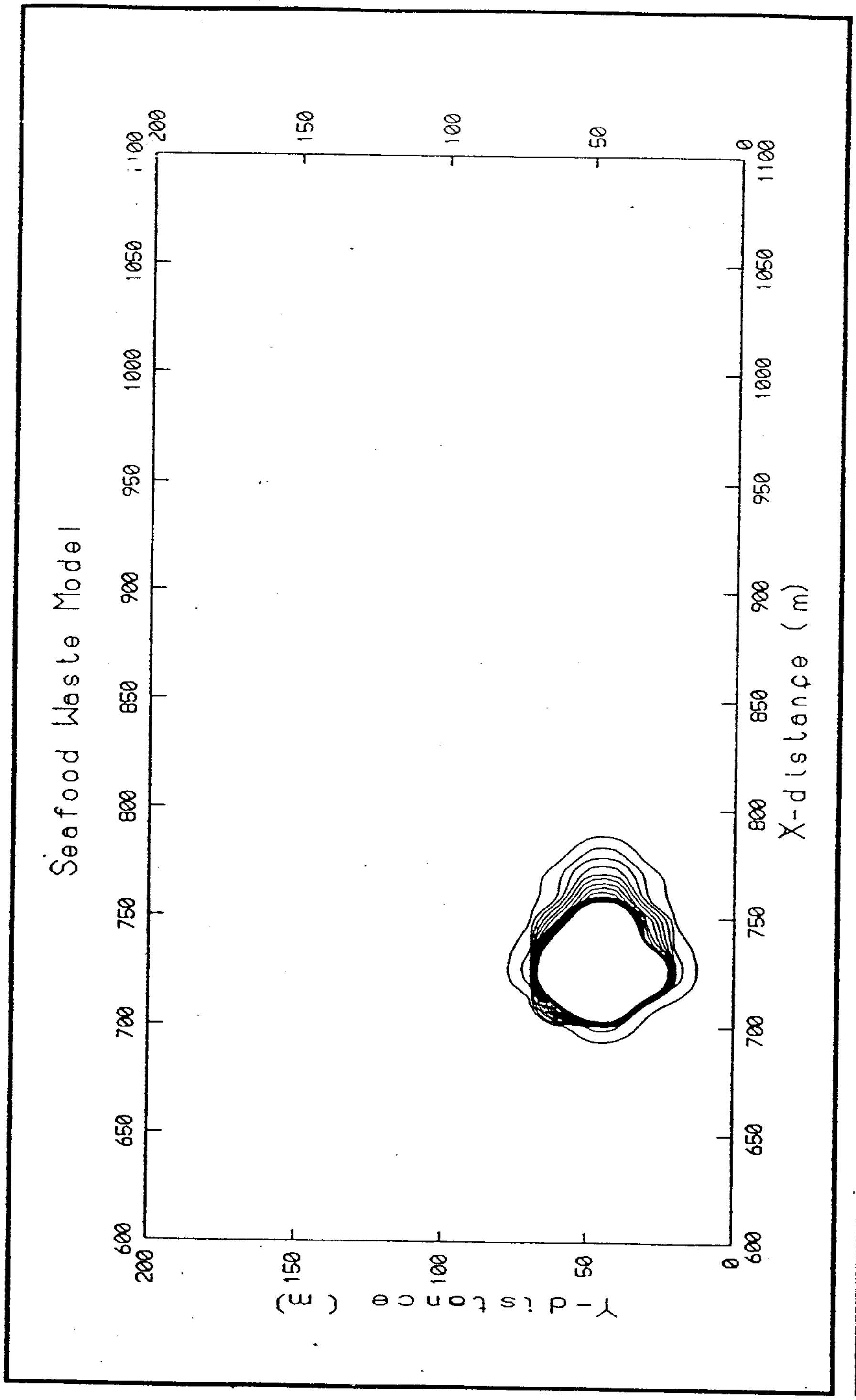

Figure 2. Top View of a 1-Acre Seafood Waste Pile Created by a Steady Shore-Based Discharge of 1.9 Million Pounds (wet weight) Per Year to Waters With a Steady Along-Shore Current of 5 cm/sec (0.1 Knots).

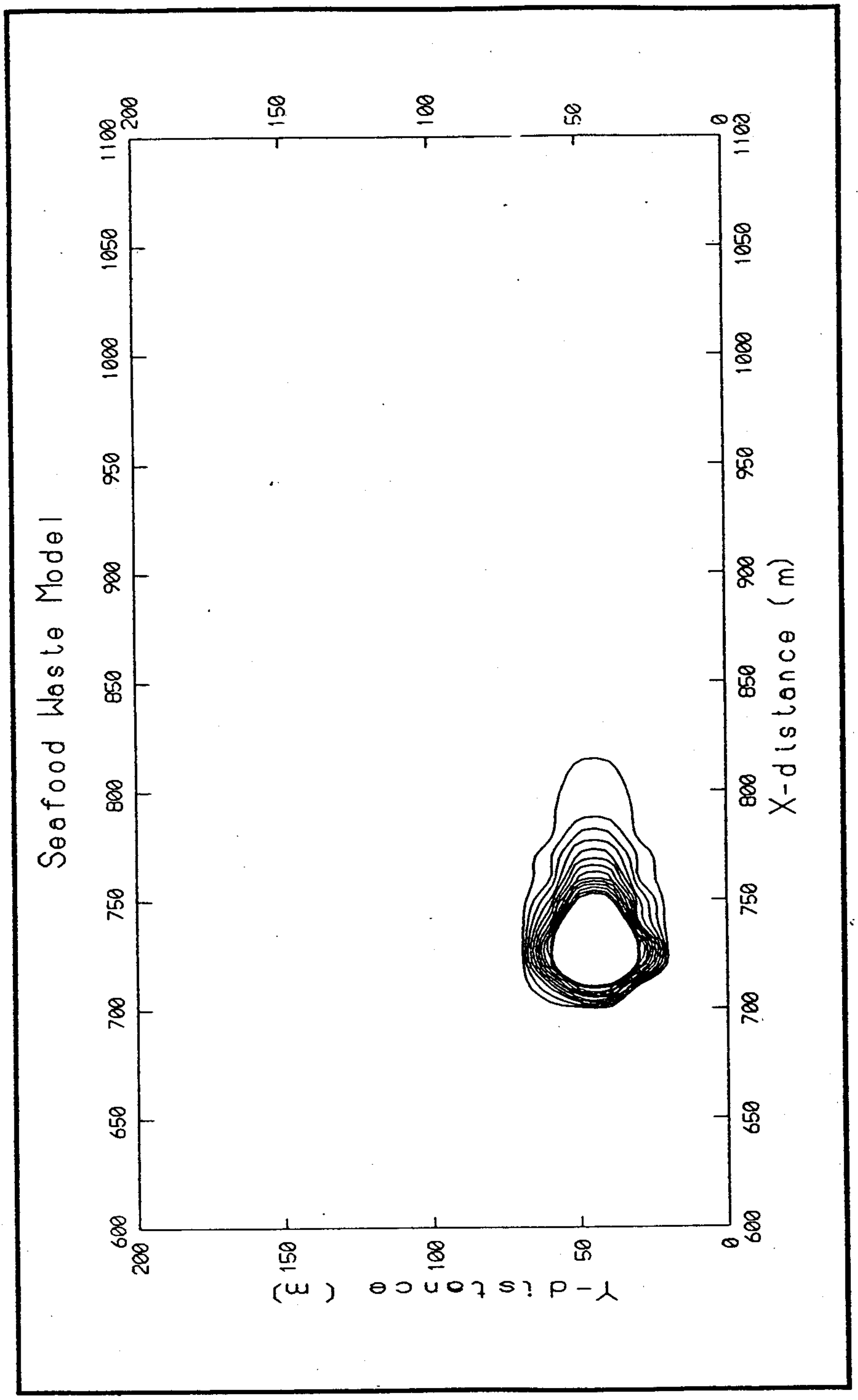

Figure 3. Top View of a 1-Acre Seafood Waste Pile Created by a Steady Shore-Based Discharge of 0.7 Million Pounds (wet weight) Per Year to Waters With a Steady Along-Shore Current of 15 cm/sec (0.3 Knots).

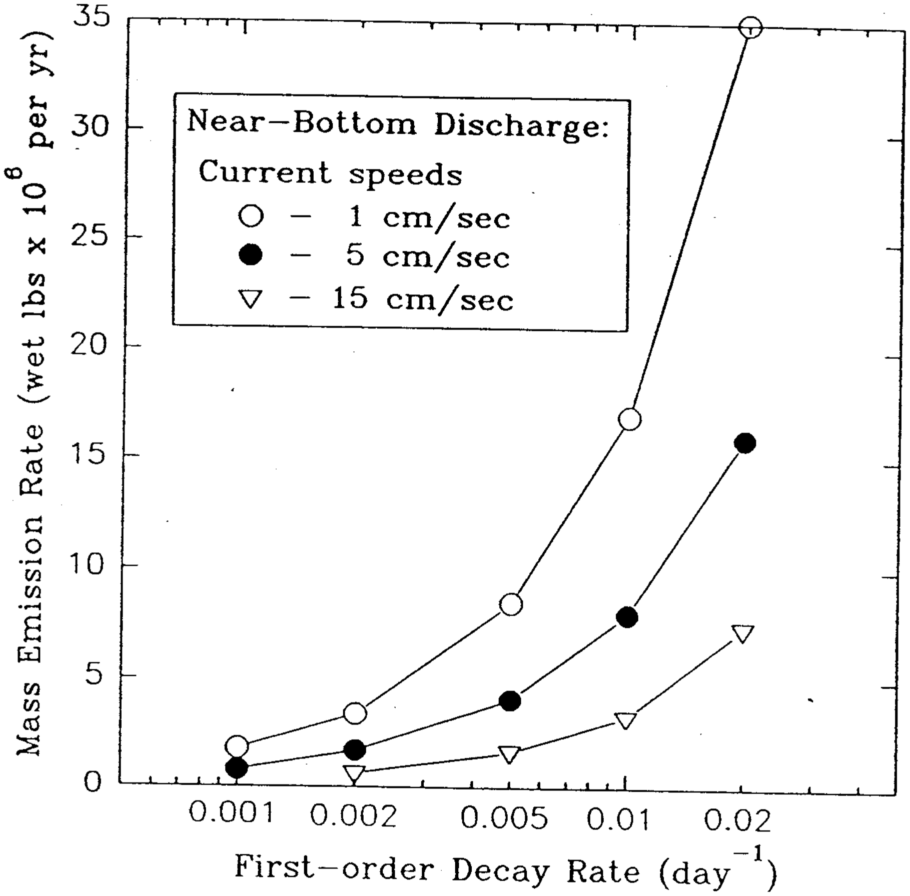

Figure 4. WASP5 Seafood Waste Model Mass Emission and Decay Rates that Result in a 1–acre Bottom Accumulation of Waste From a Near–Bottom Discharge.

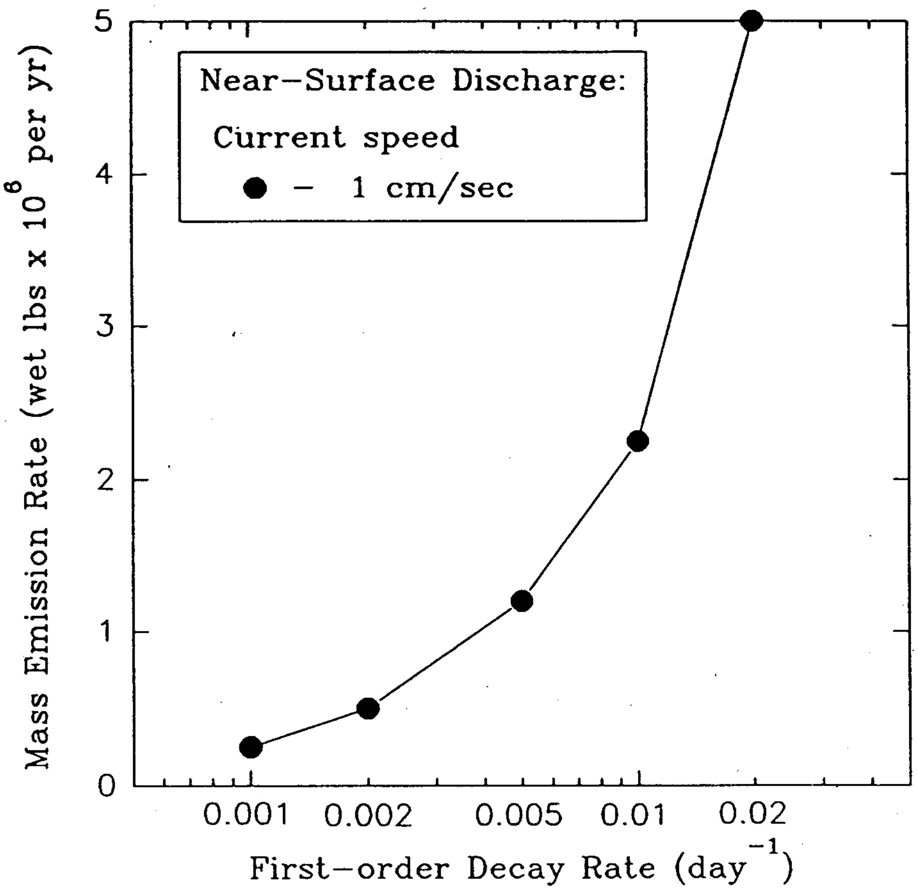

Figure 5. WASP5 Seafood Waste Model Mass Emission and Decay Rates that Result in a 1–acre Bottom Accumulation of Waste From a Near–Surface Discharge.